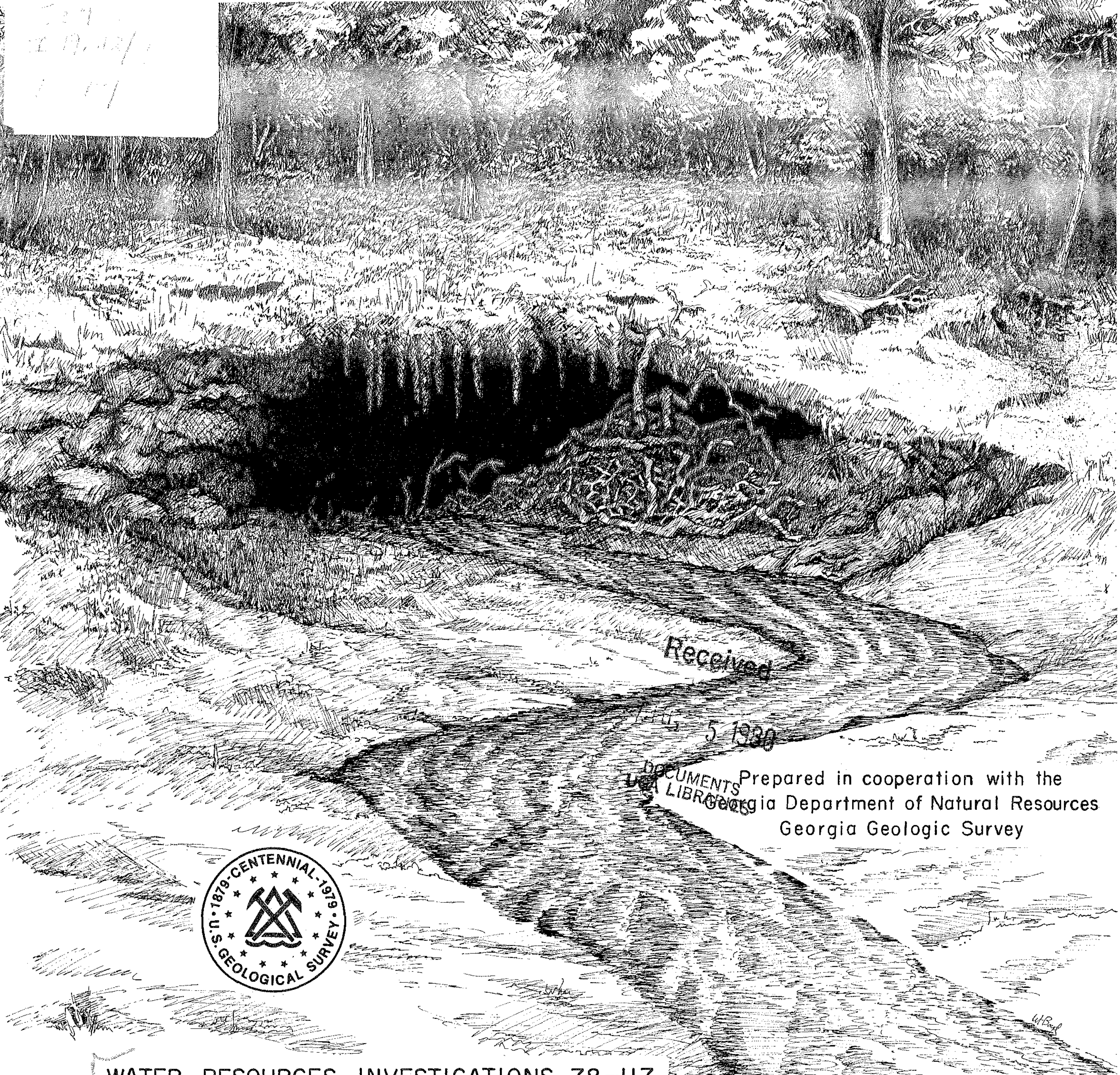

Prepared in cooperation with the
Georgia Department of Natural Resources
Georgia Geologic Survey

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U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS 78-117

GEOHYDROLOGY OF BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOHYDROLOGY OF BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA

By R. E. Krause

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UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

Open-File Report

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Doraville, Georgia 30360

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply inch-pound units	By	To obtain SI units
feet (ft)	0.3048	meters (m)
inches (in)	2.540	centimeters (cm)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
	43.81	liters per second (L/s)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
	28.32	liters per second (L/s)
cubic feet per second per square mile [$(ft^3/s)/mi^2$]	10.93	liters per second per square kilometer [$(L/s)/km^2$]
Specific capacity		
gallons per minute per foot [(gal/min)/ft]	0.207	liters per second per meter [(L/s)/m]
Transmissivity		
feet squared per day (ft^2/d)	0.0929	meters squared per day (m^2/d)

GEOHYDROLOGY OF BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA

By

R. E. Krause

ABSTRACT

The principal artesian aquifer is the main source of water supply for Brooks, Lowndes, and western Echols Counties in south Georgia. The aquifer is chiefly a limestone of Eocene to Miocene age that crops out in some of the study area but is as much as 200 feet below land surface in other parts of the area. Pumpage of about 22 million gallons per day from this prolific aquifer in the area has not posed any problems of declining water levels or depletion of the reservoir.

Water-quality problems, however, do occur, especially in the immediate Valdosta area. The Withlacoochee River north of Valdosta contributes an average of 112 cubic feet per second of recharge water into caverns and sinks in the aquifer. Wells near the recharge area withdraw water that has an iron concentration and a color intensity that exceed standards for drinking water.

South of Valdosta, water from the aquifer contains as much as 3.0 milligrams per liter of hydrogen sulfide, rendering the water undesirable for drinking.

Below 550 feet in the lower part of the aquifer in Valdosta, and most likely at that depth throughout the study area, water has a high sulfate concentration. Generally, sufficient quantities of freshwater can be obtained without drilling to this depth.

INTRODUCTION

The Valdosta area comprising Brooks, Lowndes, and western Echols Counties is a relatively high ground-water use area, pumping more than 20 Mgal/d from the principal artesian aquifer. The complex relation of the artesian water to surface-water flow and recharge complicates water management in the Valdosta area. Water-quality problems result locally from stream water, which is high in color and iron, recharging the principal artesian aquifer and being withdrawn by wells prior to sufficient quality improvement. Hydrogen sulfide is also present in objectionable amounts in ground water in the Valdosta area. Wells have been abandoned because they yielded water with high color intensity and hydrogen sulfide concentration.

Regionally, wells drilled deeper than about 550 ft yield water high in sulfate concentration. In those wells that tap the lower zone of the principal artesian aquifer in Valdosta and Clyattville, sulfate concentrations exceed Georgia Environmental Protection Division safe drinking water standards (1977). Pumpage from the upper freshwater zone has caused a slight head differential between the two zones, allowing poorer quality water to migrate vertically into the freshwater zone. These water-quality problems may affect the selection of well sites and overall water management in the Valdosta area.

Water quality of the Withlacoochee River is affected by municipal sewage effluent. During low-flow periods, most or sometimes all of the flow upstream from the sewage-treatment plant on Sugar Creek in Valdosta (location, fig. 7) goes into the principal artesian aquifer through sinkholes. The low-flowing Withlacoochee River then receives flow from Sugar Creek (largely effluent) and the river water quality is affected as far downstream as the Georgia-Florida State line.

Purpose and Scope

The intent of this study was to (1) determine the availability and quality of water in the principal artesian aquifer in Brooks, Lowndes, and western Echols Counties, (2) study discharge from and recharge to the aquifer, both quantitatively and qualitatively, and relate precipitation, evapotranspiration, and streamflow to ground-water levels where recharge to the aquifer occurs, and (3) identify problems regarding water quality and find alternatives for solution of those problems.

The study lasted 3 years and involved collecting water-use data; measuring ground-water levels; sampling well, spring, and river water for physical and chemical analyses; and measuring streamflow to determine gains and losses. A test well was drilled in Valdosta so that individual water-bearing units could be isolated and their water level and water quality determined. Cores from the test well were described and geophysical well logs were run.

Location and Extent of Study Area

Brooks, Lowndes, and western Echols Counties include about 1,130 mi^2 in south Georgia, adjacent to the Georgia-Florida State line (fig. 1). All of Brooks and Lowndes Counties and Echols County west of longitude 83° make up this study area. The study was concentrated in the Valdosta area, as that is the center of greatest population; the largest industrial, commercial, and population growth; and the most problems regarding the development and management of ground water.

Topography of the study area varies from low, rolling hills in Brooks County to a relatively flat plain in Echols County. The altitude ranges from about 70 to 290 ft and the topographic slope is toward the southeast. The Withlacoochee River system (location, pl. 1) drains the western half of Lowndes County and all of Brooks County except the southwest corner. The Alapaha River system drains the eastern half of Lowndes County and all of Echols County within the study area. The entire study area is marked by

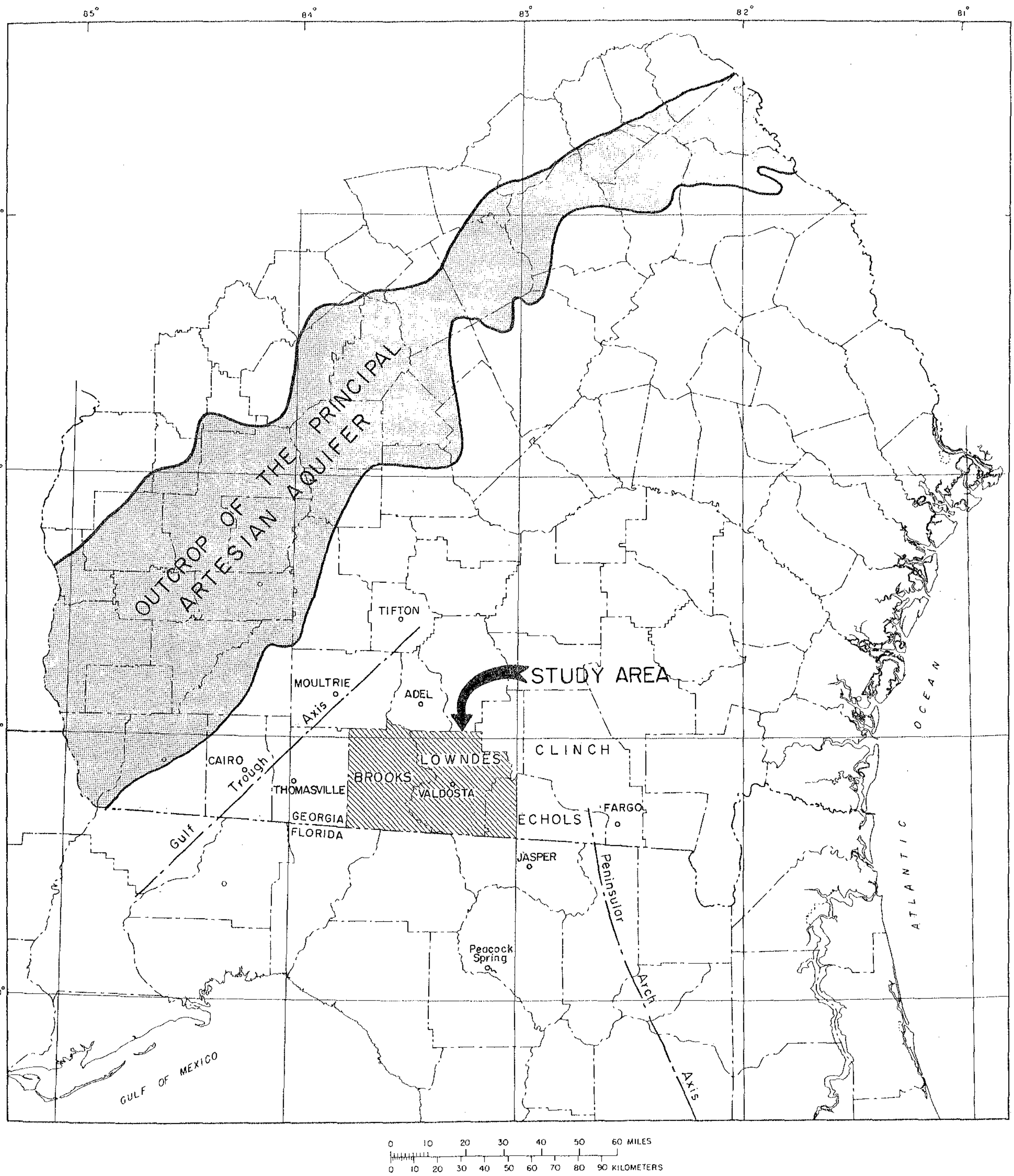


Figure 1.—Location of study area, outcrop of the principal artesian aquifer, and selected structural features.

swamps and bogs, either along very small streams, or landlocked with no outlet for surface flow. The study area also has many sinkholes and sinkhole lakes, especially in the southern part of Lowndes County.

PREVIOUS STUDIES

The Brooks-Lowndes-Echols County area had previously been studied only as a part of general investigations of the Coastal Plain of Georgia and Florida. Other more detailed studies have discussed certain aspects of the hydrology for parts of the study area.

McCallie (1898 and 1908) included one well in Quitman, two wells in Valdosta, and two springs on the Withlacoochee River in a discussion of the artesian water in the Coastal Plain of Georgia.

Stephenson and Veatch (1915) included the area in a broad areal study of the geology and ground-water resources of the Coastal Plain of Georgia. Water-quality information is included in that report in sections by Dole. This work, and that of McCallie, although giving interesting historical information on the artesian water system, are outdated and of limited utility. Warren (1944) also included the study area in a report on the artesian water of the Coastal Plain of Georgia.

Herrick (1961) included 24 wells in the study area in a tabulation of lithologic and paleontologic well logs of the Coastal Plain. Most of the logged wells are shallow and do not completely penetrate the water-bearing limestones of the Tertiary System, but the report remains the most comprehensive of its kind. Herrick and Vorhis (1963) interpreted and used data from Herrick (1961) in their report on the subsurface geology of the Coastal Plain of Georgia. They mapped the stratigraphy (altitude of tops and thicknesses) and showed geologic sections of formations from Cretaceous through Holocene age, with emphasis on the Tertiary formations.

Stringfield (1966) is the most comprehensive reference on the artesian water from Tertiary limestone in the Southeastern States. The current study area is included in his report on the geology, artesian water, and ground-water surface-water relations of the Southeastern States.

Vorhis (1961) made a short study of surface reservoir possibilities in northern Lowndes County. The study did not add much new data on the hydrology of the area because of its limited duration and scope. It did, however, state many of the conditions and problems relating to the hydrology of the study area.

Acknowledgments

This investigation was made by the U.S. Geological Survey in cooperation with the Georgia Department of Natural Resources, Georgia Geologic Survey. T. M. Kramer, formerly of the Georgia Geologic Survey, assisted in early field work and geologic and geochemical interpretations.

The ground-water data gathered for this report would have been unobtainable without the cooperation of the many property owners who allowed use of their wells for water-level measurements and for water-sampling purposes, and who gave construction information on their wells. Assistance was also given by M. B. Price, R. L. Bond, D. A. Moody, and Raymond Sutton of the city of Valdosta regarding historical and current information and for obtaining permission to measure and sample city supply wells. E. W. Hull of Moody Air Force Base, and John Rogers and Ormond Rolfe of Owens-Illinois Co., aided in collecting well data, measuring water levels, and sampling wells at their respective installations.

Valuable information regarding the geology, hydrology, water quality, and well construction was given by water-well contractors in the area. Special thanks are due Frank Creasy, Dayton Everetts, and R. H. Davis.

GEOLOGY

The study area is underlain by more than 2,000 ft of Cenozoic marine sediments (Toulmin, 1955). Consolidated rocks of Tertiary age, chiefly carbonates, crop out along the Withlacoochee River and elsewhere in the area, and are overlain by as much as 200 ft of Tertiary and Quaternary deposits of sand, silt, and clay. Plate 1 shows the thickness of post-Oligocene sediment in the study area.

Stratigraphic Section

The Paleocene and lower Eocene Wilcox Group ranges from about 200 to 400 ft in thickness (table 1). The Wilcox Group consists of lignitic, glauconitic fossiliferous clay and marl; fine to coarse sand; and some sandy limestone in the study area, but downdip toward the southeast it grades into limestone. The transition zone between the updip sand and downdip limestone trends northeast-southwest through the southeast corner of the study area (Herrick and Vorhis, 1963). The Wilcox Group is a granular, glauconitic, somewhat fossiliferous limestone in the southeast corner of the study area. Generally, only oil-test wells have been drilled deeply enough to penetrate the Wilcox Group.

The middle Eocene Claiborne Group overlies the Wilcox Group, and is a dense, highly calcitized glauconitic fossiliferous limestone containing interbedded dolomite and anhydrite, gypsum, and other evaporites. Gypsum is abundant, especially in highly fossilized zones. The Claiborne Group ranges from about 500 to 900 ft in thickness in the study area. It is the oldest geologic unit penetrated by the U.S. Geological Survey test well 1, well 185-60-68 (location, pl. 8) in Valdosta (fig. 2).

The upper Eocene Ocala Limestone overlies the Claiborne Group in the study area. The Ocala Limestone is a cream to white fossiliferous limestone containing abundant interbedded dolomite. The dolomite is secondary in origin, wherein magnesium replaced calcium. In some places, voids in the rock

Table 1.--Generalized stratigraphy and water-bearing and water-quality characteristics of Paleocene to Pleistocene formations, Brooks, Lowndes, and western Echols Counties.

SERIES		STRATIGRAPHIC UNIT		THICKNESS, IN FEET	LITHOLOGY	WATER-BEARING CHARACTERISTICS		WATER-QUALITY CHARACTERISTICS
Pleistocene and Pliocene		Undifferentiated		0-100	Fine to coarse sand and gravel.	Coarse material yields small domestic supplies to dug or jetted wells. Deep material yields more water to drilled wells. Clay acts as confining layer for underlying artesian aquifer.		Generally of good quality; low hardness and dissolved solids.
Miocene		Miccosukee Formation (Hendry and Yon, 1967)			Yellow to red-brown clayey sand, silt, clay, and gravel.			
		Hawthorn Formation		0-175	Clay, claystone, silt, sand, marl, and cherty sandy phosphatic limestone.	PRINCIPAL ARTESIAN AQUIFER	Very prolific water-bearing unit, with the Suwannee Limestone chiefly utilized. Greatest porosity and yield in zones at formation contacts where the limestone has been eroded, and in zones of secondary porosity caused by jointing and solutioning. Porosity and yield decrease with depth below the Suwannee Limestone.	Good quality, calcium bicarbonate type water with dissolved solids less than 250 mg/L. High iron and color in recharge areas; high hydrogen sulfide south of Valdosta.
Oligocene		Suwannee Limestone		100-200	Yellow to white, fossiliferous, porous, crystalline limestone.			
Eocene	upper		Ocala Limestone	350-700	White, fossiliferous, porous limestone and interbedded dolomite.			Calcium, magnesium sulfate type water with dissolved solids greater than 2,800 mg/L. Very hard and high in most constituents, including strontium.
	middle	Claiborne Group	Undifferentiated	500-900	Dense, calcitized, glauconitic, fossiliferous dolomitic limestone containing evaporites.			
	lower	Wilcox Group	Undifferentiated	200-400	Carbonaceous, fossiliferous, glauconitic clay and marl; sand and sandy limestone.	Not a significant water-bearing unit because of less porosity and greater depths than units above.		No data available.
Paleocene								

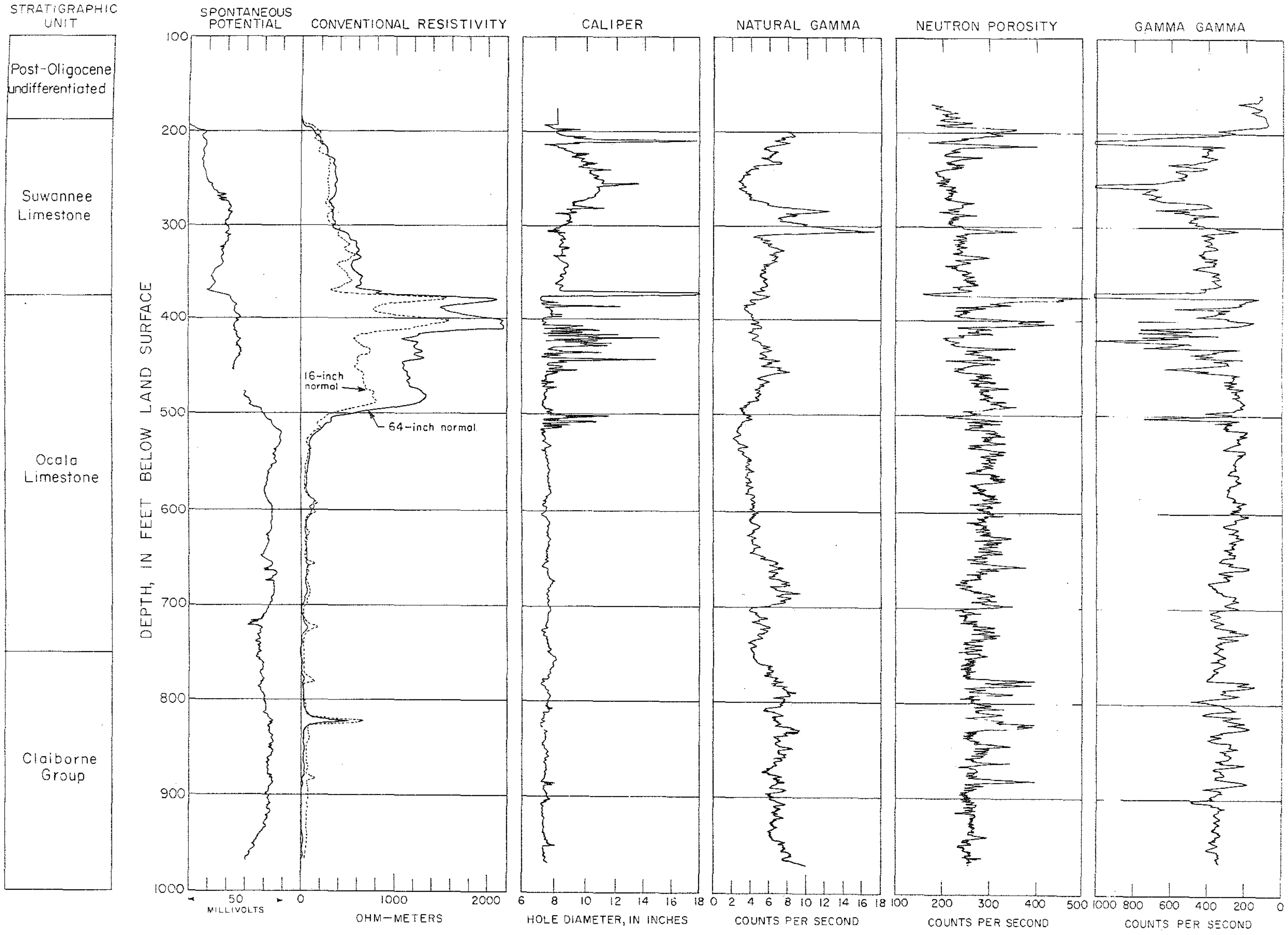


Figure 2.—Geophysical well logs, test well 1, Valdosta.

have been filled by quartz, and by gypsum and other evaporites. The Ocala ranges from about 350 to 700 ft in thickness in the study area. It has primary and well-developed secondary porosity, including large solution cavities and caverns. Secondary porosity is attained after deposition, and is mainly due to fracturing and solutioning.

Porosity is greatest at the interface between the Ocala Limestone and the overlying Suwannee Limestone of Oligocene age. Large cavities and caverns, produced by erosion and solutioning, are common at this interface. Geophysical logs of test well 1 in Valdosta show the top of the Ocala Limestone to be about 375 ft below land surface. (See fig. 2.) Caliper and accoustic televiewer logs indicate the presence of a 4-ft cavity at 375 ft. Fisk and Exley (1977) note that the Peacock Springs cave system in northern Florida is at this Eocene-Oligocene contact.

The Suwannee Limestone of Oligocene age unconformably overlies the Ocala Limestone, and is the oldest formation to crop out in the study area (pl. 2). The Suwannee is a yellow to white fossiliferous porous crystalline limestone ranging from about 100 to 200 ft in thickness. The formation is exposed along the Withlacoochee River from the Georgia-Florida State line to within about 8 river miles of U.S. Highway 84. The river has eroded through the overlying sediments and into the Suwannee Limestone, which was uplifted during the Miocene (pls. 1 and 2).

