THE GROUND-WATER RESOURCES OF CHARLESTON, BERKELEY, AND DORCHESTER COUNTIES SOUTH CAROLINA

STATE OF SOUTH CAROLINA

WATER RESOURCES COMMISSION
REPORT NUMBER 139

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by
A. Drennan Park

Prepared in cooperation with the
United States Geological Survey
and the
Coastal Plains Regional Commission

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THE GROUND-WATER RESOURCES OF CHARLESTON, BERKELEY, AND DORCHESTER COUNTIES, SOUTH CAROLINA.

A. Drennan Park

ABSTRACT

Ground water of good quality exists in most of Charleston, Berkeley, and Dorchester Counties. This ground water is obtained from aquifers in the Middendorf, Black Creek, Peedee, and Black Mingo Formations, the Santee Limestone, and shallow sand and shell beds of Miocene to Pleistocene age. The Late Cretaceous Middendorf, Black Creek, and Peedee Formations contain the thickest and most extensive water-bearing units. Wells screened in the Middendorf Formation typically produce more than 1,000 gallons per minute, whereas wells screened in the overlying Black Creek or Peedee Formations usually produce less than 1,000 gallons per minute.

Sand beds of the Paleocene-Eocene Black Mingo Formation and permeable zones within the Santee Limestone are the most widely developed artesian aquifers. Aquifers in the two formations are tapped by open-hole wells that yield as much as 500 gallons per minute, the same well commonly penetrating, and thus to a limited degree connecting, the formations.

Pleistocene terrace deposits supply sufficient water for domestic purposes and are relied on by a number of public water utilities on the coastal islands. The shallow aquifers are thickest and most productive near the coast, thinnest and least productive in central Dorchester and Berkeley Counties.

The chemical quality of ground water varies considerably with locality and depth. The Cretaceous formations contain a soft, alkaline, sodium bicarbonate type of water, and fluoride concentrations typically exceed the 1.6 mg/L maximum recommended by the U.S. Environmental Protection Agency.

Water from the Black Mingo Formation is also of the sodium bicarbonate type and is characteristically high in fluoride and dissolved silica. Water from the Santee Limestone is hard to moderately hard and of a calcium bicarbonate type. Open-hole wells that tap both the Black Mingo Formation and Santee Limestone generally produce water with a chemistry reflecting that of the lowermost aquifer penetrated, indicating the higher productivity of the Black Mingo aquifers.

Shallow aquifers contain water that is low in dissolved solids but locally hard and high in iron.

Substantial water-level declines have occurred in the Black Creek aquifers at Mt. Pleasant and in the Santee Limestone and Black Mingo aquifers in the central part of the study area and at Charleston. Although a partial water-level recovery has occurred in the Black Mingo Formation and Santee Limestone at Charleston, the declines are expected to continue as the area's population and economy expand.

Saltwater intrusion may be occurring in the Black Creek Formation at Mt. Pleasant, and increased chloride concentrations have been recorded in the Santee Limestone and Black Mingo Formation in the vicinity of Charleston. Contamination has also occurred in southern Charleston County, where open-hole wells have permitted interchange between saltwater and freshwater aquifers of the Santee Limestone and Black Mingo Formation.

INTRODUCTION

Charleston, Berkeley, and Dorchester Counties, referred to collectively as the Trident Area, have experienced a rapid expansion of population and industry. The population of the area increased 27.9 percent between 1970 and 1980, with Berkeley and Dorchester Counties increasing 68.6 and 82.1 percent, respectively. Current projections indicate that the population of the area will increase by more than 50 percent by 2000, with the population of Berkeley and Dorchester Counties increasing 99 and 120 percent, respectively. These projections portend a significant increase in water use and emphasize the need for a better understanding of the region's water resources. Ground water supplies have been greatly affected, and, in certain areas, the availability of ground water is threatened by unregulated development of the resource. Furthermore, although ground water is abundant in the area, it is locally unacceptable for many uses. With these problems in mind, the South Carolina Water Resources Commission (SCWRC), with funding from the Coastal Plains Regional Commission, and in cooperation with the U.S. Geological Survey (USGS), embarked on a reconnaissance-level study of the region's ground water resource.

Purpose and Scope

The objectives of the study were to:

1. Map the principal water-bearing units and confining beds in the area.
2. Determine the chemical quality of ground water in each unit and identify sources of potable water.
3. Ascertain the relationships among recharge, pumpage, and water-level changes.
4. Establish a water-level monitoring network for the principal aquifers.
5. Establish a water-quality monitoring network.
6. Assemble sufficient data to predict the availability of ground water on a local, "site-specific", scale.
7. Identify factors that would impede ground-water development or threaten the viability of ground water as a source of water supply.
8. Identify areas where more comprehensive investigations are needed.

THE STUDY AREA: BERKELEY, CHARLESTON, AND DORCHESTER COUNTIES, SOUTH CAROLINA

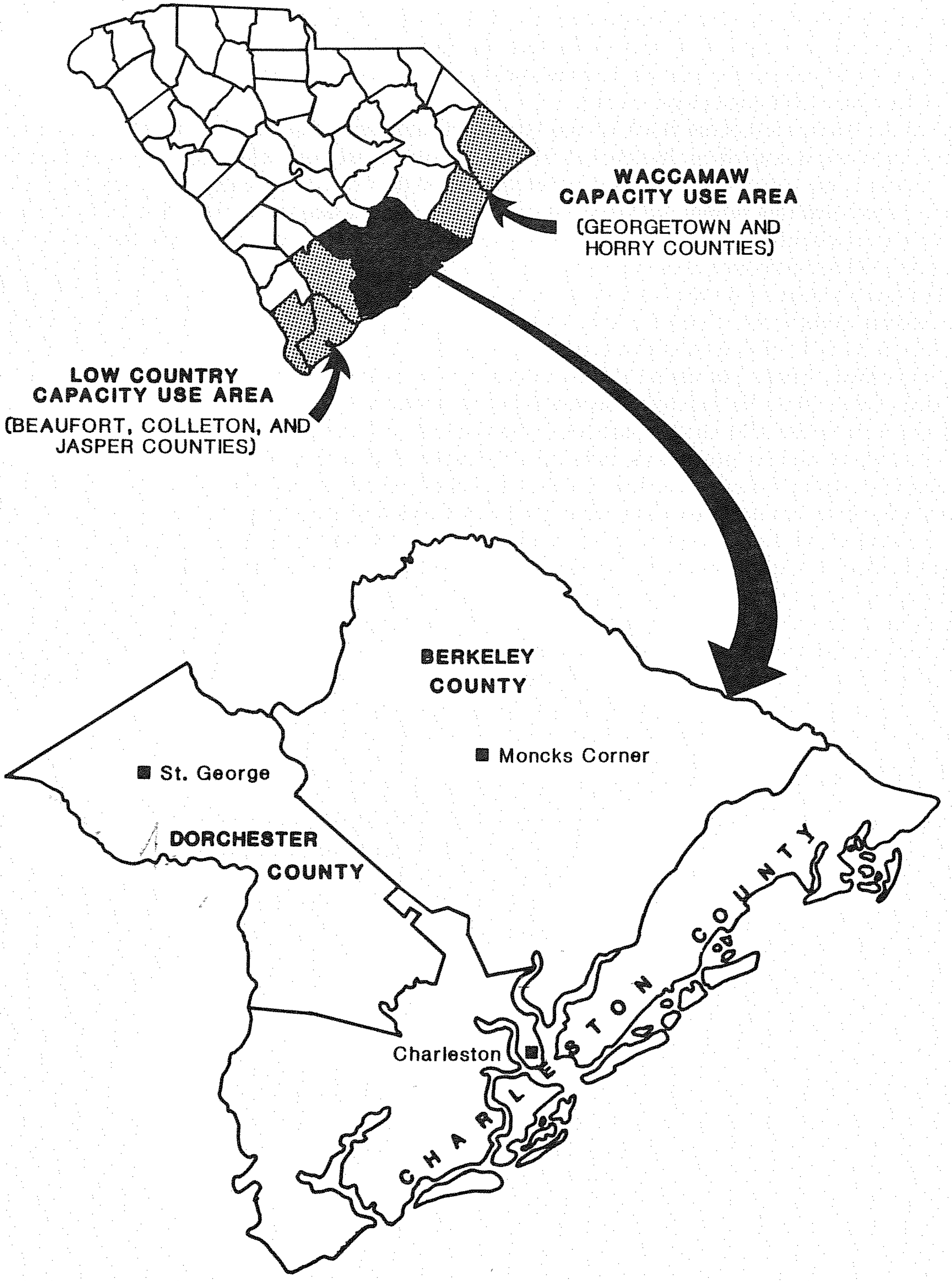


Figure 1. Location of Charleston, Berkeley, and Dorchester Counties, S.C.

Data Collection

Except in the Waccamaw and Low-Country Capacity Use Areas (Ground-Water Management Districts) (Fig. 1), owners of wells in South Carolina, other than public suppliers, have not been required to submit information on well construction and location or well-water quality. Consequently, most of the subsurface data assembled for this report were obtained from individual well owners and their respective contractors. Approximately 1,100 wells were inventoried in the field, and general locations, construction data, and drilling logs were obtained from about 700 additional wells. Although funds for test drilling were not included in the project, geological data were obtained from some 400 holes augered or drilled by the South Carolina Geological Survey and the U.S. Geological Survey since 1962. Drill cuttings were obtained for the six private deep wells (1,200 to 2,000 feet) drilled during the course of the project; and cuttings and cores were collected by USGS personnel at three test holes near Clubhouse Crossroads during 1975 and 1976 and at St. George in 1982. A number of those test holes penetrated consolidated pre-Cretaceous rocks. G.S. Gohn (USGS) shared his interpretation of the data collected from test holes drilled near Summerville, Goose Creek, and Charleston.

Geophysical logs for 240 wells were obtained and were greatly relied upon for the construction of hydrologic sections, isopach maps, and structure maps. The correlation of the Cretaceous strata mainly depended on electrical logs that could be keyed to the USGS test hole at Clubhouse Crossroads. Natural gamma-ray logs proved to be the best tools for correlating Tertiary strata that contained phosphate and glauconite. Both of those materials emit greater amounts of gamma radiation than do clay, sand, and pure limestone. Neutron porosity and gamma-gamma density logs have but recently become available to the author. However, they appear to be useful for checking gamma-ray log correlations and may be better suited for identifying the top of the Black Mingo Formation and members within the Cooper Formation than are gamma-ray logs.

Water-level data were collected on both a periodic and a continuous basis. One hundred and thirty-six wells open to the Santee Limestone were measured periodically in order to construct water level maps; a map representing the January 1982 water levels is included in this report. The South Carolina Land Resources Commission provided data for an additional 26 wells that monitored water levels monthly at a limestone quarry near Jamestown. Automatic water-level recorders were maintained at 13 wells on behalf of the project, while another 13 recorders were maintained in the St. Stephen area as part of a cooperative project between the USGS and the U.S. Army Corps of Engineers.

Interpreting ground-water quality was a particularly important aspect of the study, and much time and effort were devoted to the collection of samples and chemical analyses. More than 400 analyses, representing about 300 wells, were compiled and tabulated. Most samples were analyzed by the SCWRC laboratory in Columbia. Other analyses were obtained through the USGS laboratory (Atlanta), the South Carolina Department of Health and Environmental Control, and various commercial laboratories.

Parameters such as pH, alkalinity, and temperature were usually determined at the time a sample was collected. Samples collected for analysis by the USGS and SCWRC laboratories usually consisted of filtered (40-micron) and unfiltered components to differentiate between dissolved and total concentrations of various constituents. Samples to be analyzed for trace metals were acidified with nitric acid to retard oxidation and precipitation. Graphical comparisons of water quality are presented by the methods of Piper (1944, 1953) and Stiff (1951).

Previous Investigations

Many reports addressing the geology of the area, either in part or in whole, have been published since the early nineteenth century; Vanuxem (1826, 1829) Ruffin (1843), and Lyell (1845) being among the earlier of these. An extensive phosphate mining industry developed in the Charleston area during the late 1800's and early 1900's; until it was supplanted by the richer phosphate mines of central Florida. During that period, reports by Homes (1870), Chazal (1904), and numerous others were devoted to the geology and development of the phosphate district. Malde (1959) later published a more comprehensive report on the phosphate area, which described the lithology and paleontology of Oligocene and younger units and included a structure map for the Cooper Marl (Formation), a geologic map of the Ladson quadrangle, a number of sections, and an extensive list of references.

Cretaceous formations are not exposed in the area, hence most attention has been directed toward Tertiary and younger formations. Toumey (1848) recognized the "Santee beds" and Cooper Formation as different geologic units, and Cooke (1936) applied the terms "Santee Limestone" and "Cooper Marl", which still remain in general usage. Ward and others (1979) defined separate members within the Santee Limestone and Cooper Formation, based on subsurface and outcrop data.

The report by Ward and others (1979) is one of many that have resulted from an investigation into the Charleston earthquake of 1886 by the USGS. Many of these reports are included in Rankin's (ed.), "Studies related to the Charleston, South Carolina, earthquake of 1886 - a preliminary report" (1977), which contains papers on geophysics, stratigraphy, and seismicity, and in Gohn's (ed.) compilation on tectonics and seismicity (1983).

Although much has been written about the geology of the region, relatively little has been published concerning the area's ground-water resources. Lynch and others (1881) described the drilling of several deep wells at Charleston between 1823 and 1876, and compared the quality of water obtained from those wells. Darton (1896) referred to those same wells in his review of artesian well prospects along the Atlantic Coastal Plain. A 2,000-foot well drilled at Charleston in 1911 was the subject of a USGS report by L.W. Stephenson (1914). Cooke (1936) included a section on ground water in his review of South

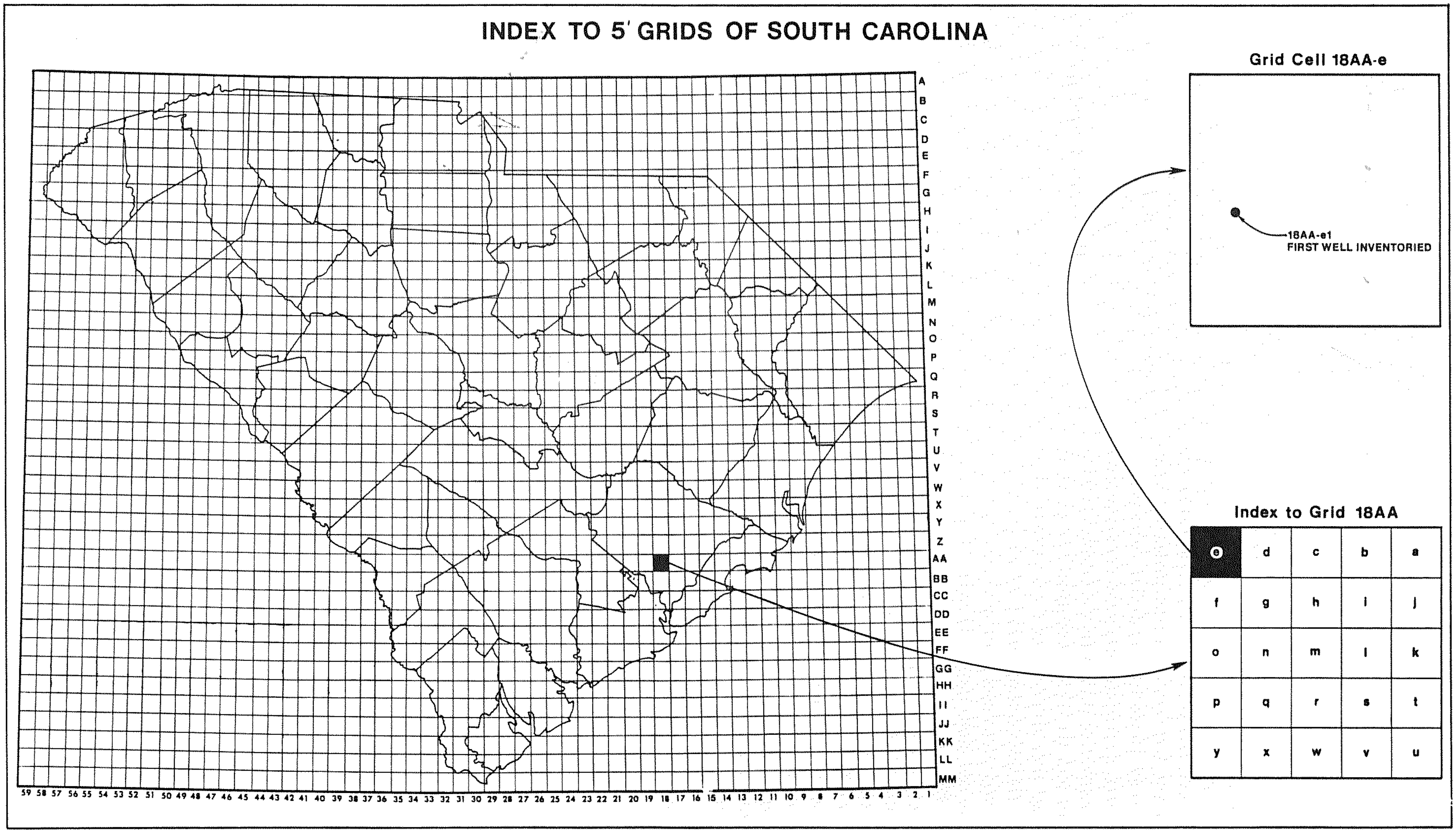


Figure 2. Illustration of the well-numbering system.

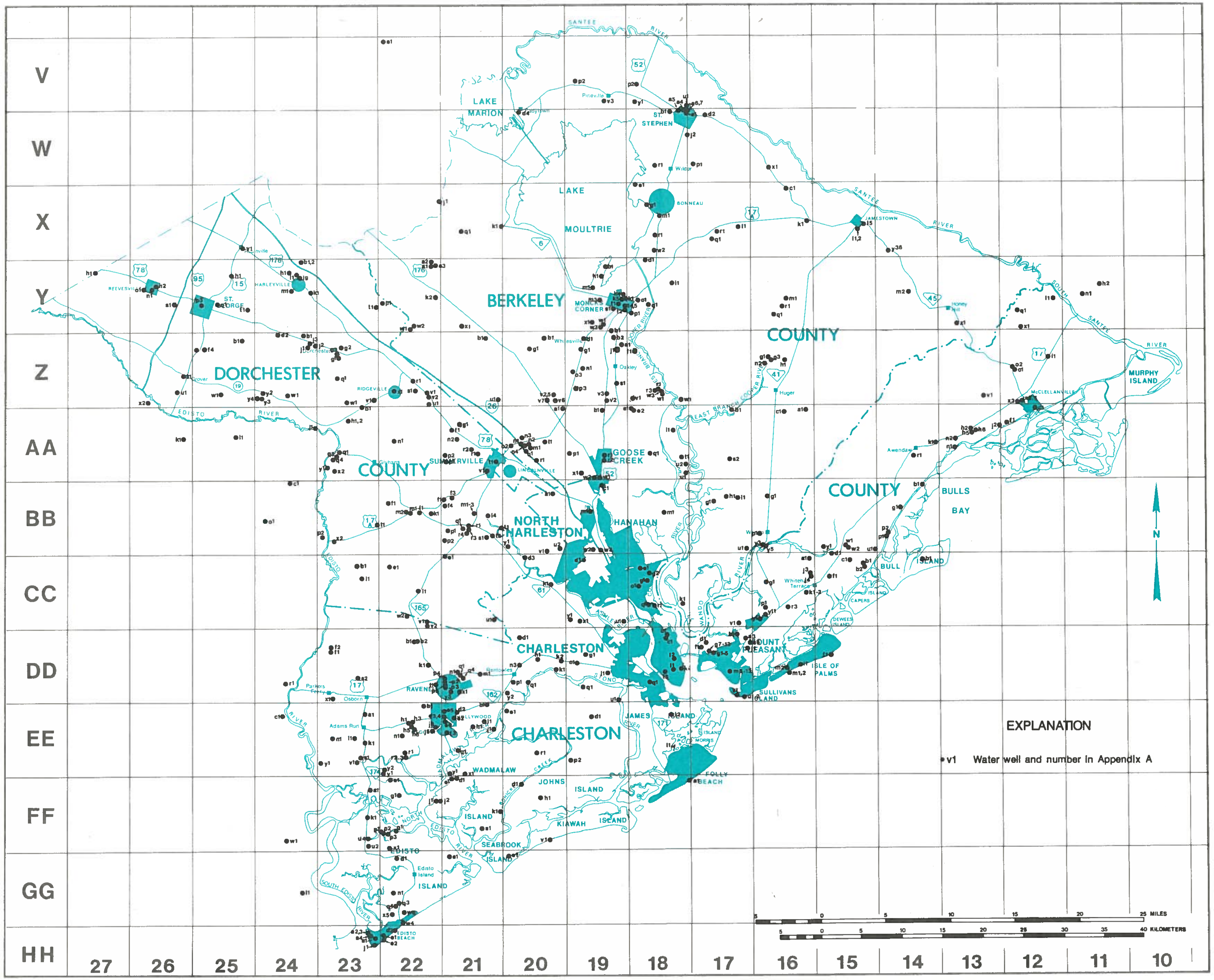


Figure 3. Locations of wells referred to in this report.

Carolina's coastal-plain geology and tabulated information on 33 wells and 15 chemical analyses for Charleston, Berkeley, and Dorchester Counties. Siple (1946) also included data for a number of wells in the area in his summary of ground water investigations in South Carolina. In later reports, Siple (1967, 1969), discussed saltwater encroachment in Tertiary and Cretaceous aquifers along the South Carolina coast. Reports by Taber (1935, 1939), Siple (1968), and Spiers (1975) described the geology and the hydrologic effects of dam and canal construction in northern Berkeley County.

Well-Numbering System

The South Carolina Water Resources Commission well numbers are based on a latitude-longitude grid system. The larger grid encompasses 5 minutes of latitude and 5 minutes of longitude. Each 5 minute grid is further divided into twenty-five 1-minute latitude-longitude grids that are designated by the lower-case letters "a" through "y". As wells are inventoried, they are assigned a four-part well number which consists of a number, an upper-case letter, a lower-case letter, and a number. The first number and the upper-case letter(s) indicate the coordinates of the 5-minute grid; the lower-case letter refers to the 1-minute grid; and the last number(s) refers to a well within the 1-minute grid. The well grid system for the study area is illustrated in Figures 2 and 3. Appendix A contains selected well records, by grid numbers, for the project area.

Physiography and Climate

Charleston, Berkeley, and Dorchester Counties lie within the central part of the Lower Coastal Plain Province of South Carolina (Figure 1). The area is bordered by Georgetown, Williamsburg, and Clarendon Counties to the north, Orangeburg County to the west, and Colleton County to the south. Elevations range from about 125 ft (feet) above mean seal level in the western part of Dorchester County, to mean sea level along the coast in Charleston County. Areas northwest of Summerville generally lie at elevations greater than 75 ft, whereas the areas to the southeast are mostly less than 50 ft above mean sea level. Four broad, gently sloping terraces, caused by temporary halts of a retreating Pleistocene sea, are parallel to the coast and between the elevations of 100 ft and mean sea level.

Four major river systems drain the area. The largest of these is the Santee, a through-flowing stream whose headwaters originate in the Blue Ridge and Piedmont Provinces of North Carolina and South Carolina. Until the Santee was partially diverted into the Cooper River system, it was the largest Eastern Seaboard river south of the St. Lawrence. It marks the northern border of the study area and drains the northernmost quarter of Berkeley County. The Edisto River forms the southern boundary of the study area and originates in the South Carolina Piedmont; its main distributaries, the North Edisto River and the South Edisto River, enclose Edisto Island at its mouth. Between the Santee and the Edisto, lie the Cooper and Ashley Rivers. Their entire drainage systems are within the study area, and their confluence forms the Charleston Peninsula and Charleston Harbor. Both river systems are tidally influenced over most of their lengths.

East of U.S. Highway 17, much of Charleston County is a region of tidal estuaries. Numerous islands are formed by shallow bays and meandering saltwater streams, the largest of which are the Wando and Stono Rivers. The eastern border of the county is marked by an almost continuous chain of barrier islands which are separated from the mainland by great tracts of saltmarsh.

Inland, as far west as Summerville and Moncks Corner, the study area is dominated by timberland in the high areas, and by freshwater swamps and Carolina Bays in the low areas. The Carolina Bays are unique in that they are confined principally to the Coastal Plain Province of North and South Carolina. They are readily recognized on aerial photographs and topographic maps as shallow, poorly drained depressions whose major axes are oriented northwest-southwest; and they typically occur in areas underlain at shallow depth by carbonate material such as limestone or shelly sand (Siple, 1960).

The climate of Charleston, Dorchester, and Berkeley Counties is temperature modified by the ocean in all areas within 10 miles of the coast, and to a lesser degree farther inland. The marine influence is most noticeable during winter when nightly minimum temperatures are sometimes 10 to 15 degrees higher on the immediate coast than inland. By the same token, maximum temperatures are dampened a few degrees in the proximity of the ocean, although afternoons, on the average, experience more sunshine than areas inland. The sea/land breeze regime is well established, especially during the warmer portion of the year; and under ideal conditions the sea breeze will move 10 to 30 miles inland during the afternoon. The prevailing winds are northerly during the late fall and winter, but they are mostly southerly for the remainder of the year.

Summers are long, warm, and humid. Late summer and early fall is the period of maximum threat to the South Carolina coast from hurricanes. Some memorable hurricanes that have affected the area occurred in August 1885, August 1893, August 1911, July 1916, September 1928, August 1940, August 1952, September 1959, and September 1979. In each storm, there was considerable damage to property, and in some storms there was loss of life.

Rainfall occurs throughout the year and ranges, on the average, from a maximum of 8 inches or more in July to a minimum of 3 inches or less in November. Annual rainfall varies from less than 46 inches on the outer coast to 52 inches 20 or 30 miles inland (Fig. 4).

The monthly average temperature varies from the low 80's in July to the upper 40's during midwinter.

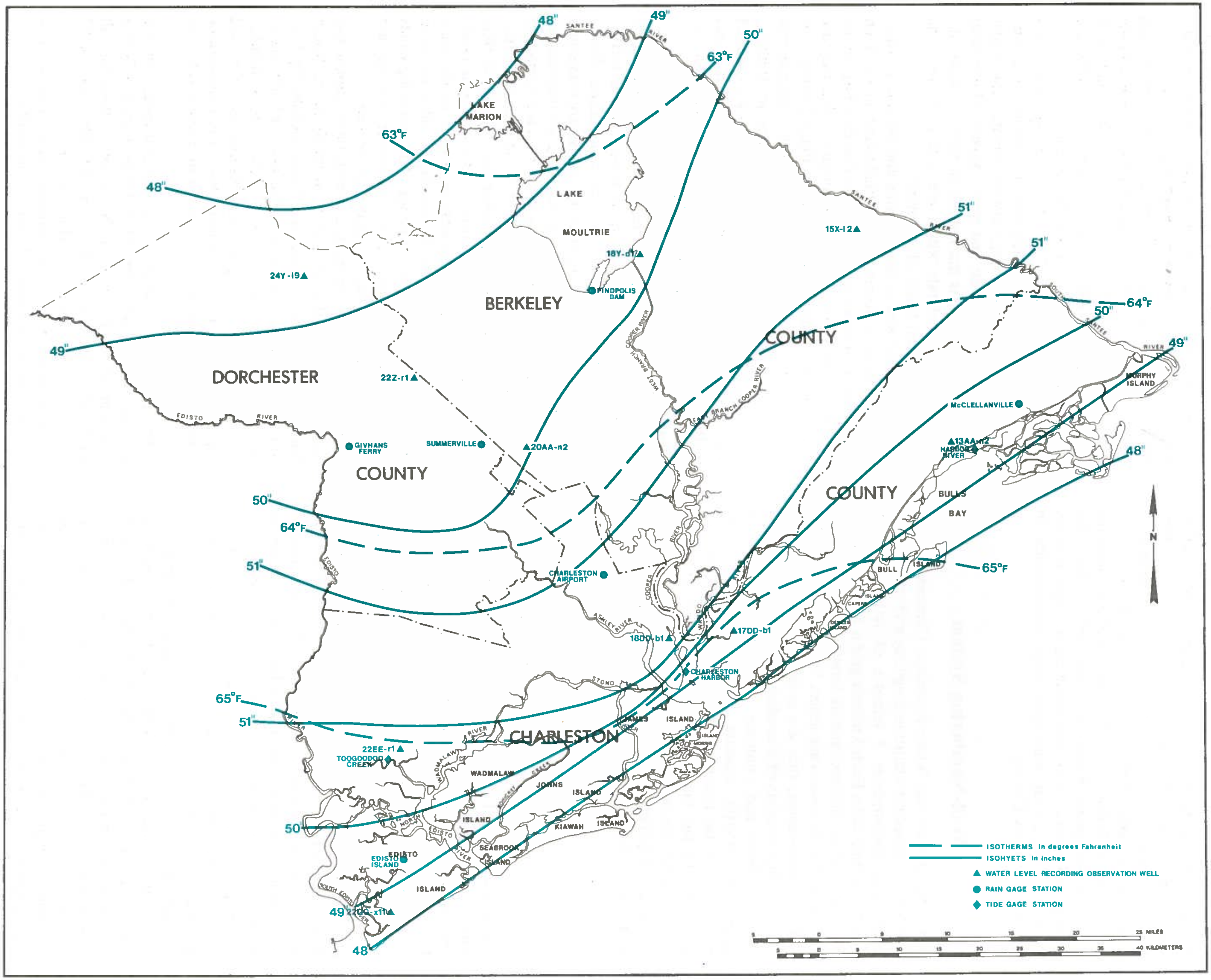


Figure 4. Variation in average annual rainfall and temperature and locations of water-level recorders, rain gages, and tide gages in the Trident Area.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to the staff members of the South Carolina Water Resources Commission and USGS for their advice and efforts on behalf of this report. Particular thanks are due Mr. Rodney Cherry, District Chief, USGS, for his support during the project, and to the Coastal Plains Regional Commission, which provided much of the project funding.

The author is also indebted to the staffs of the many public works agencies and the consulting engineers who serve them. Special thanks are also extended to the G.W. Ackerman Well Company and T.A. Clyde Well Drilling for their assistance in obtaining drill samples, geophysical logs, and well-construction data.

GEOLOGIC FRAMEWORK

The rock units underlying Charleston, Berkeley, and Dorchester Counties represent a broad range of lithologies, depositional environments, and ages (Table 1). The oldest units, the Middendorf, Black Creek, and Peedee Formations, are of Late Cretaceous age and were deposited in environments ranging from continental to innershelf marine. Their lithologies are predominantly clastic, consisting of sand, silt, and clay. The bulk of the units overlying the Late Cretaceous formations consists of the Tertiary Black Mingo Formation, Santee Limestone, and Cooper Formation. These units are the result of deposition in marine environments ranging from marginal marine to outer shelf. Sand, silt, and clay dominate the

Table 1. Stratigraphic units and their water-bearing characteristics.

SYSTEM	SERIES	FORMATION	LITHOLOGY	WATER-BEARING CHARACTERISTICS
Quaternary	Holocene and Pleistocene	Terrace Deposits	Highly variable. Light-colored fine-to medium-grained sands, shelly sands, and shell beds; varicolored clays. Locally coarse-grained sand or gravel; thin limestone beds.	Ground water occurs under water-table or poorly confined conditions. Transmissivities are generally less than 1,000 ft^2/day. Well yields are variable, ranging from 0 to 200 gpm. Water is commonly acidic at shallow depths and high in iron.
	Miocene	Hawthorn	Fine, sandy, phosphatic limestone, and thin remnents of sand and clay. Generally absent from study area.	
		Edisto	Pale-yellow, sandy, fossiliferous limestone. Present to the northwest along the Edisto River.	
Tertiary	Oligocene	Cooper	Pale-green, or yellowish-gray to olive-brown, sandy, phosphatic limestone. *Harleyville Member:* phosphatic, calcareous clay to clayey, very fine-grained limestone. *Parkers Ferry Member:* glauconitic, clayey, fine-grained, abundantly fossiliferous limestone. *Ashley Member:* phosphatic, muddy, calcareous sands.	Confining unit. Porous bryozoan limestone unit of limited extent will yield up to 300 gpm of freshwater. Yields unknown quantities of brackish water in southern Charleston County.
	Eocene	Santee Limestone	Creamy-white to gray, fossiliferous, locally phosphatic limestone. *Moultrie Member:* biosparrites and bryozoan hash. *Cross Member:* brachiopod-bivalve biomicrite.	Artesian, except in outcrop areas. Typically yields less than 300 gpm. Calcium bicarbonate type water with iron commonly in excess of 0.3 mg/L. Contains brackish water along coast.
Tertiary	Paleocene	Black Mingo	Fossiliferous, white to pale gray limestones, green to gray argillaceous sands, carbonate-and silica-cemented sandstones, and dark-gray to black clays.	Artesian. Transmissivities range from 500 to 8,500 ft^2/day. Will yield 300 to 500 gpm in most areas. Water is soft, alkaline, sodium bicarbonate type. Locally, contains high fluoride and brackish water.
		Peedee	Olive-to-medium gray, fossiliferous, muddy sands and olive-to-medium gray, silty and sandy calcareous clays.	Artesian. Poor aquifer, yielding less than 300 gpm. Very mineralized sodium bicarbonate type water with high concentrations of fluoride. Contains brackish water along coast.
Cretaceous	Upper Cretaceous	Black Creek	Gray to gray-green muddy sands, silty clays, fine-to-medium grained white to gray sands, and shelly limestones with minor amounts of glauconite, phosphate, mica, and pyrite.	Artesian. Transmissivities range from 930 to 2,000 ft^2/day. Yields 250 to 1,000 gpm. Water is soft, alkaline, sodium bicarbonate type. Fluoride exceeds 1.6 mg/L in eastern half of study area.
		Middendorf	Red, brown, and gray-green, poorly sorted feldspathic sands, and reddish or gray-green clay, silty clay, and clayey silt in lower half. Red, brown, yellow to olive-gray clay and silty clay, and greenish-gray, muddy, locally feldspathic sand in upper half.	Artesian. Transmissivities are probably less than 4,300 ft^2/day in most areas. Yields range up to 2,000 gpm. Very mineralized, sodium bicarbonate type water. Fluoride concentrations up to 11 mg/L.
Triassic		Unnamed	Diabase, basalt, or quartzitic sandstone, depending on locality.	Hydraulic properties are unknown. Probably a poor source of water.

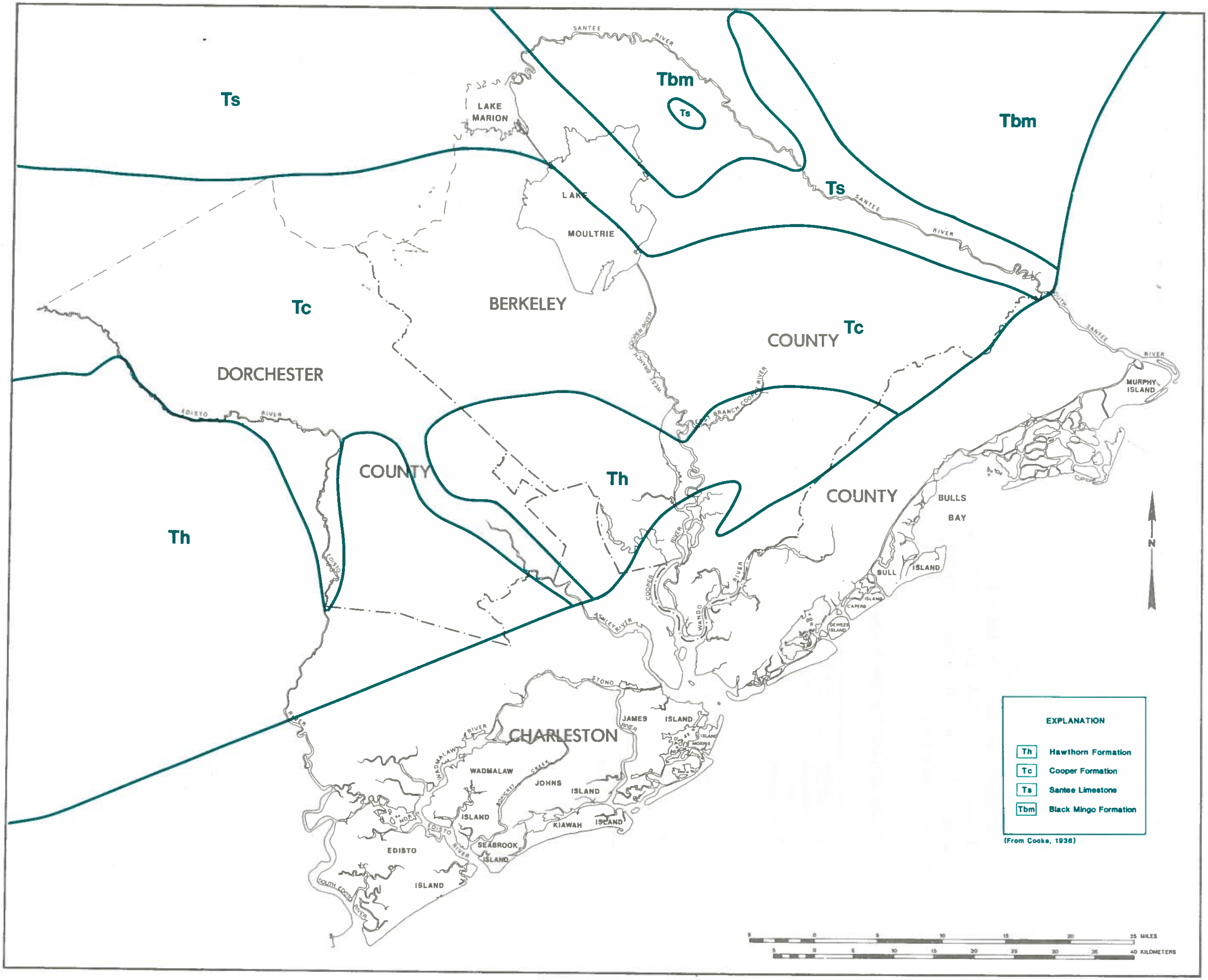


Figure 5. Generalized areal geology of Charleston, Berkeley, and Dorchester Counties.

lithology in the lower part of the Tertiary section, and pure to very impure limestone dominates the upper part. The major Tertiary units are in turn overlain by a shallow sequence of sand, silt, clay, and shell having an average thickness of less than 50 ft. Tertiary and Quaternary rocks are exposed at various locations, and the general distribution of their subcrop areas is shown in Figure 5.

The stratigraphic units that occur in the study area are part of a wedge of successively overlapping formations that thicken coastward from a feather edge at the fall line to about 3,000 ft at the southern extreme of Charleston County. Within the limits of the study area they have an average thickness of about 2,200 ft. The Late Cretaceous units lie at depths of 300 ft or more and crop out 30 to 70 miles north and west of the study area. Their occurrence is defined in cross section (Figs. 6, 7, 8, and 9).

Pre-Cretaceous Basement Rocks

Well-indurated sedimentary rocks and their metamorphic equivalents, volcanic flows, or crystalline rock such as granite underlie the unconsolidated sedimentary formations of the Coastal Plain. These rocks do not represent the true "basement" but are herein referred to as such for convenience.

Recent studies of seismic activity in the Charleston area have greatly modified traditional beliefs concerning the nature of these rocks. It was previously thought that the consolidated rocks underlying the Coastal Plain sediments were buried extensions of metamorphic and intrusive rocks exposed in the Appalachian Piedmont Province. However, the Coastal Plain basement is much different and is more complex than previously supposed.

Much of the basement surface beneath Charleston, Berkeley, and Dorchester Counties is dominated by an extensive volcanic field and large mafic plutons mixed with or separated by units of consolidated clastic rock. Three deep test wells drilled in the area have encountered differing lithologies beneath the unconsolidated Coastal Plain sediments. The basement test well at Summerville is reported to have penetrated volcanic diabase at −2,430 ft msl; the Clubhouse Crossroads well pentrated 138 ft of basalt beginning at −2,430 ft msl and a deep well at Seabrook Island encountered fine-grained quartzitic sandstone at −2,670 ft msl.

The basalt encountered at Clubhouse Crossroads is similar to basalts from the Atlantic-type continental margins of eastern North America, Tasmania, Antarctica, and South Africa and have estimated ages of 94.8 to 109 million years. The basalts are of a type associated with tensional faulting, hence suggesting the existence of a buried Triassic basin beneath the Charleston area (see Gottfried and others, 1977).

The basement surface, shown in Figure 10, dips generally south-southeast at an average rate of about 40 ft per mile. It lies at approximately −1,500 ft msl in northernmost Berkeley and Dorchester Counties, dipping to −3,000 ft msl in southern Charleston County. A trough-like depression in the basement surface west of Charleston has been defined by Campbell (1977) and Ackerman (1977).

Features within the basement rocks are shown in Figure 11. The features include east-west and northwest trending faults through northern Berkeley and Dorchester Counties, large northwestern trending diabase dikes, and several large Triassic (?) plutons whose tops occur at about −4,900 ft msl or about 2,600 ft below the basement surface (see Popenoe and Zietz, 1977). Layers possibly representing deeper volcanic flows or the true crystalline basement have been identified at several depths below the basaltic basement surface (Ackerman, 1977; Campbell, 1977; Phillips, 1977).

Cretaceous Units

Middendorf Formation

The name "Middendorf" was applied by Sloan (1904) to presumed Lower Cretaceous exposures near the town of Middendorf, Chesterfield County, South Carolina. Berry (1914) assigned the unit to the Upper Cretaceous, and C.W. Cooke (1926) revised the terminology and correlations of earlier investigators and included the "Middendorf" and lower beds of Sloan (1907) and the "Middendorf" arkose member of Berry (1914) in the Middendorf Formation. Cooke (1936) later considered the Middendorf and "Hamberg" beds of Sloan to be similar to the Tuscaloosa Formation of Alabama, and he used the name "Tuscaloosa", as did Mansfield (1937). Dorf (1952) referred to the Formation in Chester County as the "Middendorf Member" of the Black Creek Formation and to the underlying rocks as "Lower Cretaceous (undifferentiated." Subsequently, Heron (1958b) and Swift and Heron (1969) returned to the term Middendorf Formation for its occurrence in the Cape Fear area of North Carolina. The USGS has recently used the term for Upper Cretaceous units within the boundaries of the present study area (Gohn and others, 1977; Hazel and others, 1977).

Gohn and others (1977) also described an underlying unit at Clubhouse Crossroads as the "Cape Fear Formation". Gohn and Hazel (1979) suggested that the Middendorf and Cape Fear Formations of Gohn and others (1977) and Hazel and others (1977) are not the same units as those so named in the outcrop areas. Therefore the Middendorf and Cape Fear Formations of Gohn and others (1977) and Hazel and others (1977) are grouped under the name "Middendorf" in this report for the sake of convenience.

The lower 200 ft of the Middendorf Formation (Cape Fear of Gohn and others, 1977) is composed of interbedded red, brown, yellow, or olive-gray clay and silty clay; and greenish-gray, muddy, locally feldspathic sand. The sand and clay contain varying amounts of mica, pyrite, and shell fragments. The upper part of the formation consists of a cyclical sequence of red to reddish-brown and gray-green, poorly sorted feldspathic sand, reddish or red and gray-green mottled clay, clayey silt, and silty clay. The sediments represent continental and marginal marine depositional environments (see Gohn and others, 1977).

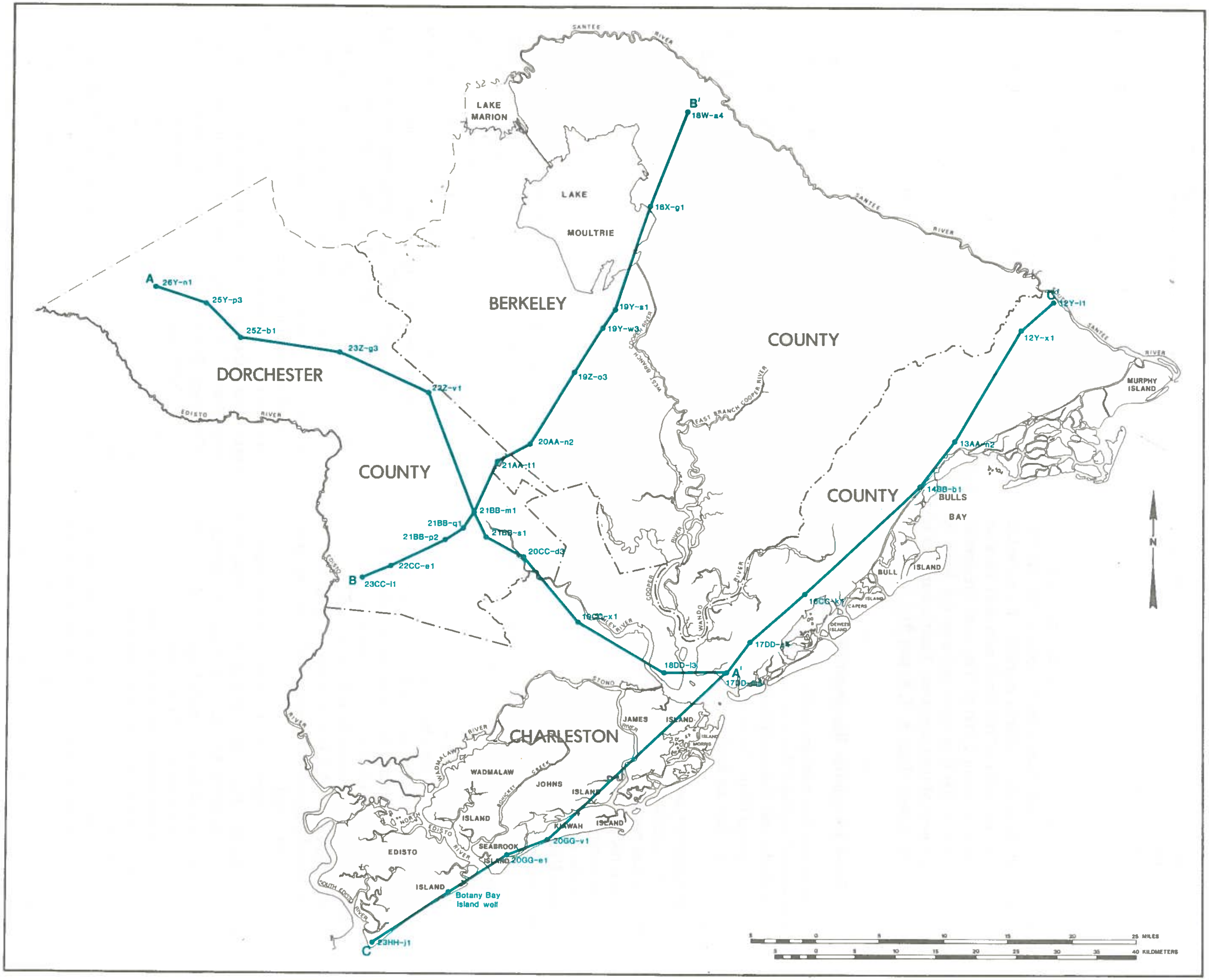


Figure 6. Location of hydrologic sections.

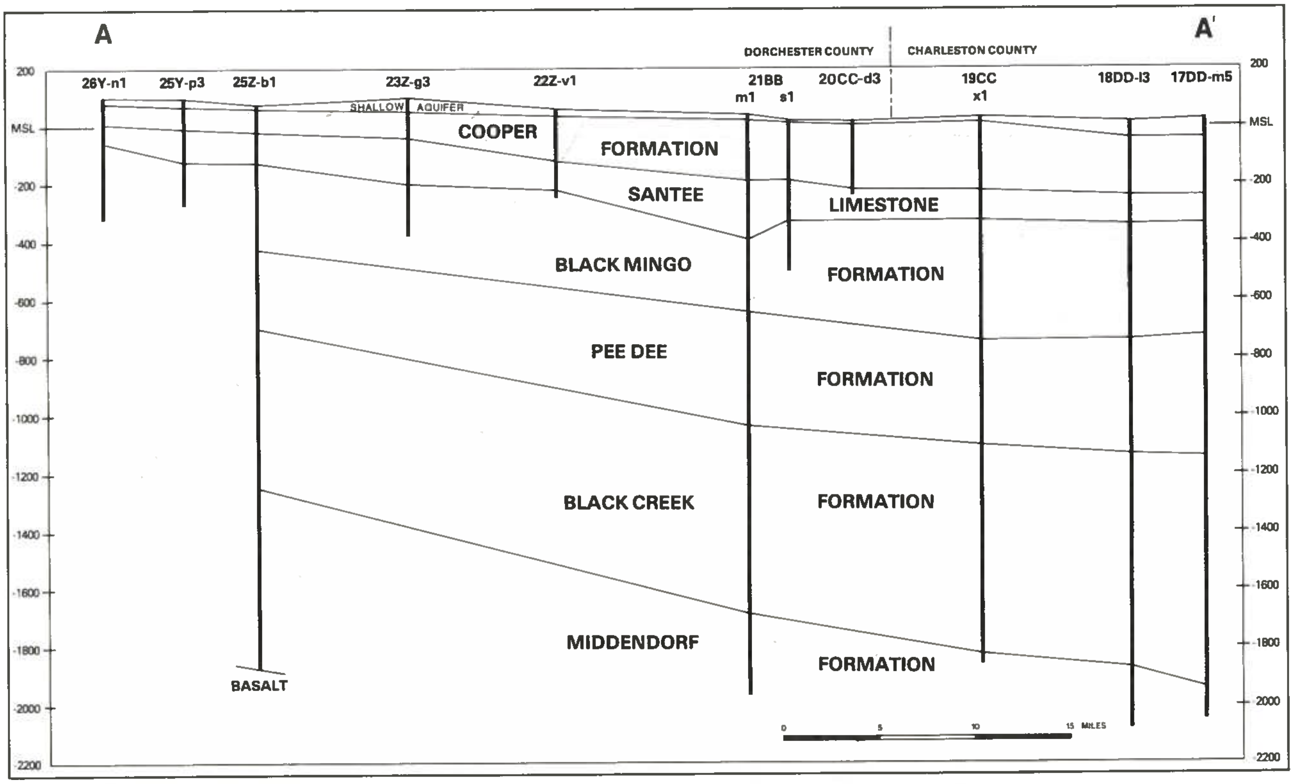


Figure 7. **Hydrologic section A-A', from Reevesville to Charleston.**

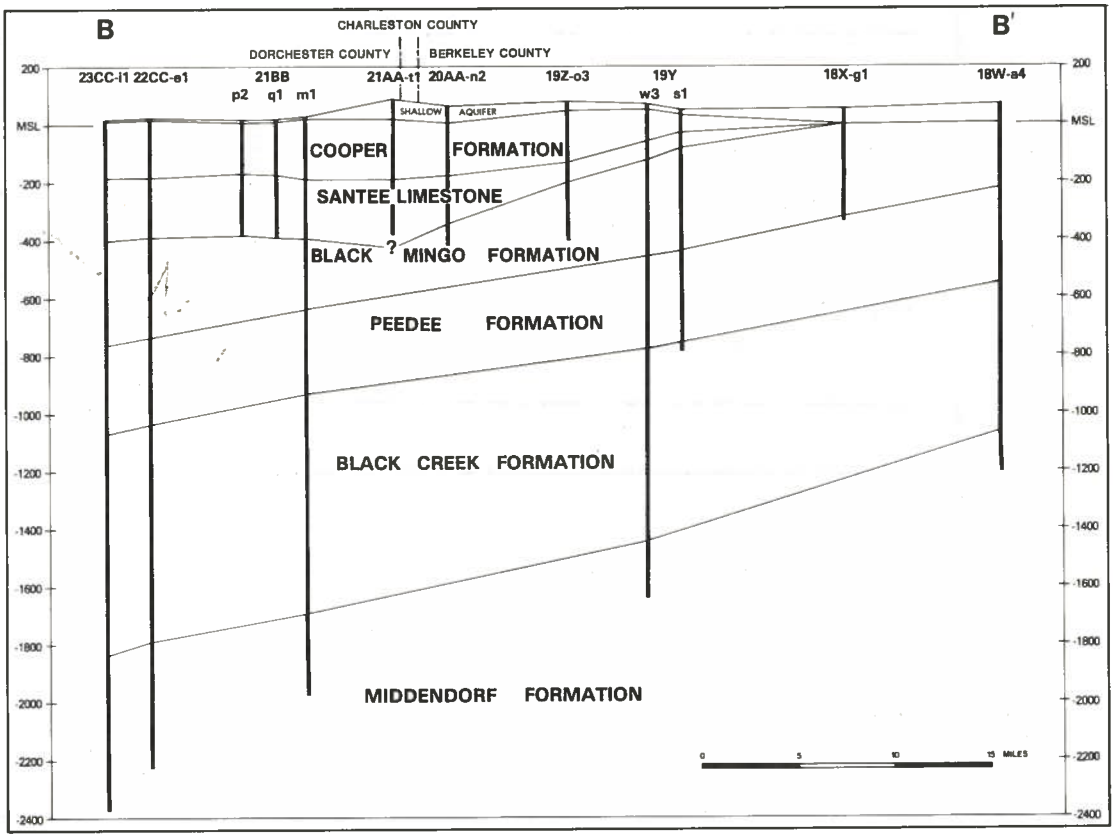


Figure 8. **Hydrologic section B-B', from Clubhouse Crossroads to St. Stephen.**

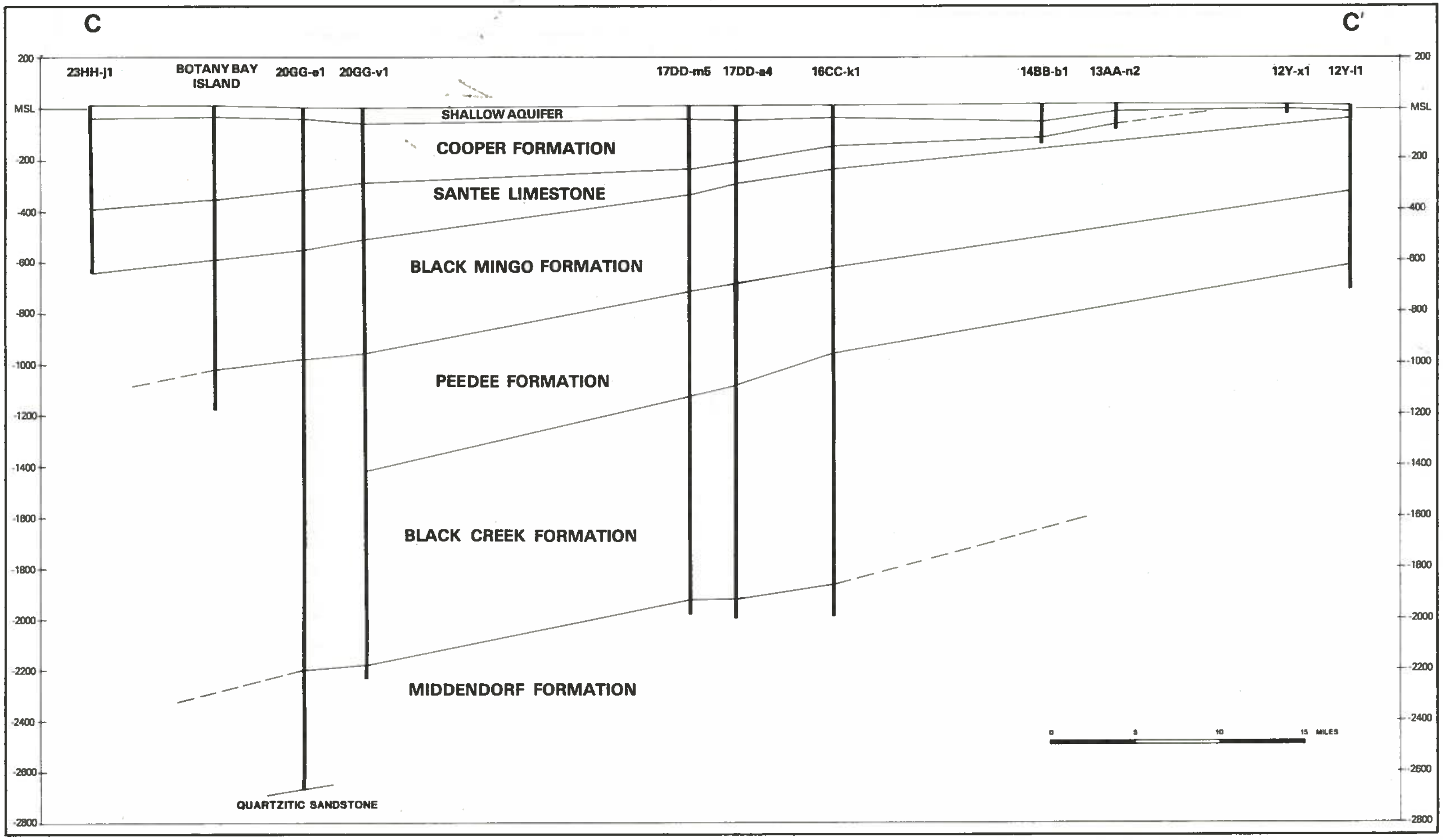


Figure 9. Hydrologic section C-C', from Edisto Beach to Hampton Plantation.

