INTERIM REPORT ON

GROUNDWATER CONDITIONS IN NORTHEASTERN NORTH CAROLINA

REPORT OF INVESTIGATIONS NO. 15

BY

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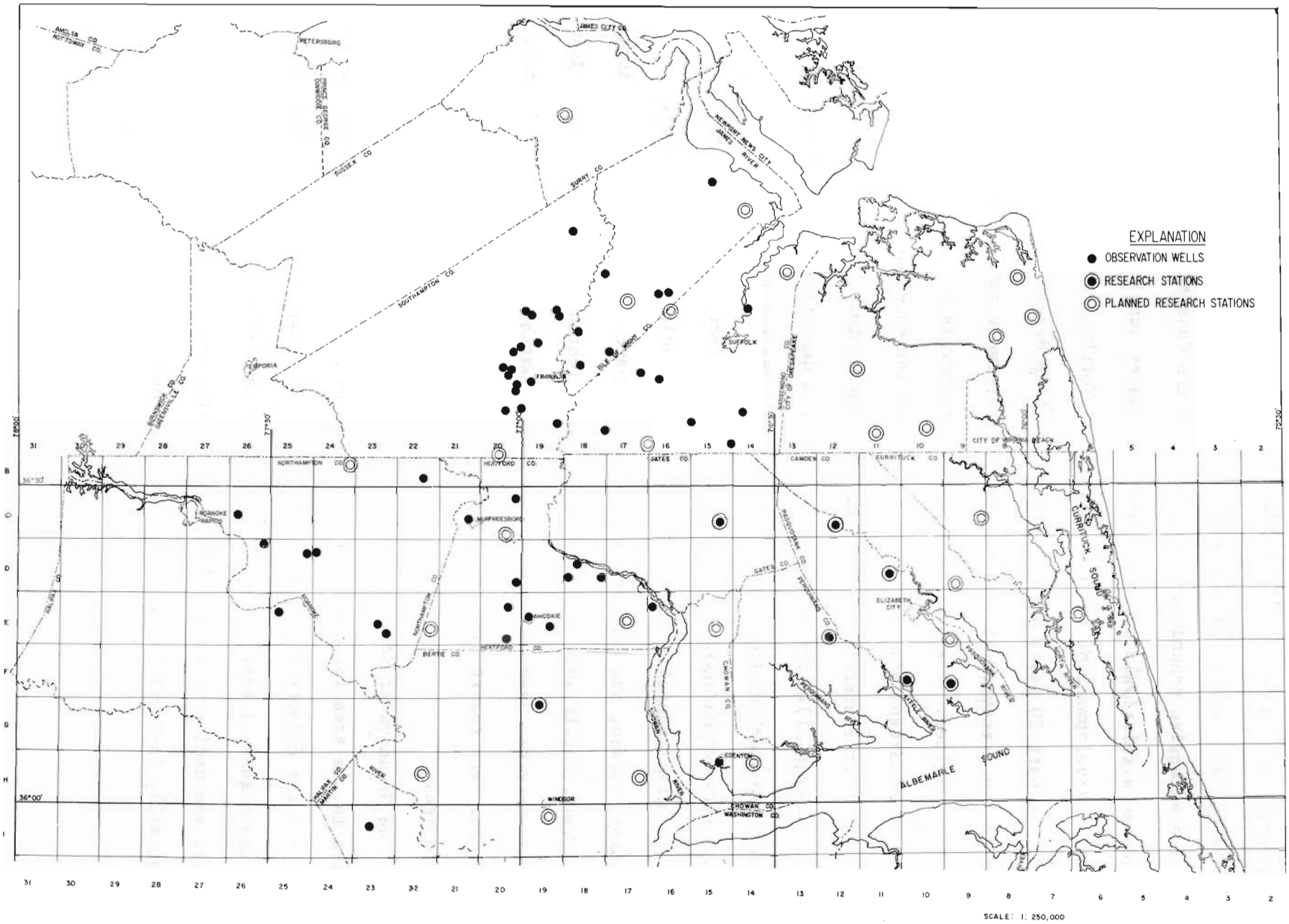
PURPOSE OF REPORT

The extensive groundwater reservoirs of the Coastal Plain region were considered a relatively unlimited source of water supply until recent years. Expanding development of these reservoirs in North Carolina and adjacent states during the past 20 years and the effects of this development on water levels and artesian pressures have shown that the reservoir capacities and recharge rates are limited. The effects of large withdrawals at many sites have been dramatic and extensive, and indicate the need for management of the aquifer systems. Northeastern North Carolina and southeastern Virginia comprise one such area (Fig. 1). Southeastern Virginia was designated a "Critical Groundwater Area" by the Virginia State Water Control Board in January 1975, and groundwater management regulations became effective at that time.

The area generally covered in this report includes Bertie, Gates, Hertford, Chowan, and Perquimans counties and parts of Halifax, Northampton, Pasquotank, Martin and Camden counties, as indicated in Fig. 1. Most of the work to date has been concentrated in Bertie, Gates, Hertford and Northampton counties. The report also correlates data on the aquifers in Virginia to the report area.

The Groundwater Section has been collecting data and monitoring water levels in the area for many years to determine groundwater conditions and to evaluate the effects of large withdrawals. The purpose of this report is to provide a general evaluation of groundwater conditions in the area where water levels are declining as a result of continuing and increasing withdrawals, principally in Virginia; and to show that some water management measures are needed.



SCALE: 1: 250,000

FIGURE 1.- MAP SHOWING EXISTING AND PLANNED RESEARCH STATIONS AND MONITOR WELLS IN CUA AREA NO. 2 AND SOUTHEAST VIRGINIA

PREVIOUS STUDIES

Few comprehensive groundwater studies have been previously conducted in any part of the area in North Carolina. A reconnaissance study including Northampton and Halifax counties was made in 1942 by M. J. Mundorf. (See references) A reconnaissance study that included Bertie, Chowan, Gates, Hertford and Martin Counties was completed by P. M. Brown in 1958. A fairly comprehensive report on Martin county by G. G. Wyrick was published in 1966, and a detailed report on Chowan county by O. B. Lloyd, Jr. was published in 1968. More recent information was contained in a paper by H. M. Peek and P. F. Nelson in 1967 as a part of a symposium on Hydrology of the Coastal Waters of North Carolina. A report on the water resources of Northeastern North Carolina has been completed by the U. S. Geological Survey in cooperation with the Corps of Engineers (Wilder 1975). Several studies of southeastern Virginia have been made and reports published, and studies are presently in progress by the State of Virginia and the U. S. Geological Survey to evaluate the aquifer system, including a digital computer model. A report by the Groundwater Sub-Committee of the North Carolina-Virginia Water Resources Committee provides a summary of general groundwater conditions in the two States.

CURRENT STUDIES

The Groundwater Section is conducting a continuing program of investigations, data collection, monitoring of water levels and water quality, and other related activities in all of northeastern North Carolina as a part of the Capacity Use Study and the statewide groundwater program. One of the most important activities is exploratory drilling and the construction of groundwater research stations and observation wells, as these are essential for aquifer