A highly porous zone is at the contact between the Suwannee Limestone and the overlying limestones of Miocene age. Large springs near the Georgia-Florida State line are at this interface. Caliper and accoustic televiewer logs of test well 1 in Valdosta show a cavernous zone at 210 ft below land surface (fig. 2). The zone is most likely in the upper part of the Suwannee Limestone, which was extensively weathered before deposition of the Miocene beds. In some areas, parts of the Suwannee Limestone are included in the Miocene beds.

The Hawthorn Formation of Miocene age unconformably overlies the Suwannee Limestone, except in areas where the Hawthorn Formation has been eroded away or is breached by sinkholes and sinkhole lakes. The Hawthorn Formation consists of clay, claystone, sand, limestone, and marl, locally cherty and commonly phosphatic. The upper part of the formation is made up of clastics, and the lower part is a brown cherty sandy limestone that is highly porous and contains breccia. The breccia is rock made up of angular chert or agate fragments.

The limestone in the lower part of the Hawthorn Formation is somewhat similar in lithology to the underlying Suwannee Limestone. The thickness of the limestone part of the Hawthorn is less than 100 ft and it generally ranges from about 20 to 60 ft thick. The entire Hawthorn Formation is less than about 175 ft thick. The formation crops out along streams, flood plains, swamps, and other areas of low altitude (pl. 2).

The Miccosukee Formation as used by Hendry and Yon (1967) crops out in the upland areas, mainly in Brooks and western Lowndes Counties (pl. 2).

The Miccosukee, which overlies the Hawthorn Formation, consists of yellow to red-brown clayey sand, clay, silt, and gravel, commonly crossbedded and lenticular. Deposition of the formation was continental to near-shore marine (Weimer and Hoyt, 1964; Hendry and Yon, 1967), and the age has generally been accepted as late Miocene to early Pliocene.

Pliocene and Pleistocene sands and gravels overlie the Miccosukee Formation and crop out mainly in the immediate Valdosta area and on the uplands toward the northeast, and in eastern Lowndes and western Echols Counties. The Pliocene and Pleistocene sands and gravels and the Miccosukee Formation attain a maximum thickness of about 100 ft.

Geologic Structure

Clastic sediments of gravel, sand, silt, and clay and the carbonate formations in the study area are nearly flat lying, but generally thicken and dip gently toward the south-southeast. This structural attitude is related to the slight seaward tilting of the Coastal Plain and the advance and retreat of the sea in a north-northwest and south-southeast direction.

Deposition of sediments in the area was controlled by structural and tectonic factors. Large depositional basins lie north of the study area and were oriented in a northeast-southwest direction. In contrast, arches or anticlines south and southeast of the area influenced the thickness and dip of the sediments. Uplift of the Coastal Plain sediments occurred from time to time in different areas in Georgia and Florida. The most notable was during the early Miocene at the northern end of the Peninsular Arch (fig.1) in Florida (Vernon, 1951), which caused extensive erosion of the Oligocene sediments to the extent that the Oligocene is thin in the study area. The uplift also created a dip toward the north that continues into the southern part of the study area. Farther north, the regional dip toward the south-southeast again prevails (Stringfield, 1966).

Uplift during the Miocene also produced two major sets of joints in the carbonate rocks. The joints are oriented northwest-southeast and northeast-southwest. Vernon (1951) mapped similar-trending joints in northern Florida on the basis of alinements of physiographic features shown on aerial photographs. These alinements are present in the study area and are evidenced by trends of surface drainage, alinement of sinkholes, and preferential flow direction in the subsurface as indicated by water quality. High-altitude imagery clearly shows the northeast-southwest and northwest-southeast trending surface drainages. Plate 2 shows lines drawn on the basis of alinements of physiographic features that are shown on aerial imagery and topographic contour maps.

Joints in the carbonate rocks allowed preferential flow of water along them, thus producing greater dissolution of the carbonate rocks along the joints. Both surface drainage and subsurface ground-water movement (conduit flow) was and still is controlled by this jointing and solutioning.

Karst Topography

The study area is a typical karst region; it is marked by many sinkholes, sinkhole lakes, and little surface drainage. Circulating ground water dissolves the limestone, forming large solution openings, cavities, and caves. Solutioning of the rock removes support for the overlying sediment to the point that collapses occur at the surface, and sinkholes and sinkhole lakes are thus formed. Karst features are more common in Lowndes and western Echols Counties as a result of the thinner overburden and higher altitude of Oligocene and Eocene limestone in that part of the study area.

Karst features also occur at several levels in the subsurface, and represent remnants of surface features that developed during Tertiary time between depositional events.

GROUND-WATER RESERVOIRS

Ground water occurs in sand deposits in the Pleistocene, Pliocene, and upper part of the Miocene in the study area (table 1). These beds yield small to moderate amounts of water, generally sufficient for domestic and small farm supply, to dug, jetted, or shallow drilled wells. The water-bearing units are generally the coarser sand beds, and gravel beds where present. Some sand beds are overlain by clay layers that confine the water in the sand under artesian pressure. In the western part of Valdosta, shallow wells that tap Pliocene and Pleistocene sand beds flow small quantities of water. Yields from wells in the clastic sediments are usually less than 50 gal/min.

Principal Artesian Aquifer

The main water-bearing unit underlying the study area is the principal artesian aquifer, which includes rocks of the Claiborne Group, Ocala Limestone, Suwannee Limestone, and limestone of the lower part of the Hawthorn Formation. (See table 1.) Plate 1 shows the thickness of sediments overlying the Suwannee Limestone. Although the Suwannee is not the uppermost unit of the principal artesian aquifer, it is the highest mappable unit in the aquifer and is generally within a few feet of the top of the aquifer. In the study area, the Suwannee Limestone furnishes almost all of the water for domestic, commercial, industrial, irrigation, and municipal use. The high yields obtained from the Suwannee make drilling below it unnecessary.

Because of the high porosity and hydraulic conductivity, the aquifer is able to transmit very large quantities of water in some areas. The specific capacities of three production wells (185-24, 185-25, and 185-26) tested at the Owens-Illinois plant in Clyattville (location, pl. 8), are 333, 452, and 712 (gal/min)/ft. Specific capacity is an indication of a well's yield capability, and is measured in terms of yield per unit drawdown. Estimates of transmissivity utilizing specific-capacity data (Lohman, 1972) for those wells are 100,000 ft^2/d, 130,000 ft^2/d, and 220,000 ft^2/d. Transmissivity is a measure of an aquifer's ability to transmit water, and is defined as the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

The aquifer is artesian except in those small areas where it crops out at the surface (pl. 2). An artesian aquifer is one in which the water in the aquifer is confined under pressure by impermeable or semipermeable material so that water in tightly cased wells will rise above the top of the aquifer. A higher head in the aquifer in outcrop areas and relatively impermeable clay layers in overlying Miocene to Pleistocene sediments cause the artesian pressure in the aquifer in the study area. Where the aquifer is unconfined, ground water is not under artesian pressure and the water level reflected in wells is the water table.

The principal artesian aquifer has excellent water-bearing properties. Large interconnected cavities are common in the limestones that make up the aquifer. Wells tapping these limestones obtain the greatest yields from zones of jointing and subsequent dissolution of the limestone, at interface zones between formations, and from zones containing abundant shell fragments. Porosity, the percentage of pore space in the limestone, decreases with depth, owing to the fact that ground-water circulation and dissolution, which increases porosity, are greatest nearer the earth's surface. Shallow ground water contains carbonic acid derived from the solution of carbon dioxide from the atmosphere or soil environment, and water containing carbonic acid is able to more readily dissolve the limestone. The flow of ground water through solution openings abrades the limestone, further increasing porosity. Ground-water circulation is greatest in the upper zones where flow is facilitated by the solution cavities, thus enhancing further dissolution of the limestone.

Recharge

Recharge of the principal artesian aquifer occurs chiefly where the aquifer crops out at higher altitudes updip from the study area (fig. 1). Rainwater, storm runoff, and stream water all contribute recharge to the aquifer. Water entering the aquifer then moves laterally downgradient to points of discharge.

Recharge to the aquifer also occurs in several ways within the study area. For all of these types of recharge, the altitude of the recharging water is higher than the potentiometric surface of the aquifer. In the study area, the potentiometric surface is the surface connecting points to which water rises in tightly cased wells tapping the principal artesian aquifer.

Recharge occurs locally where overburden above the aquifer is thin or lacking and water from rivers, ponds, and lakes flows through sinkholes, or infiltrates through permeable lake bottoms, into the aquifer. This type of recharge is common in the study area, especially north of Valdosta, where the Withlacoochee River contributes a large amount of water to the aquifer, and in the sinkhole-lakes area around Lake Park. (See pl. 2.)

A large amount of recharge to the aquifer also takes place as vertical transfer of water from overlying clastic sediments. Although the clastic sediments are separated from the limestone aquifer by clay confining layers, the clays are not completely impermeable, and water migrates slowly through the clays into the limestone. This type of recharge increases as the potentiometric surface of the artesian aquifer declines as a result of ground-water withdrawal. Although this recharge appears to be very slow, and small in terms of the quantity of water that moves through individual clay layers, over a large area, a large amount of water recharges the aquifer.

A minor amount of recharge in the Valdosta area takes place through drainage, or "down" wells. Drainage wells were, and some still are, being used to lower the water level in ponds to facilitate the mining of peat.

Discharge

Natural discharge from the principal artesian aquifer occurs through springs that issue from the aquifer at points where the potentiometric surface or head in the aquifer is greater than the altitude of the aquifer outcrop. Springs along the Withlacoochee River discharge water where the head in the aquifer is above the level of the river. Flow of the springs is discussed in a later section.

Ground-water pumpage in the study area is currently (1976) about 22 Mgal/d. About half of that amount is for industrial use at the Owens-Illinois plant at Clyattville. Pumpage of 11 Mgal/d began there in 1954 and has continued at that rate to the present (1976). The city of Valdosta is the next largest user, withdrawing about 3.8 Mgal/d. Pumpage for the city of Valdosta began in 1893 (McCallie, 1908) and has gradually increased since then. Quitman, pumping water from the aquifer since 1884 (McCallie, 1898), uses about 1 Mgal/d. The remainder of the pumpage is primarily for smaller municipal and other public supply, and for domestic and agricultural use. At this time (1976), springs are not being utilized as a water supply, but they continue to discharge water from the principal artesian aquifer.

Areal Ground-Water Levels

The regional configuration of the potentiometric surface of the principal artesian aquifer is controlled by amounts of recharge, discharge, and ground-water flow. In general, water levels are higher in areas of recharge and lower in areas of discharge. Plates 3 and 4 show the potentiometric surface of the aquifer for May and November 1975. There are differences in the two surfaces (discussed in a later section), but they both show the effects of natural recharge and discharge. Although pumpage from the aquifer is rather large in some areas such as at Clyattville, no depression of the potentiometric surface is apparent. This is due to the high transmissivity of the aquifer. Some depression of the potentiometric surface at Clyattville is certain, but it is not indicated on the maps because of a lack of data near the center of pumpage.

The highest potentiometric surface on both maps is in the area of maximum recharge north of Valdosta where Withlacoochee River water entering the aquifer produces a ground-water mound. In May 1975 the potentiometric surface at the ground-water mound was greater than 105 ft above mean sea level, and in November 1975 it was greater than 100 ft. Ground water flows laterally downgradient from this mound in all directions.

Water-Level Trends

Seasonal fluctuations

Seasonal changes in precipitation and evapotranspiration cause corresponding changes in streamflow and in the ground-water level of the principal artesian aquifer. Figure 3 compares precipitation at a station 4 mi northwest of Valdosta (Valdosta 4 NW) with streamflow of Alapaha River at Statenville (location, pl. 5), and with the water level in the principal artesian aquifer in the Valdosta downtown area (well 185-7) (location, pl. 8). Pan evaporation data at the Tifton Experiment Station (fig. 1) are also included for comparison; climatic conditions at Tifton are similar to those at Valdosta. Pan evaporation represents the amount of water lost from a free water surface, whereas evapotranspiration includes water loss from vegetation. Total water loss from evapotranspiration would be less than that measured from pan evaporation, but the amounts would be roughly proportional as the growing season parallels temperature and solar radiation which affect evaporation. Values for precipitation, streamflow, and the ground-water level used in the graph are mean monthly, arithmetic averages of each of the three parameters for the period 1957-75. Evaporation data covers the period 1964-75, reliable for comparison, although for a shorter period.

Precipitation is highest in late winter and in midsummer and lowest in October and November. Streamflow increases rapidly with the onset of late winter rains and highest flows for the year usually occur in March or April. The ground-water level also rises during this period and highest ground-water levels also occur in March and April. More hours of daylight and greater plant growth during spring and summer increase the rate of evapotranspiration, which correspondingly decreases the amount of water available for streamflow and ground-water recharge. Therefore, streamflow and the ground-water level are low during this period. The evaporation curve clearly indicates that increasing amounts of evaporation, and hence evapotranspiration, occur during the summer months, causing a major decrease in streamflow and decline in the ground-water level.

Heavy precipitation in midsummer usually increases streamflow and the ground-water level only slightly, as evapotranspiration is still very high. Also, the ground-water level remains low in the summer months as a result of the increased withdrawal of ground water for irrigation and for other consumptive uses.

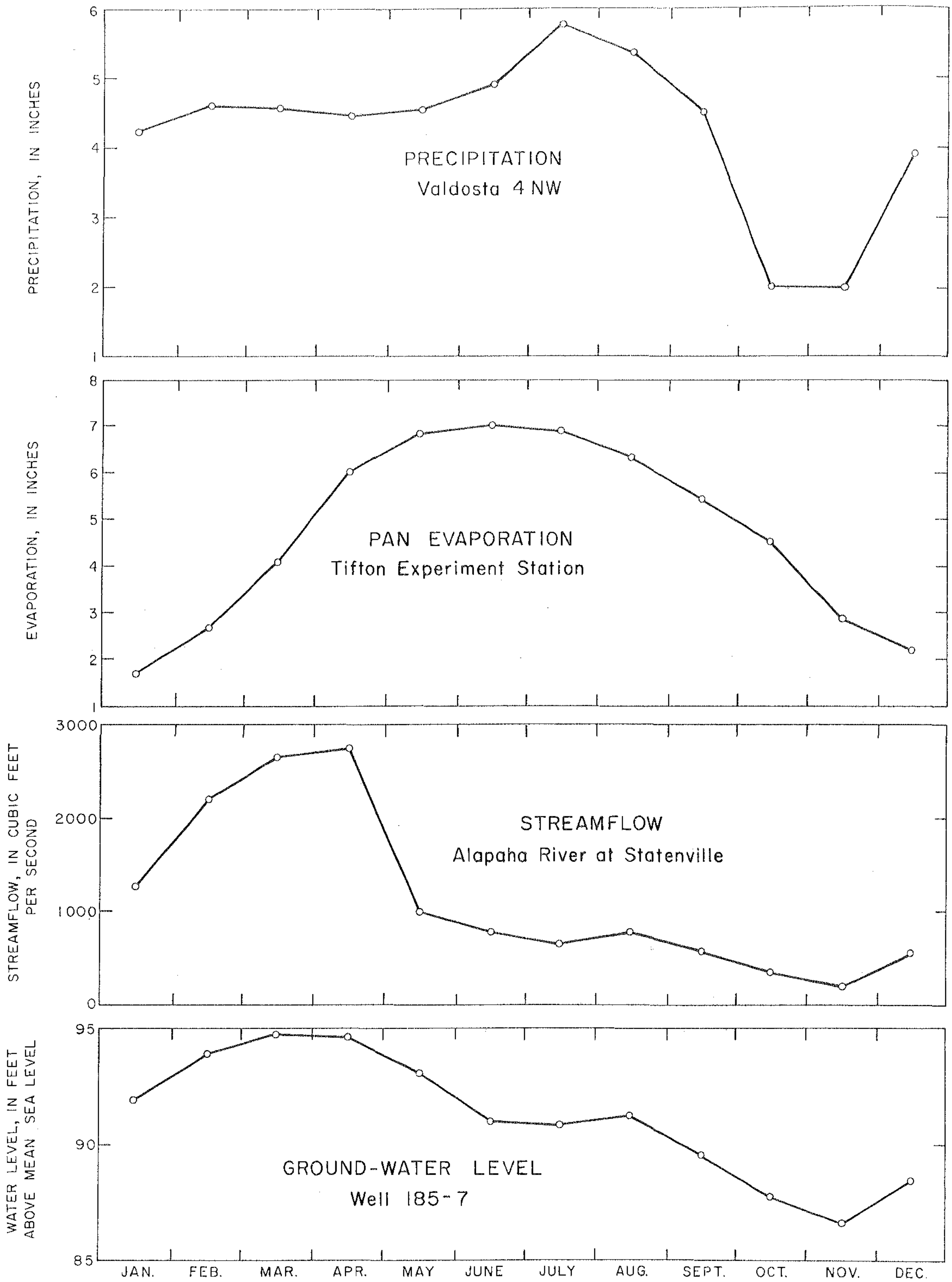


Figure 3.—Seasonal relation of mean monthly precipitation, evaporation, streamflow, and ground-water level, Valdosta area.

Light precipitation in October and November generally causes streamflow and the ground-water level to recede to their annual lows. This is followed by decreased evapotranspiration and heavy winter precipitation that produces a rise in streamflow and the ground-water level.

The effects that precipitation, evapotranspiration, and hence streamflow have on the ground-water level is very pronounced in the recharge area north of Valdosta. The aquifer, unconfined in the immediate recharge area, is recharged by surface water flowing into sinkholes, and the ground-water level fluctuates according to fluctuations in the surface water. Away from the area of recharge, the aquifer is confined by an overburden of silt and clay, and is better separated from surface water. Therefore, the ground-water level away from the recharge area does not show as clear a response to seasonal fluctuations in streamflow and recharge.

The effects that precipitation, evapotranspiration, and streamflow have on the water level in wells at varying distances from the recharge area is illustrated in plate 5. Water-level fluctuations determined from measurements made monthly in 21 observation wells from May 1974 through December 1975 are shown on the map in plate 5. The water level in wells near the recharge area responds to the recharge much more than it does in wells away from the recharge area. Fluctuations between the high water level in spring and the low water level in autumn is as much as 20 to 25 ft near the recharge area. This pattern of seasonal fluctuation is indiscernible in the western part of Brooks County, away from the recharge area.

The ground-water level fluctuates in response to recharge south of Valdosta in the sinkhole-lakes region, although not as much as it does near the Withlacoochee River north of Valdosta (pl. 5). The water level in the lakes is often higher than that in the aquifer. The lakes, as much as 200 ft deep (Stringfield, 1964), have bottoms composed of permeable material or semipermeable material thin enough to allow infiltration of water into the aquifer. Some lakes may extend through the confining layer of silt and clay and be directly connected with the aquifer.

Areas of recharge where the aquifer is at or near the surface can also be seen on water-level change maps. Changes in the water level from one season to the next are greatest in the recharge area, but are small where the aquifer is deeply buried. Plate 6 shows the water-level change from November 1974 to May 1975 in wells tapping the principal artesian aquifer. All changes are positive, indicating a rise in water level, except for the extreme northwest corner of Brooks County. This rise in water level from the late autumn low to a late spring high is greatest in the areas of recharge. (See pls. 5 and 6.)

Plate 7 shows the water-level change from May to November 1975. Changes are negative, indicating a decline in the water level, except in the northwestern part of Brooks County and in the extreme northern part of Lowndes County. The decline in water level from late spring to late autumn is greatest in the sinkhole-lakes area of recharge in Lowndes County. (See pls. 5 and 7.)

Long-term fluctuations

Long-term changes in precipitation cause corresponding long-term fluctuations in streamflow and the ground-water level in the Valdosta area. Figure 4 shows the comparison of annual precipitation at the station Valdosta 4 NW with annual mean streamflow of Alapaha River at Statenville (location, pl. 5) with annual mean water level in well 185-7 (location, pl. 8) in downtown Valdosta, for 1957-75. The curves show a good correlation between precipitation, streamflow, and the ground-water level. Notable declines and rises in the water level in the principal artesian aquifer as shown on the graph compare very well with similar changes in precipitation and streamflow. The large amount of precipitation during 1964 and the small amount during 1967-68 brought about corresponding highest and lowest streamflows and ground-water levels experienced during the period of record shown in figure 4. Without the record of precipitation and streamflow, it might be erroneously interpreted that these water-level fluctuations were the result of periodic changes in ground-water withdrawal that affect the water level in the observation well. Ground-water withdrawal in the Valdosta area does affect the ground-water level, but does not cause the fluctuations shown in figure 4.

Long-term decline

The long-term effect on the ground-water level in Valdosta by ground-water withdrawal from the principal artesian aquifer in the Valdosta area and elsewhere in the Coastal Plain, seems to be that of a gradual decline in the water level. Figure 5 is a plot of the monthly mean water level for 1957-75 in well 185-7 (location, pl. 8) in the Valdosta downtown area. A first-degree plot of the data points makes the straight line and represents the best possible match that the line can make with the data points, as determined by a computer program that solves equations for polynomial regressions (Kopitzke). The straight-line plot shows that the ground-water level experienced a net decline over the 19 years of record. This decline is attributed primarily to pumpage from the principal artesian aquifer throughout the Coastal Plain, although a small part of the decline may also be attributed to a slight long-term decrease in precipitation. Pumpage of more than 500 Mgal/d from the principal artesian aquifer in Georgia and north Florida has contributed to the steady decline of the potentiometric surface in that area (Krause and Gregg, 1972). According to the straight-line plot of the water-level trend, the water level declined 8.2 ft for the period 1957-75, or about 0.43 ft per year.

Other wells in the area have also experienced similar water-level declines over the past 10 years. Water-level declines in nearby observation wells have been 0.35 ft per year at Tifton, 0.46 ft per year at Adel, 0.50 ft per year near Fargo, and 0.90 ft per year at Thomasville (location, fig. 1).

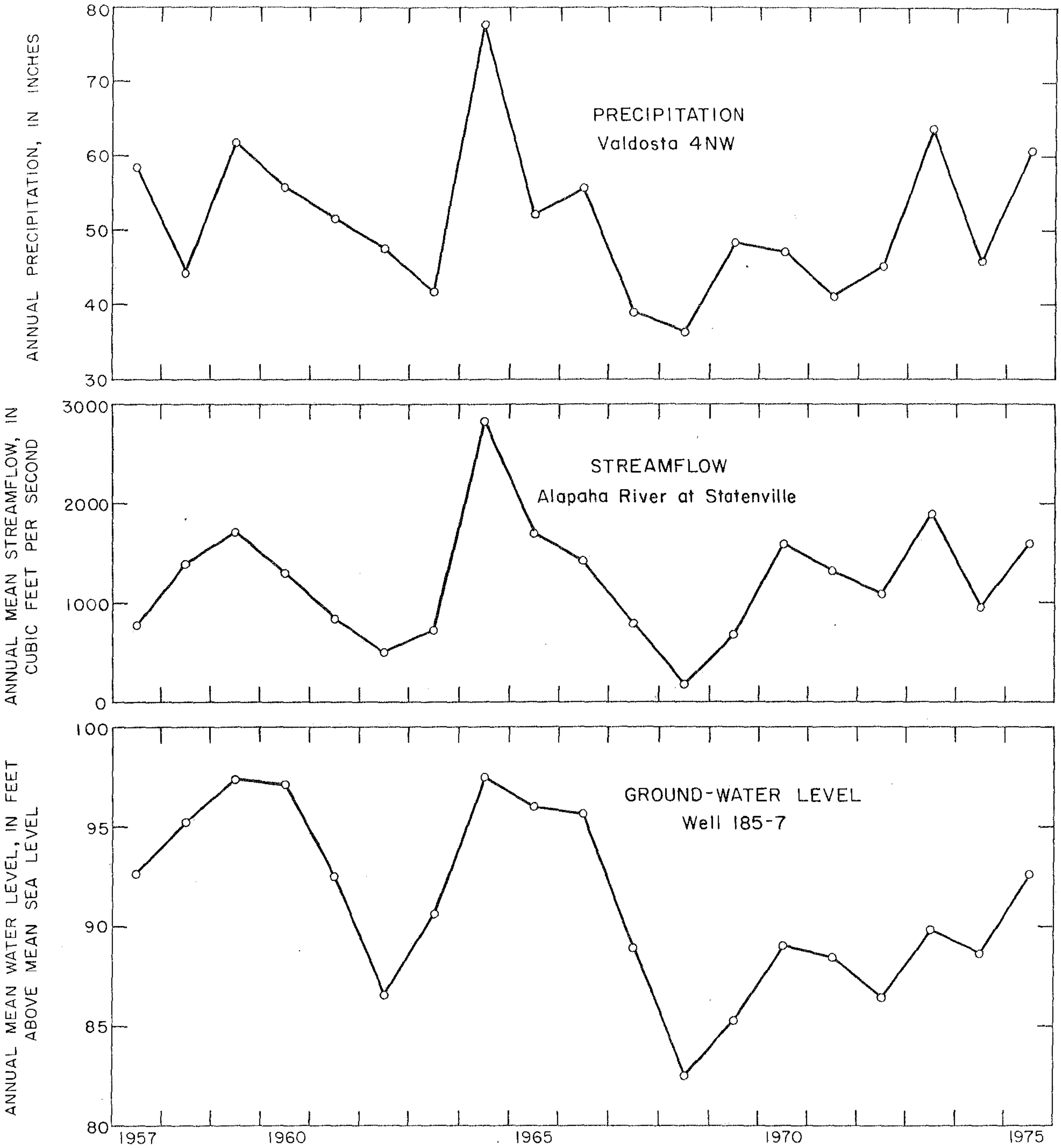


Figure 4.—Long-term relation of precipitation, streamflow, and ground-water level, Valdosta area, 1957-75.

