GROUND-WATER CONDITIONS IN THE FRANKLIN AREA, SOUTHEASTERN VIRGINIA

BY

G. Allan Brown and Oliver J. Cosner

Prepared in cooperation with the
Virginia State Water Control Board
Bureau of Water Control Management

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INTRODUCTION

Purpose and Scope

During the past 30 years large quantities of ground water have been withdrawn at Franklin, and a cone of depression has formed in the water level of the Lower Cretaceous aquifer. This cone extends westward to the Fall Line, coalesces to the north and east with other small cones caused by pumping, and reaches southward into North Carolina. The water-level decline has caused concern about future ground-water supplies.

This atlas presents the results of a field investigation of geology and hydrology and an interpretation of the aquifer systems in the Franklin area. The hydrology presented here has been used for other studies in progress by the U.S. Geological Survey, including the digital modeling of the Lower Cretaceous aquifer in the Franklin area and interpretation of the subsurface geology and hydrology of the southeastern Virginia Coastal Plain.

Fieldwork for the atlas was done from August 1968 through July 1972. Drill cuttings from several deep wells were collected and studied. Electric and gamma-ray logs were made of these wells, and gamma-ray logs were also made of many other wells. Electric logs made by water-well drillers provided additional subsurface geologic information. Water-level recorders were installed on five wells to obtain continuous records of water-level changes. Synoptic water-level measurements were made during September 1970, December 1970, and December 1971. Water from selected wells was analyzed for various chemical constituents.

Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in Virginia is based on the "Index to Topographic Maps of Virginia." The 7 1/2-minute quadrangles are identified by numbers and letters starting in the southwest corner of the State. The quadrangles are numbered 1 through 69 from west to east beginning at longitude 83° 45' and are lettered A through Z (omitting letters I and O) from south to north, beginning at latitude 36° 30'. These numbers and letters are shown in the left and bottom margins of the potentiometric map. Wells are numbered serially within each 7 1/2-minute quadrangle. For example, well 55B4 is in quadrangle 55B and is the fourth well inventoried in that quadrangle.

Cooperation and Acknowledgments

This investigation was made by the U.S. Geological Survey in cooperation with the Virginia State Water Control Board, E. T. Jensen, Jr., Executive Secretary. The work was done under the immediate supervision of J. W. Gambrell, district chief and his successor, W. E. Forrest.

Acknowledgment is here given to the cooperation of officials of Union Camp Corp., Hercules, Inc., and the cities of Franklin and Norfolk for furnishing information on ground-water pumpage and water levels. Thanks are also given the following well-drilling companies for their help: Layne Atlantic Co., R. L. Magette Co., and Pittman Wood and Metal Co.

DESCRIPTION OF THE AREA

Location and Extent of Area

The Franklin study area (fig. 1), of approximately 1,300 square miles, includes parts of the counties of Isle of Wight, Nansemond, Southampton, Surry, and Sussex, as well as the city of Franklin.

Geologic Setting

The Franklin area is entirely within the Virginia Coastal Plain and is underlain by unconsolidated sediments, which, in turn, rest on a massive body of hard rock called the basement complex. In this report, rocks of Triassic age or older are considered to be basement.

The names, age relationships, and general nature of the sequence of rock and sediments are given in table 1. The diagrammatic section A-A', fig. 2, illustrates how the Lower Cretaceous sediments, which constitute the principal aquifer, are confined below by the basement complex and above by the younger sediments, collectively called here "post-Lower Cretaceous confining beds." The section also illustrates how the basement complex, at the surface in the Piedmont province, extends eastward beneath the sediments that overlap it in a featheredge along the Fall Line.

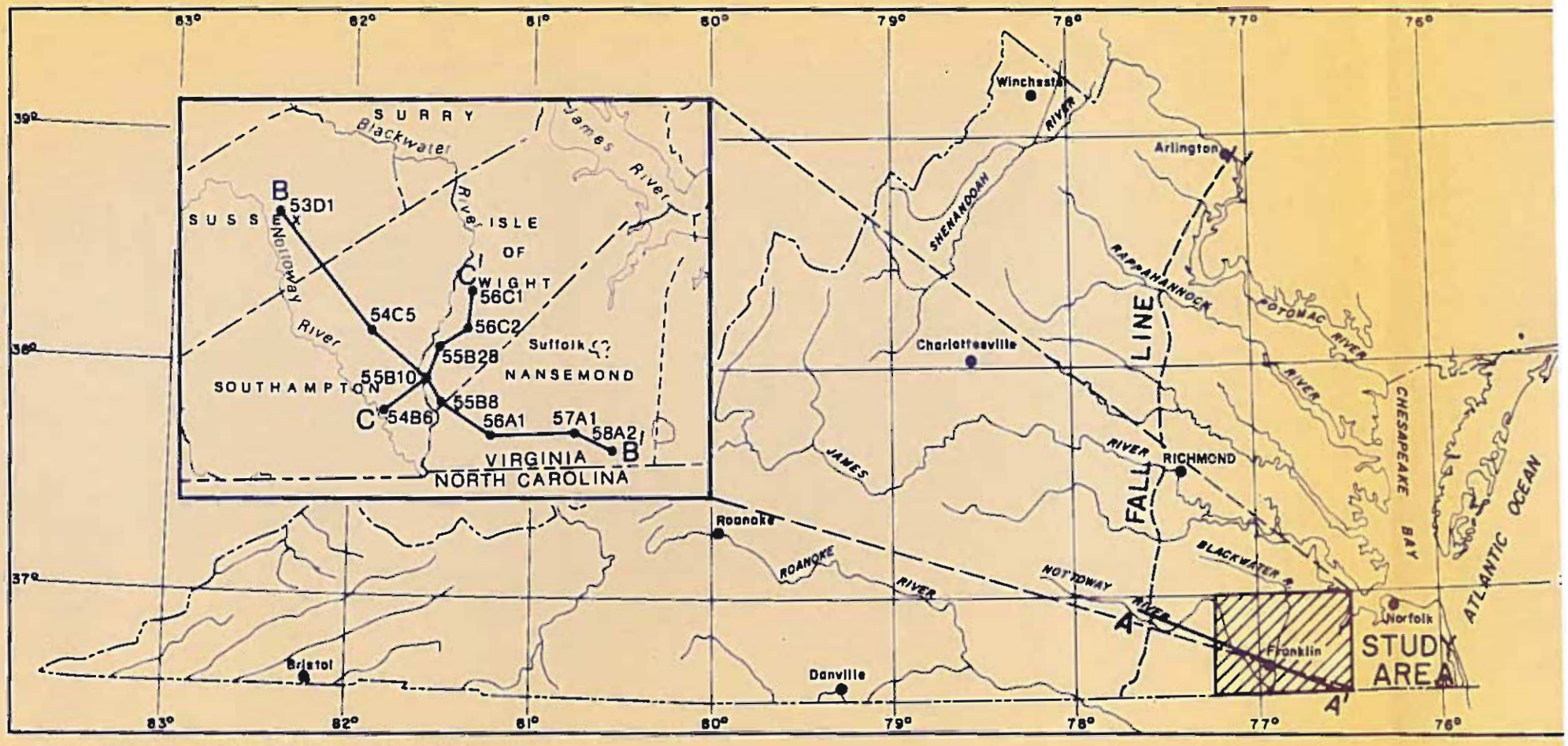

Figure 1. Index map showing location of Franklin study area, diagrammatic section A-A' and geologic sections B-B' and C-C'.

The sediments consist of alternating beds of various mixtures of clay, silt, sand, and gravel that generally thicken eastward, as a wedge, and extend eastward to the Continental Shelf (geologic sections B-B' and C-C', figs. 3 and 4). At well 53D1 near the western edge of the area, the top of the basement complex lies at a depth of 530 feet (-410 msl). At well 58A2 near Dismal Swamp, Triassic basement rock is at a depth of 1,874 feet (-1,818 msl).

POST-LOWER CRETACEOUS AQUIFERS

There are five aquifer systems in the Franklin area (table 1). Individual aquifers are separated by beds of fine-grained sediments, which act as confining layers. The water in the Pleistocene sand is generally under water-table conditions, whereas that in the other aquifers is confined under artesian pressure. The deepest aquifer, the Lower Cretaceous, is the major water-bearing unit and is the main subject of this report.

