SUMMARY OF NORTHERN ATLANTIC COASTAL PLAIN HYDROLOGY AND ITS RELATION TO DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE IN BURIED CRYSTALLINE ROCK - A PRELIMINARY APPRAISAL

By Orville B. Lloyd, Jr., Jerry D. Larson and Robert W. Davis

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4146

Raleigh, North Carolina
1985

UNITED STATES DEPARTMENT OF THE INTERIOR

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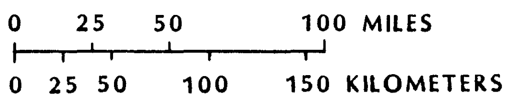
Errata sheet

Add the following scale to figures 2, 5, 6, and 7, on pages 7, 40, 42, and 44 respectively.



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INTERNATIONAL SYSTEM UNITS

The following factors may be used to convert inch-pound units herein to the International System of Units (SI).

Multiply inch-pound unit	By	To obtain SI unit
	Length	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
yard (yd)	0.9144	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	0.003785	cubic meter (m^3)
million gallons (10^6gal)	3785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
	Flow	
foot per day (ft/d)	0.3048	meter per day (m/d)
square foot per day (ft^2/d)	0.0929	square meter per day (m^2/d)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3)/d
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
	0.02832	cubic meter per second (m^3/s)
million gallon per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
gallon/day (gal/d)	0.0038	cubic meter per day (m^3/d)

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ABSTRACT

Interpretation of available hydrologic data suggests that some areas underlying the Coastal Plain of the States of Delaware, Maryland, New Jersey, North Carolina and Virginia might be worthy of further study regarding the disposal of high-level radioactive waste in crystalline rock buried beneath the Coastal Plain sediments. The areas of major interest occur where the top of the basement rock lies between 1,000 and about 4,000 ft below sea level, the aquifer(s) immediately above the basement rock is (are) saturated with saline water, confining material overlies the saline-water bearing aquifer(s), and ground-water flow in the saline-water aquifer(s) can be estimated. These criteria define some of the more important geohydrologic factors necessary to help insure that any waste nuclides remain in the deep subsurface isolated from the freshwater-circulation system.

Four geohydrologic characteristics ((1) thickness of saline-water bearing sediments, (2) thickness of confining beds, (3) permeability of the aquifer(s) and (4) the lateral direction of ground-water flow) were used to make a preliminary evaluation of the hydrologic suitability of the sediments for the disposal of high-level radioactive wastes in crystalline rocks that lie beneath the area. The saline-water bearing sediments, which form a buffer zone between the crystalline rocks and the freshwater-circulation system, are more than 3,000 ft thick in eastern parts of the area. The estimated effective thickness of the confining beds that overlie the deepest saline-water bearing aquifers generally increases toward the east and averages between 100 and 300 ft in southern parts of the area and about 500 feet in the north. The permeability of the saline-water bearing aquifers that directly overlie the basement rock or occur in the lower part of the sedimentary section generally decreases toward the east. It is estimated that ground-water withdrawals from the lowermost aquifers have significantly decreased the freshwater pressure along more than 50 percent of the saline-water front within these aquifers. Consequently, water from parts of the saline-water zone has moved and may still be moving very slowly toward the centers of pumping.

When viewed collectively, the data suggest that eastern parts of the sediment mass best meet most of the preliminary criteria proposed for any potential buried crystalline-rock disposal site. Further study and test drilling will be needed to more accurately define the geology and hydrology and assess these preliminary findings for any specific area.

INTRODUCTION

Background

With a mandate from the Congress of the United States, the Department of Energy has been studying various waste-disposal and storage methods and physical environments to determine which are suited for the disposal of high-level radioactive wastes. One of the physical environments that has received much attention and study is that found in crystalline igneous or metamorphic rocks that are exposed at land surface. The crystalline rocks have been studied as potential sites for waste repositories because they (a) are easily mined, (b) are stable at fairly high temperatures, (c) have a reasonably high thermal conductivity, (d) have low permeability when not fractured and (e) are abundant on the continents (Bredehoeft and Maini, 1981).

Most crystalline rocks are fractured, however, and these fractures constitute a major disadvantage of the exposed crystalline-rock waste-storage environment. It is very difficult to predict the direction and rate of ground-water movement through a system of fractures with any reasonable certainty, because the orientation, spacing, interconnection and continuity of the fractures are difficult to characterize. Such knowledge is important because ground-water movement is the major vehicle for the possible migration of waste(s) at proposed repository sites on the continents.

By contrast, ground water in many sedimentary rocks occurs in and moves through pores and intergranular openings between the rock particles. The orientation, spacing and interconnection of these openings is regular and predictable; consequently, the rate and direction of ground-water movement in such sedimentary rocks is easy to characterize relative to that in fractured crystalline rocks, and the theory and methods of measurement are well-established. In sedimentary rock, under favorable hydrogeologic conditions, the flow paths are very long and the flow rates are very slow in the deep subsurface. Also, in many places, sedimentary rocks contain water with excessive concentrations of dissolved solids at depth, which minimizes the possibility of human intrusion. Pointing out these facts, Bredehoeft and Maini (1981) proposed the buried crystalline-rock concept in which a repository for nuclear waste might be developed in crystalline rock that is buried beneath a thick blanket of sedimentary rock. They emphasize that, with this approach, the major advantages of the crystalline rock (mineability, stability, and so forth) can be retained while the ability to predict the rate and direction of ground-water movement is increased substantially because a thick sequence of sedimentary rocks overlying crystalline rocks will dominate and control the ground-water flow regime.

This buried crystalline-rock concept was endorsed by the National Academy of Sciences in 1983 as worthy of further consideration. Thus, a study was conducted by the U.S. Geological Survey in 1983 (Davis, 1984), to determine the regions in the eastern part of the United States where the conditions described by Bredehoeft and Maini (1981) exist.

Davis (1984) used the following four criteria to summarize and describe the hydrogeologic conditions pertinent to the "thick blanket of sedimentary rocks" that Bredehoeft and Maini (1981) proposed for their buried crystalline-rock concept:

1. The top of the crystalline basement rock is 1,000 to 4,000 ft below land surface.

2. The crystalline rock is overlain by sedimentary rock whose lowermost part, at least, contains ground water with a dissolved-solids concentration of 10,000 mg/L (milligrams per liter) or more.

3. Shale or clay confining beds overlie the saline-water aquifer. (Saline water contains dissolved-solid concentrations of 10,000 mg/L or more).

4. The flow system in the saline-water aquifer is known or determinable from presently available data.

Application of these criteria in the eastern part of the United States revealed two regions that meet most of the criteria and are suitable for further study -- the Atlantic Coastal Plain and the Cincinnati arch. The northern Atlantic Coastal Plain is the subject of this report.

Location of Study Area

The study area includes about 50,000 mi^2 in the northern part of the Atlantic Coastal Plain province extending from the North Carolina-South Carolina State line through New Jersey (fig. 1). Fifty percent of the area lies in North Carolina, 23 percent in Virginia, 13 percent in Maryland, 11 percent in New Jersey, and the remaining 3 percent in Delaware.

Purpose and Scope

The purpose of this report is to present, summarize and evaluate the existing knowledge about the ground-water hydrology of the Coastal Plain sediments relevant to the suitability for disposal of high-level radioactive wastes in underlying crystalline rock. Particular emphasis is given to those parts of the Coastal Plain sediments that best meet the conditions that were outlined by Davis (1984) and were previously listed in this report. Cross sections are used to illustrate and describe the general geohydrologic conditions that occur with depth along a number of selected lines that cross the study area. Maps are used to illustrate and describe the general areal distribution of selected geohydrologic conditions in the study area.

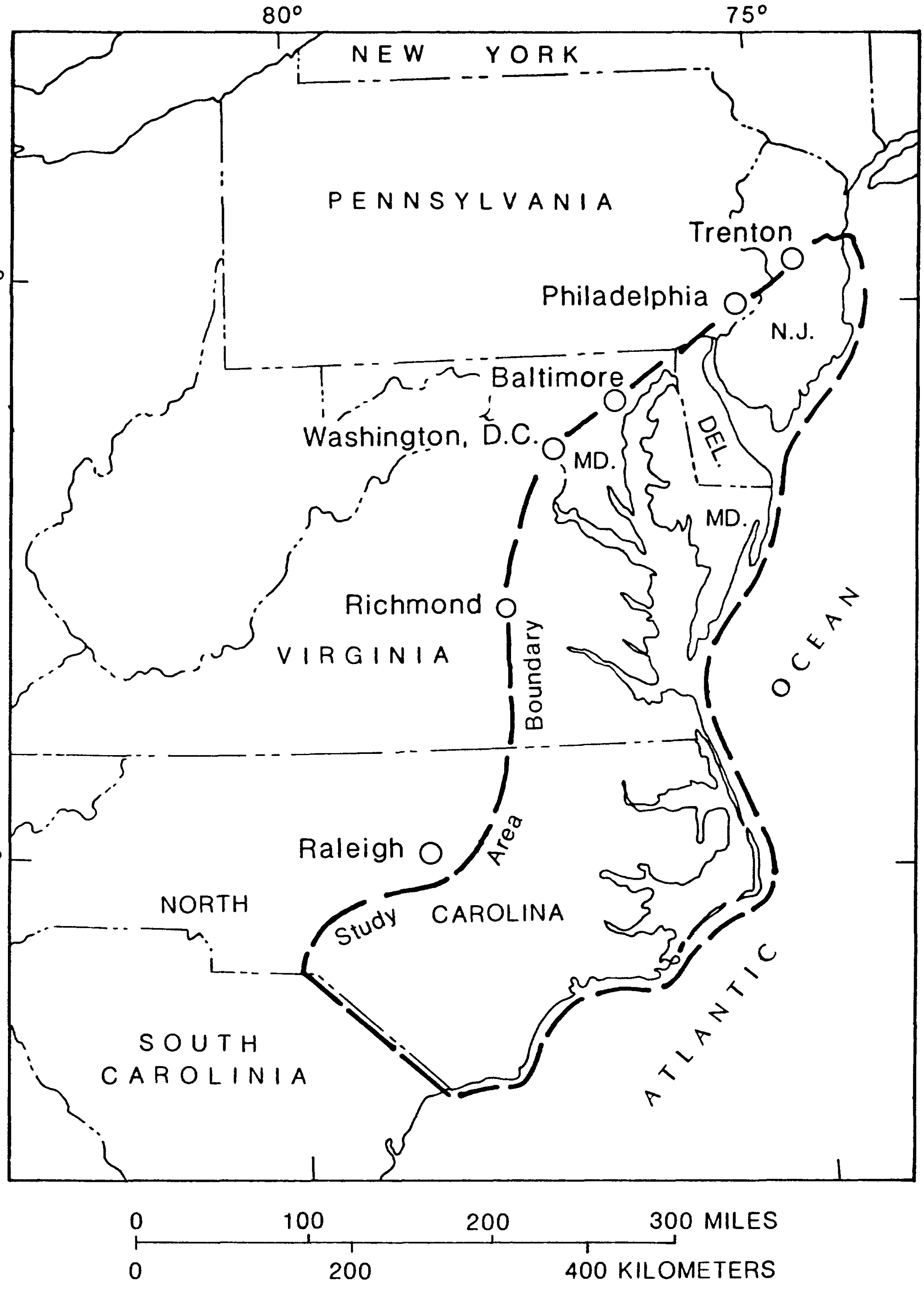


Figure 1.--Location of study area.

Previous Investigations

Published reports by Brown, Miller and Swain (1972), Brown and others (1979), Brown and Reid (1976), Cushing, Kantrowitz and Taylor (1973), Gohn and others (1978), Gohn (1983), Hazel and Brouwers (1982), Maher (1971), Martin (1984), Meisler (1980b; and written communication, 1984), Meisler, Leahy and Knobel (1985), Meng and Harsh (1984), Rankin (1977), Sohl and Christopher (1983), Trapp and others (1984), Valentine (1982) and Zapecza (1985) are among the many useful publications that describe the geologic and hydrologic characteristics of the Atlantic Coastal Plain sediments in and near the study area. Work done for the U.S. Geological Survey study entitled "Regional Aquifer System Analysis (RASA) of the northern Atlantic Coastal Plain" proved invaluable during the present investigation.

Methods of Investigation

From published and unpublished geologic, hydrologic and water-quality data, the staff members of the RASA study have divided the northern Atlantic Coastal Plain sediments into 10 regional aquifers separated by regional confining beds. The emphasis of the RASA study is on the freshwater part of the sedimentary section. However, the regional geohydrologic framework was extended to the east of the freshwater/saline-water interface providing some data for the area where the sediments contain saline water and the top of the basement rocks lie between 1000 ft and about 4000 ft below sea level.

Within the limits of the data distribution and the measurement and interpretation accuracy, the staff members of the RASA study prepared maps depicting the depth to the top, thickness, transmissivity, potentiometric surface, and chloride concentration of ground water for the appropriate units. These data are being used as input for finite-difference ground-water flow models for each State and for the entire region.

The data for the discussions and illustrations in this report are derived primarily from the preliminary maps and reports of the staff of the RASA study. Data for the geohydrologic framework, transmissivity, hydraulic conductivity, head and saline-water distribution are from regional maps compiled by the regional staff of the RASA study -- Harold Meisler (Project Chief), Henry Trapp, Jr., Phillip P. Leahy, Mary M. Martin, and LeRoy Knobel (U.S. Geological Survey, Trenton, New Jersey). The bulk of the data for the regional maps are from state maps constructed by District staff members of the RASA study -- Maurice D. Winner, Jr., Gerald L. Giese and Ronald W. Coble (U.S. Geological Survey, Raleigh, North Carolina); Andrew A. Meng, III, John F. Harsh, and Randall J. Laczniak (U.S. Geological Survey, Richmond, Virginia); Donald A. Vroblesky and William B. Fleck (U.S. Geological Survey, Towson, Maryland); Mary M. Martin and Otto S. Zapecza (U.S. Geological Survey, Trenton, New Jersey).

Originally, the data came from wells drilled for water supply, stratigraphic tests, and oil and gas exploration. The distribution of many of the deep wells in the area is shown in plate 1, and the kinds of data available for these wells are listed in table 4 in the back of this report. The wells shown on plate 1 are numbered consecutively within each state.

A series of cross sections were constructed from the data, and are used to show the general geohydrologic conditions at selected places throughout the study area.

Four geohydrologic characteristics were chosen to summarize and evaluate the hydrology of the sediments relevant to the potential suitability for the disposal of high-level radioactive wastes in any crystalline rock that may lie beneath the study area. The geohydrologic characteristics used for the evaluation are the estimated:

1. thickness and distribution of sediments containing saline water and brine,
2. thickness of the confining beds overlying the two lowermost aquifers,
3. water-transmitting ability of the two lowermost aquifers, and
4. direction of lateral ground-water flow in the two lowermost aquifers.

Maps of most of these characteristics were prepared and the relation between the long-term isolation of high-level radioactive waste and each characteristic is discussed individually. Data are insufficient to prepare a map for the water-transmitting ability of the two lowermost aquifers where these aquifers contain saline water or brine.

Acknowledgements

The staff members of the RASA study of the northern Atlantic Coastal Plain are thanked for the invaluable basic data and interpretative contributions they made to this study.

GEOHYDROLOGY

General Geology and Hydrologic Framework

The basement complex, as discussed in this report, is composed primarily of igneous and metamorphic rocks of Precambrian and Paleozoic age (American Association of Petroleum Geologists, 1983), with subordinate igneous and sedimentary rocks of Triassic and Early Jurassic age. The basement rocks crop out at the western edge of the Coastal Plain near the Fall Line (pl. 1), and their eroded surface dips to the east beneath the Coastal Plain sediments. The general configuration of the basement surface is shown in figure 2.

The sedimentary rocks that overlie the basement complex are composed primarily of interbedded layers of sand, silt, clay, shale and limestone that range in age from Late Jurassic(?) to Holocene. In aggregate, these rocks form a wedge-shaped mass that thickens from a featheredge at the Fall Line to as much as 10,000 ft at Cape Hatteras, North Carolina. Different stratigraphic and structural interpretations have been proposed to explain the internal arrangement or geometry of the rocks that comprise this sediment mass. Examples of the different interpretations are given in accounts by Brown, Miller and Swain (1972), and Owens and Gohn (1984).

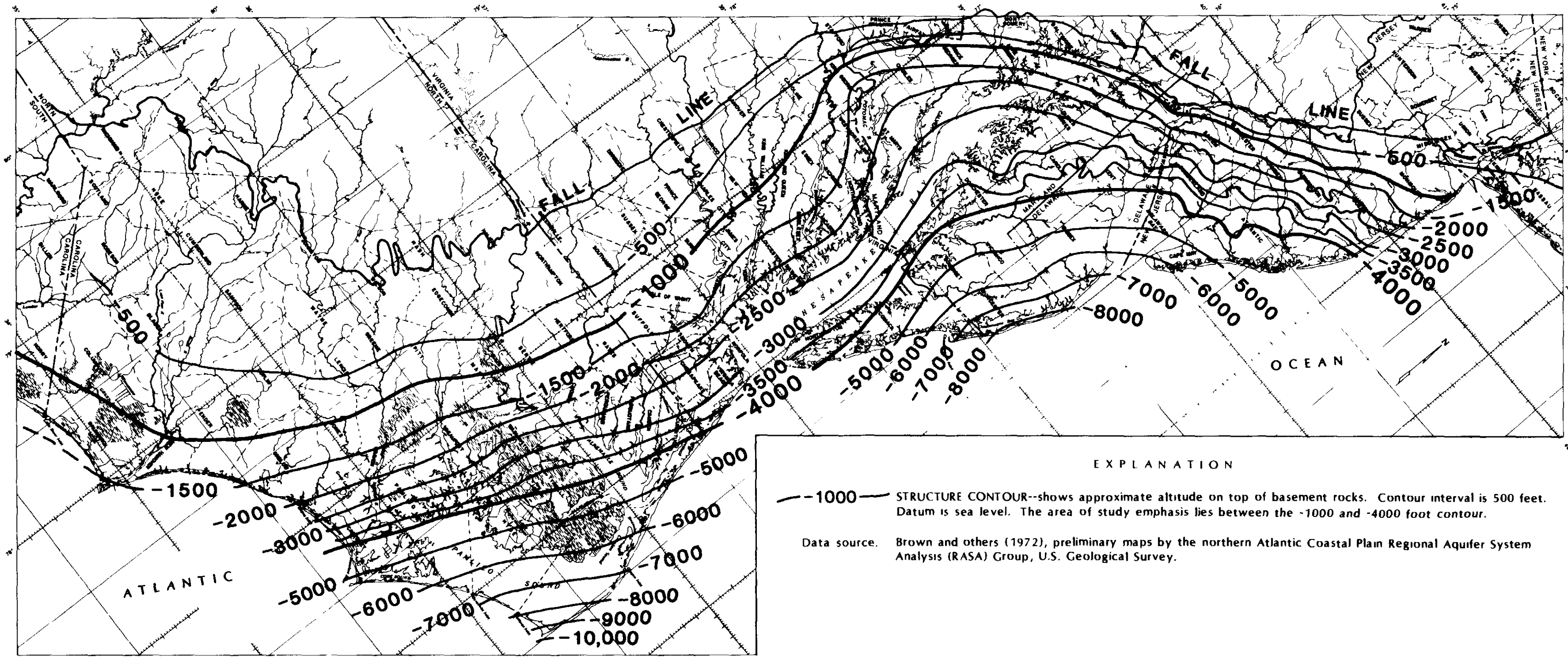


Figure 2.--Approximate altitude of basement surface in parts of the northern Atlantic Coastal Plain.

The different interpretations range from a maximum to a minimum reliance on various types of tectonic and structural control to explain the spacial and temporal distribution of the rock types or facies that comprise the Coastal Plain sediments. The amount and kind of structure displayed or postulated is dependent on the stratigraphic or structural interpretations made by the different authors.

Structures that would have the most significant influence on the application of the buried crystalline-rock concept in the northern Atlantic Coastal Plain are vertical or near vertical faults that cut the sediment mass. Many such faults have been proposed, and a few have been documented with direct and indirect evidence in outcrops and places where the Coastal Plain sediments are relatively thin, but the occurrence and distribution of such faults is difficult to substantiate in the subsurface owing to the lack of data.

Because of this lack of data, and the regional nature of the RASA study, the geohydrologic framework devised by the RASA staff members was constructed without faults. More data are needed to map the occurrence and distribution of any vertical faults that may occur in the subsurface and to evaluate their influence on the hydrology of the area.

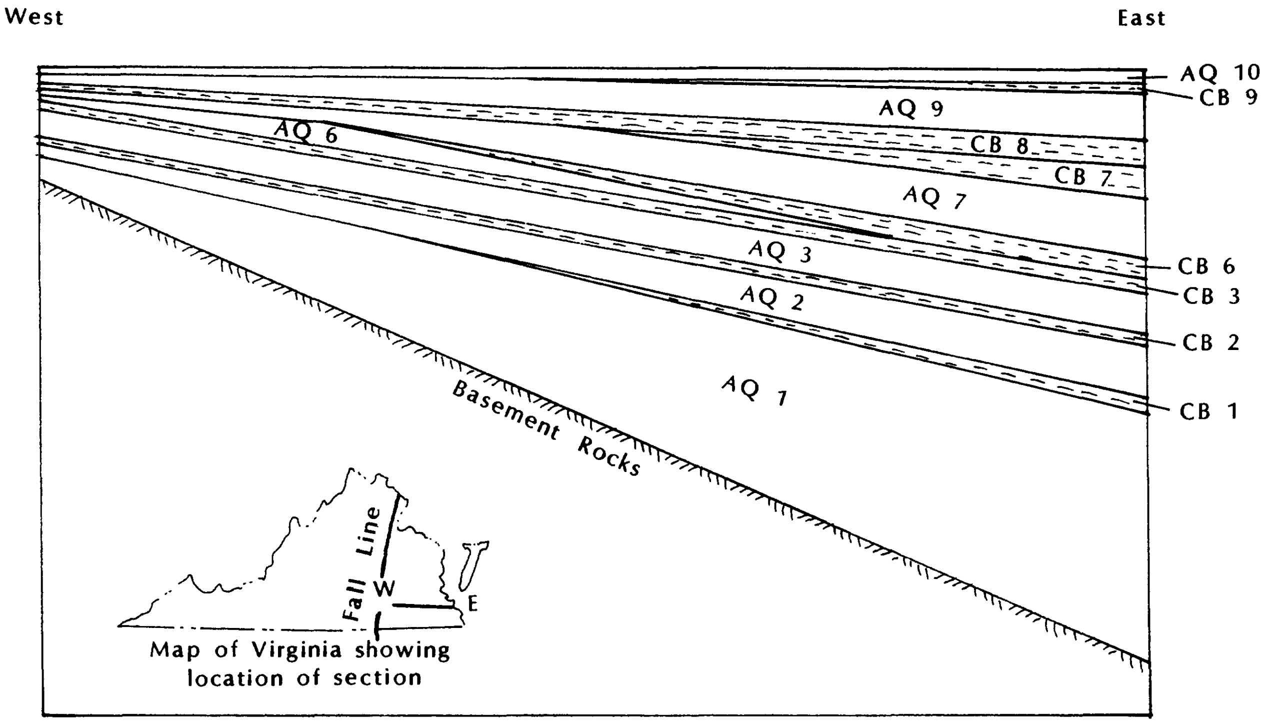
The sediments in the northern part of the Atlantic Coastal Plain have been divided according to their lithology or age into a number of mappable units by different workers. Table 1 shows the general relation between some of the stratigraphic units, and the regional aquifers and confining beds (geohydrologic units that were established by the RASA staff members). The aquifers were established by studying the available data and estimating the boundaries of a formation, group of formations or parts of formations that contain a preponderance of saturated permeable material (sand and limestone in the study area) that will yield significant quantities of water to wells. An aquifer may be composed of interconnected saturated permeable materials of different age. In general, the aquifers are stratigraphically adjacent to confining beds that are composed of a preponderance of impermeable material (silt and clay in the study area). Impermeable is used as a relative term here and refers to the water-transmitting ability of confining beds, which is distinctly lower than that of the aquifers. A confining bed, like an aquifer, may be composed of materials of different age.

The geohydrologic units have been numbered 1 through 10 from oldest to youngest, respectively. Figure 3 illustrates the general distribution of the aquifers, confining beds, and the underlying basement rock in a diagrammatic cross section drawn from the west-central part of the Coastal Plain of Virginia to the ocean. As shown in figure 3, not all aquifers and confining beds are present at any one place, and different combinations and distributions of these hydrologic units occur at different places in the study area.

Table 1.--Generalized correlation chart of some stratigraphic and geohydrologic units in parts of the northern Atlantic Coastal Plain.

SYSTEM	SERIES	Aquifer (AQ) and confining bed (CB)	NORTH CAROLINA	Aquifer (AQ) and confining bed (CB)	VIRGINIA	Aquifer (AQ) and confining bed (CB)	MARYLAND	Aquifer (AQ) and confining bed (CB)	DELAWARE	Aquifer (AQ) and confining bed (CB)	NEW JERSEY
QUATERNARY	HOLOCENE	AQ 10	UNDIFFERENTIATED	AQ 10	UNDIFFERENTIATED	AQ 10	UNDIFFERENTIATED	AQ 10	UNDIFFERENTIATED	AQ 10	UNDIFFERENTIATED
QUATERNARY	PLEISTOCENE	AQ 10	UNDIFFERENTIATED	AQ 10	UNDIFFERENTIATED	AQ 10	SINEPUXENT FORMATION; PARSONSBURG SAND; KENT IS; IRONSHIRE FM; OMAR FORMATION	AQ 10	SINEPUXENT FORMATION; PARSONSBURG SAND; KENT IS; IRONSHIRE FM; OMAR FORMATION	AQ 10 CB 9	CAPE MAY FORMATION
TERTIARY	PLIOCENE	CB 9 AQ 9	YORKTOWN FORMATION	CB 9 AQ 9 AQ 9	YORKTOWN FORMATION		WALSTON SILT BEAVERDAM SAND		WALSTON SILT BEAVERDAM SAND		
TERTIARY	MIOCENE	AQ 9 CB 8 CB 8 AQ 8 CB 7 CB 7	EASTOVER FORMATION PUNGO RIVER FORMATION BELGRADE FORMATION	AQ 9 CB 8 CB 8 AQ 8 CB 7 AQ 7	EASTOVER FORMATION ST MARYS FORMATION CHOPTANK FORMATION CALVERT FORMATION OLD CHURCH FORMATION	AQ 10 CB 9 AQ 9 CB 8 AQ 8 CB 7 CB 7 AQ 7	CHESAPEAKE GROUP: BRANDYWINE FM; EASTOVER FORMATION; ST MARYS FORMATION; CHOPTANK FORMATION; CALVERT FORMATION OLD CHURCH FORMATION	AQ 10 CB 9 AQ 9 CB 8 AQ 8 CB 7 CB 7 AQ 7	PENNSAUKEN FORMATION CHESAPEAKE GROUP UNDIFFERENTIATED OLD CHURCH FORMATION	AQ 9 AQ 9 CB 8 AQ 8 CB 7 CB 7	PENNSAUKEN FORMATION BRIDGETON FORMATION CHANSEY SAND; BEACON HILL GRAVEL KIRKWOOD FORMATION OLD CHURCH FORMATION
TERTIARY	OLIGOCENE	AQ 7	RIVER BEND FORMATION							CB 7	UNNAMED BEDS
TERTIARY	EOCENE	AQ 7 CB 6	CASTLE HAYNE FORMATION	AQ 7 AQ 7 CB 6	CHICKAHOMINY FM PINEY POINT FORMATION NANJEMOY FORMATION MARLBORO CLAY	AQ 7 AQ 7 CB 6	PINEY POINT FORMATION NANJEMOY FORMATION MALBORO CLAY	AQ 7 AQ 7 CB 6	PINEY POINT FORMATION NANJEMOY FORMATION	AQ 7 CB 6	PINEY POINT FORMATION SHARK RIVER FORMATION
TERTIARY	PALEOCENE	CB 6 AQ 6 CB 5	BEAUFORT FORMATION	AQ 6 CB 3 AQ 3S	AQUIA FORMATION BRIGHTSEAT FORMATION	AQ 6 CB 3 AQ 3S CB 5	RANCOCAS GROUP: AQUIA FORMATION; BRIGHTSEAT FORMATION	AQ 6 CB 3 AQ 3S CB 5	RANCOCAS GROUP: AQUIA FORMATION; BRIGHTSEAT FORMATION	AQ 6 CB 5	RANCOCAS GROUP: MANASQUAN FORMATION; VINCENTOWN FORMATION; HORNERSTOWN SAND
CRETACEOUS	UPPER CRETACEOUS	AQ 5 CB 4 AQ 4 CB 3 AQ 3S CB 2 AQ 2	PEEDEE FORMATION BLACK CREEK AND MIDDENDORF FORMATIONS CAPE FEAR FORMATION	CB 3 CB 3 AQ 3S	UNDIFFERENTIATED	CB 5 AQ 5 CB 4 AQ 4 CB 3 AQ 3N	SEVERN FORMATION; MT LAUREL SAND MATAWAN FORMATION MAGOTHY FORMATION	AQ 5 AQ 4 CB 3 CB 3 AQ 3N CB 2	MOUNT LAUREL SAND MARSHALLTOWN FM; ENGLISHTOWN FM; WOODBURY CLAY; MERCHANTVILLE FM MAGOTHY FORMATION	CB 5 AQ 5 CB 4 AQ 4 CB 3 AQ 3 CB 2 AQ 2 CB 1	MONMOUTH GROUP MARSHALLTOWN FM; ENGLISHTOWN FM; WOODBURY CLAY; MERCHANTVILLE FM MAGOTHY FORMATION RARITAN FORMATION
CRETACEOUS	LOWER CRETACEOUS	CB 1 AQ 1	? — ? — ? UNNAMED BEDS	CB 2 AQ 2 CB 1 AQ 1	POTOMAC FORMATION WASTE GATE FM OF HANSEN (1982)	CB 2 AQ 2 CB 1 AQ 1	POTOMAC GROUP: PATAPSCO FORMATION; ARUNDEL FORMATION; PATUXENT FORMATION WASTE GATE FM OF HANSEN (1982)	AQ 2 CB 1 AQ 1	POTOMAC FORMATION WASTE GATE FM OF HANSEN (1982)	AQ 1	POTOMAC FORMATION
JURASSIC (?)	UPPER JURASSIC (?)	?	UNNAMED BEDS	?	UNNAMED BEDS	?	UNNAMED BEDS	?	UNNAMED BEDS	?	UNNAMED BEDS
Basement rock may be composed of subordinate amounts of Jurassic (?) and Triassic sedimentary rocks, but primarily consists of Paleozoic and Precambrian igneous and metamorphic rocks.		BASEMENT COMPLEX									

Note: Chart adapted from a correlation chart by Henry Trapp, Jr. (U.S. Geological Survey written commun., 1985).
AQ 3S is Brightseat-Upper Potomac aquifer
AQ 3N is Magothy aquifer



RASA model aquifers (AQ) and confining beds (CB).

Note: Not to scale and the vertical dimension is greatly exaggerated. Dip of the basement surface ranges from about 25 feet per mile near the Fall line to about 150 feet per mile near the coast.

Figure 3.--Diagrammatic cross section showing aquifers, confining beds and the basement complex across the Coastal Plain of Virginia.

The geohydrologic units of greatest importance to this study are those that comprise the two lowermost aquifers and confining beds--the units for which the least amount of data exists. These lowermost units are composed of aquifers 1 and 2 (or 2 and 3 in places where aquifer 1 is missing) and confining beds 1 and 2 (or 2 and 3 in places where confining bed 1 is missing). In general, most of the sediments that comprise these older units were deposited in nonmarine to marginal marine environments (see Unit D through Unit I in Brown, Miller, and Swain, 1972, pl. 3) and their lithologies change rapidly both laterally and vertically. Interpretations of geophysical logs and drill cuttings of these rocks indicate that significant amounts of silt and clay occur in the sand aquifers, and that many individual sand, silt and clay beds are lenticular and discontinuous. These characteristics and the paucity of data combine to make it difficult to define and correlate these geohydrologic units from one place to another. Consequently, some differences in interpretation of the thickness and extent of the lowermost aquifers and confining beds may occur from one state to another.

Most of the younger units (aquifers and confining beds 4 through 10) have somewhat more consistent and continuous lithologies because they are comprised of sediments that have been deposited in near-marine and marine environments. These younger units contain freshwater in large part.

Aquifer and Confining-Bed Characteristics

The aquifers in the northern Atlantic Coastal Plain are composed predominantly of sands and silty sands; however, limestone constitutes aquifer 7 in the central and southern parts of the North Carolina Coastal Plain (M. D. Winner, U.S. Geological Survey, written commun., 1984). In the area where the top of the basement complex lies between 1,000 and about 4,000 ft below sea level (fig. 2), the thicknesses of aquifers 1, 2 and 3 vary from place to place but their aggregate thickness may comprise about one-half of the total sedimentary section in the eastern part of the study area. These lower aquifers are generally found throughout the study area except in southeastern North Carolina where aquifer 1 is missing (M. D. Winner, U.S. Geological Survey, written commun., 1984). Some of the shallower aquifers are missing over large parts of the study area.

The transmissivity of the aquifers (their ability to transmit water) was calculated by district staff members of the RASA study -- M. D. Winner and R. W. Coble in North Carolina, A. A. Meng and J. F. Harsh in Virginia, D. A. Vroblesky in Maryland and Delaware, and O. S. Zapecza in New Jersey -- by multiplying estimates of the hydraulic conductivity and thickness of the aquifer material at any one place. In general, these calculations were made only where the aquifers contain water with chloride concentrations less than 10,000 mg/L. The hydraulic conductivity and thickness estimates were made from an analysis of aquifer-test data, lithologic logs compiled by drillers and geologists, and geophysical electric and gamma-ray logs. The hydraulic conductivity of the bulk of the aquifer material is estimated to range from about 5 ft/d for the silty sand to about 100 ft/d for limestone and the coarser, well-sorted sand.

Depending on the estimates of aquifer thickness and hydraulic conductivity, the transmissivities of the aquifers range from less than 7,000 ft^2/d to greater than 21,000 ft^2/d. For the purpose of displaying the general water-transmitting ability of the aquifers in cross section, the transmissivity values were divided into 4 groups: low - less than 7,000 ft^2/d, medium - 7,000 to 14,000 ft^2/d, medium high - 14,000 to 21,000 ft^2/d, and high - greater than 21,000 ft^2/d.

Those few hydraulic conductivity and transmissivity data that do exist for the deeper saline-water bearing parts of the section indicate a rather low water-transmitting capacity. For example, Trapp and others (1984) calculate the average horizontal hydraulic conductivity to be about 12 ft/d for sands in aquifer 1 that lie between about 3180 and 3210 ft below sea level in well MD-42 (pl. 1 and table 4). In addition, the average horizontal hydraulic conductivity is reported to be less than 1 ft/d for sands in aquifer 1 that lie between about 3890 and 4020 ft below sea level in well MD-82 (Hansen, 1982; and pl. 1 and table 4).

Also, Brown and others (1972, pls. 7-9) indicate that the relative intrinsic permeability of basal chronostratigraphic (time-rock) units ranges from moderate to very low and generally decreases toward the east. These trends generally hold for areas where both the basal chronostratigraphic unit lies directly on basement rock and the top of the basement rock lies between 1,000 and about 4,000 ft below sea level. The chronostratigraphic units mapped by Brown and others (1972) differ from the geohydrologic units mapped during the RASA study, and the data cannot be correlated directly with the RASA aquifers and confining beds. Therefore, the intrinsic permeability data are not mapped on the cross sections shown in plates 2 through 15. However, the general trends are very useful in the absence of abundant hydraulic conductivity and transmissivity data for the saline-water bearing aquifers.

The confining beds are composed primarily of clay and silt. In the area where the top of the basement complex lies between 1,000 and about 4,000 ft below sea level, the estimated aggregate thickness of confining beds 1, 2 and 3 generally increases from between 100 and 300 ft in the southern and northernmost parts of the area, to as much as 1,000 ft near the Delaware Bay. Confining beds 4 and 5 are missing mainly in Virginia (Meng and Harsh, 1984; and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984) and southern Maryland (D. A. Vroblesky, and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984), and confining beds 1 and 6 through 9 are missing in the southern part of North Carolina (M. D. Winner, U.S. Geological Survey, written commun., 1984). The hydraulic conductivity of the bulk of the confining-bed material is estimated to range from $1x10^{-3}$ to $1x10^{-5}$ ft/d.

The ratio of the horizontal to the vertical hydraulic conductivity in the entire sediment mass could range from 1,000:1 to 1,000,000:1. Meisler, Leahy and Knobel (1985) indicate 30,000:1 is a realistic average ratio for the sediments in the Coastal Plain in New Jersey; and G. L. Giese, (U.S. Geological Survey, oral commun., 1984) suggests an average ratio of 10,000:1 is reasonable for the sediments in the Coastal Plain in North Carolina.

Distribution of Fresh and Saline Water

In general, the aquifer and confining units are saturated with freshwater in the upper part of the sediment mass and with saline water and brine in the lower part. The term "saline water", as used in this report, refers to ground water with chloride concentrations of between 5,000 and 18,000 mg/L. These are the approximate chloride concentrations that are found in ground water with total dissolved-solids concentrations of 10,000 mg/L (relatively nonusuable ground water) and 33,000 mg/L (almost seawater concentrations), respectively. The term "brine", as used in this report, refers to ground water with chloride concentrations greater than 18,000 mg/L.

The source of the freshwater is precipitation. The source of the saline water is presumed to be some combination of fresh ground water and the seawater in which the sediments were deposited or by which they were later invaded. The contact or interface between the freshwater and saline water in the sediment mass is actually a transition zone that may be as thick as 2,300 ft (measured vertically) between the 250 and 18,000 mg/L chloride concentrations (Meisler, 1980b). (The 250 mg/L chloride concentration is used as a potable water standard).

The chloride concentration in the saline water generally continues to increase and reaches brine concentrations with depth. The water-quality data in table 2 are from chemical analyses of water samples collected from deep wells tapping the Coastal Plain sediments in Maryland, North Carolina and Virginia. These data indicate that chloride concentrations in the ground water at 4,000 ft below sea level can be more than twice that found in seawater, and at 6,500 to 7,000 ft below sea level the chloride concentrations can be more than four times that found in seawater. The brine may be derived from the solution of evaporite sediments (Meisler and others, 1985) or ionic filtration by shales during the process of sediment compaction (Bredehoeft and others, 1963; and Groot, 1983).

Table 2.--Chloride content of ground-water samples and sea water

Source of water	Depth at which sample was collected (feet below sea level)	Chloride concentration in water (milligrams per liter)	Data source
Moore's Bridges Filter Plant Well (USGS TW1), Norfolk, Va.	2,500	27,000	Brown (1971)
Crisfield Airport and Janes Island Wells, Dorchester County, Md.	4,000	42,000	Meisler (1980b)
Mobil Oil No. 2 Dare County, N.C. DA-OT-12	6,500	80,000	Petroleum Information Corporation
Standard Oil of New Jersey, Esso No. 1 or	6,500	71,000	Maher (1971)
Hatteras Light well Dare County, N.C. DA-OT-10	7,000	79,000	do.
Seawater	-----	19,000	Hem (1970)

a/ Rounded to nearest 100
b/ Rounded to nearest 1000
c/ Petroleum Information Corporation, Midland, Texas (data files).

Hydraulic Heads, Ground-Water Movement and the Position of the Freshwater/Saline-Water Interface

Part of the precipitation that falls on the Coastal Plain infiltrates the land surface, reaches the water table, which is the upper surface of the saturated zone, and enters the ground-water system. "Water enters the ground-water system in recharge areas and moves through them, as dictated by hydraulic gradients and hydraulic conductivities, to discharge areas. In the humid part of the country, recharge occurs in all interstream areas -- that is, in all areas except along streams and their adjoining flood plains. The streams and flood plains are, under most conditions, discharge areas," (Heath, 1983, p. 14).

About 9 to 20 inches of the average annual precipitation (about 46 inches) that falls on the Coastal Plain infiltrates the land surface, and enters the ground-water system. More than 90 percent of this ground water moves through the shallow unconfined aquifers (those aquifers located above the shallowest confining beds) to nearby discharge areas (streams, esturaies, or the ocean). Less than 10 percent of the ground water moves downward across confining beds, into and through the deeper confined aquifers (those aquifers located beneath confining beds) to distant discharge areas.

Water moves through the ground-water system in response to gravity, from areas where hydraulic heads are high to areas where they are low. Hydraulic heads in shallow aquifers in interstream areas are higher than heads in the same aquifers adjacent to nearby streams. Thus, the ground water flows from the interstream areas and discharges in the streams.

Ground water moves into, through, and out of the deeper aquifers in response to hydraulic-head differences also. Before man started to withdraw large amounts of ground water from the aquifers in the area, estimated head values in the western parts of the Coastal Plain ranged from an average of about 100 ft above sea level in the shallowest aquifers to about 80 ft above sea level in the deepest aquifers. In the coastal parts of the area, heads ranged from an estimated average of about 25 or 30 ft above sea level in the deepest aquifers to only a few feet above sea level in the shallow aquifers. Thus, some ground water flowed from the shallow aquifers downward across confining beds to the deeper aquifers in the western part of the area, then laterally toward the east, and upward across confining beds to shallower aquifers near the coast, and eventually to streams and estuaries, or the ocean. These conditions prevailed around the turn of the century and are illustrated and discussed for different places in the study area later in this report in the section entitled "Geohydrologic Cross Sections".

The freshwater circulation has flushed the saline water from parts of the sedimentary rocks, and a transition zone or interface occurs between the fresh and the saline water (fig. 4). Under equilibrium conditions, and assuming the interface is a rather sharp boundary, the freshwater pressure would be balanced by the pressure of the more dense saline water at any point along the interface. Under these conditions, the interface would remain stationary. However, changes in the freshwater and saline-water pressure have produced imbalances that cause the interface to move either landward or seaward toward a new equilibrium position. Such pressure changes and movements have occurred and are still occurring because of large and increasing ground-water withdrawals from the aquifers and sea-level changes that have occurred in the past.

Regarding sea-level changes, Meisler, Leahy and Knobel (1985) have concluded that the present interface position in the Coastal Plain of New Jersey "probably reflects a long-term average sea level of between 50 and 100 ft below the present sea level". Thus, they postulate that the position of the interface off the New Jersey coast is moving slowly landward at the rate of about 0.2 of a mile per 10,000 years. These estimates were made from finite-difference computer model simulations. Further, Meisler, Leahy and Knobel (1985) postulate that the broad transition zone between the freshwater and saline water is the result of mixing during alternating landward and seaward movements of the interface in response to eustatic sea-level changes in the past.

Regarding the ground-water withdrawals, table 3 indicates the modern-day quantities that are being pumped from wells screened in the Coastal Plain aquifers -- over 1 billion gallons per day in 1980 (Harold Meisler, U.S. Geological Survey, oral commun., 1985). Most of the large withdrawals are concentrated in urban and industrial areas where they have resulted in declining water levels (heads) and the development of large cones of depression. Hydraulic heads have decreased as much as 200 ft or more at some of the pumping centers and 50-foot declines are very common. Both single and multiple coalescing cones of depression have spread over broad areas of up to 5,000 mi^2 or more (Meisler, 1980a). About 40 percent of the total estimated ground-water withdrawal is pumped from wells that tap aquifers 1, 2 and 3 (table 3), which lie directly on basement rock or primarily occur in the lower half of the sediment mass. The cones of depression have spread to areas where these aquifers contain saline water in many places in the eastern part of the Coastal Plain. Thus, it can be expected that the position of the interface and water from the saline-water zone has moved and may still be moving very slowly landward throughout most of the area in response to the decreased freshwater pressure caused by the large ground-water withdrawals (see "Geohydrologic Cross Sections" part of text).

In homogeneous aquifers that are saturated with water of constant or nearly constant density, a head difference between two points (a hydraulic gradient) will indicate flow, and flow volumes and velocities can be calculated within aquifers and across confining beds from one aquifer to another using general equations that are expressions of Darcy's Law (Lohman, 1972, p. 10-13).

