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GARLAND PEYTON, Director

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GEOLOGY AND GROUND-WATER RESOURCES OF CENTRAL-EAST GEORGIA

By

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With a Chapter on the Surface-Water Resources

By

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Prepared in cooperation with the
Geological Survey, United States Department of the Interior,
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ATLANTA

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Plant and Quarry of Weston and Brooker Company, Camak, Warren County, Georgia.

LETTER OF TRANSMITTAL

Department of Mines, Mining and Geology

Atlanta, December 31, 1956

To His Excellency, Marvin Griffin, Governor
Commissioner Ex-Officio of State Division of Conservation

Sir:

I have the honor to submit herewith Georgia Geological Survey Bulletin No. 64, "Geology and Ground-Water Resources of Central-East Georgia," by H. E. LeGrand of the Ground Water Division, United States Geological Survey and A. S. Furcron, Chief Geologist of the Georgia Department of Mines, Mining and Geology. The report also includes a chapter on surface water resources by R. F. Carter and A. C. Lendo of the Surface Water Division, United States Geological Survey.

This is a comprehensive report covering Richmond, Columbia, McDuffie, Warren, Glascock, Jefferson and Burke counties, which district includes the geology of both the crystalline rocks and rocks of the upper Coastal Plain. A colored geologic map accompanies the report as well as a map which gives ground water conditions over the area investigated. The geology and distribution of the important minerals and rocks are discussed; they are, granites, granite gneisses, serpentine and phyllite in the Crystalline area, and kaolin and fullers earth in the Coastal Plain. Much of the report is devoted to ground and surface water which have become of vital importance with the increase in population and expansion of industry.

Very respectfully yours,

Director

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CHAPTER I

ABSTRACT

This report gives the results of a preliminary investigation of the geology and water resources of seven counties in eastern Georgia covering 2,684 square miles. The area is largely rural; Augusta is the only city having a population of more than 10,000.

The northern part of the area is in the Piedmont province, which is composed of igneous and metamorphic rocks. The Piedmont is characterized by flat to rolling upland surfaces, separated by stream valleys; a few scattered hills rise above the level of the upland surface. The crystalline rocks of this district crop out from beneath Coastal Plain sediments and are exposed in most of Columbia County, in the northern halves of McDuffie and Warren Counties, and, along the streams only, in the northern part of Glascock County.

An old (probably Precambrian) metasedimentary biotite gneiss injected and migmatized by granite gneisses and granites (probably Paleozoic) underlies a volcanic series (Little River series of Crickmay), which is probably of Paleozoic age and which also is injected by the granite gneisses and granites. The volcanic series crops out on both flanks of a nearly east-trending arch in the older crystalline rocks, the axis of which extends approximately through Warrenton, Thomson, and Appling. Both the crystalline and the volcanic rocks were folded, metamorphosed, and eroded before the deposition of Cretaceous sediments.

The southern part of the area is in the Coastal Plain province, which is underlain by unconsolidated and semiconsolidated sediments of Cretaceous and younger age. These sediments, lying on a floor of igneous and metamorphic rocks representing an extension of those exposed in the Piedmont, dip gently south-southeast. The deposits in aggregate also thicken in that direction.

The precipitation averages approximately 47 inches a year and is fairly evenly distributed throughout the year. Much of the surface soil, especially in the Coastal Plain, is permeable enough to capture most of the precipitation, so that direct surface runoff is not great. There is continual leakage of ground water as diffuse seepage into the streams, maintaining their flow in dry weather.

From the igneous and metamorphic rocks of the Piedmont, water is drawn by means of dug wells in the weathered material, which generally extends to an average depth of about 30 feet, and drilled wells in the fractured bedrock below the weathered material. The average yield from the drilled wells is about 20 gallons a minute, although there is a great range in yield from individual wells. The shallower dug wells generally yield only a few gallons a minute, which is adequate for most domestic needs.

Wells in the Coastal Plain sediments draw water from the unconsolidated sand deposits and in some places from limestone. The Tuscaloosa formation, representing the Cretaceous deposits in the area, contains good water-bearing sands capable of yielding as much as 1,000 gallons a minute to individual wells in Jefferson and Burke Counties. The overlying deposits of sand and limestone of Tertiary age also are capable of furnishing large amounts of water.

The present study is largely qualitative rather than quantitative because the water supply has not yet been developed sufficiently to permit determining the potential supply, especially that of the Coastal Plain deposits.

The local geographic, geologic, ground-water, and quality-of-water conditions are described in separate sections for each county. Also described in each section are wells representative of the area. Tables of ground-water analyses and well data are given in each county section.

The low-flow characteristics of the streams largely determine their suitability for development, for it is the low flows that indicate the amount of water available without storage during the dry seasons when all the flow of streams is derived from ground-water sources.

Low-flow characteristics of streams differ widely in the three physiographic regions of the area: dry-season flows of streams in the Piedmont Plateau are low for short periods; those in the Tifton Upland are low for long periods; and those in the Fall Line Hills-Louisville Plateau are comparatively high.

Within regions where low-flow characteristics of streams are similar it is possible to transpose, with varying degrees of accuracy, the characteristics of a stream on which a continuous discharge record is collected to a stream on which only a partial record is collected. Hydrologic techniques are demonstrated whereby occasional discharge measurements at a partial-record station are used to establish a relationship between that station and a complete-record station on another stream. Such deduced records are adequate for many purposes, and permit the appraisal of the surface-water resources of an area on basis of a comparatively few complete-record gaging stations. However, for purposes of development that require information on the day-by-day flow of a stream, a partial-record station would be inadequate.

The techniques referred to in the preceding paragraph are not applied to intermittent or artifically regulated streams. Farm ponds in the area are increasing in number and may eventually affect the low-flow regimen of many small streams. The regimen may be affected also by conservation practices, such as withdrawing steep land from cultivation and putting more land into trees, pasture, and cover crops. The effects of ponds and conservation practices cannot be predicted, but no large changes in the low-flow regimen of the small streams are anticipated.

Available chemical analyses of surface water in the area show the water to be generally soft and of suitable chemical quality for most uses. The softest water is in the streams of the Fall-Line Hills-Louisville Plateau.

INTRODUCTION

Scope of the Investigation

This report includes the study of the geology and water resources of seven counties in eastern Georgia where Cretaceous deposits are exposed. It constitutes the second of a planned series of systematic investigations of the geology and ground-water resources of the Cretaceous deposits of Georgia. (Bulletin 52 of the Georgia Geological Survey, prepared by P. E. LaMoreaux, of the United States Geological Survey, represents the first of this series and describes the geology and ground-water resources of the Coastal Plain of east-central Georgia.)

The ground-water studies are being made by the United States Geological Survey in cooperation with the Department of Mines, Mining and Geology, Georgia State Division of Conservation. The geology and ground-water resources of the Coastal Plain deposits and the ground-water resources of the igneous and metamorphic rocks are described by H. E. LeGrand of the Ground Water Branch, U. S. Geological Survey. A. S. Furcron, Assistant State Geologist of Georgia, has described the igneous and metamorphic rocks and the mineral resources.

Location of the Area

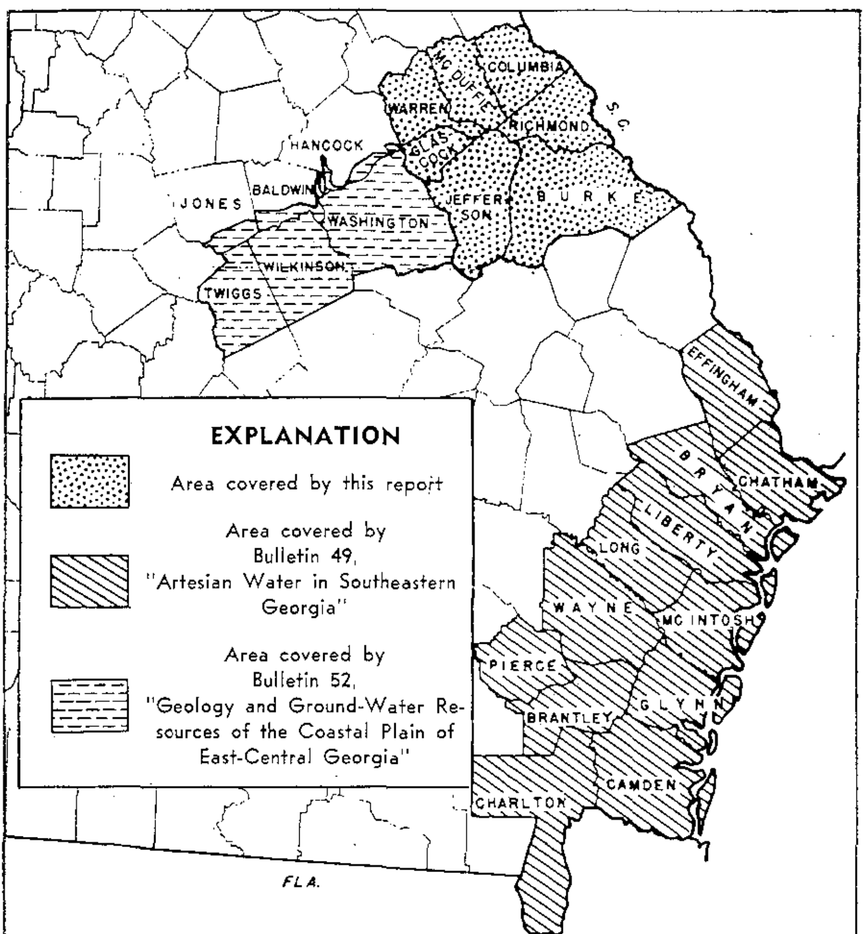
The area covered in this report includes 2,684 square miles, representing seven counties in central-east Georgia; these are: Burke, Columbia, Glascock, Jefferson, McDuffie, Richmond, and Warren. The area is bordered on the east by the State of South Carolina and on the south, west, and north by nine counties of Georgia. Its location with respect to other areas under the previous ground-water study is shown in figure 1.

Field Work

The field work for this report was begun in April 1946 and was essentially completed in August of the same year. Records were collected of wells and springs that furnish ground-water supplies for public, industrial, and domestic use. No attempt was made to obtain data for every well in the area, but information concerning representative wells in every section of the area was obtained, and a detailed study was made of ground-water conditions in each community.

The initial phase of the field work included the making of a geologic map of the area suitable for the interpretation of ground-water conditions. In an agreement made with the Georgia Geological Survey at the outset of the program, the junior author mapped the geology of that part of the area in which crystalline rocks are exposed.

In order to determine the chemical nature of water from the different rock types and in different parts of the area, samples were collected from 36 wells. Analyses of these samples were made at the laboratory of the U. S. Geological Survey in Raleigh, N. C.



The investigation was made under the general supervision of O. E. Meinzer and A. N. Sayre, successive chiefs of the Ground Water Branch, U. S. Geological Survey, and under the immediate supervision of S. M. Herrick, district geologist of the Federal Survey, who was in charge of the cooperative ground-water investigations in Georgia.

Previous Investigations

Prior to the beginning of the investigation leading to this report, F. Stearns MacNeil, of the Federal Survey, had completed a geologic map of the Tertiary outcrop area of Georgia. This map was published in 1947 as U. S. Geological Survey Oil and Gas Investigations Preliminary Map 72. In 1943 a report by Cooke was published on the geology of the entire Coastal Plain, and earlier reports by L. W. Stephenson and Otto Veatch (1911, 1915) and one by S. W. McCallie (1908) give information on ground water in the area. These reports cover the entire Coastal Plain and contain much useful information concerning the central-east area of Georgia.

The bibliography at the end of the second chapter lists the principle publications that were consulted during the present study.

Acknowledgments

The preparation of this report was facilitated by the cooperation of well owners, drillers, and superintendents of the town waterworks throughout the area, who readily offered available information concerning wells.

Appreciation is expressed to Captain Garland Peyton, Director of the Georgia Division of Mines, Mining and Geology, who generously cooperated in the completion of the project. F. Stearns MacNeil, S. M. Herrick, and P. E. LaMoreaux of the United States Geological Survey spent several days in the field with the author and made valuable suggestions on the stratigraphy of the area.

GEOGRAPHY

Northeastern Georgia is a part of the Piedmont province, which is underlain by an ancient complex of igneous and metamorphic rocks. Adjacent to the Piedmont is the Coastal Plain province, which extends southward and which is underlain by Cretaceous and younger sediments. Because of differences in structure, composition, and time of exposure these two provinces have topographic features that in many places are distinctly different.

Inasmuch as deposits of the Coastal Plain extend as a wedge thinning northward on rocks of the Piedmont and subsequent erosion has differentially removed parts of them, the boundary between the two provinces is necessarily irregular. In some neighboring States the contact is marked by falls or rapids where the streams flow from hard, resistant rocks of the Piedmont onto the softer sediments of the Coastal Plain. This has led to the use of the terms "Fall Line" and "Fall Zone" for a line connecting the contacts, even where no escarpment exists. There appears to be no prominent topographic distinction along the Fall Zone in most of east Georgia, although features of each province are discernible.

Piedmont Province

The Piedmont province is a relatively smooth upland surface sloping gradually southeastward. In northern Warren County several places reach an elevation of 600 feet, whereas on the Fall Line at Augusta, in Richmond County, the elevation is approximately 200 feet. No ridges or peaks stand out conspicuously above the surrounding terrain. Although the lithology of the crystalline rocks in the Piedmont area is diverse, there appears to be little contrast between the strong and weak types in their resistance to erosion. The valleys are broad and shallow and have long, gentle slopes. Along the eastern side the valleys have extensively dissected the area, but because of the general descent of the surface toward the southeast the valleys have not become deep.

In general the rocks are deeply weathered, and the topography therefore tends to be smooth and the rocks to be obscure. However, on the interstream areas underlain by granite many bold exposures of fresh rock are seen, but even here the uplands have smooth, convex forms and are almost flat.

Coastal Plain

The Coastal Plain is almost flat and featureless; yet certain topographic features related to the underlying geologic formations do exist. The subdivisions of the Coastal Plain adopted for the area under consideration are those made by LaMoreaux (1946, p. 9-12) for the adjacent area in east-central Georgia. They include the "Sand Hills," the "Red Hills," and the "Tifton Upland."

Sand Hills

The area in which the Tuscaloosa formation is exposed in eastern Georgia is known as the Sand Hills. The hills that give the area its name form an irregular belt less than 10 miles wide along the inner margin of the Coastal Plain; this belt is interrupted in Warren County by an overlap of Eocene deposits. Much of the area is covered by rather clear, light-colored sand which is the residual material after much of the interstitial clayey material has been washed away. This loss of clay and silt makes the soil less productive than the average soils of Georgia.

The relief of the Sand Hills, although sharp, is restricted by the thinness of the Tuscaloosa formation and by low regional surface gradients. The drainage is southeastward in consequence of the regional slope.

Red Hills

The Red Hills represent that area which is underlain by rocks of Eocene and Oligocene age which forms an irregular belt about 20 miles wide trending eastward through the central portion of eastern Georgia. This area borders the Sand Hills on the north, except in Warren County, where it borders the Piedmont province. The Red Hills are a series of hills of an accordant level, which are undergoing degradation. They are characterized by brilliant red sand and sandy loam, representing residual material of weathered Eocene rocks, many of which were limestone. The land surface slopes gently to the southeast, and ranges from about 500 feet above sea level near Stapleton, in the northern part of Jefferson County, to about 320 feet at Louisville, in the southern part of the county.

The sandy loam is moderately productive. Owing to the lack of consolidation of the sands, gullies are common. These gullies are the headward extensions of the drainage basins of Briar Creek and Rocky Comfort Creek, which are the largest streams in the belt.

Tifton Upland

The Tifton Upland (Cooke, in LaForge, and others, 1925, p. 36-37) occupies that part of central-east Georgia underlain by deposits of Miocene age. It is south of, and essentially parallel to, the belt of Red Hills. The topography is gently rolling but more subdued than in the hilly areas, owing to the compactness of sandy clay which prevents deep entrenchment of streams; the relief rarely exceeds 50 feet.

The Tifton Upland has light-brown and yellow soils containing scattered limonite pebbles. The soils are less sandy than those of the Red Hills and are better adapted to the raising of crops.

Drainage

The eastern and western boundaries of the area of this report are formed by two through-flowing streams, trending southeastward, which rise in the Piedmont north of the Coastal Plain. These streams, the Savannah River on the east and the Ogeechee River on the west, drain the entire area. The Savannah River meanders across its wide, swampy valley, which is at a considerably lower level than the Coastal Plain which it dissects. The river is navigable as far upstream as Augusta. The Ogeechee River is bordered by swamps throughout the Coastal Plain of eastern Georgia. The flood plain in which it lies is several miles wide, encouraging the growth of cypress and other aquatics.

The Little River, which forms the northern boundary of Warren, McDuffie, and Columbia Counties, drains much of the area underlain by crystalline rocks before it empties into the Savannah River. Smaller streams that drain much of the Piedmont area in Columbia County are Kiokee Creek, Greenbriar Creek, and Uchee Creek. All these flow north-eastward into the Savannah River.

Briar Creek, which rises in the Piedmont Upland of Warren County, is a moderately swift stream until its slope lessens and it becomes bordered by swamps near Waynesboro in Burke County. It carries water drained from the Coastal Plain sediments of McDuffie, Jefferson, and Burke Counties.

Some of the unused water from the flowing wells of the tributary part of Burke County empties into Briar Creek; the rest evaporates. Many of the small Coastal Plain streams head in the outcrop area of the Cretaceous and of the northern fringe of the Eocene deposits, and flow south and east before entering the Savannah and Ogeechee Rivers.

Climate

The climate of central-east Georgia is relatively mild and humid. The area has a mean annual temperature of approximately 61°F. Fair and pleasant weather with intermittent cold snaps characterize the winter months, and the summers are long and warm.

The average annual precipitation of approximately 47 inches is fairly well distributed throughout the year and is generally ample for crops. The greatest rainfall occurs during the summer when crops are growing, and the least occurs during the fall of the year. Because the winter rains are usually gentle and steady, much of the water soaks into the ground to increase the ground-water storage. Much of the summer precipitation is in the form of heavy, sporadic showers favoring runoff through surface streams; much of the water that does not run off is retained in the soil and later evaporated.

CHAPTER II

Geology of the Coastal Plain and Ground-Water Resources

By

H. E. LeGrand

Geology of the Crystalline Rocks and Mineral Resources

By

A. S. Furcron

GEOLOGY

General Features

A generalized section briefly describing the geologic formations of the Coastal Plain of central-east Georgia is shown in the following table. Plate 1, a geologic map, shows the general distribution of the geologic formations at or near the surface.

The oldest rocks exposed in central-east Georgia are the metamorphic and igneous rocks of pre-Cretaceous age, which are present in the Piedmont province in the northern parts of Warren, McDuffie, and Columbia Counties. These rocks are crystalline schists and gneisses in which granite has been intruded, and also a group of slaty rocks of volcanic origin. Most of the rocks trend northeast. Erosion through the ages has bevelled the edges of the upturned beds.

The Tuscaloosa formation of Late Cretaceous age lies unconformably on the crystalline rocks and crops out in a discontinuous belt along the northern margin of the Coastal Plain. The formation contains poorly bedded deposits of sand and white clay in varying degrees of assortment.

Sedimentary rocks of middle and late Eocene age overlie the Tuscaloosa formation. They dip southeastward slightly less than 15 feet per mile and have a maximum thickness of about 350 feet in the southern part of the area of this report. They include beds of sand, clay, marl, and limestone. Some of the limestone beds have been dissolved to such an extent that subsidence of the overlying sediments has obscured the bedding and altered the deposits into an assemblage of mottled sandy clay.

Deposits of Oligocene age are represented by a thin limestone bed in southeastern Burke County. The Hawthorn formation, of Miocene age, is the surface formation in the southern part of the area. It is composed largely of compact sandy clay.

The following table summarizes the character and water-bearing properties of the Coastal Plain sediments. It does not include the alluvial deposits bordering some of the streams.

Structure of the Coastal Plain Sediments

A coastal plain may be defined as an emerged portion of the continental shelf, the emergence generally being brought about by an uplift of the land or by a general lowering of the sea. The depositional slope of the beds composing the Atlantic Coastal Plain has been slightly modified by uplift, and the resulting regional slant of the beds is called the regional dip. In eastern Georgia the beds in the Coastal Plain dip gently and consistently to the southeast, indicating that there has been no substantial folding or faulting since Cretaceous time.

Local structural features may result from solution of the various limestone beds. Solution and removal of soluble rocks by circulating ground water causes the unsupported overlying rocks to slump and cave in. The settling of the overlying debris into depressions is reflected on the surface as undulating topography and sinks. The amount of soluble bedrock of Eocene and Oligocene age that has been removed by solution is unknown, but certainly it is enough to add considerable confusion in locally distinguishing Eocene, Oligocene, and Miocene deposits.

A few inliers, or windows, exposing older formations in the valleys of the Coastal Plain, such as the exposure of the granite beneath the Tuscaloosa formation in a stream east of Gibson, Glascock County, do not involve structural phenomena; these inliers are merely erosional features resulting from local changes in the gradient of a stream.

The surface on which the Coastal Plain sediments lie slopes southeast but not at a uniform rate. In the general outcrop area of the Tuscaloosa formation the slope of the basement rocks is less than 25 feet per mile, but along the line connecting Columbia and McDuffie Counties it appears to be less than 10 feet per mile. In the general outcrop area of the Barnwell formation the slope of the basement rock is approximately 50 feet per mile, and this slope is maintained in the area to the south.

Summary of the Coastal Plain Sediments in Central-East Georgia

System	Series	Formation	Thickness within the area (feet)	General character	Water-bearing properties
Tertiary	Miocene	Hawthorn formation	0-125±	Commonly massive, mottled orange and gray coarse sandy clay.	Thin, relatively impervious unit. Yields moderate supplies to dug wells only.
	Oligocene	Suwannee limestone	0-50	Cherty limestone and some mottled red clay.	Too thin to be of major importance. Solution cavities in limestone yield some water.
	Eocene	Barnwell formation	0-220	Composed chiefly of brilliant red sand grading downward into interbedded yellow sand and gummy clay lamina. Thick beds of fuller's earth typical of basal member, called Twiggs clay member. Thin fossiliferous limestone beds are present throughout formation, though sporadically leached away.	Very permeable. Coarse, loose sands, characterizing much of formation, yield bountiful supplies of potable ground water. Extensive outcrop area favors high recharge. Artesian water is obtained from this area southeastward from area of outcrop. Impermeable basal clay member acts as confining stratum between sands of the Barnwell and water-bearing strata below.
		McBean formation	0-150	Consists of gray and yellow calcareous sand and fossiliferous limestone beds. Is overlapped by Barnwell formation, the only exposures being along three dissected streams in Burke and Richmond Counties.	Composed of permeable sand and marl beds, but relatively unimportant as an aquifer because of its thinness and limited outcrop area.
Cretaceous	Upper Cretaceous	Tuscaloosa formation	0-850	Generally composed of pink and white kaolinic, micaceous sands. Cross-bedded sands are common but thin clay beds are rare. Upper part of formation generally contains considerable white kaolin.	Excellent aquifer. Preponderance of sand allows easy transmission of water in zone of saturation. Deep permeable beds hold artesian water and are practicable source of water in much of area. Natural recharge of the aquifer is abundant.

GROUND WATER

Of the water that seeps into the ground, a portion is retained by the soil as soil moisture, which may eventually be returned to the atmosphere either through evaporation from the soil or through absorption and transpiration of plants. If the soil moisture is depleted, the water from rain and snow must replenish it before any substantial amount of water can percolate farther downward to the zone of saturation. In this lower zone, fractures in the rocks and the spaces between rock particles are filled with water, which is known as ground water. It may be recovered where it issues as springs or it may be withdrawn from wells.

In the area under consideration the rocks differ greatly in their ability to contain and transmit ground water. The underground spaces or interstices through which water moves vary in size, shape, and arrangement as they are affected by geologic conditions. Some rocks are characterized by large openings such as solution channels and fractures, whereas others may possess numerous interstices of small size. So different is the occurrence of water in the rocks of the Piedmont from that in the deposits of the Coastal Plain that a separate description of each is necessary.

Ground Water in Rocks of the Piedmont

The crystalline rocks, such as granite, schist, and gneiss, occur in the Piedmont belt north of the Fall Line in eastern Georgia. Too few wells have been drilled in these rocks to determine the water-yielding capacity of each type, and the following discussion is therefore based on examination of the crystalline rocks in the area covered by this report and on investigations of similar rocks in other parts of the Piedmont area of Georgia.

The constituent grains of these rocks, by virtue of their crystallization and interlocking nature, have left very little pore space through which water may be transmitted. The circulation of ground water, therefore, is controlled by fractures and other openings developed after the crystallization. The amount of water yielded by the crystalline rocks depends on the number, size, and position of the openings, and the quantity is more likely to be small to moderate than moderate to large. Some ground water may be obtained from the porous, decomposed and disintegrated parts of the crystalline rocks near the land surface.

Several factors, generally acting together, control the amount of water yielded to wells and springs in the Piedmont area; these include (1) type of rock, (2) structure, (3) weathering, and (4) topography.

(1) A classification of rocks based on their mineral constituents reveals well-recognized types having properties that, strictly speaking, have little influence on the circulation of water. Rock type in this sense is of no great importance, inasmuch as the constituent grains of practically all are so closely interlocked that they virtually deny access to circulating water. However, it should be noted that individual rocks vary greatly in their susceptibility to alteration, and the water-bearing properties of these rocks are influenced according to the degree and type of alteration.

(2) Almost all crystalline rocks contain some structural planes or openings through which water can circulate. These structural planes include those resulting from schistosity, faulting and folding, and intrusion, and, finally, fractures, which may or may not be systematically developed. The most prominent planes accessible to water are those due to schistosity (in the metamorphic rocks), which in Georgia have a prevailing northeast trend and a relatively steep southeast dip. Fault planes probably are not uncommon in the Piedmont, but their general coincidence with the schistose planes makes impossible their identification in many places; where intersected by wells they usually contribute relatively large quantities of water. Faults do not produce large springs in the area, and, in fact, it is thought that most of the springs are unrelated to faults.

Igneous material has been injected into many of the preexisting rocks, the resulting rock types being interlaminated. Joints, through which water circulates, commonly develop along such intrusive planes. Well drillers are in general agreement that such alternation of rocks is a favorable indication of relatively large water supplies.

Almost all igneous and metamorphic rocks are traversed by fractures, which in many cases are systematically developed, and these openings furnish storage for ground water. The metamorphic rocks, which have undergone some degree of deformation, possess better developed jointing than the true igneous rocks. However, many igneous rocks, especially granites, contain nearly flat joints which are of considerable importance to the occurrence of water in these rocks. This system of jointing, known as exfoliation or sheeting, is generally conformable to surface topography but has less relief. Thus, on hills the joints are convex upward, and in valleys apparently concave. Ground water drains naturally from the upland joints to the lowland joints (LeGrand, 1949, p. 116).

(3) The crystalline rocks of the eastern Georgia Piedmont generally are deeply weathered, except where there are bold exposures of granite on some of the interstream areas. The residual weathered material furnishes appreciable storage for ground water, which in turn permits a constant recharge to the joints in the underlying bedrock.

(4) An important factor affecting the occurrence of water in crystalline rocks is topography. Mundorff (1945, p. 14) and others have recognized that lowlands generally yield greater amounts of water to wells than uplands. Among the causes of relatively large yielding wells in lowlands are (1) the frequent localization of fractures in draws and valleys, (2) the enlargement of fractures by solution, resulting from continuous circulation of water in lowlands, and (3) the natural movement of ground water away from wells on hills and toward the wells drilled in lowlands.

Ground Water in the Coastal Plain Deposits

As noted previously, the Coastal Plain of eastern Georgia is formed by alternating beds of sand, clay, marl, and limestone. The beds dip to the southeast at about 15 feet per mile, this dip being slightly steeper than the regional surface slope. Under these conditions water entering the outcrop area of the more permeable beds—usually composed of sand or limestone—moves down dip under the force of gravity until it becomes confined between impermeable beds. The pressure exerted by the weight of water at higher levels in a confined aquifer results in the water rising above the top of the aquifer in a well that penetrates it down dip from the intake area. Such a well is called an artesian well, even though water may not flow out at the surface. The level to which this water will rise is called the piezometric surface. In some lowland areas of the Coastal Plain, wells penetrate one or more beds containing water under hydrostatic pressure great enough to bring the level of the water higher than the mouth of the well. Under these conditions an artesian flow or flowing well is developed.

Large quantities of artesian water are stored in the permeable sands that are confined between impermeable beds of the Coastal Plain. Wells drilled to depth of 35 to 600 feet may, depending on geologic conditions, reach artesian water. No great demands have been made on the confined water, and consequently no one has seriously worried about the possibility of a waning ground-water supply. Inasmuch as flowing wells are regarded with pride by the owners, most of them are allowed to flow freely without thought of conserving the water not immediately needed. Some flowing wells have been abandoned by sawmill crews and owners of summer estates. Such flows do not dewater the aquifer in the immediate area, but they may appreciably lower the artesian head.

The Water Table and its Fluctuation

The upper limit of the zone of saturation is known as the water table. The depth to the water table at any one place usually fluctuates in response to daily and seasonal variations in precipitation and to the rate at which water is extracted by pumping. The depth to the water table also varies from place to place according to the topography and the texture and porosity of the rocks. Generally it is conformable with the topography but expresses less relief. In a dissected region the water table may be exposed, at which places springs or seeps occur. In the crystalline rocks the water table ranges from a few feet below the land surface to 60 feet or more below it. In the deposits of the Coastal Plain the water table ranges from a few feet to approximately 150 feet below the land surface.

When water is taken from a well more water from the rock material near the well moves in to take its place. The withdrawal of water results in formation of an inverted cone, called a cone of depression, in the water table or piezometric surface. Heavy pumping lowers the water level in the area around the well and deepens the cone as well as enlarges the surface area influenced by the withdrawal. This area of influence may extend for tens of feet or several miles, depending on the rate of pumping and the ground-water conditions in the formation. Heavily pumped wells so closely spaced that their areas of influence overlap are less productive than they would be if spaced at greater distances.

Drilled Wells

If large quantities of water are desired it is usually necessary to penetrate deeper into the ground than is possible by means of dug wells. Therefore, many of the industrial and municipal ground-water supplies in this area are obtained from drilled wells. Drilled wells are common sources of domestic supplies in the Coastal Plain area where artesian water can be reached at reasonable depths. The wells are lined with iron or steel casing to bedrock in the consolidated rocks and to such depths as will prevent caving in the unconsolidated deposits.

There are several methods of drilling wells, but the most common is the cable-tool method, in which is used a portable percussion rig powered with a gasoline engine. Drilling is done by raising and dropping a heavy bit into the hole, the bit being connected to the end of a steel drill stem suspended by a rope or steel cable. The crushed and broken material is removed by means of a bailer or sand pump. Drilling continues until an adequate supply of water is encountered or, in rare cases, until the hole is abandoned.

Some wells are drilled by the hydraulic-rotary method, which is especially adapted to conditions on the Coastal Plain and which differs from the cable-tool method in the manner of breaking and removing the rock material. In this method the bit is rotated and the abraded rock material is removed by the circulation of a mud fluid descending through the drill pipe and ascending outside the pipe. The mud fluid carries the broken rock fragments to the surface in suspension.

Driven Wells

In the loose, granular sands of the Coastal Plain area some wells for small domestic use have been produced by driving a piece of pipe into the ground until it reaches water-bearing material. It is necessary for the pipe to be slotted and pointed at one end and extra heavy in order to withstand the driving.

Driven wells are not suited to consolidated rocks or to areas where the water table is far below the surface, but they are not uncommon in the unconsolidated sands of Cretaceous age in eastern Georgia.

Dug Wells

More than 50 percent of the wells in eastern Georgia have been dug by hand, with a pick and shovel. They are usually more than 30 inches in diameter and are dug to a depth slightly below the water table. Dug wells are normally constructed at small cost because they penetrate chiefly unconsolidated sands and clay or decomposed crystalline rocks. They yield sufficient water for normal household requirements, except in dry seasons when the water table may be lowered below the bottom of the well.

Many of the wells in the rural areas are left open, and the water is lifted from them by means of a bucket on the end of a rope. Others are fitted with hand pumps or pumps driven by wind, but more and more of the dug wells are being fitted with electric pumps.

Dug wells have proved very satisfactory when lined properly with concrete, brick, or other materials. However, many of the wells are uncased or cased only enough to prevent caving of the walls. This encourages bacterial pollution by allowing surface water to seep into the well.

Springs

Springs are natural openings in the ground from which ground water is discharged. They are common in eastern Georgia, in both the Piedmont and the Coastal Plain areas. They furnish a portion of the domestic water supplies, but normally they have not been utilized to any great extent. They range in size from mere diffuse effluent seepage to flows of more than 700 gallons per minute. Geologic conditions determine the size and nature of springs. For this reason the discussion of springs is more appropriately treated later in the report, together with the formations from which they arise.

QUALITY OF GROUND WATER

General Conditions

Rainwater in its downward descent through the atmosphere into the soil dissolves carbonic acid, which favors solution of mineral matter in the water as it moves to the zone of saturation. Mineral matter in ground water is commonplace. The materials commonly present in the ground water of central-east Georgia are silica, iron, aluminum, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, nitrate, chloride, free carbonic acid, and hydrogen sulfide. Rarely is any one substance sufficiently concentrated to affect the taste or use of the ground water.

Chemical Constituents[1]

Silica (SiO_2) is derived from practically all rocks. The more alkaline water has a tendency to take more silica in solution than the less alkaline water. Silica does not affect the usefulness of water except in contributing to the formation of scale.

Iron (Fe) is a common constituent of ground water dissolved from practically all rocks and frequently from iron pipes. Excessive iron in water causes stains on fixtures and laundry and leads to clogging of pipes. Such water is generally unsuitable for industrial uses except as a coolant, unless it contains less than a few tenths of a part per million.

Although the chemical analyses in this investigation did not include tests for iron, only one well is known to contain water having an undesirable quantity of the metal. According to Stephenson and Veatch (1915, p. 258), this well at Gibson, Glascock County, contains 4.0 parts per million of iron. It is no longer used for the public supply of that community.

Calcium and magnesium (Ca and Mg) are dissolved from many rocks, but particularly from limestone, which is predominantly calcium carbonate. Calcium and magnesium are the principal cause of hardness; hard water is universally recognized as undesirable for some uses, both domestic and industrial. Calcium occurs in greater amounts than magnesium in the ground water of the area.

Water derived from limestone beds in the Barnwell forma-

[1]Adapted from Lamar, W. L., 1940, Industrial quality of public water supplies in Georgia, p. 7-15.

tion has the highest calcium content and the highest average hardness.

Sodium and potassium (Na and K) are dissolved from practically all rocks and soils, but they make up only a small part of the dissolved mineral matter in the ground water of this area. Moderate quantities of sodium and potassium have no effect on the suitability of water for domestic and most industrial purposes.

Carbonate and bicarbonate (CO_3 and HCO_3) occur in water largely through the action of carbon dioxide, which allows the water to dissolve carbonates of calcium and magnesium. Carbonate is not present in appreciable quantities in the ground water of central-east Georgia. The bicarbonate content in the water samples ranged from 4 to 204 parts per million, the higher content coming from water in solution cavities of limestone beds of the Barnwell formation.

Sulfate (SO_4) is dissolved from rocks and soils and especially from material containing gypsum. It is also formed by the oxidation of sulfides, such as the sulfide of iron called pyrite. Although sulfate itself has little effect on the general use of water, its presence often complicates the process of softening hard water.

Chloride (Cl) is dissolved in small quantities from rock materials in most parts of the country. Large enough quantities of chloride give a salty taste to the water and, when present in sufficient quantity to balance the calcium or magnesium, may increase the corrosiveness. The chloride content of water in this area is low and has little effect on the suitability of water.

Fluoride (F) in water has received considerable study in recent years because of its effect on teeth. More than about 1.0 part per million of fluoride (Dean, 1936) is said to be associated with the dental defect known as mottled enamel if the water is used by children during the period of calcification, or formation, of the teeth. The effect of contents up to 1.5 parts per million is small, and the Public Health Service has established that as the recommended limit. On the other hand, it is reported that fluoride in water in concentrations up to about 1.0 part per million is a factor in retarding dental caries, the decay of teeth (Dean and others, 1941). The fluoride content of water analyzed from the Coastal Plain formations in the area studied does not exceed 0.1 part per million. Water in the granite-schist complex was found to contain as much as 0.6 part per million of fluoride.

Nitrate (NO_3) is a relatively unimportant constituent of water derived from drilled wells in the area. It is generally considered to be a final oxidation product of nitrogenous organic material. Water from some of the uncased dug wells in central-east Georgia contains as much as 80 parts per million of nitrate. The high nitrate content is believed to be due to surface contamination of water entering the well.

Hardness in water is normally produced by calcium and magnesium; it may be recognized by the increased quantity of soap required to produce lather and by the deposits of insoluble salts formed when the water is heated or evaporated. Water having a hardness, as calcium carbonate, of less than about 60 parts per million is considered soft. Hardness of more than about 120 parts per million requires the use of a large amount of soap, and it is economically feasible to soften the water for many uses.

GEOLOGY OF THE CRYSTALLINE ROCKS

The crystalline rocks considered in this report crop out over most of Columbia County, and over the northern halves of McDuffie and Warren Counties. The eroded surface of these crystalline rocks dips gently southward, where it is covered by the unaltered sediments of the Coastal Plain. Locally, and especially in McDuffie County, outcrops are poor and are confined to stream valleys.

The oldest are metasedimentary rocks which are widespread at the surface and are thoroughly injected by granite. Younger sedimentary rocks are of unknown, but probably Paleozoic, age. All these rocks, especially the old metasedimentary rocks, are intruded by granite and granite gneiss.

Tongues of crystalline rocks extend southward into the Coastal Plain along the major stream valleys, and in Glascock County these rocks, principally granite, extend to the vicinity of Gibson.

Gneiss-Granite Complex

The gneiss-granite complex is classified as the oldest mapped unit of the district; however, the various facies involved are obviously of different ages. A metasedimentary biotite gneiss composes the oldest member of the complex, and if the hornblende rocks are all igneous, they should be of later age. These facies are older than the metavolcanic series. Much of this complex is migmatite produced by assimilation of the above-mentioned rocks; locally, the biotite gneiss is affected by lit-par-lit injection and is crosscut by the later granites. The old metasedimentary part of this complex should be Precambrian because the massive bodies of granite and porphyritic granite crosscut it. Migmatite-forming muscovite-biotite granites are not porphyritic.

A few local outcrops of quartzite in the area considered occur with the biotite gneiss-hornblende gneiss facies. The distribution of quartzite in this type of complex in the crystalline area of Georgia has been discussed in a recent article (Furcron, 1951). Quartzite beds can be seen about 1½ miles northwest of Thomson, the quartzite being similar to that found near Milledgeville and Lawrenceville. Quartzite is too rare, however, and too poorly exposed in this area to serve as an adequate criterion of age of associated metasediments.

Fresh outcrops of the biotite gneiss-hornblende gneiss facies are rare, but reasonably good exposure can be seen in Columbia County, east and north of Appling. This complex is classified as the Carolina gneiss on the State Geologic Map of 1939. The rock is generally a pepper-and-salt-appearing, even granular, metasedimentary oligoclase-andesine biotite gneiss, locally interlayered with hornblende gneiss and extensively granitized.

In most of the outcrops the rock is generally migmatite, produced by a muscovite-biotite granite of varying composition. This granite is much younger than the host rock, and is essentially undeformed; also, it crosscuts its migmatite. Bodies of porphyritic granite and smaller bodies of fine-grained granite do not seem to be directly responsible for migmatization, which in general preceded their emplacement. Migmatite xenoliths are locally included in the massive granite, which intrudes migmatite. This complex is most widely distributed in Columbia County and the southern part of McDuffie County; however, its extent in the State is not generally known, nor has it been definitely related thus far to other Precambrian complexes. The rocks crop out in the central portion of a large structural arch or anti-clinorium, the axis of which strikes about N. 60° E.