LOWER CRETACEOUS AQUIFER

Geology

The Lower Cretaceous deposits (Potomac Group) are composed of interbedded clay, sandy clay, and sand. Plant remains and limonite are found throughout the Lower Cretaceous and variegated clay is common. Individual sand and clay beds are commonly not more than 40 feet thick but may be as thick as 100 feet in places. The thick sand beds are the major water-bearing units in the Franklin area.

The sand is predominantly quartz, with lesser amounts of feldspar, and is commonly micaceous. The sand varies in texture from fine to coarse, with gravelly sand occurring locally. Interstitial silt and clay are generally present. Thin streaks of water-bearing sand are interbedded with thin streaks of clayey sand and clay. In places, more than half the total thickness of sediments of Early Cretaceous age is relatively clean water-bearing sand. Studies of formation samples indicate that sand constitutes about 50 percent of the Lower Cretaceous at the site of well 54B6 and about 35 percent at the site of well 55B28.

Lower Cretaceous deposits form a wedge that deepens and thickens from west to east (sections A-A' and B-B', figs. 2 and 3). Along the western edge of the Franklin area, the top of the section ranges in altitude from just above sea level to about 100 feet below sea level, and the total thickness ranges from 200 to 300 feet (W. F. Lichtler, oral commun. May 1972). At well 53D1 (section B-B', fig. 3) Lower Cretaceous deposits were found at an altitude of -127 feet and are 283 feet thick. Farther east, at well 55B10 near Franklin, the top of these sediments is at an altitude of -224 feet, and they are about 600 feet thick. Along the eastern edge of the area, the top of the Lower Cretaceous ranges from about 400 feet below sea level in the northeast corner to about 700 feet below sea level in the southeast corner. The thickness ranges from about 1,400 feet in the northeast to about 1,300 feet in the southeast. In the southeast corner, these beds were reached at 524 feet below sea level and are 1,294 feet thick in well 58A2.

Both the thickness and composition of the individual beds vary considerably over short distances. The absence of reliable horizon markers makes it difficult to correlate beds between wells. The reason for the poor lateral continuity of these beds lies in their origin, which has been attributed by Cederstrom (1945, p. 21-25) to deltaic deposition. Sand was deposited in stream channels, while silt and clay were deposited as natural levees and flood plains and in interchannel marshes, lakes, and bays. Thus, most of the sand beds are lenses, no more than a few miles long, that grade laterally into fine-grained sediments.

Electric logs, measuring natural electrical potential (spontaneous potential) and resistence (resistivity) were useful in determining relative clay content and relative porosity of sediments. Natural gamma-ray logs record the natural gamma radiation emitted by the sediments. Higher gamma-ray counts in the Franklin area generally indicate a higher relative content of clay. However, glauconitic or phosphatic sand also gives high gamma-ray counts. The correlation diagram (fig. 5) shows the correlation of a gamma-ray log, an electric log, and a time-drilling log of well 54B6 near Franklin. The time-drilling log is a graphic representation of the rate of penetration of the drill. Drilling was rapid in sands and slower in the more clayey sediments. The thick sand section from 555 to 610 feet penetrated by this well illustrates how these logs can be used jointly to determine lithology. The logs show a low gamma-ray count, negative spontaneous potential, high resistivity, and rapid rate of penetration. The sandy clay immediately below, from 610 to 615 feet, reacts in an opposite manner, with a high gamma-ray count, positive spontaneous potential, low resistivity, and slower drilling rate.

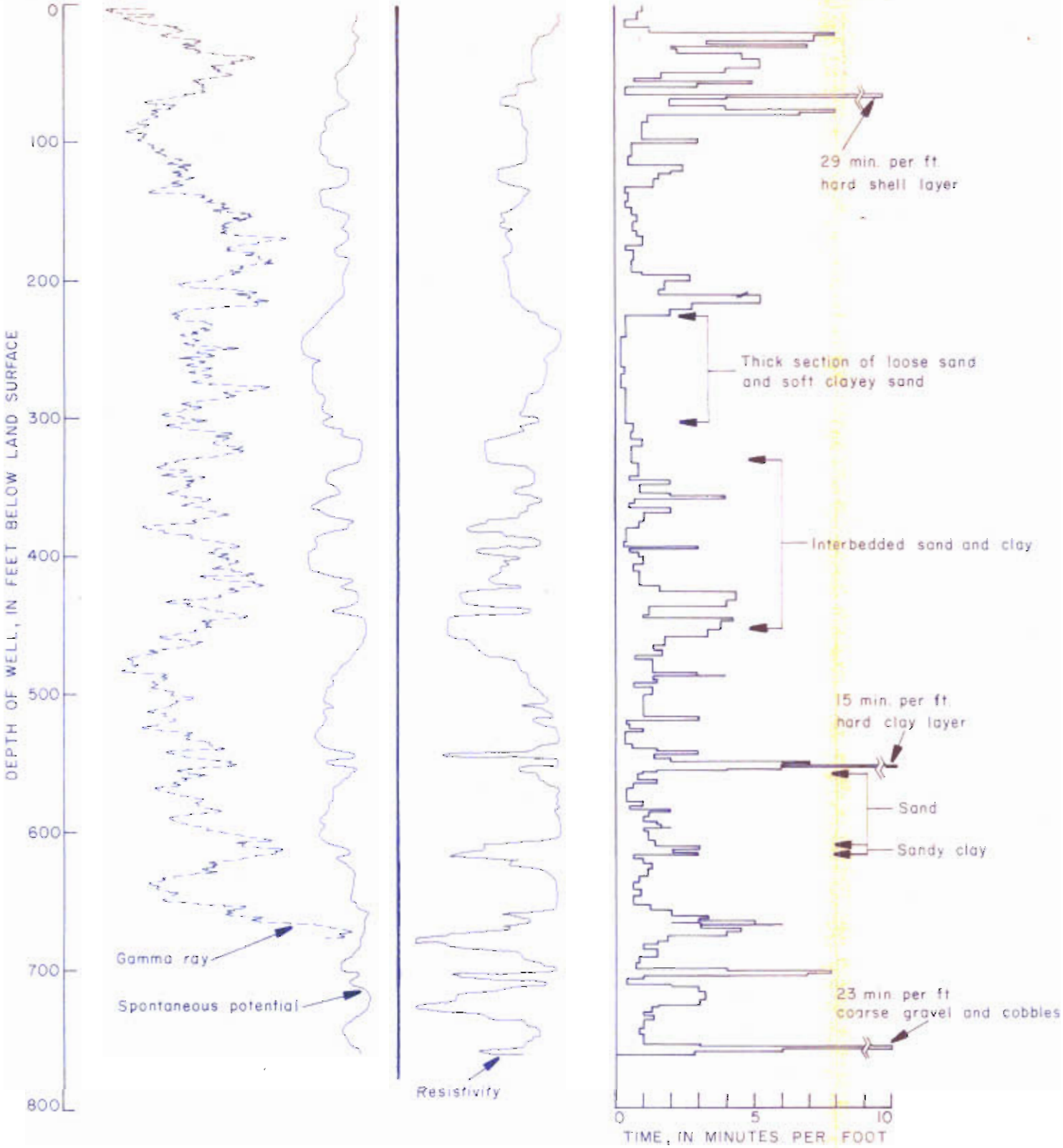

Figure 5. Diagram showing correlation of gamma-ray, spontaneous potential, resistivity, and time-drilling logs, well 54B6.

Source of Ground Water

Precipitation is the source of all fresh ground water in the Coastal Plain. A part of the precipitation that soaks into the ground recharges the aquifers. A small amount of the recharge to the Lower Cretaceous aquifer occurs directly on the outcrops along the Fall Line. But, as these outcrops are scarce, most of the recharge is by downward percolation from shallower ground-water bodies that overlie the Lower Cretaceous aquifer. Water seeping downward over the entire Coastal Plain into the Lower Cretaceous represents a significant source of recharge. Upward water movement through the weathered and fractured zone of the basement rocks underlying the Lower Cretaceous aquifer may contribute a small amount of recharge.