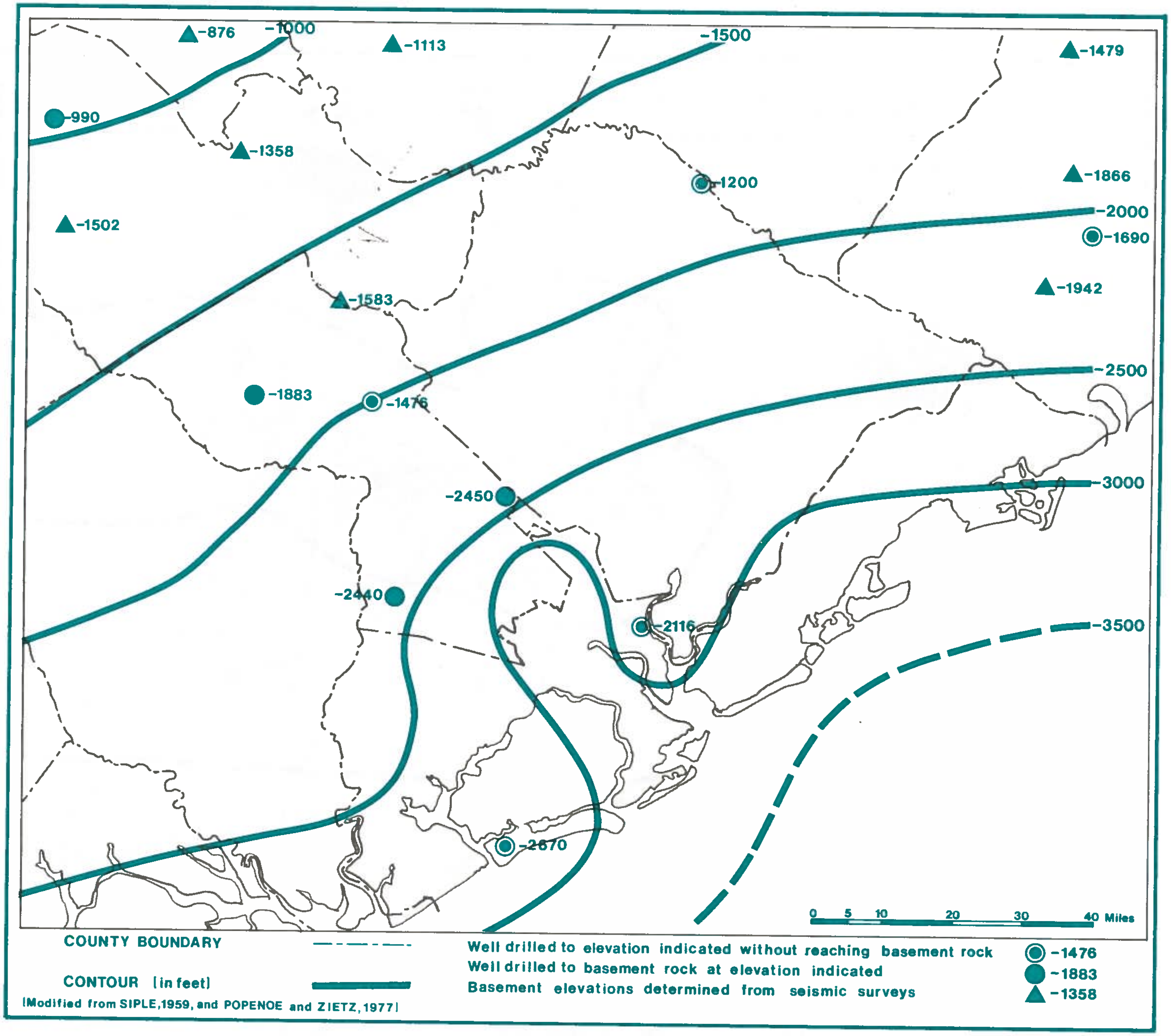
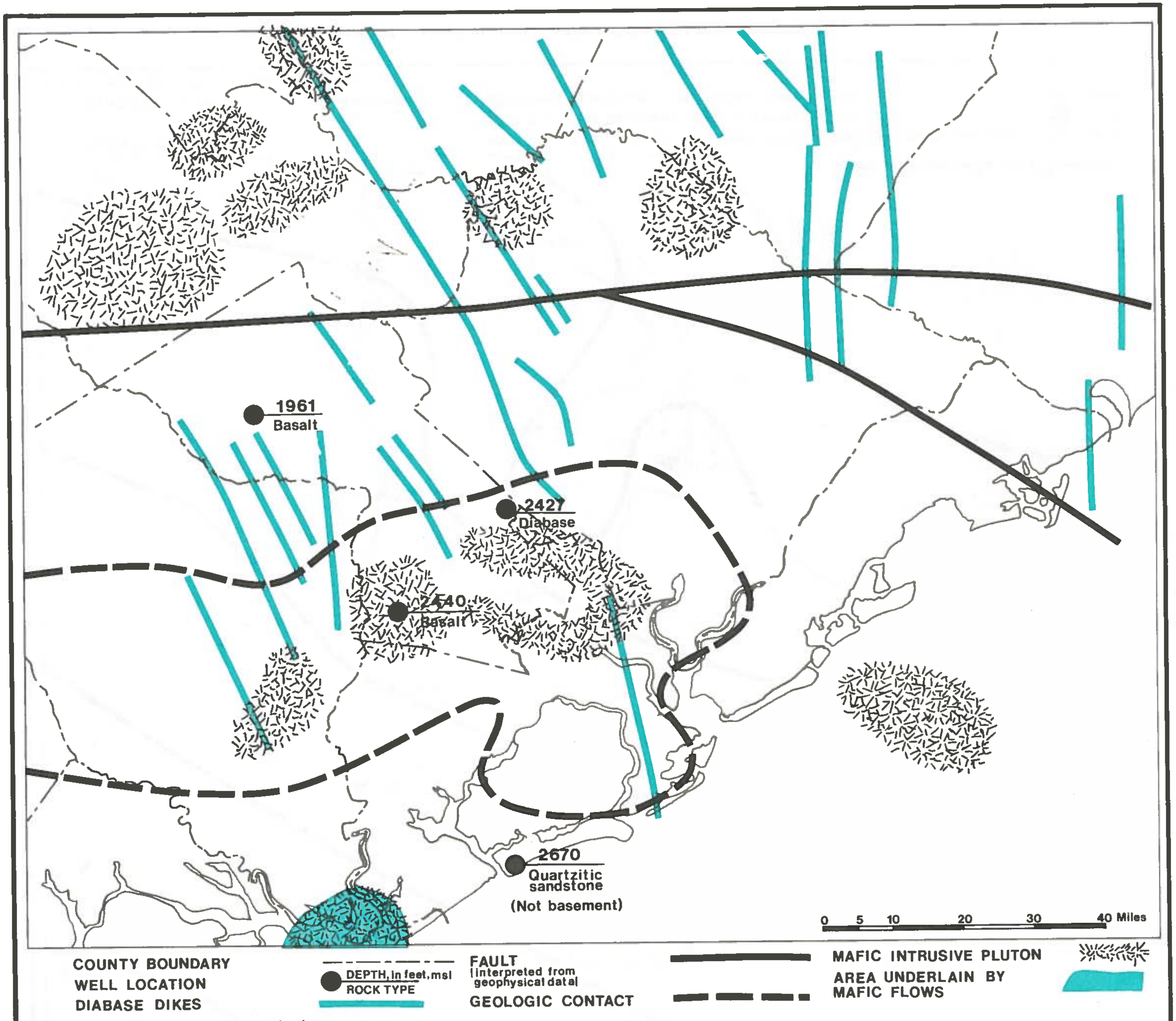


Figure 10. Contours on the surface of the Pre-Cretaceous basement.



(Modified from POPENOE and ZIETZ, 1977)

Figure 11. Major geologic features of the pre-Cretaceous basement.

The top of the formation occurs at about −1,000 ft msl at St. Stephen, −1,860 ft msl at Clubhouse Crossroads, and at −2,180 ft msl at Kiawah Island. The average dip of the surface of the formation is southwest at about 36 ft per mile. The formation is 600 ft thick at Clubhouse Crossroads and approximately 600 ft thick at Kiawah Island, with the thickness increasing toward the southeast.

Black Creek Formation

Ruffin (1843, p. 25) first noted the black shales in Darlington and Florence Counties that were later referred to as the "Black Creek Shales" by Sloan (1907, p. 12-14), and which Sloan (1908) described as the Black Creek Formation. The term Black Creek Formation has since been used to include the Snow Hill Marl Member (Stephenson, 1923; Cooke, 1926; Dorf, 1952; Heron, 1958a, 1958b) and all or part of the Middendorf Formation as a member. Swift and Heron (1969, p. 217) thought the Black Creek interfingered with the Middendorf (Tuscaloosa), a conclusion predominantly based on outcrop data. Woolen (1978) assembled both outcrop and subsurface data for northeastern South Carolina and suggested a similar contact.

The lithology and paleontology of the formation in the subsurface of the study area were described by Cooke (1936), Mansfield (1937), Gohn and others (1977), Hazel and others (1977), and Hattner and Wise (1980).

Gohn and others (1977, p. 67) describe the formation as abundantly fossiliferous silty clay, muddy sand, and clean sands alternating in 50- to 150-ft thick sequences with thinly interbedded sand and clay and some shelly limestone. The silty clay and muddy sand are gray to gray-green with minor quantities of glauconite, phosphate, mica, and pyrite. Locally, macrofossil shells and microfossil tests are abundant, and the calcium carbonate content is high. Feldspathic quartzitic silt and well-sorted fine sand occur near the base of the formation, and well-sorted calcareous quartz sand occurs in the upper part. The clay has as much as 20 percent black carbonaceous material. Black Creek sediments were deposited in environments ranging from marginal marine to middle shelf (Gohn and others, 1977; Hazel and others, 1977).

The top of the Black Creek Formation occurs at −530 ft msl at St. Stephen, −1,050 ft, at Clubhouse Crossroads, and −1,420 ft at Kiawah Island. The dip is toward the southeast at a rate of about 30 ft per mile. Thickness increases from about 500 ft in northern Berkeley County to 750 ft in southern Charleston County.

Peedee Formation

The Peedee Formation is named for beds cropping out along the Pee Dee River in Florence County. Ruffin (1843, p. 7) first described the "Peedee beds" that were later designated as the "Burches Ferry marl" at a type locality in Florence County by Sloan (1907, p. 12-14). Stephenson (1923) returned to the use of the term "Peedee," which has been retained in subsequent publications. The formation occurs only in the subsurface within the project area.

At Clubhouse Crossroads the formation is represented by calcareous muddy sand and calcareous mud. There, the lower part of the Peedee is predominantly composed of olive- to medium-gray, fossiliferous, muddy sand containing small amounts of glauconite, phosphate, and mica. The upper part is composed of olive- to medium-gray, silty and sandy calcareous caly. Calcium carbonate, in the form of fossils and cement, ranges from 10 to 40 percent; accessory minerals include glauconite, phosphate, pyrite, and mica (Gohn, and others, 1977, p. 68).

The Peedee underlies the entire study area. The top lies at about −200 ft msl in northern Berkeley County, dipping southwestwardly to −800 ft at Clubhouse Crossroads and −700 ft at Charleston. The average dip is about 25 ft per mile. Its thickness ranges from 320 to 450 ft, increasing at about 4 ft per mile toward the south.

Principal Tertiary Units

Black Mingo Formation

The name "Black Mingo" was originally applied to exposures of "shale" along Black Mingo Creek in adjacent Williamsburg and Georgetown Counties by Sloan (1907). He later (1908) used the term "Black Mingo phase" to include all rocks of lower Eocene age east of the Santee River. After mapping the outcrop and subcrop areas, Cooke (1936, p. 41) referred to all Eocene rocks older than the McBean Formation as the "Black Mingo formation". As used in this report, the name is applied to strata referred to as the "Black Mingo" and "Beaufort (?)" Formations by Gohn and others (1977) and Hazel and others (1977).

The Black Mingo is a heterogeneous, fossiliferous sequence of white to pale-gray limestone, green to gray argillaceous sand, carbonate and silica-cemented sandstone, and dark-gray to black clay. In the outcrop areas of northern Berkeley County, the formation chiefly consists of clay, shale, sand, and limestone; shale and clay being more abundant in the lower part, and sand and limestone being more prevalent in the upper part. The sand is white to pale gray in the absence of glauconite and pale green to dark green where glauconite is present (Taber, 1939, p. 4; Poozer, 1965, p. 11; Spiers, 1975, p. 15). Montmorillonite clay is common in the updip portion of the Black Mingo (Heron, 1969, p. 34; Heron and others, 1965) and is commonly dark gray with small quantities of pyrite. Lithological and paleontological data indicate that the updip portion of the Black Mingo was deposited in inner-shelf and marginal-marine environments (Poozer, 1965, p. 11). Downdip, the subsurface section at Clubhouse Crossroads reflects a broader range of depositional environments. The lower segment (Beaufort (?) of Gohn and others (1977)) is predominantly a yellow-gray to greenish-gray, somewhat calcareous or sandy clay including glauconite, carbonized wood, and pyrite, generally deposited in an inner- or middle-shelf environment. The overlying segment is similar, consisting of gray-green silty clay and muddy sand, interbedded sand and clay, and quartzose shelly limestone. Illite is the most common clay mineral. Gohn and others (1977) suggested that these sediments are the result of inner-shelf and marginal marine environments.

Black Mingo sediments generally are a mixture of detrital material and volcanic ash (Heron, 1969, p. 28). The silicate minerals, opal and clinoptilolite, are common in the updip regions of the formation (Heron, 1969, p. 37), and cristobalite is reported to be abundant in much of the formation in the Clubhouse Crossroads corehole (Gohn and others, 1977, p. 63).

The formation crops out north of Moncks Corner in Berkeley County and throughout much of adjacent Georgetown and Williamsburg Counties. Its surface dips south-southwest beneath the Santee Limestone at a rate of 17 ft per mile, lying at sea level in the vicinity of Bonneau in Berkeley County and dipping to more than −600 ft msl in southern Charleston County (Fig. 12). The formation thickens from approximately 300 ft at Moncks Corner to 400 ft at Seabrook Island.

Santee Limestone

Early geologists grouped the undifferentiated Santee Limestone and Cooper Formation with the Upper Cretaceous, until Lyell classed them with the Eocene. Tuomey (1848, p. 154-169) and Clark (1891, p. 52-54) differentiated between the Eocene "Santee beds" and the overlying Cooper Formation, and Sloan (1908, p. 462-463) later applied the names "Santee marl" and "Mt. Hope marl" to the limestone. In 1936, Cooke (p. 75) gave the name "Santee Limestone" to limestone he then considered as part of the Eocene Jackson Group but which he and F.S. MacNeil (1952, p. 24) later identified with Claiborne units. The Santee Limestone is a creamy-white to gray, fossiliferous and slightly glauconitic calcilutite to calcirudite. In the outcrop areas it usually contains more than 80 percent calcium carbonate, and locally it contains 90 to 96 percent calcium carbonate (see Heron, 1962). The base of the limestone becomes increasingly glauconitic and arenaceous at the north edge of the outcrop, where it intertongues with underlying limestone of the Wharley Hill Formation (Poozer, 1965, p. 16-17). Downdip, the calcium carbonate content decreases to between 40 and 80 percent, and quartz sand, glauconite, and phosphate percentages increase (Gohn and others, 1977, p. 68-69). The distribution of carbonates and sediments is shown in Figure 13.

Two members have been recognized within the Santee Limestone, the lower unit being referred to as the Moultrie Member and the upper unit as the Cross Member. The Moultrie Member is characterized by biosparites in the form of mold and cast limestone and bryozoan hashes of a Middle Claibornian age. The Cross Member unconformably overlies the Moultrie and consists of a brachiopod-bivalve biomicrite of late Clairbornian age (Ward and others, 1979). The upper surface of each member tends to be rich in phosphate and can be identified by a marked departure from the zero baseline on natural gamma-ray logs (Fig. 14).

The Santee Limestone lies on the southern flank of the Cape Fear Arch, from which it has been partially eroded. It extends south and west of the arch and underlies all of the study area except the northernmost corner of Berkeley County. It occurs at shallow depths in a belt extending westward from northeastern Charleston County into southern Orangeburg County (Fig. 5). The limestone is overlain by a thin veneer of Miocene to Pleistocene sand and clay in the subcrop area and by the Cooper Formation south of parallel 32° 11 '00". The surface of the Santee dips southward at an average rate of 8.3 ft per mile between Moncks Corner and Edisto Beach. The dip averages 6 ft per mile in the outcrop area, and locally is as much as 17 ft per mile in the subsurface (Fig. 15). Its thickness increases southward at an average rate of 5 ft per mile and ranges from a few feet at the north edge of the limestone to more than 300 ft at Edisto Beach (Fig. 16).

Cooper Formation

The Cooper Formation is the most extensively studied rock unit in the Trident Area; its earliest observers included Vanuxem (1826), Morton (1834), and Lyell (1845). Toumey (1845) differentiated between the Cooper Formation and the underlying Santee Limestone. Between 1867 and 1920, when the Charleston area was a major source of agricultural lime and phosphate, the Cooper Formation received further attention from Holmes (1870), Moses (1872), Rogers (1914), and numerous others (Malde, 1959, p. 4). Many additional reports, addressing the Cooper in part or in whole, have resulted from recent USGS investigations into the Charleston earthquake of 1886. These include Gohn and others (1977), Hazel and others (1977), Higgins and others (1978), and Ward and others (1979).

The names applied to the formation have been varied. Ruffin (1843, p. 7), in describing the "Great Carolina beds" (present Cooper Formation and Santee Limestone), referred to "Marl of the Ashley and Cooper Rivers . . . ". His predecessors used a great number of other terms: "Cooper River Beds" (Holmes, 1870), "Cooper River Marls" (Dall 1898), "Ashley Marl" and "Cooper Marl" (Sloan, 1908), and others. Reports between Stephenson (1914) and Hazel (1976) generally referred the formation as the "Cooper Marl". Malde (1959, p. 10) and Poozer (1965, p. 20) noted that the formation was not a true marl because of its small clay component and large sand component, and the USGS has since accepted the name "Cooper Formation" (Hazel, 1976, p. 54; *in* Cohee, 1976).

Early nineteenth century geologists assigned the Cooper Formation and underlying limestones to the Upper Cretaceous until Charles Lyell (1845, p. 434) pronounced the formations Eocene. Toumey (1884), Holmes (1870, p. 13), and Cooke (1936, p. 72) also classed the Cooper with the Eocene, but Dall (1898), Cooke and McNeil (1952, p. 27), Malde (1959, p. 25), and Poozer (1965, p. 22) referred it to the Oligocene. Hazel and others (1977, p. 74-75) give evidence that the Cooper contains both Eocene and Oligocene beds.

Lithologically, the Cooper Formation is a sandy, phosphatic limestone that is uniform in color and texture and has no obvious signs of bedding. Malde (1959, p. 9), referring mainly to surface exposures, describes the forma-

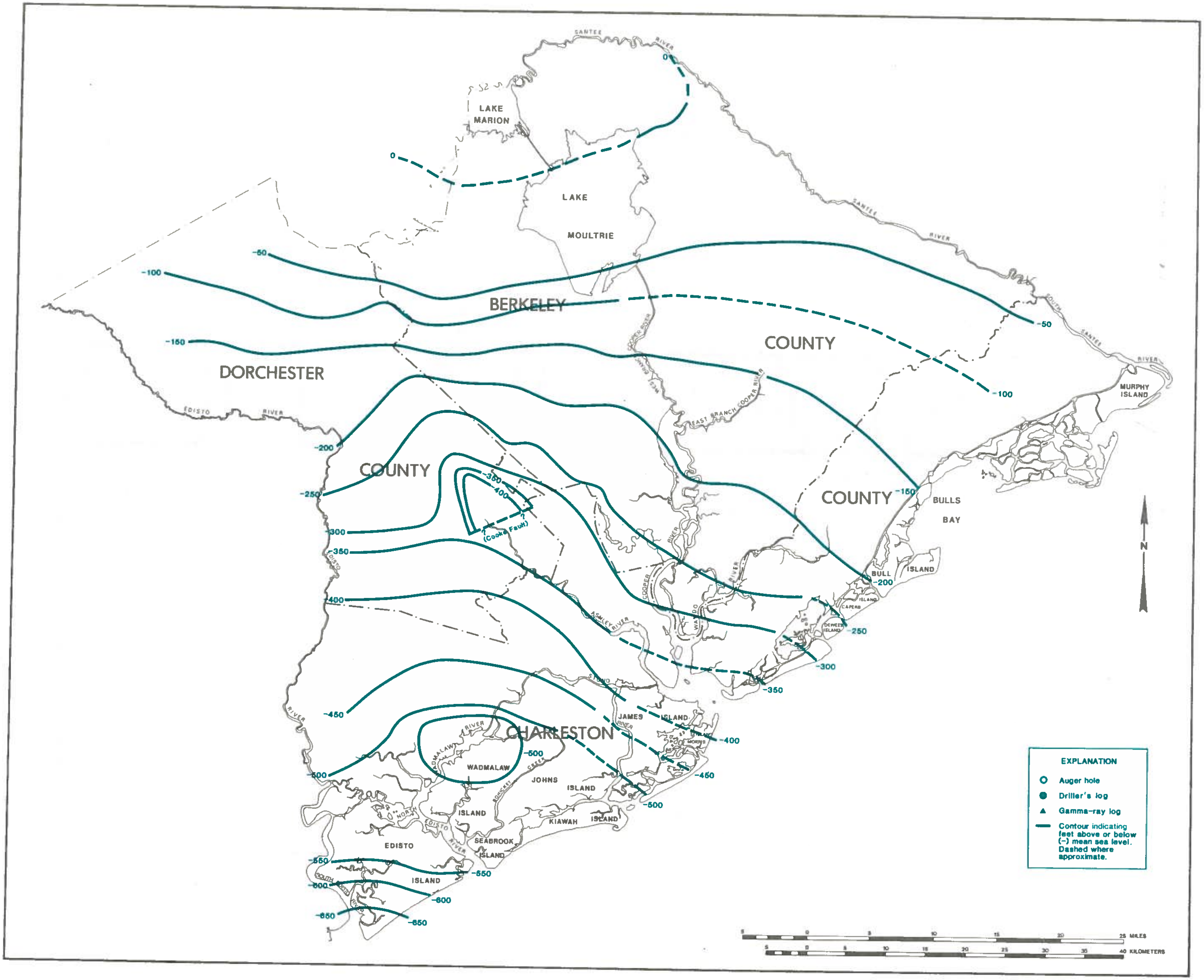
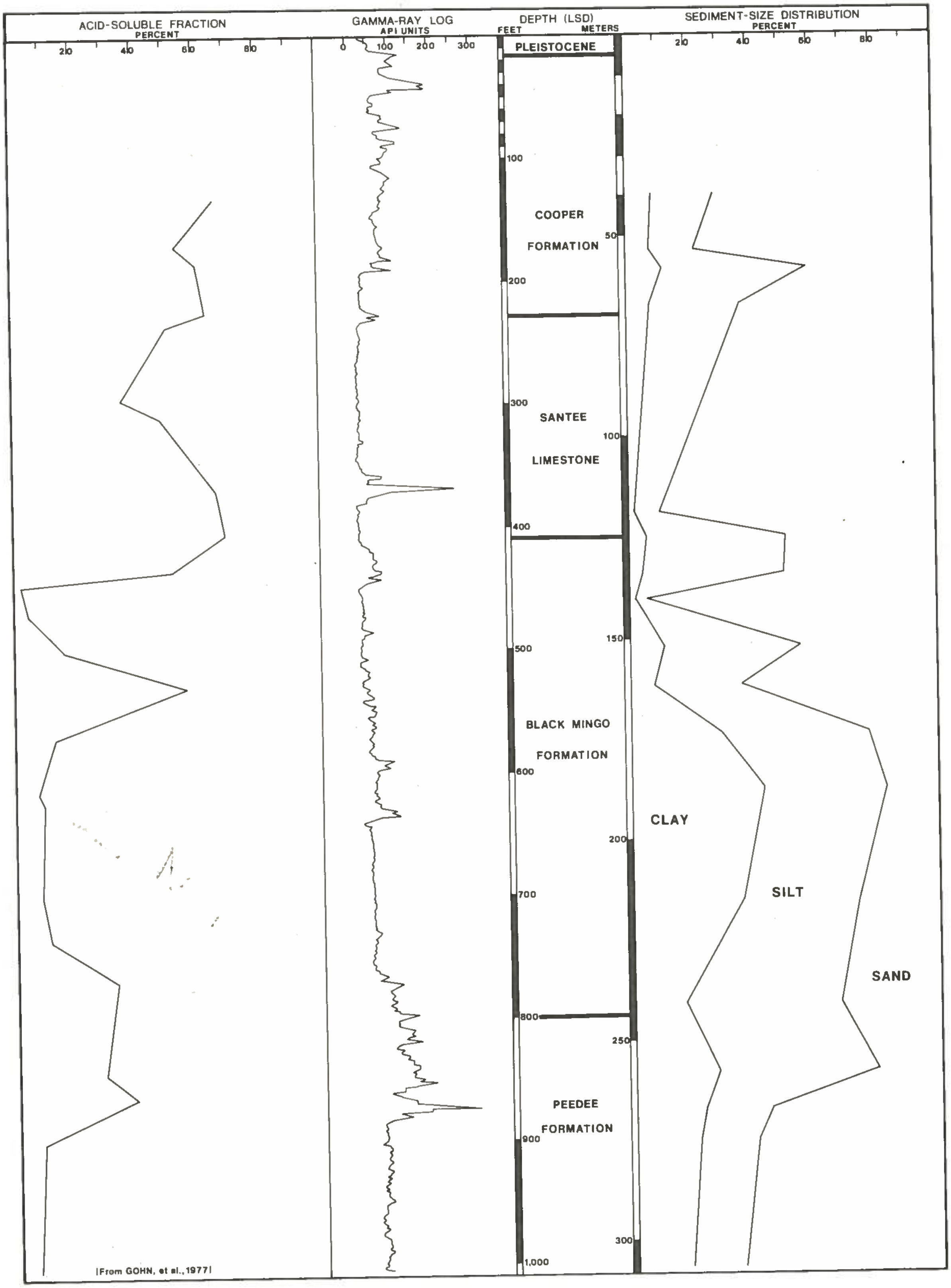


Figure 12. Contours on top of the Black Mingo Formation.



(From GOHN, et al., 1977)

Figure 13. Distribution of carbonate and sediment size in well 23CC-i1 at Clubhouse Crossroads.

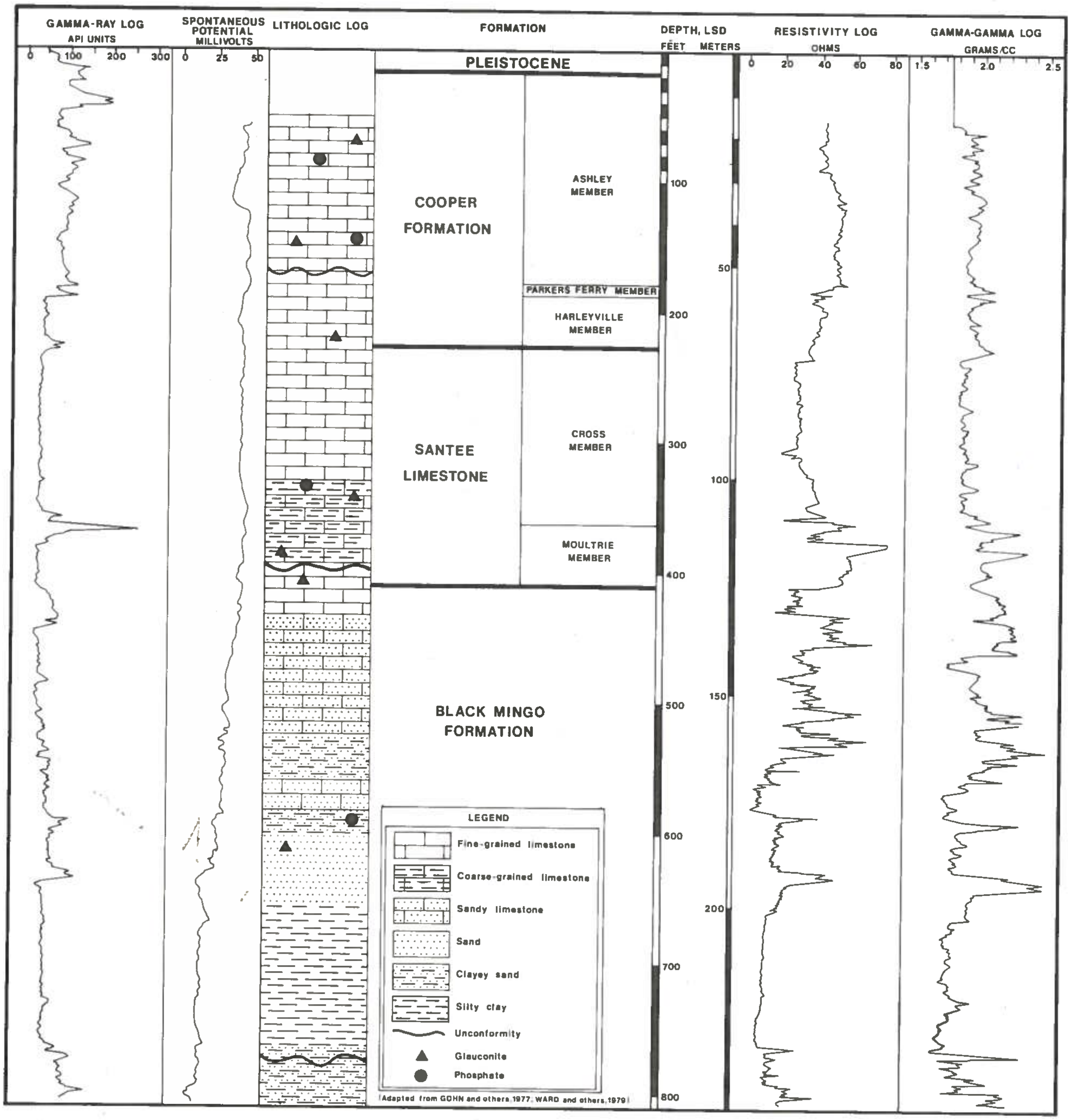


Figure 14. Geophysical and lithologic logs for the Tertiary section in well 23CC-i1 at Clubhouse Crossroads.

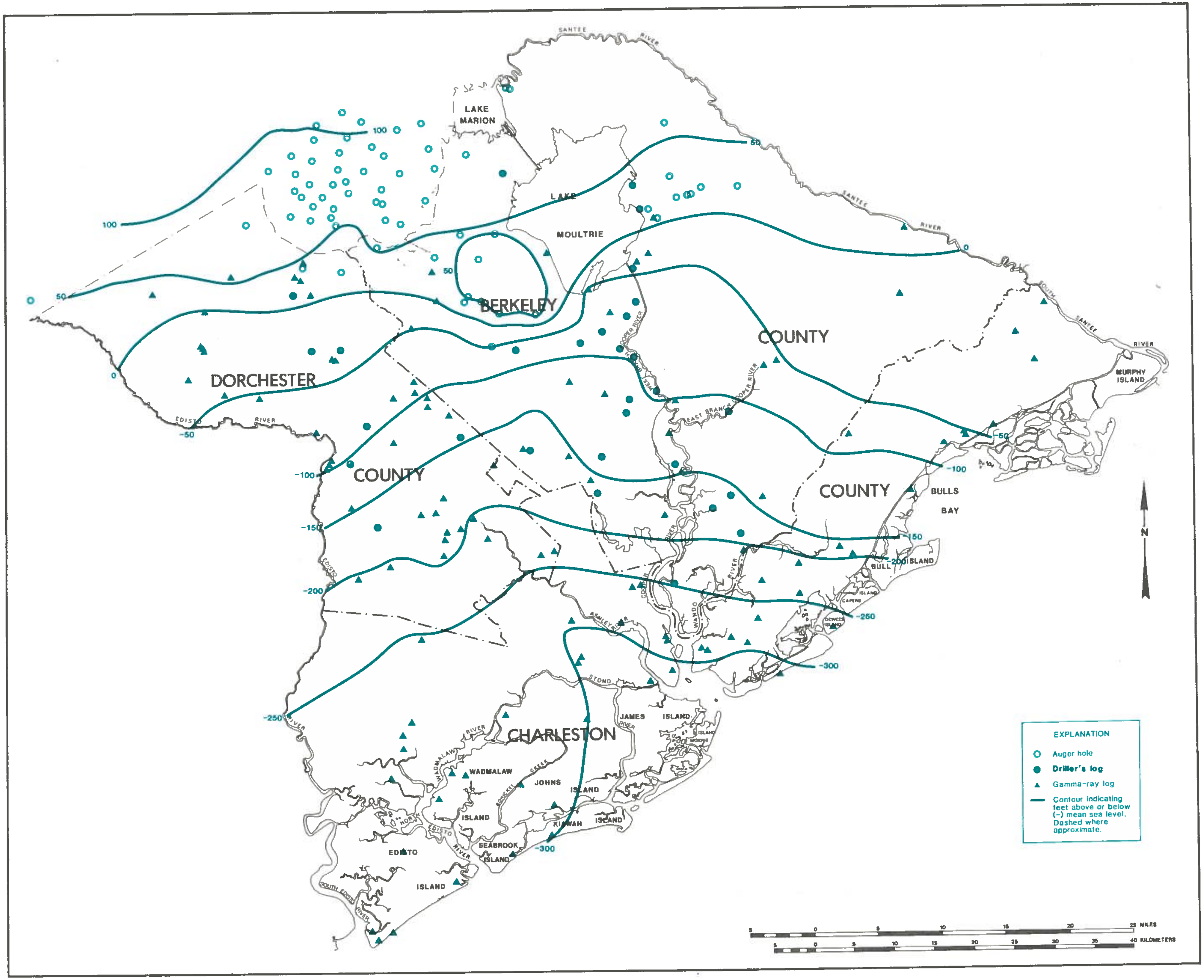


Figure 15. Contours on top of the Santee Limestone.

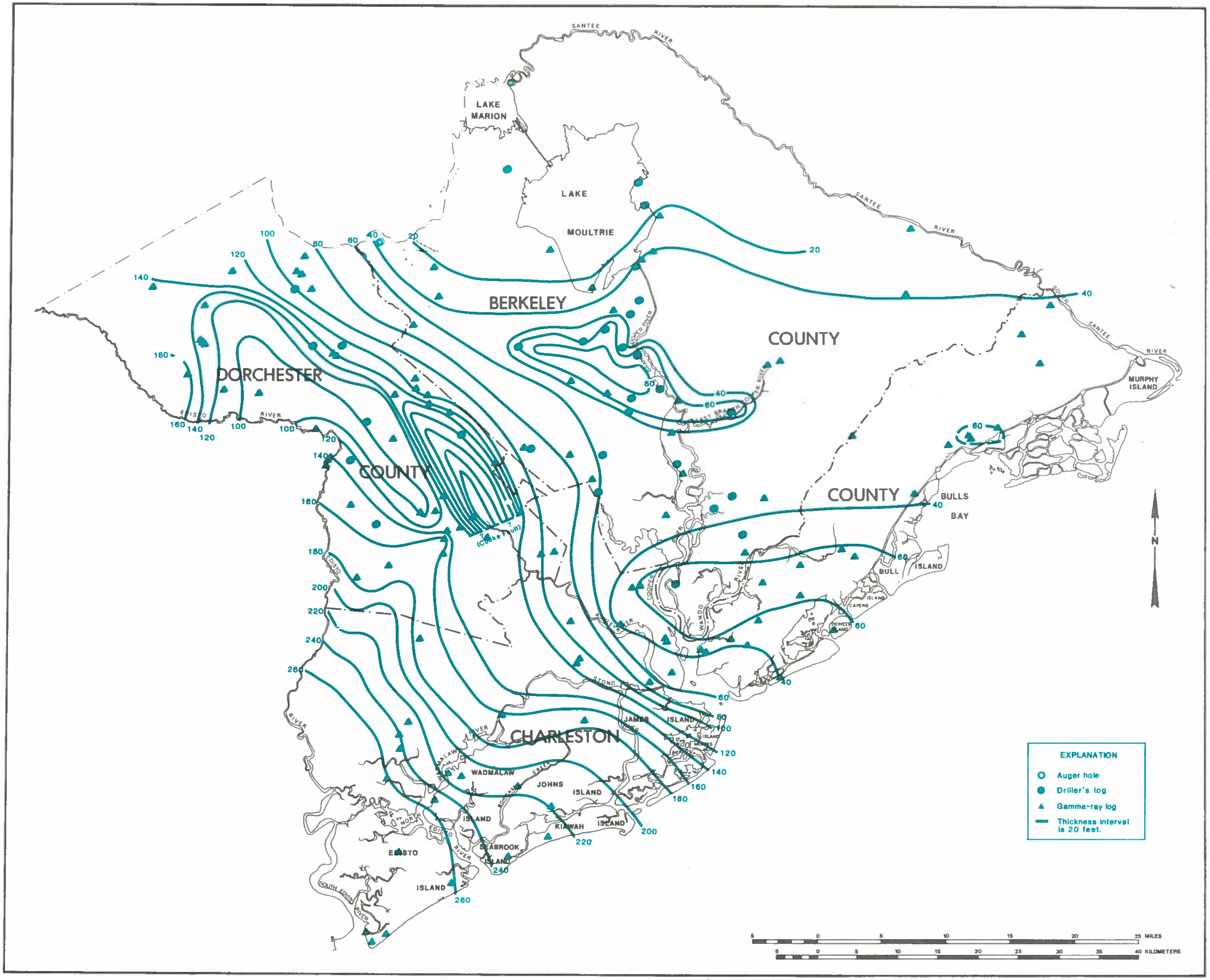


Figure 16. Thickness contours for the Santee Limestone.

tion as "carbonates (25-75 percent), sand (10-45 percent), clay (2-3 percent), and phosphate (5-20 percent). A description of a core taken near Summerville is similar: calcium carbonate (60-75 percent), quartz sand (5-25 percent), clay (10-30 percent), phosphatic sand and pebble (1-5 percent), and small amounts of glauconite, bone, shell hash, and mica (Gohn and others, 1977, p. 69). The carbonate component consists principally of foraminiferal shell (Malde, 1959, p. 9, 12; Gohn and others, 1977, p. 69). Color ranges from pale-green or yellowish gray to olive brown, becoming lighter when dried.

The Cooper has been divided into three members, which are, in ascending order; Harleyville Member (Eocene), Parkers Ferry member (Eocene), and Ashley member (Oligocene) (Ward and others, 1979, p. 14-26). The Harleyville varies from a phosphatic, calcareous clay and clayey calcarenite at the type exposure to a clayey, very fine-grained limestone in the subsurface. It thins out northward toward the Santee River and thickens toward Charleston, filling a local basin. The overlying Parkers Ferry Member is a glauconitic, clayey, fine-grained limestone with abundant microfossils and mollusk and bryozoan fragments; the unit occurs only in the subsurface and is absent in northern Berkeley and Dorchester Counties. Phosphatic, muddy, calcareous sand comprises the Ashley Member, which unconformably overlies the Parkers Ferry Member and, locally, the Harleyville Member (Ward and others, 1979, p. 14-26).

The Cooper Formation underlies most of the area south of the Santee River and occurs near land surface in a 12- to 20-mile wide east-west trending belt through upper Charleston, Berkeley, and Dorchester Counties. It thickens southward from a few feet in the vicinity of Moncks Corner to more than 300 ft at Edisto Island (Fig. 17). Its surface dips south-southeast at 8 ft per mile, occurring at about 80 ft msl in northern Dorchester County and 40 ft msl in southern Charleston County (Fig. 18; also see Malde, 1959, plate 2; Colquhoun, 1961).

Locally, the surface of the Cooper exhibits a relief of 15 to 20 ft. The greatest relief occurs within an erosional basin in the vicinity of Charleston and is on the order of 40 to 50 ft. Higgins and others (1978, Fig. 1) depict a similarly oriented basin in the underlying Eocene surface of the Cooper. Intraformational units also contain some signs of faulting that are not readily apparent at the surface of the Cooper, according to Colquhoun and Comer (1973). However, the apparent discontinuities observed in their seismic data could instead be related to erosion.

Shallow Tertiary and Quaternary Units

Edisto Formation

Ward and others (1979, p. 26) have applied the name "Edisto Formation" to the pale-yellow, sandy, fossiliferous limestone that overlies the Cooper Formation in western Dorchester County. They designated the left bank of the Edisto River, 0.3 mile above S.C. Highway 61 near Givhans as the lectostratotype. Sloan (1908) originally applied the name "Edisto Marl"; Cooke (1936, p. 86) grouped it with the Eocene Cooper Formation in the vicinity of Givhans; and Malde (1959, p. 26) separated it from the Cooper, referring to the formation under the heading of "Lower Miocene (?) Deposits". The Edisto Formation occurs as an erosional remnant southwest of the type location and pinches out to the northeast. In the vicinity of the Ashley River, Sloan's "Edisto Marl" is grouped with the Hawthorn Formation by Cooke (1936, p. 113-115); Ward and others restricted the unit to the area northwest of U.S. Highway 17 at the Edisto River.

Hawthorn Formation

The Hawthorn Formation was named from the town of Hawthorne, Alachua County, Florida (Dall and Harris, 1892, p. 107). C.W. Cooke (1936, Fig. 2) mapped the Hawthorn into South Carolina as far north as Charleston, including parts of Sloan's (1908) "Ashley" and "Edisto Marls" and generally describing the formation as a middle Miocene "fine sandy, phosphatic limestone". Johnson and Geyer (1965, p. 4) reported that the Hawthorn occurs as a feather edge along the Edisto River, dipping south-southwest and attaining a thickness of about 120 ft. The Hawthorn appears to have been removed by erosion in the Charleston area but may occur locally as thin remnants of sand and clay (Malde, 1959, p. 28).

Pleistocene Formations

Pleistocene deposits within the limits of the study area provisionally are represented by the "Wicomico", "Penholoway", "Talbot", and Pamlico" Formations (see Cooke, 1936, p. 130-154). The names were adopted from work by Shattuck (1906), Stephenson (1912), Cooke (1925), and others. Cooke described the formations as resulting from a glacially controlled Pleistocene sea whose retreat was periodically interrupted by rises of sea level. The result was a topographic succession of terraces and abrupt shorelines cut during interglacial stands of sea level. The local occurrence of each formation was therefore determined on the basis of topographic elevation, as well as by lithology. Thus the Wicomico lies between +100 ft and +70 ft msl; the Penholoway lies between +70 ft and +42 ft msl; the Talbot lies between +42 ft and +25 ft msl; and the Pamlico lies between +25 ft and 0 ft msl. Differing and more detailed interpretations of the geomorphology and lithology of these units have been published by Flint (1940), Richards (1943, 1959), Doering (1958, 1960), Maulde (1959), Colquhoun (1961, 1962, 1969), and others.

The Wicomico generally is composed of fine sand, but it contains some clay, coarse sand, and gravel locally. Estuarine deposits are coarser and contain more gravel than sediments deposited in the open sea. The thickness averages less than 25 ft and rarely exceeds 50 ft (Cooke, 1936, p. 143). As the result of leaching, carbonate clastics are scarce (Colquhoun, 1961, p. 48).

Cooke (1936, p. 147-148) defined the Penholoway as deposits laid down when the sea was about 70 ft above present mean sea level. He gave three locations in Dor-

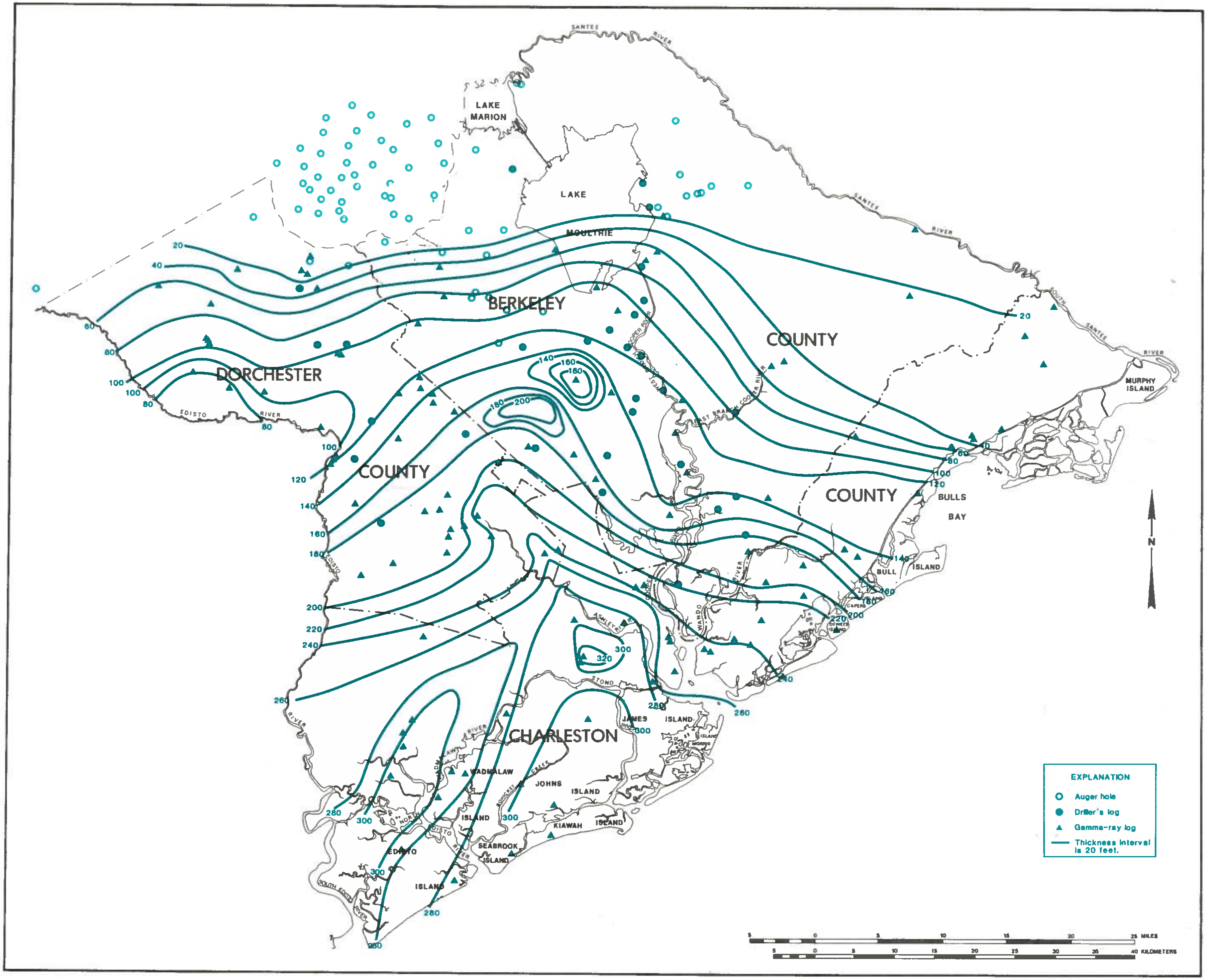


Figure 17. Thickness contours for the Cooper Formation.

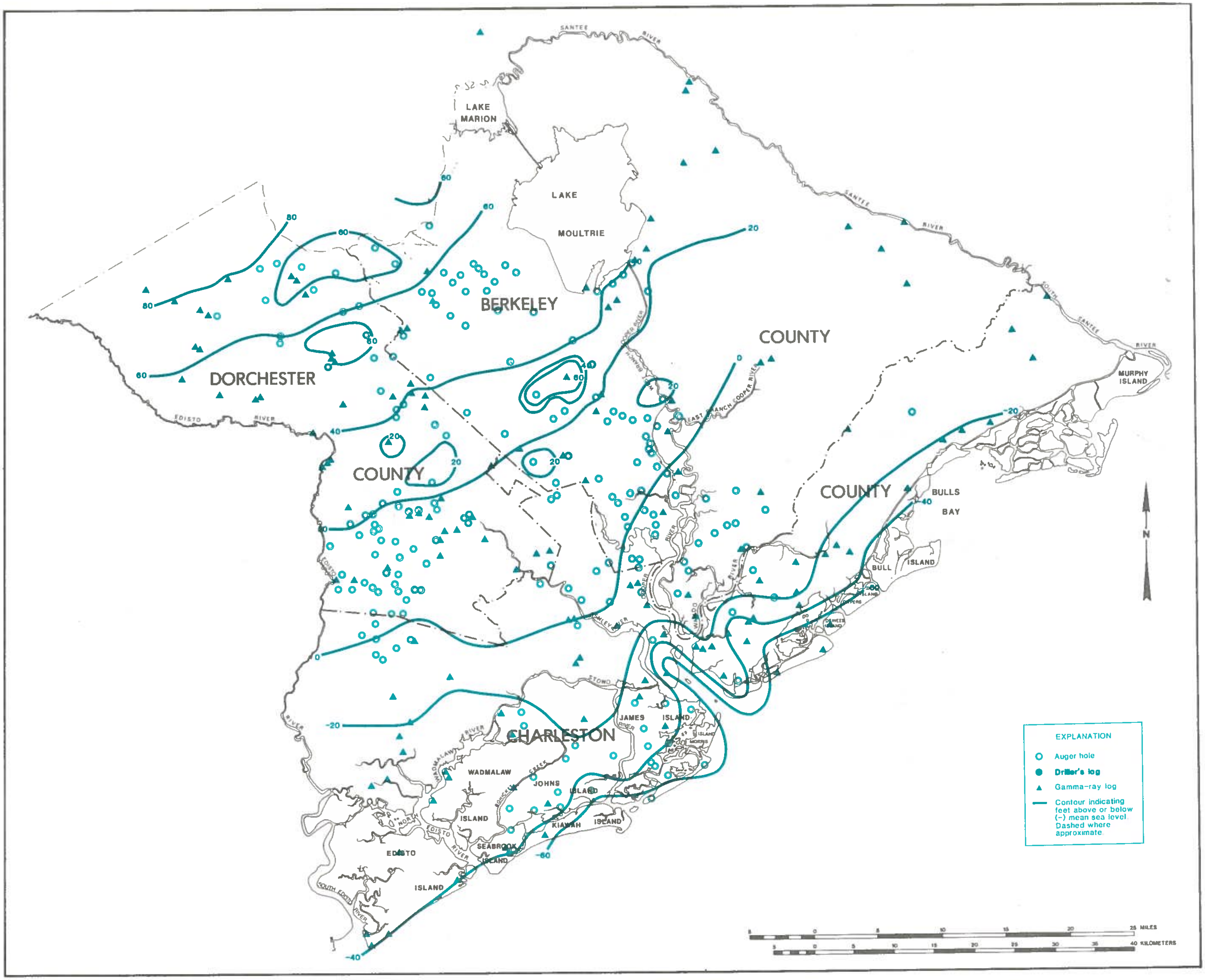


Figure 18. Contours on top of the Cooper Formation.

chester County and described a section at Four Hole Swamp as 4½ ft of "dark grey pebbly sand . . . passing upward into fine black carbonoecqus sand" overlain by 15 ft of "Fine white crossbedded sand weathering yellow (beach or river deposit)". Locally, coarse basal sands in the Penholoway appear similar to those underlying the Wicomico (Colquhoun, 1962, p. 72). Penholoway sediments are reported to overlap those of the Talbot in the vicinity of Summerville (Malde, 1959, p. 36).

The Talbot Formation generally consists of very fine gray to red or pink thin-bedded sand and clay. Malde (1959, p. 36) includes it as a unit within his "Ladson Formation". According to Cooke (1936, p. 149), the Talbot may have been formed in bays and drowned river valleys. The landward limit of the Talbot is represented by an abandoned shoreline lying at +42 ft msl.

As described within the confines of the study area, the Pamlico Formation occurs at and below the 25-ft topographic contour. Adapting a section described by Sloan (1908) at Johns Island in Charleston County, Cooke (1936, p. 151) listed a section containing 5 ft of green glauconite clay-sand, underlain by 3 feet of sand, in turn underlain by 2 ft of Pleistocene shell. Pugh (1905) reported 179 species of shells collected from the formation in the vicinity of Charleston. The thickest sequence of Pamlico deposits occurs in the coastal section of Charleston County where 40 to 60 ft of sand, clay, and shell overlie the Cooper Formation.

HYDROGEOLOGY

General Principles of Ground-Water Occurrence

The occurrence, movement, availability, and chemical quality of ground water in Charleston, Berkeley, and Dorchester Counties are intimately related to the geology. Ground water is obtained from aquifers, geologic formations that are capable of yielding water to wells or springs. Aquifers in the study area consist of sand and limestone. Confining beds overlie or underlie aquifers and are strata that cannot yield appreciable amounts of water to wells or springs. The confining beds identified in the study area are composed of sandy limestone and clay.

Ground water in an aquifer may occur under artesian (confined) or water-table (unconfined) conditions. The water level in a tightly cased well penetrating the first few feet of a water-table aquifer defines the water table, on which the pressure is atmospheric only.

Artesian aquifers are contained by confining beds. Ground water in artesian aquifers is under pressure, as in a pipe, and the water level in a well completed in an artesian aquifer will rise above the top of the aquifer. The water level in such a well represents a point on the potentiometric surface, an imaginary surface to which water will rise in tightly cased wells completed in the same aquifer. The slope of the potentiometric surface determines the direction of flow of water in an artesian aquifer.

Ground water flows from areas of recharge to areas of discharge. The rate of ground-water movement is dependent upon the hydraulic gradient and the hydraulic conductivity. Hydraulic gradient is the change in hydrostatic head per unit of distance and is usually expressed in feet per mile. Hydraulic gradients are determined from the slope of the potentiometric surface.

The quantity of water that can be pumped or will flow from a properly constructed well is dependent upon certain properties of the aquifer being tapped. These properties include the hydraulic conductivity, transmissivity, and storage coefficient. Aquifer properties can be determined by means of aquifer tests and the use of specific formulas and graphical computations. When these methods are combined with adequate geologic knowledge of an area, useful projections of ground-water availability can be made.

Hydraulic conductivity (K) is the ability of an aquifer to transmit water. It is the rate of flow, in feet per day or meters per day, through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot at the prevailing water viscosity.

Transmissivity (T) is the rate of flow of water, at the prevailing water temperature, through a vertical strip of the aquifer 1 foot wide and extending the full saturated height of the aquifer under a hydraulic gradient of 1 foot per foot. Transmissivity is K multiplied by aquifer thickness (m) and is expressed in ft^2/day or m^2/day (reduced forms of ft^3/day/ft and m^3/day/m).

Storage coefficient (S) is related to the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The storage coefficient is a dimensionless term, and typical values range between 0.3 and 0.03 for water-table aquifers and between 0.005 and 0.0005 for artesian aquifers. Values from 0.03 to 0.005 indicate conditions that are neither truly water-table nor artesian (American Water Works Association, 1973.)

A characteristic of wells commonly utilized by well drillers, hydrologists, and engineers, and which is related to K, T, and S, is specific capacity. The specific capacity of a well is the rate of discharge divided by the drawdown in water level after a specified period of time (commonly 24 hours) and is expressed as gallons per minute per foot. Specific capacity can be used to compare the performance of wells and to estimate transmissivity, but not storage coefficient.

Middendorf Formation

The Middendorf Formation occurs throughout the study area and is the most extensive water-bearing formation in the South Carolina Coastal Plain. It underlies nearly all of the Coastal Plain Province between North Carolina and Alabama. In the areas north and west of Charleston, Berkeley, and Dorchester Counties, it is greatly relied upon where large quantities of water are required for public supply, industry, and irrigation.

Few wells in the study area obtain water only from the Middendorf Formation. The aquifers in the overlying formations are less expensive to develop and, in most areas, contain water of equal or better chemical quality. Wells screened in the formation usually are screened in the overlying Black Creek Formation also. Only two test wells, 19Y-w3 and 18AA-e2, and four production wells, 18W-a1, 18W-a5, 18W-b1, and 18AA-e4, are screened solely in the Middendorf Formation.

Well 18AA-e4, located north of Goose Creek, was constructed with 88 ft of screen set between −1,510 and −1,640 ft msl, in the upper 200 ft of the formation, and is by far the most productive well in the study area. During initial testing it yielded more than 2,000 gpm, and non-pumping flow was greater than 900 gpm. A pumping test conducted by maintaining non-pumping flow at 800 gpm indicated a specific capacity of 17 gpm/ft. Middendorf aquifer wells 18W-a1 and 18W-a5, at St. Stephen, yield 300 to 500 gpm with specific capacities on the order of 8 gpm/ft.

Only limited hydraulic data are available from pumping tests in Charleston, Berkeley, and Dorchester Counties. However, it is apparent that the transmissivity and hydraulic conductivity of Middendorf aquifers are far lower in the study area than in areas to the west. Siple (1975, p. 35) estimated transmissivities as great as 21,000 ft²/day in central Orangeburg County. The average transmissivity calculated for several sites in Sumter and Richland Counties was about 6,000 ft²/day (Park, 1980, Table 3). The highest transmissivities observed are at the Savannah River Plant in Aiken and Barnwell Counties, where an average value calculated for 25 pumping tests was 20,000 ft²/day (Siple, 1967b, p. 31-35). These high transmissivities occur in areas where the Middendorf Formation contains coarse-grained deltaic deposits that are generally absent in the study area.

The transmissivity of sand beds in the upper 100 to 150 ft of the formation may lessen toward the southeast where drill samples and geophysical logs generally indicate thinner, finer-grained sand beds that were deposited in delta-fringe and marginal-marine environments.

Medium- to coarse-grained sand beds are reported in the lower section of the formation near St. George (25Z-b1), Clubhouse Crossroads (23CC-i1), and Seabrook Island (20GG-e1). However, core and drilling-sample descriptions indicate small amounts of silt and clay that may significantly reduce permeability. Test well 18AA-e2 produced only 1½ gpm with 43 ft of drawdown during a "packer" test on the lower section.

Although transmissivities in the study area may locally be greater than those estimated for the Goose Creek area, they probably do not approach the transmissivities that exist in the Upper Coastal Plain and Middle Coastal Plain Provinces of South Carolina.

Throughout the study area, static water levels in the Middendorf Formation are above land surface. The static level at well 18AA-e2 is about +120 ft msl, and in well 20GG-e1, at Seabrook Island, the static level is +140 msl (Walter Aucott, USGS, written communication). Ground water in the Cretaceous aquifers has generally been assumed to flow toward the south or southeast. However, the static levels in wells penetrating the Middendorf Formation at Hilton Head Island and Parris Island, 50 to 60 miles to the southwest, are 10 to 40 ft higher than the levels measured near Moncks Corner, Goose Creek, and Seabrook Island. Thus it appears that the potentiometric surface slopes toward the east, or possibly the east-northeast.