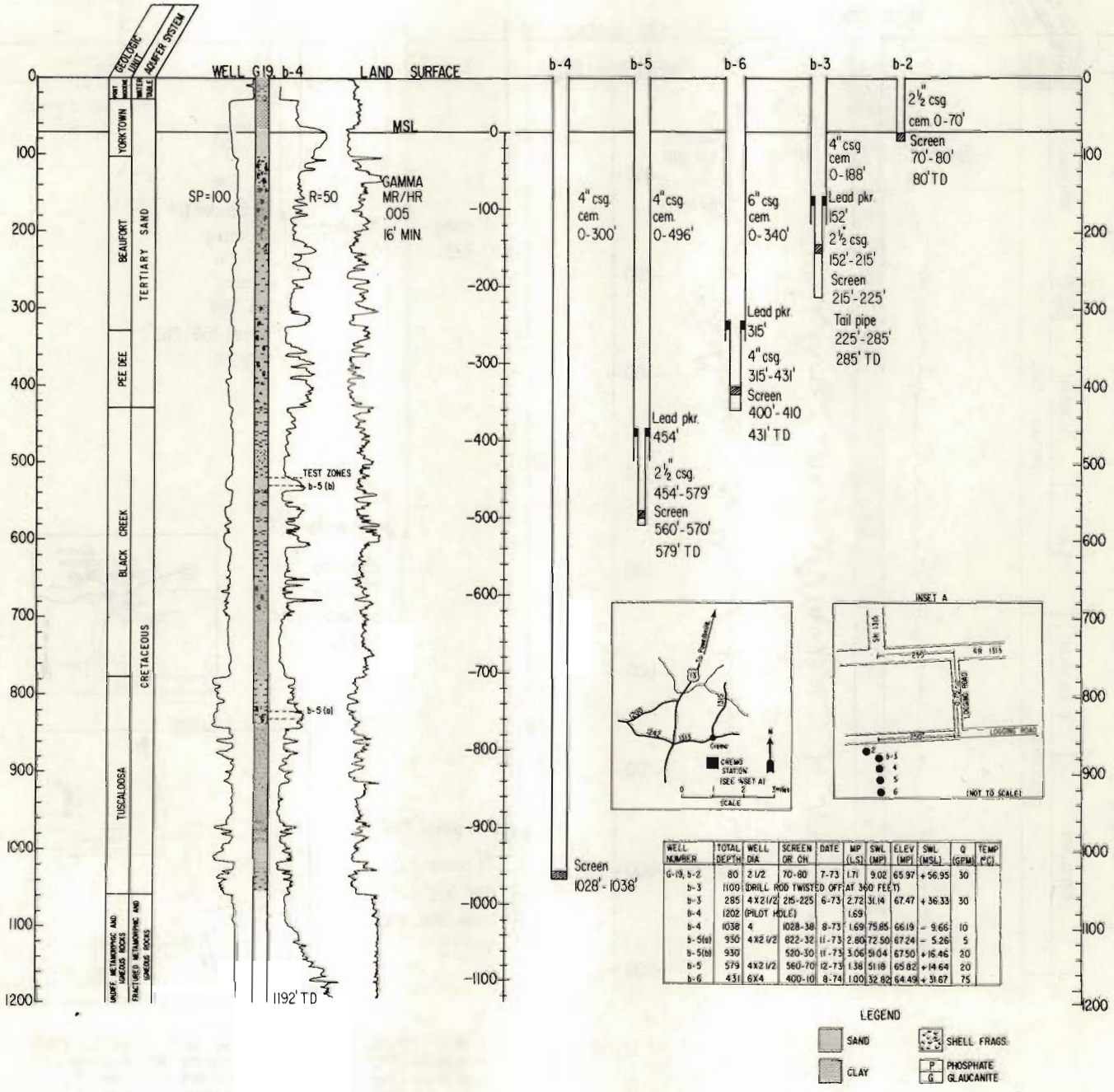
evaluation and management. Existing observation wells and research stations and those planned for construction during the next three years in the area are shown in Fig. 1. Diagrams of research stations at Cremo, in Bertie County, and Sunbury, in Gates County, are shown in Fig. 2 and 3, which illustrate the type information provided by these installations.

The continuing studies will yield a series of reports, including interstate reports, individual county reports, and periodic status reports on the Capacity Use Study Area and the Coastal Plain Region.

ACKNOWLEDGEMENTS

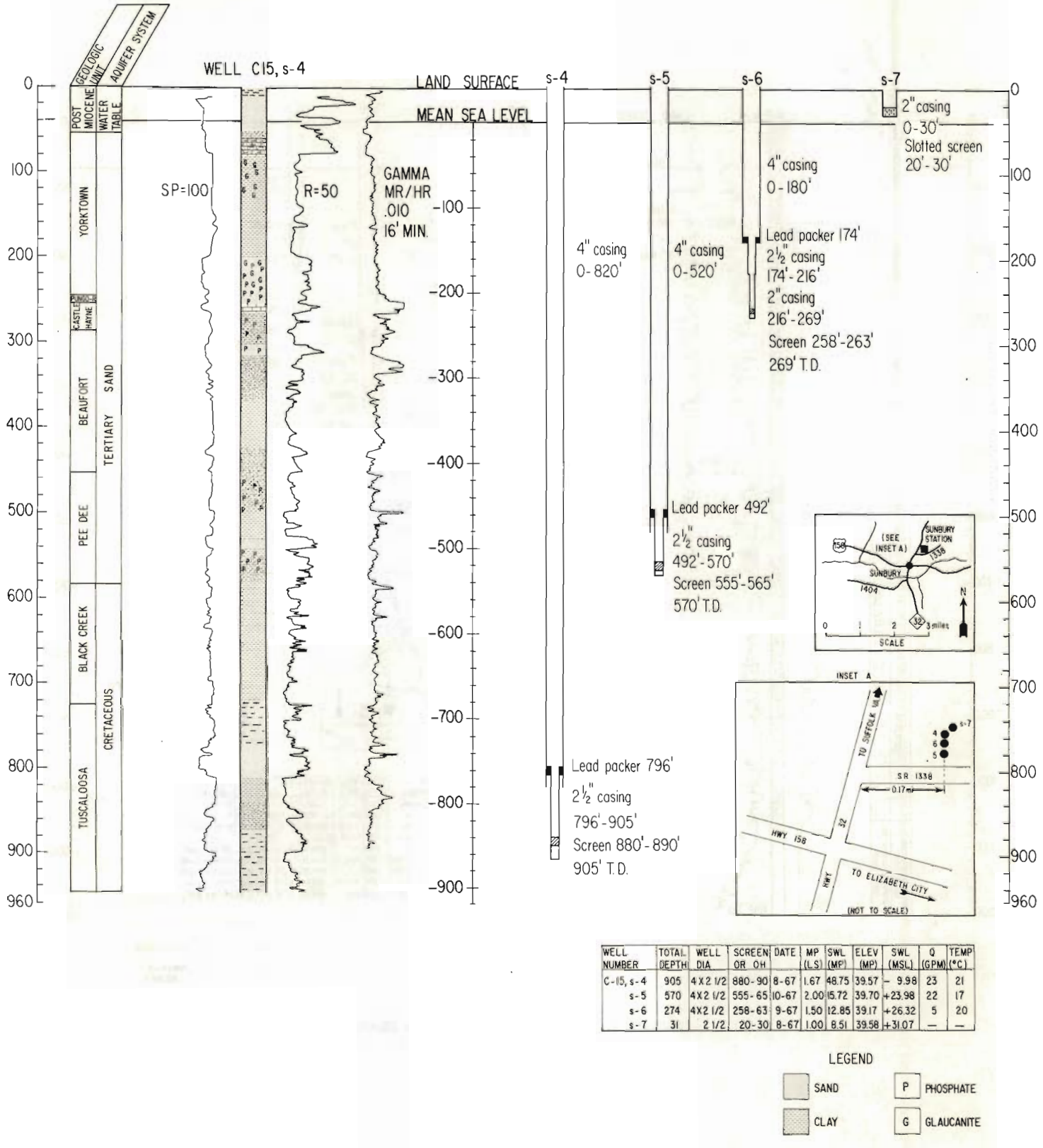
Field investigations in the area were conducted for several years by Frederic L. Hurd, who is principally responsible for data collection, interpretation and mapping accomplished through 1971. Since that date, field studies have been conducted by Robert B. Cheek under the supervision of L. A. Register.

Acknowledgement and appreciation are extended to municipal officials, drilling contractors and individuals for cooperation in providing data. The Union Camp Corporation and other industries in the area have also provided much valuable information. Federal agencies furnishing assistance and data include the U.S. Geological Survey and the Agricultural Research Service and the Soil Conservation Service of the U.S. Department of Agriculture. The State of Virginia has provided much assistance and information and will be cooperating in future studies in the area.



WELL NUMBER	TOTAL DEPTH	WELL DIA	SCREEN OR CH.	DATE	MP (LS)	SWL (MP)	ELEV (MP)	SWL (MSL)	Q (GPM)	TEMP (°C)
G-19, b-2	80	2 1/2	70-80	7-73	1.71	9.02	65.97	+56.95	30	
b-3	1100	(DRILL ROD TWISTED OFF AT 360 FEET)								
b-3	285	4 X 2 1/2	215-225	6-73	2.72	31.14	67.47	+36.33	30	
b-4	1202	(PILOT HOLE)			1.69					
b-4	1038	4	1028-38	8-73	1.69	75.85	66.19	- 9.66	10	
b-5(a)	930	4 X 2 1/2	822-32	11-73	2.80	72.50	67.24	- 5.26	5	
b-5(b)	930		520-30	11-73	3.06	51.04	67.50	+16.46	20	
b-5	579	4X2 1/2	560-70	12-73	1.38	51.18	65.82	+14.64	20	
b-6	431	6X4	400-10	8-74	1.00	32.82	64.49	+31.67	75	

FIGURE 2.- DIAGRAM OF RESEARCH STATION AT CREMO, BERTIE COUNTY



WELL NUMBER	TOTAL DEPTH	WELL DIA	SCREEN OR OH	DATE	MP (LS)	SWL (MP)	ELEV (MP)	SWL (MSL)	Q (GPM)	TEMP (°C)
C-15, s-4	905	4 X 2 1/2	880-90	8-67	1.67	48.75	39.57	- 9.98	23	21
s-5	570	4X2 1/2	555-65	10-67	2.00	15.72	39.70	+23.98	22	17
s-6	274	4X2 1/2	258-63	9-67	1.50	12.85	39.17	+26.32	5	20
s-7	31	2 1/2	20-30	8-67	1.00	8.51	39.58	+31.07	—	—

FIGURE 3. - DIAGRAM OF RESEARCH STATION AT SUNBURY, GATES COUNTY

HYDROGEOLOGY

GENERAL HYDROGEOLOGIC FRAMEWORK

The Coastal Plain region of northeastern North Carolina is underlain by a "wedge" of sedimentary rocks that range in age from Recent to Cretaceous or older. These sediments lie unconformably on "basement" or crystalline rocks that are similar or equivalent to the igneous and metamorphic rocks of the Piedmont region. The sediments range in thickness from a feather edge along the western edge of the Coastal Plain to several thousand feet along the coast. An oil-test well near Elizabeth City reached basement at a depth of about 3,000 feet.