Movement of Ground Water

The prehistoric potentiometric surface of the Lower Cretaceous aquifer throughout the Coastal Plain had a gradient from the Fall Line eastward to the sea. Before ground-water was withdrawn, water moved downgradient (eastward) to a point where the static head in the aquifer became higher than the head in the overlying beds. From this point eastward, water also moved upward through the semipermeable confining beds into the overlying aquifers. The average recharge in and near the Fall Line was balanced by this natural discharge into the upper aquifers, a process called dynamic equilibrium by Hantush (1955, p. 45) in his work in the Roswell Basin, N. Mex.

When pumping began from Lower Cretaceous sand beds, the dynamic equilibrium was disturbed and in the Franklin area, the head was lowered so that it became lower than that in the upper aquifers. The upward movement of water from the Lower Cretaceous beds ceased, and water began moving downward from the upper aquifers to recharge the underlying Lower Cretaceous aquifer. This downward movement of water through the semipermeable confining layers is a major source of recharge.

The lateral movement of ground water is now (1972) toward Franklin from all directions, as shown by the arrows on the potentiometric map (fig. 6). The gradient of the 1971 potentiometric surface is gentle east of Franklin and steep west of Franklin. This difference is caused mainly by an eastward increase in transmissivity. As discussed previously and as shown on the diagrammatic section A-A' (fig. 2), the Lower Cretaceous thickens appreciable eastward. Transmissivity probably increases in approximate proportion to this increase in thickness to a point a few miles east of Franklin and remains fairly constant from there to the eastern edge of the area.

The great lateral variation in the character of the Lower Cretaceous sediments restricts application of a single determined value of transmissivity to a small area. In addition, all the methods used to determine transmissivity assume that certain physical conditions are satisfied by the aquifer and the wells penetrating it. As none of these conditions can be wholly satisfied, any determined value of transmissivity is approximate.

The authors have determined transmissivity by several methods. The circumference method developed by D. O. Gregg (oral commun., June 1972) was used to compute a transmissivity value from the spacing of the contours on the potentiometric map (fig. 6). The value computed by this method for the area between the -50-foot and -70-foot contours around Franklin is about 19,000 ft^3/day/ft (cubic feet per day per foot) or 140,000 gpd/ft (gallons per day per foot) and is probably a good average value for the area around Franklin. A series of estimates of transmissivity were calculated using the slope of the 1971 potentiometric surface. The lowest of these estimates is 6,000 ft^3/day/ft (45,000 gpd/ft) between Branchville and Boykins in the southwest corner of the map area. Next greater is 15,000 ft^3/day/ft (110,000 gpd/ft) at a point 10 miles west of Franklin. The highest estimate calculated by this method is 24,000 ft^3/day/ft (180,000 gpd/ft) for the area beginning about 4 miles east of Franklin to the eastern boundary of the area. This estimate agrees well with Geraghty and Miller's (1967) values for the Norfolk city well field in Nansemond County. The authors conclude that several miles east of Franklin the value of transmissivity for the Lower Cretaceous aquifer reaches a maximum and remains relatively constant to the eastern boundary of the area.

Discharge of Ground Water

Development of water from the Lower Cretaceous aquifer began in the late 1800's. The artesian head was sufficient to allow many homes, farms, and industries to have flowing wells. The hydraulic ram was commonplace. The city of Franklin, which for many years depended on the Blackwater River for its water supply, switched to ground water about 1927. Flowing wells continued to be popular, but, as more and more water was withdrawn from the Lower Cretaceous for industrial and municipal supplies, the artesian head in the aquifer declined, and so did the number of flowing wells. By the late 1940's, nearly all wells tapping the Lower Cretaceous aquifer had ceased flowing.

Originally, water from the Lower Cretaceous aquifer discharged upward through the overlying confining beds; now water moves downward through these confining beds and recharges the aquifer. All discharge is now through wells. Large industrial and municipal water supplies are drawn from wells tapping the Lower Cretaceous. At the end of 1971, approximately 47 mgd (million gallons per day) of water was pumped from wells in the Lower Cretaceous aquifer in the Franklin study area. About 45 mgd was pumped from large-yield industrial and municipal wells within a 5-mile radius of the center of the city.

Water-level measurements made during 1937-39 by Cederstrom (1945) indicated that a small cone of depression had formed around Franklin. At the center of the cone, water levels were slightly lower than 20 feet above sea level.

The potentiometric map (fig. 6) shows the configuration of the potentiometric surface in December 1971, at which time water levels at the center of the cone were 165 feet below sea level. The water-level decline map (fig. 7) shows that declines of the potentiometric surface ranging from 30 feet to 170 feet have occurred in the Franklin area between 1937-39 and December 1971. In December 1971, water levels in the center of the cone had declined about 185 feet (180' contour not shown on map, fig. 7).

The graphs of fig. 8 show the relation between pumpage at Franklin and water levels in three observation wells. The water level in well 55B22, owned by the city of Franklin, declined 159 feet from 1942 to 1971. At Sebrell, the water level in well 54C1 declined 63 feet from 1940 to 1971. The water level in well 58C1 declined 45 feet from 1956 through 1971.

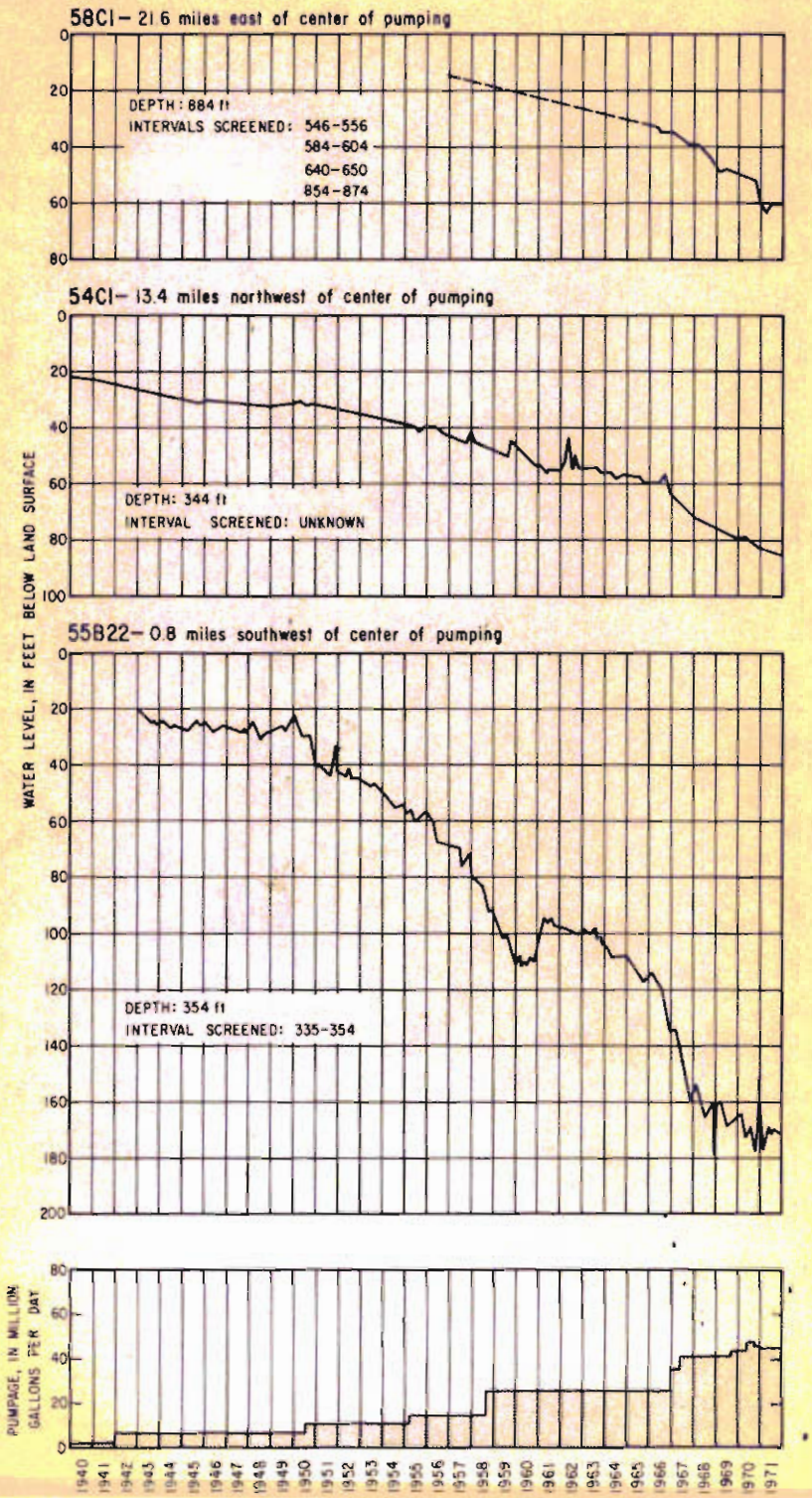

Figure 8. Graphs showing relation between water levels in Lower Cretaceous observation wells and pumpage near Franklin.

