RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF CLARENDON AND WILLIAMSBURG COUNTIES, SOUTH CAROLINA

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Water Resources Commission

1978

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CLARENDON AND WILLIAMSBURG COUNTIES, SOUTH CAROLINA

by Phillip W. Johnson

Prepared by the

U. S. Geological Survey

in cooperation with

South Carolina Water Resources Commission

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CONVERSION FACTORS

Factors for converting U.S. customary units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the units.

U.S. Customary units	Multiply by	Metric units
ft (foot)	3.048×10^{-1}	m (meter)
ft/mi (feet per mile)	1.894×10^{-1}	m/km (meter per kilometer)
ft/d (feet per day)	3.048×10^{-1}	m/d (meter per day)
ft/s (feet per second)	3.048×10^{-1}	m/s (meter per second)
ft^3/s (cubic feet per second)	2.832×10^{-1}	m^3/s (cubic meter per second
$(ft^3/s)mi^2$ (cubic feet per second per square mile)	1.093×10^{-2}	$(m^3/s)/km^2$ (cubic meter per second per square kilometer)
ft^2/d (square feet per day)	9.290×10^{-2}	m^2/d (square meter per day)
gal (gallon)	3.785	L (liter)
gal/min (gallons per minute)	6.309×10^{-2}	L/s (liter per second)
(gal/min)/ft (gallon per minute per foot)	2.070×10^{-1}	(L/s)/m (liter per second meter)
$(gal/min)/in^2$ (gallons per minute per square inch)	$9.778 \times 10^{+1}$	$(L/s)/m^2$ (liter per second per square meter)

U.S. Customary units	Multiply by	Metric units
in (inch)	2.540	cm (centimeter)
in (inch)	$2.540 \times 10^{+1}$	mm (millimeter)
in^2 (square inch)	6.452×10^{-4}	m^2 (square meter)
in/mo (inch per month)	2.54×10^{-1}	mm/month (millimeter per month)
mi (mile)	1.609	km (kilometer)
Mgal/d (million gallons per day)	4.381×10^{-2}	m^3/s (cubic meter per second)
	Temperature Conversion	
°F (degree Fahrenheit)	5/9(F°-32)	°C (degree Celsius)

RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF CLARENDON AND WILLIAMSBURG COUNTIES, SOUTH CAROLINA

by Philip W. Johnson

ABSTRACT

Water-bearing sands of the Black Creek Formation, the principal zones tapped for ground-water supplies in Clarendon and Williamsburg Counties, will yield 150 to 500 gallons per minute to wells. The water is soft, low in dissolved solids concentration (about 200 milligrams per liter or less), and is generally of good quality. Total iron in the water is locally greater than the recommended limits of 300 micrograms per liter. Fluoride concentrations exceed the proposed limit of 1.6 milligrams per liter in eastern Williamsburg County. Fluoride minerals associated with sandstone interbedded with water-bearing sand are the possible source of the excessive fluoride in the water.

The Peedee Formation overlies the Black Creek Formation and will yield 50 to 150 gallons per minute to wells. The water is probably similar in quality to that of the Black Creek Formation but is not believed to contain excessive iron or fluoride.

The Middendorf Formation (Tuscaloosa Formation equivalent) is mostly unexplored as a source of water in the area. Only the upper 100 feet or so of the formation has been tapped by a few wells. It is estimated that the water-bearing sands in the formation, in conjunction with overlying aquifers, will yield as much as 1,200 gallons per minute to wells.

A water-table aquifer consisting of Pleistocene-Holocene deposits, the Santee Limestone, and the Black Mingo Formation will yield as much as 50 gallons per minute to wells; although the usual yield is probably about 10 gallons per minute. The maximum thickness of the water-table aquifer is about 200 feet.

The ground-water resources of the area are relatively untapped. Ground-water use in 1970 was estimated to be 9 million gallons per day.

INTRODUCTION

The South Carolina Water Resources Planning and Coordinating Committee was established by the Acts and Joint Resolutions of the General Assembly in 1967 under Act 61 which sets forth the purpose and intent of the General Assembly as related to the water resources of the State; in brief:

> The General Assembly realizes that one of the State's most valuable resources is its water. The proper utilization and control of the water resources of the State can be best achieved through a coordinated, integrated state water resources policy, through plans and programs for the development of such water resources and through other activities designed to encourage, promote and secure the maximum beneficial use and control of such water resources, all coordinated by a committee. (South Carolina Water Resources Committee, 1967.)

Having thus been organized and charged, the South Carolina Water Resources Committee (later renamed Commission) in 1968 received approval from The General Assembly to implement a study of the ground-water resources of the Coastal Plain area of the State. The study was to be part of a long-range cooperative program with the U.S. Geological Survey. The purposes of the study were (1) to evaluate the quantity, quality, and availablility of ground water, and (2) to assess the feasibility of using ground water as a supply to meet the present and future growing demands of industry and municipalities.

This report summarizes the results of a reconnaissance study of the ground-water resources in Clarendon and Williamsburg Counties (fig. 1). The report is based on data avialable in the files of the U.S. Geological Survey which were collected from drillers, industrial and municipal officials, and from private individuals. Geophysical logging of selected wells was done by the Geological Survey.

The cooperation, help, and time given by drillers, industrial and municipal officials, and private individuals in furnishing information, records, and well data to the personnel involved in this investigation are greatly appreciated. I particularly wish to thank T. V. Wilson of Clemson University for the data he and H. O. Vaigmeur collected during a study of the water-table aquifer at Morris Farm northwest of Kingstree, South Carolina.

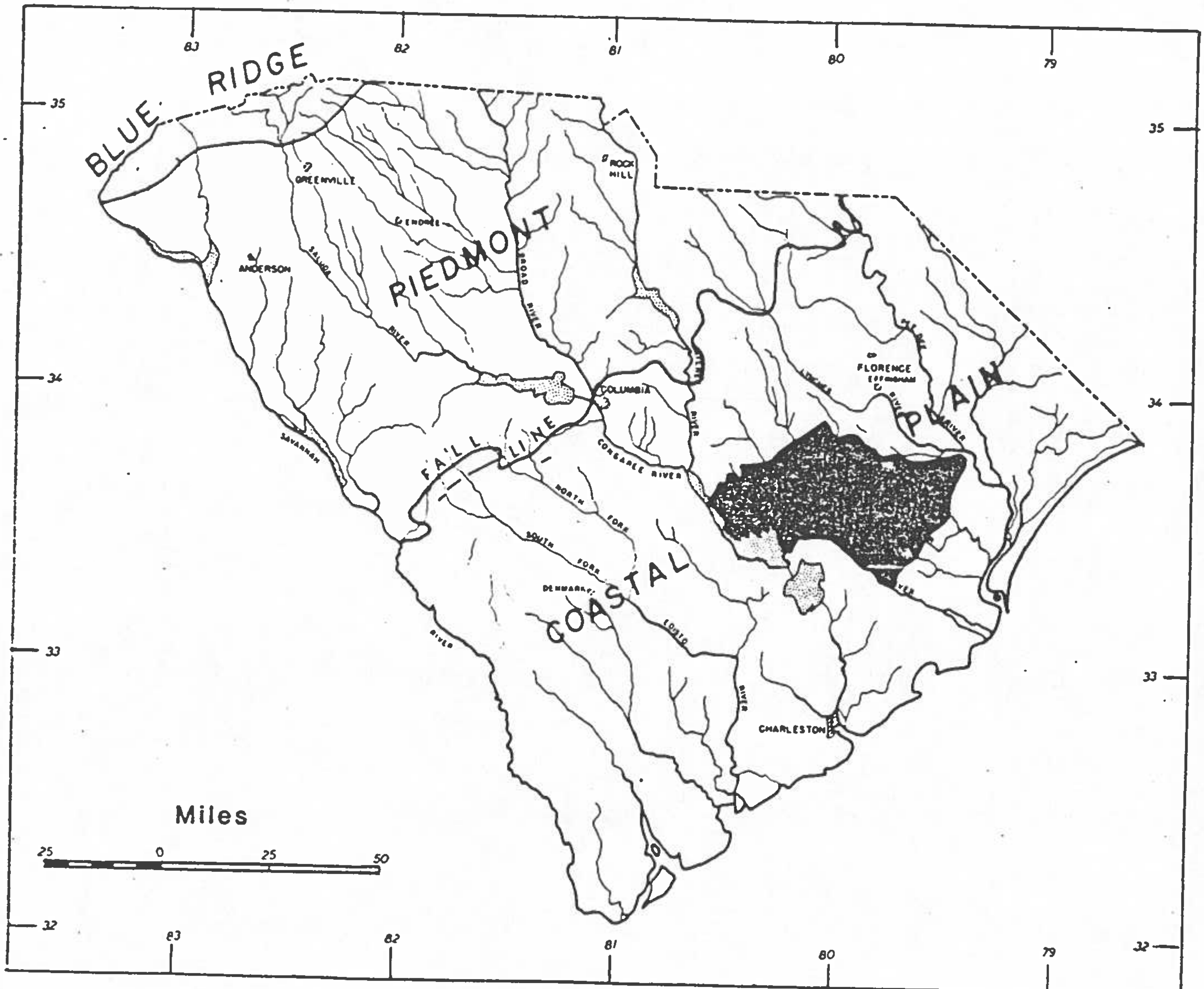

Figure 1. Location of Clarendon and Williamsburg Counties and physiographic provinces in South Carolina.

GEOGRAPHY

Physiography

Clarendon and Williamsburg Counties lie in the middle third of the Coastal Plain physiographic province (fig. 1). The topography of the Coastal Plain is a gently sloping surface that decreases in altitude from about 400 ft at the Fall Line to sea level at the coast--a distance of about 100 mi. The greatest amount of relief occurs in the Upper Coastal Plain within 10 to 20 mi of the Fall line where the average slope of the land surface ranges from about 8 to 15 ft/mi. Farther coastward in the lower Coastal Plain, which includes the middle and lower thirds of the Coastal Plain, the surface flattens and for many miles has less than the overall average slope of 4 ft/mi.

Prominent features of the Coastal Plain are the terraces and their accompanying escarpments that were cut when the sea stood at various higher levels during the Pleistocene. Wide swampy flood plains are characteristic of the rivers and larger streams. The Coastal Plain is dotted by unusual swamp- or lake-filled circular depressions called Carolina Bays.

Drainage

Clarendon and Williamsburg Counties are drained principally by the Black and Santee Rivers and tributaries of the Lynches River (fig. 2). The Black River flows southeastward across the central section of the area, draining the major part of the two counties. The headwaters of the Black River are within the Coastal Plain province below the Fall Line. The Santee River flows parallel to the Black River and forms the southern boundary of the area. Tributaries of the Lynches River drain the northernmost part of Clarendon and Williamsburg Counties. The Lynches River, part of the Pee Dee drainage, flows parallel to the Black and Santee Rivers. A small corner of Williamsburg County drains to the Pee Dee River.

Stallings (1967, p. 7), shows the difference in streamflow under low-flow conditions in five geologic zones of the State. The Black River system is in the first zone, or lower Coastal Plain, which is characterized by low, flat, swampy land and the shallow streams that cut the surfical deposits of clay, sand, and marl. The Black River system had low flows for the period studied ranging from 0 to 0.002 $(ft^3/s)/mi^2$. Ground-water discharge to streams generally maintains natural flow during periods of low rainfall. However, ground-water discharge into the Black River drainage is not sufficient to maintain flow during drought conditions.