Black Creek Formation

The Black Creek Formation generally is not as productive as the underlying Middendorf Formation and is largely undeveloped. Eleven wells are open only to the Black Creek Formation and another 10 wells are screened in both the Black Creek and Middendorf. Thirteen of these wells are incorporated in public water-supply systems that typically blend Black Creek and Middendorf aquifer water with that of shallow wells or with surface water.

The Black Creek wells in operation in 1983 were located at Hampton Plantation, in northern Charleston County, and in the vicinities of Jamestown, St. Stephen, and Mt. Pleasant. The well at Hampton Plantation (12Y-L1) and the two wells at Jamestown (15X-L1 and 15X-L5) have 40 to 60 ft of screen set opposite sand in the upper 200 ft of the Black Creek Formation. These wells produce 125 to 275 gpm and have specific capacities of 0.8 to 2.3 gpm/ft.

Two Mt. Pleasant Water Works and Sewer Commission wells (16CC-y1 and 17DD-m5) are screened in the lower 200 ft of the Black Creek Formation and, within the study area, are the highest yielding wells in the formation. Both wells have been tested at discharges greater than 700 gpm, with specific capacities of 2.5 gpm/ft for 16CC-y1 and 4.8 gpm/ft for 17DD-m5. Well 19CC-x1, northwest of Charleston, was screened in corresponding sand beds, but it produces only 240 gpm with a specific capacity of 0.8 gpm/ft.

Wells screened in both Black Creek and Middendorf aquifers are, on the whole, better producers than are those screened only in the Black Creek Formation. In the St. Stephen area, industrial and public-supply wells that have 50 to 60 ft of screen set between 1,060 and 1,260 ft are pumped at 270 to 400 gpm. Specific capacities range from 6 to 10 gpm/ft. The two wells operated by the Town of Summerville have approximately 65 ft of screen set between 1,600 and 1,700 ft and yield about 500 gpm with a specific capacity of 4 gpm/ft. One of these, well 21BB-m3, was tested at 900 gpm.

Comparable wells in the Mt. Pleasant area have been between 80 and 100 ft of 8-inch diameter screen set in the interval of 1,800 to 1,975 ft. These wells produce 400 to 1,000 gpm and have specific capacities of 4.1 to 7.8 gpm/ft.

Transmissivity and hydraulic-conductivity estimates were made for four sites in the study area on the basis of aquifer tests at Jamestown (well 15X-L1) and Mt. Pleasant (wells 17DD-g1, 17DD-m5, 16CC-y1). In each test, water-level measurements were made only in the pumping well; no observation wells were used. The wells were shut down for at least 24 hours prior to the beginning of their tests, and drawdown and recovery measurements were made over a 48-hour period. Transmissivity calculations were based on the recovery data, which are illustrated for well 16CC-y1 in Figure 19. The values for hydraulic conductivity were obtained by dividing the transmissivity by the

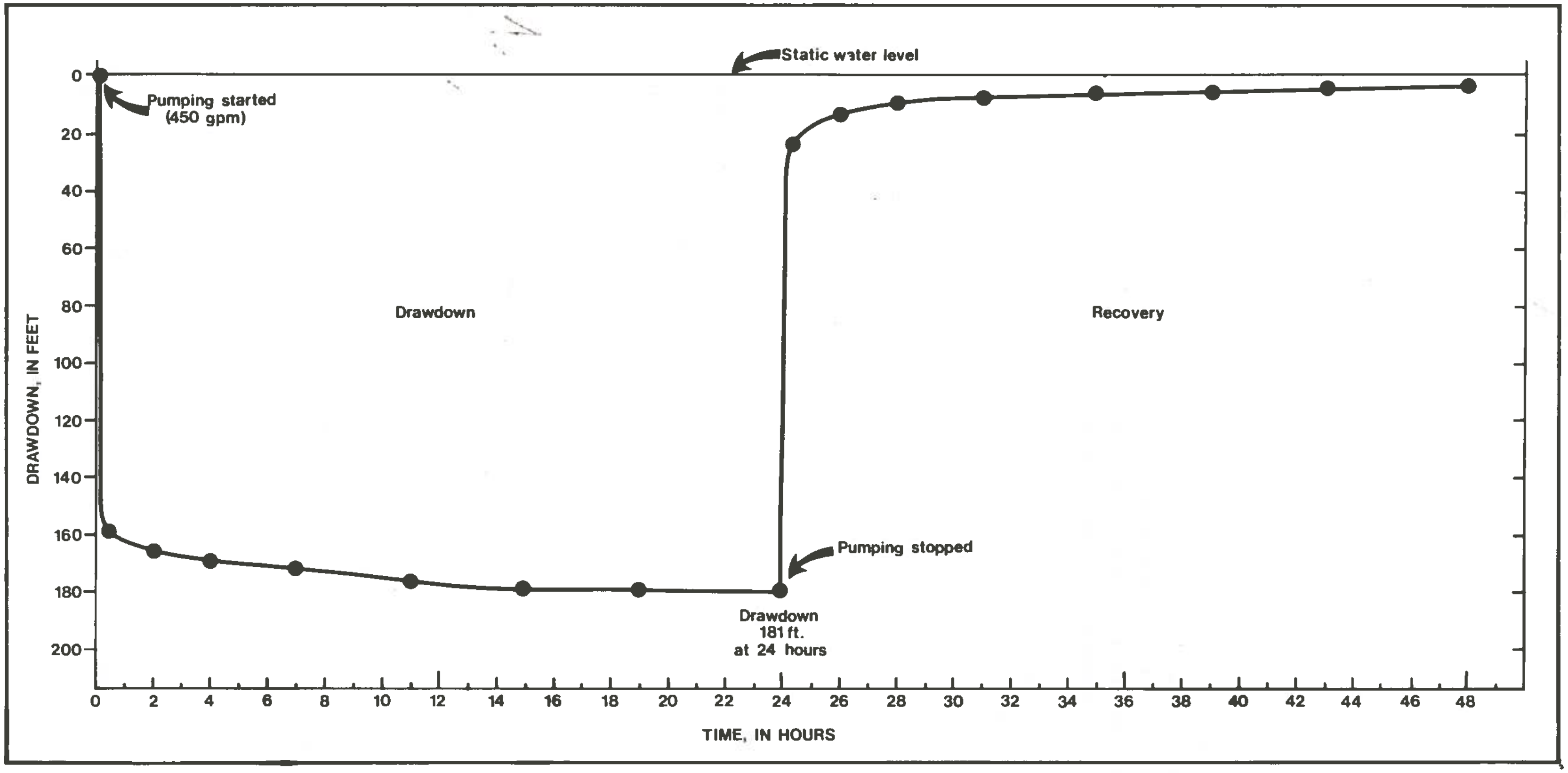


Figure 19. **Drawdown and recovery plot for well 16CC-y1 at Mt. Pleasant.**

length of screen in the pumped well. Tests of this nature do not account for the effects of partial screen penetration, multiple screen locations, or well inefficiency; nor do they permit calculation of the storage values.

The data from the test at Jamestown indicate a transmissivity of about 930 ft²/day and an average hydraulic conductivity of 19 ft/day. This well is mainly screened in the upper half of the Black Creek system, and it is possible that more permeable sand exists at greater depths in the Jamestown area.

The transmissivities calculated for the Mt. Pleasant area were only slightly greater than that for Jamestown. They range from approximately 1,200 ft²/day, at wells 16CC-y1 and 17DD-m5, to about 2,600 ft²/day at 17DD-g7, which is screened in both Black Creek and Middendorf aquifers. Hydraulic conductivities range from 21 to 32 ft/day.

Zack (1977, p. 31) reported the values of transmissivity and hydraulic conductivity for the Black Creek System at 14 well sites in Horry and Georgetown Counties. His calculations indicated that transmissivities there range from 390 to 5,350 ft²/day and that hydraulic conductivities range between 2 and 59 ft/day. He reported storage coefficients that range from 0.0001 to 0.0004.

The transmissivity and hydraulic conductivity values measured in the study fall well within the range of values reported for Horry and Georgetown Counties, although they are somewhat below the averages of 1,733 ft²/day and 30 ft/day reported by Zack (1977). Nonetheless, a comparison of pumping-test data for Black Creek wells in the study area, Horry County, and Georgetown County indicate similar hydraulic characteristics.

Water levels in the Black Creek Aquifer System are generally higher than +80 ft msl, except in the vicinity of the major pumping centers and in the northeastern section of the study area. Ground water in the system evidently moves toward the east, since static levels of about +160 ft msl are reported at Walterboro, in Colleton County; Zack (1977) reported levels of +20 to zero feet msl in Georgetown County.

A noticeable cone of depression exists in the vicinity of Mt. Pleasant, where six public supply wells withdraw about 1.5 mgd from the Black Creek and Middendorf aquifers. The static level at well 17DD-a4, near the center of the cone of depression, has declined from approximately +90 ft msl in 1973 to +53 ft msl in 1983. The decline should be a matter of concern, since relatively high chloride concentrations have been observed in Black Creek aquifers near Charleston. The chlorides suggest the existence of saltwater-bearing zones to the east, from which saltwater could intrude as pumping increases and water levels decline further.

Peedee Formation

Scant information is available for the Peedee Formation. The earliest known Peedee well was drilled for the City of Charleston in 1823 and penetrated to a depth of 1,250 ft. Two wells of similar depth and construction were drilled in 1849 and 1896; both of which were disappointments in the quantity and the quality of ground water produced. Since that time, no Peedee wells have been drilled in the Charleston area.

Less than 10 Peedee wells are known to have been drilled in the remainder of the study area. Of these, only one, which belongs to the Town of Moncks Corner, is fully cased and screened. That well has a total depth of 807 ft and has 8-inch diameter screen set between 633 and 693 ft. When drilled, the well had a static water level above land surface (55 ft msl) and produced 200 gpm with 240 ft of drawdown for a specific capacity of 0.8 gpm/ft.

For central Orangeburg County, Siple (1975, p. 36) and the writer have observed coarse-grained, well-sorted Peedee sand that suggests highly permeable zones, at least locally. However, the facts that the Peedee is largely ignored as a source of water supply in the study area and that the few wells tapping it have very modest yields attest to the generally low transmissivity of the formation. This characteristic is not unique to the present study area. Siple (1945, 1957) reports that the permeability of Peedee sand is quite low in most areas of the Coastal Plain and that water levels in the system are substantially affected in areas of heavy pumping.

Water levels in the Peedee are above land surface throughout most of the study area, but the direction of ground-water movement is not known. USGS records report water levels higher than +25 ft msl at Charleston and Sullivans Island; well 18DD-k1 at Charleston had a static head of 29.5 psi (70 ft msl) in April, 1983; and well 19Y-s1 had a static level greater than 55 ft msl when completed in September, 1975.

Santee Limestone and Black Mingo Formation

The Santee Limestone in Charleston, Berkeley, and Dorchester Counties is the northernmost segment of one of the most extensive limestone aquifers in the United States. It is part of a series of limestone formations that extend southward from the Santee River into eastern and southeastern Georgia, Florida, and adjacent parts of Alabama. Formations within the system occur near land surface in a southeast-trending belt between Tallahassee and Tampa, Florida, and in a northeast-trending belt that parallels the fall line from Alabama to southeastern South Carolina. The system dips coastward and away from the Cape Fear Arch of North Carolina and the Peninsula Arch and Ocala uplift of Florida, thickening from a few feet in the outcrop areas to more than 12,000 ft in parts of Florida.

The limestone is an important source of fresh ground water in many parts of the Trident Area. As defined for the purposes of this report, it includes the lower Eocene "Fishburne Formation" of Gohn and others (1981), the middle Eocene Santee Limestone, and, locally, the uppermost limestone of the Paleocene Black Mingo Formation. Its lower boundary is everywhere marked by sand or clay of the Black Mingo, and, except in the northern portion of the study area, it is overlain by the Eocene and Oligocene Cooper Formation. The Cooper Formation is an effective confining unit, resulting in artesian conditions throughout most parts of the Santee Limestone.

The Black Mingo Formation underlies all of the study area, thinning out toward the north where it crops out in Sumter, Clarendon, Williamsburg, and Georgetown Counties, and thickening toward the south. Rocks of equivalent age extend into Georgia where they are generally undifferentiated in eastern Georgia and are assigned to the Tuscahoma, Nanafalia, and Clayton Formations in western Georgia. Ground water in the Black Mingo Formation occurs under artesian conditions except in the outcrop areas where water-table conditions may exist in the upper few feet of the aquifer.

Well Construction

Most wells tapping the Santee Limestone and the Black Mingo Formation are of open-hole construction. Because the limestones are poorly productive in many areas, wells typically penetrate the entire thickness of the limestone as well as sand beds in the upper 20 to 100 ft of the Black Mingo Formation. During development, large amounts of sand are pumped from the well, leaving a small cavity at the base of the well bore. This practice is generally satisfactory if the sand is overlain by limestone or hard clay, if large quantities of water are not required, and if the well does not penetrate the Black Mingo too deeply. A number of wells having as much as 500 ft of hole open to the Black Mingo and Peedee Formation are reported to have operated successfully in the past, but have since collapsed or been plugged by debris.

The local practice of constructing open-hole wells in unconsolidated rock carries the risk of partial well collapse. However, the chance of well failure is small if only a few feet of unconsolidated material is penetrated, and the risk is largely offset by the savings in casing and screen costs. The greater concern lies with the risk of interconnecting freshwater-bearing and saltwater-bearing aquifers and is discussed later in the section on water quality.

Domestic open-hole wells are typically 4 inches in diameter and are pumped by ½- to 1- horsepower submersible or jet pumps.

Irrigation and industrial wells are commonly 6 to 10 inches in diameter and are equipped with submersible or conventional turbine pumps of up to 40 horsepower.

Where the Cooper Formation is present, casing is set 20 to 100 ft into the formation; elsewhere the casing is usually seated a few feet below the top of the limestone or in Black Mingo clay. Both steel and polyvinyl chloride (PVC) casing are used, but PVC is the better choice for coastal areas where the ground water is brackish and corrosive.

Industrial and public supply wells have 20 to 100 ft of cement grout and usually have sanitary seals at the well head. However, domestic wells commonly are not grouted, and sanitary seals are often inadequate or nonexistent.

Wells completed only in the Black Mingo sand beds are usually screened. Because the sand is typically fine grained, a screen slot size of 0.015 inch or less is used locally, unless the well is to be constructed with a gravel filter. The gravel filter helps control the entrance of fine sand into the well and allows the use of larger screen openings. Slot sizes reported for gravel-filter wells range between 0.020 and 0.040 inch.

Water Bearing Zones and Well Yields

The permeable zones in the Santee Limestone consist of permeable limestone confined by layers of lower permeability limestone. Where the confining beds extend over a large area, the permeable zones are isolated from one another and have different hydraulic characteristics.

The conditions of ground-water occurrence and movement in these zones are not entirely analogous to those in sand-and-gravel aquifers. In the limestone, the ground water available to wells occurs in fractures and openings along bedding planes. As water moves through the fracture system, the limestone is dissolved, the fractures are enlarged, and the permeability increases. However, the permeability development is not uniform with depth or locality, for it is strongly controlled by factors such as the proximity to recharge areas, the chemistry of the ground water, and local variations in lithology and geologic structure.

Both the degree of permeability development and the position of water-bearing zones relative to the thickness of the aquifer vary from one part of the study area to another. Water-bearing limestone is believed to occur within the upper 50 ft of the system nearly everywhere except in central Berkeley and Dorchester Counties. This permeability is particularly marked in the outcrop/subcrop area of Berkeley and Charleston Counties where the very pure limestone has been weathered by circulating meteoric ground water. The permeability of the upper zones generally decreases in areas south of the outcrop area where the limestone is overlain by the Cooper Formation. Water-bearing zones also occur within the lower 50 to 150 ft of the aquifer system in southern Charleston and Dorchester Counties and are most productive in western Dorchester County and southernmost Charleston County. By contrast, permeability development is negligible in a large area surrounding Summerville and Goose Creek, where a combination of faulting (?) and relatively impure limestone may have hampered ground-water flow and the dissolution of the aquifer material.

The permeability of the Santee Limestone is low in comparison with the underlying Black Mingo Formation and with limestones in the counties to the south of the study area. Consequently, well yields are modest and, typically, will not exceed 300 gpm without causing more than 100 ft of drawdown in the well. However, yields are usually sufficient to supply domestic and light industrial needs. Wells in the outcrop areas east of Moncks Corner are between 30 and 100 ft in depth, and yields of up to 300 gpm are reported locally. Similar yields can be obtained from individual 200- to 450-ft wells in central and southern Charleston County and adjacent parts of Berkeley and Dorchester Counties. Permeabilities appear to be lowest in the central part of the study area, between Goose Creek and Summerville, where domestic wells have specific capacities of less than 2 gpm/ft and "dry holes" are reported locally.

Although the Santee Limestone usually can provide enough water to satisfy most domestic requirements, more than three-quarters of the wells open to the limestone are also open to the uppermost sand beds of the Black Mingo. Industrial and public supply wells of this kind generally produce 100 to 300 gpm and have specific capacities on the order of 4 gpm/ft. Wells having much higher yields and specific capacities have been reported locally: a 229-ft well at Pinopolis and a 285-ft well at Mt. Holly are reported to have produced 400 gpm with less than 30 ft of drawdown. Well 17BB-u1, near Wando, penetrated 150 ft of the Black Mingo system and produced more than 1,000 gpm. In western Dorchester County, where the Santee Limestone is relatively productive, open-hole Santee-Black Mingo wells produce 400 to 700 gpm.

The upper 100 ft of the Black Mingo Formation consists of fine- to medium-grained sand and silty sand interbedded with dark organic or silty clay, dark-colored limestone, sandy limestone, and calcium carbonate-cemented sandstone. The sand predominates and forms the principal water-bearing units in the Black Mingo Formation. Sand beds, 5 to 15 ft thick and interspersed with thick sequences of clay, also occur within the lower half of the formation in central and northern Berkeley County. However, these sand beds are generally absent in other parts of the study area. The distribution of sand, silt, and clay in the Black Mingo Formation at Clubhouse Crossroads is shown in Figure 13 and is generally typical of the area as a whole. While sand constitutes the major water-bearing sediments, 20- to 40-ft thick limestone beds near the top of the formation yield water to domestic wells in northernmost Berkeley County (Spiers, 1975), and sandstone or sandy limestone marking the top of the system reportedly produced small quantities of water in southern Charleston County.

Except in the outcrop area, few domestic wells are open only to the Black Mingo Formation. Wells in the outcrop area are 2 to 4 inches in diameter, are usually less than 150 ft deep, and may be either screened or open-hole. Open-hole test wells near St. Stephen, ranging from 80 to 140 ft in depth, are reported to produce an average of about 100 gpm, with specific capacities ranging from 3 to 22 gpm/ft. Transmissivities range from 500 to 3,700 ft^2/day and hydraulic conductivities range between 29 and 170 ft/day (Spiers, 1975). However, the highest specific capacities and permeabilities reported by Spiers (1975) are not typical of the formation elsewhere in the study area. Public supply wells of similar depth and construction have produced up to 300 gpm.

In the Moncks Corner area, 180- to 240-ft wells having 20 to 30 ft of screen are operated at 100 to 200 gpm, and their specific capacities are generally less than 2 gpm/ft. Wells in the vicinity of Goose Creek and Charleston produce from 140 gpm with 23 ft of drawdown (6.1 gpm/ft) to 320 gpm with 136 ft of drawdown (2.4 gpm/ft). These wells commonly have 20 to 40 ft of 0.015- to 0.025-inch slot size screen. Greater yields have been obtained in southern Berkeley County where open-hole wells have produced as much as 660 gpm with specific capacities as high as 14 gpm/ft; and yields of 250 to 600 gpm have been obtained from industrial and public supply wells in western Dorchester County. Throughout the study area, open-hole Santee Limestone-Black Mingo wells also yield moderately large quantities of water, most of which is believed to be derived from the deeper formation. Therefore it should generally be possible to obtain 300 to 500 gpm from the Black Mingo Formation, so long as the amount of drawdown and the quality of the water are acceptable.

Recharge and Ground-Water Movement in the Santee Limestone and Black Mingo Formation

Ground water in the Santee Limestone and upper sand beds of the Black Mingo Formation is replenished both beyond and within the boundaries of the study area. Much of this water enters the formations at the outcrops in Orangeburg and Clarendon Counties and flows into the study area from the northwest. The remainder is derived from recharge at the outcrop in northern Berkeley and Charleston Counties.

In a broad sense, the areas of recharge and discharge and the direction of ground-water movement can be determined by constructing potentiometric-surface maps. This surface represents the level to which water in an artesian aquifer will rise in a tightly cased well. The ground water flows downgradient from areas where the potentiometric surface is relatively high toward areas where the surface is relatively low. The direction of ground-water movement is perpendicular to the contour lines.

The contours in Figure 20 approximate the potentiometric surface(s) of the Santee Limestone and upper 50 ft of the Black Mingo Formation. All observation wells are of open-hole construction, and they generally penetrate both formations. At a number of sites, observation wells do not fully penetrate the Santee Limestone; such wells are used in areas where wells open to both formations cannot be located. However, it is assumed that (1) there is generally a significant degree of hydraulic connection between the base of the Santee and the upper part of the Black Mingo and (2) differences in water levels are negligible when considered on a regional scale.

Much of the recharge occurs west of the study area in the karst region of Orangeburg and Clarendon Counties where the potentiometric surface is above +80 ft msl. The aquifers are also recharged in Berkeley and Charleston Counties where the formations crop out along a 10- to 15-mile wide belt paralleling the Santee River.

On a regional scale, the direction of flow is southeastward, where ground water is discharged mainly through wells in the areas between Moncks Corner, Summerville, and North Charleston. Water levels in these areas are less than +10 ft msl and are below sea level in the vicinity of Charleston.

Locally, transmissivity differences, topography, and pumpage affect hydraulic gradients and the direction of ground-water flow. The hydraulic gradient averages about 2 ft per mile between the western part of the study area and the coast. However, flow is retarded by low-transmissivity limestone in central Dorchester and Berkeley Counties,

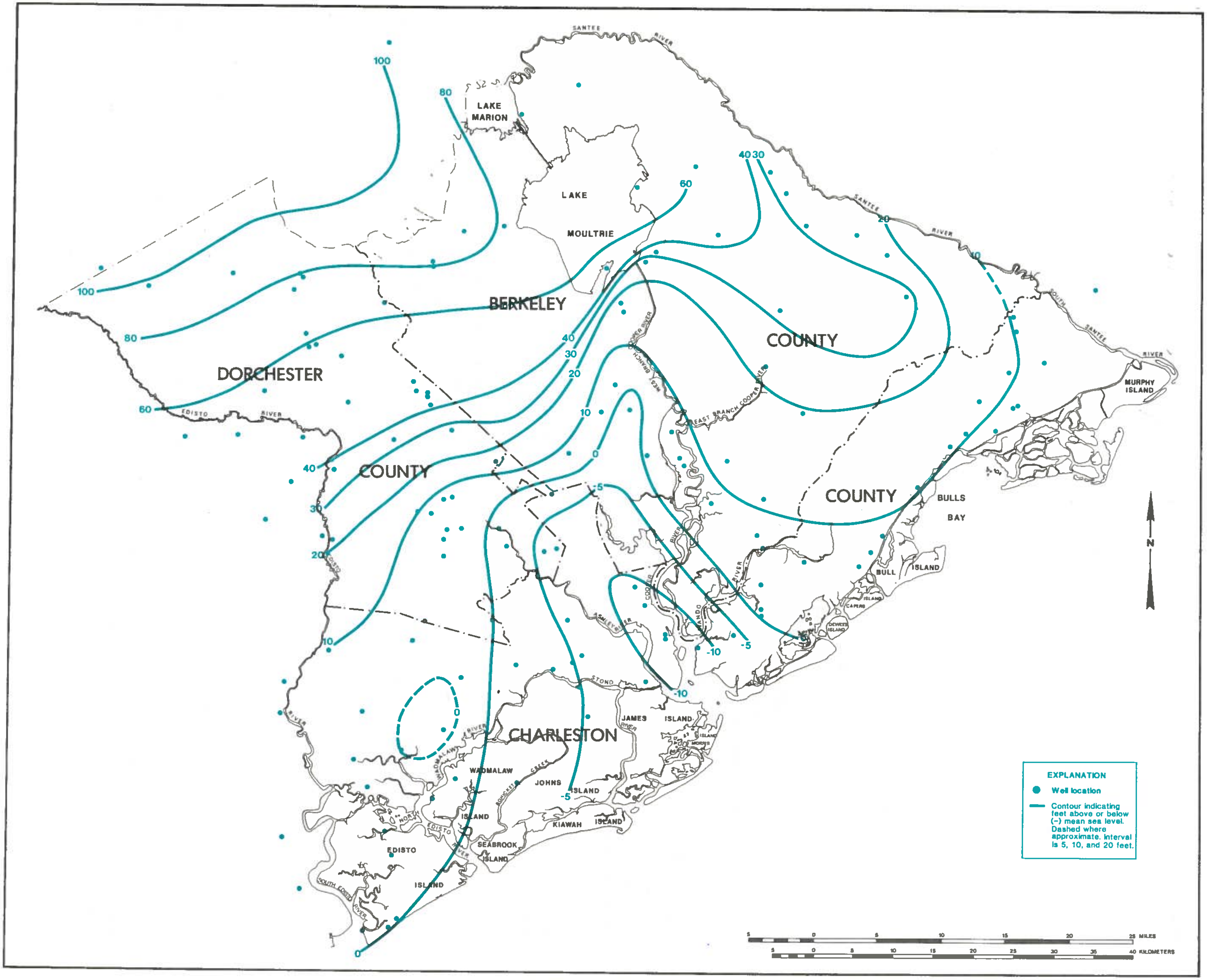


Figure 20. Water-level contours for the Santee Limestone, November 1982.

resulting in steeper gradients in the northern half of the study area (3.0 to 3.5 ft/mile) than in the southern half (0.6 to 1.5 ft/mile). Relatively greater transmissivities prevail in the subcrop area of northeastern Berkeley and Charleston Counties because of the greater purity of the limestone and its exposure to meteoric water. Ground water flows toward the southeast and south under a gradient of about 1 ft/mile, but the gradient steepens and flow becomes more southwesterly as lower transmissivities are encountered.

The most significant topographic influences are Lake Moultrie and the Santee River valley. Lake Moultrie, whose elevation is maintained at about 75 ft above mean sea level, serves as a source of recharge and controls ground water flow patterns in the vicinity of the lake. The 60-ft contour line is believed to have originally lain farther north and passed beneath the area now covered by the southern half of the lake. As the lake filled, ground-water levels rose in the vicinity of the lake and the contours moved farther south and east. The direction of ground-water flow is also affected by the Santee River valley, which forms a line sink for discharge. Contour lines trend toward the northeast throughout most of northern Charleston and Berkeley Counties, but they bend toward the northwest and roughly parallel the river as they approach the river valley, where ground water discharges through sink holes and springs and into overlying aquifers.

Although ground-water use has declined in the Charleston area during the past decade, a number of industries in the area still partially rely on water from the Santee Limestone and Black Mingo Formation. As a result of that pumpage, water levels in the vicinity of the Charleston peninsula generally remain at elevations lower than −10 ft msl. The extent of the cone of depression has apparently decreased, for, as can be seen in the hydrograph of well 18DD-b1 at Charleston (Fig. 21), water levels rose approximately 40 ft between 1974 and 1982. The decline in ground-water use is partially attributable to saltwater contamination.

Artesian-Pressure and Water-Level Fluctuations

Artesian pressures and water levels in wells tapping the Santee Limestone and Black Mingo Formation fluctuate continuously. These fluctuations occur in response to rainfall, surface-water levels, earth and ocean tides, barometric pressure, loading as water levels change in overlying aquifers, or pumping, or combinations of these factors. Many of these effects are evidenced in the records of the continually monitored observation wells whose locations are shown in Figure 2.

Rainfall affects water levels on a regional scale and has its greatest effect in the recharge areas of northern Berkeley and Charleston Counties, where water-table conditions commonly occur. The greatest monthly change is generally on the order of 1 to 4 ft, depending on the location; annual variations are as much as 10 ft. Figure 22 shows water-level fluctuations in well 13AA-n2 near Awendaw, Charleston County, just beyond the northern limit of the confining Cooper Formation. Because of the dry conditions during much of 1980, water levels in the wells declined 3 ft between January and December of that year; as rainfall returned to normal during 1981, water levels recovered. A similar trend occurred at well 15X-L1 at Jamestown (Fig. 23) where the water level declined about 10 ft during 1980. The more extreme response is probably due to ground-water discharge into the Santee River valley and to the observation well's position near the crest of a ground-water divide. Ground water southwest of the divide flows toward the south, while that on the northwest side flows toward the Santee River. Well 15X-L1 also shows the effects of loading by the Santee River. Flood stages caused by heavy rainfall and releases at Wilson Dam are reflected in the hydrograph and partially mask the effects of recharge at the outcrop area.

Water levels in deeper artesian wells southeast of the recharge area have similar, but less pronounced, responses to rainfall. The effects of this rainfall are transmitted to the downgradient parts of the aquifer system, but the response is slower, depending on the distance and hydraulic conditions. As a rule, the range of fluctuations decreases with increasing distance from the area receiving the recharge and with increasing well depth. The difference can be seen in Figure 22, which permits comparison of water levels in well 24Y-i9 at Harleyville, near the outcrop, with water levels in 22Z-r1, 20 miles downgradient from the outcrop. During the period in which water levels declined almost 10 ft in well 24Y-i9, they declined only 1½ ft in well 22Z-r1, which is located 13 miles to the southwest.

In areas along the coast, semidiurnal fluctuations are superimposed on the more gradual fluctuations caused by recharge and discharge. The semidiurnal fluctuations are caused by ocean tides and appear on the hydrograph as a continuous series of sinusoidal pulses (Fig. 24). Water levels rise as the aquifer is compressed by the additional weight of an encroaching tide, then fall as the aquifer expands on tidal retreat.

In areas that lie within or seaward of the intertidal zone, and which are not overlain by confining material, water from the tidal body may flow into the aquifer system. This event is possible in the offshore extension of the Santee Limestone's outcrop area, but only where the artesian head is below the maximum tide elevation. Since those points are generally a number of miles offshore, the effect on landward water levels is negligible in comparison to the effects of loading.

The ratio of amplitude of water-level fluctuations to that of the corresponding tide range is termed the "tidal efficiency." The tidal efficiencies of observation wells 13AA-n2, 17DD-b1, and 22EE-r1 are 4, 1, and 3 percent, respectively, and tide-induced flucuations in those wells are typically less than 0.2 ft. Tidal efficiencies vary inversely with the distance between the well and tidal body and can be greater than 75 percent for wells within a few feet of the shoreline. The lag time between a change in tide elevation and the corresponding water-level response also varies with distance and was observed to vary from 20 to 180 minutes. Other factors controlling tidal efficiency and lag time include well construction, hydrology of the aquifer,

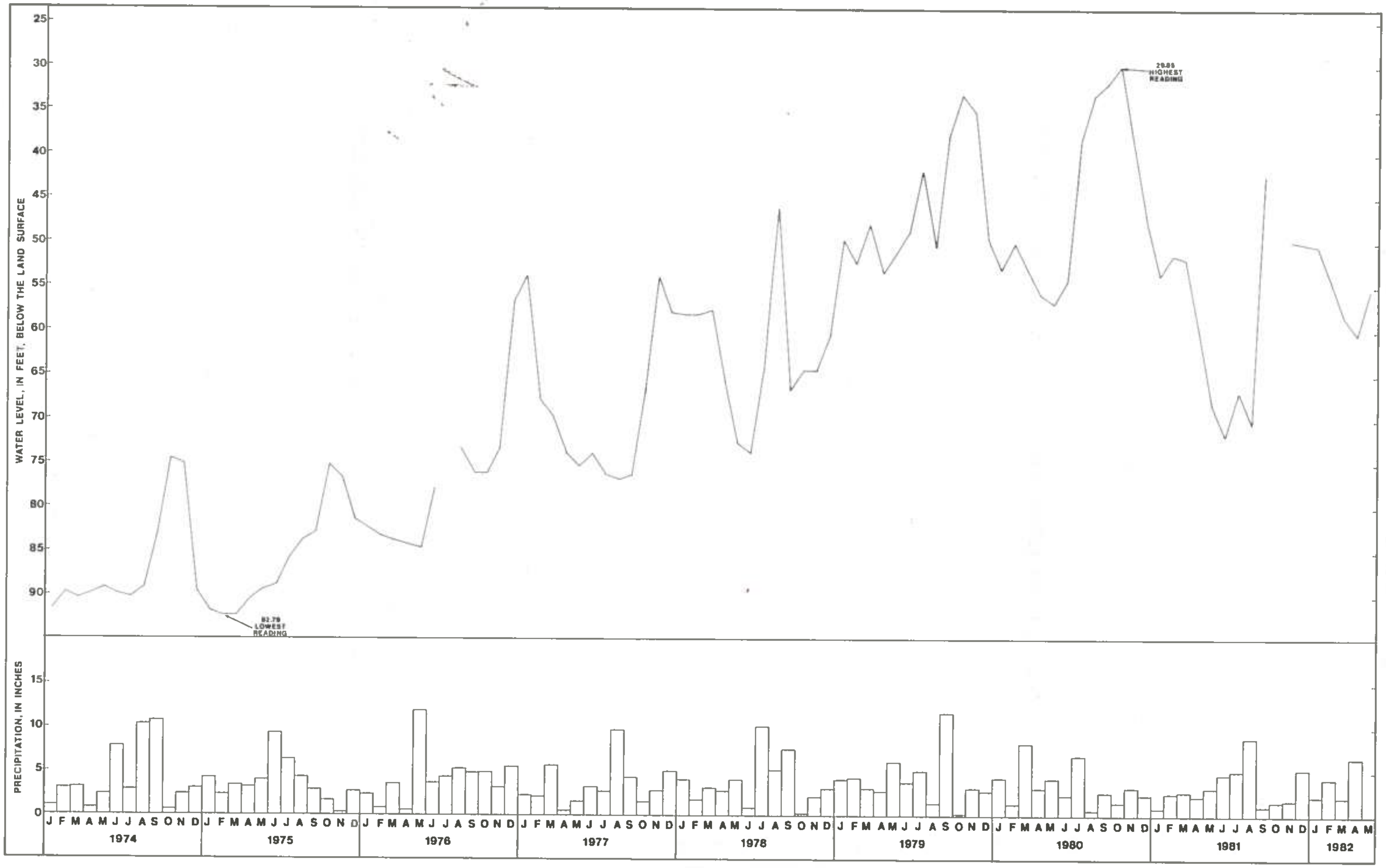


Figure 21. Hydrograph of observation well 18DD-b1, at Charleston.

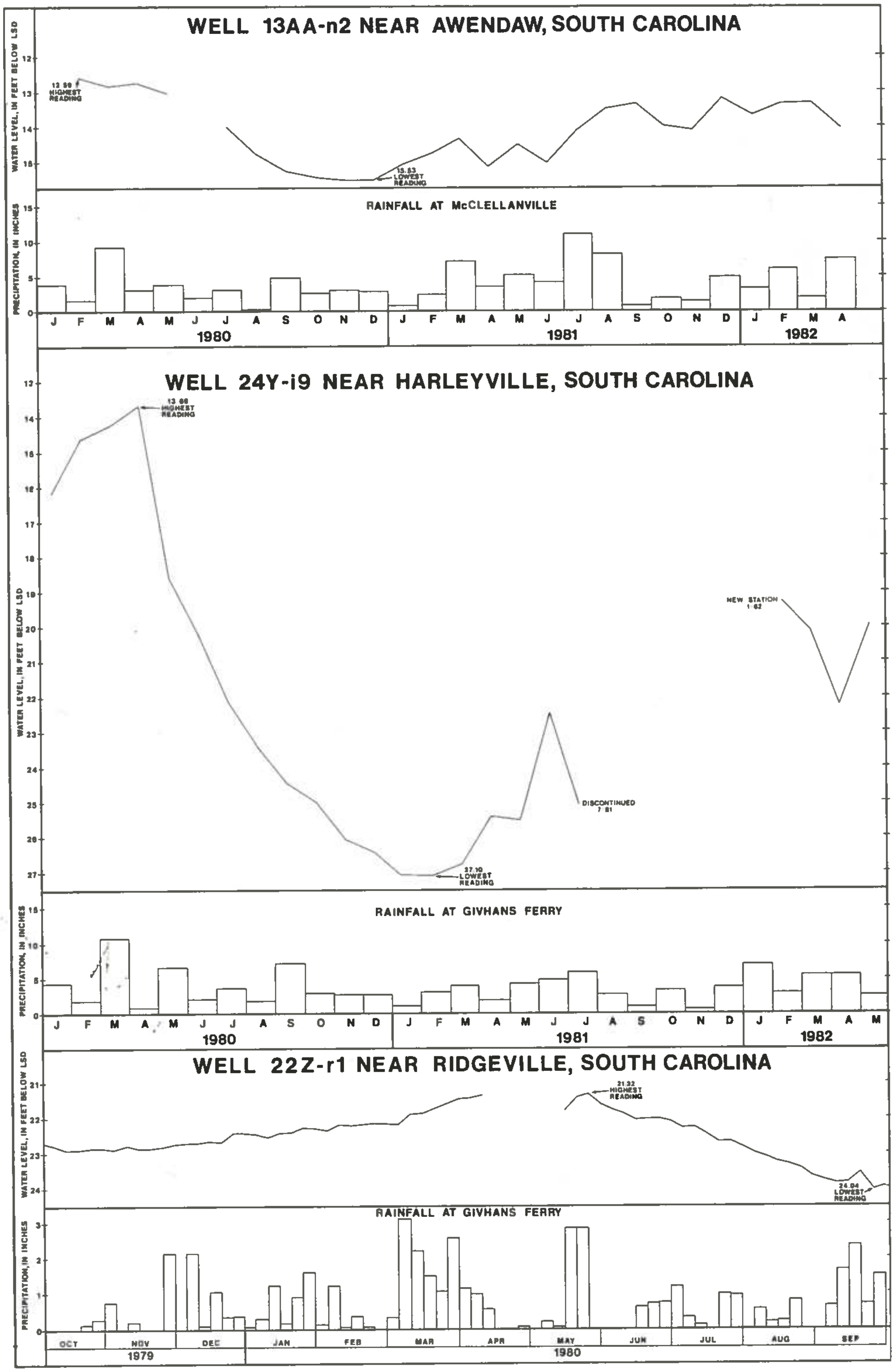


Figure 22. Hydrograph of observation wells 13AA-n2, 24Y-i9, and 22Z-r1, and monthly rainfall.

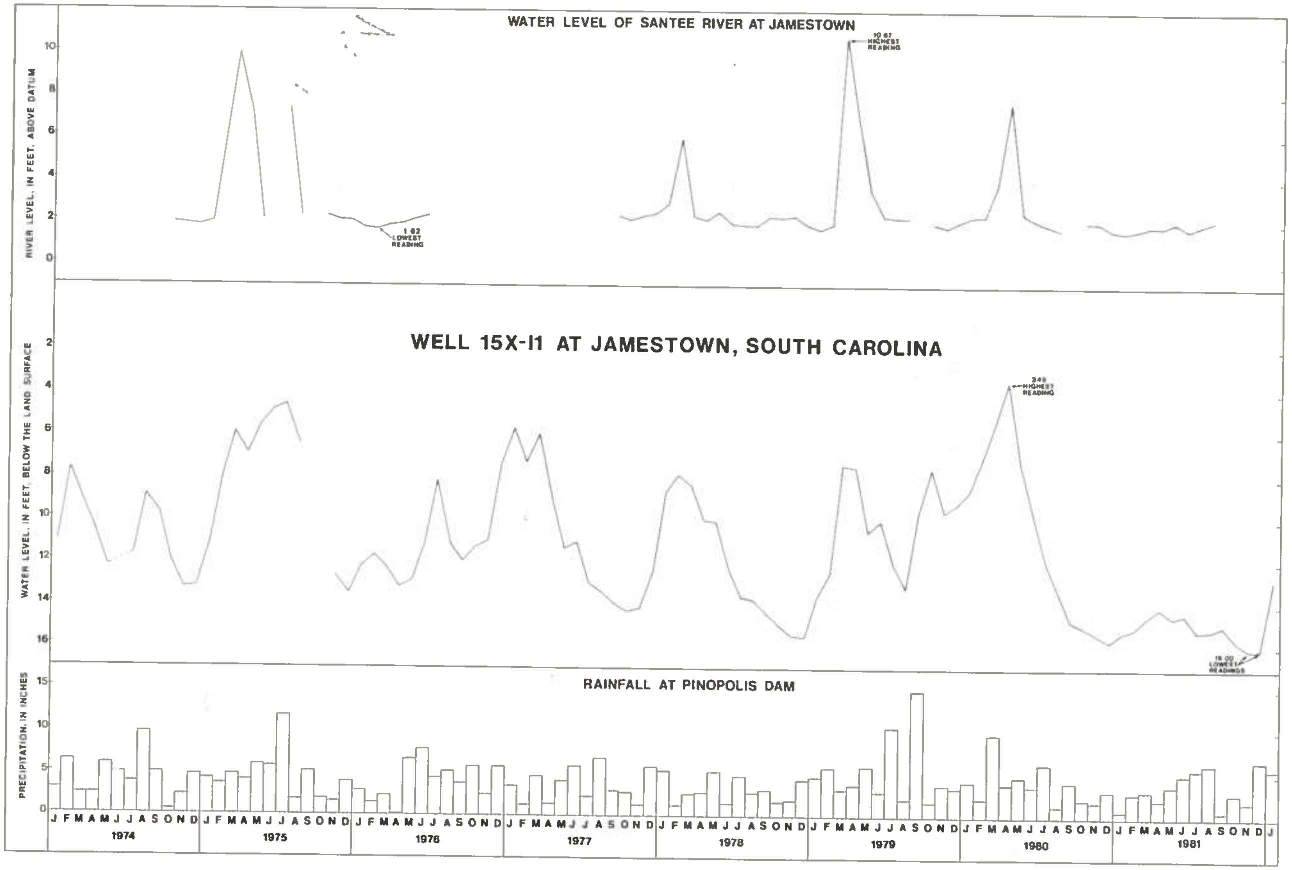


Figure 23. **Hydrographs of observation well 15X-L1 and Santee River at Jamestown, and monthly rainfall at Pinopolis Dam.**

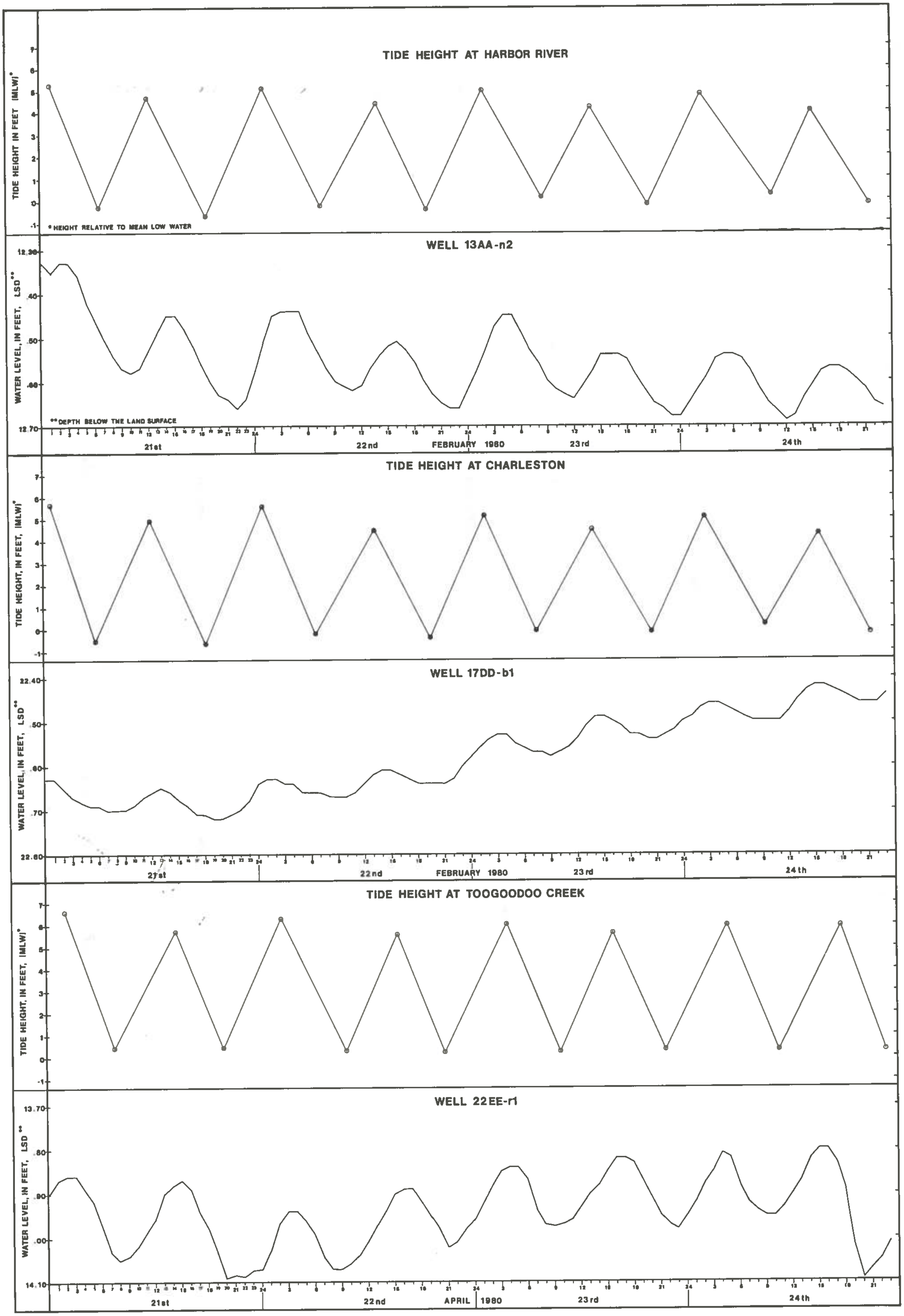


Figure 24. Tide-induced water-level fluctuations in observation wells 13AA-n2, 17DD-b1, and 22EE-r1.

thickness and mechanical response of overlying confining beds, and variations in the surface area inundated by the tides.

Changes in barometric pressure can also cause water-level fluctuations in wells in confined aquifers. As an increase in atmospheric pressure is transmitted to the water surface in the well, the water level declines; as the atmospheric pressure decreases, the water level rises. The water level in observation well 22EE-r1 responds slightly to barometric changes, but fluctuations are less than 0.1 ft and are usually masked by the effects of tide and pumping. Barometric effects are not evident in wells near the outcrop area where the confining Cooper Formation is thin or absent.

The most notable water-level fluctuations are caused by local variations in ground-water withdrawal. When a well is pumped, the water level or artesian pressure in the vicinity of the well declines. The water-level change is greatest at the well and becomes less as the distance from the center of pumping increases. A cone of depression is formed about the well, and the size and shape of that cone is controlled by the amount and rate of pumping, the ability of the aquifer to transmit water, and the amount and source of recharge water. The cone of depression may be either local or regional in extent, depending on the quantity of water being removed.

Figure 25 illustrates the response of a Santee Limestone/Black Mingo well (18Y-d1) to local industrial ground-water use. The observation well is situated about 300 ft from two wells pumping approximately 0.25 mgd, and daily water level fluctuations are on the order of 5 to 10 ft. Because of the pumping, fluctuations caused by rainfall are obscured.

A long-term decline in water level is evidenced at well 20AA-n2 (Fig. 26), which is affected by three nearby public-supply wells. When the well was inventoried in early 1978, the water level in the well was 62 ft below the top of the casing; by late 1981 the level had fallen below 120 ft. The level will continue to decline until ground-water discharge in the vicinity is balanced by a like amount of recharge. Water levels recover somewhat during the winter months as the demands for water decrease, but the recoveries have been less than previous seasonal declines. The decline is the most extreme observed during the course

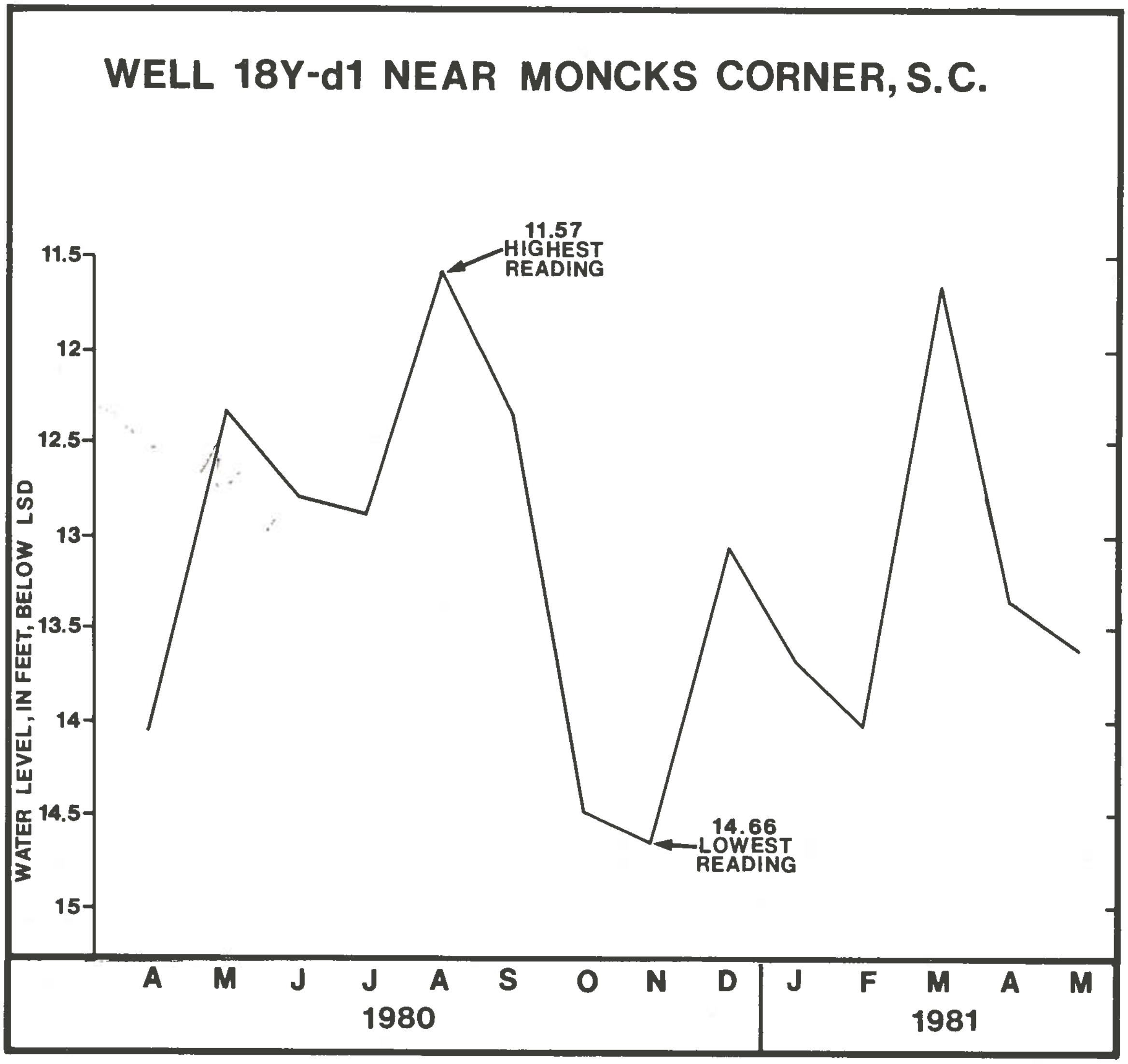


Figure 25. Hydrograph of observation well 18Y-d1, near Moncks Corner.

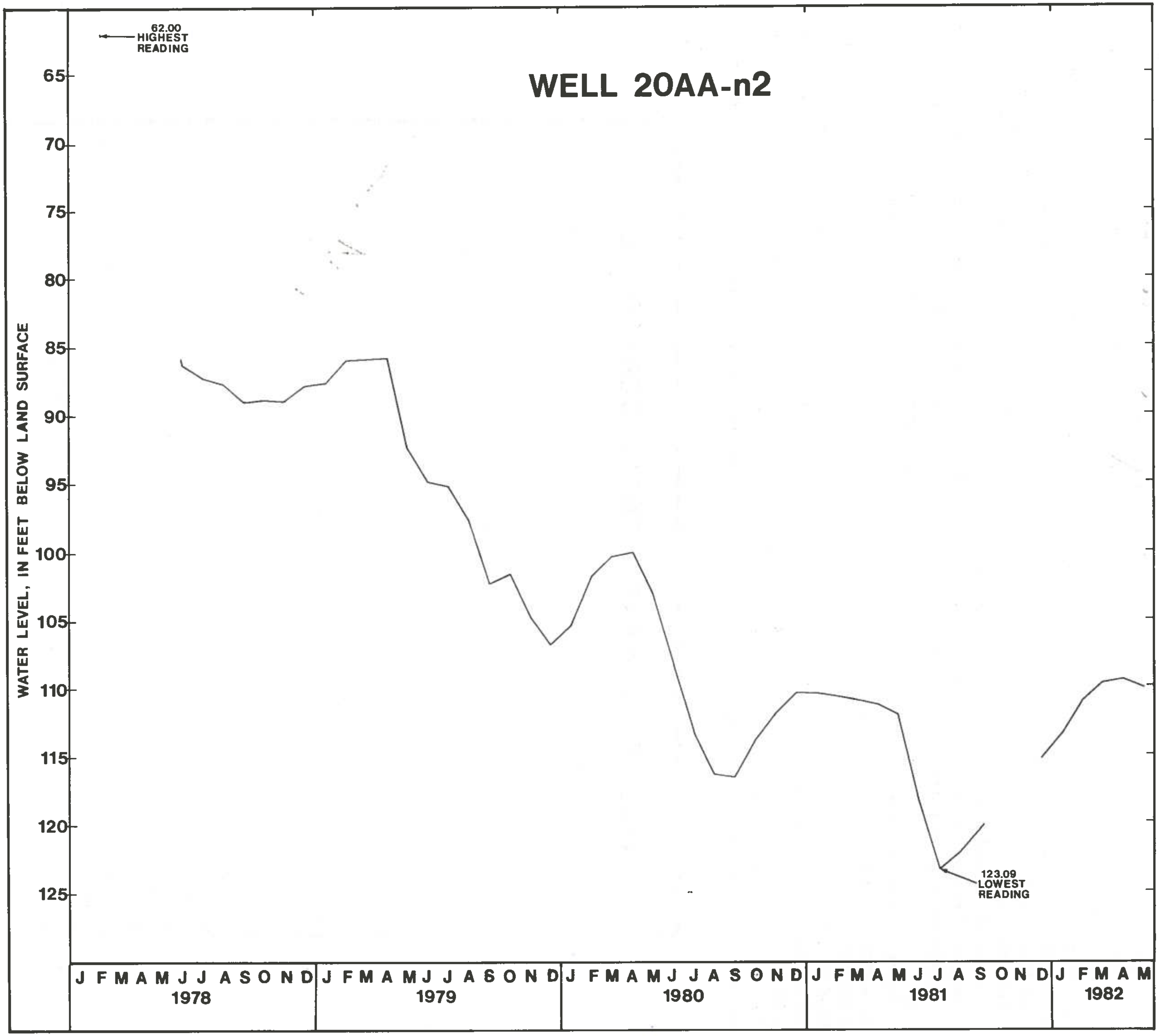


Figure 26. Hydrograph of observation well 20AA-n2, near Summerville.

of the study and is partially due to the very low permeability that occurs in this part of the study area.

Water level declines have also occurred in the vicinity of a limestone quarry located 2 miles east of Jamestown in Berkeley County. During 1978 the quarry withdrew as much as 36 mgd from the Santee Limestone to permit dry mining for road aggregate and agricultural lime. Until the operation reduced its pumping, water levels in the quarry frequently fell below sea level, spring-fed Dutart Creek dried up, and nearby property owners experienced problems with well-water supplies and sinkholes. The sinkholes ranged up to 25 ft in diameter and formed as a result of frequent water-level flucuations in the quarry and loading or vibrations caused by rainfall and the passage of heavy equipment. Although there were no personal injuries resulting from sinkhole collapses, collapses did occur on rights of way, adjacent to houses, and in cultivated fields near the quarry.

Cooper Formation

The Cooper Formation is significant as a hydrologic unit mainly by virtue of its impermeability. In most localities, its sandy, finely granular limestones produce little or no water, but instead act as confining material that causes artesian conditions in the underlying Santee Limestone. Only a few feet of the formation need to be present to effectively retard the vertical movement of ground water. The Charleston Public Works Department has taken advantage of this impermeability by boring a 5-foot diameter, 23-mile-long unlined tunnel through the Cooper Formation from the Edisto River at Givhans to their treatment plant at Hanahan.

Locally, permeable zones exist within the Cooper. A number of drilling logs report penetrating thin, soft, water-bearing limestone beds at depths of −200 to −250 ft msl in the vicinity of Edisto Island; whether they contribute significant amounts of water is not known.

A more noteworthy water-bearing zone occurs in the vicinity of Ravenel in southern Charleston County. There, a porous bryozoan limestone occurs between approximately −50 ft and −90 ft msl and is reported to yield as much as 300 gpm to some wells. The limestone is easily distinguished in gamma-ray logs as a zone of very low gamma-ray intensity sandwiched between the high gamma-ray intensity of limestone of the Ashley and Parkers Ferry Members. Although the unit is 30 to 40 ft thick at Ravenel, it pinches out only a few miles east, south, and west of the town limit, and apparently it extends no more than 10 or 12 miles to the north. Because the unit is limited to a small area and is overlain by a 30- to 40-ft confining unit that inhibits recharge, it may not be a reliable source of ground water for users such as public supply systems or industries.