During 1971, withdrawals by the main industrial user at Franklin were reduced by 15 percent. This resulted in stabilized water levels at the center of the cone of depression, although levels in wells elsewhere continue to decline. If pumpage is not increased, outlying water levels will probably decline at decreasing rates, and the potentiometric surface may eventually reach equilibrium. Discharge through wells would be balanced by downward leakage from overlying aquifers and recharge from the Fall Line. If, however, the water level at the center of the cone declines below the top of the Lower Cretaceous aquifer, which is at an altitude of about -220 feet, dewatering of the aquifer will begin.

In most places in the Franklin area, wells in a single Lower Cretaceous sand may be expected to yield as much as 700 gpm (1 mgd). Many of the wells at Franklin, screened in several sand beds, yield 2,000 to 2,500 gpm (3.6 mgd). A theoretical distance-drawdown graph, fig. 9, shows the decline in the potentiometric surface caused by a well pumping 700 gpm (1 mgd) continuously for specified periods of time, assuming a value of transmissivity for the aquifer of 19,000 ft^3/day/ft (140,000 gpd/ft) and a coefficient of storage of 0.0003. For example, after 10 years of pumping, drawdown 1 mile from the pumped well would be 5.6 feet. If pumping was 2 mgd instead of 1 mgd, the drawdown would be twice as great or 11.2 feet. The drawdown factor obtained from the graph would be modified by recharge due to leakage from overlying aquifers and by the regional decline in water levels. The curves are approximations of drawdown due only to the withdrawal of water from storage at the specified pumping rate.

Quality of Ground Water

Water being withdrawn from the Lower Cretaceous aquifer in the study area is excellent for domestic, municipal, and most industrial purposes. However, the chloride concentration of the water in the aquifer increases eastward and with depth. The lower sand beds in the eastern part of the area contain water relatively high in chloride. Although this high chloride water is not used it is a potential threat to the good quality water in the area immediately southeast of Franklin.

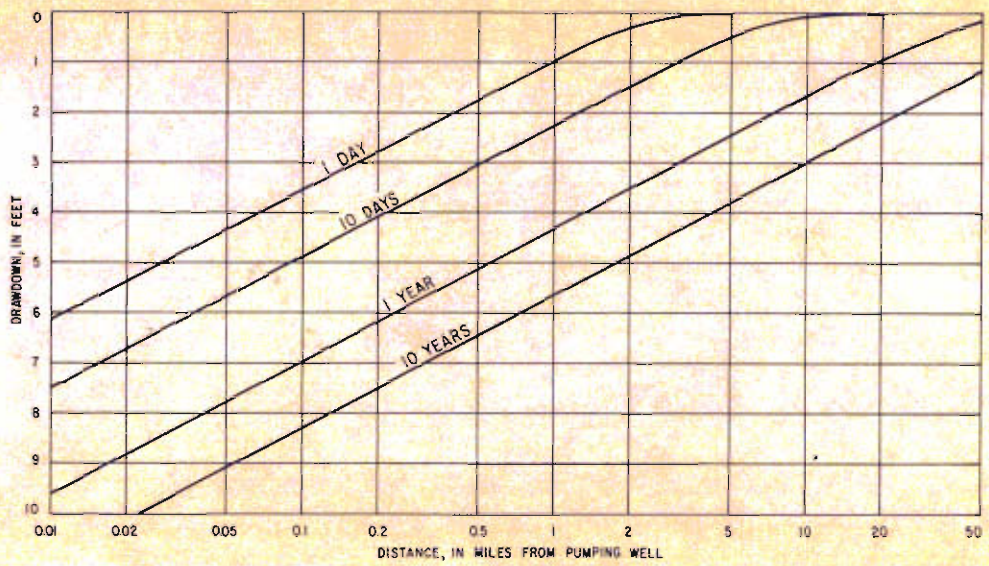

Figure 9. Theoretical distance-drawdown graph for the Franklin area, showing decline caused by a well pumping 700 gpm (1 mgd). Transmissivity 19,000 ft^3/day/ft (140,000 gpd/ft); coefficient of storage 0.0003.

Water from the Lower Cretaceous, except in the zone of high chloride water, is very soft and of the sodium bicarbonate type. Chemical character of water from wells tapping the Lower Cretaceous is shown in table 2. Dissolved solids are low, ranging from about 200 to 400 mg/l (milligrams per liter) throughout most of the area, but may be more than 800 mg/l (well 58C1 near Suffolk). Concentrations of calcium, magnesium, potassium, and sulfate are low and cause no problems. Iron concentration is not more than 0.2 mg/l and is commonly less than 0.1 mg/l, except at Boykins, where it is 0.46 mg/l. The high sodium and bicarbonate concentrations may cause problems if the water is used for irrigation and for some industrial purposes, such as boiler feed water. The sodium content increases eastward. Observed values are 41 mg/l at Boykins, a range of 85 to 162 mg/l at Franklin, 208 mg/l at Lake Prince (well 57C15), and 313 mg/l near Suffolk (well 58C1). Bicarbonate also generally increases eastward--concentration is 186 mg/l at Boykins, 203-363 mg/l at Franklin, and 573 mg/l in water from well 58C1. Fluoride concentrations are high at Franklin and to the east and northeast, averaging 4 mg/l. Chloride concentration is low throughout most of the area, generally less than 35 mg/l.

Water in the Lower Cretaceous aquifer having a relatively high chloride concentration was noted by Cederstrom (1945), who reported water with as much as 100 mg/l chloride in Nansemond County along the James River, immediately northeast of the study area. A chemical analysis of a water sample from well 55B36 indicates 195 mg/l chloride 1 mile east of Franklin. The well has screens near the bottom of the Lower Cretaceous between 720 and 860 feet. Analyses of water from well 56A1, 7 miles southeast of Franklin, show a chloride content of 1,300 mg/l in the lowermost sand beds. A chloride content of 16,000 mg/l was found in water from the lowermost sand penetrated by well 58A2, about 20 miles southeast of Franklin. The chloride content of water from these wells and from well 57A1 near Whaleyville has been used on section B-B' (fig. 3) to define a zone where chloride concentration ranges from 1,300 to 16,000 mg/l. Additional water samples taken during development of wells 56A1 and 58A2 indicate that the chloride content of the water probably exceeds 250 mg/l between depths of 727 and 994 feet in well 56A1 and between depths of 730 and 1,879 feet in well 58A2. Water samples from the upper sand beds may not be representative of formation water; thus, the analyses are not included in the chemical analyses table. As few wells have been drilled deep enough to reach the zone of high chloride water, the boundary shown on section B-B' is only approximate.

On the diamond-shaped water-quality diagram, fig. 10, chemical analyses of water from the Lower Cretaceous are plotted according to the percentage of chemical equivalents of the major cations and anions. Water analyses plotting near the bottom of the diamond represent the sodium bicarbonate water found throughout most of the area; those at the right corner represent the sodium chloride water collected from the lowest sand beds screened in wells 56A1 and 58A2. The alinement of the points suggests that differences in the quality of water are related to the extent to which the fresh sodium bicarbonate water has been mixed with the high sodium chloride water predominant east of the study area and present at the bottom of the aquifer in the southeastern corner of the study area. The analysis of water from well 55B36 and its position on the diagram show that this water is intermediate in composition between the sodium bicarbonate and sodium chloride types.