In the study area, the sediments consist of sand, silt, clay, gravel, limestone and combinations of these lithologies. The sediments may be divided into several hydrogeologic units, based primarily on hydrologic characteristics, as shown on the cross section in Fig. 4. The deeper aquifer units are penetrated by water supply wells only in the western part of the area where they are a few hundred feet deep or less. In the eastern part of the area, few water supply wells are drilled to depths greater than 300 to 400 feet.

HYDROGEOLOGIC AND STRATIGRAPHIC SUB-DIVISIONS

For the purposes of this report, the sedimentary rocks have been sub-divided into hydrogeologic units based largely on differences in permeability and hydrologic characteristics and relationships, as determined from existing information.

Table 1 shows the stratigraphic units of both North Carolina and Virginia and the equivalent hydrogeologic units. As indicated in the table and also Figs. 2 - 4, the sediments may be sub-divided into three principal hydrogeologic units; the Cretaceous aquifer system, the Tertiary system, and the Quaternary aquifer

FIGURE 4. - HYDROGEOLOGIC CROSS - SECTION - MURFREESBORO TO MORGANS CORNER

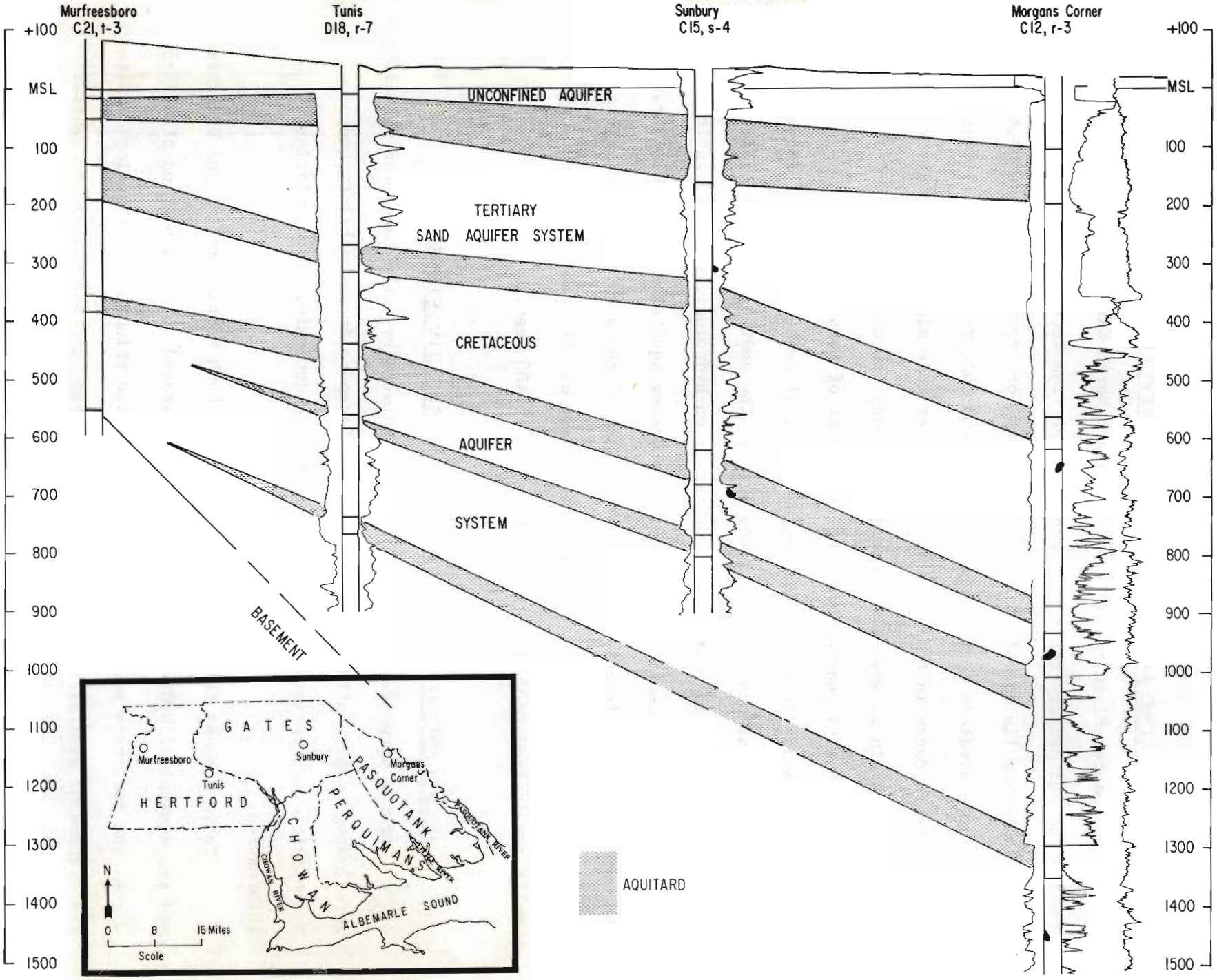


TABLE I - STRATIGRAPHIC AND HYDROGEOLOGIC UNITS - NORTHEASTERN NORTH CAROLINA

		VIRGINIA			NORTH CAROLINA		
SYSTEM	SERIES	STRATIGRAPHIC UNITS	HYDROGEOLOGIC UNITS	STRATIGRAPHIC UNITS	HYDROGEOLOGIC UNITS		CHARACTER
QUATERNARY	RECENT PLEISTOCENE	RECENT COLUMBIA GROUP	WATER TABLE OR QUATERNARY AQUIFER	POST-MIOCENE (UNDIFFERENTIATED)	WATER TABLE OR QUATERNARY AQUIFER		UNCONSOLIDATED SAND, SILT, CLAY AND SOME GRAVEL, PRINCIPALLY ASSOCIATED WITH MIOCENE TERRACE DEPOSITION. THIS UNIT COMPRISES THE UNCONFINED OR "WATER-TABLE" AQUIFER AND AT SOME PLACES MAY INCLUDE SANDS OF THE MIOCENE - PALEOCENE UNIT. THIS UNIT IS THE RECHARGE RESERVOIR FOR THE UNDERLYING ARTESIAN SYSTEM.
TERTIARY	MIOCENE UPPER MIOCENE MIDDLE	CHESAPEAKE GP. — YORKTOWN, ST. MARYS, CHOPTANK, CALVERT	TERTIARY AQUIFER SYSTEM	YORKTOWN PUNGO RIVER	TERTIARY AQUIFER SYSTEM	SAND AQUIFER	INTERBEDDED SAND AND CLAY WITH SOME BEDS OF LIMESTONE AND SHELLS. THE UPPERMOST CLAY BEDS COMPRISED AN EFFECTIVE AQUITARD AND CONFINE THE WATER IN THE SANDS UNDER PRESSURE. EXTENSIVE CLAY BEDS COMPRISE AQUITARDS THAT SEPARATE MAJOR AQUIFER UNITS IN AT LEAST PART OF THE AREA. THIS SYSTEM IS THE PRINCIPAL AQUIFER SYSTEM IN MOST OF THE AREA AT THE PRESENT TIME. CLAYS OF THE LOWER PART OF THE SYSTEM AND THE UPPER PART OF THE CRETACEOUS SYSTEM COMPRISE AN EFFECTIVE AQUITARD BETWEEN THE TWO SYSTEMS. THE CASTLE HAYNE AQUIFER IS ABSENT IN MOST OF THE AREA, AND THE BEAUFORT UNIT IS A PART OF THE SAND AQUIFER SYSTEM.
	EOCENE	CHICKAHOMINY PAMUNKEY GP.		CASTLE HAYNE LIMESTONE		LIMESTONE AQUIFER	
	PALEOCENE			BEAUFORT			
CRETACEOUS	UPPER LOWER	MATTAPONI ? PATOMAC GP. — PATUXANT	CRETACEOUS AQUIFER SYSTEM	PEEDEE BLACK CREEK UNNAMED	CRETACEOUS AQUIFER SYSTEM	UPPER UNIT LOWER UNIT	INTERBEDDED SAND AND CLAY, IN MUCH OF THE AREA, THE SYSTEM IS SEPARATED INTO TWO MAJOR AQUIFER UNITS BY A CLAY BED THAT COMPRISES AN AQUITARD. THIS IS THE PRINCIPAL AQUIFER SYSTEM IN THE WESTERN PART OF THE AREA.

system.