The foliation of the migmatite is steep locally, but folds are usually gentle. Southwestward, in Warren County, the complex is extensively assimilated by later granite. On the north and south flanks of the anticlinorium of older gneiss the metavolcanic series occurs, but it is removed over the central part of the arch.

Hornblende Gneiss and Ultramafics

Hornblende gneiss and ultramafics are found in northern Columbia and northern McDuffie Counties, where they compose a part of the schist-gneiss complex. Small local occurrences in this complex may be found in other places. In northwestern Columbia County is a belt of such rocks, which extends into South Carolina. Associated with the hornblende gneiss in this belt are soapstone and serpentine, the latter derived from peridotite. Hornblende gneiss occurs extensively along the headwaters of Green Briar and Buggs Creek just north of the Columbia-McDuffie County line; other occurrences are in the old complex in north-central McDuffie County. Locally this rock produces a definite migmatite, which may be seen on State Highway 180 just east of Appling, Columbia County.

A marked feature of the gneiss is the development of epidote near intrusive granite. Although outcrops are generally too weathered for detailed examination, fresh specimens of hornblende-epidote gneiss may be obtained from extensive occurrences of this rock about 7½ miles northeast of Thomson and east of Cobham crossroads, McDuffie County. Epidote and hornblende are micrographically intergrown, both containing abundant inclusions of plagioclase and quartz.

The origin of hornblende-bearing rocks in the Georgia Piedmont area is a debatable one in many cases. In this district the hornblende rocks seem to be interlayered with the old sedimentary biotite gneiss; but where they are associated with metaperidotite, an igneous origin is indicated.

Metavolcanic Series

(Little River Series of Crickmay)

Metavolcanic rocks extend into Georgia from South Carolina. They are recognized by Crickmay (1952) as the southwestern extension of the Carolina Slate Belt and there named by him the Little River series in Georgia (Geologic Map of Georgia, 1939). The series crops out over the northern and southern flanks of an extensive uplift of Precambrian gneisses. Part of the northern belt extends through the northern parts of Columbia, McDuffie, and Warren Counties, continuing southward at least to the general vicinity of Macon. The rocks of this belt are intruded by bodies of porphyritic granite gneiss, porphyritic granite, and small younger plutons of fine-grained granite. These intrusions are common near the southern border of the belt but become rare or absent in the deep parts of the syncline. The southern belt, referred to as the Kiokee Belt by Crickmay (1952) is covered generally by Coastal Plain sediments, but it is exposed locally where it is crossed by certain large stream valleys. The most extensive exposure is in Richmond County in the vicinity of Augusta. There is also an isolated exposure of some prominence on Butler Creek in that county. Other exposures are found in southern McDuffie County, and there is an extensive exposure along the Ogeechee River in southwestern Warren and eastern Washington Counties, south of Mitchell.

The geologic age of the series is not known. The older, underlying greatly injected metasedimentary gneiss represents a rather uniform and characteristic grade of metamorphism where biotite and, locally, garnet are important minerals. In no way does the old sedimentary facies of the underlying complex resemble the Little River series of Crickmay, which not only differs in composition and origin from this basement but is only slightly metamorphosed, except locally near intrusions. Interfolding of the two types and their extensive mutual injection near contacts are sufficient to disguise evidence of unconformity. Thus it is believed that the series is younger than Precambrian; it is intruded by Triassic dikes.

Porphyritic Granite Gneiss

The term "porphyritic granite gneiss" is used in this district for granite gneiss, which occurs principally in Warren County. In composition and distribution it seems to be merely a facies of coarse porphyritic granite, described below.

This rock occurs chiefly as a belt in north-central Warren County, between Warrenton and Norwood, extending from near the Hancock County line on the southwest into McDuffie County on the northeast. The principal commercial quarrying in the area is in this belt of rock.

The belt occurs in the metavolcanic series and, although apophyses of the gneiss have not been noted in that series, the distribution of the gneiss indicates that it should be intrusive. North of the principal belt, this particular type recurs locally where more bodies of gneiss and granite are found in the metavolcanic series, as for example, along Tanyard Branch about 2 miles northwest of the Camak quarry.

The gneiss differs from the other associated granites in several ways. Foliation is very noticeable in this rock, which is also generally coarser grained than the associated granites. The gneiss carries considerably more biotite, which marks the foliation. The large feldspar "phenocrysts" have a tendency to be drawn out parallel to foliation, and thus may show no crystal outline.

The groundmass of the gneiss is composed of minerals that exhibit no crystal outline and that are coarse grained. Feldspar is the dominant mineral; quartz and biotite are abundant. Potash feldspar, principally orthoclase, is abundant, but there is also considerable plagioclase. Micropegmatitic intergrowths of quartz and feldspar are common.

The most noticeable feature of the rock is the occurrence of large white and light-gray to pink porphyroblasts of potash feldspar, which enclose the other minerals of the groundmass, especially a considerable amount of biotite.

At the village of Cedar Rock, near the Weston and Brooker quarry, the stone is coarsely porphyritic, but it is no more gneissic than many facies of the porphyritic granites. Veins of orthoclase porphyroblasts crosscut the rock here, apparently following joints produced in the rock shortly after its consolidation. Evidence of this type indicates a late origin for the large feldspar crystals.

The increase of pink potash feldspar with the occurrence of muscovite and the decrease or absence of biotite produce a pink straight-banded granite gneiss, which seems to be a local facies of the rock described above. This variety is not mapped separately. It is well exposed in a belt about a quarter of a mile wide, which occurs in and against the southeastern side of the principal area of the metavolcanic series, where its physical character seems to be determined by its contact with that series and its mode of intrusion. This belt of gneiss enters Columbia County from South Carolina, near the junction of the Little River with the Savannah. It takes an almost straight course S. 60° W., extending about 4 miles into McDuffie County. Another belt of similar rock crops out in Warren County along the south side of the granite and granite-gneiss belt just north of the Norwood-Wrightsboro road.

The details of age relationship of these gneisses with other granites can be determined only by large-scale mapping and petrography. The gneiss is crosscut by fine-grained granites, which resemble the other types in physical character, but which closely resemble the gneiss in actual mineral composition. It seems probable that the gneisses were intruded under conditions different from those under which the massive granites were emplaced. The old theory that the gneisslike character of this rock was produced by metamorphism of massive granite is not justified by observation, because the rock grades into massive granite; moreover, it intrudes the metavolcanic series, which exhibits low-grade metamorphism where it is distant from the granite-gneiss intrusions. It seems probable that this gneiss facies was injected under conditions of regional stress. The large feldspar crystals have been generally oriented with the schistosity, and because they include the other minerals of the rock, it is believed that they formed late in the crystallization history of the magma, and thus are porphyroblastic and not true phenocrysts.

"Porphyritic" Granites

"Porphyritic" granites occur as plutons in the gneiss-granite complex and in the metavolcanic series. The largest body of this rock occurs in south-central Columbia County, east of Appling, where numerous good quarry sites are exposed. Extensive outcrops occur in southern Warren County, and into Hancock County; also, west of Warrenton, on the east side of the Ogeechee River, there is another occurrence which seems to grade into the extensive belt of porphyritic granite-gneiss of the Camak area. Small local bodies of this type occur in the northern syncline of the metavolcanic series near its southern borders. The large feldspar crystals postdate the granite host rock.

Muscovite-Biotite Granite

Small bodies of fine-grained granite, which resemble the Stone Mountain type (Crickmay, 1952), are scattered over almost the entire area of crystalline rocks. The rock is massive and fine grained and, locally, is a true muscovite granite. It forms oval-shaped bodies in the gneisses or in the metavolcanic series and narrow dikes in the gneisses. It differs from bodies of fine-grained porphyritic granite only in its lack of large feldspar crystals. Most of the bodies are too small to quarry. They represent small later intrusions and thus are the purest granite bodies of the district, suitable for monumental and dimension stone.

GEOLOGIC FORMATIONS OF THE COASTAL PLAIN AND THEIR WATER-BEARING PROPERTIES

Cretaceous System

TUSCALOOSA FORMATION

Geology.—The Tuscaloosa formation was named by Smith and Johnson (1887, p. 95-116) after the city of that name in Alabama. It has long been known that Cretaceous deposits extend across Georgia, and in 1936 C. W. Cooke (p. 17) extended the name Tuscaloosa to represent the basal Upper Cretaceous strata in South Carolina and Georgia. No identifiable fossil remains have been found in this formation in eastern Georgia, and therefore its correlation with the Tuscaloosa elsewhere is based on lithology and stratigraphic position.

While mapping the outcrop area of the Cretaceous formations in Georgia in 1949 for the Federal Survey, Hoye Eargle (personal communication) found evidence to suggest that deposits now called Tuscaloosa in eastern Georgia may be of younger Cretaceous age than the Tuscaloosa. However, until further work is done in the Cretaceous deposits in adjacent parts of South Carolina, where similar deposits also are called Tuscaloosa, it seems desirable to retain the name in eastern Georgia.

In eastern Georgia the Tuscaloosa is exposed in a belt as much as 18 miles wide bordering the Piedmont area and trending slightly north of east. The extreme irregularity of the belt is due to erosion by southeast-flowing streams, which have cut valleys through the formation in the outcrop area where it is relatively thin. Farther south it has V-shaped exposures pointing southward in the valleys. Progressive overlap of younger beds of Eocene age is a factor in limiting the width of the Tuscaloosa belt, and in Warren and Glascock Counties the younger sediments overlap the Tuscaloosa to break the continuity of the belt. Numerous outliers of the formation lie on the Piedmont in the other counties north of the main belt.

In its outcrop area the Tuscaloosa nowhere greatly exceeds 150 feet in thickness and it generally is much thinner, especially toward the north. Under cover, down the dip, it is 355 feet thick at Wrens in Jefferson County, and at Louisville an inferred thickness of 800 feet is indicated by a driller's log (McCallie, 1908, p. 125-126). Although no record is known of any well penetrating the complete formation in southern Burke and Jefferson Counties, it probably reaches a thickness of 850 feet there.

The Tuscaloosa formation consists of arkosic sand composed largely of angular to subangular quartz grains. Disseminated kaolin and mica are present throughout much of the sand, the latter ranging in color from white to gray, yellow, and pink. Lenses of white and gray clay are present throughout the formation (fig. 2). Balls and boulders of pure white kaolin are common. The Tuscaloosa formation is generally massive, both the sand and the clay showing very little bedding or lamination. A typical section of the Tuscaloosa formation follows:

Section in road cut on U. S. Highway 1, 5 miles south of Butler Creek, Richmond County

		Thickness (feet)
Barnwell formation (Eocene):		
13	Sand, coarse, red	15
Tuscaloosa formation (Upper Cretaceous):		
12	Sand, compact, pink, and thin kaolin lenses	20
11	Sand, white, micaceous	70
10	Sand, clayey, compact, pink, and gravel	18
9	Sand, kaolinic, white, micaceous, crudely stratified	20
8	Sand, medium-grained, white, and disseminated kaolin	25
7	Sand, coarse-grained, and gravel with white kaolin balls	2
6	Sand, white, medium- and fine-grained, poorly stratified, and disseminated kaolin and mica	18
5	Clay, sandy, mottled red and gray, somewhat plastic	18
4	Sand, clayey, compact, pink	11
3	Sand, medium-grained, white, containing disseminated mica and kaolin	12
2	Sand, white, coarse-grained, water-bearing, and sparsely scattered white kaolin particles	14
Metavolcanic series (pre-Cretaceous):		
1	Clay, soft, white and yellow, sericitic, to level of bridge	20

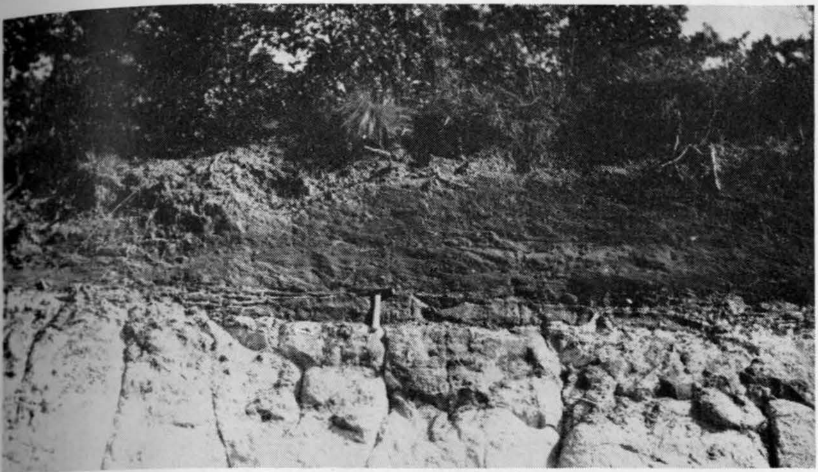


Figure 2. White massive sandy kaolin of the Tuscaloosa formation overlain by red clayey sand of the Barnwell formation, Camp Gordon Military Reservation, 1 mile north of U. S. Route 1, Richmond County.

Ground water.—The coarse, permeable sands of the Tuscaloosa formation are an excellent source of water. Water from these sands, where they are exposed or are buried beneath younger sediments at depths accessible to wells, is extensively used for domestic and municipal supplies.

In the outcrop area of the formation shallow dug wells locate water readily at depths usually less than 40 feet. At the surface the clay normally present in the formation has been washed away, leaving coarse, loose sand to receive water from precipitation. Therefore, despite the hilly topography, water seeps into the formation to recharge that part of the aquifer that is covered beneath younger sediments down the dip. Water in the outcrop area is generally under water-table conditions. Relatively high yields may be obtained if the underlying basement rock is not encountered at a shallow depth, that is, if the zone of saturation is at least a few tens of feet thick.

South of, and parallel to, the outcrop belt lies another belt as much as 25 miles wide, from which large water supplies can be derived from the sands of the Tuscaloosa. Yields of 500 gallons a minute or more may be obtained from individual wells in the water-bearing beds. The deposits become deeper to the south and east because of the inclination of the strata, but even there the aquifer is accessible to deep wells.

Where buried beneath relatively impermeable beds down the dip, sands of the Tuscaloosa formation yield artesian water, the level of which may be above the ground surface in most of the lowland areas of Jefferson, Burke, and southern Richmond Counties. Therefore, conditions for the development of flowing wells are favorable in the flood plains of most of the streams in the counties mentioned. (See area of artesian flow, pl. 2).

Owing to the hilly topography and irregularity of the outcrop area, considerable leakage of water from the formation occurs. Springs are common where permeable sands overlie clay beds at the surface. The presence of impermeable crystalline rocks beneath the permeable Tuscaloosa formation gives rise to many springs where this contact is exposed. The numerous outliers of the Tuscaloosa on the Piedmont in Columbia, McDuffie, and Warren Counties act as superficial permeable deposits from which springs issue. However, not all water emerging from the Tuscaloosa is necessarily lost to the aquifer, because much of the leakage from the formation returns as influent seepage at a lower surface level.

Analyses of water collected from the Tuscaloosa formation at 13 localities in central-east Georgia indicate that water of that formation is low in dissolved mineral content. The water generally contains less than 40 parts per million of bicarbonate, 6 parts per million of chloride, 0.1 part per million of fluoride, 25 parts per million of sulfate, and 5 parts per million of nitrate. A faint odor of hydrogen sulfide is detected from some of the flowing wells that derive water from the Tuscaloosa formation. Many of the wells drilled into the Tuscaloosa are cased only as deep as a clay or limestone bed in the overlying Barnwell formation; this allows water from the limestone beds and the sands of the Tuscaloosa formation to be mixed.

Tertiary System

McBEAN FORMATION

Geology.—The McBean formation was named by Veatch and Stephenson (1911) after a village in Richmond County, Ga., and after McBean Creek, which forms the boundary of Richmond and Burke Counties. The original description of this formation included an upper clay member which Cooke and Shearer (1918, p. 41-81) placed in the Barnwell formation and called the Twiggs clay member. Therefore Cooke and Shearer restricted the name McBean formation to the deposits of early Claiborne (Lisbon) age along the Savannah River and its tributaries.

The McBean formation, as herein mapped, does not crop out in a continuous belt across eastern Georgia. Because it is commonly overlapped by the Barnwell formation, its area of outcrop is restricted to two localities, the best known being along McBean Creek from a point 3 miles west of McBean station to its junction with the Savannah River and extending a few miles along the west bank of the river in each direction. The other locality represents an inlier centered on Briar Creek about 5 miles southeast of Keysville.

The formation is composed chiefly of green, fossiliferous calcareous sand and marl. At the type locality, a quarter of a mile southeast of McBean on the south side of McBean Creek, the following section is exposed:

Section in gulley on south side of McBean Creek a quarter of a mile southeast of McBean station

		Thickness (feet)	Elevation of base of bed (feet)
Barnwell formation:			
7	Sand, red, massive	19	167
6	Sands, loose, yellow and gray, ranging from fine- to coarse-grained	30	137
McBean formation:			
5	Sand, greenish-yellow, fine-grained, argillaceous, and blobs of calcareous and carbonaceous material	5	132
4	Marl, green, sandy, and calcareous sand with shell fragments	3	129
3	Sand, incoherent, gray and yellow	18	111
2	Sand, argillaceous, and green marl containing cream-colored calcareous nodules	12	99
Tuscaloosa formation:			
1	Clay, sandy, micaceous, blue		Below 99

Elevation 129 feet represents the land-surface elevation. Information concerning beds 1, 2, and 3 was derived from exploratory drilling.

The McBean formation unconformably overlies the Tuscaloosa formation in eastern Georgia. It is in turn overlain by the Barnwell, which laps over the McBean onto the Tuscaloosa formation north of McBean Creek.

The thickness of the McBean formation at McBean station is approximately 38 feet. The formation probably thickens under cover, but no accurate records are available to show its thickness farther south.

The Foraminifera of the type locality of the McBean formation, from beds 4 and 5 of the preceding section, have been described by Cushman and Herrick (1945).

The McBean formation appears to have no real economic importance. Several exposures of limestone in the formation have led to sporadic attempts at quarrying but none has proved successful. The low carbonate content, the small quantity of the stone, and its inaccessibility have prevented the deposits from becoming commercially important.

Ground water.—The water-bearing properties of the McBean formation have never been fully tested. This has been due to the lack of knowledge of the formation under cover and to the fact that adequate water supplies have been obtained from the overlying Barnwell formation and the underlying Tuscaloosa formation. No well is known to be drawing water from the McBean in its limited outcrop area. If the sand and marl beds are extensive farther south where the formation undoubtedly thickens, they might yield considerable water.

No analysis was made of water that is known to come from the McBean formation. The calcareous nature of the formation suggests that its water would be moderately hard.

BARNWELL FORMATION

Geology.—The Barnwell formation was named by Sloan (1907, p. 90) to represent the red ferruginous sands so prominently exposed in Barnwell County, S. C. Sloan classified this formation as middle Eocene. Veatch and Stephenson (1911, p. 285-296) applied the name to similar deposits in Georgia but included the McBean formation and the Barnwell in the Claiborne group. Some of the fauna on which Veatch and Stephenson based their correlation with the Claiborne group also occur in deposits of Jackson age, according to Cooke and Shearer (1918, p. 41-81), who reclassified the Barnwell as of Jackson age.

The Barnwell formation extends across eastern Georgia in a belt south of the outcrop area of the Tuscaloosa formation. It has a greater areal extent than any other formation in the area and is exposed, in part, in each of the counties covered in this report. Numerous outliers of the formation are found north of the main belt. (See pl. 1 and fig. 3).

In southern Jefferson and Burke Counties the Barnwell attains a thickness of approximately 220 feet. To the north it thins progressively toward the Fall Line, and in part of western Warren County it is only 70 feet thick (underground thickness, not that due to post-Miocene erosion). It dips approximately 13 feet per mile toward the southeast.

Bright-red sands compose most of the Barnwell formation, but some limestone and clay beds also are present. Its diverse lithology requires the division of the formation into three members in order to discuss properly the geology and ground water. The division used in this report is that adopted by LaMoreaux (1946, p. 10) in east-central Georgia. No exposure includes all three members of the Barnwell formation.

The Twiggs clay member of the Barnwell formation is named after Twiggs County, Ga., where it is typically exposed at Pikes Peak station, on the Macon, Dublin, & Savannah Railroad. It was described by Veatch and Stephenson (1911, p. 238) as the Congaree clay member of the McBean formation. Cooke and Shearer (1918, p. 41-81) placed it in the Barnwell formation and called it the Twiggs clay. The thickness of this clay member probably does not exceed 60 feet in eastern Georgia. It is composed chiefly of a drab or green hackly clay interbedded with thin layers of sand and marl. To the west it becomes more calcareous and merges laterally into the Ocala limestone.

As the basal member of the Barnwell formation, the Twiggs clay lies unconformably on the McBean formation in Richmond and Burke Counties. Farther west, where the McBean formation pinches out, the Twiggs clay member appears to rest unconformably on the Tuscaloosa. It is absent to the north near the Fall Line, where the upper red sand member (LaMoreaux, 1946, p. 52) lies directly on the Tuscaloosa. At the Albion Kaolin Mine near Hephzibah, Richmond County, the Twiggs clay member is absent, and the red sands of the Barnwell rest unconformably on a kaolin zone in the upper part of the Tuscaloosa formation.

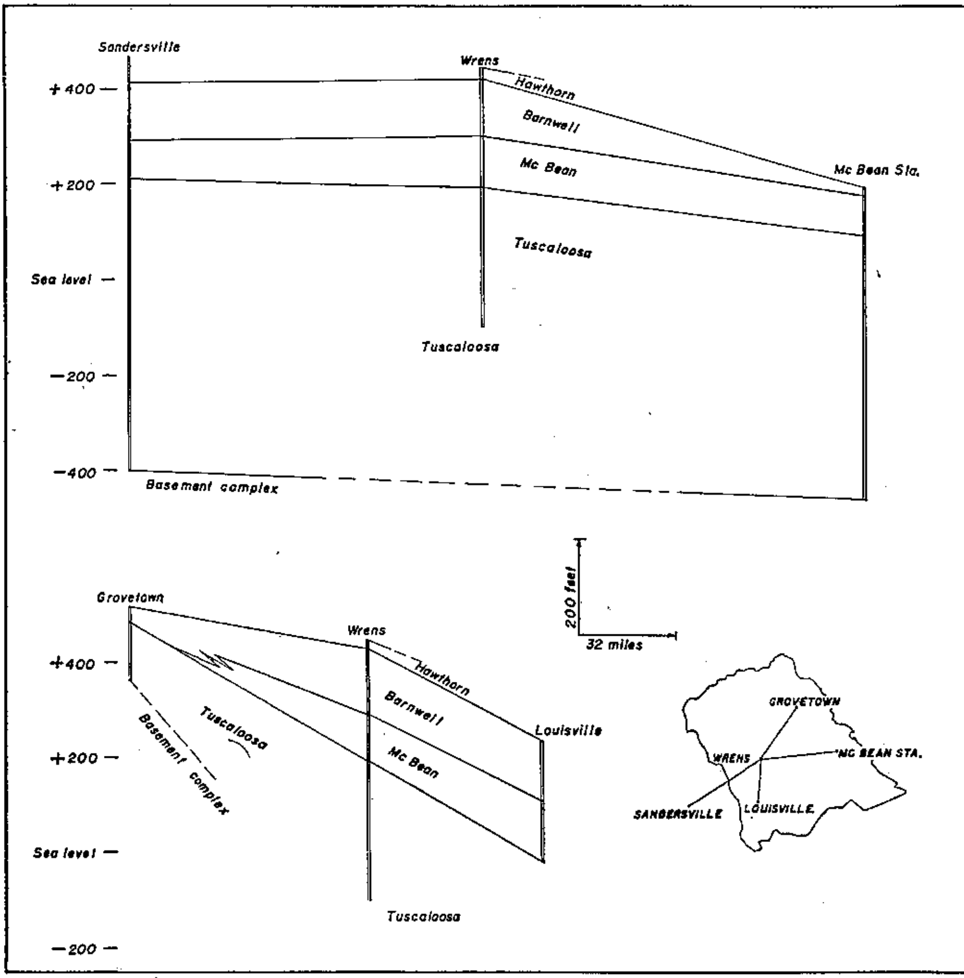


Figure 3. Geologic cross sections of a part of central-east Georgia. Constructed by S. M. Herrick from wells at Grovetown, McBean Station, Wrens, and Louisville, and at Sandersville in adjacent Washington County.

The Irwinton sand member of the Barnwell formation was named by LaMoreaux (1946, p. 17) after a town by that name in Wilkinson County, Ga. In central-east Georgia it is composed of light-colored fine-to medium-grained sand interbedded with thin layers of yellow and gray clay. The Irwinton sand member is well exposed on the Camp Gordon Reservation in Richmond County, where deep gullies resulting from recent unimpeded erosion along the abandoned section of Tobacco Road have exposed fresh sections of gray and white fine sand and numerous interbedded laminae of clay.

In other parts of Richmond County, however, and in Burke County it is difficult to identify the Irwinton sand member; it appears to merge laterally eastward into the undifferentiated deposits of the Barnwell.

The upper sand member of the Barnwell formation in eastern Georgia consists of coarse red sand and mottled red sandy clay. It is typical of the undifferentiated Barnwell formation of Barnwell County, S. C. This upper sand member is generally massive and commonly mottled with streaks of gray clay.

The upper sand member includes at least one limestone bed; fragments of limestone at several horizons indicate that several beds of limestone were present before being removed in solution by circulating ground water. The Sandersville limestone member of the Barnwell formation described by Cooke (1943, p. 62) may be represented in the upper 30 feet of the Barnwell formation. Fossils are not known to be present in the massive red sand beds, although the various limestone beds are everywhere fossiliferous. The sporadic occurrence of limestone and the mottled character of the sandy clay indicates that intrastratal solution has occurred in the bed (or beds) and that this solution has resulted in subsidence of the overlying sand and clay. The subsidence has disarranged the original bedding into a nondescript mass of red sand and mottled sandy clay.

The thickness of the upper sand member is generally indeterminable because its contact with the underlying Irwinton sand member is indistinct. Also, the overlying residue of the Suwannee limestone closely resembles the upper sand member of the Barnwell formation, making this contact difficult to map. It is believed that the upper sand member of the Barnwell formation is of Jackson age, although a part of this sand in Southeast Burke County may represent material weathered from limy deposits of Oligocene age.

Ground water.—The Barnwell formation is an important aquifer over the area in which it lies at or near the surface. It supplies water to many shallow nonartesian wells and deeper artesian wells. Flowing wells, deriving water from the Barnwell formation, can be developed in lowland areas of southern Jefferson and Burke Counties. Flowing wells at Bartow, Wadley, and Midville are located in the Barnwell formation and are 100 to 250 feet deep.

The Twiggs clay member is a compact hackly green clay that is impervious, requiring well drillers to find water either above or below this bed. However, as its thickness rarely exceeds 40 feet, the clay is not objectionable; moreover, it is extensive enough to form an effective confining bed for the retention of ground water under pressure.

The Irwinton sand member ranks after the Tuscaloosa formation in importance as a water-bearing deposit in eastern Georgia. It yields an adequate supply of water to many shallow wells for domestic and stock use in its area of outcrop, and down the dip, where it is under cover, it is the source of most of the artesian water from the Barnwell formation. Being composed of sands interbedded with thin lamina of clay the Irwinton sand member yields water from several strata of sand.

Springs are common in the outcrop area of the Irwinton member. Water from precipitation readily percolates downward through the loose, permeable sands until it reaches an impermeable clay layer in the Irwinton or Twiggs, where it is shunted laterally, but chiefly down dip; where the relief is great enough to allow the clay to crop out, the water emerges as springs at the contact of the clay and the overlying sand. Such contact springs developed in the Coastal Plain of eastern Georgia are normally small, but the aggregate water discharged by effluent seepage is considerable. However, much of the water is regained by influent seepage at a lower surface level.

Because of the exposure of the porous sands of the upper sand member in much of Burke and Jefferson Counties, the rate of recharge to the upper part of the Barnwell formation is considerable. Most of the wells penetrating these sands are shallow dug wells, which generally produce 3 to 12 gallons a minute.

On the upland area of southern Burke and Jefferson Counties the upper sand member lies beneath thin deposits of Miocene and Oligocene age. It is deep enough to be within the zone of saturation and will therefore yield water to drilled wells ranging in depth from 50 to 150 feet. Such wells generally obtain water from one or more cavernous lenses of limestone in the upper sand member, in amounts exceeding 100 gallons a minute.

Ground water of the Barnwell formation varies in chemical character according to the geologic horizon from which it comes. Thin limestone beds make up only a small part of the Barnwell formation, yet practically half the drilled wells tap solution channels in the limestone. Consequently, this water commonly has hardness in excess of 140 parts per million and a bicarbonate content greater than 175 parts per million. The sands of the Barnwell formation yield water that is low in mineral content. Water from well 20, in Glascock County, typically expressing the chemical nature of water from sands of the Barnwell formation, shows a hardness of only 5 parts per million.

HIGH-LEVEL GRAVELS

In Warren County a discontinuous belt of sedimentary outliers extends from a hill 4 miles northwest of Norwood southward through Norris to Glascock County. These deposits, capping the hills, are composed of egg-shaped quartz gravel in a matrix of pink quartz sand with disseminated white kaolin balls. Because of the concentration of these gravels, their areal extent, their accessibility by rail or truck, and their ease of extraction, they are regarded as having a potential commercial importance. They probably do not exceed 60 feet in thickness. Although the composition of these outliers resembles that of the Tuscaloosa formation, the complete overlap of the Tuscaloosa by the Barnwell formation in Warren County weakens the suggestion that they might be remnants of the Tuscaloosa formation. They may be post-Miocene, but they appear to be the up-dip continuation of the Barnwell formation. They are too thin, and too limited in area to have any value as water-bearing deposits.

SUWANNEE LIMESTONE

The only representative of the Oligocene series in eastern Georgia is a relatively thin formation which is named the Suwannee limestone (MacNeil, 1947). The formation has been identified in this area only in southeastern Burke County, where boulders of yellow vitreous chert in red sand are present. Elsewhere in eastern Georgia the Suwannee is overlapped by younger beds of Miocene age, and it probably never extended much farther northwest than its present limits.

The Suwannee limestone unconformably overlies the Barnwell formation. The contact of these two formations is not distinct, and the red residual material characterizing much of both these units makes them almost inseparable. Consequently some of the material mapped as the upper part of the Barnwell may properly belong to the Suwannee limestone. The maximum thickness of the Suwannee is about 40 feet.

Because of its thinness and limited areal extent the Suwannee limestone has no real importance as an aquifer. Well drillers have experienced difficulty in penetrating the dense vitreous chert beds in this formation.

HAWTHORN FORMATION

The Hawthorn formation of early Miocene age, was named from the town of Hawthorn, in Alachua County, Fla. Cooke (1943, p. 89) applied the name in Georgia to a widespread geologic formation that had previously been known as the Altamaha grit (Dall and Harris, 1892, p. 81).

An erosional unconformity separates the Hawthorn from the underlying Suwannee limestone. Progressive overlap onto the Barnwell formation and subsequent erosion have left thin deposits of the Hawthorn over much of the upland south of the Fall Line. The Hawthorn is characterized by mottled yellow and orange sandy clay in the area covered by this report. Rarely are beds distinctive, at least in outcrops. Massive green fuller's earth is exposed near the base of the formation in a few places in southern Burke County. The Hawthorn formation attains a maximum thickness of 100 feet in that part of the county.

Because it is thin and contains a large amount of clay, the Hawthorn formation yields only a small amount of water. Dug wells on the upland plain in Southern Burke and Jefferson Counties obtain water from this formation, but the yield is barely adequate for normal domestic uses. The hardness of samples analyzed to date does not exceed 24 parts per million. Minor amounts of fluoride, chloride, and sulfate are present. The high nitrate content of the water from some dug wells is probably due to contamination by organic material from the surface.

Quaternary System

Deposits of sand and gravel occur in the valleys of the larger streams. These deposits consist chiefly of clay, sand,

and gravel derived from the adjacent older crystalline rocks of the Piedmont and deposits of the Coastal Plain. With the exception of those forming the lowland terrace bordering the Savannah River, these deposits are thin and small in areal extent. The terrace bordering the west side of Savannah River averages 2 miles in width in Richmond County and forms a desirable site for airfields and industrial activities for which level ground is preferable. Southward, in Burke County, it is swampy. The deposit underlying the terrace ranges in thickness from a featheredge to 80 feet, and is underlain by the Tuscaloosa formation in Richmond County south of the Fall Line. Parts of trees have been buried in these deposits. These superficial deposits receive water from rainfall, from surface drainage of adjacent upland slopes, from springs emerging along the slope, and from infiltration from the streams themselves. It is evident that, where these deposits are relatively thick, exceedingly large supplies of water may be obtained. The water is doubtless low in mineral matter and satisfactory for practically all purposes.

MINERAL RESOURCES

The principal mineral resources of the crystalline-rock portion of this area are granite and granite gneiss, which are used especially for aggregate.

One of the chief crushed-stone operators of the State, the Weston Brooker Co., has a large plant at Camak in Warren County. Gold has been mined in McDuffie County and serpentine in Columbia County. Sericite phyllite of the metavolcanic series may have future use as sources of very fine flake mica; also, clays of that series have been mined extensively west of Augusta and used in the manufacture of brick and tile. Sand and gravel deposits occur in both the crystalline-rock and the Coastal Plain areas. Kaolin is the most important mineral product of the Coastal Plain section.

Granite

Granite suitable for crushed stone is found in numerous places in Warren, McDuffie, and Columbia Counties. Most of the commercial production is from the quarries of the Weston Brooker Co. in Warren County, near Camak, where a large amount of aggregate is prepared. This operation is in porphyritic biotite granite gneiss. It is described in detail by Watson (1902, p. 226-227). Other important outcrops of granite described by Watson (p. 227-237) are the Brinkley place (Flat Rock), now owned by C. P. Lazenby of Camak and Mrs. B. M. Moore, the English quarry southeast of Warrenton, owned by Lord Shivers, the Hillman-Mathews properties south of Thomson, and the Heggie Rock, 3 miles east of Appling, now owned by the Weston Brooker Co. The latter is the most extensive "flat rock" exposure in the district.

Other localities where stone may be quarried are indicated on the geologic map by symbols. Aggregate for construction of the AEC plant near Augusta was obtained from a quarry in pink and greenish granite on the river just north of Augusta. The Clark Hill dam on the Savannah River was constructed with local granite.

Just west of the Macon road, southwest of Warrenton on Fowlers Branch, is approximately 2 acres of flat rock which is porphyritic granite. It crops out on the old Harrel place, now owned by Henry Howell. Another good outcrop of porphyritic granite, owned by Murray Gibson, is in McDuffie

County, about 10 miles N. 30° E. of the center of Thomson, in a district where good granite is relatively scarce. Another is on Harts Creek west of the Washington-Thomson road, about 1¾ miles southeast of the Columbia mines. Porphyritic granite has been quarried from a large exposure in Columbia County on the J. B. Anderson property, 3.3 miles S. 48° E. of Appling.

Gold

Gold mining has been commercially important in the past in the northern part of McDuffie County, and this section of the State offers good possibilities for development of gold-bearing veins. It is claimed (Fluker, 1903) that the first discovery of gold in Georgia was made in this locality, and that one of the first stamp mills to be operated in the United States was constructed on Little River, near the Columbia County line. In this district the gold deposits occur upon the flat uplands and generally consist of veins characterized by distinct walls, thus resembling fissure veins; also, in places they occur along shear zones. This district has remained inactive, and the reader must obtain his information about the deposits chiefly from older reports (Jones, 1919; Fluker, 1903; Park, 1945; Pardee and Park, 1948). Some of these veins are in granite, and fragments of coarse porphyritic granite and fine-grained pink granite compose the dumps at the Hamilton mine. In other places the veins seem to be in the volcanic series, but near the intrusives.

The Warren mine is in the northern part of Warren County, near Cadley and the McDuffie County line. It is reported that about $8,000 worth of gold was secured by use of a stamp mill. Other localities in this vicinity have been prospected (Jones, 1909, p. 80-81).

Most of the mining in this part of Georgia has been done on or near the Forty-Acre lot, about 11 miles northwest of Thomson. The new Thomson-Washington paved highway passes just south of the lot, and the Little River lies about 2 miles to the north. The mine was worked in 1922 and then remained idle until 1939, at which time the main shaft on the Hamilton vein was carried to a greater depth. The Columbia shaft was sunk on a 45° incline to a depth of 450 feet (Park, 1945). At least four levels were driven from the shaft. The fourth level is the most extensive, having been driven nearly 950 feet to connect with the Hamilton shaft, west of the property. The

Columbia vein is reported to have a maximum width of about 8 feet, but it pinches and swells, and locally it is made up of alternating ribbons of country rock. Pyrite is widely distributed in the ores, but the best ore contains galena. Pyromorphite is common in the oxidized zone. The mint return of gold shipped from the Columbia mine during the operating period, 1899-1901, amounted to $19,433.54.

Other mines and prospects in the district are: Edwards, Balbach, and Gerald mines, in southwest McDuffie County, near the Warren County line; Carl Henrich property, three-fourth of a mile north of Columbia mine; Parks mine, nearly a mile northeast of Columbia mine; Landers prospect, about a fourth of a mile north of the Parks mine; Tatham mine, about 1½ miles northeast of Parks mine; Woodall mine, about half a mile northeast of Tatham mine; and Griffin mine, about 1½ miles east of Woodall mine.

Serpentine

An extensive body of serpentine occurs in Columbia County on the Savannah River, between Lloyd and Kiokee Creeks (Clark Hill quadrangle). In this district the seprentine has resulted from alteration of dunite, which is associated with other ultramafic rocks. Attention was called to this deposit by Hopkins (1914, p. 300-301), and many possible uses for the serpentine have been well summarized by Barnes and others (1950).

The serpentine is found in a low mountain ridge three-fourths of a mile southeast of Pollard's crossroads. In the westernmost part of the mountain ridge, known as Burt Mountain, the ultramafics have been replaced largely by flint which may be massive and compact or cellular and veined. Most of the serpentine occurs east of the gap on the east side of this mountain and along the east side of the crest of Dixie Mountain, which is a somewhat lower ridge east of Burt Mountain. These two ridges are not continuous and appear to have been shifted out of line by a south-trending normal fault. However, the presence of such a fault has not been demonstrated. Serpentine may be found on the Dixie Mountain trend, slightly east of north, all the way to the banks of the Savannah River. Samples of the serpentine collected by Furcron in 1939 were examined by J. H. Goldstein, then Associate Chemist in the Georgia Survey's laboratory. He found a total MgO content ranging between 36.56 and 47.60 percent. The total MgO present is recoverable by acidulation of the serpentine ground to pass 100-mesh. Goldstein reported at that time: "Indicative of the usual reactivity of this mineral is its behavior when mixed with concentrated sulphuric acid. Upon simply stirring the mixture for a few minutes, sufficient heat is spontaneously developed by the reaction to evolve fumes of sulphur trioxide and to convert the pasty mixture into a dry granular mass. Addition of water to the mixture and subsequent cooling then result in the formation of a solid mass of magnesium sulphate crystals."

A quarry was opened shortly after this time on the south side of Dixie Mountain by International Minerals Chemical Corp. This company mined a considerable tonnage of serpentine over a 5-year period, beginning in 1940 or 1941. The material was processed in a plant built in Augusta, where crude epsom salt was made by digesting the serpentine with sulfuric acid, filtering off the gelatinous silica, and crystallizing the salt from the filtrate.