Shallow Aquifers

The shallow aquifers encompass all rocks younger than the Cooper Formation; they include the Hawthorn Formation, Edisto Formation, and Pleistocene terrace deposits. South of latitude 33°12′00″, they directly overlie the Cooper, and elsewhere they overlie the Black Mingo Formation or Santee Limestone. In most areas, the shallow aquifers consist of discontinuous layers of sand, clay, and locally occurring beds of shell and limestone. The thickest sequence occurs in Charleston County where the base of the shallow aquifers lies 40 to 65 ft below land surface. Elsewhere, their thickness is generally less than 30 ft.

For most parts of the study area, ground water in the shallow aquifers occurs under water-table conditions. Although the shallow system locally may receive some recharge from the underlying Santee Limestone, most recharge is supplied by local rainfall. The water moves by gravity from areas of high elevation to areas of low elevation at a rate that depends on the slope of the water table and the permeability of the aquifer. Reported water levels are commonly 3 to 15 ft below land surface and, in part, reflect variations in the local topography. In general, water levels lie at greatest depth in areas of high elevation and are near land surface where elevations are low. Swampy areas result where the water table is at or very near the land surface much of the time.

The water table rises and falls in response to fluctuations in rainfall, seasonal variations in the rate of evapotranspiration, the topography, and the hydraulic characteristics of the aquifer. Typical water level changes in the area are on the order of 1 to 6 ft within a year. Figure 27 shows the fluctuations in water level in a shallow well, unaffected by pumping, at Edisto Island from May 1981 to January 1983. The minimum water levels occurred during November and December and coincided with a period of slight rainfall; during the following months the level recovered nearly 3 ft in response to increasing amounts of precipitation during a period of low rates of evapotranspiration.

Discharge from the shallow aquifers occurs as a result of pumping for domestic, irrigation, and industrial uses; natural seepage into lakes and streams; loss to evapotranspiration; and downward movement into underlying aquifers. Natural seepage and evapotranspiration are the principal means of discharge, since shallow wells account for only small amounts of water lost from the system, and the underlying Cooper Formation inhibits downward leakage where it occurs. However, downward leakage is a significant means of discharge where the Cooper is absent and the shallow system is underlain by the Santee Limestone and Black Mingo. As shown in Figure 28, water levels in shallow wells and Black Mingo wells near St. Stephen have a similar response to rainfall. Water levels in well 18W-a7 are slighly higher than in Black Mingo well 18W-a6, indicating that the shallow water has some head and can move downward. The sharp decline during 1980 and 1981 is the result of dewatering during construction of a power plant at the Santee River rediversional canal.

Shallow wells are used in all parts of the study area, but they are most common in Charleston County where the shallow system is thickest and most permeable and where water quality in the underlying formations is poor. In much of the area near the coast and south of Mt. Pleasant,

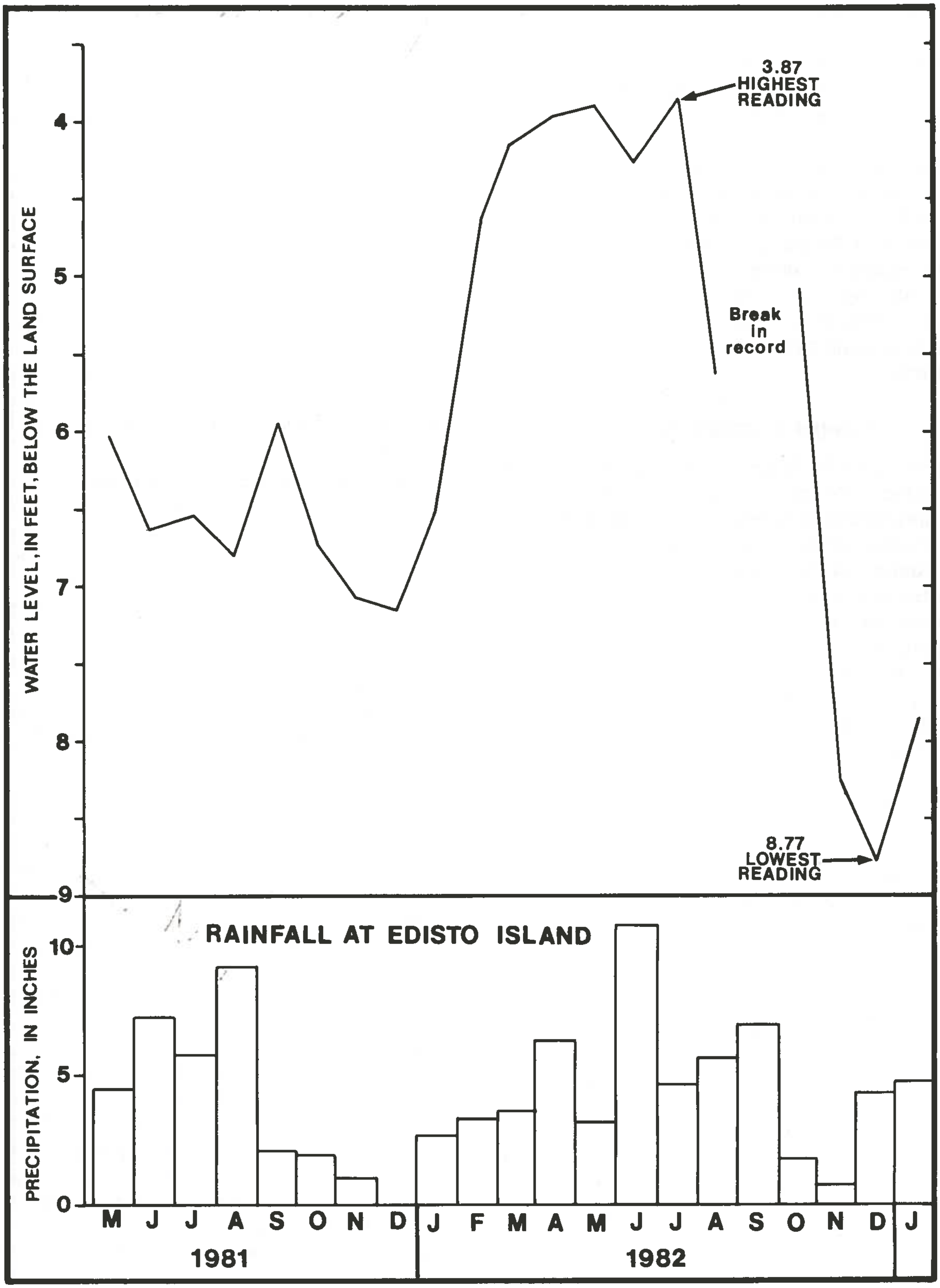


Figure 27. Hydrograph of observation well 22GG-x9, at Edisto Island.

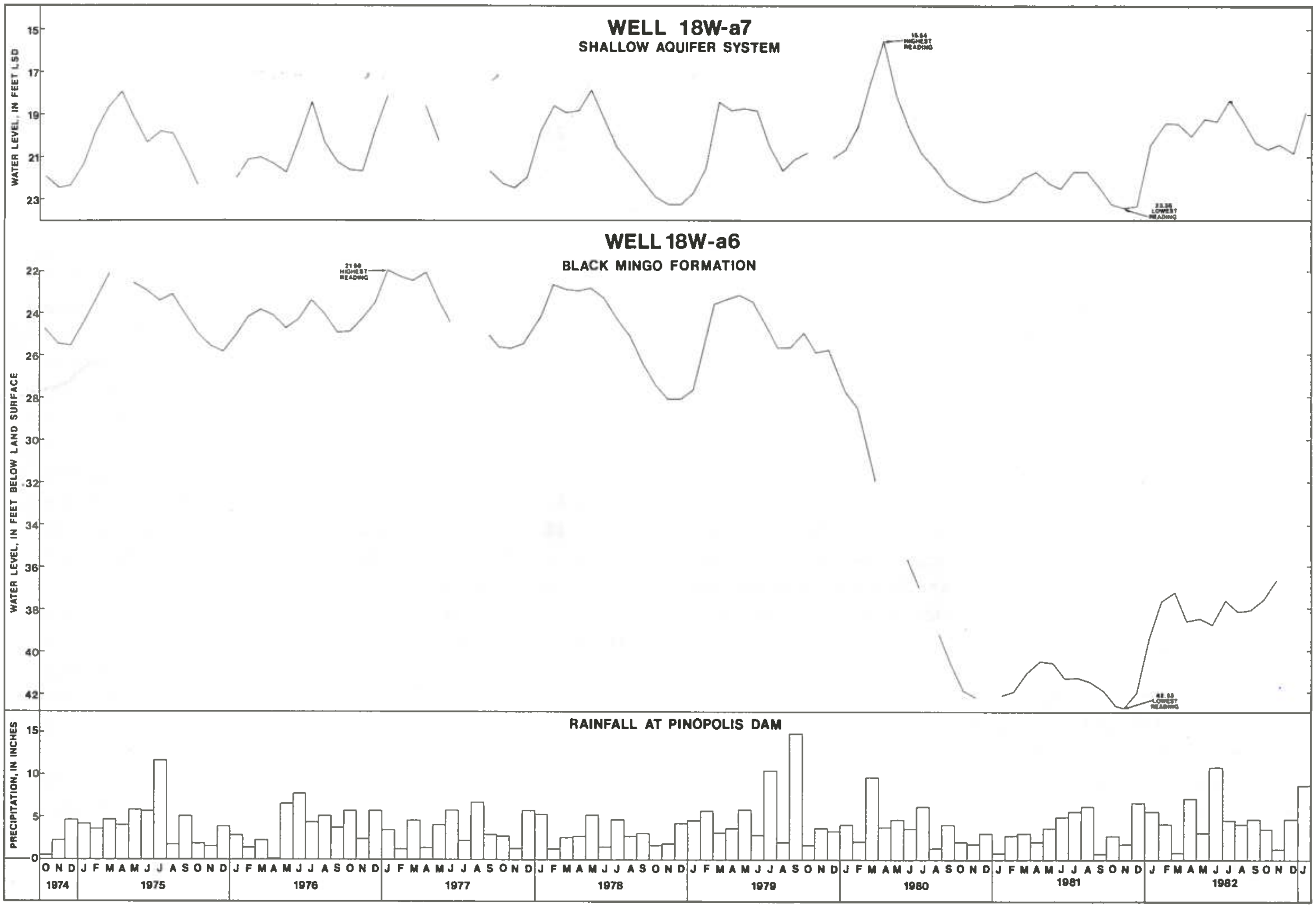


Figure 28. Hydrograph of observation wells 18W-a6 and 18W-a7, near St. Stephen.

the shallow system is the only economical source of fresh ground water for domestic users. The shallow system also supplies small public water systems and is used at Mt. Pleasant, Isle of Palms, Sullivans Island, and Edisto Beach to dilute high-fluoride water from the Black Creek Formation or Santee Limestone.

Although at least 10 gpm can be obtained from the shallow aquifers in nearly all parts of Charleston County, the same is not true for Berkeley and Dorchester Counties. Locally, the shallow sand beds are thin or contain high percentages of clay and silt. Consequently, wells must be drilled into the Santee Limestone and Black Mingo aquifers. The limestone is also a preferred source of ground water in its outcrop areas, where an open-hole well in the limestone may be constructed as economically as a shallow, screened well.

The thickness and permeability of the shallow aquifers vary greatly, even within a small area, so the quantity of water produced by individual wells is likewise variable. Small-diameter domestic wells are usually equipped with jet pumps of less than 1 horsepower and produce about 8 gpm. Most municipal and industrial wells are 4 to 6 inches in diameter, have 15 to 30 ft of screen, and yield between 20 and 200 gpm. In a typical well field, such as those maintained by the Town of Mt. Pleasant, individual well yields range from 40 gpm, with a specific capacity of 1.3 gpm/ft, to175 gpm, with a specific capacity of 7 gpm/ft. Municipal well fields located on the barrier islands use 15- to 20-ft deep well-point systems which spread withdrawals over large areas but restrict the depth of pumping in order to avoid saltwater intrusion or upconing.

The transmissivities of the shallow aquifers are assumed to be relatively low since the system averages less than 40 ft in thickness, commonly consists of fine-grained or poorly sorted sand, and reported specific capacities are generally less than 4 gpm/ft. An aquifer test at Edisto Island indicated a transmissivity of about 600 ft^2/day (J.T. Johnson, 1981). The saturated thickness of the aquifer was 45 ft, indicating a hydraulic conductivity of 13 ft/day. Discharge during the test was 32 gpm and water-level measurements were taken in the pumping well and two observation wells over a period of 30 hours.

GROUND-WATER QUALITY

Introduction

The precipitation that recharges aquifers in Charleston, Berkeley, and Dorchester Counties contains only small amounts of dissolved gases and dust. As the precipitation enters the ground-water system it dissolves mineral matter from the surrounding rocks. The amount and kind of dissolved mineral matter depend upon the temperature and chemical composition of the water, the composition and solubility of the rocks through which the water flows, and the length of time the water and rocks have been in contact. As a rule, the amount of dissolved mineral matter is relatively small in the recharge area but increases with depth and with distance from the recharge area.

Chemical quality is an important factor in determining the suitability of ground water for use in public and industrial water supplies. In Charleston, Berkeley, and Dorchester Counties, chemical species that locally exceed recommended water-quality standards include iron, calcium and magnesium (hardness), fluoride, chloride, and silica. The sources and effects of these various constituents are shown in Table 2.

Selected chemical analyses of ground water from wells in the study area are listed in Appendix B. Samples analyzed by the USGS and the South Carolina Water Resources Commission were collected, stored, and analyzed by methods recommended by the USGS. The alkalinity and pH of ground water commonly change after being exposed to the atmosphere, hence these parameters were measured at the time the samples were collected. Analyses by other laboratories did not include on-site determinations of alkalinity, pH, or specific conductance. The total concentration of a chemical species was determined with raw samples for nonmetals and acidified samples for metals. The dissolved concentrations were determined with samples filtered through a 40-micron membrane.

Iron

Iron compounds are present in most geologic formations, and dissolved or suspended iron commonly occurs in ground water in the study area. Locally, iron concentrations exceed the 0.3 mg/L (300 micrograms per liter) maximum recommended by the South Carolina Department of Health and Environmental Control. Such water may stain clothing and plumbing fixtures, turning them a yellow or rusty color. Domestic-well owners remove iron with small ion-exchange filters that are effective if iron concentrations are not too high. Public-supply systems remove iron by oxidation with chemicals, or by aeration followed by filtration. Where iron concentrations are high, filters must be flushed frequently.

Iron exists in two chemical-oxidation states — ferric iron (Fe^{+++}), which is relatively insoluble, and ferrous iron (Fe^{++}), which is soluble. When water containing large concentrations of ferrous iron is pumped from a well and exposed to atmospheric oxygen, the ferrous iron is oxidized to ferric iron and precipitates as rust-colored ferric hydroxide. As a result, water containing dissolved iron may be clear when pumped from the well but, with time, becomes cloudy from an insoluble ferric hydroxide precipitate.

Table 2. **The source and effects of selected constituents and properties in ground water (Fairchild, 1972).**

Constituent	Source and/or solubility	Effects
Iron (Fe)	Very abundant element, readily precipitates as hydroxide.	Stains laundry and porcelain, bad taste.
Manganese (Mn)	Less abundant than iron.	Stains laundry and porcelain, bad taste.
Fluoride (F)	Not very abundant, sparingly soluble, seldom found in industrial wastes except as spillage, some in sewage.	Over 1.5 mg/L causes mottling of children's teeth, 0.88 to 1.5 mg/L aid in preventing tooth decay.
Silica (SiO_2)	Most abundant compound in earth's crust. Resistant to solution.	Causes scale in boiler and deposits on turbine blades.
Calcium (Ca)	Dissolved from most rock, especially limestone and dolomite.	Causes hardness, forms boiler scale, helps maintain good soil structure and permeability.
Hardness as $CACO_3$	Calcium and magnesium dissolved from rocks.	Excessive soap consumption, scale in pipes, interferes in industrial processes. up to 60 mg/L - soft 60-120 mg/L - moderate - hard 120-200 mg/L - hard over 200 mg/L - very hard
Bicarbonate (HCO_3)	Abundant and soluble from limestone, dolomite, and soils.	Causes foaming in boilers and embrittlement of boiler steel.
Sodium (Na)	Dissolved from rock, industrial wastes.	Injurious to soils and crops and to certain physiological conditions in man.
Potassium (K)	Abundant, but not very soluble, in rocks and soils.	Causes foaming in boilers.
Sulfate (SO_4)	Sedimentary rocks, mine water, and industrial wastes.	Cathartic, unpleasant taste.
Chloride (Cl)	Rocks, soils, industrial wastes, sewage, brines, seawater.	Salty taste, increases corrosiveness.
Nitrate (NO_3)	Rocks, soil, sewage, industrial waste, normal decomposition, bacteria.	High concentration indicates pollution, causes methemoglobinemia in infants.

Fluoride

Excessive amounts of fluoride (more than 1.0 mg/L) may cause problems for some industries, such as food, beverage, and pharmaceutical companies. However, small amounts of fluoride in drinking water can be beneficial. Research has shown that fluoride in concentrations of 0.8 to 1.5 mg/L reduces dental cavities in children. At concentrations exceeding about 1.5 mg/L, fluoride may cause permanent mottling of teeth (Van Burkalaw, 1946). Because air temperature affects the quantity of water children drink, the maximum acceptable limit varies according to the annual average of maximum daily air temperatures. In the study area, the fluoride concentration limit for public drinking water is 1.6 mg/L.

Silica

Silica (SiO_2) in ground water results from the decomposition of silicate minerals, which are common in most rocks. For simplicity, silica is commonly considered to occur in water as finely divided or colloidal suspended matter, although reported as "dissolved." In natural water, silica occurs in concentrations of up to 40 mg/L (McKee and Wolfe, 1963, p. 225) and usually poses no problem to health or for most industrial uses. However, silica is undesirable in boiler feed water, where it forms scale on heater tubes and steam-turbine blades, and in some pulp, paper, and rayon production processes.

Calcium and Magnesium

Calcium and magnesium are dissimilar in many of their chemical reactions, but they are usually considered together because both are important factors in determining hardness and scale formation. Calcium compounds are less soluble than magnesium compounds, and where scale formation is a problem, calcium is the major cause.

Hardness

There are two types of hardness in ground water: (1) carbonate hardness caused by calcium and magnesium bicarbonates, and (2) noncarbonate hardness caused mainly by dissolved metals and chlorides, sulfates, and chelates of calcium and magnesium. Ground water with a hardness of more than 60 mg/L (as $CaCO_3$) is classified as hard to very hard (Table 2). Excessive hardness interferes with the cleaning action of soaps and forms a precipitate or scale on plumbing fixtures, boilers, and utensils when the water is heated. Carbonate hardness can be treated by the addition of soda-ash or lime-soda, or removed by heating. Noncarbonate hardness is more difficult to treat but can be reduced with ion-exchange filters.

pH (Hydrogen-Ion Concentration)

The concentration of hydrogen ions in water determines whether the water is acidic, neutral, or alkaline. The concentration of hydrogen ions varies greatly, and is expressed as a negative logarithm (base 10) to represent the absolute concentration. Values of pH that are less than 7.0 represent acidic solutions, 7.0 is neutral, and values of 7.0 to 14.0 are alkaline. pH is important because of its effect on mineral solubility and the rate of well corrosion or encrustation.

Sodium

Sodium compounds constitute almost 3 percent of the crust of the earth, and sodium-bearing minerals are abundant in Coastal Plain sediments. However, these minerals are poorly soluble, and most sodium instead is associated with the occurrence of residual seawater or base-exchange. Base-exchange takes place as calcium and magnesium ions substitute for loosely bonded sodium and potassium ions held in clay minerals; calcium and magnesium are removed from ground water as sodium is released. Where freshwater contains high concentrations of sodium, the exchange process is the principal cause.

The presence of sodium affects the suitability of water for many uses, including drinking, irrigation, and steam boilers. Concentrations of as much as 200 mg/L may be injurious to persons with cardiac or circulatory diseases. The taste threshold of sodium in distilled water is 134 mg/L if in the form of sodium chloride and 290 mg/L in the form of sodium bicarbonate (Lockhart and others, 1955). The application of irrigation water having high concentrations of sodium causes soil colloids to swell, reducing soil permeability.

The extent to which soil permeability is reduced is largely dependent on the Sodium Adsorption Ratio (SAR), which represents the relative activity of sodium in exchange processes with calcium in soil. The SAR is expressed as: $Na/(1/2(Ca+Mg))^{1/2}$, in which the concentrations of sodium, calcium, and magnesium are in milliequivalents per liter. Irrigation water with SAR less than 10 can be used on most crop-soil combinations without detrimental effect. Water with SAR greater than 10 poses a hazard, particularly with poorly drained soils.

Chloride

Chloride is present in most ground water, but concentrations are usually small when it is derived only from the material that composes the aquifer, and concentrations are typically less than 25 mg/L.

Concentrations are much greater in residual seawater, in which chloride is the most abundant anion. Chloride is acceptable for drinking in concentrations up to 250 mg/L, but greater concentrations promote corrosion and impart an unpleasant taste. Chloride may cause a salty taste at concentrations as low as 100 mg/L, but for most individuals the taste threshold is above 400 mg/L. Vegetable crops and ornamental shrubs generally tolerate no more than 200 mg/L. For the purposes of this report, water containing more than 250 mg/L is considered to be saltwater, although water having much lower concentrations may represent diluted, residual seawater.

Sulfate

Sulfates occur as a result of the oxidation of the sulfur minerals found in Coastal Plain sediments or where ground water dissolves limestone containing sodium, magnesium, and calcium sulfate minerals. Sulfate is also associated with residual seawater in which it occurs in concentrations much higher than those found in most fresh ground water. The oxidation of organic matter can produce sulfates that, in turn, may become a source of energy for sulfur-fixing bacteria.

It is recommended by the U.S. Environmental Protection Agency that drinking-water supplies not contain more than 250 mg/L sulfate, although concentrations of 2,000 to 3,000 mg/L produce no toxic effects. However, water having high concentrations of sulfate may have a cathartic effect on new users. Sulfates are less toxic than chlorides in irrigation water, but concentrations of less than 200 mg/L are usually desirable (McKee and Wolf, 1963, p. 276). Sulfate tolerances for industrial uses are variable, but they may be as low as 20 mg/L for sugar manufacturing; more than 25 mg/L is corrosive to concrete.

Temperature

The thermal regime of the earth involves the flow of heat from deep layers of rock toward land surface. This heat flow is evidenced by the presence of a geothermal gradient, which is an increase of temperature with successively greater depth. On the average, the temperature in the study area increases at a rate of 27.7°C/Km (1.5°F/100 ft), and according to Sass and Ziagos (1977) the geothermal gradient and heat-flow values in the area are typical of those found in other parts of the Coastal Plain physiographic province.

At any given depth, the gradient is controlled by seasonal changes in air temperature; differences in the thermal conductivity of individual rock formations; or the effects of ground-water convection. Shallow aquifers are the most affected by climatic changes, and seasonal temperatures vary by several degrees, depending on air temperature and rainfall. Temperatures in the deeper, artesian aquifers are unaffected by climate and remain relatively constant. Hence the temperature and geothermal gradient are controlled mainly by thermal conductivity and ground-water convection. The convection is caused by hydraulic forces that redistribute heat within the aquifer or by variations in ground-water density that result from temperature differentials. Thus a relatively low geothermal gradient of 18.2°C/KM (1°F/100 ft) found in the Middendorf Formation (Fig. 29) may be attributed to the presence of coarse sand and gravel which facilitate ground-water convection (Sass and Ziagos, 1977).

Ground-water temperatures range between 19°C (66°F) and 24°C (75°F) in the Santee Limestone and Black Mingo Formation; and 26°C (79°F) and 38°C (100°F) in the Black Creek Formation. The temperature of water in shallow aquifers typically ranges between 17°C (63°F) and 24°C (75°F). The geothermal gradients measured by Sass and Ziagos at Clubhouse Crossroads range from 18.2°C/Km (1°F/100 ft) to 42.2°C/Km (2.3°F/100 ft).

Cretaceous Aquifers

Freshwater (less than 250 mg/L chloride) can be obtained from the Cretaceous formations in nearly all parts of Charleston, Berkeley, and Dorchester Counties. However, the potability of that water may be somewhat compromised by large concentrations of dissolved sodium, bicarbonate, and fluoride. Ground water from the Cretaceous System is least mineralized in northern Berkeley County; it becomes increasingly mineralized as it moves coastward.

Middendorf Formation

Of the wells known to have penetrated the Middendorf Formation, five were tested to obtain discrete Middendorf samples. The resulting analyses show that, in the study area, Middendorf aquifers contain an alkaline, sodium bicarbonate type of water in the upper 200 ft of the formation, with dissolved solids ranging from about 500 mg/L to 2,300 mg/L. Samples collected from individual Middendorf sand beds at wells 18AA-e2, 20FF-vl, 20GG-el, and 21BB-m2 also show that dissolved-solids concentrations increase with depth (see well numbers 18AA-e2, 20FF-vl, and 20GG-el, Appendix B-1 and Fig. 30).

Sodium chloride type water was obtained at 300 to 350 ft below the top of the formation (−1,500 ft msl) at Goose Creek (18AA-e2) and Seabrook Island (20GG-el). The concentrations of dissolved solids were 1,270 and 2,830 mg/L.

Sodium constitutes more than 80 percent of the dissolved cations in Middendorf water. The reported sodium concentrations ranged from about 20 mg/L in central Berkeley County to as much as 800 mg/L at Kiawah Island, Charleston County.

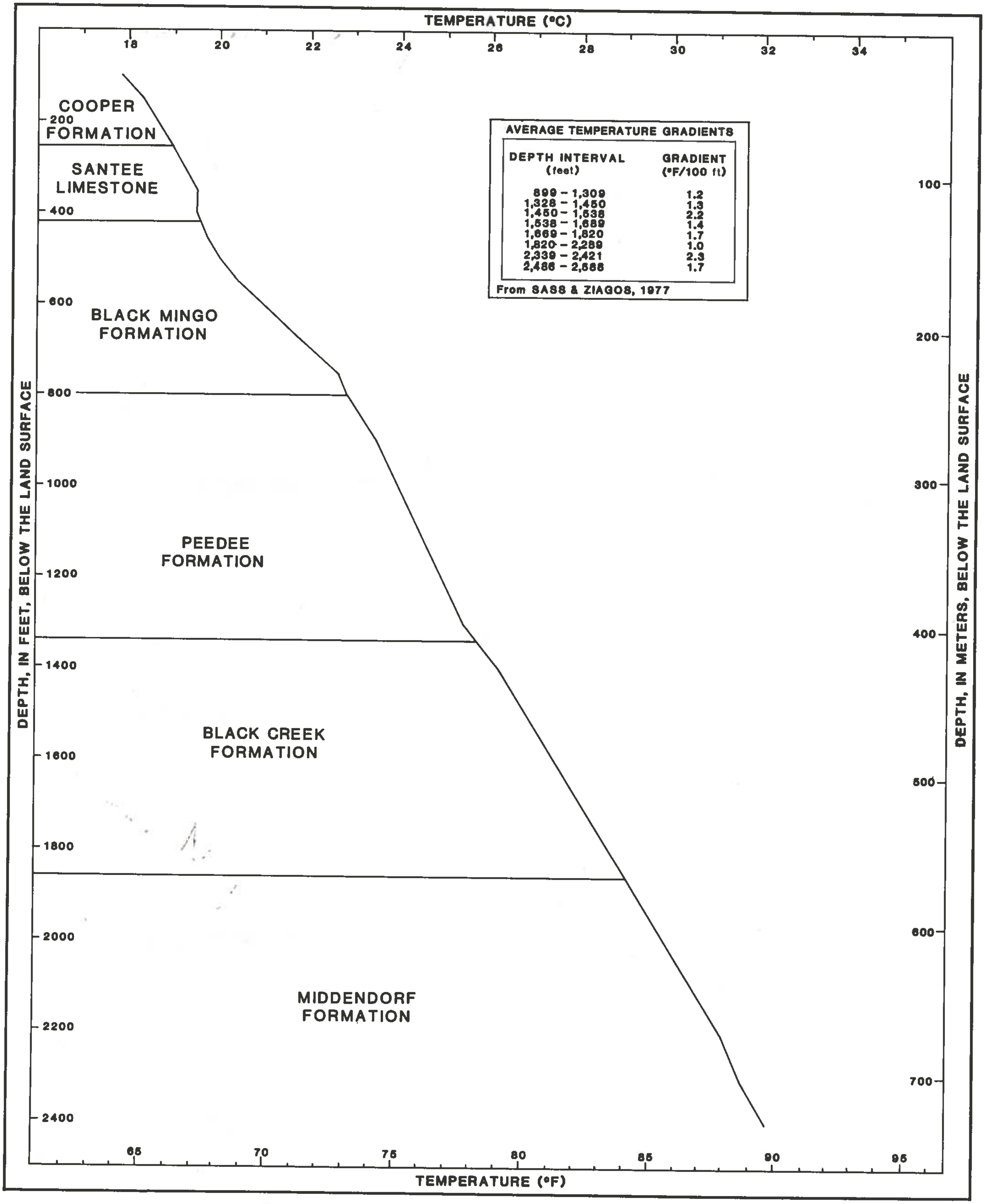
Increasing sodium concentrations are accompanied by alkalinities that increase from 500 to 1,300 mg/L; much of the alkalinity being due to the presence of bicarbonate anions. Nine samples had pH values greater than 8.3, indicating the presence of carbonate alkalinity also.

The concentrations of chloride in most samples obtained from wells 18AA-e2, 20FF-vl, 20GG-el, and 21BB-ml were less than 250 mg/L. At 18AA-e2, the upper 200 ft of the formation produced water with a chloride concentration of 19 mg/L, whereas screens set 330 to 390 ft below the top yielded water with 270 mg/L chloride. The lowest zone sampled at well 20GG-el yielded water in which the chloride concentration was 1,440 mg/L, or about 70 percent of the total anions present.

Middendorf water samples contained some of the highest fluoride concentrations found in the study area. The concentrations ranged from 2.0 to 11.1 mg/L, the greatest concentration being measured in a sample from 1,900 ft in well 18AA-e2 in Berkeley County. At well 20FF-vl (Kiawah Island), concentrations increased from 4.5 mg/L at a depth of 2,115 ft to 6.5 mg/L at 2,220 ft.

Analyses for dissolved silica are available only for wells 20FF-vl and 20GG-el at Kiawah and Seabrook Islands, where silica concentrations were no greater than 18 mg/L.

Carbonate material is rare in rocks composing the Middendorf Formation, and calcium and magnesium concentrations are low, possibly because of exchange with



AVERAGE TEMPERATURE GRADIENTS

DEPTH INTERVAL (feet)	GRADIENT (°F/100 ft)
899 - 1,309	1.2
1,328 - 1,450	1.3
1,450 - 1,538	2.2
1,538 - 1,669	1.4
1,669 - 1,820	1.7
1,820 - 2,289	1.0
2,339 - 2,421	2.3
2,486 - 2,566	1.7

From SASS & ZIAGOS, 1977

Figure 29. Temperature versus depth at Clubhouse Crossroads (23CC-i1).

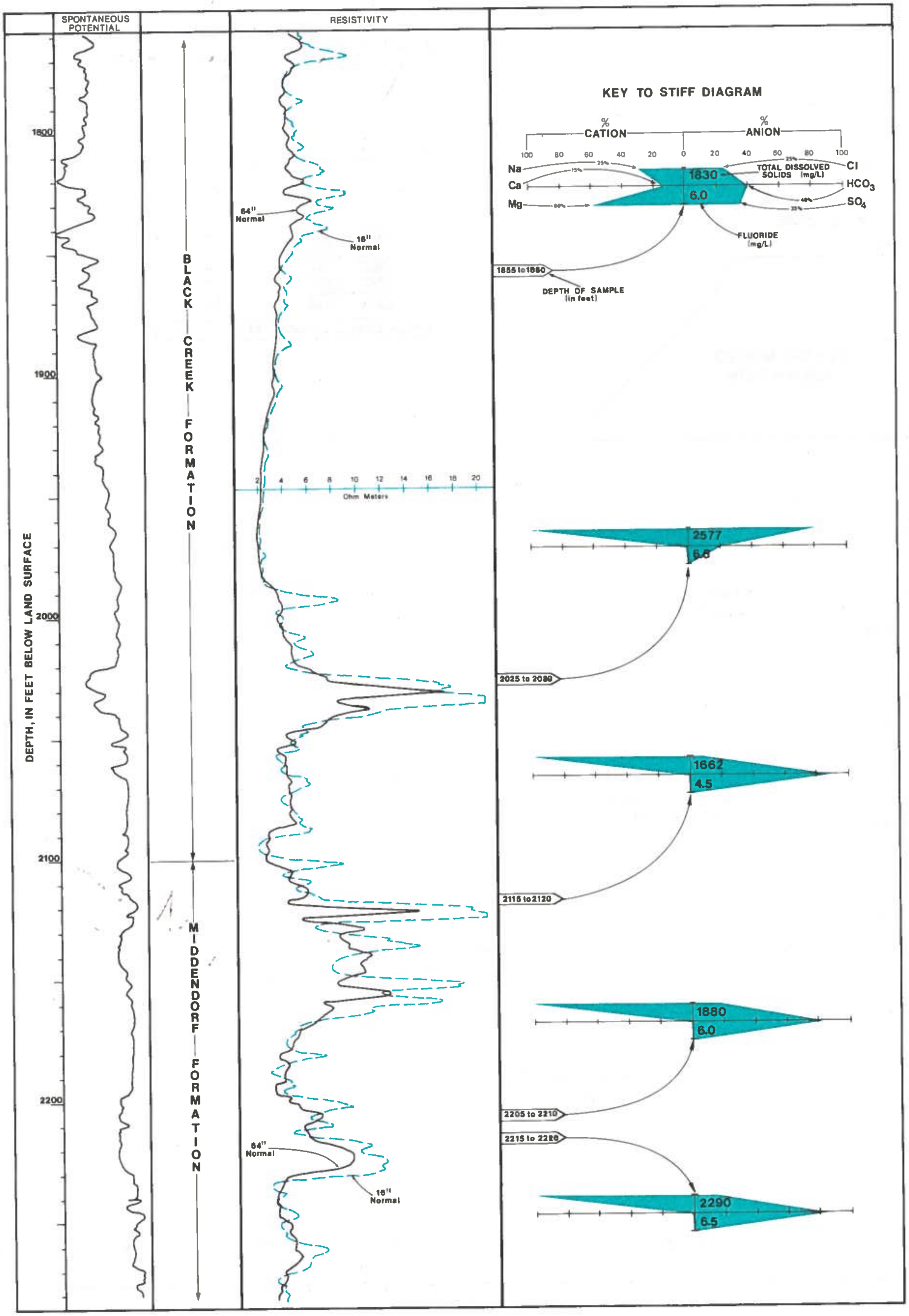


Figure 30. Comparison of water quality in the Black Creek and Middendorf Formations.

sodium. Consequently, Middendorf water is very soft. The total hardness in eight samples collected at wells 20FF-vl and 20GG-el ranged from 4 to 30 mg/L as calcium carbonate and averaged about 10 mg/L. Such concentrations are typical of Middendorf water in other parts of the South Carolina Coastal Plain.

Iron concentrations are variable. The reported concentration of total iron was between 10 and 950 ug/L (micrograms per liter). The total iron concentration equaled or exceeded 300 ug/L in 6 of 10 samples.

Black Creek Formation

Overall, Black Creek aquifers produce water with characteristics similar to water in the upper part of the Middendorf. The water is generally a fresh, sodium bicarbonate type (Figs. 31 and 32); it is soft and of moderately high pH; and it contains objectionable amounts of fluoride. A comparison of chemical analyses for wells 18V-ul, 20FF-vl, 20GG-el, and 21BB-m2 and Stiff diagrams in Figure 31 indicate that Black Creek Formation water is better in the northern parts of the study area, whereas water in upper sand beds of the Middendorf Formation is better in some areas near the coast.

Sodium occurs in concentrations between 160 and 800 mg/L and constitutes more than 96 percent of the cations in Black Creek Formation water. The lowest concentrations ranged from 137 to 230 mg/L and were found in the northwestern half of the study area. However, individual aquifers contain water with concentrations greater than 400 mg/L (see Appendix B-1 well 21BB-m2). Wells in the northern half of Charleston county produce freshwater with sodium concentrations of 340 to 500 mg/L, increasing toward the coast.

Bicarbonate represents 55 to 98 percent of the anions present, and the resulting alkalinities range from 260 to 1,200 mg/L as calcium carbonate. The lowest alkalinities were between 260 and 300 mg/L, measured in samples from St. Stephen and Jamestown. Alkalinities of 800 to 1,260 mg/L occurred in the vicinity of Charleston and areas farther south.

Black Creek Formation water is a sodium chloride type in southern Charleston County. Sodium concentration increases from approximately 500 mg/L at Charleston to more than 800 mg/L at Kiawah and Seabrook Islands, but bicarbonate concentrations remain about the same. However, chloride concentrations rise from about 300 mg/L to more than 1,000 mg/L; the amount of chloride increasing from 20 percent to 80 percent of the total anion concentration (Fig. 31).

The lateral trend from sodium bicarbonate water to sodium chloride water is illustrated in Figure 32. When ratios of the principal chemical species are plotted on the Piper diagram, a very fresh sodium bicarbonate water will plot near point A and a salty sodium chloride water will plot near point B. The line A-B theoretically represents points where various ratios of A and B type water will plot when the two water types mix. Plots of Black Creek aquifer water from wells in the study area fall roughly parallel to line A-B, indicating mixtures of the two water-quality types. Because of the coastward trend toward sodium chloride water, it is probable that much greater chloride concentrations occur in Black Creek aquifers beneath the offshore areas.

Apparently the chloride concentrations of Black Creek Formation water do not consistently increase with greater depth. Samples from test wells 20GG-el, 21BB-ml and 21BB-m2 at Seabrook Island and Summerville indicate that water from basal Black Creek sand contains less chloride than water in the overlying sand beds. At Summerville, chloride concentrations were 177 mg/L at 1,595 ft and 10 mg/L at 1,740 ft: at Seabrook Island the concentrations were 534 mg/L at 1,849 ft and 390 mg/L at 2,056 ft.

Black Creek Formation water is moderately alkaline. The pH values range from 7.7 to 9.3 and average 8.5 in the analyses listed in Appendix B-1. The water is highly mineralized and has dissolved-solids concentrations of 500 mg/L or more in the area south of Moncks Corner in Berkeley County. Concentrations increase toward the southeast from 400 mg/L at St. Stephen to more than 1,000 mg/L in the vicinity of Charleston. Concentrations rise the most sharply near the coast. Between Moncks Corner and Charleston, concentrations increase at an average rate of 13 mg/L per mile, while they increase at about 27 mg/L per mile between Charleston and Mt. Pleasant, where much greater concentrations of sodium and chloride occur.

Black Creek aquifers yield water with fluoride concentrations of 1.6 mg/L or more in nearly all of the study area (Fig. 33). The lowest concentrations occur in northern Berkeley County, where fluorides range from 1.3 to 1.5 mg/L. Concentrations increase toward the south, and wells in the vicinity of Charleston yield water with fluoride concentrations of 4.0 to 6.5 mg/L. The highest concentration was measured in a sample from well 20FF-vl at Kiawah Island. The vertical distribution of fluoride is not uniform, and a consistent pattern of occurrence has not been identified.

In nearby Horry and Georgetown Counties, the greatest fluoride concentrations are associated with calcareous sandstones in the upper third of the Black Creek Formation (Zack, 1977, p. 57). Zack (1980) demonstrated that the principal source of fluoride ions is fluorapatite in the form of fossil shark teeth. These fluoride ions are released by means of anion exchange with the hydroxyl ions in ground water in the Black Creek Formation. Much of the fluoride in Black Creek aquifers of the Trident Area may result from the same process.

Dissolved-silica concentrations in Black Creek aquifers are generally low. Concentrations ranged from 1.3 to 21.8 mg/L in samples tested. The average concentration listed in Appendix B-1 is 14.0 mg/L.

Although calcium carbonate is commonly present in Black Creek sediments (between 10 and 20 percent) in the form of shell debris, the water is very soft. The total hardness rarely exceeds 30 mg/L as calcium carbonate and averages less than 15 mg/L in the analyses listed in Appendix B-1. Calcium and magnesium, the principal hardness-causing ions, are typically present in concentrations of less

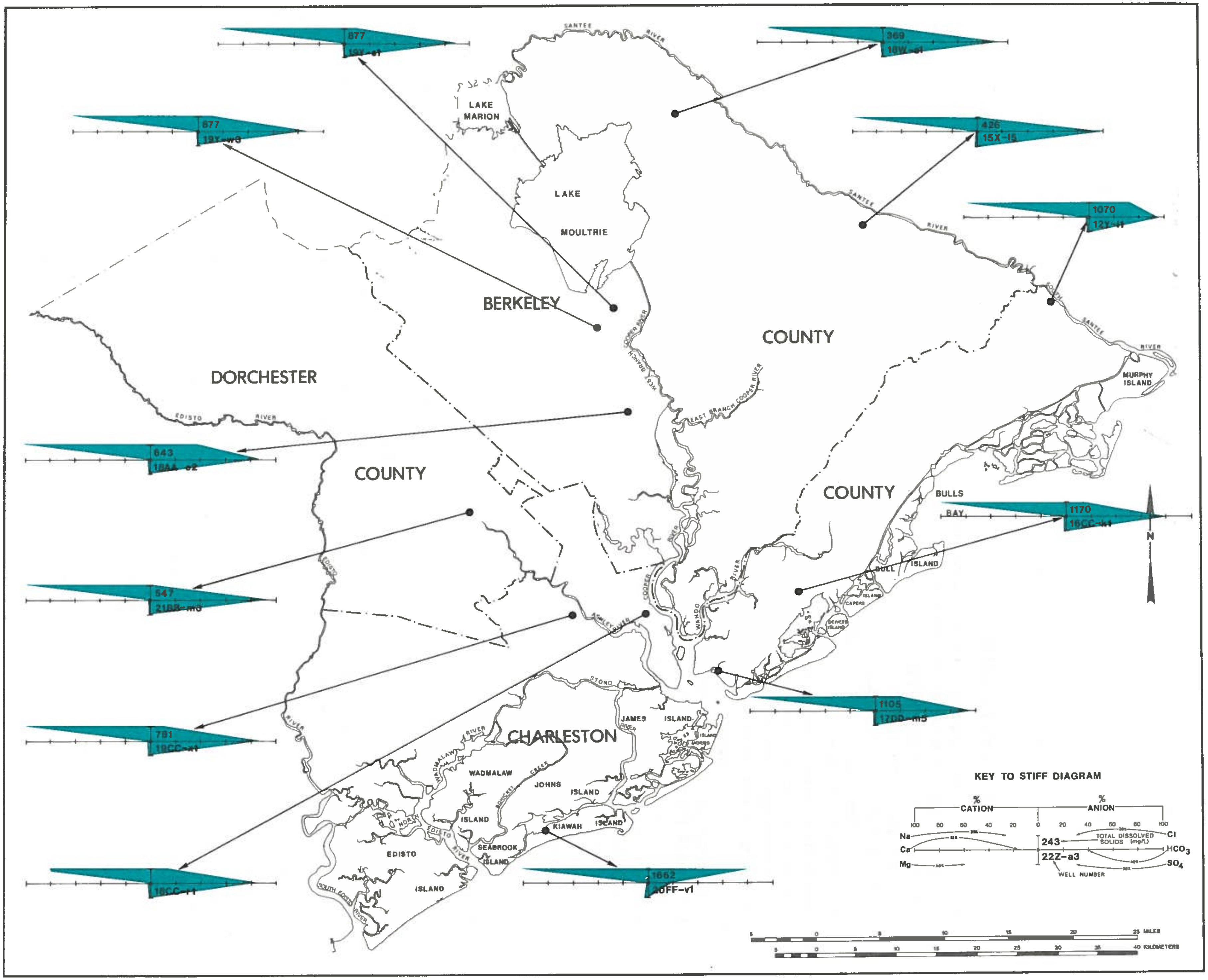
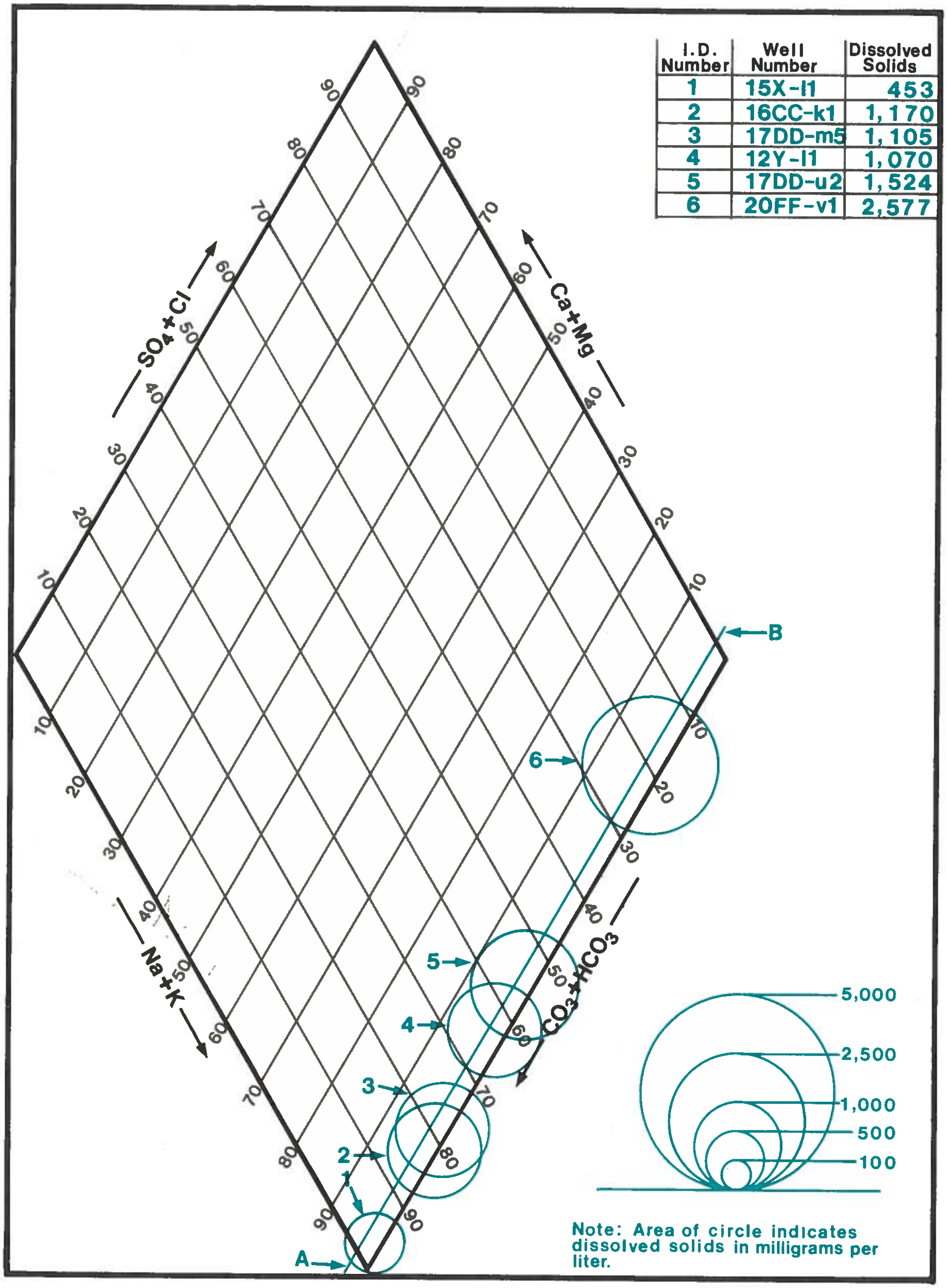


Figure 31. Representative Stiff patterns for samples from Cretaceous Formations.



I.D. Number	Well Number	Dissolved Solids
1	15X-I1	453
2	16CC-k1	1,170
3	17DD-m5	1,105
4	12Y-I1	1,070
5	17DD-u2	1,524
6	20FF-v1	2,577

Note: Area of circle indicates dissolved solids in milligrams per liter.

Figure 32. Piper diagram depicting the distribution of water-quality types in the Black Creek Formation.

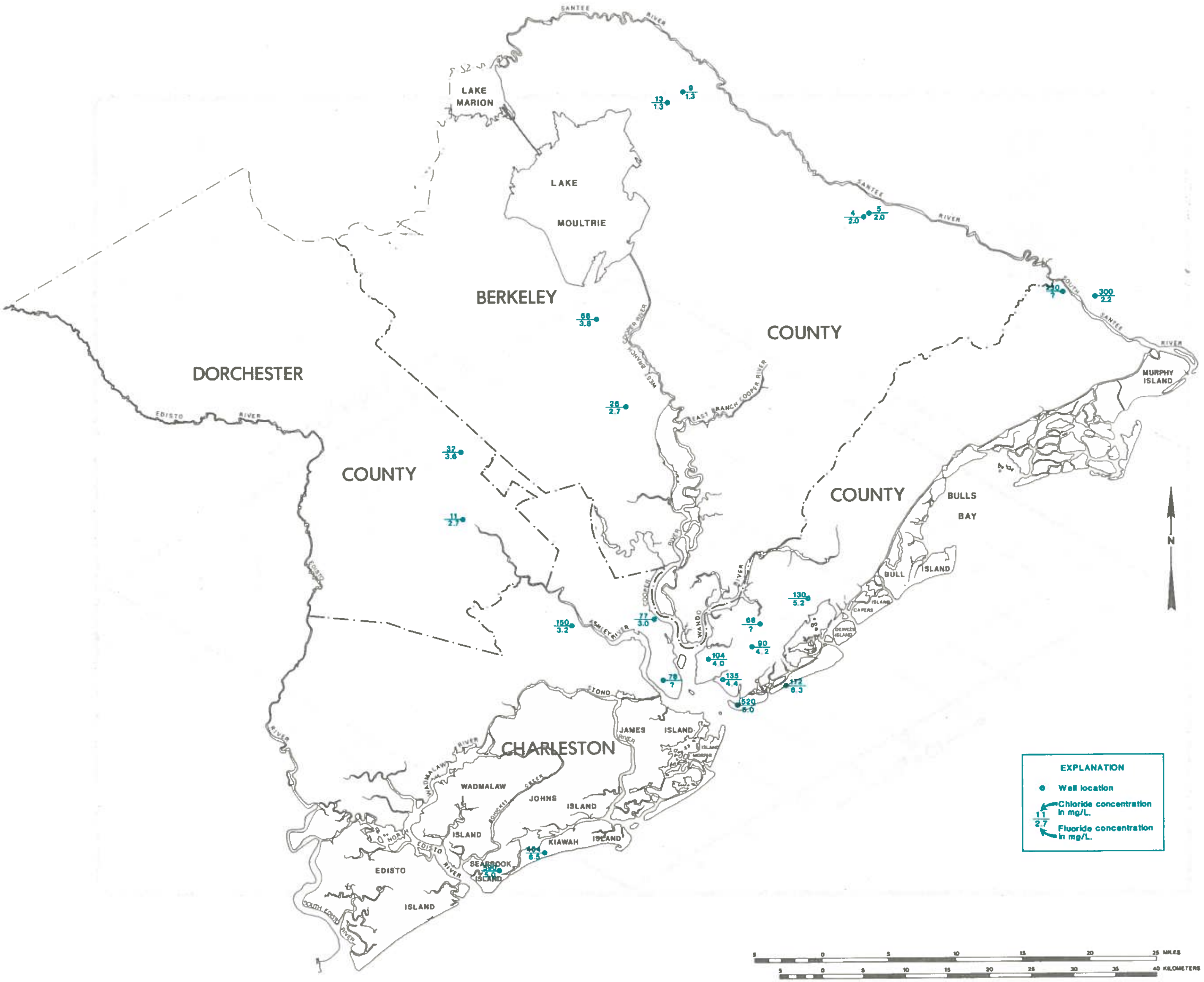


Figure 33. Distribution of chloride and fluoride in the Black Creek and Middendorf Formations.

than 4.0 mg/L and 0.5 mg/L, respectively. The absence of these ions is partially due to the presence of base-exchange minerals that absorb calcium and magnesium while releasing sodium. At the same time, a high pH and high concentrations of bicarbonate, carbonate, and hydroxide inhibit the dissolution of calcium carbonate.

Iron concentrations are generally low, and most samples contained less than 300 ug/L. In the vicinity of Charleston, Black Creek wells usually produce water with concentrations below 60 ug/L. The average total iron concentration for 20 samples was 193 ug/L; the average for nine wells in the Charleston area was approximately 100 ug/L. This tendency toward low iron concentrations is generally opposite that noted in the outcrop areas where concentrations as high as 7,000 ug/L occur (Park, 1980, p. 29).

Sulfate concentrations are uniformly low, even in very mineralized water of the sodium chloride type. The average concentration in 27 samples was 3.5 mg/L. The greatest concentration was 8.6 mg/L, measured in a sample from well 12Y-L1 at Hampton Plantation. Foster (1942) attributed the absence of sulfate in deep, brackish-water aquifers to chemical reduction during or subsequent to deposition of the formations. The processes probably occurred rather early in the history of the Black Creek Formation and account for the presence of pyrite (iron sulfide). Current geochemical conditions are such as to favor continuation of the process.

Peedee Formation

Water in the Peedee Formation is of the sodium bicarbonate type, except perhaps along the coast of Charleston County. Well 19Y-sl, at Moncks Corner, produces water having a sodium concentration of 400 mg/L and a bicarbonate alkalinity of 700 mg/L: the pH is 8.0, so little carbonate alkalinity is present. Total hardness is about 22 mg/L as calcium carbonate. The concentration of dissolved solids is 877 mg/L. Chloride, sulfate, and iron concentrations are 59 mg/L, 0.5 mg/L and 20 mg/L, respectively, and are among the lowest values reported for these constituents in water from the Cretaceous aquifers. The fluoride concentration is 1.5 mg/L, which is comparable to the concentrations found in the Black Creek Formation in northwestern Berkeley County.

Tertiary and Shallow Aquifers

Black Mingo Formation

The chemical quality of ground water from the Black Mingo Formation is generally good, but it varies with both locality and depth. Chemical quality is best in the upgradient areas of Berkeley and Dorchester Counties, whereas it deteriorates downgradient to the point where it is only marginally potable or is nonpotable throughout much of coastal Charleston County. As can be seen in Appendix B-2, sodium, fluoride, and hardness-causing species are the most troublesome chemical constituents. The principal controls on Black Mingo water quality are lithology and the presence of intruded saltwater.

Sodium, bicarbonate, and chloride are the major ionic species in Black Mingo ground water, although high percentages of calcium occur locally. Sodium bicarbonate is the predominant cation/anion pair and its presence dominates Black Mingo water quality west of the Goose Creek/Hanahan area in Berkeley and Dorchester Counties (Fig. 34). The ground water falls within water quality groups I or II (Fig. 35); group I being typical of wells screened in sand, and group II being typical of open-hole wells obtaining water from a combination of sand, carbonate-cemented sandstone, and limestone. Ground water from wells open to limestone facies in the outcrop of the Black Mingo fall within the group III category, which is fresh and is calcium bicarbonate dominated.

In the central and southern sections of the study area, sodium water types plot along line A-B (Fig. 35), which represents various mixing ratios of fresh sodium bicarbonate water and saline sodium chloride water. Chloride concentrations increase to the point that they exceed bicarbonate as a percentage of the total anions present, owing to the presence of brackish ground water that has not been completely flushed from the formation. Black Mingo water in much of the area falls in group IV, which is marginally potable and transitional between fresh and saline water. In areas near the coast, Black Mingo water is saline (group V).

In general, sodium concentrations are less than 600 mg/L and chloride concentrations are less than 400 mg/L in areas west of U.S. Highway 17 in Charleston County (Fig. 34). East of Highway 17, sodium and chloride concentrations increase greatly, locally exceeding 2,000 mg/L. The ratio of sodium to chloride is usually greater than 5 to 1 in areas where water in the Black Mingo is fresh, but it decreases to about 2.3 to 1 in southern coastal Charleston County.

In addition to the coastward increase, the concentrations of sodium and chloride also increase with depth. An example is seen by comparing water quality data for wells 17BB-gl and 17DD-hl in southern Berkeley county (Appendix B-2). Well 17BB-gl is of open-hole construction, obtaining water from the Santee Limestone between the depths of 230 and 260 ft and the Black Mingo between 260 and 315 ft. An analysis of samples from the well represents a mixture of both Santee Limestone and Black Mingo ground water. The concentrations of sodium and chloride are 153 and 64 mg/L respectively. By contrast, nearby well 17DD-hl is screened only in sand of the Black Mingo and the concentrations of sodium and chloride are much higher, being 242 and 176 mg/L, respectively. Similarly, samples from a deep test hole at Kiawah Island (20FF-vl) show that sodium and chloride increase from 1,778 and 2,390 mg/L, respectively, at 592 ft; to 1,905 and 2,560 mg/L, respectively, at 638 ft.