Present data are inadequate to clearly define the zone, or zones, of high chloride water and its movements. Because movement of water in the Lower Cretaceous aquifer is toward Franklin from all directions, defining the zone and monitoring its movement may become increasingly important to the area's future.

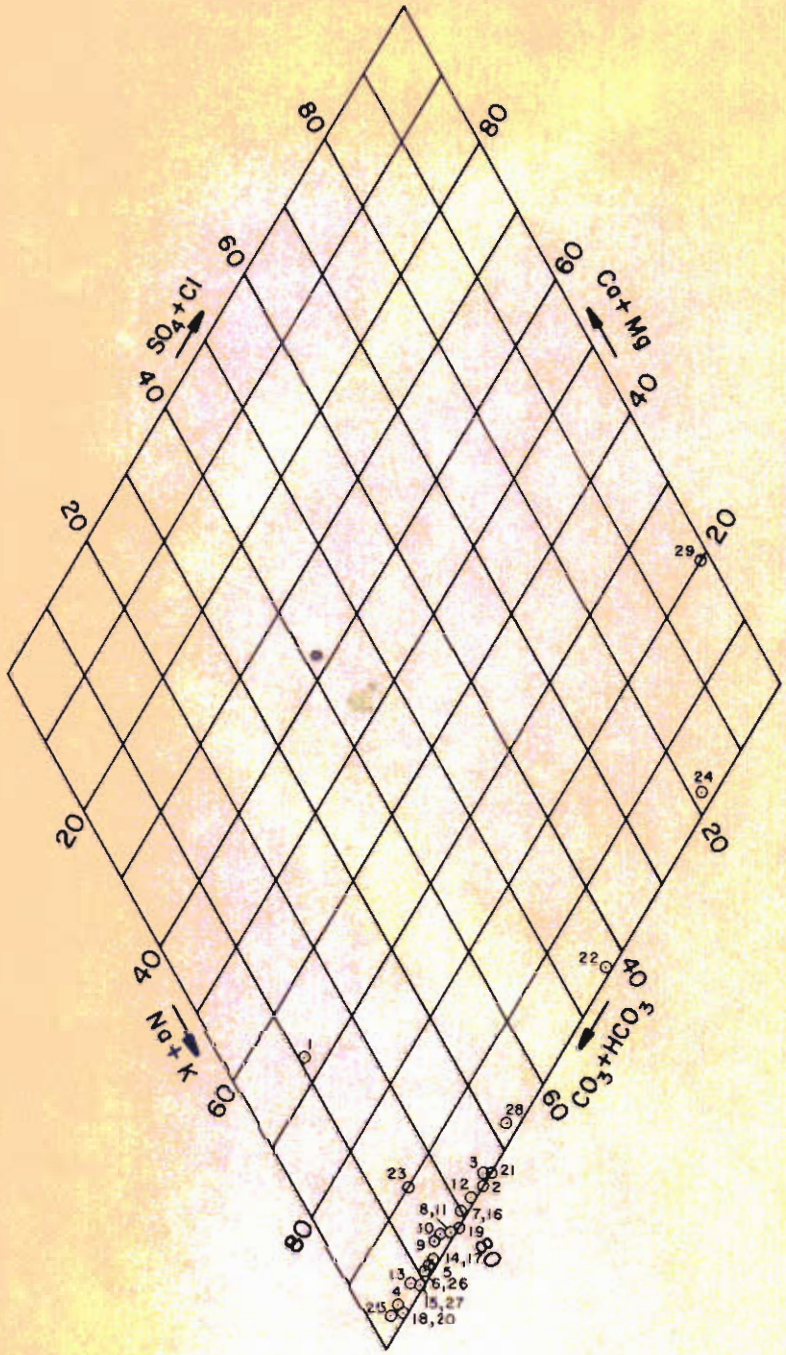

Figure 10. Water-analysis diagram for the Lower Cretaceous aquifer, showing analyses plotted in percent of total equivalents per million of the major cations and anions. Numbers refer to analyses given in the chemical analyses table.

SUMMARY

Water in the Lower Cretaceous aquifer in most of the Franklin area is of excellent quality for domestic, municipal, and most industrial uses. Extensive industrial development of the aquifer at Franklin has created a large regional cone of depression, which extends in all directions and reaches south into North Carolina. Water levels have declined as much as 185 feet near the center of the cone since 1937-39. Water with relatively high concentrations of chloride is known to be present in the aquifer in the southeastern corner of the study area and to the east. Movement of water in the aquifer is toward Franklin; thus, defining the location and extent of the zone, or zones, of the high chloride water and monitoring its movement would seem to be indicated.

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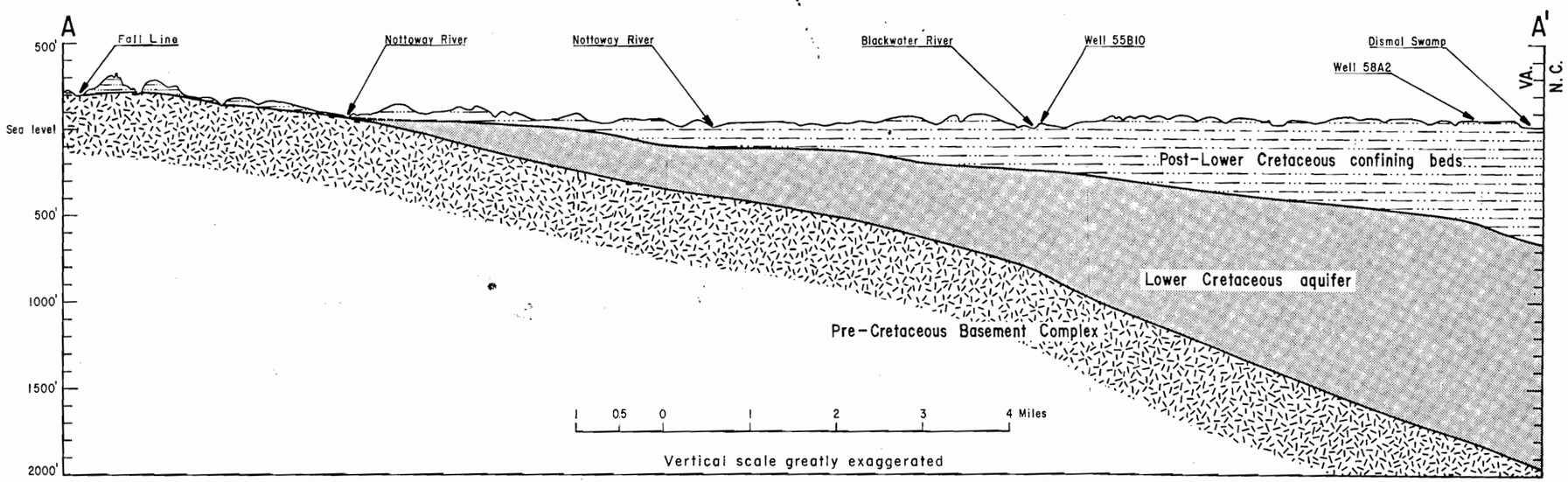


Figure 2. Diagrammatic section A-A' of the Coastal Plain of Virginia.