Phyllite

Phyllite of the southern belt of the volcanic series was examined by Smith (1931, p. 284-293), who studied it for possible use in the manufacture of ceramics. In most places the rock has a high content of sericite and silica, and therefore it does not respond favorably to ceramic tests. It shows iron staining near the surface, but at depth the material of some of the deposits is quite white and pure. It is possible that the sericite, properly separated from quartz and other impurities, would be suitable as a filler for use in the paint trade. The extent of the phyllite is unknown, because it occurs in a belt completely covered by Coastal Plain sediments, except where it is exposed in certain stream valleys; exposures are rather rare.

The phyllite is well exposed west of the town of Mitchell, on the Mitchell-Sandersville road, on the west side of the Ogeechee River in Washington County. This deposit is described in detail by Smith (1931, p. 284-293). The exposed material is a soft light-gray to white weathered phyllite, which was found to be unsuited for the manufacture of heavy clay products. A sample of this material was submitted by the Georgia Geological Survey to the Asheville, N. C., laboratory where it was examined. The laboratory produced a high-grade sericite concentrate and reported that the crude ore consisted of 30 to 40 per cent sericite, 55 to 60 percent quartz, and 5 percent feldspar. The deposit crops out again on the John Gilmer property, about a mile northeast, and just east of Hamburg millpond.

Extensive deposits of this phyllite recur along Briar Creek in the panhandle of Warren County. Exposures may be seen along the Thomson-Wrens Highway south of the creek, and along the country roads west of these exposures. On the south side of Little Briar Creek, just north of Aldrich Church, are extensive exposures of white phyllite along the road between the creek and the church. The exposed belt is at least one-fifth of a mile wide. The thin-bedded phyllite strikes N. 70° E. and dips 47° SE.

In southern McDuffie County there is a small exposure of sericite phyllite which strikes N. 50° E. on Headstall Creek, 1.9 miles S. 57° W. of Avondale (Harlem quadrangle). Other occurrences may be discovered in the area mapped in southern McDuffie County, 3 to 4 miles southwest of Dearing.

In Richmond County white phyllite is well exposed about 2½ miles west of the city limits of Augusta, on W. R. Reeves' property, on Skinner Road, and 2 miles south of Martinez, on the Charleston and Western Carolina Railroad. This deposit is described by Smith (1931, p. 287-291), who found it unsuitable for use alone in the manufacture of heavy clay products. Other occurrences may be noted near Camp Gordon, along the Atlanta-Augusta Highway.

At Bellaire, east of Augusta, the Georgia Vitrified Brick Co. has produced paving brick, sewer pipe, and firebrick, the paving brick having been made entirely from weathered phyllite taken from pits at the place. In other cases, this material has been mixed with clays from other localities. (See Smith, 1931, p. 285-289.)

Kaolin

Much of the kaolin produced in the United States is mined in Georgia. Although most of that mined in Georgia comes from counties to the west, two active mines and a number of kaolin prospects are in the area studied. These deposits have been described in detail by Smith (1929). The kaolin is confined to the Tuscaloosa formation, where it occurs as pure, massive white bodies as much as 20 feet thick and as impure bodies containing varying amounts of sand. The kaolin mined and prospected is in the upper part of the formation immediately underlying the Barnwell formation (see pl. 1). In 1952 the only active kaolin mines in the area were those of the Albion Clay Co. in Richmond County and the Harbison-Walker Mining Co. in Glascock County.

The mine of the Albion Clay Co., which has been worked since 1900, is in the valley of Grindstone Creek about a mile west of Hephzibah. Because the mine is of the pit type, about 60 to 80 feet of sand and clay overburden has had to be removed. The thickness of the good grade of kaolin is about 14 feet. The active mine of the Harbison-Walker Co. is about 3 miles south of Gibson, Glascock County, between Rocky Comfort Creek and Georgia State Highway 80. The deposit there consists of flint kaolin which is quite hard and which breaks with a conchoidal fracture. The deposit is 12 to 15 feet thick and is overlain by a gray clay about 8 feet thick.

COUNTY DESCRIPTIONS

In the following pages, the geography, geology, and ground-water conditions of the central-east Georgia area are described by counties in alphabetical order. Discussions of the public, industrial, and local water supplies are given.

Descriptions of the wells studied are given in the tables that follow the individual county descriptions. The number of each well in the tables corresponds with the number on plate 2, which shows well locations. These well numbers also correspond with the numbers used in the tables of chemical analyses and in the text of the report. Plate 2 shows also the three principal parts or zones of the area within each of which the ground-water conditions are relatively uniform.

The occurrence of ground-water in specific parts of each county are described according to the geologic formation from which the water is derived. For this reason, it is suggested that reference be made to the accompanying geologic map (pl. 1) for information concerning the ground-water conditions of a particular locality. Much of the information regarding wells was given from memory by the owners and drillers, and consequently the data may not be accurate in every case; also, most of the yields recorded indicate those used or required by the well owner and not necessarily the true yields of wells constructed to extract the maximum amount of water. Therefore, in most cases they are lower than the maximum potential yields. All figures of population are from the 1950 census.

Burke County

Area: 832 square miles   Population: 23,458

Geography

Burke County forms the southeast corner of the area covered by this report. It is bounded on the north by Richmond County, on the west by Jefferson County, and on the east by the Savannah River and South Carolina. By virtue of its large areal extent, Burke County ranks higher in agricultural products than any other county in this part of Georgia. The soils are dominantly sandy and easy to till. Productive yields are derived from cotton, which in 1946 was the important cash crop. Corn, wheat, oats, and peanuts are raised in subordinate amounts. Three railroad lines extend across the county and are spaced to serve the important communities. With the town of Waynesboro as the hub, several paved roads cross the county, and numerous well-kept sand-clay roads give access to the rural areas. Waynesboro, the county seat, has a population of 4,461 and is the only town with more than 1,000 people. Midville, with a population of 682, and Girard, with 244, are next in size. Small villages distributed throughout the county are Vidette, Sardis, Keysville, Blythe, and Alexander.

The entire county lies in the Coastal Plain, which here includes two physiographic divisions. The Red Hills occupy that part of the county north of a line connecting St. Clair, Waynesboro, and Sardis; south of this line is the Tifton Upland. The red sandy loams, derived from the sand, sandy clay, and clay of the Barnwell formation, typifying the Red Hills, are conspicuously present south of McBean Creek. Both McBean Creek and Briar Creek flow southeastward and cut deeply into the Barnwell formation, causing the relief of the northern section of the county to exceed 200 feet. The leaching of the prevalent limestone beds in eastern Burke County has increased the deep-red color in that area. South of the line connecting St. Clair, Waynesboro, and Sardis is the Tifton Upland underlain by the Hawthorn formation. Flat-lying fields with shallow elliptical depressions are common. Only Savannah River has cut a deep valley and this incision has consequently attracted much of the drainage, especially from the Red Hills. However, the Ogeechee River, bordered by broad swamps, flows in consequence of the surface slope of the south border of the county and drains much of that area.

Geology

Tuscaloosa formation.—The Tuscaloosa formation crops out only in the northern part of Burke County, where the Savannah River and McBean and Briar Creeks have cut through the overlying deposits to expose it in limited areas. It underlies the entire county, being buried deeply toward the south.

McBean formation.—In the central-east Georgia area the McBean formation is exposed only in northern Burke County, on the slopes of stream valleys as indicated on plate 1. The formation consists of gray and green sandy marl and thin fossiliferous sandy limestone beds. It is underlain by the Tuscaloosa formation and in turn is buried beneath the Barnwell formation. The McBean formation thickens to the south; well 24 in the valley of Briar Creek north of Waynesboro penetrated at least 126 feet of strata of the McBean, and did not reach the underlying Tuscaloosa formation at the bottom depth of 170 feet. The log of that well, prepared by S. M. Herrick, is given below:

	Depth (feet)
No samples	0-44
Limestone, sandy, fossiliferous, carrying finely disseminated glauconite, abundant macroshells, and a few foraminifera	44-60
Limestone, sandy, fossiliferous, more glauconitic than above, some carbonaceous (lignitic) material	60-70
Limestone, sandy, fossiliferous, more calcitized and recrystallized than material above	70-100
Marl, light-gray, fossiliferous, finely glauconitic, indurated; probably marl with inclusions of hard, lime nodules	100-110
Limestone, gray, crystalline, fossiliferous	110-120
Limestone, gray, crystalline, fossiliferous, plus abundant macroshells and occasional black, polished phosphatic pellets	120-140
No samples	140-169
Sand, fine- to medium-grained, unconsolidated, coarsely glauconitic, unfossiliferous	169-170

Barnwell formation.—The Barnwell formation is exposed along the upland in northern Burke County and along the more dissected valleys in the southern part. Where covered by later deposits it lies less than 100 feet below the surface.

The Twiggs clay member, composed of fuller's-earth clay, is not conspicuous in Burke County, and the basal part of the Barnwell formation here is normally represented by red sands or marl and oyster-shell beds. Along Savannah River a bed of enormous oyster shells (**Ostrea gigantissima** Finch) lies at the base of the formation (Cooke, 1943, p. 63-64). The concentration of these shells at the mouth of McBean Creek resulted in the name Shell Bluff for this locality.

The members of the Barnwell described farther west are hardly distinguishable in Burke County. The formation here is composed of red sands in which one or more limestone and chert beds occur. One fossiliferous limestone bed is present within the upper 40 feet of the Barnwell formation. This bed, ranging in thickness from 2 to 20 feet, may be equivalent to the Sandersville limestone member in Washington County.

The Barnwell is approximately 100 feet thick at Greens Cut, 200 feet at Waynesboro, and 220 feet at Midville in the southern part of the county.

Suwannee limestone.—The only deposits of Oligocene age in the area considered are in southeastern Burke County, where remnants of the Suwannee limestone occur along the lower slopes of the valleys. This formation consists of a bed of dense, vitreous chert, which may or may not represent the true thickness of the Suwannee.

Hawthorn formation.—The Hawthorn formation overlies the Barnwell in most of Burke County except the southeastern part, where the Suwannee formation intervenes. Deposits of the Hawthorn cap the hills in the north and cover most of the southern part except in the valleys, where some of the streams expose the Barnwell or Suwannee. At its outcrop the formation is composed of a massive and compact sandy clay including some disseminated coarse sand and grit.

Ground Water

Abundant supplies of ground water are available in Burke County. The Tuscaloosa formation, containing a considerable thickness of coarse water-bearing sands, underlies the entire county at moderate depths. Although containing abundant water south of Waynesboro, the Tuscaloosa has been penetrated by few wells, owing to the fact that adequate supplies are generally available from the overlying Barnwell formation. At Keysville, in the northwest, wells drilled to depths of 25 to 80 feet yield water from the Tuscaloosa. Well 24, in the valley of Briar Creek north of Waynesboro, penetrated glauconitic sands of the McBean to a depth of 170 feet without reaching the Tuscaloosa formation. Farther south, at Waynesboro, the depth to the Tuscaloosa is approximately 300 feet.

Dug and drilled wells have yielded supplies adequate for most purposes from the Barnwell formation. Although much of the sand in this formation is water bearing, the porous limestone beds furnish water to most of the wells. Even where the Hawthorn formation overlies the Barnwell, a limestone aquifer can be penetrated at a depth of less than 200 feet. Water obtained from the limestone is moderately hard.

The Hawthorn formation does not yield water readily, but this condition is not a serious handicap inasmuch as drilled wells pass through the formation to find water within 50 feet in the lower lying Barnwell formation. Although dug wells are abundant in the Hawthorn formation, most of them are not cased and the water in them is likely to be contaminated.

Springs are rather common in Burke County but are rarely utilized. Many represent leakage of water from outcropping sands and clay of the Barnwell formation, and a few emerge from a limestone bed in the Barnwell. One spring, 2 miles northwest of Magruder, emerges from a 3-foot hole in the bottom of a small sink, limestone being exposed at the vent. The water is exceptionally clear and has a temperature of 65° F. On July 20, 1946, the measured flow was 715 gallons a minute.

Local Supplies

Waynesboro (population 4,461) has the only public surface-water supply system in Burke County, the water being derived from Briar Creek. It is treated by the addition of alum, lime, and charcoal and by filtration.

Midville (population 682) has a municipally owned well which flows more than 80 gallons a minute. This well was reportedly drilled in 1914 to a depth of 482 feet. An artesian flow was encounted at 225 feet which reduced the static head in many wells in the vicinity. To prevent the possibility of litigation, the well was deepened to its present depth and the upper aquifer sealed off. The water, with a static head of 20 feet above the ground, flows from a 6-inch casing into a covered concrete reservoir. The water from the 482-foot level may come from the upper part of the Tuscaloosa formation, although Stephenson and Veatch (1915, p. 168) have placed the top of the Tuscaloosa at a greater depth. Several flowing wells in Midville obtain water at depths slightly greater than 200 feet.

Vidette (population 159) has a public well 94 feet deep which is pumped at the rate of 16 gallons a minute. It ends in a cavernous limestone bed near the top of the Barnwell formation. The water contains 147 parts per million of bicarbonate and has a hardness of 138 parts per million.

Sardis (population 695) obtains water from a well that is reported to be 575 feet deep, ending in sands of the Tuscaloosa formation. The water is pumped at the rate of 150 gallons a minute into a concrete reservoir. The static level is reported to be 30 feet below the land surface and there is no appreciable drawdown.

Table 4.—Records of Wells in Burke County

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
1	Blythe	Wayne Dye	96	36	95	Irwinton	Upland	—92	7- 8-46	445	T, 65° F.
2	3 mi. E of Blythe	Janie Streetman	62.7	40	62	Barnwell	Hilltop	—60.5	7- 8-46	421	T, 65° F. Analysis.
3	..... do	S. T. Corley	124	30	123	Tuscaloosa	.....do.....	—121	7- 5-46	402	Do.
4	2 mi S of Blythe	C. E. Perkins	67	36	Uncased	Irwinton	Upland flat	—62	7- 5-46	405	T, 66° F.
5	3 mi. SE of Blythe	Allen Campbell	31.5	36	30	.....do.....	.....do.....	—27.3	7- 8-46	390	T, 65° F.
6	3 mi. E of Keysville	John L. Murray	165	3	.....	Tuscaloosa	Upland	—135	5-21-46	386	T, 67° F.
7	2 mi. E of Keysville	C. F. Morris	95	2½	30	.....do.....	Valley bottom	+6.6	5-26-46	243	T, 67° F. Analysis, Flow, 37 g.p.m.
8	Keysville	Q. B. Russell	65	2	60	.....do.....	Upland	—10	5-21-46	275	T, 68° F.
9	10 mi. N of Waynesboro	J. P. McDaval	198	1½	180	.....do.....	Hilltop	—140	5-21-46	258	T, 67° F. Supplies water for 3 homes.
10	McBean Creek 2 mi. E of Rte. 25	Country Church	60	2	.....	.....do.....	Stream bank	+10.2	7- 1-46	160	T, 64° F.
11	0.2 mi. E of McBean	State Highway Commission	620	6	Uncased	.....do.....	Lowland	.....	8- -46	129	USGS test hole. Artesian flow at 157 ft.
12	1 mi. E of McBean	Mrs. E. C. Scott	104	2	.....	Lower Barnwell	Upland	—75	5-21-46	260	T, 67° F.
13	4 mi. E of McBean	Millers Pond	50	1½	25	Irwinton	Lowland	+3	5-21-46	145	T, 66° F.

Table 4.—Records of Wells in Burke County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
14	3 mi. E of McBean	N. L. Peeke	160	2½	145	Irwinton	Upland	—135	5-21-46	280	T, 69° F., Slightly hard water Shelly Ls. throughout.
15	5 mi. E of McBean	Millers Pond	95	3	30	Tuscaloosa	Lowland	+4	5-22-46	155	T, 65° F., Flow diminished after another well dug nearby.
16	do	do	92	4	42	do	Stream bank	+14.9	7- 1-46	150	T, 67° F.
17	2 mi. S of McBean	A. W. Knight	80	36	Uncased	Irwinton	Upland slope	—75	8-22-46	245	T, 65° F. Water cloudy
18	2.1 mi. N of Shell Bluff	C. H. Griffin	115	2	110	do	Upland flat	—40	8-22-46	265	T, 65° F.
19	2.5 mi. NE of Shell Bluff	H. A. Hill	86	2		do	do	—60	8-22-46	295	Do.
20	2.8 mi. NE of Shell Bluff	M. W. Lively	90	36	Uncased	do	Gentle slope	—70	8-22-46	285	T, 64½° F.
21	2.1 mi. N of Shell Bluff	Mrs. H. A. Hill	135	2		Barnwell	do	—40	8-22-46	255	T, 65° F.
22	5 mi. NE of Waynesboro	W. V. Flake	65	36	60	Upper Barnwell	Upland	—48	5-21-46	304	T. 69° F.
23	Briar Creek, 1 mi. W of Rte. 25	J. C. Stockman	170	3		Upper Tuscaloosa	Stream level	+8	7- 3-46	202	T, 65° F.
24	Briar Creek, Rte. 25	John Thompson	168	3	100	McBean	do	+11	8- 7-46	199	T, 65° F. Analysis, flow, 60 gpm.

Table 4.—Records of Wells in Burke County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
25	4 mi. N of Waynesboro	D. O. Smith	225	3	127	McBean	Hilltop	—80	7- 3-46	315	T, 65° F.
26	7.8 mi. NE of Waynesboro	Alvin Neely	61	36	Uncased	Irwinton	Upland flat	—51.8	7- 5-46	295	T, 66° F. Water is muddy and unfit for drinking.
27	Stevens Pond, 7 mi. NW of Waynesboro	R. C. Stevens	180	1½	....	Upper Tuscaloosa	Bank of stream	+6.4	7- 5-46	219	T, 65° F.
28	Beaverdam Branch, 7 mi. NW of Waynesboro	Mozelle Palmer	250	3	240	......do......	......do......	+2.5	7- 5-46	232	T, 64° F.
29	6 mi. NW of Waynesboro	......do......	700	2	....	Lower Tuscaloosa	Upland flat	—60	7- 5-46	325	T, 66° F.
30	4.5 mi. SE of Keysville	O. G. Timmonds	175	3	....	Tuscaloosa	Stream level	+5.9	6-28-46	251	T, 64½° F. Well has lost some pressure since first drilled.
31	2 mi. SE of Keysville	Hollingsworth Candy Co.	70	2	60	Irwinton	Upland	—35	5-20-46	286	T, 67° F.
32	3 mi. S of St. Clair	C. H. Swint	210	1½	60	......do......	......do......	—40	5-20-46	386	Do.
33	8 mi. W of Waynesboro	Mrs. B. E. Rawlins	165	2	....	......do......	Gentle slope	—80	7- 8-46	350	T, 66° F.
34	2 mi. N of Waynesboro	O. H. Welborn	350	3	150	Upper Tuscaloosa	Hilltop	—80	7- 5-46	312	Do.

Table 4.—Records of Wells in Burke County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
35	2 mi. N of Waynesboro	L. S. Sims	353	4	130	Upper Tuscaloosa	Upland flat	—60	7- 5-46	292	T, 66° F.
36	3.4 mi. NE of Waynesboro	Town of Waynesboro	75	2½	----	Irwinton	Stream level	+2.6	6-26-46	180	T, 65° F. Analysis. Flow, 5 gpm.
37	2 mi. S of Shell Bluff	Cicero Williams	301	1½	----	Lower Barnwell	Upland slope	—50	5-21-46	250	T, 65½° F.
38	1 mi. N of Shell Bluff	D. B. Morgan	354	3	100	Barnwell	Upland	—45	5-21-46	285	T, 67° F.
39	Shell Bluff	N. P. Lamar	86	2	81	Upper Barnwell	do	—40	5-21-46	322	T, 68° F.
40	3 mi. SE of Shell Bluff	J. I. Holland	350	1½	----	Upper Tuscaloosa	do	—80	7- 1-46	280	Do.
41	4 mi. SE of Shell Bluff	Richard Smith	150	1½	130	Upper Barnwell	Upland flat	—85	5-22-46	281	Do.
42	7 mi. E of Waynesboro	Sterling Chance	180	2	----	Irwinton	Stream level	+14.2	6-26-46	180	T, 65° F. Analysis.
43	Moore Branch, 5 mi. SE of Waynesboro	Baptist Church	180	2	80	do	Gentle slope	+1.4	7-11-46	235	T, 67° F.
44	2 mi. SE of Waynesboro	Clyde Manley	222	3	90	Twiggs	do	—30	7-11-46	250	T, 66° F.
45	1 mi. SE of Waynesboro	E. R. Blount	495	3	----	do	Hilltop	—90	8-22-46	301	T, 66° F. Water slightly hard.
46	Gough	S. B. Thigpen	218	3	----	Irwinton	Upland	—35	8-23-46	392	T, 68° F.
47	Vidette	Town of Vidette	94	4	40	Upper Barnwell	Upland slope	—35	5-28-46	162	T, 68° F. Analysis.
48	3 mi. SE of Vidette	A. W. Neely	21.1	36	Uncased	Hawthorn	Upland	—15.7	8- 7-46	258	T, 66° F. Analysis.

Table 4.—Records of Wells in Burke County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
49	2.5 mi. E of Rosier	P. A. Davil	250	2	----------	Irwinton	Upland flat	—25	8-22-46	257	T, 65° F.
50	do	W. C. McBride	70	2	----------	Upper Barnwell	Upland	—22	8-22-46	260	Do.
51	1 mi. N of Cates Store	Frank Cates	25	36	Uncased	Hawthorn	Upland flat	—15	8-22-46	250	
52	Cates Store	F. M. Cates	180	2	75	Irwinton	Upland	—20	8-22-46	255	
53	do	do	25	3	----------	do	Upland flat	—20	8-22-46	260	
54	7 mi. S of Waynesboro	Mr. Marshman	35.5	36	Uncased	Hawthorn	do	—18.2	7-12-46	265	T, 65° F. Water cloudy.
55	Rte. 25, 8 mi. S of Waynesboro	E. W. Prescott	94	3	----------	Upper Barnwell	Upland	—40	7-12-46	250	T, 66° F.
56	Rte. 25, 9 mi. S of Waynesboro	I. P. Herrington	255	3	----------	Irwinton	do	—22	7-12-46	245	T, 65° F.
57	Rte. 25, 1 mi. N of Munnerlyn	B. F. Herrington	400	3	----------	Tuscaloosa	Upland flat	—70	7-12-46	238	T, 66° F.
58	1 mi. NE of Alexander	J. V. Burton	215	3	110	Irwinton	do	—70	7-11-46	280	Do.
59	3 mi. NW of Girard	W. F. Prescott	85	2	75	Upper Barnwell	do	—65	8- 7-46	257	T, 67° F.
60	2.2 mi. N of Sardis	Roy Kirchner	151	3	100	Irwinton	Stream bed	+2	6- 5-46	142	T, 66° F.
61	Sardis	Town of Sardis	535	8	70	Tuscaloosa	Upland	—30	6- 5-46	235	Do.
62	3.1 mi. W of Munnerlyn	J. Smith	35	36	20	Hawthorn	Upland flat	—17.3	7-12-46	220	Do.
63	7 mi. E of Rosier	Mrs. Frost	35	36	Uncased	do	Upland	—10	8-22-46	245	T, 67° F. Water slightly cloudy.

Table 4.—Records of Wells in Burke County (Concluded)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
64	2 mi. NE. of Magruder	Mamie Smith	19.4	36	Uncased	Hawthorn	Upland flat	—9	8-22-46	245	T, 69° F. Water slightly cloudy.
65	3 mi. N of Midville	do	22.1	36	do	do	Gentle slope	—12.1	8-14-46	250	T, 69° F. Analysis.
66	0.5 mi. W of Midville	Mr. Sanderford	420	2	----	Tuscaloosa	Lowland	+13.4	6-28-46	195	T, 67° F. Analysis.
67	Midville	Town of Midville	482	6	200	do	do	—20	6-24-46	190	T, 68° F.

Table 5.—Chemical Analyses, in Parts Per Million, of Water From Burke County.

(Well Numbers Correspond to Numbers in Table 4 and on Plate 2)
(Analyst, F. H. Pauszek, U. S. Geological Survey)

Well no. / Geologic formation	2 Barnwell	3 Tuscaloosa	7 Tuscaloosa	24 Tuscaloosa	36 Barnwell
Bicarbonate (HCO_3)	28	20	8.0	176	158
Sulfate (SO_4)	1	2	3	9	2
Chloride (Cl)	4	2	2	9	3
Fluoride (F)	.0	.0	.1	.0	.1
Nitrate (NO_3)	1.4	4.3	.0	.0	2.6
Hardness as $CaCO_3$	30	21	9	140	124
Date of collection	Aug. 8, 1946	Aug. 8, 1946	Aug. 8, 1946	Aug. 8, 1946	Aug. 7, 1946

Well no. / Geologic formation	42 Barnwell	47 Barnwell	48 Hawthorn	65 Hawthorn	66 Tuscaloosa
Bicarbonate (HCO_3)	183	176	7.0	4.0	136
Sulfate (SO_4)	8	1	1	1	25
Chloride (Cl)	3	6	18	10	1
Fluoride (F)	.0	.0	.0	.0	.1
Nitrate (NO_3)	.0	9.2	44	12	.0
Hardness as $CaCO_3$	138	138	32	9	105
Date of collection	Aug. 7, 1946	Aug. 7, 1946	Aug. 7, 1946	Aug. 14 1946	Aug. 14, 1946

Columbia County

Area: 306 square miles Population: 9,525

Geography

Columbia County occupies the northeast corner of the area covered by this report. The Savannah River forms its east boundary and the Little River the north boundary; on the west it is bounded by McDuffie County, and on the south by Richmond County.

The county lies in two physiographic provinces—the Piedmont and the Coastal Plain. The Piedmont covers more than four-fifths of the county; the Coastal Plain extends along the southern border. The broad upland plain of the Piedmont has been subdivided into a series of ridges by streams cutting through to form valleys trending northeastward toward the Savannah River. Several ridges reach an elevation of 600 feet above sea level, although none stands out with any prominence above the others.

The Coastal Plain deposits that were once present in the central part of the county have been stripped off by erosion, which has left a north-facing escarpment along the southern border. The divide thus formed, connecting Harlem, Grovetown, and Martinez, is being narrowed and encroached upon by small streams of the Piedmont on the north and by the small streams of the Coastal Plain which flow south in consequence of the regional surface slope. All streams empty into the Savannah River.

The population is evenly distributed over the county, there being no towns larger than Harlem, which has 1,033 people. Other small villages are Appling, Martinez, and Grovetown.

Railroads furnish transportation facilities to the southern and southeastern parts of the county, although none are available to the northern part. Several paved roads link the rural settlements.

The annual rainfall averages 48.5 inches, which is well distributed throughout the year. Agriculture is the only industry of importance, cotton and corn being the chief crops.

Geology

Tuscaloosa formation.—In Columbia County the Tuscaloosa formation crops out only along the southern part and lies unconformably on the crystalline rocks. The contact of the Tuscaloosa and the crystalline rocks is irregular but is generally less erratic than in the other Fall Line counties. Only a few small outliers of the Tuscaloosa formation cap the knolls north of the main belt.

The formation is similar in character to that found in the adjoining counties; light-gray and pinkish-white micaceous sands are prevalent and crossbedding is not uncommon. Deposits of kaolin in the Tuscaloosa formation are not concentrated to the extent of commercial importance, although gray kaolinic sands make up much of the formation near Grovetown.

The maximum thickness of the Tuscaloosa in the county is reached southeast of Harlem, where it is about 220 feet. The dip at the top of the formation is 15 feet per mile and the dip at the base is approximately 45 feet per mile.

Overlying the Tuscaloosa formation in Columbia County is the Barnwell formation. The Barnwell occurs as isolated outliers on the ridges along the southern border of the county.

The Barnwell formation consists of red sandy clay and yellow sands with interbedded thin gray clay laminae. Limestone beds were not noted during the investigation. The two most extensive exposures of sands of the Barnwell formation are south of Grovetown and the east-west outlier centered at Harlem. The formation does not exceed 60 feet in thickness in Columbia County.

The following log of a well at Grovetown indicates the character of subsurface material along the interstream areas of the southern part of the county. The log was prepared by S. M. Herrick.

	Depth (feet)
Barnwell formation:	
Sand, fine to medium-grained, argillaceous, tan, plus thin stringers of white clay (kaolin); brown limonitic pellets common	0-40
Tuscaloosa formation:	
Clay (kaolin), gray, carrying individual grains of quartz, (sand)	40-80
Sand, yellow, argillaceous, fine to coarse-grained	80-88
Clay, (kaolin), white, very sandy, highly micaceous	88-135
Clay, yellow, very sandy, carrying grains of garnet and some hornblende (?)	135-156
Rocks, weathered crystalline	156-204
Rocks, unweathered crystalline	204-350 (+)

Ground Water

Inasmuch as there is no great concentration of population in Columbia County, no strong demand for water has been made on any one locality. As a result, dug wells have proved adequate for most needs.

The igneous and metamorphic rocks of the northern part of the county yield adequate supplies, both from the surficial weathered material (to dug wells) and from fractures in the bedrock (to drilled wells). Too few wells have been drilled in these rocks to determine their yields, although it is probable that they range from 10 to 40 gallons a minute.

Along the southern border of the county the Tuscaloosa formation takes in considerable quantities of water and yields adequate supplies to dug wells, and also to drilled wells where the formation is 50 feet or more in thickness. Much of the water in the Tuscaloosa formation to the south enters the formation as precipitation in Columbia County.

The Barnwell formation, although containing porous sands, occupies only a small portion of the county and is too thin to yield water to drilled wells. A few dug wells obtain water from it along the southern edge.

Water from the crystalline rocks, especially the granite and granite gneiss, is normally low in mineral matter and is satisfactory for most purposes. Water from one dug well (6) is thought to contain more than the average amount of mineral matter—125 ppm of sulfate, 81 ppm of chloride, and 0.5 ppm of fluoride. Water from the Tuscaloosa formation in the south probably is low in mineral constitutents.

Local Supplies

Harlem (population 1,033) obtains its municipal supply from four wells, of which one is drilled and the others are dug. Each is about 35 feet deep and yields water from the Tuscaloosa formation. The water is chlorinated before being distributed at the reported rate of 20,000 gpd.

A municipal water supply was installed at Grovetown (population 500) in 1952. A well 350 feet deep, capable of yielding about 100 gpm, furnishes the supply. The water comes from fractures in the crystalline rocks below 135 feet.

Other communities in the county get water from individually owned dug wells and springs.

Table 6.—Records of Wells in Columbia County

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
1	0.2 mi. S of Leah	Floyd Motes	19.2	38	Uncased	Granite	Gentle slope	—17.3	8- 5-46	495	
2	2 mi. NE of Pollards	J. J. Motes	35	36	......do......	Granite-schist complex	......do......	—30	8- 5-46	436	T, 65° F.
3	1.5 mi. NW of Phinizy	Marshall Blanchard	14.1	36	14	Granite	......do......	—15.4	8- 5-46	468	T, 65° F. Supply not adequate in dry season.
4	2 mi. W of Phinizy	L. L. Pashall	25	40	22	Granite-schist complex	Upland flat	—21	8- 5-46	490	T, 64° F.
5	1 mi. N of Cobbham	T. D. Lane	46	36	40	Granite	Top of steep slope	—40	7-17-46	525	T, 65° F.
6	1 mi. W of Howells	Roy Tankersley	22	36	22	......do......	Gentle, undulating slope	—23.5	7-17-46	420	T, 65° F. Analysis.
7	0.8 mi. W of Howells	......do......	34	36	33	......do......	Gentle slope	—29	7-17-46	417	T, 65° F.
8	3 mi. S of Pollards	Mark Collins	60	36	55	Granite-schist complex	Hilltop	—54	8- 5-46	264	Do.
9	Lamkin Grove School	Joe Means	65	36	64	......do......	......do......	—58	8- 5-46	382	Do.
10	......do......	George Hardwick	47	36	42	......do......	Upland slope	—43	8- 5-46	387	Do.
11	1 mi. S of Lamkin School	Bud Pollard	27.3	36	27	Granite	Gentle slope	—28.5	8- 5-46	392	Do.
12	2 mi. W of Evans	Steve Davis	21.1	42	20	Granite-schist complex	......do......	—14.8	6-29-46	320	T, 64½° F.
13	Rte. 28, 0.2 mi. S of Water Branch Church	H. O. Sprouse	39.6	40	32	......do......	......do......	—33	6-29-46	361	T, 65° F.

Table 6.—Records of Wells in Columbia County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
14	Rte. 28, 0.5 mi. S of Reed Creek	O. C. Applewhite	49.2	2	40	Granite-schist complex	Hill slope	—39.1	7-15-46	290	T, 66° F.
15	Rte. 28, 1 mi. S of Reed Creek	J. E. Vaughn	43	30	35	......do......	......do......	—39.6	7-15-46	305	T, 66° F. Analysis.
16	Rte. 28, 1 mi. N of Richmond Co.	......do......	65	20	65	......do......	......do......	—61	7-15-46	360	T, 66° F.
17	1.8 mi. S of Evans	L. F. Young	78	2	60	Granite	Upland	—60	7-15-46	460	Do.
18	5 mi. W of Martinez, 1 mi. S of Rte. 150	G. W. Gibbs	80	3	80	Lower Tuscaloosa	......do......	—55	7-15-46	480	Do.
19	4 mi. NE of Grovetown	C. B. Wilkins	59	36	54	Granite	Upland flat	—61	7-15-46	425	T, 65° F.
20	Grovetown	H. H. Brand	35	36	30	Tuscaloosa	Gentle slope	—29	7-15-46	520	T, 66° F.
21	2 mi. S of Appling	Hugh Buffton	22.8	36	20	Granite-schist complex	......do......	—21.3	8- 5-46	401	T, 65° F.
22	6 mi. N of Berzelia on Wrightsboro Road	George Magruder	34	36	30	......do......	Crest of ridge	—27	8- 5-46	450	T, 65° F. Analysis
23	6.5 mi. N of Berzelia on Wrightsboro Road	M. E. Miller	53	36	53	......do......	Upland slope	—43	8- 5-46	458	T, 66° F. Analysis.
24	4 mi. N of Berzelia	Archie Wren	19.6	36	Uncased	......do......	......do......	—18.3	8- 5-46	378	T, 66° F.

Table 6.—Records of Wells in Columbia County (Concluded)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
25	3 mi. N of Harlem	Louis Hawthorne	12.3	38	Uncased	Tuscaloosa-granite contact	Lowland	—6.2	8- 5-46	490	T, 69° F. Water is milky because of surface contamination.
26	Harlem	Town of Harlem	35	8	30	Upper Tuscaloosa	Upland	—25	8- 6-46	542	T, 65° F. Towns owns 4 wells, each 35 ft. deep; only 2 used.
27	0.3 mi. N of Berzelia	M. C. Branch	35	36	35	Lower Tuscaloosa	Gentle slope	—31	8- 5-46	450	T, 65° F.
28	1 mi. S of Harlem	L. G. Whitaker	48	2	48	Tuscaloosa	Upland	—10	7-15-46	530	T, 66° F.

Table 7.—Chemical Analyses, in Parts Per Million, of Water From Columbia County

(Well numbers correspond to numbers in table 6 and on plate 2)
Analyst, F. H. Pauszek, U. S. Geological Survey

Well no. Geologic formation	6 Granite gneiss	15 Granite gneiss	22 Granite gneiss	23 Granite gneiss
Bicarbonate (HCO_3)	92	37	34	26
Sulfate (SO_4)	125	1	1	1
Chloride (Cl)	81	2	12	31
Fluoride (F)	.5	.2	.1	.1
Nitrate (NO_3)	3.4	.3	32	39
Hardness as $CaCO_3$	141	18	40	42
Date of collection	Aug. 15, 1946	Aug. 15, 1946	Aug. 15, 1946	Aug. 15, 1946

Glascock County

Area: 142 square miles Population: 3,579

GEOGRAPHY

Glascock County is bounded by Warren County on the north and east, Jefferson County on the south, and the Ogeechee River on the west. The population is entirely rural. Gibson, the county seat, has a population of 460. Smaller communities are Mitchell and Edgehill.

Glascock County lies within the Coastal Plain province, although crystalline rocks of the Piedmont are exposed in the valleys of the northern part. The Red Hills, displaying the brilliant red sands of the Barnwell formation, are present on the uplands and border the Piedmont to the north in Warren County. The Red Hills are prominent along the ridge connecting Mitchell and Edgehill and on the ridge separating Rocky Comfort and Joes Creek. Considerable relief results from the incision of the erodible sands by three southeast-trending streams, the Ogeechee River, Joes Creek, and Rocky Comfort Creek.

GEOLOGY

Streams in the northern half of Glascock County have cut through the overlying Coastal Plain sediments, exposing crystalline rocks in three valleys. The crystalline rocks crop out along the Ogeechee River, Joes Creek, and Rocky Comfort Creek before dipping under the Coastal Plain deposits in the central part of the county.

Tuscaloosa formation.—The Tuscaloosa formation overlies the crystalline rocks in Glascock County except in the northern part, where the Barnwell formation overlaps the Tuscaloosa and rests on the crystalline rocks. The thinness of the Tuscaloosa formation in the county limits its outcrop area to the stream valleys south of a line roughly connecting the towns of Mitchell and Gibson.

In Glascock County the Tuscaloosa formation consists of incoherent gray, pink, and white sand and disseminated white kaolin particles. At some localities flint kaolin represents the upper part of the formation. It has a rocklike hardness and breaks with a sharp conchoidal fracture. It ranges in color from cream to dark gray. The following section, measured by Smith (1929, p. 343) on Joes Creek, 4 miles south of Gibson, shows the stratigraphic position of the flint kaolin bed. His Middendorf formation is now called the Tuscaloosa.

"Section at Thompkins Hill south of Joe's Creek on the Edgehill Road, four miles south of Gibson, Glascock County

		Feet
Eocene		
Barnwell formation		
15	Covered with fine loose gray sand, residual and perhaps partly windblown. Also covering most of underlying formations	22
14	Dark-red argillaceous "pimply" sand, full of small ironstone pebbles	6
13	Brownish-red argillaceous sand, somewhat mottled in places. Resembles bed (9)	11
12	Mottled gray and red sticky gumbo clay	10
11	Covered	3
10	Dark brown indurated rock consisting of shell fragments and coarse sharp quartz grains, cemented by iron and perhaps some lime	2½
9	Dark reddish-brown argillaceous sand, fairly fine and loamy at bottom, coarser and more compact at top	8
8	Coarse brown indurated sandstone with occasional thin sandy ironstone pebbles	1½
7	Fairly coarse reddish-brown compacted sand, with some white streaks and lenses sometimes containing fragile white shell fragments; somewhat cross-bedded near top	12

Twiggs clay member		
6	Cream to greenish cream-colored fuller's earth, somewhat brownish stained near top. Some layers massive, breaking with a blocky fracture, and looking like commercial grade; others with a more irregular fracture, more sandy, and breaking with an irregular fracture; still others weathering flaky	28
5	Brown and greenish-gray sand containing enough gumbo clay to make it plastic	2
Unconformity (not plainly marked)		
Upper Cretaceous		
Middendorf formation		
4	Semi-hard to hard white and gray somewhat sandy kaolin. Softer, less sandy, and cuts smoother than bed (2)	2½
3	Hard white flint (?) kaolin, a little less indurated than the typical flint kaolin and breaking with a straight rather than a concoidal fracture; containing a very little quartz sand; grades gradually into the bed below	11
2	Hard white kaolin with a rough fracture; a little stained in fractures and on surface outcrop. Grades gradually from bed above to very sandy at bottom	7+
1	Covered to creek	10+"

Flint kaolins are known to occur only in Glascock County along Joes Creek where it unites with Rocky Comfort Creek, and in Rocky Comfort and Deep Creek south of Gibson.

The thickness of the Tuscaloosa formation at Gibson is approximately 80 feet. In the southern part of the county it may reach 200 feet in thickness.