Black Mingo ground water is buffered by high alkalinity and contact with limestone and fossil-shell material. This being the case, pH values are stable and lie within a rather narrow range. Total alkalinities are between 100 and 700 mg/L and are mainly of the bicarbonate type. Carbonate alkalinity, which occurs in water having pH of 8.3 or

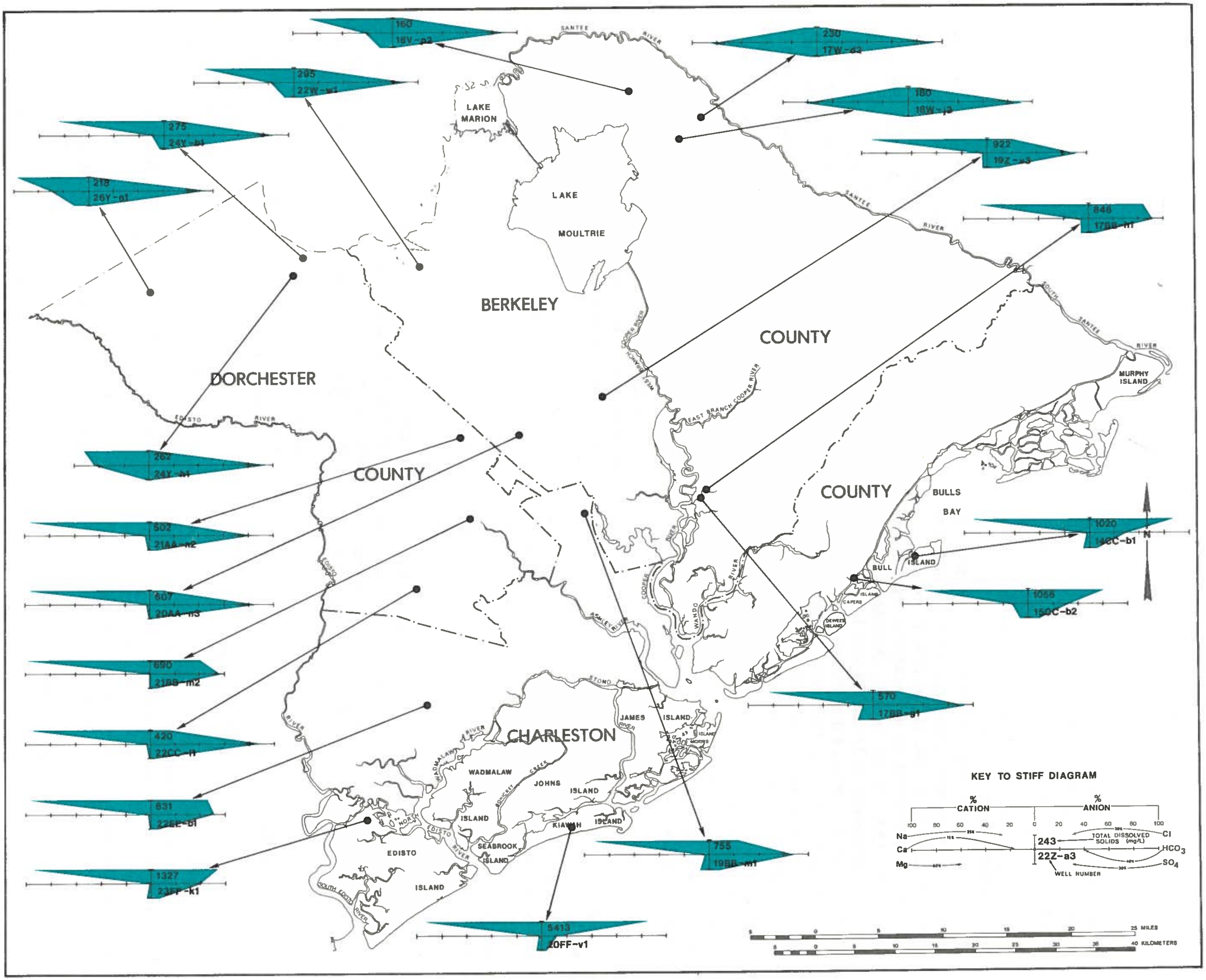
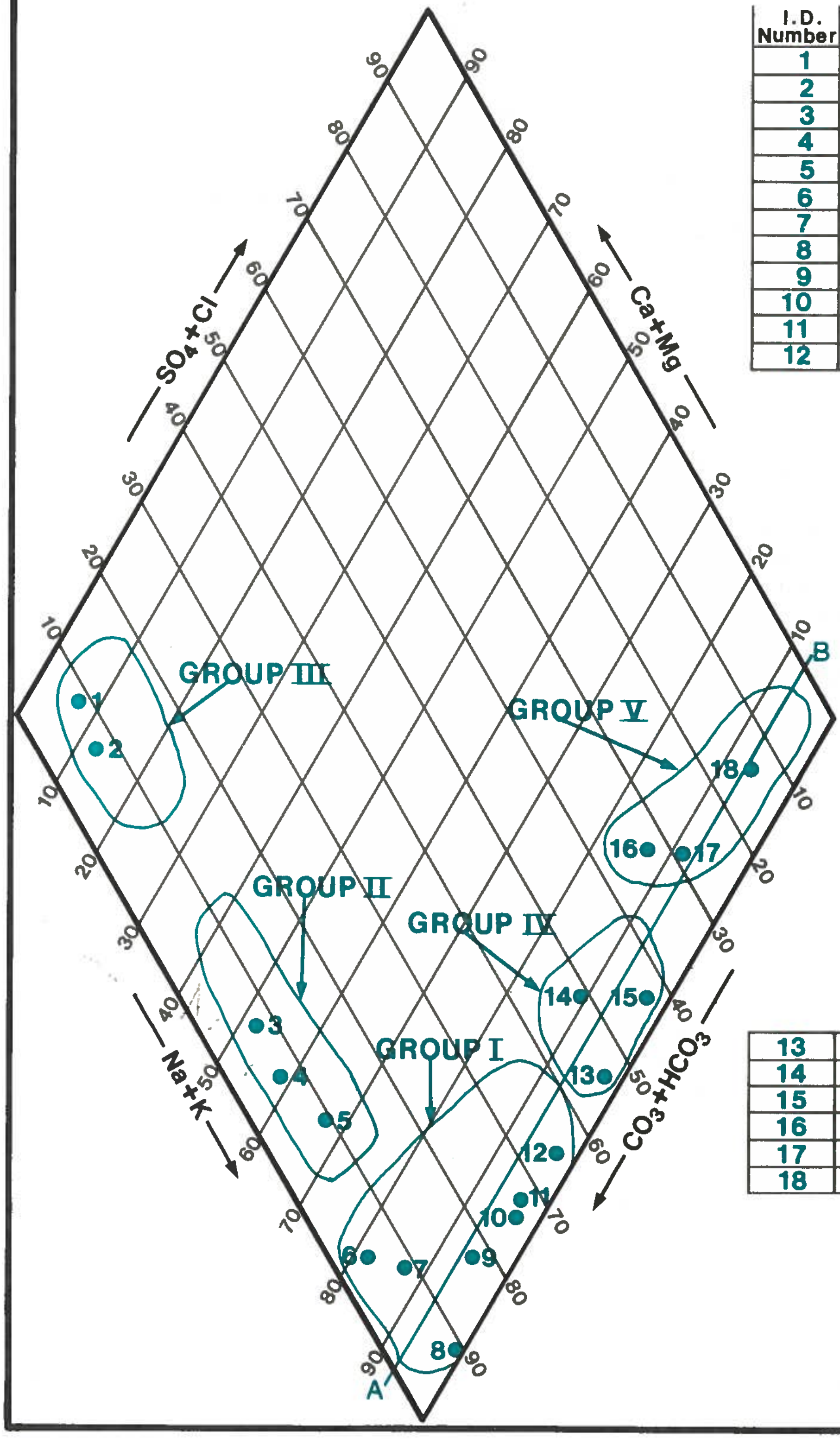


Figure 34. Representative Stiff patterns for samples from the Black Mingo Formation.

I.D. Number	Well Number	Dissolved Solids
1	18W-j1	180
2	17W-d2	230
3	24Y-h1	213
4	26Y-n1	218
5	18V-p2	185
6	22Y-w2	224
7	24Y-b1	275
8	20AA-n3	607
9	21AA-n2	502
10	18AA-i1	1,148
11	19Z-v3	922
12	18AA-u1	809



13	21BB-m2	1,460
14	17BB-h1	846
15	17DD-a3	1,638
16	15CC-b2	1,056
17	14CC-b1	1,020
18	20FF-v1	5,070

Figure 35. Piper diagram depicting the distribution of water-quality types in the Black Mingo Formation.

more, exists in less than half of the well samples listed in Appendix B-2. The lowest alkalinity generally occurs in northern Berkeley and Dorchester Counties and ranges from 100 to 150 mg/L, with pH of 7.3 to 8.0. Elsewhere, alkalinity is usually above 250 mg/L and the pH ranges from 8.0 to 8.5.

Fluoride occurs in water of the Black Mingo Formation in concentrations ranging from 0.1 to about 5.0 mg/L (Fig. 36). The concentration increases coastward from the upgradient areas of Berkeley and Dorchester Counties and is highest in southern Charleston County. Because of increasing concentrations, fluoride exceeds the EPA limit of 1.6 mg/L in nearly all Black Mingo and Santee/Black Mingo wells south of the Summerville-Hanahan area, the result being that the Black Mingo is technically an unacceptable source of public supply in almost half of the study area.

The source of fluoride in Black Mingo ground water has not been determined. However, the occurrence of high fluoride concentrations in Black Mingo ground water is conceivably analogous to the occurrence of high fluorides in the Black Creek Formation. The overall chemical quality of Black Mingo and Black Creek ground water are similar in that they are both of the sodium bicarbonate type, with like ranges of pH. Furthermore, it has been noted that the sediments composing the Black Mingo were deposited in shallow-marine and estuarine environments similar to the depositional environment of the Black Creek Formation. And, as in the Black Creek, fossil shark teeth, blackened by the presence of crytocrystalline fluorapatite, are found in some drill cuttings from the Black Mingo, although it cannot be said that they are common. Hence, there is a possibility the fluoride in the Black Mingo Formation is derived from the exchange of hydroxyl ions in solution for the fluoride ions held in the crystalline structure of fossil shark teeth, as described by Zack (1980) for Black Creek aquifers north of the study area.

The data now available are not sufficient to identify specific aquifers in the Black Mingo system which typically could be expected to yield either high-fluoride or low-fluoride ground water. However, it can be generally observed that high fluoride concentrations (greater than 1.6 mg/L) can be expected from any well deriving water from sand or sandstone in the upper 50 to 100 ft of the Black Mingo in the lower half of the study area.

Dissolved silica is a major constituent in Black Mingo water. When viewed in conjunction with fluoride concentrations and water-quality types, it is useful in identifying Black Mingo aquifers as the source of ground water from wells for which no lithologic or geophysical information is available. Silica concentrations are typically greater than 25 mg/L, average about 30 mg/L, and locally exceed 40 mg/L. The occurrence of silica in Black Mingo water is probably related to the relative abundance of amorphous micro-crystalline silica in the Black Mingo Formation. As noted previously, silica-cemented sandstone, cristobalite, and clinoptilolite are common in the Black Mingo, particularly in the upper half of the formation. Furthermore, the solubility of silica from those minerals is enhanced by the alkaline conditions that exist in Black Mingo water.

The hardness of water samples from Black Mingo aquifers ranged from 11 to 250 mg/L as calcium carbonate. Wells screened in sand generally produce moderately hard to hard water because of the substantial amount of limestone within the formation. The greatest hardness values are encountered in wells open only to Black Mingo limestone and are usually between 100 and 150 mg/L. Water samples from test hole 20FF-vl are very hard (250 mg/L as $CACO_3$) as a result of unusually high magnesium (37 mg/L) and chloride (2,390 mg/L) concentrations, and much of that hardness is of the noncarbonate type. In areas where Black Mingo water is fresh, dissolved carbonate related species are the principal hardness-causing constituents.

Objectional amounts of iron are rare in wells open to Black Mingo aquifers, and in that regard the Black Mingo is a good source of water supply. Only five of the analyses in Appendix B-2 revealed ground water having more than the EPA standard of 300 ug/L for total iron. Of these five, only two analyses indicated total iron concentrations in excess of 1,000 ug/L. The small concentrations of iron may be due to high pH and high bicarbonate concentrations that tend to inhibit the dissolution of iron-bearing minerals. No pattern of distribution can be discerned, although higher iron concentrations occur in the outcrop area where pH values and alkalinities are lower and the Black Mingo is recharged by iron-rich shallow ground water.

In most parts of the study area, Black Mingo water is not known to contain more than 50 mg/L sulfate, which is acceptable for domestic and most industrial purposes. The highest sulfate concentrations occur in wells sampled in Charleston County and are associated with residual saltwater. The sulfate concentrations in those wells ranged from 40 to 210 mg/L.

Santee Limestone

The Santee Limestone contains freshwater in most areas of Charleston, Berkeley, and Dorchester Counties. The chemical analyses of water from selected wells penetrating the Santee Limestone (Appendix B-2) show that water quality varies with both location and depth. Its water is least mineralized in the outcrop areas and in western Dorchester County. The mineral content increases toward the south and east, and along the coastal margin of Charleston County the formation contains brackish water. Objectionable amounts of hardness-causing species and iron are common, and fluoride concentrations exceed 1.6 mg/L in much of Charleston and eastern Dorchester Counties.

Owing to the abundance of calcareous material in the Santee Limestone, the water sampled was generally of the calcium bicarbonate type. This water quality type falls within group I on the Piper diagram illustrated in Figure 37. The total calcium concentration typically ranges between 20 and 60 mg/L; bicarbonate concentrations generally range between 100 and 400 mg/L. Locally, the Santee contains sodium bicarbonate water (group II) that is atypical of what would be expected from a limestone aquifer. This anomalous water quality occurs in southern

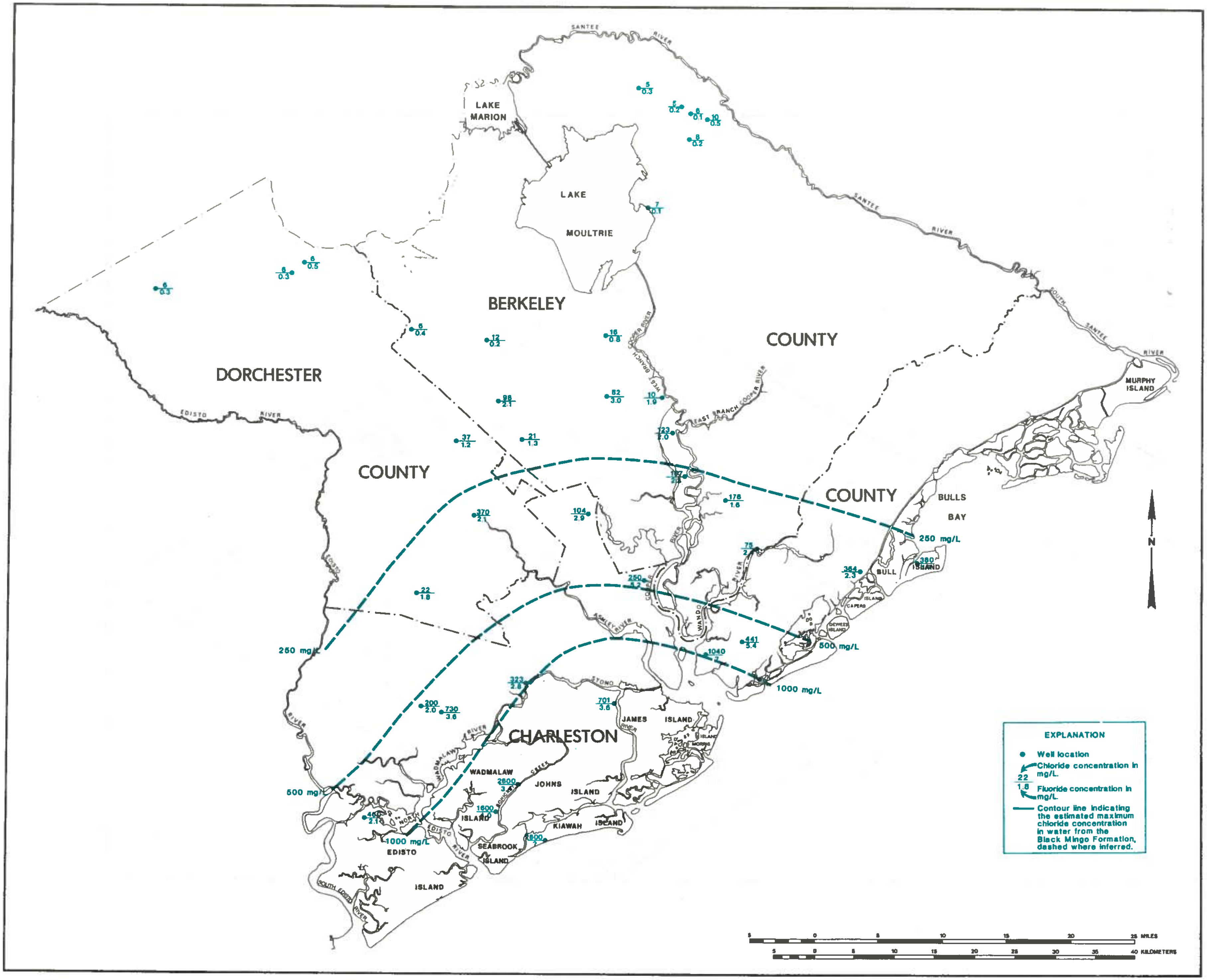
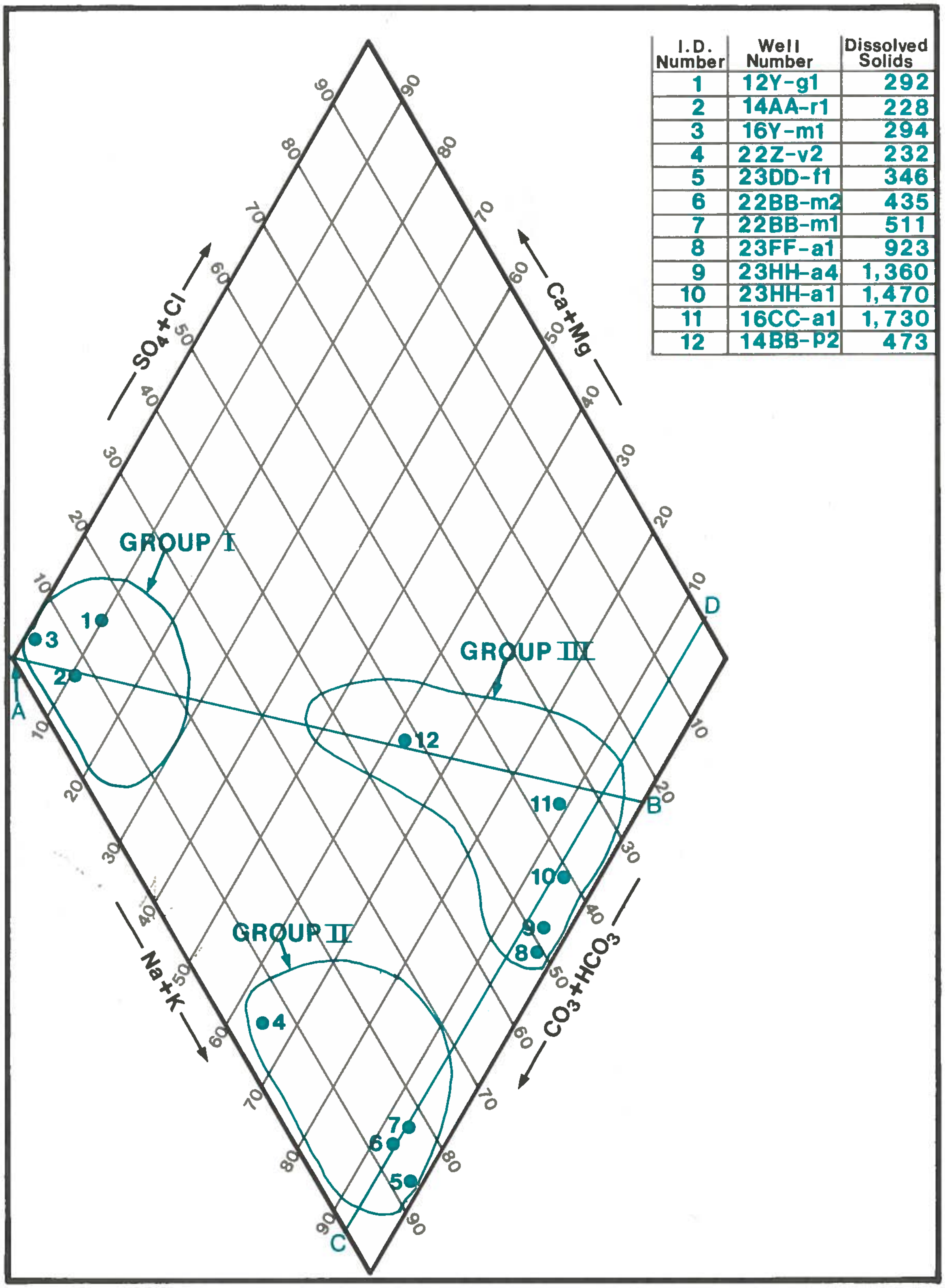


Figure 36. Distribution of chloride and fluoride in the Black Mingo Formation.



I.D. Number	Well Number	Dissolved Solids
1	12Y-g1	292
2	14AA-r1	228
3	16Y-m1	294
4	22Z-v2	232
5	23DD-f1	346
6	22BB-m2	435
7	22BB-m1	511
8	23FF-a1	923
9	23HH-a4	1,360
10	23HH-a1	1,470
11	16CC-a1	1,730
12	14BB-p2	473

Figure 37. Piper diagram depicting the distribution of water-quality types in the Santee Limestone.

Charleston and Dorchester Counties and appears to be restricted to the lower half of the Santee Limestone. In addition to high sodium concentrations in relation to calcium, the water tends to have greater fluoride and silica concentrations than are normal for the formation in most areas. Hence, there seems to be a geochemical similarity between water in the lower part of the limestone and water in the underlying Black Mingo Formation. This suggests the possibility that the Black Mingo and lower Santee Limestone are hydraulically connected, that the Black Mingo locally provides recharge to the Santee Limestone, and that some saltwater in the Santee Limestone is derived from the Black Mingo. Where saltwater intrusion occurs, the water grades into a sodium chloride type. The area in which sodium chloride water lies south of Awendaw and east of U.S. Highway 17 in Charleston County, where sodium and chloride concentrations exceed 250 mg/L and 400 mg/L, respectively. Bicarbonate usually occurs at concentrations of 400 and 600 mg/L and remains a major component, even in water in which chloride concentrations are relatively high.

Because of the paucity of wells open only to the Santee Limestone, few representative samples could be obtained for transition water-quality types (group III). Water representing transition from calcium bicarbonate to sodium chloride was not detected during the sampling program but can be presumed to exist as a result of a mixture of calcium bicarbonate and sodium chloride types of water.

Transition water falling within group III is similar to the transition water-quality type found in some Black Mingo wells. Water in this category is a mixture of sodium bicarbonate and sodium chloride type water. The Stiff diagrams in Figure 38 illustrate the coastward transition from fresh sodium bicarbonate water to slightly brackish sodium chloride water: the sample at 23DD-fl falls in group II, and the samples from wells 23FF-al and 23HH-a2 fall within group III. Comparison of the analyses from wells 23FF-al and 23HH-a2 also shows that bicarbonate generally increases in the coastward direction and is a major component even where chlorides are high. The chloride percentage exceeds that of bicarbonate at chloride concentrations greater than 500 mg/L.

Chloride concentrations are less than 25 mg/L throughout the western part of the study area. Concentrations increase toward the coast and are more than 1,000 mg/L locally (Fig. 39).

Generally, water from wells close to the recharge area contains fewer dissolved solids than water from wells farther downgradient. As shown by the analyses in Appendix B-2, total dissolved solids are less than 400 mg/L in the northwestern third of the study area. In the same area, water from the upper 30 to 50 ft usually contains less than 200 mg/L in total dissolved solids. In the southern part, wells penetrating the entire thickness of the limestone yield water with dissolved solids of more than 500 mg/L. At any given location, wells producing both from the Santee Limestone and Black Mingo aquifers produce water with greater dissolved-solids concentrations than wells open only to the Santee Limestone.

The alkalinity of water in the limestone is due almost entirely to the presence of bicarbonate ions. Carbonate, which is significant only in water having a pH of 8.3 or greater, is indicated in only nine analyses in Appendix B-2,

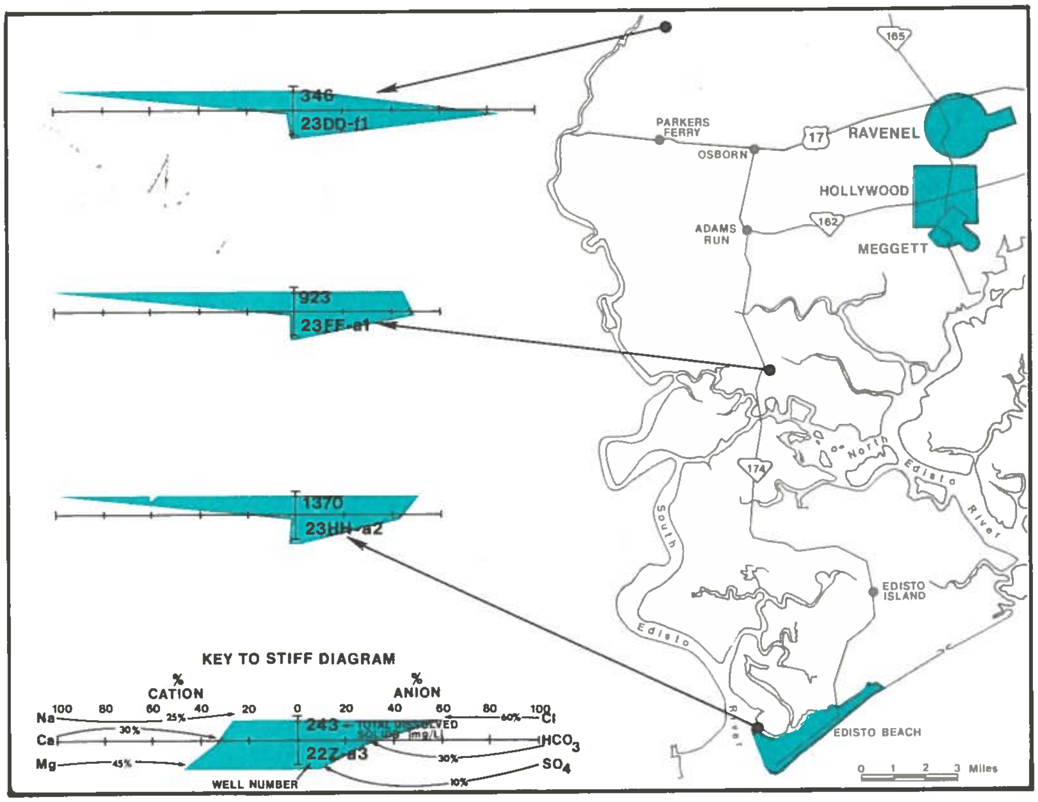


Figure 38. Stiff patterns illustrating the transition of water-quality types in the Santee Limestone in southern Charleston County.

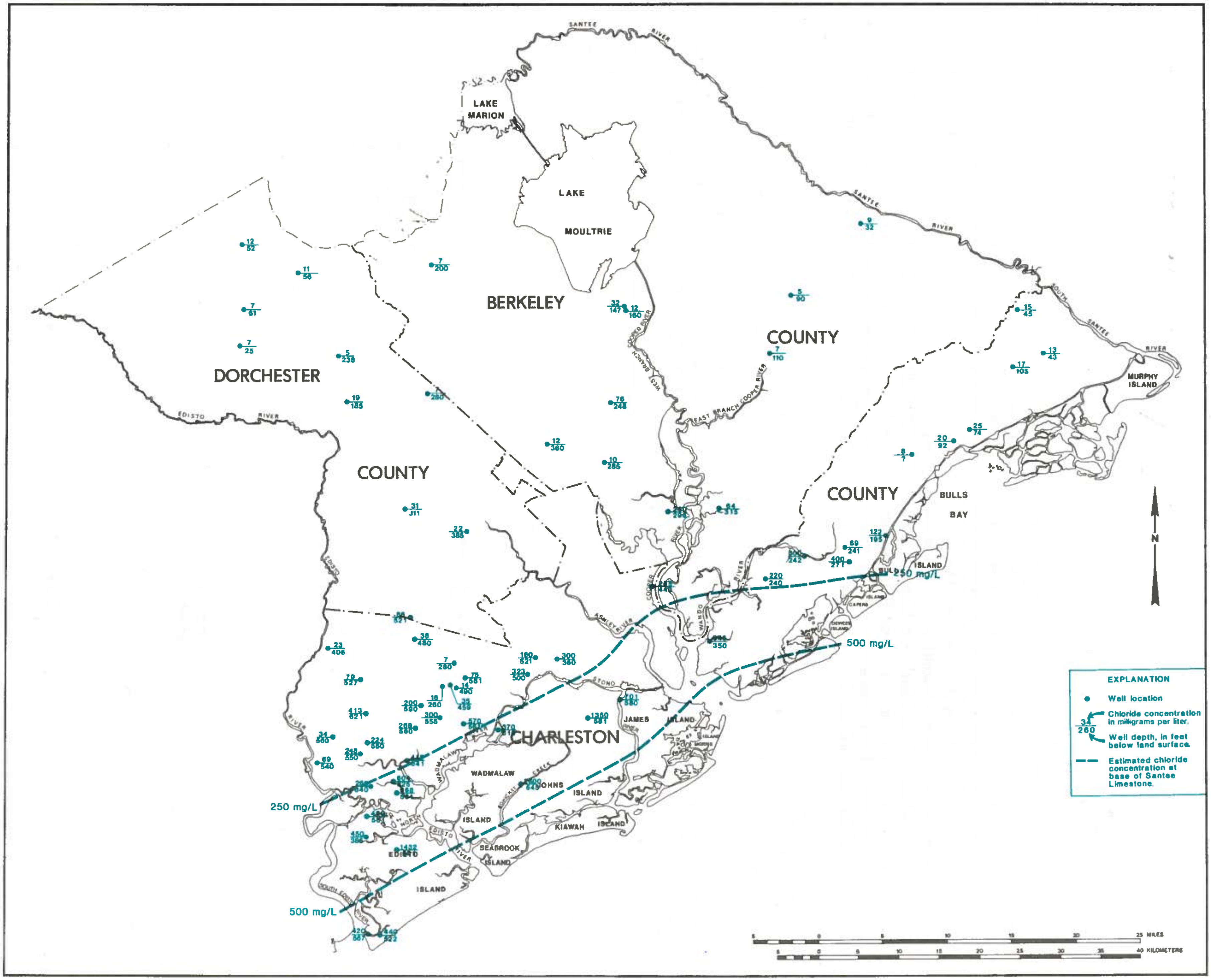


Figure 39. Distribution of chloride in the Santee Limestone and upper part of the Black Mingo Formation.

and in most cases the sampled well was open to both the Santee Limestone and the Black Mingo. Alkalinities of 100 to 300 mg/L as ($CaCO_3$) generally occur in a 15- to 20-mile wide band that roughly overlaps the outcrop area and extends from northern Charleston County to western Dorchester County. The alkalinity increases toward the south and ranges between 400 and 600 mg/L in much of southern Charleston County. Samples having alkalinities greater than 400 mg/L usually are associated with chloride concentrations of more than 250 mg/L and fall within group III.

Fluoride concentrations increase from less than 1.0 mg/L in the northwestern part of the study area to as much as 5.0 mg/L in southernmost Charleston County (Fig. 40). Locally, wells penetrating nearly the entire thickness of the Santee Limestone produce water having the greatest fluoride concentrations, while wells of lesser depth yield lower fluoride water. Figure 41 indicates that fluorides in water in the lower part of the Santee Limestone and upper part of the Black Mingo Formation increase with depth, commonly exceeding 1.6 mg/L.

Silica concentrations averaged 21 mg/L in 25 samples. The lowest concentrations occurred in relatively shallow wells near the outcrop areas and ranged between 2.0 and 18 mg/L. High concentrations were found in wells that are open to the entire thickness of the Santee and ranged from 32 to 42 mg/L. High silica concentrations were also common in samples taken from wells penetrating the upper part of the Black Mingo.

As might be expected from a limestone aquifer, the water is moderately hard to very hard. Most samples had total hardness values between 100 and 200 mg/L as $CaCO_3$, and the average hardness was 140 mg/L. Wells open to both the Santee Limestone and Black Mingo generally produced soft water, but concentrations as high as 160 mg/L were measured in some samples. Few of the limestone wells sampled produced water with a hardness less than 60 mg/L.

The hardness of Santee Limestone water is primarily caused by the abundance of calcium and magnesium derived from the dissolution of limestone. Calcium concentrations are usually much lower, ranging from 2.0 to 37 mg/L in samples and averaging about 7.4 mg/L. Wells open to both the Santee Limestone and the underlying Black Mingo Formation produce soft water, and on the average both calcium and magnesium concentrations are less than 10 mg/L.

Excessive iron concentrations are a common problem in wells open to the Santee Limestone. More than 20 percent of the wells sampled yielded water with total iron concentrations of more than 300 ug/L. Samples taken from 30 to 120 ft deep wells near the outcrop area usually contained greater concentrations than samples collected from deeper wells farther downgradient. Overall, total iron averaged 665 ug/L and ranged from 25 to 4,000 ug/L.

The samples analyzed for sulfate contained concentrations far below the maximum limit recommended by the EPA. The average concentration in 27 samples was 16 mg/L; concentrations ranged from 0 to 64 mg/L. Samples from the northern and central parts of the study area usually contained less than 10 mg/L of sulfate; samples from coastal Charleston County commonly contained between 30 and 60 mg/L. In the same area, wells open to the top of the Black Mingo produced water with as much as 190 mg/L of sulfate. The higher concentrations found in the coastal area coincide with the presence of brackish water.

The saltwater present in the Santee Limestone and Black Mingo Formation entered the aquifers during past geologic time, probably when the sea stood above its present level. Subsequently, freshwater entered the system and flushed out or diluted most of the saltwater. The saltwater that now remains is a source of contamination of fresh ground water.

The approximate extent of saltwater in the Santee Limestone is delineated by the 250-mg/L isochlor in Figure 39. Saltwater in the underlying Black Mingo Formation could not be accurately mapped but is believed to extend inland beyond the 250 mg/L isochlor of the Santee Limestone.

The most common mechanism for saltwater contamination is the process of interaquifer transfer (Fig. 42). It occurs where wells are constructed in such a way as to connect relatively shallow freshwater zones with underlying saltwater zones. As a rule, artesian pressure increases with depth, hence water from the lowest zone penetrated by an open-hole well flows up the well bore and into the overlying permeable zones. The upward flow continues until the pressure in the upper and lower zones becomes equal. As a result, the chemical quality of water in all aquifers connected to the lowest aquifer via the well bore approaches the chemical quality of water in the deepest aquifer: where the lowest aquifer penetrated contains saltwater, the overlying aquifers are contaminated.

An example of interaquifer transfer of saltwater occurred at well 20DD-n3 near Ravenel in Charleston County. The well was drilled to 500 ft, penetrated the upper 50 ft of the Black Mingo Formation, and was of open-hole construction. Older wells in the same area produced water with chlorides of 180 to 240 mg/L. When samples were collected soon after the well was completed, the well produced freshwater having a chloride concentration of 52 mg/L. In samples collected two months later, the chloride concentration was 190 mg/L. The original sample apparently was a mixture of water from the Santee Limestone and Black Mingo aquifers; the later sample was more typical of water from the top of the Black Mingo Formation.

Well-construction practices and ground-water conditions are such that contamination by interaquifer transfer is a common occurrence in Charleston County. Nearly all wells drilled into or through the Santee Limestone are of open-hole construction; they commonly penetrate the base of the limestone aquifer and sand in the upper 30 to 50 ft of the Black Mingo Formation; and water in the lower part of the limestone and in the Black Mingo is salty and is under greater pressure than water in the overlying freshwater zones. Most of the wells are used for domestic

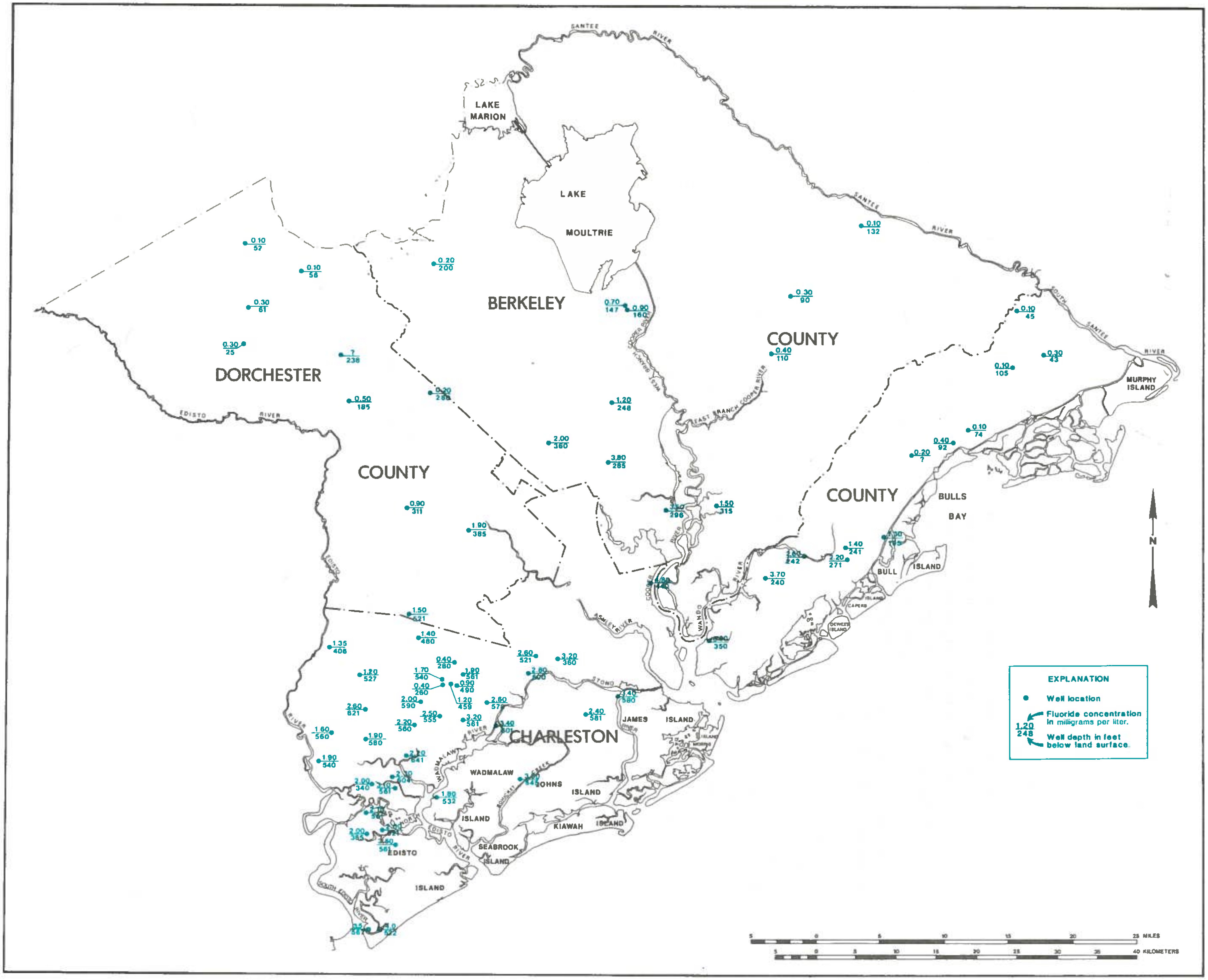


Figure 40. Distribution of fluoride in the Santee Limestone and upper part of the Black Mingo Formation.

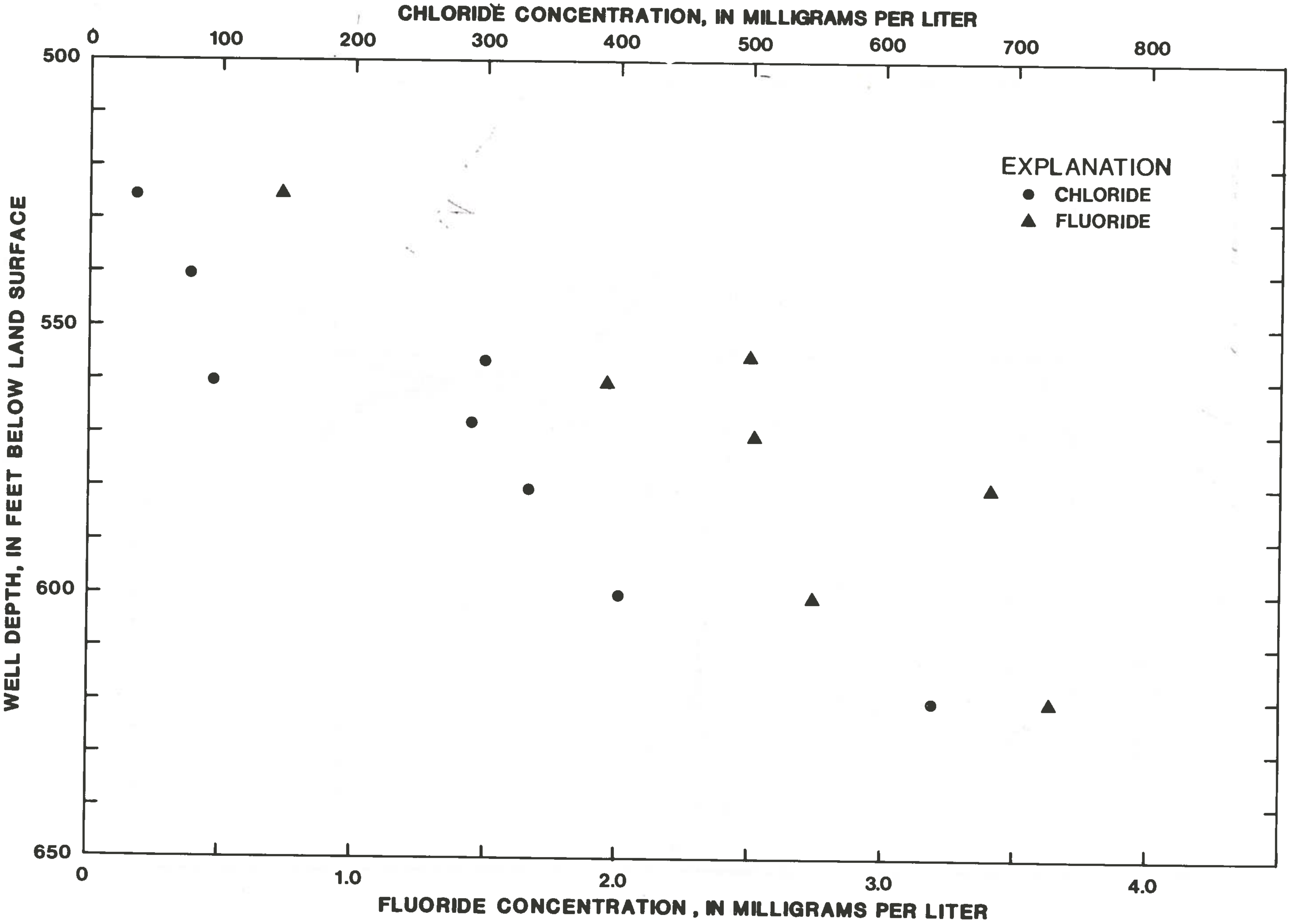


Figure 41. Chloride and fluoride concentrations in open-hole wells at Hollywood, Charleston County.

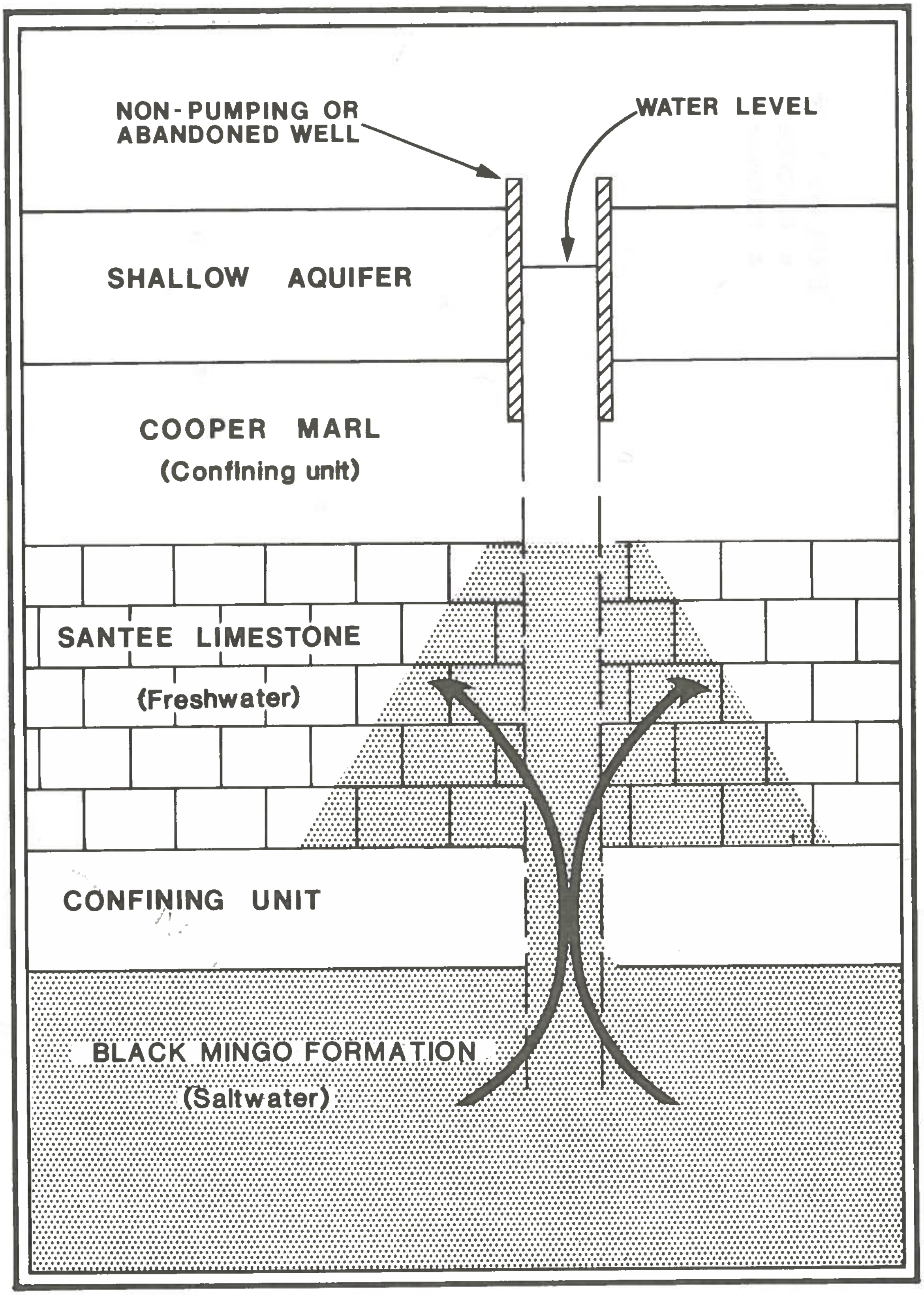


Figure 42. Interaquifer transfer of saltwater in an open-hole well.

water supply and pump only a few hundred gallons each day. Consequently, saltwater flows into the well bore and the surrounding aquifers faster than it can be removed by pumping.

The process has probably affected many hundreds of wells, but for a variety of reasons it has gone undetected or, at least, unreported. In many wells, the water becomes less potable but not undrinkable. Furthermore, the contamination occurs soon after the well is developed, often precluding a comparison of initial water quality with later water quality. Locally, brackish well water is accepted as the norm, and the cause is never questioned.

Cooper Formation

The only water-bearing zones definitely identified in the Cooper Formation occur at Edisto Island and Ravenel. Little is known about the chemical makeup of water in the zones identified at Edisto Island; although a single driller's log reports "brackish" water at approximately −220 ft msl.

The quality of water in the bryozoan unit at Ravenel is inferred from a comparison of water samples taken at open-hole wells having similar depths but different lengths of casing. In that area, chloride concentrations in the Santee Limestone and the Black Mingo Formation increase with depth; and wells having more than 100 ft of casing and total depths greater than 500 ft typically produce water with chlorides above 50 mg/L and alkalinities above 370 mg/L.

Wells having less than 100 ft of casing are open to the bryozoan unit of the Cooper, and they produce water having chlorides of less than 10 mg/L and alkalinities less than 120 mg/L, regardless of well depth. Hydraulic head is greater in the bryozoan unit than in the underlying aquifers, and freshwater is apparently flowing down the well bore. Consequently, many of the analyses for wells in grid "21DD" in Appendix B-3 represent water from the Cooper Formation. That water is of the calcium bicarbonate type and resembles the chemical quality of water from the Santee Limestone outcrop area. Alkalinities range from 80 to 116 mg/L and calcium concentrations are between 28 and 33 mg/L; reported hardness, as calcium carbonate, is greater than 60 mg/L. Chloride and fluoride concentrations average about 7 and 0.4 mg/L, respectively. The concentrations of dissolved solids are less than 200 mg/L, and specific conductances are below 250 umohs. Total-iron concentrations range from 28 to 3,000 mg/L and average 683 mg/L.

Shallow Aquifers

The chemical quality of water from shallow aquifers is generally acceptable for domestic use and most industrial purposes. Shallow ground water here usually contains low concentrations of dissolved solids and is acidic to slightly alkaline, with objectionable amounts of iron and hardness-causing species occurring locally. As can be seen in Figures 43 and 44 and Appendix B-3, shallow ground water encompasses a broad range of water quality. For most samples collected in the study area, the predominant cation-anion pairs are sodium chloride or calcium bicarbonate.

Sodium chloride type water occurs in nearly all parts of the study area and is most commonly obtained from wells less than 25 ft deep. Sodium and chloride represent 50 to 90 percent of the ions present. The majority of wells sampled in Berkeley and Dorchester Counties yielded water of this type. In Charleston County, sodium chloride type water is associated both with very shallow wells and many wells in close proximity to saline surface water. The highest sodium and chloride concentrations occur in the latter situation, and the proportion of sodium and chloride in such wells usually exceeds 80 percent of the total ions present.

Calcium bicarbonate type water is commonly obtained from shallow wells in Charleston County. In most samples, calcium represents 50 to 80 percent of the total anion concentration. Wells yielding calcium bicarbonate water are usually 35 to 55 ft deep and are screened in the shell beds and shelly sand beds of the Pamlico Formation. Carbonate clastics are not as abundant in the shallow aquifers of Berkeley and Dorchester Counties, hence calcium bicarbonate water is not so prevalent in those areas.

Sodium bicarbonate, calcium chloride, or calcium sulfate types of water were obtained from less than 10 percent of the shallow wells sampled.

Sodium concentrations, even in sodium chloride type water, are usually less than 30 mg/L. Chloride concentrations are correspondingly low, ranging from 5 to 50 mg/L. In most of the wells sampled, chloride concentration was 40 to 60 percent higher than the sodium concentration.

The greatest sodium and chloride concentrations occur in areas within a few hundred yards of saline surface-water bodies. On barrier islands such as the Isle of Palms and Edisto Beach, sodium and chloride concentrations are usually less than 100 mg/L in 15- to 20-ft wells but increase to more than 250 mg/L near the base of the shallow aquifer.

The alkalinity and pH of shallow ground water are generally low. In most of the shallow wells sampled, total alkalinity was below 150 mg/L as calcium carbonate, while the pH was generally below 8.0. Wells yielding water with alkalinity of 50 mg/L or less are common, and accompanying pH values are less than 7.0. Locally, 10- to 20-ft wells yield very acidic ground water with pH ranging from 4.8 to 5.5 and alkalinity less than 10 mg/L. The highest alkalinity and pH are found in aquifers containing large amounts of shell and limestone.

Fluoride concentrations fall well below the 1.6 mg/L EPA standard and no pattern of fluoride distribution is discernible. Of more than 100 shallow-well samples, only one well (21BB-L4) contained a fluoride concentration greater than 1.6 mg/L. Nearly all other wells sampled produced water with less than 0.4 mg/L of fluoride.

Although fluoride concentrations in the shallow aquifers are stable and uniformly low in almost all of Charleston, Berkeley, and Dorchester Counties, there are areas where concentrations may be increasing as a result of contamina-

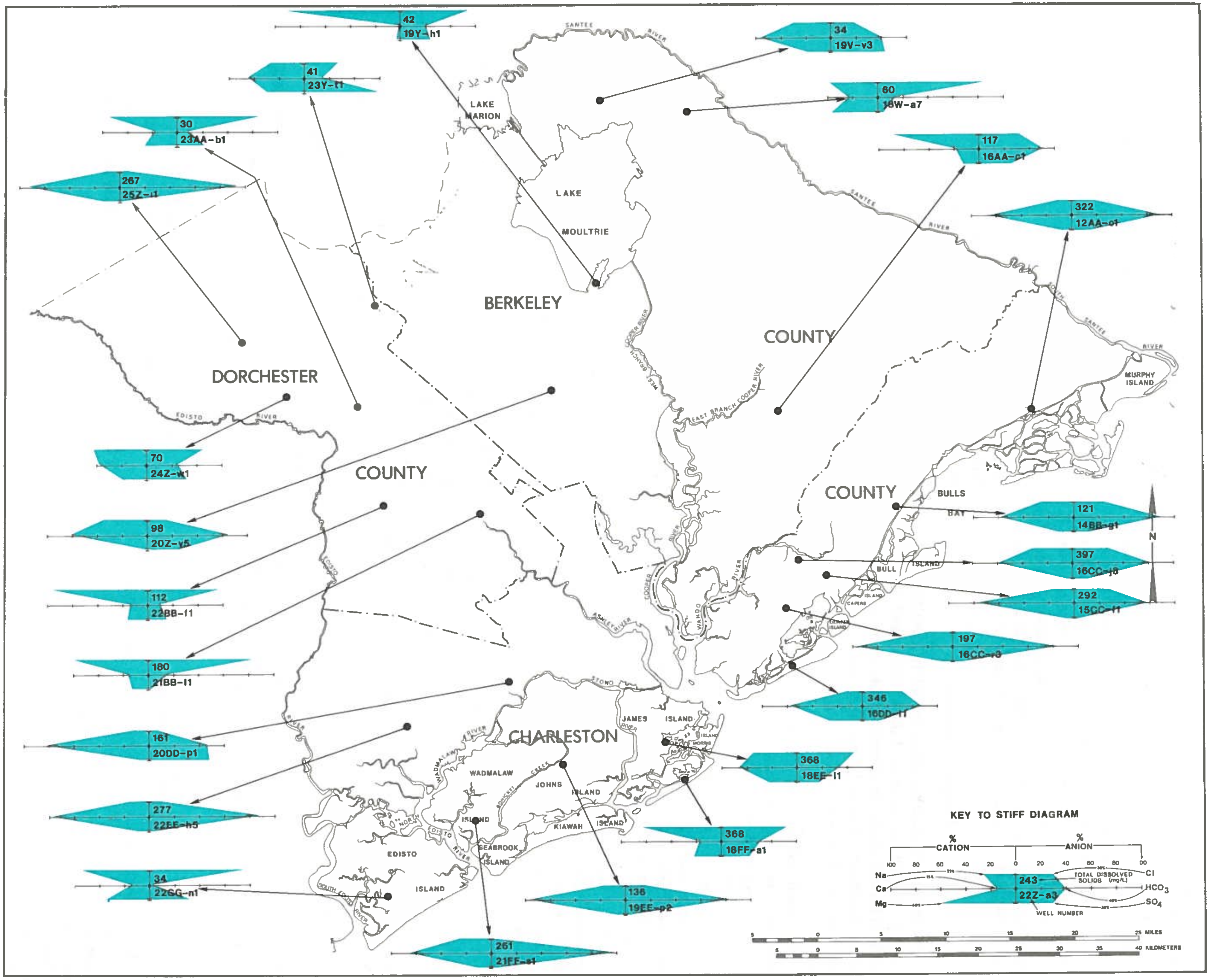
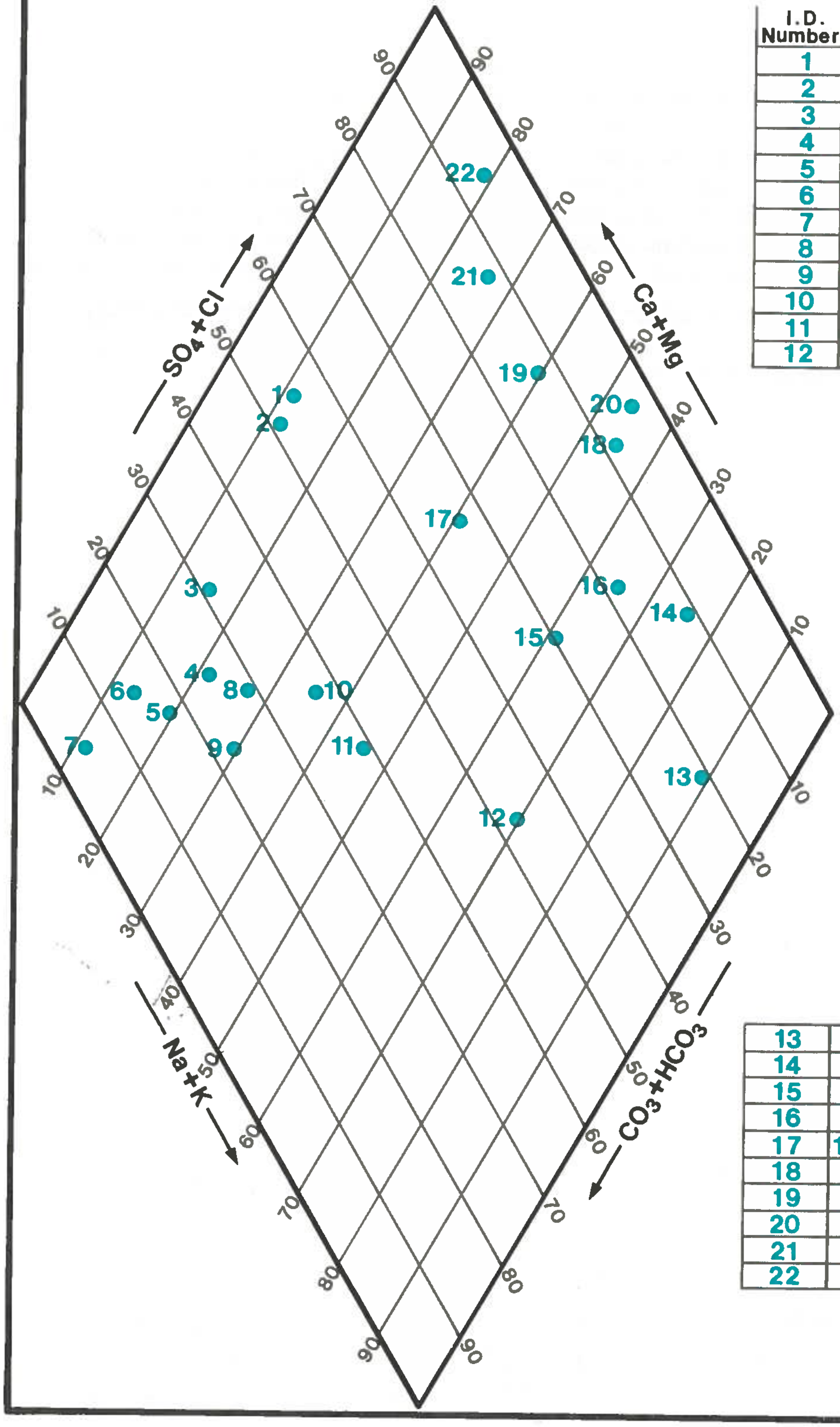


Figure 43. Representative Stiff patterns for samples from shallow aquifers.