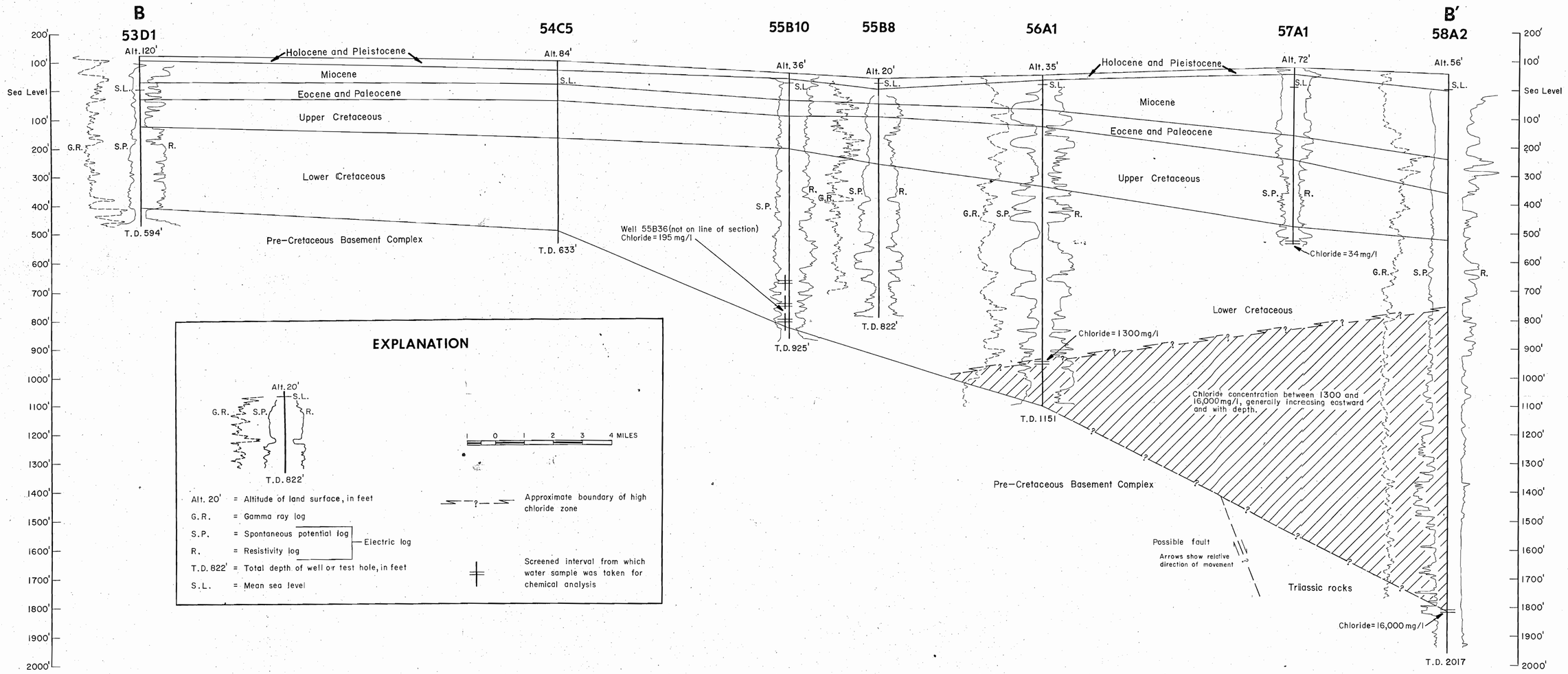


Figure 3. Geologic section B-B' showing correlation of geologic formations between wells.

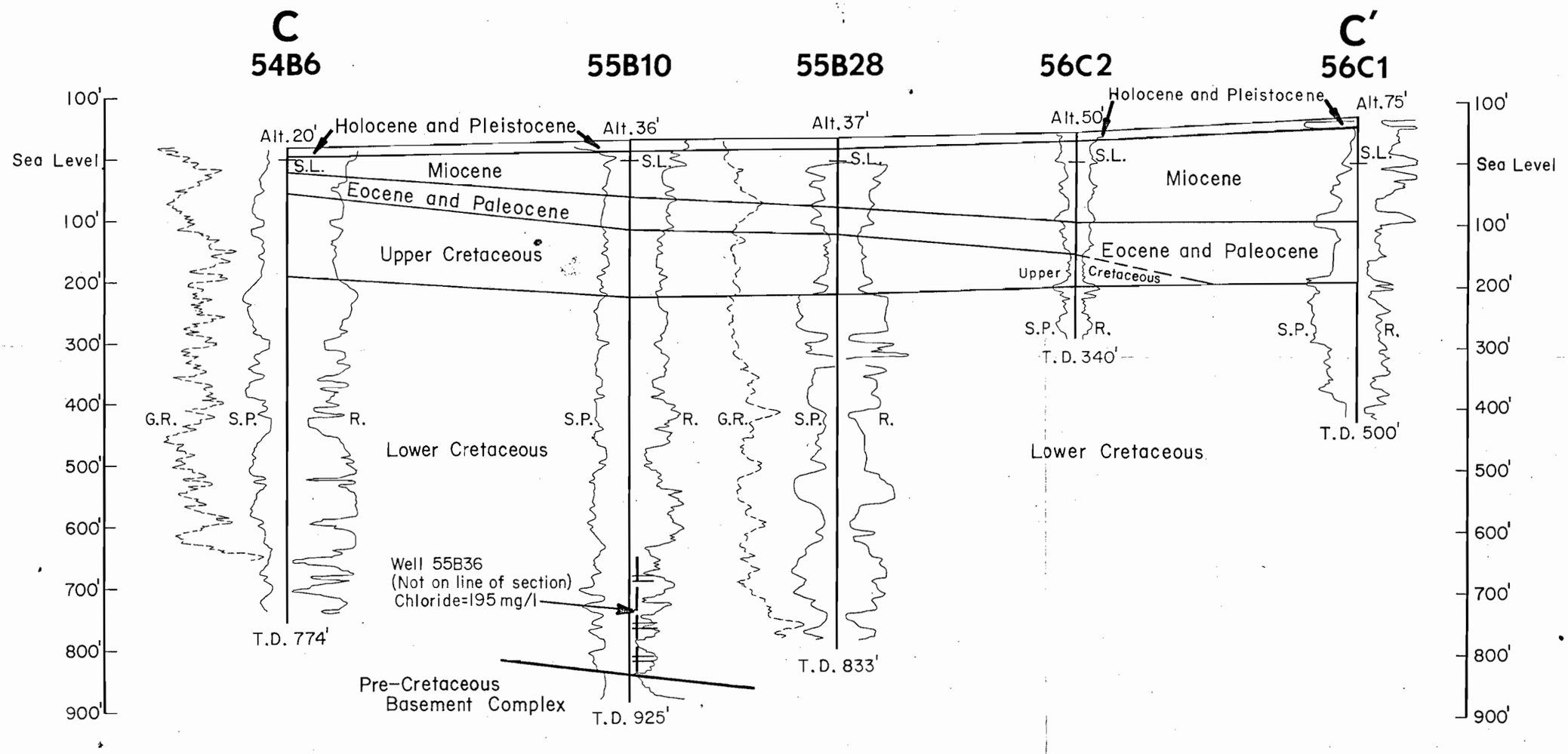
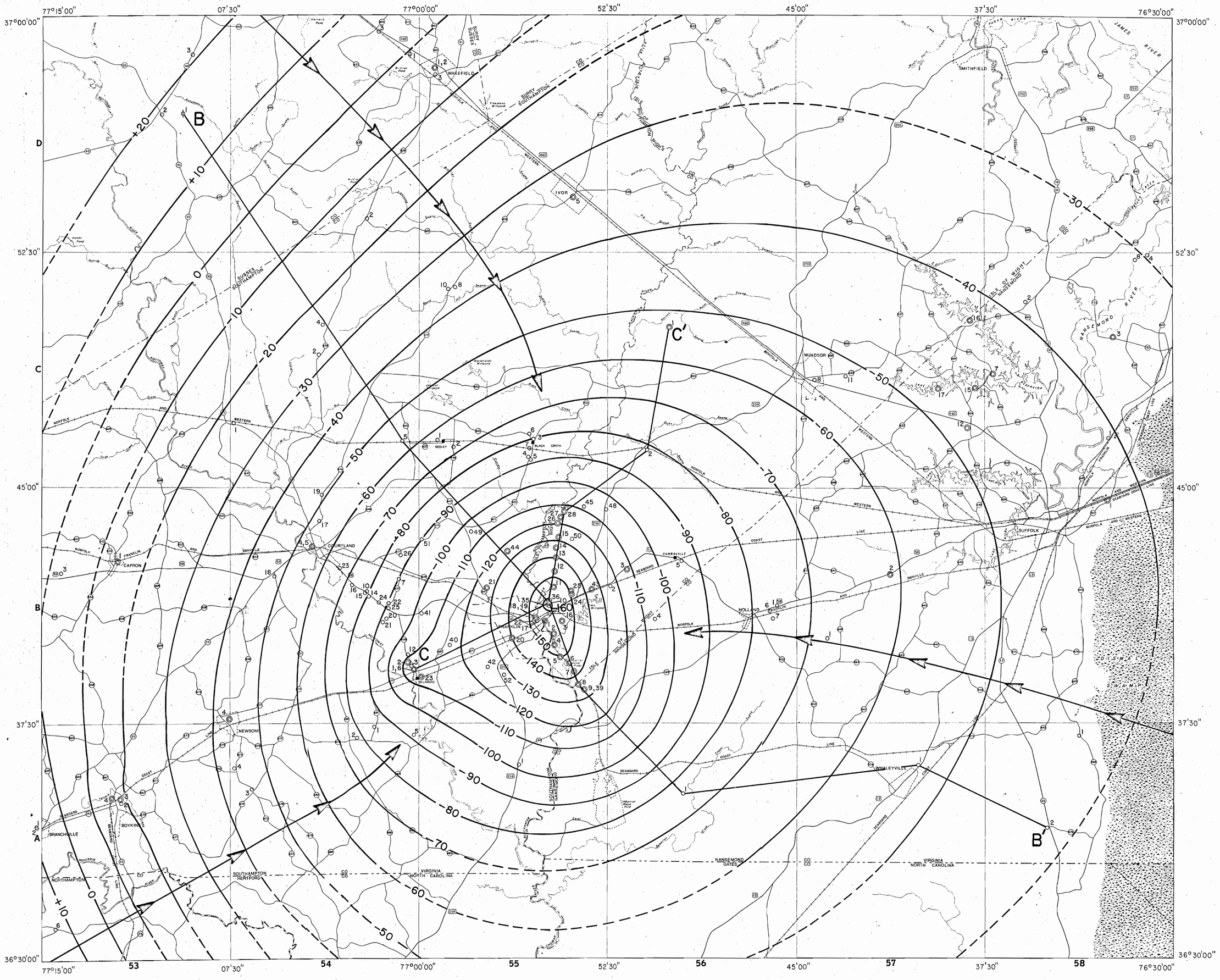