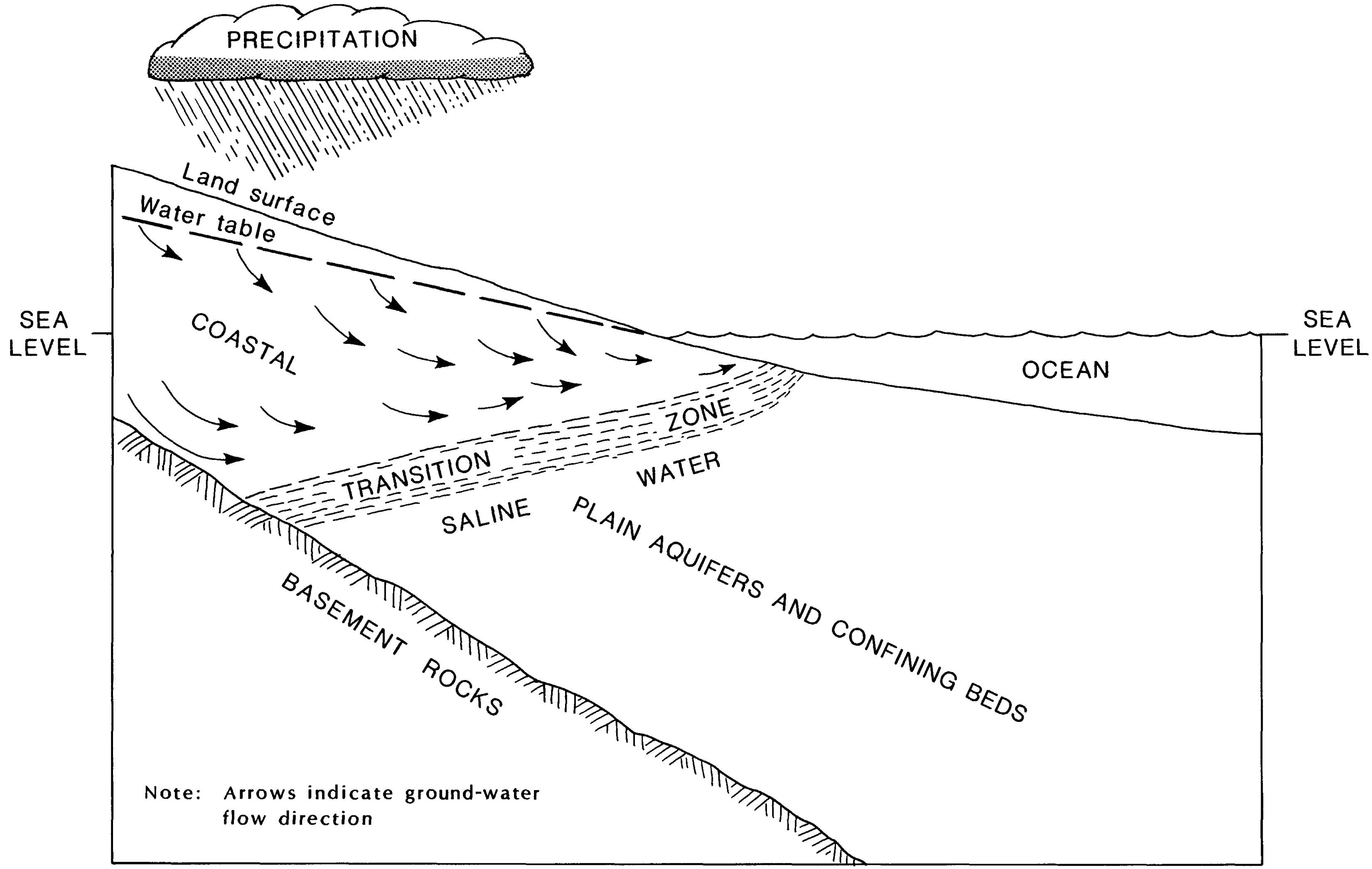


Figure 4.--Diagrammatic cross section showing relation of freshwater and saline water in the Coastal Plain sediments.

Table 3.--Estimated ground-water withdrawals from Coastal Plain rocks in 1980

NACP RASA Aquifer Units	Estimated ground-water withdrawals fromn the aquifers in the Coastal Plain (in millions of gallons per day)				
	Delaware, District of Columbia and Maryland	New Jersey	North Carolina	Virginia	Total
4-10	130	155	225	90	600
3	10	85	12	20	127
2	33	90	3	60	186
1	32	70	0	15	117
Total by area	205	400	240	185	1030

Data source: William B. Fleck (Delaware, District of Columbia and Maryland), Mary M. Martin (New Jersey), Gerald L. Giese (North Carolina), Randall J. Laczniak (Virginia), and Harold Meisler, U.S. Geological Survey, oral commun., 1985.

[a] NACP RASA - Northern Atlantic Coastal Plain Regional Aquifer System Analysis

However, in an aquifer system where the density of the water varies greatly in space, such as in the northern Atlantic Coastal Plain sediments (Meisler, 1985), the apparent hydraulic gradients calculated from uncorrected measured heads may be caused, in large part, by variations in density and will not necessarily cause proportionate ground-water flow. Even if accurate head data were available, further complications are caused by the heterogeneous and anisotropic nature of large parts of many of the aquifers in the area. Interspersed silt and clay particles and lenticular bodies of silt and clay that occur within aquifers 1, 2 and 3, can cause local flow directions to be something other than perpendicular to generalized equipotential lines or lines of equal head (Freeze and Cherry, 1979, p. 177-178).

Head corrections to account for varying water density, and an accurate determination of flow direction and velocity require a rather detailed knowledge of the distribution of formation facies and attendant porosity and permeability, pressure or head, water temperature and water density (Hubbert, 1953; and Lusczynski and Swarzenski, 1966). The distribution and combinations of data needed to determine these factors on a meaningful scale are lacking at places in the freshwater part of the system and, by comparison, are practically nonexistent where the sediments contain water with chloride concentrations greater than 10,000 mg/L. Thus, it is presently impossible to determine the exact hydraulic gradient and direction of ground-water flow in the aquifers that contain saline water and brine.

Consequently, the estimates of hydraulic gradient and flow direction shown in this report for sediments containing saline water are very qualitative and only indicate approximate magnitudes and directions. Estimates of ground-water flow velocity are deferred until more geologic data and concurrent head and water-quality data can be obtained for the deep part of the system. If and when these data are obtained, the most practical means for estimating flow velocities in an aquifer system with variable water density and heterogeneous, multi-layered framework characteristics is with the aid of appropriate ground-water flow models.

Geohydrologic Cross Sections

Fourteen cross sections are used to define the geohydrologic environment in the Coastal Plain sediments at selected places primarily where the basement rocks lie between 1,000 and about 4,000 ft below sea level (fig. 2). The locations of the lines of section are shown in plate 1.

The diagrammatic representation of the aquifers and confining beds in the sections generally reflects the hydrologic framework as it is delineated for data input to the ground-water flow models of the northern Atlantic Coastal Plain regional aquifer study (Henry Trapp, Jr., G. L. Giese, R. J. Laczniak, W. B. Fleck, M. M. Martin, and P. P. Leahy, U.S. Geological Survey, written commun., 1984). The geology and hydrology is much more complex than illustrated, particularly for the oldest aquifers and confining beds. However, a generalized framework is used because the paucity of data precludes detail. Consequently, the depiction of the hydrology such as hydraulic heads, ground-water movement, aquifer distribution, thickness and transmissivity, and confining-bed distribution and thickness is generalized also.

The 5,000 and 18,000 mg/L chloride-concentration lines on the sections illustrate the general distribution and configuration of part of the transition zone between freshwater and saline water in the sediment mass. In most cases, these data were taken directly from chloride maps by Meisler (U.S. Geological Survey, written commun., 1984, and 1980b), and were transferred to the cross sections without regard for displacement of concentration lines that may occur in response to variations in the ground-water flow pattern resulting from differences between aquifer and confining-bed hydraulic conductivity.

The lines of approximately equal hydraulic head mapped in the freshwater part of the system were carried a short distance below the 5,000 mg/L chloride-concentration line to show that some flow of saline water is also taking place in response to the hydraulic gradients. Wherever flow lines are shown below the 5,000 mg/L line they are dashed to indicate they are inferred.

The physical and chemical characteristics shown in the cross sections are three-dimensional and the sections can show only two of the dimensions. This concept is crucial for the correct interpretation of all the geologic and hydrologic characteristics of the sediments. It is particularly emphasized here with respect to heads and ground-water movement. Maximum components of head and flow may occur at any angle up to 90 degrees to the plane of the sections, particularly where the sections transect cones of depression that have developed because of ground-water withdrawals from the aquifers.

Prior to 1900, ground-water withdrawals are assumed to have been small and to have produced no significant water-level declines in the study area. Where the term "since 1900" is used in conjunction with ground-water withdrawals, it does not necessarily mean that withdrawals produced significant water-level declines beginning with the year 1900, but that significant withdrawals and head declines started to occur sometime between 1900 and 1980.

Although very slow landward movement of the transition zone between the freshwater and the saline water is inferred from the estimated hydraulic head changes that occurred from 1900 to 1980, data are insufficient to establish the amount and rate of the movement. Thus, the estimated present-day position of the 5,000 and 18,000 mg/L chloride-concentration lines are used for both the 1900 and the 1980 configurations shown on the cross sections. Future estimates of the amount of movement might be made with the aid of the computer models developed during the RASA study, or with simulation methods like those described by Meisler and others (1984).

Section A-A'.--This section, shown in plate 2, is approximately 82 mi long and is constructed from wells that lie along or are projected to a northeast-trending line drawn from southwestern Brunswick County to southeastern Onslow County, North Carolina (pl. 1). The altitude of the top of the basement rocks ranges from about 1,300 to 1,700 ft below sea level at the ends of the section and is about 1,000 ft below sea level near the center of the section. Aquifers and confining beds 1, 8, and 9 are not present on the section, and aquifers and confining beds 6 and 7 thin and pinch out in the eastern and central parts (pl. 2A; M. D. Winner, and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984).

Estimated horizontal transmissivities range from low to medium where the aquifers in this section contain water with chloride concentrations less than about 10,000 mg/L (pl. 2A; M. D. Winner, G. L. Giese, and M. M. Martin, U.S. Geological Survey, written commun., 1984). Aquifers 2 and 3 are estimated to have low transmissivity except at the western end of the section where a small part of aquifer 2 is estimated to have medium transmissivity.

At places along the section, aquifers 2, 3 and 4 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from 800 to 1,200 ft below sea level at the ends of the section and is about 400 ft below sea level near the center of the section. Water with 18,000 mg/L chloride occurs at about 500 ft deeper than water with 5,000 mg/L chloride at the eastern end of the section (pl. 2A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 range from nearly 110 ft above sea level in aquifer 2 at the western end of the section to less than 10 ft above sea level in aquifer 10 in the central and eastern parts (pl. 2B; G. L. Giese, M. D. Winner, and M. M. Martin, U.S. Geological Survey, written commun., 1984). Some flow is upward from the deep to the shallow aquifers in the discharge areas around the Cape Fear and Northeast Cape Fear Rivers, and the New River just north of well NC-81.

Since 1900, increased withdrawals of ground water in and around Wilmington, North Carolina (located in central-western New Hanover County, (pl. 1), Camp Lejeune and Jacksonville, North Carolina (located in central Onslow County, pl. 1) and Myrtle Beach, South Carolina (located on the coast, 20 mi south of well NC-98, pl. 1), have lowered heads within aquifers 3 through 7. The greatest amount of head decline (20 to 25 ft) along this section has occurred in aquifers 4 and 5 near well NC-98. Flow directions have changed around the areas nearest the largest head declines, but overall they have changed very little at the section since 1900 (pl. 2C).

Confining beds 2, 3 and 4 are estimated to range from about 75 ft to 150 ft in thickness along the section. Based on the head difference between aquifers 2 and 3, confining bed 2 appears to have the most effective confining properties along this section. In spite of this confining layer, it appears that some saline water is moving out of the deeper aquifers and upward toward the main natural discharge areas at the Cape Fear, Northeast Cape Fear and New Rivers (pl. 2).

Section B-B'.-- This section, shown in plate 3, is approximately 58 mi long and is constructed from wells that lie along or are projected to a southeast-trending line drawn from the southwestern part of Columbus County, to the southern part of New Hanover County, North Carolina (pl. 1). The altitude of the top of the basement rocks ranges from 771 ft below sea level at well NC-90 to 1,536 ft below sea level at well NC-95 (pl. 3A). Not all the aquifers and confining beds are present along the section. Aquifers 1, 6, 8, and 9 and confining beds 1, 6, 7, 8, and 9 pinch out to the east and northeast of the section, and aquifer 7 pinches out west of well NC-96 (pl. 3A; M. D. Winner, and Henry Trapp, Jr., U.S. Geological Survey, written and oral commun., 1984).

Estimated horizontal transmissivities range from low to medium where the aquifers in this section contain water with chloride concentrations less than 10,000 mg/L (pl. 3A; M. D. Winner, G. L. Giese, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Aquifers 2 and 3 are estimated to have low transmissivity except near the central part of the section where aquifer 2 is estimated to have medium transmissivity.

At places along the section, aquifers 2, 3 and 4 contain water with chloride concentrations of 5,000 mg/L or more, but no unit contains water with chloride concentrations as high as 18,000 mg/L. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 800 ft below sea level in the western part of the section to about 700 ft below sea level at the eastern end (pl. 3A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 range from about 110 ft above sea level in aquifer 2 near well NC-94, to near sea level in aquifer 10 near the Cape Fear River (pl. 3B; G. L. Giese, M.D. Winner, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Some flow was upward from the deep to the shallow aquifers. The high heads at depth result from the deeper aquifers being continuous to the west and southwest, where they crop out or lie close to land surface at much higher altitudes and where heads are as much as 200 ft or more above sea level.

Since 1900, only small to moderate ground-water withdrawals have occurred in the area. The ground-water withdrawals have caused a general lowering of water levels throughout the section, but overall flow directions appear to have remained much like those estimated for 1900 (compare pl. 3B and 3C).

Confining bed 2 thickens toward the east from 50 ft at the western end of the section to about 225 ft at the eastern end. Confining bed 3 thickens from 50 ft near the center of the section to about 150 ft at the western end and to about 100 ft at the eastern end. Based on the head differences between aquifers 2 and 3, confining bed 2 appears to have the best confining properties along the section. Confining beds 4 and 5 generally thicken toward the east from a combined thickness of 50 ft at the western end of the section to about 250 ft at the eastern end (pl. 3).

Section C-C'.--This section, shown in plate 4, is approximately 56 mi long and is constructed from wells that lie along or are projected to a southeast-trending line drawn from the southwestern part of Jones County, to the south-central part of Carteret County, North Carolina (pl. 1). The altitude of the top of the basement rocks ranges from an estimated 950 ft below sea level at well NC-61 to about 4,900 ft below sea level at well NC-71 (pl. 4A). All aquifers and confining beds are present at the eastern end of the section. From the apparent angular relationship between aquifer 1, confining bed 1, and the basement rocks (pl. 4A), it seems likely that both aquifer and confining bed 1 pinch out on basement rock just east of well NC-64. Aquifers and confining beds 8 and 9 are absent about 10 mi west of well NC-64 (M. D. Winner, and Henry Trapp, Jr., U.S. Geological Survey, written and oral commun., 1984).

Estimated horizontal transmissivities range from low to high where the aquifers in this section contain water with chloride concentrations less than 10,000 mg/L (pl. 4A; M. D. Winner, G. L. Giese, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Aquifers 2 and 3 are estimated to have low transmissivity in the freshwater part of the section.

At places along the section, aquifers 2 through 7 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 800 to 1,150 ft below sea level near the east-central and western parts of the section, respectively. Water with chloride concentrations of 18,000 mg/L or more is found throughout aquifer 1 and occurs about 500 ft deeper than water with 5,000 mg/L chloride (pl. 4A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written commun., 1984).

Estimated hydraulic heads for the year 1900 range from slightly more than 60 ft above sea level in aquifer 10 near well NC-61, to near sea level in aquifer 10 near the Newport and North Rivers at the eastern end of the section (pl. 4B; G. L. Giese, M. D. Winner, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Water flowed from west to east and upward across confining beds to discharge along the coast and into the Newport and North Rivers (pl. 4B). The high heads in the confined aquifers in the western part of the section are derived, in part, from an area 60 mi to the west where the aquifers crop out or lie close to land surface and heads are as much as 175 ft above sea level.

Since 1900, ground-water withdrawals by the municipalities of Jacksonville (located in the center of Onslow County, pl. 1) and Morehead City (located between wells NC-70 and NC-71 in Carteret County, pl. 1), and the Onslow County Water System, have lowered heads by more than 60 ft in aquifer 4, and more than 10 ft in aquifers 5 and 7 (pl. 4C). As a consequence of the withdrawals and lowered heads, the direction of ground-water flow has been reversed in aquifers 2 through 5 in the western part of the section and in aquifer 7 in the eastern part, and some water is now moving updip from the freshwater-saline water interface toward the centers of pumping.

Confining bed 1 thickens toward the east from about 25 ft at its western extent near well NC-64, where aquifer 1 appears to pinchout against the basement, to about 100 ft at the eastern end of the section. Confining bed 2 thickens toward the east from about 50 ft at the western end of the section to about 150 ft at the eastern end, and confining bed 3 thickens from 50 ft near well NC-65 to about 100 ft at the eastern and the western ends. Based on confining-bed thickness and the head differences in aquifers 2 and 3, confining bed 2 appears to have the most effective confining properties at the section. However, confining bed 1 may pinch out on basement rock to form an effective barrier to retard the westward movement of ground water and any contaminant that might occur in aquifer 1 (pl. 4).

Section D-D'.--This section, shown in plate 5, is approximately 80 mi long and is constructed from wells that lie along or are projected to a northeast-trending line drawn from northeastern Craven County to the eastern part of Hyde County, North Carolina (pl. 1). The altitude of the top of the basement rocks ranges from about 1,000 ft below sea level at the western end of the section to about 5,800 ft below sea level at the eastern end. All the aquifers and confining beds are present at well NC-41, and generally thin along the section to the southwest. Aquifers and confining beds 1, 8 and 9 pinch out near the central and western parts of the section (pl. 5A; M. D. Winner, and Henry Trapp, Jr., U.S. Geological Survey, written and oral commun., 1984). From the apparent angular relationship between aquifer 1, confining bed 1 and the basement rocks (pl. 5A), it seems likely that both aquifer and confining bed 1 pinch out on the basement rock.

Estimated horizontal transmissivities range from low to high in the section where the aquifers contain water with chloride concentrations less than 10,000 mg/L (pl. 5A; M. D. Winner, G. L. Giese, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Aquifers 1, 2 and 3 are estimated to have low transmissivity except near the northeastern end of the section where aquifer 1 is estimated to have medium transmissivity.

At places, aquifers 1 through 7 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from over 1,100 ft below sea level near well NC-51, to about 500 ft below sea level near well NC-45. East of well NC-45, the depth increases to about 800 feet at well NC-41. Water with chloride concentrations of 18,000 mg/L or more is found throughout aquifer 1 and occurs about 500 to 800 ft deeper than water with 5,000 mg/L chloride (pl. 5A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 range from greater than 40 ft above sea level in all the aquifers at the western end of the section to near sea level in aquifer 10 adjacent to the Pamlico River (pl. 5B; G. L. Giese, M. D. Winner, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). The ground water generally flowed from west to east and upward across confining beds to discharge into small streams and the Pamlico River (see pl. 1 for location of river) in the eastern part of the section. The relatively high heads in the deep, confined aquifers are derived from an area to the west near the Fall Line, where the lower aquifers of this section crop out or lie close to land surface at higher altitudes, and heads are as much as 125 ft above sea level.

Since the middle 1960's, large ground-water withdrawals from aquifer 7 have occurred in the central part of Beaufort County, North Carolina (see pl. 1 for location of county). The ground water is pumped to lower the water level and facilitate the mining of phosphate deposits that lie directly above aquifer 7. In addition, large amounts of ground water presently are being pumped from both municipal and industrial wells finished in aquifers 3 and 4 in Lenoir and Craven Counties, North Carolina (see pl. 1 for location of counties). The withdrawals have lowered the hydraulic heads at the section from 40 to more than 80 ft in aquifers 3, 4 and 7, and head declines have reached the transition zone between the fresh and saline water. Consequently, most of the ground-water flow in the confined aquifers is now toward the pumping centers, and some slow westward movement of the saline water is postulated (pl. 5C).

Confining bed 1 thickens toward the east from an estimated 25 ft at its western limit in the central part of the section, to about 50 ft at well NC-41. Confining beds 2 and 3 thicken toward the east from about 50 ft at the western end of the section to about 200 and 100 ft, respectively, at the eastern end. Based on confining-bed thickness and the head differences in aquifers 2 and 3, confining bed 2 appears to have the most effective confining properties of these lower confining units. However, confining bed 1 may pinch out on the basement rock to form an effective barrier to retard the westward movement of ground water and any contaminant that might occur in aquifer 1. Confining beds 4 through 9 generally thicken toward the east and reach a maximum combined thickness of about 700 ft near the eastern end of the section (pl. 5).

Section E-E'.--This section, shown in plate 6, is approximately 75 mi long and is constructed from wells that lie along or are projected to a southeast-trending line drawn from the north-central part of Martin County, to eastern Hyde County, North Carolina (pl. 1). The altitude of the top of the basement rocks ranges from about 550 ft below sea level on the western end of the section to a projected altitude of about 5,800 ft below sea level on the eastern end (pl. 6A). All aquifers and confining beds are present in the eastern part of the section (M. D. Winner, and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984). The units generally thin westward and aquifers 5, 6, 7 and 8, and confining beds 4, 5, 6 and 7 pinch out near the western end of the section. From the apparent angular relationship between aquifer 1, confining bed 1 and the basement rocks (pl. 6A), it seems likely that both aquifer 1 and confining bed 1 pinch out on basement rock just east of well NC-25 in eastern Washington County, North Carolina (see pl. 1 for location of county).

Estimated horizontal transmissivities range from low to high where the aquifers contain water with chloride concentrations less than 10,000 mg/L (pl. 6A; M. D. Winner, G. L. Giese, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Aquifers 1, 2 and 3 have low transmissivity except around well NC-25 where aquifer 3 is estimated to have medium transmissivity.

At places along the section, aquifers 2 through 7 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L is about 1,100 ft below sea level on the western end of the section, about 500 ft in the central part, and about 800 ft below sea level at the eastern end. Water with chloride concentrations of 18,000 mg/L or more is found throughout aquifer 1, and occurs at about 500 to 700 ft deeper than water with 5,000 mg/L chloride (pl. 6A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 ranged from more than 50 ft above sea level in the aquifers at the western end of the section, to near sea level in aquifer 10 at the eastern end (pl. 6B; G. L. Giese, M. D. Winner, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). In general, water flowed from west to east with a small downward component at the western end of the section, and upward across confining beds to shallower aquifers and local streams in the eastern part of the section. The relatively high heads in the confined aquifers near well NC-20 are derived, in part, from an area about 30 miles to the west of the section, where the aquifers crop out or lie close to land surface and the heads in these aquifers are as great as 125 ft above sea level.

Since 1900, ground-water withdrawals in Martin County (see pl. 1 for location of county) have lowered the heads more than 25 ft in aquifers 3 and 4 at the western end of the section (pl. 6C). Heads in aquifer 7 have declined below sea level in the central part of the section owing to withdrawals of about 65 million gallons per day for phosphate-ore mining operations about 25 mi south of this section. As a result, water is moving into the closed depression outlined by the zero-head line, and to the south in a plane perpendicular to this section. It is possible that some of the water flowing toward the pumping center is saline water from the transition zone.

The estimated thickness of confining bed 1 ranges from zero at its western limit to about 100 ft at well NC-25. It is possible that this confining bed might pinch out against the basement rock to form an effective barrier to impede the westward movement of ground water and any contaminant that might occur in aquifer 1. Confining bed 2 thickens toward the east from about 100 ft at well NC-20 to about 200 ft at the eastern end of the section. Likewise, confining bed 3 thickens toward the east from about 50 ft at well NC-20 to about 125 ft at the eastern end of the section. Based on thickness, confining bed 2 appears to provide the most effective confinement of the lower three confining units. Confining beds 4 through 9 generally thicken toward the east and have a combined thickness of about 800 ft near the eastern end of the section (pl. 6).

Section F-F'.--This section, shown in plate 7, is approximately 61 mi long and is constructed from wells that lie along or are projected to a southeast-trending line drawn from the southern part of Isle of Wight County, Virginia, to the central part of Currituck County, North Carolina (pl. 1). The altitude of the top of the basement rocks ranges from about 830 ft below sea level on the western end of the section to about 4,500 ft below sea level on the eastern end (pl. 7A). Aquifer and confining bed 5 are missing because they pinch out to the south of the section. Aquifer and confining bed 4 thin along the section line to the northwest and pinch out near the North Carolina-Virginia border (M. D. Winner, and Henry Trapp, Jr., U.S. Geological Survey, written and oral commun., 1984; and Meng and Harsh, 1984).

Estimated horizontal transmissivities range from low to medium where the aquifers in this section contain water with chloride concentrations less than 10,000 mg/L (pl. 7A; Meng and Harsh, 1984; R. J. Laczniak, M. D. Winner, G. L. Giese, M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Aquifer 1 is estimated to have low and medium transmissivity at the western and central parts of the section, respectively; aquifer 2 is estimated to have medium transmissivity; and aquifer 3 is estimated to have low transmissivity (pl. 7A).

At places along the section, all aquifers except 9 and 10 contain water with chloride concentrations of at least 5,000 mg/L. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 1,400 to 700 ft below sea level from the western to the eastern end of the section, respectively. Water with chloride concentrations of 18,000 mg/L occurs from 500 to 600 ft deeper than water with 5,000 mg/L chloride (pl. 7A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 ranged from slightly more than 50 ft above sea level in aquifer 1 at the western end of the section, to near sea level in aquifer 10 near the North River (pl. 7B; A. A. Meng, J. F. Harsh, R. J. Laczniak, G. L. Giese, M. D. Winner, M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). In the shallow part of the freshwater-circulation system, water flowed away from the highest heads in the shallow aquifers. In the deeper part of the system, flow was downdip toward the freshwater-saline water interface and upward across the confining beds to discharge areas at Currituck Sound and coastal streams, such as North River (see pl. 1 for location of the sound). The estimated 40- and 50-foot heads in the confined aquifers near well VA-73 are derived from 20 to 30 mi west of the section where the lower aquifers crop out or are very near land surface, and heads are as much as 100 ft above sea level.

Since the late 1930's, large amounts of ground water have been and continue to be pumped from wells screened in the deeper aquifers in and around the municipalities of Franklin and Suffolk, Virginia (Franklin is located near well VA-73, and Suffolk is located about 20 mi east of Franklin, pl. 1). These withdrawals have lowered heads more than 200 ft in aquifers 1 and 2 at well VA-73. Lowering of the hydraulic head is widespread along the section (pl. 7C) primarily owing to the pumpage at Franklin and Suffolk. The direction of ground-water flow has been reversed in most of the freshwater-circulation system shown in the section, and flow is now downward across the confining beds and westward updip toward the center of pumping. As a result of the head declines, some slow westward movement of the saline water is postulated, particularly in aquifers 1 and 2.

Confining beds 1, 2 and 3 are estimated to range between about 50 to 150 ft in thickness along the section. Based on confining-bed thickness and the head differences in aquifers 2 and 3 (pl. 7C), confining beds 2 and 3 appear to provide effective confinement, and confining bed 2 appears to have the best confining properties in the section. It is impossible at present to estimate the confining potential of confining bed 1 based on the distribution of the lines of equal hydraulic head, because ground-water withdrawals from aquifers 1 and 2 have lowered the heads to nearly the same values in each of these aquifers. However, confining bed 1 is approximately the same thickness as confining beds 2 and 3 and, on this basis, all these confining beds may be expected to have similar confining properties. Confining beds 4, and 6 through 9 thicken to the east, reaching a combined thickness of about 450 ft near well NC-13 (pl. 7).

Section G-G'.--This section, shown in plate 8, is approximately 65 mi long and is constructed from wells that lie along or are projected to a line drawn from north-central Sussex County, to the coast at Virginia Beach, Virginia (pl. 1). The altitude of the top of the basement rocks ranges from about 450 ft below sea level on the western edge of the section to an estimated 3,300 ft below sea level on the eastern end (pl. 8A). Aquifers 4, 5 and 8, and confining beds 4 and 5 are not present. Confining bed 1 is very thin just west of well VA-46 (Meng and Harsh, 1984; Henry Trapp, Jr., U.S. Geological Survey, written and oral commun., 1984).

Estimated horizontal transmissivities range from low to medium high where the aquifers in the section contain water with chloride concentrations less than 10,000 mg/L (pl. 8A; A. A. Meng, J. F. Harsh, R. J. Laczniak, M. M. Martin, U. S. Geological Survey, written and oral commun., 1984). Aquifers 1 and 3 are estimated to have low transmissivity except in the east-central part of the section where aquifer 1 is estimated to have medium transmissivity. Most of aquifer 2 is estimated to have medium transmissivity except around well VA-53 where the transmissivity is medium high.

The downdip parts of aquifers 1, 2, 3 and 7 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 1,500 ft below sea level near the center of the section to about 800 ft below sea level at Virginia Beach (well VA-58). Water with chloride concentrations of 18,000 mg/L or more occurs in aquifers 1 and 2 at the eastern end of the section. The water with 18,000 mg/L chloride occurs about 700 ft deeper than the water with 5,000 mg/L chloride (pl. 8A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 range from greater than 75 ft above sea level at the western end of the section, to near sea level in aquifer 10 near the James River (see pl. 1 for location of river) (pl. 8B; R. J. Laczniak, J. F. Harsh, A. A. Meng, M. M. Martin, U.S. Geological Survey, written commun., 1984). As the flow arrows indicate, the flow was from west to east, downward across confining beds in the western part of the section, and upward toward the James River, and the Atlantic Ocean (just east of the section).

Since the late 1930's, it is estimated that ground-water withdrawals in and around the municipalities of Franklin (located near well VA-73, pl. 1) and Suffolk, Virginia (located about 20 mi east of Franklin), have lowered heads along this section by more than 50 ft in aquifers 1, 2 and 3 (pl. 8C). Smaller head declines ranging from 5 to 25 ft in aquifers 6, 7 and 9 are the combined result of the Suffolk-Franklin pumping and the many water users that withdraw small amounts of ground water from the upper aquifers. As a result of the head declines, some slow westward movement of the saline water is postulated in aquifers 1, 2 and 3.

Confining bed 1 thickens toward the east from about 10 ft in the western part of the section, to an estimated 100 ft at the eastern end. Confining bed 2 thickens toward the east from about 50 ft at the western end of the section to 75 ft at the eastern end. Also, confining bed 3 thickens from 25 to about 50 ft from the western to the eastern end of the section (pl. 8C). Based on consistent thickness, confining bed 2 appears to provide the best confinement potential of the lower three confining units. Because it is very thin, the effectiveness of confining bed 1 is probably negligible between wells VA-44 and VA-46. Confining beds 6, 7, 8 and 9 become progressively thicker toward the eastern part of the section and reach a combined thickness of about 500 ft near well VA-58 (pl. 8).

Section H-H'.--This section, shown in plate 9, is approximately 75 mi long and is constructed from wells that lie along or are projected to a line drawn from western New Kent County, Virginia to near the mouth of Chesapeake Bay (pl. 1). The section is used to display the general geohydrologic conditions beneath the peninsula bounded by the York and James Rivers (see pl. 1 for location of rivers). The altitude of the top of the basement rocks ranges from about 500 ft below sea level at well VA-25 to a projected depth of about 3,000 ft below sea level at well VA-45 (pl. 9A). Aquifers and confining beds 4 and 5, and aquifer 8, are not present in this section (Meng and Harsh, 1984; Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984).

Estimated horizontal transmissivities range from low to medium high where the aquifers in this section contain water with chloride concentrations less than 10,000 mg/L (pl. 9A; R. J. Laczniak, J. F. Harsh, A. A. Meng, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). Aquifer 1 is estimated to have low transmissivity except in the east-central part of the section where it has medium transmissivity. Aquifer 2 is estimated to have medium and medium high transmissivity in the central and eastern parts of the section and low transmissivity at the western end. All of aquifer 3 is estimated to have low transmissivity.

The downdip parts of aquifers 1, 2 and 3 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 1,500 ft below sea level near the center of the section to about 900 ft below sea level at the eastern end. Water with chloride concentrations of 18,000 mg/L or more occurs only in aquifer 1, and is found at about 1,000 to 1,300 ft deeper than water with 5,000 mg/L chloride (pl. 9A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 ranged from more than 60 ft above sea level at the western end of the section, to near sea level in aquifer 10 at the Chickahominy River and Chesapeake Bay (pl. 9B; R. J. Laczniak, J. F. Harsh, A. A. Meng, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). As the heads and flow arrows indicate, the flow was primarily from west to east with a downward component in the western part of the section and an upward component in the central and eastern parts toward the Chickahominy River, and the Chesapeake Bay.

By 1980, ground-water withdrawals in and around Williamsburg, Virginia (located on the James City and York Counties line, pl. 1), had lowered heads in the central part of the section by 50 to 90 feet. The major head declines have occurred in aquifers 1, 2, 3 and 6 (pl. 9C), and the ground-water flow in these aquifers is presently toward the center of pumping in the Williamsburg area. As a result of the head declines, some slow westward movement of the saline water is postulated in aquifers 1, 2 and 3.

Confining bed 1 has an estimated average thickness of 50 to 75 ft at the section. Confining bed 2 thickens eastward from about 25 ft at the western end of the section to about 100 ft at the eastern end. Confining bed 3 pinches out against confining bed 2 just to the east of well VA-25 and thickens to about 50 ft at the eastern end of the section. Based on the confining-bed thickness and the distribution of the hydraulic-head lines (pl. 9C), it appears that these lower confining units have only moderately to poorly effective confining properties. Confining beds 6, 7 and 8 thicken progressively toward the eastern part of the section, and reach a combined thickness of about 450 ft at well VA-45.

Section I-I'.--This section, shown in plate 10, is approximately 68 mi long and is constructed from wells that lie along or are projected to a line drawn from the western part of New Kent County to the western edge of Northampton County, Virginia (pl. 1). The altitude of the top of the basement rocks ranges from about 520 ft below sea level on the western end of the section to a projected depth of about 3,300 ft below sea level on the eastern end (pl. 10A). Aquifer and confining bed 4 are not present along this section (Meng and Harsh, 1984; Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984). In addition, aquifers 3, and 5 through 8, and confining beds 2, 5, 8 and 9 pinch out within the section.

Estimated horizontal transmissivities range from low to medium high where the aquifers in the section contain water with chloride concentrations less than 10,000 mg/L (pl. 10A; R. J. Laczniak, J. F. Harsh, A. A. Meng, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). The estimated transmissivity for aquifer 1 is low in the western part of the section and medium in the eastern part. Aquifer 2 is estimated to have medium transmissivity except in the western and east-central parts of the section where it has low and medium high transmissivity, respectively. Aquifer 3 has low transmissivity.

At places along the section, aquifers 1, 2, 3 and 5 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 1,800 ft below sea level near the center of the section to about 900 ft below sea level at the eastern end. Water with chloride concentrations of 18,000 mg/L or more occurs only in aquifer 1, and is found at about 1,400 ft deeper than water with 5,000 mg/L chloride (pl. 10A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 range from about 50 to 75 ft above sea level from the lower to the upper aquifers, respectively, at the western end of the section, to near sea level in aquifer 10 along Chesapeake Bay (pl. 10B; R. J. Laczniak, J. F. Harsh, A. A. Meng, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). The ground-water flow generally was from west to east with a downward component across confining beds at the western end of the section and an upward component to discharge at the York River in the central part of the section, and the Chesapeake Bay in the eastern part (pl. 1).

Since 1900, ground-water withdrawals at the city of West Point (located near well VA-24) and around the cities of Gloucester and Urbanna (located in central Gloucester and Middlesex Counties, Virginia, respectively; see pl. 1), have lowered heads along this section by 50 to 90 ft in aquifers 1, 2 and 3 (pl. 10C). Both heads and flow directions in aquifers 7, 9 and 10 have been little effected by the pumping, but the withdrawals have caused the heads in the deeper aquifers to decline far below sea level in parts of the section, and ground-water flow in these deeper aquifers is toward the centers of pumping. Flow in most of the eastern part of the section has been reversed and is now westward and vertically downward. As a result of the head declines, some slow westward movement of the saline water is postulated in aquifers 1, 2 and 3.

Confining bed 1 and 2 each thicken toward the east from about 20 ft at the western end of the section to over 100 ft at the eastern end. Confining bed 2 is considered to be more continuous and consistent than confining bed 1. Confining bed 3 also thickens toward the east from about 25 ft at the western end of the section to about 75 ft at the eastern end. Based on thickness, it appears that these lower confining beds would provide moderately effective confinement in the eastern part of the section, and moderately to poorly effective confinement in the central and western parts of the section, respectively. Confining beds 5 through 9 thicken progressively toward the eastern part of the section, reaching a combined thickness of about 550 ft near well VA-35. Here, these upper confining beds act as a highly effective retardant to vertical flow between the freshwater and saline-water parts of the section (pl. 10).

Section J-J'.--This section, shown in plate 11, is approximately 92 mi long and is constructed from wells that lie along or are projected to a line drawn from central Caroline County to the eastern shore of Chesapeake Bay in Northampton County, Virginia (pl. 1). The altitude of the top of the basement rocks ranges from about 480 ft below sea level near well VA-7 on the western end of the section to an estimated 3,300 ft below sea level near well VA-36 at the eastern end (pl. 11A). Aquifer 4 and confining bed 4 are not present in this section (Meng and Harsh, 1984; Henry Trapp, Jr., U.S. Geological Survey, written and oral commun., 1984).

Estimated horizontal transmissivities range from low to medium where the aquifers in the section contain water with chloride concentrations less than 10,000 mg/L. The medium transmissivity occurs in aquifers 1 and 2 in the central and eastern parts of the section. The western parts of aquifers 1 and 2, and all of aquifer 3 are estimated to have low transmissivity (pl. 11A; A. A. Meng, J. F. Harsh, R. J. Laczniak, and M. M. Martin, U.S. Geological Survey, written commun., 1984).

The downdip parts of aquifers 1, 2, 3 and 5 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentration of 5,000 mg/L ranges from about 2,100 ft below sea level near the center of the section to about 900 ft below sea level at the eastern end. Water with chloride concentrations of 18,000 mg/L occurs about 1,400 ft deeper than water with 5,000 mg/L chloride (pl. 11A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 range from over 100 ft above sea level in the unconfined surficial aquifer and more than 50 ft above sea level in the confined aquifers at the western end of the section, to near sea level in the surficial sediments near the Piankatank River and the Chesapeake Bay (pl. 11B; R. J. Laczniak, J. F. Harsh, A. A. Meng, and M. M. Martin, U.S. Geological Survey, written and oral commun., 1984). As the flow arrows indicate, the flow was from west to east, with a downward component across confining beds in the western part of the section and an upward component in the eastern part to discharge into the Piankatank River, Chesapeake Bay and the Atlantic Ocean (just east of the section, see pl. 1).

Since 1900, ground-water withdrawals in and around the cities of Gloucester and Urbanna (located in central Gloucester and central Middlesex Counties, Virginia, respectively; pl. 1), and the city of West Point (located near well VA-24 at the southeastern tip of King William County, Virginia, pl. 1), have lowered heads along this section by 40 to 80 ft in aquifers 1, 2 and 3 (pl. 11C). Smaller head declines, estimated to range from 5 to 20 ft, have occurred, at least locally, in aquifers 6, 7, 9 and 10, and are the result of ground-water withdrawals from these upper aquifers combined with the withdrawals from the lower aquifers. As a result of the head declines, some slow westward movement of the saline water is postulated in aquifers 1, 2 and 3.

The thickness of confining bed 1 varies from about 50 to 125 ft along the section. Confining bed 2 thickens and thins between 50 and 100 ft; and confining bed 3 thickens from where it pinches out in the central part of the section to about 75 ft at well VA-35. The combined thickness of these lower confining beds is between about 150 and 200 ft along the section. Based on the distribution of the hydraulic-head lines and confining-bed thickness, confining beds 1, 2 and 3 appear to have moderately to poorly effective confining properties. Confining beds 5 through 9 thicken to the east and have a combined thickness of about 550 ft near well VA-35 (pl. 10).

Section K-K'.--This section, shown in plate 12, is approximately 94 mi long and is constructed from wells that lie along or are projected to a southeast-trending line drawn from southern Prince Georges County, Maryland, to near the Atlantic Coast in northeastern Accomack County, Virginia (pl. 1). The altitude of the top of the basement rocks ranges from about 1,400 ft below sea level on the western end of the section to about 6,100 ft below sea level at well VA-10 on the eastern end of the section. Aquifers and confining beds 4 and 5 are not present along this section and aquifers 3, 6, 7 and 8, and confining beds 3, 8 and 9 pinch out within the section (pl. 12A; D. A. Vroblesky, and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984; Meng and Harsh, 1984).

Estimated horizontal transmissivities range from low to medium where the aquifers in the section contain water with chloride concentrations less than 10,000 mg/L (pl. 12A; D. A. Vroblesky, W. B. Fleck, A. A. Meng, J. F. Harsh, R. J. Laczniak, and M. M. Martin, U.S. Geological Survey, written commun., 1984). With the exception of the medium transmissivity estimated to occur in aquifers 1 and 2 in the central and eastern part of the section, respectively, all aquifers are estimated to have low transmissivity.

In the eastern part of the section, aquifers 1 and 2 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing 5,000 mg/L chloride concentrations ranges from about 3,200 ft below sea level near the center of the section to about 1,800 ft below sea level around well VA-10 near the Atlantic Coast (see pl. 1 for location of coast). Water with chloride concentrations of 18,000 mg/L or more occurs in aquifers 1 and 2 at about 400 to 800 ft deeper than water with 5,000 mg/L chloride (pl. 12A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 ranged from about 50 to 125 ft above sea level from the deepest confined aquifer to the water-table aquifer, respectively, on the western end of the section, to near sea level in the unconfined surficial aquifer near Chesapeake Bay and Pocomoke Sound (pl. 12B). As the flow arrows indicate, ground-water flow was primarily from areas where the hydraulic heads were high in the western part of the section, toward areas of natural discharge like the Patuxent River, Chesapeake Bay and Pocomoke Sound in the eastern part (pl. 12B).

Since 1900, withdrawals of ground-water in St. Marys and Calvert Counties, Maryland (see pl. 1 for location of counties) have lowered heads from 25 to 75 ft, with the majority of the decline occurring in aquifer 6 near well MD-74 (pl. 12C). As the flow arrows indicate, ground-water flow in the confined aquifers is predominantly toward the cone of depression that has developed in aquifer 6. This flow is downward across confining beds from the upper aquifers, laterally from east and west in the plane of the section in aquifer 6, and upward across confining beds from the lower aquifers. As a result of the head declines, some very slow westward movement of the saline water may have occurred in aquifers 1 and 2.

Confining bed 1 ranges in thickness from about 200 to 400 ft along the section and confining bed 2 ranges from 50 to about 120 ft in thickness. Confining bed is directly overlain by and is considered an integral part of the younger confining units in this section (pl. 12). Based on the distribution of the hydraulic-head lines, confining bed 2 appears to have effective confining properties. The lack of detailed head data across confining bed 1 makes it difficult to assess the effectiveness of this unit based on the distribution of the hydraulic-head lines. However, the 200- to 400-foot thickness of confining bed 1 suggests that its confining properties may be more effective than those of confining bed 2.

Section L-L'.--This section, shown in plate 13, is approximately 100 mi long and is constructed from wells that lie along or are projected to a line drawn from north-central Anne Arundel County, Maryland to the Atlantic Coast in northeastern Worcester County, Maryland (pl. 1). The altitude of the top of the basement rocks ranges from about 500 ft below sea level on the western edge of the section to over 8,000 ft below sea level on the eastern end (pl. 13A). Aquifer 4 is not present, and aquifers 5 through 10 and confining beds 3 through 9 pinch out or crop out along the section (D. A. Vroblesky, and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984).

Estimated horizontal transmissivities range from low to medium high where the aquifers in the section contain water with chloride concentrations less than 10,000 mg/L. Aquifers 1 and 3 are estimated to have low transmissivity except at the western end of the section where a small part of aquifer 1 is estimated to have medium transmissivity. Aquifer 2 is estimated to have medium transmissivity except at the eastern end of the section where it has medium-high transmissivity (pl. 13A; D. A. Vroblesky, W. B. Fleck, and M. M. Martin, U.S. Geological Survey, written commun., 1984).

In the central and eastern parts of the section, aquifers 1, 2, 3 and 5 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 2,800 ft below sea level in the west-central part of the section to about 1,800 ft below sea level at well MD-64 on the Atlantic Coast. Water with chloride concentrations of 18,000 mg/L or more occurs in aquifers 1 and 2 at about 300 to 800 ft deeper than water with 5,000 mg/L chloride (pl. 13A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 ranged from between 50 and 75 ft above sea level in the unconfined and confined aquifers at the western end of the section, to near sea level in the water-table aquifer near Chesapeake and Chincotaegue Bays (pl. 13B; W. B. Fleck, D. A. Vroblesky, and M. M. Martin, U.S. Geological Survey, written commun., 1984). As the head values and flow arrows indicate, the flow is both east and west in the shallow aquifers with a downward component in the western and east-central part of the section. In aquifers 1, 2 and 3 flow was west to east with an upward component across confining beds to natural discharge at Chesapeake and Chincoteague Bays, and the Atlantic Ocean (just east of the section).

Since 1900, ground-water withdrawals have lowered heads from 25 to about 40 ft in aquifers 1, 2, 3, 5 and 6 (pl. 13C). Ground-water withdrawals in aquifer 6 near well MD-23 appear to account for the majority of head decline along this section. As a result of the head declines, some very slow westward movement of the saline water may have occurred in aquifers 1, 2 and 3.

Confining bed 1 thickens from 150 ft at the western end of the section to over 700 ft in the central part, and thins to about 300 ft at the eastern end. Confining bed 2 thickens toward the east from about 15 ft at well MD-13 to about 200 ft in the eastern part of the section. Based on thickness, confining beds 1 and 2, in the central and eastern part of the section, appear to have relatively effective confining properties, and confining bed 1 appears to have the best confinement potential (pl. 13C). Confining bed 3 is directly overlain by and is considered an integral part of the younger confining units in this section. Confining beds 3 through 9 thicken to the east, reaching a total combined thickness of about 1,000 ft near well VA-64.