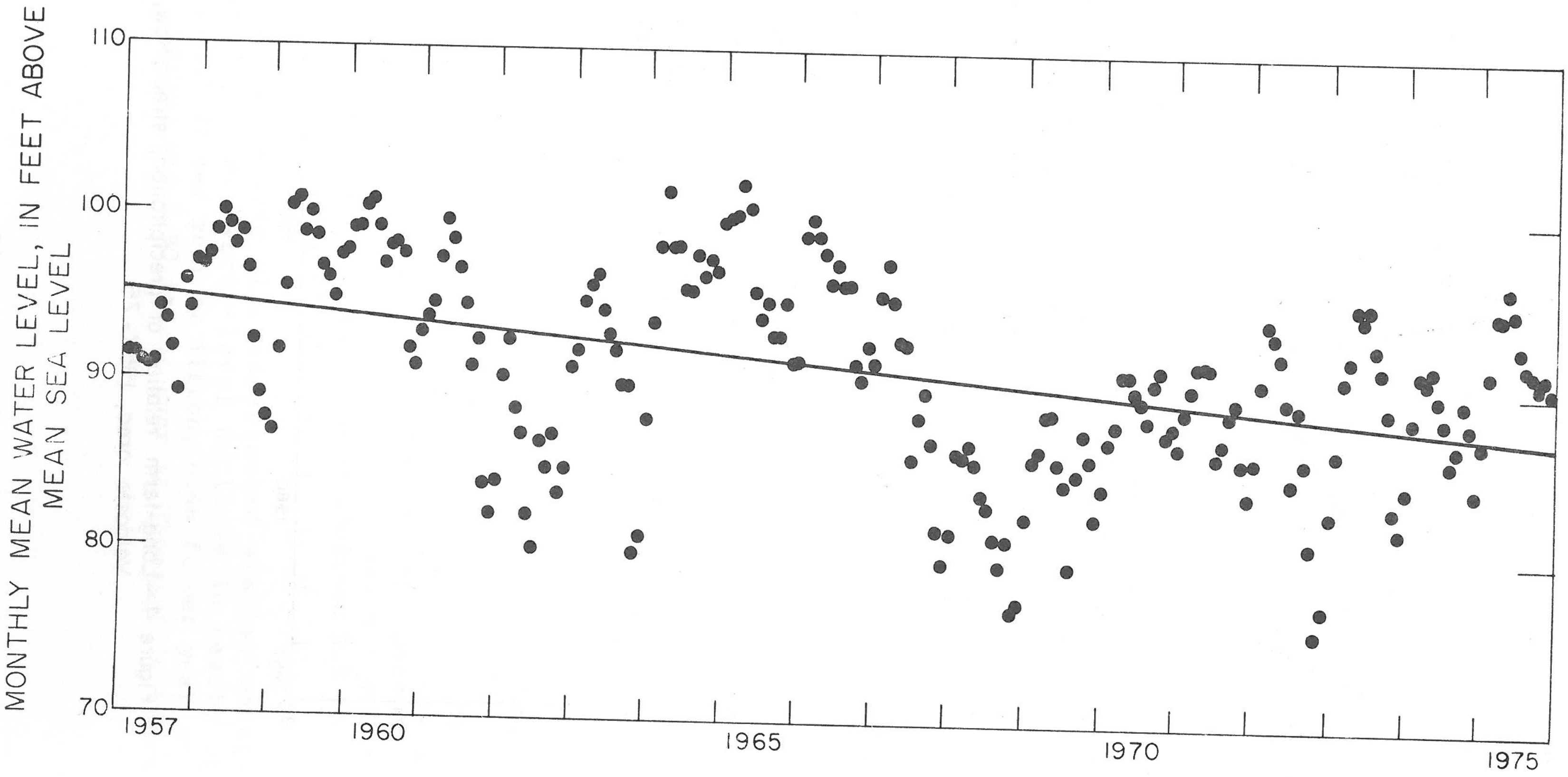


Figure 5.—Water-level trend in well 185-7 in Valdosta, 1957-75.

STREAMFLOW-GROUND-WATER RELATIONSHIPS

The amount of water that a stream loses or gains can be used to determine the interaction between streamflow and ground water. The gain or loss of a stream can be determined by a series of discharge measurements made at various points along a reach of river at about the same time. The difference in the flow at two points on the river represents the net amount of water lost or gained in that reach. Measurements of this type, called seepage-run measurements, are useful where it is impossible to measure gain or loss directly, as where the flow from a spring enters below the surface of a river, or where flow is lost through a sinkhole, such as occurs along the Withlacoochee River. Such measurements are best made during times of low flow because the amount of water gained or lost is likely to be a larger portion of the total flow.

Seepage-run measurements were made for the entire reach of the Withlacoochee River in Lowndes and Brooks Counties in November 1974 and July and November 1975, when streamflow in the river was lower than normal. These measurements are shown in figure 6. Withlacoochee River station names used herein best describe the actual locations, but do not conform to the formal station names of the Geological Survey. For example, this report uses "at Staten Road" for the Survey station "above Valdosta"; and uses "at Georgia Highway 94" for the Survey station "near Valdosta" (U.S. Geological Survey, 1977). The graph in the figure shows the streamflow at selected points along the reach, with the river-mile distance for each point. Triangular symbols denote sites that were measured; square symbols denote sites where the streamflow was computed by totaling actual measurements made upstream or on tributaries (fig. 6).

The streamflow for all sites is also shown near each measuring site on the map. Additional measurements and computed flows in the recharge and discharge areas are shown, and these are described in later sections.

The graph in figure 6 shows that, in general, the streamflow of the Withlacoochee River gradually increases downstream as tributaries enter the channel and the drainage area becomes larger. The relationship or ratio of the amount of flow to the size of drainage area is typically uniform, varying from 0.03 to 0.04 $(ft^3/s)/mi^2$ along this reach of the river. The exceptions to this are in the recharge area north of Valdosta and in the discharge area south of Valdosta. The ratio is nearly zero north of Valdosta where the Withlacoochee River loses water to the underlying aquifer through sinkholes, and is 0.07 to 0.08 $(ft^3/s)/mi^2$ near the Georgia-Florida State line where the river gains water from spring discharges in the channel.

If the amount of flow lost or gained by a river is nearly uniform, the stream has a characteristic ratio of streamflow to drainage area. However, if that ratio deviates appreciably from the typical found for a reach of stream and for nearby streams, then recharge and discharge are particularly noticeable.

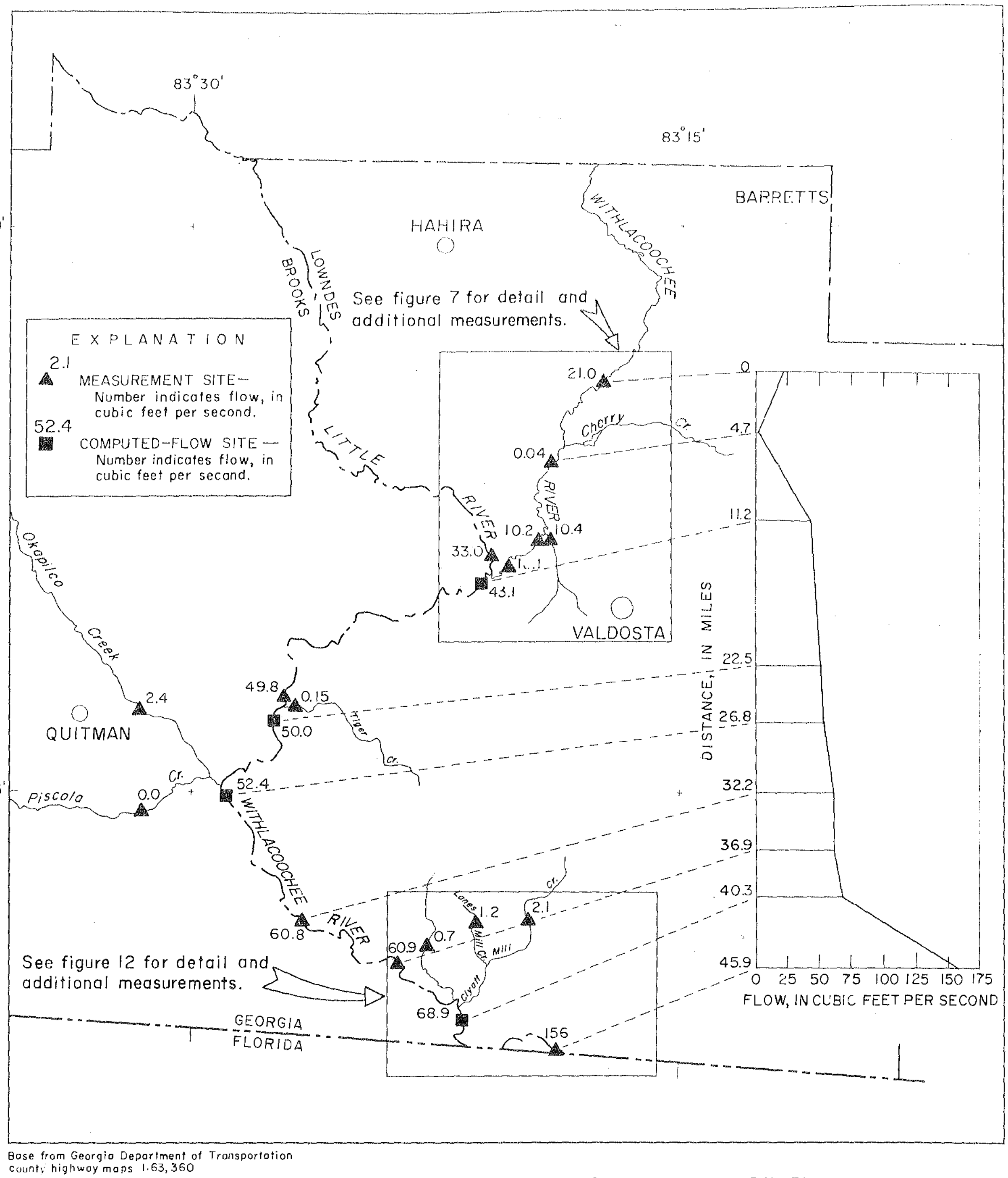


Figure 6.—Seepage—run measurements, Lowndes and Brooks Counties, November 1974.

Losing Streamflow in the Recharge Area

Seepage-run measurements made on the Withlacoochee River from its crossing on Staten Road to below its crossing on Georgia Highway 94, in the area northwest of Valdosta, indicate that the river loses water to the aquifer through sinkholes along this reach of the river. (See fig. 7.) The loss is especially noticeable during periods of very low flow, as the river ceases to flow downstream from the sinkholes. The water level in the aquifer is lower than the river stage so river water flows into the sinkholes, directly recharging the aquifer.

Surface-Water Quality

Surface-water-quality problems arise because municipal sewage effluent in Sugar Creek flows into the Withlacoochee River and is undiluted or poorly diluted until the Little River joins the Withlacoochee River below Georgia Highway 94. In November 1974 when seepage-run measurements were made, the flow of Sugar Creek was 10.4 ft^3/s. About 8 ft^3/s of this flow was sewage effluent. A sewage-effluent flow of 8 ft^3/s is an average derived from design-status flow from the Valdosta sewage treatment plant (Georgia Environmental Protection Division, 1974b). The streamflow of the Withlacoochee River above Sugar Creek was negligible, 0.04 ft^3/s, so the Withlacoochee River water was essentially 75 percent sewage effluent until the Little River contributed 33 ft^3/s of relatively unpolluted flow.

The quality of the Withlacoochee River water at Georgia Highway 94 ranges from slightly degraded to grossly polluted during times of low streamflow. During the period 1970-74, the fecal coliform bacteria count of the river exceeded the standard of a one-time maximum density of 4,000 in 100 milliliters, in 27 of 41 samples (Georgia Environmental Protection Division, 1972, 1973, 1974a, and 1975). Except during periods of high streamflow, the Withlacoochee River remains polluted from the confluence with Sugar Creek to the Georgia-Florida State line near Georgia Highway 31 (Georgia Environmental Protection Division, 1975). During 1974, a year of average streamflow of the Withlacoochee River, fecal coliform bacteria counts as MPN (most probable number) per 100 milliliters were as follows:

Date	At Staten Road	At Ga. Highway 94	At Ga. Highway 31
Jan. 23	73	9,300	430
Feb. 6	640	2,300	1,500
Apr. 24	150	93,000	15,000
May 15	91	4,300	230
Oct. 4	73	9,300	30
Dec. 10	230	2,300	30

From Georgia Environmental Protection Division, 1975.

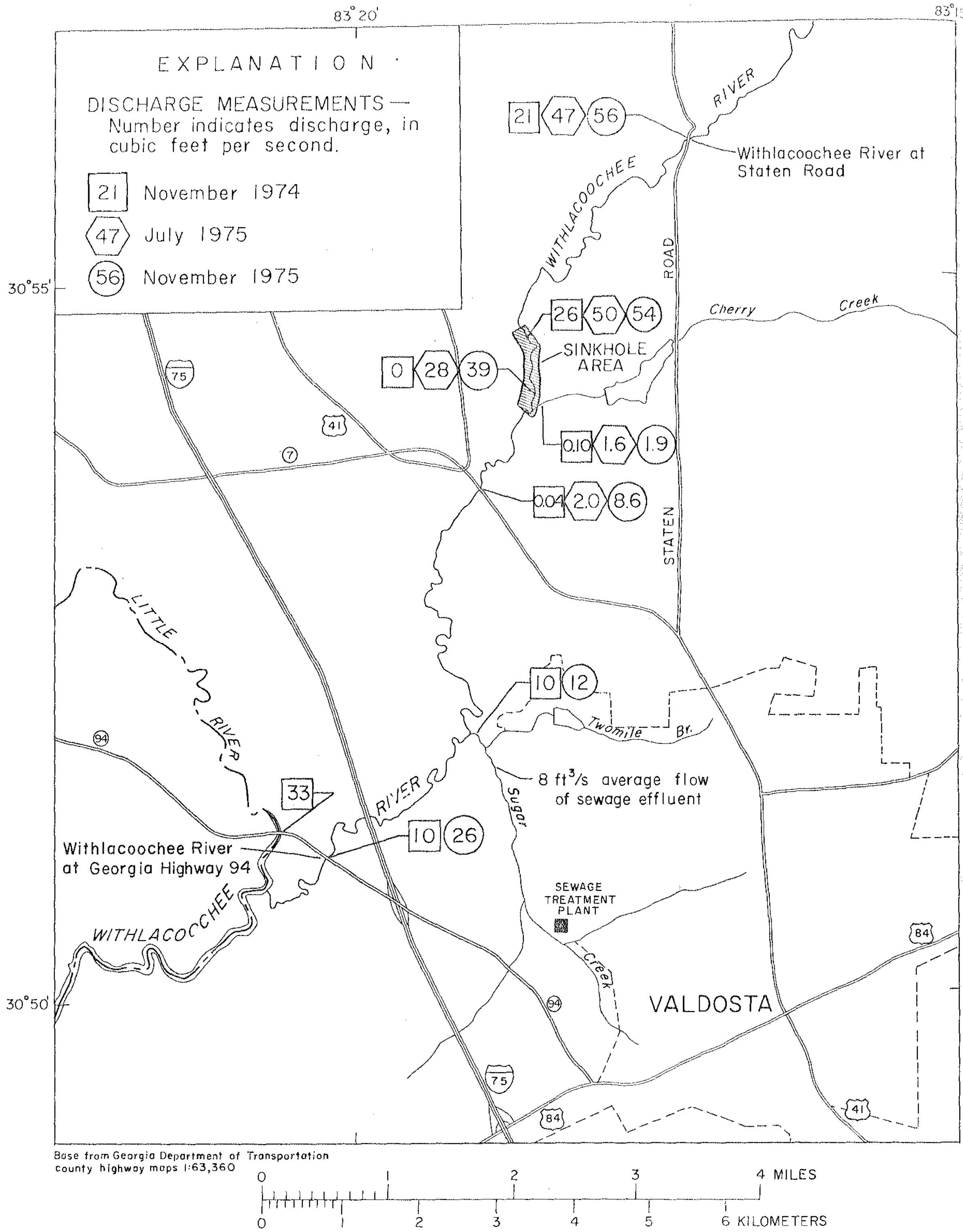


Figure 7.—Seepage-run measurements, recharge area, Valdosta area, November 1974, July and November 1975.

Streamflow and Recharge

Streamflow measurements of the Withlacoochee River were made at Staten Road and at Georgia Highway 94 to determine the relationship of the river stage to the quantity of flow at those two sites. Adjustments to the flows were made to determine more accurately the amount of water being recharged to the aquifer. First, because the drainage area at Georgia Highway 94 is about 10 percent larger than at Staten Road, the streamflow may be reasonably expected to be greater, on the average, by a factor of 1.1. This factor was applied to the streamflow at Staten Road. Second, the city of Valdosta discharges an average of 8 ft^3/s of sewage effluent into Sugar Creek, which flows into the Withlacoochee River above Georgia Highway 94. That amount was subtracted from the streamflow at Georgia Highway 94 to determine the adjusted streamflow.

Figure 8 shows a plot of concurrent, adjusted streamflow of the Withlacoochee River at Staten Road and at Georgia Highway 94. Also shown is the estimated relationship between the two sites if there were no loss in the reach. The deviation of the adjusted streamflow from the theoretical flow indicates that the Withlacoochee River loses water in the reach between Staten Road and Georgia Highway 94 at various rates of flow.

Figure 9 shows a plot and best-fitting curve of the streamflow of the Withlacoochee River at Staten Road versus the estimated amount of flow lost in the recharge area. The loss in the recharge area is determined by subtracting the adjusted streamflow at Georgia Highway 94 from the adjusted streamflow at Staten Road. During periods of higher streamflow, a greater quantity, but a smaller percentage of the flow, is lost to the aquifer. The maximum quantity of recharge is unknown, although the computed recharge was more than 300 ft^3/s when the measured streamflow at Staten Road was 1,450 ft^3/s. The amount of recharge that takes place is largely controlled by the physical size limitations of sinkholes in the river channel. The altitude of the potentiometric surface of the artesian aquifer may also affect the rate of recharge. Recharge is probably greater when the altitude of the potentiometric surface is low than when it is high. This could account for some of the data-point scatter in figure 9.

According to the curve in figure 9, all of the flow downstream from Staten Road is lost when it is less than about 40 ft^3/s. When the flow is greater than about 40 ft^3/s, water flows past the sinkholes in the recharge area. The ratio of loss to flow then decreases for streamflow above about 40 ft^3/s. The ratio of loss to flow increases when the flow is 90 to 100 ft^3/s, causing the "step" on the curve. This is due to the loss of water into sinkholes in secondary channels and into sinkholes higher on the river bank. The ratio of loss to flow again decreases, to an average maximum loss of about 300 ft^3/s. This average maximum was determined from the best-fitting curve and may be exceeded.

The Withlacoochee River at Staten Road is not continuously gaged, but the rate of flow can be estimated on the basis of the streamflow records of Alapaha River at Statenville in Echols County. Reasonable flow estimates can generally be prepared if an ungaged stream is related to a nearby gaged

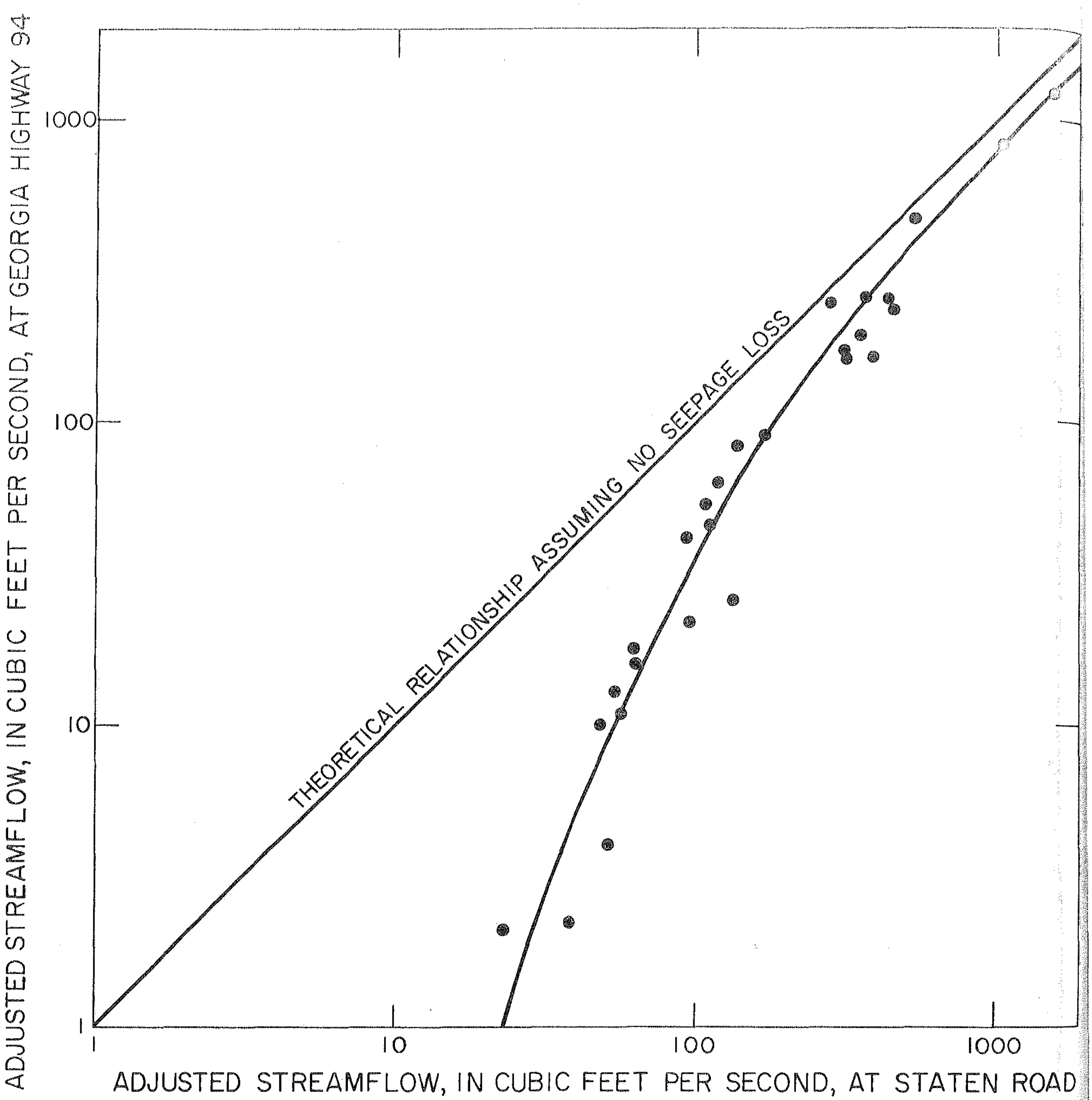


Figure 8.—Relation of adjusted streamflow of the Withlacoochee River above (at Staten Road) and below (at Georgia Highway 94) the recharge area.