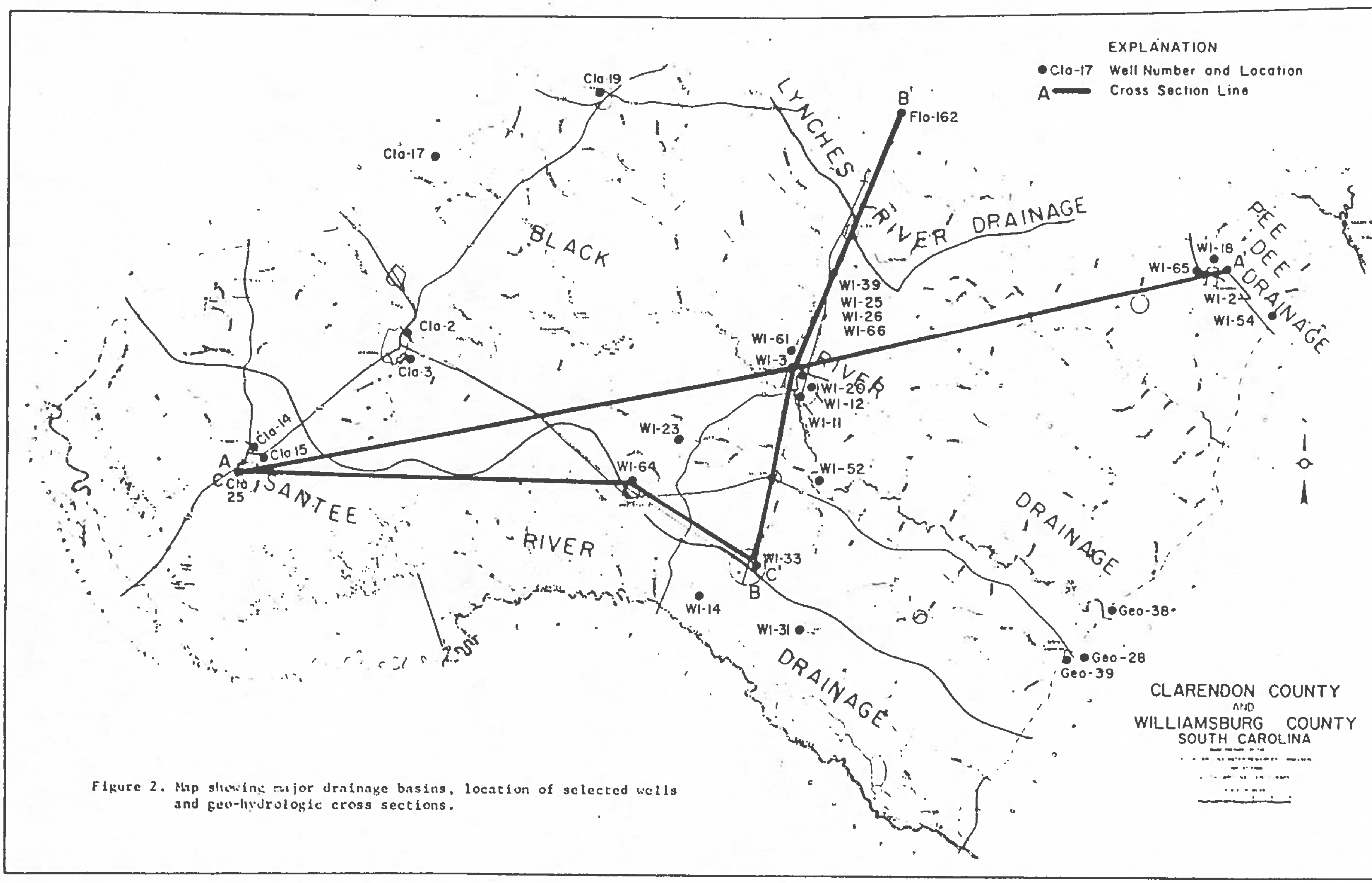

Figure 2. Map showing major drainage basins, location of selected wells and geo-hydrologic cross sections.

Climate

The area has a warm, humid climate. Long-term monthly mean temperatures for the city of Kingstree near the center of Williamsburg County range from 49°F to 81°F. Record extremes for the same station show a low of 7°F and a high of 107°F.

Average annual rainfall at Kingstree was 46.19 inches for the period 1935-64. Extremes in annual rainfall ranged from 34.20 inches during 1951 to 52.65 inches during 1964. The average annual rainfall varies as much as 14 inches across the two counties--ranging from 52 inches in eastern Williamsburg County to less than 38 inches near Lake Marion (fig.3).

Precipitation is well distributed throughout the year, ranging from greater than 6 in/mo during the peak of the growing season to greater than 2 in/mo during the nongrowing season. The distribution of precipitation is important to the water resources of the area, because during the growing season water is available when peak demands are made on the system by evapotranspiration. Due to the large rainfall, considerable water is available for recharging the ground-water reservoir.

GROUND-WATER USE

The principal municipalities in Clarendon and Williamsburg Counties utilizing ground water for public supply are listed in table 1, a summary of available information on these supplies. The estimated capacity of the municipal wells in 1970 was 9.5 Mgal/d. Average daily use was estimated to be about 1.4 Mgal/d. Because future water use is not expected to increase substantially, the municipalities seem to have a sufficient reserve capacity.

Two major industrial users of ground water have their own wells (table 2). Travenol Laboratories, Inc., with an average daily use of 7.6 Mgal is by far the largest user of ground water in the two counties. Several smaller industrial users obtain water from the municipalities of Kingstree and Manning (table 1).

As of 1970, ground water withdrawal for irrigation was limited to one well in Clarendon County, which pumped about 8 Mgal annually for application on 250 acres.

According to the 1970 census, Clarendon and Williamsburg Counties had a population of 59,850 living mainly in rural areas. Ground-water use for domestic purposes by the rural population is estimated to be 2.5 Mgal/d. Probably another 2.5 Mgal/d is used for water stock and for other farm purposes.

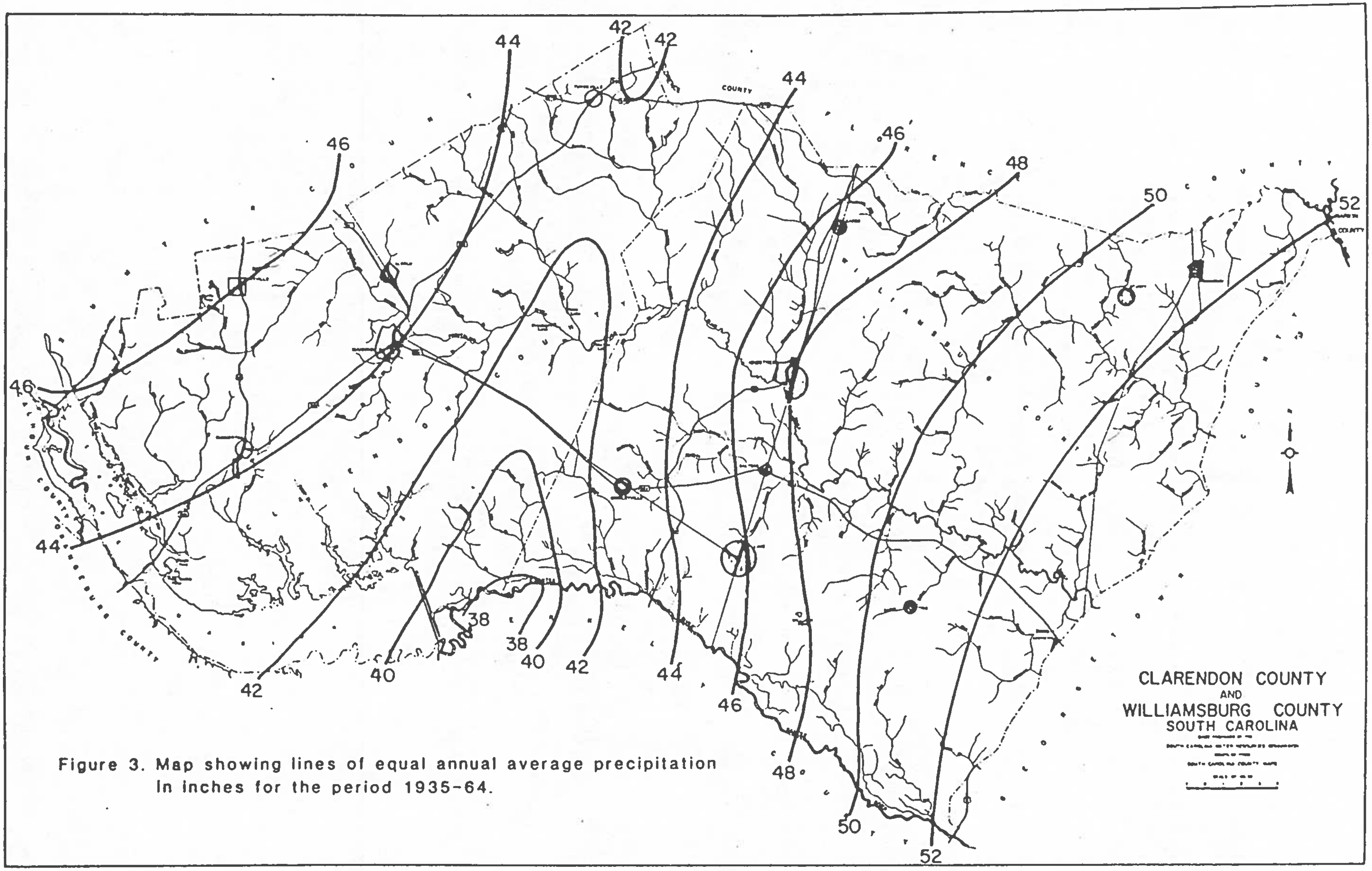

Figure 3. Map showing lines of equal annual average precipitation in inches for the period 1935-64.

Table 1. Municipal ground-waterr supplies in Clarendon and Williamsburg Counties, 1970

Municipality	Number of wells	Total Capacity Mgal/d	Average Daily Use Mgal/d	Projected 1980 use Mgal/d
Manning	5	4.000	0.500 1/	0.550
Summerton	3	2.268	.083	.267
Hemingway	2	1.138	.310	.400
Kingstree	4	1.260	.500 2/	.600
Turbeville	1	0.400e	.004	--
Greelyville	1	0.400e	.003e	--
Total (rounded)	16	9.5	1.4	1.8

1/ Includes 0.120 Mgal/d supplied to industry

2/ Includes 0.075 Mgal/d supplied to industry

e estimated?

Sources of data - South Carolina Water Rresources Commission, 1971
U. S. Geological Survey files

Table 2. Industrial ground-water supplies in Clarendon and Williamsburg Counties, 1970

Industry	Number of wells	Total Capacity (Mgal)	Average Daily use (Mgal/d)	Projected 1980 use (Mgal/d)
Georgia-Pacific Corp.	1	0.720	0.009	0.009
Travenol Laboratories, Inc.	5	9.220	7.640	9.200
Total (rounded)	6	9.9	7.6	9.2

Source of data - South Carolina Water Resources Commission, 1971

Although water can move vertically as well as horizontally through many rocks, the hydraulic conductivity is generally better developed laterally. The rate of movement depends on the permeability, and the head gradient. The water transmitting capacity of the entire thickness of an aquifer is termed transmissivity (T), which is defined as "the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient" (Lohman, 1970, p. 43).

A knowledge of the volume of water in the aquifer readily available to wells is also important. The term storage coefficient (S) denotes the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in head (Lohman, 1970, p. 38).

A ground-water reservoir is either unconfined or confined. The terms "unconfined" and "confined" refer to the presence or absence of a layer of relatively less permeable material, usually clay, stratigraphically adjacent to one or more aquifers (Lohman, 1970, p. 12). The confining layer, therefore, always has a permeability less than that of the aquifer. "Unconfined ground water is water in an aquifer that has a water table" (Lohman, 1970, p. 19). A water table is the surface of the unconfined water body at which the pressure is atmospheric.

Where a confined aquifer exists, the ground water in it is under pressure significantly greater than the atmosphere which causes the water level to rise above the top of the aquifer. The pressure may cause the water to rise only a few feet, or it may rise enough to flow at the surface. Such wells are known as artesian.

Recharge to the aquifer systems is derived from precipitation falling on the outcrop areas or from leakage through the confining beds.

When a well is pumped, a cone of depression is formed around the well bore. The difference between the static water level that existed prior to pumping and the level at the bottom of the cone during pumping is the drawdown. This distance, in feet, divided into the rate of water pumped in gallons per minute gives the specific capacity of the well. Both the yield and the specific capacity of a well, therefore, do not necessarily reflect the actual hydraulic properties of the aquifer tapped by the well. The specific capacity in a well also may change with time due to wear and deterioration of the well.

The specific capacity of wells is a usefull parameter for estimating transmissivity. However, the validity of such estimates should be checked by using data from controlled aquifer tests. Estimated transmissivities and specific capacities of wells for which yield and drawdown data area available are given in table 3.

Water Table Aquifer

The unconfined or water-table aquifer in Clarendon and Williamsburg Counties is restricted to the Santee Limestone, the shallow fine-to medium sand of the Black Mingo Formation, possibly the Peedee Formation in northeast Williamsburg County, and the surficial Pleistocene-Holocene sands that mantle the older formations. The combined thickness of these sediments and rocks at any one site generally is less than 200 ft. The thin but clayey Duplin Marl, which underlies the Pleistocene-Holocene deposits in northern Clarendon and Williamsburg Counties probably acts as a local confining bed, and in this area the underlying formations would contain confined aquifers.

Much of the rain that falls on the land surface infiltrates into the surficial deposits. Runoff apparently is limited to the major rainstorms when the infiltration capacity of the soil is exceeded or when water levels in the surficial material are so high that recharge is rejected.

An indication of the large infiltration capacity of the surficial material is the paucity of stream channels as there is little surface runoff. Water levels in the aquifer, however, are controlled by the depth to which the stream channels are incised into the land surface. Water levels rise rapidly in wet weather to within a foot or so of land surface but decline in dry weather to the base level of the nearest stream as shown in Figure 6.

Local stream flow is largely maintained by discharge from the water-table aquifers. Stream flow shown in figure 6 is the difference between discharge at gaging stations, adjusted for ungaged areas. Consistent negative differences indicate losses that are attributed to reduce ground-water discharge from the water-table aquifer and evapotranspiration losses from the swamps adjacent to the streams. Stream flow (fig. 6) was deficient in 1963, even though annual rainfall was near average, because ground-water discharge for a large part of the year was insufficient to overcome evapotranspiration losses from the swamps adjacent to the streams. Ground-water discharge to the streams is estimated to range between 5 and 10 inches during a year of normal rainfall.