Figure 4. Geologic sections C-C' showing correlation of geologic formations between wells.



Base map after U.S. Geological Survey 1:24,000 quadrangles

5 0 5 10 MILES

B B' Location of geologic section

General direction of ground-water flow

-40- Potentiometric contour
Shows altitude of potentiometric surface Dashed where approximate; contour interval 10 feet; datum is mean sea level

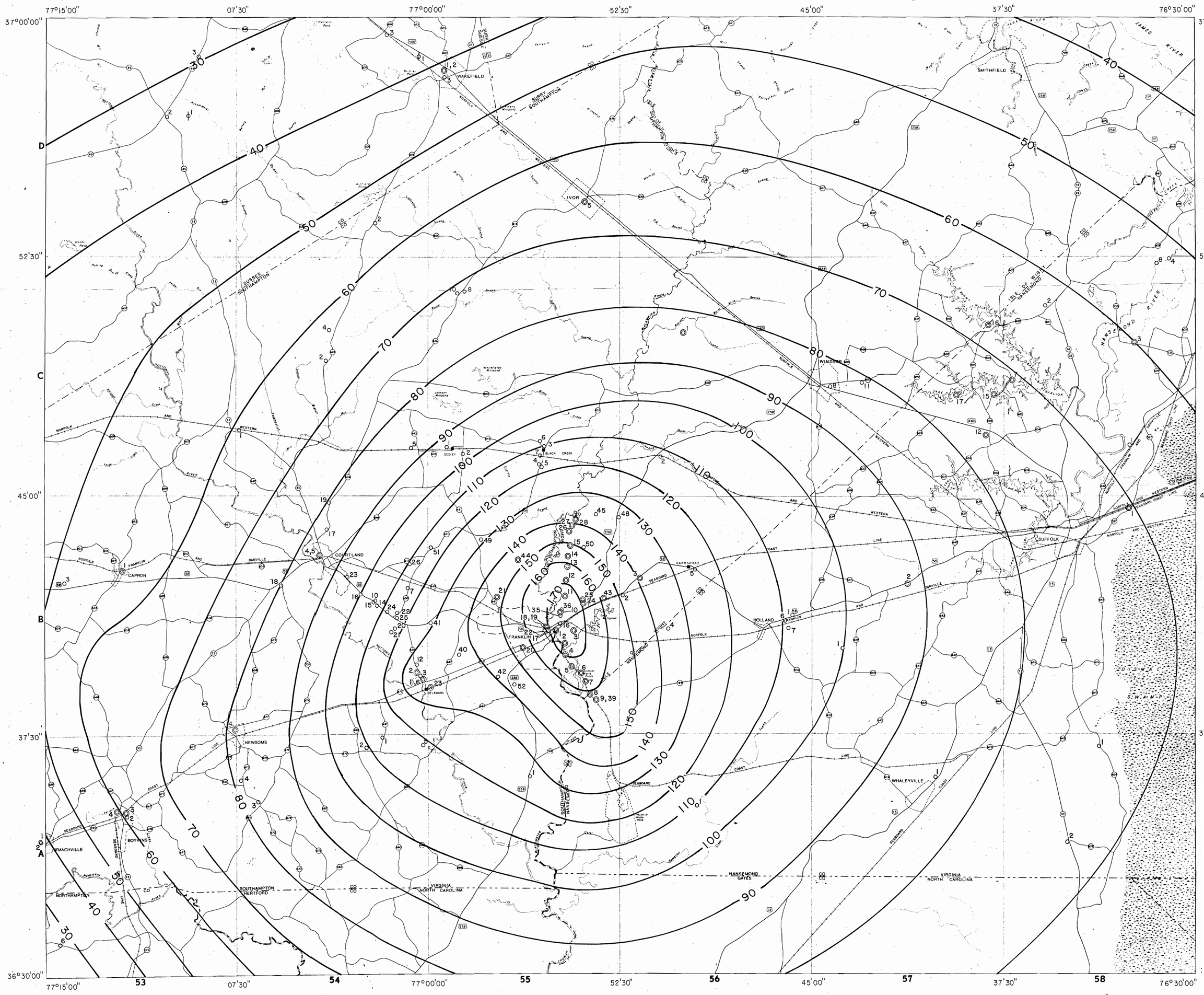
o2 Domestic well and number

27 Municipal, industrial, institutional or commercial well and number

Destroyed well

53 A Numbers and letters in margin refer to well-numbering system

Figure 6. Map of potentiometric surface of Lower Cretaceous aquifer, December 1971.



Base map after U.S. Geological Survey 1:24,000 quadrangles

5 0 5 10 MILES

100 — Line of equal approximate decline of potentiometric surface, 1937-39 to 1971. Interval 10 feet.

2 — Domestic well and number

27 — Municipal, industrial, institutional or commercial well and number

ϕ — Destroyed well

53A — Numbers and letters in margin refer to well-numbering system

Figure 7. Map of decline of water level in Lower Cretaceous aquifer, from 1937-39 to December 1971.

Table 1.--Generalized lithologic and water-bearing properties of the geologic units in the Franklin area.