In North Carolina, the Cretaceous aquifer system is generally moderately to highly productive where it is utilized. It is the principal aquifer system in the eastern part of Halifax and Northampton Counties and in much of Hertford and Bertie Counties. East of the Chowan River, the minteral content of the water is greater, and is gradationally more saline toward the coast.

Clay beds in the aquifer system and the overlying unit confine the water in the system under pressure. In much of the area, the system is separated by beds of clay into two or more major aquifer units. These clays, of considerable thickness and low permeability, also greatly retard recharge to the system throughout the region, thereby greatly limiting potential withdrawals from the system, particularly from the deeper units.

The Tertiary aquifer system consists of interbedded sands and clays with some beds of limestone and shells. The clays serve as aquitards and confine the water under pressure, and also separate the system into two or more aquifer units in part of the area. This aquifer is the principal aquifer in part of Hertford and Bertie and Gates Counties and in most of the area east of the Chowan River, where the Cretaceous system contains saline water. The aquitards greatly reduce the potential for natural recharge to the aquifer system in much of the area and, thereby, limit the potential for large withdrawals.

In the eastern part of the report area, the Tertiary aquifer system of this report includes a limestone unit which probably represents the Castle Hayne aquifer. This unit generally contains water with a relatively high chloride content that is unsuitable for most uses, however it is a productive aquifer in at least part of the area and may provide a storage reservoir in the future through development of artificial recharge systems.

The Quaternary aquifer system, generally considered as the water-table aquifer, consists of the sands and gravels that lie above the first significant clay layer, and generally conprises the Quaternary geologic unit. The thickness of the aquifer is generally less than 100 feet, but it is an important part of the hydrologic system as it serves as a recharge reservoir to the underlying confined aquifer systems. The aquifer is widely used as a source of individual domestic water supplies. It will become increasingly important as a principal source of water as the demand for water increases and development methods are improved.

RECHARGE

Recharge to the aquifer systems of the Coastal Plain is derived principally from precipitation in the region. It is estimated that twenty percent or more of the average annual precipitation of about 49 inches, or about 10 inches, enters the water-table aquifer. This represents about 170 million gallons per square mile. The water-table aquifer serves as the reservoir for recharge to the underlying artesian aquifer units. Except in a very narrow zone near the fall line along the western boundary of the Coastal Plain, the artesian units are recharged by vertical leakage from the water-table aquifer through the confining beds. The water-table aquifer may receive recharge from the artesian units in areas where the artesian head is greater than the water table.

The rate of recharge to the artesian aquifer units depends on the vertical permeability of the confining beds and the hydraulic head, which is generally controlled by the elevation of water table. Recharge is also affected by pumping which increases the gradient between the water table and the principal aquifer and thereby increases recharge.

Because of the low permeability of the several confining beds in the Cretaceous and Tertiary aquifer systems, the rate of recharge to the aquifer units of these systems over most of the area is low and, of course, decreases with depth. Therefore, the potential yield of these systems is limited. In some parts of the area, conditions may be favorable for artificial recharge of some aquifer units.

GROUNDWATER QUALITY

CRETACEOUS AQUIFER SYSTEM

The natural chemical and physical quality of groundwater in the Cretaceous aquifer system varies areally and also vertically in most of the study area. In eastern Halifax and Northampton Counties and in western Bertie and Hertford Counties the water is generally low in mineral content and suitable for any purpose. In eastern Bertie and Hertford Counties the lower units of the system contain water relatively high in mineral content, as indicated by the chloride content. The mineral content generally increases eastward, so that east of the Chowan River, most or all of the aquifer units contain water that is too high in mineral content for most uses. The salinity of the water is considered to represent residual sea water from earlier hydrogeologic conditions. The exact boundary between fresh and salt water has not been mapped.

TERTIARY AQUIFER SYSTEM

The limestone unit of the Tertiary aquifer system occurs only in the eastern part of the study area and is not known to contain fresh water north of Albemarle Sound. The chloride content at Elizabeth City is about 2,900 milligrams per liter (mg/1) and at Morgans Corner about 1,900 mg/1.

Water of generally good quality occurs in all or part of the sand aquifer units throughout most of the study area. Brackish water occurs in the lower part of the system in most of the area east of Chowan and Gates Counties, but the upper part contains fresh water suitable for most uses except in southern Pasquotank and Camden Counties and eastern Currituck County. The exact boundary between fresh and saline water in the sand aquifer systems has not been mapped throughout the area.

WATER-TABLE AQUIFER

The water-table aquifer contains fresh water throughout the area that is suitable for general use. The water is low in mineral content except for relatively high iron. The low mineral content and pH make the water corrosive, but it can be readily treated.

The water-table aquifer is very vulnerable to pollution from many sources such as land fills, septic tank concentrations, industrial and municipal waste disposal, and various agricultural activities. Because of the increasing importance of this aquifer as a source of water supply, more attention must be given to its protection from unnecessary pollution, and to the development of more efficient recovery of water from the aquifer.

EFFECTS OF GROUNDWATER WITHDRAWALS

GROUNDWATER WITHDRAWAL AND USE

Groundwater is the principal source of water supply in the area so that the location of withdrawals for domestic and municipal purposes is fairly well distributed over the area, generally related to population density. The largest withdrawals for any municipality or industry in North Carolina is about 5 million gallons per day (MGD), which is from the Cretaceous aquifer system at the Caledonia Prison Farm in Halifax County. A few municipalities and industries withdraw up to 2 or 3 MGD but these are fairly scattered. The larger withdrawals that effect the area are in adjacent areas of Virginia, with the largest withdrawals in the vicinity of Franklin. Withdrawals in the Franklin area are shown on the graph in Fig. 5.

WATER LEVEL DECLINE

Water levels in the report area have been declining for many years, partly as a result of gradual increase in withdrawals for municipal and industrial use in the area. The large regional decline of water levels, particularly in the Cretaceous aquifer system, however is principally the result of the withdrawals in adjacent counties in Virginia. The largest center of withdrawals, as mentioned above, is at Franklin, Virginia, where pumping from the Cretaceous aquifer system gradually increased over many years.

CRETACEOUS AQUIFER SYSTEM

The approximate configuration of the potentiometric surface of the Cretaceous aquifer system in 1940, prior to any large groundwater withdrawals is shown in Fig. 6. Water levels were 30 feet or more above sea level in most of the area.