Evapotranspiration (evaporation plus water used by vegetation) of ground-water takes place when the water level is near land surface. Figure 7 shows a graphical method used to estimate monthly evapotranspiration loss of ground water in relation to the depth of the water table below land surface. Adjusted monthly stream flow, as determined for the data illustrated in figure 6, was plotted against the average monthly ground-water level in the water-table aquifer above an arbitrary base of 10 ft. Parallel curves were drawn through the points for those months in the growing season and nongrowing season where stream flow was not affected by storm runoff. The difference between the parallel curves is the monthly evaporation loss from the aquifer in relation to the depth to water below land surface.

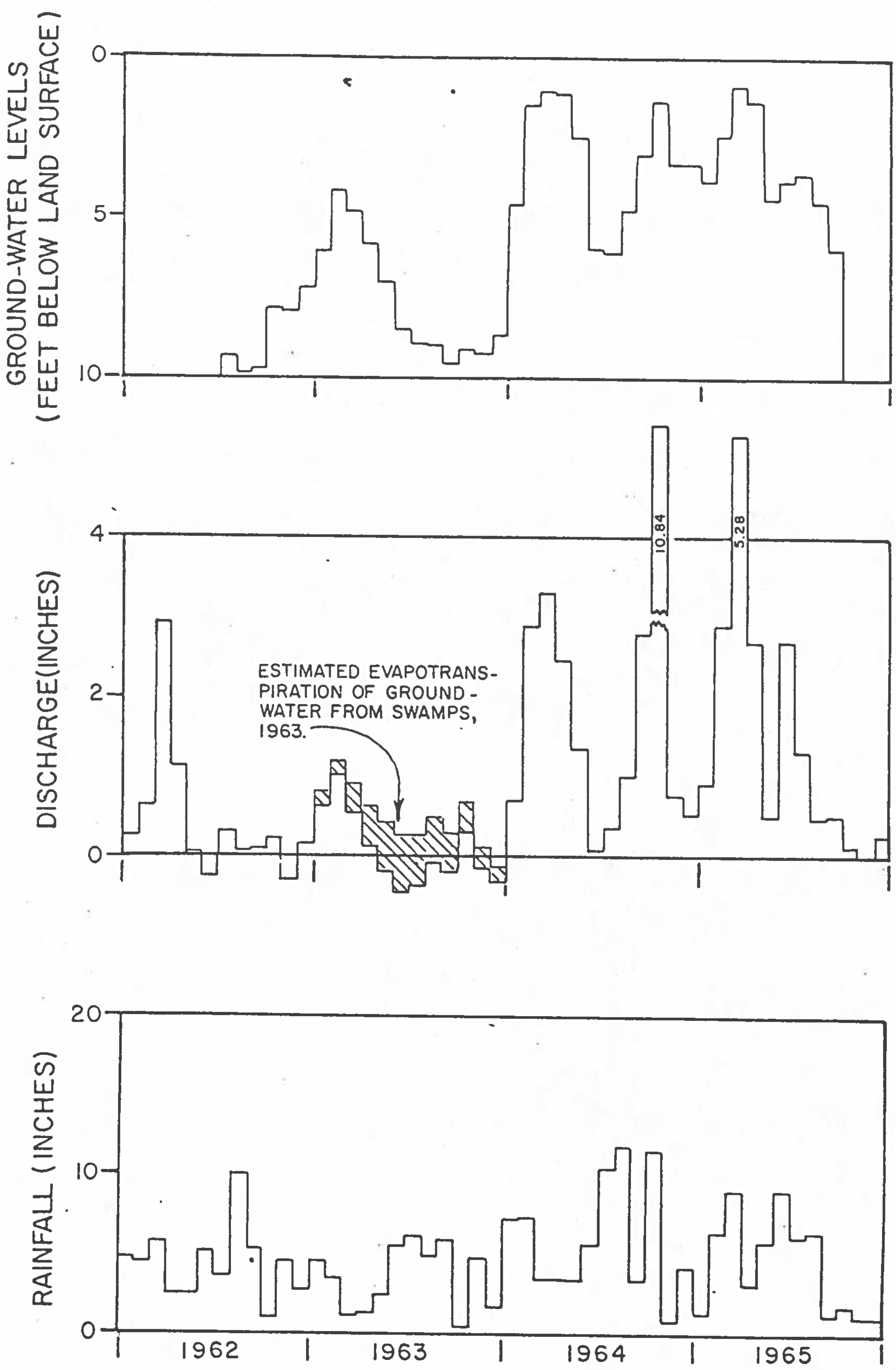

Figure 6. Graph showing average monthly ground-water levels in the water-table aquifer at Morris Farm, monthly discharge at Black River between the confluence of Black River and Pocotaligo River and Kingstree, and rainfall at Kingstree.

Losses range from 0.04 inches/month when the water-table is 9 feet below land surface to 0.3 inches/month when the water-table is 1 foot below land surface. An estimated 1 inch of water was lost from the water-table surface due to direct evaportranspiration in 1963. Evapotranspiration loss from the water-table surface is in addition to that lost from soil moisture.

Most of the rainfall that infiltrates into the surficial deposits goes to replenish soil moisture that is lost by evapotranspiration. Recharge to the aquifer occurs only when soil moisture demands are satisfied. As a result, only about 20 percent of the rainfall recharges the aquifer; although nearly all the rainfall infiltrates into the surficial deposits.

Diffusivity (transmissivity divided by the storage coefficient) of the water-table aquifer was computed by a method developed by Rorabaugh (1960) using data from Morris Farm (fig. 8). The diffusivity of 5,300 ft^2/d that was obtained must be considered an estimate as the distance from the observation well to the ground-water divide in the aquifer was assumed to be 1,000 ft. If the distance were doubled, the diffusivity would be quadrupled. The slope used in computing the diffusivity was obtained from water-level data recorded during periods when evaporation was high. The effect was to produce the steepest possible slope and, therefore, the largest possible diffusivity and transmissivity.

The specific yield of 0.085 for the water-table aquifer was determined by using rises in ground-water levels at Morris Farm and rainfall records at Kingstree (fig. 9). Because of the possible difference in rainfall between the two sites, the specific yield must also be considered an estimate. In an unconfined aquifer, the specific yield is essentially equivalent to the coefficient of storage (S).

An approximate transmissivity (T) of 1000 ft^2/d for the water-table aquifer was obtained by using a modified Theim equation (Lohman, 1972, p. 12) and data collected by Wilson and Vaigmeur (1962 a) at Morris Farm, a site about 10 mi northwest of Kingstree. Transmissivity of the aquifer can be obtained by multiplying diffusivity by storage. The transmissivity of 450 ft^2/d obtained from the diffusivity and storage values is considered a better estimate than that of 1000 ft^2/d obtained by the modified Theim method. Estimates of transmissivity of the water-table aquifer based on the modified Theim equation $T = \frac{528}{7.48} C_s \log_{10} r_e/r_w$ (Lohman, 1972, p. 12) and using specific capacities, ranges from 250 to 530 ft^2/d for five wells (table 3).

On the basis of available information, the water-table aquifer will probably yield as much as 50 gal/min to properly designed wells. The areas of greatest potential yield are those where saturated sands have the greatest thickness, which likely will be where surficial deposits are underlain by the Black Mingo Formation.

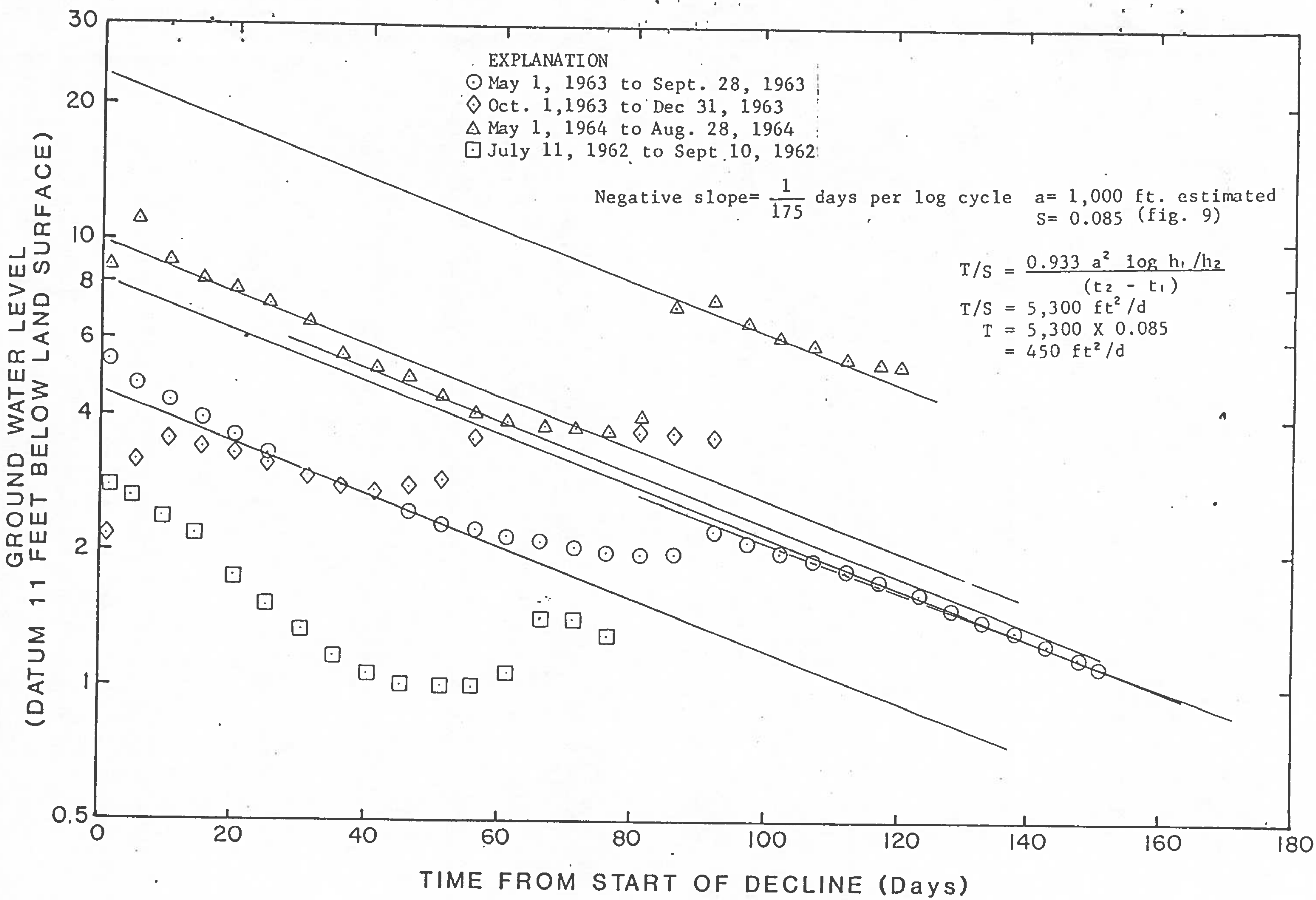

Figure 8. Graph showing use of water-level decline in estimating diffusivity of water-table aquifer at Morris Farm