Barnwell formation.—The Barnwell formation crops out over a greater area than any other formation in Glascock County. It overlies the Tuscaloosa. The maximum thickness of the Barnwell, 150 feet, is along the railroad entering Jefferson County. The Twiggs clay member of the Barnwell formation is persistent and commonly rests on the Tuscaloosa formation. Some of the kaolin prospects, occupying the uppermost part of the Tuscaloosa, expose good sections of fuller's earth from the Twiggs clay member as the overburden.

The Irwinton sand member occupies the upland east of Gibson and is well exposed on the road from Mitchell to Edgehill. The loose fine sand and the interbedded clay laminae offer little resistance to erosion, and therefore deep gullying is common.

The upper sand member of the Barnwell formation is exposed east and north of Gibson. It is usually characterized by brilliant red sands and red and gray mottled sandy clay. Thin limestone beds present in the upper sand member in Jefferson and Burke Counties were not noticed in Glascock County. Thin calcareous sand and limestone beds are present in the Twiggs clay member along Deep Creek.

Thin deposits of the Hawthorn formation lie unconformably as outliers on the Barnwell formation in eastern Glascock County. The largest outlier occupies the crest of the upland along the Savannah and Atlanta Railroad. The maximum thickness of the Hawthorn formation in Glascock County is 60 feet.

GROUND WATER

Several dug wells derive water from the granitic rocks in Glascock County. All these are less than 40 feet deep and obtain water from the weathered upper portions of the granite. A few drilled wells pass through the Coastal Plain sediments into the underlying granite. The well owned by the town of Gibson passed through approximately 100 feet of Coastal Plain sediments before penetrating 76 feet of fresh granite. It is probable that much water in this well comes from the sands of the Tuscaloosa formation above the granite. Where the granite is buried beneath thin deposits of Coastal Plain material its joints and fractures are charged with water from the overlying material. It would seem, therefore, that the crystalline rocks of the county should produce more than similar rocks in adjacent counties.

Although its outcrop area is limited to the valleys in the southern part of the county, it is thought that the Tuscaloosa formation contains water-bearing sands which could furnish considerable water to wells.

The Barnwell formation is the source of much water because it is the surface formation on the uplands. However, because of its thinness, many wells drilled into the Barnwell west of Joes Creek pass into the underlying Tuscaloosa formation. Dug wells obtain water from the Irwinton sand member at depths as great as 90 feet. The hilly topography causes considerable ground-water leakage from the uplands, and this in turn causes the water table to be low in much of the county.

Table 8.—Records of Wells in Glascock County

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
1	3.3 mi. N of Mitchell	Pheltz Kitchen	22	38	Uncased	Twiggs	Upland slope	—8	7-18-46	501	T, 71° F. Water has milky color because of surface contamination.
2	3 mi. N of Mitchell	Levi Kitchens	22	40	20	Granite	Gentle slope	—10	7-18-46	480	T, 69° F.
3	Mitchell	George Denton	45	40	Uncased	Irwinton	do	—32	7-18-46	540	T, 63° F.
4	5 mi. N of Gibson	A. J. Guy	48	36	48	do	Upland slope	—41	7-19-46	555	T, 65° F.
5	do	F. E. Peebles	37	36	36	do	Gentle slope	—34	7-19-46	550	
6	0.4 mi. W of Rocky Comfort Creek on county line	George Counsel	44.7	36	44	do	Hilltop	—41.5	7-19-46	505	T, 65° F.
7	5.5 mi. NE of Gibson, Rte. 80	S. O. Smith	51	36	50	do	do	—40	7-19-46	525	T, 64° F.
8	6 mi. NE of Gibson	Ray Johnson	38.4	36	38	Upper Barnwell	Upland slope	—31.3	7-19-46	540	Do.
9	1.4 mi. S of Bastonville	James Willifred	64.8	24		Irwinton	Ridgetop	—61	7-19-46	555	T, 65° F.
10	Bastonville	Cecil Davis	48.8	36	48	do	Upland flat	—32.4	7-19-46	550	T, 64° F.
11	3.6 mi. E of Gibson	Glenn Poole	25.8	36	20	Upper Barnwell	Gentle slope	—18.7	7-19-46	505	T, 65° F. Water derived from perched water body.
12	4 mi. NE of Gibson, Rte. 80	Ellis Chalker	25	36	10	Irwinton	do	—17	7-19-46	487	T, 67° F.

Table 8.—Records of Wells in Glascock County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diam-eter (in.)	Depth of casing (ft.)	Geologic horizon	Topog-raphy	Water level (ft.)	Date of measure-ment	Elevation above mean sea level (ft.)	Remarks
13	3 mi. N of Gibson	Les Matthews	38	36	22	Twiggs	Steep slope	—34	7-19-46	505	T, 65° F.
14	1 mi. N of Gibson	Leon Usery	25	36	25	Granite	Valley flat	—17	7-19-46	344	T, 66° F.
15	Gibson	Town of Gibson	176	4	176	do	Gentle slope	—20	7-18-46	355	T, 66° F. Analysis.
16	do	J. L. Usery	25	36	Uncased	Upper Tuscaloosa	Undula-ting slope	—18.6	7-18-46	341	T, 64° F.
17	do	Mrs. Swint	96	4	----	Granite	Gentle slope	—18	7-18-46	339	T, 65° F.
18	2 mi. SE of Mitchell	Blanche Gibson	59.9	40	59	Twiggs	Upland flat	—56.5	7-18-46	500	T, 66° F. Well often dry.
19	3.3 mi. N of Edgehill	H. L. Downs	40	40	Uncased	do	Upland slope	—37	7-18-46	480	T, 64° F.
20	2.3 mi. N. of Edgehill	T. G. Kent	33.7	40	5	do	Upland flat	—25.7	7-18-46	478	T, 64° F. Analysis.
21	3 mi. SW of Gibson, Rte. 171	Homer Dickson	49.8	36	49	Irwinton	Upland slope	—40	7-18-46	405	T, 66° F.
22	2 mi. S of Gibson	Joe Poole	30.2	36	25	Twiggs	Gentle slope	—26	8- 9-46	315	T, 66° F. Analysis.
23	1 mi. E of Gibson	Clinnen Chalker	45.4	40	Uncased	Upper Tuscaloosa	do	—37.8	7-19-46	370	Not in use at date of measure-ment.
24	3 mi. S of Gibson, Rte. 80	Joe Wilcher	70.5	40	60	Twiggs	Moderate slope	—48.3	7-19-46	485	T, 66° F.
25	4 mi. SE of Gibson	Blankenship School	41.5	36	40	Upper Barnwell	Gentle slope	—35.2	7-18-46	458	T, 64° F.

Table 8.—Records of Wells in Glascock County (Concluded)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
26	2 mi. E of Gibson	Jim Thompson	42.2	36	15	Irwinton	Upland slope	—37.8	7-18-46	481	T, 65° F.
27	0.8 mi. S of Bastonville	Mrs. H. S. Wilkerson	49	36	44	Upper Barnwell	Upland flat	—42.2	7-19-46	545	Do.
28	7 mi. E of Gibson	E. O. Hadden	69	40	68	......do......	Small hilltop	—62.5	7-19-46	550	Do.
29	......do......	Coreen Rivers	63.5	36	60	......do......	Upland flat	—58.7	7-19-46	531	Do.
30	......do......	J. A. Rivers estate	40	36	40	......do......	Gentle slope	—34	7-19-46	500	Do.
31	Steep Hollow, 9 mi. SE of Gibson	C. L. Usery	30	30	30	Sandersville	......do......	—22	7-19-46	485	T, 64° F. Water is hard.
32	......do......	Carrie Walker	41.9	36	Uncased	Hawthorn	Upland flat	—36.4	7- 1-46	494	
33	6 mi. SE of Gibson	J. H. Thigpen	30	38	......do......	Upper Barnwell	......do......	—20	7-18-46	510	T, 65° F.
34	7 mi. SE of Gibson	T. D. Louis	35	40	3	Hawthorn	......do......	—15	7-18-46	515	Do.
35	4.5 mi. S of Gibson	Sam Williams	65.5	40	Uncased	Twiggs	Hilltop	—61	7-19-46	512	Do.
36	4 mi. S of Gibson	J. B. May	29.5	36	29	Irwinton	Lowland	—16.3	8-20-46	310	Do.
37	1 mi. NE of Edgehill	R. L. Melber	60	40	Uncased	......do......	Upland flat	—55	7-18-46	451	Do.
38	Edgehill	Town of Edgehill	90	48	90	Twiggs	......do......	—80	7-18-46	489	T, 65° F. Supplies 6 families
39	0.5 mi. S of Edgehill	J. M. Morgan	86	36	85	......do......	......do......	—81	7-18-46	480	T, 65° F.

Table 9.—Chemical Analyses, in Parts Per Million, of Water From Glascock County

(Well Numbers Correspond to Numbers in Table 8 and on Plate 2)
Analyst, F. H. Pauszek, U. S. Geological Survey

Well no. Geologic formation	15 Granite	20 Barnwell	22 Barnwell
Bicarbonate (HCO_3)	49	5.0	4.0
Sulfate (SO_4)	8	1	1
Chloride (Cl)	2	4	3
Fluoride (F)	.6	.1	.1
Nitrate (NO_3)	.0	6.4	19
Hardness as $CaCO_3$	28	6	10
Date of collection	Aug. 9, 1946	Aug. 9, 1946	Aug. 9, 1946

On the uplands east of Joes Creek, dug wells ranging in depth from 30 to 60 feet obtain water from the Irwinton sand member or the upper sand member of the Barnwell. The Hawthorn formation in the east is too thin and limited in areal extent to have any ground-water importance.

The quality of ground water in Glascock County is good, and soft water is present everywhere. However, a well (15) formerly used by the town of Gibson was reportedly abandoned because of a high iron content.

LOCAL SUPPLIES

No community in Glascock County has a municipally owned water supply system, water being derived in all cases from private wells or springs.

Jefferson County

Area: 532 square miles Population: 18,855

GEOGRAPHY

Jefferson County occupies the southwestern part of the area under consideration; it includes the towns of Louisville, Wrens, Wadley, Bartow, and Stapleton. Agriculture is the leading industry and the production of cotton, corn, wheat, peanuts, and pecans is of considerable economic importance. Much of the farmland, however, is untilled.

The county lies entirely in the Coastal Plain province. It is here that the Red Hills reach their maximum development, especially in the area north of Louisville. This area is called the Louisville Plateau by Cooke (LaForge, 1925, p 39-40), who describes the plateau as being

"typically developed on the divide between Big Creek and Duhart Creek in Jefferson County between Louisville and Stapleton. It is characterized by wide flat areas which slope gently southward at a rate of about 10 feet per mile. The altitude of the upland surface ranges from about 500 feet above sea level near Stapleton to about 320 feet near Louisville. Briar Creek near Waynesboro and Rocky Comfort Creek near Louisville have cut their valleys 100 feet below the upland. Near the northern edge the plateau is considerably dissected and its separation from the adjoining Fall Line Hills (Sand Hills) is not precise."

GEOLOGY

No crystalline rocks are exposed in Jefferson County. The Tuscaloosa formation crops out only in the valleys of Briar Creek and Reedy Creek in the north. This formation is composed of white and pink sands and disseminated clay and mica flakes.

The Tuscaloosa formation dips southeastward under rocks of Eocene and later age at the rate of 15 to 20 feet a mile. The depth to the top of the Tuscaloosa formation at Wrens is 194 feet and at Louisville approximately 310 feet. This formation is present under cover in the entire county.

The McBean formation overlies the Tuscaloosa in the southern part of the county but is overlapped in the northern part of the county by the Barnwell formation, which lies unconformably on the Tuscaloosa. The Barnwell underlies the entire county except where worn away along Briar and Reedy Creeks. A thin veneer of Miocene deposits conceals it on the uplands south of Louisville and in a few isolated outliers throughout the county.

The Twiggs clay member of the Barnwell formation is exposed only in a few places, these being limited to the valleys of Briar and Reedy Creeks. At Henderson's Ranch on Reedy Creek, 5 miles north of Wrens, indurated fuller's earth of the Twiggs clay member overlies the Tuscaloosa formation. The clay represents a massive deposit of blue and white silicified fuller's earth, which breaks into angular 1-inch masses. This material resembles the flint kaolins derived from the Tuscaloosa formation.

The Irwinton sand member, although not clearly distinguished from the overlying upper sand member of the Barnwell formation, is prevalent throughout the county north of Louisville. A section of the typical Irwinton sand member is exposed on the north slope of Brushy Creek on the Louisville road, a mile south of Wrens.

Section 1 mile south of Wrens

		Depth (feet)
Eocene		
Barnwell formation:		
4	Clay, gray interlaminated, and yellow sand, apparently conformable with underlying fuller's earth	19
3	Fuller's earth, green and white indurated; breaks into pieces with irregular, conchoidal fracture	20
2	Sand, gray, slightly indurated coarse	4
1	Concealed interval to Brushy Creek	6

The upper sand member of the Barnwell formation is extensively exposed on the Louisville plateau north of Louisville and along the lowlands in the southern part of the county. A relatively thin limestone bed within this upper sand member, largely dissolved away, is probably the reason for the many sinks on the upland.

That deposits of Miocene age once covered Jefferson County is indicated by the existence of outliers of the Hawthorn formation in the northwest section of the county. Erosion since Miocene time has removed all but scattered remnants of this formation north of Louisville. South of Louisville the dip of the Hawthorn formation is greater southeastward than the slope of the land surface, so that the formation covers all the upland area. However, its thickness does not exceed 75 feet. Where the Hawthorn is present the soils are light-yellow sandy clays containing scattered brown iron nodules.

GROUND WATER

No well in Jefferson County draws water from the crystalline rocks lying beneath the Coastal Plain sediments.

Although the outcrop of the Tuscaloosa formation is limited to a small area north of Wrens, this formation exists under cover at depths increasing southeastward. The porous sands of the Tuscaloosa formation exposed in the counties north and west of Jefferson County allow the easy entrance of water, which is then transported by gravity down the dip. Therefore the water in the Tuscaloosa formation in Jefferson County south of its outcrop area is under artesian pressure, sufficient to produce flowing wells in the lowlands of the Louisville area and southward.

The Tuscaloosa formation yields large quantities of water to wells in the county that reach its water-bearing sands. However, because most well owners obtain adequate supplies of ground water from the overlying Barnwell formation, very few wells tap the Tuscaloosa.

An oil prospect 3½ miles southwest of Louisville penetrated the Coastal Plain deposits before encountering the crystalline basement complex at 1,140 feet (McCallie, 1908, p. 125-126). Although the log furnishes no direct evidence of the water-bearing strata encountered, it is helpful in deciphering beds that might be water bearing and in calculating the approximate thickness of the Tuscaloosa formation. It is thought that the Tuscaloosa formation was encountered at a depth of 307 feet and that the 200 feet of sand below this depth was water bearing. Diorite gneiss is the crystalline rock underlying the Tuscaloosa.

Because it covers most of the county, the Barnwell formation is generally penetrated by wells. Dug wells locate water in the sands of this formation at depths ranging from 20 to 110 feet. The deep gullying and entrenchment by streams along the west border of the county causes considerable effluent seepage from the formation, which results in a low water table beneth the uplands. Two dug wells (66 and 67) are more than 100 feet deep.

Clay strata interbedded with sands of the Barnwell formation locally retard the downward percolation of ground water. This leads to the presence of perched zones of saturation, from which many dug wells derive water.

Wells drilled into the Barnwell formation in Jefferson County have no great difficulty in obtaining water. Water-bearing sands in the area around Wrens are found at depths of 100 to 130 feet, and in the area around Louisville sands of the Barnwell formation yield large supplies of water at depths ranging from 130 to 220 feet. Some drilled wells obtain water from limestone beds, where present, at depths no greater than 130 feet. South of Louisville drilled wells 60 to 150 feet deep obtain water from the Barnwell formation.

Wells drilled into the Hawthorn formation in Jefferson County pass through it and obtain water from the underlying Barnwell formation. Although the Hawthorn formation covers much of the county south of Louisville, its thickness nowhere exceeds 75 feet. The compact sandy clay of the Hawthorn allows the wells to stand without curbing. Dug wells are commonly shallow and not completely curbed.

Flowing wells can be obtained along the lowlands bordering Williamson Swamp Creek and the Ogeechee River south of Louisville. Probably small artesian flows can be produced also along the Ogeechee River, Rocky Comfort Creek, and Duhart Creek in the western part of the county.

A group of springs worthy of note is located in the northwestern part of Jefferson County, 2 miles south of Avera. The beautiful woodland setting and the palatable spring water prompted the erection of the Omaha Hotel at the site many years ago. The springs are at the base of a local scarp and emerge from fissures in slightly indurated sands of the Barnwell formation. Two of the largest springs flow approximately 100 gallons per minute each.

LOCAL SUPPLIES

Wrens, Louisville, and Wadley are the only communities in Jefferson County that have public water-supply systems; all are supplied by drilled wells.

Wrens (population 1,380) derives water from a 12-inch well drilled in 1941 to a depth of 159 feet. The water-bearing sand was penetrated at 117 feet, at which point the hole was reamed to 20 inches to the 159-foot depth. A screen was set at 118 feet and 15 cubic yards of gravel was placed around the screen. The well originally yielded 150 gallons per minute on pumping test for 4 hours. The water comes from the Irwinton sand member of the Barnwell formation.

Louisville (population 2,231) is supplied with water by three flowing wells, two of which were drilled more than 40 years ago, on the southeast side of town along the Ogeechee River. The more recent well, drilled in 1951, is 251 feet deep, and the two older wells are reported to be 350 feet deep. The wells yield water from the Tuscaloosa formation at a depth of 250 feet or greater. The water rises 20 feet above the land surface, the aggregate flow of the two older wells being more than 125 gallons a minute. Treatment consists only of chlorination.

Wadley (population 1,624) owns six flowing wells ranging in depth from 225 to 445 feet. The water from the different strata rises 4 to 20 feet above the land surface, according to the topography and the aquifer tapped. The aggregate flow of these wells is more than 40 gallons a minute. Analysis of water from one of these wells (71), probably representing the shallow depth, shows 193 parts per million of bicarbonate and a hardness of 142 parts per million. This water comes from a limestone bed in the Barnwell formation or the McBean formation. The deeper wells obtain water from the Tuscaloosa formation. A well, 480 feet deep, was drilled for the town in 1951. An examination of the electric log of the well suggests that permeable sands occur between the depths of 350 and 450 feet. These sands probably belong to the Tuscaloosa formation. Water from this well is reported to contain an objectionable quantity of iron.

Bartow (population 347) is on the lowland plain bordering Williamson Swamp Creek in southern Jefferson County. The town has no public water-supply system but there are several privately owned artesian wells. These wells, ranging in depth from 75 to 300 feet, presumably obtain water from the Barnwell formation; the water rises 2 to 10 feet above the land surface.

The villages of Stapleton, Matthews, and Avera in the northern part of the county have no system of waterworks. Few individual dug wells in these places exceed 50 feet in depth; drilled wells more than 100 feet deep generally find water adequate for individual supplies.

Table 10.—Records of Wells in Jefferson County

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
1	5.2 mi. N of Wrens, Rte. 17	R. L. McNair	90	36	85	Twiggs	Top of hill	—78	8-23-46	495	
2	4.5 mi. N of Wrens, 1 mi. W of Henderson Ranch	Mr. Jenkins	62	36	Uncased	do	Upland	—62	8-23-46	470	Well dry when measured.
3	Warren County line, Rte. 17	Reedy Creek Church	52	2	52	Irwinton	Gentle slope	—40	8-23-46	460	T, 65° F.
4	4 mi. N of Wrens	W. R. Gay	70	36	68	do	do	—60	8-23-46	495	Do.
5	4.2 mi. N of Wrens, Rte. 17	Joe Duprew	20	40	5	Upper Tuscaloosa	Lowland slope	—16	8-23-46	380	T, 67° F.
6	3 mi. N of Matthews	Mollie Pennington	85	40	Uncased	Irwinton	Top of hill	—75	8-21-46	405	T, 65° F.
7	3 mi. N of Wrens	S. J. Arrington	80	2	----------	do	Gentle slope	—45	8- 5-46	446	T, 66° F.
8	4 mi. NE of Wrens, U. S. Rte. 1	C. D. James	48	6	48	Upper Tuscaloosa	Hill slope	—42	7-10-46	348	T, 65° F.
9	1.7 mi. N of Stapleton	John Raburn	51.4	36	51	Upper Barnwell	Upland flat	—47.3	7-19-46	520	Do.
10	1.1 mi. N of Wrens, Rte. 17	W. E. Millborn	67	36	67	Irwinton	do	—55	8-23-46	470	T, 66° F.
11	2.2 mi. NE of Wrens	A. T. Russell	80	2	80	do	Gentle slope	—50	8- 6-46	370	T, 67° F.
12	1.2 mi. NE of Wrens	L. C. Poole	66	3	60	do	Upland flat	—45	8-23-46	460	T, 65° F.

Table 10.—Records of Wells in Jefferson County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
13	Wrens	U. S. Government	549	6	Uncased	Metavolcanic series	Upland	----------	7-26-46	459	USGS test hole. Water-bearing sands encountered at 120 and 180 feet below surface.
14	1 mi. NE of Wrens	Ellis McNair	24	1½	24	Upper Barnwell	Lowland	—20	8- 6-46	438	T, 68° F.
15	0.8 mi. E of Wrens	O. G. Lancaster	39	36	35	do.	Upland slope	—30	8-22-46	420	T, 65° F.
16	0.2 mi. N of Matthews	Thompson Church	25	36	Uncased	Irwinton	Gentle slope	—21.7	8-21-46	390	T, 66° F. Water has slight milky color.
17	Matthews	H. C. Jones	30	36	30	do.	Upland flat	—25	3- 7-46	385	T, 67° F.
18	2 mi. E of Wrens	J. C. Bell	30.9	40	20	Upper Barnwell	Gentle slope	—18.1	8-23-46	370	T, 65° F.
19	Wrens	Town of Wrens	130	12	120	Irwinton	Upland	—22	5-20-46	423	T, 66° F. Yields 40 gpm.
20	1.4 mi. SE of Stapleton	L. R. Hobbs	60	36	55	Upper Barnwell	Upland flat	—45	5- 8-46	455	T, 67° F.
21	1.6 mi. W of Stapleton	R. B. Beckworth	55	48	50	do.	Gentle slope	—50	7-19-46	485	T, 65° F.
22	Avera	Mrs. P. W. Dixon	100	3	96	do.	Upland flat	—50	5- 7-46	420	T, 67° F.
23	2 mi. S of Avera	Maude Kelly	105	3	100	Irwinton	Upland	—48	5- 7-46	415	Do.

Table 10.—Records of Wells in Jefferson County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
24	3 mi. S of Stapleton, Rte. 16	R. A. Wilson	50	36	45	Irwinton	Upland	—48	5- 7-46	424	T, 66° F.
25	3 mi. SW of Wrens	Will Avera	35	36	36	......do......	Upland flat	—32	8-23-46	395	T, 64½° F.
26	Stellaville	J. F. Perdue	50	2	50	......do......	......do......	—45	8-23-46	387	T, 66° F.
27	0.8 mi. SW of Stellaville	H. E. King	35	36	34	Upper Barnwell	Gentle slope	—31	5- 7-46	361	Do.
28	Zebina	Mrs. C. E. Milton	65	3	60	......do......	Upland flat	—30	5- 7-46	397	T, 68° F.
29	2.4 mi. SE of Stellaville	Coy Clifton	37.9	36	35	Irwinton	Undulating upland	—28.3	8-23-46	379	T, 65° F.
30	3.2 mi. SE of Avera	G. H. Landrum	80	2.5	75	......do......	Top of hill	—55	8-23-46	410	T, 64° F.
31	Glascock County line, Rte. 171	R. L. Lamb	86	3	86	Twiggs	Upland flat	—78	7-18-46	460	T, 68° F.
32	Rocky Comfort Creek on Wrens-Grange Road	Floyd L. Norton	30.6	36	Uncased	Irwinton	Moderate slope	—28.8	8-14-46	340	T, 67° F.
33	1 mi. N of Rocky Comfort Creek on Wrens Road	Herman Jordon	81	40	76	......do......	Upland slope	—77	8-19-46	375	T, 66° F.
34	6 mi. S of Avera	C. C. Brown	63.9	36	30	......do......	Moderate slope	—60.8	8-23-46	440	Do.
35	6.6 mi. S of Avera	Cliff McGahee	75	36	70	......do......	Upland slope	—68.8	8-23-46	445	T, 65° F.
36	6.5 mi. S of Avera	Mitchell Simmons	52	36	47	Upper Barnwell	Gentle slope	—45	8-19-46	410	T, 66° F.

Table 10.—Records of Wells in Jefferson County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
37	2 mi. N of Duhart Church, Rte. 16	Eva Rhodes	65	2	60	Irwinton	Gentle slope	—50	5- 7-46	371	T, 68° F.
38	7.5 mi. N of Louisville, Rte. 1	J. J. Norton	166	3	120	Upper Tuscaloosa	Upland	—60	5-16-46	360	T, 67° F.
39	2.6 mi. N of Grange	W. E. Dye	110	36	....	Irwinton	do	—104	8-23-46	410	T, 65° F.
40	2 mi. NE of Grange	do	100	36	Uncased	do	do	—92	8-23-46	400	Do.
41	1 mi. E of Grange	Lamar English	57	40	55	do	do	—53	8-23-46	480	T, 66° F.
42	5.1 mi. NW of Louisville	A. L. Burch	350	3.5	80	Tuscaloosa	Top of hill	—60	5- 7-46	340	T, 67° F. Water has slight sulfur odor.
43	4 mi. N of Louisville, Rte. 16	P. F. Hudson	260	3	70	Upper Tuscaloosa	Upland	—55	5-16-46	356	T, 68° F.
44	3 mi. N of Louisville, U. S. Rte. 1	M. L. Henson	65	2.5	60	Irwinton	Gentle slope	—56	6-29-46	365	T, 69° F.
45	2.7 mi. NW of Louisville	M. O. Bridges	77	3	73	Upper Barnwell	Valley flat	—45	5- 7-46	320	T, 66° F. Water is hard. Limestone at 60 ft.
46	2 mi. N of Louisville	Alec Barfield	47.1	40	Uncased	do	Gentle slope	—40.8	7- 1-46	365	T, 67° F.
47	do	J. J. Brown	125	3	120	Irwinton	Upland	—55	5-16-46	350	T, 65° F.
48	1.4 mi. NE of Louisville	R. M. Beckworth	50	36	45	Upper Barnwell	Gentle slope	—46	5- 7-46	340	T, 67° F.

Table 10.—Records of Wells in Jefferson County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
49	5.5 mi. NW of Louisville, Rte. 171	Baptist Church	21.5	36	Uncased	Upper Barnwell	Lowland flat	—14.5	8-19-46	321	
50	3 mi. SE of Grange, Rte. 171	R. L. Farmer	125	3	....	Irwinton	Top of hill	—25	8-14-46	325	T, 65° F.
51	0.2 mi. SE of Louisville, Rte. 17	J. J. Waters	170	3	....	....do....	Lowland	—5.4	6-28-46	245	
52	Louisville	Town of Louisville	350	6	....	Tuscaloosa	Stream level	+20	7- 2-46	238	T, 66° F. Flow, 75 gpm.
53	Ogeechee River, 1 mi. SE of Louisville	Jack Davis	215		....	....do....	....do....	+17.2	6-25-46	235	T, 66° F. Flow, 60 gpm.
54	Ogeechee River, Rte. 24	J. M. Walden	213	3	....	Irwinton	Lowland	+5.5	6-28-46	255	T, 67° F. Analysis. Flow, 20 gpm.
55	4 mi. SW of Louisville, Rte. 24	Annie Jones	210	3	....	....do....	Upland	—70	7- 3-46	330	T, 69° F. Hard water.
56	1.5 mi. E of Eden Church	J. R. Penrow	36.1	36	Uncased	Upper Barnwell	Upland slope	—26	8-22-46	305	T, 66° F.
57	1 mi. N of Walton Grove Church	C. S. Mosely	200	3	....	Irwinton	Upland	—30	8-14-46	325	T, 65° F. Analysis. Water slightly hard.
58	5 mi. SE of Louisville	E. A. McNeill	183	4	....	Upper Tuscaloosa	Stream level	+15	8-23-46	183	T, 65° F. Flow, 35 gpm. Water has slight sulfur odor.

Table 10.—Records of Wells in Jefferson County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
59	5 mi. N of Wadley	H. D. Thomas	189	3	90	Irwinton	Upland	—52	5-16-46	285	T, 67° F.
60	0.3 mi. N of Moxley	Craig Caldwell	40	36	Uncased	Hawthorn	Upland flat	—21	8-24-46	350	T, 68° F. Water has slight milky color.
61	4.8 mi. NE of Wadley	I. D. New	19.6	36	do	do	Gentle slope	—15.8	8-23-46	302	T, 67° F.
62	1 mi. SE of Moxley	John L. Adams	30	36	do	do	Moderate slope	—23	8-24-46	350	T, 70° F. Water has slight milky color.
63	1 mi. N of Bartow	S. J. Cameron	215	3	90	Irwinton	Upland	—15	6-28-46	284	T, 67° F.
64	0.4 mi. N of Bartow	H. R. Morris	45	36	45	Upper Barnwell	do	—38	6-28-46	280	T, 66° F.
65	Bartow	Lonnie Smith	128	1	120	Irwinton	Lowland	—10	6-26-46	244	T, 68° F.
66	do	J. E. Greenway	81	2	----	do	Valley bottom	+4.2	6-28-46	230	T, 64½° F. Analysis. Flow, 6 gpm.
67	do	L. A. Rachels	78	2.5	60	do	Lowland	+2.4	6-26-46	230	T, 68° F. Flow, 5 gpm.
68	do	B. C. Jordan Cotton Gin Co.	60	4	----	do	Valley bottom	+8.99	6-29-46	218	T, 65° F. Analysis.
69	2.3 mi. S of Bartow	W. C. Bailey	25	36	Uncased	Lower Hawthorn	Lowland	—13	6-26-46	230	T, 69° F. Analysis.

Table 10.—Records of Wells in Jefferson County (Concluded)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
70	Mill Creek, 2 mi. SW of Wadley	Mr. Overstreet	110	4	100	Irwinton	Stream level	—.3	6-25-46	210	Water level Aug. 10, 1946, was +0.8, Flow, 1½ gpm. T, 68° F. Analysis.
71	Wadley	Town of Wadley	445	2	....	Tuscaloosa	Lowland	+4.5	6-25-46	220	Flow, 8 gpm. 3 other flowing wells furnish city supply. Aggregate flow 40 gpm. Analysis.
72	2 mi. NE of Wadley, Rte. 78	Ada Calhoun	34.6	36	Uncased	Hawthorn	Lowland flat	—28.6	8-24-46	310	T, 68° F.
73	3 mi. E of Wadley, Rte. 78	Mark Lamb	25.4	36	do	Upper Barnwell	do	—21.3	8-24-46	300	T, 69° F.
74	7 mi. S of Bartow	J. W. Stevens	50	38	do	Hawthorn	Upland	—16	6-26-46	275	T, 66° F.

Table 11.—Chemical Analyses, in Parts Per Million, of Water From Jefferson County.

(Well Numbers Correspond to Numbers in Table 10 and on Plate 2).
Analyst, F. H. Pauszek, U. S. Geological Survey

Well no. Geologic formation	54 Tuscaloosa	57 Barnwell	66 Irwinton member	68 Irwinton member	69 Hawthorn
Bicarbonate (HCO_3)	86	12	204	204	24
Sulfate (SO_4)	12	1	7	10	1
Chloride (Cl)	3	11	3	2	66
Fluoride (F)	.1	.1	.1	.0	.1
Nitrate (NO_3)	.0	16	.0	.0	80
Hardness as $CaCO_3$	76	33	153	153	75
Date of collection	Aug. 14, 1946	Aug. 14, 1946	Aug. 14, 1946	Aug. 14, 1946	Aug. 14, 1946

Well no. Geologic formation	70 Barnwell	71 Barnwell
Bicarbonate (HCO_3)	203	193
Sulfate (SO_4)	13	10
Chloride (Cl)	6	4
Fluoride (F)	.1	.1
Nitrate (NO_3)	.0	.0
Hardness as $CaCO_3$	153	142
Date of collection	Aug. 14, 1946	Aug. 14, 1946

McDuffie County

Area: 263 square miles Population: 11,443

GEOGRAPHY

McDuffie County lies on the Fall Line between Columbia and Warren Counties. Thomson, the county seat, has a population of 3,088 and is on the Augusta-Atlanta highway, 35 miles west of Augusta.

The county represents parts of two physiographic provinces—the Piedmont Plateau, which covers the northern two-thirds, and the Coastal Plain, which occupies the remainder. The Piedmont Plateau is a gently rolling plateau broken by the valleys of the Little River and Hart Creek and by high knobs, which have offered greater resistance to erosion. The Coastal Plain south and east of Thomson is a gently sloping plain dissected by small, shallow southward-trending valleys. The streams forming these valleys have irregularly stripped off much sedimentary material and have destroyed the escarpment separating the Coastal Plain from the Piedmont.

The elevation of some knolls northeast of Thomson, near Columbia County, exceeds 600 feet. The central part of the county is an upland where the general elevation is more than 500 feet. The lowest land is along the Little River and Briar Creek, which form the northern and southern boundaries of the county. The Little River drains the Piedmont area and Briar Creek the Coastal Plain area, both streams flowing eastward into the Savannah River.

GEOLOGY

The Coastal Plain sediments do not extend into the northern half of McDuffie County. Where the crystalline rocks are overlain by Coastal Plain deposits, the overlying formation is the Tuscaloosa, except in the southwest corner of the county. There the Barnwell formation overlaps the Tuscaloosa and rests unconformably on the crystalline rocks.

The accompanying geologic map (pl. 1) shows that the Tuscaloosa formation has an irregular outcrop area south and east of Thomson. Streams cutting through the relatively thin veneer of sediments of the Tuscaloosa have exposed the underlying crystalline rocks in the valleys toward Briar Creek in the south.

The Tuscaloosa formation in McDuffie County is characterized by pink and white arkosic sands. Crossbedded sands containing small white kaolin balls are common. Coarse granular sands, white from disseminated kaolin particles and large segregated kaolin balls, are prominent on Boggy Gut Creek, 4 miles south of Harlem and 2 miles north of Avondale. Deposits of white kaolin sands are extensively exposed along the valley of Briar Creek near the Jefferson County line.

A reasonably accurate calculation of the thickness of the Tuscaloosa formation can be made where it is present in the county. In Thomson no more than 20 feet of the Tuscaloosa is present. Although crystalline rocks underlie the village of Dearing, a hill half a mile north of that community exposes a thickness of 60 feet of sand of the Tuscaloosa. In the southwest corner of the county, on the ridges between Little Briar Creek and Big Briar Creek, the formation is less than 45 feet thick. At Luckie Bridge on the Wrens road at Briar Creek the formation reaches its maximum thickness of 190 feet.

Overlying the Tuscaloosa formation unconformably in McDuffie County is the Barnwell formation. It caps the hills as isolated outliers south and east of Thomson. This formation consists chiefly of brilliant red sands. The intercalated yellow sand beds and thin clay laminae that characterize the Irwinton sand member farther south in Jefferson County are poorly developed in McDuffie County. No limestone beds were noted in the county.

Red ferruginous pebbles are present in the soil near Iron Hill Church, 3 miles south of Dearing. These pebbles were apparently formed at the base of the Barnwell formation by precipitation from iron-bearing waters. The precipitation from such water has caused the sands of the Barnwell to be consolidated into a red ferruginous sandstone on a small outlier 1 mile southeast of Dearing. The sandstone is used locally for building purposes. A deposit of similar material lies on U. S. Highway 78 near the Columbia County line, 3 miles east of Dearing.

The Barnwell formation is not thick. Its maximum thickness in McDuffie County is at the Richmond County line on Route 47, where 95 feet of sands of the Barnwell are exposed.

GROUND WATER

Practically all the domestic supplies of ground water in McDuffie County are obtained from dug wells ranging from 15 to 90 feet in depth.

In the extreme northern part of the county, where the quartz-sericite schist of the metavolcanic series forms an east-west belt, conditions for obtaining ground water are less favorable than in other parts of the county, chiefly because of the hilly topography. The area is sparsely populated and very few wells have been drilled into the schist.

The Coastal Plain sediments overlying much of the southern half of McDuffie County are of no importance in the yield of artesian water. More than two-thirds of the water entering the porous sands of the Tuscaloosa formation is dissipated in the form of unutilized springs and seepage along the contact of this formation with the underlying crystalline rocks. However, much of the water entering the Tuscaloosa between Boggy Gut Creek and Briar Creek is retained in the formation and carried down the dip under cover, to be tapped by artesian wells in Richmond and Jefferson Counties. Although no flowing wells are known in McDuffie County, it is thought that enough artesian pressure is built up in the Tuscaloosa

Table 12.—Records of Wells in McDuffie County

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
1	0.5 mi. S of Little River, Rte. 78	A. L. Hunt	70	36	30	Metavolcanic series	Hilltop	—67	7-17-46	440	T, 66° F.
2	1 mi. N of Big Creek, Rte. 78	Bob Howell	35	40	Uncased	Granite-schist complex	do	—33	7-17-46	448	T, 64° F.
3	1.6 mi. S of Little River, Rte. 43	J. S. Boyd	28.7	36	18	do	Upland	—18.5	7-17-46	395	T, 63½° F.
4	1 mi. NE of Pine Grove Church, Rte. 43	J. J. Brown	450	36	43	Granite	Gentle slope	—39	7-17-46	516	T, 64° F.
5	6.5 mi. N of Thomson, Rte. 78	W. A. Knox	285	6	75	Granite-schist complex	Upland	—15	7-17-46	550	T, 65° F. Analysis.
6	6 mi. N of Thomson, Rte. 78	R. A. Dudley	37	36	36	do	Hilltop	—33	7-17-46	535	T, 67° F.
7	1 mi. E of Germany Creek, Rte. 150	C. F. Samuel	45	36	40	Granite	do	—28	7-17-46	540	T, 65° F.
8	3 mi. E of Thomson Rte. 150	B. C. Perry	20	36	20	do	Upland flat	—14	7-17-46	540	T, 64° F.
9	0.3 mi. N of Thomson	W. J. Burgamy	20	36	36	Granite-schist complex	do	—8	8-17-46	545	T, 67° F.
10	2 mi. W of Thomson	W. F. Farr	27	36	26	do	Gentle slope	—13	7-16-46	490	Do.