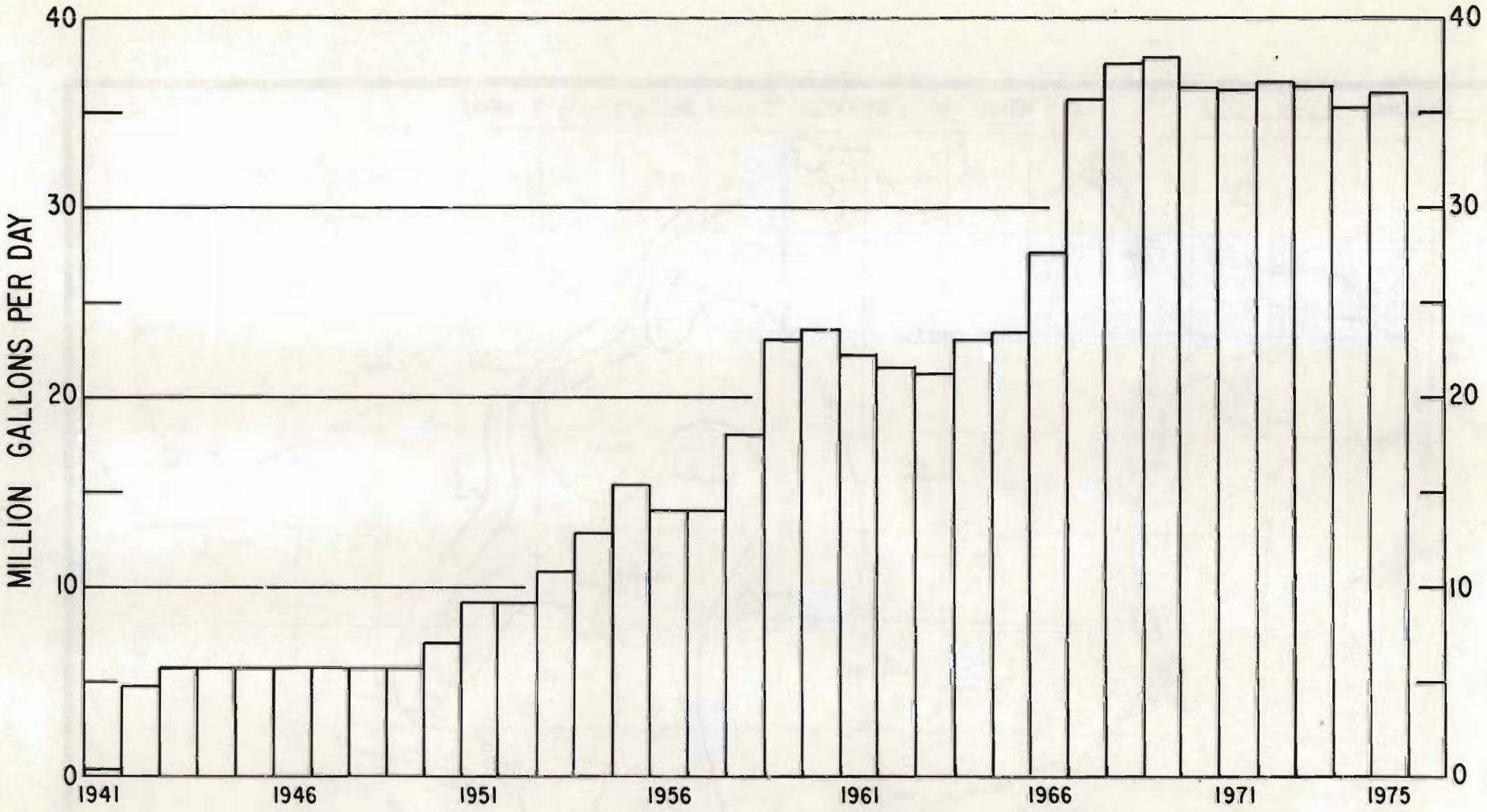


FIGURE 5.— GRAPH SHOWING GROUNDWATER WITHDRAWALS IN THE FRANKLIN, VIRGINIA AREA

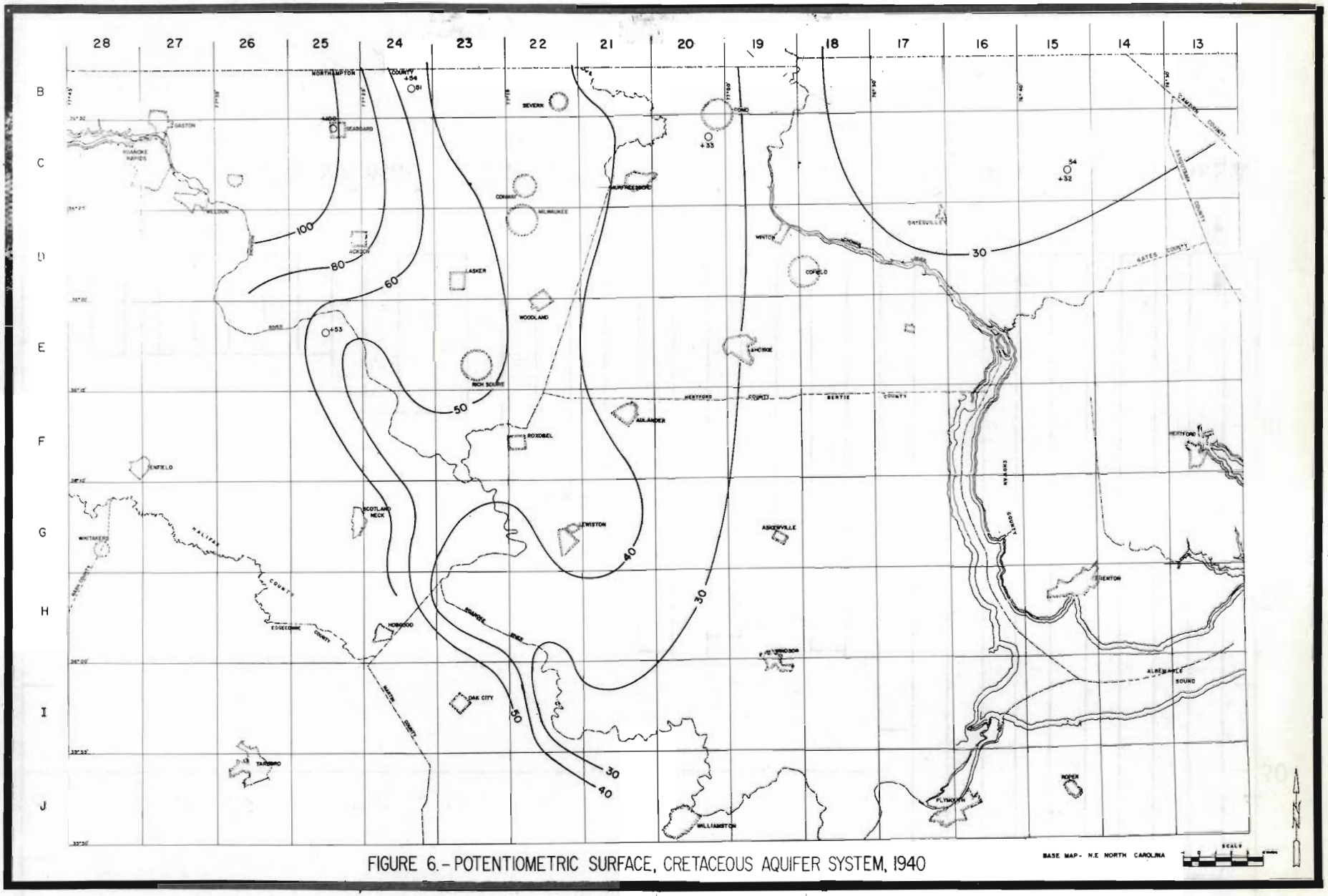


FIGURE 6.- POTENTIOMETRIC SURFACE, CRETACEOUS AQUIFER SYSTEM, 1940

West of the Chowan River, movement of water through the aquifer system was generally from west to east with recharge rates greatest where the overlying beds are thinnest and land surface elevations highest. Natural discharge areas were centered along the river valleys. On the east side of the Chowan River, the movement of water was from a high area in the north to the east, south and west toward the river. Movement of the water was probably extremely slow, as natural discharge into the Miocene aquifer and thence to the water-table aquifer and the surface was greatly retarded by the low permeability and thickness of the clay beds in the aquifer systems.

The potentiometric surface of the aquifer system in 1965 is shown in Fig. 7. After about 25 years of large withdrawals at Franklin and increasing use at other sites in Virginia and North Carolina, the potentiometric surface had been lowered below sea level in much of Gates and Hertford Counties. Increased pumping at Caledonia Prison in Halifax County had created a significant drawdown cone in Halifax and Northampton Counties, the center of which was also below sea level.

By 1971, as shown in Fig. 8, the potentiometric surface of the system was below sea level in an area of about 1,000 square miles, including all of Gates and Hertford Counties and extending into Bertie, Chowan and Perquimans Counties. By January 1976 the potentiometric surface was below sea level in an area of more than 2,000 square miles, extending to the Albemarle Sound and into the southern part of Bertie County (Fig. 9).

Hydrographs of wells at the research station at Sunbury in Gates County for 1967-1976 are shown in Fig. 10. These hydrographs illustrate the rate of water level decline.