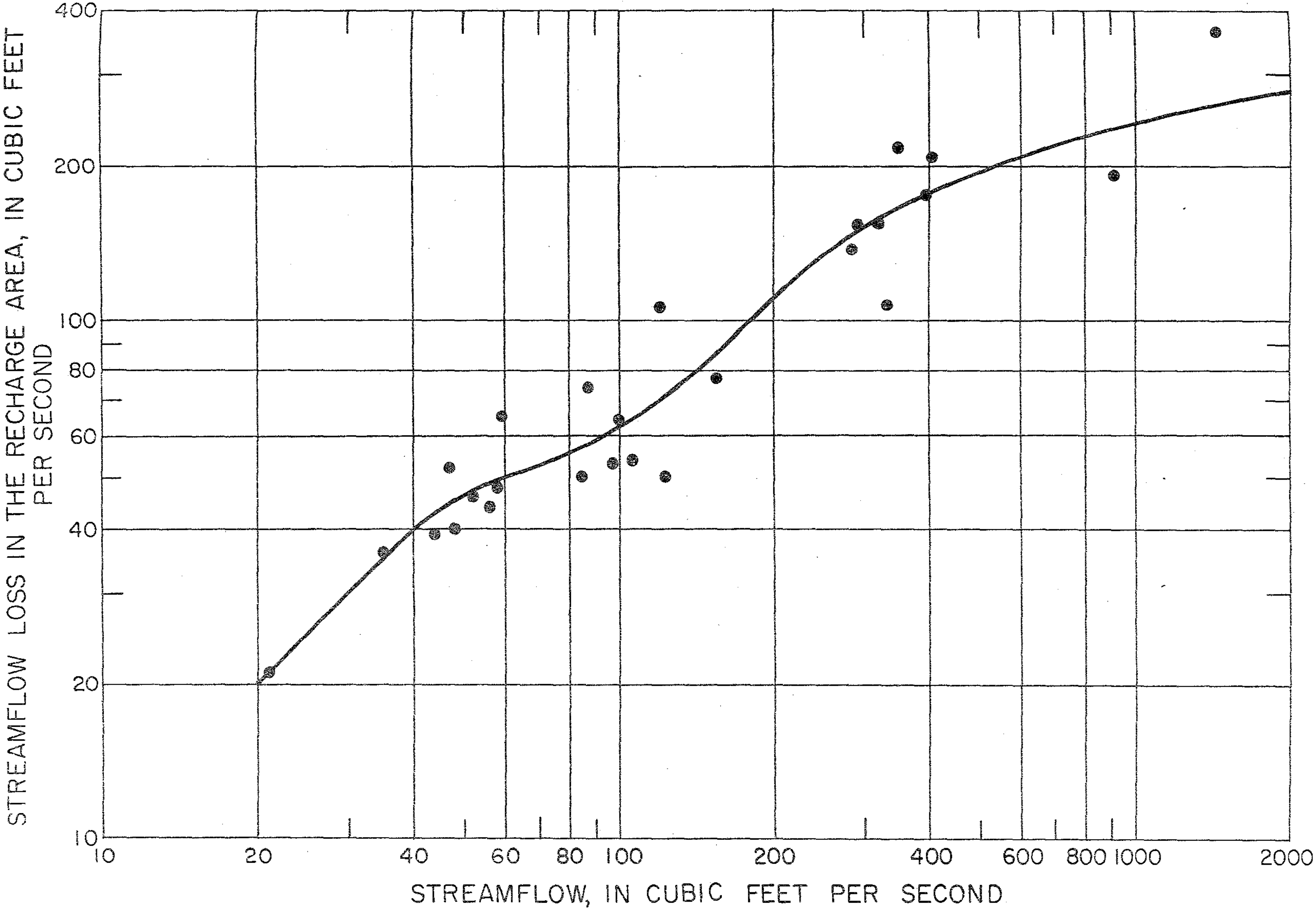


Figure 9.—Relation of streamflow of the Withlacoochee River at Staten Road and loss in the recharge area.

stream that has similar basin characteristics. Stage and flow of Alapaha River at Statenville have been monitored continuously since 1932. It was assumed that the flows of the two streams are related in proportion to the size of the drainage areas. The drainage area of Alapaha River at Statenville is about 1,400 mi^2, and the drainage area of the Withlacoochee River at Staten Road is 508 mi^2. Therefore, the streamflow of the Withlacoochee River at Staten Road may be roughly estimated to be about 0.36 times the streamflow of Alapaha River at Statenville. Streamflow data and characteristics determined for Alapaha River at Statenville were applied to estimate the flow of the Withlacoochee River at Staten Road.

Observed flow of the Withlacoochee River at Staten Road and the concurrent streamflow of Alapaha River at Statenville are plotted in figure 10. A straight line is drawn best fitting the data from the two sites. A theoretical line drawn on the basis of the ratio of drainage areas is also shown. The agreement of the two lines shows that using the ratio of the area of the drainage basins to estimate streamflow of the Withlacoochee River at Staten Road is valid.

One of the more useful methods of analyzing streamflow characteristics is the flow duration table or flow duration curve, which indicates the percentage of time, during a given period, that any specified flow is equaled or exceeded. Flow-duration summaries were available for Alapaha River at Statenville and were estimated for the Withlacoochee River at Staten Road by applying the drainage-area-ratio factor (0.36) to the flows at Alapaha River at Statenville. Duration curves for flow loss in the recharge area were then estimated using the relationship between flow at Staten Road and loss in the recharge area as shown by the curve in figure 9.

By this method, a duration curve for loss in the recharge area was prepared for the period 1932-75. From this curve it was determined that during the period 1932-75, recharge to the aquifer averaged 112 ft^3/s.

Flow durations for individual years were used to determine loss during particular years of interest in the manner previously described. For example, during 1955, the year when lowest streamflow was recorded for Alapaha River at Statenville, loss by the Withlacoochee River in the recharge area averaged only 41 ft^3/s. During 1964, the year when highest streamflow was recorded, loss from the Withlacoochee River averaged 202 ft^3/s. During 1974 and 1975, the losses averaged 118 ft^3/s and 150 ft^3/s, respectively.

Hydrographs were constructed to show the streamflow and the amount of loss throughout each of the selected years, illustrating seasonal fluctuations in streamflow and loss. Figure 11 shows daily mean streamflow of the Withlacoochee River at Staten Road for the 4 years, 1955, 1964, 1974, and 1975. The streamflow of the Withlacoochee River at Staten Road was again estimated by multiplying the factor for difference in drainage-area size (0.36) by the daily mean streamflow of Alapaha River at Statenville. Also shown are hydrographs of the streamflow lost in the recharge area. The amount of streamflow lost is determined by matching daily mean streamflow at Staten Road to the curve in figure 9.

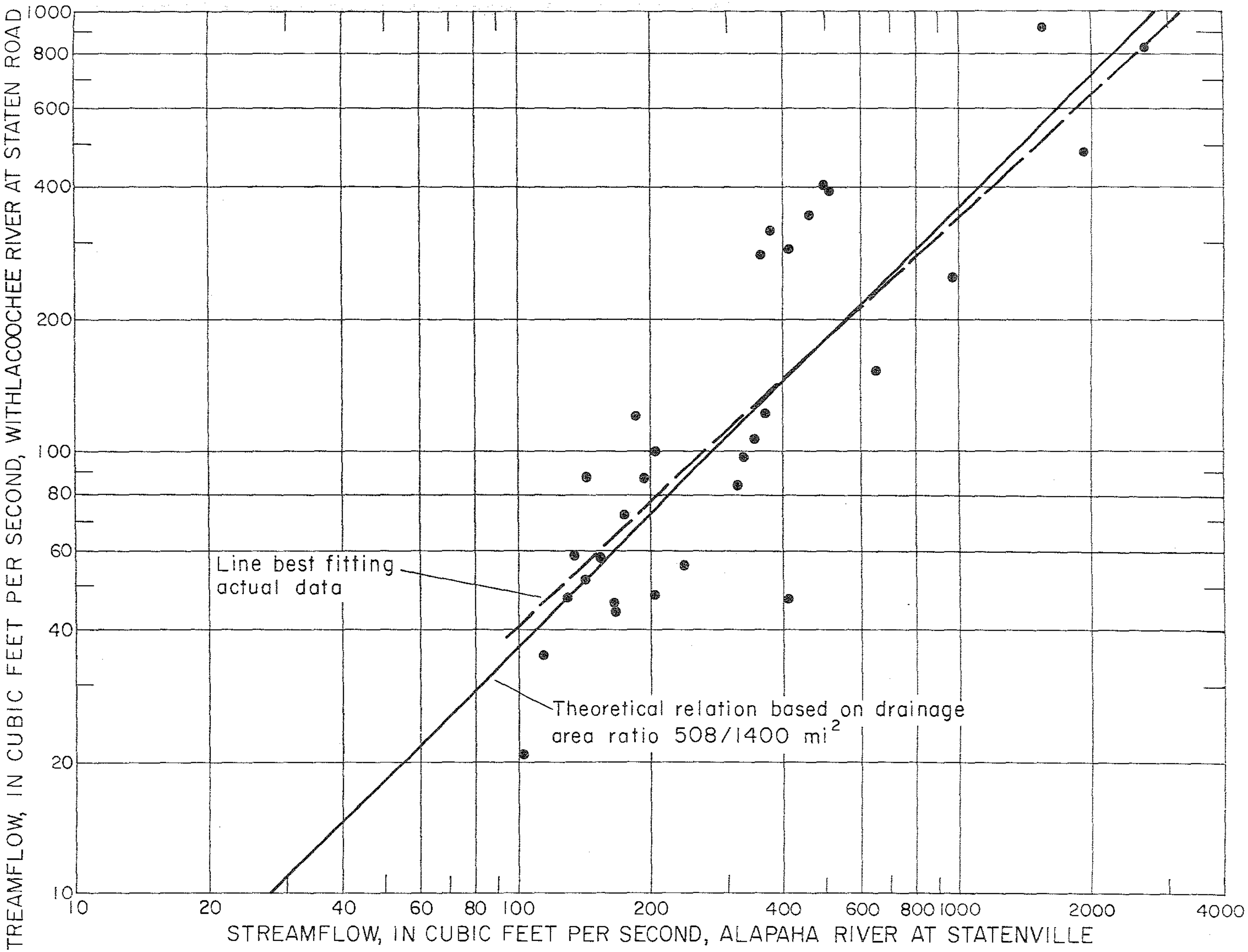


Figure 10.—Relation of streamflow of Alapaha River at Statenville and the Withlacoochee River at Staten Road.

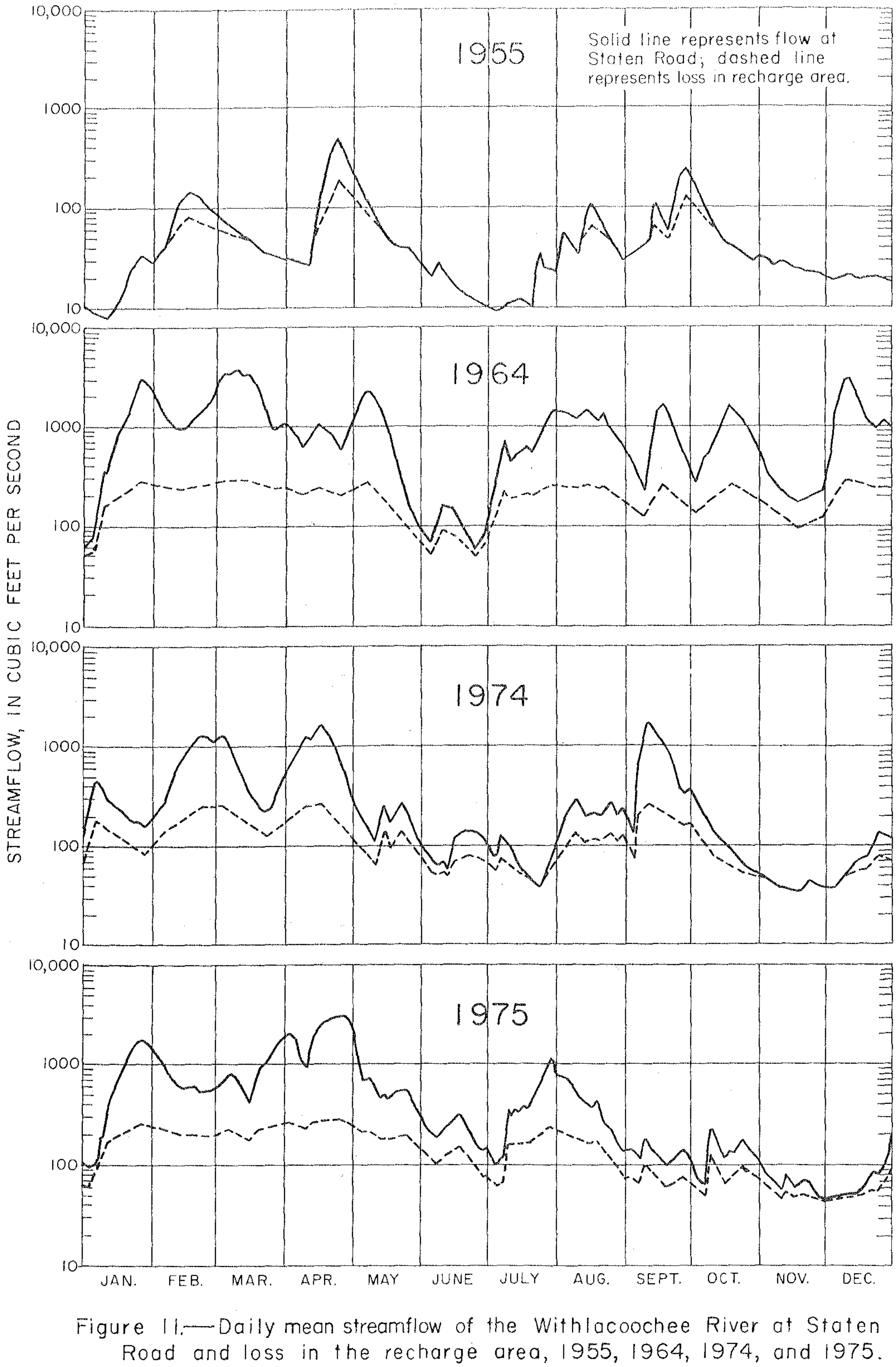


Figure 11.—Daily mean streamflow of the Withlacoochee River at Staten Road and loss in the recharge area, 1955, 1964, 1974, and 1975.

The upper curve on each graph represents the streamflow of the Withlacoochee River at Staten Road. The lower curve represents the streamflow that is lost to the aquifer through sinkholes in the recharge area. The difference in the two curves represents the streamflow that goes past the recharge area. Where the curves coincide, the loss equals the streamflow, resulting in no streamflow below the recharge area.

During 1955, the driest year of record, all of the streamflow was lost in the recharge area for almost 70 percent of the year. Only during short periods of time in February-March, April-May, August, and September-October was streamflow maintained below the recharge area. Even then, maximum streamflow past the recharge area was only about 300 ft^3/s.

During 1964, the wettest year of record, loss of river water into the sinkholes in the recharge area was much greater than it was in 1955. The sinkholes never intercepted all of the streamflow, however, and flow was maintained past the recharge area during the entire year.

During 1974-75 streamflow was maintained below the recharge area except during about 5 days in July 1974 and from about November 2 to December 10, 1974. The year 1974 was a more typical year, and all of the streamflow was lost to the recharge area about 12 percent of the year.

Gaining Streamflow in the Discharge Area

Seepage-run measurements made on the Withlacoochee River from the Clyattville-Nankin Road to where it crosses into Florida at Georgia Highway 31 indicate that the river is gaining streamflow in that reach (fig. 12). Rivers generally maintain a base flow by gaining water from the water-table aquifers that they intersect. However, where a river intersects outcrops of a confined aquifer, a much larger gain in water can occur. In the reach shown in figure 12, the potentiometric surface of the principal artesian aquifer is higher than the stage of the Withlacoochee River, and therefore the aquifer discharges water from solution openings in the limestone. The amount of discharge is governed by the size of the rock openings and by the difference between the head in the aquifer and the stage of the river.

Two major springs (McIntyre and Arnold) in the reach are very visible, as they discharge clear aquifer water into a somewhat turbid, colored river. In addition, seeps occur along the river channel, although they discharge much less water than the springs.

McIntyre Spring is the larger of the two; it discharged about 70 ft^3/s in November 1974 and about 100 ft^3/s in November 1975. The spring discharges were determined by measuring the river's flow above and below the spring. The measurements would thus include discharges of any smaller springs or seeps between measurement sites, but these discharges would be very small compared to the discharge of McIntyre Spring.

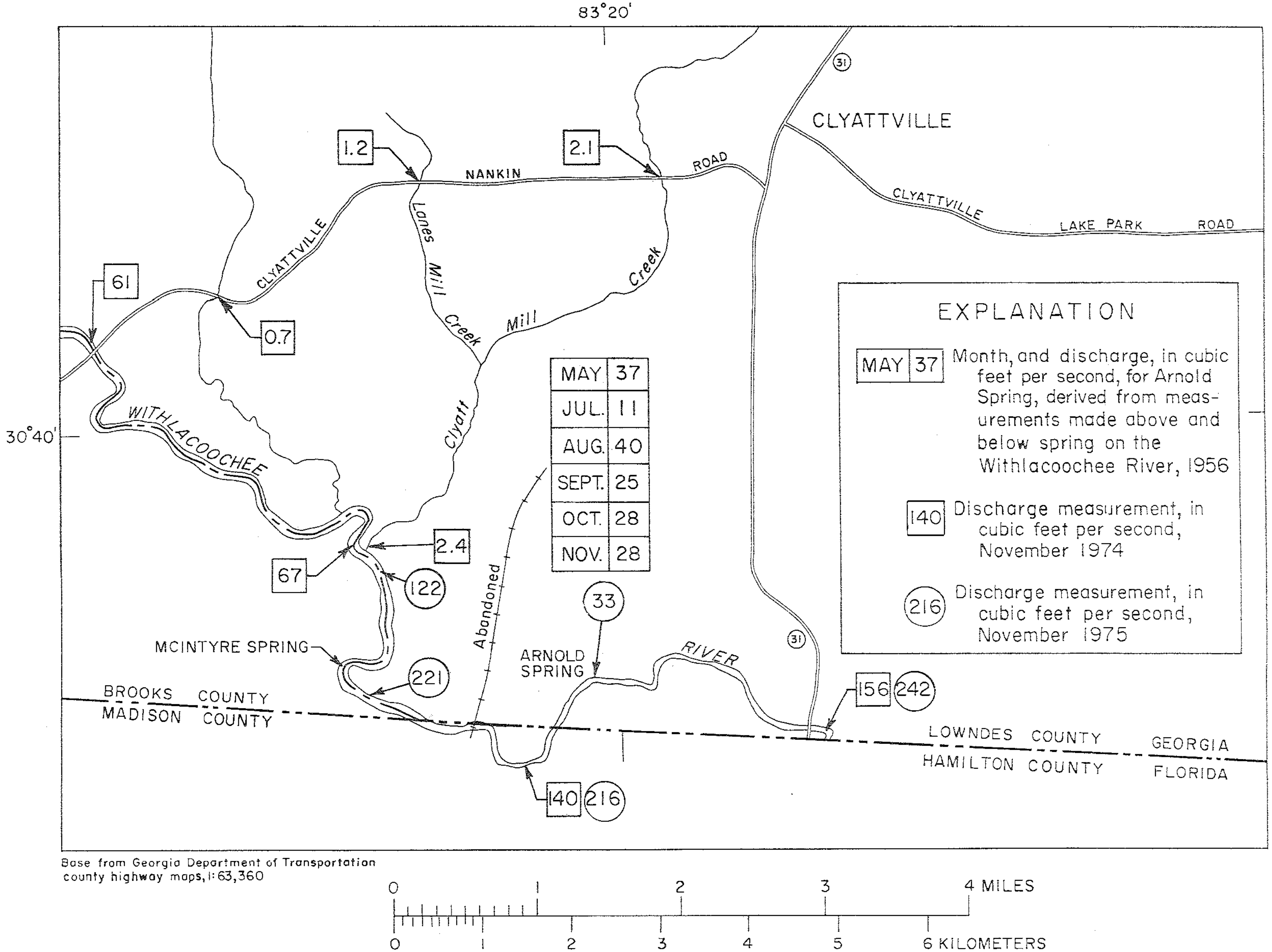


Figure 12.—Seepage-run measurements, discharge area, southern Lowndes and Brooks Counties.

Arnold Spring's discharge was about 16 ft^3/s in November 1974 and 33 ft^3/s in November 1975. The 1974 discharge was determined from measurements made above and below the spring. The 1975 discharge was measured directly, as the spring is off the river's channel far enough to create its own stream. Several miscellaneous measurements were made in 1956. (See fig. 12.) These measurements were made within about 300 ft above and below the spring and are reasonably representative of the spring's discharge.

The discharge of both springs fluctuates with changes in the potentiometric surface of the aquifer and the stage of the river. Too few measurements have been made, however, to correlate spring discharge with seasonal variations in precipitation, river stage and flow, and the ground-water level; or to estimate an accurate minimum, maximum, or mean discharge. A knowledge of these characteristics would be important if any use of the springs is planned. The springs are unused and discharge good-quality water into a somewhat polluted river.

GROUND-WATER QUALITY

Rainfall is the ultimate source of ground water. Rainfall infiltrates through sediments to the water table, or recharges the principal artesian aquifer through rock outcrops or sinkholes. The longer the water remains in contact with materials of the earth's crust, the more mineral matter it dissolves.

Overland runoff has little time in contact with the earth's crust and is thus similar to rainfall in quality—low in dissolved solids. During periods of heavy rainfall, overland runoff makes up most of the streamflow so the dissolved solids content of the stream water is low. During times of reduced rainfall when there is little overland runoff, streamflow consists mainly of ground-water discharge and is therefore higher in dissolved solids. Thus, seasonal variations occur in the quality of surface water that recharges the aquifer.

Surface-water recharge to the aquifer is beneficial in a quantitative sense, but the quality of the recharge water is generally not within Georgia Environmental Protection Division standards (1977) for drinking water. Before the Withlacoochee River flows into the recharge area, it receives municipal effluent from the city of Tifton about 50 mi upstream, effluent from small towns and industries, and agricultural runoff. Although the river water flowing into the recharge area is of good quality for most surface-water uses (Georgia Environmental Protection Division, 1975), it may be of an undesirable quality as recharge water to the principal artesian aquifer. It may carry pesticides and fertilizers from agricultural runoff, or any number of pollutants from industrial processes and municipal effluent. The river water is rarely analyzed for pollutants.

Biological pollutants have been discovered in 34 of 70 wells sampled in the immediate Valdosta area by the Georgia Environmental Protection Division (written commun., 1976). Protozoa were found in 11 samples (all from wells in the recharge area north of Valdosta); bacteria, in 15 samples; and fungi, in 24 samples.

Even unpolluted, surface water is very different in its chemical composition from ground water in the principal artesian aquifer. Table 2 shows the chemical and physical properties of water in the Withlacoochee River in the recharge area. The river was sampled just upstream from a large sinkhole that receives much of the river's water. At the time the sample was collected, the flow of the river was less than 100 ft^3/s and more than half of this amount was entering the sinkhole. A pond was also sampled where it discharges into a drainage well near Lake Park. Flow into the drainage well was estimated to be about 1 ft^3/s.

Generally, surface water contains fewer dissolved chemical constituents and is lower in hardness than ground water. However, it does contain more iron and aluminum and has a higher color intensity. (See table 2 for a comparison of the quality of typical aquifer water with surface water.) Because the surface water flows into sinkholes or drainage wells, or infiltrates through thin layers of soil, very little filtration and adsorption of impurities takes place to improve the quality of the water before it gets into the aquifer. This could be particularly serious if the water contains harmful bacteria or viruses. North of Valdosta, the water moves downgradient from the recharge mound through large solution openings in the limestone. Some filtering may take place, but water similar in quality to river water is withdrawn from wells tapping the aquifer more than 3 mi away from the points of recharge. Because the river water is different in quality from the aquifer water, it can be traced within the aquifer. Specific conductance and color, discussed in later sections, best show the movement of the river water in the aquifer.

Water from the upper zone of the principal artesian aquifer in the study area is generally of good quality and is within limits set for drinking water by the Georgia Environmental Protection Division (1977). Only in the immediate Valdosta area and north of Valdosta, where the Withlacoochee River recharges the aquifer, do water-quality problems exist. These are discussed in later sections. Water from the upper zone of the aquifer is of the calcium bicarbonate type, that is, its major dissolved constituents are calcium and bicarbonate. Table 2 includes analyses of water from 65 wells (seven of which had been previously sampled), two springs, and one drainage well, all collected during the study. Also included are analyses of water from five previously sampled wells that were not sampled during the study.

Table 2 also shows the quality of "typical" water from the principal artesian aquifer in the study area. The typical quality is determined by averaging each constituent for all the wells that tap the upper zone of the aquifer. A median is used where more meaningful, and is the value that would just as likely be exceeded as not. Because only the upper-zone wells are included to determine the typical water, the two deep wells at Clyattville (185-25 and 185-26) and the packer intervals below 550 ft in test well 1 are not included. Arnold and McIntyre Springs are included, as they discharge water from the upper zone of the aquifer.

Water quality varies with depth and this can be seen by comparing the quality of water from packer intervals in test well 1. (See table 2 and figs. 13 and 14.) Various intervals in the borehole were isolated by placing inflatable packers above and below the interval. A deep-well submersible pump placed between the packers pumped water to the surface for sampling. In the interval from the top of the aquifer to a depth of 461 ft, the water is of the calcium bicarbonate type and has a dissolved-solids concentration of less than 200 mg/L (milligrams per liter). Water from a transition zone from 481 to 543 ft has a dissolved-solids concentration that exceeds 400 mg/L. In the lower zone, below a depth of 550 ft, the water is of poor quality—a calcium, magnesium sulfate type. The dissolved-solids concentration in this interval exceeds 2,800 mg/L, the sulfate concentration is about 2,500 mg/L, and the strontium concentration is 12 mg/L. (See table 2.)