Table 12.—Records of Wells in McDuffie County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
11	1.2 mi. E of Thomson	Joe Hinton	15	30	12	Tuscaloosa	Gentle slope	—10	7-16-46	560	T, 69° F.
12	5 mi. E of Thomson	Steve Anderson	55.5	36	55	do	Upland flat	—47.6	7-16-46	540	T, 68° F.
13	1 mi. S of Thomson, Rte. 17	Leonard Lokie	270	6	101	Granite-schist complex	Hilltop	—60	7-17-46	520	
14	3 mi. SW of Thomson, Rte. 17	S. Johnson	33	36	33	do	Gentle slope	—15	7-16-46	485	T, 67° F.
15	3.7 mi. NE of Bonesville	Milton Ansley	64	30	63	Tuscaloosa	Upland	—60	7-16-46	573	T, 65° F.
16	0.3 mi. NE of Bonesville	Lloyd Watson	30.1	30	30	Lower Tuscaloosa	Upland flat	—25	7-16-46	496	T, 66° F.
17	4 mi. S of Thomson, Rte. 17	T. V. Benson	28.7	36	28	Granite	Small hilltop	—23	7-17-46	500	Do.
18	5 mi. SW of Thomson	R. H. Montgomery	27	36	23	do	Upland	—13	7-16-46	455	T, 68°F.
19	3 mi. W of Dearing, Rte. 78	W. F. McCorkle	51	36	50	Tuscaloosa	Upland slope	—47	7-16-46	540	T, 66° F.
20	1 mi. N of Big Briar Creek, Rte. 17	John Guy	23.6	38	Uncased	Granite	Gentle slope	—13.3	7-17-46	420	Do.
21	1.2 mi. NW of Jones Grove Church	D. F. Raeborn	34	30	30	Tuscaloosa	Upland	—28	7-16-46	490	Do.
22	Dearing	Town of Dearing	400	6	75	Granite-schist complex	do	—23	10-18-46	470	

Table 12.—Records of Wells in McDuffie County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diam-eter (in.)	Depth of casing (ft.)	Geologic horizon	Topog-raphy	Water level (ft.)	Date of measure-ment	Elevation above mean sea level (ft.)	Remarks
23	1.8 mi. S of Dearing	Viola Brown	18	38	Uncased	Tuscaloosa	Gentle slope	—4	7-16-46	489	T, 69° F. Water is slightly milky.
24	Iron Hill Church	Ed Reeves	12.2	36	11	Lower Barnwell	......do......	—5.5	7-16-46	436	T, 68° F. Represents perched water table.
25	1 mi. S of Iron Hill Church	H. J. McGahee	32	30	30	......do......	Upland flat	—26.5	7-16-46	498	T, 67° F.
26	2.2 mi. NW of Arrington Pond	Stacy Turner	30	40	Uncased	Tuscaloosa	......do......	—17	7-16-46	460	T, 68° F.
27	0.5 mi. N of Warren County, Rte. 17	Cliff Guy	18	40	......do......	Lower Tuscaloosa	Gentle slope	—35	7-16-46	505	T, 64° F. Analysis.
28	Headstall Creek, 3 mi. S of Dearing	S. T. Holloman	35	40	......do......	Granite	Moderate slope	—10	7-16-46	375	T, 66° F.
29	2 mi. NE of Arrington Pond	C. S. McCorkle	55	36	54	Tuscaloosa	Gentle slope	—35	7-16-46	505	T, 64° F.
30	Arrington Pond	G. W. Arrington	19.2	36	19	Lower Tuscaloosa	Base of slope	—13.5	7-16-46	340	T, 67° F.
31	1 mi. NW of Silver Run Church	L. Whitaker	42	36	40	Upper Tuscaloosa	Upland flat	—32	7-16-46	485	T, 65° F.

Table 12.—Records of Wells in McDuffie County (Concluded)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
32	0.4 mi. NE of Silver Run Church	L. Whitaker	28.5	36	28	Upper Tuscaloosa	Upland	—24.5	7-16-46	480	T, 64° F.
33	5.8 mi. S of Dearing, E of Headstall Creek	W. A. McCorkle	17.4	30	15	Tuscaloosa	Base of slope	—11.6	7-16-46	348	T, 67° F.
34	Bowdens Lake on Big Branch	A. H. Reeves	14	36	13	......do......	Gentle slope	—7	7-16-46	345	T, 66° F.

Table 13.—Chemical Analyses, in Parts Per Million of Water From McDuffie County

(Well numbers correspond to numbers in table 12 and on plate 2)
Analyst, F. H. Pauszek, U. S. Geological Survey

Well no. Geologic formation	5 Granite gneiss	27 Tuscaloosa
Bicarbonate (HCO_3)	82	6.0
Sulfate (SO_4)	2	1
Chloride (Cl)	6	3
Fluoride (F)	.5	.1
Nitrate (NO_3)	.2	3.1
Hardness as $CaCO_3$	52	12
Date of collection	Aug. 13, 1946	Aug. 8, 1946

formation along Briar Creek near the Jefferson County line to produce artesian flow.

The Tuscaloosa formation yields water to dug wells readily, commonly at depths less than 40 feet. No drilled wells were noted in the Tuscaloosa formation. A well drilled deeper than 150 feet will pass into the underlying crystalline rocks except in the extreme southern part of the county, where the Tuscaloosa formation is nearly 200 feet thick.

The red sands of the Barnwell formation capping the hills are too thin and small to produce more than enough water for domestic purposes. Depths of the dug wells range from 20 to 55 feet. Wells drilled through the Barnwell will pass into the Tuscaloosa or lower lying crystalline rocks, where adequate supplies for most needs can be obtained.

LOCAL SUPPLIES

Thomson (population 3,489) derives its municipal water supply from Sweetwater Creek south of the town. Treatment consists of filtration and the addition of alum, activated carbon, and chlorine. An abandoned well more than 500 feet deep in granite originally supplied the town, but because of its meager yield it has not been used for many years.

Dearing (population 325) obtains its supply from a well producing approximately 70 gallons of water a minute. The well, 400 feet deep, penetrated granite gneiss. The original pumping test of 24 hours produced 90 gallons of water a minute with a pumping head of 153 feet. The static level is 23 feet.

Richmond County

Area: 325 square miles Population: 108,876

GEOGRAPHY

Richmond County lies north of Burke County, the Savannah River forming its east boundary. The city of Augusta and its close environs account for the bulk of population in the county; small centers of population include the villages of Hephzibah, Blythe and McBean.

The county lies essentially in the Coastal Plain province although crystalline rocks of the Piedmont are exposed in a small area north of Augusta. The plain has been dissected by eastward-flowing streams, which have continued to extend and deepen their valleys. The Sand Hills of the Tuscaloosa formation are well developed in the area south of Augusta, where light-colored sandy soils prevail. Contrasting sharply in color are the Red Hills, typifying the red sands of the Barnwell formation, which predominate on the upland area in the southern half of the county.

A rather flat, featureless plain, at an elevation slightly below 140 feet, borders the Savannah River from Augusta southward. This flood plain is generally more than 2 miles wide, becoming swampy toward the river.

GEOLOGY

The Tuscaloosa formation, which overlies the crystalline rocks in Richmond County, is extensively exposed in the lowland plains south of Augusta. All streams south of this city flow entirely, or in part, through the Tuscaloosa formation.

The tendency of the overlying Barnwell formation to overlap the Tuscaloosa is indicated along the Fall Line, where the Tuscaloosa is only 100 feet thick.

At the U. S. Arsenal in Augusta the Tuscaloosa formation is not more than 175 feet thick, at Tobacco Road on U. S. Highway 1 it is about 200 feet thick, and at McBean station and along McBean Creek it is about 580 feet thick.

The Tuscaloosa formation in Richmond County consists of loose, coarse light-colored sands and disseminated white kaolin particles, or segregated kaolin balls, in a pink sandy matrix. Considerable white kaolin is present in the upper part of the formation in the Hephzibah area. On the slopes of Briddle

Ridge, 4 miles northwest of Hephzibah, the formation shows soft white sandy kaolin, which might be of commercial value. The Albion Kaolin Mine on Grindstone Creek west of Hephzibah is the only kaolin mine in production in the county. The following section was recorded south of Spirit Creek, 4½ miles northwest of Hephzibah.

Section ½ mile southwest of Richmond Factory Road, 4½ miles northwest of Hephzibah

		Thickness (feet)
Barnwell formation:		
13	Clay, red, mottled, sandy	25
12	Sand, incoherent loose red, with scattered ¼-inch subangular quartz pebbles	20
11	Sand, loose even-grained gray and brown	20
10	Clay, hard, yellow sandy	13
9	Sand, loose to compact, red and orange, clayey	31
Tuscaloosa formation:		
8	Kaolin, white and brown-stained, containing sand grains and mica	11
7	Kaolin, interbedded, white, sandy, with mica and brown kaolinic mica sand	16
6	Concealed—brown sandy soil with kaolin balls	20
5	Sand, coarse, loose brown argillaceous mica, with white kaolin blobs	25
4	Sand, orange clayey, with white kaolin balls, sand locally crossbedded, containing subangular quartz gravel up to ½-inch long	19
3	Sand, compact, crossbedded, pink	8
2	Kaolin, white, micaceous, containing very little grit	2
1	Concealed interval to creek	14

The McBean formation overlies the Tuscaloosa along McBean Creek in the southeast corner of the county. Its known areal extent is limited to the valley of McBean Creek from its junction with the Savannah River westward about 9 miles. No accessible exposures of the McBean formation occur in Richmond County.

The McBean formation is overlapped north of McBean Creek by the Barnwell formation.

Except along the valleys, the strata of the Barnwell formation form the surface material over the southern half of the county. In the north they cap the ridges, forming outliers north of Spirit Creek. These beds rest unconformably on the sands of the Tuscaloosa except along McBean Creek in the southeast corner of the county, where the McBean formation intervenes. The thickness of the Barnwell in Richmond County does not exceed 200 feet.

The Barnwell formation in Richmond County consists of massive red sands and some discontinuous limestone beds. Thick beds of fuller's earth, characterizing the basal part of the formation in counties to the west, are less prominent or nonexistent here. Also, interbedded gray sands and laminated clay, resembling the Irwinton sand member, are locally present but not prevalent.

Thin limestone beds, made discontinuous by removal of soluble material in solution, are present in the Barnwell formation in the southern section of the county. A few sinks occur near Blythe and south of Hephzibah.

The Hawthorn formation does not extend into Richmond County.

GROUND WATER

In the rural areas dug wells 12 to 100 feet deep normally furnish domestic supplies of ground water. The quartz-sericite schist in the area north of Augusta yields water less readily than do the Coastal Plain sediments. Dug wells in this type of rock usually reach a depth greater than 50 feet before an adequate supply is obtained.

The outcrop area of the Tuscaloosa formation contains porous sands which receive and store large quantities of water of excellent quality. Most of the wells in this area are dug wells, ranging in depth from 15 to 50 feet, and their yields are usually sufficient for domestic purposes. Near the Fall Line the deposits of the Tuscaloosa are too thin and too high on the stream divides to yield large amounts of water. However, the formation thickens rapidly to the south, and in the southern half of the county abundant supplies of water can be obtained at depths of 200 to 500 feet.

Because almost all the streams flow through the Tuscaloosa formation and numerous ponds cover the land surface, influent seepage from these water bodies into the porous sands probably is great. Coupled with the influent seepage from rainfall, which also is high, it amounts to a considerable quantity of water that enters the formation to be carried along the strata down the dip and to be confined under pressure. Wells drilled into the aquifer in lowlands areas to the southeast will tap this artesian water and obtain flowing wells.

All flowing wells in Richmond County tap the Tuscaloosa formation. Those in the northern half of the county, where artesian conditions exist, do not flow more than 15 gallons a minute. Only along McBean Creek in the south do flowing wells have a high yield. Analyses of water from the Tuscaloosa in seven localities in the county are given in the table at the end of this section. Most of the water is very low in dissolved mineral matter.

LOCAL SUPPLIES

Augusta (population 71,508), which obtains its supply from the Savannah River about 4½ miles northeast of the city, has the only municipal waterworks in Richmond County. Treatment consists of adding alum, and of settling, filtering, and chlorinating the water. Lime is added for the final pH adjustment. Approximately 15 million gallons was used daily in 1946.

The amount of water available to wells in the Augusta area varies considerably according to the presence or absence of Coastal Plain sediments. The Tuscaloosa formation, containing permeable sand, begins near Lake Olmstead on the north side of the city and thickens gradually southward. The greatest thickness of sediments is along the west side of town, where as much as 210 feet of sand underlies the hill. However, owing to the large local relief, the water table in some places lies more than 100 feet below the surface. With the exception of this erosional outlier, the only area within the city where the Tuscaloosa is thick enough to yield water is along the south side, where sand of the formation is as much as 80 feet thick. Several wells of the Babcock & Wilcox Co., on this side, have penetrated 70 feet of sediments before encountering the hard, basement rocks.

Inasmuch as deep wells on the north side of Augusta penetrate crystalline rocks, expected yields from wells drilled at random are approximately 10 or 20 gallons a minute. A 480-foot well drilled in 1952 at the Bon Aire Hotel yields only 20 gallons a minute; the Barnwell formation, extending to a depth of about 35 feet, and the Tuscaloosa formation, between 35 and 160 feet, are cased off, and the entire yield of the well is from fractures in the crystalline rocks. Wells drilled on the south side of the city (not on the alluvial terrace) may penetrate as much as 70 feet of sedimentary material, the yield of which may range from 15 to 150 gallons per minute.

Along the flood plain south and east of Augusta considerable water may be obtained from the sand and gravel of the flood-plain deposits. Wells 42, 43, and 44 are on this flood plain, although well 43, which is 270 feet deep, apparently derives its entire yield of 48 gallons per minute from the underlying crystalline rocks. In the area surrounding these wells and southward more than 90 feet of alluvial material of high permeability exists which may yield supplies of several hundred gallons a minute to individual wells. At Bush Air Field, 8 miles south of Augusta, three wells were drilled in 1941 to supply the military demands there. Each well is approximately 85 feet deep, and water rises to within 15 feet of the surface. The wells probably end in aluvium, although the underlying Tuscaloosa formation may contain an additional 100 feet of water-bearing sands. The well used in 1946 was pumped at the rate of 73 gallons a minute.

Hephzibah's (population 525) water supply comes from dug and drilled wells individually owned. Dug wells normally obtain water in the sands in the lower part of the Barnwell formation at depths ranging from 40 to 65 feet. A drilled well (30) obtains water from coarse white sands of the upper part of the Tuscaloosa formation at 88 feet. The water level in this well is reported to be 59 feet below the ground surface.

Blythe (population 164) is supplied with water by a dug well 100 feet deep. The water comes from the sands of the Barnwell and stands about 85 feet below the ground surface.

McBean (population 200) is supplied by individually owned artesian wells. Four flowing wells, ranging in depth from 80 to 140 feet, obtain water from the upper part of the Tuscaloosa formation. None of the flows exceeds 15 gallons a minute.

Table 14.—Records of Wells in Richmond County

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
1	3 mi NW of Augusta Rte. 28	Ed Nichols	108	2	60	Metavolcanic series	Upland flat	—18	6-29-46	358	T, 66° F.
2	1 mi. S of Cane Creek, on Skinner Road	W. R. Reeves	72	2	33	do	Gently sloping hillside	—1.2	6-29-46	300	T, 66° F. Analysis.
3	Augusta	Babcock & Wilcox	68	8	35	Tuscaloosa	Gentle slope	—50	8- 8-46	135	
4	1.2 mi. W of Lake Aumond	H. S. Davis	190	2		Metavolcanic series	do	—180	8- 6-46	335	T, 65° F.
5	Reynolds School	T. J. Lassiter	90	1¾		Tuscaloosa	Valley flat	+3.4	7-20-46	338	T, 64° F.
6	do	M. W. Brown	89	2		do	Stream level	+5.5	8- 6-46	336	T, 66° F. Analysis.
7	1 mi. SE of Reynolds School	L. L. Jackson	84	3	80	do	Gentle slope	—15	7-15-46	370	T, 68° F.
8	Wrightsboro Road, 2 mi. W of Augusta	H. S. Cage	39.4	36	38	do	Upland flat	—33.7	7-15-46	370	T, 66° F.
9	Bayville School, Rte. 78	J. H. Maddox	122	2		Metavolcanic series	Gentle slope	—37	8- 6-46	230	Do.
10	1.2 mi. N of Barton's Chapel	Jim Shavers	49	36	43	Tuscaloosa	Upland	—45	8- 6-46	401	T, 65° F.
11	Lombard Pond, 2 mi. S of Augusta	O. H. Hall	20	60	10	do	Lowland slope	—5	7-12-46	150	T, 66° F.

Table 14.—Records of Wells in Richmond County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
12	4 mi. SW of Augusta, Rte. 1	J. H. Human	123	2	115	Tuscaloosa	Upland	—65	7-12-46	300	T, 65° F. Analysis.
13	Lombard Mill	Lombard Pond	170	2½	------	Metavolcanic series	Stream level	—12	8- 5-46	222	
14	1 mi. N of Mt. Lebanon Church	Julian James	10.7	36	8	Tuscaloosa	Gentle slope	—4.6	8- 6-46	340	T, 66° F.
15	Old Savannah Road	Gracewood Home for Children	355	6	------	Lower Tuscaloosa	....do....	—150	8- 6-46	164	T, 65° F. Analysis.
16	Butler Creek, Savannah Road	Sancken's Dairy	75	3	60	Tuscaloosa	Valley flat	—30	8- 6-46	163	Do.
17	....do....	....do....	320	8	300	....do....	Lowland slope	—150	8- 6-46	163	Do.
18	5 mi. S of Augusta, Savannah Road	I. C. Conn	165	2	------	....do....	Gentle slope	—70	8- 6-46	210	T, 65° F.
19	6 mi. S of Augusta	Bush Field	85	3	82	....do....	Valley flat	—15	7- 5-46	122	T, 68° F.
20	Little Spirit Creek, Rte. 1	Rural Ice Co.	275	2	------	....do....	....do....	+8	7-12-46	242	T, 64° F.
21	3.1 mi. N of Hephzibah	Leta Mae Whitehead	18.2	40	15	....do....	Upland flat	+15.2	8- 6-46	270	T, 66° F.
22	Richmond Factory Pond	Richmond Factory Pond	175	1¼	------	....do....	Bank of pond	+1.1	7- 3-46	191	T, 65° F. Analysis. Flow, 1 gpm.
23	0.2 mi. S of Spirit Creek, Rte. 25	Julian Cadle	28	30	20	....do....	Lowland	—21	7- 3-46	202	T, 68° F.

Table 14.—Records of Wells in Richmond County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
24	5.8 mi. NE of Hephzibah	Ella Johnson	25	30	20	Tuscaloosa	Valley flat	—18	7-11-46	195	T, 66° F.
25	2 mi. SW of Bush Field, Savannah Road	H. J. Wood	244	2	60	do	Upland flat	—30	8- 6-46	244	T, 65° F.
26	do	do	40	36		do	do	—36	8- 6-46	246	Do.
27	5 mi. E of Hephzibah	J. E. Stephenson	63	36	58	do	Gentle slope	—59	7-11-46	270	T, 66° F.
28	1 mi. S of Spirit Creek, Rte. 25	S. H. Smith	140	1½		do	Hillside	—85	7- 3-46	304	T, 68° F.
29	1.8 mi. S of Spirit Creek, Rte. 25	Dan Zanzo	276	2	260	do	Gentle slope	—126	8- 6-46	380	
30	Hephzibah	Mrs. Barguson	88	2	85	Upper Tuscaloosa	Upland flat	—59	8- 6-46	410	T, 65° F.
31	do	T. E. Anderson	63	36	58	Lower Barnwell	Upland	—58	5-23-46	408	
32	2 mi. NW of Hephzibah	Frank MacMurray	130	2		Tuscaloosa	Gentle slope	—20	8-21-46	281	T, 66° F.
33	2 mi. N of Blythe, Rte. 88	Harper Trowbridge	84	36	80	Irwinton	Upland flat	—78	8- 6-46	470	
34	Blythe	Town of Blythe	100	36		do	do	—85	7- 8-46	450	T, 66° F.
35	1.3 mi. W of Blythe, Rte. 1	L. A. Newman	120	3	112	Barnwell	Crest of sink	—75	7-12-46	457	T, 65° F.
36	McBean Creek, 5 mi. S of Hephzibah	Willie Rhodes	80	3		Upper Tuscaloosa	Bank of stream	+13.6	7- 5-46	200	Do.

Table 14.—Records of Wells in Richmond County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diam-eter (in.)	Depth of casing (ft.)	Geologic horizon	Topog-raphy	Water level (ft.)	Date of measure-ment	Elevation above mean sea level (ft.)	Remarks
37	McBean Creek	Flowing Well Grocery	30	3	----------	Upper Tuscaloosa	Stream level	+12	8- 8-46	170	T, 65° F. Analysis. Flow, 20 gpm.
38	1 mi. N of McBean	J. H. Mosely	145	2	----------	McBean	Hilltop	—130	8- 6-46	278	T, 65° F.
39	McBean	McBean School	165	2	----------	Upper Tuscaloosa	Upland slope	—125	8- 6-46	270	Do.
40	----do----------	J. O. Collins	120	2	100	----do----------	Gentle slope	+2	8-22-46	165	T, 65° F. Flow, 3 gpm.
41	----do----------	Collins Lumber Co.	96	3	68	Tuscaloosa	Lowland	+3	6-30-46	----------	T, 66° F. Flow, 2½ gpm.
42	1 mi. E of Augusta	W. H. Green	88	12	----------	Alluvial deposits	Flood plain	—15	----------	----------	Yield, 275 gpm.
43	----do----------	----do----------	270	6	129	Slate	----do----	—10	----------	----------	Yield, 47 gpm. Bedrock at 125 ft.
44	----do----------	C. C. Pollard	78	12	78	Alluvial deposits	----do----	—15	----------	----------	Yield, 380 gpm. Well gravel packed.
45	Gracewood	Ed Parris	160	2	----------	Tuscaloosa	Hill	—110	----------	----------	
46	----do----------	Gracewood Public School	230	3	----------	----do----------	----do----	—100	----------	----------	Well did not reach bedrock.
47	6 mi. W of Augusta	Camp Gordon	231	1	----------	Schist	Slope	—20	----------	----------	Yield, about 3 gpm.
48	2 mi. S of Augusta	The Piedmont Co.	68	8	----------	Tuscaloosa	Low terrace	—25	----------	----------	Yield, more than 50 gpm.
49	Augusta	Truckers Stop	330	8	50	Metavolcanic series	Slope	—12	----------	----------	Yield, about 100 gpm.

Table 14.—Records of Wells in Richmond County (Concluded)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
50	6 mi. S of Augusta	Augusta Airport	85	2	----------	Alluvial deposits and Tuscaloosa	Low terrace	—10	----------	----------	Good yield.
51	3 mi. NE of McBean	Ed Douglas	285	3	----------	Tuscaloosa	Edge of cliff	—150	----------	----------	Yield, 25 gpm. 100 ft. of limestone penetrated above the Tuscaloosa.
52	4 mi. SE of Gracewood	Oscar Richardson	340	2	----------	do	Valley	—6	----------	----------	Well reached bedrock.
53	3 mi. SW of Gracewood	Mr. Browning	125	2	----------	do	Slope	—85	----------	----------	
54	Hephzibah	W. T. Foster	115	2	----------	do	Hill	—85	----------	----------	Good yield.
55	Augusta	Mr. Brittingham	210	4	----------	do	do	—145	----------	----------	
56	2 mi. N of Augusta	Montgomery Harris	205	3	----------	Metavolcanic series	do	—65	----------	----------	Yield, 50 gpm. Bedrock at 70 ft.
57	3 mi. W of Augusta	Mr. Rhoden	65	2	----------	Tuscaloosa	----------	—40	----------	----------	
58	Augusta	Merry Brothers Co.	75	2	----------	do	Low terrace	+2	----------	----------	Natural flow, 4 gpm.
59	4 mi. SW of Augusta	Dr. Fulghum	245	2	----------	do	Hill	—120	----------	----------	
60	do	G. W. Staffen	260	2	----------	do	do	—125	----------	----------	
61	7 mi. W of Augusta	Camp Gordon	267	6	----------	do	Slope	----------	----------	----------	Yield, 35 gpm. Bedrock at 150 ft.
62	Gracewood	Gracewood Institute	1200	8	340	Sericite schist	do	----------	----------	----------	Yield, 5 gpm. Bedrock at 340 ft.

Table 15.—Chemical Analyses, in Parts Per Million, of Water From Richmond County

(Well numbers correspond to numbers in table 14 and on plate 2)
Analyst, F. H. Pauszek, U. S. Geological Survey

Well no. Geologic formation	2 Meta-volcanic series	6 Tusca-loosa	12 Tusca-loosa	15 Tusca-loosa	16 Tusca-loosa
Bicarbonate (HCO_3)	176	5.0	28	77	4.0
Sulfate (SO_4)	15	1	1	7	1
Chloride (Cl)	34	2	4	4	3
Fluoride (F)	.4	.1	.1	.1	.0
Nitrate (NO_3)	.3	.8	1.2	.0	2.8
Hardness as $CaCO_3$	150	8	14	46	8
Date of collection	Aug. 15, 1946	Aug. 8, 1946	Aug. 15, 1946	Aug. 8, 1946	Aug. 8, 1946

Well no. Geologic formation	17 Tusca-loosa	22 Tusca-loosa	37 Tusca-loosa
Bicarbonate (HCO_3)	12	6.0	154
Sulfate (SO_4)	1	1	8
Chloride (Cl)	1	2	3
Fluoride (F)	.0	.0	.0
Nitrate (NO_3)	8.8	.0	.0
Hardness as $CaCO_3$	14	6	126
Date of collection	Aug. 8, 1946	Aug. 8, 1946	Aug. 8, 1946

Warren County

Area: 284 square miles Population: 8,779

GEOGRAPHY

Warren County occupies the northwestern corner of the area covered by this report. It is bounded on the east by McDuffie County and on the south by Glascock and Jefferson Counties. The only towns are Warrenton, the county seat, Camak, and Norwood.

The county lies essentially in the Piedmont Plateau, although sediments of the Coastal Plain extend into the county from the south. The most elevated parts lie along the drainage divide on which Georgia Route 12 passes through Norwood and Warrenton.

GEOLOGY

Crystalline rocks are exposed in most of the northern part of the county, and only along the valleys of Briar Creek and Reedy Creek in the panhandle section of southeast Warren County is the Tuscaloosa formation exposed. On Briar Creek it overlies soft sericite schists of the metavolcanic series and probably overlies similar rocks 4 miles to the south, on Reedy Creek.

The character of the Tuscaloosa formation shows little variation from that typically exposed in other counties of the area. Light-gray and pink sand and sandy clay with small kaolin nodules are present in it on Georgia Highway 17, 1 mile south of Briar Creek. East of McLean Branch, on Georgia Highway 16, the formation shows 12 feet of hard conchoidal, gritty kaolin lying above 10 feet of compact pink sand.

Overlying the Tuscaloosa formation in the panhandle section and then overlapping it onto the crystalline rocks farther west is the Barnwell formation. It lies on the uplands along the southern edge of the county and extends northward onto the crystalline rocks as outlying remnants on some of the hills.

The Barnwell formation in Warren County consists chiefly of red residual sand and sandy clay, of massive structure. The formation shows distinct bedding only in the extreme eastern part of the county, where sands and clays are laminated. The distinctive fuller's earth of the Twiggs clay member is absent and the Irwinton sand member is not distinguishable. Therefore, the Barnwell cannot be subdivided in Warren County. The maximum thickness of the formation does not greatly exceed 100 feet.

The accompanying geologic map (pl. 1) reveals the presence of outlying bodies of this formation in a distinct belt which trends approximately N. 25° W. These outliers appear on the upland between Long Creek and Rocky Comfort Creek. They consist of coarse rounded quartz gravel in a matrix of pink mottled sandy clay. The pebbles range in size from 1 to 2 inches in diameter and are usually rotten and granular. The matrix resembles parts of the Tuscaloosa formation, but the fact that the Tuscaloosa is completely overlapped farther south would seem to lessen the possibility of their belonging to that formation. They appear to be erosion remnants of the main body of the Barnwell formation. Future study may show that they are channel deposits of an ancestral stream, either the Ogeechee River or Rocky Comfort Creek; if this is true, they may have been deposited in Pliocene or Pleistocene time.

At present none of the gravel deposits are worked, although a number of years ago the deposit near Norris was mined for ballast. The most extensive deposit lies along the road from Norris to Georgia Highway 16. The gravel appears abundant and can be easily extracted from the loose sandy clay matrix. It is doubtful if any of the outliers is more than 50 feet thick, and commonly they are less than 15 feet thick.

Two small outlying bodies, representing orange and yellow sandy clay of the Hawthorn formation, overlie the Barnwell formation south of Beulah Church in the panhandle section of the county. Because of their limited extent they need not be discussed further.

GROUND WATER

Most of Warren County is underlain by crystalline rocks which have a great range in yield. Except for a few drilled wells in the area around Warrenton and Camak and for the surface-water supply for the town of Warrenton, practically all sources of water are dug wells.

The granite-schist complex is exposed sporadically throughout the Piedmont area and yields water readily to dug wells at depths ranging from 20 to 60 feet. Fresh exposures of these rocks are rarely seen near the surface. For this reason dug wells locate the water table in the decomposed parts above the fresh hard rock. No drilled wells in Warren County are known to derive water from the granite-schist complex. The granite and schist have many openings along joint planes and planes of schistosity through which water can travel. The probability of obtaining considerable amounts of water from these rocks at a depth of less than 300 feet is fairly good.

The granites that have intruded the granite-schist complex are prominent in the Piedmont section of the county. These granites normally yield supplies of water to dug wells where the surface is underlain by at least 30 feet of residual, decomposed material. The surficial portion of the granites is commonly a sandy arkose that takes in water readily. In many places on the uplands bald exposures of fresh granite are found. Granites on the uplands are the least favorable source of water in Warren County, although in lowland areas the same granites may provide relatively large quantities of water.

The metavolcanic series, composed of phyllites and quartz-sericite schists, does not produce large supplies of water in the county. Its development in the northern part of the county and along Briar Creek in the panhandle section is in areas where population is sparse. Dug wells obtain their supplies from the weathered zone and are rarely more than 50 feet deep. There are no drilled wells in the outcrop area of this formation. It is reasonable to assume, however, that moderate supplies could be obtained from drilled wells in lowland areas.

The Tuscaloosa formation furnishes water to a few dug wells in Warren County, but it is not an important source of ground water because of its limited extent. Fewer than 10 dug wells obtain water from this formation at depths no greater than 3.0 feet. Water entering the porous sands at the intake area passes down the dip under the overlying sediments to be confined under hydrostatic pressure in areas to the southeast. South of the junction of Georgia Highways 16 and 17, drilled wells ranging in depth from 40 to 150 feet might produce moderate amounts of water from this formation. Its thickness does not exceed 150 feet in Warren County.

The Barnwell formation occupies much of the upland in the southern part of the county. The deposits are relatively thin, and wells drilled into the red sands and sandy clay of this formation likely would yield little water and would have to penetrate the underlying Tuscaloosa formation or crystalline rocks. At present, no drilled wells in Warren County acquire water from the Barnwell formation. Dug wells 20 to 50 feet in depth furnish adequate supplies for domestic needs.

The gravelly deposits appearing as outliers and thought to belong to the Barnwell formation are too thin to yield even small domestic supplies.

LOCAL SUPPLIES

Warrenton (population 1,442) until 1948 obtained its supply of water from three wells having depths of 500, 632, and 1,200 feet, and respective yields of 15, 30, and 38 gallons a minute. The 1,200-foot well has a 10-inch casing, and the water rises to within 40 feet of the land surface; it is not known at what level water was encountered. All wells were drilled in granite on upland areas. In 1948 the town abandoned its wells in favor of a surface supply from Rocky Comfort Creek.

Camak (population 379) subsisted on a well that could be pumped at only 9 gallons a minute during the summer of 1946. This well is reported to be 650 feet deep and to end in granite gneiss. A well drilled in October 1946 to a depth of 355 feet yields an additional supply of 15 gallons a minute from the same rock.

Table 16.—Records of Wells in Warren County

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
1	Cadley	W. E. Saggus	21.8	30	21	Granite-schist complex	Gentle slope	—17.2	8-12-46	610	T, 64½° F.
2	6 mi. NW of Norwood	E. C. Harrell	60	30	60	Granite	do	—55	8-20-46	580	T, 65° F.
3	4 mi. NW of Norwood	J. C. Scott	60	40	Uncased	Metavolcanic series	Upland	—53	8-20-46	640	T, 64° F. Well dry in summer of 1945.
4	4 mi. NE of Norwood	W. J. Smith	25	36	do	Granite-schist complex	do	—14	8-12-46	605	T, 63½° F. Analysis.
5	4 mi. W of Norwood	L. D. Schubert	24.6	36	do	do	do	—18	8-12-46	615	T, 66° F.
6	2 mi. E of Norwood	Matt Kitchen	31.6	40	do	do	do	—26.5	8-20-46	601	T, 65° F.
7	Norwood	M. N. Kitchen	20	36	20	do	Gentle slope	—9	8-12-46	605	T, 68° F.
8	1.2 mi. E of Norwood	James Stedman	20	36	20	Granite	Upland	—18	8-20-46	580	T, 66° F. Supply not adequate in dry season.
9	Camak	Town of Camak	650	6	220	Granite-schist complex	do	—200	8-12-46	590	T, 65° F. Yield, 9 gpm. Analysis.
10	1 mi. NW of Warrenton	Burt Poole	26.6	36	25	do	Gentle slope	—21.7	8-20-46	498	T, 65° F.
11	Warrenton	Town of Warrenton	1200	10	105	Granite	Upland	—40	8-12-46	495	T, 67° F. Yield, 38 gpm.
12	4 mi. E of Warrenton	W. A. Norris	25.4	36	20	Granite-schist complex	do	—14.8	8-20-46	520	T, 65° F.

Table 16.—Records of Wells in Warren County (Continued)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
13	4.6 mi. SE of Warrenton	David Lowe	10.1	40	Uncased	Granite	Upland flat	—7.6	8-13-46	501	T, 68° F.
14	3 mi. SE of Warrenton	Jody Walker	14.5	36	14	......do......	Gentle slope	—10	8-12-46	503	T, 69° F.
15	Norris	J. W. Poole	37.8	36	5	Granite-schist complex	Hilltop	—28.5	8-20-46	620	T, 65° F.
16	2.2 mi. S of Norris	Rob Kelly	18.3	40	Uncased	Granite	Upland	—16.6	8-12-46	510	Do.
17	2 mi. SE of Norris	J. G. Shelton	22	36	......do......	......do......	......do......	—18	8-20-46	580	T, 68° F.
18	5 mi. SW of Warrenton	B. Roberts	12.6	36	12	Gravel	Gentle slope	—8.8	8-20-46	470	T, 69° F.
19	5 mi. S of Warrenton	E. B. Dye	30	36	25	Granite	......do......	—24	8-20-46	470	T, 65½° F.
20	4.5 mi. S of Warrenton Rte. 80	Mattie Preston	19.6	38	Uncased	......do......	Upland	—12.5	8-20-46	480	T, 66° F.
21	6 mi. S of Warrenton near Johnson's Church	Farris Coxwell	18	8	18	......do......	Gentle slope	—11.5	8-20-46	480	
22	1 mi. SE of Reese	Camp Branch Church	13.8	36	13	Irwinton	......do......	—9.7	8-12-46	510	T, 67° F.
23	2 mi. SE of Reese, Rte. 16	Olin Reeves	26	40	10	......do......	Upland flat	—19.8	8-12-46	505	T, 66° F.
24	3 mi. NE of Beulah	Mount Aldrich Church	27.6	40	Uncased	Metavolcanic series	Gentle slope	—14	8-12-46	398	T, 67° F.
25	0.5 mi. W of Rte. 80, Glascock County Road	S. W. Johnson	21.5	45	15	Granite	Moderate slope	—15.5	7-19-46	505	T, 64° F.

Table 16.—Records of Wells in Warren County (Concluded)

Well no. (pl. 2)	Location	Owner	Depth (ft.)	Diameter (in.)	Depth of casing (ft.)	Geologic horizon	Topography	Water level (ft.)	Date of measurement	Elevation above mean sea level (ft.)	Remarks
26	1 mi. E of Williams Church, Glascock County Road	W. E. Usery	40	38	Uncased	Barnwell	Hilltop	—35	7-19-46	550	T, 63½° F.
27	County line road, 5 mi. E of Shoals	W. B. Todd	35	40	do	Lower Barnwell	Upland	—32	8-20-46	547	T, 65° F.
28	do	do	50	40	do	do	Hilltop	—44	8-20-46	550	Do.
29	4 mi. E of Jewell	Marvis Dye	29.3	30	25	Granite	Gentle slope	—24.6	8-20-46	582	T, 67° F.
30	Jewell	B. F. Hall	27.1	36	27	do	Moderate slope	—23.2	8-20-46	450	T, 64½° F. Supplies 6 families

Table 17.—Chemical Analyses, in Parts Per Million, of Water From Warren County

(Well numbers correspond to numbers in table and on plate 2)
Analyst, F. H. Pauszek, U. S. Geological Survey

Well no. Geologic formation	4 Mica schist	9 Granite gneiss
Bicarbonate (HCO_3)	4.0	42
Sulfate (SO_4)	1	1
Chloride (Cl)	21	3
Fluoride (F)	.1	.1
Nitrate (NO_3)	32	.2
Hardness as $CaCO_3$	10	21
Date of collection	Aug. 12, 1946	Aug. 12, 1946

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SURFACE-WATER RESOURCES

By R. F. Carter and A. C. Lendo

INTRODUCTION

This chapter on the surface-water resources of central-east Georgia supplements information on the geology and ground-water resources of the area, and completes the presentation of current knowledge of the water resources available for water supply and related uses. No effort is made to treat such subjects as power, flood control, navigation, and bridge design, which are primarily concerned with river development but not closely related to geology and ground water and for which water-resources information would normally appear elsewhere. All data available in 1953 that might be useful in evaluating streamflows for water-supply purposes have been included.

Purpose and Scope of Investigation

The discussion in this chapter proposes to serve in three ways. First, it assembles all the available data pertinent to surface-water supplies within the study area. Second, it explains the use and limitations of the data for the benefit of those who may be familiar with geology and ground water but not wholly familiar with streamflow characteristics. Third, it presents some runoff characteristics of the area, as illustrated by the streamflow data, and discusses general information supplemental to those data.

The chapter includes streamflow information only and does not attempt to present structural, economic, or legal aspects of surface-water utilization and control.

Field data and computed data are presented for five complete-record gaging stations on principal streams located in the study area or in similar areas nearby. These data are presented in tables and graphs in special form to facilitate interpretation of their significance with respect to water-supply problems. Field data for 51 partial-record gaging stations are given. These stations are all located within the study area and most of them are on the lesser streams. Data for these stations have been analyzed and used to determine relationships with the data for the complete-record gaging stations. These relationships have been used to provide reliable estimates of the 1951 minimum flow at 35 sites. The methods of preparing such relationships and the basic principles involved are described in detail to provide a means for transposing complete-record gaging-station data to equivalent estimated data at partial-record gaging stations or at ungaged sites.

General characteristics of streamflow are discussed as well as natural and artificial factors in the study area which have an effect on streamflow. Trends in water utilization and possible future prospects are also considered.

Available data on the quality of surface water in the area are presented in a table and some of the factors that affect water quality are described.

Previous Investigations

No previous surface-water studies of this nature have been published for this area. Streamflow data for the gaging stations used in this investigation are published annually in water-supply papers of the U. S. Geological Survey, "Surface Water Supplies of the United States; South Atlantic and Eastern Gulf Coasts". In this report, these gaging stations are designated "complete-record gaging stations".

In October 1942, the U. S. Geological Survey made low-water measurements at a number of sites, including several sites in the study area, called "partial-record gaging stations" in the Piedmont Region of Georgia. As a wartime expedient, minimum flows for the 1941 drought were estimated at that time. The results of the work were presented on a map which was distributed to military and defense agencies in order to meet their urgent requirements for surface-water information in the war emergency.

During the dry periods of several succeeding years, additional low-water measurements were made in Central-East Georgia as well as in other sections of the state. Those periods were October 1943, October 1950, June 1951, and August and September 1951. The latter period was unusually dry so that the flow measurements obtained at that time were especially significant.

Cooperation and Acknowledgments

Streamflow information has been collected by the U. S. Geological Survey in cooperation with the Georgia Department of Mines, Mining and Geology, Garland Peyton, Director, and the Georgia State Highway Department, J. L. Gillis, Director. Assistance in the form of funds was given by the Corps of Engineers.

At the request of the Director of the Georgia Department of Mines, Mining and Geology in 1952, the Atlanta Surface-Water District undertook this investigation and the preparation of this chapter. Additional field work in the area was done in October and November 1952 under the immediate supervision of A. C. Lendo, Hydraulic Engineer, who also made the initial compilations of the data and some of the analyses. R. F. Carter, Hydraulic Engineer, completed the analyses and prepared the text. M. T. Thomson, District Engineer, Atlanta District, Surface Water Branch, directed the investigation under the general supervision of C. G. Paulsen, Chief Hydraulic Engineer, and J. V. B. Wells, Chief of the Surface Water Branch.