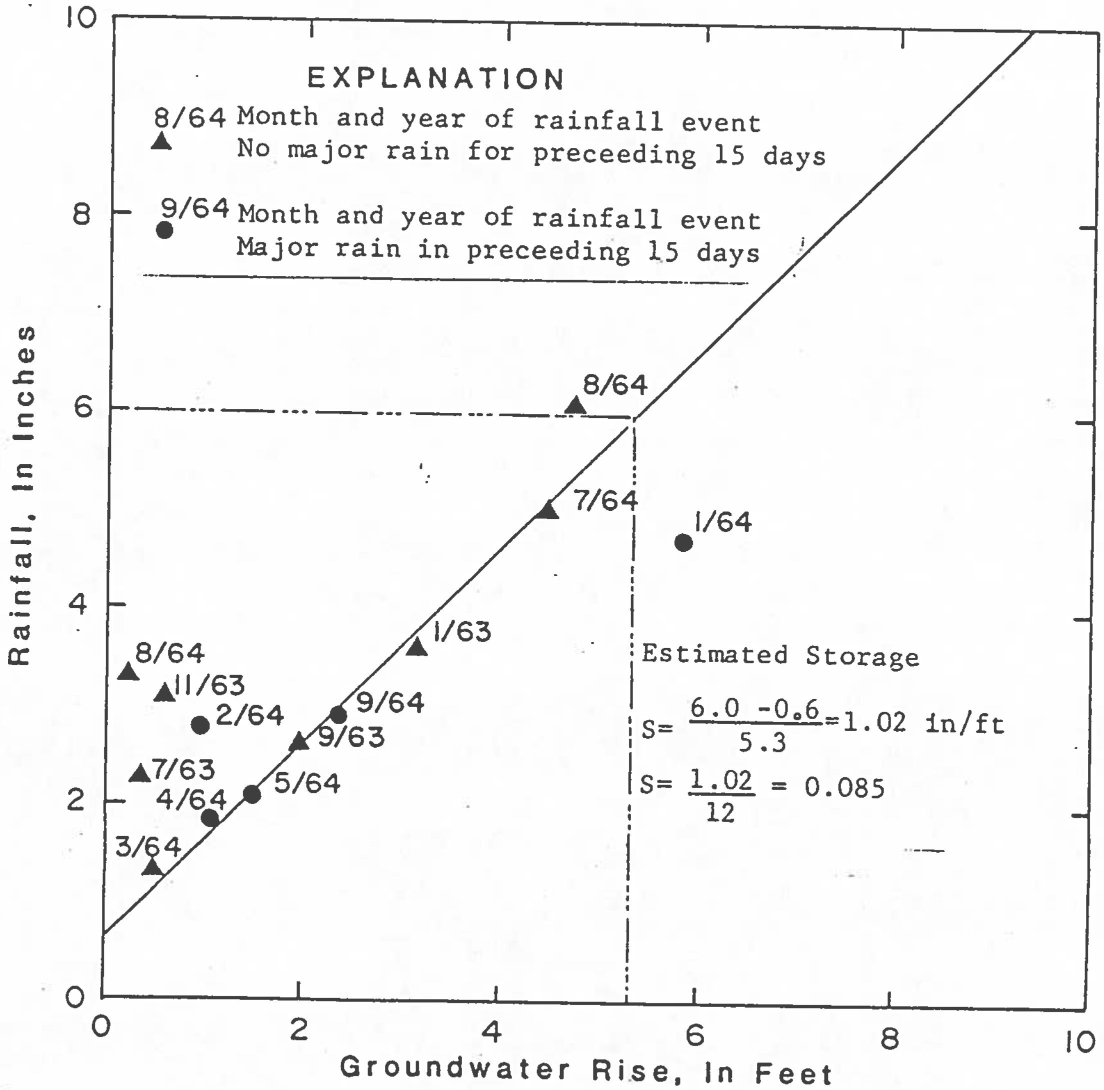

Figure 9. Graph showing relation of rises in ground-water level of water-table aquifer at Morris Farm to rainfall events at Kingstree, 1963-64.

Confined Aquifers

The confined aquifers consist of the Peedee, (except where it is overlain directly by surficial deposits), the Black Creek, and the Middendorf Formations, all of which contain water-bearing sand units under artesian head.

The principal recharge area for the confined aquifers is believed to be in their outcrop areas north and northeast of Clarendon and Williamsburg Counties. The outcrop of the Peedee Formation in northeast Williamsburg County is probably the only major area of recharge to the confined aquifers within the two counties.

Some recharge from the water-table aquifer to the confined aquifer by downward leakage through the confining beds probably occurs in the upland areas where there is a head differential. A hydraulic inter-connection probably exists between water-bearing units in the Peedee and Black Creek Formations. A thick clay unit in the lower part of the Black Creek Formation apparently prevents any major hydraulic interconnection between the underlying Middendorf Formation and the overlying Black Creek Formation.

The hydraulic properties of the confined aquifers have not been determined in Clarendon and Williamsburg Counties. The estimated values that follow are based on a comparison of hydraulic and geologic data from adjacent areas with data obtained in the study area. Hydraulic data available in the study area consists mainly of pumping rates and specific capacities of wells, most of which tap more than one formation.

Siple (1975) estimated the transmissivity of the sands in the Middendorf Formation to average about 20,000 ft^2/d in nearby Orangeburg County. Few wells have been drilled to the upper part of the Middendorf in Clarendon and Williamsburg Counties. The available data indicate that the water-bearing sands may be finer and thinner than they are to the south and probably reflect depositional changes caused by the Cape Fear arch. Data from two wells (table 3) that are assumed to tap the Black Creek and upper part of the Middendorf have estimated transmissivities of 2500 ft^2/d and 5800 ft^2/d. Estimates of transmissivity of the upper part of the Middendorf in Clarendon and Williamsburg Counties range from 1000 to 3000 ft^2/d.

The water-bearing sands of the Black Creek Formation are the principal source of water to wells in the study area. Specific capacities of wells tapping those sands range from 3 to 17 (gal/min)/ft of drawdown (table 3). The wide range in specific capacities probably reflects changes in lithology and hydraulic properties of the aquifers and the depth, diameter, and varying efficiency of the wells.

Figure 10 shows the water-level fluctuation in well WL-30 that taps the Black Creek Formation. The decline in water level starting in May 1972 is caused by the pumping of three wells located 100 to 500 ft from the observation well. The pumping rates of these wells are about 1000 gal/min each. The drawdowns of more than 100 ft in the observation well indicate that possible interference between the pumping wells is taking place (in effect the pumping wells are stealing available drawdown from each other), and that the transmissivity of the water-bearing sands is low.

Estimates of transmissivity of the Black Creek-Peedee Formations given in table 3 range from 900 to 5,000 ft^2/d. The transmissivity of the Black Creek Formation alone will probably range from 1,500 to 4,000 ft^2/d.

Water-bearing sands in the Peedee Formation reportedly are very fine to fine grained, but they are commonly in beds as much as 20 ft thick. The hydraulic conductivity of the sands is likely to be less than those of the Black Creek, but because of this thickness the sand beds might have tranmissivities as great as 2000 ft^2/d. Transmissivities in individual beds will probably average about 1000 ft^2/d.

The transmissivity of the confined aquifers appears to lessen to the east and north. The thinning of the water-bearing sands on the flanks of the Cape Fear arch to the northeast of the study area may be a factor. The general reduction in grain size of the water-bearing sands toward the east, away from their source areas, could also be an important factor.

Development of the Ground-Water Potential

In Clarendon and Williamsburg Counties, only limited well data are available, and the hydrologic and geologic conditions are known in only a few places. However, reasonable correlations of the geology and hydrology can be obtained by using available geophysical logs and other hydrologic and geologic data.

Figures 11, 12, and 13, based on geophysical logs, show tentative correlation of the geologic formations. Although the entire thickness of the formations is saturated, only the more permeable zones, which themselves vary in thickness, will yield significant volumes of water to individual wells.

Yields to wells from the confined aquifers depend upon transmissivity and potentiometric head. Data are not available to determine the potentiometric surface in the area, but it is known that wells, located in the major river valleys, which tap the deeper confined aquifers will flow at the land surface. Thus there is approximately 300 to 350 ft of head within the confined aquifers. Estimates of potential yield to wells by the confined aquifers, therefore, should be judged accordingly in relation to the available head and transmissivity of the water-bearing units.

GEOLOGY

Coastal Plain formations consist of sand, silt, and clay and interlayered limestone. Lithologic changes take place over relatively short distances so that sand may grade into sandy clay, or silt and limestone may grade into marl or clay.

The geologic setting forms the framework for the control, occurrence, and movement of ground water. The size, kind, shape, and assortment of materials forming the sediments and rocks, and the manner and degree in which they have been deformed are the controlling parameters.

Geologic Structure

No surface evidence of geologic structures are present in the area, but seismic profiles by Woolard, Bonini, and Mayer (1957) indicate that the surface of the basement rock is undulating. One major fold in the basement rock occurs outside the report area. This structural high, called the Cape Fear arch, or Carolina ridge, strikes northwest along the North Carolina-South Carolina State line, with the crest of the ridge mostly in North Carolina.

The arch was a major feature in early geologic time controlling the invading seas and the deposition of Coastal Plain sediments in the immediate area. This is indicated by the shallow depth to basement rock, the absence of most sediments of Tertiary age, and the overall thinning of sediments of Cretaceous age, all of which affect the presence, thickness, and hydrologic characteristics of the aquifers along the flanks of the arch.

Inland the effects of the arch are probably minor, although in Williamsburg County, especially in the northeast, it probably contributes to the control and movement of ground water in the Cretaceous aquifers.

Stratigraphy and Water-Bearing Characteristics

The age of the unconsolidated sediments of the Coastal Plain in the study area ranges from Late Cretaceous to Holocene. Precambrian and Paleozoic crystalline and metamorphic rocks form the underlying basement complex which dips coastward from the Fall Line. These rocks are exposed above the Fall Line in the Piedmont province.

The Middendorf Formation of early Late Cretaceous age is the oldest sedimentary formation in the area and is exposed or lies near the surface in a belt 10 to 40 miles wide that crosses the State below the Fall Line. Progressively younger formations crop out in a coastward direction (fig. 4). Figure 4 also shows the surficial geologic formations present in Clarendon and Williamsburg Counties.

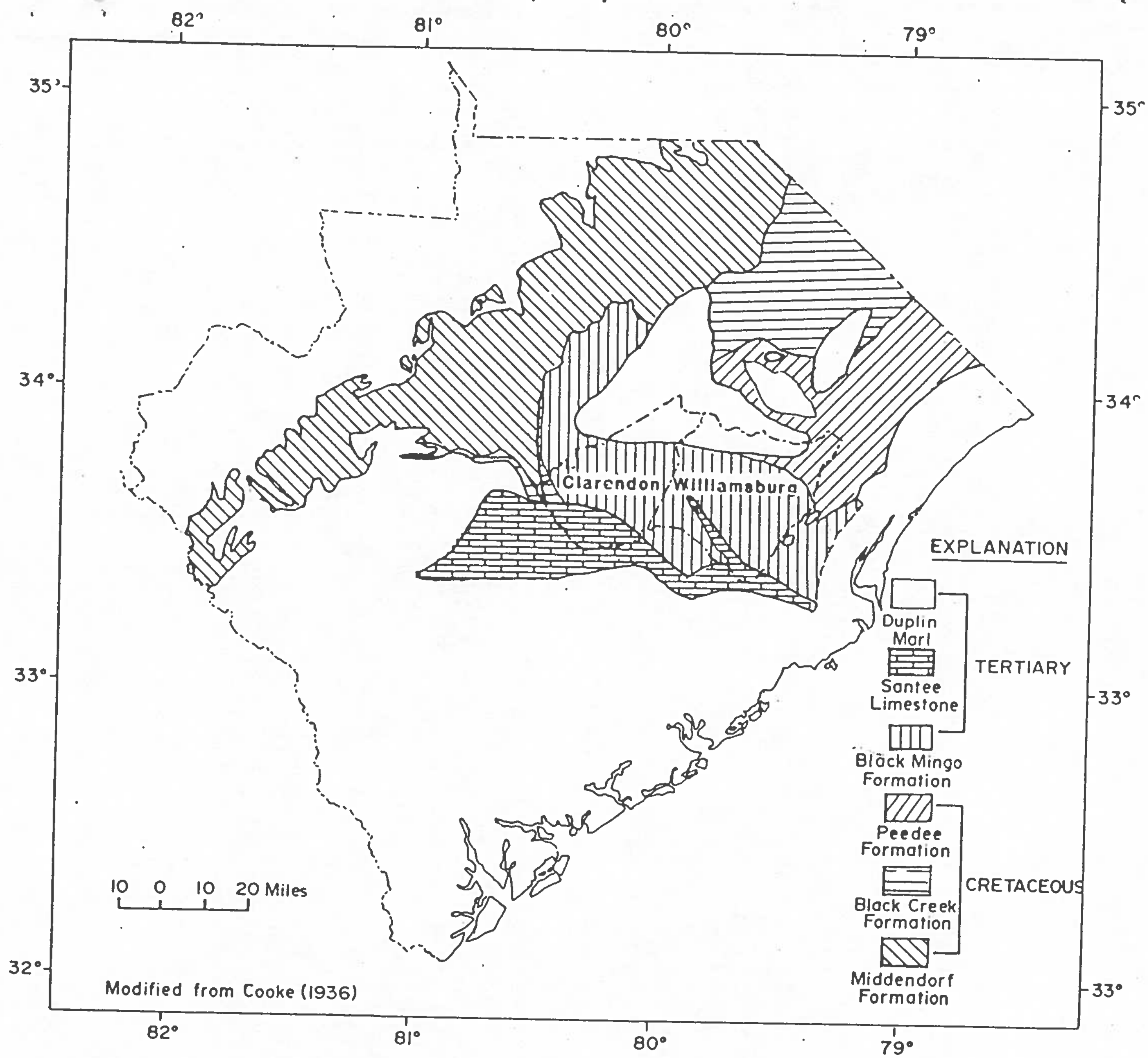

Figure 4. Map showing partial distribution of Coastal Plain geologic formations in relation to Clarendon and Williamsburg Counties.

Where these formations are at or near the surface, they receive precipitation, some of which infiltrates and recharges the aquifer systems. Figure 5 gives the stratigraphic position and the lithologic and water-bearing characteristics of the formations present in the study area.

Cretaceous System

Middendorf Formation--The Middendorf Formation (locally called the "Tuscaloosa Formation") of early Late Cretaceous age is the oldest sedimentary formation in Clarendon and Williamsburg Counties and lies unconformably on the crystalline basement rocks.