Poor-quality water is found at depth because the water there has been in contact with the water-bearing formation longer than has water in shallower beds. Also, because of the geothermal gradient, water temperature increases with depth and the higher temperature of the lower-zone water increases the solubility of most elements and the rate of solution of the rock (Hem, 1970). The occurrence of poor-quality water at depth in the study area also is related to the presence of evaporites at depth in the aquifer. Gypsum ($CaSO_4 \cdot 2H_2O$), and probably anhydrite ($CaSO_4$) and celestite ($SrSO_4$), are present in the lower zone of the aquifer. These sulfates are more soluble than limestone or dolomite, and contribute calcium, sulfate, and strontium to the aquifer water. Although the poor-quality water is first found in the lower part of the Ocala Limestone, the quality degrades even more in the underlying rocks of the Claiborne Group. In test well 1, the Claiborne Group yields water containing much higher strontium concentrations than do the overlying formations. Fluid resistivity logs for test well 1 show that poor-quality water begins at about 550 ft, and that water of even poorer quality occurs at greater depths, especially at about 810 and 890 ft.

Poor-quality water, similar to that found below 550 ft in test well 1, probably is present at about the same depth throughout the study area. Resistivity logs of three oil-test wells in Lowndes County also indicate the presence of poor-quality water in the lower part of the Ocala Limestone and the Claiborne Group. Low resistivity in the oil-test wells compares with that in test well 1, indicating similar lithology and formation fluid.

Wells drilled 800 ft deep at the Owens-Illinois plant in Clyattville yield water of somewhat poorer quality than do other wells in the area that are less than about 300 ft deep and tap only the upper zone. (See table 2.) Water at the 800-ft level in the aquifer is probably more mineralized than the analyses indicate. The water is probably highly mineralized below about 550 ft, but the wells are cased to only 170 ft, and most of the water supplied by the wells is from the upper zone that yields water of low dissolved-solids concentration.

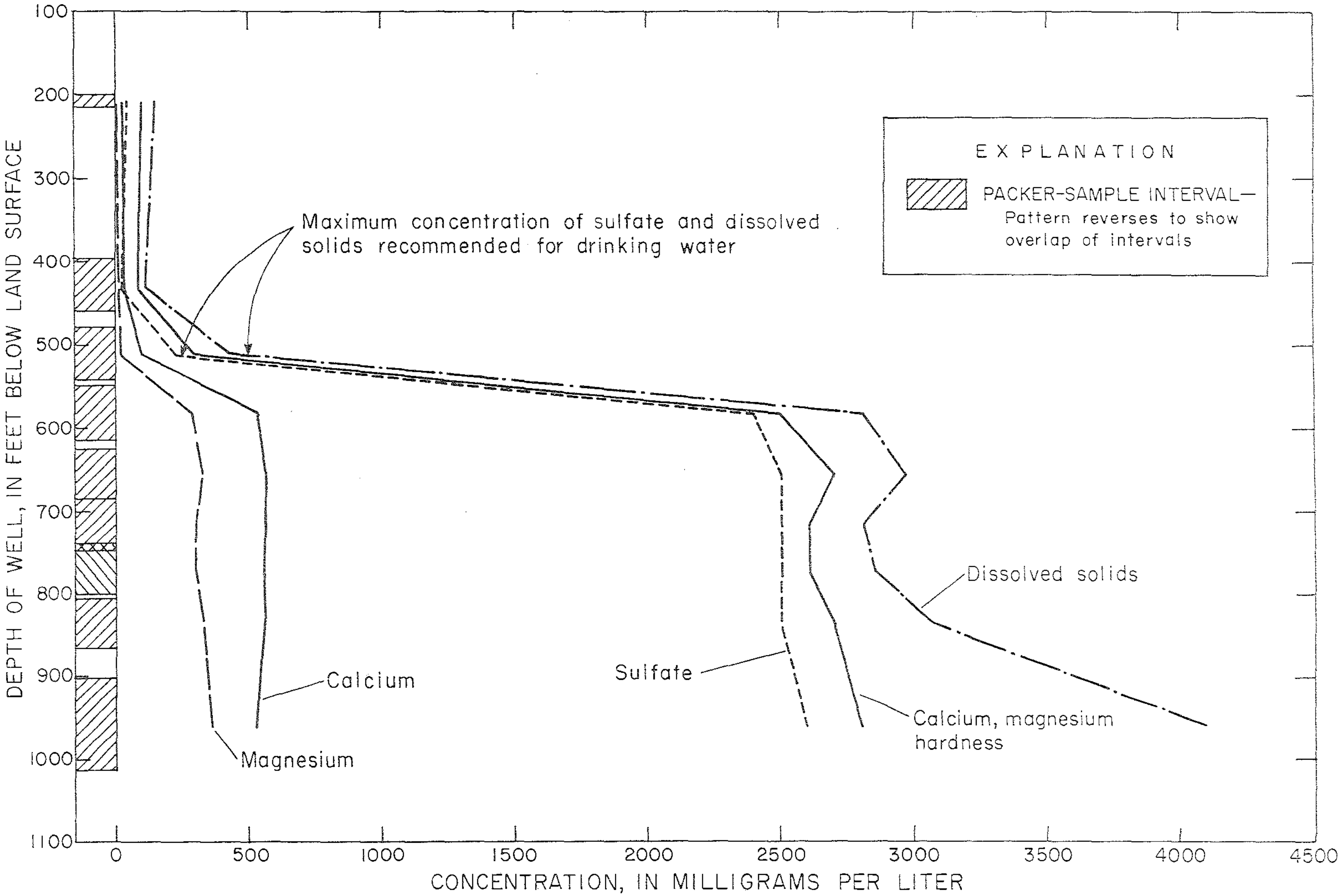


Figure 13.—Relation of magnesium, calcium, sulfate, dissolved solids, and calcium, magnesium hardness with depth, test well 1, Valdosta.

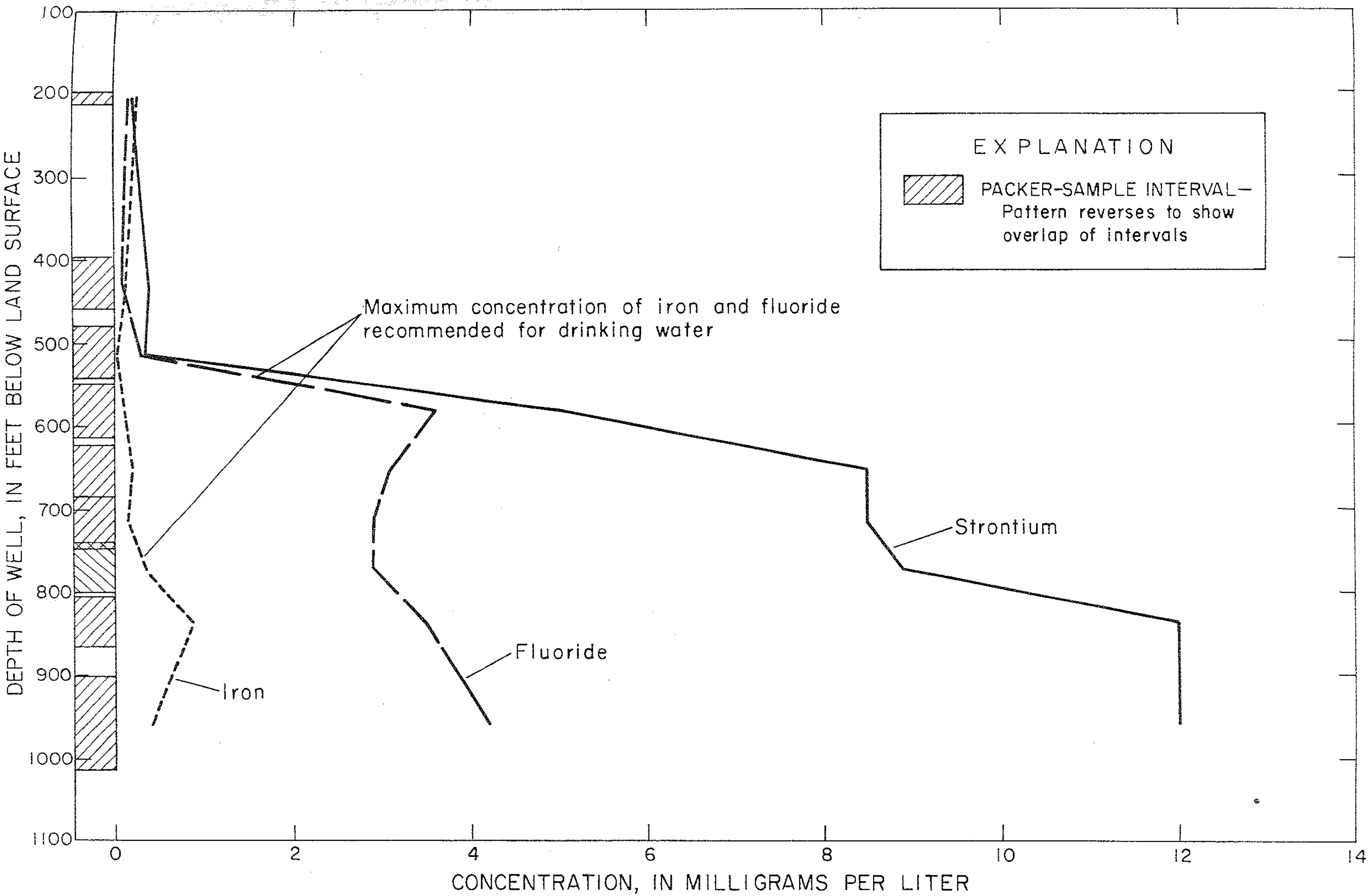


Figure 14.—Relation of iron, fluoride, and strontium with depth, test well 1, Valdosta.

Poor-quality water was also found at depth in a city of Valdosta supply well (185-9) (location, pl. 8). In the interval from 530 to 818 ft the dissolved-solids concentration was about 2,500 mg/L and the sulfate concentration exceeded 1,700 mg/L. The well has since been plugged back to 367 ft and yields water of drinking-water quality.

The poor-quality water also is present in the lower zone of the aquifer north and west of the study area. Herrick and Vorhis (1963) stated that a structural trough (the Gulf Trough) trends northeast-southwest and lies northwest of the study area. (See fig. 1.) This trough is responsible for the poor-quality water found in that area, as it contains great thicknesses of low-yielding clastic sediments, and the resulting poor circulation of ground water in this area has left the rocks containing mineralized water. The northwest corner of the study area is on the southeast flank of this trough. Wells in Cairo and Moultrie (location, fig. 1) yield water high in sulfate concentration from thick sequences of Oligocene and upper Eocene sediments associated with this trough.

Herrick (1961) stated that in Clinch County just east of the study area (fig. 1), the lower part of the Ocala Limestone and the Claiborne Group contain large amounts of gypsum and yield mineralized water. Also, in Echols County, gypsum is abundant in the Claiborne Group.

Sever (1972) reported mineralized water from the Ocala Limestone as sampled by a U.S. Geological Survey test well in Adel, 23 mi north of Valdosta (location, fig. 1). The sulfate concentration was 612 mg/L and the dissolved-solids concentration was 1,020 mg/L in the uppermost water-bearing unit of the Ocala.

South of the study area, wells tapping the principal artesian aquifer yield water high in sulfate. A municipal well tapping the Ocala Limestone and the upper part of the Claiborne Group in Jasper, Fla., 30 mi southeast of Valdosta (location, fig. 1), yields water that has a sulfate concentration of about 200 mg/L (Florida State Board of Health, 1960).

The presence of mineralized water at depth in the Valdosta area may pose a problem to future ground-water development. At present, pressure heads in the freshwater zones are about equal to those in the lower, poorer quality zones. However, if heavy ground-water withdrawal takes place in the freshwater zone, it will cause a head or pressure imbalance. Poor-quality water could then migrate upward into the freshwater zone. This may already be occurring, as sulfate concentration, the best indicator of poor-quality water in the study area, is increasing in the heavily pumped downtown Valdosta area. Valdosta supply wells 185-5, 185-9, and 185-10 increased in sulfate concentration from 2 to 6 mg/L; 50 to 73 mg/L; and 62 to 90 mg/L, respectively, during the period 1962-74.

Hardness

Hardness is a property of water that affects its consumption of soap, and causes encrustations to form on heated surfaces. Chemically, hardness is a function of calcium and magnesium concentration and is called calcium, magnesium hardness. Hardness is high where water is from calcium- or magnesium-rich rocks such as those that make up the principal artesian aquifer in the study area.

Relative degrees of hardness are expressed as soft—less than 60 mg/L calcium, magnesium hardness; moderately hard—61 to 120 mg/L; hard—121 to 180 mg/L; and very hard—more than 180 mg/L of hardness. (Durfor and Becker, 1964).

Water in the study area is generally moderately hard to hard. Water is generally softer in Lowndes and Echols Counties, nearer the recharge area, than in Brooks County where the water is more deeply buried and has been in the formation a greater length of time. One well (27-05) tapping the upper zone of the aquifer in Brooks County yielded very hard water.

Test well 1 yielded water that had a hardness of 85 to 101 mg/L in the upper zone and 2,515 to 2,803 mg/L in the lower zone. The transition zone contained water having a hardness of 303 mg/L. (See fig. 13.)

The very hard water found below 550 ft can be attributed to the greater length of time that the water has been in the formation and to a higher temperature that increases the solubility of calcium and magnesium. The water's hardness can also be attributed to the presence of gypsum and probably anhydrite, which contribute large amounts of calcium to the water.

Iron

Iron is an abundant mineral of the earth's crust, and is thus found in most water. The presence of iron in water is objectionable because of its taste, staining capacity, and encrustating property. The Georgia Environmental Protection Division (1977) sets a limit of 0.3 mg/L of iron in drinking water. The limit is not exceeded in any of the water from the upper zone of the principal artesian aquifer in the Valdosta area.

The source of most iron in ground water in the Valdosta area is the Withlacoochee River and other surface water that recharges the aquifer. The iron concentration in the Withlacoochee River at the recharge site is 0.62 mg/L, and in the pond that contributes water to the drainage well near Lake Park, it is 0.2 mg/L.

Iron is an essential element in organic processes, and therefore is one of the metals that accumulates in vegetation and is dissolved by surface water as the plants decay, producing organic debris. The iron content of water increases during times of maximum plant decay (Hem, 1970). Water from Valdosta city well 8 (185-22) (location, pl. 8), near the recharge area on the Withlacoochee River, had an iron concentration of 0.21 mg/L. In the upper zone of test well 1, the iron concentration ranged from 0.13 to 0.26 mg/L. In the sinkhole-lakes region of southeast Lowndes County, the iron concentration was relatively high in 3 of the 4 wells in the vicinity of the drainage well near Lake Park. Wells 185-11, 185-23, and 185-30 had iron concentrations of 0.25, 0.21, and 0.15 mg/L, respectively.

Iron also occurs in large concentrations at depth in the Valdosta area as shown in test well 1 (fig. 14). High iron concentration in the lower zone of the aquifer is probably related to iron-bearing minerals in the rock. The presence of pyrite (iron sulfide) in the rock in the interval from 804 to 866 ft could account for the iron concentration of 0.86 mg/L.

Strontium

Strontium occurs in large concentrations in the lower zone of the principal artesian aquifer. In water from the bottom two packer intervals from 804 to 866 ft and 902 to 1,014 ft in test well 1, the concentration of strontium was 12 mg/L (fig. 14). Although no standards for drinking water have been established for strontium, that concentration, especially relative to the calcium concentration, is high. The strontium to calcium ratio (Sr milliequivalents per liter per 1,000 Ca milliequivalents per liter) is 10.4 in the lower packer interval. This is higher than averages based on analyses of ground water collected throughout the United States (Skougstad and Horr, 1963). Strontium makes up as much as 0.39 percent of the dissolved solids in water from the lower zone. This is also considered higher than average for analyses of ground water made throughout the United States (Skougstad and Horr, 1963).

Although no strontium-bearing minerals were found in the cores from test well 1 (only 5 percent of the hole was cored), the high strontium concentration indicates that they are present. Strontianite ($SrCO_3$) and celestite ($SrSO_4$) undoubtedly are present in the aquifer. These two minerals are commonly found in thin beds or lenses in limestone, dolomite, or gypsum—all present in the lower water-bearing zone. Celestite, the more common of the two, would also account for some of the high sulfate.

The strontium concentration in the upper zone of the aquifer is low, and does not vary much in the study area.

Specific Conductance

Water containing ionized chemical constituents conducts electricity. Specific conductance is the measure of water's ability to conduct an electric current, and is measured in micromhos per centimeter at 25°C (Celsius). The specific conductance increases as the ion concentration increases, so it is a rough indicator of the concentration of chemical constituents in the water.

Ground water, slowly percolating through sediments or rocks dissolves materials, thus increasing its conductance. In general, the longer water has been in contact with materials in the earth's crust, the greater its conductance.

Specific conductance was determined in the field for all samples collected for complete analyses (table 2). In addition, field determinations of specific conductance were made on water from other wells near the recharge area to better define the movement of recharge water in the aquifer. The areal distribution of specific conductance shows that near the recharge area, conductance is less than 150 micromhos. (See pl. 8.) The specific conductance of water in the Withlacoochee River at the point of recharge was 68 micromhos. Away from the recharge area, where the water has been in contact with the deeply buried aquifer for a long time, specific conductance is as much as 450 micromhos (pl. 8).

In test well 1 the specific conductance was 173 to 205 micromhos in the interval from 200 to 461 ft; 454 micromhos in the transition zone from 481 to 543 ft; and 2,950 to 3,620 micromhos below 550 ft.

Although the specific conductance is an indicator of water quality, it does not reveal what constituents are present. Specific conductance also will not denote the presence of small but dangerous quantities of inorganic and organic pollutants. Thus, it is not an indicator of water purity.

Color

Color in water in the Valdosta area is mainly the result of natural organic processes. Rivers, ponds, and swamps gain color as their waters contact and dissolve organic debris.

Although color in water is not a health hazard, it is aesthetically undesirable and it may dull clothes or stain food and fixtures. The intensity of color is measured in platinum-cobalt units by visually comparing the color intensity of water to a known standard. It is, thus, not a precise determination and also may be complicated if the hue of the water does not match that of the standard. The Georgia Environmental Protection Division (1977) has set a limit of 15 platinum-cobalt units of color for drinking water.

Figure 15 shows the areal distribution of color in ground water in the immediate Valdosta area; color was not found to be a problem elsewhere in the study area. The highly colored Withlacoochee River water is the source of high color intensity of ground water north of Valdosta (Krause, 1976). The recharged, highly colored water migrates rapidly downgradient and is withdrawn by wells before much color removal or reduction of color by dilution takes place in the aquifer. The migration is probably facilitated by those channels or solution openings that are oriented from the recharge area in a northwest-southeast direction. The relatively rapid movement of the water through the aquifer may explain the presence of highly colored water in city well 8 (185-22) north of Valdosta (location, pl. 8). The

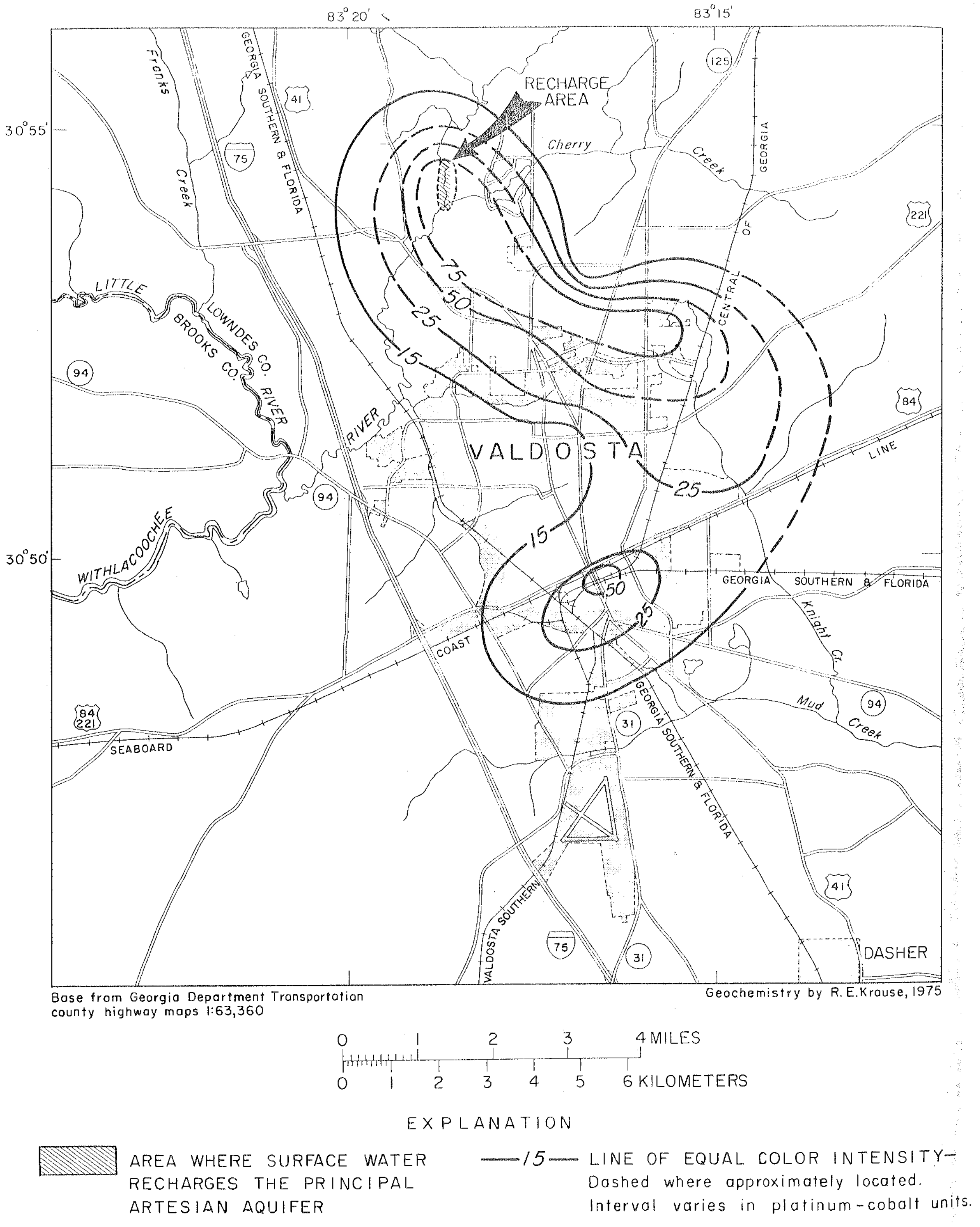


Figure 15.—Color intensity of water from the principal artesian aquifer, Valdosta area, 1974.

color intensity in city well 8 (90 units) is almost as great as that of the Withlacoochee River (100 units). This indicates that the water has been in the aquifer a short time, and that the extent of color reduction has been minimal.

Color in water from wells in the Valdosta downtown area is partially due to the presence of poorly filtered recharge water from the Withlacoochee River. Ground-water pumpage in the downtown area intercepts some water migrating from the recharge area. In addition, some of the color may be due to very small suspended particles entering the wells through breaks in the well casings.

Color due to organic material dissolved in the water is expensive to remove in water treatment. For this reason, public supply wells generally are located in areas of low color intensity.

Hydrogen Sulfide and Sulfate

Other water-quality problems in the Valdosta area include the presence of objectionable quantities of hydrogen sulfide in the upper part of the principal artesian aquifer, and large concentrations of sulfate in the lower part of the aquifer. Hydrogen sulfide gas is formed by the decomposition of organic matter or by the reduction of sulfate in water. In the Valdosta area, the reduction of sulfate is the probable source of objectionable concentrations of hydrogen sulfide in water from the principal artesian aquifer (Krause, 1976). Hydrogen sulfide imparts a taste and odor to water, so its presence in drinking water is considered undesirable. No limits have been set for hydrogen sulfide concentrations in drinking water, but the Georgia Environmental Protection Division (1977) states that drinking water should not cause offense to the senses of sight, taste, or smell.

In the Valdosta area, ground water high in hydrogen sulfide is also high in sulfate. Figure 16 shows that for wells sampled in the Valdosta area for both constituents, there was a direct correlation between the concentrations of hydrogen sulfide and sulfate.