<u>Section M-M'</u>.--This section, shown in plate 14, is approximately 93 mi long and is constructed from wells that lie along or are projected to a line drawn in an east-northeast direction from eastern Cecil County, Maryland, to the Atlantic Coast in Ocean County, New Jersey (pl. 1). The altitude of the top of the basement rocks ranges from about 600 ft below sea level on the western end of the section to about 3,900 ft below sea level on the eastern end. Confining bed 8 and 9, and aquifer 10 are not present in this section (pl. 14A; O. S. Zapecza, and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984).

Estimated horizontal transmissivities range from low to high where the aquifers in the section contain water with chloride concentrations less than 10,000 mg/L. Aquifers 1, 2 and 3 are estimated to have low transmissivity along the section (pl. 14A; M. M. Martin, and O. S. Zapecza, U.S. Geological Survey, written commun., 1984).

At places along the section, aquifers 1 and 2 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 1,000 ft below sea level in the western part of the section to about 3,000 ft below sea level at the eastern end. A small part of aquifer 1 near well NJ-24 contains water with chloride concentrations of 18,000 mg/L or more. This water occurs at about 800 ft deeper than water with 5,000 mg/L chloride (pl. 14A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900 ranged from 75 to more than 100 ft above sea level in the unconfined surficial aquifer in the central part of the section, to near sea level in the unconfined aquifer at the Delaware River near the western end, and Barnegat Bay at the eastern end of the section (pl. 14B; M. M. Martin, and O. S. Zapecza, U.S. Geological Survey, written commun., 1984). As the flow arrows indicate, ground water flowed away from the high heads toward low heads and discharged to the Delaware River estuary and Barnegat Bay, and to the Atlantic Ocean (just east of the section, pl. 1).

Since 1900, ground-water withdrawals in Camden County, New Jersey, and New Castle County, Delaware (see pl. 1 for location of counties), have lowered heads as much as 75 ft in the central part of the section, and more than 100 feet in the western part (Martin, 1984; and pl. 14C). The largest declines have occurred in the lower confined aquifers, and ground-water movement in these aquifers is toward the centers of pumping. By comparison, heads in the shallow unconfined aquifer appear to be little affected (pl. 14C). As a result of the head declines, some slow westward movement of the saline water is postulated in aquifers 1 and 2.

The thickness of confining bed 1 ranges from 100 to 50 ft from the western to the central part of the section, and from 50 to 400 ft from the central to the eastern part of the section. Confining bed 2 ranges in thickness from about 50 ft at well MD-1 to about 300 ft at the eastern end of the section. Confining bed 3 thickens from about 20 ft near its western limit, to about 400 ft at well NJ-24. It is difficult to assess the confinement potential of these confining units based on the head differences between aquifers 1, 2 and 3. However, based on the thickness of confining beds 1, 2 and 3, the best confinement potential is provided by confining bed 1 in the westernmost part and eastern half of the section, and by confining bed 2 in the west-central part of the section. Confining beds 4 through 7 thicken to the east and reach a combined thickness of about 1,500 ft near well NJ-24 (pl. 14).

Section N-N'.--This section, shown in plate 15, is approximately 65 mi long and is constructed from wells that lie along or are projected to a north-south trending line drawn from northeastern Camden County to the southern end of Cape May County, New Jersey (pl. 1). The altitude of the top of the basement rocks ranges from a projected altitude of about 850 ft below sea level on the northern end of the section to about 6,300 ft below sea level at the southern end. All aquifers and confining beds are present (pl. 15A; O. S. Zapecza, and Henry Trapp, Jr., U.S. Geological Survey, written commun., 1984).

Estimated horizontal transmissivities range from low to high where the aquifers in the section contain water with chloride concentrations less than 10,000 mg/L. Aquifers 1, 2 and 3 are estimated to have low transmissivity except near the western end of the section where parts of these aquifers are estimated to have medium transmissivity (pl. 15A; M. M. Martin, and O. S. Zapecza, U.S. Geological Survey, written commun., 1984).

The downdip parts of aquifers 1, 2 and 3 contain water with chloride concentrations of 5,000 mg/L or more. The altitude of water containing chloride concentrations of 5,000 mg/L ranges from about 1,400 ft below sea level 5 to 10 mi west of well NJ-40, to about 2,200 ft below sea level near well NJ-47. Water with chloride concentrations of 18,000 mg/L or more occurs in aquifers 1 and 2 at from 900 to 1,600 ft deeper than water with 5,000 mg/L chloride (pl. 15A; Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984).

Estimated hydraulic heads for the year 1900, ranged from about 125 ft above sea level in aquifer 9 in the northern part of the section, to near sea level in aquifer 10 at the Delaware Bay, near the southern end of the section (pl. 15B; M. M. Martin, and O. S. Zapecza, U.S. Geological Survey, written commun., 1984). As the hydraulic heads and flow arrows indicate, ground-water flow in the plane of the section is divided to the north and the south away from the high heads in the unconfined surficial aquifer just north of well NJ-30. Although data are not sufficient to mark the exact location of this ground-water flow divide in the confined aquifers, it appears that the divide migrates southward with increasing depth. The discharge area for flow north of the divide is the Delaware River, and south of the divide discharge is to the Delaware Bay and the Atlantic Ocean (just south of the section).

Since 1900, ground-water withdrawals have lowered heads as much as 100 ft near the northern end of the section (pl. 15C). Major ground-water withdrawals from aquifers 1, 2 and 3 (table 3) in Camden County (see pl. 1 for location of county) have lowered heads in these aquifers from 50 to 100 ft. Most of the ground-water flow in the confined aquifers is north toward the pumping center. The flow in aquifers 8, 9 and 10 is much like it was in 1900, except at the ends of the section where some of the water that would have discharged to rivers, bays and the ocean, is being diverted to pumping wells (pl. 15B and 15C). As a result of the head declines, some slow westward movement of the saline water is postulated in aquifers 1 and 2.

Confining bed 1 thickens from about 100 ft at the northern end of the section to about 1,000 ft at the southern end. Confining bed 2 also thickens toward the south from about 50 ft at well NJ-21 to nearly 700 ft at well NJ-47. In the central part of the section, confining bed 3 is directly overlain by confining bed 4 and these units have an average aggregate thickness of about 150 ft. In the northern part of the section confining bed 3 has an average thickness of about 100 ft. It is difficult to assess the confinement potential of these units based on head differences between aquifers 1, 2 and 3, because the large ground-water withdrawals (table 3) have lowered heads to nearly the same values in each of these aquifers in the northern part of the section. However, based on thickness, the confining properties of confining beds 1 and 2 appear to be moderately effective in the northern part of the section, and very effective in the southern part. Confining bed 3 appears to have moderately effective confinement potential throughout and may provide the best confinement potential in the northern part of the section. Confining bed 1 provides the best confinement potential of the three lowermost confining units in the central and eastern parts of the section. Confining beds 4 through 9 thicken to the south, and reach a combined thickness of over 1,500 ft at well NJ-47 (pl. 15A).

RELATIVE SUITABILITY OF HYDROLOGIC CONDITIONS FOR THE DISPOSAL OF RADIOACTIVE WASTE IN BURIED CRYSTALLINE ROCK

Four general geohydrologic characteristics were selected to summarize and make a preliminary evaluation of the hydrology of the Coastal Plain sediments relevant to the suitability for the disposal of high-level radioactive waste in crystalline rocks that lie beneath the area. These characteristics are (1) the estimated thickness of sediments saturated with saline water or brine, (2) the estimated thickness of the deepest confining beds, (3) the estimated permeability of the deepest aquifers and (4) the inferred direction of lateral ground-water flow in the deepest aquifers. The following discussions and illustrations of these characteristics are limited to the area where the surface of the basement complex lies between 1,000 and about 4,000 ft below sea level.

Thickness of Sediments Containing Saline Water or Brine

A major criterion for burial of waste below the Coastal Plain aquifers is the existence of saline water or brine in the aquifers that occur just above the basement rocks (Bredehoeft and Maini, 1981). In general, the saline water or brine will serve to separate any potential disposal site in buried crystalline rock from the freshwater-circulation system. This is particularly true where little or no hydrocarbon resources have been discovered and, consequently, only very few wells have been drilled into and through the sediments saturated with saline water or brine.

For the purpose of this study, it is assumed that the thicker the saline water and brine section the less the risk of man's intrusion and contamination of a usable water source by the introduction of contaminants from any basement-rock repository. Figure 5 shows the estimated thickness of sediments containing saline water and brine, and the present western limits of ground water with at least 5,000 and 18,000 mg/L chloride. The figure was derived by subtracting the altitude of the top of water that contains 5,000 mg/L chloride (Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984), from the approximate altitude of the top of basement rock (map modified from Brown, Miller and Swain, 1972) and contouring the difference. The areas where basement rocks are overlain by brine are considered to have the best assurance of isolation with respect to this criterion. These areas were identified from a map of the altitude of the top of water that contains 18,000 mg/L chloride (Meisler, 1980b; Harold Meisler, U.S. Geological Survey, written and oral commun., 1984). The western extent of the saline water (zero line, fig. 5) constitutes a preliminary western boundary for the potential application of the buried-crystalline rock concept throughout most of the area. However, this boundary is constituted by the contour that indicates the top of the basement rock occurs at 1,000 ft below sea level in the southern part of the Coastal Plain in North Carolina (fig. 5). Here the saline water is found above altitudes of 1,000 ft below sea level, but the depth criterion for the basement rock supersedes the saline-water criterion.

The greatest thickness of sediments containing saline water and brine occurs in the Coastal Plain of southern Virginia, the southern tip of the Delmarva Peninsula, and the northern and central parts of the Coastal Plain of North Carolina, where these sediments attain a thickness of over 3,000 ft (fig. 5). Another thick mass of sediments saturated with saline water and brine occurs in the northern part of the area at the Delaware River estuary and in the adjacent parts of New Jersey and Delaware. Here the thickness is as much as 2,600 ft (fig. 5).

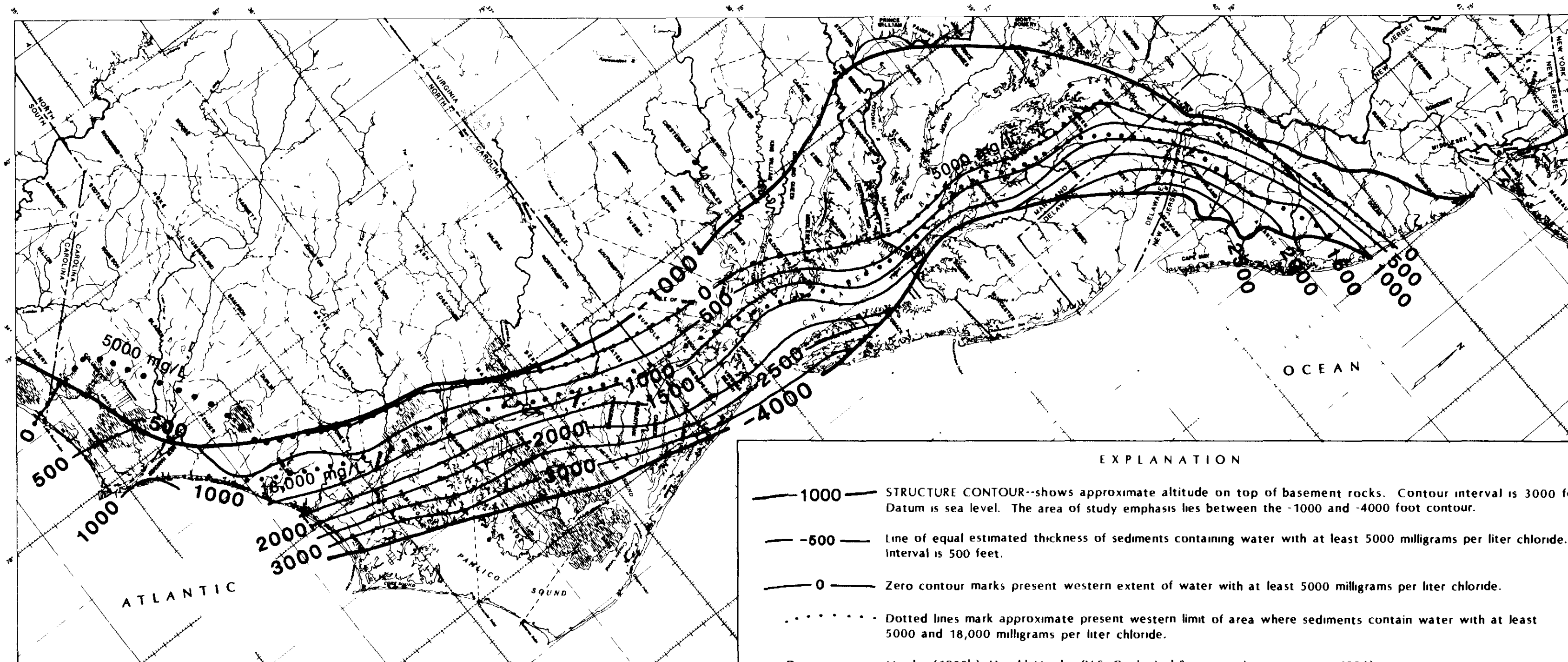


Figure 5.--Approximate thickness of sediments containing saline water and brine in parts of the northern Atlantic Coastal Plain.

Thickness of Confining Beds

The confining beds serve as barriers to impede vertical ground-water flow, and they have sorptive properties that tend to trap and hold contaminants. Their effectiveness as vertical-flow barriers and sorptive agents is here assumed to be directly proportional to their thickness. Because of the inferred discontinuous and lenticular nature of the sediments that constitute the lower confining beds, it is assumed further that at least the two lowermost confining beds would be involved in the barrier and sorptive roles necessary for waste isolation. Thus, the thicknesses of the two lowermost confining beds at any one place are added together and used as a single value for the purpose of evaluating their relative confining potential.

Figure 6 shows the combined estimated thickness and distribution of the two lowermost confining beds. The combined thickness exceeds 900 ft near the eastern limit of the area in a small part of New Jersey and Delaware, and is less than 100 ft in parts of Virginia and North Carolina, near the western limit of the area. The average thickness ranges between 100 and 300 ft in southern parts of the northern Atlantic Coastal Plain and is about 500 ft in the northern part.

Some of the regional difference in the confining-bed thickness may result from differences in interpretation regarding the definition and correlation of geohydrologic units that are comprised of lenticular and discontinuous beds of sand, silt and clay. Consequently, the thickness values shown and the continuity implied on figure 6 should be considered as first approximations only.

Permeability of Aquifers

Because of the inferred discontinuous and lenticular nature of the confining beds, it is likely that ground-water movement in the two lowermost aquifers, at least, could be involved in the migration of radionuclides. Ground-water movement is directly proportional to the hydraulic conductivity of and hydraulic gradient within the aquifers. However, owing to the lack of definitive hydraulic-conductivity and hydraulic-gradient data for the lowermost aquifers in the downdip saline-water bearing parts of the section, the potential migration rate is assumed to be directly proportional to the estimated relative permeability of the aquifer material. In general, the sedimentary material comprising the lowermost aquifers becomes finer grained, more compacted and less porous and permeable toward the east. Thus, the potential migration rate through the aquifer material is estimated to be lowest in the eastern parts of the area where both the saline-water and depth criteria are met. In addition, the finer-grained aquifer material may have high clay content with attendant sorptive properties.

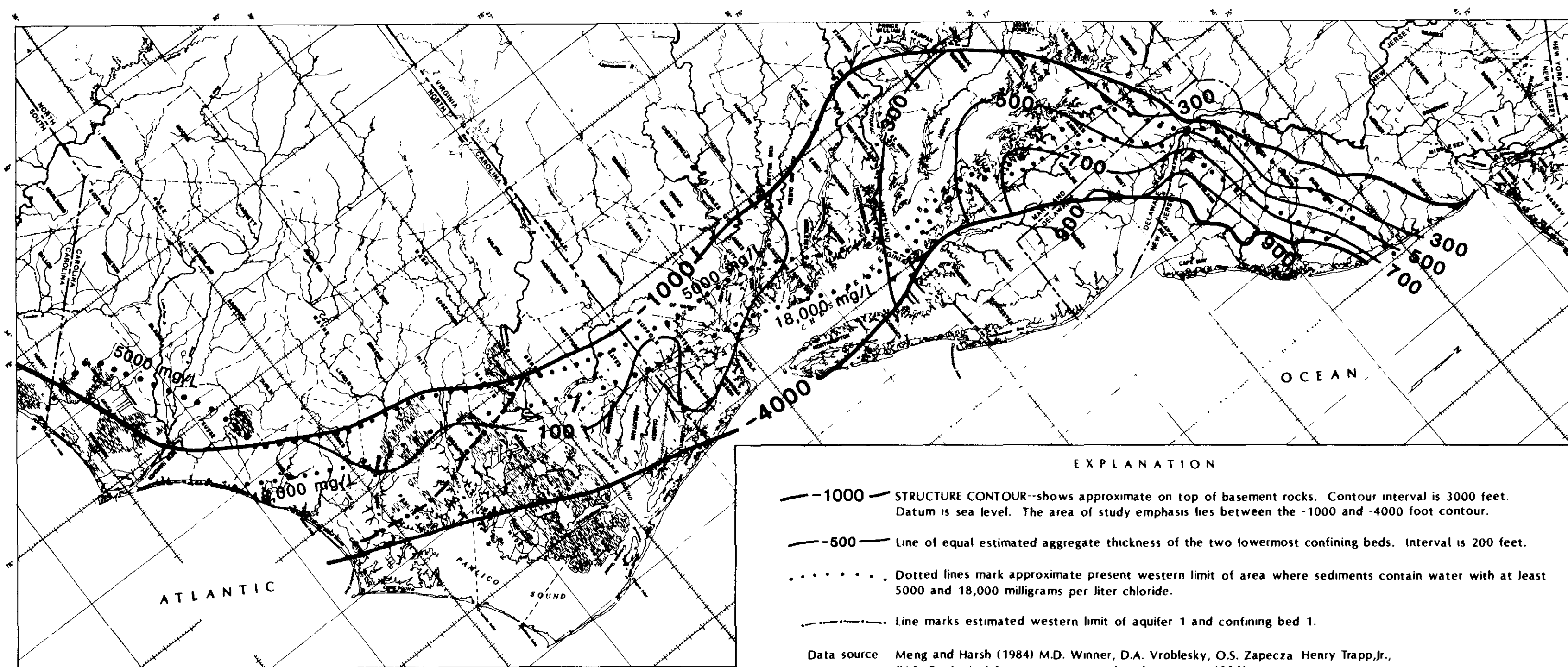


Figure 6.--Estimated combined thickness of the two lowermost confining beds in parts of the northern Atlantic Coastal Plain.

Direction of Lateral Ground-Water Flow

The estimated direction of lateral ground-water flow in the two lowermost aquifers is used as a factor to indicate the lateral direction of any potential contaminant migration in the area. It is assumed that the lateral ground-water flow conditions are least favorable to the application of the buried crystalline-rock concept in areas where movement is toward major centers of ground-water withdrawal.

Preliminary hydraulic-head data and potentiometric-surface maps from G.L. Giese, M. D. Winner, A. A. Meng, J. F. Harsh, R. J. Laczniak, D. A. Vrobleskey, W. B. Fleck, O. S. Zapecza, M. M. Martin, P. P. Leahy (U.S. Geological Survey, written and oral commun., 1984); Martin (1984); and Hopkin and others (1981), indicate cones of depression that have developed around centers of ground-water withdrawal in the two lowermost aquifers have spread to areas where these aquifers are saturated with saline water. It is assumed that the saline-water front is moving very slowly westward toward centers of pumping wherever the ground-water withdrawals have caused the heads in these aquifers to decline significantly and continually with time, at or near the 5,000 mg/L chloride line.

Figure 7 shows the location of the major centers of ground-water withdrawal from the two lowermost aquifers and indicates that, for 1980, saline water was estimated to be moving very slowly toward the pumping centers from more than 50 percent of the length of the saline-water front in the area. For the same time period, hydraulic heads near the saline-water front in the west-central part of the Delmarva peninsula and the southeastern part of North Carolina are estimated to be much less affected by ground-water withdrawals from the two lowermost aquifers. These patterns are temporal and can change with a change in the amount or distribution of the ground-water withdrawals.

Figure 7 also shows the general location of the possible pinch out of aquifer 1 and confining bed 1 on the basement rocks. As previously discussed (see text on cross sections C-C', D-D' and E-E'), such a pinch out might form a barrier that would significantly retard the westward movement of ground water and any contaminant that might occur in aquifer 1.

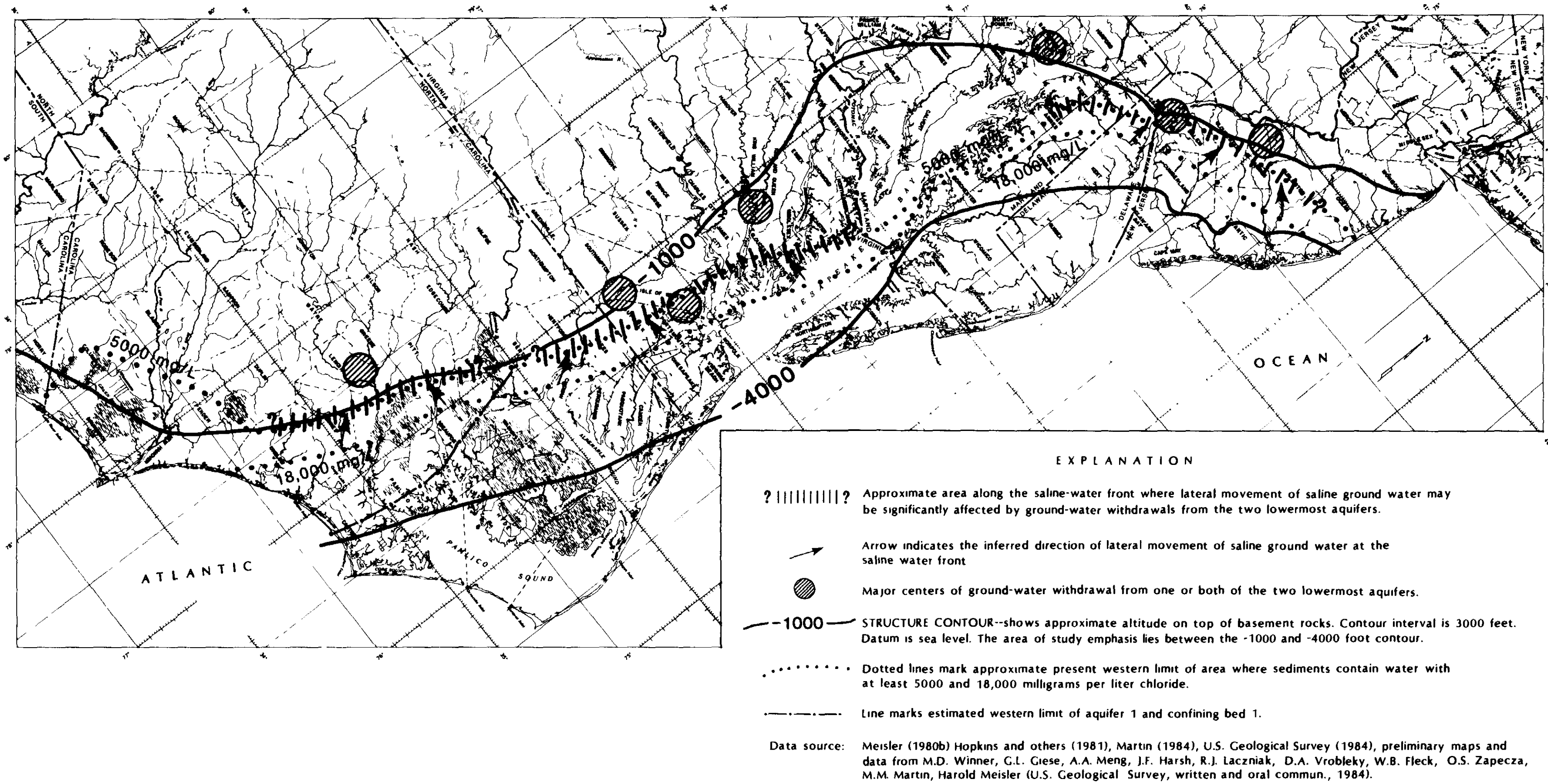


Figure 7.--Estimated direction of lateral ground-water flow in the two lowermost aquifers at the saline-water front in parts of the northern Atlantic Coastal Plain, 1980.

SUMMARY AND CONCLUSIONS

A preliminary investigation by Davis (1984) indicated that the northern part of the Atlantic Coastal Plain is one of two areas in the Eastern United States where hydrogeologic conditions might meet most of the criteria established by Bredehoeft and Maini (1981) for the disposal of radioactice waste in crystalline rocks that are buried beneath a thick blanket of sedimentary rocks. The present study was undertaken to summarize and evaluate the existing knowledge about the hydrology of the northern Atlantic Coastal Plain sediments relevant to the suitability for the application of the buried crystalline-rock concept (Bredehoeft and Maini, 1981). The data and many of the interpretations used in this study are derived from published reports and from reports that are being prepared by the U.S. Geological Survey from its Regional Aquifer System Analysis (RASA) study of the northern Atlantic Coastal Plain.

The major area of interest occurs in the States of Delaware, Maryland, New Jersey, North Carolina and Virginia where the top of the basement complex lies between 1,000 and about 4,000 ft below sea level. The sedimentary rocks that overlie the basement complex in this area have been divided into 10 regional aquifers that are composed of sand, silty sand and limestone. These aquifers are separated by confining beds composed of silty clay and clay. The aquifer and confining-bed units (geohydrologic units) have been numbered from 1 to 10, oldest to youngest, respectively.

Aquifers 1, 2 and 3, and confining beds 1, 2 and 3 (the oldest and deepest geohydrologic units for which the least amount of data exists) are of primary importance because they lie just above the basement complex and their chararacteristics control the potential for the long-term isolation of any contaminant that might be introduced to the sediment mass from a buried crystalline-rock repository. These deep geohydrologic units occur throughout most of the area except in the southeastern part of the North Carolina Coastal Plain where aquifer 1 and confining bed 1 are missing. Most of the sediments that comprise these units were deposited in environments that varied from nonmarine to marginal marine with both time and space. Consequently, the deposits are lenticular and discontinuous in nature. These characteristics and the lack of data combine to make it difficult to define and correlate these units from one place to another.

The transmissivity of aquifers 1, 2 and 3 is estimated to range from low to medium high (7,000 to 21,000 ft^2/d) in the freshwater part of the section. The hydraulic conductivity of the bulk of the aquifer material is estimated to range from less than 5 ft/d for the silty sand to about 100 ft/d for the well-sorted coarser sand. Data from deep wells in Maryland indicate the horizontal hydraulic conductivity of saline-water bearing sands in aquifer 1 is rather low (about 12 ft/d at about 3200 ft below sea level in well MD-42, Trapp and others, 1984; and less than 1 ft/d at about 4000 ft below sea level in well MD-82, Hartsock and others, 1980). The estimated vertical hydraulic conductivity for the confining beds ranges from about $1x10^{-3}$ to $1x10^{-5}$ft/d. A realistic average ratio of horizontal to vertical hydraulic conductivity in the area is estimated to be between 10,000 to 1, in the coastal plain of North Carolina (G. L. Giese, U.S. Geological Survey, oral commun., 1984), and 30,000 to 1, in the coastal plain and off shore sediments of New Jersey (Meisler, Leahy and Knobel, 1985).

The deep aquifers and confining beds are saturated with saline water and brine mainly in the eastern part of the area where the top of basement rock is 1,000 ft or more below sea level. The dissolved-solids concentration in the ground water increases from that of freshwater in the shallow aquifers, to at least twice that of seawater at about 4,000 ft below sea level in the eastern part of the area; and water density increases accordingly. The transition zone between the freshwater and water with chloride concentrations of 18,000 mg/L is as much as 2,300 ft thick. This zone is thought to have formed by a mixing of the waters during advances and retreats of the saline water caused by long-term eustatic sea level changes (Meisler, Leahy and Knobel, 1984). The transition zone deepens landward except in New Jersey and in the vicinity of the Delaware Bay where it deepens toward the ocean. The zone is shallowest in North Carolina and deepest in eastern New Jersey (Meisler, Leahy and Knobel, 1985).

Since 1900, increasing amounts of ground water have been pumped from the aquifers in the area until, at present, the withdrawals are more than 1 billion gallons per day. Water levels (heads) have declined from 50 to 200 ft or more at the centers of pumping and large cones of depression are estimated to influence the ground-water movement in aquifers 1, 2 or 3 along more than 50 percent of the saline-water front in the study area.

In homogeneous and isotropic aquifers saturated with water of relatively constant temperature and density, and for which the values of porosity and permeability are known, both the direction and velocity of ground-water movement can be predicted by mapping the hydraulic head and substituting the appropriate values into general equations that are expressions of Darcy's Law. However, aquifers 1, 2 and 3 in the study area contain ground water that has different temperature and density from place to place, and interspersed silt and clay particles and lenticular bodies of silt and clay that introduce an anisotropic and heterogeneous character to the sediments. The geologic and hydrologic data needed to accurately define and correct for these complications are lacking in some places in the freshwater part of the sediment mass and, by comparison, are practically nonexistent on a meaningful scale where the sediments contain water with more than 10,000 mg/L chloride. Thus, the estimates of hydraulic gradient and flow direction shown in this report are qualitative at this stage. Accordingly, estimates of flow velocity are deferred until more geologic and hydrologic data are obtained for the deep, saline-water bearing parts of the sedimentary section.

Fourteen geohydrologic cross sections (pls. 2 through 15) show the estimated distribution and thickness of the aquifers and confining beds; the distribution of aquifer transmissivity in the freshwater part of the section, and estimated hydraulic heads and inferred flow directions for 1900 and 1980; and the distribution of freshwater, saline water and brine in the sediment mass at selected places throughout the area.

Four general geohydrologic characteristics are used to summarize and make a preliminary evaluation of the hydrology of the sediments with regard to their suitability for the application of the buried crystalline-rock concept: (1) estimated thickness of saline water and brine in the sediments, (2) estimated aggregate thickness of the two lowermost confining beds, (3) estimated permeability of the two lowermost aquifers and (4) estimated direction of lateral ground-water flow in the two lowermost aquifers. Within the area where the top of the basement rock lies between 1,000 and about 4,000 ft below sea level, the estimated thickness of the saline-water bearing sediments ranges from zero to more than 3,000 ft; the estimated aggregate thickness of the two lowermost confining beds ranges from less than 100 ft to more than 900 ft; the relative permeability of the two lowermost aquifers is estimated to decrease toward the east; and increasing ground-water withdrawals from the two lowermost aquifers are estimated to have caused (and probably are still causing) saline water to move very slowly toward the centers of pumping from along more than 50 percent of the length of the saline-water front in the area. When viewed collectively, the data suggest that eastern parts of the study area best meet most of the preliminary criteria established for the buried crystalline-rock concept (figs. 5 through 7). Further investigation will be needed to test these preliminary findings and to more accurately define the geology and hydrology of aquifers and confining beds 1, 2 and 3.

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Table 4.--Records of selected wells

Report or state well number: Number is that shown in reports or used by the appropriate state to identify the well. Map number: Number is that assigned to identify the well and its location on figure 2. Coordinate location: Numbers in the lat. and long. columns represent the location of the well in degrees, minutes and seconds of latitude north of the equator and of longitude west of the zero meridian, respectively. Elevation of GL (ft): Number is elevation of ground level (GL) or land surface in feet (ft). Data source: Ba., Bain (1970); B., Brown (1959); C., Cederstrom (1957 and 1968); D. F., data in files of District office of Water Resources Division, U.S. Geological Survey; F. and L., Floyd and Long (1970); H. and W., Harris and Wilder (1966); La., Larson (1981); Le., LeGrand (1960); Leen., Leenheer, Malcolm, and White (1976); L. and F., Lloyd and Floyd (1968); L., Lloyd (1968); NRCD, North Carolina Department of Natural Resources and Community Development file data; RASA, Regional Aquifer System Analysis (northern Atlantic Coastal Plain); S., Siudyla and others (1981); Su., Sumsion (1970); VASWCB, Virginia State Water Control Board; V.P.I., Virginia Polytechnical Institute and State University; W., Woodruff (1969); Wy., Wyrick (1966). Well Logs: GR, gamma ray; E, resistivity or spontaneous potential; POR, bulk density, sonic travel time or neutron; T, temperature; LITH; lithologic samples or core samples descriptions; X, indicates data are available.

Report or State well number	Map no.	Well name	Coordinate location		Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs					Water quality	Head data
			Lat.	Long.					GR	E	POR	T	LITH		
						DELAWARE									
Dc 53-23	DE-1	Getty Oil	393513	753629	32	712	Basement at -646	W. and D.F.		X			X	X	
Dc 15-6	DE-2	Amoco Oil Co.	393406	753554	20	629	Basement at -600	RASA and D.F.		X			X		
Eb 34-3	DE-3	Canal Realty	393204	754157	38	845	Basement at -792	do.		X			X		
Ed 51-3	DE-4	Port Penn, Fisher	393048	753439	10	943	RASA Unit 2 at -395	do.	X	X					X
Fb 33-10	DE-5	Middletown	392708	754259	65	590	RASA Unit 2 at -395	do.	X	X			X		
Gd 33-4	DE-6	Shell Oil Co.	392212	753318	21	2,312	Basement at -2,280	do.	X	X			X	X	
Hc 24-4	DE-7	Jurgens	391851	753618	35	584	RASA Unit 5 at -185	do.	X	X			X		
Id 31-26	DE-8	International Latex	391215	753409	38	1,200	RASA Unit 3 at -960	W., RASA, and D.F.	X	X			X	X	
Je 32-4	DE-9	U.S. Air Force, Dover	390740	752859	23	1,422	RASA Unit 3 at -1,230	RASA and D.F.	X	X			X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
DELAWARE--Continued															
Kb 32-1	DE-10	U.S. Geological Survey	390221	754354	55	867	Upper Creta-ceous	RASA and D.F.	X	X			X		
Kd 51-5	DE-11	Felton-Swift and Company	390015	753443	50	583	RASA Unit 6 at -390	do.	X	X			X	X	
Me 15-29 and SUS-T-7	DE-12	U.S. Geological Survey, Milford	385459	752518	10	958	Middle Eocene at -890	PP 796	X	X			X	X	
Nc 13-3	DE-13	U.S. Geological Survey	384935	753659	62.7	1,506	RASA Unit 6 at -520	RASA and D.F.	X	X			X	X	
Nh 24-1	DE-14	Broad Kill Beach	384845	751141	4	732	RASA Unit 7 at -330	do.		X			X	X	X
Od 23-1 and SUS-OT-5	DE-15	Apple Orchard D-6, Sun Oil	384325	753200	25	2,585	RASA Unit 2 and Unit F	RASA and PP 796		X			X		
MARYLAND															
CEC-T-10	MD-1	T. Foard (Parsons et al.)	393218	754753	62	695	Basement at -622	RASA and PP 796	X	X					
HA-DG-3	MD-2	Maryland Geo-logical Survey	392643	760415	5	777	RASA Unit 1 at -420	RASA	X	X			X		
CE-E-29	MD-3	U.S. Geological Survey	392403	755218	75	1,458	RASA Unit 1 at -1,024	do. and D.F	X	X			X	X	
KE-AC-20	MD-4	do.	392007	760755	7(?)	1,151	RASA Unit 2 at -90	do.	X	X			X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							MARYLAND--Continued								
KE-BE-43	MD-5	U.S. Geological Survey	391823	755947	75	1,672	RASA Unit 2 at -365	RASA	X	X			X	X	X
KE-BG-33	MD-6	do.	391815	754721	67(?)	2,185	Basement at -2,059	D.F.	X	X	X		X	X	X
BA-FG-66	MD-7	Baltimore Co. Forest & Parks	391524	762456	20	791	RASA Unit 1 at -590	do. and RASA	X	X			X	X	X
BA-GE-2	MD-8	Consolidated G.,E.,L., and Power Company	391400	763000	10	600	Basement	D.F.						X	X
BA-GF-35	MD-9	Bethlehem Steel Company	391339	762817	10	680	RASA Unit 1	do.						X	X
BA-GF-139	MD-10	do.	391236	762928	10	615	do.	do.						X	
KE-CB-36	MD-11	U.S. Geological Survey	391406	761014	36	1,540	Basement(?) at -1,474(?)	do. and RASA	X	X			X	X	X
QA-BE-15	MD-12	do.	391203	760243	22	2,009	Basement at -1,928	D.F.	X	X		X	X	X	X
ANAR-P-25	MD-13	Glen Burnie	390900	763830	100	625	Basement at -520	PP 796	X	X			X		
KE-DB-40	MD-14	U.S. Geological Survey	390837	761404	20	1,822	Basement at -1,740	RASA and D.F.	X	X			X	X	X
AA-CC-78	MD-15	Anne Arundel Co. Sanitary Com.	390422	764148	178	916	Basement at -738	D.F.		X			X	X	X
AA-CC-114	MD-16	Anne Arundel Co. Dept. of Public Works	390256	764131	148	1,017	Basement at -869	do.	X	X			X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							MARYLAND--Continued								
AA-CE-120	MD-17	Anne Arundel Co. Dept. of Public Works	390303	763443	162	1,340	RASA Unit 1 at -880	RASA and D.F.	X	X				X	
AA-CF-108	MD-18	do.	390207	762928	130	598	RASA Unit 2 at -370	do.		X				X	
AA-CG-22	MD-19	U.S. Geological Survey	390123	762416	10	1,858	Basement at -1,798	D.F.	X	X	X			X	X
AA-CC-105	MD-20	Anne Arundel Co. Dept. of Public Works	390100	764032	130	1,242	Basement	do.		X				X	X
PG-CF-53	MD-21	Levitt and Sons	385816	764345	114	1,172	Basement at -1,047	D.F. and RASA		X					
PG-CE-16	MD-22	Dist. of Columbia, Glen Dale Sanitarium	385750	764833	145	946	Basement at -800	D.F.						X	X
QA-EB-110	MD-23	U.S. Geological Survey	385751	761716	14	2,550	RASA Unit 1 at -2,175	D.F. and RASA	X	X		X	X	X	X
AA-DE-124	MD-24	Anne Arundel Co. Dept. of Public Works	385528	763346	35	1,105	RASA Unit 2 at -376	do.	X	X				X	
	MD-25	Cole Associates	385304	763017	21	572	RASA Unit 2	do.	X	X					
	MD-26	Caroline Poultry Farms, Inc.	385306	755031	18	980	RASA Unit 4 at -925	do.					X		
TA-CB-89 and Tal-T-4	MD-27	Pan-Am Refining	384914	761732	13	1,520	RASA Unit 2 at -1,025	PP 796 and RASA	X	X			X	X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
							MARYLAND--Continued								
AA-FE-47	MD-28	U.S. Geological Survey	384843	763126	6	674	RASA Unit 2 at -625	RASA	X	X			X		X
	MD-29	New German Orphanage	384744	764834	215	924	RASA Unit 2 at -180	do					X		
PG-EC-41	MD-30	Washington Sub-urban Sanitary Commission	384744	765952	180	870	RASA Unit 1 at -440	do.		X			X		X
TA-CE-67	MD-31	Easton Airport Well	384740	760400	56	1,092	RASA Unit 5 at -565	do.						X	
TA-CE-5	MD-32	Easton Utilities Commission	384629	760439	30	1,148	RASA Unit 3	RASA and D.F.						X	X
CA-BB-23	MD-33	Kaine-Shores	384458	763800	148	562	RASA Unit 5 at -105	do.	X						
PG-OT-42	MD-34	Washington Gas Lt., Mudd 1	384400	765212	124	1,727	Basement at -1,366	PP 796 and RASA		X			X		
TA-DC-2	MD-35	Town of Oxford	384057	761020	6	559	RASA Unit 6	RASA and D.F.						X	
	MD-36	HCF Elementary School	384107	765842	104	710	RASA Unit 2 at -125	RASA					X		
PG-OT-41	MD-37	Washington Gas Lt., Wedding 1	383945	765520	202	1,750	Basement at -1,430	PP 796 and RASA	X	X			X		
CH-BF-144	MD-38	C.C. of C. C.	383913	765102	205	1,977	RASA unit 1 at -1,200	RASA and D.F.	X	X			X		
PG-EC-29	MD-39	Oxon Hill Recreation Club	384720	765837	75	822	Basement	do.					X	X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						MARYLAND--Continued									
CA-CC-56	MD-40	U.S. Naval Research Lab.	383934	763200	94	900	RASA Unit 2 at -690	RASA and D.F.	X	X				X	X
DO-BB-12	MD-41	R. Carpenter	383724	761642	5	1,025	RASA Unit 3 at -780	do.	X					X	
DO-CE-88	MD-42	U.S. Geological Survey	383401	760320	9.4	3,337	Basement at -3,299	do.	X	X	X		X	X	X
CH-CE-39	MD-43	Carmel Water Co.	383403	765949	180	595	RASA Unit 2 at -310	do.		X					
CH-CE-37	MD-44	U.S. Geological Survey	383236	765639	185	2,017	RASA Unit 1 at -1,365	do.	X	X	X		X	X	
CH-CF-28	MD-45	T.C. Martin School	383219	765035	185	661	RASA Unit 3 at -380	do.	X	X					
PG-HF-40	MD-46	Maryland Geological Survey	383348	764113	28	1,095	RASA Unit 2	do.	X	X			X	X	
PG-HF-31	MD-47	Pepco, Chalk Point	383250	764053	10	2,453	Basement at -2,437	do.	X	X			X	X	
PG-HF-24	MD-48	P.E. Power Co.	383228	764057	6	645	RASA Unit 3 at -550	do.	X	X					
CH-CG-18	MD-49	U.S. Geological Survey	383120	764514	165	1,030	RASA Unit 2 at -575	do.	X	X			X	X	X
CA-DC-35	MD-50	do., Scientist Cliff	383050	763055	85	1,000	RASA Unit 2 at -760	do.	X	X					X
DO-DB-31	MD-51	Dorchester Co.	382804	761722	5	536	RASA Unit 6	do.						X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							MARYLAND--Continued								
DO-DH-11	MD-52	Delmarva Power and Light Co.	382916	754917	10	588	RASA Unit 6 at -545	RASA and D.F.	X	X				X	
CH-DA-18	MD-53	Pepco	382654	771525	90	772	RASA Unit 1 at -450	do.	X	X					
CA-ED-22	MD-54	Baltimore Gas and Electric Co.	382603	762643	117	789	RASA Unit 5 at -435	do.	X	X					
DO-DB-16	MD-55	D. Donahue	382552	761746	4	1,706	RASA Unit 2	do.	X						
DO-DC-7	MD-56	U.S. Geological Survey	382649	760548	3	800	RASA Unit 3 at -780	do.					X		
DO-DF-11	MD-57	Lloyd Willey	382510	755740	3	534	RASA Unit 7	do.					X	X	X
WI-CD-65	MD-58	Grvy. Fed., Inc.	382326	754119	40	950	RASA Unit 6 at -700	do.		X					
WI-CG-35	MD-59	Hastings Hatchery	3823-	7528-	75	685	RASA Unit 7	do.					X	X	
WI-CH-36	MD-60	U.S. Geological Survey	382254	752213	44	617	RASA Unit 8	do.	X	X			X		
WO-AH-6	MD-61	do.	382632	750318	5	1,210	RASA Unit 7	do.		X			X	X	
WO-BG-15	MD-62	Sacre Lumber	382331	750621	4	1,706	RASA Unit 3	do.	X						
WOR-OT-10	MD-63	Socony Vacuum, Bethards 1	381805	751640	43	7,178	Basement at -7,070	RASA and PP 796		X			X		
WOR-OT-11	MD-64	Esso, Maryland No. 1	382419	750341	22	7,710	RASA Unit 1 at -4,193	do.		X			X		
WIC-OT-11	MD-65	Ohio Oil, Hammond 1	382046	752910	54	5,568	Basement at -5,428	do.		X			X		

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						MARYLAND--Continued									
WI-CF-63	MD-66	Marshall Bornt	382034	753304	38	1,003	RASA Unit 7	D.F.		X					
WI-DD-23	MD-67	Robert Smith	381757	754013	23	525	RASA Unit 7	do.	X	X			X		
WI-DB-56	MD-68	U.S. Geological Survey	381844	755328	10	1,230	RASA Unit 3 at -990	RASA and D.F.	X	X			X	X	X
DO-FE-14	MD-69	Garlen Jones	381806	760413	2	504	RASA Unit 7	D.F.						X	
CA-FE-19	MD-70	Columbia Corp.	382316	762436	120	824	RASA Unit 5 at -480	RASA and D.F.	X	X					
CE-FD-24	MD-71	U.S. Geological Survey	382407	762603	120	698	RASA Unit 6	D.F.	X	X			X	X	
CH-EE-78	MD-72	International Realty	382240	765828	75	1,220	RASA Unit 1	do.	X	X		X		X	
CHA-P-31	MD-73	Pot. Electric Co.	382152	765823	20	1,152	RASA Unit 2 at -245	RASA and PP 796	X	X					
SM-DF-84	MD-74	Maryland Geological Survey	381548	762721	105	2,679	Basement at -2,519	RASA and D.F.	X	X		X	X	X	
	MD-75	St. Peter Claver Church	380720	762900	7	612	RASA Unit 6	do.	X					X	
SM-FF-36	MD-76	Kitts Pt. Utility	380719	762518	7	940	RASA Unit 5 at -520	do.	X					X	
SM-GG-14	MD-77	Dept. of Forests and Parks	380342	762005	3	728	RASA Unit 6 at -315	D.F.	X	X			X	X	X
SM-GH-8	MD-78	Pt. Lookout State Park	380312	761927	5	720	RASA Unit 6	do.	X	X					