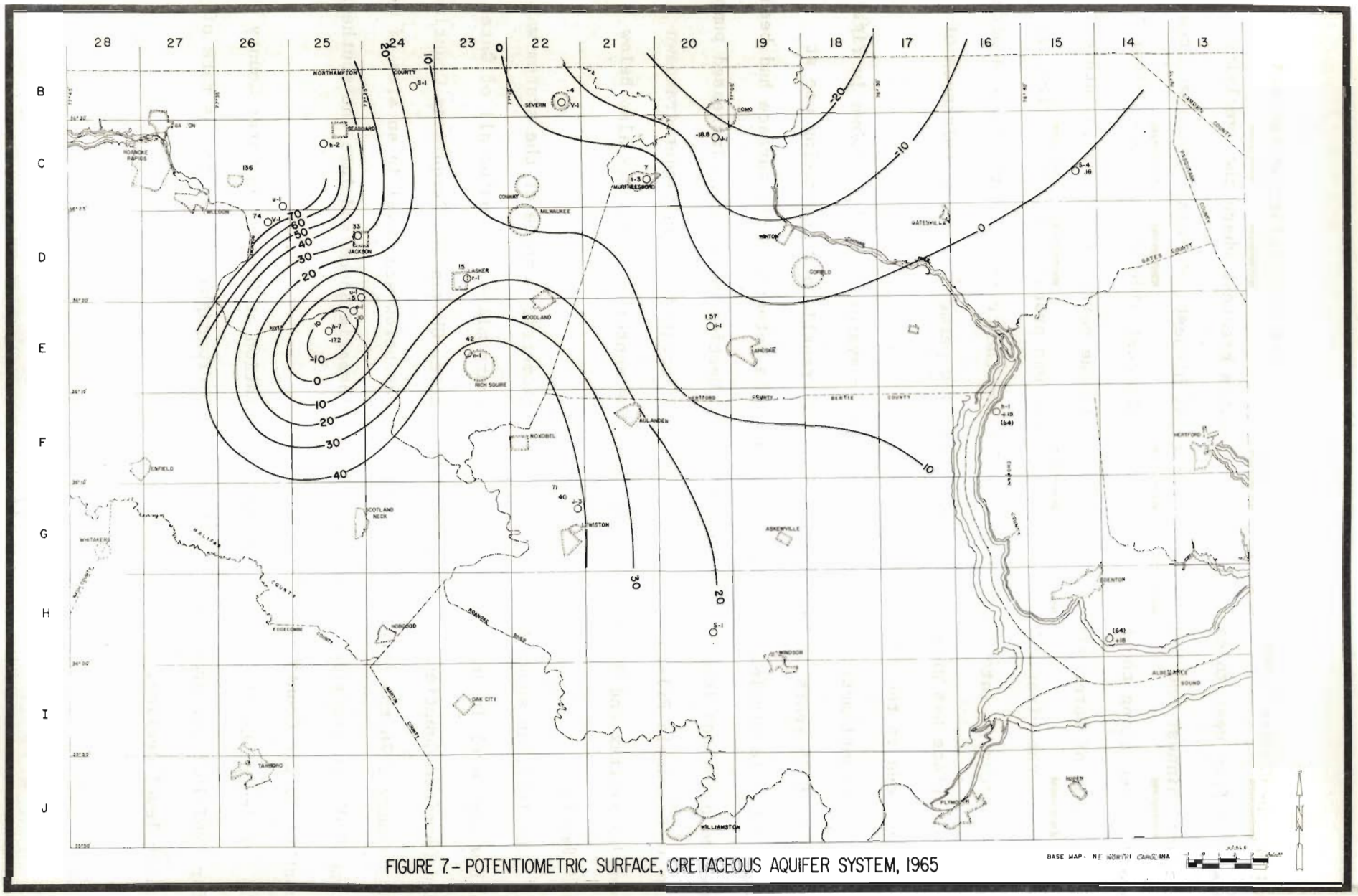


FIGURE 7.- POTENTIOMETRIC SURFACE, CRETACEOUS AQUIFER SYSTEM, 1965

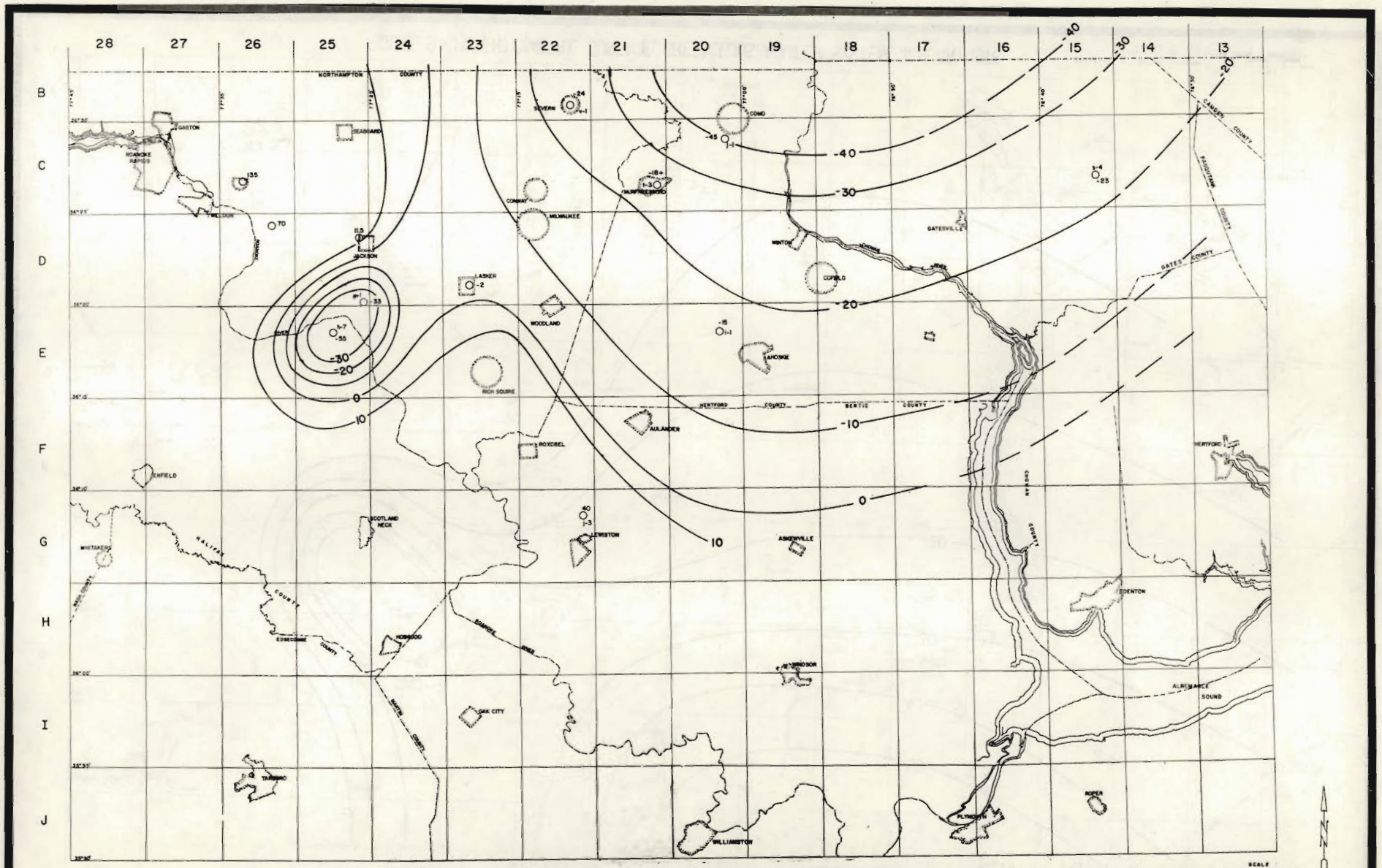


FIGURE 8.- POTENTIOMETRIC SURFACE, CRETACEOUS AQUIFER SYSTEM, 1971

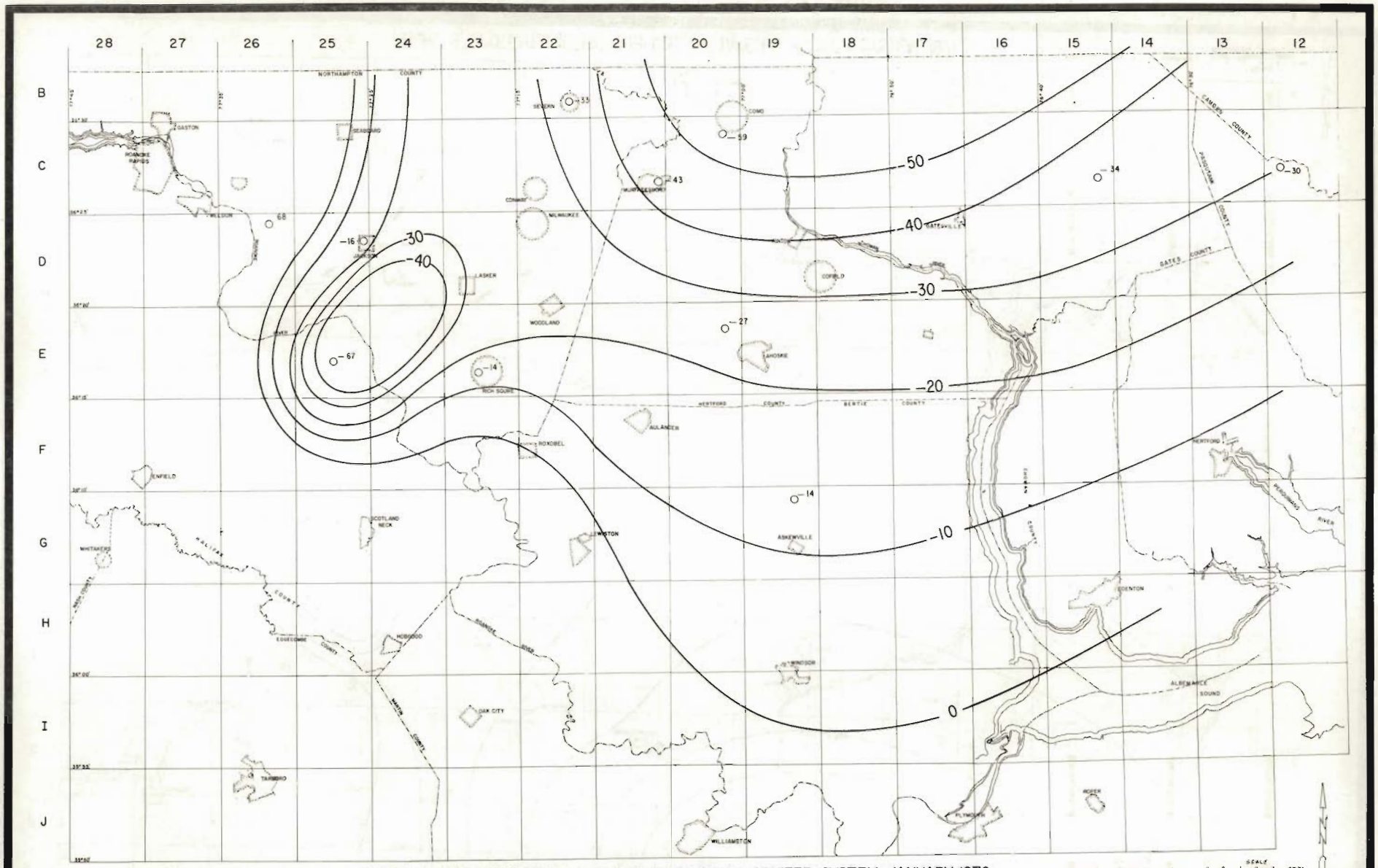


FIGURE 9.- POTENTIOMETRIC SURFACE, CRETACEOUS AQUIFER SYSTEM, JANUARY 1976

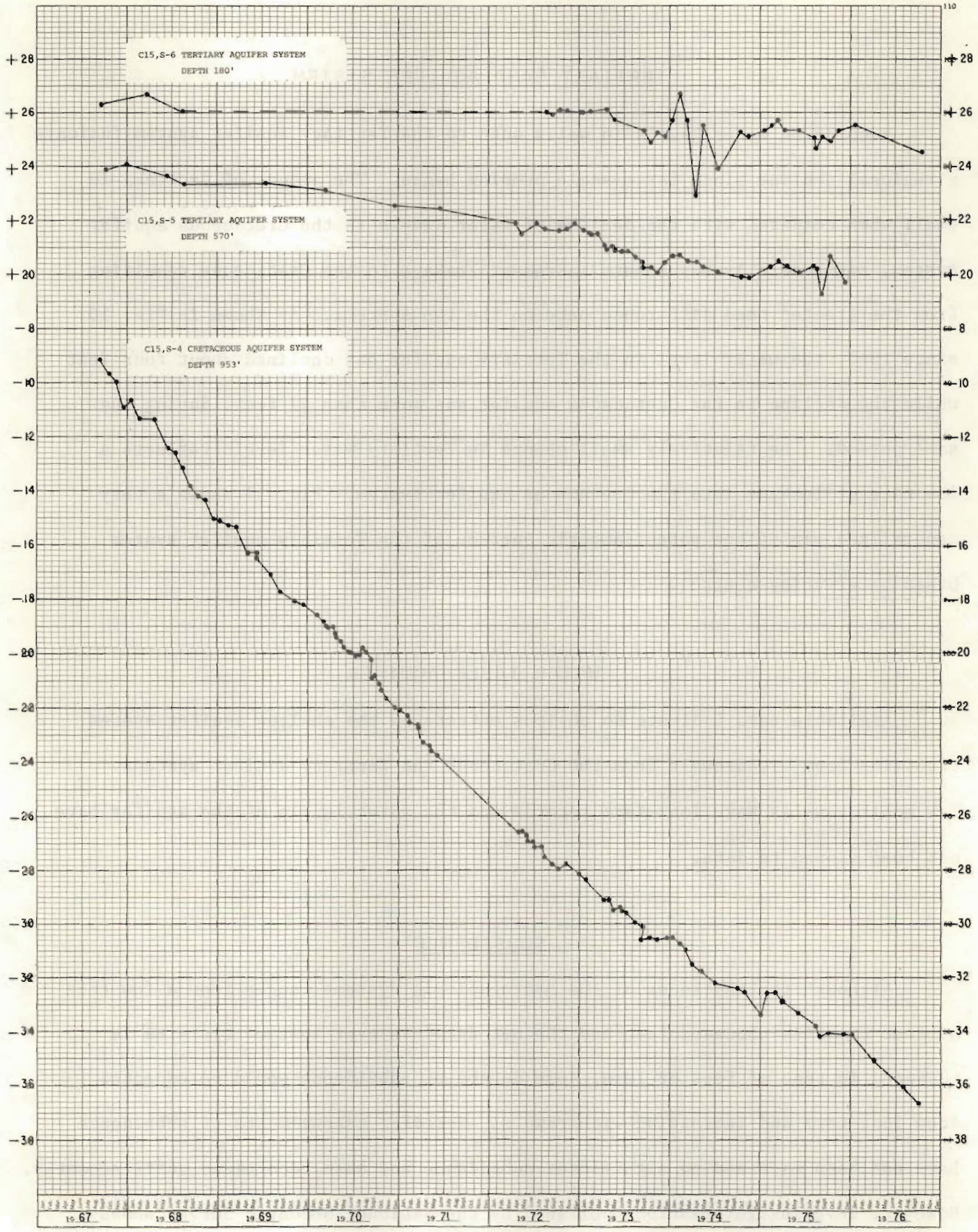


FIGURE 10. -- HYDROGRAPHS OF WELLS AT SUNBURY RESEARCH STATION.

TERTIARY SAND AQUIFER SYSTEM

Records of water levels in wells open to the Tertiary aquifer system indicate a regional decline since large-scale pumping began. The amount of decline is small when compared with the decline of water levels in the Cretaceous aquifer system, and generally represents increased leakage to the Cretaceous resulting from the greater head difference between the two systems. As shown in Fig. 10, since 1967, the water level in the Tertiary aquifer has declined about four feet while the decline in the Cretaceous aquifer was more than 27 feet, during the same period. The relatively small change in Tertiary water levels reflects a low rate of leakage into the Cretaceous aquifer system. Fig. 11 shows a very generalized map of the potentiometric surface of the Tertiary aquifer system based on existing control.

WATER TABLE AQUIFER

Available data indicate no obvious effects on the shallow aquifer system resulting from withdrawals from the Cretaceous and Tertiary aquifer systems. Few monitor wells have long-term records and the water levels of the aquifer have not been mapped to date.

SUBSIDENCE

Although the thickness of the hydrogeologic systems ranges from a few tens of feet to a few thousand feet and the net drawdown over most of tje area is measured in tens of feet or less, some degree of subsidence would be expected from long-term and increasing withdrawals. Specific measurements of subsidence have not been made and no significant subsidence had been recognized until recently. However, leveling information published by the National Geodetic Survey shows a