I.D. Number	Well Number	Dissolved Solids
1	20DD-p1	161
2	16DD-l1	346
3	15CC-f1	292
4	22FF-g1	55
5	16CC-r3	397
6	22EE-h5	277
7	21FF-s1	261
8	16CC-j4	238
9	23DD-x1	228
10	20Z-v5	98
11	24Z-w1	70
12	16AA-c1	117
13	19Y-h1	42
14	22BB-f1	112
15	18FF-a1	409
16	23EE-l1	55
17	17DD-m13	227
18	23AA-b1	30
19	18W-a7	60
20	22GG-n1	34
21	23Y-t1	41
22	21BB-l4	180

Figure 44. Piper diagram depicting the distribution of water-quality types in the shallow aquifers.

tion. Three water systems, Mt. Pleasant, Sullivans Island, and Isle of Palms, are now diluting high-fluoride Black Creek Formation ground water (4.5 to 6.0 mg/L) with low-fluoride shallow ground water. All three systems distribute treated water having fluoride concentrations over the recommended limit of 1.6 mg/L. As a result of distributing high-fluoride water, these water systems may be contributing, in varying degree, to increases in fluoride concentrations in the shallow aquifers. Although the extent of fluoride contamination may not be severe in most areas, it can occur wherever water from the public supply systems is allowed to recharge the shallow aquifers. The principal sources of recharge are lawn and garden irrigation, septic-tank systems, and leakage from distribution lines.

The concentration of silica in shallow ground water ranges from 1.0 to 70.0 mg/L; it is usually less than 25 mg/L. Only about 20 percent of the wells sampled yielded water with more than 25 mg/L of dissolved silica.

Total hardness varies greatly, but it roughly corresponds to water-quality type. Except in areas near saltwater bodies, aquifers producing sodium chloride water also produced water with hardness less than 60 mg/L. Calcium bicarbonate and calcium sulfate water types are hard to very hard (120 mg/L and above).

Iron is the most frequently troublesome chemical constituent found in shallow ground water. Of the samples tested for iron, more than 60 percent contained dissolved iron in concentrations greater than 300 ug/L and almost 80 per-

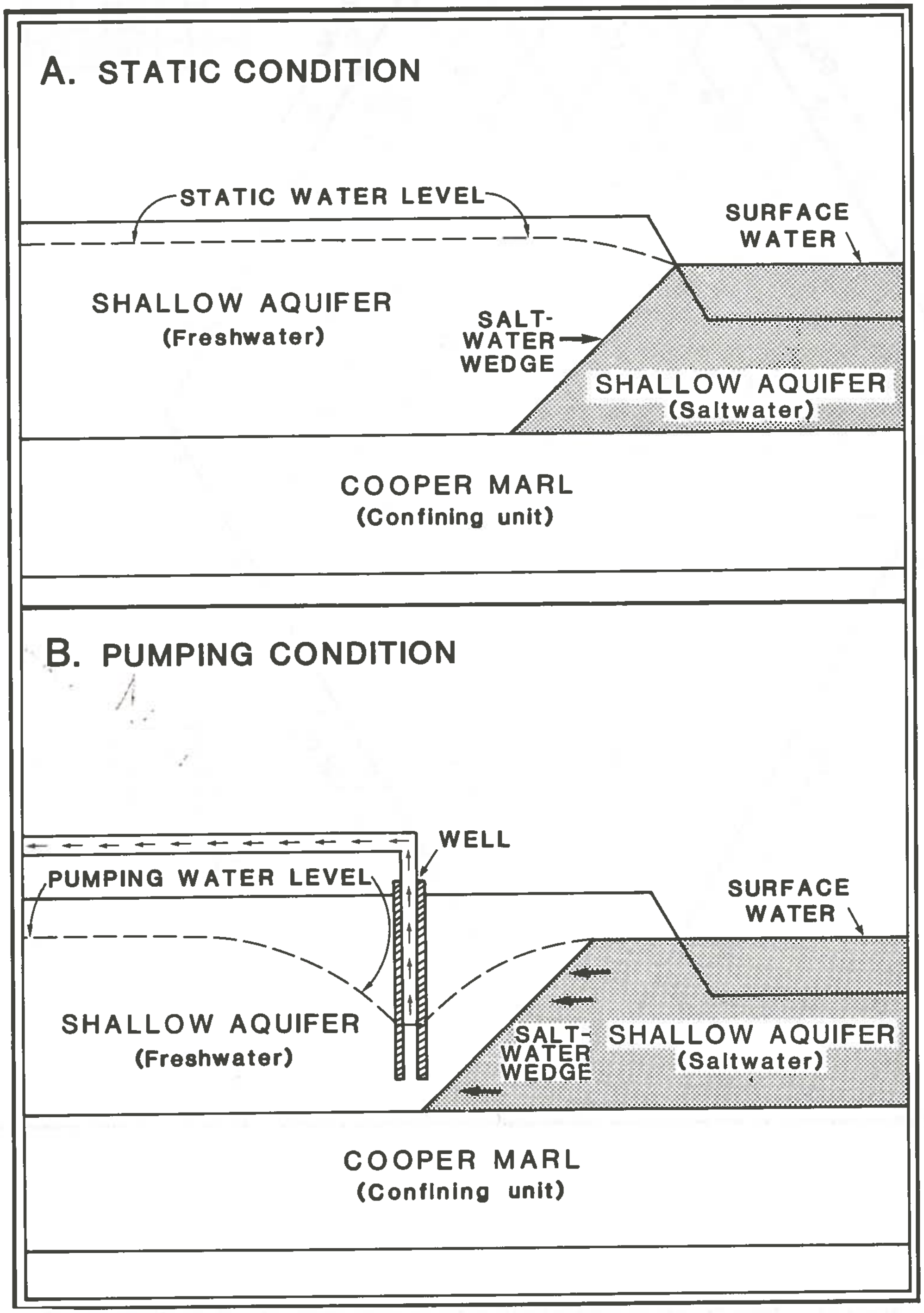


Figure 45. Saltwater intrusion into a shallow water-table aquifer.

cent of the samples had total-iron concentrations above 300 ug/L. Dissolved iron ranged from 20 to 23,000 ug/L and averaged 2,830 ug/L. The total-iron concentrations locally exceeded 30,000 ug/L. At many sites, samples could not be collected at the wellhead, but instead passed through pressure tanks and steel plumbing. Shallow-well ground water samples commonly have low pH, contain dissolved oxygen, are undersaturated with iron, and thus are easily contaminated by metals from the plumbing pipes and equipment. Oxygen also causes dissolved iron to precipitate as colloidal iron oxide and contributes to the presence of the suspended iron so common in the analyses listed in Appendix B-3.

Shallow ground water contains very low concentrations of sulfate; they average 14 mg/L and are rarely greater than 40 mg/L. However, hydrogen sulfide is common and is often detected in shallow wells near the coast of Charleston County.

Unlike the underlying artesian systems, the shallow aquifers are not protected from surface contaminants by layers of impervious material. In most areas, the land surface is the principal interface between man's activities and shallow ground water. Thus chemicals introduced at or below land surface, or changes in the hydraulic balance, may lead to undesirable changes in ground water quality.

In a study of waste-disposal sites in the Lower Coastal Plain, the South Carolina Department of Health and Environmental Control (1979) identified numerous cases of contamination. Some of the principal sources included septic tanks, sanitary landfills, feed lots, and spray-disposal sites. Typical contaminants included dissolved metals, nitrates, and phosphates.

In addition to contaminants introduced by man, shallow aquifers also contain naturally occuring saline water. This latter condition exists in areas where the shallow system is hydraulically connected with saline surface-water bodies. Under these conditions, saline water invades the margin of the shallow aquifer to the point at which the coastward pressure exerted by a higher level of freshwater compensates for the landward pressure exerted by the higher density of the saline water. At that interface an equilibrium is established.

The main factors controlling the position of the saltwater-freshwater interface are the heads and densities of the opposing water bodies and the permeability and thickness of the aquifer.

The interface between the saltwater and freshwater is not an abrupt change from seawater to freshwater. Instead it consists of a zone of diffusion or mixing. The zone is the result of the dispersion that occurs when water flows through porous media; from interface fluctuations caused by tidal and seasonal water table changes; and from molecular diffusion (Todd, 1959, p. 282).

The introduction of a discharging well to the vicinity of the saltwater-freshwater interface can disrupt the natural equilibrium. When the interface lies within the well's radius of influence, the interface moves towards the center of pumping and may eventually contaminate the well (Fig. 45). Contamination begins as a slight increase in salt content as the leading edge of the zone of diffusion arrives at the well. As pumping continues, the salt content increases to the point that the water is no longer potable.

Saltwater intrusion of this type occurred at Folly Beach during 1956 and 1957. At that time, the town drilled a line of shallow wells parallel to the beach of the barrier island as a source of public water supply. After the wells began pumping, saltwater moved into the well field and chloride concentration in the public water supply system increased from 140 mg/L to 800 mg/L in less than a year (Figure 46).

Similar events are known to have occurred at other localities in Charleston County. Wells at Mt. Pleasant and Fort Sumter were contaminated by water from Charleston Harbor, and wells at Porchers Bluff were contaminated by water from tidal creeks. Figure 47 shows the locations of the contaminated well fields and outlines areas susceptible to intrusion.

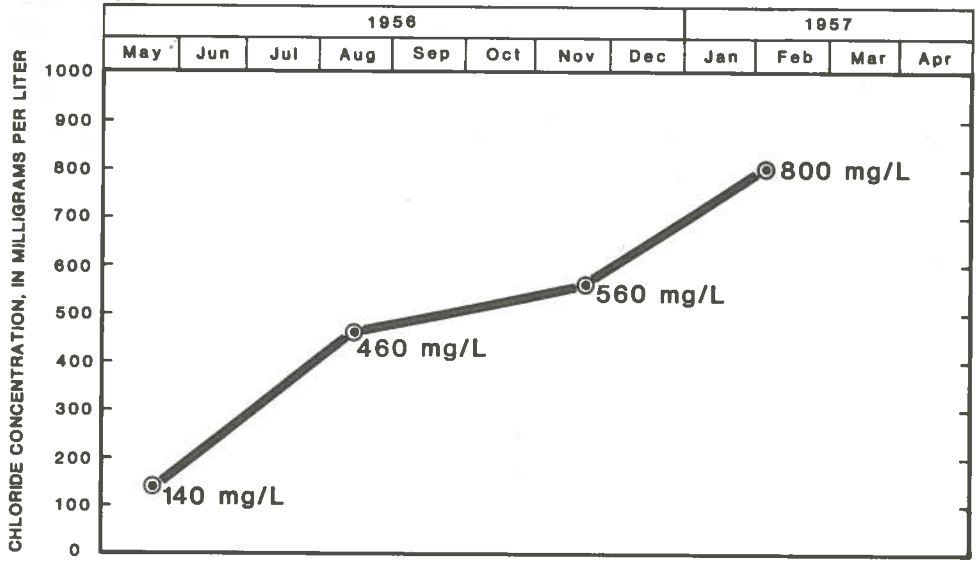


Figure 46. Changes in chloride concentrations in wells at Folly Beach, May 1956 to February 1957.

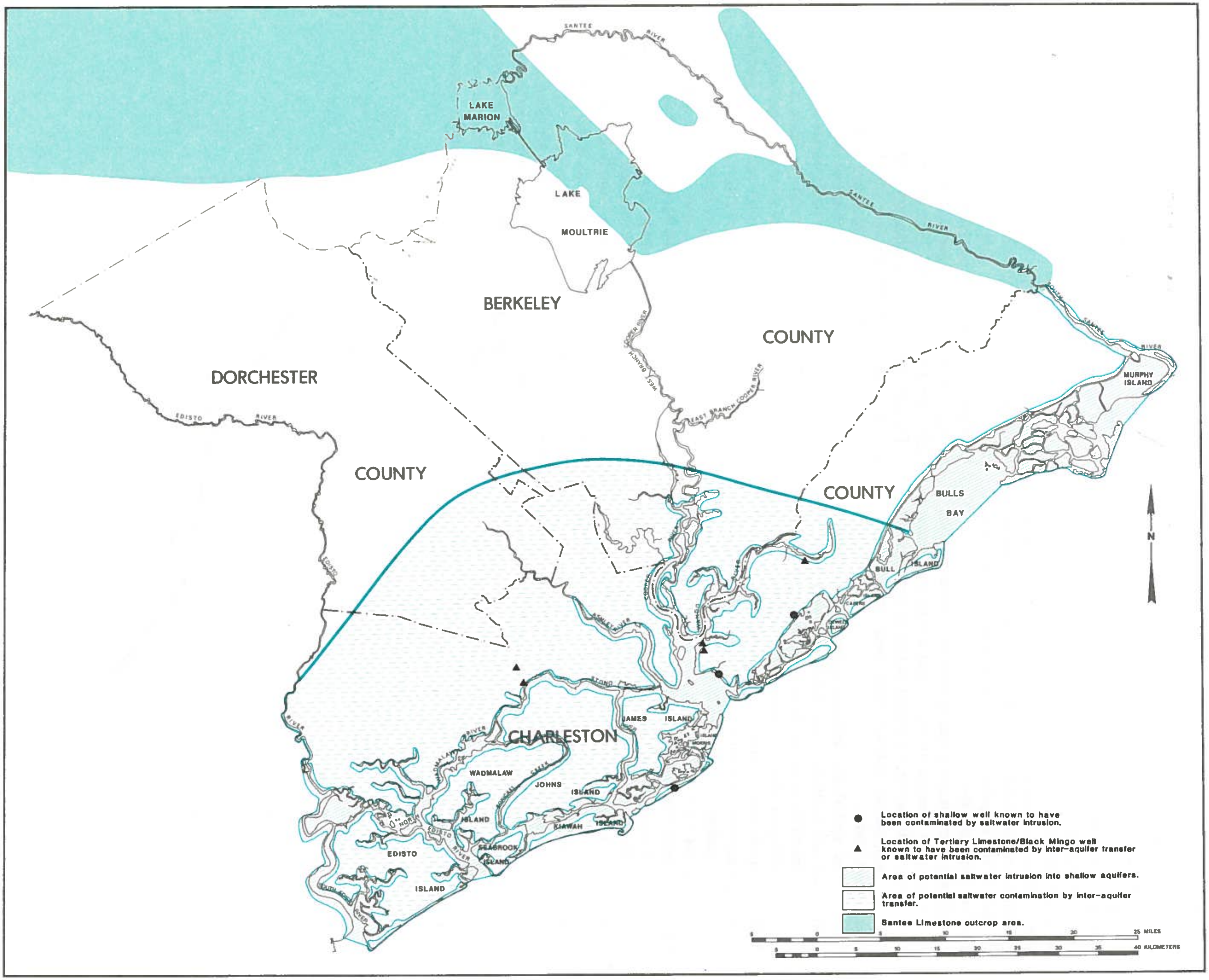


Figure 47. Areas of potential or documented saltwater contamination in the study area.

WATER USE

The 1980 water use information presented in Table 3 was assembled from the files of the SCWRC and represents data collected as part of a statewide cooperative program with the U.S. Geological Survey. Table 4 represents the projected use of both ground water and surface water by six categories of water users. Information on water use by public supply systems was obtained through the assistance of the S.C. Department of Health and Environmental Control. Agricultural use was obtained through agents of the U.S. Soil Conservation Service and the Clemson University Extension Service. Industrial water-use figures were obtained through the U.S. Department of Labor, which included SCWRC water-use questionnaires in its annual review of labor statistics. Water use by private households was determined on the basis of the number of persons who were not served by public water supply systems. The amounts of water used to generate electricity were obtained directly from the generation plants.

Public-supply water usage constitutes the second largest category of water use. Most of that water (65.7 mgd) was withdrawn from the Edisto River Basin and transferred into the Ashley and Cooper River Basins by the Charleston Commission of Public Works. About 33 percent of the water was distributed directly to private households; 1 mgd of raw water was sold to the Town of Summerville, which mixes surface water with water from wells tapping Middendorf and Black Creek aquifers; and the remaining water, both raw and treated, was sold to commercial and industrial concerns. Public-supply surface-water use is projected to increase by 44 percent between 1980 and 2000.

Fourteen public water systems were supplied by wells in 1980. These systems withdrew a total of 4.8 mgd in 1980 and are expected to be withdrawing more than 10 mgd by 2000. Withdrawals by Mt. Pleasant, Moncks Corner, Summerville, and Berkeley County Water and Sewer Authority constitute the bulk of public-supply ground-water use.

Rural domestic water users pumped an average of 8.6 mgd from ground water sources, and this use category represents the greatest amount of ground water withdrawal in the study area. Domestic water users are defined as rural and suburban homes not served by public water-supply systems and represent about 25 percent of the area's population. The domestic water use was computed by multiplying average daily per capita use (80 gpd) by the population not served by public water systems (107,153). Ground water use by this category is expected to remain relatively high, increasing by 92 percent to 16.5 mgd, by 2000.

Self-supplied industry used 17.2 mgd, 5.3 mgd of which was obtained from wells. Projected industrial ground water use for 2000 is 6.7 mgd.

Water use by farms in the area is relatively insignificant. The total amount of water used for livestock and irrigation was less than 1 mgd in 1980 and is projected to rise to only 3.2 mgd by 2000. About 70 percent of that increase, or 2.2 mgd, will be used for irrigation. Less than 800 acres of farmland were irrigated in 1980.

By far the largest withdrawals are made by thermoelectric power plants. Three plants withdrew a total of 372 mgd of surface water, of which 16 mgd was saline surface water. projected withdrawals for 2000 are 432 mgd. Nonwithdrawal use for hydroelectric power generation is not given in Table 3, but it averaged 10,000 mgd in 1980.

Table 3. **Average water use, 1980, in million gallons per day.**

COUNTY	MUNICIPAL	DOMESTIC	INDUSTRIAL	LIVESTOCK	IRRIGATION (ACRES)	THERMO-ELECTRIC	TOTAL
BERKELEY							
Ground water	0.834	5.572	2.245	0.040	0.130 (175)	—	8.821
Surface water	—	—	10.181	.050	.156 (210)	356.000	366.387
Total	.834	5.572	12.426	.090	.286 (385)	356.000	375.208
CHARLESTON							
Ground water	2.116	1.239	.844	.030	.222 (300)	—	4.451
Surface water	65.664	—	.018	.020	—	16.000 (saline)	81.702
Total	67.780	1.239	.862	.050	.222 (300)	16.000	86.153
DORCHESTER							
Ground water	1.772	1.760	2.236	.060	—	—	5.828
Surface water	—	—	1.710	.060	.060 (80)	—	1.830
Total	1.772	1.760	3.946	.120	.060 (80)	—	7.658
TOTAL							
Ground water	4.772	8.571	5.325	.130	.352 (475)	—	19.100
Surface water	65.664	—	11.909	.130	.216 (290)	372.000	449.919
Total	70.386	8.571	17.234	.260	.567 (765)	372.000	469.019

Table 4. 1980 and projected water use in Charleston, Berkeley, and Dorchester Counties, in million gallons per day.

	1980	1990	2000	2010	2020
PUBLIC SUPPLY					
Ground water	4.772	7.892	10.314	12.848	14.494
Surface water	65.664	80.701	94.743	108.291	116.521
Total	70.386	88.593	105.057	121.139	131.015
DOMESTIC					
Ground water	8.571	12.130	16.458	20.979	23.900
Surface water	—	—	—	—	—
Total	8.571	12.130	16.458	20.979	23.900
LIVESTOCK					
Ground water	.130	.148	.168	.192	.219
Surface water	.130	.148	.168	.192	.219
Total	.260	.296	.336	.384	.438
IRRIGATION					
Ground water	.352	1.239	2.168	3.035	3.433
Surface water	.215	.593	.683	.887	1.074
Total	.567	1.932	2.851	3.922	4.507
INDUSTRIAL (Self-supplied)					
Ground water	5.325	6.081	6.731	7.738	8.027
Surface water	11.909	13.516	15.057	16.623	18.086
Total	17.234	19.597	21.788	24.361	26.113
THERMOELECTRIC					
Ground water	.00	.00	.00	.00	.00
Surface water	372.00	419.96	432.56	445.54	458.90
Total	372.00	419.96	432.56	445.54	458.90
TOTAL					
Ground water	19.100	27.490	35.839	44.792	50.073
Surface water	449.919	514.918	543.211	571.533	594.800
Total	469.019	542.508	579.050	616.325	644.873

SUMMARY AND RECOMMENDATIONS

Ground-Water Availability

A largely undeveloped supply of ground water exists in Charleston, Berkeley, and Dorchester Counties. This ground water is obtained from, in ascending order, the Middendorf, Black Creek, Peedee, and Black Mingo Formations, the Santee Limestone, and the shallow sand and shell aquifers. The Black Creek and Black Mingo Formations and the Santee Limestone are the region's principal sources of ground-water supply.

The Middendorf Formation is the most permeable and is potentially the most productive ground-water source. The wells known to tap the Middendorf yield as much as 2,000 gpm and have specific capacities of 4 to 15 gpm/ft. The transmissivity is approximately 4,300 ft^2/day in central Berkeley County. Water in the upper 200 ft of the system is soft, slightly alkaline, and of the sodium bicarbonate type with dissolved solids of 500 to 2,300 mg/L. The concentrations of dissolved solids increase with depth, as sodium and chloride concentrations increase, and sodium chloride type water is found at 400 ft below the top of the system (−2,500 ft msl) at Seabrook Island. Fluoride concentrations in wells sampled ranged from 2.0 to 11.1 mg/L and iron concentrations from 10 to 950 ug/L.

Wells screened in the Black Creek Formation range from 800 to 2,000 ft in depth. Well yields range from 125 to 700 gpm, with specific capacities of 0.8 to 7.8 gpm/ft. Yields of at least 500 gpm can be obtained almost everywhere in the study area. Pumping tests indicated transmissivities ranging from 930 ft^2/day at Jamestown to 1,200 ft^2/day at Mt. Pleasant; hydraulic conductivities ranged from 19 to 25 ft/day. Static water levels in the system are generally higher than +80 ft msl and the direction of ground-water flow is toward the east.

Water from the Black Creek aquifers is generally a fresh, sodium bicarbonate type; it is soft and has a moderately high pH; and in most areas it contains dissolved solids in concentrations above 500 mg/L. Fluoride concentrations range from 1.3 to 6.5 mg/L and increase in the direction of the coast. Brackish water occurs in the Black Creek in coastal Charleston County, and chloride concentrations as great as 500 mg/L are found at Seabrook Island.

The few wells open to the Peedee Formation have produced no more than a few hundred gallons per minute, and the transmissivity of the system is evidently quite low. The only active well is at Moncks Corner and produces 200 gpm with a specific capacity of less than 1 gpm/ft. In terms of water quality, it is similar to that in the underlying Black Creek Formation. At Moncks Corner, the Peedee contains sodium bicarbonate type water having dissolved solids of 877 mg/L, fluorides of 1.5 mg/L, and chlorides of 20 mg/L. At Sullivans Island the unit produces sodium chloride type water having dissolved solids of 2,900 mg/L, fluorides of 4.5 mg/L, and chlorides of 950 mg/L.

The Black Mingo Formation underlies the entire study area, thickening from 200 ft in the outcrop areas of northern Berkeley County to 650 ft in southern Charleston County. The upper part of the formation is the most permeable, and it is generally possible to obtain 300 to 500 gpm in most parts of the region. Wells in the outcrop area are as deep as 200 ft, may be screened or of open-hole construction, and yield as much as 300 gpm with specific capacities between 3 and 22 gpm/ft. Transmissivities and hydraulic conductivities in that area range from 500 to 8,500 ft^2/day and 20 to 170 ft/day, respectively. Wells in the vicinity of Goose Creek and Charleston have 20 to 40 ft of screen and produce up to 320 gpm with specific capacities between 2.3 and 6.0 gpm/ft.

The chemical quality of water in the Black Mingo Formation is generally good but varies greatly with locality and with depth. The water is characteristically soft, low in iron, and of the sodium bicarbonate type, with dissolved silica concentrations between 25 and 40 mg/L. Black Mingo water becomes increasingly brackish toward the south and changes to sodium chloride type water in central and southwestern Charleston County, where chloride concentrations typically exceed 500 mg/L. Fluoride concentrations increase toward the south, exceeding 1.6 mg/L in areas south of Summerville and Hanahan, and are as great as 5.0 mg/L at Edisto Beach.

The Santee Limestone occurs in the areas to the south of Bonneau, in Berkeley County. Yields to individual wells are usually sufficient for domestic and light industrial needs but typically do not exceed 300 gpm. Yields of up to 300 gpm are reported in the outcrop areas where a combination of very pure limestone and weathering by meteoric ground water has enhanced the permeability of the system. In the Summerville area permeability development has been inhibited by the occurrence of faulting and impure limestones; individual well yields are typically less than 50 gpm with specific capacities of less than 1 gpm/ft, and "dry holes" are common.

Water levels in the Santee Limestone and upper sand beds of the Black Mingo Formation range from +100 ft msl in western Dorchester County to about −10 ft msl at Charleston. Ground-water movement is toward the south and southeast, away from the principal recharge areas in Orangeburg County and northern Berkeley County. In the outcrop area, water levels and direction of flow are affected by the presence of Lake Moultrie, which acts as a source of recharge, and the Santee River valley, into which ground water is discharged.

The Santee Limestone contains freshwater in most parts of the region. Where freshwater occurs, it is usually of the calcium bicarbonate type, is hard to moderately hard, and locally contains objectionable amounts of dissolved iron. Sodium bicarbonate water occurs in the lower part of the system in southern Dorchester and Charleston Counties, possibly as the result of recharge from the underlying Black Mingo Formation. Elevated chloride concentrations are found in central and southern Charleston County, and both sodium bicarbonate and calcium bicarbonate water types undergo a transition to a sodium chloride type in the direction of the coast.

Because of the generally low transmissivities of the Santee Limestone and the prevalence of open-hole well construction, the limestone aquifers and the Black Mingo Formation are usually developed conjunctively rather than individually. Wells of this type produce up to 300 gpm and have specific capacities averaging about 4 gpm/ft. The largest yields are obtained from wells penetrating the upper 100 to 140 ft of the Black Mingo and range from 400 to 1,000 gpm.

The practice of constructing open-hole Santee Limestone/Black Mingo wells usually results in wells that produce a sodium bicarbonate type water typical of the Black Mingo, although such wells penetrate several water-bearing zones and the quality of water obtained from an individual well may vary somewhat, depending on the discharge rate and the duration of pumping. In southern Charleston County, the Black Mingo contains saltier water than does the overlying Santee Limestone, and wells that interconnect the two systems are commonly contaminated by saltwater as it flows up the well bore from the sand beds of the Black Mingo and into the overlying limestone.

The Cooper Formation is an impure, sandy limestone that partially overlies the Santee Limestone throughout most of the study area and mainly acts as a confining unit. Although brackish water-bearing zones are reported near its base at Edisto Island and a freshwater-bearing bryozoan limestone occurs near Ravenel, the Cooper is not generally a source of water supply. Where freshwater exists, it is of the calcium bicarbonate type and is similar to water obtained from the outcrop areas of the Santee Limestone.

Probably the most widely used sources of ground water are the sand and shell beds in the shallow aquifers. These aquifers are most productive in Charleston County where they generally are between 40 and 60 ft in aggregate thickness. Wells drilled to obtain maximum yield produce between 15 and 200 gpm, and yields can very greatly even within very small areas. Water in the shallow aquifers is usually low in dissolved solids and high in iron. Sodium chloride type water predominates in Berkeley and Dorchester Counties and in the upper 25 ft in Charleston County. Shell beds and shelly sand commonly exist in the lower beds in Charleston County, and wells screened in them usually produce calcium bicarbonate type water. Brackish or salty water occurs where the shallow aquifers are in contact with saline surface water, and a number of areas have experienced saltwater encroachment as a result of overpumping shallow-well fields.

Water-Level Declines

Water levels have declined appreciably in four parts of the region; Jamestown, the Moncks Corner/Goose Creek/Summerville area, Charleston, and Mt. Pleasant. Declines at Jamestown affect the Santee Limestone and are caused by dewatering operations at a local limestone quarry. Before the quarry began to regulate its ground-water withdrawals, pumping sometimes exceeded 30 mgd, water levels fell below the intakes of nearby domestic wells, and rapid water-level fluctuations triggered land subsidence. Additional water-level declines and land-surface collapse can be expected if the quarry expands and further dewatering is required.

The most rapid growth in ground-water development is centered between Moncks Corner, Goose Creek, and Summerville. The many domestic, industrial, and public supply wells tapping the Santee Limestone and Black Mingo Formation in the area have small discharges and are broadly distributed. A shallow potentiometric trough exists in the area, and water levels are estimated to be 15 to 25 ft lower than pre-pumping levels. In the vicinity of well 20AA-n2, where transmissivities are very low, withdrawals by public-supply wells lowered water levels more than 60 ft between 1978 and 1982. Further declines will occur as the population and economy of the area continue to expand.

A significant cone of depression exists in the Santee Limestone and Black Mingo Formation in the vicinity of Charleston. A combination of industrial ground-water withdrawals, low aquifer transmissivities, and possibly a natural potentiometric trough have resulted in water levels as low as −75 ft msl at some locations. Water levels recovered approximately 40 ft between 1974 and 1982, but the recovery was not great enough or soon enough to prevent saltwater encroachment. Determination of the exact timing, magnitude, and extent of saltwater encroachment is prevented by a lack of observation wells and the paucity of historical water-use and water-quality data.

In the Mt. Pleasant area, water levels are declining in the Black Creek Formation because of withdrawals by six public water-supply systems. During 1980, these withdrawals averaged less than 1.3 mgd but static levels near the center of the cone of depression declined about 38 ft between 1970 and 1983. Because the transmissivity of the system is relatively low, even small increases in pumping will have a marked impact on water levels. Because brackish water is believed to occur in the Black Creek at, and to the east of, Sullivans Island, saltwater may encroach the area if withdrawals continue. Encroachment may, in fact, have already begun, but present knowledge is insufficient to prove or refute the possibility.

Saltwater Contamination

Saltwater (water with chlorides greater than 250 mg/L) occurs in all aquifers along the southeast margin of the study area (Fig. 47). This water entered the aquifers during past geologic time when the sea stood above its present level, or it was trapped in the aquifers at the time their sediments were deposited.

Much of that ancient seawater has been diluted or flushed out; that which remains is a potential source of contamination to fresh ground water.

Saltwater contamination has occurred through two processes: (1) salt-water encroachment caused by overpumping, and (2) interaquifer transfer caused by interconnecting freshwater and saltwater aquifers. As previously noted, ground-water withdrawals at Charleston have caused saltwater to migrate westward, which has resulted in the abandonment of an undetermined number of wells. On a much smaller scale, overpumping shallow-well fields at Mt. Pleasant, Folly Beach, and Edisto Island has resulted in very localized saltwater intrusion. As the shallow-well field at Folly Beach was contaminated, chloride concentrations increased from 140 to 800 mg/L in less than one year.

Contamination by interaquifer transfer may be a common cause for the poor quality of water obtained from many wells in southern Charleston County. Throughout much of that area, the Santee Limestone contains fresher water than the underlying Black Mingo Formation. Open-hole wells that interconnect the two units have allowed brackish water to flow upward into the limestone and contaminate freshwater aquifers. There are numerous wells interconnecting the two systems, and their impact on the quality of ground water could be significant.

Recommendations for Future Studies

Many topics that are essential to the understanding and protection of the ground-water resources of the region are beyond the scope of this report. More detailed studies are required to assess the impact of existing ground-water development problems and to determine the need for a ground-water management program. The problems of most immediate concern are the occurrences of saltwater contamination by encroachment and interaquifer transfer.

The first requirement for assessing the problem of saltwater contamination is to better determine the distribution of saltwater within the Black Mingo and Santee Limestone aquifers. The common practice of constructing open-hole, multi-aquifer wells limits the usefulness of water-quality data obtained from most existing wells. In order to define the vertical distribution of saltwater, test wells must be drilled so that discrete samples can be obtained from each water-bearing unit. Those same wells will also serve to monitor water levels and water quality, to compare water levels in different aquifers, to calculate transmissivities, and to study the problem of interaquifer transfer. Either with or without the benefit of test wells, water-level and water-quality monitoring should continue in Charleston County and eastern Berkeley and Dorchester Counties, and the construction of new wells should be monitored so that instances of interaquifer transfer can be documented.

Much additional ground-water development is expected to be concentrated in the areas between Moncks Corner, North Charleston, and Summerville. Hence, the combination of increasing ground-water withdrawals and relatively low transmissivities in the Black Mingo Formation and Santee Limestone may eventually create a second and larger cone of depression northwest of Charleston, and the problems of saltwater encroachment at Charleston could be greatly aggravated. To monitor the progress and effects of increasing ground-water withdrawals, the existing water-level monitoring network should be expanded, additional automatic recorders should be installed, and more refined potentiometric maps should be constructed.

It is conceivable that saltwater is already encroaching upon the Black Creek Formation near Mt. Pleasant. Routine monitoring of water levels and chloride concentrations is needed in order to determine the rate and direction of encroachment, if it is occurring. The deep wells at Sullivans Island and Isle of Palms should be sampled regularly, and an automatic water-level recorder should be installed near Mt. Pleasant.

SELECTED REFERENCES

Ackerman, H.D., 1977, Exploring the Charleston, South Carolina, earthquake area with seismic refraction - A preliminary study in Rankin, W.D. (ed.), 1977, Studies related to the Charleston, South Carolina, earthquake of 1886 - A preliminary report: U.S. Geological Survey Professional Paper 1028, p. 167-176.

American Water Works Association, 1983, Groundwater - a manual of water supply practices: American Water Works Association, New York, N.Y., 130 p.

Banks, R.S., 1977, Stratigraphy of the Eocene Santee Limestone in three quarries of the Coastal Plain of South Carolina: South Carolina State Development Board Division of Geology, Geologic Notes, v. 21, no. 3, p. 88-149.

Bear, Jacob, and Todd, D.K., 1960, The transition zone between fresh and salt waters in coastal aquifers: University of California, Berkeley, Water Resources Center Contribution no. 29, 146 p.

Beck, W., Jr., 1983, Correlation of Pleistocene barrier islands in the coastal plain of South Carolina as inferred by heavy minerals, South Carolina State Development Board, Division of Geology, Geologic Notes, v. 17, no. 3, p. 55-67.

Behrendt, J.C., Hamilton, R.M., Ackermann, H.D., Henry, J.V., and Bayer, H.C., 1982, Marine multichannel seismic reflection evidence for Cenozoic faulting and deep crystal structure near Charleston, South Carolina, **in** Gohn, G.S., editor, 1982, studies related to the Charleston, South Carolina, earthquake of 1886 - tectonics and seismicity (collected abstracts): U.S. Geological Survey Open-File Report 82-134, p. 19-20.

Behrendt, J.C., Hamilton, R.M., Ackermann, H.D., and Henry, V.J., 1981, Cenozoic faulting in the vicinity of the Charleston, South Carolina, 1886 Earthquake: Geology, V. 9, No. 3, p. 117-122.

Bennett, C.S., Hayes, R.D., Gissendanner, J.W., and Herlong, H.E., 1983, Water resources data, South Carolina, water year 1982: U.S. Geological Survey Water-Data Report SC-82-1, 330 p.

Berry, E.W., 1914, The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U.S. Geological Survey Professional Paper 84, 200 p.

Bonini, W.E., and Woollard, G.P., 1960, Subsurface geology of the North Carolina Coastal Plain from seismic data: American Association Petroleum Geologists Bulletin, v. 44, no. 3, p. 298-314.

Brown, P.M., Brown, D.L., Reid, M.S., and Lloyd, O.B., Jr., 1979, Evaluation of the geologic and hydrologic factors related to the waste-storage potential of Mesozoic aquifers in the southern part of the Atlantic Coastal Plain, South Carolina and Georgia: U.S. Geological Survey Professional Paper 1088, 37 p.

Campbell, D.L., 1977, Electric and electromagnetic soundings near Charleston, South Carolina - A preliminary report, **in** Rankin, W.D. (ed.), 1977, Studies related to the Charleston, South Carolina, earthquake of 1886 - A preliminary report: U.S. geological Survey Professional Paper 1028, p. 189-198.

Cazeau, C.J., 1962, Leaching of Santee Limestone, Calhoun County, South Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 6, no. 4, p. 45-47.

Chazel, P.E., 1904, The century in phosphates and fertilizers; a sketch of the South Carolina phosphate industry: Charleston, Lucus-Richardson.

Clark, W.B., 1891, Correlation papers, Eocene: U.S. Geological Survey Bulletin 83, p. 52-54.

Colquhoun, D.J., 1961a, Wicomico shoreline in Orangeburg, Dorchester, and Berkeley Counties, South Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 5, no. 4, p. 45-50.

Colquhoun, D.J., 1961b, Contours drawn on top of the Cooper Marl in the Ladson quadrangle, South Carolina: South Carolina State Development Board, Division of Geology, map series MS-4, 1:24,000.

Colquhoun, D.J., 1962, On surficial sediments in central South Carolina - a progress report: South Carolina State Develompent Board, Division of Geology, Geologic Notes v. 6, no. 6, p. 63-78.

Colquhoun, D.J., 1969, Geomorphology of the lower Coastal Plain of South Carolina: South Carolina State Development Board, Division of Geology, MS-15, 36 p., scale 1:500,000.

Colquhoun, D.J., and Comer, C.D., 1973, The Stono Arch, a newly discovered breached anticline near Charleston, South Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 17, no. 4, p. 97-105.

Colquhoun, D.J. and Duncan, D.A., 1966, Geology of the Eutawville quadrangle, South Carolina: South Carolina State Development Board, Division of Geology, MS-12.

Colquhoun, D.J., Heron, S.D., Jr., Johnson, H.S., Jr., Poozer, W.K., and Siple, G.E., 1969, Updip Paleocene - Eocene stratigraphy of South Carolina reviewed: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 13, no. 1, p. 1-25.

Colquhoun, D.J., Wollen, I.D., Van Niewenhuise, D.S., Padget, G.G., Oldham, R.W., Boylan, D.C., Bishop, J.W., and Howell, P.D., 1983, Surface and subsurface stratigraphy, structure and aquifers of the South Carolina Coastal Plain: Department of Geology, University of South Carolina, 78 p.

Cooke, C.W., 1926, Corelation of the basal Cretaceous beds of the southeastern states: U.S. Geological Survey Professional Paper 140-F, p. 137-143.

Cooke, C.W., 1931, Seven coastal terraces in the southeastern states: Washington Academy of Science Journal, v. 21, p. 503-513.

Cooke, C.W., 1936, Geology of the Coastal Plain of South Carolina: U.S. Geological Survey Bulletin no. 867, p. 195.

Cooke, C.W., and MacNeil, F.S., 1952, Tertiary stratigraphy of South Carolina: U.S. Geological Survey Professional Paper 243-B, p. 19-29.

Cooper, H.H., Jr., and Jacob, C.E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: American Geophysical Union Transactions, v. 27, no. 4, p. 526-534.

Dall, W.H., 1898, A table of North American Tertiary horizons: U.S. Geological Survey 18th annual report, p. 330, 341.

Dall, W.H. and Harris, G.D., 1892, Correlation Papers — Neogene: U.S. Geological Survey Bulletin 84, p. 349.

Darton, N.H., 1896, Artesian well prospects in the Atlantic Coastal Plain region: U.S. Geological Survey Bulletin No. 138, 232 p.

Doering, J.A. 1958, Citronelle age problem: American Association of Petroleum Geologists Bulletin, v. 42, p. 764-786.

Doering, J.A., 1960, Quaternary surface formations of the southern part of the Atlantic Coastal Plain: Journal of Geology, v. 68, p. 182-202.

Dorf, Erling, 1952, Critical analysis of Cretaceous stratigraphy and paleobotany of the Atlantic Coastal Plain: American Association of Petroleum Geologists Bulletin, v. 36, p. 2161-2184.

Fairchild, R.W., 1972, The shallow aquifer system in Duval County: Florida Department of Natural Resources Report, Investigation 59, p. 50.

Flint, R.F., 1940, Pleistocene features of the Atlantic Coastal Plain: American Journal of Science v. 238, no. 11, p. 757-787.

Force, E.R., Gohn, G.S., Force, L.M., and Higgins, B.B., 1978, Uranium and phosphate resources in the Cooper Formation of the Charleston region, South Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 22, no. 1, p. 17-31.

Foster, M.D., 1942, Base-exchange and sulfate reduction in salty ground-water along Atlantic and Gulf Coasts: American Association Petroleum Geologists Bulletin, v. 26, no. 6, p. 838-851.

Gardner, R.A., and Johnson, P.W., 1973, Water supply evaluation and proposed comprehensive study of the Charleston-Bushy Park Industrial Complex, South Carolina: **in** Nelson, F.P., editor, 1974, Cooper River environmental study, South Carolina Water Resources Commission, report no. 117.

Gohn, G.S. (editor), 1982, Studies related to the Charleston, South Carolina, earthquake of 1886 - tectonics and seismicity (collected abstracts): U.S. Geological Survey Open-File Report 82-134, p. 38.

Gohn, G.S., (ed), 1983, Studies related to the Charleston, South Carolina, earthquake of 1886 - tectonics and seismicity: U.S. Geological Survey Professional Paper 1313, 375 p., 8 p.

Gohn, G.S., Bybell, L.M., Smith, C.G., and Owens, J.P., 1978, Preliminary stratigraphic cross sections of Atlantic Coastal Plain sediments of the southeastern United States -Cenozoic sediments along the South Carolina coastal margin: U.S. Geological Survey Misc. Field Studies Map MF-1015B, 2 sheets.

Gohn, G.S., Christopher, R.A., Smith, C.G., and Owens, J.P., 1978, Preliminary stratigraphic cross sections of Atlantic Coastal Plain sediments of the Southeastern United States - Cretaceous sediments: U.S. Geological Survey map MF-1015-A, 2 sheets.

Gohn, G.S., and Hazel, J.E., 1979, Review and stratigraphic data from the Mableleanor (Summerville) oil test, South Carolina: U.S. Geological Survey Open-File Report 79, p.21.

Gohn, G.S., Hazel, J.E., Bybell, L.M., Edwards, L.E., and Poore, R.Z., 1981, The Fishburne Formation (lower Eocene), a newly defined subsurface unit in the South Carolina Coastal Plain: U.S. Geographical Survey Bulletin, Contributions to Stratigraphy, open-file report, p. 30.

Gohn, G.S., Higgins, B.R., Smith, C.C., and Owens, J.P., 1977, Lithostratigraphy of the deep corehole (Clubhouse Crossroads Corehole 1) near Charleston, South Carolina: **in** Rankin, D.W., editor, Studies related to the Charleston, South Carolina, earthquake of 1886 - a preliminary report: U.S. Geological Survey Professional Paper 1028, p. 59-70.

Gottfried, David, Annell, C.S., and Schwarz, L.S., 1977, Geochemistry of subsurface basalt from the deep corehole (Clubhouse Crossroads Corehole) near Charleston, South Carolina - magma type and tectonic implications: **in** Rankin, D.W., (editor), 1977, Studies related to the Charleston, South Carolina earthquake of 1886 - a preliminary report: U.S. Geological Survey Professional Paper 1028, p. 91-114.

Hattner, J.G., and Wise, S.W., Jr., 1980, Upper Cretaceous nannofossil biostratigraphy of South Carolina: South Carolina Research and Statistical Services Division, Geological Survey, South Carolina Geology, v. 24, no. 2, p. 41-117.

Hayes, L.R., 1979, The ground-water resources of Beaufort, Colleton, Hampton, and Jasper Counties, South Carolina: South Carolina Water Resources Commission Report No. 9, 91 p.

Hazel, J.E., 1976, Cooper Marl in the Coastal Plain of South Carolina and Georgia: **in** Cohee, G.V., and others, 1976, changes in stratigraphic nomenclature by the U.S. Geological Survey; U.S. Geological Survey Bulletin 1422-A, p. A54-A55.

Hazel, J.E., Bybell, L.M., Christopher, R.A., Frederiksen, N.O., May, F.E., McLean, D.M., Poore, R.Z., Smith, C.C., Sohl, N.F., Valentine, P.C., and Witmer, R.J., 1977, Biostratigraphy of the deep core hole (Clubhouse Crossroads Corehole 1) near Charleston, South Carolina: Studies related to the Charleston, South Carolina, **in** Rankin, D.W., editor, 1977, earthquake of 1886 - a preliminary report: U.S. Geological Survey Professional Paper 1028.

Hem, J.D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473.

Heron, S.D., Jr., 1958a, History of terminology and correlations of the basal Cretaceous formations of the Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 2, no. 11-12, pp. 77-88.

Heron, S.D., Jr., 1958b, The stratigraphy of the basal

Cretaceous beds between the Cape Fear River, North Carolina, and Lynches River, South Carolina: Thesis, University of North Carolina, Chapel Hill, Chapel Hill, N.C., p. 155.

Heron, S.D., Jr., 1960, Notes on the calcium-carbonate content of the Santee-Limestone: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 4, no. 4, p. 31.

Heron, S.D., Jr., 1962, Limestone resources of the coastal plain of South Carolina: South Carolina State Development Board, Division of Geology, Geological Bulletin 28, p. 128.

Heron, S.D., Jr., 1969, Mineralogy of the Black Mingo mudrocks: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 13, no. 1, p. 27-42.

Heron, S.D., Jr., Robinson, G.C., and Johnson, H.S., Jr., 1965, Clays and opal-bearing claystones of the South Carolina Coastal Plain: South Carolina State Development Board, Division of Geology, Bulletin 31, p. 64.

Higgins, B.B., Gohn, G.S., and Bybel, L.M., 1978, Preliminary contour map on the top of the Eocene series, Charleston area, South Carolina: U.S. Geological Survey Open-File Report 78-548, p. 5.

Holmes, F.S., 1870, Phosphate rocks of South Carolina and the "Great Carolina marl beds": 87 p., Publisher unknown, Charleston, South Carolina.

Johnson, H.S., Jr,. and Geyer, F.R., Jr., 1965, Phosphate and bentonite resources, Coosawatchie District, South Carolina: South Carolina State Development Board, Division of Geology, Open-File Report, 41 p.

Johnson, J.T., and Associates, 1981, Consulting report to the Town of Edisto Beach, South Carolina.

Lowman, S.W., 1972, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p.

Lyell, Charles, 1845, Observations on the White Limestone and other Eocene or older Tertiary formations of Virginia, South Carolina, and Georgia: Geological Society of London Quarterly Journal, v. 1, p. 429-442.

Lynch, P.N., Shepard, C.V., and Geddings, J.F.M., 1881, Artesian wells, 1823-1879: Municipal report of the City of Charleston, South Carolina, 24 p.

Malde, H.E., 1959, Geology of the Charleston phosphate area, South Carolina: U.S. Geological Survey Bulletin 1079, 105 p.

Mansfield, W.C., 1937, Some deep wells near the Atlantic Coast in Virginia and the Carolinas: U.S. Geological Survey Professional Paper 186, p. 159-161.

McKee, J.E., and Wolfe, H.W., 1963, Water quality criteria California State Water Resources Control Board, Publication 3-A, revised 1978, 548 p.

Morton, S.G., 1834, Synopsis of the organic remains of the Cretaceous group of the United States; cateloge of the fossil shells of the Tertiary formations of the United States: unknown publisher, Philadelphia, Pa., 8 p.

Moses, O.A., 1883, The phosphate deposits of South Carolina: U.S. Geological Survey, Mineral Resources, 1882, p. 504-521.

Park, A.D., 1980, The ground-water resources of Sumter and Florence Counties, South Carolina: South Carolina Water Resources Commission Report Number 133, 62 p.

Phillips, J.D., 1977, Magnetic basement near Charleston, South Carolina - a preliminary report: in Rankin, D.W., editor, 1977, studies related to the Charleston, South Carolina earthquake of 1886 - a preliminary report: U.S. Geological Survey Professional Paper 1028, p. 139-150.

Piper, A.M., 1944, A graphical procedure in the geochemical interpretation of water analyses: American Geophysical Union Transactions, v. 25, p. 914-923.

Piper, A.M., 1953, A graphical procedure in the geochemical interpretation of water analyses: U.S. Geological Survey Water Resources Division, Groundwater Branch, Groundwater Notes, no. 12.

Poozer, W.K., 1965, Biostratigraphy of Cenozoic Ostracoda from South Carolina: University of Kansas Paleontological Contributions, Arthropoda, Article 8, p. 1-80.

Popenoe, Peter, and Zietz, Isidore, 1977, The nature of the geophysical basement beneath the Coastal Plain of South Carolina and northeastern Georgia, in Rankin, D.W., editor, 1977, studies related to the Charleston, South Carolina, earthquake of 1886 - a preliminary report: U.S. Geological Survey Professional Paper 1028, p. 119-138.

Pugh, G.T., 1905, Pleistocene deposits of South Carolina, with a special attempt at ascertaining what must have been the environmental conditions under which the Pleistocene Mollusca of the State lived: Master's thesis, Vanderbilt University, Nashville, Tenn., 74 p.

Rankin, D.W., editor, 1977, Studies related to the Charleston, South Carolina, earthquake of 1886 - a preliminary report: U.S. Geological Survey Professional Paper 1028.

Richards, H.G., 1943, Pliocene and Pleistocene mollusks from the Santee-Cooper area, South Carolina: Academy of Natural Science, Philadelphia, no. 118, p. 1-7.

Richards, H.G., 1959, Recent studies on the Pleistocene of the South Atlantic Coastal Plain: Southeastern Geology, v. 1, no. 1, p. 11-21.

Rogers, G.S., 1914, The phosphate deposits of South Carolina: U.S. Geological Survey Bulletin 580, p. 183-220.

Ruffin, Edmund, 1843, Report of the commencement and progress of the agricultural survey of South Carolina for 1843: publisher unknown, Columbia, South Carolina, 56 p.

Sanders, A.E., 1974, A paleontological survey of the Cooper Marl and Santee Limestone near Harleyville, South Carolina - preliminary report: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 18, no. 1, p. 4-12.

Sass, J.H., and Ziagos, J.P., 1977, Heat flow from a corehole near Charleston, South Carolina, in Rankin, D.W., studies related to the Charleston, South Carolina, earthquake of 1886 - a preliminary report:

U.S. Geological Survey Professional Paper 1028, p. 115-117.

Shattuck, G.R., 1906, The Pleistocene problem of the North Carolina Coastal Plain: Johns Hopkins University Circular, v. 20, no. 152, pp. 69-75 (reprinted in American Geologist, v. 28, p. 87-107).

Siple, G.E., 1946, Ground-water investigations in South Carolina: South Carolina Geological Survey Bulletin, no. 15, 116 p.

Siple, G.E., 1957, Groundwater in the South Carolina Coastal Plain: Journal American Water Works Association Reprint, v. 49, no. 3, p. 283-299.

Siple, G.E., 1958, Stratigraphic data from selected oil tests and water wells in the South Carolina Coastal Plain: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 2, no. 9, p. 62-66.

Siple, G.E., 1959, Guidebook for the South Carolina Coastal Plain field trip of the Carolina Geological Society: South Carolina State Development Board, Division of Geology (Nov. 16-17, 1957).

Siple, G.E., 1960, Some geologic and hydrologic factors affecting limestone terranes of Tertiary age in South Carolina: Southeastern Geology, v. 2, no. 1, p. 1-11.

Siple, G.E., 1967a, Salt-water encroachment in coastal South Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 11, no. 2, p. 21-36.

Siple, G.E. 1967b, Geology and ground water on the Savannah River Plant and vicinity: U.S. Geological Survey Water Supply Paper 1841, 113 p.

Siple, G.E., 1968, Memorandum report on the impact of the proposed canals on the ground-water regimen of Berkeley and Charleston Counties, South Carolina: **in** Cooper River, South Carolina (shoaling in Charleston Harbor), U.S. Congress, 90th, 2nd session, Senate Document 88, p. 153-160.

Siple, G.E., 1969, Salt-water encroachment of Tertiary limestones along coastal South Carolina: South Carolina State Development Board, Division of Geology, Geologic Notes, v. 13, no. 2, p. 51-65.

Siple, G.E., 1975, Ground-water resources of Orangeburg County, South Carolina: South Carolina State Development Board, Division of Geology, Bulletin No. 36, 59 p.

Sloan, Earle, 1904, A preliminary report on the clays of South Carolina: South Carolina Geological Survey, series 4, Bulletin no. 1, Columbia, S.C., 175 p.

Sloan, Earle, 1907, Geologic and mineral resources, **in** Handbook of South Carolina: State Department of Agriculture, Commerce, and Immigration, Columbia, S.C., p. 77-145.

Sloan, Earle, 1908, Catalogue of the mineral localities of South Carolina: South Carolina Geological Survey, series 4, Bulletin no. 2, 505 p.

Soil and Materials Engineers, Inc., 1980, Land surface subsidence study, Jamestown, South Carolina: For South Carolina Land Resources Conservation Commission, Division of Mining and Reclamatation, 116 p.

Spiers, C.A., 1975, The effect of the Cooper River rediversion canal on the ground-water regimen of the St. Stephens area, South Carolina: U.S. Geological Survey, Columbia, S.C., U.S. Army Corps of Engineers, Charleston, S.C., 53 p.

Spignor, B.C., 1978, Land-surface collapse and groundwater problems in the Jamestown area, Berkeley County, South Carolina: South Carolina Water Resources Commission open-file report number 78-1, 71 p.

Stephenson, L.W., 1912, The Cretaceous formations, **in** Clark, W.B., and others, the geology of the Coastal Plain of North Carolina: North Carolina Geological Survey, v. 3, p. 73-11.

Stephenson, L.W., 1914, A deep well at Charleston, South Carolina: U.S. Geological Survey Professional Paper 90, p. 69-90.

Stephenson, L.W., 1923, The Cretaceous formations of North Carolina: North Carolina Geological and Economic Survey, v. 5, p. 1-59.

Stiff, H.A., Jr., 1951, The interpretation of chemical analyses by means of patterns, Journal of Petroleum Technology, v. 3, no. 10, p. 15-17.

Swift, D.J.P., and Heron, S.D., Jr., 1969, Stratigraphy of the Carolina Cretaceous: Southeastern geology, v. 10, no. 4, p. 201-245.

Taber, Stephen, 1935, Supplement to the preliminary geological report on the proposed Santee and Pinopolis dam and reservoir sites of December 29, 1934: South Carolina Public Service Authority, 42 p.

Taber, Stephen, 1939, Geology of the Santee-Cooper Project: Report to the South Carolina Public Service Authority, 21 p.

Todd, D.K., 1959, Ground water hydrology: John Wiley and Sons, Inc. New York, N.Y., 336 p.

Tuomey, Michael, 844, Report of the geological and agricultural survey of the State of South Carolina: unknown publisher, Columbia, S.C., 63 p.

Tuomey, Michael, 1848, Report on the geology of South Carolina: A.S. Johnson, Columbia, S.C., 293 p.

Tomey, Michael, 1884, Report on the geology of South Carolina: Columbia, S.C. pp. 154-169.

Van Burkalaw, Anatasia, 1946, Fluoride in United States water supplies: Geographical Review, v. 36, no. 2, p. 177.

Vanuxem, Lardner, 1826, Report on a mineralogical and geologic examination of South Carolina: **in** Statistics of South Carolina (Mills, Robert), p. 25-30, publisher unknown, Charleston, S.C., United States. Reprinted in report on geology of South Carolina by Tuomey, M., 1848, Columbia, S.C.

Vanuxem, Lardner, 1829, Geologic observations on the secondary, Tertiary, and alluvial formations of the Atlantic Coast of the United States: Academy of National Science of Philadelphia, no. 6, p. 59-71.

Vorhis, R.C., 1977, Anomalous ground-water quality caused by earthquakes in South Carolina: Geological Society of America, 26th Annual Meeting (Southeastern Section), Abstracts, v. 9, no. 2, p. 192.

Ward, L.W., Blackwelder, B.W., Gohn, G.S., and Poore, R.Z., 1979, Stratigraphic revision of Eocene, Oligocene, and Lower Miocene formations of South

Woolen, I.D., 1978, Structural framework, lithostratigraphy, and depositional environments of Upper Cretaceous sediments of eastern South Carolina: Ph.D. Dissertation, University of South Carolina, Department of Geology, 276 p.

Woolard, G.P., Bonini, W.E., and Meyer, R.P., 1957, A seismic refraction study of the subsurface geology of the Atlantic Coastal Plain and Continental Shelf between Virginia and Florida: Madison, Wis., University of Wisconsin, Department of Geology, 128 p.

Zack, A.L., 1977, The occurrence, availability, and chemical quality of ground water, Grand Strand area and surrounding parts of Horry and Georgetown Counties, South Carolina: South Carolina Water Resources Commission Report No. 8, 100 p.