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						MARYLAND--Continued									
SO-BB-1	MD-79	Piney Point	381000	755650	6	670	RASA Unit 7	D.F.						X	
SO-CC-7	MD-80	Robert Dykes	380621	755103	5	1,144	RASA Unit 3	do.	X	X				X	
SO-CC-5	MD-81	E. Stevens	380457	755145	12	1,170	RASA Unit 6 at -720	RASA and D.F.	X	X					
SO-DD-47	MD-82	U.S. Dept. of Energy, Crisfield 1	380058	754948	11.5	5,562	Basement at -4,457(?)	do.	X	X	X	X	X	X	X
SO-EA-11	MD-83	Mr. Fowler	375822	760003	0	1,000	RASA Unit 3 at -940	do.		X				X	
CA-DB-36	MD-84	Calvert Road Commission	383317	763507	130	1,515	RASA Unit 2	RASA	X						
						NEW JERSEY									
250319,-20	NJ-1	Natl. PK. Serv., Ft. Hancock 5 and 6	402705	735959	14	878	RASA Unit 2 at -715	RASA and D.F.	X			X			
250453	NJ-2	Union Beach W.D., UBWD 3 1977	402632	741051	10	609	Basement at -599	do.	X				X		
250262	NJ-3	Marlboro State Hospital 15	402102	741353	135	870	RASA Unit 2 at -575	do.	X	X					
250360	NJ-4	Red Bank W.D. 4-75	402054	740320	146	769	RASA Unit 3 at -458	do.	X	X					

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						NEW JERSEY--Continued									
250034	NJ-5	Nad Earle 2(8)	401558	740908	135	836	RASA Unit 3 at -505	RASA and D.F.	X						
250218	NJ-6	Boy Scouts of America, Quail Hill 2	401557	742318	258	527	RASA Unit 3 at -186	do.	X						
250494	NJ-7	Monmouth Con. W.C., Whitesville	401323	740156	18	777	RASA Unit 4 at -442	do.	X	X		X			
250013	NJ-8	Avon Water Dept., AWD 4	401137	740121	29	1,298	RASA Unit 3 at -956	do.	X	X					
250407	NJ-9	Punk Bros. Deep Well	401005	742939	129	952	Basement at -659	do.	X			X			
290575	NJ-10	Jackson Twp. MUA, Jackson 9	400652	741717	135	1,655	Basement at -1,515	do.	X	X					
290045	NJ-11	Brick Twp. MUA, Forg Pond 9-73	400431	740832	8	1,817	Basement at-1,764	do.	X	X			X		
290134	NJ-12	Jackson Twp. MUA, SCM 1	400320	741954	95	1,782	RASA Unit 1 at -1,430	do.		X					
BU-P-14	NJ-13	U.S. Air Force, McGuire Base	400300	743514	126	1,008	Basement at -882	RASA and PP 796	X				X		
050440	NJ-14	Rhodia Corp. 1	400242	744223	75	641	Basement at -566	RASA and D.F.		X			X	X	
290504	NJ-15	N.J. Water Co., Mantoloking 7	400210	740310	5	1,369	RASA Unit 1 at -1,278	do.	X					X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
						NEW JERSEY--Continued									
050334	NJ-16	U.S. Army Fort Dix 3	400138	743753	165	869	RASA Unit 2 at -670	RASA and D.F.	X				X	X	
OC-T-12	NJ-17	Toms River Chem. Test 84	395930	741421	65	2,254	RASA Unit 1 at -1,868	RASA and PP 796	X	X			X		
290453	NJ-18	Lavallette W.D., LWD 4	395808	740416	10	1,515	RASA Unit 3 at -1,334	RASA and D.F.	X						
070278	NJ-19	N.J. Water Co., Haddon 15	395238	750316	65	594	Basement at -535	do.		X				X	
070117	NJ-20	N.J. Water Co., Hutton Hill 1	395229	745712	156	562	RASA Unit 3 at -271	do.	X	X					
CAM-P-9	NJ-21	N.J. Water Co. 21	395130	745845	95	584	RASA Unit 3	RASA and PP 796		X					
BU-T-4	NJ-22	U.S. Geological Survey, Butler Place 1	395122	743017	132	2,265	Basement at -2,098	RASA and PP 796	X	X			X	X	
290585	NJ-23	State of New Jersey, DGE C-39	395028	741044	15	959	RASA Unit 7 at -160	RASA and D.F.	X						
OC-T-1	NJ-24	U.S. Geological Survey, Island Beach	394829	740535	10	3,881	Basement at -3,844	PP 796	X	X			X	X	
	NJ-25	Warren Grove	3946-	7418-		1,785	RASA Unit 3	RASA and D.F.						X	
290572	NJ-26	Transcontinental Gas, T.H. 18	394617	741933	148	1,737	RASA Unit 3 at -1,468	do.		X					

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
							NEW JERSEY--Continued								
050672	NJ-27	Transcontinental Gas P.L. 13	394452	742950	90	1,519	RASA Unit 3 at -1,182	RASA and D.F.		X					
290607	NJ-28	Barnegat Lt. W.D., Test-78	394454	740655	5	639	RASA Unit 6 at -590	do.	X				X		
	NJ-29	AMOCO 6011	394330	735836	0	926	RASA Unit 6 at -706	do.	X	X	X		X		
CAM-T-2	NJ-30	U.S. Geological Survey, New Brooklyn 1	394215	745617	111	2,090	Basement at -1,919	PP 796	X	X			X	X	
SAL-T-2	NJ-31	U.S. Geological Survey, Point Airy	394035	751945	71	666	RASA Unit 2	RASA and PP 796	X				X	X	
330064	NJ-32	E.I. DuPont, Courses Landing 3A	393912	752436	20	830	RASA Unit 1 at -640	RASA and D.F.	X	X			X	X	
15001	NJ-33	Clayton W.D., CWD 3	393912	750522	133	1,000	Rasa Unit 4 at -606	do.		X				X	
330354	NJ-34	Woodstown Boro W.D. 2	393904	751946	45	640	RASA Unit 2	do.						X	
BU-T-19	NJ-35	Transcontinental Gas P.L. 16	393847	743036	18	1,658	RASA Unit 3 at -1,401	RASA and PP 796		X					
290547	NJ-36	Ship Bottom W.D., SHWD Test 1973	393845	741053	7	993	RASA Unit 6 at -340	RASA and D.F.	X	X			X		
SAL-T-9	NJ-37	Salem Obs. Well 1	393410	752800	6	800	B.-Unit G	PP 796	X					X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						NEW JERSEY--Continued									
330389	NJ-38	E.I. DuPont, Test 2-66	393223	750442	80	1,048	RASA Unit 3 at -860	RASA and D.F.	X	X			X		
SAL-P-8	NJ-39	Public Electric Service	392755	753215	5	906	RASA Unit 2; B.-Unit F	RASA and PP 796		X					
CU-OT-8	NJ-40	Anchor Gas Co.- USGS Ragovin 1	392512	745212	91	3,717	Basement at -3,616	RASA and PP 796	X	X		X	X	X	
110072	NJ-41	Cumberland Co., Sheppards 1	392442	751916	12	638	RASA Unit 6 at -146	RASA and D.F.	X	X		X	X		
010649	NJ-42	U.S. Dept. of Energy, DG-ETW4-78	392246	742714	5	1,007	RASA Unit 6 at -902	do.	X	X	X	X	X		
	NJ-43	Atlantic City (1888)	3921-	7427-		1,020	RASA Unit 7	T.						X	
110096	NJ-44	Cumberland Co., Jones Island 2	391829	751208	10	570	RASA Unit 6 at -343	RASA and D.F.	X	X		X	X	X	
090110	NJ-45	N.J.W.C. Ocean City 12-1965	391604	743539	6	814	RASA Unit 7 at -471	do.	X	X					
	NJ-46	Wildwood Pines 1	3859-	7449-		880	RASA Unit 8	RASA						X	
CM-OT-1	NJ-47	Anchor Gas Co., Dickenson 1	385718	745700	14	6,410	Basement at -6,357	PP 796	X	X			X		

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
							NORTH CAROLINA								
B-20-u-6	NC-1	NRCD Como Research Station	363026	770019	62	818	Basement at -752	NRCD, RASA, and D.F.	X	X			X	X	X
Gates 15	NC-2	F. E. McCoy	363100	763600	35±	552	RASA Unit 2	B.						X	X
Gates 11	NC-3	W. K. Parker	362800	763400	40±	538	RASA Unit 3	B.						X	X
Perqui-mans 11	NC-4	N. Riddick	362000	762800	12±	620	Beaufort Fm.	H. and W.						X	X
C-12-r-3	NC-5	NRCD Morgans Corner Research Station	362601	762307	10	1,529	RASA Unit 1 at -1,351	NRCD, RASA, and D.F.	X	X			X	X	X
Pasquo-tank T1	NC-6	U.S. Geological Survey - R. F. Hewitt	362615	762445	14	702	B.-Unit F, RASA Unit 4 at -570	PP 796, D.F. and RASA	X	X			X	X	X
Pasquo-tank 11	NC-7	P. B. Weeks	362600	762600	11±	630	Beaufort Fm.; RASA Unit 6	H. and W. and RASA						X	X
GA-OT-15	NC-8	Cullinan, Weyerhaeuser No. 1	362610	763005	15	2,138	Basement at -2,088	RASA, D.F. and PP 796		X			X		
C-15-s-4	NC-9	NRCD Sunbury Research Station	362646	763614	42	942	RASA Unit 2 at -560	NRCD, RASA, and D.F.	X	X			X	X	X
	NC-10	Conway	362603	771339	105	520	Basement at -415	RASA							
CAM-OT-10	NC-11	Edwin Blair, Weyerhaeuser No. 1	362440	761030	8	3,742	Basement at -2,814	PP 796	X	X			X		

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						NORTH CAROLINA--Continued									
E-10-u-1	NC-12	NRCD Elizabeth City Research Station	362050	761637	7	500	RASA Unit 7 at -447	NRCD, RASA, and D.F.	X	X			X	X	X
CUR-OT-12	NC-13	E. F. Blair and Assoc., Twiford No. 1	361810	755530	5	4,553	Basement at -4,516	PP 796	X	X			X		
Pasquotank 38	NC-14	L. R. Forman and Sons Lumber Co.	361900	761300	6	1,208	Black Creek Fm.	H. and W.						X	X
E-13m-2	NC-15	NRCD Parkville Research Station	361736	762737	16	1,210	RASA Unit 2 at -989	NRCD, RASA, and D. F.	X	X			X	X	X
Chowan 9	NC-16	U.S. Geological Survey (T1)	361906	763655	36	946	RASA Unit 2 at -697	RASA and D.F.	X	X			X	X	X
G-9-c-4	NC-17	NRCD Big Flatty Creek Res. Station	360909	760749	3	731	RASA Unit 6	NRCD, RASA, and D.F.	X	X			X	X	X
G-19-b	NC-18	NRCD Cremo Research Station	360955	765650	67	1,192	Basement at -985	do.	X	X			X	X	X
Chowan 303	NC-19	U.S. Geological Survey (T-2)	360113	763407	8	857	RASA Unit 3 at -654	RASA and L.	X	X			X	X	X
MAR-T-1	NC-20	U.S. Geological Survey T1-61	355615	771200	73	624	RASA Unit 2 at -510; B.-Unit F	RASA, Wy. and PP 796	X	X			X	X	
J-13-d-3	NC-21	NRCD Scuppernong Research Station	355459	762814	8	1,316	RASA Unit 3 at -910	NRCD, RASA, and D.F.	X	X			X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
							NORTH CAROLINA--Continued								
OT-32-177-1	NC-22	Exchange O. and G. Co., Westvaco No. 2	355333	760935	12	4,198	Basement at -3,882	RASA	X	X	X				
DA-OT-14	NC-23	E. F. Blair, Westvaco Pulp and Paper No. 1	355150	755530	3	5,147	Basement at -5,119	PP 796	X	X			X		
J-11-v-5	NC-24	NRCD Newlands Research Station	355050	761607	8	1,449	RASA Unit 3 at -1,214	NRCD, RASA, D.F.	X	X			X	X	X
K-17-a-3	NC-25	NRCD Plymouth Research Station	354925	764530	33	1,494	RASA Unit 2 at -1,148	do.	X	X	X		X	X	X
MAR-P-7	NC-26	Williamston, Church Street	355120	770350	60	665	RASA Unit 3 at -435 and B.-Unit D	RASA, PP 796, and Wy.		X			X	X	
L-24-6-3	NC-27	NRCD Bethel Research Station	354457	772155	65	690	Basement at -625	NRCD, RASA, and D.F.	X	X	X		X	X	X
L-10-a-4	NC-28	NRCD Gum Neck Research Station	354419	761057	3	1,530	RASA Unit 3	NRCD, RASA, and D. F.	X	X	X	X	X	X	X
DA-OT-001-73	NC-29	Gentles, Westvaco 2	354515	754624	6	6,079	Basement at -6,057	D.F.	X	X	X		X		
WAS-OT-2	NC-30	Davidson Oil Co., Furbee 1	354330	763730	16	2,693	Basement at -2,673	PP 796		X			X		
MAR-T-2	NC-31	U.S. Geological Survey, Jamesville	354235	765230	35	970	RASA Unit 3 at -615; B.-Unit D	RASA, PP 796 and Wy.		X			X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							NORTH CAROLINA--Continued								
BEA-OT-11	NC-32	Coastal Plains, H. M. Jackson 1	353815	765115	40	1,526	RASA Unit 2 at -1,243; B.-Unit F	RASA and PP 796		X			X		
Belhaven 29	NC-33	U.S. Geological Survey	353730	764200	12	711	Peedee Fm.; RASA Unit 5 at -530	L. and F., and RASA	X	X			X	X	X
M-12-1-2	NC-34	NRCD New Lake Research Station	353720	762118	8	1,500	RASA Unit 3 at -1,410	NRCD, RASA, and D.F.	X	X			X	X	X
BEA-T-24	NC-35	City of Washington	353320	770125	25	770	RASA Unit 3 at -658; B.-Unit D	RASA and PP 796		X			X	X	
Pitt 26 and PI-T-1	NC-36	City of Greenville	353625	772315	59	754	RASA Unit 2 at -595; B.-Unit F	RASA, B., PP 796, and Su.		X			X	X	X
	NC-37	NRCD Maury Research Station	352840	773601	78	568	Basement at -490	NRCD, RASA, D.F.	X	X			X	X	X
0-17-i-3 and BEA-T-31	NC-38	NRCD Bath Research Station	352824	764659	7.65	699	RASA Unit 5 at -530; B.-Unit B	NRCD, RASA, PP 796 and D.F.	X	X			X	X	X
0-15-n-4	NC-39	NRCD Winsteadville Res. Station	352748	763808	2	710	RASA Unit 5, at -690; Beaufort Fm.	NRCD, RASA, and D.F.	X	X			X	X	X
0-10-w-2	NC-40	NRCD Hydeland Research Station	352527	761231	1	1,510	RASA Unit 5 at -1,230	NRCD, RASA, D.F.	X	X			X	X	X
HY-OT-6	NC-41	E. F. Blair and Assoc., Ballance 1	352725	760150	2	5,570	B.-Unit H, at -4,910; RASA Unit 1 at about -4,000	PP 796 and RASA	X				X		

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
						NORTH CAROLINA--Continued									
DA-OT-12	NC-42	Mobil Oil Co., State of North Carolina 2	352620	753435	1.5	8,386	Basement at -8,336	PP 796	X	X			X		
HY-OT-11	NC-43	Socony Mobil, State of North Carolina 3	351825	754945	1.5	7,314	Basement at -7,236	do.	X	X			X		
DA-OT-10	NC-44	Std. Oil N.J., Hatteras Light No. 1	351500	753145	9	10,044	Basement (Jurassic?) at -9,853	do.		X			X		
P-17-h and BEA-T-28	NC-45	NRCD Lee Creek Research Station	352311	764701	9	954	RASA Unit 4 at -751; B.-Unit C	NRCD, RASA, D.F., and PP 796	X			X	X	X	
P-19-m-4	NC-46	NRCD Cox Crossroads Res. Station	352224	765705	27	800	RASA Unit 4 at -521	NRCD, RASA, D.F.	X	X			X	X	X
P-21-k-5	NC-47	NRCD Wilmar Research Station	352230	770507	40	918	RASA Unit 3 at -684	do.	X	X			X	X	X
Craven 24	NC-48	U.S. Geological Survey	352305	771042	50	959	Cape Fear Fm.	F. and L.	X	X			X	X	X
R-17-i-3	NC-49	NRCD Bay City Research Station	351313	764628	15	620	RASA Unit 5 at -150	NRCD, RASA, and D.F.	X	X			X	X	X
Q-15-u-2	NC-50	NRCD Hobucken Research Station	351517	763547	7	1,003	RASA Unit 5 at -851	do.	X	X			X	X	X
R-24-n-5	NC-51	Peter Havfich	351236	772320	60	1,195	Basement at -998	RASA and D. F.	X	X			X		
Craven 431	NC-52	City of New Bern	351038	771752	34	915	RASA Unit 3 at -732	RASA and F. and L.	X	X			X	X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							NORTH CAROLINA--Continued								
S-22-j-6	NC-53	NRCD Clark Research Station	350816	771018	28	1,286	Basement at -1,254	NRCD, RASA, D.F.	X	X			X	X	X
Craven 175	NC-54	U.S. Geological Survey	350818	770630	27	964	RASA Unit 3 at -911	RASA and F. and L.		X			X	X	X
S-18-u-12	NC-55	NRCD Arapahoe Research Station	350508	765008	38	1,050	RASA Unit 4 at -991	NRCD, RASA, D.F.	X	X			X	X	X
S-15-y-2	NC-56	NRCD Whortonville Research Station	350525	763924	9	1,521	RASA Unit 4 at -1,267	do.	X	X			X	X	X
PAM-OT-9	NC-57	Carolina Pet., N.C. Pulpwood 1	350435	763900	4	3,666	Basement at -3,648	PP 796		X			X		
HY-31	NC-58	Ocracoke Electric Corp.	350650	755901	3	640	RASA Unit 7	RASA and D.F.						X	
Craven 258	NC-59	U.S. Geological Survey	350544	770908	25±	605	RASA Unit 4 at -553	F. and L., and RASA		X			X	X	X
Craven 311	NC-60	do.	350458	771049	35	1,000	RASA Unit 3 at -907	do.		X			X	X	X
U-26-j-2	NC-61	NRCD Comfort Research Station	345809	773014	70	877	RASA Unit 3	NRCD, RASA, D.F.	X	X			X	X	X
V-12-i-3,4	NC-62	NRCD Atlantic Research Station	345300	762120	16	1,500	RASA Unit 7	do.	X	X	X	X	X	X	X
ON-OT-11	NC-63	B. P. Seay, Hoffman Forest 1	345400	772345	50	1,433	Basement at -1,368	PP 796		X					
CR-OT-30	NC-64	Carolina Petroleum Co., Bryan 1	345055	765745	32	2,435	Basement at -2,369	do.		X			X		

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
NORTH CAROLINA--Continued															
ON-OT-10	NC-65	E. T. Burton, Hoffman Forest 1	345000	771640	40	1,570	Basement at -1,520	PP 796		X					
V-23-x-2	NC-66	NRCD Deppe Research Station	345016	771814	45	1,001	RASA Unit 4 at -714	NRCD, RASA, and D.F.	X	X			X	X	X
W-29-d-6	NC-67	NRCD Chinquipin Res. Station	344922	774847	45	822	Basement at -743	do.	X	X			X	X	X
Onslow 54	NC-68	Rural Electrification Authority	344400	772000	22	588	RASA Unit 5 at -480	Le.					X	X	X
X-17-i-6	NC-69	NRCD Camp Glenn Res. Station	344323	764513	8	1,120	RASA Unit 6 at -1,096	NRCD, RASA, D.F.	X	X			X	X	X
CAR-OT-8	NC-70	F. L. Karston, Laughton 1	344540	764330	10	4,044	Basement at -4,011	PP 796		X			X		
CAR-OT-7	NC-71	Coastal Plains, Huntley Davis 1	344350	763430	8	4,965	Basement at -4,938	do.		X			X		
ON-T-7	NC-72	Camp LeJeune Well T-8	343920	771950	20	500	RASA Unit 5 at -332	RASA and PP 796		X			X		
PEN-OT-6	NC-73	North Carolina O. and G. Co., Cowan No. 1	344030	774230	33	1,002	Basement at -956	PP 796	X				X		
Y-25-a-2	NC-74	NRCD Folkstone Research Station	343642	772901	67	1,220	RASA Unit 3	NRCD, RASA, D.F.	X	X			X	X	X
Y-30-s-5	NC-75	NRCD Burgaw Research Station	343616	775120	19	931	Basement at -912	do.	X	X			X	X	X
Y-34-p-1	NC-76	NRCD Ivanhoe Research Station	343625	781412	34	583	Basement at -544	do.	X	X			X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
							NORTH CAROLINA--Continued								
Z-47-m-1	NC-77	NRCD Rowland Research Station	343156	791747	145	548	Basement at -357	NRCD, RASA, D.F.	X	X			X	X	X
RO-P-1	NC-78	Town of Fairmont	343004	790634	108	612	Basement at -504	RASA and PP 796		X			X		
AA-35-n-2	NC-79	NRCD Kelly Research Station	342718	781831	28	670	Basement at -642	NRCD, RASA, D.F.	X	X			X	X	X
PEN-P-4?	NC-80	National Park Service, Moores Creek	342731	780630	30	650	RASA Unit 3 at -486	RASA and PP 796	X	X				X	
ON-OT-25	NC-81	North Carolina O. and G. Co., Justice 1	343300	772230	8	1,681	Basement at -1,658	PP 796	X				X		
PEN-OT-7	NC-82	North Carolina O. and G., Batts 2	342600	773350	10	1,462	Basement at -1,445	do.		X			X		
BB-28-j-3	NC-83	NRCD Topsail Research Station	342357	774042	60	1,348	Basement at -1,288	NRCD, RASA, and D.F.	X	X			X	X	X
PEN-OT-9	NC-84	North Carolina O. and G., Lea 1	342235	774400	34	1,253	Basement at -1,213	PP 796 and RASA		X			X		
BB-45-m-2	NC-85	NRCD Marietta Research Station	342225	790738	94	549	Basement at -455	NRCD, RASA, and D.F.	X	X			X	X	X
CC-38-b-1 and 7	NC-86	NRCD Lake Waccamaw Res. Station	341932	783151	63	858	RASA Unit 2 at -595	do.	X	X			X	X	X
NH-T-16	NC-87	Hercules, Inc. (wells 1-16)	341856	775851	13	1,080	RASA Unit 2 at -908	Leen. and PP 796 and RASA	X	X		X	X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							NORTH CAROLINA--Continued								
New Hanover 87	NC-88	U.S. Geological Survey (NH-T-13)	341741	775123	32	740	RASA Unit 4 at -458	B., Ba., RASA, and PP 796	X	X			X	X	X
DD-37-1-1	NC-89	NRCD Green Swamp Research Station	341230	782630	48	932	Basement at -884	NRCD, RASA, D.F.	X	X			X	X	X
DD-42-n-2	NC-90	NRCD Clarendon Research Station	341237	785342	108	879	Basement at -771	do.	X	X			X	X	X
New Hanover 347	NC-91	U.S. Geological Survey (NH-T-14)	340905	775406	22	630	RASA Unit 4 at -530; Black Creek Fm.	B., Ba., PP 796 and RASA	X	X			X	X	X
BR-OT-13	NC-92	Colonial O. and G., M. Trask 1	340820	775745	15	1,254	Basement at -1,220	PP 796	X	X			X		
EE-36-k-2	NC-93	NRCD Bear Pen Research Station	340743	782017	64	1,118	Basement at -1,054	RASA and D.F.	X	X			X	X	X
EE-34-o-2	NC-94	NRCD Nakina Research Station	340733	783952	60	1,028	Basement at -966	do.	X	X			X	X	X
NH-OT-15	NC-95	North Carolina O. and G. Co., Ft. Fisher 1	335825	775510	5	1,558	Basement at -1,536	PP 796	X	X			X		
GG-34-s-2	NC-96	NRCD Sunset Harbor Research Station	335629	781154	28	1,367	Basement about -1,335	RASA and D. F.	X	X			X	X	X
Brunswick 1	NC-97	Baptist Assembly	335345	780100	7±	1,543	Basement at -1,530	B.						X	X
HH-39-j-2	NC-98	NRCD Calabash Research station	335336	783522	50	1,335	Basement at -1,282	RASA and D.F.	X	X			X	X	X

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						VIRGINIA									
54R3/ 140-015	VA-1	Colonel Cralle	382242	770347	110	670	RASA Unit 2 at -272	RASA and D.F.		X			X		
53P4/ 148-019	VA-2	Mt. Rose Canning Company	381418	770916	180	765	RASA Unit 1 at -662	do.		X			X	X	
55P8/-	VA-3	Colonial Beach	381359	765740	10	824	RASA Unit 2	do.					X	X	
54P3/ 196-133	VA-4	U.S. Geological Survey, Oak Grove	381010	770219	185	1,386	RASA Unit 1 at -890	do.	X	X		X	X		
57P1/-	VA-5	H. T. E. Corp.	380855	764022	10	780	RASA Unit 2 at -686	do.		X			X		
56N7/ 196-017	VA-6	Arrowhead Association	380516	764730	145	817	RASA Unit 2 at -643	do.		X			X	X	
52N9/-	VA-7	Town of Bowling Green	380246	772053	213	1,550	Basement (Triassic) at -477	D.F. and C.					X		
59M2/-	VA-8	Lewisetta Packing Company	375946	762750	5	660	RASA Unit 3	RASA and D.F.						X	
56M10/ 128-017	VA-9	Town of Tappahanock	375541	765143	18	553	RASA Unit 2 at -466	do.					X	X	
66M1/ 100-363	VA-10	J. and J. Ent., E. G. Taylor 1	375303	753101	42	6,279	Basement (Triassic) at -6,031	do.	X	X			X		
58L5/-	VA-11	J. W. Welch	375032	763708	90	622	RASA Unit 3	do.					X	X	
60L18/-	VA-12	Blundon and Hinton	375023	761638	15	725	RASA Unit 6	do.						X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
						VIRGINIA--Continued									
63L4/-	VA-13	Westridge Water Association	374940	755945	2	1,033	RASA Unit 3	RASA and D.F.	X					X	
59K21/-	VA-14	Town of Kilmar-nock	374244	762244	90	740	do.	do.						X	
59K13/-	VA-15	Bernard Willing	373919	762522	8	750	do.	do.					X	X	
59K12/-	VA-16	William R. McAteer	373749	762331	5	680	do.	RASA, D.F. and La.						X	
58K7/-	VA-17	Rose Gill	373802	763402	15	652	do.	RASA, D.F.					X	X	
60J5/-	VA-18	Wendell Wood	373702	761731	4	682	do.	RASA, D.F. and La.						X	
58J3/-	VA-19	Middlesex County School Board	373614	763344	85	700	do.	do.						X	
58J9/ 159-004	VA-20	J. Barnhardt	373622	763121	60	750	RASA Unit 3	RASA and D.F.					X	X	
59J8/-	VA-21	Wilton Elementary School 1	373304	762618	65	707	do.	do.						X	
60J6/-	VA-22	A. Thomason	373259	761913	6	822	do.	do.						X	
56J13/ 150-087	VA-23	Chesapeake Corp.	373317	764904	27	1,315	Basement	do.	X	X				X	
56J11/ 149-004	VA-24	do.	373126	764541	15	1,278	RASA Unit 1	do.		X			X	X	
53J7/-	VA-25	Henrico Co. No. 1	373058	771359	130	605	Basement at -521	D.F.		X			X	X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							VIRGINIA--Continued								
59C1/-	VA-26	R. L. Magette	365012	762543	10	640	RASA Unit 6	RASA and D.F.	X	X			X	X	
60H1/-	VA-27	Elkins Oil and Gas	372530	761918	7	2,325	Basement at -2,307	D.F. and C.					X	X	
59H1/ 157-018	VA-28	G. T. Abernathy	372545	762401	3	568	RASA Unit 3	RASA and D.F.						X	
58H2/-	VA-29	Town of Glouster	372458	763214	77	815	RASA Unit 2	do.					X	X	
58H4/-	VA-30	VASWCB	372331	763126	75	1,860	Basement at -1,785	do.	X	X			X	X	
55H1/ 163-017	VA-31	City of Newport News	372428	765615	10	778	RASA Unit 1 at -650	do.	X	X			X		
54G10/ 118-050	VA-32	VASWCB	371956	770552	40	600	Basement at -545	do.	X	X			X	X	
59G14/-	VA-33	P. W. Hamilton	371947	762724	5	716	RASA Unit 3	do.						X	
59G2/-	VA-34	L. Shackelford	371739	762500	8	600	RASA Unit 6	do.						X	
62G2/-	VA-35	P. and N. R.R.	371602	760037	20	1,800	RASA Unit 2 at -1,325	RASA and C.					X		
63F1/-	VA-36	Northampton School Board	371159	755732	30	465	RASA Unit 9	D.F.	X	X			X	X	X
58F3/ 147-022	VA-37	Dow Badische	371120	763654	22	1,560	RASA Unit 1 at -1,124	RASA and D.F.		X			X	X	
57F16/ 190-070	VA-38	VASWCB	371132	764055	5	1,240	RASA Unit 1 at -815	do.	X	X			X	X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
						VIRGINIA--Continued									
58F8/-	VA-39		370919	763504	34	660	RASA Unit 3	RASA and D.F.					X	X	
57E4/-	VA-40	City of Newport News	370610	764400	70	1,060	RASA Unit 1 at -850	do.	X					X	
59E5/ 211-006	VA-41	NASA Research Center	370538	762243	9	2,092	Basement at -2,053	do.	X	X			X	X	
	VA-42	Hotel Chamberlain	3700-	7619-		945	RASA Unit 2	C.					X	X	
59D20/-	VA-43	City of Newport News	365840	762550	20	855	do.	RASA and D.F.		X			X	X	
53D3/ 191-027	VA-44	VASWCB	365843	770902	90	554	Basement at -448	do.	X	X			X	X	
62D2/-	VA-45	Chesapeake Bay Bridge	365759	760647	3	1,502	RASA Unit 2 at -1,350	D.F.	X	X			X	X	
VPI-26	VA-46	V.P.I.	365431	764208	80	1,680	Basement at -1,300	V.P.I	X			X	X		
57D20/-	VA-47	City of Va. Beach	365232	764056	50	1,020	RASA Unit 2 at -412	RASA and D.F.		X			X		
59D2/-	VA-48	Cedar Point Country Club	365359	762916	10	717	RASA Unit 2	RASA and D.F.		X			X	X	
59D1/-	VA-49	Tidewater Water Company	365255	762311	15	588	RASA Unit 3	do.		X			X	X	
61D2/ 228-059	VA-50	Nepralex Corp.	365333	761117	25	1,142	RASA Unit 2	do.	X	X			X	X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
						VIRGINIA--Continued									
61C1/-	VA-51	U.S. Geological Survey	365223	761221	10.8	2,581	RASA Unit 1 at -1,580	RASA and D.F.	X	X			X	X	
60C9/ 220-009	VA-52	Virginia Chemical	364702	762156	15	1,015	RASA Unit 2	do.		X			X	X	
VPI-25A	VA-53	V.P.I.	365101	762850	77	2,005	Basement (?) at -1,800(?)	V.P.I.	X			X	X		
59C14/-	VA-54	Tidewater Water Company	365025	762422	16	614	RASA Unit 2	RASA and D.F.		X			X	X	
60C7/ 220-004	VA-55	City of Portsmouth	365115	761917	10	1,459	RASA Unit 1 at -1,306	do.	X	X			X	X	
60C3/-	VA-56	Old Va. National Bank	365046	761725	12	822	RASA Unit 2	do.	X					X	
60C6/-	VA-57	LN. STR. CMT. Corp.	364853	761709	5	780	do.	do.		X			X	X	
63C1/ 228-001	VA-58	Bush Development	365200	755831	20	1,593	RASA Unit 2 at -1,404	do.	X	X			X	X	
55B10/-	VA-59	Union Bag	364121	765451	36	925	Basement at -889	do.		X			X	X	
55C12/-	VA-60	City of Va. Beach	364605	765318	15	927	RASA Unit 1 at -685	RASA and D.F.	X	X			X	X	
57C15/-	VA-61	City of Norfolk	364808	763752	52	1,037	RASA Unit 1	do.		X			X	X	
58C7/ 161-200	VA-62	do.	364838	763709	43	949	RASA Unit 2 at -493	do.		X			X		
58C1/ 161-004	VA-63	Nestle Company	364635	763232	20	1,024	RASA Unit 1	do.	X	X			X	X	

Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	E	POR	T	LITH	Water quality	Head data
							VIRGINIA--Continued								
59C7/ 234-124	VA-64	Chesapeake	364703	762451	21	1,540	RASA Unit 1	RASA and D.F.		X		X	X	X	
60C8/-	VA-65	Layne Atlantic	364617	762216	15	680	RASA Unit 3	do.					X	X	
59C12/-	VA-66	Sunray Water Co.	364601	762537	19	645	do.	do.						X	
58B11/ 161-241	VA-67	Joel Harrell	364428	763332	20	674	RASA Unit 1 at -1,100	do.		X			X	X	
58C11/	VA-68	City of Suffolk	364501	763509	35	1,302	RASA Unit 1	do.		X			X	X	
58B5/ 161-265	VA-69	City of Portsmouth	364330	763612	40	856	RASA Unit 1 at -480	do.					X	X	
57B6/ 161-158	VA-70	City of Suffolk	364248	763913	55	717	RASA Unit 2	do.	X	X			X	X	
55B63/ 146-236	VA-71	Union Camp	364121	765451	36	714	RASA Unit 1 at -677	do.	X	X			X	X	
55B36/ 146-185	VA-72	do.	364125	765448	37	860	RASA Unit 1	do.	X	X				X	
IW-P-8	VA-73	do.	364115	765430	40	920	Basement at -828	PP 796		X			X		
SWCB 234-66	VA-74	Merrifield Sub-division	365242	762317	15	760	RASA Unit 6	S.						X	
SWCB 234-65	VA-75	VASWCB	364227	760749	15	1,200	RASA Unit 2(?) at -1,011(?)	do.						X	
60B2/-	VA-76	John Lensey	364149	762019	15	822	RASA Unit 2	do.		X				X	

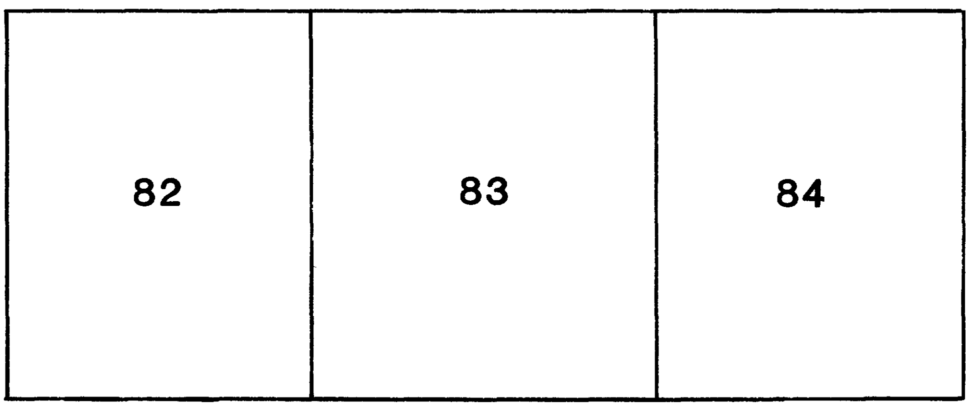
Table 4.--Records of selected wells--Continued

Report or State well number	Map no.	Well name	Coordinate location Lat.	Coordinate location Long.	Elev. of GL (ft)	Total depth (ft)	Deepest stratigraphic penetration and altitude of unit top (ft)	Data source	Well logs GR	Well logs E	Well logs POR	Well logs T	Well logs LITH	Water quality	Head data
							VIRGINIA--Continued								
60B3/ 234-134	VA-77	VASWCB	363836	762017	16	1,000	RASA Unit 2 at -934	RASA and D.F.		X			X	X	
61A1/ 234-079	VA-78	Tidewater Chemical	363613	761158	6	760	RASA Unit 3	do.						X	
SWCB 234-146	VA-79	City of Chesapeake	363536	761236	8	709	do.	S.						X	
58B39/-	VA-80	Union Camp	363837	765327	26	891	Basement	RASA and D.F.					X	X	
55A3/-	VA-81	VASWCB	363632	765801	18	749	do.	do.		X			X	X	
56A11/ 161-350	VA-82	do.	363653	764554	79	1,220	RASA Unit 2 at -487	do.	X	X			X	X	
56A9/-	VA-83	do.	363625	765226	73	1,063	Basement	do.	X	X		X	X	X	
56A1/ 161-047	VA-84	do.	363511	764929	35	1,150	RASA Unit 1 at -1,114	do.	X	X			X	X	X
56A10 161-349	VA-85	do.	363345	764702	45	1,200	RASA Unit 1 at -841	do.	X	X			X	X	
57A6/ 161-348	VA-86	do.	363611	764009	73	1,200	RASA Unit 1	do.	X	X			X	X	
57A2/-	VA-87	R. R. Branton	363506	764011	71	641	RASA Unit 2	RASA and D.F.							X
58A2/ 161-042	VA-88	VASWCB (NAN-T-26)	363409	763500	58	2,017	Basement (Triassic) at -1,822	D.F. and PP 796	X	X		X	X	X	

*U.S. GOVERNMENT PRINTING OFFICE: 1986-491-405:20110

PLATE 1

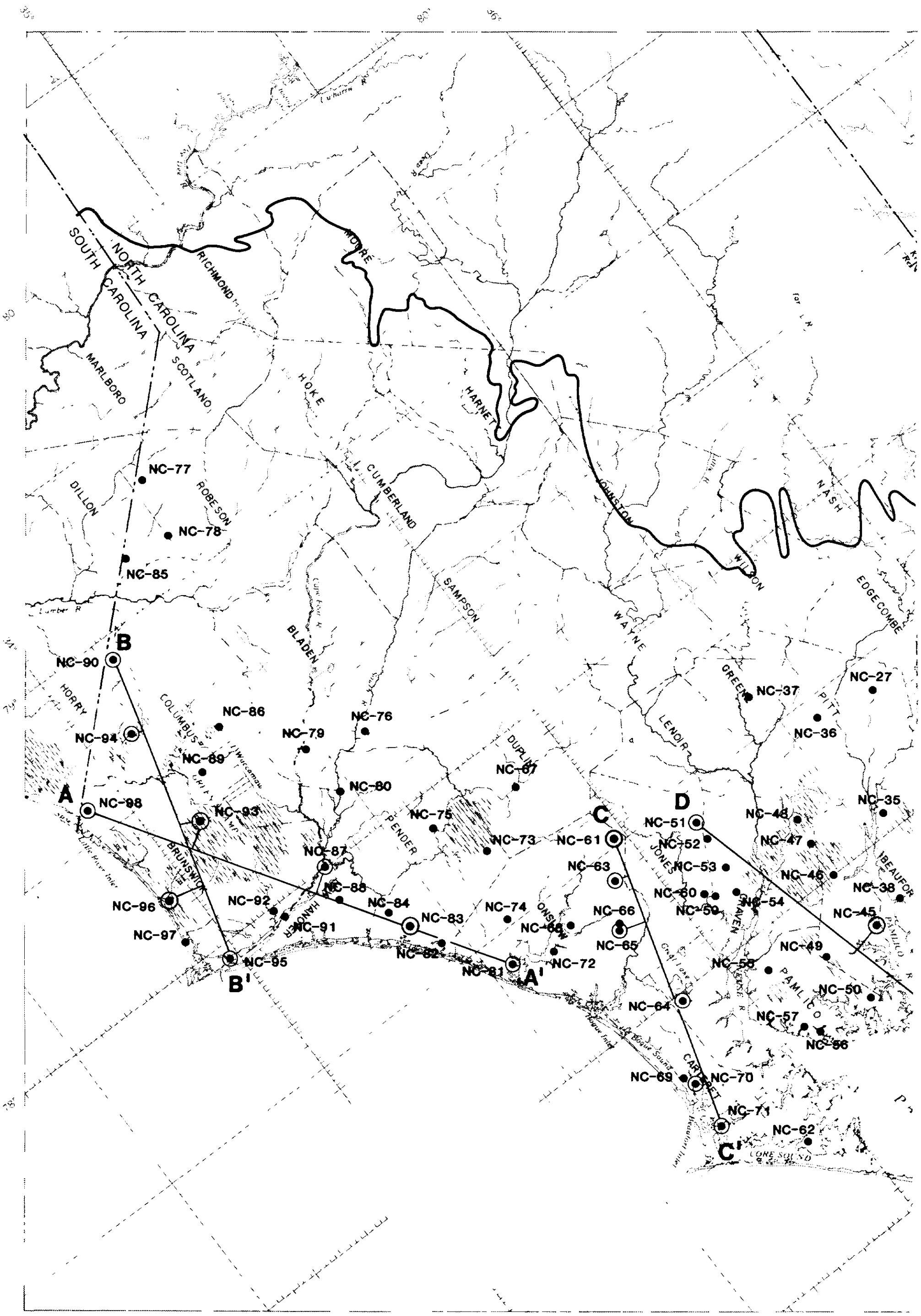
LOCATION OF WELLS AND GEOHYDROLOGIC CROSS SECTIONS.