The Middendorf Formation consists of loosely consolidated, medium to course-grained sand, interbedded fine gravel, varicolored clays, and some kaolinitic clay. The color of the clays may be red, brown, purple, pink, gray, or white. Drill cuttings and lithologic logs of known Middendorf wells elsewhere in the State indicate that three or four coarse white sand beds, ranging in thickness from 15 to 25 ft are generally prsent throughout the formation. The remainder of the formation consists of sandy clay and dense plastic clay beds. The sand and sandy clay appear to be rather evenly spaced throughout the total thickness. Thick, dense clay beds as much as 100 ft thick generally occupy the top, middle, and the bottom of the formation and form confining units that restrict the vertical movement of ground water between the water-bearing zones.

Very little is known about the Middendorf Formation in the study area, because only a few wells penetrate it.

The deepest test hole known to have been drilled in the two-county area is near Kingstree. It was logged to 1,318 ft. Correlation of this geophysical log with geophysical logs of wells outside the area, where more precise geologic data are availble indicates that the top of the Middendorf lies at a depth of about 1,030 ft. A freshwater sand, about 20 ft thick, lies at the top of the formation and likely is the aquifer for the one or two wells in the area screened below 1,030 ft. The electric log shows a near baseline deflection to the right of the S.P. (Spontaneous Potential) curve below 1,180 ft which can be interpreted as salty water. If this is true, only the top 150 ft of the formation has been flushed, and the freshwater-saltwater interface in the deeper part of the formation lies somewhere to the northwest of Kingstree. The position of the interface in the aquifer also is apparently affected by the south flank of the Cape Fear arch, north of Kingstree, where the lower hydraulic conductivity of the aquifer apparently has retarded flushing of the saltwater.

Interestingly enough, the hole did not reach basement rock. Bonini and Woollard (1960) estimated from gravimetric studies that the top of the basement rock was about 1,300 ft deep. At the present time neither the depth to basement nor the thickness of the Middendorf Formation is known.

System	Series		Formation		Estimated depth (feet)	Lithologic Description	Estimated yield for wells of indicated depths, drawing water from aquifers within the shaded area.	Remarks
Quaternary	Holocene and Pleistocene					Sand, gravel and varied colored clay interbedded with sand and gravel.	0-10 gal/min	Potable water obtained mostly from unconfined aquifers. Supplies small diameter wells used for rural and domestic needs.
Tertiary	Miocene		Duplin Marl		25	Brown buff sand, shell marl; fossils.		
	Eocene	Middle	Santee Limestone		50	Sand interbedded with marl, shell beds and clay in upper part. Soft white-gray-greenish limestone in lower part.		
		Lower	Black Mingo Formation		100			Iron may exceed EPA (Environmental Protection Agency) National Interim Primary Drinking Water Regulations 1975.
	Paleocene				200	Fine yellow to white sand interbedded with sandy clay in upper part. Dark gray to black clay containing some sand in lower part	10-50 gal/min	
Cretaceous	Upper Cretaceous	Uppermost	Peedee Formation		300, 400, 500	Very fine to fine greenish-gray sand and silt interbedded with gray sandy marl or marlstone and dark blue-green marine clay with streaks of sand.	50-150 gal/min	$CaCO_3$ precipitate may occur.
		Middle	Black Creek Formation	Snow Hill Marl Member	600, 700	Fine-to-medium black and white laminated sand interbedded with lenses of calcareous green sand and clay; layers of marl, and calcareous sandstone. Fossil wood present.	150-500 gal/min	Most industrial and municipal wells obtain water from the confined aquifers of the Peedee and Black Creek formations. Iron and fluoride often exceed EPA regulations.
				Lower Member	800, 900, 1000	Black shaly clay with lenses of fine hard calcareous sand or marl layers.		
		Lowermost	Middendorf Formation (Equivalent of the Tuscaloosa Formation)		1100, 1200, 1300	Medium to coarse sand interbedded with gravel, kaolinitic sand and varied colored clay ranging from red to brown, purple to pink, and gray to white.	500-1200 gal/min	Very few wells obtain water from the confined aquifers of the Middendorf Formation. Iron may exceed EPA regulations.
Pre-Cretaceous			Basement Complex			Gneiss or shist.		

Figure 5.-- Stratigraphic sequence of the geologic formations in Clarendon and Williamsburg Counties, with lithologic description and aquifer data.

The few wells in the study area that tap the Middendorf Formation also tap the overlying formations. These wells are reported to yield as much as 1,200 gal/min, about half of which may be from the Middendorf.

Black Creek Formation.--The Black Creek Formation of middle Late Cretaceous age lies unconformably on the Middendorf Formation. On the basis of differences in lithology and the presence of characteristic fauna, the Black Creek Formation was separated by Stephenson in 1923, (Cooke, 1936 p. 26), into two members. The upper unit, the Snow Hill Marl member, consists of fine to medium-grained black and white laminated sand, sometimes called by drillers "pepper sand," interstratified with lenses of calcareous green sand and clay that contain many fossils and some fossil wood.

Black shaly clay containing lenses of fine-grained sand and marl characterizes the lower member (unnamed in South Carolina). The lower member contains more clay than the overlying Snow Hill Marl member and includes interbedded hard calcareous sand or marl layers that may be as much as 5 ft thick. The lower member is not well defined in the sub-surface because of the lack of fossils.

The Black Creek Formation is about 460 ft thick and dips southeastward about 18 to 20 ft/mi. The formation is at or near the land surface north and northeast of the study area, and the outcrop affords a good recharge area to the water-bearing sand beds.

The upper part of the Black Creek Formation, the Snow Hill Marl Member, is the major source of water to many wells in Clarendon and Williamsburg Counties. Water-bearing sand-units in the Black Creek are usually developed in conjunction with water-bearing units in overlying formations. Yields of 150 to 500 gal/min can be obtained from individual wells when the full thickness of the Black Creek and overlying formations are tapped.

Peedee Formation.--The Peedee Formation is the youngest or uppermost formation of Late Cretaceous age in the Coastal Plain of South Carolina. This formation overlies the Black Creek Formation and consists of greenish-gray, very fine-grained, glauconitic sand and silt interbedded with gray sandy marl or marlstone, and dark blue-green marine clay containing streaks of sand. Fossils are scarce but do occur in places. Sand layers are generally from 10 to 20 ft thick but contain much silt or clay. The Peedee Formation is about 230 ft thick. The lithology of the Peedee Formation is so similar to that of the Black Creek Formation that they commonly are considered as one unit. The combined Black Creek-Peedee section is about 690 ft thick.

Wells in the Peedee Formation will yield 50 to 150 gal/min of water. Generally water in this formation is confined, but in the northeast corner of Williamsburg County where the overlying Tertiary sediments are absent, the Peedee Formation is part of the water-table aquifer. Yields of as much as 20 gal/min of water are available to wells in the water-table aquifer in this area.

Tertiary System

Paleocene rocks are reported in the Savannah, Georgia area and are extensive in southwest Georgia and southeast Alabama (Stringfield, 1966 p. 24). In South Carolina these rocks generally are included as part of the Black Mingo Formation of Paleocene and early Eocene age.

Black Mingo Formation.--The Black Mingo Formation directly underlies most of the southern two-thirds of Clarendon and Williamsburg Counties. The lowermost 10 to 20 ft of the formation is dark-gray to black clay containing some sand; the upper part is light colored sandy clay, and interbedded thin yellow to white fine-grained indurated sand. This formation in Clarendon and Williamsburg Counties is between 50 to 140 ft thick.

The sands of the Black Mingo in conjunctino with the surficial Pleistocene-Holocene deposits make up the principal part of the water-table aquifer. This aquifer will yield as much as 20 gal/min to wells. On the basis of hydraulic data obtained at Morris Farm, it is possible that a well in a favorable location would yield as much as 50 gal/min.

Santee Limestone.--The Santee Limestone of Eocene age derives its name from the type locality along the Santee River. The upper part of the Santee Limestone Formation is sand interbedded with green, glauconitic marl, shell beds, and varicolored clay. The lower part consists of soft, white, gray or brownish limestone containing fossils. Extensive solution of the limestone has resulted in karst-type features in the outcrop area.

In the study area the Santee Limestone has a maximum reported thickness of 26 ft (north of Lake Marion at Summerton). It is present only in the southern part of Clarendon County and in a belt about 5 miles wide cutting northwesterly across Williamsburg County (fig. 4).

Shallow domestic wells obtain water from the Santee Limestone. Yields to wells open only to the Santee are probably 10 gal/min or less. In many places, however, the Santee is hydraulically connected to the underlying Black Mingo Formation and wells open to both of these formations probably will produce as much as 20 gal/min.

Duplin Marl.--The Duplin Marl of Pliocene age occurs only in the northern part of the study area where it lies unconformably on sediments of Eocene age or older (fig. 4). This formation contains brown or buff colored sand, shell marl, and some clay. Fossils and phosphatic pebbles occur in places.

The Duplin Marl ranges in thickness from about 0 to 10 ft. Locally in the outcrop area the Duplin apparently is missing.

The clayey Duplin Marl is generally non-water bearing; and where the Duplin is present, the water table aquifer generally is limited to the overlying deposits. The denser stream pattern in the area underlain by the Duplin Marl is an indication that the surficial deposits are thin--likely less than 15 to 20 ft in thickness--and that recharge to the water table aquifer from rainfall probably drains rapidly to the nearby streams.

Quaternary System

Overlying the Tertiary formations is a mantle of marine deposits associated with terraces of Pleistocene and Holocene ages. These mantle deposits are mostly yellowish-red sand containing lenses of dense clay. The average thickness of these sediments is about 30 ft. Cook, (1936 p. 6), shows seven separate terraces ranging from 25 ft to 270 ft in altitude, five of which are present across Clarendon and Williamsburg Counties. Fluctuations of the sea level during glacial and interglacial periods caused the deposition and erosion that resulted in these terraces.

The wide-spread use of the water-table aquifer in rural areas is good evidence of its potential as a source of water to low yield wells for domestic and stock supplies. Estimated yields to wells range from 10 to 50 gal/min dependent primarily on the water-bearing units of the Santee Limestone, Peedee Formation, and Black Mingo Formation underlying the surficial deposits except in areas where the Pleistocene-Holocene deposits are unusually thick.

Where the Pleistocene-Holocene deposits overlie the duplin Marl, yeilds to wells probably will be 5 gal/min or less and wells may go dry during periods of prolonged drought.

HYDROLOGY

Hydrologic Properties

The movement of ground water through the sediments and rocks depends on the size, type, and degree of connection of pore spaces. Intrinsic permeability is a measure of the relative ease with which a porous medium can transmit a fluid under a hydraulic gradient. Another measure of permeability is hydraulic conductivity which "is dependent primarily on the nature of the pore space, the type of fluid occupying it, and the strength of the gravitation field" (Lohman, 1970, p. 10). Primary openings are the natural pore spaces inherent to a rock type and its mode of deposition. Secondary openings are caused by mechanical deformation or chemical reaciton resulting in cracks, fractures, and solution channels.

In clastic sediments, coarse sand and gravel are the best water-producing zones or aquifers. Although fine-grained material, such as silt, clay, or mud, has high porosity, it is relatively impermeable and does not allow water to move freely through it. Limestone that is fine-grained, unfractured, and well cemented has a low primary permeability, but as a result of fracturing and solution may have very high secondary permeability.

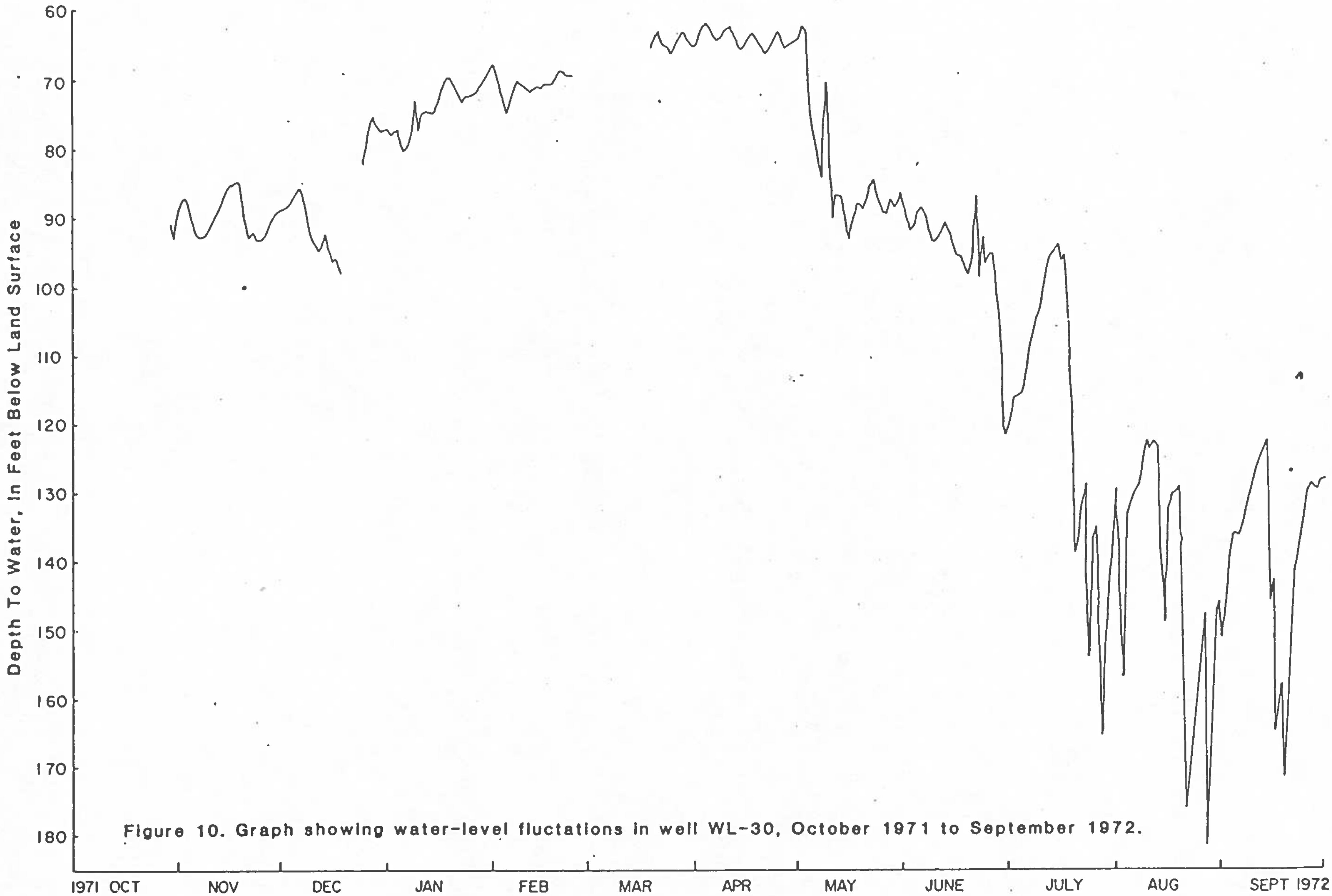

Figure 10. Graph showing water-level fluctations in well WL-30, October 1971 to September 1972.