Zack, A.L., 1980, Geochemistry of fluoride in the Black Creek aquifer system of Horry and Georgetown Counties, South Carolina - and its physiological implications: U.S. Geological Survey Water - Supply Paper 2067, 40 p.

APPENDIX A. SELECTED WELL DATA

EXPLANATION

Well Number: Location of well on Figure 3.

Elevation: Given in feet msl. Estimated elevation unless given to nearest tenth of foot.

Well Use:
- OBS - Observation
- ABN - Abandoned
- STB - Standby (backup)
- DOM - Domestic
- IND - Industrial
- IRR - Irrigation
- STK - Livestock
- UNU - Unused
- PS - Public Supply

Total Depth: Depth of well, in feet

Casing Diameter: Casing diameter

Casing Depth: Depth to open hole section or top of screen

Pump Rate: Pumping rate, in gallons per minute

Date Comp: Date construction finished

Geophysical Logs: Available geophysical logs
- C - Caliper
- Cd. - Conductivity/Resistivity
- E - Single point electric with spontaneous potential
- G - Natural gamma-ray
- G-G - Gamma-Gamma density
- L - 6-foot lateral
- Micro - Micro-lateral
- N - Neutron porosity
- STD - Standard electric
- T - Temperature

Chemical Analysis: Chemical analyses available in Appendix B or in file:
- COM - Commercial laboratory
- DHEC - South Carolina Department of Health and Environmental Control
- SC-WRC - South Carolina Water Resources Commission
- USGS - United States Geological Survey

Aquifer System: Aquifer (formation) tapped by well
- S - Shallow
- C - Cooper Formation
- TL - Tertiary Limestone
- BM - Black Mingo
- PD - Peedee
- BC - Black Creek
- M - Middendorf

Remarks - Driller Log: Drillers log available

Q/S = : Specific capacity in gallons per minute per foot of drawdown

Appendix A Selected well data.

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
11Y-h2	331312 792250	28	OBS DOM	65	3			1971			L	Piezometer Open Hole
11Y-n1			DOM	680	3	620		8/82		B-1	BC	Driller Log Screened 620-680
12Y-L1	331202	10	DOM	801	6	761	125	1/74	E,G	B-1	BC	Driller Log Screened 761–801 (0.018 slot)
12Y-q1	331154 792813	16	OBS DOM	45	4			5/58		B-2	L	Piezometer Open Hole
12Y-x1	331009 792810	20	OBS DOM	80	2				G,L		L	Piezometer Logged to 57 ft Open Hole
12Z-i1	330802 792643	25	OBS ABN	43	4		30	4/63	G,L	B-2	L	Piezometer Driller Log Open Hole
12Z-o1	330732 792921	20	DOM	105	2					B-2	L	Open Hole
12Z-o2	330732 792923	20	OBS ABN	40	1 1/4						L	Piezometer Open Hole
12Z-x2	330539 792836	5	OBS DOM	30	2						L	Piezometer Open Hole
12Z-x3	330540 792838	5	OBS ABN	27	1 3/4					SCWRC 3/80	L	Piezometer Open Hole
12Z-x5	330536 792834	5	DOM	40?						B-3	S	Screened

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
12AA-c1	330451 792133	5	PS	60	4	38				B-3	S	Screened
13Y-x1	331024 793340	28	PAB		4					B-2	L	Plugged with cement
13Z-v1	330531 793104	30	OBS DOM	78	1 1/4						L	Piezometer Open Hole
13AA-h2	330321 793249	15	OBS DOM	74	2			1976		B-2	L	Piezometer Open Hole
13AA-j2	330341 793014	5	OBS ABN	65	4	48	55	8/64	G		L	Piezometer Driller Log Open Hole
13AA-n1	330224 793347	10	PS	73	4		15	1961			L	Driller Log Open Hole
13AA-n2	330245 793401	24.8	OBS ABN	91	4	83			G,C	B-2	L	Piezometer Water Level Recorder Open Hole
14X-y36	331518 793606	35	OBS ABN	80	2				G		L	Piezometer Open Hole
14Y-m2	331223 793738	35	OBS	105	4				G		L	Piezometer Open Hole
14AA-k1	330232 793525	20	STB	10	1 1/4	10		1950?		B-3	S	Screened 7.5 - 9.5
14AA-r1	330150 793727	2	DOM	10	1 1/4			1935		B-2	L	Open Hole(?)

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
14BB-b1	325926 793652	11	UNU	198	4	89	flow		E,G,C	SCWRC 2-80	L	Piezometer
14BB-g1	325811 793825	15	DOM	20	1 1/4	20		9/79		B-3	S	Screened
14BB-p1	325624 793930	5	PS	+180	2					B-2	L	Open Hole
14BB-p2	325627 793927	6	PS	220	6	183		8/81	G,E	B-2	L	Piezometer Driller log; Cuttings Open Hole
14CC-b1	323929 793650	10	PS	240	4	90		1972		B-2	L	Driller Log Open Hole Q/s=1.1
15X-L1	331707 794142	32	PS	894	8	160 691		1971	G	B-1	BC	Driller Log Screened 770-793 (.012 slot) 804-815 (.016 slot) 864-891 (.012 slot); Q/S=0.8
15X-L2	331707 794142	32	OBS	32	6			1971	G	B-2	L	Water-Level Recorder since 1971; Open Hole
15X-L5	331728 794113	35	IND PS	885	16 6	885	475	1954	E	B-1	BC	Pump test-1980, Driller Log Screened 700-710, 730-740, 756-766, 770-780, 870-880; Q/S=2.1
15X-n1	331709 794313	40	DOM	362	8			1910		USGS 1/54	L BM	Open Hole (?)
15BB-u1	325520 794052	10	OBS	226	2	207					L	Piezometer Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
15BB-w1	325539 794240	16	DOM	241	4	212				B-2	L	Driller Log Open Hole
15BB-w2	325539 794249	16	DOM	35						B-3	S	Screened
15BB-y1	325535 794416	10	DOM	425	2 1/2	230		1972		B-2	L BM	Open Hole
15CC-b1	325425 794151	5	ABN	228	4						L	Piezometer
15CC-b2	325430 794147	7	ABN	300	2	156			G,C	B-2	L BM	Open Hole
15CC-c1	325435 794227	12	ABN	271	4					B-2	L BM	Open Hole
15CC-f1	325345 794406	20	DOM	30	1 1/4	27				B-3	S	Screened
16W-x1	332049 794852	40	UNU	43.5	1 1/4 stl			1930?			L	Piezometer Open Hole
16X-c1	331924 794725	38	PS OBS	27.7	2						L	Piezometer Open Hole
16X-k1	331718 794533	35	PS	37.8	2 stl						L	Piezometer Open Hole
16Y-m1	331207 794716	53	DOM	90	3			1942		B-2	L	Open Hole (?)
16Y-q1	331121 794817	60								B-3	S	Screened

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
16Y-r1	331146 794735	51	PS OBS	684	2						L	Piezometer
16Z-g1	330811 794858	22	DOM	110	6	100	110 GPM	1963		B-2	L	Driller Log Open Hole; Q/S=3.8
16Z-g3	330805 794846	15	PS	142	4	42.4	90	1974			L	Driller Log Open Hole; Q/S=7.5
16Z-h1	330824 794747	20	UNU	110	2	45	flows 3 gpm		G,C	B-2	L	Open Hole Logged to 80 ft
16Z-n2	330753 794840	5	PS	122		42	flow @ 120	1974	G,	B-2	L	Driller Log Open Hole
16AA-a1	330444 794557	35	PS OBS	31.7	2						L	Piezometer Open Hole
16AA-c1	330457 804723	32		20?						B-3	S	Dug Well
16BB-g1	325854 794853	30	UNU OBS	167	2		42		G,		L	Piezometer Open Hole; Q/S=9.3
16BB-p1	325601 794953	15	DOM OBS	239	4 3	158		1948		SCWRC 1/81	L BM	Piezometer Driller Log; Open Hole
16BB-y3	325533 794925	5	DOM	237	4	127.6	10	1963		SCWRC 1/81	L BM	Driller Log Open Hole; Q/S=3.4
16BB-y5	325531 794915	5	DOM OBS	250	5			1940?			L BM	Piezometer Open Hole (?)
16CC-a1	325412 794543	10	ABN	242	2	151			G,E	B-2	L	Piezometer (Distroyed)

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
16CC-g1	325318 794854	10	DOM OBS	245	2	80			E,G	B-2	L	Piezometer Open Hole
16CC-j3	325342 794537	18	ABN	52	2	454				B-3	S	Screened
16CC-j4	325332 794537	15	ABN	60	2	454				B-3	S	Screened
16CC-k1	325205 794556	25	UNU	2297	12	1840	30 flow	1/74	STD.,G,N	B-1	BC	Driller Log Screened 1709-1742, 1757-1771, 1805-1840
16CC-p1	325125 794922	10	STK	350+	4						L BM	Piezometer Open Hole
16CC-r3	325131 794708	15	COM	28	1 1/4					B-3	S	Screened
16CC-y1	325043 794937	15	PS	2141	8	1870	737	1/71	E, STD.	B-1	BC	Driller Log; Pump Test Screened 1740-1756, 1824-1848, 1854-1872 (.030 slot); Q/S=2.5
16CC-y11	325047 794933	20	DOM OBS	287	4	194			G,C		L BM	Piezometer Open Hole
16DD-L1	324737 794619	10	DOM	15	1 1/4			6/78		B-3	S	Screened
16DD-m1	334715 794717	10	DES	505						COM	L	High Chlorides
16DD-m2	334715 794717	10	PS	2267	16	1775 2023		1973	STD.,G	B-1	BC	Driller Log, Cuttings Screened 1790-1830, 1846-1871, 1960-2000

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
17W-d2	332423 795358	77.05	OBS	143		125		1973	G,	B-2	BM	Water-Level Recorder Open Hole
17W-pl	332126 795435	60	UNU	1102	2	82?			G,C		BM	Piezometer Open Hole
17X-L1	331714 795119	45	PS	43	4	39				B-3	S	
17X-rl	331656 795259	40	UNU	31	1 1/2						BM	Piezometer
17AA-sl	330117 795109	28	UNU	220						SCWRC 2-80	L BM	Open Hole
17AA-s2	330115 795110	30	PS	226	6	187	330	7/79			L BM	Piezometer Open Hole
17BB-gl	325824 805302	34.5	UNU	315	6	219	421	3/76		B-2	L BM	Driller Log Open Hole; Q/S=30
17BB-hl	325835 795247	30	IND	304	6 4	271	113	9/79		B-2	BM	Driller Log Screened 271-301 ft Q/S=8.1
17BB-ul	325519 795034	10	PS	340	8	84	1100	3/72	E,G	DHEC 5/77	L BM	Driller Log Open Hole; Q/S=35
17CC-vl	325030 795109		ABN	315	6 4	129 260	50	12/48			TL BM	Driller Log Open Hole; Q/S=1.7
17DD-a3	324922 795052	15	IND	415	5	200				B-2	L BM	Driller Log Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
17DD-a4	324914 795015	15	PS	2282	8	1980	400	1975	STD.,G,C	B-1	BC	Driller Log Screened 1775-1820, 1878-1913, 1950-1975
17DD-b1	324931 795117	16.95	OBS	330	8	140	98	11/64	G,C		L BM	Driller Log Open Hole; Q/S=1.8
17DD-d1	324917 795353	10	PS	350	4					B-2	L BM	Open Hole
17DD-f1	324853 795414	10	ABN	344	3	100			E,G		L BM	Piezometer Open Hole
17DD-g1	324826 795325	20	PS	65	8	44	75	8/61		B-3	S	Driller Log Screened 39-44; Q/S=4.2
17DD-g2	324821 795326	20	PS	65	8	50	50	8/61		COM 9/61	S	Driller Log Screened 17-22, 31-36, 40-45; Q/S=1.2
17DD-g3	324822 795321	20	PS	65	8	50	70	8/61		COM 9/61	S	Driller Log Screened 17-22, 31-36 40-45; Q/S=1.9
17DD-g4	324822 795328	20	PS	65	8	49	70	8/61		COM 9/61	S	Driller Log Screened 21-31, 39-44 Q/S=2.9
17DD-g5	324825 795323	20	PS	65	8	44	69	8/61		B-3	S	Driller Log Screened 24-39; Q/S-2.3
17DD-g7	324829 795330	24	PS	2039	8	1993	720	7/69	E,G	B-1	BC	Driller Log Screened 1800-1850, 1940-1960, 1976-1986; Q/S=7.8

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
17DD-g8	324829 795330	24	ABN	515	10	89	250	6/67	E,C	COM 7/62	L BM	Driller Log, Abandoned, Increased Chlorides; Open Hole; Q/S=2.8
17DD-g9	324829 795330	24	PS	60	8	60	50	4/58			S	Driller Log; Screened 30-34, 40-44, 54-58; Q/S=1.1
17DD-g10	324829 795327	22	PS	120	8	55	40	4/58			S	Driller Log; Screened 21-25, 28-32, 48-52; Q/S=0.9
17DD-g11	324828 795328	22	PS	60	8	48	200	3/58			S	Driller Log; Screened 23-27, 31-36, 39-43; Q/S=8.3
17DD-g12	324825 795330	22	PS	48	8	45	150	4/58			S	Driller Log; Screened 20-25, 28-32, 38-42; Q/S=6.8
17DD-g13	324824 795331	22	PS	50	8	44	75	4/58			S	Driller Log; Screened 19-24, 28-33, 38-43; Q/S=3.9
17DD-m5	324717 795218	26	PS	2292	8	1919	720	4/69	E,STD.	B-1	BC	Driller Log; Pump Test Screened 1829-1912; Q/S=4.8
17DD-m6	324717 795218	20	PS	142	8	50	70	2/54			S	Driller Log; Screened 25-30, 35-40, 45-50; Q/S=2.9
17DD-m7	324707 795215	10	PS	62	8	50	175	3/54			S	Driller Log; Screened 25-30, 40-50; Q/S=7.0
17DD-m8	324726 795218	25	PS	66	10	46	40	3/55			S	Driller Log; Screened 26-32, 38-42; Q/S=1.2
17DD-m9	324727 795215	25	PS	68	10	65	160	4/55			S	Driller Log; Screened 30-34, 40-42, 47-51, 55-57, 60-62; Q/S=3.1
17DD-m10	324725 795227	10	PS	66	10	40	80	3/55			S	Driller Log; Screened 36-40, 56-62; Q/S=1.9

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
17DD-m11	324710 795232	10	IRR	35?	4					B-3	S	Screened
17DD-m13	324725 795245	5	IRR	15	1 1/4	15		3/80		B-3	S	
17DD-u1	324531 795123	5	PS	1920	9 6	1820	flow	1906		B-3	BC	
17DD-u2	324535 795059	5	PS	2090	6	2030		4/29		B-1	BC	Driller Log; Screened 1840-1850, 1916-1926, 1970-1980, 1990-2000, 2020-2030
17DD-v1	324531 795122	5	UNU	1238	12 3		flow	1898		B-1	PD	Open Hole
18V-p2	332620 795915	58.57	OBS	130	6	102		4/73	G	B-1	BM	Water-Level Recorder; Open Hole
18V-u1	332508 795524	60	UNU	802	6		40	1955	G,N	B-1	BC	Driller Log
18V-v2	332551 795613	49.59	OBS	113	6	73	48		G	B-2	BM	Piezometer Open Hole
18V-y3	332929 795924	78	PS	220	6		50	1954			BM	Driller Log
18W-a1	332420 795534	75	PS	1280	6 16	855 400	350	4/64	E	B-1	M	Driller Log Screened 1200-1260
18W-a4	332459 795532	60	ABN	1260	8 6	1066	210	11/55	E	B-1	BM	Driller Log Screened 1066-1076, 1128-1148, 1180-1190, 1208-1218; Abandoned- Ruptured Casing

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
18W-a5	332453 795541	60	PS IND	1309			393	1/74	E,G	DHEC 10/75	M	Driller Log Pump Test Q/S=8.3
18W-a6	332455 795505	72.11	OBS	158	6	133			G	B-2	M	Water-Level Recorder
18W-a7	332455 795505	17.91	OBS	33	6	21				B-3	S	Water-Level Recorder Open Hole
18W-b1	332423 795604	75	PS	1260	18		305	7/80	E	B-1	BC/M	Driller Log Q/S=10.2
18W-j2	332323 795502	77.31	OBS	140	6	120	58		G	B-2	BM	Water-Level Recorder Open Hole
18W-r1	332104 795750	70	UNU	34	1 1/2					B-3	S	
18X-e1	331954 795924	80	PS	92	8	543		7/76				Piezometer; Driller Log; Open Hole
18X-g1	331825 795812	50	STK DOM	364	8	327	100	10/76	E	B-2	BM	Driller Log; Q/S= 1.1; Screened 110-120, 142-147, 167-172, 198-203, 210-220, 263-268, 303-308, 317-322
18X-m1	331742 795730	62.3	OBS	69.6	4	49			G,C		L	Water-Level Recorder Open Hole
18X-r1	331619 795752	52	PS	102	4	40	50	5/74			L	Driller Log; Piezometer; Q/S=3.8
18X-w2	331524 795748	62	DOM	91	4				G		L	Piezometer Open Hole
18Y-d1	331438 795858	41.6	OBS UNU	137	6	50			G,C		L, BM	Water-Level Recorder Driller Log; Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
18Y-i1	331346 795619	55	DOM	25?	1 1/2					B-3	S	Screened
18Y-o1	331210 795919	58	PS OBS	202	6		150	1963			BM	Driller Log Screened 185-200 (0.25 slot); Q/S=1.7
18Y-p1	331118 795956	53.9	PS	211	8 10		225	1968			BM	Driller Log Screened 174-211; Q/S=1.6
18Y-q1	331149 795849	50	Heat Pump	377	8			1981			BM	Driller Log; Cuttings; Screened 210-215, 224-244, 324-334, 353-369
18Z-r3	330604 795738	12	DOM	201	4	61.2	70	6/79			L BM	Driller Log Open Hole; Q/S=2.4
18Z-w1	330537 795709	10	DOM	220	4	63		2/79		B-2	L BM	Driller Log Open Hole
18Z-w3	330545 795713	10	DOM	200	3	62.11	23	10/63		SCWRC 1/82	L BM	Driller Log Open Hole; S.L.=0ft, 10-63
18AA-e1	330444 795957	15	STK DOM	261	4	58.5		1/69			L BM	Piezometer Driller Log; Open Hole
18AA-e2	330441 795958	18	IND	1900	4		135	12/81	STD.,G	B-1	M	Driller Log; Q/S=0.8 Screened 1548-1553, 1560-1565, 1580-1585, 1598-1603, 1638-1643, 1845-1850, 1869-1874, 1895-1900, 1922-1927,1955-1960
18AA-e3	330436 795927	20	IND	260	6		60	1982			L BM	Pump Test T=8,800 gpd/ft Q/S=1.5

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
18AA-e4	330436 795927	18	IND	1660	8	1530	800	1982			M	Screen 1530-1550, 1570,1620, 1632-1642 Q/S=15
18AA-i1	330337 795612	261	UNU	298	6	280	660	10/73		B-2	BM	Driller Log Open Hole; Q/S=14.7
18AA-q1	330150 795805	8.8	DOM	248	6	63	173	10/65			L BM	Piezometer; Driller Log; Open Hole; Q/S=3.5
18AA-t1	330105 795557	20	UNU	272	6	66.11	82	5/70			L	Piezometer; Driller Log Open Hole; Q/S=13.7
18AA-u1	330031 795526	8.0	IND DOM	300	4 10	203	130	8/73	E,STD.	B-2	L BM	Driller Log Screened 200-280; Q/S=2.7
18AA-u2	330056 795549	21	UNU	310	6	64.4	33	4/70	G,C		L BM	Piezometer Driller Log
18BB-m1	325147 795704	12	PS	296	6	218.5	100	7/80	E,G,C	B-2	L BM	Driller Log Open Hole; Q/S=2.1
18CC-e1	325413 795915	40	IRR REC	361	6	198	400	5/66			TL BM	Driller Log Open Hole; Q/S=16.7
18CC-g1	325308 795838	30	IND	440	8	308	310	11/51	E	B-2	L BM	Driller Log Open Hole; Q/S=2.2
18CC-g2	325354 795813	15	IND	450?	6		80			B-2	L BM	Open Hole
18CC-k1	325226 795556	5	DOM	15	1 1/2					B-3	S	Screened
18CC-o1	325254 795919	30	UNU	325	4	126	73	2/65	G,C		L BM	Piezometer; Driller Log Open Hole; Q/S=2.3

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
18CC-q1	325143 795811	20	ABN	315	6	184			G,C		L BM	Piezometer
18CC-r1	325121 795741	12	UNU	2136	18 8			3/43		B-1	BC	Driller Log
18DD-b1	324920 795657	15	ABN OBS	573	6	504	220 (251)	4/60 (7/61)	G,T		BM	Water-Level Recorder Driller Log; Open Hole; Q/S=5.4; Screen added, 1961, 340-370, 460-504
18DD-c1	324927 795702	15	ABN OBS	510	6	505	244 (400)	5/60 (4/61)			L BM	Driller Log; Open Hole Q/S=51; Screen added, 1961, 384-390, 441-505
18DD-k1	324701 795555	10	UNU	1260			flow	1849		B-1	PD	SWL: 68.5 MSL on 4/11/83
18DD-L1	324709 795612	10	PS	1970			flow	1878		B-1	BC	Driller Log & Chemical Anal. in Lynch, et. al., 1881; Open Hole
18DD-L2	324758 795623	10	UNU	1945	20 6		flow	1885		B-1	BC	
18DD-L3		10	IRR	2078					E,G,T,N,C, G-G, STD.		BC	
18DD-q1	324637 795814	14.9	ABN OBS	345	10	138	13		E,G,C,N		L BM	Piezometer; Open Hole Pump Test; Q/S=0.6
18EE-i2	324329 795606		ABN	80	6		62	1937		B-3	S	Screened; Pump Test Q/S=1.2
18EE-L1	324219 795621	5	DOM	58	2					B-3	S	Sceened

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
18FF-a1	323958 795510	5	DOM	13	1 1/2					B-3	S	Screened
19V-p2	332654 800410	79	UNU OBS	130?	3						L BM	Piezometer Open Hole(?)
19V-v3	332519 800154	80	UNU	55	2					B-3	S	Screened (?)
19Y-b1	331420 800152	82.3	PS OBS	180	4	80		6/79			TL BM	Piezometer
19Y-h1	331342 800214	90	UNU	15	3					B-3	S	Screened
19Y-k1	331211 800014	50	IND	252	8 12	173 110	55	1/69			BM	Driller Log; Pump Test Screened 173-188, 230-240 Q/S=13.5
19Y-k4	331205 800016	50	IND	185	6	145	189	5/64		USGS 6/78	L BM	Driller Log Open Hole
19Y-k5	331203 800025	50	UNU OBS	104	10	47			G,C		L	Piezometer Open Hole
19Y-m1	331258 800247	90	PS	229	6	156	412	5/65	E,G,C	DHEC 9/78	L BM	Driller Log Open Hole; Q/S=15.2
19Y-m3	331208 800208	77	DOM	261	4	145	90	3/67			L BM	Driller Log Open Hole; Q/S=1.3
19Y-s1	331132 800105	55	PS	835	8	595	200	1975	E,G	B-1	PD	Driller Log Screened 633-693; Q/S=0.8
19Y-t1	331149 800058	45	PS	147	4			1936		B-2	L	Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
19Y-t2	331142 800023	58.4	PS	190	8	125	100	1951		USGS 11/55	L BM	Open Hole
19Y-t4	331136 800020	55	PS	170	8			1939		B-2	L BM	Open Hole(?)
19Y-t5	331136 800020	55	PS	160	8			1944		B-2	L BM	Driller Log Open Hole (?)
19Y-w1	331022 800215	50	PS	315	12	183		9/76	G,C		BM	Driller Log Screened 199-204, 219-234, 259-274, (.015 slot)
19Y-w3	331022 800815	65	TEST	1704	4 3	99 1704	flow	1/82	G,E,T	B-1	M	Driller Log Screened 1602-1607
19Y-x1	331048 800314	94.2	PS	312	6	136	110	6/73			BM	Driller Log Open Hole; Q/S=3.7
19Z-b1	330944 800154	50	PS	317	8	160		10/76		B-2	BM	Driller Log Screened 187-197, 234-250
19Z-d1	330920 800335	91	DOM	436	8	79.2	135	9/61		DHEC 9/75		Driller Log Open Hole; Q/S=1.6
19Z-g1	330837 800348	87	UNU	8	1 1/2					B-3	S	Screen
19Z-n1	330730 800335	65	PS	280	4	64	15	7/78		DHEC 1/78	L BM	Open Hole Q/S=0.5
19Z-o3	330794 800416	80.3	UNU OBS	282	4	127			G,C		L BM	Piezometer Open Hole
19Z-s1	330647 800107	20.5	PS	252	6	64	250	10/74			L BM	Piezometer Driller Log; Q/S=6.2

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
19Z-v2	330514 800151	30	IND	296	6	120		10/78	E,G	B-2	L BM	Driller Log Open Hole
19Z-v3	330533 800146	28	STB	265	6	265	95	1/76	E,G	B-2	BM	Driller Log Screened 235-265; Q/S=1.7
19AA-b1	330414 800200	22	UNU OBS	147	3	20		1981	G		L	Piezometer Driller Log; USGS Test Hole
19AA-p1	330140 800458	12	UNU OBS	202	3	10		1981	G		L	Piezometer Driller Log; USGS Test Hole
19AA-r2	330113 800207	40	PS UNU	350	6	44	165	9/63		B-2	L BM	Driller Log Open Hole; Q/S=4.2
19AA-w2	330006 800256	40	PS UNU	323	8	65	550	11/60		COM 7/78	L BM	Open Hole Q/S=14.1
19BB-c1	325938 800219	40	PS ABN	322	10 8		326	5/64		DHEC 7/75	L BM	Driller Log Open Hole; Q/S=5.6
19BB-m1	325157 800243	28	DOM	325	6	270	17	7/62		B-2	BM	Open Hole Q/S=0.9
19BB-w2	325512 800228	40	UNU	359	6	82	40	1/51			L BM	Driller Log Open Hole; Q/S=4.0
19BB-w3	325550 800200	40	IND	365	4	86	115	1/77		SCWRC 2/81	L BM	Driller Log Open Hole; Q/S=2.7
19CC-u1	325023 800021	13	IND	450	10	120			G	SCWRC 2/80	L BM	Open Hole
19CC-x1	325049 800053	15	ABN	1852	8	1840	250	4/71	E,STD.		BC	Driller Log Screened 1470-1475, 1760-1840; Q/S=0.7

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
19CC-y1	325020 800445	10	UNU	398	4	83	100	7/69	G,C	USGS	L BM	Driller Log Open Hole; Q/S=1.6
19DD-g1	324808 800337	10	UNU	365	6	274	14		T,G,C, STD., CD.		L BM	Piezometer Open Hole; Pump Test; Q/S=1.1
19DD-L1	324718 800145	10	ABN	424	4	70	80	7/60			L BM	Driller Log Open Hole; Q/S= 3.5
19DD-o1	324745 800014	9.40	OBS	434	8	180	13		E,G,C		L BM	Water-Level Recorder Open Hole; Q/S=2.9
19DD-q1	324602 800358	10	DOM	501	4	105		3/71		SCWRC 6/81	L BM	Piezometer Driller Log; Open Hole
19DD-u1	324509 800050	8	IND	580	4	240		9/77		B-2	L BM	Open Hole
19EE-d1	324401 800323	28.7	UNU	581	4	148	110	1/71	G,E	B-2	L BM	Piezometer Driller Log; Open Hole; Q/S=12;
19EE-p2	324104 800455	20	DOM	58						B-3	S	Screened
20W-d4	332451 800824	80	DOM	100	2	90	flow	1958			L	Piezometer Open Hole
20Z-g1	330855 800853	73	UNU	260	2			1955			L BM	Piezometer Open Hole(?)
20Z-v2	330547 800616	80	PS	560	4	147	18	1978			L BM	Open Hole Q/S=0.1
20Z-v5	330547 800616	80	PS	60	4	60		1979		B-3	S	Screened

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
20AA-a1	330442 800506	55	DOM	460	4	100?		1981		SCWRC 2/82	L BM	Open Hole
20AA-L1	330242 800649	75	DOM	360	4			8/79		B-2	L BM	Open Hole
20AA-m1	330208 800753	70	PS	402	12	293	140	10/74			BM	Driller Log Screened 358-402; Q/S=1.2
20AA-n2	330218 800807	66.6	OBS	454	6	75	50	10/73	E,STD., G,N,C			Water-Level Recorder Open Hole; Driller Log
20AA-n3	330256 800829	75	PS	327	6	327	201	5/65		B-2	BM	Driller Log Screened 296-327; Q/S=2.1
20AA-n4	330216 800842	50	DOM	341	4	212		6/78		SCWRC 2/82	BM	Driller Log Screened 321-341
20AA-o2	330203 800940	80	DOM	401	4	83	11	3/67			L BM	Driller Log Open Hole; Q/S=0.2
20AA-q1	330152 800817	75	PS	390	12	352	317	12/73			BM	Driller Log Screened 352-390; Q/S=2.3
20AA-r1	300115 800724	50	DOM	45	1 1/2	45		1958		B-3	S	Screened 41-45
20BB-a1	325915 800556	45	OBS	380?	4						L BM	Piezometer Open Hole(?)
20BB-u2	325502 800539	30	PS	352	6	83	470	9/71	G		L	Piezometer; Driller Log Open Hole; Q/S-1.5
20BB-v1	335510 800656	10	PS	360	4	43		1979?			L BM	Piezometer Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
20BB-y1	325522 800908	31.2	DOM	360	4	60		8/78			L BM	Piezometer Open Hole
20CC-d1	325415 800826	20	IND	421	10	126		9/71			L BM	Driller Log CL=210 mg/L
20CC-k1			DES	720	4	400	60	1/55	E		BM	Driller Log Open Hole; CL=500
20DD-d1	324913 800825	10	DOM	650+	3					SCWRC 1/81	L BM	Piezometer Open Hole
20DD-h1	324800 800735	5	DOM	521	4	147	75	2/71		B-2	L BM	Driller Log Open Hole
20DD-k1	324728 800559	5	DOM	435	4	83	10	11/56		SCWRC 2/80	L BM	Piezometer Open Hole
20DD-k2	324759 800534	10	IRR	360	4	72		1956		B-2	L	Open Hole
20DD-n3	324712 800847	8	IRR	520	4	119		4/82		B-2	L BM	Piezometer Open Hole; CL Increased
20DD-p1	324746 800911	30	DOM	58						B-3	S	Screened
20DD-q1	324608 800808	10	DOM	500	4			10/74		B-2	L BM	Open Hole CL Increased
20DD-y2	324544 800952	20	IND	611	6	150	300	1979		SCWRC 2/81	L BM	Open Hole Q/S=5.3
20EE-e1	324426 800942	5	UNU	560	4	152		4/78	Cd.,E	B-2	L BM	Piezometer Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
20EE-rl	324146 800753	25	DOM	50						B-3		Screened
20FF-dl	323937 800845	10	UNU	557	3	224			G,C	B-2	L BM	Driller Log Open Hole; Point Sample 245, 295, 345, 395, 445, 495, 545
20FF-hl	323848 800716	10	DOM	18						B-3	S	Screened
20FF-vl	323600 800622	8	Test	2282			flow	1974	STD.,N	B-2	BM BC M	Driller Log; Pump Test Point Sample 592, 638, 2030, 2120, 2150,; Q/S=2.1
20GG-el	323530 800830	10	PS	2696	16 8	1970 1733- 2040	1613 flow 568 gpm	2/73	G,E,C	B-1	BC M	Driller Log; Point Samples 1843, 2040, 2050, 2148, 2155, 2188, 2387, 2513; Q/S=5.0
21X-ql	331648 801320	95	IRR	88	1 1/2			1940			L	Piezometer Open Hole
21X-kl	331701 801003	84	DOM UNU	90	2			1945			L	Piezometer Open Hole
21Z-bl	330921 801111	67	DOM	249		40				B-2	L BM	Driller Log Open Hole
21Z-ul	330521 801007	70	DOM	540	4	85		1978		B-2	L BM	Open Hole
21AA-fl	330320 801416	63	DOM	386	4	96		1976			L BM	Piezometer Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
21AA-n2	330250 801323	70	IND	398	8		428	9/71		B-2	BM	Driller Log Screen 347-398 Q/S = 2.9
21AA-pl	330101 801450	55	PS	420	8	372		9/71		Com 11-71	BM	Driller Log Screen 372-420
21AA-p2	330123 801453	48		573	10 8 6	393	120 Flow @ 25	7/54		SCWRC 2-82	L BM	Piezometer Driller Log Open Hole
21AA-rl	330156 801220	70	IND	344	6	109	109	12/63		SCWRC 1-80	L BM	Driller Log Open Hole Q/S = 2/3
21AA-r2	330150 801220	75	PS	1800	18 12 6		510	11/81		B-1	BC	Driller Log Screen 1587-1590, 1606-1623, 1631-1642, 1650-1660, 1672-1686, 1695-1705 Q/S = 3
21AA-tl	330107 801036	71.4	UNU	320	8			1930	G	USGS 11-50	L	Original Depth ± 900 ft
21AA-vl	330057 801120	75	UNU	35	2					B-3	S	Screened
21BB-fl	325852 801441	69.7	UNU	516	2	50			E,G,C		L BM	Piezometer Low Yield
21BB-f3	325848 801426	70	DOM	401	4	84	75	1967		HACH CL	L BM	Piezometer Driller Log Open Hole. Q/S = 1.6 CL = 14 mg/L

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
21BB-f4	325820 801456	60	PS	461	6	75	261	2/67		HACH CL	L BM	Piezometer Driller Log Q/S = 3.6 CL = 68
21BB-L4	325746 801113	35	UNU	18	2					T-F	S	Screened
21BB-m1	325734 801208	30	DES	2000				9/78	E, std., G,C	B-1	BC	Driller Log Test Hole
21BB-m2	325734 801207	25	DES	1700						B-1 B-2	BC	Driller Log, Test Hole Point samples 515, 1585, 1690, 1730
21BB-m3	325734 801207	28	PS	1790	6	1790	900		std.	B-1	BC	Driller Log Screen 1625-1631, 1644-1662, 1685-1705, 1789-1731, 1740-1750
21BB-p1	325645 801407	40	UNU	386	6	65		1976	E,G		L BM	Piezometer Open Hole
21BB-p2	325603 801458	15	TEST	393	4				G		L BM	Piezometer USGS Test Hole Open Hole
21BB-q1	325648 801307	18.7	UNU	416		85	300	5/69	G		L BM	Piezometer Diller Log Open Hole
21BB-r1	325659 801250	28	IND	405	6	70	150	12/59			L BM	Driller Log Open Hole Q/S =3.7

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
21BB-r3	325654 801256	26.2	UNU	380	4	92	125	12/67			L BM	Piezometer Open Hole Q/S = 1.4
21BB-r4	325632 801238	32	DOM	385	3					B-2	L	Piezometer Open Hole
21BB-s1	325620 801101	22	UNU	514	3	30		9/80	E,G		L BM	Piezometer USGS Test Hole Open Hole
21BB-t1	325652 801009	25	UNU	350	4	128	25			DHEC 8-74	L BM	Piezometer Driller Log Open Hole. Q/S = 2.3
21BB-t3	325625 801101	25	DOM	363	4	83	15	4/62			L BM	Driller Log Open Hole Q/S = 2.5
21CC-e1	335500 801425	22	OBS	500	4	20			G		L BM	Piezometer USGS Test Hole Open Hole
21CC-u1	325015 801017	10	ABN		4						L	Piezometer Open Hole
21DD-m1	324707 801206	20	DOM	60						B-3	S	Screened
21DD-n1	324709 801354	35	UNU	280	4	77		1970		B-2	C L	Open Hole
21DD-p2	324634 801451	40	DOM	540	4	165	10	2/57		B-2	L BM	Driller Log Open Hole Q/S = 1.1

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
21DD-p3	324611 801432	32	DOM	260	2					B-2	C L	Open Hole
21DD-p4	324639 801459	42	DOM	320		80				B-2	C L	Open Hole
21DD-p5	324621 801448	35	DOM	300	4	80		1969		B-2	C L	Open Hole
21DD-q1	324649 801351	40	DOM	603	4			1970		B-2	C L BM	Open Hole
21DD-q2	324648 801351	40	DOM	364	3	94		10/63		B-2	L	Open Hole
21DD-q4	324648 801338	40	DOM	561	2	169	125	4/71		B-2	L BM	Driller Log Open Hole Q/S = 5.1
21EE-e2	324406 801414	30	IND	600	4			1960		B-2	L BM	Open Hole
21EE-e3	324403 801452	30	DOM	555	4	148	10	7/56		B-2	L BM	Driller Log Open Hole Q/S = 5
21EE-e4	324403 801448	30	DOM	581	4	155		8/68		B-2	L BM	Driller Log Open Hole
21EE-e5	324421 801427	30	IND	620	4	147	25+	1/79		B-2	L BM	Driller Log Open Hole
21EE-e6	324230 801456	30	DOM	525	4	129		2/55		B-2	L BM	Driller Log Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
21EE-f3	324301 801420	5	PS	490	5		60			B-2	L	Piezometer Open Hole
21EE-hl	324310 801236	10	DOM	60						B-3	S	Screened
21EE-il	324357 801139	14	ABN	602	12	132	350	1955		B-2	L BM	Driller Log Open Hole Q/S = 4.3
21EE-jl	324316 801045	10	DOM	601	4	160		6/68		B-2	L BM	Driller Log Open Hole
21EE-ql	324158 801327	10	DOM	561	4	192		7/78	E,G,N,Cd.	B-2	L BM	Piezometer Driller Log Open Hole
21EE-xl	323740 801301	10	ABN	585	4	126		4/57	G,C,N		L BM	Piezometer Driller Log Open Hole
21EE-yl	324012 801405	6	DOM	585	10				G,C.	B-2	L BM	Open Hole
21FF-dl	323958 801356	5	ABN	330	4				G,C		L	Piezometer Open Hole
21FF-el	323438 801357	10	DOM	30	3			before 1920		B-3	S	Screened
21FF-kl	323734 801007	8	PS	580	4	470				B-2	BM	Driller Log Open Hole Cl = 1600 mg/L

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
21FF-s1	323652 801137	15	DOM	30						B-3	S	Screened
21GG-e1	323421 801953	10	DOM	30	1 1/4					B-3	S	Screened
22V-e1	332404 801956	106	UNU OBS	76	2						L	Piezometer Open Hole
22X-j1	331859 801513	93	UNU OBS	80	2			1959			L	Piezometer Open Hole
22Y-a1	331403 801558	96	DOM OBS	200	4			1968		B-2	L BM	Piezometer Open Hole
22Y-a2	331417 801546	96	UNU OBS	101	2				G		L	Piezometer Open Hole
22Y-p1	331153 801953	58	UNU OBS	90	3		Flow 15		G			Piezometer Open Hole
22Y-w1	331001 801748	85	PS	550	12 6	382	300	1/65	E	B-2	BM	Driller Log. Q/S = 4.6 Screen 283-293, 301-311, 330-340, 362-372
22Y-w2	331014 801730	85	PS	663	12	394	250	11/64	E	B-2	BM	Driller Log Q/S = 2.3 Screen 308-323, 336-351 374-384
22Z-r1	330639 801708	5	OBS	344	8	45	480	1955	E,G,C		L BM	Water-level Recorder Driller Log
22Z-s1	330603 801700	68	DOM OBS	291	3	40		6/73	E,G,C		L BM	Piezometer Open Hole
22Z-u1	330507 801555	20	UNU OBS	300	4	21			E,G		L BM	Piezometer Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
22Z-v1	330539 801605	60	UNU OBS	306	4	20		12/77	E,G,C		L BM	Piezometer Open Hole
22Z-v2	330536 801606	40	DOM OBS	280	4			1940		B-2	L	Piezometer Open Hole
22Z-x1	330538 801852	60	PS	325	12	227	250	9/70	G		L	Driller Log Open Hole Q/S = 13.5 @ 500 GPM
22AA-n1	330235 801858	53	UNU OBS	305	2				G		L BM	Piezometer
22BB-f1	325819 801926	60	DOM	25	2	24		1960		B-3	S	Screened
22BB-k1	325759 801559	15	UNU OBS	205	4				G		L	Piezometer
22BB-L1	325750 801630	15	UNU OBS	350	4	51	50		E,G,C		L	Piezometer Driller Log Open Hole Q/S = ± 2.0
22BB-m1	325751 801713	20	DOM	322	5				G	B-2	L	Piezometer Open Hole Log to 309:
22BB-m2	325754 801745	20	PS	301	4	65		1955		B-2	L	Driller Log Open Hole
22CC-e1	325409 801902	20	Test	2250	10			1977	E,G,C			USGS Test Hole Core Samples to Basement

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
22CC-L1	325203 801642	25	DOM	525	4	86	100	1/77		B-2	L BM	Driller Log Open Hole Q/S = 2.6
22CC-v1	325032 801608	28.8	UNU OBS	394	4						L BM	Piezometer
22CC-v2	325019 801600	25	DOM	65						B-3	S	Screened
22CC-w2	325050 801720	29	DOM	521	4	127		8/70		B-2	L BM	Driller Log Open Hole
22DD-b1	324916 801630	32.2	OBS	427	3				E,G,C	B-2	L	Piezometer Open Hole
22DD-b2	324909 801655	25	PS	480	4					B-2	L BM	Open Hole
22DD-t1	324623 801529	45	DOM	400	4	105				B-2	L	Open Hole
22EE-b1	324458 801634	30	DOM	590	4	126		1/78		B-B-2	L BM	Open Hole
22EE-h1	324341 801731	36	PS	603	4	129		8/64	E,G,C,T	B-2	L BM	Driller Log Open Hole
22EE-h3	324342 801722	35	PS	605	6	127	440	8/64		B-2	L BM	Driller Log Open Hole Q/S = 5.9
22EE-h5	324337 801723	32	DOM	35						B-3	S	Screened

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
22EE-h6	324328 801705	25	DOM	560	4	106		6/79		B-2	L BM	Open Hole
22EE-j3	324306 801535	10	DOM	581	4	159		4/68		B-2	L BM	Driller Log Open Hole
22EE-j5	324311 801602	17	DOM	655	4	147	15	7/78		B-2	L BM	Driller Log Open Hole Q/S = 0.5
22EE-n1	324226 801804	12	PS	565	4	148			E,G,C,T,Cd.	B-2	L BM	Driller Log Open Hole
22EE-r1	324155 801753	15	OBS	600	6	244	55	1953	G,N		L BM	Water-Level Recorder Driller Log Open Hole
22EE-r2	324144 801753	15	DOM	601	6	142		2/73		B-2	L BM	Driller Log Open Hole
22EE-r3	324140 801752	15	DOM	641	4	148		6/80		B-2	L BM	Driller Log Open Hole
22EE-y1	324031 801907	19	DOM	632	4	220		1974		B-2	L BM	Driller Log Open Hole
22EE-y2	324040 801919	17	DOM	604	4	107		11/75		B-2	L BM	Driller Log Open Hole
22FF-e1	323958 801905	7	DOM	601	4			1/81	G	B-2	L BM	Driller Log Cuttings Open Hole
22FF-g1	323853 801845	10	DOM	35	1 1/2					B-3	S	Screened

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
22FF-j1	323843 801513	8	UNU OBS	532	6	130	60		E,G,C,T,N	B-2	L BM	Piezometer Driller Log Open Hole
22FF-j2	323838 801513	12	DOM	52	6	52	37	6/70		B-3	S	Driller Log Screened
22FF-p1	323633 801958	5	DOM	518	2			1972		B-2	L BM	Driller Log Open Hole
22FF-p2	323634 801953	5	COM	521	4	103	60	4/69		B-2	L	Driller Log Open Hole Q/S = 6
22FF-p3	323629 801945	5	UNU OBS	561	4	105		5/72		B-2	L	Piezometer Driller Log Open Hole
22FF-q1	323630 801841	5	DOM	561	4	106	50	4/71		B-2	L	Driller Log Open Hole
22FF-x1	323517 801817	7	DOM	561	4	106		2/72		B-2	L BM	Driller Log Open Hole
22GG-d1	323455 801822	7	UNU OBS	560	12	280		1956	G		L BM	Piezometer Open Hole
22GG-n1	323202 801838	10	DOM	10						B-3	S	Screened
22GG-q3	323121 801809	9								B-3	S	Screened
22GG-q4	323123 801837	10	DOM	10	1 1/4	6				B-3	S	Screen 6-10

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
22GG-w4	323042 801758	9	UNU OBS	545	6	516				B-2	L	Piezometer Open Hole
22GG-w6	323058 801758	15	DOM	25	1 1/4	20		5/70		B-3	S	Screen 20-25
22GG-x5	323051 801844	10	DOM	25						B-3	S	Screened
22GG-x9	323043 801856	8	OBS	50	4	20	30	1981		B-3	S	Screen 20-50: Aquifer Test
22HH-d2	322945 801828	10	UNU	541	4	512		8/57	G		L	Piezometer Open Hole
22HH-e1	322931 801943	5	UNU	552	6	346	135	9/62		B-2	L	Driller Log Open Hole CL = 383 mg/L, 9/62
22HH-e2	322904 801954	20	UNU	757	10	120	50	1/62	G	B-2	L BM	Open Hole. CL=1305 mg/L @ 700' Driller Log CL=2175 mg/L @ 757' Q/S= 2.7
23Y-t1	331131 802013	100	DOM	9	1 1/4					B-3	S	Screened
23Z-g1	330808 802334	106.2	DOM	238	4	58		2/78	E,G	B-2	L	Open Hole
23Z-g2	330900 802315	85	PS	325	6	206	600	10/73			L BM	Driller Log Q/S = 37
23Z-q1	330649 802331	80	UNU	21	2	20		1940		B-3	S	Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
23Z-w1	330512 802250	39	UNU OBS	185	3				G	B-2	L	Piezometer Open Hole
23AA-b1	330441 802134	76	UNU	18	1 1/2			1930		B-3	S	Screened
23AA-h1	330359 802238	60	PS	396	6	65	238	9/63				Driller Log Open Hole Q/S = 6.4
23AA-q1	330156 802310	70	PS	352	6	60	320	1/68		DHEC 9-76	L	Driller Log Open Hole Q/S = 6.8
23AA-q4	330118 802355	40	UNU	263			flows 0-3 gpm		G		L	Piezometer Open Hole
23AA-x2	330057 802317	65	UNU	305	2				G,C		L	Piezometer Open Hole
23AA-y1	330037 802414		ABN OBS	275					G		L	Piezometer Open Hole
23BB-p2	325654 802448	40	DOM OBS	389	4			1978			L BM	Piezometer Open Hole
23BB-t1	325639 802005	30	DOM	465	8	422	300	7/56		USGS 11-56	L BM	Driller Log Open Hole Q/S=1.8
23BB-x2	325539 802345	20	DOM OBS	360+	4			1975			L BM	Piezometer Open Hole
23CC-i1	325317 802133	20	Test Hole	2599					E,std.,N,G, GG, Micro			USGS Test Hole Core Samples to Basement

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
23CC-b1	Approx. Loc.	25		400					G		L	Data from S.C. Geol. Survey gamma Log #18GR14
23DD-f1	334838 802407	20.85	DOM	406	3			1960		B-2	L	Piezometer Open Hole
23DD-f2	324848 802406	20	DOM	501	4	85	120	3/79		B-2	L BM	Driller Log Open Hole Q/S=1.0
23DD-s2	322141 801634	30	DOM	527	3			1950		B-2	L BM	Open Hole
23DD-x1	322345 801520	57	DOM	56	2					B-3	S	Screened
23EE-a1	324416 802100	40	DOM OBS	621	4			1969		B-2	L BM	Piezometer Driller Log Open Hole
23EE-k1	324221 802058	30	DOM	580	4	80+		1943		B-2	L BM	Driller Log Open Hole
23EE-L1	324225 802154	30	DOM	55						B-3	S	Screened
23EE-n1	324227 802338	20	DOM	560	4	120		1972		B-2	L BM	Open Hole
23EE-s1	324111 802108	10	IND	550	6			1951		B-2	L BM	Open Hole
23EE-v1	324025 802147	21.50	DOM OBS	610	4	105				COM 5-73	L BM	Piezometer Open Hole

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
23EE-y1	324053 802457	27	DOM	540	4	84		4/66		B-2	L BM	Open Hole
23FF-a1	323935 802026	10.1	ABN	340	6		15		G	B-2	L	Piezometer Open Hole
23FF-k1	323720 802053	5	STK	561	4	127		2/74		B-2	L BM	Driller Log Open Hole
23FF-u2	323529 802048	10	DOM	52	1 1/4	52		4/78		B-3	S	Screen 44-52 ft
23FF-u4	323600 802047	7	DOM OBS	520	4	120				B-2	L BM	Piezometer Open Hole
23HH-a1	322925 802011	8	PS	534	8 6 stl	68 534		4/73		B-2	L	Driller Log Open Hole
23HH-a2	322942 802045	5	ABN	567	4	168	30	8/57		B-2	L	Piezometer Driller Log Open Hole Destroyed (1982)
23HH-a3	322939 802044	5	PS	552	6	346	130	9/62		B-2	L	Driller Log Open Hole
23HH-a4	322937 802025		DOM	549	4	103	135	12/53		B-2	L	Driller Log Open Hole
23HH-j1	322851 802003	8	PS	805	4	540	125	1/75	E,Std,G,N,C	COM 5-78	L	Completed @540 Open Hole. Q/S=3.5 Sample @540-565, CL=750; F=2.9 mg/L
24Y-b1	331443 802623	93.7	PS IRR	489	10	120		1960	E	B-2	BM	Driller Log Screen 270-320, 449-489

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
24Y-b2	331437 802630	80	ABN	482	8	458	600+	5/94		USGS 3-60	BM	Screen 449-479
24Y-h1	331401 802701	75	IND	320	10	320			G	B-2	BM	Screen 163-289
24Y-i1	331343 802641	80	UNU OBS	91	4						L	Piezometer Open Hole
24Y-i9	331339 802634	82	OBS	212	6	43	15		G,C	B-2	L	Water-level recorder Driller Log Collapsed @ 56 ft
24Y-k1	331239 802547	81	ABN OBS	150	2				G		L BM	Piezometer Open Hole
24Y-m1	331249 802658	87.5	STB	228	6	49		1955			L BM	Piezometer Open Hole
24Z-b1	330932 802601	93.7	IRR OBS	301	12	120	810	1/59			L BM	Piezometer Q/S=10.9
24Z-j1	330849 802550	105.5	UNU	280	20	152	567	4-66			L	Piezometer Driller Log Open Hole
24Z-j2	330901 802538	100	IND	306	20	130	690	4/66			L BM	Driller Log Open Hole
24Z-j3	330902 802557	100	IND	320	12	124	692	5/53		USGS 7-79	L BM	Driller Log Open Hole Q/S=32.9
24Z-w1	330543 802712	105	DOM	25	1 1/2			1969		B-3	S	Screened

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
24Z-y2	330526 802925	100	UNU OBS	233	2				G,C		L	Piezometer Open Hole
24Z-y3	330510 802905	90	DOM	400	4	104		5/75			L BM	Driller Log Open Hole
24Z-y4	Approx. Loc.	62		490					G			Data from S.C. Geol. Survey gamma Log #18GR4
24AA-jl	335320 802515	35	TEST	275					G		L BM	S.C. Geol. Survey Gamma Log #18GR6
24BB-cl		50	OBS UNU	337	4	61			E,Std.,G,GG, N,C		L	Piezometer Open Hole
24DD-ol	325111 802917	45	DOM OBS	401	4	64.2	400	7/75			L BM	Piezometer Open Hole
24DD-rl	324625 802734	30	DOM OBS	500	4	50					L BM	Piezometer Open Hole
24EE-cl	324411 802709	10	OBS	604	4	94.6		4/76			L BM	Piezometer Open Hole
24FF-wl	323533 802750	10	DOM OBS	505	4	152	35	10/63		Field 1978	L	Piezometer Driller Log Open Hole
24GG-kl	323234 802513	10	OBS	504	2		flows	1970	G		L	Piezometer Open Hole
25X-vl	331519 803134	96	UNU OBS	52	1 1/2					B-2	L	Open Hole
25Y-hl	331345 803224	100	UNU OBS	280	6		16	1959	E,G,C	SCWRC 3/80	L BM	Piezometer Open Hole Q/S=11.8

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
25Y-p3	331136 803414	95	UNU	1000			701		E,G,C			Open Hole Collapsed
25Y-q1	331128 803304	105	PS	325	6	62	27	1962			L BM	Driller Log Q/S=1.3
25Y-t1	331109 803045	87	UNU	61	1 1/2			1940's		B-2	L	Open Hole
25Z-b1	330925 803118	78	TEST	450	None				E,G			Drilled to "basement"
25Z-f2	330856 803442	85	UNU	480	4	24		1950	G,C		L BM	Open Hole
25Z-i1	330859 803111	80	UNU	25	1 1/2			1950		B-2	L	Open Hole
25Z-w1	330520 803228	50	DOM OBS	253	4				G		L	Piezometer Open Hole
25AA-L1	330258 303130	95	DOM OBS	450	4"						L BM	Piezometer Open Hole
26Y-n1	331225 803841	105	PS	370		330	900	3/78	E	B-2	L BM	Driller Log Screen 330-370 Test Hole to 600'
26Y-n2	331225 803841	100.7	OBS	116.6					E,G,C		L	Water Level Recorder
26Y-o1	331240 803934	120	OBS	76	1 1/2						L	Piezometer Open Hole
26Z-t1	330629 803538	86	DOM	370	3	38			G,C		L BM	Open Hole Flowing Well

Well Number	Latitude/ Longitude	Elevation (msl)	Well Use	Total Depth	Casing Diameter	Casing Depth	Pump Rate	Date Comp.	Geophysical Logs	Chemical Analysis	Aquifer	Remarks
26Z-u1	330542 803559	80	DOM	20						B-3	S	Screened
26Z-x2	330502 803358	80	ABN OBS	300+	4			10/75			L	Piezometer Open Hole
26AA-k1	330251 803556	80	OBS	500	4	132		4/76	E,G,C		L	Piezometer SCWRC Test Hole
27Y-h1	331345 804214	100	UNU	197	3		flows		G.C		L BM	Piezometer Open Hole

APPENDIX B. SELECTED CHEMICAL ANALYSES

EXPLANATION

WELL NUMBER:	Ground location of well in Figure 3.
AQUIFER:	Formation(s) from which sample was obtained: M-Middendorf Formation; BC-Black Creek Formation; PD-Peedee Formation; BM-Black Mingo Formation; L-Santee Limestone; C-Cooper Formation; S-Shallow, Post-Eocene Formation
SAMPLED INTERVAL:	Screened or open-hole section in feet below land surface.
ANALYSIS BY/DATE:	Laboratory and date of sample collection. Com-Commercial, DHEC-South Carolina Department of Health and Environmental Control, SCWRC-South Carolina Water Resources Commission, USGS-United States Geological Survey.
ALKALINITY:	Concentration in milligrams per liter (mg/L)
TDS:	Total Dissolved Solids. Concentration in milligrams per liter (mg/L)
PH:	Self explanatory
TEMPERATURE:	Temperature in degrees Celsius (°C)
CHLORIDE:	Concentration in milligrams per liter (mg/L)
FLUORIDE:	Concentration in milligrams per liter (mg/L)
HARDNESS:	Concentration in milligrams per liter (mg/L)
NITRATE:	Concentration in milligrams per liter (mg/L)
IRON:	Concentration in micrograms per liter (ug/L)
MAGNESIUM:	Concentration in milligrams per liter (mg/L)
MANGANESE:	Concentration in micrograms per liter (ug/L)
POTASSIUM:	Concentration in milligrams per liter (mg/L)
SILICA:	Concentration in milligrams per liter (mg/L)
SODIUM:	Concentration in milligrams per liter (mg/L)

Appendix B-1. Selected water-quality data for wells open to Cretaceous Formations.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	TDS	pH Field/Lab	Temperature Field	Chloride	Fluoride
11Y-n1		SCWRC	-		7.6			
BC		8-15-82	674.	1277.	-	26.	300.	2.2
12Y-11	761-	USGS	-		9.3			
BC	801	7-6-76	658.	1070.	-	23.	230.	-
15X-11	770-	USGS	-		8.5			
BC	891	7-19-79	370.	453.	8.6	26.	4.0	2.0
15X-15	700-	USGS	-		-			
BC	880	2-8-56	365.	-	8.7	-	4.5	2.0
16CC-k1	1709-	USGS	-		7.4			
BC	1840	7-23-79	880.	1170.	8.4	34.	130.	5.2
16CC-y1	1575-	SCWRC	1020.		8.8			
BC	1862	1-26-82	-	1180.	-	35.	68.	5.4
16DD-m2	1790-	SCWRC	884.		8.5			
BC/M	2000	2-1-82	-	1330.	-	34.	172.	6.3
17DD-a4	1775-	SCWRC	884.		8.3			
BC/M	1975	1-26-82	-	1170.	-	36.	90.	4.2
17DD-g7	1800-	SCWRC	767.		8.6			
BC/M	1986	3-5-81	-	1024.	-	36.	104.	4.0
17DD-m5	1829-	SCWRC	841.		8.6			
BC	1912	3-5-81	-	2962.	-		135.	4.4
17DD-u1	1820-	USGS	-		-			
BC	1920	5-26-63	943.	-	8.4	36.1	295.	5.4
17DD-u2	1840-	SCWRC	924.		8.4			
BC/M	2030	3-5-81	-	1524.	-	36.	520.	5.0
18V-u1		USGS	-		8.1			
BC	820	6-28-79	240.	317.	8.7	-	8.3	1.3
18V-u1		USGS	-		-			
BC	820	10-12-55	305.	306.	8.2	-	8.5	1.3
18W-a1	1200-	SCWRC	296.		9.0			
BC/M	1260	1-25-82	-	369.	-	26.	10.	1.4
18W-a4	1066-	USGS	-		-			
BC/M	1218	12-30-55	264.	308.	8.6	-	9.0	1.4
18W-b1	1094-	SCWRC	276.		8.8			
BC/M	1260	1-25-82	-	366.	-	23.5	13.	1.3
18AA-e2	1548-	SCWRC	-		-			
BC/M	1900	11-25-81	-	643.	-	-	26.	2.7
18AA-e2	1548-	COM	-		-			
BC/M	1638	-	495.	504.	8.7	-	19.	2.6
18AA-e2	1845-	COM	-		-			
M	1900	-	727.	1272.	8.2	-	265.	11.1
18CC-r1	1736-	USGS	818.		-			
BC/M	1906	6-23-62	-	-	8.6	-	77.	3.0
18DD-k1	depth	USGS	989.		-			
PD	1260	1-25-67	-	1130.	-	-	139.	3.3
18DD-11		USGS	947.		-			
BC		3-1-60	-	-	8.3	-	132.	4.4

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
136.		42.5	9000.	7.0	30.	46.5	-	492.
-	-	36.5	4000.	5.0	26.	43.6	-	478.
20.	-	-	-	-	-	-	-	-
		4.2	360.	2.3	0.	13.	14.	400.
5.0		-	-	-	-	-	-	-
-	-	1.5	0.	0.3	1.	4.2	18.	190.
16.		1.6	30.	1.5	-	4.2		163.
	0.	-	20.	-	-	-	15.	-
6.		-	-	-	-	-	-	-
-	-	1.7	30.	0.4	1.0	3.8	14.	530.
9.		2.5	36.	0.6	0.	5.4	-	425.
0.	-	2.2	30.	0.6	0.	5.2	13.7	420.
7.7		2.1	42.	0.6	0.	4.9	-	464.
-	-	2.0	24.	0.6	0.	4.8	8.6	450.
90.		3.1	60.	0.5	0.	4.6	-	394.
-	-	2.1	35.	0.5	0.	4.4	4.1	390.
14.		2.1	43.	0.8	0.	4.1	-	365.
-	-	2.0	20.	0.3	0.	3.6	11.1	345.
16.		2.2	15.	0.7	0.	5.0	-	380.
-	-	2.1	0.	0.3	0.	4.5	19.9	360.
14.		2.9	-	1.8	0.	5.5	15.	640.
-	0.2	-	0.02	-	-	-	-	-
18.		3.3	60.	1.3	0.	8.9	-	480.
-	-	3.1	18.	1.1	0.	8.3	16.5	463.
4.	-	-	-	-	-	-	-	-
0.	-	1.4	10.	0.1	0.1	1.4	14.	120.
4.	-	1.2	70.	0.2	0.01	1.5	15.	119.
-	0.8	-	10.	-	-	-	-	-
4.8		1.6	10.	0.2	0.	2.2	-	135.
-	-	1.6	0.	0.1	0.	2.0	18.9	128.
8.		1.6	70.	1.0	0.01	2.2	15.	118.
-	0.	-	10.	-	-	-	-	-
6.3		2.0	250.	0.2	6.	2.1	-	128.
-	-	1.9	100.	0.2	0.	2.1	11.8	125.
-		-	-	-	-	-	-	-
-	-	1.8	200.	0.	0.	3.1	13.3	182.
-		-	250.	-	-	-	-	137.
-	-	-	-	-	-	-	-	-
-		-	950.	-	-	-	-	329.
-	-	-	-	-	-	-	-	-
6.		2.0	50.	0.4	-	7.0	17.	390.
-	0.5	-	-	-	-	-	-	-
7.		2.0	-	0.4	-	3.8	15.	460.
-	0.2	-	20.	-	-	-	-	-
7.		1.1	100.	1.0	0.	4.3	17.	455.
-	0.2	-	-	-	-	-	-	-

Appendix B-1. Selected water-quality data for wells open to Cretaceous Formations.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	TDS	pH Field/Lab	Temperature Field	Chloride	Fluoride
18DD-L2		USGS	-		-			
BC/M	1945	11-21-68	733.	-	8.5	-	78.	3.8
18DD-L2		USGS	-		-			
BC/M	1945	3-1-60	898.	1000.	8.6	-	89.	40.
19Y-s1	633-	USGS	-		8.0			
PD	693	7-12-79	700.	877.	8.1	25.	59.	1.5
19Y-w3	1602-	SCWRC	684.		7.7			
M	1607	1-26-82	-	870.	-	20.	68.	3.8
19CC-x1	1470-	USGS	-		7.5			
BC	1840	7-23-79	620.	868.	8.6	22.	50.	3.2
20FF-v1		COM	-		-			
BC	2030	12-16-74	1092.	2577.	8.4	-	464.	6.5
20FF-v1		COM	-		-			
M	2120	12-16-74	960.	1662.	8.7	-	62.	4.5
20FF-v1		COM	-		-			
M	2150	12-16-74	960.	1660.	8.7	-	60.	4.5
20FF-v1		COM	-		-			
M	2210	3-7-77	1000.	1880.	8.5	-	151.	6.0
20FF-v1		COM	-		-			
M	2220	11-19-74	1244.	1510.	8.6	-	162.	6.5
20GG-e1	1843-	USGS	-		-			
BC	1849	7-31-72	1260.	-	8.1	90.F	534.	-
20GG-e1	2050-	COM	-		-			
BC	2056	7-25-72	1050.	-	8.3	85.F	390.	5.
20GG-e1	2148-	COM	-		-			
M	2154	7-22-72	1040.	-	8.6	99.F	65.	5.
20GG-e1	2155-	COM	-		-			
M	2160	6-20-72	1020.	1200.	8.6	97.F	60.	5.
20GG-e1	2188-	COM	-		-			
M	2194	7-20-72	1168.	1400.	8.6	-	130.	4.5
20GG-e1	2513-	COM	-		-			
M	2522	7-2-72	740.	2830.	8.3	-	1440.	2.0
20GG-e1	2040-	COM	-		-			
M	2260	2-20-73	1040.	1850.	8.5	-	87.	5.0
21AA-r2	1587-	COM	-		-			
BC/M	1705	10-29-81	631.	736.	8.6	-	32.	3.6
21BB-m1	1730-	USGS	-		8.8			
M	1740	5-23-78	490.	557.	-	29.2	10.	1.8
21BB-m2	1585-	USGS	-		8.3			
BC	1595	8-30-78	730.	-	-	29.	177.	2.1
21BB-m2	1690-	USGS	-		8.8			
BC	1700	8-10-78	170.	-	-	29.		
21BB-m3	1622-	USGS	-		8.4			
BC/M	1750	7-9-79	460.	547.	8.7	34.	11.	2.7

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
5.		-	370.	-	-	-	-	-
0.	0.07	1.4	-	0.4	0.	2.8	17.	408.
6.		1.8	410.	0.4	0.	3.4	17.	420.
-	0.2	-	-	-	-	-	-	-
22.		-	-	-	-	-	-	-
0.	-	5.1	20.	2.3	1.	10.	20.	400.
15.8		3.1	3000.	0.6	41.	5.1	-	340.
-	-	2.5	2200.	0.5	38.	4.9	21.8	336.
7.		-	-	-	-	-	-	-
0.	-	2.3	300.	0.2	20.	2.5	5.3	340.
18.		3.6	1400.	2.2	0.	-	12.	800.
-	-	-	-	-	-	-	-	-
8.		3.2	800.	0.0	0.	-	10.	483.
-	-	-	-	-	-	-	-	-
9.		3.6	800.	0.0	0.	-	16.	481.
-	-	-	-	-	-	-	-	-
6.		1.6	100.	0.5	0.	-	18.	557.
-	-	-	-	-	-	-	-	-
9.		3.6	500.	0.0	0.	-	16.	680.
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
12.		-	1000.	-	-	-	-	-
-	-	-	-	-	-	-	-	-
8.		-	300.	-	-	-	-	-
-	-	-	-	-	-	-	-	-
5.		-	200.	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	2400.	-	-	-	-	-
-	-	-	-	-	-	-	-	-
30.		-	4000.	-	-	-	-	-
-	-	-	-	-	-	-	-	-
4.		1.6	10.	0.	0.	-	9.	536.
-	-	-	-	-	-	-	-	-
3.		0.9	40.	0.2	0.05	-	16.6	272.
-	-	-	-	-	-	-	-	-
3.		-	400.	-	-	-	-	-
0.	-	1.1	60.	0.1	10.	1.7	16.	230.
10.		-	1400.	-	20.	-	-	-
0.	-	2.9	20.	0.7	10.	4.8	-	430.
6.		-	600.	-	30.	-	-	-
0.	-	1.9	80.	0.2	20.	2.0	-	210.
3.		-	-	-	-	-	-	-
0.	-	1.0	50.	0.2	4.	1.7	16.	210.