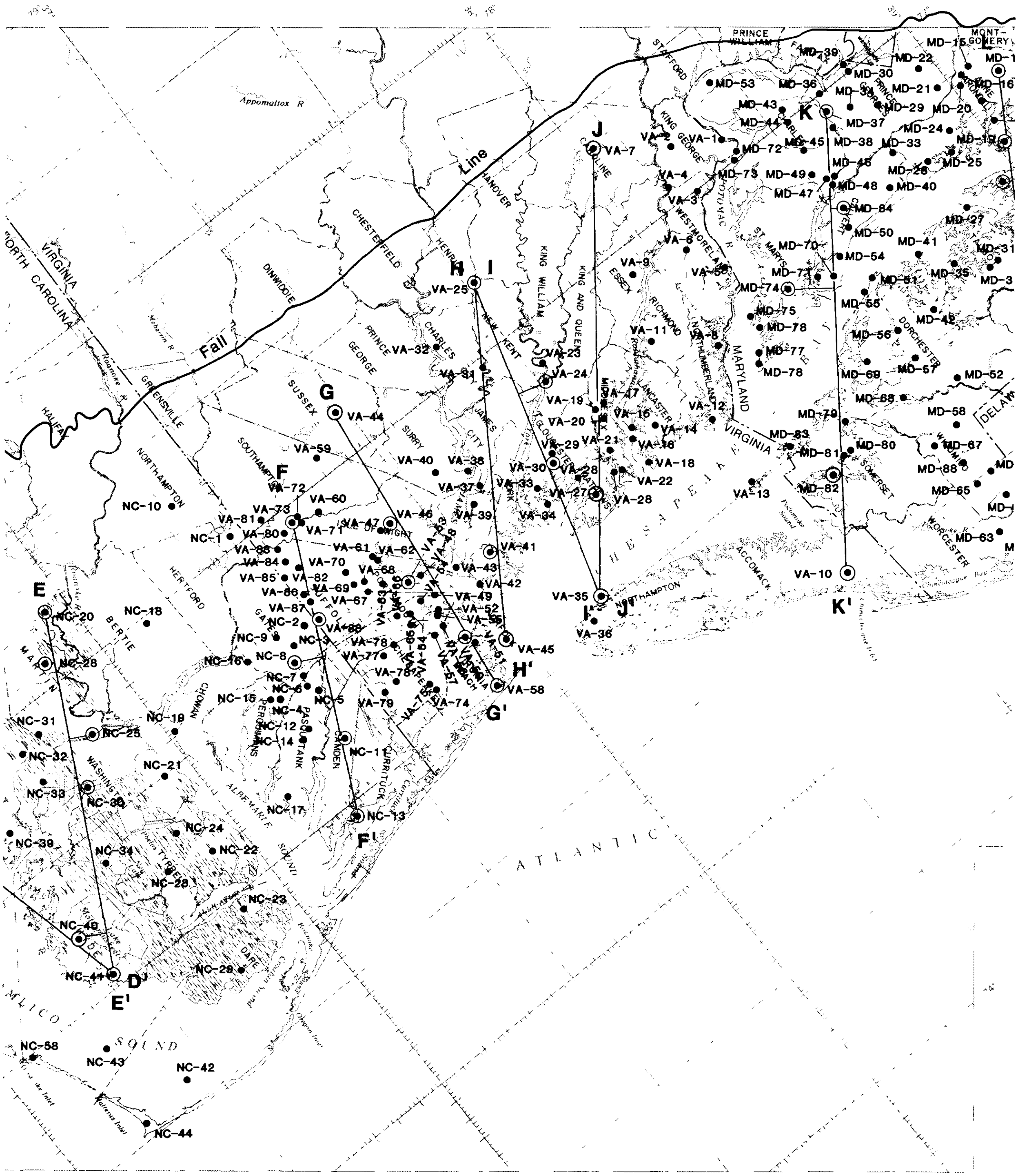
Index map showing page numbers of each component of plate 1

DEPARTMENT OF THE INTERIOR

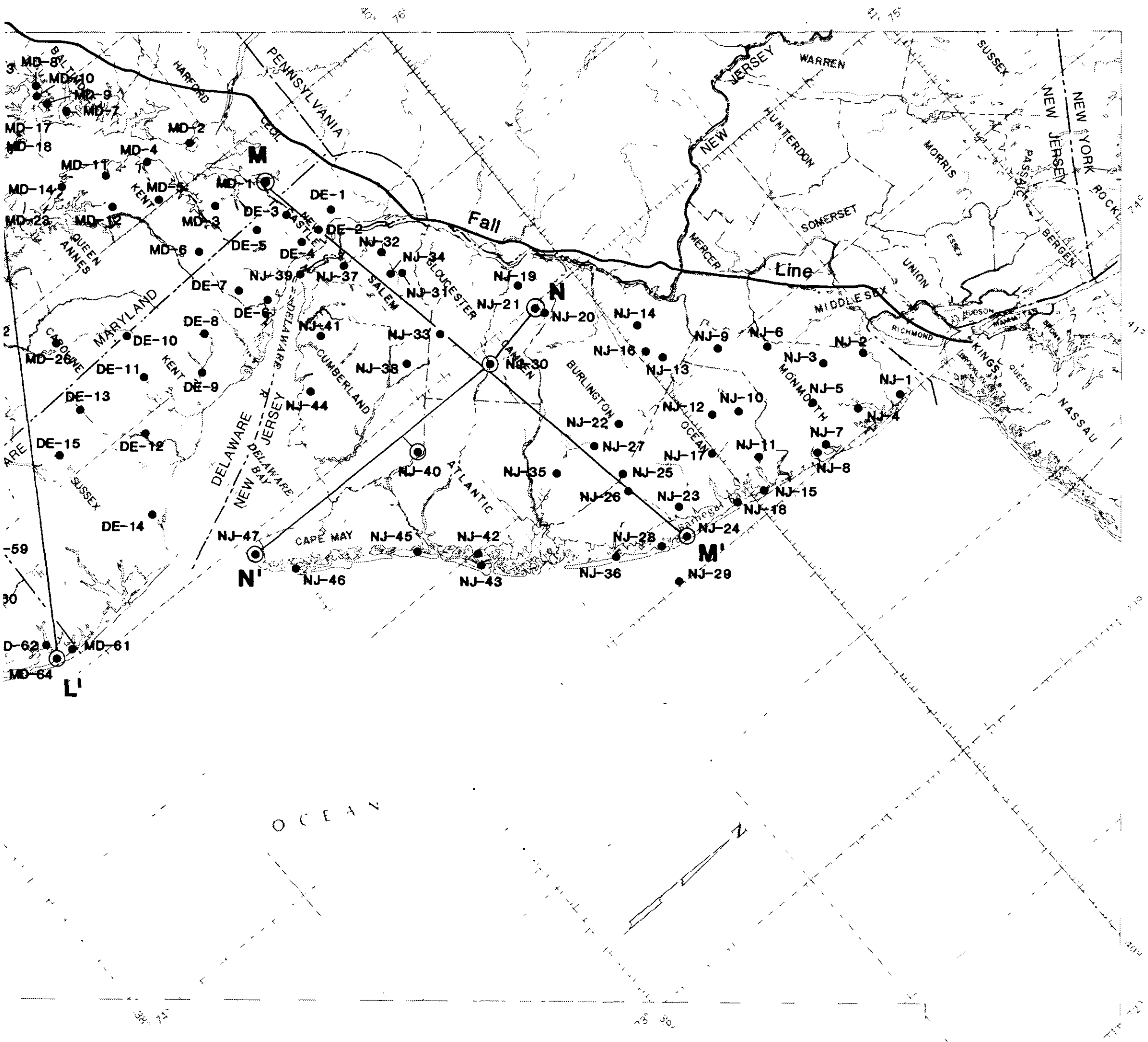
UNITED STATES GEOLOGICAL SURVEY



Base from U.S. Coast and Geodetic Survey



LOCATION OF WELLS AND GEOHYDROLOGIC CROSS SECTIONS.



EXPLANATION

VA-22 • Well and well number.
Number refers to data in table 4.

VA-35 ⊙ Well and well number in geohydrologic cross sections, figure 6 - 19.

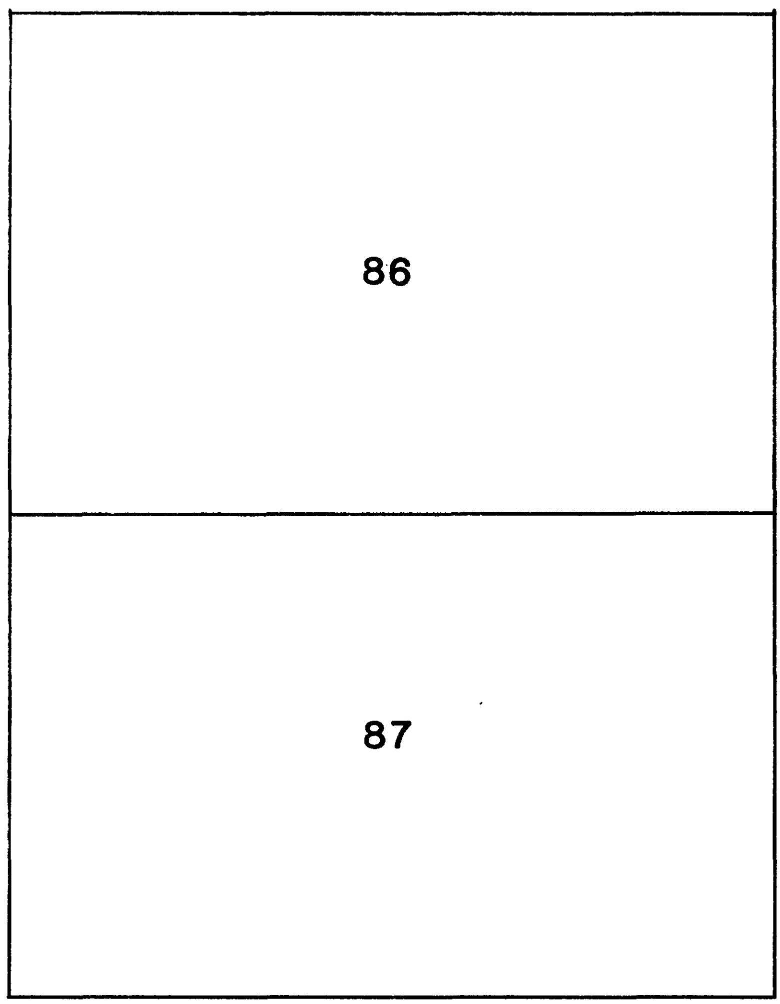
A———A' Line of geohydrologic cross section.

25 0 25 50 75 MILES

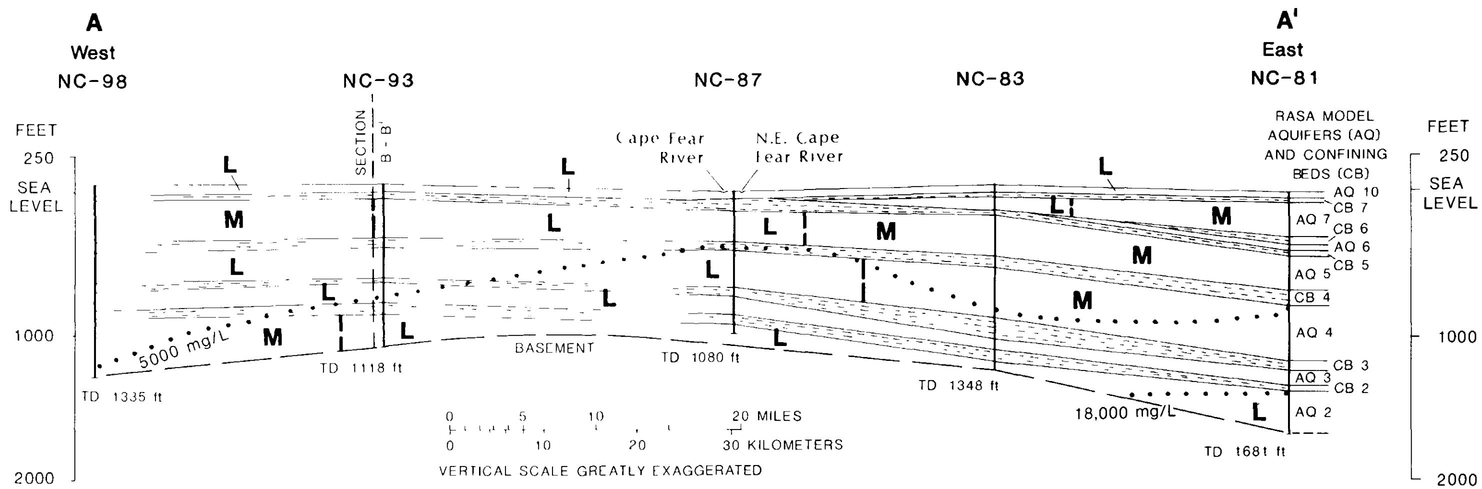
25 0 25 50 75 100 KILOMETERS

PLATE 2

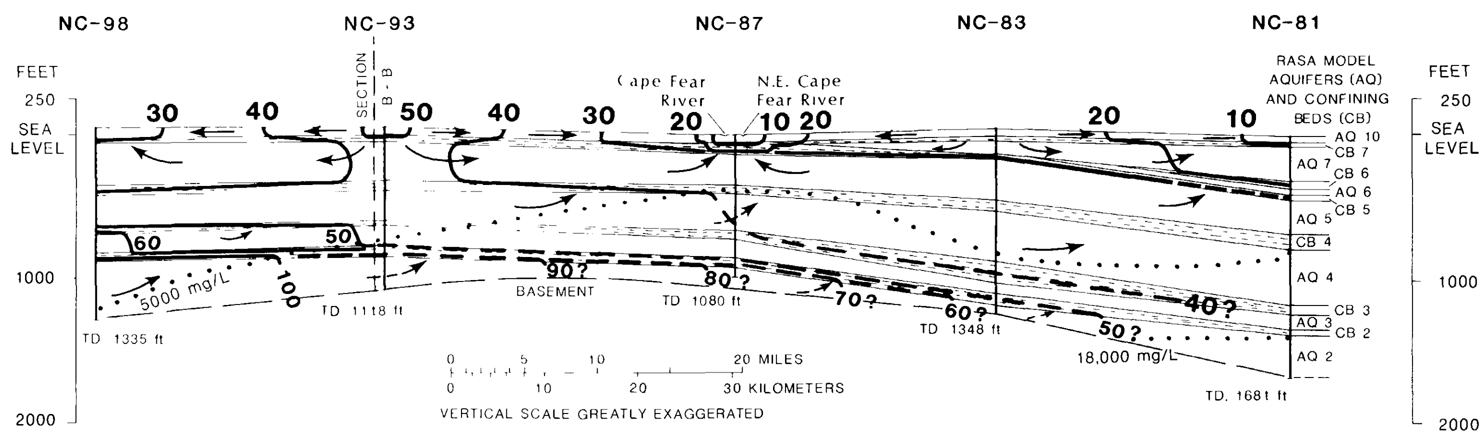
GEOHYDROLOGIC CROSS SECTION A - A' FROM
BRUNSWICK COUNTY, N.C., TO ONSLOW COUNTY, N.C.



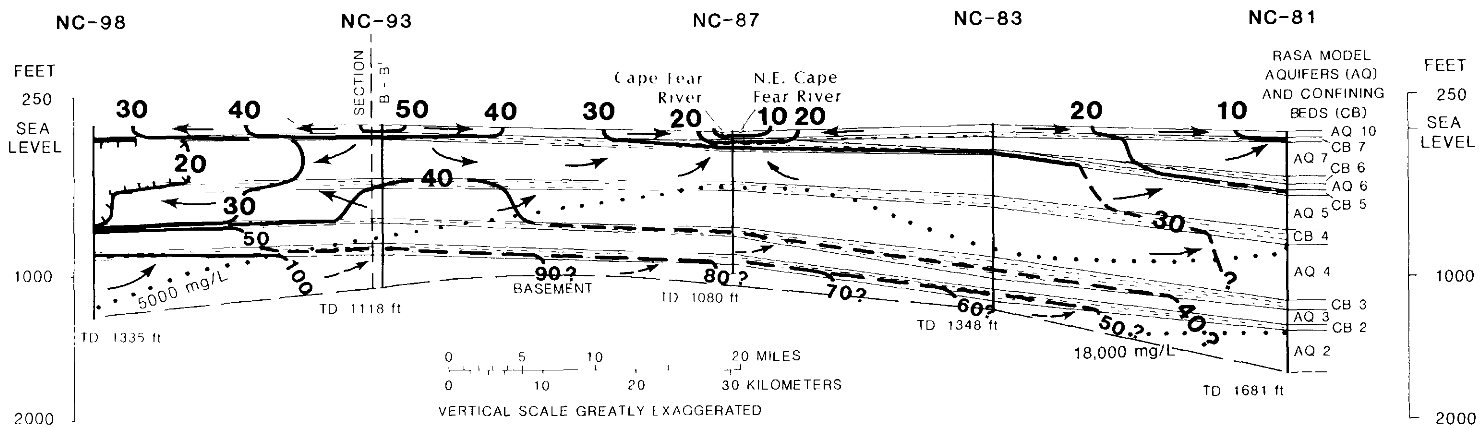
Index diagram showing page numbers of each component of plate 2



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

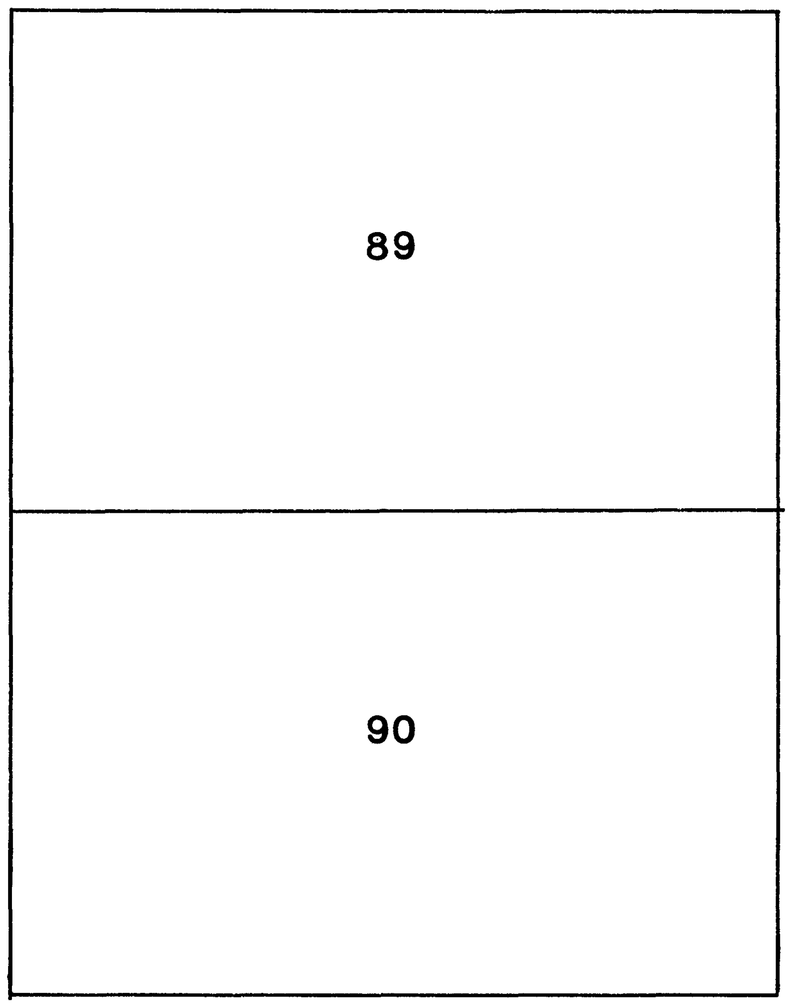
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
—20—?—	Line of approximate equal head, in feet above and below (-) sea level: interval is 10 feet. Dashed where inferred. Queried where location is uncertain
←— – –	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
. . . . 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
NC-98	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD: 1335 ft.	Total depth of well, in feet
Data source:	Meisler (1980b); M.D. Winner, G.L. Giese, M.M. Martin, Henry Trapp, Jr., Harold Meisler (U.S. Geological Survey, written and oral commun.,1984)

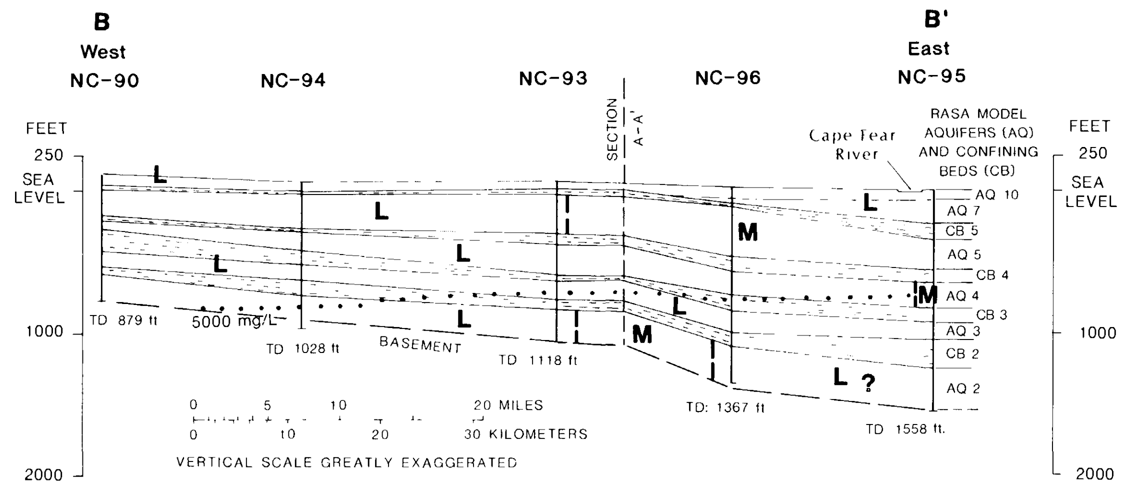
GEOHYDROLOGIC CROSS SECTION A-A' FROM BRUNSWICK COUNTY, N.C., TO ONSLOW COUNTY, N.C.

PLATE 3

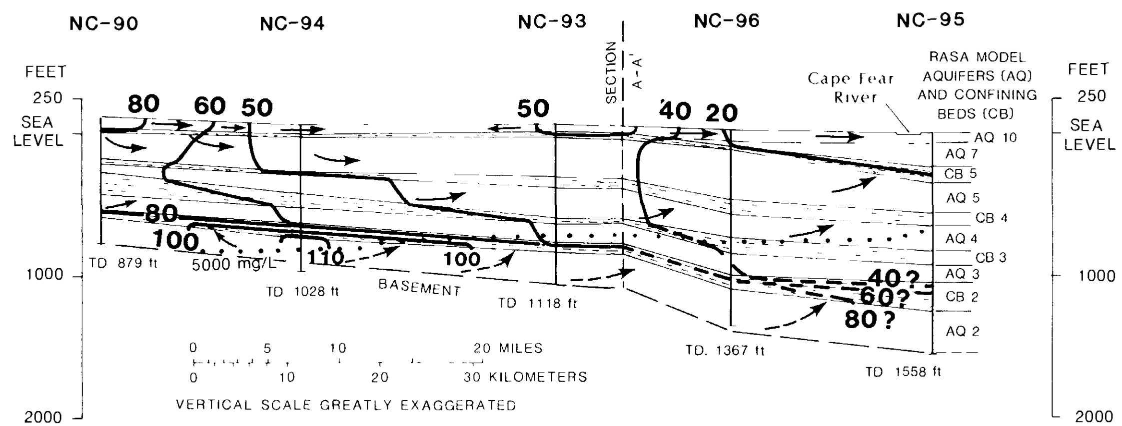
GEOHYDROLOGIC CROSS SECTION B - B' FROM
COLUMBUS COUNTY, N.C., TO NEW HANOVER COUNTY, N.C.



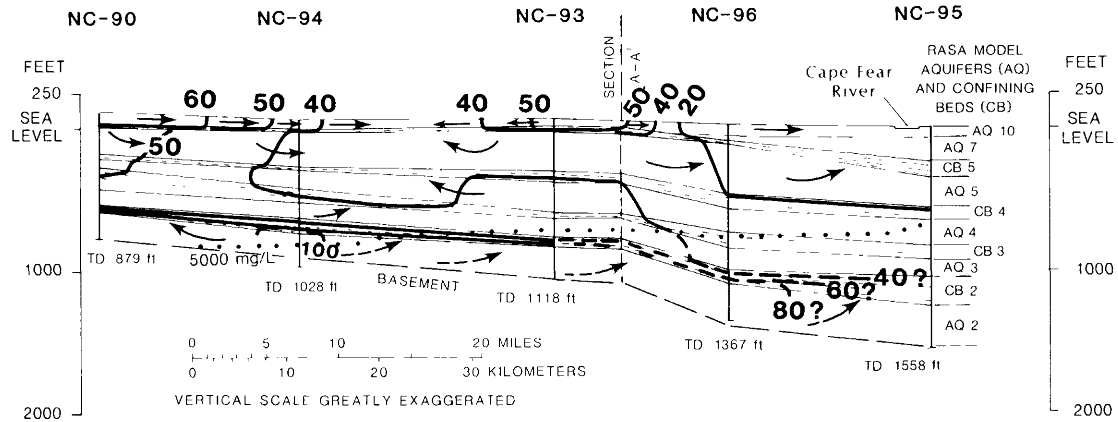
Index diagram showing page numbers of each component of plate 3



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

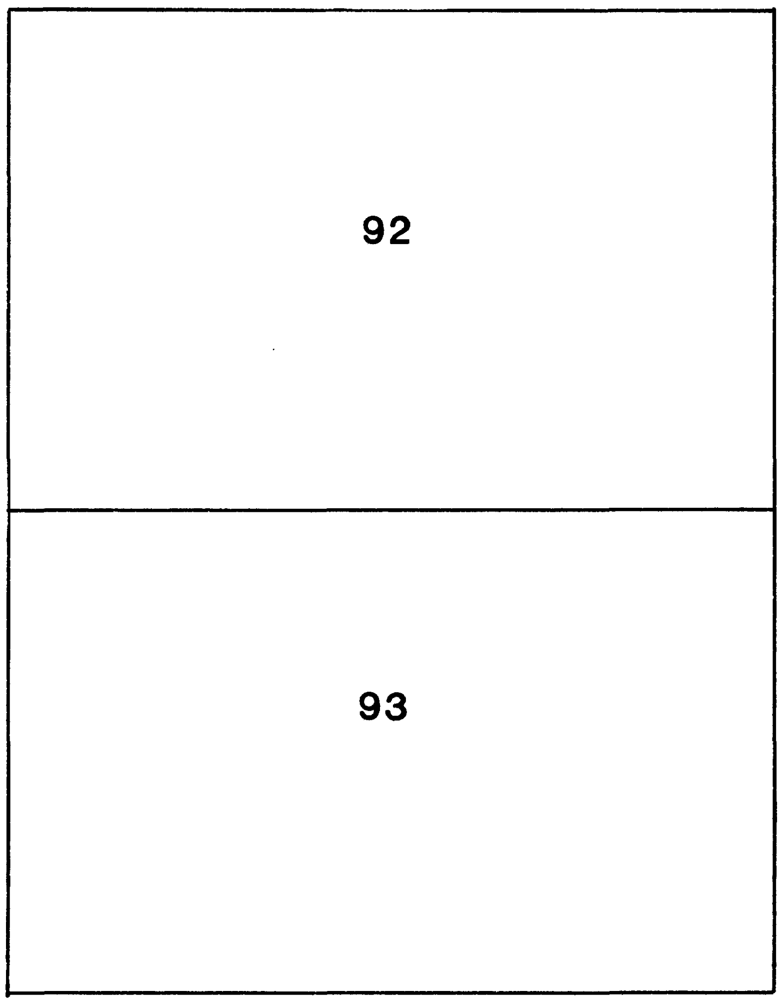
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
——20——?—	Line of approximate equal head, in feet, above and below (-) sea level: interval is variable. Dashed where inferred. Queried where location is uncertain
←— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
• • • • • • • • 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
NC-93	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD: 1118 ft.	Total depth of well, in feet
Data source:	Meisler (1980b;)M.D. Winner, G.L. Giese, M.M. Martin, Henry Trapp, Jr., Harold Meisler (U.S. Geological Survey, written and oral commun.,1984)

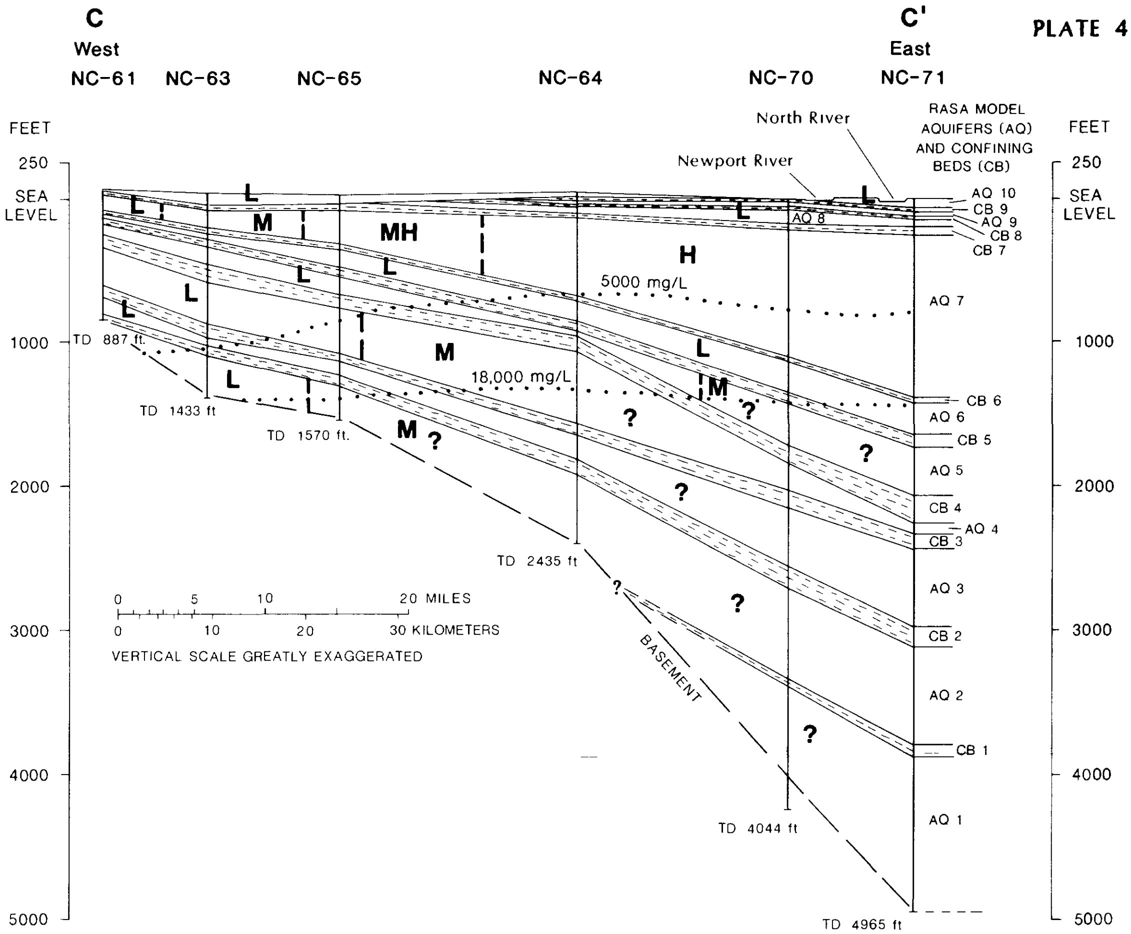
GEOHYDROLOGIC CROSS SECTION B-B' FROM COLUMBUS COUNTY, N.C., TO NEW HANOVER COUNTY, N.C.

PLATE 4

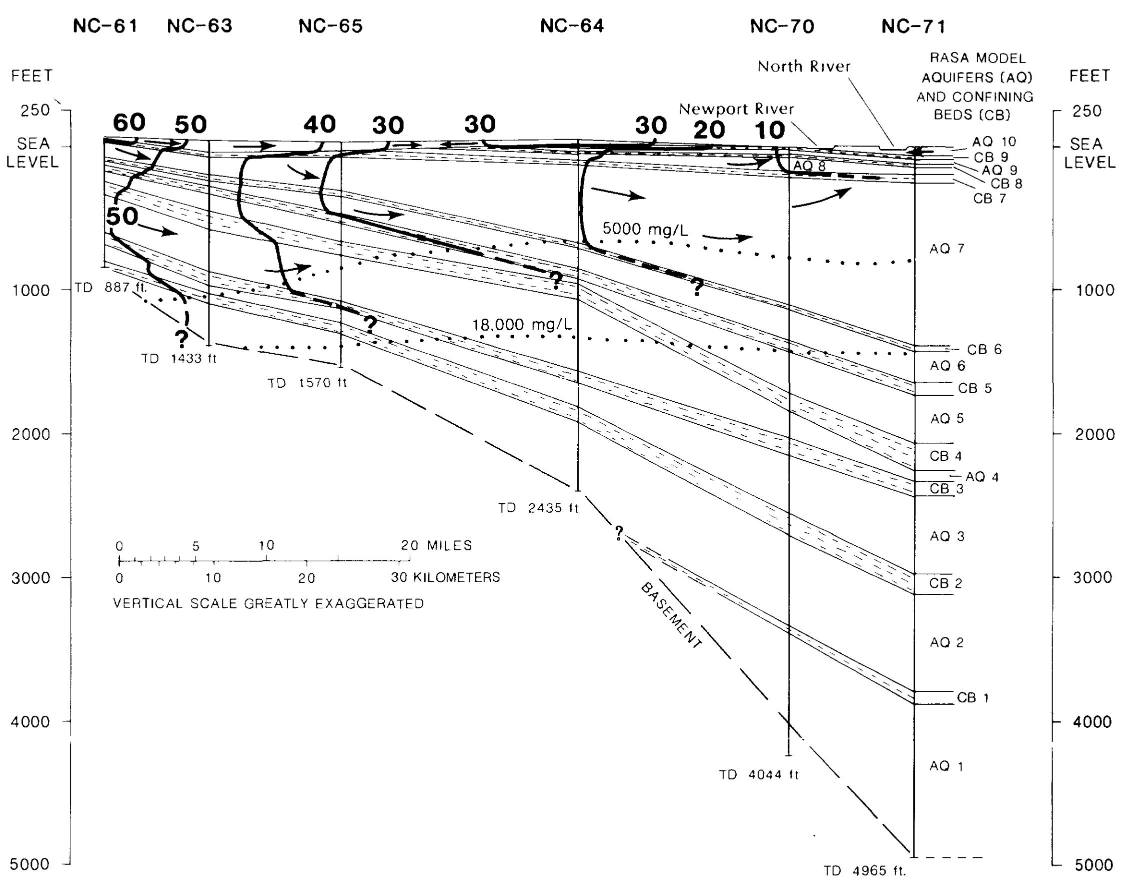
GEOHYDROLOGIC CROSS SECTION C - C' FROM
JONES COUNTY, N.C., TO CARTERET COUNTY, N.C.



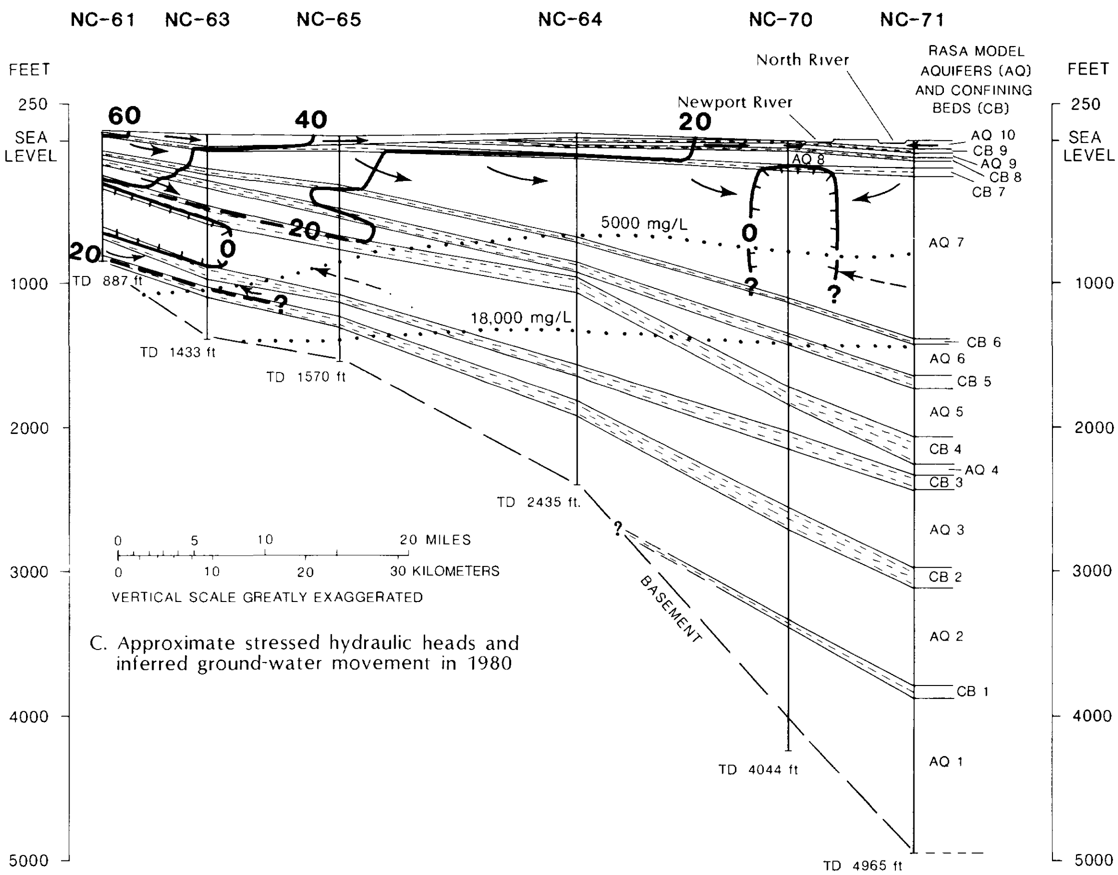
Index diagram showing page numbers of each component of plate 4



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

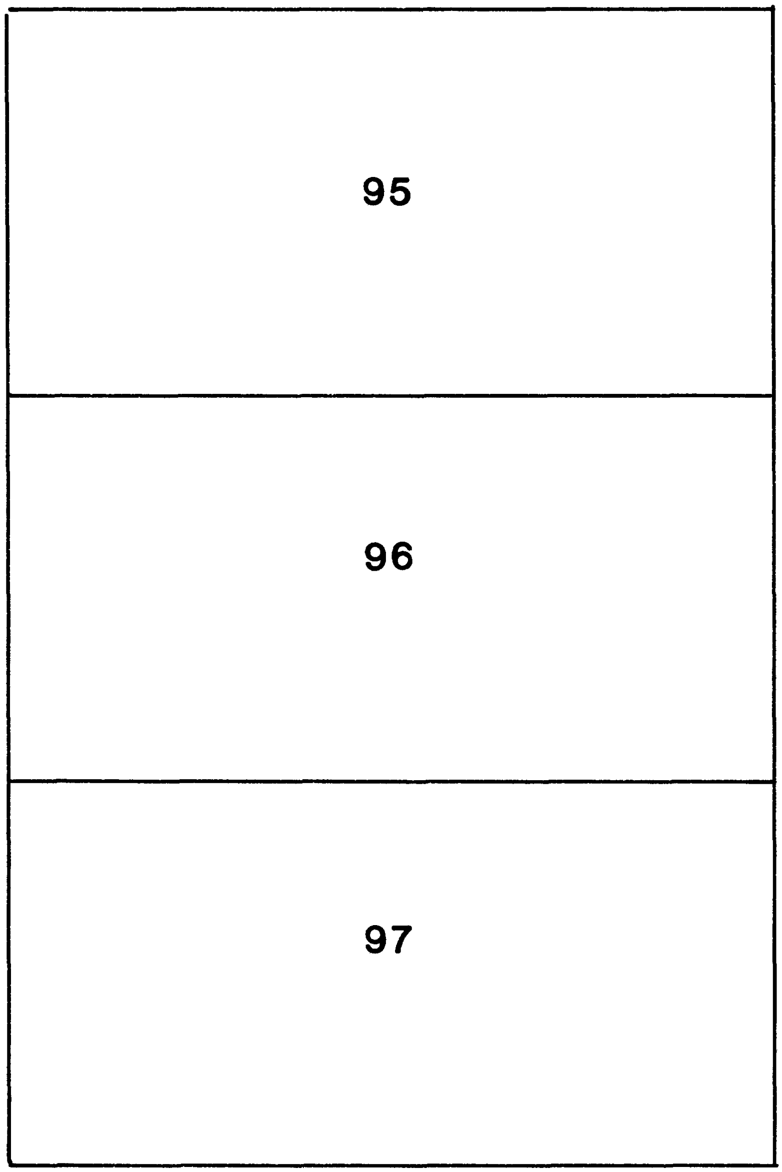
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
MH	Medium high: between about 14,000 and 21,000
H	High: greater than 21,000
——20——?—	Line of approximate equal head, in feet, above and below (-) sea level: interval is variable. Dashed where inferred. Queried where location is uncertain
←—— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
. . . . 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
NC-64	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD 2435 ft.	Total depth of well, in feet
Data source:	Meisler (1980b); M.D. Winner, G.L. Giese, M.M. Martin, Henry Trapp, Jr., Harold Meisler (U.S. Geological Survey, written and oral commun., 1984)

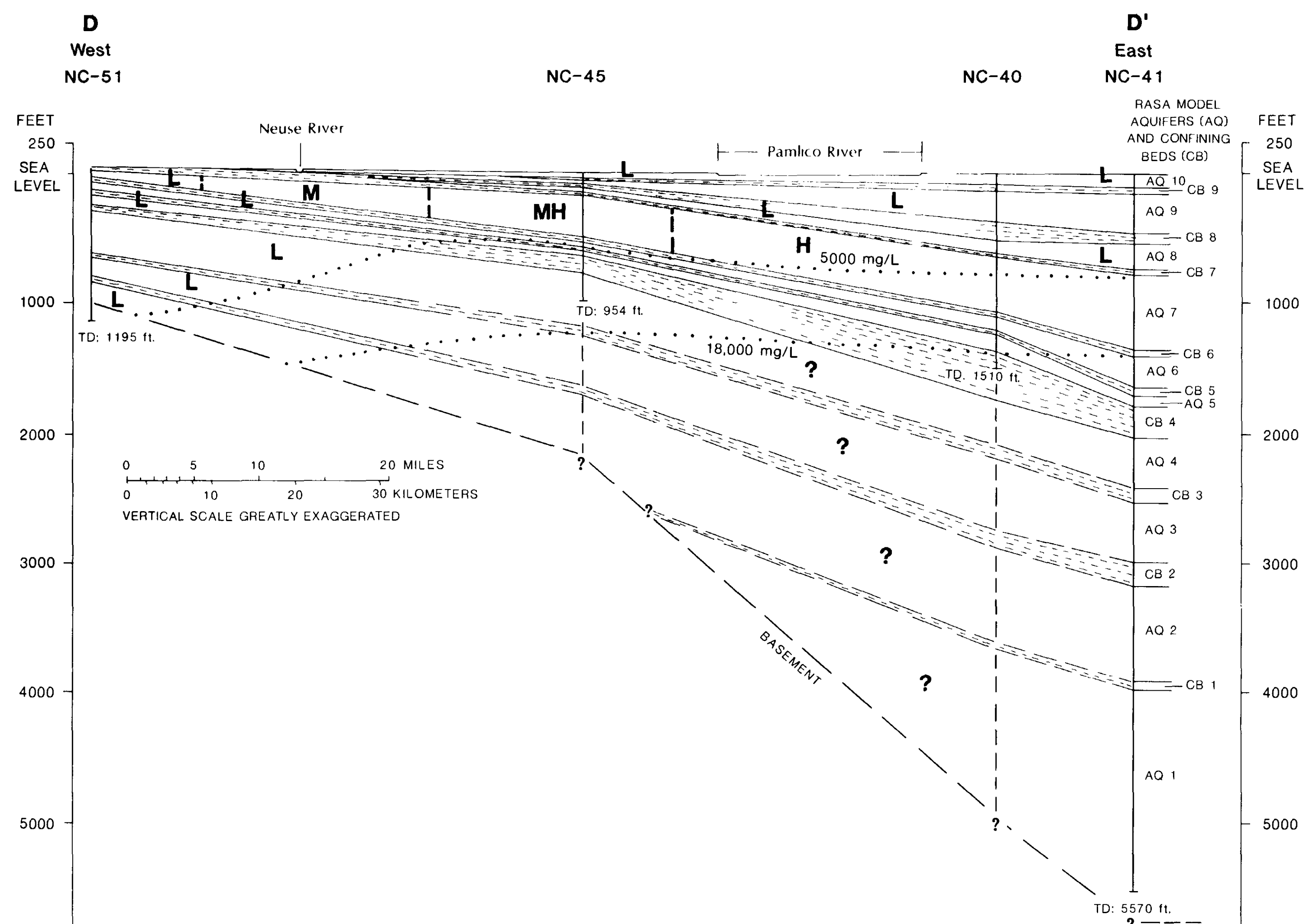
GEOHYDROLOGIC CROSS SECTION C-C' FROM JONES COUNTY, N.C., TO CARTERET COUNTY, N.C.

PLATE 5

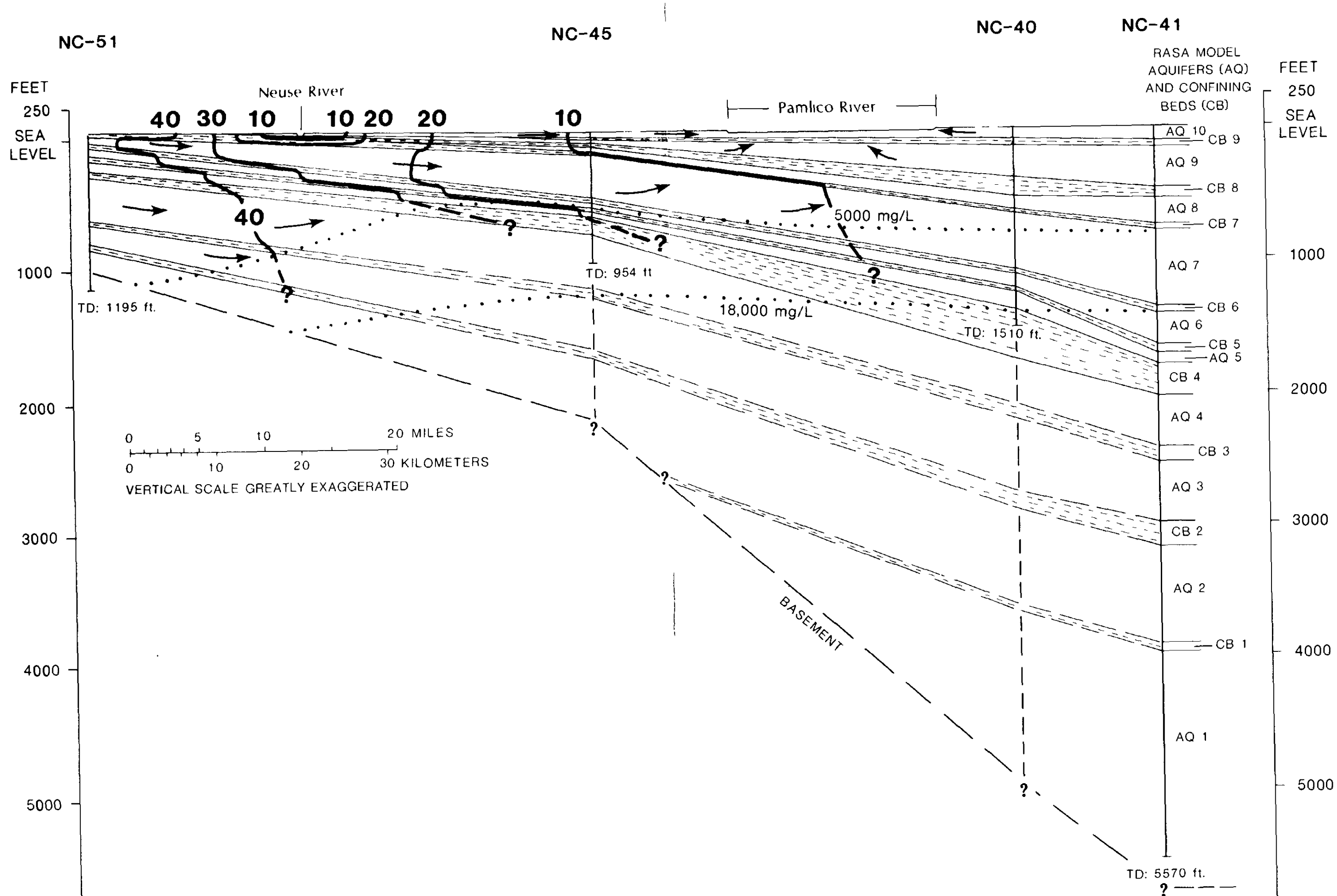
GEOHYDROLOGIC CROSS SECTION D - D' FROM
CRAVEN COUNTY, N.C., TO HYDE COUNTY, N.C.