GEOGRAPHY

The study area includes seven counties of Central-East Georgia; Burke, Columbia, Glascock, Jefferson, McDuffie, Richmond and Warren. The physical geography is adequately described for the purposes of this chapter on pages 9-12, except that the "Sand Hills", "Red Hills", and "Louisville Plateau" of the Coastal Plain are treated herein as one region under the composite name "Fall Line Hills-Louisville Plateau." (Cooke, C. W., 1925 pp. 39, 40, 42-44). Due to great similarity in surface water runoff characteristics of the Sand Hills, Red Hills, and Louisville Plateau, this grouping into a single region is desirable and convenient. The three physiographic regions, Piedmont Plateau, Fall Line Hills-Louisville Plateau, and Tifton Upland, have striking significance in the evaluation of the surface water resources of the area.

A map (Figure 4) shows the location of sites mentioned in this chapter.

THE PRINCIPAL STREAMS

Only a limited amount of information about the principal streams, including the rivers and major creeks of the area will be given in this chapter. Complete hydrologic data for the utilization and control of those rivers are beyond the scope of this volume. The annual series of water supply papers contains the necessary streamflow information for projects. Some information about the principal streams pertinent to the discussion of lesser streams within the study area is pre-

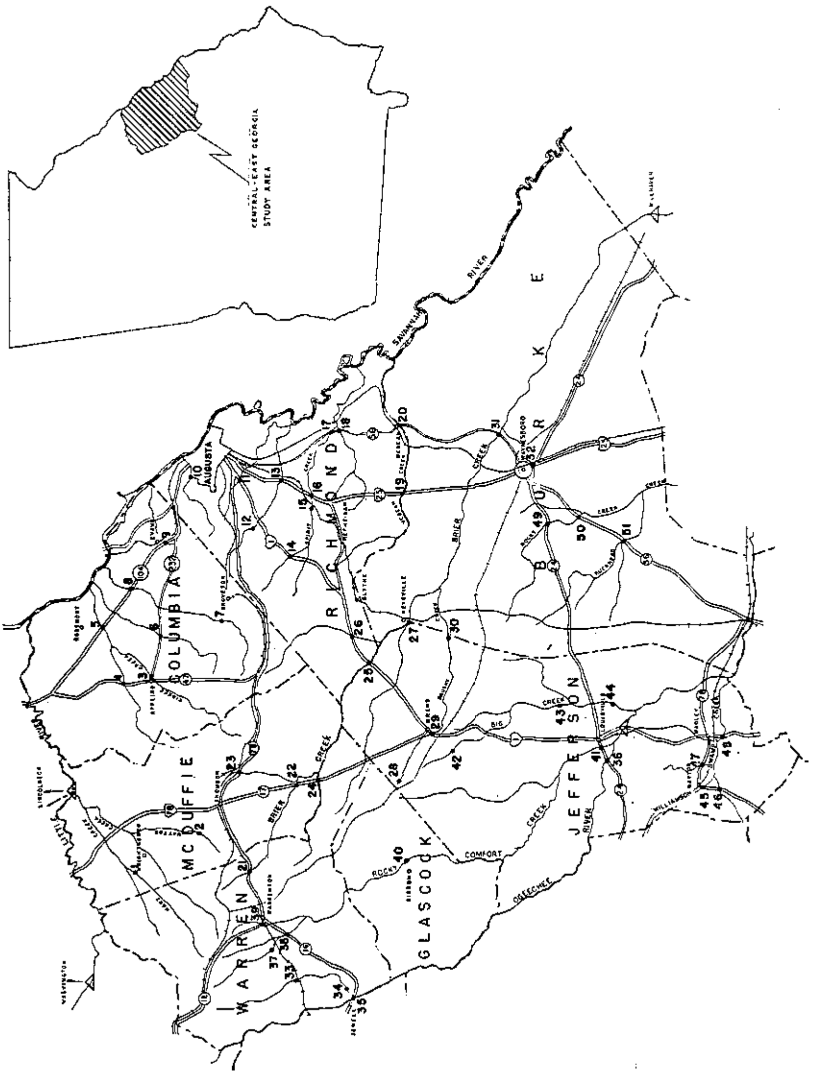

FIGURE 4
MAP OF
CENTRAL-EAST GEORGIA
SHOWING LOCATION OF STREAM FLOW INFORMATION

sented because all the complete-record gaging stations on which the analyses herein are based are on the major rivers of the area.

Some references will be made to streamflow information in areas outside the study area that supplements the data available within the area. Some of the general observations are based entirely on experiences outside the study area.

The Savannah River

The Savannah River, the principal river in the area, rises in the Appalachian Mountains and collects water from a number of major Piedmont tributaries to become a large river at Augusta where it crosses the Fall Belt. At Augusta it has a drainage area of 7,508 square miles and an average flow of 7,070 million gallons a day. Below Augusta the river is navigable to its mouth at Savannah, where there is an important harbor. Above Augusta the river has become highly developed for power and flood-control purposes.

No other streamflow data are presented for the Savannah River. Most of the flow of that river in the reach adjacent to the study area comes from the large drainage area above the study area, much of which bears little resemblance to the study area in physiographic aspects. Furthermore, the flow is highly regulated by power operations and reservoirs. Because of these factors, its flow data are not useful for comparisons with the streams being studied.

The Ogeechee River

The Ogeechee River, a much smaller river than the Savannah, rises in the Piedmont Plateau and has a drainage area of 800 square miles and an average flow of 560 million gallons a day at Louisville, where it enters the Tifton Upland. Below the limits of the study area it becomes a much larger river but it does not have the prospects for navigation that are characteristic of the Savannah River. The Ogeechee River is unique among Georgia rivers in that a major railroad runs along the greater part of the length of its valley. This combination of rail transportation and good industrial water supplies may in the future bring about the industrial growth of the small cities and villages in the valley. The installation of a major storage reservoir in the headwaters of the Ogeechee River may some day be feasible in order to increase the supply of industrial water, with the possibility of some power development in connection with such a reservoir.

The Little River

The Little River, a major tributary to the Savannah River, lies wholly within the Piedmont Plateau in an area having exceptionally low dry-season flows in contrast with rivers in other parts of the Piedmont Plateau. Most of the main course of the Little River is now submerged by Clark Hill Reservoir, and the operation of that reservoir will vary the pool level from 305 feet to 335 feet above mean sea level. No reservoir on the headwaters of the Little River is contemplated in the overall Savannah River basin plans of the Corps of Engineers. As the drainage basin is predominantly rural with little danger of pollution, the long arm of the lake up the Little River has distinct recreational possibilities and may perhaps have industrial possibilities also, if the conflicting requirements of industry, recreation and the water-level regulation from Clark Hill Dam can be adjusted.

Briar Creek

Briar Creek, another major tributary of the Savannah River, rises in the Piedmont Plateau but most of its drainage basin in the study area lies within the Fall Line Hills-Louisville Plateau (see Figure 14), from which it derives substantial contributions of water during the dry season, and in the Tifton Upland. Briar Creek is the source of water supply for the City of Waynesboro and, because it has a relatively large, fairly uniform flow of soft water in the Coastal Plain, it may become an important source of industrial water supply.

The Canoochee River

The Canoochee River, a major tributary to the Ogeechee River, lies wholly outside the study area. Streamflow data are included for the gaging station on the Canoochee River near Claxton, Georgia, because it is the nearest gaging station to the study area that has a drainage basin lying wholly within the Tifton Upland. None of the flow records within the study area furnishes a clear evaluation of the characteristics of streams of the Tifton Upland.

Whitewater Creek

Whitewater Creek is a minor tributary to the Flint River far to the west of the study area. Streamflow data for the gaging station on Whitewater Creek near Butler, Georgia, are included because it is the only gaging station in Georgia whose records are directly representative of the flow of Fall Line Hills-Louisville Plateau streams.

THE LESSER STREAMS

The words "River" and "Creek" are frequently more a matter of local custom than one of precise definition. In this chapter the term "Principal Stream" is used for the portions of rivers and major creeks that have substantial drainage basins and flows. The term "Lesser Stream" is used for smaller streams that are usually called creeks and for the headwater portions of rivers. Lesser streams generally have perennial or all-weather flows, although some of the streams for which data are given have been known to have no flow in unusually dry seasons. The study has not been extended to the very small "ephemeral", "intermittent", or "wet weather" streams.

Most of the surface-water study has been devoted to lesser streams because they, rather than the principal streams, are most likely to be related to the water-supply aspects of a report on the geology and ground water of the area.

The lesser streams are best described in general terms in groups defined by the three physiographic regions of the study area. Within each region the streams have distinct similarities. However, there are striking differences between Piedmont Plateau streams and Coastal Plain Streams and even between Fall Line Hills-Louisville Plateau streams and Tifton Upland streams within the Coastal Plain. Streams that pass from one physiographic region to another change their character more or less abruptly, depending on the relative proportions of their drainage basins within the regions.

Streams of the Piedmont Plateau

Lesser streams in the Piedmont Plateau portion of the study area tend to have well-entrenched channels and narrow flood plains as well as steeper and narrower valleys than the streams in other portions of the area. Their flow is "flashy", tending toward sudden, short, and frequent high flows, with a strikingly low dry-season flow. Many of the smaller streams have no flow for short periods every year. The stream beds are generally composed of a thin unstable mantle of silt or gravel over rock and boulders. In times past, there were many grist mills on the lesser Piedmont Plateau streams but few now remain. In recent years, large numbers of farm ponds have been built by constructing earth dams across small intermittent streams. The Piedmont streams are well suited to such easy pond construction if adequate spillways are provided.

Streams of the Fall Line Hills-Louisville Plateau

The lesser streams of the Fall Line Hills-Louisville Plateau tend to have relatively steep, narrow valleys, as in the Piedmont, but they may have somewhat less deeply entrenched channels and less well defined banks because of the more unstable surface material. Because the sandy soil of these areas readily absorbs most of the rainfall in all seasons, these streams tend to be remarkably free from flash floods, although occasional high floods cause damage owing to the low banks and limited flow capacities of the channels. The streams are most remarkable for their well sustained dry-season flows, which can be attributed to the geologic character of their drainage basins. When streams traverse the several physiographic regions, the portions that can be expected to have these good flows are best delineated on geologic maps.

The combination of infrequent floods and relatively steep channel slopes led to the early construction of small water-power developments on these creeks for grist and sawmills and for Georgia's earliest textile mills. Few of these mill sites now produce power but many of the ponds above the mill dams have been preserved as recreational lakes.

Indeed, in recent years the number of recreational ponds in the area has grown so markedly that few of the streams are entirely free from man-made regulation, a subject which will be discussed at length on pages 155 and 166.

Streams of the Tifton Upland

The Tifton Upland streams tend to be flat and sluggish with poorly defined, meandering channels in wide, swampy densely wooded valleys. Their beds are generally sand, and their usually sluggish flow is in long pools that have short, shallow riffles over the intervening sand bars. The channels are choked with fallen timber and debris at many points.

The water tends to have much less suspended sediment than in the Piedmont Plateau. It is likely to be colored by organic matter, although not as highly as the stream waters farther down in the Coastal Plain.

The Tifton Upland streams tend to have long flood periods in the spring months, which cause little damage because the swampy bottoms are unused. These periods are followed by extended periods of little or no flow during the growing season and late autumn. Although the range of extremes of flow of the Tifton Upland streams is similar to that of the Piedmont Plateau streams, the Tifton Upland streams are not "flashy", that is, they tend to rise slowly and to remain high during floods and to stay dry during droughts.

A large volume of available storage would be required to regulate a Tifton Upland stream and the likelihood of finding a suitable reservoir site in the Tifton Upland would be much less than in the Piedmont Plateau.

Summary of Characteristics of Lesser Streams

The predominant characteristics of lesser streams in the several physiographic regions of the area are summarized as follows:

Characteristic or Feature	Piedmont Plateau Streams	Fall Line Hills-Louisville Plateau Streams	Tifton Upland Streams
Average flow in million gallons per day per square mile	0.4 to 0.6	0.6 to 1.4	0.4 to 0.6
Flood Flows	Flashy, frequent and high	Infrequent	Moderate but long drawn out
Dry-season flows	Low for short periods	Plentiful flow	Low for long periods
Channel gradients	Steep	Steep	Gentle
Channels	Deep	Shallow	Swampy
Flood plains	Narrow	Narrow	Wide
Storage required to regulate	Large	Very small	Very large
Storage sites	Many	Some	Very few

UTILIZATION OF SURFACE-WATER RESOURCES

A brief statement about the utilization of the surface-water resources of the area is desirable in order to appreciate the uses that might be made of those resources and the application of the information in this chapter to such uses. Generally, the streams of the southeastern part of the United States are a resource of great importance. At the present time, few of them are being used to the fullest extent possible because of their poorly distributed natural flow. If regulating reservoirs are provided to conserve the now wasted flood waters for use in the dry seasons, that is, to distribute the flow more evenly throughout the year, the streams of the Southeast may become the region's dominant natural resource. Because the water resources in some parts of the country are rapidly approaching either complete appropriation or much contamination, industries and planners are showing a vigorous interest in the streams of the Southeast.

Navigation

Historically, the Savannah River, traversing the less productive pine barrens of the lower Coastal Plain, provided a navigable connection between the coast and the rich agricultural Piedmont and upper Coastal Plain regions. Briar Creek and the Ogeechee River also carried some navigation until the railroads replaced river steamboats and canals. At the present time, however, river navigation is practiced only on the Savannah River up to Augusta and it is extremely unlikely that river navigation will again be practiced on other rivers of the area. Because low and high flows both are hazards to navigation, the great multiple-purpose flood-control dams built and authorized on the upper Savannah River will be operated so as to provide a practically uniform river flow at Augusta of 3,500 million gallons a day. This navigation may lead to new industrial developments between Augusta and Savannah.

Hydroelectric Power

The lesser streams once provided water power at numerous small mills throughout the area. The shoals of the upper Ogeechee River and of Spirit Creek were the sites of early textile factories. The development of the dam and canals for water power at Augusta in 1845 led to the City's rise as one of the South's leading textile centers.

Electric power, which is readily transmitted over high voltage lines has supplanted direct-drive water power to such an extent that, unless large volumes of water are used in their manufacturing processes, many modern factories are built at some distance from the river whereas the earlier factories lined the river or canal banks.

More recently, steam power has moved into dominance in the electric-energy field. If present trends continue for the next few years, only 10 per cent of the electric energy in Georgia will be produced at hydroelectric plants. This small percentage, however, is more valuable than its magnitude suggests, inasmuch as it represents the flexible, variable "peak" power which steam power alone would much less effectively provide.

This factor of "peak" load use of hydroelectric power has an important bearing on the possible use of streams in the study area other than the Savannah River. In the first place, many favorable hydro-power sites on big rivers outside the study area have been considered for eventual development. Consequently, hydroelectric development of the rivers within the study area is not likely to take place for some time. In the second place, peak-power operation at a storage dam in the headwaters of Briar Creek or the Ogeechee River would send "power waves" down the rivers, and such irregular flows might be more of a handicap than an advantage for industrial purposes downstream.

It would seem, then, that power development of the rivers and lesser streams of the study area will be but a secondary consideration when eventual development of the streams take place.

Municipal and Industrial Water Supply

Streams have provided water supply for Augusta for many years and also supply the cities of Waynesboro and Thomson. Other smaller cities in the Piedmont Plateau may also provide for surface-water supply in the future if, in that portion of the area, increased demands exceed available ground-water supplies.

Industrial water supply has become a major factor in the South's expanded industry. Undoubtedly, future expansion of water consumption for industrial plants in the area both in connection with and independent of municipal water supplies can be expected. The safeguarding of potential surface-water supply sources from contamination is a serious economic, social and political problem.

Sanitation and Waste Disposal

There will also be an increase in the utilization of surface streams to carry away industrial wastes and municipal sewage. Currently so many municipalities in the area are building and extending sewer systems and sewage-treatment plants that it has not been considered practical to attempt to show the locations of sewer outfalls in this report.

Sanitation is a particularly difficult aspect of the surface-water resources of the study area because, except at Augusta, nearly all the cities, factories, transportation routes, and farms are situated on ridge tops. When communities develop to the point where they require public water-supply systems, they have disposal needs that are almost invariably served by the small surface streams draining away from the communities. Such streams may become polluted to such an extent as to be unfit for use by other communities, and, as urbanization and industrialization grow, this contamination extends further and affects potential supplies for still other communities.

Pollution abatement is relatively simple, within limits. Sewage-treatment plants may remove up to 80 percent of the pollution by so-called complete treatment. This, in effect, merely means that the stream can handle six or seven times as much waste with treatment plants as without them. Complete treatment of wastes as now practiced does not mean that the stream has an unlimited capacity to receive the treated wastes and still remain in a satisfactory biological and aesthetic condition.

Recreation and Wildlife

Much use is made of the ponds, small streams and rivers in the area for recreation, mostly fishing. Any evidence of stream pollution by industry arouses public protest. But despite public opposition and effective controls by health authorities, industrialization and municipal growth will probably cause the stream and river habitat for fish and other water-loving wildlife to deteriorate. At the present time, farmers and sportsmen's clubs tend to build recreational ponds that replace the streambank fishing of former years.

Recent increases in the number of recreational ponds would seem to indicate that generally there is adequate water to supply them. So long as the pond is intended merely to hold water and not to be used as a source of additional water to regulate streamflow or for irrigation, there should be little difficulty in having enough water. The county agents who advise rural pond builders use general rules based on a certain number of acres of drainage area per acre of pond surface, which seem to serve present needs for hydrologic design. The principal recreational pond problem is one of construction — to locate the pond where the ground will hold water, to build a watertight dam, and to avoid shallow overgrown areas that are breeding places for mosquitoes. As a measure to control the malaria-carrying mosquito, all impoundments in Georgia are required by law to have a permit.

The design of safe spillway capacities for recreational pond construction is a serious hydrologic problem. Practically all the farm ponds that are built are made with earth dams, and if such a dam is overtopped it will probably be destroyed. Usually there is little danger to life from such failures because the volume of water is small and the failure does not occur suddenly. Nevertheless, the pond is lost and serious damages have resulted to roads and bridges and sometimes to bottom-land crops from such failures.

Since the greater number of the present farm ponds have been built, there have not been any unusually heavy rainstorms in the area to test the adequacy of the spillways that have been provided to safeguard the dams. When severe rainstorms do occur, as they can and have in the area, there may be many dam failures. In any event, there should be some means of weighing the risk of failure against the cost of safeguards.

Irrigation

An increasing tendency to use supplemental irrigation for many farm crops is becoming evident in Georgia. The water supply can be obtained from either wells or ponds or occasionally from streams but it must be inexpensive and handy to the fields and of satisfactory quality. Where most cultivation is on ridge tops, the streams and rivers are usually too distant for practical use. The design of a profitable irrigation system, including the construction of the proper kind of reservoir, is a more serious problem than appears at first glance. Obviously, supplemental irrigation is practical only if the increased crop value resulting from it amounts to more than the cost of developing and applying the water. A pond for irrigation water, unlike a recreation pond, needs to be designed in such a way that water in sufficient quantities will be available when needed, as during severe droughts. For the present, however, irrigation is being practiced only where water is readily obtainable.

PRESENTATION OF SURFACE-WATER DATA

Surface-water information is usually presented in a form radically different from that used to present ground-water information. The supply of ground water changes relatively slowly, but surface water in streams is constantly in motion.

Thus, the principal purpose of a surface-water report is to show quantitively how much water flows in the stream, not where to find the stream nor to explain why water of such nature and in such quantity is there. It is mostly simple, quantitative, factual reporting. Streamflow is constantly changing by variable degrees, and, therefore, streamflow data must be related to time as well as to place. A statement that flow is so many million gallons a day may be highly significant for a well, but for a surface stream it is necessary to state not only the flow and the specific site but also when, for how long, and how often. A flow figure for a stream may be that at a specific time (at 1:30 p.m. June 13, 1953, at the peak of a flood, or when a water sample is taken); for a specific period (instantaneous daily, weekly, monthly, or annual mean flow; or the average for a number of years); or may be that for a specific frequency (annual minimum or maximum, 10-year frequency, or 90 percent duration).

Complete-Record Gaging Stations

Because streamflow is variable, the most frequently published data are flow records over a period of time. These records are collected at fixed sites known as "complete-record gaging stations" where, over a long period of time, the entire range of flow from highest to lowest is observed and recorded, generally by the daily mean flow for each day of each year of operation. Such stations are usually operated indefinitely, and the value of their records increases as the period of record grows longer. Besides the record of daily flows, monthly and annual means and extremes are computed. Volumes are computed by the summation of flows by desired periods of time. Those data are primary tools of the hydraulic engineer engaged in studies involving streamflow. They are also primary tools of the hydrologist, who uses them, together with much less complete flow data at other sites, to determine flow characteristics at those sites.

Data for complete-record gaging stations are published annually in the U. S. Geological Survey water-supply papers. Flow data in the annual series of water-supply papers is expressed in cubic feet per second. One cubic foot per second (cfs) equals 646,000 gallons per day, 0.646 million gallons per day (mgd), or 448 gallons per minute (gpm), when converted to the gallon terms commonly used in municipal water-supply problems. Conversely one mgd equals 1.55 cfs. A convenient relationship is that 2 mgd equals approximately 3 cfs. All flow data in this chapter have been converted to gallon terms. For convenience of study with reference to the other data in this report, some data for complete-record gaging stations are tabulated in this report as follows:

Table 18. Summary of flow data for complete-record gaging stations. This table merely summarizes the general information about the stations, such as the period of record, drainage area, maximum, minimum, and average flow.

Table 19. Daily flow on selected dates. These are the daily flows for all the complete-record gaging stations in the study area (except those on the Savannah River), and for Canoochee River and Whitewater Creek outside the area. The flows are given at each of the stations on those days when flow measurements were made at partial-record gaging station sites in the study area. This provides pertinent information for those who wish to make their own studies of the relationships among the flows of the various streams.

Table 20. Annual minimum daily flow at complete-record gaging stations.

The data summarized in this table provide a comparison of the relative severity of the droughts that have occurred during the periods of operation of these stations.

Some special forms of presentation of data obtained at complete-record stations (figures 5 to 11) are included to illustrate general differences in flow characteristics of streams in the three physiographic regions and to show the available water supply. These data are given as flow per square mile of drainage area for better comparison and are presented in the form of graphs.

Comparisons of the flow characteristics of streams are the most significant if the data cover an identical period of record. Also, the longer the period of record, the more likelihood that the data will reflect long-term average conditions. For these reasons, the data shown in figures 5 to 11 have been given the following adjustments. The data for Briar Creek at Millhaven have been adjusted to values equivalent to the period 1931-53 on the basis of correlation with records for the gaging station on South Fork Edisto River near Denmark, S. C., which was operated for that period of time. This adjustment not only provides a longer base period but also provides an ap-

Table 18.—Summary of flow data for complete-record gaging stations discussed in this section.

(Figures of flow pertain to period of record shown)

Station	Drainage Area sq mi	Period of Record	Maximum Flow mgd	Minimum Daily Flow		Average Flow	
				mgd	mgd per sq mi	mgd	mgd per sq mi
Briar Creek at Millhaven, Ga.	656	April 1937 to September 1953	16,400	71	0.11	418	0.64
Ogeechee River near Louisville, Ga.	800	April 1937 to December 1949	13,300	56	.070	560	.70
Little River near Washington, Ga.	242	October 1949 to September 1953	8,470	6.5	.022	141	.48
Little River near Lincolnton, Ga.	574	January 1943 to March 1951	10,900	9.7	.017	331	.58
		January 1943 to September 1953*	10,900	9.7	.017	314	.55
Canoochee River near Claxton, Ga.	555	May 1937 to September 1953	7,820	.9	.0016	275	.50
Whitewater Creek near Butler, Ga.	75	October 1943 to September 1951	866	63	.84	101	1.35

*Extended April 1951 to September 1953 on basis of records for Little River near Washington.

Table 19.—Flow recorded at complete-record gaging stations on days when measurements were made at partial-record gaging stations.

Date	Ogeechee River nr. Louisville		Little River nr. Lincolnton		Little River nr. Washington		Briar Creek at Millhaven		Canoochee River nr. Claxton		Whitewater Creek nr. Butler	
	mgd	mgd per sq mile	mgd	mgd per sq mile	mgd	mgd per sq mile	mgd	mgd per sq mile	mgd	mgd per sq mile	mgd	mgd per sq mile
Oct. 10, 1942	*119	0.149					*143	0.218	*20	0.036		
Oct. 13, 1942	*119	.149					*149	.227	*14	.025		
Oct. 14, 1942	*115	.144					*150	.229	*13	.023		
Oct. 19, 1943	* 97	.12	*34	0.059			*136	.207	* 4.6	.0083	*80	1.1
Oct. 20, 1943	*108	.135	*34	.059			*136	.207	* 4.1	.0074	*80	1.1
Oct. 21, 1943	*101	.126	*32	.056			*136	.207	* 4.6	.0083	*80	1.1
Oct. 10, 1950			37	.064	23	0.079	114	.174	*23	.041	*80	1.1
Oct. 11, 1950			37	.064	23	.079	114	.174	*31	.056	*83	1.1
Oct. 12, 1950			32	.056	19	.065	114	.174	*28	.050	*83	1.1
Oct. 13, 1950			31	.054	16	.055	114	.174	*25	.045	*80	1.1
June 6, 1951					*39	.13	*114	.174	*10	.018	*70	.93
June 8, 1951					*258	.884	*151	.230	* 7.1	.013	*70	.93
Aug. 29, 1951			#23	.040	13	.044	91	.14	3.0	.0054	67	.89
Aug. 31, 1951			#22	.039	12	.041	88	.13	2.9	.0052	70	.93
Sept. 5, 1951			#19	.032	9.7	.033	83	.13	4.8	.0086	70	.93
Sept. 7, 1951			#18	.031	9.0	.031	83	.13	8.4	.015	77	1.0
Sept. 18, 1951					*36	.12	*164	.250	*23	.041	*71	.95
Sept. 19, 1951					*26	.089	*172	.262	*44	.079	*71	.95
Oct. 27, 1952			#29	.051	17	.058	134	.204	23	.041		
Oct. 28, 1952			#29	.051	17	.058	134	.204				
Oct. 29, 1952			#26	.046	16	.055	134	.204				
Oct. 30, 1952			#26	.046	16	.055	134	.204				
Oct. 31, 1952			#26	.046	16	.055	134	.204				
Nov. 5, 1952			#31	.054	19	.065	144	.220	12	.022		
Nov. 6, 1952			#30	.052	18	.062	144	.220	11	.020		
Nov. 7, 1952			#30	.052	18	.062	144	.220				

*Not base flow conditions.

#Estimated on basis of records for Little River near Washington.

Table 20.—Annual minimum daily flow at complete-record gaging stations.

Year Starting Apr. 1	Briar Creek at Millhaven Drainage Area 656 sq mi		Ogeechee River nr. Louisville Drainage Area 800 sq mi		Little River nr. Washington Drainage Area 242 sq mi		Little River nr. Lincolnton Drainage Area 574 sq mi		Canoochee River nr. Claxton Drainage Area 555 sq mi		Whitewater Creek nr. Butler Drainage Area 75 sq mi	
	mgd	mgd per sq mi	mgd	mgd per sq mi	mgd	mgd per sq mi	mgd	mgd per sq mi	mgd	mgd per sq mi	mgd	mgd per sq mi
1937	97	0.15	114	0.142					14	0.025		
1938	95	.14	78	.10					1.9	.0034		
1939	90	.14	97	.12					1.9	.0034		
1940	95	.14	97	.12					3.2	.0058		
1941	79	.12	64	.08					.9	.0016		
1942	106	.162	72	.09					1.9	.0034		
1943	111	.169	84	.10			22	0.038	1.7	.0031		
1944	116	.177	89	.11			9.7	.017	4.2	.0076	74	0.99
1945	71	.11	56	.07			14	.024	2.0	.0036	63	.84
1946	108	.165	74	.09			17	.030	3.0	.0054	78	1.0
1947	144	.220	87	.11			21	.037	3.2	.0058	66	.88
1948	196	.299	193	.241			28	.049	5.2	.0094	78	1.0
1949	205	.312	173	.216			51	.089	14	.025	90	1.2
1950	76	.116			14	0.058	22	.038	1.5	.0027	77	1.0
1951	76	.116			6.5	.027	*14	.024	2.1	.0038		
1952	88	.134			9.7	.040	*18	.031	2.6	.0047		

*Estimated on basis of records for Little River near Washington.

praisal of drought conditions (in 1935) more severe than any that occurred during the period of operation of the station on Briar Creek at Millhaven. Records for South Fork Edisto River were used only to accomplish this adjustment and are not reproduced in this report. Data for the other four complete-record stations shown in figures 5 to 11 were similarly extended and adjusted to values equivalent to the base period 1931-53 on the basis of correlations with Briar Creek at Millhaven.

Average discharge available without storage is shown in figure 5. The curves of this graph represent the lowest average flow for various lengths of time—from 1 day to 60 months—which may be expected to recur at average intervals of 10 years. These curves illustrate the very marked variations in water yield of the various streams during periods of below average flow. Due to the adjustment explained above, the 1-day minimum flows as shown by these curves are lower than 1-day minimum flows observed during the periods of operation of the stations.

Drought-frequency curves are shown in figures 6, 7, 8, 9 and 10. These show the probable frequency of occurrence of low flows of various magnitudes for each of the complete-record stations. The frequency with which the annual minimum daily flow, or average flow for other periods of time, can be expected to fall below certain values, may be read from the curves. For example, in figure 8, the daily flow of Briar Creek at Millhaven can be expected to fall below 0.14 mgd per square mile at average intervals of 2 years, and the average 60 day flow can be expected to fall below 0.24 mgd per square mile at average intervals of 2 years. This, of course, assumes that the distribution of flow for the period 1931-53 can be taken as an indication of the distribution of future streamflow. Because the data plotted are adjusted to the period 1931-53, each 1-day curve of figures 6 to 10 has a shape and position somewhat different from that which would be obtained by plotting the data listed in table 20.

The curves of figures 6 to 10 supplement and extend the data shown in figure 5. They further illustrate the general differences of flow characteristics exhibited by streams in different physiographic regions. The curves for Whitewater Creek near Butler, in the Fall Line Hills-Louisville Plateau, and curve for Canoochee River near Claxton, in the Tifton Upland, show the most extreme contrast.

Storage graphs are shown in Figure 11. The curves show the amount of storage required at average intervals of 10 years to provide the various draft rates. The curves have been drawn up to the draft rate which would consume all the na-

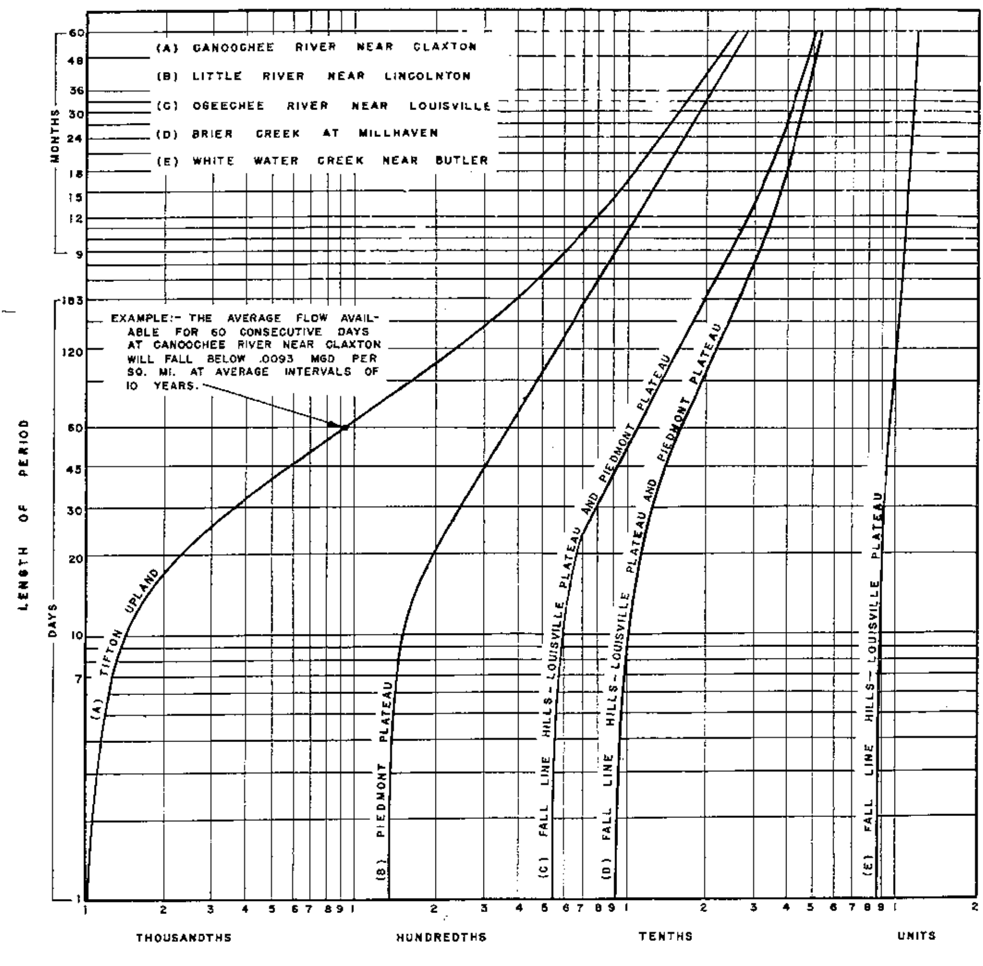

Figure 5. Discharge available without storage at various complete-record gaging stations based on the period 1931-53.
Note:—The average discharge shown in this diagram has a frequency of occurrence of once in 10 years; that is, a discharge this low can be expected to recur once every ten years on the average or for any particular year the chances are only 1 in 10 that it will be this low that year.

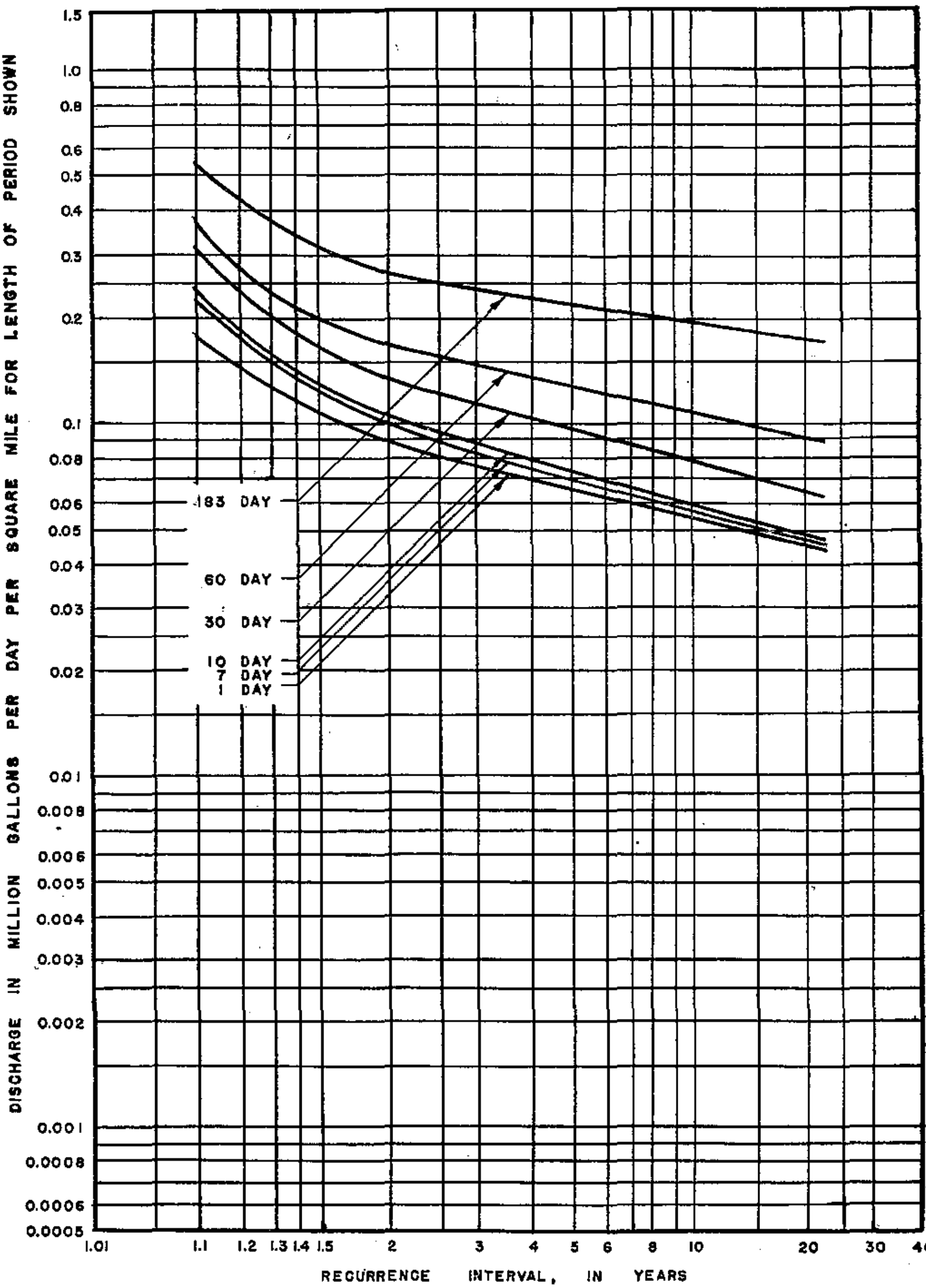

Figure 6. Drought-frequency curves. Ogeechee River near Louisville, Ga. (Based on the period 1931-53)

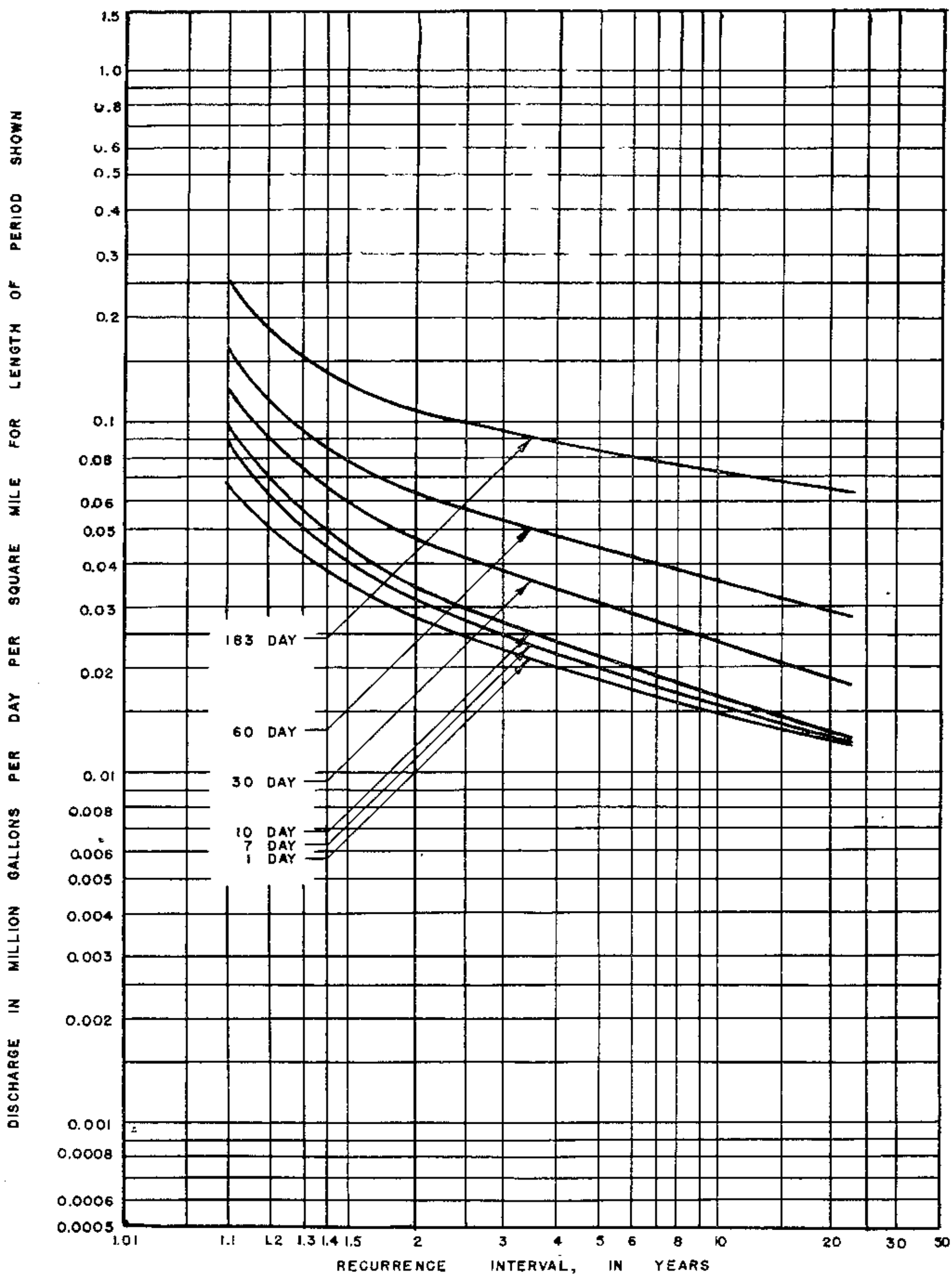

Figure 7. Drought-frequency curves. Little River near Lincolnton, Ga. (Based on the period 1931-53)