Table 3.--Specific capacities of wells and estimated transmissivities

Well No.	Aquifer	Depth (ft)	Diameter (inches)	Yield (gal/min)	Drawdown (ft)	Specific capacity (gal/min/ft)	Transmissivity (ft^2/d)
CLA-16	Kbc	618	6	200	13	15.4	4900
CLA-20	Kbc	699	8	752	43.5	17.3	5600
CLA-22	Kbc	321	8	150	18	8.3	2700
CLA-25	Kbc	748	8	525	51.5	10.2	3300
CLA-26	Wt	123	6	65	31	2.1	530
CLA-29	Kbc	768	8	754	49	15.4	5000
WL - 3	Kbc	630	8	1400	160	8.8	2800
WL -11	Kbc	530	6	350	50	7.0	2200
WL -12	Kbc	615	6	350	51	6.8	2200
WL -15	Kbc	673	6	100	6	16.7	5400
WL -17	Kbc	310	8	10	16	.6	190
WL -20	Kbc	509	8	350	95	3.7	1200
WL -21	Kbc	685	6	220	165	1.3	420
WL -26	Kbc	788	8	700	53	13.2	4200
WL -27	Kbc	345	-	100	30	3.3	1100
WL -29	Kmd	1060	12	992	123	8.1	2500
WL -32	Kbc	284	6	120	44	2.7	870
WL -37	Kbc	897	-	743	55	13.5	4300
WL -38	Kmd	1007	12	1200	63	19.0	5800
WL -46	Wt	70	6	50	37	1.4	360
WL -48	Wt	55	6	45	45	1.0	250
WL -49	Wt	70	6	50	32	1.6	400
WL -50	Wt	91	6	45	40	1.1	280

Note: The yield of a well is controlled by geohydrologic properties, well design, and construction, but can be useful to ~~determine estimated~~ estimate minimum transmissivity when accurate drawdown is available.

Only as a minimum. It is dependent on well efficiency

1/ Wt - Water table
Kbc - Black Creek/Peedee
Kmd - Middendorf/Black Creek/Peedee?

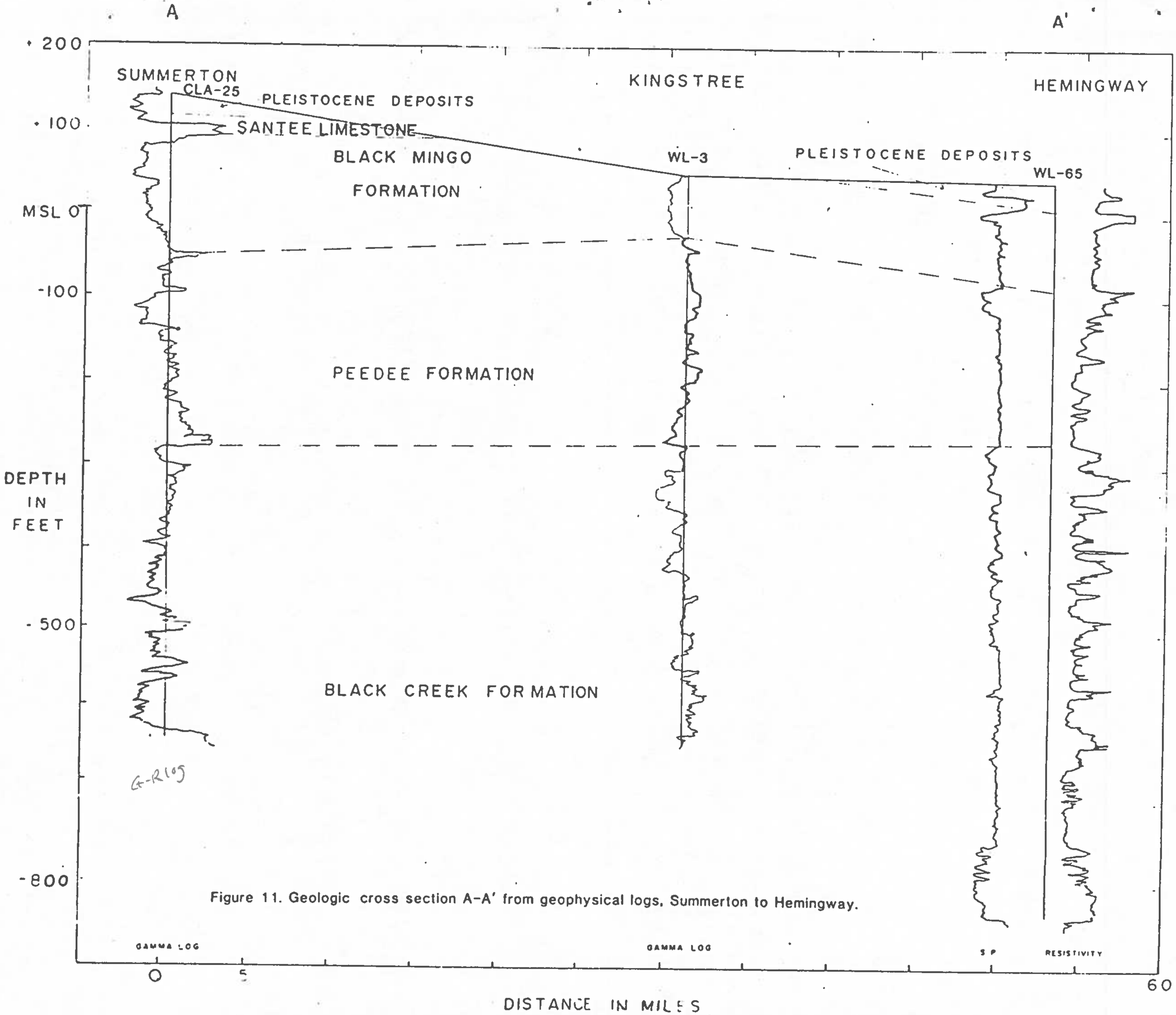

Figure 11. Geologic cross section A-A' from geophysical logs, Summerton to Hemingway.

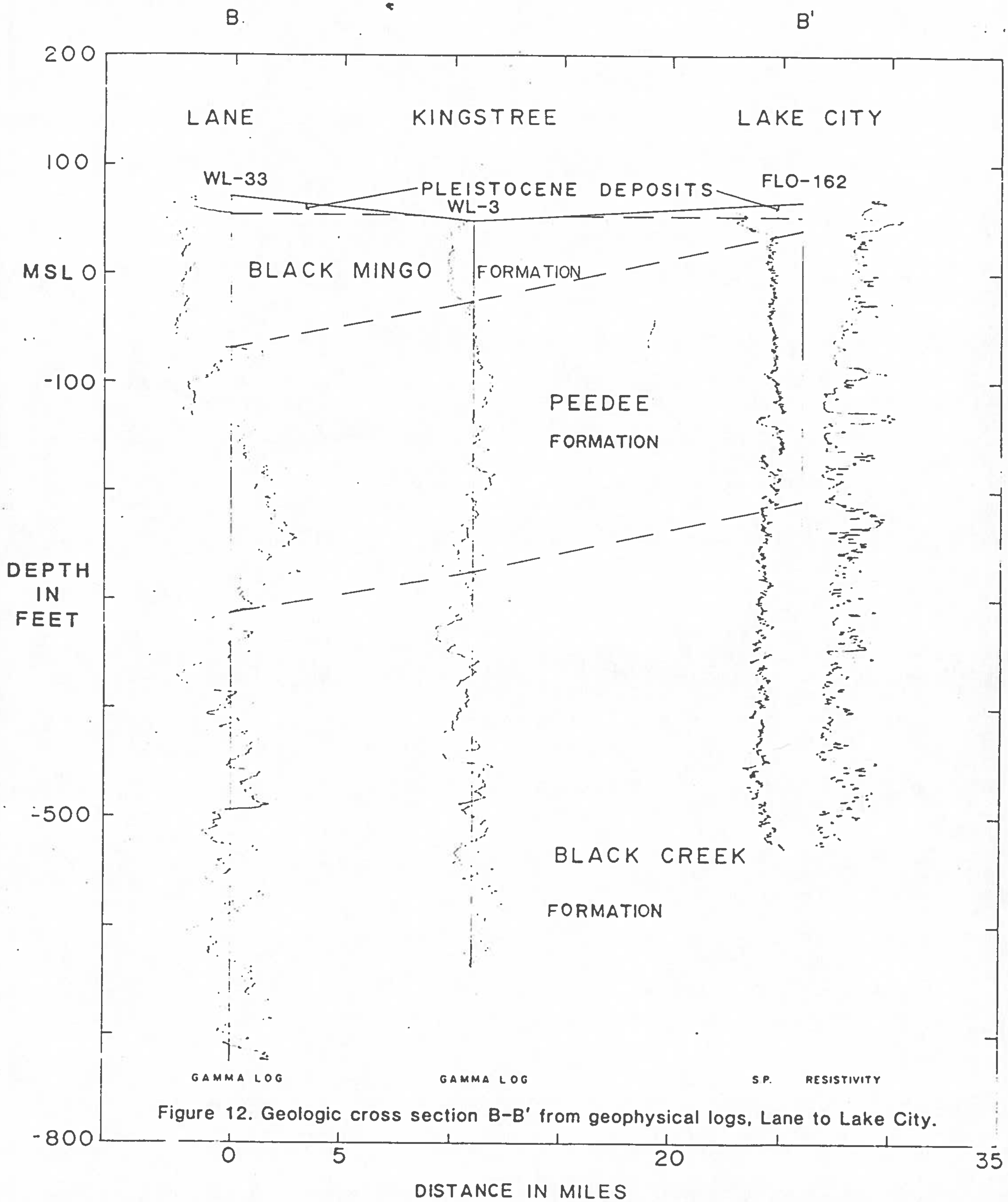

Figure 12. Geologic cross section B-B' from geophysical logs, Lane to Lake City.

Transmissivities of the confined water-bearing sands appear to decrease to the east and north. From this it might be assumed that higher yield wells probably can be obtained in Clarendon County rather than Williamsburg County. Even so, properly designed and constructed wells ranging from 500 ft to more than 1,000 ft deep will probably yield between 300 to 1,000 gal/min anywhere in the study area.

The water-table aquifer should not be overlooked, especially where yields of less than 50 gal/min are desired. Wells tapping the water-table aquifer will be shallow which has an economic advantage. Wilson and Vaigmeur (1962 b) consider irrigation to be feasible by using a series of water-table wells pumped by a common header.

Although the potential for ground-water development is great, there are problems of low yields and well interference. Low yields can be attributed to many causes. Some are inherent with improper drilling and well construction practices, and some are caused by natural geohydrologic conditions. To obtain maximum performance from a well, it is necessary to design, construct, and space it properly with respect to other wells in the area. Geophysical logs can be used to determine the best water-bearing zones. Well screens should be set opposite these zones. Once screens are set, the well must be developed so that drilling mud and fine sand are removed and the screens are open to the water-bearing zones. Pumping tests using observation wells can be useful in determining hydrologic parameters of the aquifer, the well efficency, and the yield of the well.