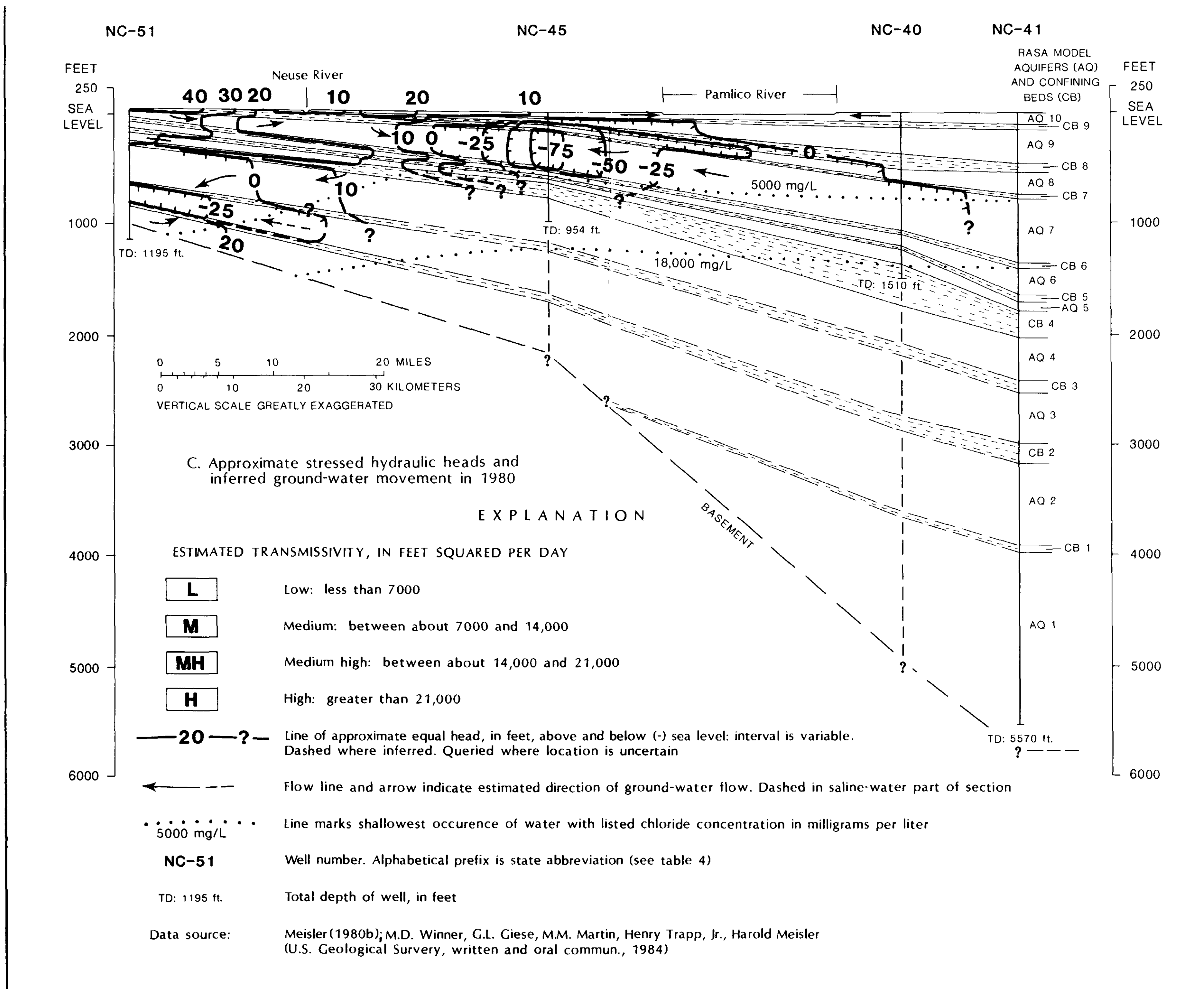
Index diagram showing page numbers of each component of plate 5



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



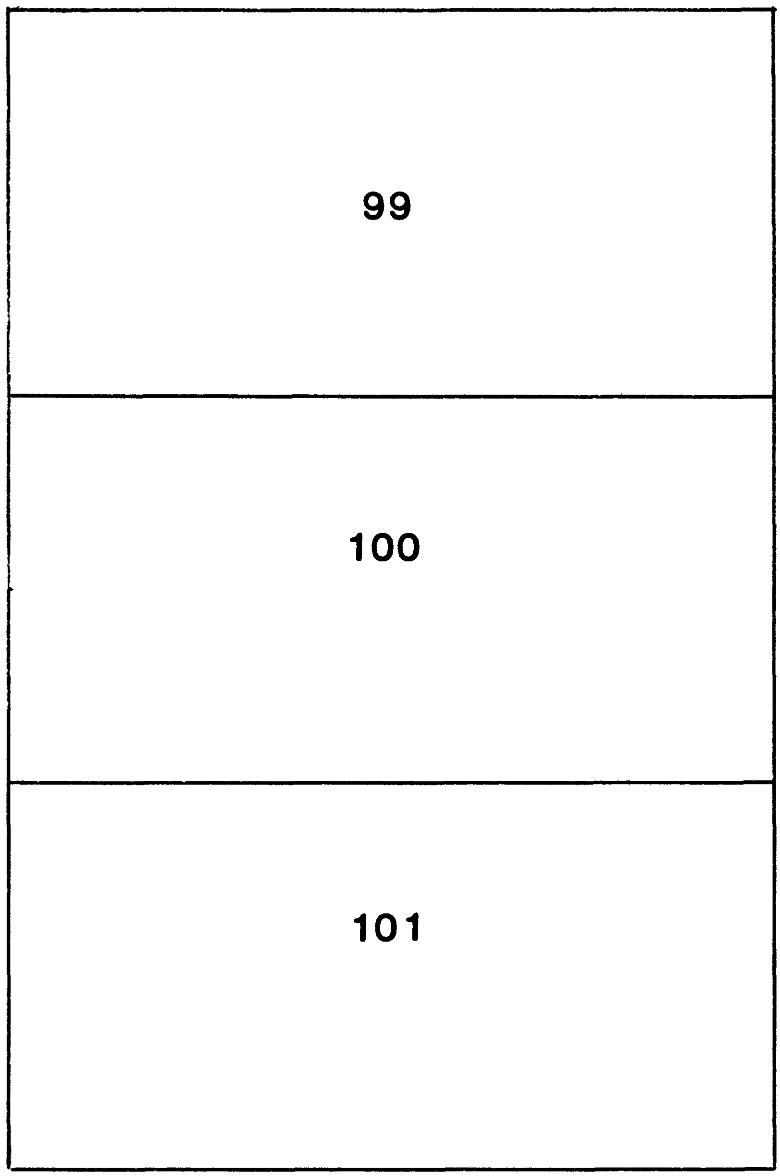
B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



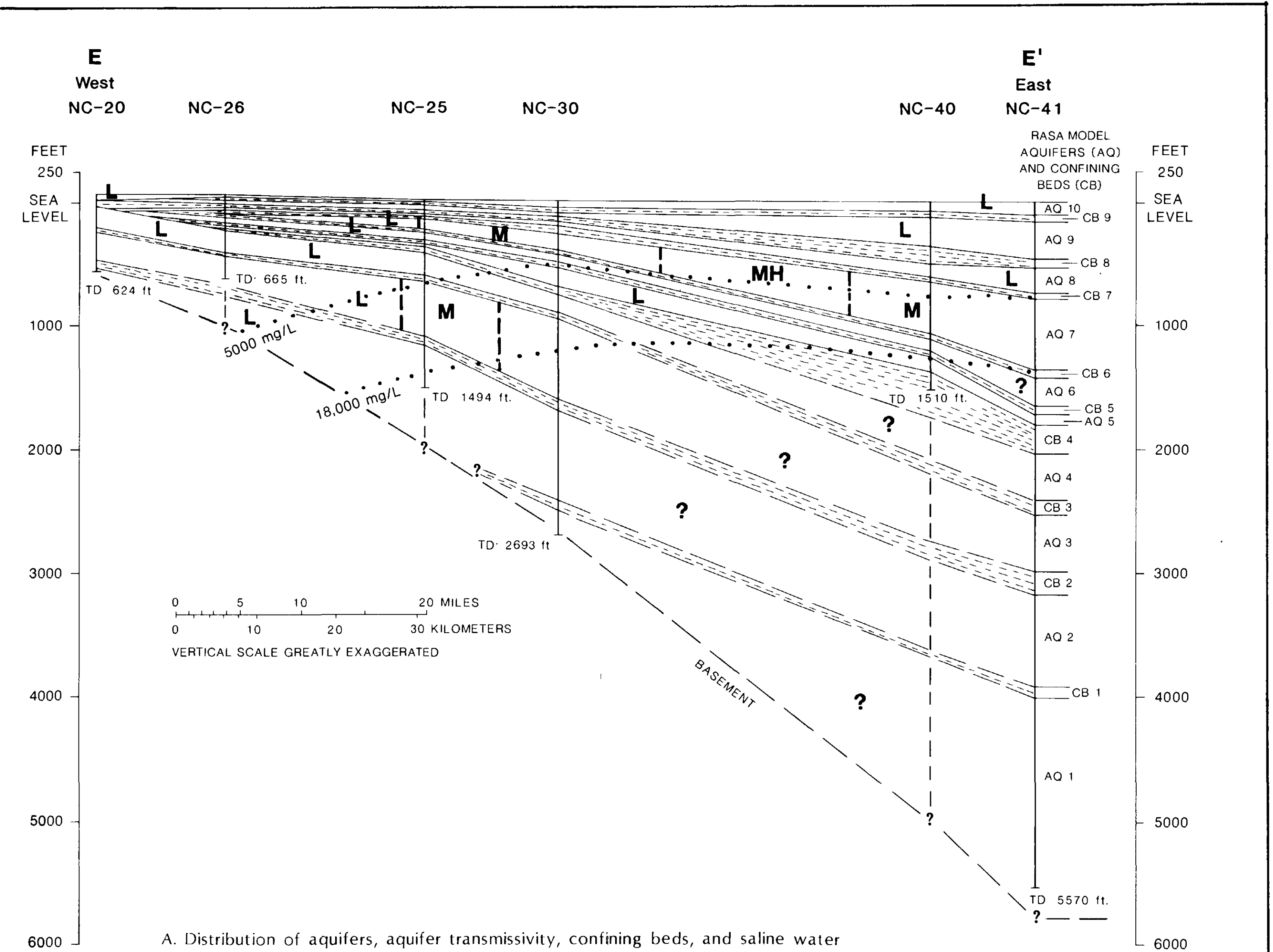
GEOHYDROLOGIC CROSS SECTION D-D' FROM CRAVEN COUNTY, N.C., TO HYDE COUNTY, N.C.

PLATE 6

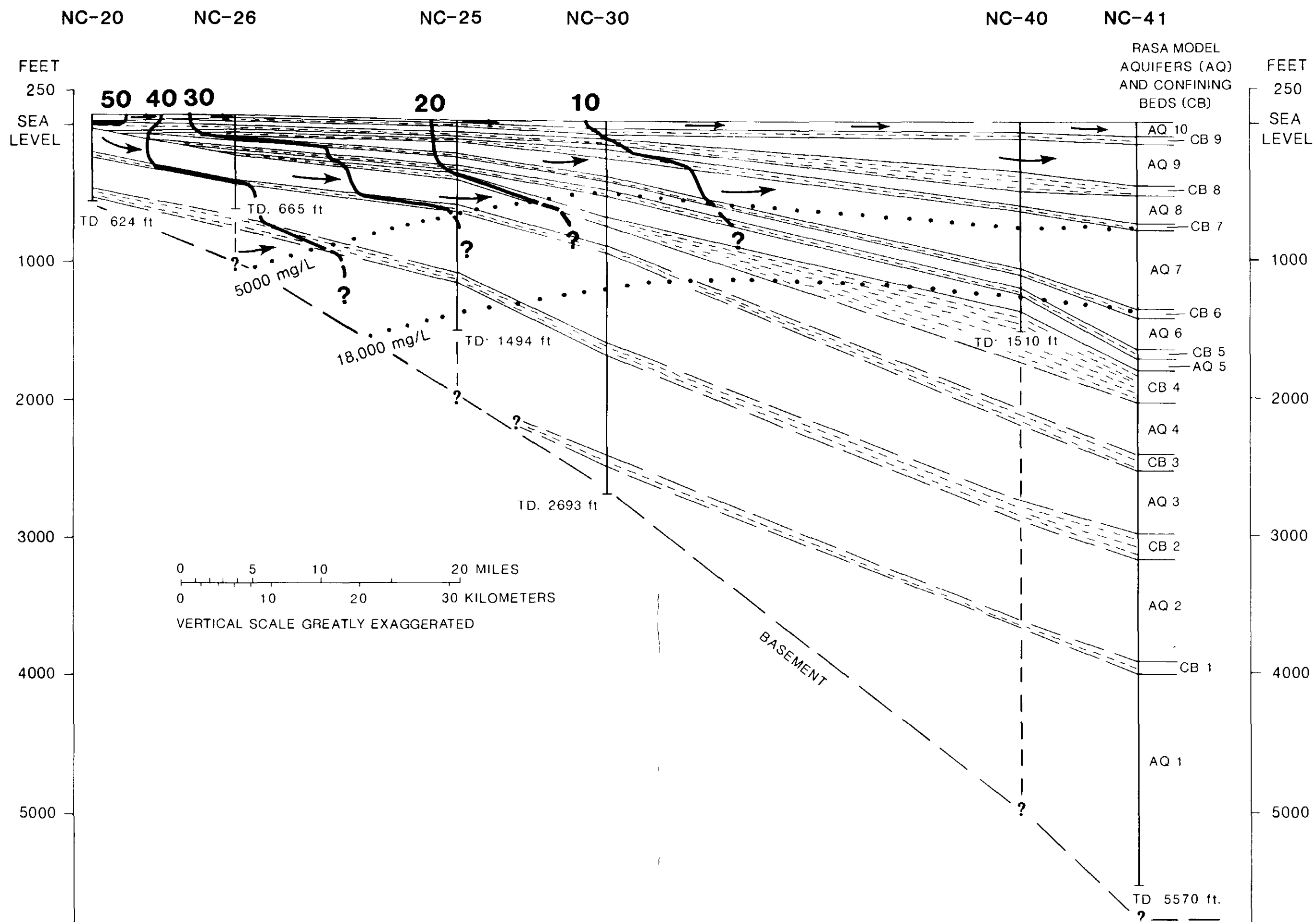
GEOHYDROLOGIC CROSS SECTION E - E' FROM
MARTIN COUNTY, N.C. TO DARE COUNTY, N.C.



Index diagram showing page numbers of each component of plate 6



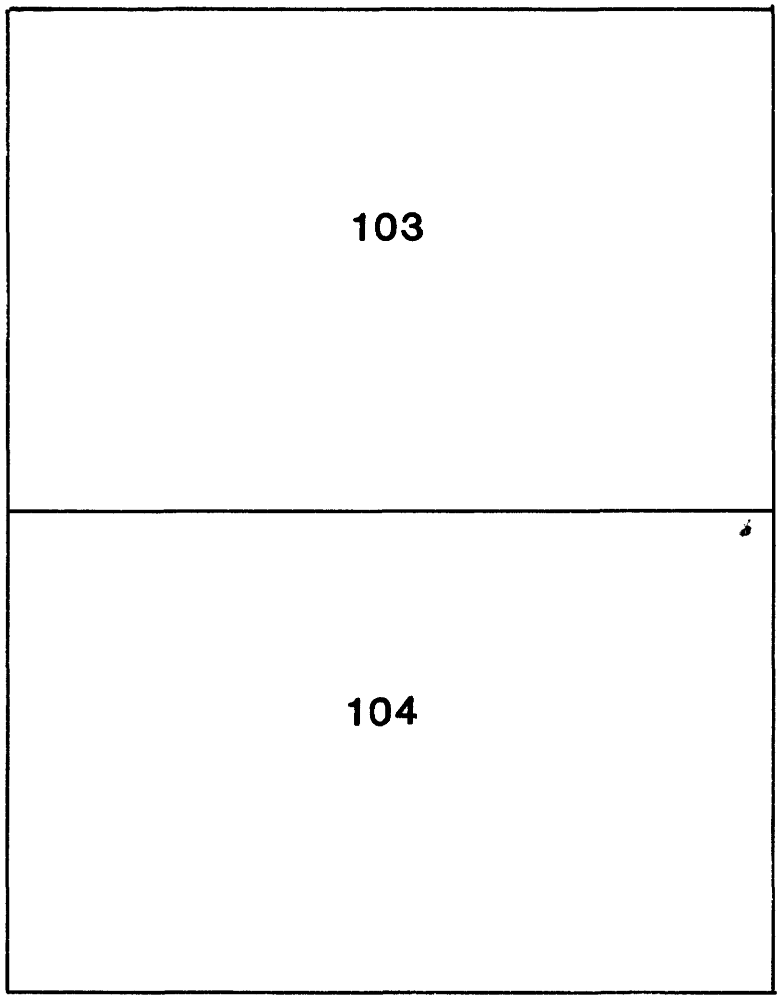
A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



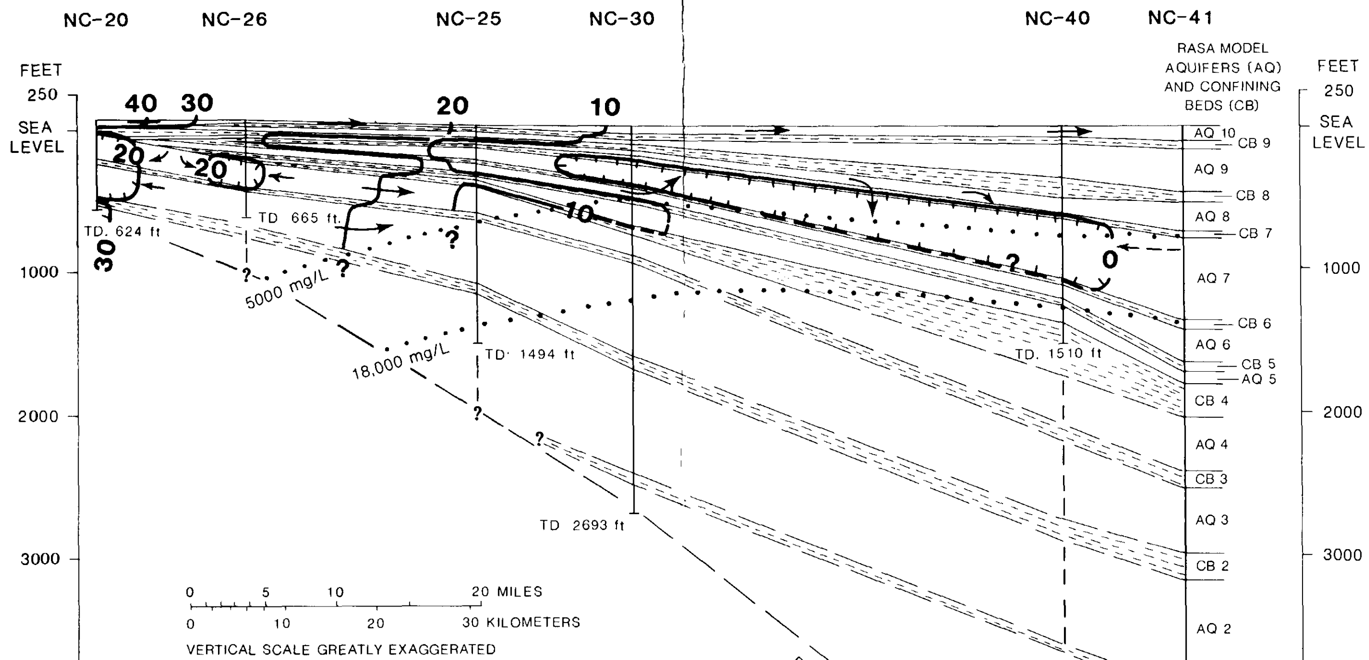
B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900

PLATE 7

GEOHYDROLOGIC CROSS SECTION F - F' FROM
ISLE OF WIGHT COUNTY, VA. TO CURRITUCK COUNTY, N.C.



Index diagram showing page numbers of each component of plate 7



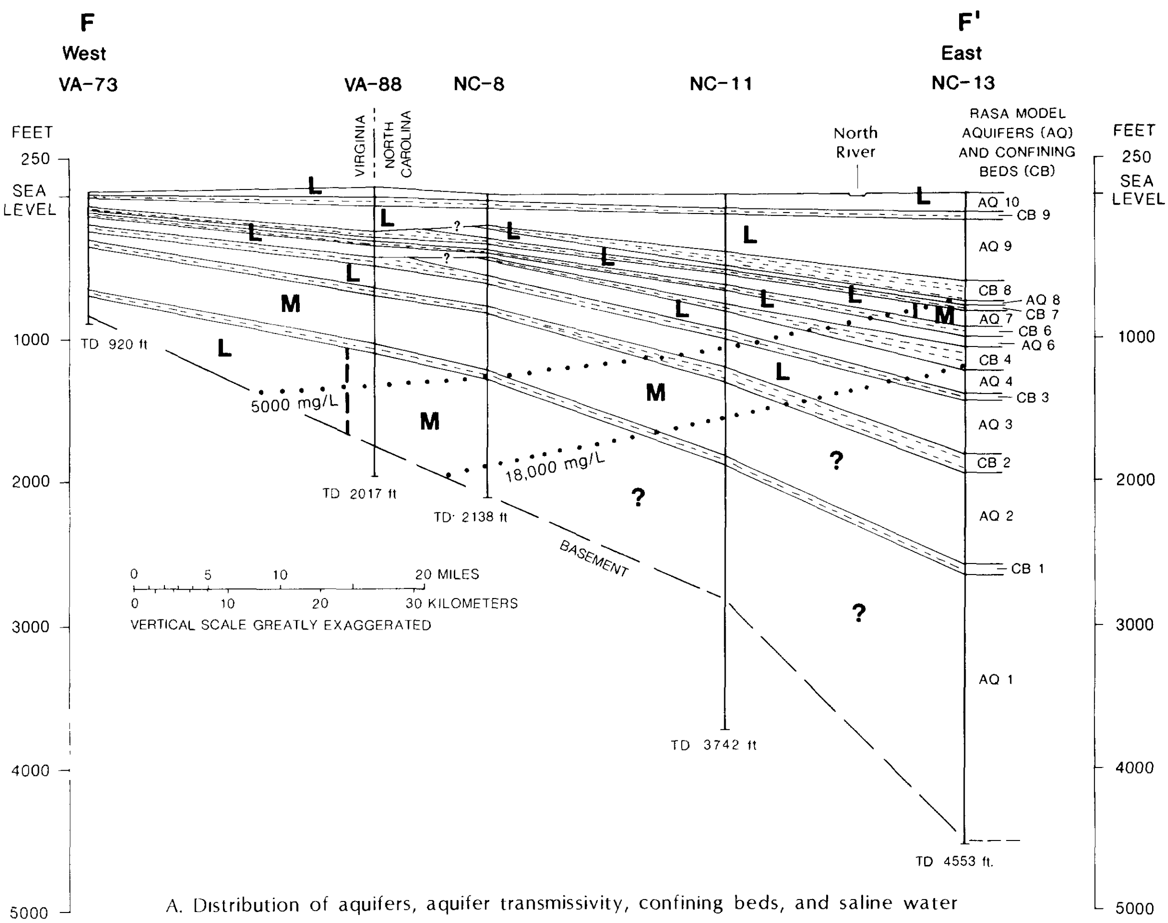
C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

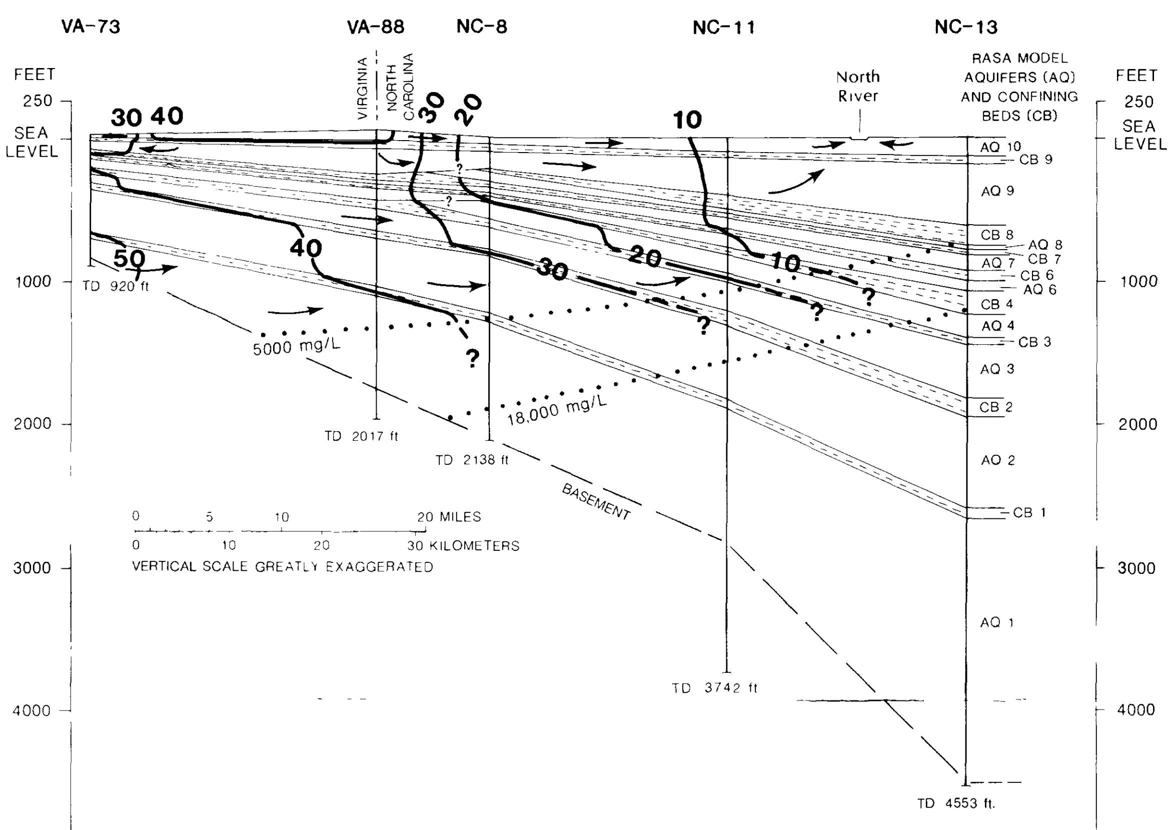
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
—20—?—	Line of approximate equal head, in feet above and below (-) sea level: interval is 10 feet. Dashed where inferred. Queried where location is uncertain
←—— – –	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
• • • • • • 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
NC-30	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD 2693 ft.	Total depth of well, in feet
Data source:	Meisler (1980b);M.D. Winner, G.L. Giese, M.M. Martin, Henry Trapp, Jr., Harold Meisler (U.S. Geological Survey, written and oral commun.,1984)

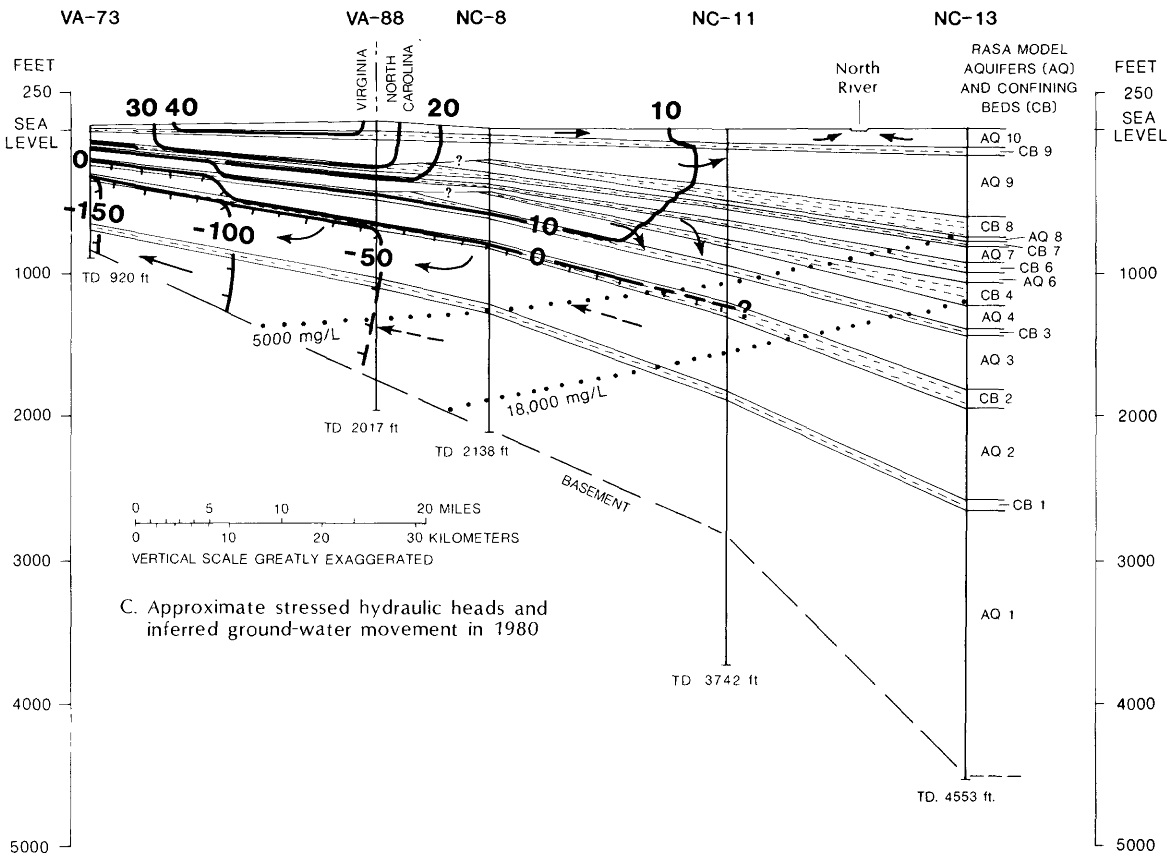
GEOHYDROLOGIC CROSS SECTION E-E' FROM MARTIN COUNTY, N.C., TO DARE COUNTY, N.C.



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L — Low: less than 7000

M — Medium: between about 7000 and 14,000

—20—?— Line of approximate equal head, in feet, above and below (-) sea level, interval is variable. Dashed where inferred. Queried where location is uncertain

←— — — Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section

. . . . 5000 mg/L — Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter

NC-8 — Well number. Alphabetical prefix is state abbreviation (see table 4)

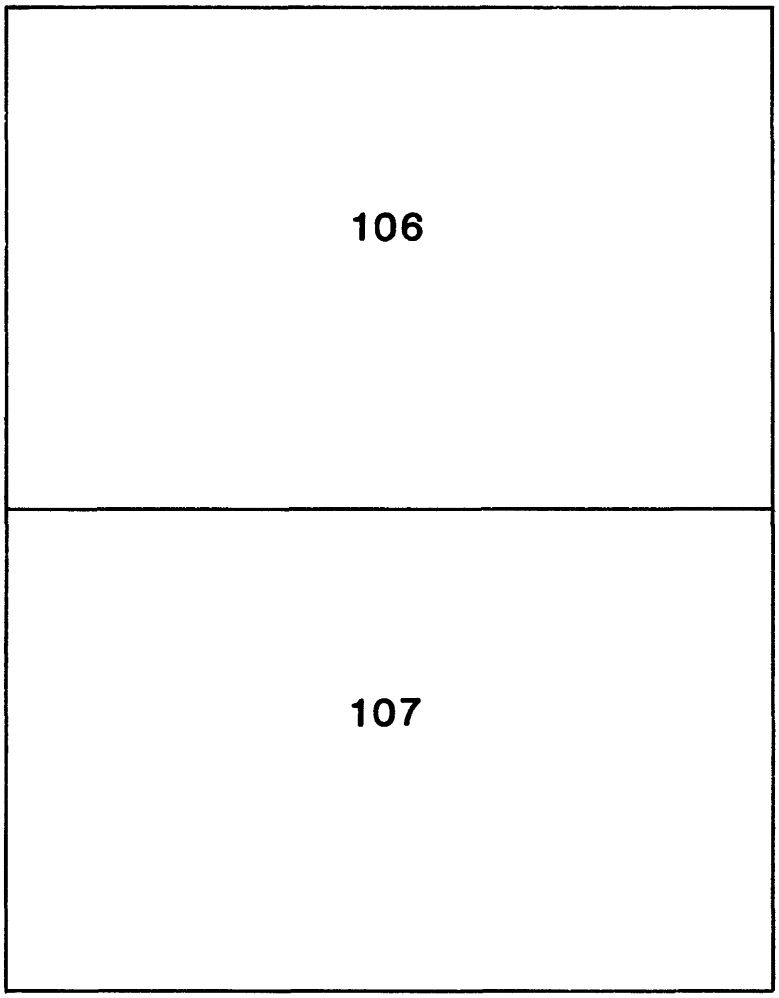
TD 2138 ft. — Total depth of well, in feet

Data source. — Hopkins and others (1981); Meng and Harsh (1984); Meisler (1980b); R.J. Laczniak, M.D. Winner, G.L. Giese, M.M. Martin, Henry Trapp, Jr., Harold Meisler (U.S. Geological Survery, written and oral commun., 1984)

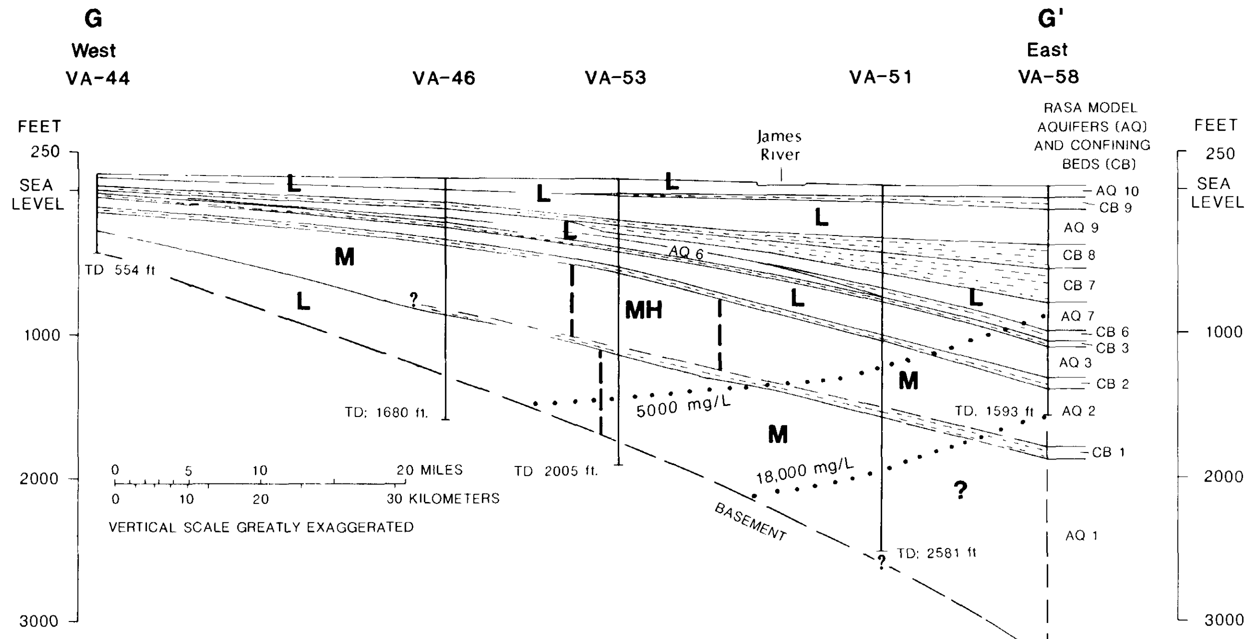
GEOHYDROLOGIC CROSS SECTION F-F′ FROM ISLE OF WIGHT COUNTY, VA. TO CURRITUCK COUNTY, N.C.

PLATE 8

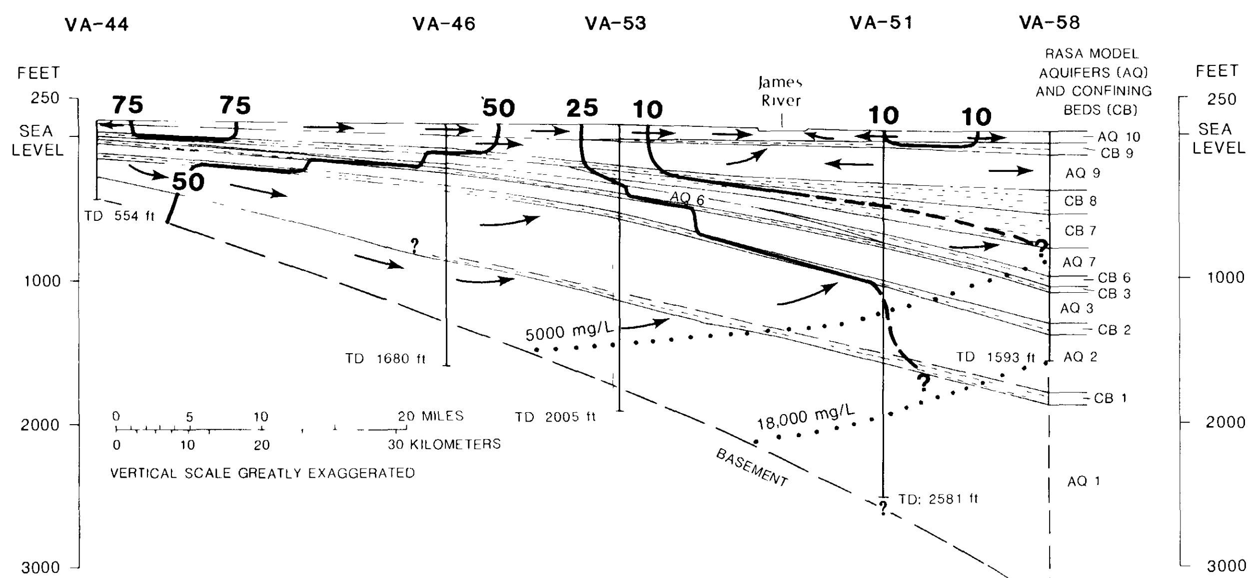
GEOHYDROLOGIC CROSS SECTION G - G' FROM
SUSSEX COUNTY, VA., TO VIRGINIA BEACH, VA.



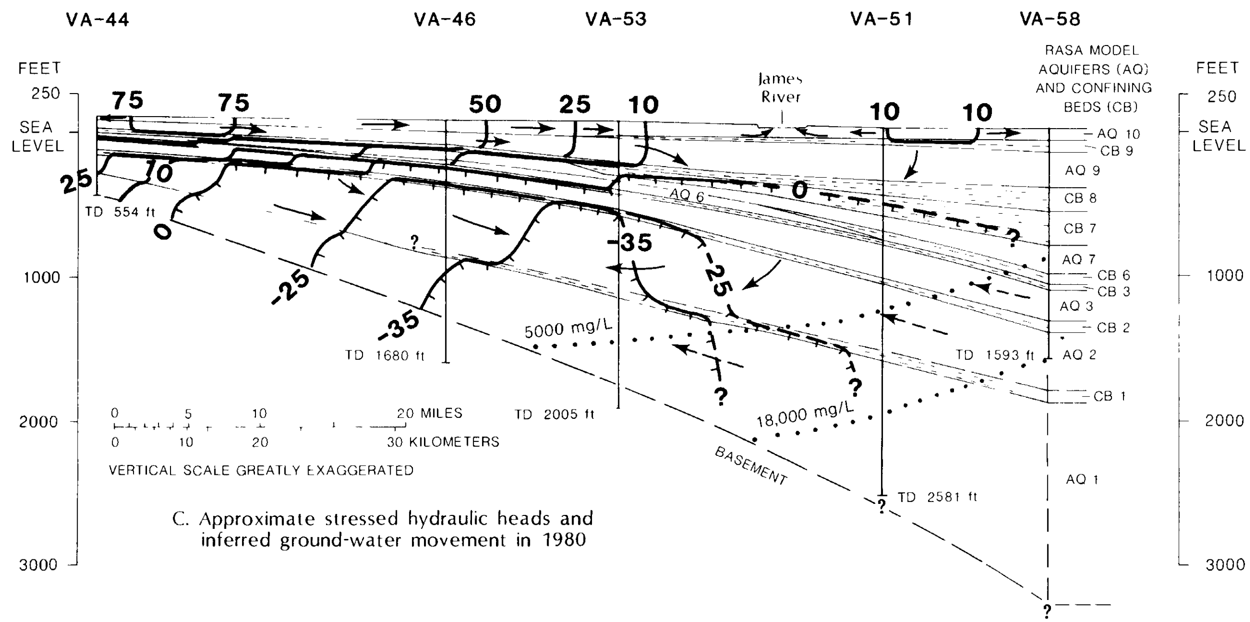
Index diagram showing page numbers of each component of plate 8



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

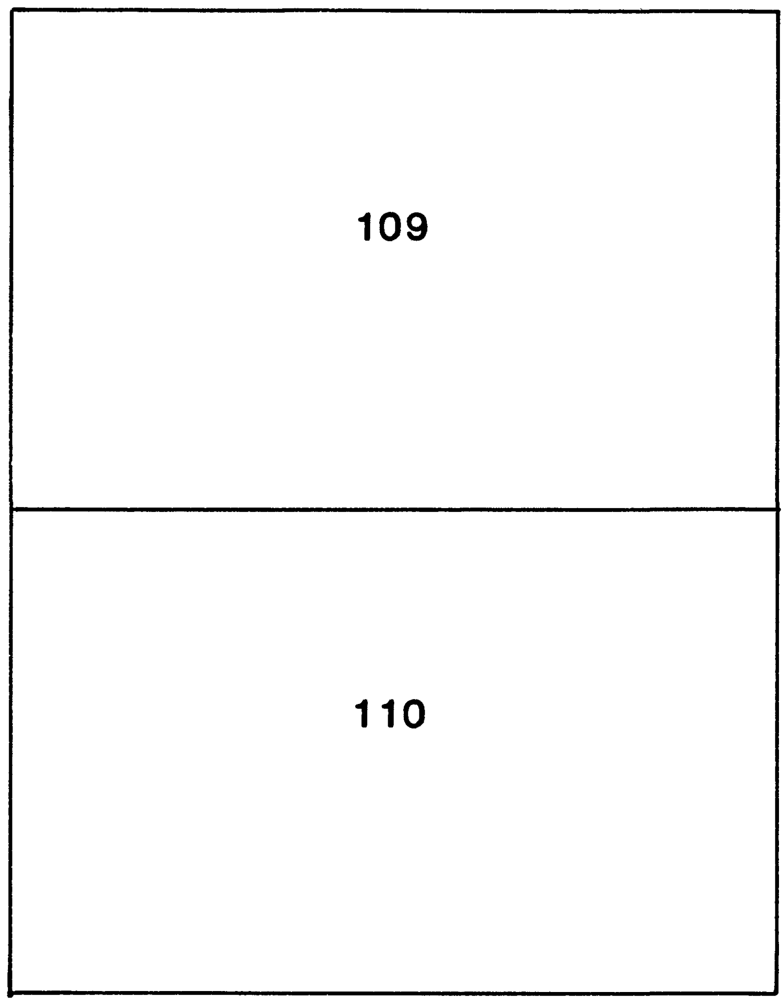
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
MH	Medium high: between about 14,000 and 21,000
—25—?—	Line of approximate equal head, in feet, above and below (-) sea level, interval is variable. Dashed where inferred. Queried where location is uncertain
←— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
• • 5000 mg/L • •	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
VA-53	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD: 2005 ft.	Total depth of well, in feet
Data source:	Hopkins and others (1981); Meng and Harsh (1984); Meisler (1980b); R.J. Laczniak, M.D. Winner, G.L. Giese, M.M. Martin, Henry Trapp, Jr., Harold Meisler (U.S. Geological Survey, written and oral commun., 1984)

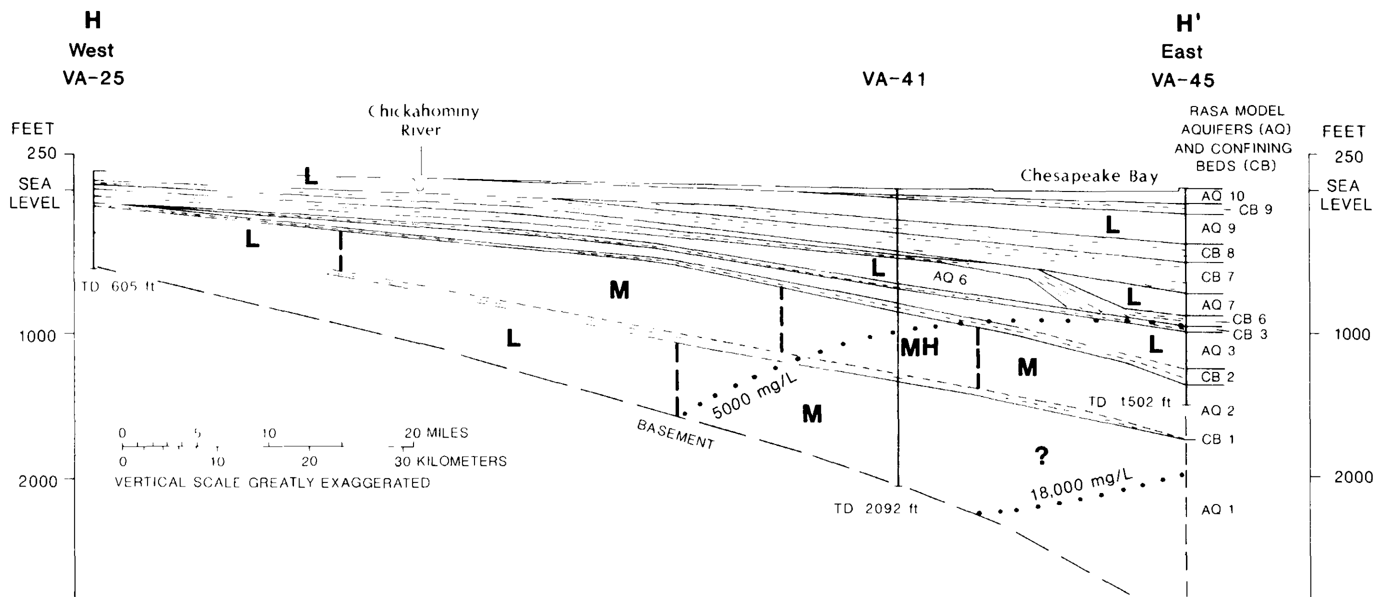
GEOHYDROLOGIC CROSS SECTION G-G' FROM SUSSEX COUNTY, VA., TO VIRGINIA BEACH, VA.