Concentrations of sulfate, and hence hydrogen sulfide, generally become greater with depth in the Valdosta area. The sulfate concentrations in test well 1 increased from 23 mg/L in the interval from 398 to 461 ft, to 230 mg/L in the interval from 481 to 543 ft, and to 2,600 mg/L below 550 ft (fig. 13). The sulfate concentration is also very high (50 to 310 mg/L) in the deep wells at the Owens-Illinois plant in Clyattville (table 2).

Figure 17 shows the distribution of hydrogen sulfide in water from the principal artesian aquifer in the Valdosta area. The hydrogen sulfide concentration is highest in an area extending from the center of Valdosta toward the southeastern part of the study area. This area is away from the area of recharge, and may represent a part of the aquifer where ground-water circulation is slow, allowing the accumulation of higher concentrations of sulfate and hydrogen sulfide.

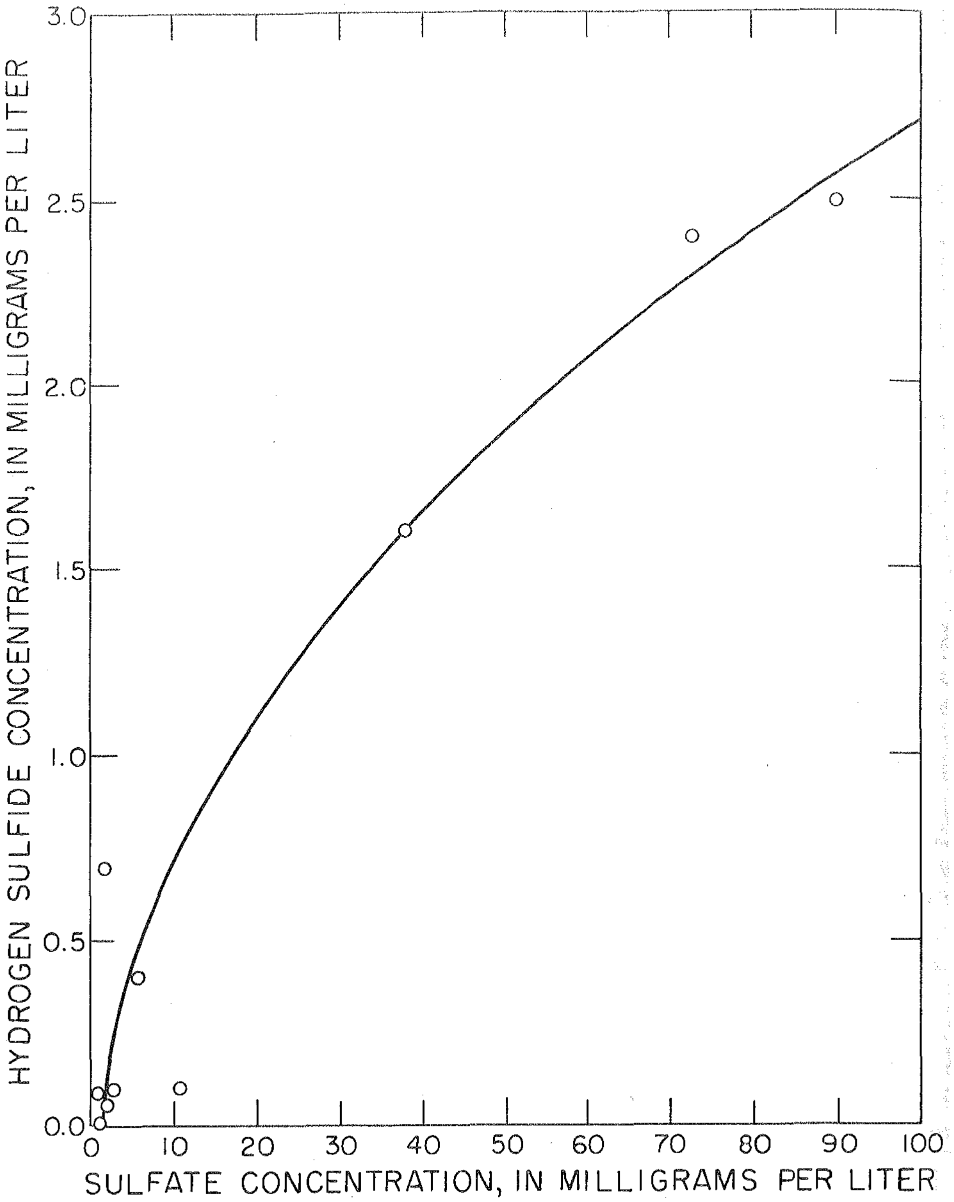


Figure 16.—Relation of hydrogen sulfide to sulfate in water from the principal artesian aquifer, Valdosta area.

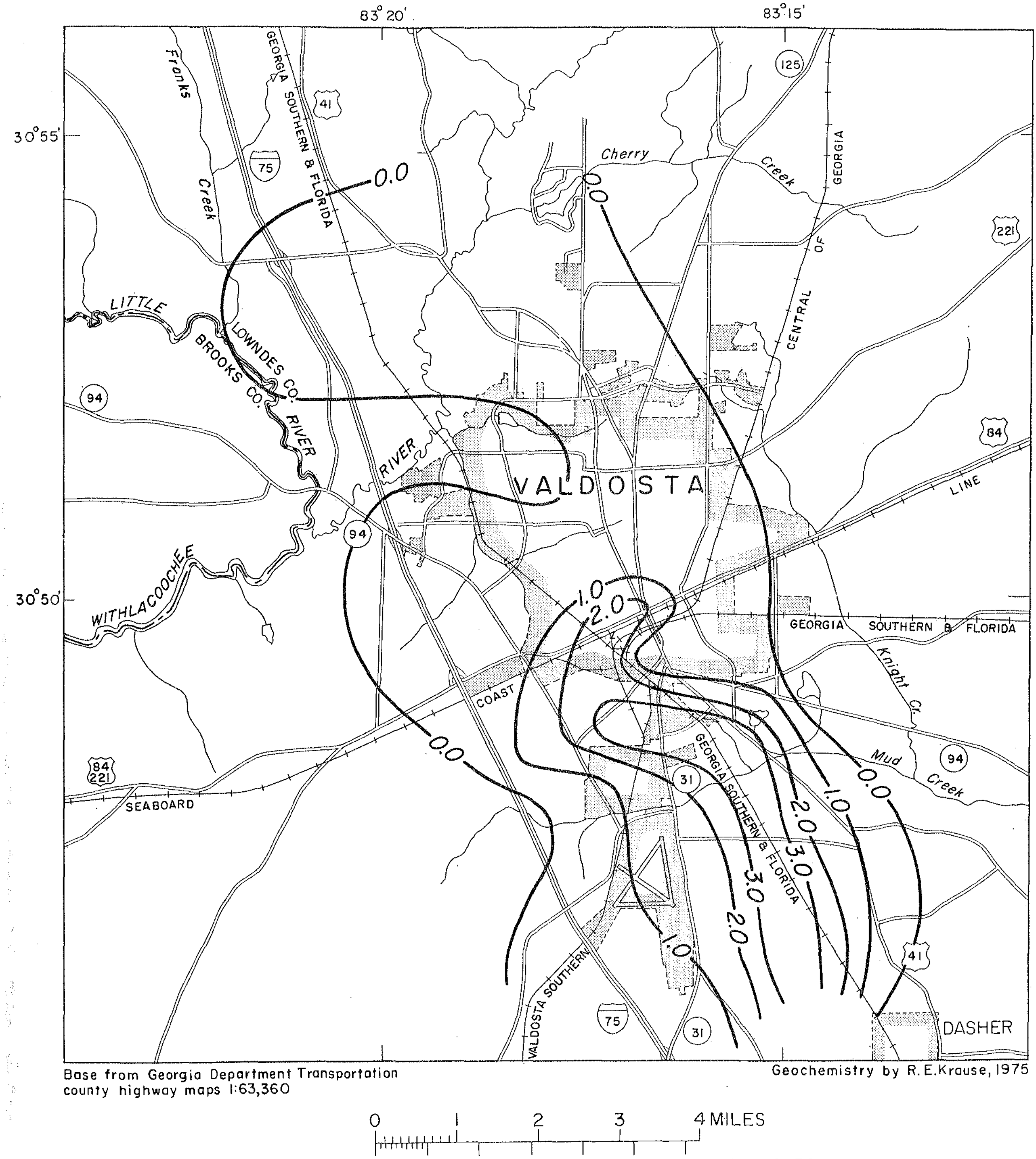


Figure 17.—Hydrogen sulfide concentration of water from the principal artesian aquifer, Valdosta area, 1975.

Hydrogen sulfide is a gas, so it may be partially removed by aeration. However, because of its corrosive nature, hydrogen sulfide in water causes corrosion of well casings and pipes.

CONCLUSIONS AND SUGGESTIONS

Almost all ground water used in Brooks, Lowndes, and western Echols Counties is withdrawn from the highly productive principal artesian aquifer, a carbonate sequence of Eocene to Miocene age. The Suwannee Limestone of Oligocene age, lying less than 250 ft below land surface, yields most of the water from the aquifer. The highly permeable contact zone between the Suwannee and the overlying carbonates of Miocene age is especially productive.

Recharge to the aquifer occurs chiefly where the aquifer crops out at higher altitudes updip from the study area, and within the study area where the Withlacoochee River flows into sinkholes and solution openings into the aquifer. Results from this study indicate an average loss by the Withlacoochee River to the aquifer of about 112 ft^3/s. Although this recharge is beneficial in a quantitative sense as it provides a large quantity of water to the aquifer and for subsequent ground-water use, it causes problems with both surface- and ground-water quality.

When streamflow entering the recharge area is about 40 ft^3/s or less, all of the flow is lost to the aquifer. Sewage effluent, flowing into the river channel downstream, is poorly diluted, rendering the river polluted throughout its reach in Georgia.

Recharge water from the Withlacoochee River is poorly filtered as it migrates through the very porous aquifer, and wells tapping the upper part of the aquifer in the area north of Valdosta yield water high in iron concentration and color intensity.

The upper part of the aquifer in the south part of Valdosta yields water containing objectionable concentrations of hydrogen sulfide. Elsewhere, water from the upper part of the aquifer is of good quality and is within limits for drinking water set by the Georgia Environmental Protection Division (1977). In the lower part of the aquifer, below a depth of about 550 ft in the Valdosta area, and most likely at that depth throughout the study area, water is of a quality unfit for most uses. The dissolved-solids concentration is about 2,500 mg/L.

Although ground water is available in large quantities to users in the study area, water-quality problems may affect the development of this important resource. Where large yields are required, multiwell supplies can be developed from the upper freshwater zone in areas of low color and hydrogen sulfide. (See fig. 18.) Adequate spacing between wells should limit the head imbalance between the upper freshwater zone and the lower poor-quality-water zone and minimize the amount of poor-quality water that migrates upward into the freshwater zone. Generally, wells drilled deeper than about 550 ft may yield water of poor quality.

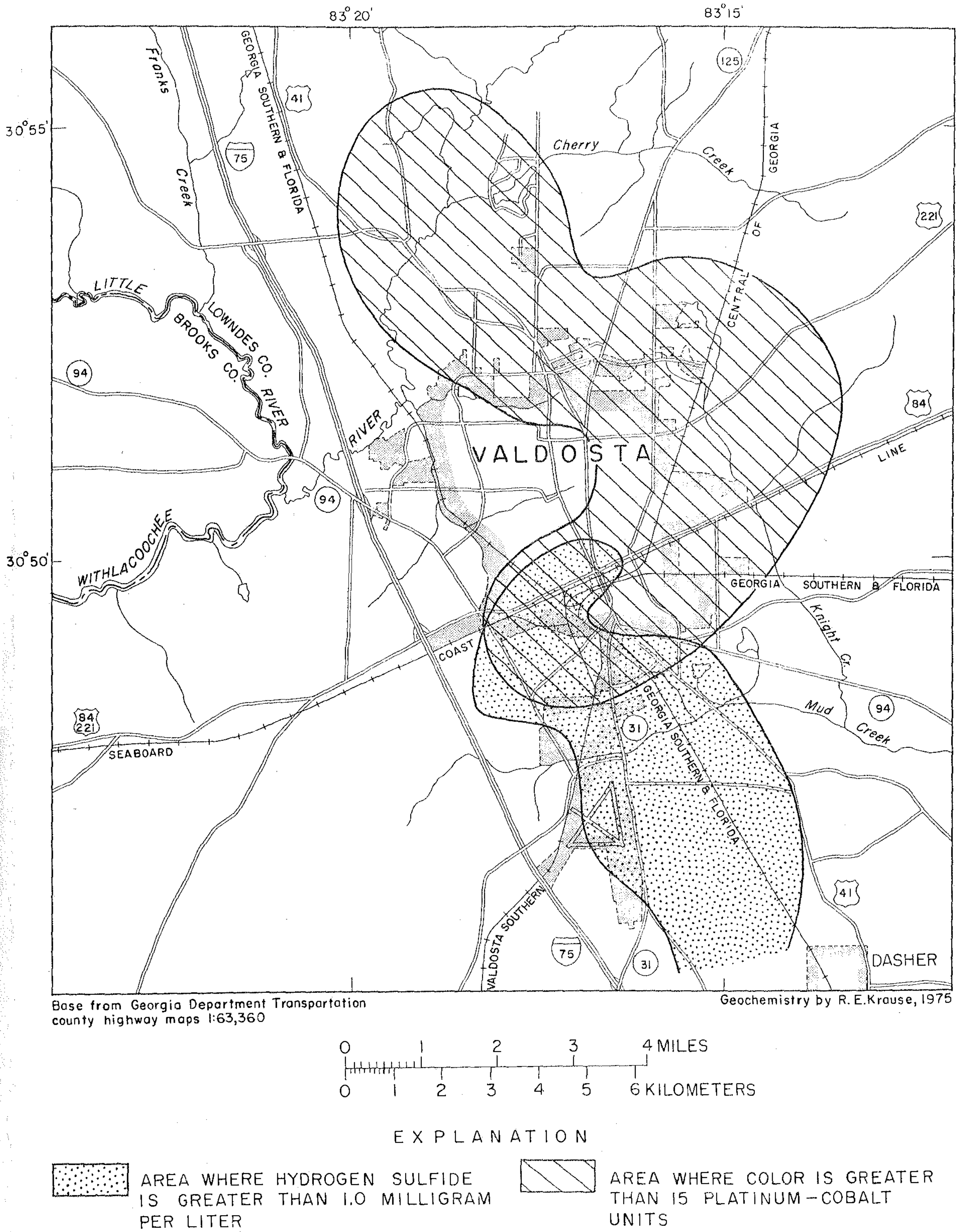


Figure 18.—Areas where wells tapping the principal artesian aquifer in the Valdosta area yield water high in hydrogen sulfide and color.

SELECTED REFERENCES

Cooke, C. W., 1943, Geology of the Coastal Plain of Georgia: U.S. Geological Survey Bulletin 941, 121 p.

Durfor, C. N., and Becker, Edith, 1964, Public water supplies of the 100 largest cities in the United States, 1962: U.S. Geological Survey Water-Supply Paper 1812, 364 p.

Fisk, D. W., and Exley, I. S., 1977, Exploration and environmental investigation of the Peacock Springs cave system in Hydrologic problems in karst regions: Bowling Green, Western Kentucky University, p. 297-302.

Florida State Board of Health, 1960, Some physical and chemical characteristics of selected Florida waters: Bureau of Sanitary Engineering, Division of Water Supply, 108 p.

Fortson, C. W., Jr., 1961, Peat deposits of Georgia: Georgia Mineral Newsletter, v. 14, no. 1, p. 1-21.

Fortson, C. W., Jr., and Navarre, A. T., 1959, Limestones exposed in the lower Withlacoochee Valley of Georgia: Southeastern Geology, v. 1, p. 73-76.

Georgia Environmental Protection Division, 1972, Water quality data—Valdosta area, 1970 and 1971, 35 p.

_____1973, Water quality monitoring data for Georgia streams, 1972, 235 p.

_____1974a, Water quality monitoring data for Georgia streams, 1973, v. 2, 261 p.

_____1974b, Wastewater treatment facility inventory.

_____1975, Water quality monitoring data for Georgia streams, 1974, 376 p.

_____1977, Rules for safe drinking water: Chapter 391-3-5, 57 p.

Georgia Geological Survey, 1939, Geologic map of Georgia.

_____1976, Geologic map of Georgia.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473, 358 p.

Hendry, C. W., Jr., and Yon, J. W., Jr., 1967, Stratigraphy of upper Miocene Miccosukee Formation, Leon and Jefferson Counties, Florida: Bulletin of the American Association of Petroleum Geologists, v. 51, no. 2, p. 250-256.

Herrick, S. M., 1961, Well logs of the Coastal Plain of Georgia: Georgia Geological Survey Bulletin 70, 462 p.

Herrick, S. M., and Vorhis, R. C., 1963, Subsurface geology of the Georgia Coastal Plain: Georgia Geological Survey Information Circular 25, 78 p.

Inman, E. J., 1971, Flow characteristics of Georgia streams: U.S. Geological Survey Open-File Report, 262 p.

Kopitzke, R. S., 9830A Math Pac (Hewlett-Packard #09830-70000, p. 57) Polynomial Regression Program.

Krause, R. E., 1976, Occurrence and distribution of color and hydrogen sulfide in water from the principal artesian aquifer in the Valdosta area, Georgia: U.S. Geological Survey Open-File Report 76-378, 10 p.

Krause. R. E., and Gregg, D. O., 1972, Water from the principal artesian aquifer in Coastal Georgia: Georgia Water Resources Survey Hydrologic Atlas 1.

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

MacNeil, F. S., 1947, Geologic map of the Tertiary and Quaternary formations of Georgia: U.S. Geological Survey Oil and Gas Preliminary Map no. 72.

McCallie, S. W., 1898, A preliminary report on the artesian-well system of Georgia: Georgia Geological Survey Bulletin 7, 214 p.

_____1908, A preliminary report on the underground waters of Georgia: Georgia Geological Survey Bulletin 15, 376 p.

Sever, C. W., 1966, Reconnaissance of the ground water and geology of Thomas County, Georgia: Georgia Geological Survey Information Circular 34, 14 p.

_____1972, Ground-water resources and geology of Cook County, Georgia: U.S. Geological Survey Open-File Report, 40 p.

Skougstad, M. W., and Horr, C. A., 1963, Occurrence and distribution of strontium in natural water: U.S. Geological Survey Water-Supply Paper 1496-D, p. D55-D97.

Stephenson, L. W., and Veatch, J. O., 1915, Underground waters of the Coastal Plain of Georgia, and a discussion of The quality of the waters, by R. B. Dole: U.S. Geological Survey Water-Supply Paper 341, 539 p.

Stringfield, V. T., 1964, Relation of surface-water hydrology to the principal artesian aquifer in Florida and southeastern Georgia, in Geological Survey Research 1964: U.S. Geological Survey Professional Paper 501-C, p. C164-C169.

_____ 1966, Artesian water in Tertiary limestone in the Southeastern States: U.S. Geological Survey Professional Paper 517, 226 p.

Toulmin, L. D., 1955, Cenozoic geology of southeastern Alabama, Florida, and Georgia: Bulletin of the American Association of Petroleum Geologists, v. 39, no. 2, p. 207-235.

U.S. Geological Survey, 1977, Water resources data for Georgia, water year 1976: U.S. Geological Survey Water-Data Report GA-76-1, 411 p.

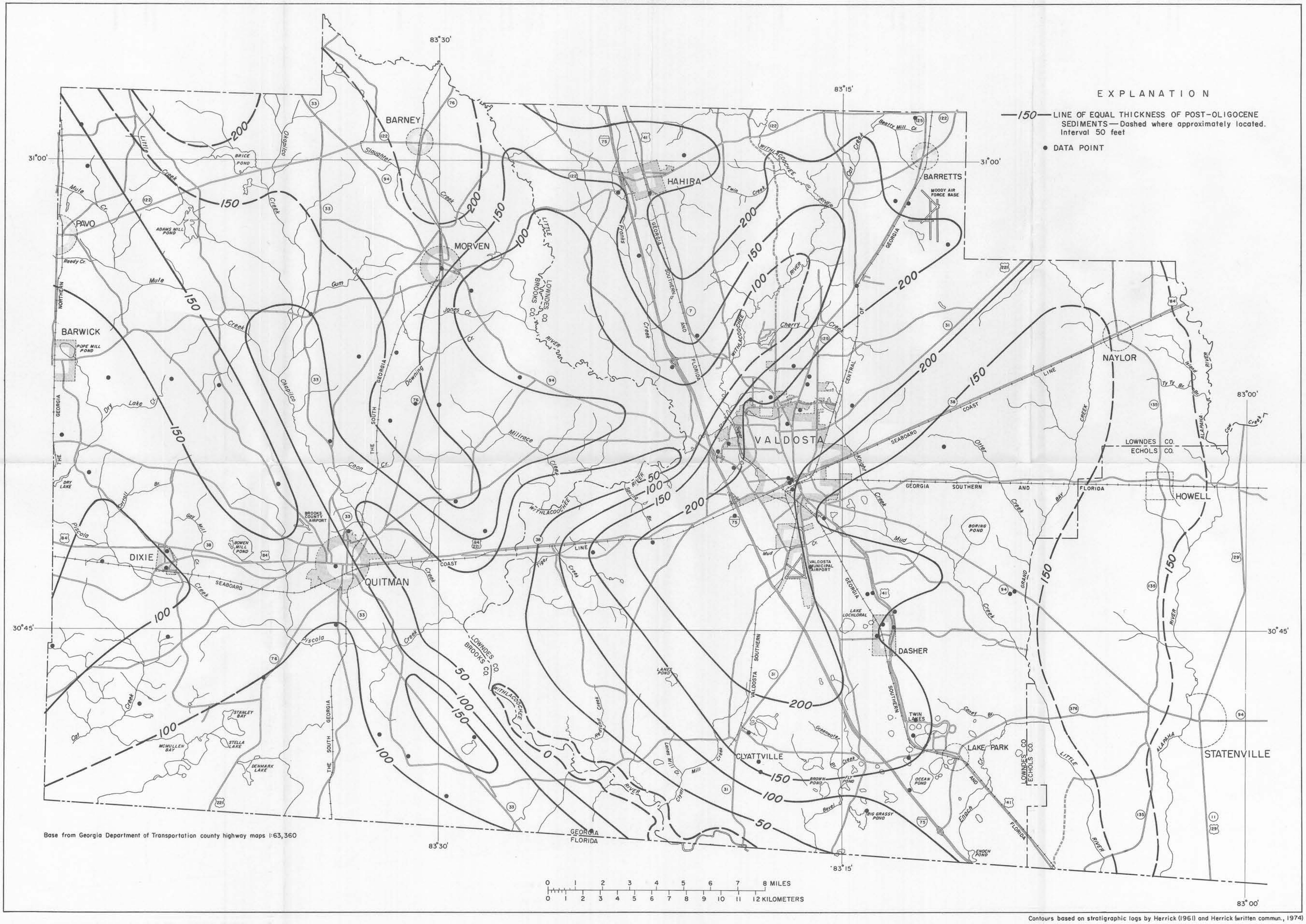
Veatch, J. O., and Stephenson, L. W., 1911, Preliminary report on the geology of the Coastal Plain of Georgia: Georgia Geological Survey Bulletin 26, 463 p.

Vernon, R. O., 1951, Geology of Citrus and Levy Counties, Florida: Florida Geological Survey Bulletin 33, 256 p.

Vorhis, R. C., 1961, A hydrogeologic reconnaissance of reservoir possibilities in northern Lowndes County, Georgia: Georgia Mineral Newsletter, v. 14, no. 4, p. 123-129.

Warren, M. A., 1944, Artesian water in southeastern Georgia, with special reference to the coastal area: Georgia Geological Survey Bulletin 49, 140 p.

Weimer, R. J., and Hoyt, J. H., 1964, Burrows of Callianassa major Say, geologic indicators of littoral and shallow neritic environments: Journal of Paleontology, v. 38, no. 4, p. 761-767.