The cone of depression created around a pumping well reaches out in all directions, assuming there are no nearby ground-water barriers and the aquifer is infinite and homogeneous. The spread of the cone of depression under water-table conditions is slower than if the spread were under artesian conditions. The drawdown generated by the pumped well becomes less with increasing distance from the well. However, if a second well (drilled only a few hundred feet away from the first well) is pumped simultaneously with the first well another cone of depression is formed around the second well. In time these two cones might coalesce, and the drawdown effects from each well then will be additive within the area of mutual influence. As other wells are added and additional cones of depression are superimposed on those already present, greater drawdowns and increased interference between wells result. Where a number of wells are closely spaced the situation can result in a significant dewatering of the aquifer or reduction of artesian pressure (fig. 10), resulting in a loss of production from all the interfering wells. Close spacing of wells has caused localized decreases in production in the report area. The problem can best be avoided by increasing well spacing and by varying well depth to utilize different water-bearing zones.

QUALITY OF WATER

The chemical quality of ground water depends upon the kind and quantity of its dissolved mineral constituents. Rainwater contains some gasses dissolved from the atmosphere and airborne mineral particles and is usually slightly acidic. It is a powerful weathering agent and solvent. As rainwater percolates through the soil and subsoil it dissolves some of the minerals with which it comes into contact. Upon entering the saturated zone, the water continues to move through the aquifer. Additional minerals may be dissolved depending upon the solubility of the material through which the water passes and the length of time it is in contact with the sediments. Ion exchange can also occur where one ion in solution replaces another ion within the crystalline structure of the aquifer material or perhaps forms a mineral precipitate.

In general, the chemical quality of ground water is very consistent year after year at the same site. Within an aquifer, however, the chemical quality of water can, and usually does, change with depth and with distance from the recharge area. The mineral concentration in the water generally increases with increasing distance from the point of recharge and with increasing depth. Figure 14 shows that the concentrations of dissolved solids in the ground-water is generally greater in the eastern part of the study area. This may indicate that recharge occurs predominately in the western part of the study area. Figure 14 also indicates that the concentration of dissolved solids is greater in the interval between 800 to 1,000 ft.

Relation of Water Quality to Source

Of the constituents listed in table 4, iron, chloride, fluoride, and nitrate, together with hardness are of primary inportance in determining the suitability of water for use as domestic and public supplies. The physical properties of color, taste, odor, and temperature are also important but primarily from an aesthetic standpoint. Bacteriological purity, of course, is a requirement for human comsumption.

The concentration of most dissolved mineral constituents in ground water in the study area generally is low. Water from some wells, however, contains more than the recommended limits of iron and fluoride for drinking water (U.S. Environmental Protection Agency 1975).

In concentrations exceeding 300 ug/L (micrograms per liter) iron stains laundry, utensils, and plumbing fixtures. High concentrations are objectionable in water used in food processing, beverages, dying, bleaching, brewing, and ice making.

LOCAL IDENTIFIER	TOTAL DEPTH OF WELL (ft)	DATE OF SAMPLE	SAMPLING DEPTH (ft)	DIS-SOLVED SILICA (SiO_2) (mg/L)	TOTAL IRON (FE) (ug/L)	DIS-SOLVED CALCIUM (CA) (mg/L)	DIS-SOLVED MAGNESIUM (MG) (mg/L)	DIS-SOLVED SODIUM (NA) (mg/L)	DIS-SOLVED POTASSIUM (K) (mg/L)	DIS-SOLVED CHLORIDE (CL) (mg/L)	DIS-SOLVED SULFATE (SO_4) (mg/L)	DIS-SOLVED FLUORIDE (F) (mg/L)	DIS-SOLVED NITRATE (NO_3) (mg/L)	BICARBONATE (HCO_3) (mg/L)	PH (UNITS)	TOTAL HARDNESS AS ($CaCO_3$) (mg/L)	DIS-SOLVED SOLIDS (RESIDUE AT 180°C) (mg/L)
CLA-14 SUMMERTON, PS	625	56-10-08	--	12	130	3.7	.2	52	1.9	1.5	7.0	.6	.50	135	7.5	10	144
CLA-15 SUMMERTON, PS	650	56-10-08	--	12	140	3.0	.2	54	2.2	4.0	8.5	.6	.20	137	7.2	8	147
CLA-17 NR SUM-CLA BDR, STK	350	57-09-27	--	36	200	12	3.5	4.6	10	3.0	5.1	.1	.50	68	7.1	44	107
CLA-19 TURBEVILLE, #1, PS	321	59-03-25	--	34	120	7.2	.5	20	4.8	.7	6.0	.2	.20	73	7.9	20	108
CLA- 2 MANNING, PS	485	55-01-17	--	27	10	4.6	1.1	38	3.6	8.0	8.6	.5	2.1	95	7.3	16	138
CLA-25 SUMMERTON, PS	750	70-07-24	--	--	20	2.8	.0	--	--	4.0	1.0	--	--	114	8.9	-	160
CLA- 3 MANNING, PS	700	55-01-17	500	11	130	2.6	.6	33	2.0	2.8	8.1	.4	.50	83	7.5	9	102
WL -11 KINGSTREE, PS	530	52-08-29	--	24	110	2.2	.3	--	--	3.1	7.5	.8	.10	150	8.6	7	208
	530	55-01-17	--	24	120	1.6	.2	77	3.0	3.5	8.3	1.5	.00	168	8.3	5	210
WL -12 KINGSTREE, PS	520	52-08-29	--	30	1800	3.0	.4	--	--	3.4	7.6	.8	.30	172	8.4	9	211
	520	55-01-17	--	22	80	1.6	.4	74	2.8	3.0	7.7	1.9	.90	147	8.7	6	207
WL -14 SW OF LANE, D	660	69-04-29	--	13	180	1.5	.3	91	3.2	3.3	7.2	2.2	.20	219	8.5	5	251
WL -18 HEMINGWAY, PS	545	59-03-26	--	24	70	2.8	.5	101	4.2	4.5	4.2	1.6	.30	205	9.1	10	277
WL - 2 HEMINGWAY, PS	456	59-03-26	--	14	250	8.4	3.6	162	12	31	23	1.0	.50	383	8.6	36	470
WL -20 KINGSTREE, PS	509	55-09-02	--	25	300	1.2	.2	69	3.0	4.5	5.8	1.4	.40	164	8.7	4	203
WL -23 SW OF KINGSTREE, D	12	57-09-06	--	--	-	14	--	--	--	41	21	--	2.1	26	6.2	42	--
WL -25 KINGSTREE, BAXTER, IND	670	60-08-31	--	21	480	3.4	.4	72	2.8	15	9.5	1.8	.00	160	8.4	11	216
WL -26 KINGSTREE, BAXTER, IND	735	67-05-02	--	16	60	2.7	.3	78	2.4	10	11	.8	--	181	7.9	8	210
WL - 3 KINGSTREE, PS	630	46-03-15	--	--	500	--	--	--	--	5.0	7.0	1.8	.20	183	--	12	--
	630	55-01-17	--	--	590	2.1	.2	89	2.6	4.2	7.2	2.9	.90	187	8.8	6	237
WL -31 WILLIAMS POND, D	972	69-05-13	--	15	130	1.0	.1	75	1.5	5.2	11	.8	.10	173	9.1	3	202
WL -33 LANE, PS	790	69-05-05	--	14	50	1.8	.2	82	2.7	3.8	13	2.1	.10	197	8.8	6	219
WL -39 KINGSTREE, BAXTER 4, IND	964	69-11-05	300	2.8	1500	4.2	.4	75	4.3	18	7.6	1.6	.00	167	8.0	12	206
	964	69-11-05	388	18	2300	3.6	.3	57	4.2	4.9	10	1.2	.60	151	7.4	10	177
	964	69-11-05	729	35	540	20	11	360	18	286	127	.7	.00	417	7.6	95	1060
WL -52 N OF BRYANS XRDS, D	450	69-05-13	--	17	90	30	4.5	32	5.4	6.5	9.4	.4	.40	184	7.9	92	176
WL -54 OUTLAND, D	325	69-02-12	--	26	60	1.5	.4	150	8.3	1.0	7.2	2.3	.10	330	8.5	5	399
WL -61 KINGSTREE, STADIUM, PS	706	69-08-25	--	19	430	5.0	.3	84	3.9	9.3	9.8	1.1	.10	190	7.8	14	251
WL -64 GREELEYVILLE, PS	350	70-10-30	--	4.0	40	3.0	.0	64	4.4	3.0	.4	1.5	.70	175	8.9	8	158
WL -65 HEMINGWAY, PS	891	70-10-12	--	.8	0	2.4	.0	151	2.7	31	5.2	2.0	.50	350	8.0	6	371
WL -66 KINGSTREE, BAXTER 2, IND	740	70-01-14	675	15	4600	2.3	.3	60	2.9	3.9	6.8	.9	--	158	8.5	6	188
	740	70-01-14	300	24	4600	3.1	.8	69	7.3	5.0	5.2	1.0	.30	196	8.2	11	214
BLACK RIVER AT KINGSTREE		64-06-21	--	6.5	70	3.5	.4	6.3	.9	8.0	1.6	0.1	.40	14	6.4	10	62
GEO-28 ANDREWS, PS	901	55-03-01	--	12	50	2.8	.7	158	4.2	13	5.0	1.9	.00	359	8.7	10	396
	901	58-05-28	--	--	80	--	--	--	--	15	--	--	2.2	404	8.2	--	--
GEO-38 NR ANDREWS, TEX, IND	53	65-03-17		16	4100	74	14	7.6	1.0	12	2.0	.1	.10	288	7.7	240	278
GEO-39 ANDREWS, PS	800	65-05-26	--	14	170	3.4	.3	139	3.6	5.0	.4	1.5	.20	351	8.3	10	365
	800	65-07-29		--	380	1.6	.2	127	4.8	6.5	3.4	2.2	.20	306	9.0	6	328
	800	65-12-30		14	0	1.4	1.0	139	3.0	7.0	.6	1.8	.10	367	8.3	9	359

USE OF WELL

PS - Public Supply
STK - Stock
IND - Industrial
D - Domestic

UNITS OF MEASURE

FT - Feet
ug/L - Micrograms per liter
mg/L - Milligrams per liter

TABLE 4 -- Chemical analyses of ground water from selected wells in Clarendon, Williamsburg, and Georgetown Counties and the Black River at Kingstree.

As shown in figure 15 there seems to be no relationship between the iron concentration in water and the well depth. The iron concentration in the ground-water varies considerably through the area, (fig. 16) and in the artesian aquifers it is probably related to concentrations of iron minerals associated with the water-bearing units when they were deposited.

Flouride in natural waters usually occurs in very low concentrations. High concentrations of fluoride are found in water from some of the aquifers of the Coastal Plain, and in particular the Black Creek Formation. In general, fluoride concentrations increase in the direction of the coast (fig. 16, table 4). Analyses from Clarendon County show the water is low in fluoride with concentrations of less than 0.6 mg/L (milligrams per liter). Fluoride concentrations in Williamsburg County, however, range from a low 0.4 mg/L to as much as 2.9 mg/L (table 4) and show a general increase in an easterly direction (fig. 16). Zack 1977 believes that the high fluoride concentration in water from the Black Creek Formation is derived from fluoride-bearing minerals present in hard sandstone layers that are interbedded with the water-bearing sands.

Acting under recent Federal legislation, such as the Federal Water Pollution Act (as amended) and the Safe Drinking Water Act 1974; the Environmental Protection Agency has published the National Interium Primary Drinking Water Regulations (EPA, 1975) and also the Secondary Drinking Water Regulations which became effective July 1, 1977. The following letter sets forth the maximum fluoride concentration for the coastal area of South Carolina.

> Based on present Environmental Protection Agency guidance, the Water Supply Division of the South Carolina Department of Health and Environmental Control anticipates the MCL (maximum concentration limit) for fluoride concentrations in public water supplies to be 1.6 mg/l for the coastal areas of South Carolina. Based on an annual average maximum daily air temperature of 73° to 75°F (22.7° to 23.8°C) -----(Shaw, 1976, written communication).

No concentration limit has been established for the study area; but considering the slight difference that may exist between the annual average maximum daily air temperature in Clarendon and Williamsburg Counties and the coastal areas, it is likely that 1.6 mg/L MCL for fluoride would apply to the study area also.

Nitrate usually occurs in ground-water in low concentrations. Common sources of nitrate are fertilizers, plants, and animal wastes. consequently, high concentrations of nitrate may be an indication of possible contamination. Water containing more than 45 mg/L of nitrate (10 mg/L nitrate as nitrogen) may cause methemoglobinemia (blue baby syndrome) if fed to infants or young animals and may cause digestive disorders in adults. The nitrate concentration in ground-wter sampled in Clarendon and Williamsburg Counties was generally less than 1 mg/L. The greatest nitrate concentration found was 2.1 mg/L from two wells.