Appendix B-2. Selected water-quality data from wells open to the Black Mingo Formation and/or the Santee Limestone.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
12Y-q1		SCWRC	184.		7.4			
L	44.5	-	-	292.	-	19.4	15.	0.1
12Z-i1		SCWRC	-		-			
L	43	-	-	303.	-	18.	13.	0.3
12Z-o1		USGS	200.		7.3			
L	105	-	-	268.	-	-	17.	0.1
13Y-x1		USGS	148.		8.0			
L		6-26-63	-	-	-	25.	6.6	0.0
13AA-h2		SCWRC	300.		7.2			
L	74	-	-	303.	-	19.0	24.6	0.13
13AA-n2	83-	SCWRC	-		-			
L	92	-	420.	312.	-	19.5	20.	0.42
14AA-r1		SCWRC	252.		7.6			
L		-	-	228.	-	19.	7.91	0.15
14BB-p1	180-	Parker	-		-			
L	195	-	238.	440.	7.7	-	92.	1.0
14BB-p2	TD	SCWRC	-		-			
L	195	-	201.	473.	-	-	122.	1.3
14CC-b1	90-	USGS	-		7.7			
L/BM	240	7-26-79	280.	1020.	8.0	21.5	380.	1.7
15X-L2		USGS	-		7.0			
L	32	6-19-74	210.	262.	-	20.5	9.2	0.1
15BB-w1	212-	SCWRC	-		-			
L	241	1-9-81	-	-	-	-	69.	1.4
15BB-y1	230-	SCWRC	-		-			
L/BM	425	6-23-80	246.	482.	-	22.2	92.	1.6
15CC-b2	156-	SCWRC	336.		8.3			
L/BM	300	3-3-81	-	1056.	-	20.7	364.	2.3
15CC-c1	TD	SCWRC	336.		81.			
L/BM	271	3-6-81	-	1020.	-	21.	400.	2.2
16Y-m1	40-	USGS	-		7.1			
L	90	1-26-54	271.	294.	-	-	4.8	0.3
16Z-g1	TD	SCWRC	-		-			
L	110	2-20-80	-	247.	-	-	7.03	0.42
16Z-h1	TD	SCWRC	-		7.1			
L	110	-	-	-	-	19.	14.	-
16Z-n2	42-	SCWRC	172.		9.0			
L	122	12-21-82	-	317.	-	18.	13.	0.4
16CC-a1	151-	SCWRC	316.		8.3			
L	242	11-21-80	-	-	-	18.	300.	2.6
16CC-g1	80-	SCWRC	-		-			
L	245	1-15-81	-	-	-	-	220.	3.7
17W-d2	125-	USGS	-		7.4			
BM	143	5-3-73	189.	240.	-	-	10.	0.5
17BB-g1	219-	COM.	-		-			
L/BM	315	4-19-76	260.	570.	8.3	-	64.	1.5

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
180.		61.	1900.	2.3	130.	1.2	-	9.2
-	-	60.	1800.	2.3	110.	1.0	11.0	8.2
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
200.		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
122.		48.	-	0.7	-	2.2	-	4.9
-	-	-	60.	-	-	-	-	-
-		0.	0.	0.	0.	0.5	-	144.
-	-	-	-	-	-	-	15.64	130.
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
183.6		66.0	114.	3.7	0.	24.	-	9.4
-	-	66.0	120.	3.7	0.	24.	19.4	9.4
-		24.	50.	15.8	0.0	-	20.	114.
125.	-	24.	-	-	-	-	-	+K
-		23.4	155.	21.3	-	23.5	-	110.
-	-	-	-	-	-	-	-	-
74.		-	-	-	-	-	-	-
0.	-	9.7	10.	12.	0.	26.	38.	380.
200.		-	-	-	-	-	-	-
-	-	78.	510.	1.8	80.	0.8	18.	7.7
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
36.		5.5	30.	5.2	0.010	18.3	-	140.
-	-	5.0	-	4.8	0.000	17.4	22.3	140.
50.		36.4	2000.	8.4	0.	25.2	-	320.
-	-	8.8	0.	8.1	0.	24.3	40.5	300.
102.		30.2	1260.	16.0	0.	27.3	-	324.
-		13.1	29.	13.1	0.	26.3	45.6	304.
-		84.	260.	4.5	0.	-	44.	2.0
228.	0.3	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		43.0	45.	11.9	0.	8.3	-	12.6
-	-	41.2	27.	11.6	0.	7.9	40.2	11.1
64.		17.2	260.	9.6	0.	39.2	-	270.
-	-	9.2	70.	9.5	0.	21.8	34.7	268.
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
180.		66.	10.	3.0	-	4.2	28.	9.8
-	0.	-	-	-	-	-	-	-
70.		11.2	120.	10.2	0.	-	22.	153.
-	-	-	-	-	-	-	-	-

Appendix B-2. Selected water-quality data from wells open to the Black Mingo Formation and/or the Santee Limestone.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
17BB-h1	271-	COM	-		-			
BM	304	11-9-79	320.	570.	8.4	-	176.	1.6
17DD-a3	200-	SCWRC	653.		8.4			
L/BM	415	12-21-82	-	1638.	-	21.	441.	5.4
17DD-d1	TD	SCWRC	653.		7.4			
L/BM	350	4-7-82	-	-	-	23.	946.	3.9
18V-p2	102-	USGS	-		7.7			
BM	130	5-16-73	109.	185.	-	-	5.	0.3
18V-v2	73-	USGS	-		7.3			
BM	113	4-30-73	103.	147.	-	-	5.	0.2
18W-A6	133-	USGS	-		7.7			
BM	158	4-16-73	154.	197.	-	-	6.	0.1
18W-j2	120-	USGS	-		7.5			
BM	140	5-25-73	139.	180.	-	-	8.	0.2
18X-g1	110-	SCWRC	112.		7.9			
BM	322	1-22-82	-	260.	-	20.5	6.9	0.13
18Z-w1	63-	SCWRC	444.		8.5			
BM	220	2-8-82	-	499.	-	17.0	10.	1.9
18AA-i1	280-	COM	-		-			
BM	298		588.	1148.	8.5	-	123.	2.0
18AA-u1	200-	SCWRC	424.		8.7			
BM	280	1-21-82	-	809.	-	20.5	167.	2.2
18CC-g1	308-	SCWRC	768.		8.5			
L/BM	440	2-15-80	-	1384.	8.3	20.7	265.	4.8
18CC-g1	308-	SCWRC	528.		8.7			
L/BM	440	12-21-81	-	-	-	20.	250.	5.2
18CC-g2	TD	SCWRC	528.		8.7			
L/BM	450	12-21-82	-	1304.	-	20.	250.	5.2
19Y-t1	TD	USGS	-		7.4			
L	147	11-12-55	376.	389.	-	25.	32.	0.7
19Y-t2	TD	USGS	-		7.6			
L/BM	170	11-12-55	222.	308.	-	25.	12.	0.9
19Y-t5	TD	USGS	-		7.7			
L	160	11-12-55	232.	236.	-	25.	12.	0.9
19Z-b1	187-	COM	-		-			
BM	250	10-4-76	222.	392.	8.0	-	16.	0.8
19Z-v2	120-	COM	-		-			
L/BM	248	1-15-79	516.	1049.	8.3	-	76.	1.2
19Z-v3	270-	SCWRC	584.		8.1			
BM	325	1-8-82	-	922.	-	19.5	82.	3.0
19AA-r2	45-	COM	-		-			
L/BM	350	1978	-	900.	8.5	-	45.	3.4
19BB-m1	270-	SCWRC	516.		8.15			
BM	325	1-29-80	-	755.	-	20.	104.	2.9
19DD-u1	240-	SCWRC	576.		8.4			
L/BM	580	12-21-82	-	-	-	15.	701.	3.6

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
70.		12.8	20.	9.2	0.	-	24.	242.
-	-	-	-	-	-	-	-	-
-		6.5	291.	9.1	0.	28.5	-	800.
-	-	6.3	23.	9.0	0.	27.4	44.1	760.
-		10.0	24.	14.1	0.	44.3	-	672.
-	-	8.5	20.	12.6	0.	35.7	38.5	660.
92.		24.	20.	7.8	-	8.0	30.	11.
-	0.	-	-	-	-	-	-	-
100.		40.	70.	1.3	-	1.7	30.	3.9
	0.	-	-	-	-	-	-	-
150.		56.	-	2.4	-	2.6	25.	7.2
-	0.	-	-	-	-	-	-	-
140.		53.	700.	1.7	-	2.0	27.	4.6
-	0.	-	-	-	-	-	-	-
112.8		40.9	270.	2.47	28.	4.20	-	5.3
-	-	40.5	102.	2.36	25.	3.85	28.2	5.0
-		3.55	40.	2.85	0.	10.1	-	16.0
20.1	-	3.46	10.	2.83	0.	9.98	43.6	15.6
20.		-	-	-	-	-	-	-
-	-	5.6	0.01	1.5	0.	-	28.	353.
-		3.50	20.	2.30	0.	15.5	-	285.
18.2	-	3.42	17.	2.15	0.	14.8	35.9	280.
252.		4.7	41.	5.1	0.	23.5	-	460.
-	-	4.6	46.	5.1	0.	23.4	19.7	460.
-		4.5	101.	60.	0.	20.2	-	507.
-	-	4.4	38.	5.8	0.	19.5	506.	483.
-		4.5	101.	6.0	0.	20.2	-	507.
-	-	4.4	38.	5.8	0.	19.6	50.6	483.
174.		33.	1100.	22.	0.01	15.	-	76.
-	0.5	-	52.	-	0.01	-	37.	-
149.		29.	1700.	19.	-	11.	-	18.
-		-	270.	-	-	-	26.	-
151.		27.	380.	20.	0.01	12.	-	22.
-	1.0	-	310.	-	0.01	-	32.	-
93.		26.8	20.	6.3	0.	71.2	32.	71.2
-	-	-	-	-	-	-	-	-
30.		6.4	0.1	3.4	0.	293.	32.	293.
-	-	-	-	-	-	-	-	-
28.		5.8	33.	5.0	0.	18.9	-	383.
-	-	5.3	26.	4.2	0.	16.3	41.9	346.
-		-	50.	-	-	-	-	-
-	-	-	-	-	-	-	-	-
28.4		6.2	181.	5.0	4.	17.4	-	260.
-	-	7.0	242	5.8	0.	18.0	19.1	266.
-		8.1	30.	10.5	0.	288.	-	930.
-	-	8.0	2.5	10.3	0.	27.6	40.2	900.

Appendix B-2. Selected water-quality data from wells open to the Black Mingo Formation and/or the Santee Limestone.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
19EE-dl	148-	COM	-		8.3			
L/BM	581	7-7-72	582.	3300.	8.3	-	1350.	2.40
20AA-L1	TD	SCWRC	-		8.4			
L/BM	360	2-17-82	198.	-	-	20.	11.7	2.0
20AA-n3	296-	COM	-		-			
BM	327	6-15-79	348.	607.	8.6	-	21.	1.3
20DD-hl	147-	SCWRC	444.		8.1			
L/BM	521	12-20-82	-	996.	-	23.	230.	2.6
20DD-k2	72-	SCWRC	472.		8.7			
L	360	12-20-82	-	1198.	-	25.	318.	3.3
20DD-n3	119-	SCWRC	326.		8.0			
L/BM	500	4-27-82	-	-	-	21.	52.	3.2
20DD-n3	119-	SCWRC	415.		8.0			
L/BM	500	6-9-82	-	819.	-	21.	179.	2.5
20DD-ql	TD	SCWRC	-		8.3			
L/BM	500	3-3-81	457.	1110.	-	20.	323.	2.8
20EE-el	152-	DHEC	-		8.1			
L/BM	560	-	400.	1700.	-	-	620.	-
20FF-dl	Point Sample	SCWRC	-		-			
L	295	7-23-80	-	-	-	-	2400.	3.4
20FF-dl	Point Sample	SCWRC	-		-			
L	345	7-23-80	-	-	-	-	2500.	3.4
20FF-dl	Point Sample	SCWRC	-		-			
L	445	7-23-80	-	-	-	-	2700.	3.4
20FF-dl	Point Sample	SCWRC	-		-			
BM	495	7-23-80	-	-	-	-	2700.	3.5
20FF-dl	TD	SCWRC	-		-			
L/BM	545	7-23-80	-	-	-	-	2600.	3.4
20FF-vl	TD	COM	-		-			
BM	592	12-27-74	570	5070.	8.4	-	2390.	-
20FF-vl	TD	COM	-		-			
BM	638	12-27-74	580.	5413.	8.4	-	2560.	-
21Z-bl	40-	SCWRC	206.		7.4			
L/BM	249	2-8-82	-	271.	-	17.	12.	0.24
21Z-ul	85-	SCWRC	672.		8.0			
L/BM	540	2-8-82	-	1040.	-	19.0	93.	2.1
21AA-n2	347-	SCWRC	370.		8.8			
BM	398	1-12-82	-	502.	-	20.	37.	1.2
21BB-m2	515-	USGS	-		7.4			
BM	525	9-19-78	690.	1460.	-	27.	370.	2.1
21BB-r4	TD	SCWRC	40.		8.6			
L	385	12-82	-	909.	-			
21DD-nl	77-	SCWRC	-		7.15			
C/L	280	2-6-80	184.	295.	-	19.3	6.49	0.38
21DD-p2	165-	SCWRC	328.		8.8			
L/BM	540	10-25-82	-	549.	-	18.5	75.	-

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
215.		20.	300.	183.	1161.	-	1161.	-
-	-	-	-	-	-	36.	-	-
-		7.5	23.	3.9	0.	8.8	-	68.
-	-	7.3	0.	3.5	0.	8.8	42.4	62.
19.		4.4	10.	1.9	0.	-	42.	168.
-	-	-	-	-	-	-	-	-
-		3.1	30.	3.0	0.	12.7	-	450.
-	-	2.8	23.	2.9	0.	12.3	34.0	430.
-		4.0	123.	4.5	0.	16.6	-	540.
-	-	3.8	101.	4.4	0.	15.9	50.6	525.
-		9.1	290.	2.1	0.	13.6	-	185.
-	-	2.4	20.	2.0	0.	13.2	36.4	178.
24.7		4.3	50.	3.4	10.	17.3	-	306.
-	-	4.0	15.	3.3	5.	16.1	-	302.
3.4		5.75	33.	5.28	0.	18.8	-	346.
-	-	5.62	14.	4.87	0.	18.3	36.4	328.
62.		20.	600.	11.	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
250.		40.	50.	36.5	0.	-	12.	1778.
-	-	-	-	-	-	-	-	-
260.		42.	100.	37.6	0.	-	15.	1905.
-	-	-	-	-	-	-	-	-
144.		46.5	37.	6.76	0.	9.16	-	25.3
-	-	45.2	25.	6.45	0.	8.96	29.1	24.6
-		9.45	142.	5.61	0.	23.5	-	360.
46.9	-	9.40	115.	5.56	0.	22.9	44.3	340.
-		3.8	95.	1.7	0.	9.4	-	214.
-	-	3.6	27.	1.3	0.	9.2	43.	198.
36.		-	1400.	-	40.	-	-	-
-	-	7.4	70.	4.3	-	19.	29.	580.
-		3.6	82.	3.5	10.	14.5	-	395.
-	-	3.4	76.	3.5	8.	14.3	29.3	393.
125.8		-	-	-	-	-	-	-
-	-	42.4	83.	6.7	10.	1.8	15.64	17.1
-		4.6	45.	1.1	0.	11.1	-	218.
-	-	2.7	42.	1.1	0.	10.9	21.6	218.

Appendix B-2. Selected water-quality data from wells open to the Black Mingo Formation and/or the Santee Limestone.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
21DD-p3	TD	SCWRC 130.			8.9			
C/L	260	10-29-82	-	185.	-	18.	10.4	0.31
21DD-p4	80-	SCWRC	108.		8.8			
C/L	320	10-29-82	-	274.	-	20.	7.5	0.4
21DD-p4	80-	SCWRC	110.		7.7			
C/L	320	2-8-80	-	121.	-	18.9	5.49	0.11
21DD-p5	80-	SCWRC	116.		8.7			
C/L	300	10-29-82	-	165.	-	165.	8.5	0.4
21DD-q1	100-	SCWRC	110.		8.9			
C/BM	603	10-29-82	-	155.	-	17.5	7.5	0.4
21DD-q2	94-	SCWRC	110.		8.8			
L	364	10-29-82	-	191.	-	18.	8.0	0.4
21DD-q4	169-	SCWRC	374.		8.7			
L/BM	561	10-29-82	-	703.	-	17.	75.	1.9
21DD-r2	TD	DHEC	-		-			
L/BM	650	8-12-76	98.	196.	6.7	-	6.	0.39
21DD-x1	100-	SCWRC	90.		8.5			
C/BM	490	12-20-82	-	191.	-	12.	8.3	0.89
21DD-y3	84-	SCWRC	86.		8.9			
C/L	459	10-29-82	-	305.	-	16.	9.4	0.6
21EE-b1	TD	SCWRC	430.		8.6			
L/BM	578	12-20-82	-	1151.	-	24.	328.	3.4
21EE-d2	105-	COM	-		-			
L/BM	553	4-5-56	430.	1512.	-	-	47.	-
21EE-d2	105-	SCWRC	400.		8.4			
L/BM	553	12-20-82	-	1455.	-	14.	475.	4.1
21EE-e2	TD	SCWRC	314.		-			
L/BM	600	12-20-82	-	535.	7.9	13.	51.	2.1
21EE-e3	147-	SCWRC	372.		-			
L/BM	555	12-20-82	-	1028.	-	17.	299.	3.4
21EE-e4	155-	SCWRC	374.		8.7			
L/BM	581	12-20-82	-	1050.	-	20.	313.	3.4
21EE-e5	147-	SCWRC	390.		8.8			
L/BM	620	12-20-82	-	1499.	-	15.	509.	2.8
21EE-e5	147-	SCWRC	-		-			
L/BM	620	1-27-81	-	-	-	24.	730.	3.6
21EE-e6	129-	SCWRC	382.		9.1			
L/BM	525	12-20-82	-	837.	-	14.	220.	4.6
21EE-f3	TD	SCWRC	374.		8.7			
L	490	10-28-82	-	1380.	-	16.	410.	2.87
21EE-i1	132-	COM	-		8.3			
L/BM	602	10-15-56	435.	1136.	-	-	290.	-
21EE-j1	160-	SCWRC	387.		8.6			
L/BM	601	12-20-82	-	1185.	-	12.	370.	3.4
21EE-q1	192-	USGS	-		7.9			
L/BM	561	6-13-79	430.	1620.	-	21.	570.	3.2

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
-		43.5	104.	4.1	0.	2.2	-	-
-	-	42.7	100.	3.9	0.	1.6	20.1	7.8
-		28.4	140.	5.3	0.	2.9	-	15.1
-	-	27.7	125.	5.0	0.	2.7	30.4	14.1
85.27		33.0	3000.	0.75	6.2	1.05	-	5.0
-	-	33.3	691.	0.71	5.6	0.92	14.70	5.8
-		33.2	176.	3.6	0.	5.0	-	35.7
-	-	31.7	144.	3.3	0.	3.0	38.3	15.2
-		-	28.	5.8	0.	3.0	-	15.2
-	-	-	27.	5.4	0.	2.6	34.2	13.9
-		28.7	260.	4.5	0.	3.3	-	16.0
-	-	28.1	130.	4.3	0.	3.1	34.0	15.2
-		2.8	50.	1.5	0.	12.6	-	214.
-	-	2.8	41.	1.4	0.	12.0	49.	213.
29.		-	300.	-	250.	-	-	-
-	0.03	-	-	-	-	-	-	-
-		33.2	375.	1.2	29.	1.00	-	23.6
-	-	30.7	312.	1.0	20.	0.98	44.3	21.8
-		19.0	260.	6.3	0.	3.1	-	21.1
-	-	18.2	253.	5.8	0.	3.1	44.9	20.7
-		3.8	41.	3.4	0.	16.1	-	520.
-	-	3.4	27.	2.9	0.	15.0	369.	500.
40.		-	0.	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		7.2	315.	7.0	0.	22.5	-	670.
-	-	6.2	260.	6.9	0.	22.0	383.	650.
-		36.	535.	10.2	10.	11.5	-	190.
-	-	33.	360.	9.3	5.	10.0	36.9	170.
-		4.0	75.	3.9	0.	16.4	-	505.
-	-	3.9	60.	3.8	0.	16.0	33.1	490.
-		4.2	53.	3.9	0.	16.5	-	500.
-	-	4.1	40.	3.9	0.	16.0	44.3	481.
-		64.	62.	5.7	10.	21.3	-	772.
-		6.0	28.	4.9	4.	17.7	50.7	650.
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	2.8	40.	2.9	10.	100.	39.6	381.
-		7.2	60.	6.1	7.	23.1	-	470.
-	-	7.1	25.	6.1	0.	21.9	50.5	457.
4.5		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		4.8	262.	4.1	10.	16.0	-	546.
-	-	4.6	56.	4.0	4.	13.5	45.6	540.
42.		-	-	-	-	-	-	-
-	-	6.9	90.	6.1	6.9	18.	41.	560.

Appendix B-2. Selected water-quality data from wells open to the Black Mingo Formation and/or the Santee Limestone.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
21EE-yl	TD	DHEC	-		8.3			
L/BM	585	9-2-77	400.	1000.	-	-	320.	-
21FF-kl	470-	SCWRC	478.		7.9			
L/BM	580	6-27-80	-	-	-	-	1600.	4.0
22Y-al	TD	SCWRC	174.		7.4			
L/BM	200	2-4-82	-	216.	-	14.	6.9	0.16
22Y-wl	283-	SCWRC	178.		8.1			
BM	382	2-8-82	-	295.	-	19.7	6.1	0.39
22Y-w2	308-	USGS	170.		8.0			
BM	384	7-24-79	-	236.	8.0	21.5	4.2	0.3
22Z-v2	TD	USGS	-		7.5			
L	280	4-18-63	234.	232.	-	25.	7.0	0.2
22BB-ml	TD	USGS	-		8.3			
L	322	10-17-78	420.	511.	-	25.	51.	1.0
22BB-m2	TD	SCWRC	268.		8.6			
L	311	3-12-81	-	435.	-	20.	31.	0.9
22CC-L1	86-	USGS	-		8.2			
L/BM	525	6-27-79	320.	420.	8.5	21.	22.	1.8
22CC-w2	127-	SCWRC	-		-			
L/BM	521	1-27-81	-	-	-	20.	86.	1.5
22DD-bl	TD	COM	-		8.3			
L	430	3-69	112.	165.	-	-	8.	-
22DD-b2	TD	SCWRC	-		8.15			
L/BM	480	1-29-80	-	528.	-	21.5	37.98	1.36
22DD-tl	TD	SCWRC	-		7.15			
L	400	2-5-80	152.	180.	-	17.7	6.49	0.26
22EE-bl	126-	USGS	-		8.1			
L/BM	590	6-13-79	380.	831.	-	23.	200.	2.0
22EE-j3	TD	SCWRC	378.		8.6			
L/BM	581	10-28-82	-	1008.	-	19.	311.	2.7
22EE-j5	147-	SCWRC	-		-			
L/BM	655	1-29-81	-	-	-	20.	415.	2.6
22EE-hl	129-	SCWRC	210.		8.7			
L/BM	603	10-28-82	-	449.	-	15.	13.	0.3
22EE-h3	127-	SCWRC	370.		8.5			
L/BM	605	10-28-82	-	972.	-	20.	231.	2.4
22EE-h6	106-	SCWRC	382.		8.2			
L/BM	560	10-28-82	-	1023.	-	18.	269.	2.7
22EE-nl	148-	SCWRC	466.		8.1			
L/BM	641	10-27-82	-	1413.	-	23.	410.	3.0
22EE-r2	TD	SCWRC	442.		8.0			
L/BM	601	10-27-82	-	1226.	-	18.	377.	3.6
22EE-r3	148-	SCWRC	-		-			
L/BM	641	1-29-81	-	-	-	19.	415.	2.2
22EE-yl	220-	DHEC	-		8.1			
L/BM	632	5-31-74	390.	872.	-	-	450.	-

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
16.		-	100.	-	0.05	-	-	-
-	-	-	-	-	-	-	-	-
163.		25.	450.	23.1	3.	-	-	760.
-	-	-	-	-	-	-	56.1	-
145.		55.7	301.	1.3	15.	1.1	-	3.4
-	-	53.2	52.	1.3	13.	1.0	12.8	3.2
38.2		10.4	20.	2.96	0.	8.50	-	51.3
-	-	9.65	10.	2.84	0.	8.13	42.1	49.9
33.		-	-	-	-	-	-	-
0.	-	1.6	10.	2.6	0.	7.7	35.	61.
65.		16.	60.	62.	0.01	8.9	-	57.
-	-	-	0.	-	0.01	-	26.	-
17.		3.8	25.	2.0	0.	9.1	-	120.
-	-	3.4	10.	1.8	-	8.7	28.3	105.
-		3.8	25.	20.	0.	9.1	-	120.
-	-	3.4	10.	1.8	-	8.7	28.3	105.
11.		-	-	-	-	-	-	-
0.	-	2.4	0.	1.2	0.	8.6	27.	160.
120.		37.	1500.	5.6	69.	2.7	-	10.4
-	-	35.	1000.	4.4	59.	2.1	43.0	9.2
82.		24.	200.	5.2	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
107.6		40.4	160.	1.7	0.	2.19	-	13.2
-	-	40.5	58.	1.74	-	2.20	13.9	13.1
14.		-	-	-	-	-	-	-
-	-	2.8	10.	1.7	2.	11.	34.	330.
-		4.5	112.	3.6	5.	17.2	-	400.
-	-	4.5	93.	3.5	0.	16.7	53.3	380.
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		75.8	4680.	5.1	130.	2.2	-	13.6
-	-	72.7	3000.	4.8	110.	2.1	53.9	12.3
-		4.1	30.	2.6	0.	15.1	-	341.
-	-	3.9	10.	2.6	0.	14.6	44.6	327.
-		4.7	380.	3.8	5.	18.7	-	374.
-	-	4.6	180.	3.7	0.	17.6	51.4	353.
-		5.2	15.	3.6	4.	18.0	-	534.
-	-	5.0	0.	3.4	0.	16.7	45.6	504.
-		5.7	75.	3.8	6.	18.6	-	493.
-	-	5.0	65.	3.4	0.	17.2	44.7	470.
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
15.		1.5	400.	2.8	0.05	-	-	-
-	-	-	-	-	-	-	-	-

Appendix B-2. Selected water-quality data from wells open to the Black Mingo Formation and/or the Santee Limestone.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
22EE-y1	220-	SCWRC	350.		8.0			
L/BM	630	10-27-82	-	872.	-	21.	250.	26.
22EE-y2	106-	SCWRC	400.		7.6			
L/BM	604	10-27-82	-	1050.	-	17.	297.	2.8
22FF-e1	TD	SCWRC	-		8.4			
L/BM	604	3-10-81	416.	953.	-	200.	325.	2.3
22FF-j1	130-	USGS	-		-			
L/BM	532	10-25-72	535.	1940.	7.8	21.8	716.	1.8
22FF-p1	TD	DHEC	-		8.1			
L	518	5-31-74	460.	1700.	-	-	1200.	-
22FF-p2	TD	DHEC	-		8.2			
L	521	5-31-74	380.	1700.	-	-	1000.	-
22FF-p3	105-	SCWRC	446.		7.8			
L	561	10-27-82	-	1570.	-	18.5	584.	3.2
22FF-q1	106-	SCWRC	-		8.3			
L	561	1-24-80	587.2	1768.	-	14.6	668.	3.05
22FF-x1	106-	SCWRC	-		-			
L/BM	561	3-10-81	534.	3203.	-	17.0	1432.	3.5
22GG-w4	516-	DHEC	-		-			
L	545	3-14-74	980.	3066.	-	-	2300.	-
22HH-e1	TD	DHEC	-		-			
L	522	5-17-78	490.	1300.	8.0	-	440.	4.0
22HH-e2	TD	USGS	-		-			
L/BM	757	3-23-64	380.	1080.	7.4	-	401.	1.8
23Z-g1	58-	SCWRC	-		7.45			
L	238	2-4-80	-	121.	-	15.3	4.49	-
23Z-w1	TD	SCWRC	121.		8.0			
L	185	3-12-81	-	77.	-	17.	19.	05.
23DD-f1	TD	SCWRC	-		8.7			
L	406	2-7-80	336.	346.	-	19.1	23.	1.35
23DD-f2	85-	SCWRC	-		-			
L/BM	501	2-3-81	-	-	-	19.	19.3	1.5
23DD-s2	TD	SCWRC	-		8.55			
L/BM	527	2-5-80	-	626.	-	18.5	78.5	1.2
23EE-a1	TD	SCWRC	-		-			
L/BM	621	2-81	-	-	-	15.	413.	2.6
23EE-k1	TD	SCWRC	-		8.1			
L/BM	580	1-25-80	-	769.	-	19.5	224.	1.90
23EE-n1	120-	SCWRC	-		-			
L/BM	560	2-3-81	-	-	-	22.	34.1	1.6
23EE-s1	TD	DHEC	-		8.25			
L/BM	550	5-31-74	-	896.	-	19.6	247.9	1.8
23EE-y1	84-	SCWRC	-		8.45			
L/BM	540	1-25-80	-	504.	-	10.5	69.4	1.85
23FF-a1	TD	SCWRC	-		8.5			
L	340	3-26-80	490.	-	-	23.	260.	2.0

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
-		4.9	41.	3.3	0.	15.1	-	366.
-	-	4.1	30.	2.7	0.	14.6	41.1	336.
-		5.5	380.	4.4	0.	19.0	-	405.
-	-	4.8	310.	4.0	0.	17.2	46.9	383.
-		5.2	310.	4.0	0.	17.5	-	338.
-	-	5.2	60.	4.0	-	15.8	-	307.
50.		6.4	0.	8.2	12.	22.	36.	700.
-	0.	-	-	-	-	-	-	-
42.		2.9	30.	8.6	0.05	-	-	-
-	-	-	-	-	-	-	-	-
8.		0.6	600.	1.5	<0.05	-	-	-
-	-	-	-	-	-	-	-	-
-		8.5	480.	9.0	0.	26.0	-	646.
-	-	8.0	80.	8.3	0.	26.5	31.6	614.
48.73		7.5	252.	8.5	13.	19.2	-	558.
-	-	7.4	175.	8.0	6.	19.6	12.75	557.
-		18.9	260.	23.0	0.	42.2	-	600.
-	-	18.9	100.	22.0	-	41.3	41.7	582.
169.		20.	600.	29.	0.05	-	-	-
-	-	-	-	-	-	-	-	-
35.		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
70.		17.	1600.	6.8	20.	17.	17.	378.
-	0.6	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
0.18	-	-	-	-	-	-	-	-
-		28.	40.	8.4	0.	8.1	-	10.3
-	-	26.	15.	8.3	0.	8.0	40.7	8.5
6.09		2.2	0.	1.17	0.	7.0	-	153.
-	-	2.0	-	1.04	-	6.2	11.59	144.
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
22.		14.7	4000.	3.8	15.	16.0	-	330.
-	-	3.3	0.	2.0	9.	10.5	21.	320.

Appendix B-2. Selected water-quality data from wells open to the Black Mingo Formation and/or the Santee Limestone.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
23FF-kl	127-	SCWRC	-		8.2			
L/BM	561	6-12-74	580.	1327.	-	24.4	460.	2.1
23FF-u4	TD	SCWRC	538.		8.1			
L/BM	385	5-15-81	-	1502.	-	23.	450.	2.0
23HH-al	TD	USGS	520.		-			
L	550	7-19-79	-	1490.	8.2	25.	480.	5.3
23HH-a2	168-	USGS	-		-			
L	567	8-3-62	638.	1370.	8.1	-	420.	3.5
23HH-a3	346-	COM	-		-			
L	552	10-6-62	504.	1350.	-	-	382.	2.8
23HH-a4	129-	USGS	-		-			
L	549	10-18-56	631.	1360.	8.0	-	450.	3.2
24Y-bl	270	SCWRC	192.		-			
BM	489	1-12-82	-	274.	-	21.	5.6	0.5
24Y-hl	163-	SCWRC	240.		7.7			
BM	289	2-15-80	-	-	-	17.1	6.	0.26
24Y-i9	TD	SCWRC	162.		7.5			
L	56	3-17-80	-	244.	7.6	19.	11.0	0.1
25X-vl	TD	SCWRC	-		7.65			
L	52	5-18-80	108.	179.	-	20.	12.	0.13
25Y-tl	TD	SCWRC	-		7.5			
L	61	7-24-80	146.	162.	-	21.	6.7	0.28
25Z-il	TD	SCWRC	-		7.4			
L	25	5-7-80	224.	267.	-	20.	7.0	0.34
26Y-nl	330-	SCWRC	168.		7.9			
BM	370	1-12-82	-	196.	-	11.5	6.1	0.3

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
36.		6.2	57.	6.2	25.	14.9	-	560.
-	-	5.3	32.	5.9	20.	14.7	21.2	540.
48.		7.7	60.	6.9	0.	20.4	-	440.
-	-	6.4	0.	6.9	-	20.2	20.	440.
40.		-	-	-	-	-	-	-
-	-	4.3	30.	7.0	10.	16.	11.	570.
38.		6.0	270.	5.7	30.	17.	28.	530.
-	0.3	-	-	-	-	-	-	-
34.		13.6	50.	0.	-	-	-	-
-	-	-	-	-	-	-	-	-
37.		4.0	70.	6.6	0.	11.	36.	531.
-	2.3	-	30.	-	-	-	-	-
-		22.7	107.	3.0	0.	8.2	-	70.
-	-	7.5	24.	1.4	0.	6.9	28.9	70.
151.		52.	250.	3.6	6.	4.4	-	23.
-	-	52.	35.	3.6	3.	4.4	16.5	72.9
200.		56.	3200.	1.4	140.	0.3	-	6.3
-	-	53.	100.	1.2	80.	0.3	2.0	6.0
130.		48.	1700.	0.9	18.	0.9	-	5.2
-	-	45.	840.	0.9	17.	0.6	5.3	4.6
171.		28.	710.	7.3	5.	3.6	-	9.3
-	-	27.	85.	7.1	1.	3.4	23.1	9.1
200.		58.	520.	7.6	20.	1.6	-	8.2
-	-	54.	390.	7.6	18.	1.6	12.	8.1
-		23.6	496.	5.3	0.	12.3	-	46.
-	-	19.9	250.	4.7	0.	11.5	37.5	44.

Appendix B-3. Selected water-quality data for wells open to the Shallow Aquifers.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
12Z-x5	TD	SCWRC	-		7.5			
S	40	8-15-82	-	256.	-	23.	16.	0.1
12AA-c1	TD	USGS	230.		7.2			
S	60	7-13-79	-	322.	7.4	23.5	33.	0.1
14AA-k1	7.5-	SCWRC	-		6.7			
S	9.5	7-30-80	-	386.	-	26.	13.	0.17
14BB-g1	TD	SCWRC	100.		6.7			
S	20	6-19-80	-	121.	7.9	18.8	18.	0.
15BB-w2	TD	SCWRC	-		6.8			
S	35	6-25-80	-	202.	-	21.	19.	0.16
15CC-f1	TD	SCWRC	160.		7.4			
S	30	6-23-80	-	292.	-	21.	37.	0.26
16Y-q1	TD	SCWRC	-		-			
S	15	7-22-80	-	126.	-	-	8.3	0.15
16AA-c1	TD	SCWRC	9.3		6.0			
S	20	7-10-80	-	117.	-	23.	11.	0.
16CC-j3	TD	COM	-		-			
S	52	9-22-80	166.	397.	7.7	-	53.	0.4
16CC-j4	TD	COM	-		-			
S	60	8-4-80	120.	238.	8.0	-	27.	0.2.
16CC-r3	TD	SCWRC	114.		7.5			
S	28	7-31-80	-	197.	-	22.7	12.	0.15
16DD-11	TD	SCWRC	93.		7.8			
S	15	6-10-80	-	346.	8.0	21.	43.	0.8
17X-11	TD	SCWRC	-		7.8			
S	43	2-14-80	-	153.	-	17.	5.7	0.13
17DD-g1	TD	COM	-		-			
S	39	8-16-61	101.	160.	7.8	-	-	-
17DD-g5	TD	COM	-		-			
S	65	9-7-61	77.	160.	7.5	-	-	-
17DD-m11		SCWRC	-		-			
S		1-23-81	-	-	-	-	34.	0.7
17DD-m13	TD	SCWRC	66.		6.0			
S	15	6-19-80	-	227.	7.7	20.	33.	0.
18W-a7	TD	USGS	-		5.1			
S	23	4-19-78	2.	60.	-	21.	7.6	0.
18W-r1	TD	SCWRC	-		7.6			
S	34	6-25-80	-	155.	-	23.	4.0	0.15
18Y-i1		SCWRC	-		7.7			
S		7-80	-	140.	-	19.	8.9	0.2
18CC-k1	TD	SCWRC	41.		5.9			
S	15	7-22-80	-	559.	-	22.	190.	0.27
18EE-i2	TD	SCWRC	-		8.0			
S	80	8-31-82	-	183.	-	17.5	31.	0.5
18EE-11	TD	SCWRC	124.		8.0			
S	58	5-13-80	-	368.	7.5	20.	97.	0.22

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
160.		59.3	983.	2.5	219.	1.3	-	9.9
-	-	55.3	933.	2.3	190.	1.2	-	9.5
210.		-	-	-	-	-	-	-
-	-	73.	670.	7.5	190.	6.2	40.	22.
80.		26.	23100.	2.6	217.	1.7	-	11.3
-	-	22.	15900.	2.3	115.	1.3	47.3	10.3
85.		23.	12000.	3.0	120.	0.7	-	12.6
-	-	22.	10800.	2.9	110.	0.7	19.3	12.1
74.		28.	90.	1.8	80.	1.9	-	13.2
-	-	23.	50.	1.5	57.	1.7	3.2	12.9
190.		62.	3100.	4.8	120.	1.6	-	15.3
-	-	61.	3000.	4.7	110.	1.6	16.7	14.5
33.		4.9	30600.	1.0	108.	3.6	-	7.8
-	-	3.1	14700.	0.85	83.	3.6	8.6	5.3
20.		2.8	1300.	1.2	15.	3.9	-	10.2
-	-	2.4	170.	1.1	0.	3.8	11.8	9.7
182.		-	-	-	-	-	-	-
-	-	65.	10.	4.9	0.	-	44.	41.6
114.		-	-	-	-	-	-	-
-	-	45.	200.	0.5	-	-	-	20.
126.		28.	1500.	1.1	42.	0.5	-	7.2
-	-	26.	790.	1.1	35.	0.5	12.6	7.2
130.		39.	460.	10.9	39.	4.0	-	8.8
-	-	37.	84.	10.1	31.	4.0	16.3	8.0
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
92.		35.	-	1.0	-	-	-	-
-	-	-	-	-	-	-	-	-
94.	-	-	1.0	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
120.		30.	6200.	8.6	210.	4.0	-	20.
-	-	29.	6000.	7.6	170.	3.5	7.7	20.
21.		-	-	-	-	-	-	-
-	-	3.1	40.	3.2	30.	2.5	80.	6.2
134.		48.	1600.	1.5	63.	1.3	-	5.6
-	-	46.	410.	1.4	43.	1.3	9.8	4.5
142.		33.	320.	2.4	10.	1.3	11.8	6.2
-	-	28.	140.	2.3	9.	1.2	-	6.2
90.		34.	2600.	3.9	51.	1.3	-	110.
-	-	32.	580.	3.5	33.	1.3	69.5	60.
100.		36.2	100.	2.3	15.	2.3	-	28.7
-	-	-	-	-	-	-	-	-
190.		55.	520.	14.0	60.	15.4	-	43.
-	-	53.	270.	14.0	60.	15.0	6.2	43.

Appendix B-3. Selected water-quality data for wells open to the Shallow Aquifers.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
18FF-al	TD	SCWRC	-		7.5			
S	13	5-7-82	-	409.	6.3	18.7	110.	1.2
19V-v3	TD	SCWRC	14.		6.3			
S	55	6-25-80	-	34.	-	23.	4.0	0.12
19Y-hl	TD	SCWRC	6.		5.6			
S	15	7-1-80	-	42.	-	21.	8.9	0.12
19Z-gl	TD	SCWRC	30.		5.3			
S	8	5-14-80	-	100.	-	17.	27.	0.1
19EE-p2	TD	SCWRC	134.		-			
S	58	5-8-80	-	136.	8.1	20.3	16.	0.16
20Z-v5	TD	SCWRC	52.		6.8			
S	60	7-3-80	-	98.	-	21.	6.2	0.
20AA-rl	TD	SCWRC	178.		7.3			
S	45	6-27-80	-	186.	-	24.	12.	0.3
20DD-pl	TD	SCWRC	113.		8.2			
S	58	5-13-80	-	161.	7.5	21.5	12.	0.22
20EE-rl	TD	SCWRC	76.		8.1			
S	50	5-8-80	-	134.	7.8	22.5	9.9	0.11
20FF-hl	12-	SCWRC	100.		7.9			
S	18	5-8-80	-	265.	7.2	21.5	-	33.
21AA-vl	TD	SCWRC	168.		7.6			
S	35	7-28-80	-	250.	-	21.6	7.3	.17
21BB-14	TD	SCWRC	-		7.8			
S	18	2-4-80	-	180.	-	17.	122.	1.9
21DD-ml	TD	SCWRC	56.		7.8			
S	60	6-4-80	-	101.	6.3	21.	10.	0.19
21EE-hl	TD	SCWRC	120.		7.9			
S	60	6-5-80	-	187.	6.9	22.5	17.	0.14
21FF-el	TD	SCWRC	140.		8.0			
S	30	6-11-80	-	140.	7.9	21.	71.	0.48
21FF-sl	TD	SCWRC	176.		9.3			
S	30	5-8-80	-	261.	7.9	23.	2.2	0.22
21GG-el	TD	SCWRC	56.		8.0			
S	30	6-11-80	-	104.	8.2	22.	10.	0.11
22BB-fl	TD	SCWRC	4.0		5.1			
S	25	7-2-80	-	112.	-	18.	12.	0.'
22CC-v2	TD	SCWRC	130.		8.4			
S	65	6-5-80	-	210.	7.5	19.5	5.3	0.18
22EE-h5	TD	SCWRC	230.		8.1			
S	35	6-5-80	-	277.	7.3	20.	12.	0.23
22FF-gl	TD	SCWRC	192.		8.1			
S	35	6-5-80	-	281.	7.4	24.	30.	0.25
22FF-j2	TD	COM	-		-			
S	52	5-19-70	120.	260.	7.5	-	53.6	0.6
22GG-nl	TD	SCWRC	2.		7.5			
S	10	6-12-80	-	34.	5.5	20.5	20.	0.0

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
110.		20.	7500.	13.0	80.	12.1	-	72.
-	-	18.	7400.	13.0	70.	12.0	7.8	70.
-		4.4	1800.	0.7	6.	1.9	-	3.0
-	-	4.3	1000.	0.7	5.	1.9	17.5	2.5
131.		0.2	11600.	0.3	15.	0.52	-	6.2
-	0.	0.2	2200.	0.27	8.	0.45	7.5	6.2
30.		6.8	1100.	3.4	0.	4.8	-	11.
-	-	5.5	30.	3.4	0.	4.7	1.0	10.1
130.		45.	1500.	2.0	50.	1.3	-	12.
-	-	42.	730.	1.9	50.	1.1	5.4	12.
39.		24.	7500.	1.3	80.	1.3	-	9.1
-	-	10.2	3300.	0.4	79.	0.7	28.7	6.6
175.		34.	3400.	7.3	27.	1.6	-	10.3
-	-	27.	3100.	6.9	26.	1.6	36.2	10.3
120.		44.	2000.	1.4	34.	0.8	-	7.1
-	-	42.	760.	1.4	31.	0.8	7.7	6.8
80.		27.	960.	2.3	33.	1.0	-	6.3
-	-	25.	260.	2.3	30.	1.0	20.5	6.1
130.		45.	890.	4.6	80.	2.4	-	15.
-	-	43.	600.	4.4	80.	2.4	10.9	15.
159.		36.	4500.	8.5	112.	2.5	-	10.8
-	-	36.	1900.	8.2	94.	2.3	41.7	10.8
-		-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
40.		18.	82.	1.2	13.	1.2	-	6.3
-	-	13.	22.	0.8	12.	0.8	9.2	5.3
84.		36.	60.	3.8	22.	2.5	-	14.2
-	-	35.	24.	3.7	21.	2.5	6.4	13.1
140.		45.2	50.	7.4	180.	4.2	-	49.
-	-	45.2	71.	6.2	47.	3.7	51.8	49.
99.		33.	250.	3.0	28.	1.8	-	16.
-	-	32.	90.	3.0	22.	1.7	19.	15.
74.		29.	12000.	2.5	110.	1.8	-	5.3
-	-	22.	0.	1.4	38.	1.0	7.0	4.9
22.		1.4	1400.	1.1	10.	2.6	-	10.9
-	-	1.3	130.	0.9	5.	1.9	9.2	8.6
120		37.	1500.	5.6	69.	2.7	-	10.4
-	-	35.	1000.	4.4	59.	2.1	43.	9.2
190.		69.	5100.	4.5	140.	2.0	-	12.6
-	-	64.	5100.	4.1	110.	1.9	35.1	12.6
200.		66.	500.	4.1	96.	0.9	-	23.
-	-	66.	360.	3.7	96.	0.9	47.3	23.
118.		32.	0.0	9.3	0.0	-	-	-
-	-	-	-	-	-	-	-	-
26.		2.5	3000.	3.7	42.	0.7	-	11.3
-	-	2.4	171.	3.7	41.	0.7	11.6	10.9

Appendix B-3. Selected water-quality data for wells open to the Shallow Aquifers.

Well Number Aquifer System	Sampled Interval	Analysis by /Date	Alkalinity Field/Lab	Total Dissolved Solids	pH Field/Lab	Temperature Field	Chloride	Fluoride
22GG-q3	TD	SCWRC	60.		6.9			
S		4-24-81	-	177.	-	22.	63.	0.3
22GG-q4	TD	SCWRC	112.		7.1			
S	10	4-29-81	-	473.	-	24.	208.	0.18
22GG-w6		SCWRC	184.		7.1			
S		4-24-81	-	547.	-	22.	104.	0.21
22GG-x5		SCWRC	164.		6.9	-		
S		4-29-81	-	309.	-	-	-	0.17
23Y-tl	TD	SCWRC	2.0		4.8			
S	9	5-14-80	-	41.	-	21.	2.6	0.
23Z-ql	TD	SCWRC	-		4.85			
S	20	5-6-80	-	71.	-	17.5	9.0	0.1
23AA-bl	TD	SCWRC	4.0		4.9			
S	18	5-6-80	-	30.	-	17.5	18.	0.1
23DD-xl	TD	SCWRC	162.		8.3			
S	56	5-21-80	-	228.	8.7	20.7	22.	0.3
23EE-ll	TD	SCWRC	4.0		7.4			
S	55	5-12-80	-	55.	5.4	21.	7.0	0.1
23FF-u2	TD	SCWRC	140.		8.2			
S	52	6-6-80	-	280.	7.6	21.	20.	0.19
24Z-wl	TD	SCWRC	8.0		5.65			
S	25	6-27-80	-	70.	-	23.	8.9	0.
26Z-ul	TD	SCWRC	34.		6.9			
S	20	6-30-80	-	104.	-	22.	6.7	0.

Hardness Total Noncarbonate	Nitrate	Calcium Total Dissolved	Iron Total Dissolved	Magnesium Total Dissolved	Manganese Total Dissolved	Potassium Total Dissolved	Silica Total Dissolved	Sodium Total Dissolved
116.		39.6	960.	3.9	35.	1.5	-	15.0
-	-	38.4	930.	3.6	30.	1.4	-	14.7
209.		69.2	926.	8.4	47.	2.0	-	48.0
-	-	67.3	40.	8.3	35.	1.8	-	48.0
206.		68.1	135.	8.7	130.	4.6	-	62.0
-	-	66.9	120.	8.4	128.	4.5	-	62.0
143.		52.0	410.	3.0	234.	1.5	-	25.3
-	-	51.0	303.	2.9	225.	1.4	-	23.7
16.		1.8	1500.	0.5	6.	1.9	-	1.0
-	-	1.2	160.	0.5	5.	1.9	10.1	0.8
18.		4.4	900.	1.0	23.	1.8	-	20.
-	-	4.1	410.	1.0	11.	1.6	0.	1.6
27.		2.9	10000.	2.2	39.	2.3	-	8.5
-	-	2.6	790.	2.2	21.	2.2	2.0	8.4
130.		47.	490.	4.8	100.	3.3	-	27.
-	-	45.	190.	4.8	90.	3.3	28.	26.
4.0		0.5	1200.	0.7	15.	0.8	-	3.8
-	-	0.5	950.	0.7	11.	0.7	1.3	3.0
140.		43.	260.	3.8	89.	1.6	-	16.8
-	-	43.	180.	3.7	83.	1.4	36.8	15.8
22.		3.2	4100.	1.1	23.	4.3	-	3.8
-	-	3.0	3700.	0.94	18.	3.6	2.1	3.5
49.		13.6	21400.	1.5	153.	1.6	-	4.1
-	-	13.2	4700.	1.4	57.	1.3	12.2	3.8