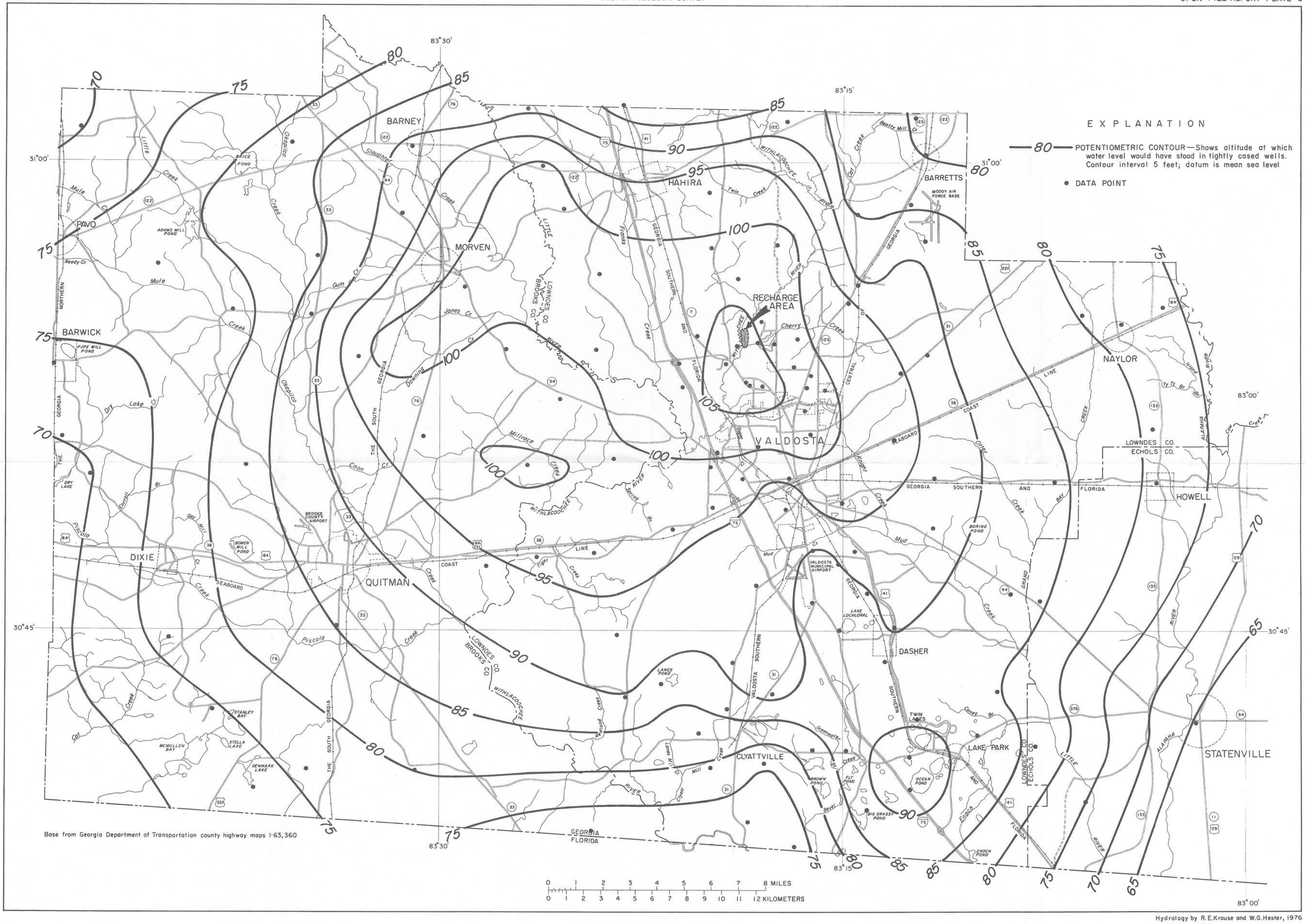


THICKNESS OF POST-OLIGOCENE SEDIMENTS, BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA.

Prepared in cooperation with the
GEORGIA DEPARTMENT OF NATURAL RESOURCES
GEORGIA GEOLOGIC SURVEY

Geology modified from Georgia Geological Survey, 1976

GEOLOGY OF BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA.



POTENTIOMETRIC SURFACE OF THE PRINCIPAL ARTESIAN AQUIFER, BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA, MAY 1975.

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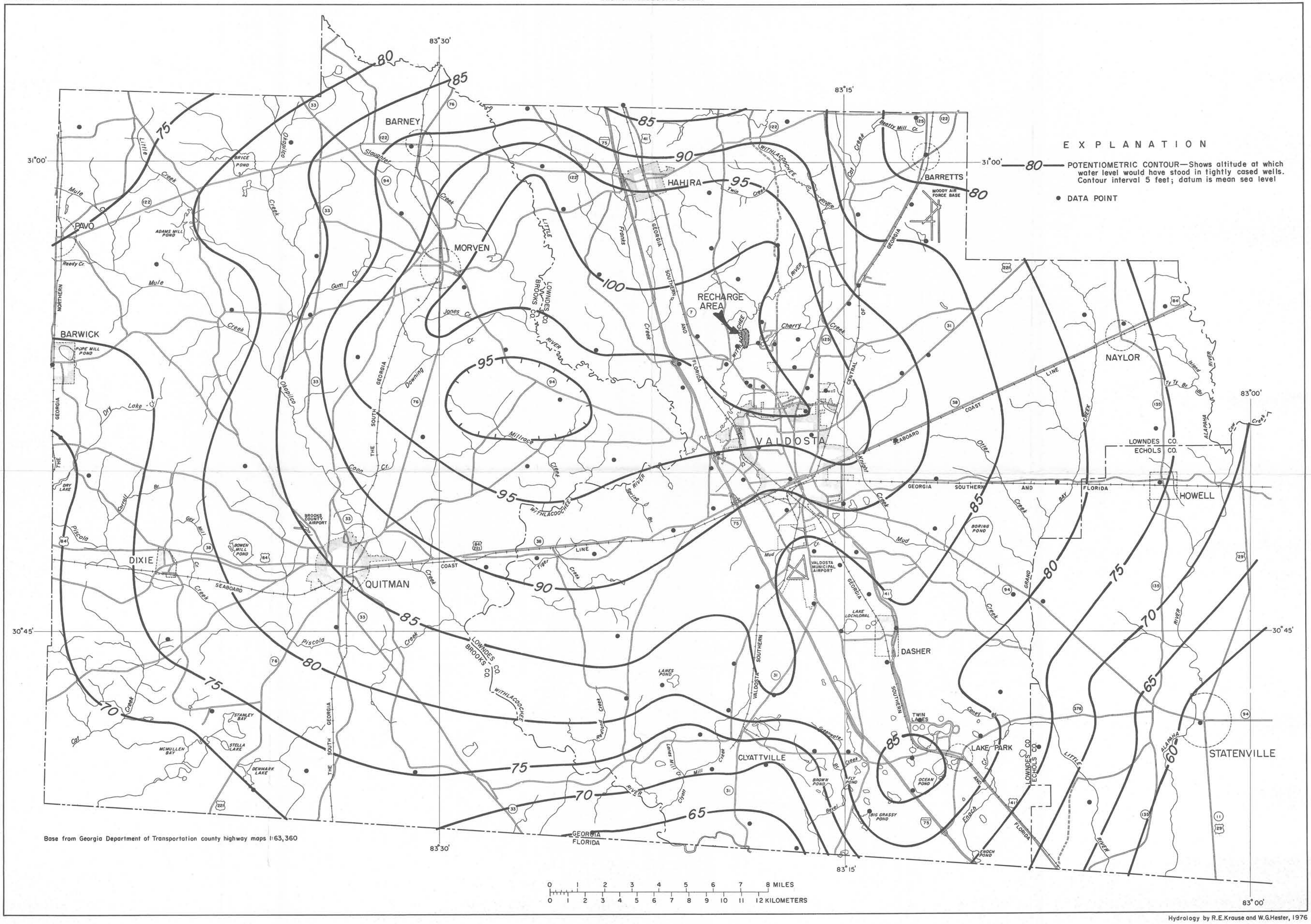
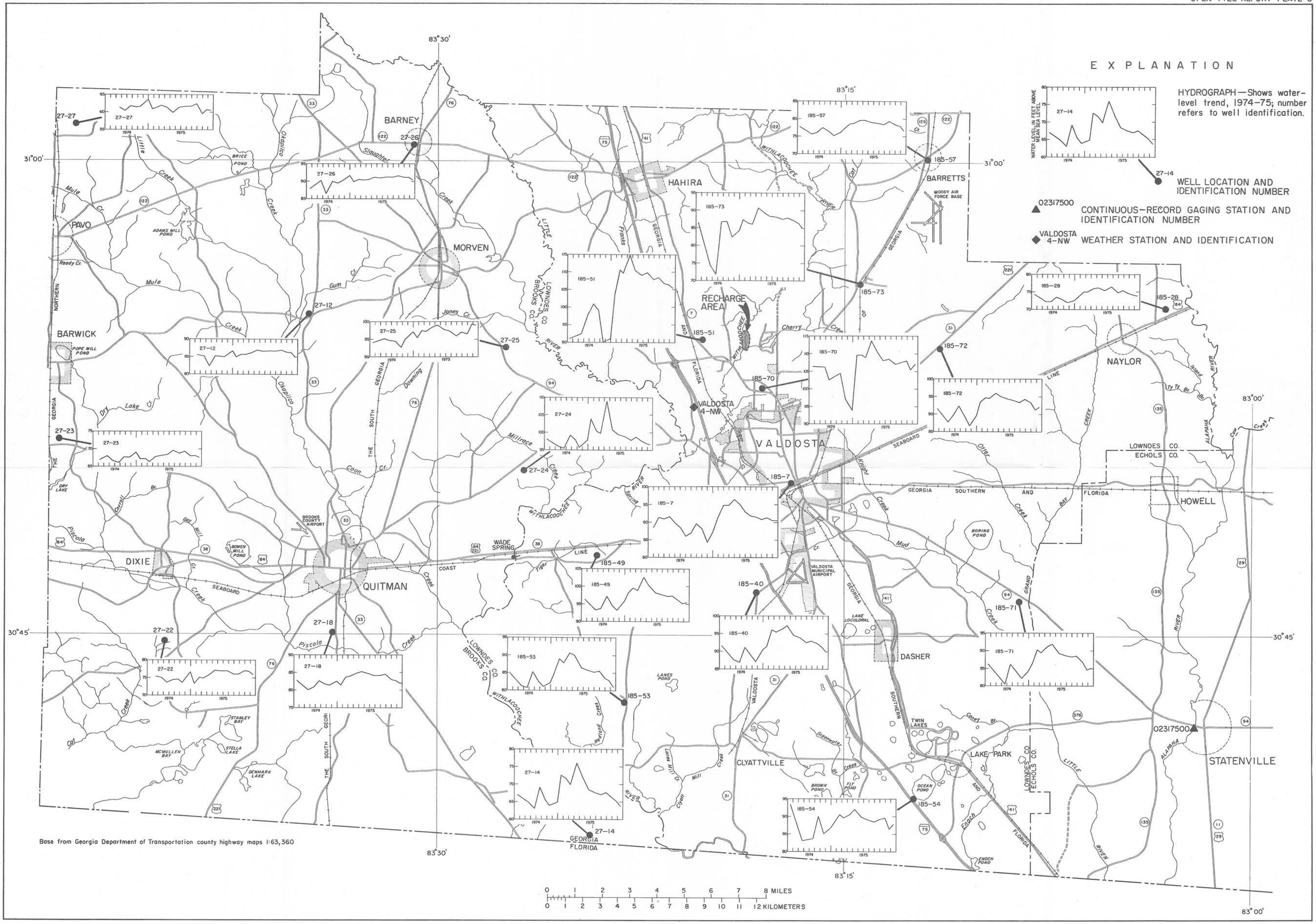
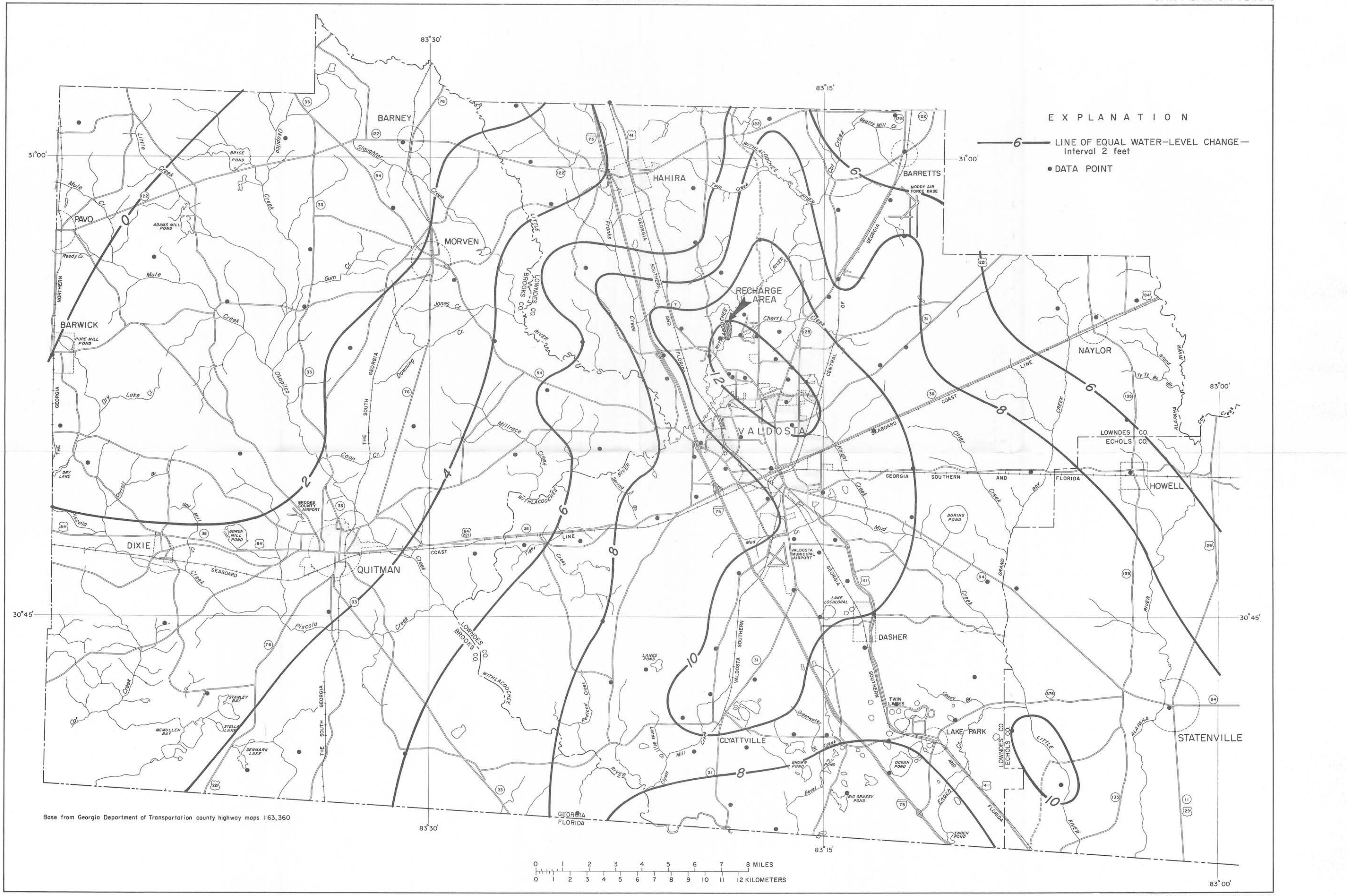


Hydrology by R.E.Krause and W.G.Hester, 1976

POTENTIOMETRIC SURFACE OF THE PRINCIPAL ARTESIAN AQUIFER, BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA, NOVEMBER 1975.

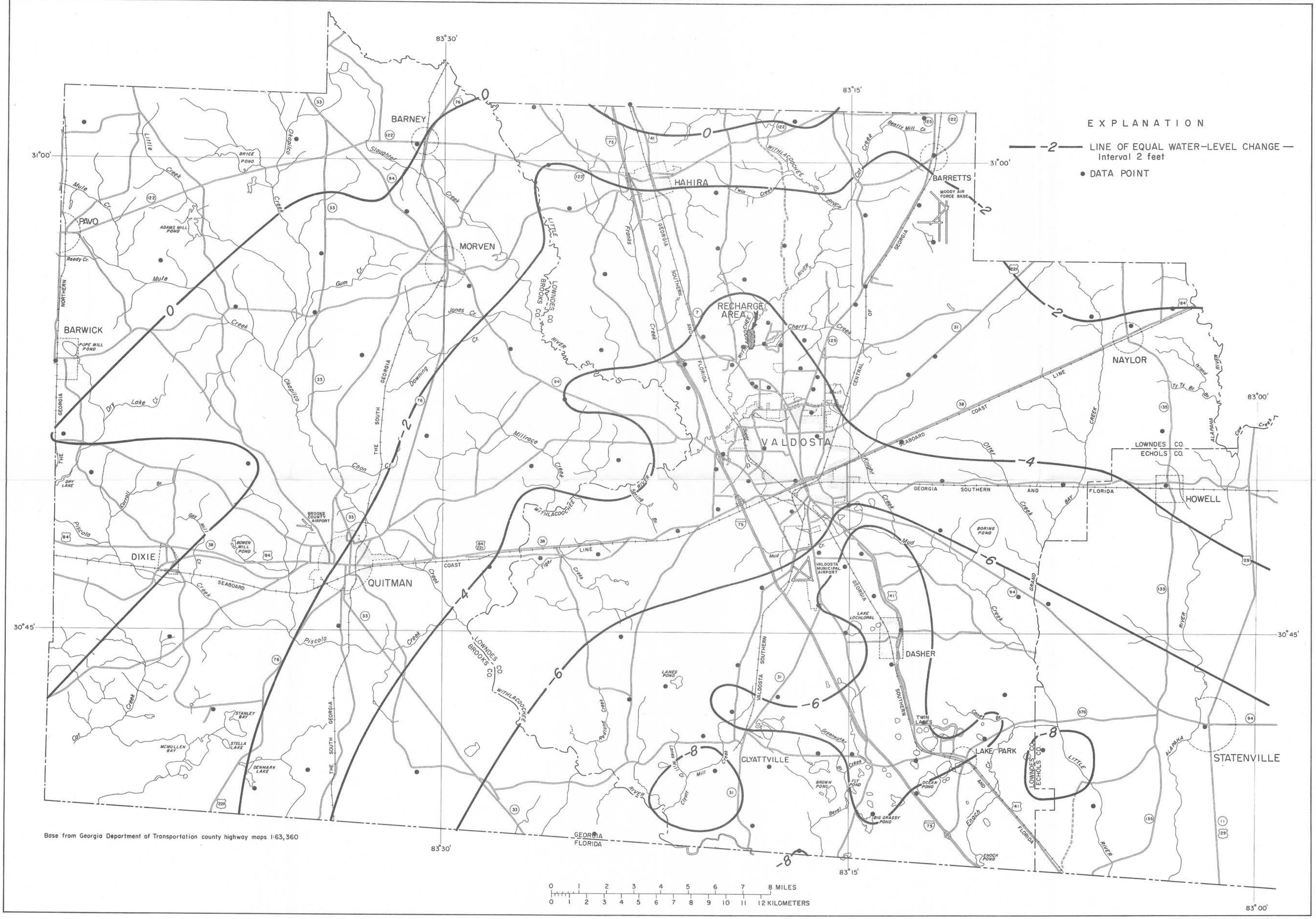


WATER-LEVEL TRENDS IN WELLS TAPPING THE PRINCIPAL ARTESIAN AQUIFER, BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA, 1974–75.



Hydrology by R.E.Krause and W.G.Hester, 1976

CHANGE IN WATER LEVEL IN WELLS TAPPING THE PRINCIPAL ARTESIAN AQUIFER, BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA, NOVEMBER 1974 TO MAY 1975.



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CHANGE IN WATER LEVEL IN WELLS TAPPING THE PRINCIPAL ARTESIAN AQUIFER, BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA, MAY TO NOVEMBER 1975.

UNITED STATES DEPARTMENT OF THE INTERIOR
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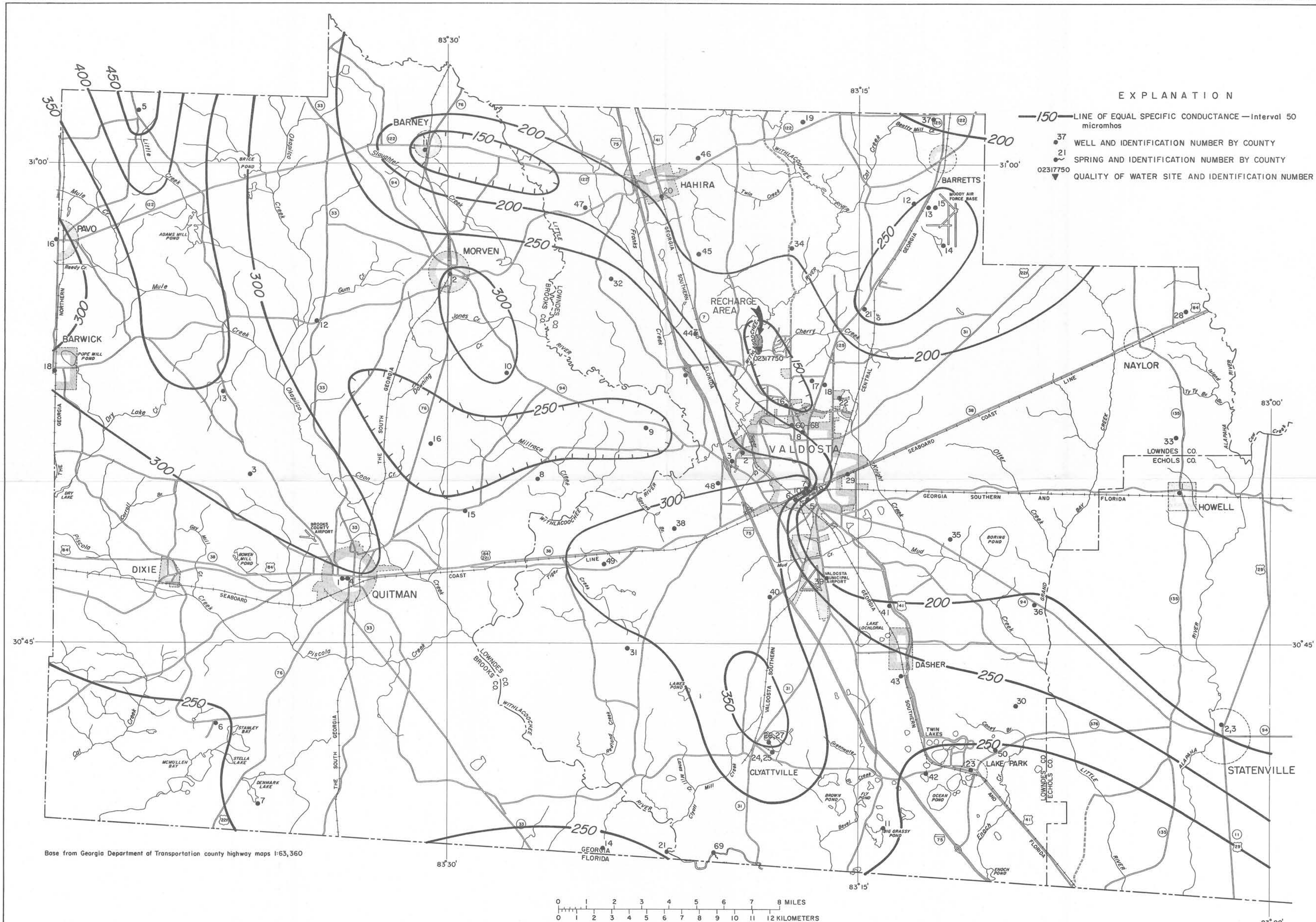
WATER-RESOURCES INVESTIGATIONS 78-117
OPEN-FILE REPORT PLATE 8



Geochemistry by R.E.Krause, 1975

SPECIFIC CONDUCTANCE OF WATER FROM WELLS TAPPING THE PRINCIPAL ARTESIAN AQUIFER, BROOKS, LOWNDES, AND WESTERN ECHOLS COUNTIES, GEORGIA, 1974.