PLATE 9

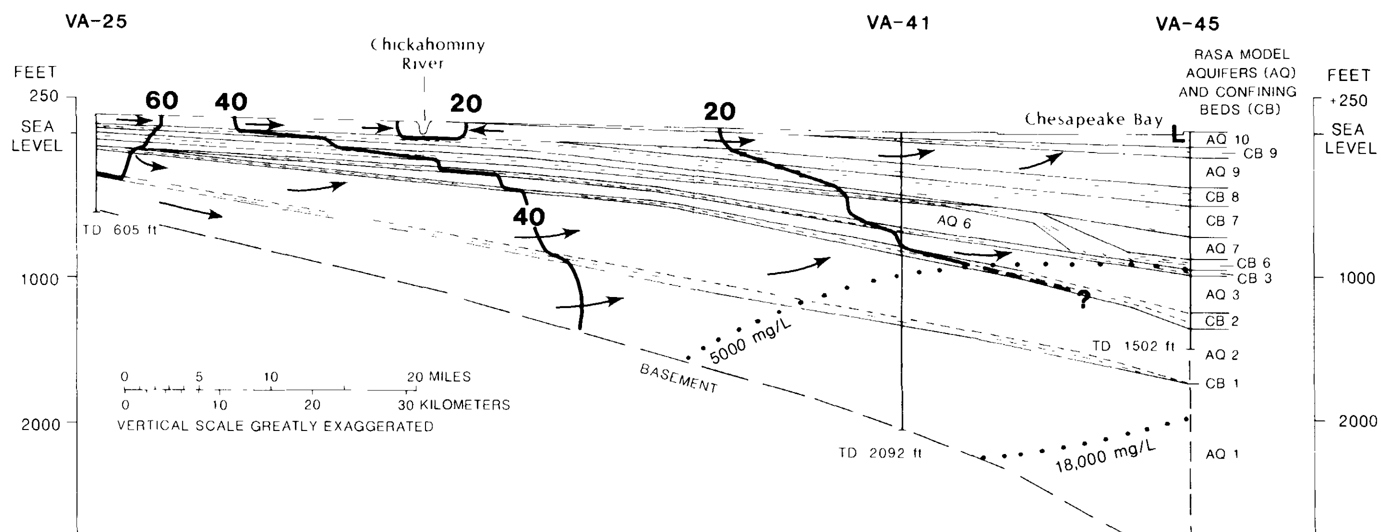
GEOHYDROLOGIC CROSS SECTION H - H' FROM
NEW KENT COUNTY, VA., TO NORFOLK, VA.



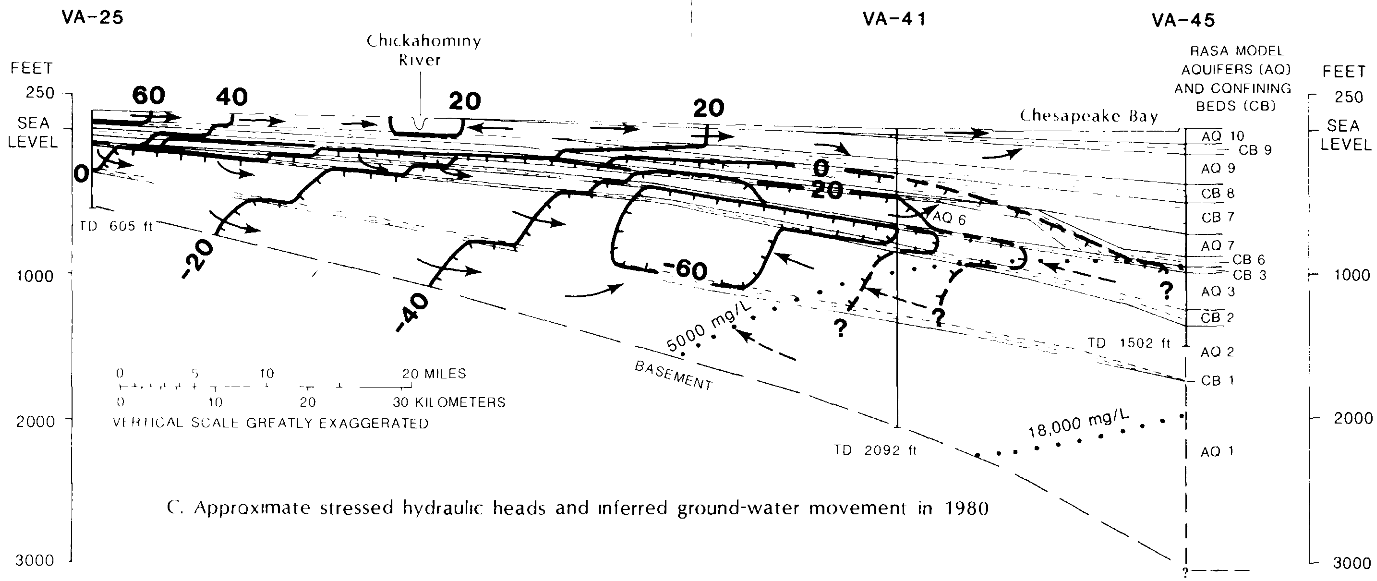
Index diagram showing page numbers of each component of plate 9



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

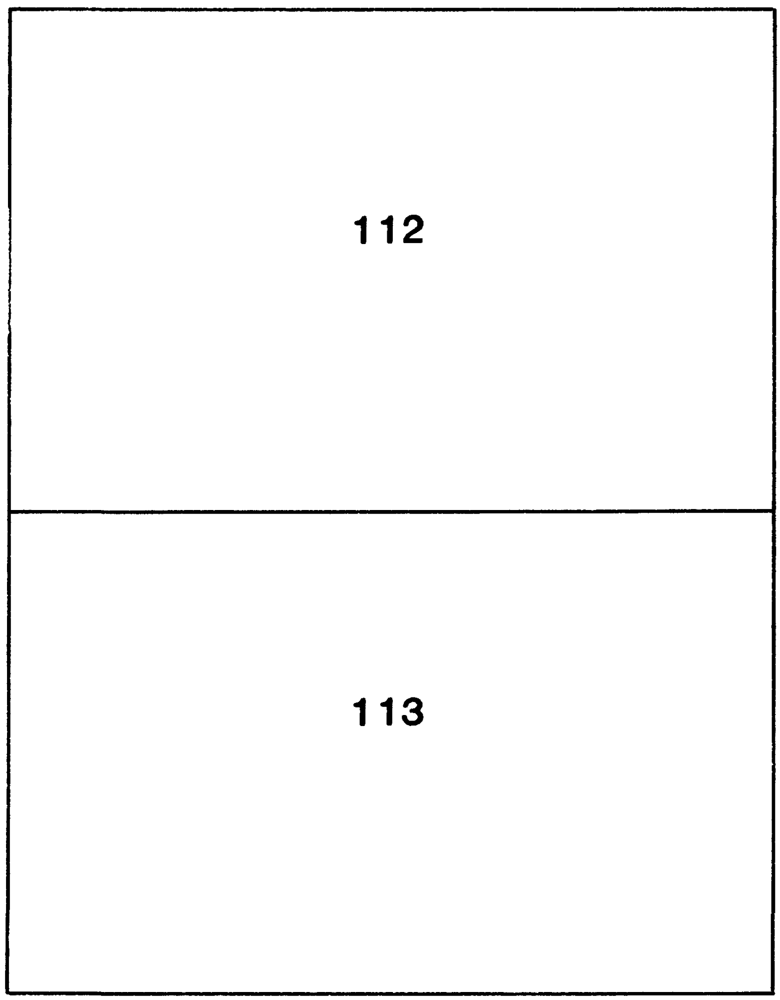
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
MH	Medium high. between about 14,000 and 21,000
—20—?—	Line of approximate equal head, in feet, above and below (-) sea level, interval is 20 feet. Dashed where inferred. Queried where location is uncertain
←—— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
• • • • • • • • • • 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
VA-41	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD. 2092 ft.	Total depth of well, in feet
Data source:	Hopkins and others (1981); Meng and Harsh (1984); Meisler (1980b); R.J. Laczniak, M.D. Winner, G.L. Giese, M.M. Martin, Henry Trapp, Jr., Harold Meisler (U.S. Geological Survery, written and oral commun., 1984)

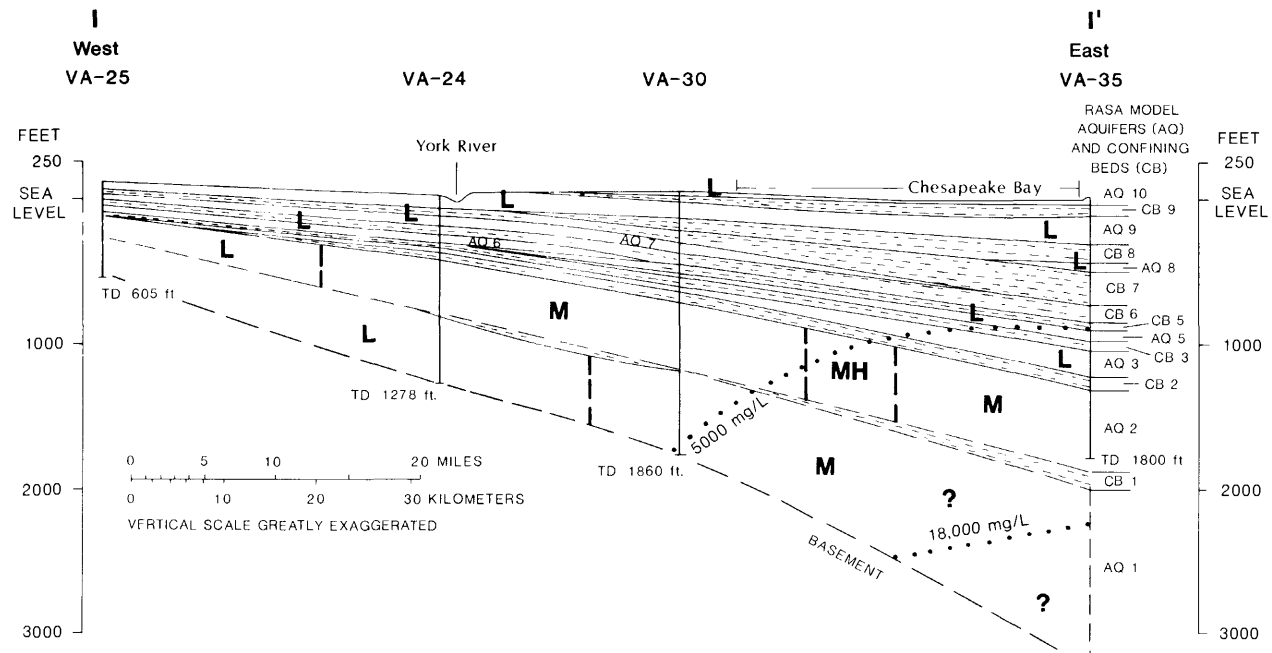
GEOHYDROLOGIC CROSS SECTION H-H' FROM NEW KENT COUNTY, VA., TO NORFOLK, VA.

PLATE 10

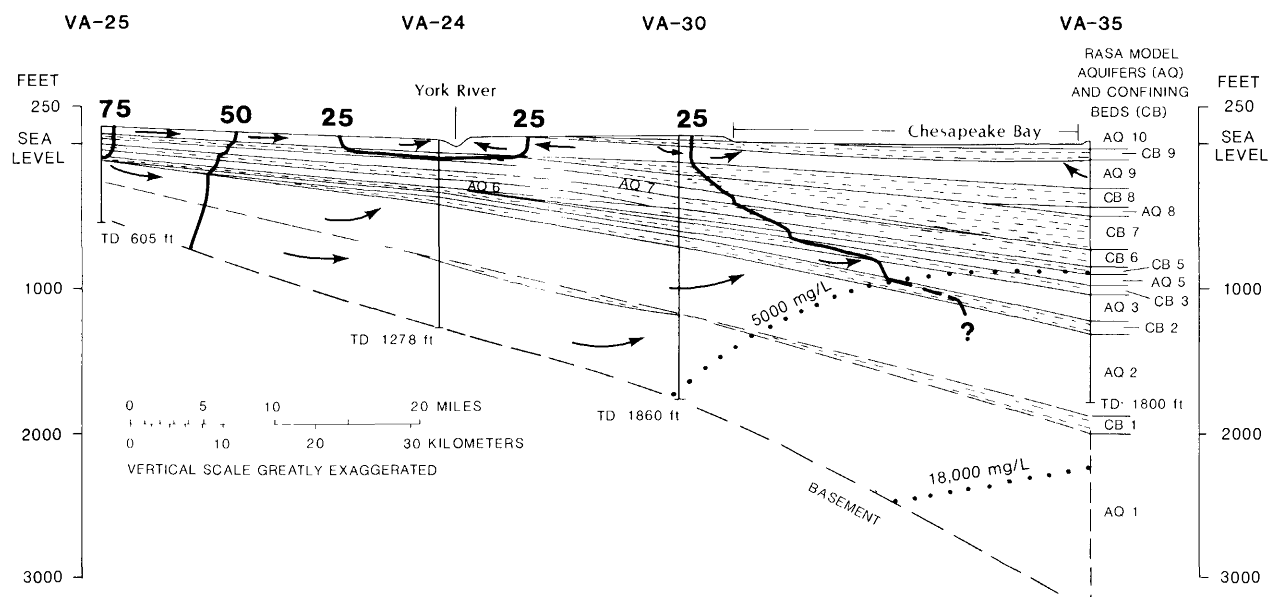
GEOHYDROLOGIC CROSS SECTION I - I' FROM
NEW KENT COUNTY, VA. TO NORTHAMPTON COUNTY, VA.



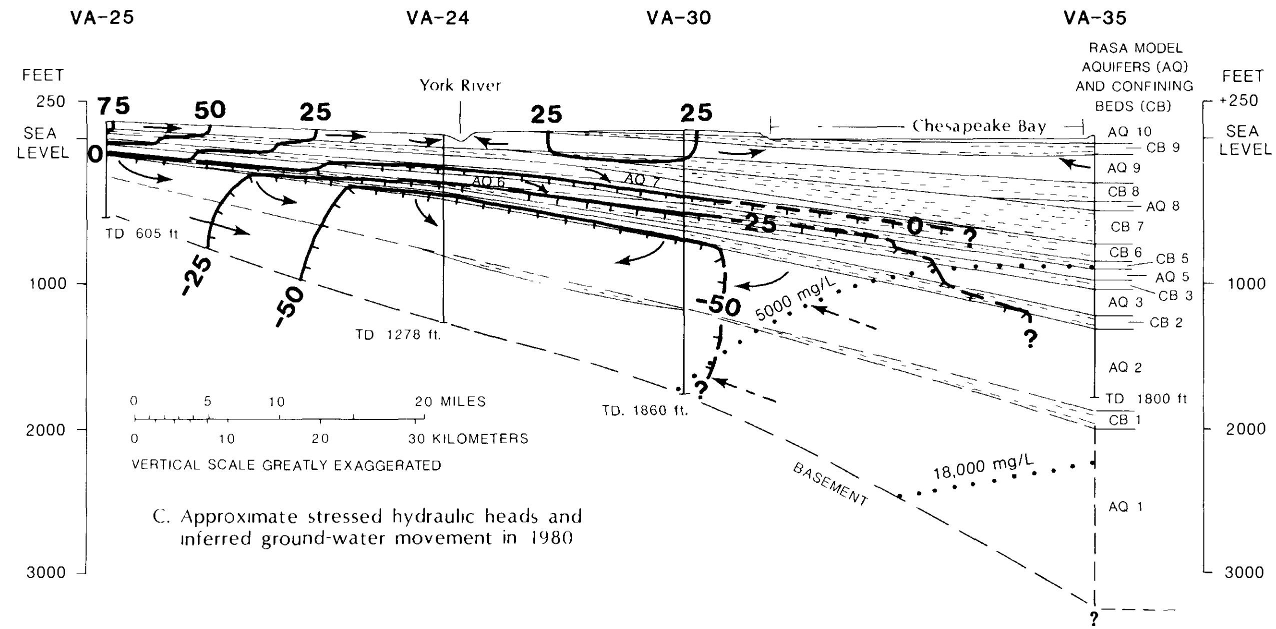
Index diagram showing page numbers of each component of plate 10



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

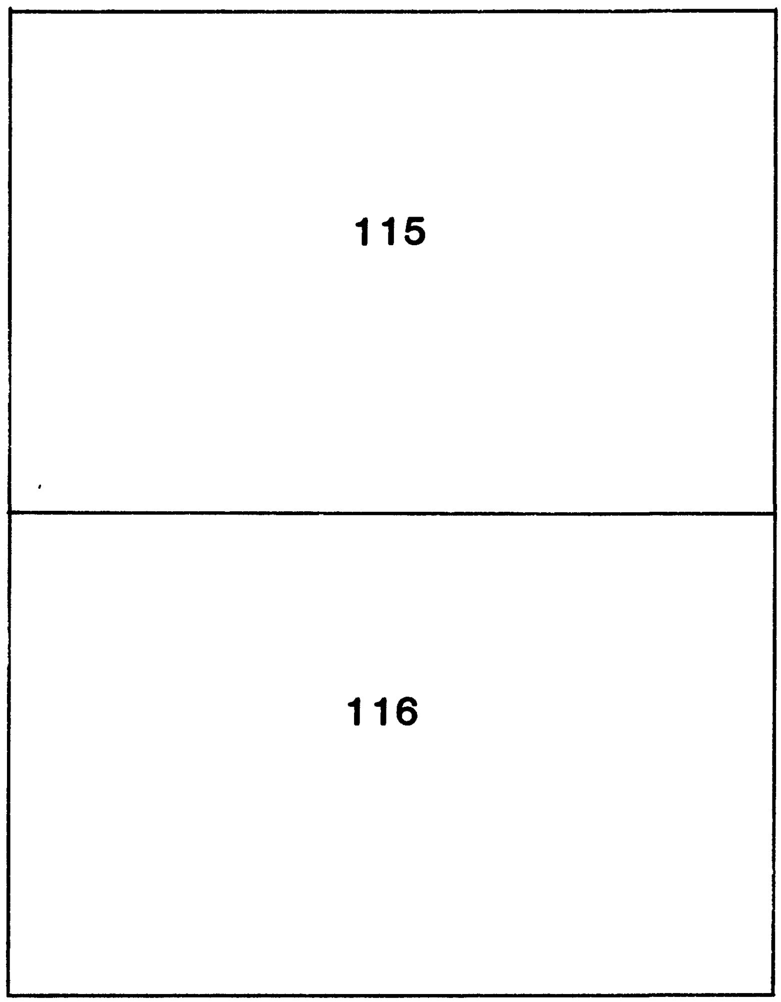
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
MH	Medium high: between about 14,000 and 21,000
——25—?—	Line of approximate equal head, in feet, above and below (-) sea level, interval 25 feet. Dashed where inferred. Queried where location is uncertain
←—— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
• • • • • • • • • 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
VA-30	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD 1860 ft.	Total depth of well, in feet
Data source:	Hopkins and others (1981); Meng and Harsh (1984); Meisler (1980b); R.J. Laczniak, M.M. Martin, Henry Trapp, Jr., and Harold Meisler (U.S. Geological Survery, written and oral commun., 1984)

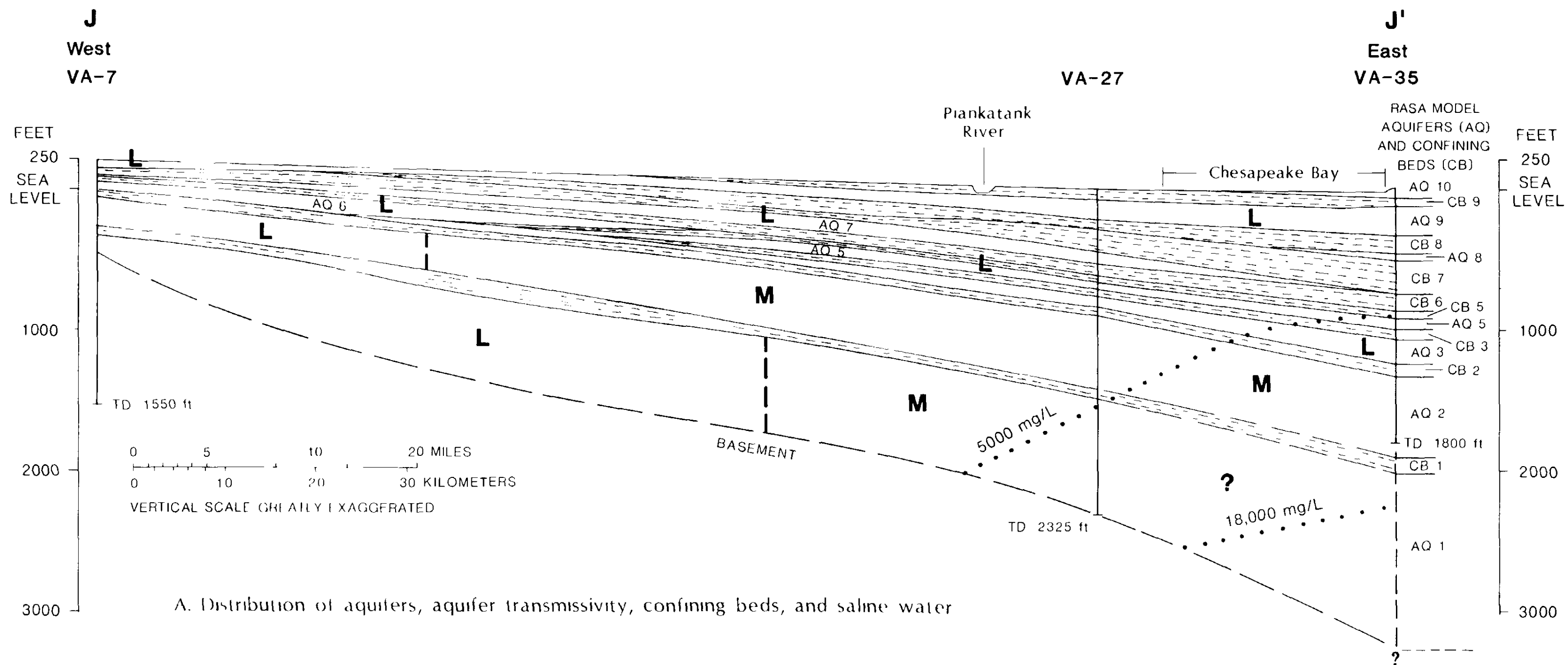
GEOHYDROLOGIC CROSS SECTION I-I′ FROM NEW KENT COUNTY, VA., TO NORTHAMPTON COUNTY, VA.

PLATE 11

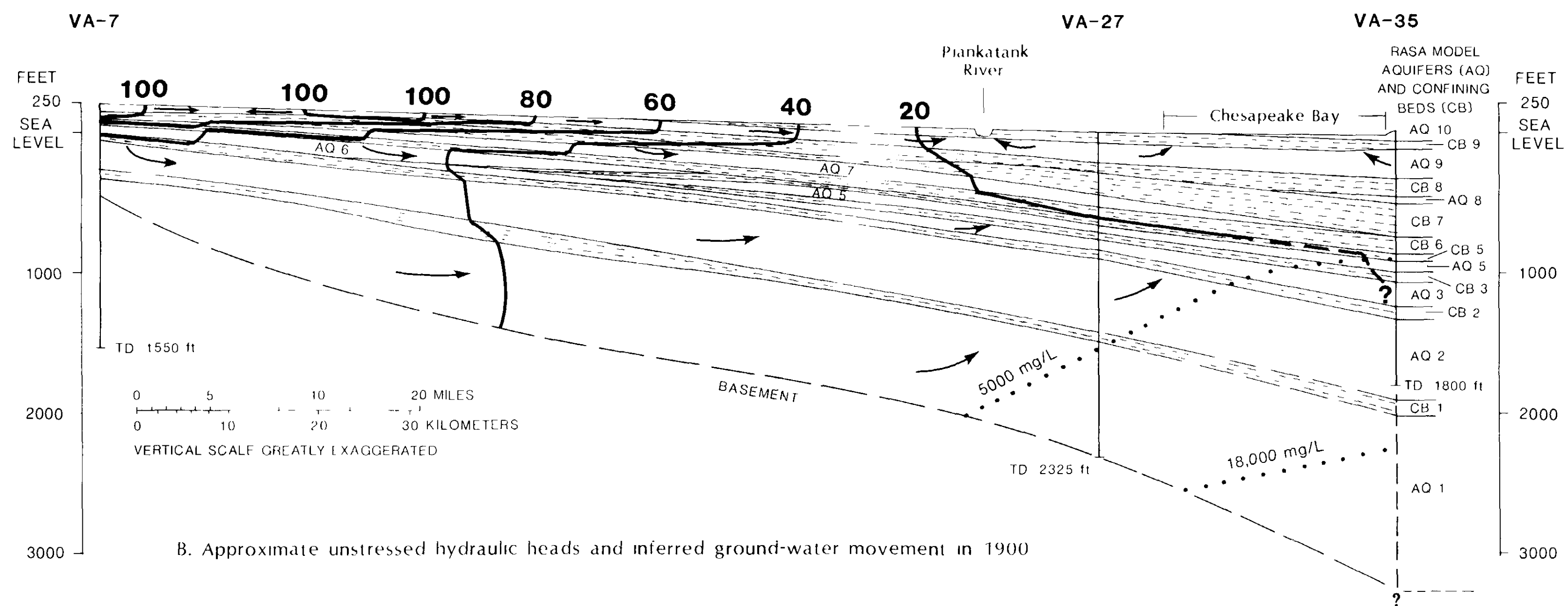
GEOHYDROLOGIC CROSS SECTION J - J' FROM
CAROLINE COUNTY, VA., TO NORTHAMPTON COUNTY, VA.



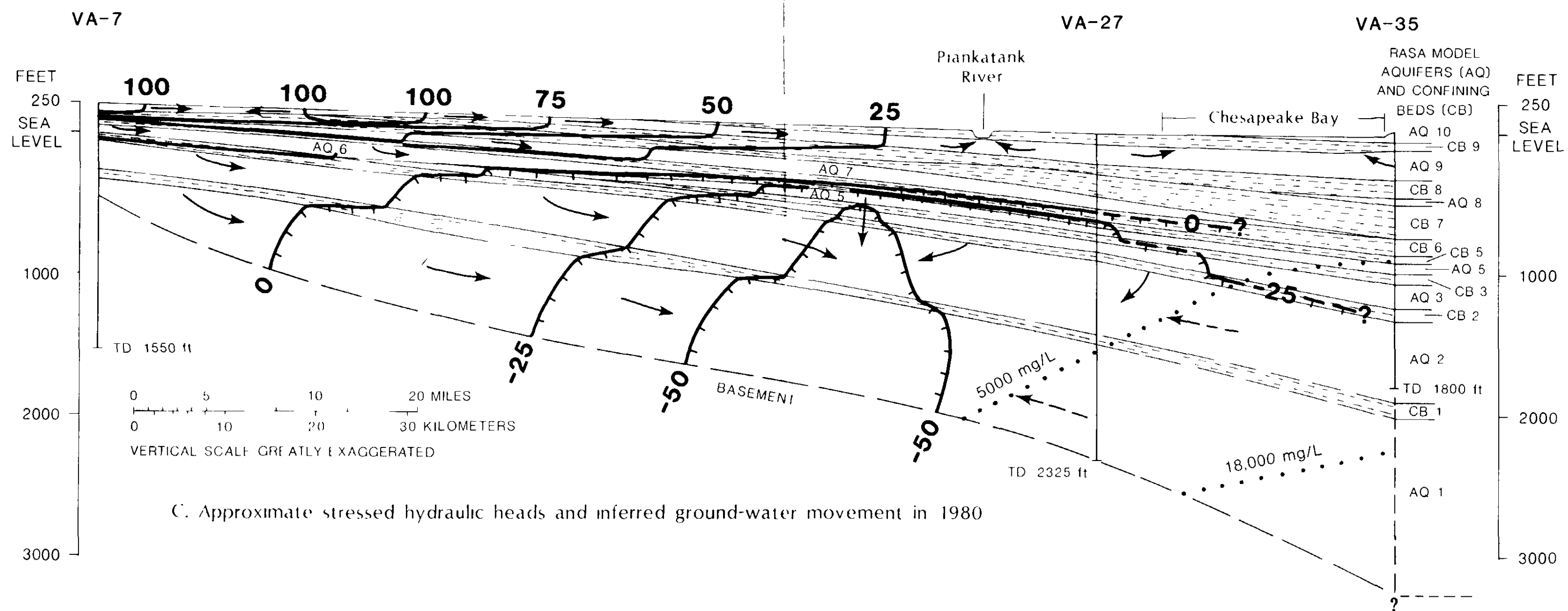
Index diagram showing page numbers of each component of plate 11



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

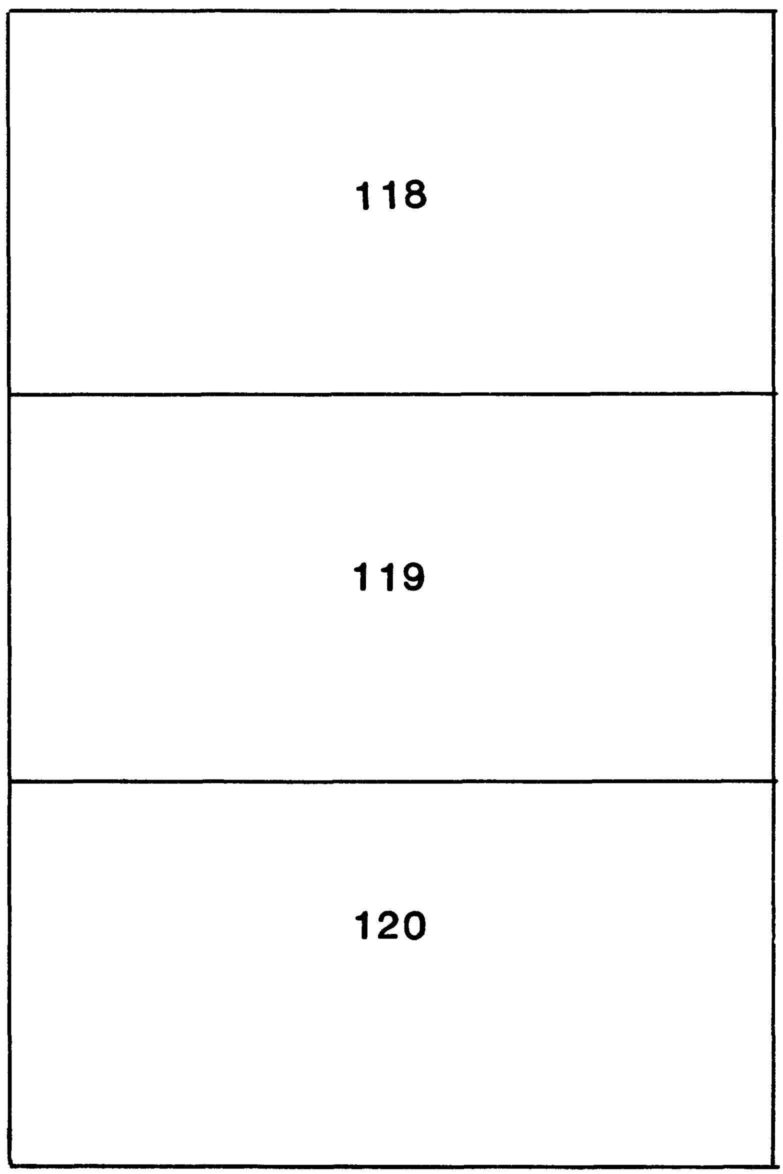
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low, less than 7000
M	Medium, between about 7000 and 14,000
—20—?—	Line of approximate equal head, in feet, above and below (-) sea level, interval is 20 and 25 feet. Dashed where inferred. Queried where location is uncertain
←—— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
·······5000 mg/L···	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
VA-27	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD. 2325 ft.	Total depth of well, in feet
Data source:	Hopkins and others (1981); Meng and Harsh (1984); Meisler (1980b); R.J. Laczniak, M.M. Martin, Henry Trapp, Jr., and Harold Meisler (U.S. Geological Survery, written and oral commun., 1984)

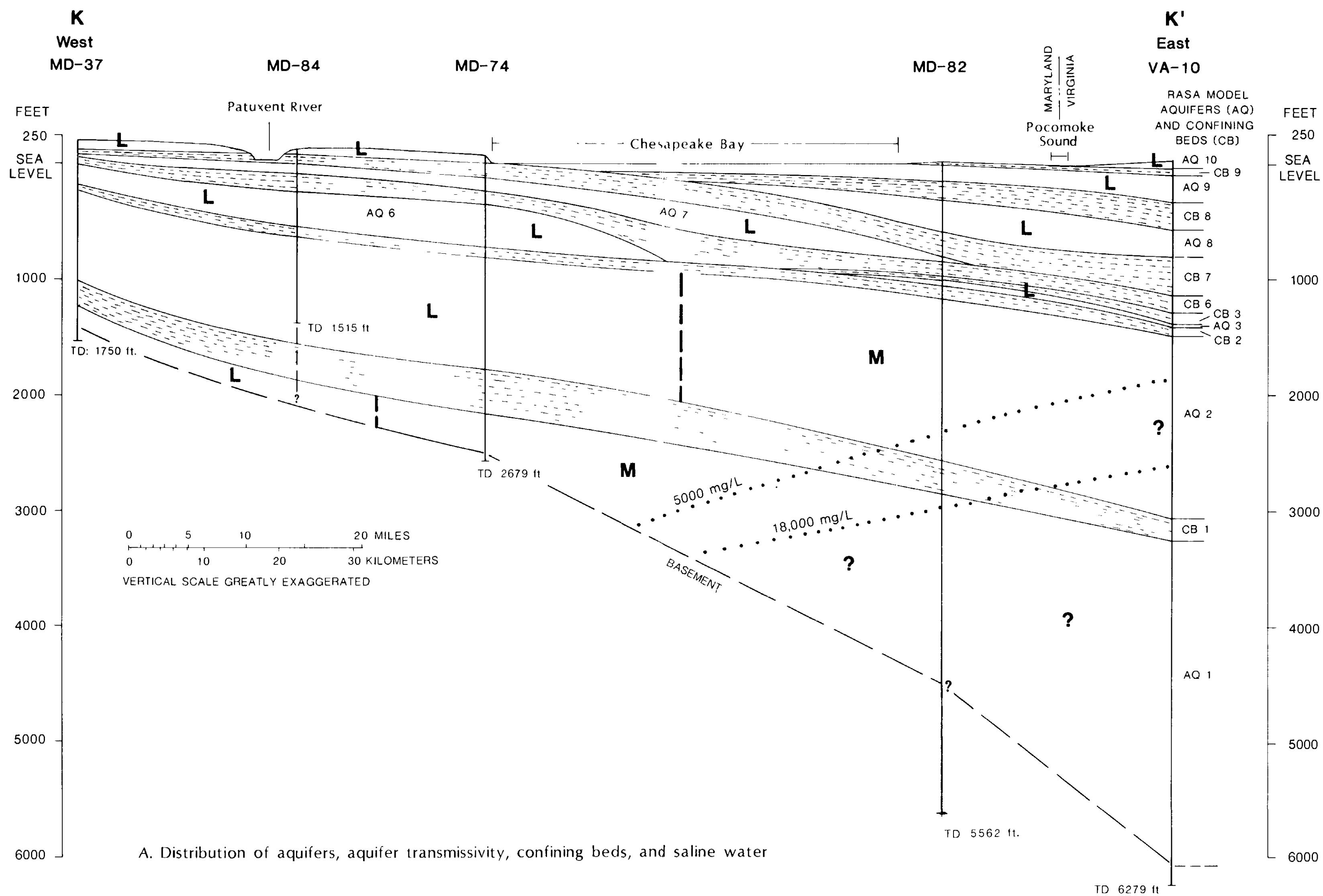
GEOHYDROLOGIC CROSS SECTION J-J' FROM CAROLINE COUNTY, VA., TO NORTHAMPTON COUNTY, VA.

PLATE 12

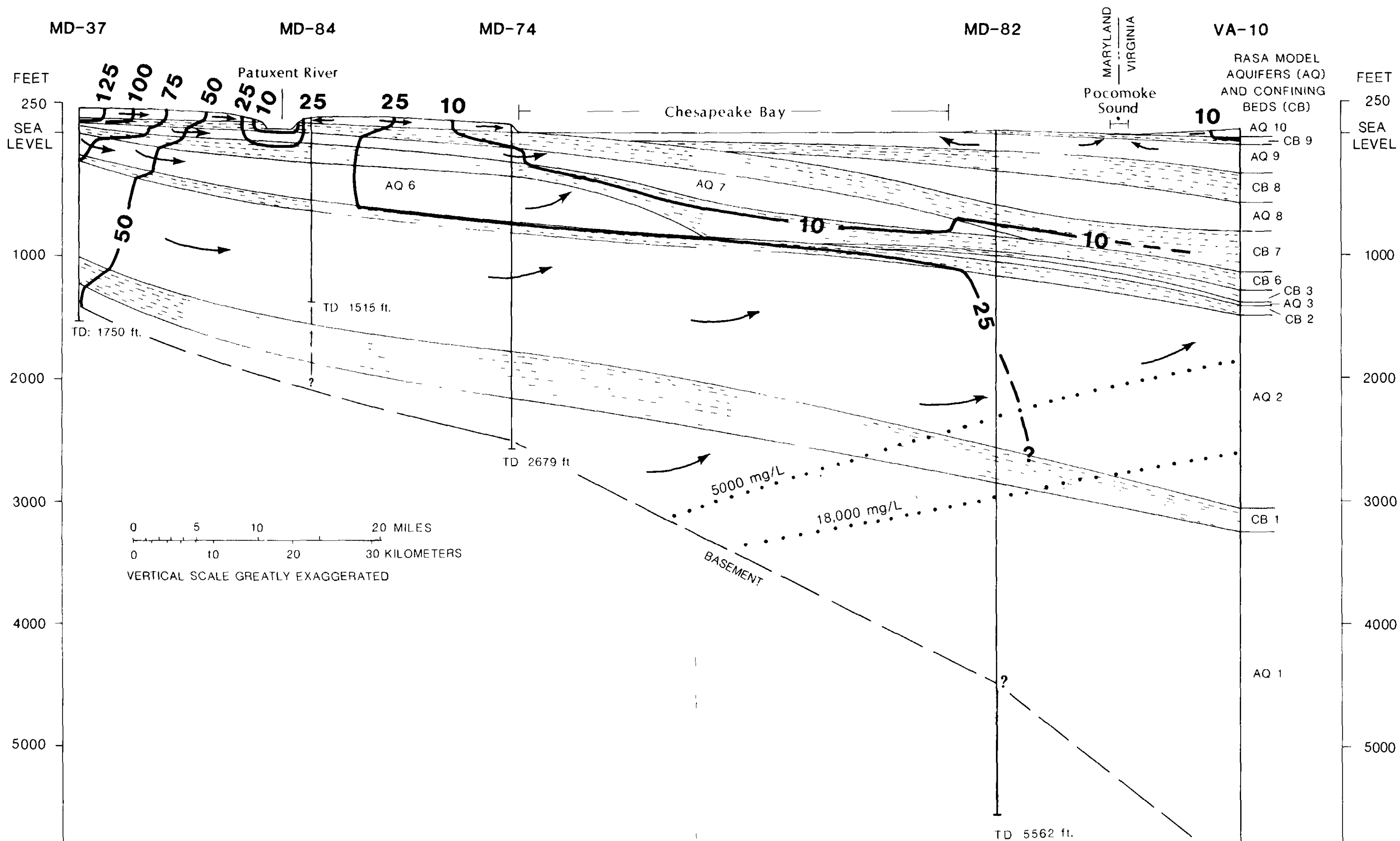
GEOHYDROLOGIC CROSS SECTION K - K' FROM
PRINCE GEORGE COUNTY, MD., TO ACCOMACK COUNTY, VA.