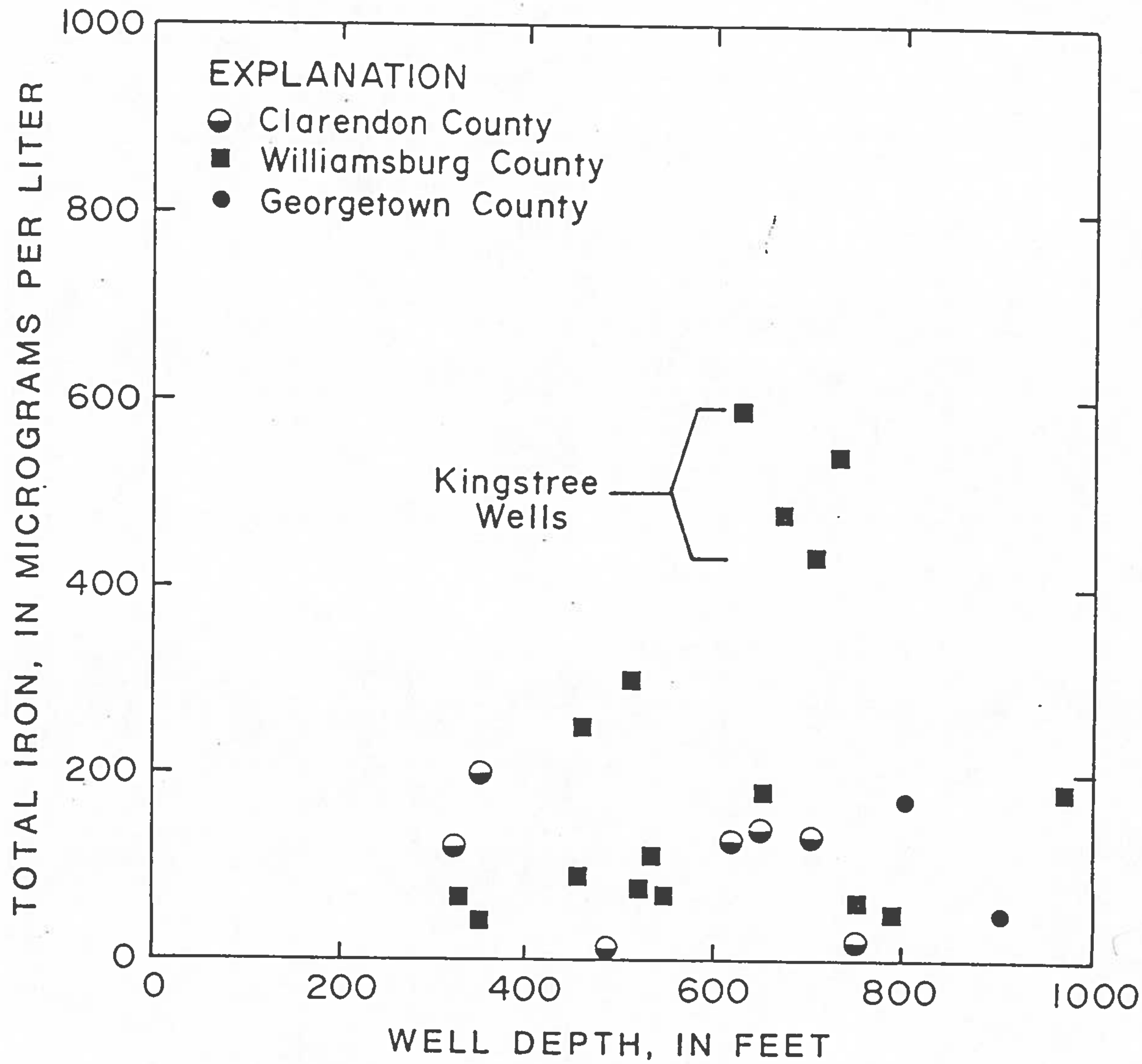

Figure 15. Graph showing relation of total iron concentration to well depth.

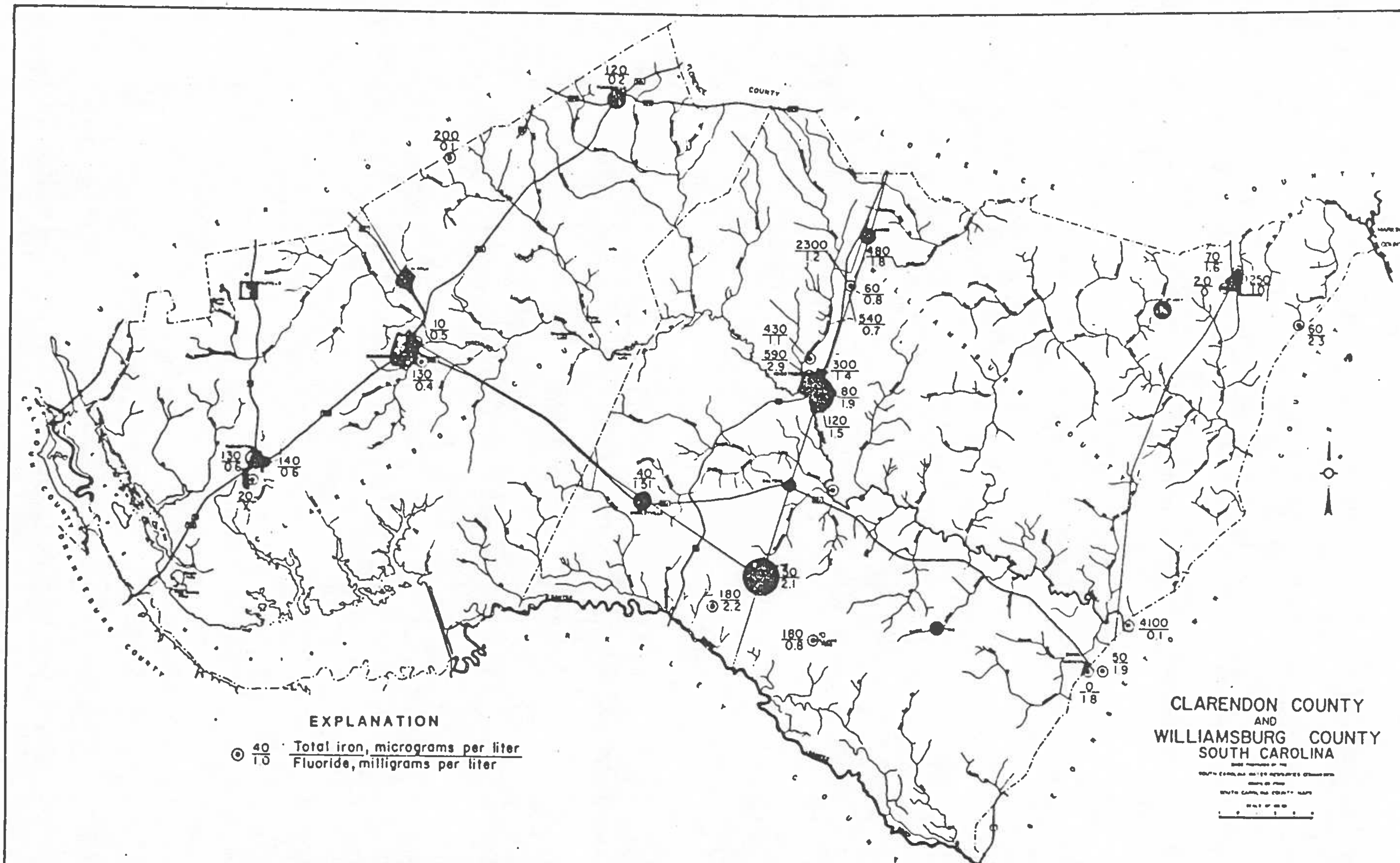

Figure 16. Map showing total iron and fluoride concentrations in ground water

Chloride in small concentrations is dissolved from many types of rock and occurs in water from most aquifers. In high concentrations it is usually associated with sediments containing evaporites. Chloride can also occur in relatively high concentrations in ground water as a result of infiltration of sewage effluent. In the coastal areas high cloride concentration can result from trapped conate seawater being present in the aquifer and from seawater encroachment. Water from the aquifers that are generally tapped for water supply in Clarendon and Williamsburg Counties usually contains less than 15 mg/L chloride. There are indications, however, that some of the deeper Cretaceous aquifers, especially in eastern Williamsburg County, may contain some diluted residual seawater (conate water) as shown in well WL-39 (table 4).

Zack (1977) reported that all the water in the Middendorf Formation in Horry and Georgetown Counties contains high concentrations of chloride making the water impotable. Because of a lack of data he was unable to locate the position of the freshwater-saltwater interface. It now seems that the Middendorf Formation may not become completely fresh for 30 to 40 miles inland from the Georgetown-Williamsburg County line, but that the uppermost water-bearing unit may contain water of low chloride concentration in most of the study area.

Hardness of ground water in the report area is caused almost exclusively by the presence of calcium and magnesium in solution. The Geological Survey classifies hardness according to the following table, in units of calcium carbonate.

Hardness range (mg/L as $CaCO_3$)	Description
0 - 60	Soft
61 - 120	Moderately Hard
121 - 180	Hard
More than 180	Very Hard

The ground water in Clarendon and Williamsburg Counties is generally soft (table 4). A few water analyses given in table 4 (wells CLA-17,WL-23, and WL-52) are in the high part of the soft range or in the moderately hard classification. These wells probably obtain water from the Black Creek Formation or overlying formations that locally contain beds of limestone or marl which are a source of calcium and magnesium.

Water circulating through an aquifer system commonly contains distinctive constituent concentrations that can be identified as typical or representative of a particular aquifer or a particular unit. Relative concentrations of chemical constituents can be compared by converting the constituent concentrations from milligrams per liter to millequivalents per liter. Figure 17 shows modified Stiff diagrams (Stiff, 1951) that illustrate the relationships between the major cations and anions present in water from the study area. As the cations and anions in an analyses did not always balance, the percentage of the cations and anions were calculated in relation to the other cations and anions in the analysis respectively.

A diagram of the dominate ions in the water at Black River at Kingstree during low flow (170 ft^3/s) and the reconstructed diagram for well WL-23 are assumed to be representative of water from the shallow water-table aquifer. The diagrams are also assumed to be representative of the water that infiltrates the deeper aquifers is their recharge areas.

The most common diagram patterns are for water from the water-bearing units in the Black Creek Formation and overlying formations. The predominate ions in the water are sodium and bicarbonate. The higher dissolved solids concentration over that of water in the water-table aquifer indicates that an increase in mineralization has resulted from the dissolution of the host rocks. In this water, however, there also appears to be a slight reduction in calcium and magnesium from that of the water-table aquifer, and a major reduction from that of the wells (CLA-17 and WL-52) that apparently are tapping limestone or marl beds. It is possible that some ion exchange has occurred in the Black Creek and overlying formations, probably in the clays where calcium and magnesium were exchanged for sodium.

Well WL-39 was sampled at three different depths (table 4). The diagrams in figure 17 show that the quality of water from the 300 and 388 foot depths is essentially the same. The water from the 729 foot depth is considerably more mineralized and shows some differences: a large percentage increase in chloride, and a smaller increase in the percentage of calcium and magnesium with corresponding reductions in the percentage of sodium and bicarbonate. The increased mineralization, particularly the increase in chloride concentration, is attributed to sea-water trapped at some earlier time in the geologic history of the aquifer but not greatly diluted by the flushing action of freshwater moving into and through the water-bearing sands.

In Clarendon and Williamsburg Counties as well as in the surrounding counties, especially to the north and east, water from some wells has a milky or cloudy appearance that is difficult to clear even with prolonged pumping. One well was abandoned because it would not produce clear water, while another well has to be pumped for 30 to 40 minutes each time it is used in order to clear the water. In other wells after months of constant pumping, the water has cleared sufficiently to be used.

The milky appearance of the water is caused by a colloidal suspension of aragonite (calcium carbonate, $CaCO_3$) which was identified by a spectrographic test. Possibly high bicarbonate content, high pH, and high artesian pressure leads to the formation of a precipitate caused by a decrease in pressure and a consequent "escape" of carbon dioxide (Hem, 1959, p. 218). However, recent work by Zack (1977, oral comm.) indicates the precipitate may be related to the presences of high silica and low magnesium.

The particular zone that the cloudy water comes from has not been determined, because the wells are multiscreened. Possibly the water comes from the late Cretaceous Peedee Formation in the interval between 300 and 500 ft below land surface.

Some of the problems mentioned can be avoided if test drilling is done, and the zones of poorer quality water are identified and cased off. Although selection of producing zones with good quality of water can improve water quality, elimination of the zones yielding poorer quality water would result in lower yield. This may require drilling a second well, but the reduced treatment costs and the probable total increase in quantity of water from two wells yielding good quality water could compensate for the additional cost of the second well.

WATER-MANAGEMENT CONSIDERATIONS

Appraisal of the water resources is an important step in estimating the potential for growth and development of any area. The concept that surface water, because it can be seen and measured, is always a ready, cheap, and plentiful source must be put into its proper perspective. Surface water cannot serve all areas economically nor is it an unfailing supply. For example, Stallings (1967) showed that the Black River at Kingstree goes dry during periods of drought.

In the Clarendon-Williamsburg County area, ground water is the only dependable source of water supply. Therefore, the future economy of the area will rely on ground water.

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