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WATER-RESOURCES INVESTIGATIONS 78-117
OPEN-FILE REPORT TABLE 2

Chemical analyses of well, spring, and river water, Brooks, Lowndes, and western Echols Counties, Georgia

[Analyses by U.S. Geological Survey]

Site number	Owner or name	Interval sampled, in feet below land surface	Date sampled	Silica (SiO_2), in milligrams per liter	Micrograms per liter: Aluminum (Al)	Micrograms per liter: Iron (Fe)	Micrograms per liter: Manganese (Mn)	Micrograms per liter: Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Nitrite (NO_2)	Dissolved solids: Residue at 180°C	Dissolved solids: Sum of constituents	Hardness: Calcium, magnesium	Hardness: Noncarbonate	Specific conductance, in micromhos at 25°C	pH	Temperature, in degrees Celcius	Color, in platinum-cobalt units	Carbon dioxide (CO_2)	Micrograms per liter: Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Selenium (Se)	Strontium (Sr)	Zinc (Zn)
DRINKING WATER STANDARDS[1]						300	50							250	250	[2]1.6			500	500						15		50	10	50	1,000	50	2.0	10		5,000
185-01	Valdosta Vocational School	144-230	7-10-63	31	—	—	—	38	13	2.9	0.4	174	143	0.4	4.0	0.3	0.00	—	180	176	148	6	260	7.9	—	5	3.5	—	—	—	—	—	—	—	—	—
Do	do	do	4-18-74	33	10	20	0	38	11	3.2	.8	174	143	1.6	3.7	.3	.27	0.00	177	178	140	0	278	7.4	19.8	0	11	1	0	0	0	4	0.0	0	50	5
185-02	Valdosta, Ga., 7	187-346	6-18-70	33	60	30	0	31	8.6	3.0	.7	137	112	1.6	3.0	.1	.00	.01	169	148	113	1	224	7.6	22.0	5	5.5	0	—	—	20	0	—	—	30	400
Do	do	do	3-12-74	36	20	0	17	31	9.1	3.1	.6	137	112	2.8	2.8	.3	.04	.00	161	153	110	3	248	7.9	20.9	5	2.8	0	4	0	1	4	1.4	5	—	4
185-03	Holiday Inn, Valdosta, 1	280-320	4-29-66	30	—	—	—	30	9.0	2.8	.6	140	115	.4	2.5	.4	.50	—	—	145	112	0	226	7.6	—	5	5.6	—	—	—	—	—	—	—	—	—
185-04	Valdosta, Ga., 1	152-408	8-11-32	15	—	—	—	30	4.2	2.7	.6	78	64	24	4.5	—	.10	—	132	119	92	28	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Do	do	do	9-30-41	15	—	—	—	32	4.4	2.3	1.0	78	64	30	3.8	.2	.30	—	136	127	98	34	—	—	22.0	35	—	—	—	—	—	—	—	—	—	—
Do	do	do	12- 2-51	23	—	—	—	—	—	—	—	80	66	26	—	—	—	—	—	—	101	35	218	7.4	20.0	—	5.1	—	—	—	—	—	—	—	—	—
Do	do	do	8- 3-61	14	—	—	—	42	3.6	3.2	.4	80	66	47	6.5	.2	.40	—	188	156	120	54	256	—	22.0	30	—	—	—	—	—	—	—	—	—	—
Do	do	do	4-19-67	16	90	30	0	34	4.4	2.8	.4	82	67	38	4.0	.2	.30	—	159	140	100	36	228	7.3	21.0	—	6.6	0	—	—	0	0	—	—	90	0
185-05	Valdosta, Ga., 5	190-400	8-27-57	12	—	—	—	23	2.8	4.7	.4	81	66	.8	2.8	.3	.00	—	105	92	69	2	149	7.3	—	34	6.5	—	—	—	—	—	—	—	—	—
Do	do	do	3-12-74	11	20	10	0	22	3.1	4.9	.6	76	62	5.8	6.6	.1	.00	.00	110	92	68	5	171	8.1	20.0	40	1.0	35	3	1	1	0	.1	5	—	20
185-06	Atlantic Ice Co.	260-608	5-26-43	—	—	—	—	—	—	—	—	78	64	150	1.0	.2	—	—	—	—	198	130	179	—	21.0	36	—	—	—	—	—	—	—	—	—	—
185-08	Valdosta, Ga., 3	168-348	3-12-74	24	10	0	120	19	6.9	3.6	.5	94	77	2.0	4.1	.2	.04	.00	108	107	76	0	196	8.0	20.5	7	1.5	12	6	0	3	4	.0	4	—	0
185-09	Valdosta, Ga., 2	168-367	12- 2-51	16	—	—	—	35	5.0	—	—	78	64	27	13	.3	.30	.00	143	—	108	44	220	7.3	—	20	6.3	—	—	—	—	—	—	—	—	—
Do	do	do	3-12-74	14	20	10	17	52	4.4	3.4	.3	79	65	73	4.1	.0	.04	.00	210	190	150	83	336	7.8	20.2	20	2.0	7	4	0	3	7	.1	6	—	4
185-10	Valdosta, Ga., 4	190-400	3-12-74	9.9	20	30	0	57	3.6	3.9	.4	75	62	90	5.3	.0	.00	.00	246	207	160	96	290	8.0	—	50	1.2	0	4	0	3	4	.0	5	—	8
185-11	USAF Moody, Grassy Pond, 7	122-293	3-12-74	17	20	250	33	38	4.3	2.7	.5	136	112	2.1	4.5	.2	.00	.00	143	137	110	1	261	7.4	21.0	10	8.7	2	5	0	8	5	.0	2	—	10
185-12	USAF Moody, 8	163-400	3-12-74	27	10	10	0	29	8.8	3.0	.7	124	102	8.5	3.2	.1	.00	.00	149	141	110	7	238	7.9	21.0	10	2.5	16	6	0	4	4	.2	5	—	0
185-13	USAF Moody, 3	225-440	3-13-74	29	10	10	17	38	12	3.0	.6	128	105	39	3.2	.2	.00	.00	207	188	140	39	291	7.6	22.0	10	5.1	5	5	0	11	6	.4	13	—	4
185-14	USAF Moody, 7	182-195	3-13-74	45	10	0	0	26	13	3.8	1.1	139	114	13	3.0	.3	.00	.00	175	174	120	4	271	7.8	20.5	4	3.5	12	6	0	4	5	.1	0	—	20
185-15	USAF Moody, 4	220-342	3-14-74	36	10	50	17	28	12	3.6	1.1	133	109	18	3.6	.3	.00	.00	168	168	120	10	275	7.5	21.0	8	6.7	3	4	0	6	3	.1	9	—	8
185-16	Thompson, M.E., Pine Ridge	173-228	3-14-74	14	20	20	17	23	3.7	2.7	.2	85	70	1.9	4.1	.0	.00	.00	100	92	73	3	160	7.9	20.0	30	1.7	7	2	0	1	0	.1	8	—	0
185-17	Thompson, M.E., Oak St.	180-300	3-14-74	32	10	20	67	26	7.4	3.4	.7	114	94	1.2	4.5	.1	.00	.00	144	132	95	2	196	8.0	19.9	10	1.8	3	5	0	4	2	.1	3	—	4
185-18	Schroer Plant Farms	209-500	3-14-74	18	10	30	17	23	4.8	2.7	.3	95	78	1.2	3.0	.1	.00	.00	107	100	77	0	175	8.5	20.8	20	.5	2	4	0	3	3	.1	8	—	8
185-19	Sheriff's Boys Ranch	195-312	3-15-74	35	10	10	17	25	10	2.4	.7	129	106	.4	2.6	.1	.00	.00	147	140	100	0	226	7.8	20.0	5	3.3	2	4	0	3	4	.1	3	50	4
185-20	Hahira, Ga.	127-360	3-15-74	33	10	40	0	28	6.1	2.1	.5	120	98	.8	2.7	.1	.04	.00	131	133	95	0	204	7.9	20.7	5	2.4	7	4	0	3	7	.1	10	25	8
185-21	Law, C.	210-310	3-15-74	45	10	0	17	21	15	5.1	1.0	143	117	1.9	2.6	.5	.04	.00	155	163	110	0	253	8.2	20.9	5	1.4	15	3	3	2	5	.2	3	—	30
185-22	Valdosta, Ga., 8	350-450	3-27-74	8.3	80	210	17	19	2.6	6.4	1.1	63	52	5.0	7.6	.2	.18	.00	96	82	58	6	154	7.5	17.8	90	3.2	3	0	0	3	0	.1	7	—	40
185-23	Lake Park, Ga.	120-165	3-27-74	45	10	210	33	29	7.5	2.9	1.4	120	98	.1	3.1	.5	.00	.00	136	149	100	5	219	7.9	21.0	2	2.4	18	0	0	0	2	.1	4	—	60
185-24	Owens-Illinois, 1	167-356	3-27-74	26	20	20	33	42	10	3.5	.7	129	106	40	3.1	.2	.04	.00	207	189	150	40	322	7.9	22.0	2	2.6	13	1	0	0	5	.0	4	—	20
185-25	Owens-Illinois, 2	170-800	3-27-74	23	20	10	17	95	48	3.7	.8	130	107	310	2.9	.7	.04	.00	555	550	440	330	875	7.9	22.2	1	2.6	18	0	0	0	2	.0	4	1,350	20
185-26	Owens-Illinois, 3	168-800	3-27-74	26	10	10	17	46	11	3.7	.7	126	103	52	2.7	.3	.04	.00	210	205	160	57	353	7.9	21.0	3	2.5	18	0	0	0	3	.0	9	—	20
185-27	Owens-Illinois, 4	175-323	3-27-74	26	10	10	17	48	13	3.7	.7	126	103	65	2.7	.3	.00	.03	228	222	170	70	381	7.9	21.0	2	2.5	0	0	0	0	2	.3	0	—	10
185-28	Larus, D.	172-200	4-18-74	22	20	10	10	23	6.8	3.4	.9	101	83	7.8	2.6	.3	.00	.00	132	117	85	3	189	8.0	20.5	10	1.6	2	0	0	1	4	.0	3	50	9
185-29	Union Camp Corp., Gate 7	191-343	4-19-74	17	30	10	0	24	3.7	3.6	.8	95	78	.8	3.9	.1	.00	.00	117	101	75	0	183	7.9	19.0	20	1.9	1	0	0	1	5	.0	8	0	0
185-30	Corbett Farm	120-160	4-19-74	37	30	150	20	30	7.9	3.3	1.0	134	110	6.8	2.7	.3	.00	.00	168	155	110	0	260	8.4	20.1	3	.9	1	0	0	0	4	.0	2	50	9
185-31	Mason, C.	160-230	4-29-74	40	30	0	0	32	12	3.9	1.1	156	128	3.9	4.3	.4	.13	.03	161	175	130	1	287	7.6	21.0	1	6.1	4	1	6	2	9	.1	7	70	30
185-32	Cowart, C.	155-240	5- 1-74	45	30	0	0	31	13	4.1	1.0	161	132	2.3	3.0	.4	.00	.03	165	179	130	0	270	—	21.0	2	—	0	1	0	2	8	.1	8	100	0
185-33	Langdale Co., Hunt	165-240	5- 1-74	11	10	30	0	25	3.0	1.8	.3	83	68	2.1	4.0	.2	.00	.00	89	88	75	7	160	—	20.6	30	—	2	1	0	2	8	.0	4	70	0
185-34	Futch, W. J.	240-260	5- 1-74	23	30	60	0	27	8.8	2.0	.9	120	98	.4	2.5	.4	.00	.00	130	124	100	5	208	—	20.8	4	—	10	1	0	2	9	.0	4	70	20
185-35	Deerwood Acres	165-230	5- 2-74	21	10	0	0	23	5.8	2.7	.7	100	82	.7	2.8	.4	.00	.00	90	106	81	0	173	7.8	20.1	7	2.5	2	1	1	2	9	.1	4	70	0
185-36	Mock, C. H.	126-200	6-13-74	26	20	0	14	29	5.3	2.5	.6	116	95	1.1	2.9	.2	.04	.00	123	125	94	0	213	7.8	20.7	10	2.9	3	8	0	1	0	.0	3	30	0
185-37	Peters, E.	178-304	6-13-74	67	20	0	0	20	11	3.9	1.3	113	93	3.8	2.9	.6	.00	.00	162	166	95	3	196	8.0	20.5	0	1.8	0	9	4	1	3	.0	3	0	60
185-38	Wetherington, J. L.	220-235	6-14-74	45	30	30	0	34	18	6.6	1.6	186	153	10	3.9	1.0	.00	.00	209	212	160	7	343	7.8	20.9	0	4.7	10	8	0	1	0	.0	2	140	7
185-39	Holland, J. W.	182-250	6-14-74	15	30	30	14	29	4.5	2.2	.5	96	79	11	3.4	.3	.00	.00	118	113	91	12	199	8.4	21.0	0	.6	2	11	0	1	0	.3	2	30	3
185-40	Dees, A.	175-212	6-19-74	46	40	50	50	39	11	5.1	1.4	164	135	—	2.6	.5	.00	.00	192	—	140	8	306	7.5	20.5	0	8.3	1	1	3	1	0	.3	1	80	20
185-41	Gold Kist, Livestock, 2	170-230	6-19-74	21	40	30	17	31	8.3	3.5	.7	105	86	23	3.1	.3	.00	.16	142	143	110	26	200	8.3	20.7	7	.8	0	1	5	1	5	.3	2	80	7
185-42	Francis Lake	140-204	6-19-74	22	30	10	17	32	3.7	2.7	.7	114	94	1.0	3.6	.3	.04	.00	136	122	95	2	226	8.3	21.1	4	.9	1	1	3	1	6	.1	3	50	3
185-43	Copeland, R. A.	122-155	6-19-74	27	40	0	0	35	6.6	3.2	.7	133	109	3.6	3.2	.3	1.90	.00	162	147	110	6	254	8.4	20.1	0	.8	2	1	3	4	0	.3	4	80	20
185-44	Stone, A. C.	155-193	6-21-74	28	40	40	50	30	8.2	3.1	.8	124	102	1.9	3.0	.3	.00	.00	128	137	110	7	166	8.2	20.3	0	1.3	0	0	5	1	0	.0	6	80	7
185-45	Hall, J. F.	161-175	6-21-74	46	40	0	84	30	10	5.0	1.1	140	115	—	1.7	.4	.00	.00	144	—	120	1	232	8.3	20.8	0	1.1	1	1	3	1	1	.7	1	80	20
185-46	Cornelius, C.	179-238	6-21-74	39	30	10	17	30	10	4.0	1.0	137	112	—	2.5	.5	.00	.00	152	—	120	4	246	8.3	21.0	0	1.1	6	1	8	1	0	.0	4	80	10
185-47	Darby, G.	194-215	6-21-74	41	30	10	17	38	6.0	3.5	.9	139	114	2.3	2.4	.2	.00	.00	154	163	120	6	164	8.3	20.7	0	1.1	0	0	3	2	0	.0	9	80	7
185-48	McCormick, C.	240-245	6-24-74	44	30	0	17	32	14	4.6	1.1	153	126	—	2.5	.5	.00	.00	166	—	140	12	280	7.9	20.1	0	3.1	0	1	5	2	2	.0	7	80	20
185-49	Southall, J. C.	185-220	6-24-74	42	30	0	17	35	16	6.2	1.4	181	148	11	2.5	.6	.00	.00	186	204	150	5	335	8.3	21.2	2	1.5	12	1	3	4	0	.0	7	100	3
185-60	USGS Test Well 1, Valdosta[3]	902-1014	9-24-74	23	10	410	10	530	360	38	16	101	83	2,600	72	4.2	.04	.00	4,100	3,710	2,800	2,700	3,620	7.4	23.8	3	6.4	2	3	1	3	8	.1	0	12,000	10
185-61	do.[3]	804-866	9-25-74	19	10	860	13	560	320	11	8.0	102	84	2,500	33	3.5	.00	.00	3,070	3,520	2,700	2,600	3,260	7.2	23.9	3	10	4	2	1	2	8	.0	0	12,000	20
185-62	do.[3]	740-802	9-25-74	17	30	350	0	550	300	6.0	3.0	102	84	2,500	15	2.9	.00	.00	2,850	3,450	2,600	2,500	2,950	7.5	23.6	4	5.2	11	4	1	3	8	.1	0	8,900	30
185-63	do.[3]	685-747	9-26-74	15	0	140	0	560	300	4.5	2.2	97	80	2,500	26	2.9	.00	.00	2,810	3,470	2,600	2,600	3,140	7.6	23.5	4	3.9	5	3	0	2	8	.0	0	8,400	10
185-64	do.[3]	624-686	9-26-74	15	10	190	0	560	320	4.7	2.0	93	76	2,500	26	3.1	.00	.00	2,960	3,490	2,700	2,700	3,290	7.3	22.0	4	7.5	8	3	1	2	8	.0	0	5,000	20
185-65	do.[3]	550-613	9-27-74	12	20	100	0	530	290	3.7	1.0	80	66	2,400	15	3.6	.00	.00	2,820	3,300	2,500	2,500	2,990	7.3	22.0	4	6.4	3	3	1	2	8	.1	0	350	0
185-66	do.[3]	481-543	9-29-74	10	0	20	20	100	13	4.0	.3	83	68	230	2.8	.3	.00	.00	424	402	300	240	454	8.0	21.2	30	1.2	17	0	1	0	10	.0	0	390	7
185-67	do.[3]	398-461	9-27-74	8.7	30	130	0	26	4.7	7.5	.5	75	62	23	5.3	.1	.00	.03	112	114	85	23	173	8.0	21.5	40	1.0	6	3	1	4	8	—	2	210	10
185-68	do.[3]	200-214	9-30-74	12	10	260	20	31	5.7	5.3	.7	70	64	39	4.4	.2	.00	.00	154	137	100	37	205	8.5	21.5	40	.3	5	0	1	2	12	.0	1	—	7
27-01	Quitman, Ga., 3	120-304	5-12-58	17	—	—	—	40	8.3	2.5	.6	162	133	1.2	3.5	.2	.50	—	154	154	134	1	268	7.5	21.0	0	8.2	—	—	—	—	—	—	—	—	—
Do	do	do	8- 3-61	17	—	—	—	40	9.7	2.5	.5	164	135	2.8	5.0	.2	.00	—	160	159	140	6	268	7.8	21.0	1	4.2	—	—	—	—	—	—	—	—	—
Do	do	do	3-28-74	18	10	0	0	37	10	2.7	.5	158	130	1.0	2.9	.9	.62	.00	151	152	130	4	288	7.7	20.0	0	5.0	2	0	0	2	4	.1	3	—	20
27-02	Morven, Ga.	156-295	3-28-74	25	10	10	17	42	10	2.9	.5	169	139	1.7	2.9	.2	.80	.03	165	169	150	7	300	7.7	20.0	1	5.4	7	0	0	3	0	.1	5	—	0
27-03	Thornhill, J.	252-400	3-28-74	18	20	0	17	41	13	2.9	.4	181	148	1.3	2.5	.2	.00	.00	161	169	160	7	306	8.0	22.0	2	2.9	23	0	0	2	3	.1	0	—	10
27-04	Quitman, Ga., 1	71-312	2- 7-38	16	—	—	—	40	10	2.4	.8	168	138	1.9	4.1	.0	.40	—	154	158	141	3	—	—	21.0	—	—	—	—	—	—	—	—	—	—	—
Do	do	do	3-28-74	17	20	0	17	43	10	4.3	.4	169	139	1.5	6.3	.2	.89	.00	163	167	150	10	316	7.7	20.2	1	5.4	3	0	0	2	0	.1	8	—	10
27-05	Robinson, R. B.	200-300	4-17-74	38	30	20	20	52	19	5.4	1.2	146	120	97	3.6	.3	.00	.00	323	289	210	89	458	7.4	20.5	0	9.3	4	0	0	0	5	.0	1	220	0
27-06	Ramsey, C. C.	133-180	4-17-74	14	30	0	0	42	2.8	2.6	.9	140	115	5.5	3.7	.1	2.70	.00	138	143	120	2	242	8.2	—	1	1.4	18	0	0	0	6	.0	2	50	30
27-07	Blackwater Plantation	87-174	4-17-74	12	20	10	0	46	3.6	2.5	.9	154	126	1.6	3.6	.1	3.10	.00	150	149	130	3	289	7.5	20.5	1	7.8	2	0	0	0	3	.0	0	50	20
27-08	Cooper, B.	140-160	5- 1-74	32	30	0	0	35	11	2.2	.7	141	116	8.8	4.7	.4	2.70	.03	159	167	130	17	266	—	20.5	3	—	0	1	0	2	9	.0	5	70	8
27-09	Cowart, J. C.	155-180	6-20-74	40	40	0	17	34	11	2.8	.8	148	121	4.0	2.5	.4	.04	.00	154	169	130	9	220	8.3	20.8	0	1.2	2	1	3	5	0	.0	7	80	3
27-10	Wilkerson, F. O.	149-205	6-20-74	38	30	0	67	44	13	3.4	.7	191	157	—	3.3	.4	.00	.00	178	—	160	7	300	8.0	20.8	0	3.1	3	1	5	1	0	.0	4	80	100
27-11	Folson, A. J.	161-228	6-20-74	50	70	0	0	10	7.4	4.6	1.0	65	53	1.3	2.8	.5	.27	.00	96	110	56	2	125	8.2	20.8	0	.7	3	1	5	2	0	.0	5	50	10
27-12	Willaford, C. L.	158-186	6-20-74	28	30	0	0	43	11	3.1	.8	164	135	10	3.0	.3	.13	.00	166	180	150	18	264	8.4	20.9	0	1.0	1	1	8	4	0	.0	6	150	60
27-13	Tyson, J. M.	186-230	6-20-74	27	30	0	17	40	16	4.1	1.1	193	158	4.1	4.0	.3	.04	.00	190	192	170	8	349	8.5	20.4	2	1.0	3	1	3	1	1	.7	7	100	90
27-14	Bass, A.	97-178	6-20-74	20	50	0	0	41	4.6	2.5	.6	139	114	2.1	3.3	.3	2.20	.00	170	145	120	7	223	8.0	—	2	2.2	0	1	5	2	1	.1	3	80	20
27-15	Patrick, P.	170-205	6-24-74	34	30	0	0	32	12	3.6	.9	147	121	—	2.6	.4	.00	.00	150	—	130	9	259	8.4	21.1	0	.9	0	0	5	3	0	.0	6	50	20
27-16	Duncan, M. C.	123-165	6-24-74	32	20	0	17	41	11	3.5	.9	158	130	27	2.3	.3	.13	.00	234	196	150	18	230	8.3	21.4	0	1.3	2	0	3	1	3	.0	1	80	70
101-01	Stickly, D.	174-187	5-10-66	14	—	—	—	21	3.4	3.2	.4	76	62	.4	7.0	.2	.40	—	—	87	66	4	144	7.3	—	40	6.1	—	—	—	—	—	—	—	—	—
101-02	Herndon & Daniels	175-256	12- 1-59	38	—	—	—	30	12	4.3	.9	155	127	4.8	1.5	.4	.50	—	183	168	124	0	253	7.6	22.0	3	6.2	—	—	—	—	—	—	—	—	—
Do	do	do	8- 3-61	38	—	—	—	30	12	4.4	.9	156	128	5.6	2.3	.4	.10	—	176	171	124	0	253	7.7	22.0	4	5.0	—	—	—	—	—	—	—	—	—
101-03	Statenville, Ga.	215-421	4-30-74	18	30	0	0	26	5.0	2.8	.5	102	84	2.1	3.7	.2	.00	.03	113	109	86	2	186	7.7	21.0	20	3.3	0	1	0	2	9	.1	4	70	0
275-16	Pavo, Ga.	104-305	1- 6-64	39	—	—	—	33	13	2.9	.6	165	135	.2	2.7	.3	—	—	182	173	138	3	245	7.6	21.0	5	6.6									
Do	do	do	4-17-74	41	30	10	0	31	14	3.7	.9	167	137	1.4	3.6	.3	.93	.00	204	179	140	0	294	8.2	20.1	2	1.7	0	0	0	1	5	.0	3	150	0
275-18	Barwick, Ga.	182-330	3-28-74	19	10	0	17	42	10	3.5	.5	161	132	9.3	3.4	.2	1.10	.00	173	168	150	14	304	7.8	20.1	0	4.1	10	1	1	3	1	.1	5		10
185-69	Arnold Spring	—	11-11-75	19	10	0	0	44	6.3	2.4	.5	146	120	12	3.6	.1	.84	.00	148	161	140	16	275	7.4	20.0	0	—	0	0	0	0	0	.0	1	140	6
27-21	McIntyre Spring	—	11-11-75	15	20	0	10	41	5.0	2.3	.5	148	121	4.3	3.9	.1	1.40	.00	142	147	120	2	258	7.4	21.0	0	—	0	0	0	0	0	.0	1	120	0
	Average or median chemical quality[4]	—	—	27	26	28	15	33	8.6	3.5	.7	128	105	14	3.6	.3	.30	.01	165	149	119	14	244	—	20.7	10	5.4	5	2	1	2	3	.1	4	86	21
02317750	Withlacoochee River above Cherry Creek	—	6-25-74	7.0	240	620	33	3.5	1.7	8.0	1.4	11	9	8.1	9.1	.3	.97	.03	76	46	16	7	69	7.0	24.2	100	1.8	0	1	5	2	0	.0	0	30	7
185-50	Carter, P. W. (Pond)	—	6-25-74	4.2	40	200	67	3.1	1.4	3.7	.2	8	7	1.9	10	.1	.00	.03	46	29	14	7	42	6.3	25.1	20	6.4	0	1	3	2	0	.0	6	30	7

[1] Georgia Environmental Protection Division standards for safe drinking water, 1977.
[2] Maximum fluoride concentration for an annual average of the maximum air temperature of 21.5° to 26.2°C (Celsius) for the study area.
[3] Packer samples.
[4] Water from the principal artesian aquifer; includes spring water.