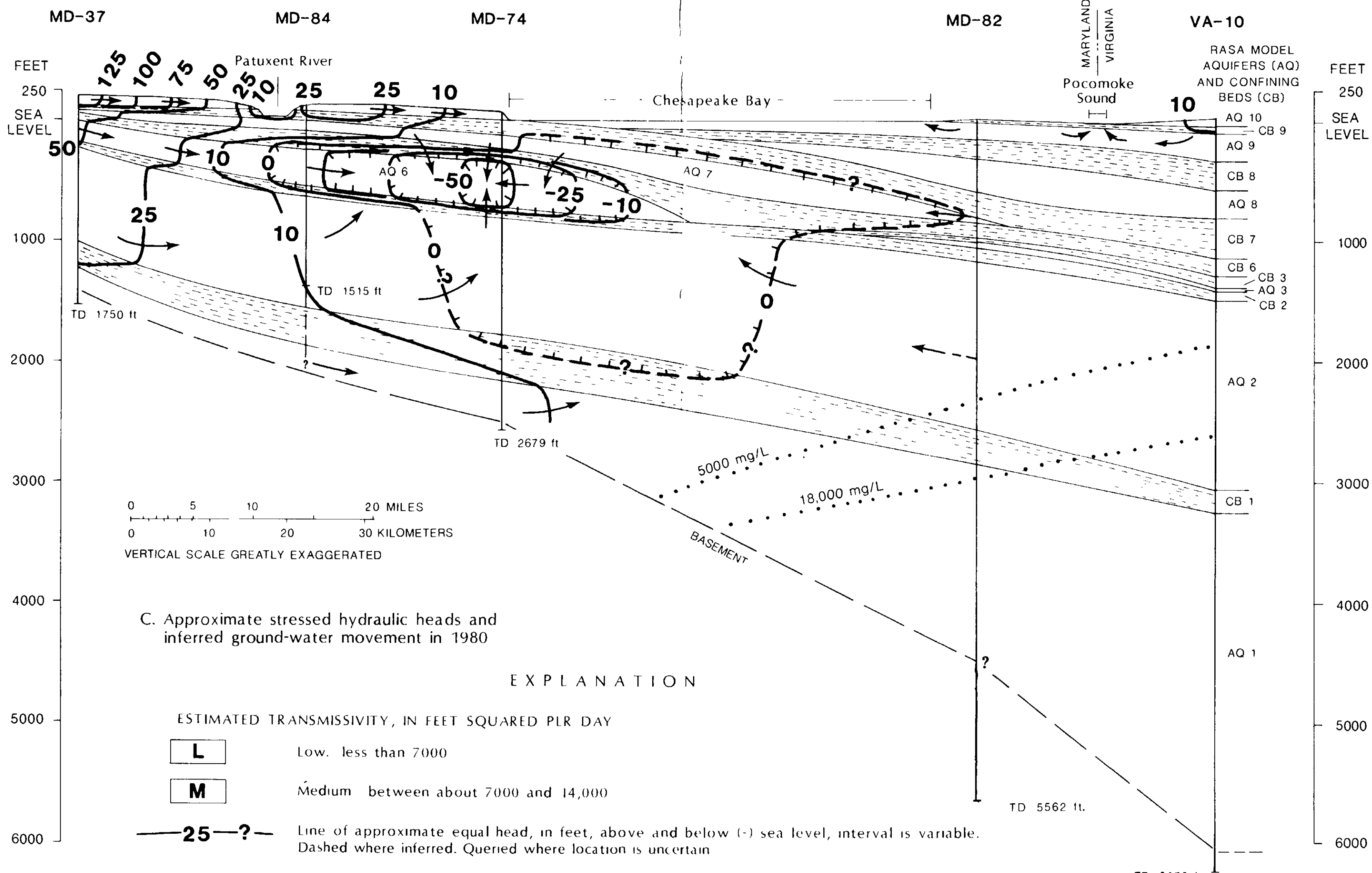
Index diagram showing page numbers of each component of plate 12



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L Low. less than 7000

M Medium between about 7000 and 14,000

—25—?— Line of approximate equal head, in feet, above and below (-) sea level, interval is variable. Dashed where inferred. Queried where location is uncertain

←— — — Flow line and arrow indicate estimated direction of ground water flow. Dashed in saline-water part of section

· · · · · · · · · 5000 mg/L Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter

MD-74 Well number. Alphabetical prefix is state abbreviation (see table 4)

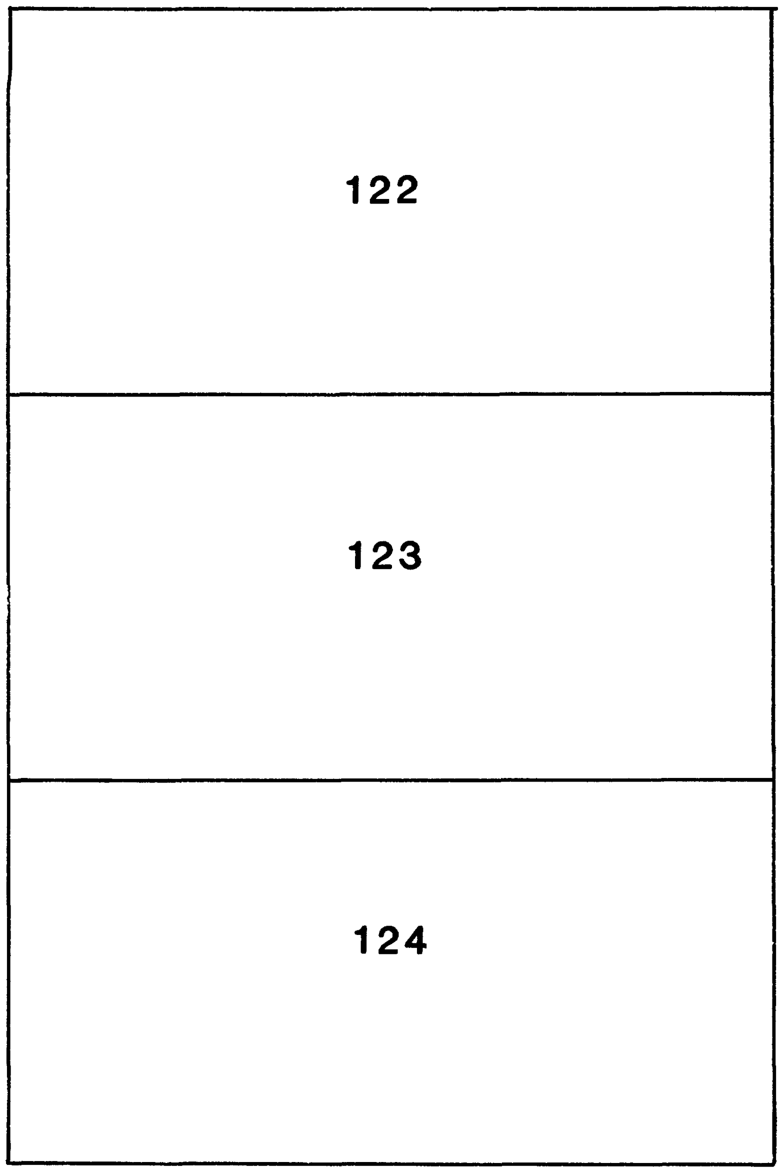
TD 2679 ft. Total depth of well, in feet

Data source Meng and Harsh (1984); Meisler (1980b); D.A. Vroblesky, W.B. Fleck, R.J. Laczniak, M.M. Martin, Henry Trapp, Jr., and Harold Meisler (U.S. Geological Survery, written and oral commun., 1984)

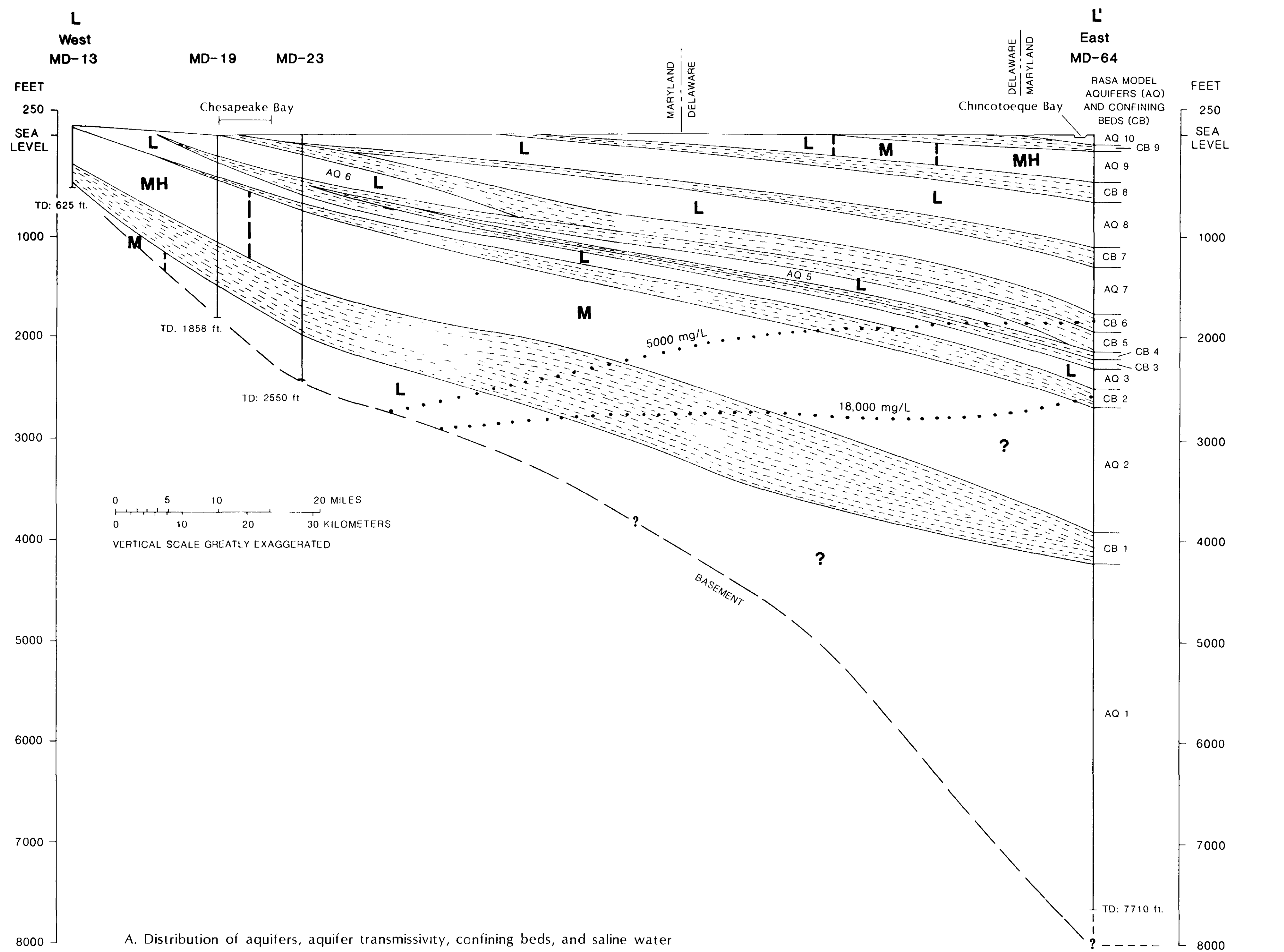
GEOHYDROLOGIC CROSS SECTION K-K' FROM PRINCE GEORGE COUNTY, MD., TO ACCOMACK COUNTY, VA.

PLATE 13

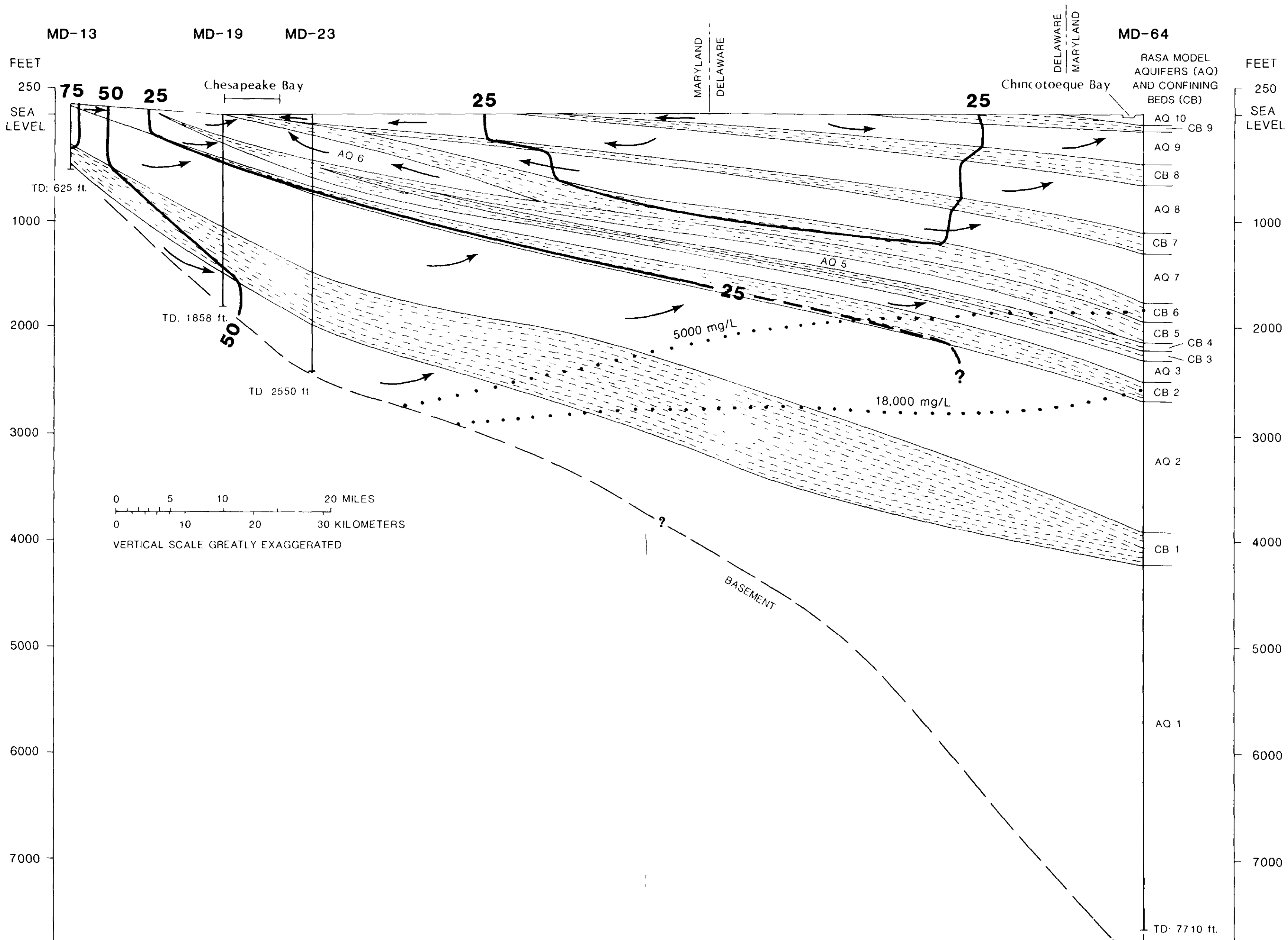
GEOHYDROLOGIC CROSS SECTION L - L' FROM
ANNE ARUNDEL COUNTY, MD., TO WORCESTER COUNTY, MD.



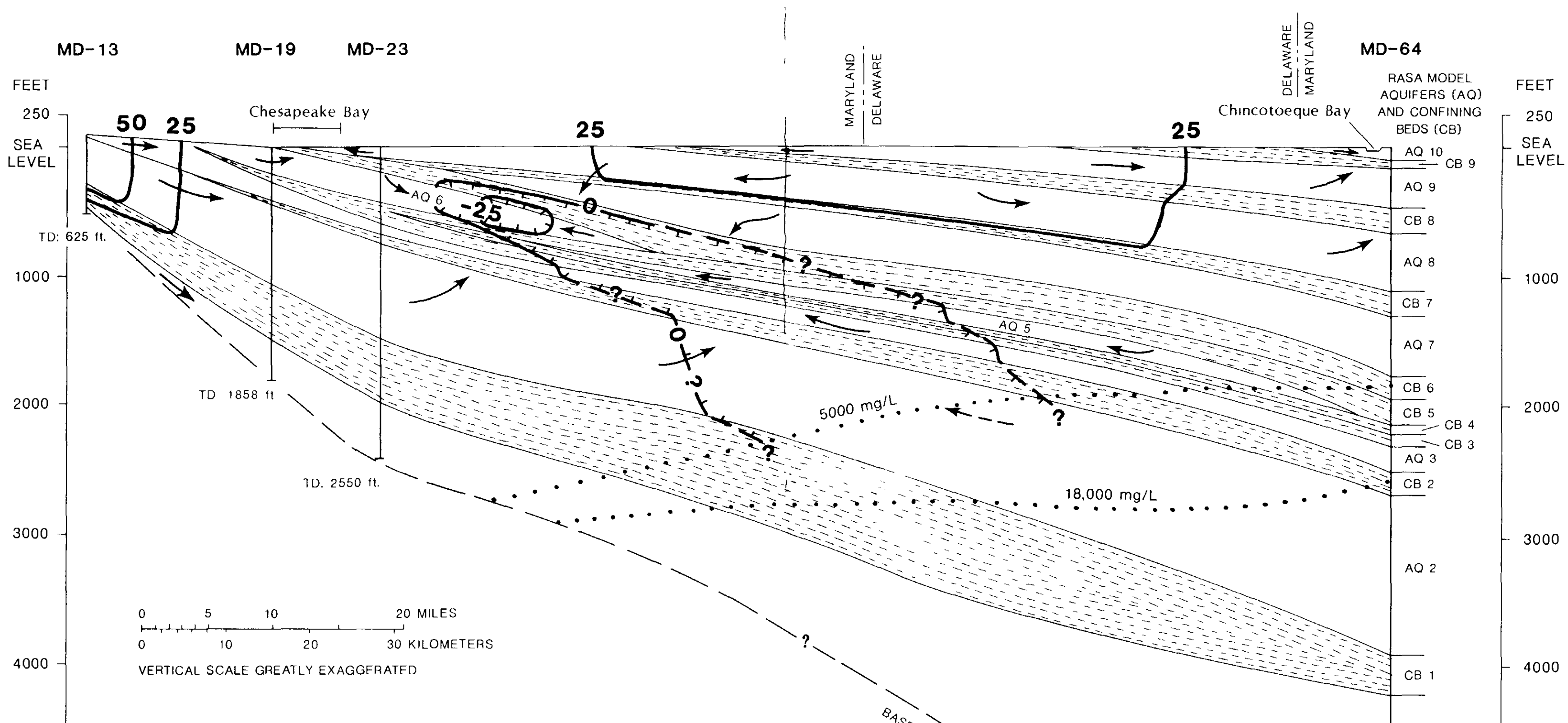
Index diagram showing page numbers of each component of plate 13



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

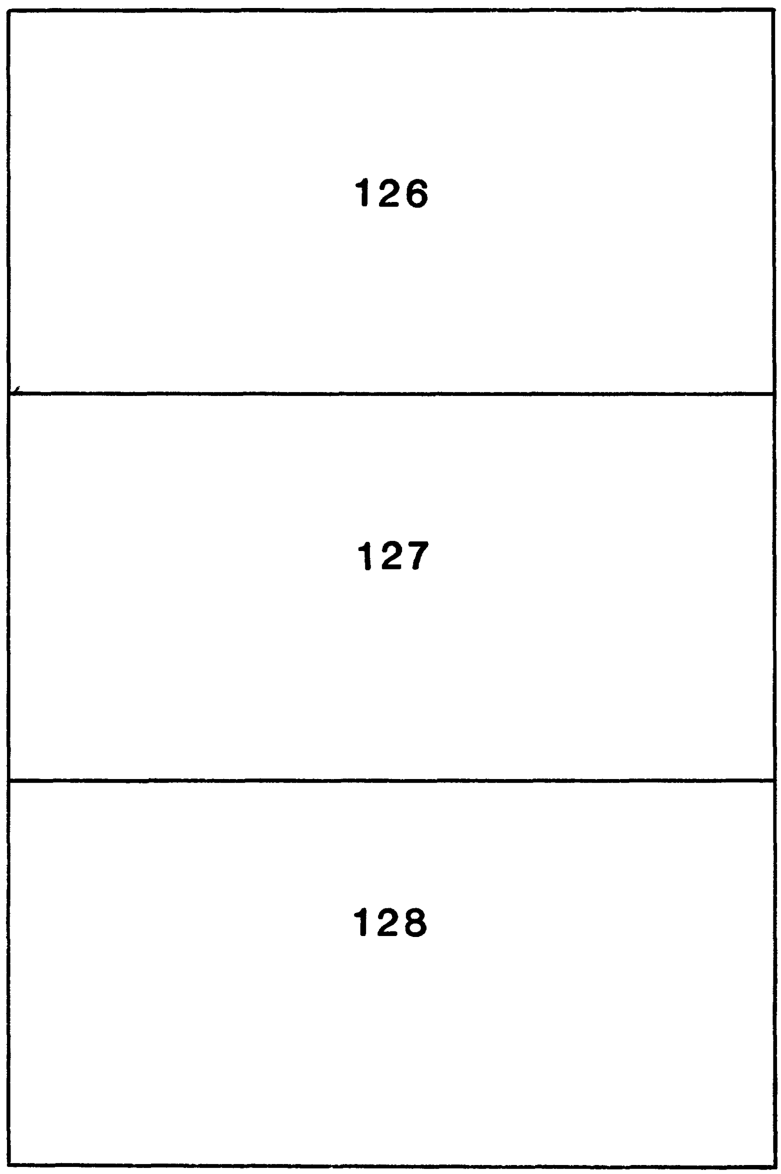
L	Low less than 7000
M	Medium between about 7000 and 14,000
MH	Medium high: between about 14,000 and 21,000
—25—?—	Line of approximate equal head, in feet, above and below (-) sea level, interval is 25 feet. Dashed where inferred. Queried where location is uncertain
←— —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
..... 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
MD-23	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD 2550 ft.	Total depth of well, in feet

Data source: Meisler (1980b); D.A. Vroblesky, W.B. Fleck, M.M. Martin, Henry Trapp, Jr., and Harold Meisler (U.S. Geological Survey, written and oral commun., 1984)

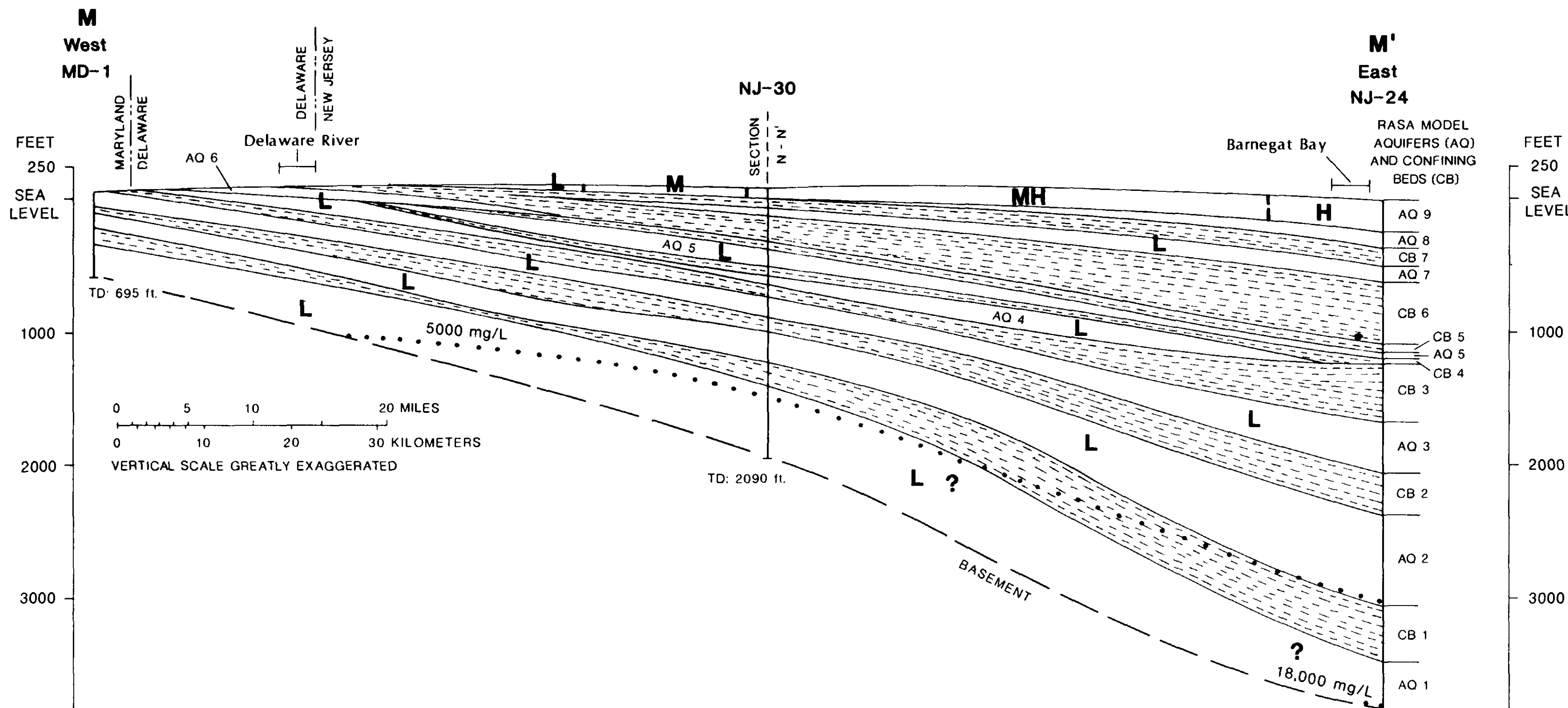
GEOHYDROLOGIC CROSS SECTION L-L' FROM ANNE ARUNDEL COUNTY, MD., TO WORCESTER COUNTY, MD.

PLATE 14

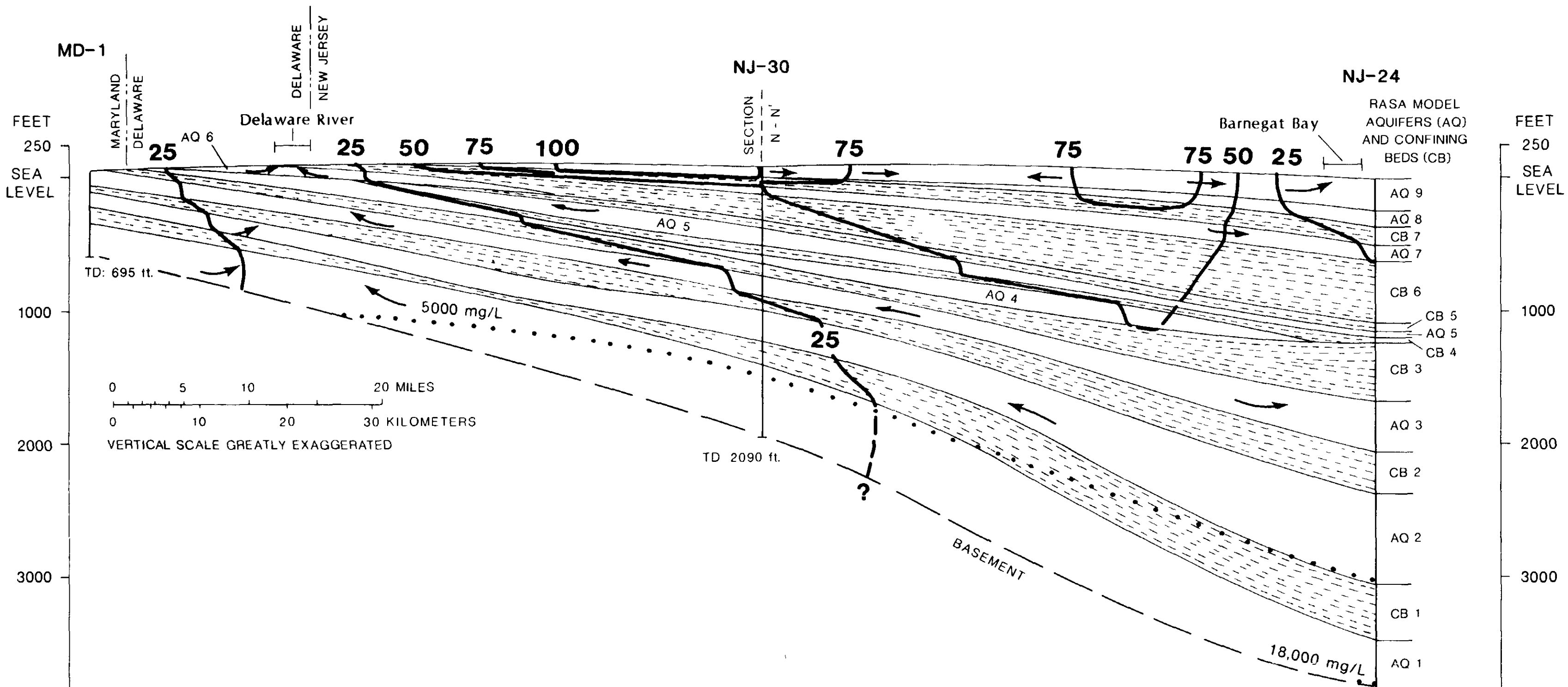
GEOHYDROLOGIC CROSS SECTION M - M' FROM
CECIL COUNTY, MD., TO OCEAN COUNTY, N.J.



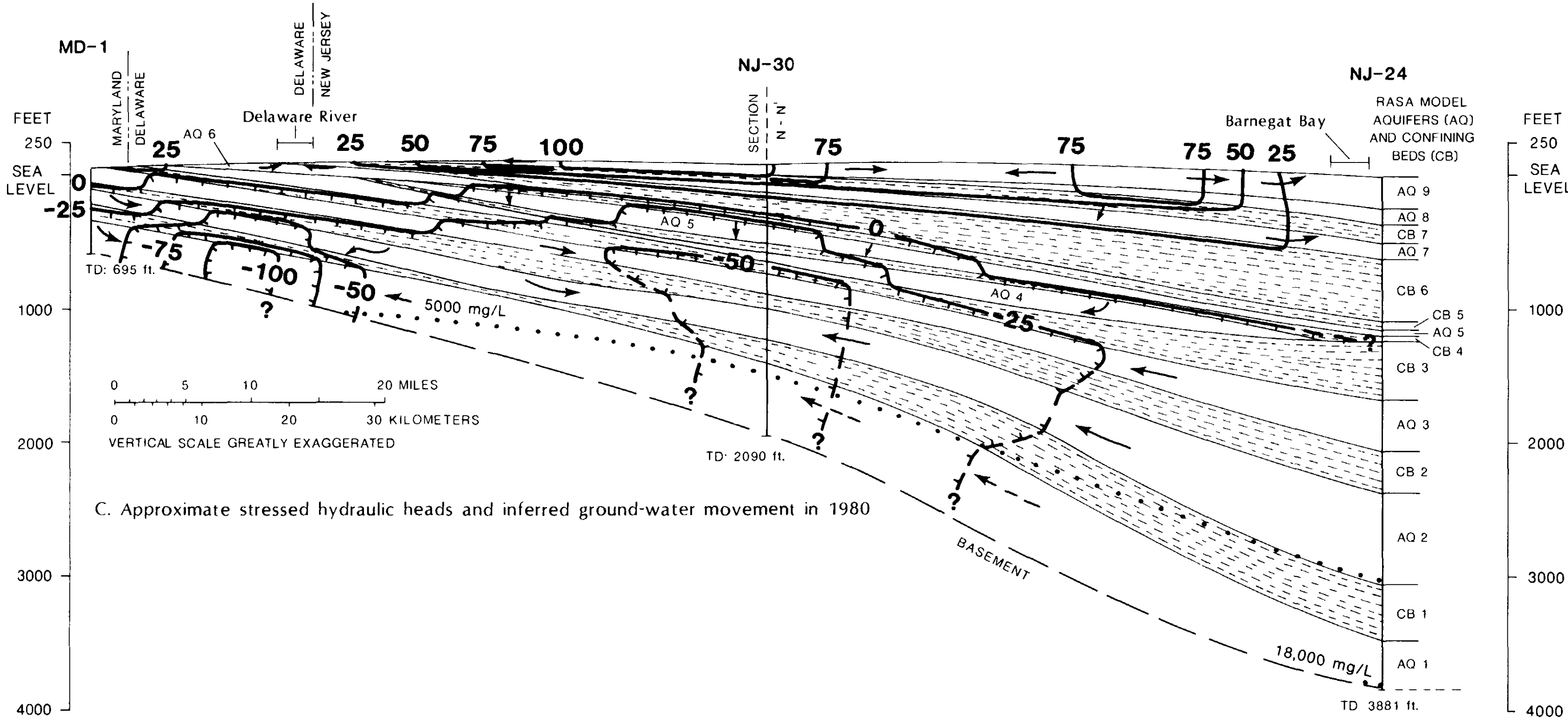
Index diagram showing page numbers of each component of plate 14



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

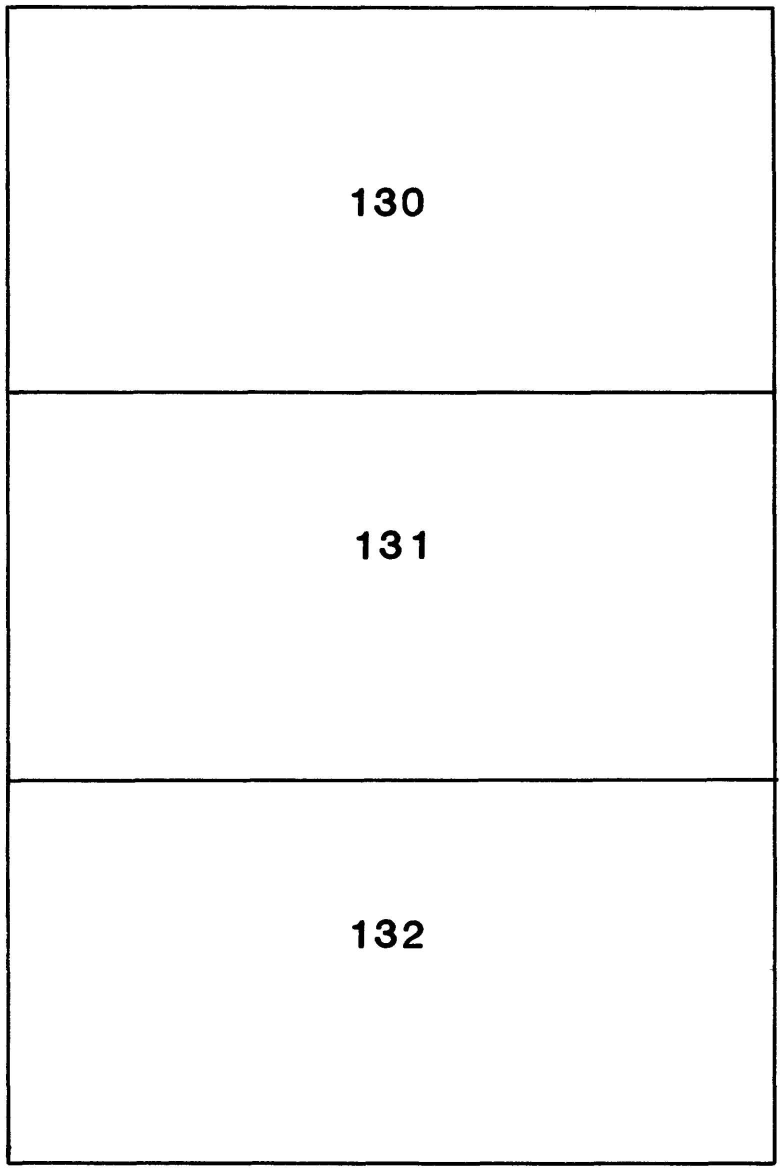
ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
MH	Medium high: between about 14,000 and 21,000
H	High: greater than 21,000
—25—?—	Line of approximate equal head, in feet, above and below (-) sea level, interval is 25 feet. Dashed where inferred. Queried where location is uncertain
←—— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
• • • • • • • • 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
NJ-30	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD: 2090 ft.	Total depth of well, in feet
Data source:	Martin (1984); Meisler (1980b); M.M. Martin, O.S. Zapecza Henry Trapp, Jr., and Harold Meisler (U.S. Geological Survey, written and oral commun., 1984)

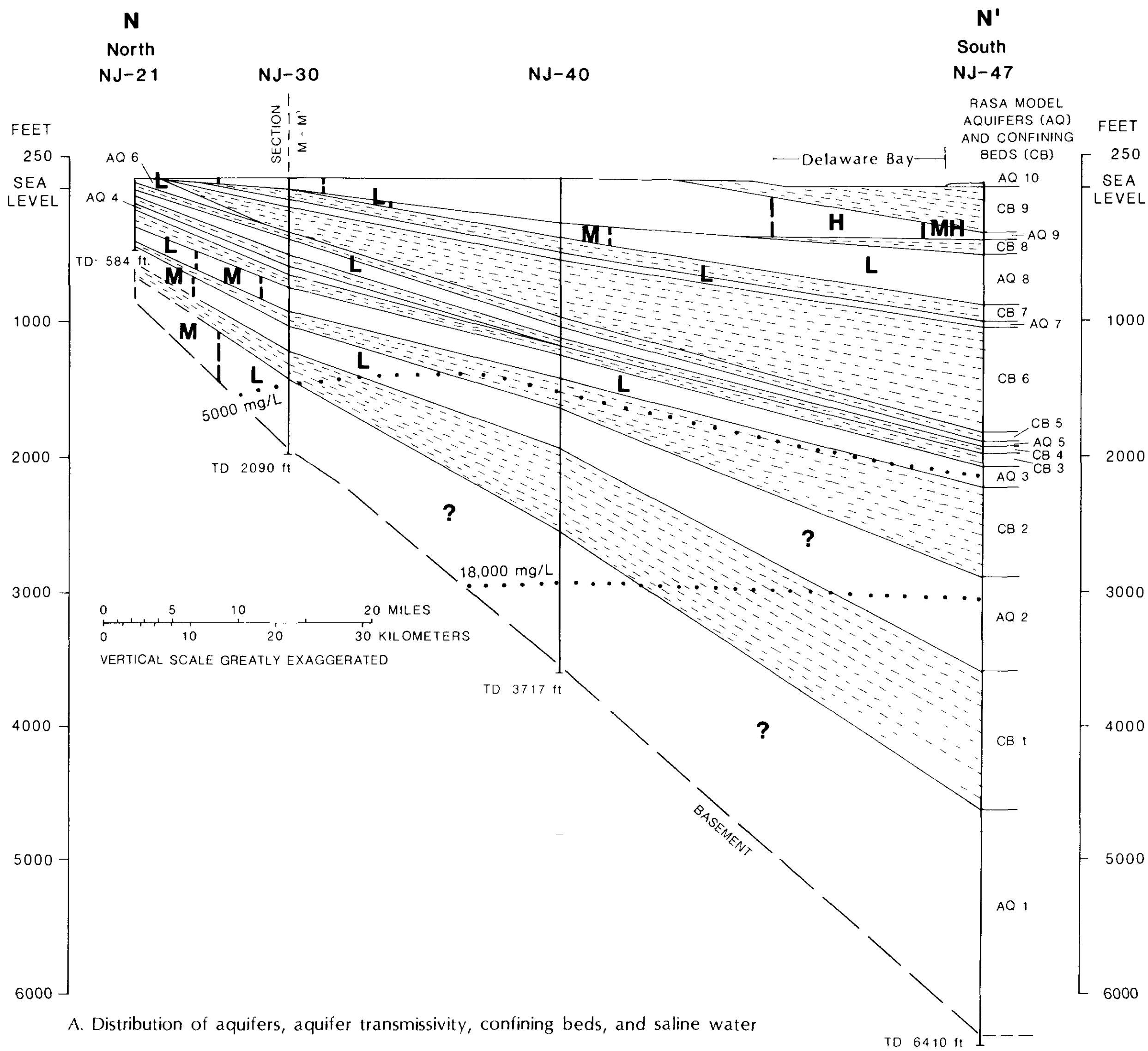
GEOHYDROLOGIC CROSS SECTION M-M' FROM CECIL COUNTY, MD., TO OCEAN COUNTY, N.J.

PLATE 15

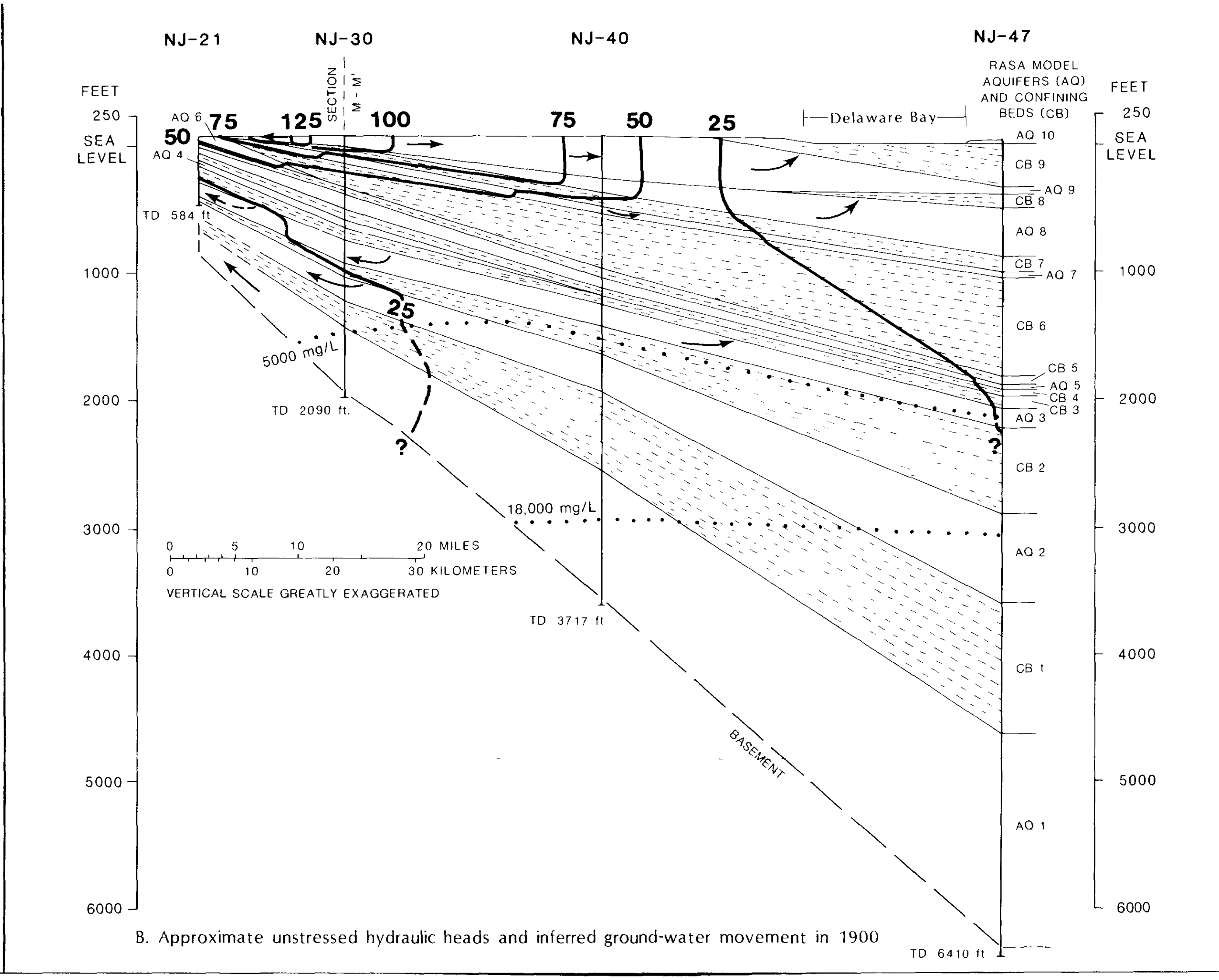
GEOHYDROLOGIC CROSS SECTION N - N' FROM
CAMDEN COUNTY, N.J., TO CAPE MAY COUNTY, N.J.



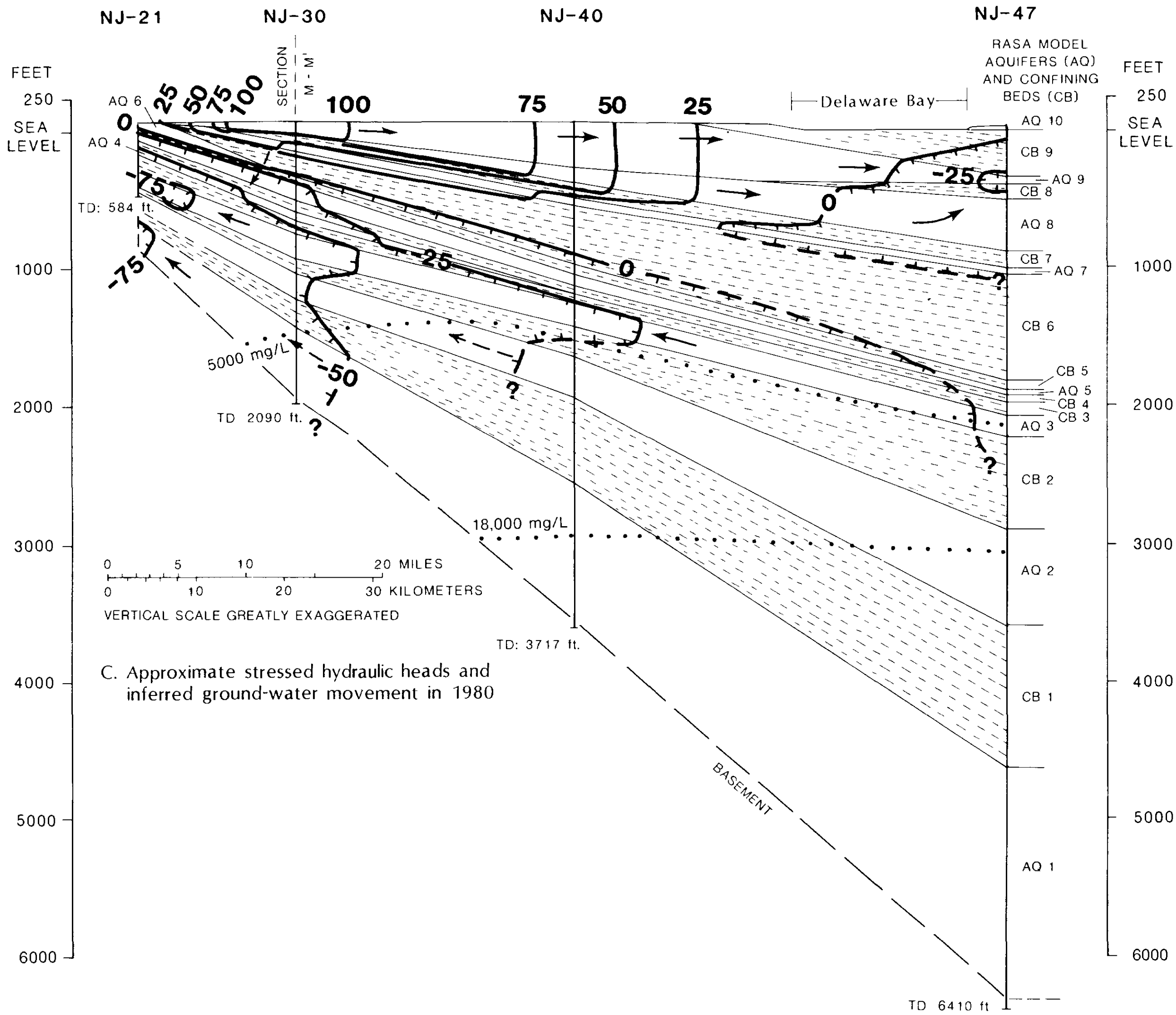
Index diagram showing page numbers of each component of plate 15



A. Distribution of aquifers, aquifer transmissivity, confining beds, and saline water



B. Approximate unstressed hydraulic heads and inferred ground-water movement in 1900



C. Approximate stressed hydraulic heads and inferred ground-water movement in 1980

EXPLANATION

ESTIMATED TRANSMISSIVITY, IN FEET SQUARED PER DAY

L	Low: less than 7000
M	Medium: between about 7000 and 14,000
MH	Medium high: between about 14,000 and 21,000
H	High: greater than 21,000
—25—?—	Line of approximate equal head, in feet, above and below (-) sea level, interval 25 feet. Dashed where inferred. Queried where location is uncertain
←— — —	Flow line and arrow indicate estimated direction of ground-water flow. Dashed in saline-water part of section
·········· 5000 mg/L	Line marks shallowest occurence of water with listed chloride concentration in milligrams per liter
NJ-30	Well number. Alphabetical prefix is state abbreviation (see table 4)
TD: 2090 ft.	Total depth of well, in feet
Data source:	Meisler (1980b); M.M. Martin O.S. Zapecza, Henry Trapp, Jr., and Harold Meisler (U.S. Geological Survery, written and oral commun., 1984)

GEOHYDROLOGIC CROSS SECTION N-N' FROM CAMDEN COUNTY, N.J., TO CAPE MAY COUNTY, N.J.