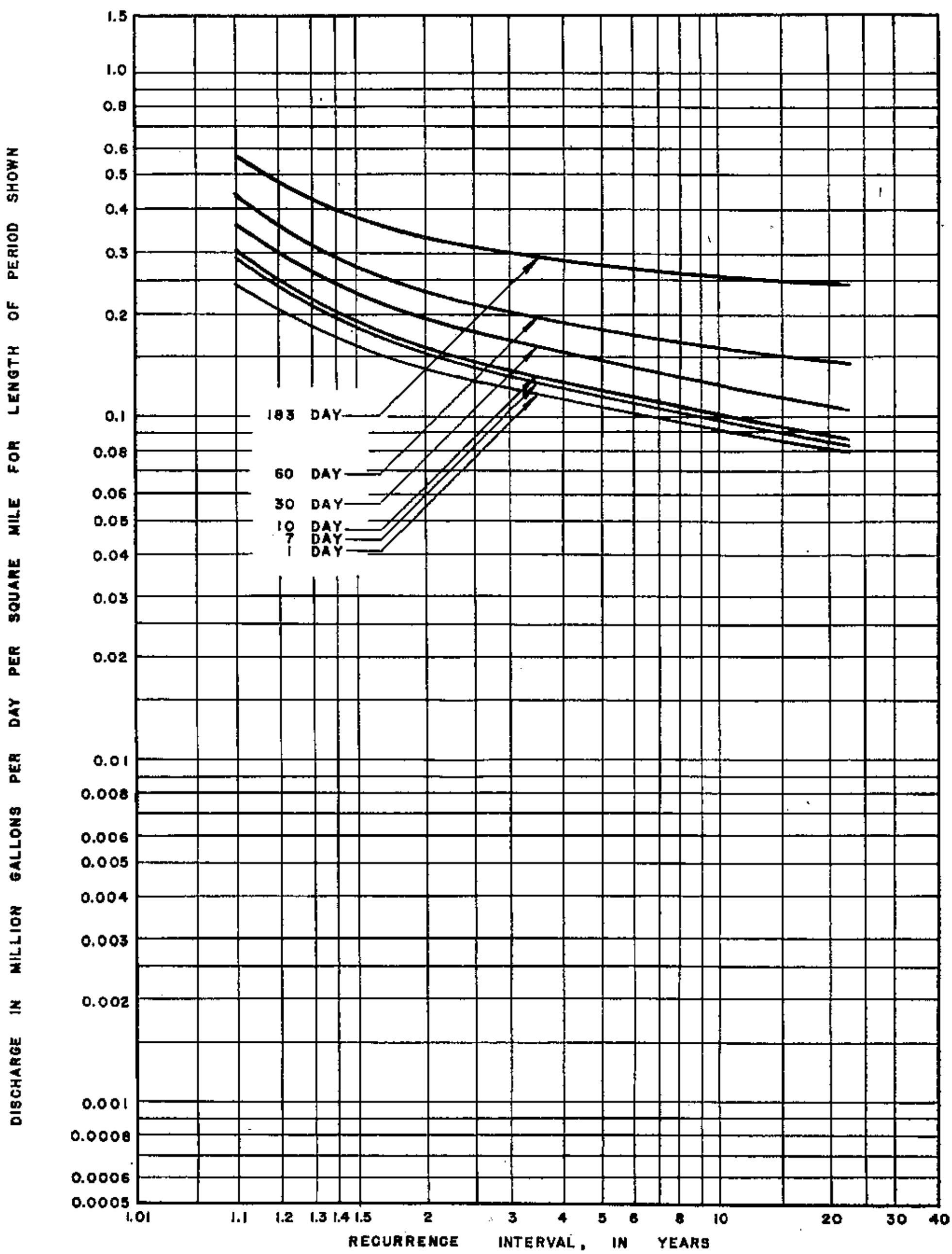

Figure 8. Drought-frequency curves. Briar Creek at Millhaven, Ga. (Based on the period 1931-53)

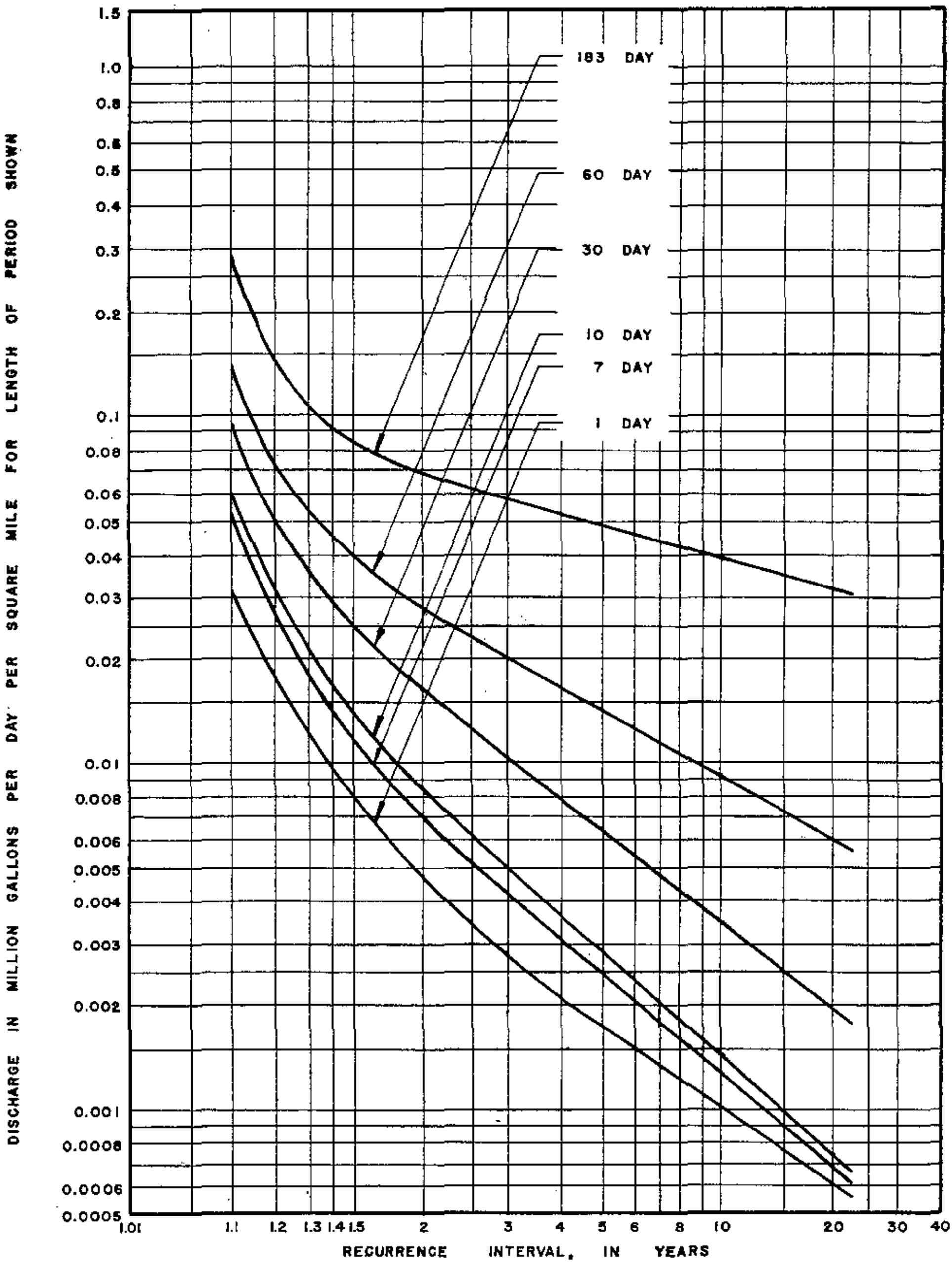

Figure 9. Drought-frequency curves. Canoochee River near Claxton, Ga. (Based on the period 1931-53)

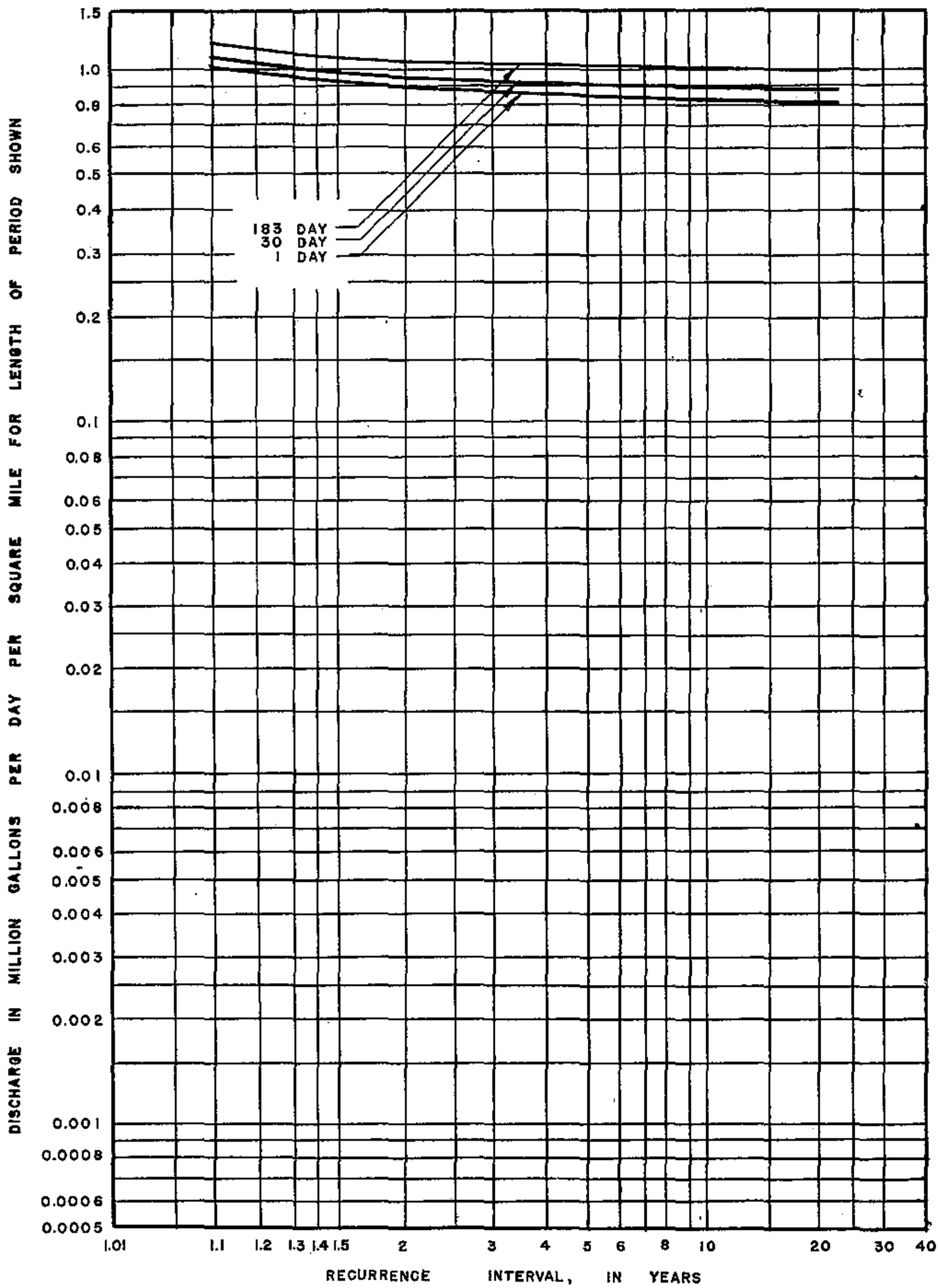

Figure 10. Drought-frequency curves. Whitewater Creek near Butler, Ga. (Based on the period 1931-1953)

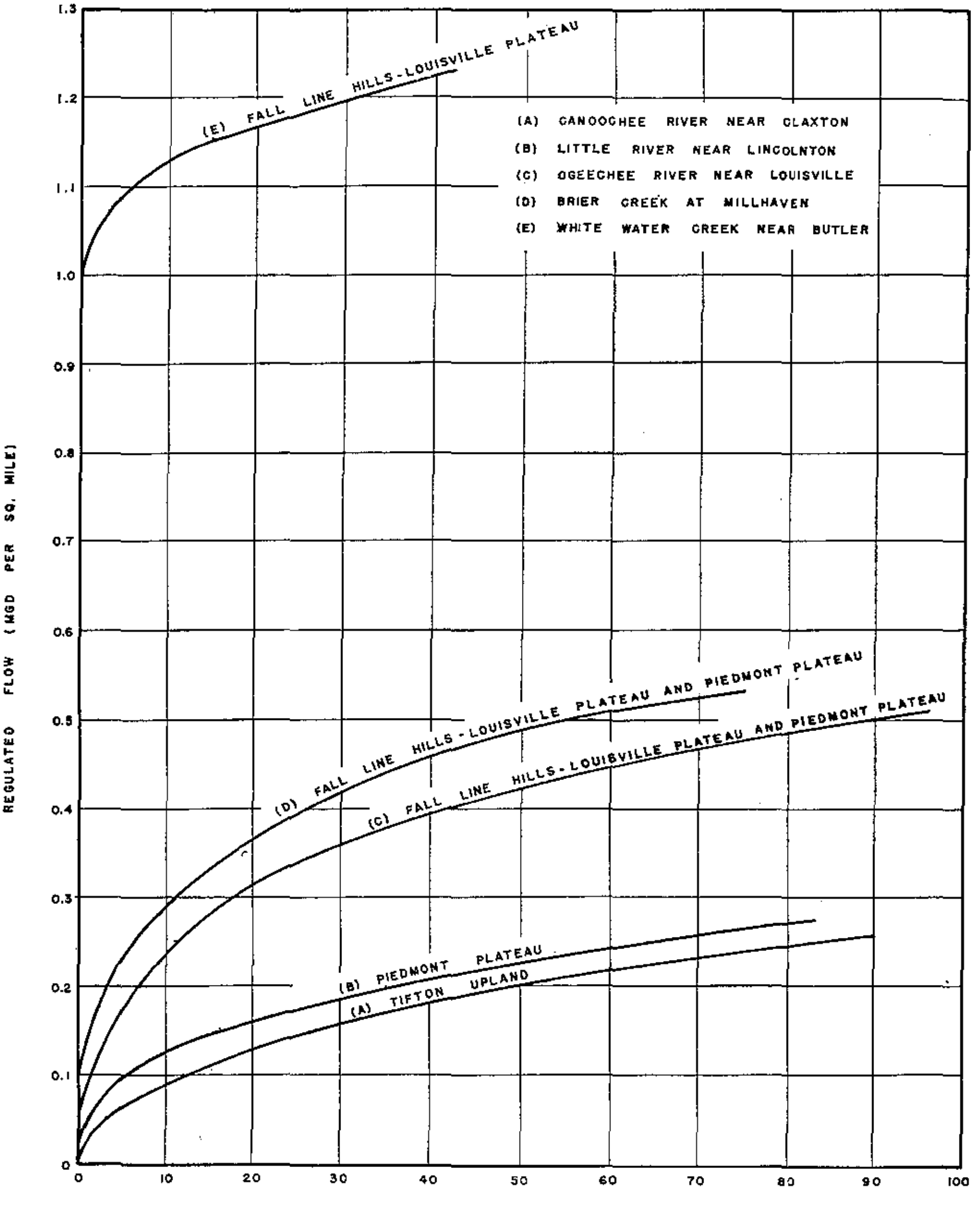

Figure 11. Storage graphs for various complete-record gaging stations. Note:—The storage required shown in this diagram would be required once every ten years on the average to sustain the regulated flow desired. Loss due to evaporation and seepage from reservoirs has not been considered in these graphs.

tural flow of the stream during the minimum 5-year period which would recur once each 10 years on the average if the period 1951-53 is taken as an indication of the distribution of future streamflow. Storage reservoirs with capacities greater than the maximum shown by these curves are unlikely to be built on streams in this section of Georgia without more extensive information than this report proposes to provide.

Losses resulting from evaporation and seepage from reservoirs would require special attention at any given reservoir site and have not been considered in drawing the curves of figure 11. On an annual basis evaporation losses from reservoirs in this area are partly compensated for by the water loss that would have occurred from the equivalent area under natural conditions had the reservoir not been built. Seepage losses are characteristic of the reservoir site and quality of dam construction, and do not lend themselves to general appraisal.

Partial-Record Gaging Stations

Partial-record gaging stations are those sites at which some (in the study area generally very few) streamflow measurements have been made, and which, in conjunction with complete-record gaging station records, may yield adequate streamflow information for many purposes. The data presented in this chapter are mostly for partial-record gaging stations.

Table 21, page 149, presents data for the partial-record gaging stations. It gives the stream name, location of the site on the stream, drainage area of the stream's basin (sometimes called watershed) above that site, and the date of each measurement of flow and the amount of that flow. The minimum flow estimated for the 1951 drought for most of the sites is also tabulated. As will be explained later a minimum daily flow as low as that experienced in 1951 can be expected to recur about every 3 years on the average.

The selection of partial-record gaging station sites deserves some comment. Opportunities to obtain base-flow measurements are usually short, so in order to make the best use of the limited time, sites are selected that have good measuring conditions, are readily accessible, and are easily identified both on maps and on the ground. Probable future needs for the information are considered; that is, most sites are selected near towns, villages, and railroads rather than in the more open countryside. The engineer making the measurements inspects the proposed sites and uses judgment in selecting those that promise to yield the most useful information for the work performed. Thus the points selected may be considered to be the best samples that can be obtained in the time available for the investigation.

FLOW RELATIONSHIPS

Flow relationships among gaging stations in Georgia are needed to obtain the greatest benefit from the investment in complete-record gaging stations. If a long-term complete-record gaging station record were available at each site where the information may eventually be needed, there would be little need to study flow relationships. Such gaging-station records at the sites of specific projects, however, are expensive to obtain and can be justified only where a large investment depends on the record. In arid parts of the west, where streamflows are appropriated virtually down to the last gallon and where there is much regulation and diversion, complete-record gaging stations may be required for each individual project. In the humid East, however, streamflows are not appropriated nor withdrawn from the stream to any great extent. It is frequently practical to interpolate streamflow data to project sites between gaging stations. The interpolation on major rivers is generally done on the basis of drainage-area ratios.

The application of gaging-station data to an ungaged site on the stream in proportion to the respective drainage areas has limitations. Where both drainage basins are similar in area and particularly when their physiographic conditions are similar, this drainage-area-ratio method, which is a standard engineering procedure, is usually reliable. Complications due to reservoir storage or powerplant operation must be considered. If, however, the method is applied to lesser streams, particularly those having drainage areas much smaller than the complete-record gaging station, serious errors may result. If the method were applied to streams in radically different physiographic regions, gross errors would result. Figures 5 to 11 show clearly the great differences in flows per unit of drainage area that exist in the three regions within the study area. It is obvious that more information than the size of the respective drainage basins is required in such a varied region before the existing gaging-station records can be applied to ungaged sites.

A single flow measurement at the ungaged site, if made at a favorable time, provides an enormous increase in factual flow information over what would be obtained by use of the drainage-area-ratio method. Obviously, such a measurement made during rapidly changing flood conditions or on a stream having powerplant regulation would have little meaning. However, if it is made under stable low-flow conditions, it may provide a better means of applying a gaging-station record to the site through the use of the discharge ratio. That is, the ratio between the simultaneous discharge at the gaging station and that at the ungaged site would be assumed to remain constant as the flow decreased, and thus provide a means of estimating minimum flows at the ungaged site. Within similar physiographic regions the discharge ratio has distinct advantages over the drainage-area ratio. Between dissimilar physiographic regions, however, it also may yield gross errors. It is obvious then, that a better flow relationship is needed before a gaging-station record may be safely applied to an ungaged site.

Relationship Principles

The principles of the relationships between streamflow at various sites are well established from analysis of records at complete-record gaging stations in many parts of the country. A graph of daily flow of such a record plotted with respect to time is called a hydrograph. Figure 12 shows annual hydrographs for three complete-record gaging stations for the year 1947. The hydrographs shown are typical of the physiographic regions in the area covered by this report and demonstrate marked differences in flow distribution throughout the year. A hydrograph of an unregulated Georgia stream shows severe irregularities most of the time with some more or less prolonged periods of relatively stable conditions. The irregularities are caused by storm runoff—floods or minor freshets following rainstorms. In the winter and spring months and in mid-summer, storm runoff is common and the hydrograph is normally quite irregular in those periods. For a brief period in late spring and a more extended period in autumn, the hydrograph is normally quite stable. These are the periods of base flow when most of the flow comes from ground-water seepage and there is little or no storm runoff. In the other periods, the storm runoff is imposed upon the base flow and makes the identification of base flows difficult, particularly on streams as large as those in the study area.

Comparisons of the flow between gaging stations during periods when storm runoff predominates are erratic. Relationships between concurrent station flows in these periods are difficult to establish and subject to large errors. However, there is a tendency for the periods with storm runoff to approach similar total or average amounts in proportion to drainage areas over long periods.

On the other hand, comparisons of the base flows between gaging stations, when they can be readily identified, yield well defined relationships subject to relatively small errors. If there is powerplant regulation at one or both stations or modification of the natural flow by reservoir storage or diversions the base-flow relationships may not be satisfactory. For this reason flow records from such gaging stations are not applied to other sites nor are natural flows applied to sites having regulated flow. Between unregulated streams, however, base-flow relationships are practical within reasonable distances if the flow characteristics from different physiographic conditions are fairly similar. The nearer the stations are to one another and the more similar the runoff characteristics, the better the relationships. As distance between drainage basins and differences in basin runoff characteristics increase, the probable deviations of concurrent flow from an average relationship increase and the reliability of the relationship decreases.

If sufficient time and resources (trained engineers and measuring equipment) were available, it might be possible to make enough flow measurements at ungaged sites to define accurately the relationship between them and complete-record gaging stations. However, the periods of base flow in Georgia are short and subject to sudden termination by showers, so the practical opportunities to obtain base-flow measurements are limited. Those measurements that are obtained tend to have similar runoff rates so that over a brief period of years it is unlikely that a great range of conditions can be established. It is, therefore, necessary to have a method of extending the base-flow relationship obtainable from flow measure-

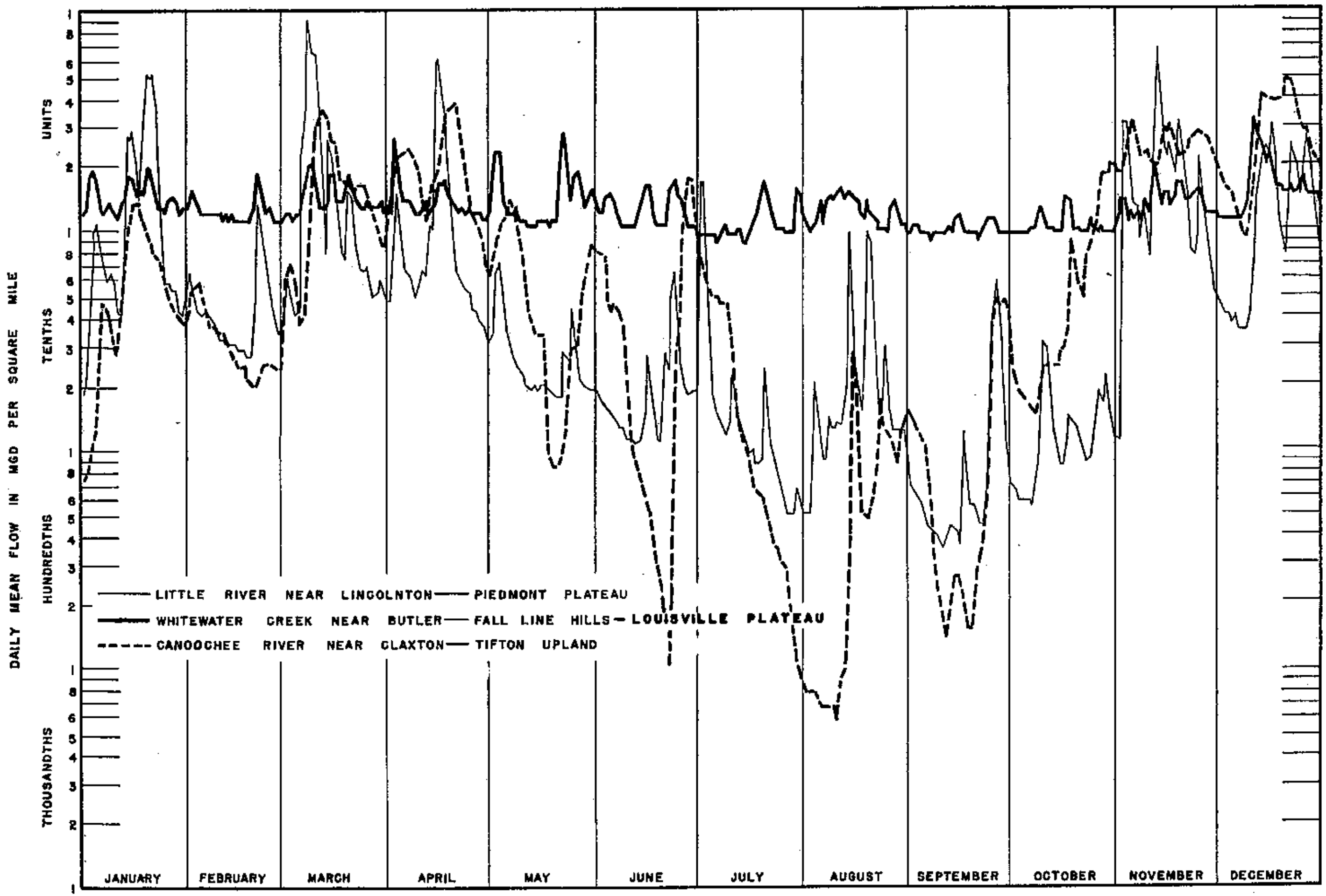

Figure 12. Annual hydrographs for 3 typical complete-record gaging stations for the year 1947.

ments upward toward average-flow conditions and downward to minimum-flow conditions.

The method of extending the relationship has been derived from studies of the relationships between complete-record gaging stations in several parts of the country. Within a region where the annual runoff of streams is relatively uniform and therefore the mean flow per unit of drainage area is similar for all gaging stations, it has been found that most streams will flow at nearly the same rate per unit of area for a short range of flow somewhat greater than the mean flow. The tendency for storm runoff to average out over a period causes this coincidence. This occurs despite the common differences in the low-water rates of flow or less common differences at higher flows. In other words, groups of relation curves tend to merge or cross at that flow. In Central-East Georgia, this merging tends to occur at a value 1.5 times the mean flow and this value has been adopted for the purpose of this study. This is termed the "control point" of the relationship curve. Any likely error in this value will not introduce serious errors in the following steps of the analysis. The studies that led to the adoption of this important control point for relation curves were conducted by Clayton H. Hardison, hydraulic engineer, of the Washington office of the Surface Water Branch.

Having established from studies of flow relationships between complete-record gaging stations a control point for the relationship considerably higher than the usual range of base-flow measurements, it becomes practical to establish the principles on which relationships may be defined between complete-record gaging stations and ungaged sites.

These principles are: First, base-flow relationship within a narrow range may be determined (by a few base-flow measurements); second, the flow relationship will merge with the equal yield line at a control point 1.5 times the average flow (determined from the complete-record gaging station); third, the relationship between these limits may be interpolated (usually by a straight-line graph on logarithmic plotting); fourth, the relationship may be extended to higher flows (usually by the drainage-area ratio if the drainage basins lie in physiographically and geologically similar regions); fifth, the relationship may be extended to lower flows within a narrow range (depending on the proximity of the sites and the similarity of the physiographic characteristics of the drainage basins).

Sites where the above principles can be applied and where systematic base-flow measurements are made are classed as partial-record gaging stations.

Application to Partial-Record Gaging Stations

The above relationship principles have been applied between complete-record gaging stations and partial-record gaging stations in the study area wherever it has been practical to do so. It has not been done for regulated streams nor at sites subject to diversions of flow. It has not been attempted for very small intermittent streams, as the entire flow of such small streams may be storm runoff. In the absence of complete-record gaging stations on streams with small drainage basins, it has not been considered practical to attempt to separate the storm runoff from the base flow, although this would have been practical if there had been complete-record gaging stations on small streams in the study area. Such information would be valuable for the design of irrigation ponds, pond spillways, and road culverts and ditches.

The present study of the flow relationships in the area has been handicapped by the limited opportunities to obtain base-flow measurements in the time available. Base-flow relationships are usually not constant in Georgia because unequal distribution of antecedent rainfall will cause variable base-flows from year to year and even from storm to storm. A yet undetermined number of base-flow measurements in different years and at different times are required to establish the average relationship and the probable range of deviations from this average. Fortunately, the base-flow measurements made in 1951 were unusually low and a good basis for estimating the 1951 minimum flows. There were not enough data, however, to justify the publication of estimates of minimum flows at partial-record gaging stations for stipulated frequencies.

Figure 13 shows a typical relationship curve between a partial-record station (No. 20, McBean Creek at State Highway 56) and a complete-record station (Briar Creek at Millhaven).

Measured flows at the partial-record station (from table 21) were plotted against corresponding flows at the complete-record station (from table 19). The only data selected were those that represented base flow conditions at both stations. The values used are in terms of flow per square mile of drainage basin to eliminate the effect of unequal drainage areas for study purposes. A simple comparison for one site can be made equally well from the actual flows at the stations.

The control point is 1.5 times the average flow of the complete-record gaging station taken from Table 18. The average flow was divided by the drainage area to reduce it to flow per square mile.

The relationship curve of figure 13 was drawn through the

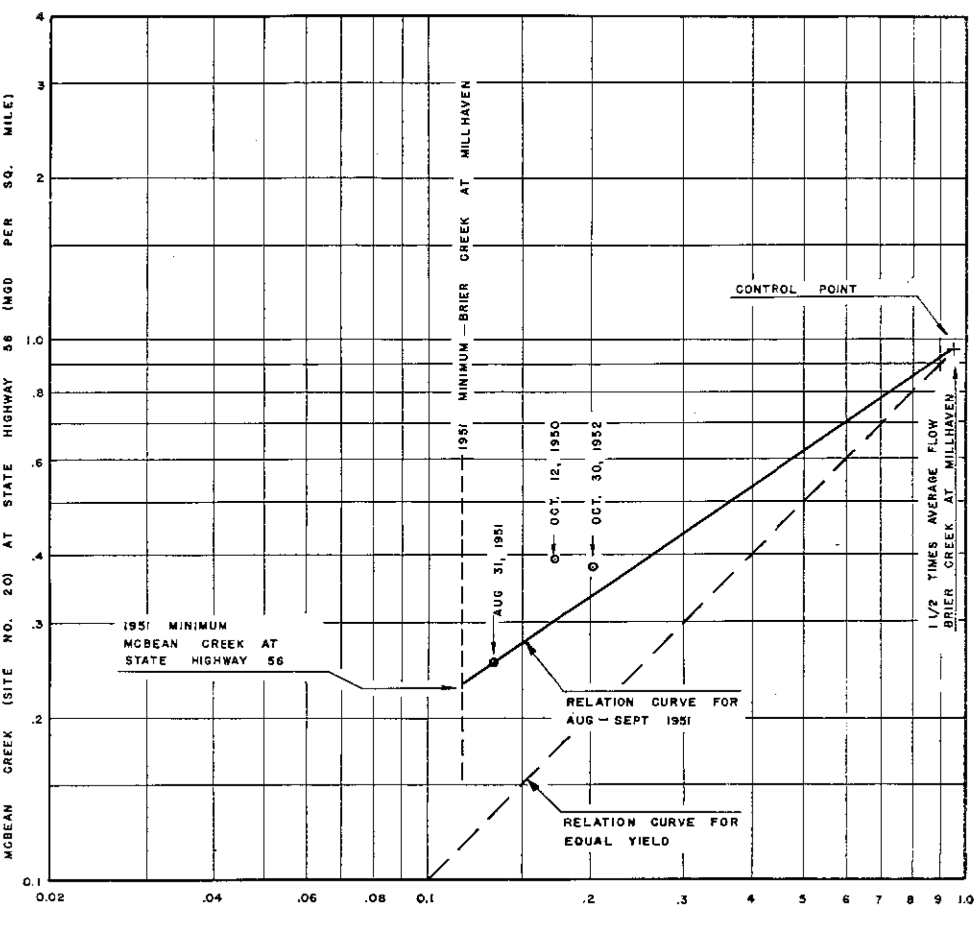

Figure 13. Base flow relation curve for Briar Creek at Millhaven and McBean Creek at State Highway 56.

control point and the point representing the measurement made in August 1951. Obviously, this relationship curve is applicable to the low-flow period of August-September 1951 but does not represent the low-flow periods of October 1950 and October 1952 during which the other plotted measurements were made. Somewhat different relationship curves would have to be drawn to apply to these periods, and an average relationship curve would require several more measurements to define it adequately.

The 1951 relationship curve has been extended downward to the 1951 minimum flow at the complete-record station (from table 20). The minimum flow for the partial-record station can then be read on the proper scale. Although this involves extrapolation beyond observed data, a dangerous practice with hydrologic information, the 1951 measurements were made so close to the 1951 minimums that the short extrapolation is unlikely to introduce a serious error.

From an examination of the annual minimum flows that have occurred at complete-record gaging stations (see table 20), it is apparent that the drought of August-September 1951 was very nearly the most severe since most of the records began in 1937, and consequently was an unusually significant drought condition. For this reason, estimates of the minimum flow during this drought were made for all the partial-record stations in the study area for which such estimates could be made with reasonable confidence. The estimates are listed in the last column of table 21. According to the 1-day curves on figures 7-9, a daily discharge as low as the minimum daily discharge for 1951 at Little River near Lincolnton, Briar Creek at Millhaven, and Canoochee River near Claxton can be expected to recur about every 3 or 4 years on the average.

In order to make these estimates, the complete-record station with drainage basin lying most nearly in the same physiographic province as each of the various partial-record stations (see note at end of table 21) was selected and relationship curves similar to that of figure 13 constructed. For those partial-record stations where a measurement during the 1951 drought was available, the relationship curve was drawn through this measurement and the estimate made as explained above.

Table 21.—Low-flow measurements and estimated flow at partial-record gaging stations.

Map Reference No. (See Fig. 4)	Stream	Location	Drainage area (sq mi)	Measurement			Minimum estimated flow (1951)	
				Date	Flow			
					mgd	mgd per sq mi	mgd	mgd per sq mi
1	Hart Creek	At county road 2 miles northwest of Wrightsboro	15.5	Oct. 14, 1942	*1.0	0.065	0	0
				Oct. 13, 1950	.14	.009		
				Sept. 5, 1951	0	0		
				Oct. 28, 1952	.46	.030		
2	Mattox Creek	At State Highway 223 near Thomson	10	Oct. 28, 1952	.01	.001	0	0
3	Kiokee Creek	At State Highway 47 at Appling	43.9	Oct. 31, 1952	3.4	.077	1.3	.030
4	Greenbriar Creek	At State Highway 47 near Appling	33.3	Oct. 14, 1942	*2.8	.085	1.0	.030
				Oct. 13, 1950	1.9	.056		
				Sept. 7, 1951	1.4	.041		
				Oct. 31, 1952	2.6	.077		
5	Kiokee Creek	At State Highway 104 near Rosemont	106	Oct. 31, 1952	5.6	.052	2.2	.021
6	Little Kiokee Creek	At State Highway 232 near Appling	13.6	Oct. 31, 1952	.42	.031		
7	Uchee Creek	At Wrightsboro Road 2 miles northwest of Groveton	24.2	Oct. 14, 1942	.32	.013		
8	Uchee Creek	At State Highway 104 near Evans	58.3	Oct. 31, 1952	.73	.012	.26	.0045
9	Reed Creek	At State Highway 104 near Evans	5.81	Oct. 31, 1952	.61	.10		
10	Raes Creek	1 mile upstream from State Highway 28 at Augusta	16.1	Oct. 31, 1952	1.3	.080		
11	Rocky Creek	At U. S. Highway 1 near Augusta	10.5	Oct. 30, 1952	1.9	.18	1.0	.097
12	Butler Creek	1 mile upstream from U. S. Highway 1 near Augusta	13.2	Oct. 30, 1952	2.4	.18	1.3	.097

*Not base flow conditions.

Table 21.—Low-flow measurements and estimated flow at partial-record gaging stations.

Map Reference No. (See Fig. 4)	Stream	Location	Drainage area (sq mi)	Measurement			Minimum estimated flow (1951)	
				Date	Flow			
					mgd	mgd per sq mi	mgd	mgd per sq mi
13	Butler Creek	At U. S. Highway 25 near Augusta	29.4	Oct. 12, 1950	14	0.46	4.3	0.15
				June 8, 1951	*13	.45		
				Aug. 31, 1951	4.9	.17		
				Oct. 30, 1952	7.9	.27		
14	Spirit Creek	At U. S. Highway 1 near Augusta	18.0	Nov. 6, 1952	10	.56		
15	Spirit Creek	At Windsor Springs Road near Hephzibah	50.3	Oct. 13, 1942	*31	.62		
#16	Spirit Creek	At U. S. Highway 25 near Hephzibah	54.0	Oct. 12, 1950	32	.59		
				June 8, 1951	*32	.59		
				Aug. 31, 1951	13	.24		
				Oct. 30, 1952	37	.69		
#17	Spirit Creek	At State Highway 56 near McBean	71.1	Oct. 30, 1952	35	.49		
18	Little Spirit Creek	At State Highway 56 near McBean	28.3	Oct. 30, 1952	10	.36	5.7	.20
19	McBean Creek	At U. S. Highway 25 near McBean	41.4	Oct. 20, 1943	*20	.49	9.1	.22
				Oct. 29, 1952	16	.39		
20	McBean Creek	At State Highway 56 at McBean	70.0	Oct. 12, 1950	27	.39	15	.23
				June 8, 1951	*22	.31		
				Aug. 31, 1951	17	.25		
				Oct. 30, 1952	27	.38		
21	Briar Creek	At State Highway 12 near Warrenton	9.4	Oct. 28, 1952	.07	.0070		
22	Briar Creek	At State Highway 17 near Thomson	55	Oct. 13, 1942	* .4	.0074		
				Oct. 19, 1943	* .1	.0017		
				Oct. 27, 1952	2.1	.039		

*Not base flow conditions.
#Subject to regulation.