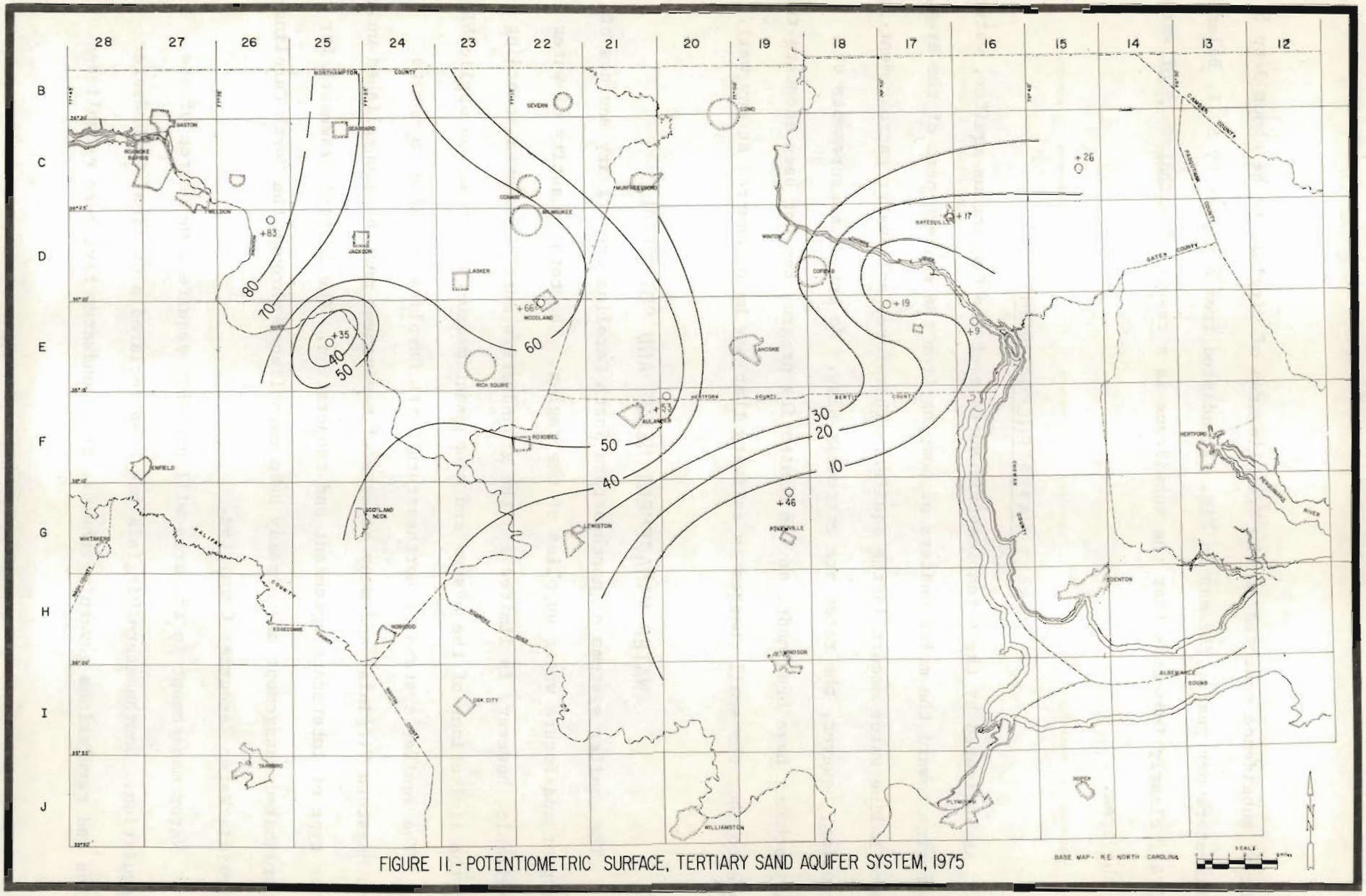


FIGURE 11.- POTENTIOMETRIC SURFACE, TERTIARY SAND AQUIFER SYSTEM, 1975

BASE MAP- N.E. NORTH CAROLINA

rate of subsidence centered at the Franklin area of Virginia to be about 3 to 5 millimeters per year. The map in Fig. 12, adapted from a report by E. I. Balazs (1974), clearly indicates that the subsidence is a result of withdrawals of water in the area.

SALT WATER ENCROACHMENT

As indicated by the potentiometric surface of the Cretaceous aquifer, water is moving toward the major centers of pumping from the eastern part of the area, where saline water occurs in the aquifer. Therefore, salt-water encroachment is occuring, however, the rates are extremely slow. No actual measurements of encroachment have been made, as the monitoring program has not been adequate to date to show the small changes in salinity that may have occurred at any well.

WATER MANAGEMENT NEEDS AND POTENTIAL

The aquifer systems of northeastern North Carolina are primary sources of current and future water supplies of the region. The total quantity of water available, however, is limited and the groundwaters must be managed according to the limitations of the system and management measures that may be applicable.

The aquifer systems of northeastern North Carolina are also common to southeastern Virginia, and many aspects of management must be accomplished under some type of interstate agreement and cooperation. The initial framework for coordinated management has already been established through the North Carolina-Virginia Water Resources Committee.

Water management in the area will probably require some degree of use regulation. Southeastern Virginia has been declared a Critical Groundwater Area and regulations governing the use of groundwater have been established.

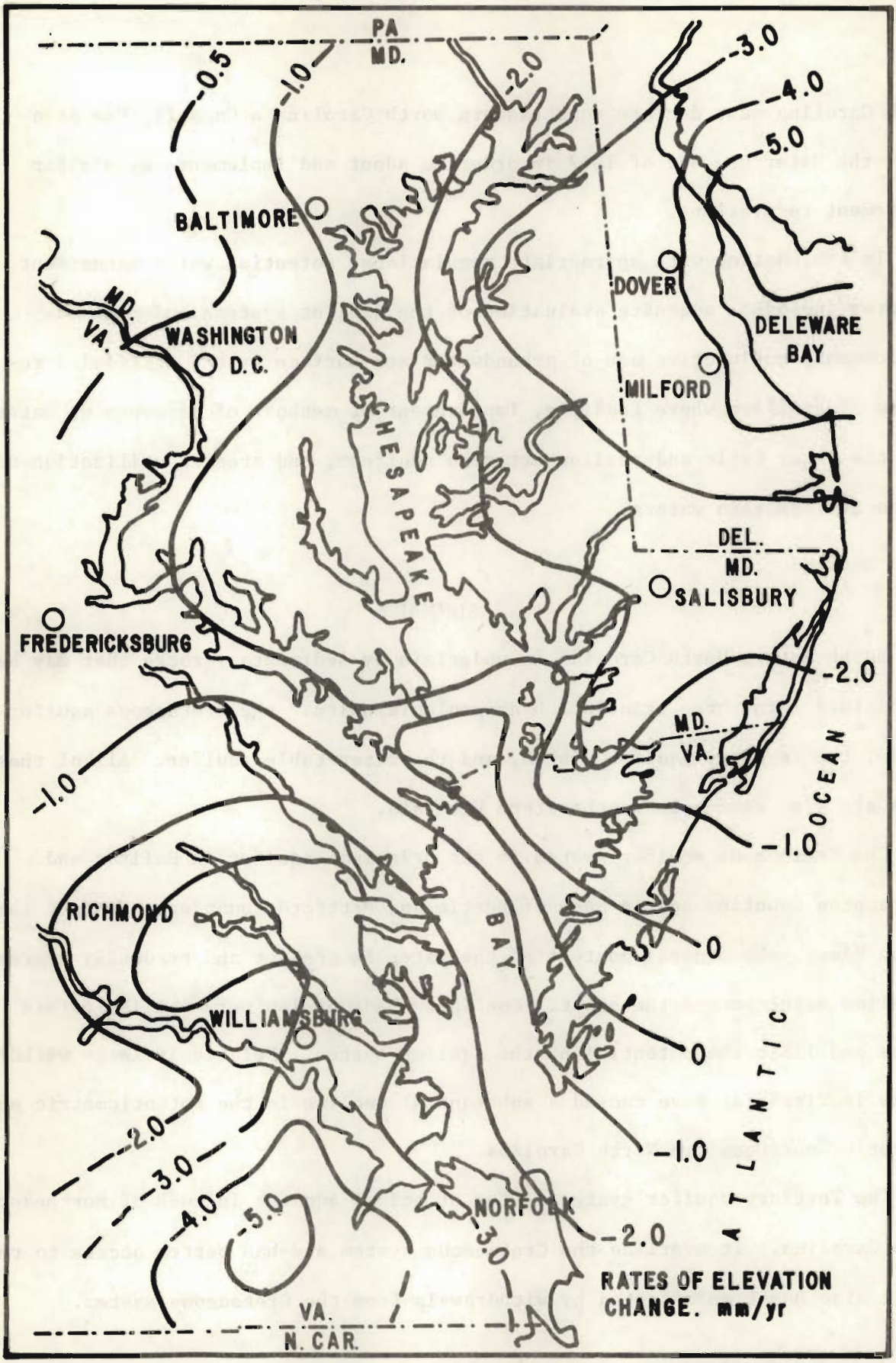


FIGURE 12.- MAP SHOWING ELEVATION CHANGES IN THE VICINITY OF FRANKLIN, VIRGINIA (AFTER EMERY I. BALAZS, 1974)

North Carolina must declare northeastern North Carolina a Capacity Use Area under the Water Use Act of 1967 in order to adopt and implement any similar management regulations.

In conjunction with appropriate regulations, potential water management measures include: adequate evaluation of the aquifer systems and planned development, conjunctive use of groundwater and surface water, artificial recharge of aquifers where feasible, improvement of methods of recovery of water from the water table and shallow artesian aquifers, and greater utilization of saline and brackish waters.

SUMMARY

Northeastern North Carolina is underlain by sedimentary rocks that may be sub-divided into three principal hydrogeologic units: the Cretaceous aquifer system, the Tertiary aquifer system, and the water-table aquifer. All of these units are also common to southeastern Virginia.

The Cretaceous aquifer system is the principal aquifer in Halifax and Northampton Counties and in much of Bertie and Hertford Counties. East of the Chowan River, the mineral content of the water is greater and gradually increases to saline water toward the coast. Confining beds of low permeability retard recharge and limit the potential of the aquifer system. Relatively large withdrawals, mainly in Virginia, have caused a substantial decline in the potentiometric surface in most of northeastern North Carolina.

The Tertiary aquifer system is the principal aquifer in much of northeastern North Carolina. It overlies the Cretaceous system and has better access to recharge, but it also has been affected by withdrawals from the Cretaceous system.

The water-table aquifer serves as the reservoir for recharge to the artesian aquifer systems, but is also a significant source of water supply and will become increasingly important in the future.

Because of the importance of the groundwater resources in the area, and because the aquifer systems are shared with Virginia, a groundwater management program should be established for northeastern North Carolina. This program should include the establishment and adoption of appropriate regulations. Southeastern Virginia has already been placed under groundwater management regulations, and there is general agreement between the States that cooperative management of groundwaters is needed.

Continuing studies are in progress to provide a comprehensive evaluation of the aquifer systems and to establish an adequate water-level and water quality monitoring system to provide for groundwater management. This program is being coordinated with a similar program in southeastern Virginia.

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