System	Series	Generalized lithology	Water-bearing properties
QUATERNARY	Pleistocene and Holocene	Surficial terrace deposits consisting of sands and clays. Alluvial deposits along streams and swamps.	Yields water for domestic and small industrial wells in Pleistocene terrace sands. Water is soft and low in mineral content, but sometimes contains excessive iron (more than 0.3 mg/l).
TERTIARY	Miocene	Blue and gray clay; sandy clay containing abundant shells; subordinate sands, mostly in lower part.	A minor aquifer in Surry and Isle of Wight Counties. Generally yields little water because of low permeability. Sands not persistent; yields poor and variable, usually less than 10 gpm. Water is hard calcium bicarbonate type; objectionable iron often present.
	Paleocene and Eocene	Glauconite-quartz sand mixtures and glauconitic clay to clayey sand; common indurated shell and limestone layers; subordinate blue or gray silty clay with little glauconite; coarse sand and gravel often present at base.	Sands and limestone beds yield moderate supplies to wells, mostly in western part of area. Reported yields up to 200 gpm. Water is generally soft sodium bicarbonate type, usually of good quality; may have objectable odor and color.
CRETACEOUS	Upper	Alternating beds of fine to medium quartz sand, silt, and silty or sandy clay; slightly glauconitic; a thick red to brown or gray clay locally; coarse sand and gravel beds sometimes present.	Important aquifer for domestic wells and small municipal and industrial wells. Reported yields up to 300 gpm. Water is soft sodium bicarbonate type and of good quality.
	Lower	Interbedded arkosic sand, clay, and sandy clay. Sand, white to gray, fine-grained to coarse gravel; beds 30 - 40 feet thick common, locally up to 100 feet. Clay beds are variegated, of many different colors, and become more compact with depth. Individual beds vary in thickness and composition laterally and may pinch out in short distances. Plant remains common.	Major artesian aquifer in area for municipal and industrial supplies. Reported yields from single sands up to 700 gpm. Multi-screened wells, as at Franklin, yield 2,500 gpm or more. Water is very soft sodium bicarbonate type and excellent for most purposes; unsuitable for some industries because of high sodium and bicarbonate; high in chloride locally in southeast corner of area.
PRECAMBRIAN, PALEOZOIC, AND TRIASSIC		Basement complex of Precambrian and Paleozoic igneous and metamorphic rocks and Triassic indurated sedimentary rocks; includes granite, andesite, gneiss, red and green shale.	Not used as aquifer in area. Water in top fractured and weathered zone. Serves as bottom confining layer for Lower Cretaceous aquifer.

Table 2.--Chemical analyses of ground water from the Lower Cretaceous aquifer, Franklin area, Va. (results in milligrams per liter except temperature and pH).

U. S. Geol. Survey well no.	Number used on figure 10	Owner	Interval sampled (feet below land surface)	Date of Collection	Temperature (°C)	Dissolved Silica (SiO_2)	Iron (Fe)	Dissolved Calcium (Ca)	Dissolved Magnesium (Mg)	Dissolved Sodium (Na)	Dissolved Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Dissolved Sulfate (SO_4)	Dissolved Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	Laboratory pH
																				Calcium, Magnesium	Non-Carbonate		
53A3	1	Town of Boykins well 3	180-275	10-9-68	16.3	27	0.46	13	6.2	41	23	186	0	13	4.4	0.1	0.4	0.30	212	58	0	355	7.5
54B1	2	Hercules Inc. well 2	370-600	10-9-68	18.0	30	.06	0.2	.1	110	5.9	210	0	16	29	3.0	.3	3.3	300	1	0	500	8.0
54B2	3	Hercules Inc. well 3	340-700	10-9-68	17.4	30	.03	.4	.1	102	5.9	203	0	16	30	2.5	.1	3.3	289	2	0	485	8.0
55B1	4	Union Camp Corp. well 1a	380-590	9-27-68	18.2	24	.11	.4	.2	97	3.9	245	0	4.6	4.4	4.3	.3	3.0	269	0	0	400	8.2
55B2	5	Union Camp Corp. well 2a	380-620	9-25-68	18.5	26	.18	.6	.2	108	3.9	256	0	8.0	15	4.1	.5	3.0	315	0	0	450	8.2
55B3	6	Union Camp Corp. well 3	473-623	9-26-68	19.5	29	.05	.8	.1	95	3.1	226	0	8.0	11	4.5	.4	3.1	276	0	0	390	8.2
55B4	7	Union Camp Corp. well 4	407-665	9-25-68	19	28	.18	.8	.1	131	4.7	280	0	15	32	3.5	.4	3.0	367	0	0	550	8.1
55B5	8	Union Camp Corp. well 5	407-602	9-25-68	20	22	.09	.8	.1	153	5.9	339	0	15	30	4.0	.3	2.6	410	0	0	660	8.2
55B6	9	Union Camp Corp. well 6	372-626	9-26-68	18.6	21	.06	.8	.5	162	6.6	354	5	14	28	4.0	.5	2.4	414	0	0	670	8.4
55B7	10	Union Camp Corp. well 7	385-620	9-26-68	19.2	24	.05	.6	.4	153	5.5	339	2	16	28	3.9	.3	2.7	402	0	0	640	8.3
55B9	11	Union Camp Corp. well 9	345-630	9-25-68	20	22	.14	1.0	.4	157	8.6	363	0	17	31	4.0	.0	2.5	432	0	0	705	8.2
55B10	12	Union Camp Corp. well 10	405-865	9-26-68	19.7	29	.07	.4	.1	104	3.9	226	0	19	24	3.5	.3	2.9	301	0	0	450	8.0
55B11	13	Union Camp Corp. well 11	380-860	9-26-68	19.6	24	.11	.4	.2	94	3.1	239	0	7.8	7.1	3.5	1.7	2.3	266	0	0	410	8.1
55B12	14	Union Camp Corp. well 12	385-860	9-27-68	19.0	28	.07	.4	.1	95	3.1	234	0	11	13	3.4	.6	2.6	282	0	0	430	8.2
55B13	15	Union Camp Corp. well 13	385-865	9-27-68	19.2	23	.03	.6	.2	106	3.9	270	2	10	9.2	2.8	.7	1.8	310	0	0	470	8.3
55B14	16	Union Camp Corp. well 14	380-865	9-27-68	20.2	31	.05	.8	.2	97	3.1	215	2	15	21	3.0	.4	2.7	294	0	0	440	8.3
55B15	17	Union Camp Corp. well 15	400-807	9-27-68	19.4	30	.05	.4	.1	90	2.7	218	2	9.4	12	3.0	.2	2.5	275	0	0	400	8.3
55B19	18	City of Franklin well 3	335-596	9-24-68	18	24	.05	.4	.1	95	3.5	244	0	6.4	3.2	3.4	.4	2.7	278	0	0	415	8.2
55B20	19	City of Franklin well 4	238-582	10-8-68	17.8	22	.10	.2	.2	143	7.8	305	0	16	29	2.9	.4	2.6	384	2	0	665	8.0
55B21	20	City of Franklin well 5	450-610	9-24-68	18.5	22	.05	.8	.1	85	3.5	223	0	5.8	2.6	3.5	.6	2.4	249	0	0	360	8.1
55B23	21	Hercules Inc. well 1	386-586	10-9-68	17.9	29	.03	.2	.1	110	5.9	214	0	17	34	2.7	.2	3.6	318	1	0	535	8.0
55B36	22	Union Camp Corp. observ. well 2	[1]720-860	7-29-69	20	17	.62	2.3	.6	366	22	438	0	187	195	.8	.1	.16	1,015	8	0	1,700	7.8
55B45	23	R. J. Goodrich	338-348	9-22-70	-	11	.02	6.0	2.2	100	8.0	268	0	5.8	24	1.8	.0	.19	290	24	0	460	8.0
56A1	24	Va. Bur. Water Control Mgt. observ. well 47	989-994	6-22-72	-	31	.30	14	11	1,300	30	620	0	400	1,300	.6	.2	.10	3,600	80	0	6,000	8.1
56C1	25	Zuni Presbyterian School	418-434	8-25-69	-	23	.08	1.2	.2	101	11	288	0	3.6	3.2	.9	.3	.16	294	4	0	430	7.6
57A1	26	Va. Dept. of Highways Whaleyville	610-620	10-10-68	17.8	11	.56	2.8	.5	257	16	631	6	16	34	2.5	1.2	.97	650	9	0	1,160	8.3
57C15	27	City of Norfolk well 2 Lake Prince	546-686	11-28-67	-	30	.08	1.0	.5	208	5.6	506	0	11	21	3.0	1.3	2.1	542	4	0	839	8.0
58C1	28	Nestle Co. well 1	[2]546-874	7-31-69	21	24	.75	2.7	.9	313	17	573	0	35	134	2.8	.5	.97	812	11	0	1,368	8.1
58A2	29	Va. Bur. Water Control Mgt. observ. well 42	1874-1879	7-11-72	-	13	.48	1,100	510	8,800	160	132	0	490	16,000	1.4	1.4	.00	31,410	4,800	4,700	45,000	7.5

1 Average of 2 analyses

2 Average of 3 analyses