Table 21.—Low-flow measurements and estimated flow at partial-record gaging stations.

Map Reference No. (See Fig. 4)	Stream	Location	Drainage area (sq mi)	Measurement: Date	Measurement: Flow mgd	Measurement: Flow mgd per sq mi	Minimum estimated flow (1951): mgd	Minimum estimated flow (1951): mgd per sq mi
23	Sweetwater Creek	At U. S. Highway 78 near Thomson	7.46	Oct. 27, 1952	0.8	0.11		
24	Little Briar Creek	At State Highway 17 near Thomson	24	Oct. 10, 1950	.6	.024		
				Sept. 7, 1951	.2	.0065		
				Sept. 19, 1951	*2.0	.081		
				Oct. 27, 1952	3.4	.14		
25	Briar Creek	At U. S. Highway 1 near Keysville	171	Oct. 13, 1942	*11	.067	11	.063
				Nov. 6, 1952	18	.10		
26	Sandy Run	At U. S. Highway 1 near Blythe	33.2	Oct. 13, 1942	*12	.37	9.0	.27
				Nov. 6, 1952	14	.42		
27	Briar Creek	At State Highway 88 at Keysville	297	Oct. 21, 1943	*70	.24	48	.16
				Oct. 10, 1950	74	.25		
				June 8, 1951	*56	.19		
				Aug. 31, 1951	56	.19		
				Nov. 6, 1952	77	.26		
28	Brushy Creek	At State Highway 16 near Stapleton	1.38	Oct. 29, 1952	0	0	0	0
29	Brushy Creek	At U. S. Highway 1 at Wrens	9.40	Oct. 10, 1942	*1.5	.16	1.2	.13
				Oct. 19, 1943	*1.6	.17		
				Oct. 11, 1950	1.5	.16		
				Sept. 18, 1951	*3.6	.38		
				Oct. 29, 1952	1.9	.20		
30	Brushy Creek	At Middle Ground Road near Keysville	40.7	Oct. 21, 1943	*12	.31	6.9	.17
				Oct. 29, 1952	11	.26		
31	Briar Creek	At State Highway 56 near Waynesboro	473	Oct. 21, 1943	*100	0.21	52	0.11
				Oct. 12, 1950	94	.20		
				Aug. 31, 1951	63	.13		
				Nov. 7, 1952	96	.20		
32	McIntosh Creek	At U. S. Highway 25 at Waynesboro	6.80	Nov. 6, 1952	.8	.12		

*Not base flow conditions.

Table 21.—Low-flow measurements and estimated flow at partial-record gaging stations.

Map Reference No. (See Fig. 4)	Stream	Location	Drainage area (sq mi)	Measurement			Minimum estimated flow (1951)	
				Date	Flow			
					mgd	mgd per sq mi	mgd	mgd per sq mi
33	Long Creek	At county road 6 miles southwest of Warrenton	13	Oct. 28, 1952	.4	.031	.10	.0078
34	Long Creek	At county road 1 mile northeast of Jewell	34	Oct. 13, 1942 Oct. 28, 1952	* .8 .7	.024 .020	.17	.0050
35	Ogeechee River	At State Highway 16 at Jewell	240	Oct. 13, 1950 Sept. 7, 1951 Sept. 19, 1951 Oct. 28, 1952	6.0 3.0 * 6.0 7.8	.025 .013 .025 .032	2.0	.0084
36	Ogeechee River	At State Highway 24 near Louisville	495	Oct. 19, 1943 Oct. 28, 1952	* 46 30	.092 .060	15	.030
37	Rocky Comfort Creek	At county road 3 miles west of Warrenton	15	Oct. 28, 1952	.2	.012	0	0
# 38	Rocky Comfort Creek	At State Highway 16 near Warrenton	27	Oct. 13, 1942 Oct. 13, 1950 Sept. 7, 1951 Sept. 19, 1951 Oct. 28, 1952	* .9 .2 0 0 .3	.034 .090 0 0 .010	0	0
39	Goldens Creek	At State Highway 12 at Warrenton	7.1	Oct. 28, 1952	0	0	0	0
40	Rocky Comfort Creek	At State Highway 80 at Gibson	94	Oct. 18, 1943 Oct. 29, 1952	* 2.5 2.2	0.026 .023	0.61	0.0065
41	Rocky Comfort Creek	At State Highway 24 at Louisville	286	Oct. 19, 1943 Oct. 11, 1950 June 7, 1951 Aug. 29, 1951 Oct. 28, 1952	*69 47 *72 42 52	.24 .16 .25 .15 .18	34	.12

*Not base flow conditions.
#Subject to regulation.

Table 21.—Low-flow measurements and estimated flow at partial-record gaging stations.

Map Reference No. (See Fig. 4)	Stream	Location	Drainage area (sq mi)	Measurement: Date	Measurement: Flow mgd	Measurement: Flow mgd per sq mi	Minimum estimated flow (1951): mgd	Minimum estimated flow (1951): mgd per sq mi
42	Big Creek	At Penns Bridge Road near Wrens	8.07	Oct. 29, 1952	2.2	.27	1.5	.18
43	Big Creek	At Middle Ground Road near Louisville	56.9	Oct. 10, 1942	*23	.41	11	.20
				Oct. 19, 1943	*24	.42		
				Oct. 28, 1952	18	.31		
# 44	Big Creek	At State Highway 17 near Louisville	95.8	Oct. 11, 1950	14	.15		
				June 6, 1951	*29	.30		
				Aug. 29, 1951	32	.33		
45	Williamson Swamp Creek	At State Highway 78 at Bartow	185	Oct. 19, 1943	*35	.19	13	.071
				Oct. 11, 1950	28	.15		
				June 6, 1951	*18	.10		
				Aug. 30, 1951	16	.086		
				Oct. 28, 1952	28	.15		
46	Nails Creek	At State Highway 78 near Bartow	5.7	Oct. 27, 1952	.04	.0066		
47	Gray Coat Creek	At State Highway 78 near Bartow	9.0	Oct. 27, 1952	.04	.0042		
48	Williamson Swamp Creek	At U. S. Highway 1 at Wadley	232	Oct. 11, 1950	22	.094	14	.061
				June 6, 1951	*23	.097		
				Aug. 29, 1951	18	.079		
				Oct. 27, 1952	28	.12		
49	Rocky Creek	At State Highway 24 near Waynesboro	31.7	Nov. 5, 1952	0.8	0.024	0.14	0.0044
50	Rocky Creek	At State Highway 56 near Waynesboro	34.8	Oct. 20, 1943	*1.4	.039	.18	.0051
				Nov. 5, 1952	1.0	.028		
51	Buckhead Creek	At State Highway 56 near Waynesboro	63.7	Oct. 20, 1943	*2.9	.045	.33	.0052
				Nov. 5, 1952	1.8	.028		

*Not base flow conditions.

#Subject to regulation.

Note: Records for Little River near Washington were used to estimate 1951 minimum flows for Nos. 1-5, 8, 33-35, 37-40; records for Briar Creek at Millhaven were used to estimate 1950-51 minimum flows for Nos. 11-13, 18-20, 25-31, 36, 41-43, 45, 48; records for Canoochee River near Claxton were used to estimate 1950-51 minimum flows for Nos. 49-51.

For those partial-record stations where a measurement during the 1951 drought was not available, the position of the relationship curves for the 1951 drought was determined by a comparison process. For all sites where both a 1952 measurement and one during the 1951 drought were available, the ratio of the 1951 measurement to the 1952 measurement was determined. These ratios showed only small variation from station to station throughout the Piedmont Plateau and Fall Line Hills-Louisville Plateau Areas. It was assumed that if 1951 measurements had been made, they would have shown comparable ratios. For stations in these areas where no 1951 measurement was available, a "synthetic" 1951 flow was computed from the ratios between 1951 and 1952 measurements at nearby stations. Only minor interpolation between measured ratios was needed. The synthetic points were considered sufficiently reliable to be used for estimating the 1951 minimum at stations without a 1951 measurement, provided that the drainage area exceeded 25 square miles. Both the 1951 and 1952 measurements were made during a two- or three-day period when base-flow conditions were obviously well established over the study area.

No 1951 measurements were available at any partial-record stations in the Tifton Upland. Instead, the ratio of the 1951 minimum flow of Canoochee River at Claxton to the flow at this station on the days when 1952 measurements were made at partial-record stations in the Tifton Upland was applied to the 1952 measurements at the partial-record stations to estimate their 1951 minimums. These estimates are less reliable than those for stations in the Piedmont Plateau and Fall Line Hills-Louisville Plateau.

During drought periods when seepage from ground water is supplying the base flow of streams, it is possible for some of the seepage from a drainage basin to bypass the surface outlet as underground flow and appear as surface runoff at some downstream site. For instance, partial-record station No. 28 (figure 4 and table 21), situated in the high yield area of the Fall Line Hills-Louisville Plateau, had no flow in October 1952. This suggests that the underground drainage basin contributing flow to a given site may not be equivalent to the surface drainage basin. Such possibility would not be likely to cause serious errors in flow estimates made by the above method except for stations with very small drainage areas.

For this reason, estimates of the 1951 minimum flow have not been made at some of the partial-record stations where the drainage areas are less than 25 square miles. However, if an observation of zero flow was made in 1951 at a site with a small drainage area or at some downstream site on the same stream, an estimate of zero for the 1951 minimum is included. Also, if the 1951 minimum estimate, based on measurements made in 1952, at a site with a small drainage area is in close agreement with the estimate for a site with a much larger drainage area downstream (thereby indicating little or no underground leakage effect), the estimate for the small drainage area has been included.

As already stated no estimates were made for sites known to be subject to serious man-made regulation. The reason for this may be illustrated by considering the conditions of flow on a stream having a large mill pond. So long as there is sufficient flow to keep the mill pond full and overflowing its spillway, the flows above and below the pond will remain nearly the same. (The evaporation loss from the pond may be a relatively small factor). Suppose, however, that the flow decreases until it no longer keeps the mill pond full. If the dam is perfectly tight, evaporation may consume all the inflow and the flow below the pond will be zero. A measurement above or a measurement below the pond will not accurately show the flow at the other place. If the mill dam leaks badly, the mill pond will lower as the leaks allow water to be withdrawn from storage. In this case, the flow below the mill pond may be considerably greater than that into the pond.

Every variation of these possibilities can be found in an area having many farm ponds and mill dams. Estimates for streams having mill ponds immediately above the partial-record station site were avoided but there probably were a number of farm ponds in the drainage basins of those sites where estimates were made. No information is available with which to evaluate the possible effects of the ponds during the 1951 drought. However, because such ponds rarely have either inflow or outflow during prolonged droughts, it is unlikely that the presence of ponds seriously affected those minimum flows.

The estimates of minimum flow during the 1951 drought are shown on a map of the area (see figure 14) as well as in table 21. The effect of geology on low streamflow is strikingly evident from this map. The reader should note the difference between flows of the streams in the Fall Line Hills-Louisville Plateau and those in the Piedmont Plateau and Tifton Upland. In this region of similar rainfall it is obvious that geology is by far the most important element affecting geographic differences in streamflow, exceeding the effect of rainfall distribution or land cover.

Minimum Flow

At the present time, nearly all the preliminary consideration for the use or development of a stream in Georgia is based on the minimum flow of the stream. No generally acceptable definition of "minimum flow" has ever been established. By definition "minimum" is generally understood to mean the lowest instantaneous flow ever known. Practically, however, the lowest daily mean flow that may be expected once in every 5 to 15 years on an average is almost as significant. For the complete-record gaging stations in the central-east Georgia area, this flow can be obtained from the 1-day curves on figures 6-10. For partial-record stations, the 1951 minimum shown in table 21 may be considered to be the lowest daily mean flow that may be expected about every 3 or 4 years on the average. The discharge to be expected every 10 years would be lower than this figure, with the percent difference depending on the low-flow characteristics of the streams. For streams in the Fall Line Hills-Louisville Plateau the difference between the discharge at the two frequencies would be much less than on streams in the Tifton Upland.

In many problems, the lowest weekly mean flow would be adequate if all the facts could be appraised. Unfortunately, many people who deal with water-supply problems are inclined to confuse "minimum" with "normal" streamflows and not to appreciate the wide differences in flow that natural streams exhibit or the vastly greater differences caused by man-made operations. Standard mill-dam operations, for example, call for releasing a full-wheel capacity of flow long enough to grind a few bushels of corn after which the flow may be shut off altogether for hours while the mill pond slowly refills. The Clark Hill hydroelectric plant can, in a matter of seconds, change the flow below the dam from zero to 22,000 million gallons per day, which could cause a rise of 17 feet in the river. However, in actuality, violent changes on the Savannah River are controlled by manipulation of the

Stevens Creek reservoir below Clark Hill Dam in such a way as to maintain a practically constant flow at Augusta.

One who desires to know the minimum flow at any of the 51 partial-record stations listed in table 21 will need first to define "minimum" in his own mind. If he means an all-time absolute figure, this report will not aid him, for it is doubtful if that phenomenon has been experienced during the period that the streams have been gaged except at those six sites where zero is shown in the last column of table 21 (and for

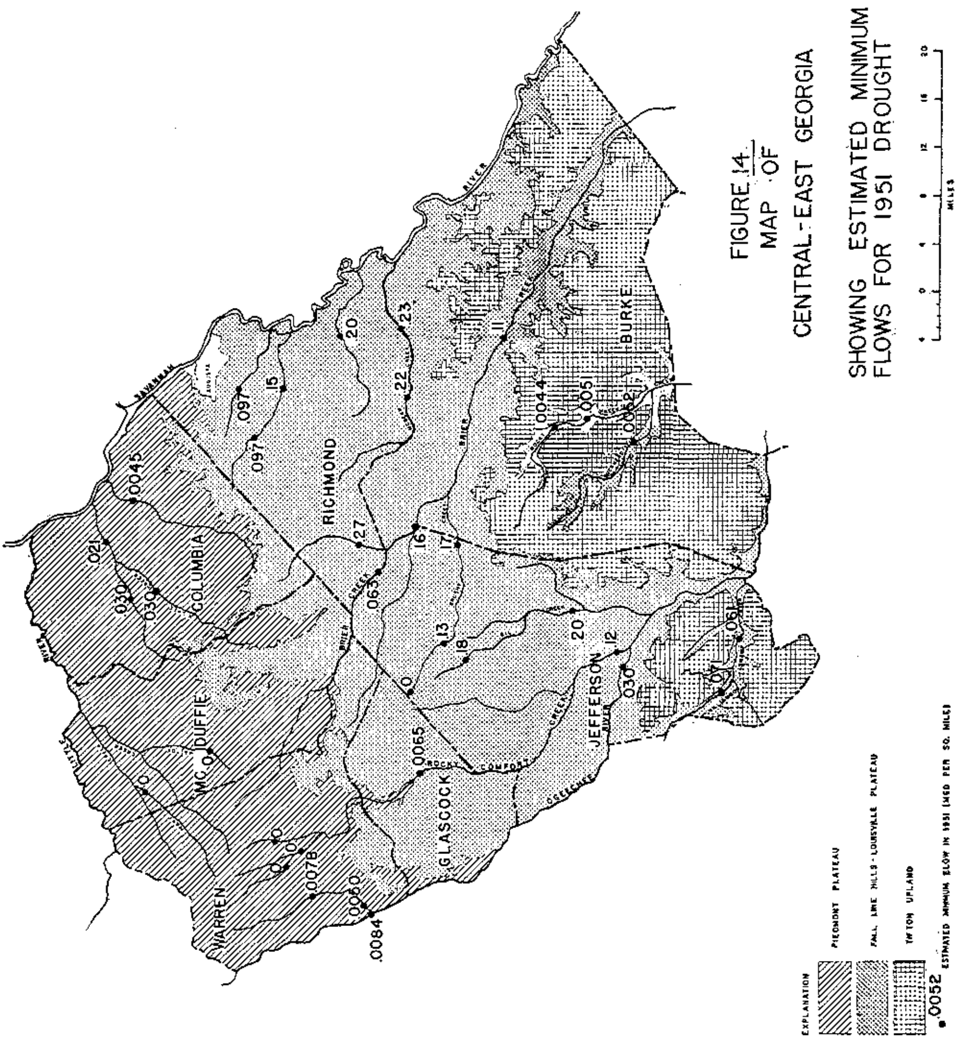

FIGURE 14. MAP OF CENTRAL-EAST GEORGIA SHOWING ESTIMATED MINIMUM FLOWS FOR 1951 DROUGHT

those it is not known for how long or how often they are dry). If he desires to consider the 1951 minimum a satisfactory indication of low-flow availability, reasonably reliable estimates for 35 sites have been computed. One should approach with caution any attempt to make estimates at the other 16 sites because intensive studies of these data have not shown sufficiently reliable results to warrant publishing estimates at this time. It may be practical to do so in the future on the basis of data that will continue to be collected.

Discharge Available Without Storage and Drought Frequency

The estimates of minimum flow in table 21 give only one feature of the low-flow characteristics of the partial-record stations. A better appraisal of these characteristics requires some knowledge of the length of time the flow is likely to remain at or near the minimum and the frequency with which such low flows are likely to occur.

The records obtained at complete-record stations provide the data needed to compute not only the minimum daily flow during the period of record at these stations but also the minimum average flow for various other periods of time (see figure 5) as well as the probable frequency of occurrence of these events (see figures 6 to 10). Similar information for partial-record stations often can be estimated by use of a relationship curve for each partial-record station and the appropriate complete-record station.

Before attempting estimates of minimum flows and their frequency, the nature of the relationship curves should be reconsidered. As explained previously, the position of the line or relationship for two gaging stations changes from time to time within a range which is, at present, unpredictable because of the few measurements now available at each partial-record site. For this reason, any estimates or curves of discharge available without storage (similar to figure 5) or drought frequency curves (similar to figures 6 to 10) for any of the partial-record stations must be considered as rough approximations. In spite of this limitation, such estimates may be made and, when used with caution, can serve a useful purpose.

One who may wish to estimate such curves for a partial-record station must first construct the necessary relationship curve. The points for this curve should be plotted in the manner previously described under "Flow Relationships". Most of the usable base-flow measurements at stations in the Piedmont Plateau area were made after the station on Little River at Lincolnton was discontinued. Estimates of the flow at this station on certain dates (based on a relationship with the station on Little River at Washington) were made and are listed in table 19 to allow relationship curves between this relatively long-record station and Piedmont Plateau partial-record stations to be drawn.

In drawing the curves, it is advisable to stay on the conservative side, that is, to draw the curve through the point representing the lowest flow at the partial-record station in relation to the flow at the complete-record station. If only one measurement is available, the relationship curves for nearby stations could be examined to determine the probable position of a conservatively drawn relationship curve with respect to this one measurement.

Once the relationship curve has been constructed, values of discharge available without storage, from the curve for the complete-record station, can be transformed by means of the relationship curve to corresponding values for the partial-record station and a curve similar to those in figure 5 produced for the partial-record station. This process can be used to produce drought-frequency curves also, but it should not be applied to the storage curves of figure 11.

As an example of the use of the relationship curve, figures 5 and 8 show that the minimum average flow of Briar Creek at Millhaven for 60 days, to be expected once in 10 years, is 0.16 mgd per square mile. Figure 13 (which shows the most conservative relationship curve that can be drawn on the basis of observed data) indicates that the corresponding flow at partial-record station No. 20 (McBean Creek at State Highway 56) is 0.28 mgd per square mile. This value multiplied by the drainage area of station No. 20 (from table 21) is the estimated minimum average flow for 60 days, to be expected once in 10 years, at partial-record station No. 20. The average flow for 60 days that may be expected with greater or less frequency may be determined from figures 8 and 13 in a similar manner.

Continuing studies of partial-record stations and their relation to complete-record stations are being made. Some of the limitations and uncertainties that now apply to estimates of partial-record station flow characteristics will eventually be eliminated. These studies and the collection of more base data will provide means for closely defining the average relationship curve for complete-record and partial-record stations and methods for evaluating the probable errors to be expected in these types of estimates of streamflow data.

In the meantime, it is emphasized that the methods of making estimates described above should be used only for rough preliminary calculations. The advice of competent engineers, familiar with the type of problem, should be obtained to insure sound design of any elaborate project involving the use of a stream in the study area.

Storage

The minimum flow is not the sole answer to water-supply questions in this area, although at the present time there are but few demands for more complete information about the lesser streams. If all water factors for an industrial development are favorable except water supply, it may still be practical to obtain a greater supply of water by the manipulation of storage reservoirs to regulate the flow, that is, to store flood waters for later release in drought season.

Reservoirs are the only practical means of regulating streamflow in the area. The reservoirs that are required for municipal or industrial purposes will almost always be serious undertakings that under Georgia Law will require design by licensed engineers. Thus, in keeping with the general purposes of this report, estimates of data pertaining to storage reservoir design for the partial-record sites have not been attempted.

Streamflow information for storage-reservoir purposes may include average-flow data that define the ultimate dependable flow that may be developed at a stream site, flow-volume data that establish storage volumes necessary to sustain flows greater than the minimum up to the average, flood data that establish spillway and bridge capacities and levee heights, and frequency data that provide the basis for economic appraisal of costs and benefits.

Application to Ungaged Sites

One may wish to estimate streamflow for a site on a lesser stream of the study area at which there are no measurements of flow. The first step is to locate the site accurately on the best map available. Delineate the drainage basin, and measure its area in square miles. Next, select on figures 4 and 14 the partial-record gaging station having a drainage basin whose physiographic character most nearly resembles that of the site. If several appear to be suitable, select those that are nearest and that have similar areas of drainage basin. From figure 14 interpolate a value for the 1951 minimum flow in million gallons per day per square mile. The same factors used in the selection of the best partial-record gaging stations should be considered in this interpolation. Similarity of physiographic character is the most important, proximity, second, and similar size of drainage area, third. The value is then multiplied by the drainage area in square miles to obtain the minimum flow in million gallons per day. Rainfall is not a factor in this process because rainfall is essentially the same over the entire study area.

The 1951 minimum flow at the site will satisfy most of the present needs for flow information. However, if further information is desired a relationship curve may be constructed between the flow at a selected site and the flow at the complete-record gaging station whose drainage basin is the most nearly similar. This is best done on logarithmic coordinates. First plot the 1951 minimum of the ungaged site (from the steps described in the preceding paragraph) against the 1951 minimum of the complete-record gaging station (from table 20). This will define the lower extremity of the relationship curve. Next, from table 18 select the average flow in million gallons per day for the desired complete-record gaging station, and multiply by 1.5 to obtain one ordinate for the control point. The other ordinate for the control point is that value multiplied by the ratio of the drainage areas—that of the ungaged site divided by that of the complete-record gaging station. These ordinates define the control point. The relationship curve may then be drawn between it and the point representing the ratios of the 1951 minimums. This relationship curve may be used as described for partial-record gaging stations to estimate the drought frequency curve and the curve of discharge available without storage at the ungaged site.

If desired, corresponding flow values may be computed for the same partial-record station from relationships with other complete-record gaging stations presented in this report. To do so may give greater validity to the results. However, there is no way to verify the accuracy of the computations except actually to measure the flow under suitable base-flow conditions and proceed as has been done in the analysis for the partial-record gaging stations.

The probable validity of estimates for ungaged sites depends entirely on the presence of suitable comparable partial-record gaging stations. The estimates should be quite valid, for example, if such a station is situated close by on the same stream, but probably would be of little or no value if no such satisfactory gaging station exists. Further, the estimates may have no meaning whatever if the ungaged stream is regulated.

SURFACE WATER CHARACTERISTICS

Certain general characteristics of the area were determined during the collection of the data listed in this report.

Relation of Geology to Stream Flow

As mentioned previously, the estimates of minimum flows during the August-September 1951 drought are shown on the map of the area (figure 14). The major physiographic regions of the area, the Piedmont Plateau, Fall Line Hills-Louisville Plateau, and Tifton Upland, are also delineated on this map.

Examination of figure 14 reveals striking differences in the flow of streams of the area; some had rates of flow per unit of drainage area which were more than 50 times as great as others, even without considering those with no flow. Streams with drainage basins lying entirely within the Fall Line Hills-Louisville Plateau had the highest flows. Those with drainage areas only partly in the Fall Line Hills-Louisville Plateau area had lesser flows and those with drainage areas lying entirely in the Piedmont Plateau or Tifton Upland areas had the least. Such marked differences in flow characteristics are due almost entirely to differences in the geological formations that underlie the several regions. During a drought as prolonged as that of 1951, the effect of any unequal distribution of antecedent rainfall almost completely disappears. Streamflows then are dependent upon the release of water from underground storage, and these flows indicate the relative ability of that storage to maintain base flow in the various physiographic regions defined by the geologic map.

In effect, the streams of the Fall Line Hills-Louisville Plateau area have huge underground storage in their drainage basins. This natural storage regulates the flow of the streams by storing some of the water which in other regions might contribute to destructive floods, and by releasing it when streams otherwise would have low flows. This is a valuable asset to the area. If this natural regulation were not available, the cost of producing a similar effect by reservoirs would probably be prohibitive. Of course, the natural storage is not subject to control by man as storage in a surface reservoir would be.

The less pervious soils and underlying structure of the Piedmont Plateau, together with the steep land slopes and lack of wide flood plains, results in the flashy storm runoff and low minimum flows of the area.

The less pervious soils of the Tifton Upland are countered by the flat land surfaces so that storm runoff is not flashy. The flat slopes of the stream beds, their low wide bottoms, choked channels, and flood plains combine to retard flood runoff still more, so that during the winter and spring months the valleys tend to fill up with slowly flowing water. Once the growing season begins, evapotranspiration losses absorb the rainfall and stored moisture rapidly so that the Tifton Upland rivers characteristically drop suddenly from high to low rates of flow. It takes a very large amount of rain to create substantial flows in those streams again until the dormant season begins in late autumn. Some of the very low-flow rates in the Tifton Upland may be caused by excessive evapotranspiration losses of swamp vegetation which may deplete the ground water adjacent to the streams sufficiently to intercept ground-water seepage from the higher ground and even cause a withdrawal of water from the stream itself.

Factors such as topography, soil types, and vegetative cover have an effect on the low-flow regimen of streams. However, study of the 1951 drought conditions as shown by figure 14 gives clear evidence that, in the study area, the effect of such factors is small in comparison with the pronounced effect of geology.

Quality of Water

Table 22, p. 216, lists the known chemical analyses of surface water in the area. All the analyses show soft water of suitable quality for most uses with the softest water coming from the Fall Line Hills-Louisville Plateau streams.

Before consideration of water-supply use of any streams in the area, the Georgia Department of Public Health should be consulted about possible sources of pollution. It was not deemed feasible to show sources of pollution in this report because authoritative up-to-date information will be available from that Department.

Water Temperature

In general, river temperatures tend to conform roughly to average air temperatures. Records of river temperatures may be found at city or industrial waterworks that maintain accurate laboratory controls. In recent years, steam-electric power plants have been recording temperatures of their intake and outfall water. Industrial use of water for cooling purposes results in warming of the water. Steam powerplants usually raise the temperature of cooling water about 5° to 15° Fahrenheit. Of course the net effect on the temperature of the water in the river is usually less than this, but warm water in a stream channel does not always mix quickly with cool water. Warm water introduced on one side may cause the water on that side to remain warmer than on the other side for many miles downstream. Some warming of the water in the Savannah River may result from the operation of the atomic energy commission plant across the river in South Carolina.

Another factor to be considered in the question of river temperatures is the distance required for river water to return to average air temperature after it has been warmed by an industry. Recent studies on some of the larger Georgia rivers suggest that 5 to 10 miles is needed for each degree of temperature change; for example, if a river has been warmed 10°F, it will take 50 to 100 miles for it to cool to the average air temperature. No general rule is applicable to this problem for in such distances tributaries will add variable quantities of unwarmed water.

Warming water tends to reduce the stream's capacity to dissolve oxygen so the effect is not unlike river pollution. An industry that warms the water may have an effect on fish life similar to one that discharges organic wastes.

Diurnal temperature changes may be expected in small streams. Recent observations of water temperatures have shown several degrees Fahrenheit fluctuation daily on rivers even larger than the Ogeechee River. Large daily fluctuations

Table 22.—Chemical quality of surface waters in East-Central Georgia

(Analyses by U. S. Geological Survey; in parts per million)

<table>
<tr><th>Index number Fig. 4</th><th>Source and location</th><th>Date of collection</th><th>Discharge mgd</th><th>Silica (SiO2)</th><th>Iron (Fe)</th><th>Calcium (Ca)</th><th>Magnesium (Mg)</th><th>Sodium (Na)</th><th>Potassium (K)</th><th>Bicarbonate (HCO3)</th><th>Sulfate (SO4)</th><th>Chloride (Cl)</th><th>Fluoride (F)</th><th>Nitrate (NO3)</th><th>Dissolved solids</th><th>Hardness (CaCO3)</th><th>Suspended matter</th><th>Color</th></tr>
<tr><td>4</td><td>Greenbriar Creek near Appling</td><td>Oct. 14, 1942</td><td>2.8</td><td>32</td><td>0.04</td><td>5.4</td><td>2.5</td><td colspan="2">8.3</td><td>38</td><td>4.2</td><td>4.4</td><td>----</td><td>0.1</td><td>79</td><td>24</td><td>------</td><td>7</td></tr>
<tr><td>15</td><td>Spirit Creek near Hephzibah</td><td>Oct. 13, 1942</td><td>31</td><td>6.9</td><td>.04</td><td>2.6</td><td>.8</td><td colspan="2">4.1</td><td>5.0</td><td>2.7</td><td>4.5</td><td>----</td><td>6.8</td><td>39</td><td>9.8</td><td>------</td><td>12</td></tr>
<tr><td>25</td><td>Briar Creek near Keysville</td><td>Oct. 13, 1942</td><td>11</td><td>6.4</td><td>.25</td><td>1.0</td><td>.5</td><td colspan="2">2.4</td><td>6.0</td><td>1.2</td><td>2.4</td><td>----</td><td>.2</td><td>21</td><td>4.6</td><td>------</td><td>25</td></tr>
<tr><td>29</td><td>Brushy Creek at Wrens</td><td>Oct. 10, 1942</td><td>1.5</td><td>12</td><td>.15</td><td>2.4</td><td>1.0</td><td colspan="2">2.0</td><td>8.0</td><td>1.6</td><td>3.4</td><td>----</td><td>1.9</td><td>32</td><td>10</td><td>------</td><td>12</td></tr>
<tr><td>31</td><td>Briar Creek near Waynesboro</td><td>Jan. 17, 1938</td><td>---------</td><td>9.3</td><td>.12</td><td>4.8</td><td>.9</td><td>2.6</td><td>0.8</td><td>20</td><td>1.7</td><td>3.2</td><td>.1</td><td>.26</td><td>37</td><td>16</td><td>4.3</td><td>15</td></tr>
<tr><td></td><td>Briar Creek at Millhaven</td><td>Dec. 4, 1937</td><td>295</td><td>10</td><td>.19</td><td>6.2</td><td>1.2</td><td>2.3</td><td>.8</td><td>22</td><td>1.5</td><td>4.0</td><td>.0</td><td>.10</td><td>45</td><td>20</td><td>2.3</td><td>22</td></tr>
<tr><td>34</td><td>Long Creek at Jewel</td><td>Oct. 13, 1942</td><td>.8</td><td>21</td><td>.02</td><td>2.7</td><td>1.4</td><td colspan="2">7.2</td><td>24</td><td>2.4</td><td>4.1</td><td>----</td><td>.1</td><td>52</td><td>12</td><td>------</td><td>5</td></tr>
<tr><td></td><td>Ogeechee River near Louisville</td><td>Dec. 5, 1937</td><td>272</td><td>13</td><td>.42</td><td>2.8</td><td>1.4</td><td>3.3</td><td>1.0</td><td>16</td><td>1.7</td><td>4.0</td><td>.0</td><td>.08</td><td>40</td><td>13</td><td>3.8</td><td>16</td></tr>
<tr><td>43</td><td>Big Creek near Louisville</td><td>Oct. 10, 1942</td><td>23</td><td>12</td><td>.02</td><td>4.6</td><td>1.0</td><td colspan="2">1.5</td><td>16</td><td>1.6</td><td>2.4</td><td>----</td><td>.9</td><td>34</td><td>16</td><td>------</td><td>8</td></tr>
</table>

of temperature may be expected on small shallow streams, especially if they are much exposed to sunlight.

Ponds and Regulation

There are few streams in the area that are not affected to some extent by man-made regulation. The trend is toward more regulation as the number of farm and recreation ponds increases. As already discussed it makes a great deal of difference in the streamflow below a dam whether the dam is water-tight or leaky. It is theoretically possible so to construct and operate every farm pond that it would have a beneficial effect on general streamflow conditions downstream, but the benefits derived from the plan would hardly be realized because of the impracticability of enlisting the cooperation and community effort of many individuals, most of whom want their ponds to stay full rather than fluctuate for the benefit of water users downstream.

Farm ponds as generally built have little beneficial effect on streamflow. In order to do so, they need to be operated in the same manner as a major storage reservoir, which is seldom feasible. Regulation of storage for the improvement of low-water streamflow requires the design and careful operation of reservoirs for the specific purpose that is desired. In general such undertakings for industrial purposes will require the assistance of competent consultants.

So much pond construction is probable in the study area that any general estimates or minimum flow conditions are subject to future large errors and possibly radical change. An appraisal of general water resources of the study area expressed in terms of average flows or perhaps somewhat more complex engineering terms may eventually serve better than one expressed in terms of minimum flows recorded during a given period of record. For example, the rate of flow that is equaled or exceeded for a certain per cent of the time or the minimum 7-day average discharge to be expected once in 5 years may prove to be a better index of stream characteristics.

Future Prospects

As stated at the beginning of this section, the water resources of the area is one of its great natural advantages. There is little doubt that there will be considerable industrial growth in the area based in part on water supplies both from surface and underground sources. Municipal growth will require development of surface water resources in the Piedmont and the establishment of sewage- and waste-treatment plants in all parts of the area. Irrigation will undoubtedly increase because it has been demonstrated to be profitable. Also, truck farming likely will increase with urban growth, and result in increased irrigation. Recreational facilities in the form of ponds likely will grow in number and probably also in size. The conservation movement likely will result in less cultivation of steep hillsides, better protection of road ditches, more forest, more cover crops, and more land in pasture. The effects of such conservation practices on streamflow cannot be predicted on the basis of available data, but it should not be large. It may be expected that these practices will reduce siltation, make streams clearer, and prolong the life of ponds and reservoirs.

Realization of the full benefits possible from the surface-water resources of the area will require wise planning and thorough consideration of all factors, based on all the facts of streamflow as shown by objective scientific investigations. Such investigations point the way to effective compromise of conflicting demands on our streams and provide an evaluation of potentialities for development.

Streamflow Investigations

Studies of surface-water resources are a continuing project, for the very heart of the studies is the long-time records of streamflow. Many complete-record gaging stations will probably be continued at their present sites. As pointed out earlier, there is a critical need for additional complete-record gaging stations on small streams that are representative of the Fall Line Hills-Louisville Plateau streams. When they are established, partial-record stations will yield much more reliable information than is now available.

This report on the surface-water resources of this area gives only the information at hand. There has been insufficient time to collect the necessary data to make this a complete comprehensive report on surface-water resources. As time goes on, additional data will be accumulated.

Future Runoff Trends

There is much interest at the present time in improved land-management practices as a means of conserving soil and water resources. Much of the literature on the subject suggests that widespread adoption of improved conservation measures would result in flood reduction and an increase in low flows of our streams. If this were so, there might be some question as to how accurately runoff data given in this report represents what can be expected in the future. Thus, some evaluation of the possible trends of runoff is presented here, in order to assist in appraising the validity of the data given herein in connection with problems involving future flows.

There is no evidence of any long-term trend in runoff, either upward or downward, in this area. The variation in streamflow from month to month and from year to year is often large, especially in the Tifton Upland and Piedmont Plateau regions. Because of this variation, accurate long-term streamflow records will be required to recognize any persistent trend.

Also, because of this variation, it is difficult to determine with certainty what effect improved land-use practices have on streamflow. A well-planned program of basic data collected for a fairly long period in advance of the land-use changes and for another fairly long period subsequent to them would be required to show the effect. Naturally, the larger the effect of the practices on streamflow, the easier it would be to identify and evaluate it.

Improved land-management practices will probably be adopted regardless of their effect on streamflow as they usually are beneficial in other ways. At this time, it is possible only to guess their probable effect on streamflow, although it is generally agreed that, regardless of what the effect may be on small floods, improved land-use practices will not reduce major floods to any appreciable extent.

Improved land-use practices and other water-conservation measures are perhaps as likely to cause a reduction in low-water flow as to result in an improvement. The increased stand of vegetation could possibly use enough additional water to more than offset any increased infiltration.

Control of riparian vegetation, that is, trees and growth in the swampy bottom close to the stream might result in increased flow during low-water periods. This has proved to be the case in arid areas, but in Georgia the expense of controlling the vegetation would probably not be justified except as an emergency measure during extreme droughts.

Growing cities and towns have an opposite effect on streamflow characteristics from that caused by improved land-use practices. Rooftops and paved streets permit no infiltration and contribute to a more flashy runoff. Such reduced infiltration could result in lower summer flow. A completely paved drainage basin would give a much larger total annual runoff than would a natural drainage basin, as the evapotranspiration loss would be very small, but the runoff would be poorly distributed throughout the year.

Additional Information

Inasmuch as this is an admittedly incomplete report of the surface-water resources more information about some stream or area may be obtained from the Director, Georgia Department of Mines, Mining and Geology, Atlanta 3, Georgia.

SUMMARY AND CONCLUSIONS

This chapter has assembled all surface-water information available in 1953 for the seven counties of Central-East Georgia that might assist in evaluating streamflows for water-supply purposes. Field data and computed data for five complete-record gaging stations are summarized in condensed readily usable tables and graphs. Field data for 51 partial-record gaging stations are given. Those data have been analyzed by relationships with the data at the complete-record gaging stations to provide estimates of the 1951 minimum flow at the 35 sites where the estimates are considered reliable. The basic conditions, underlying principles, and practical methods of analysis are discussed and methods for further analysis are explained.

The text includes much general discussion of the area as it affects surface-water resources, the general nature of stream characteristics, the uses of streams, trends in surface-water utilization, and other general factors helpful to an understanding of the many aspects of surface-water development. In a way, the chapter provides a textbook on the surface-water resources of the study area for one who is already familiar with the geological and ground-water aspects of water-supply projects.

The Central-East Georgia area includes three physiographic regions, defined by their geology, in which there are distinct and widely varying streamflow characteristics. The striking effect of the geology on surface streams is emphasized. In an area of such diverse characteristics, a knowledge of the geology is an important element in the understanding, interpretation, and application of streamflow data from gaging stations to ungaged sites where the water resources are to be used.

In general, the surface-water supplies of the lesser streams of the area are plentiful, especially in the Fall Line Hills-Louisville Plateau, but the flow of streams lying wholly within the Piedmont Plateau and Tifton Upland is unevenly distributed during the year. The low flows of the Piedmont Plateau streams may be increased by storage reservoirs. Those of the Tifton Upland may be increased only in limited amounts because of the scarcity of practical and economical reservoir sites. In the Fall Line Hills-Louisville Plateau there would be little need for storage reservoirs because the flow is already well regulated naturally.

The surface-water supplies of the area are in general of good quality; however, sustained chemical quality data are not available. High temperatures for prolonged periods during summer produce high water temperatures and result in low dissolved oxygen content in the smaller streams of the area.

Any development of a stream for use as a source of water supplies requires skillful and careful analysis. The information now available is limited, but the collection of additional data will continue in the future. There are serious deficiencies in knowledge of streamflow and quality of water in the area, especially for those streams with drainage areas less than about 25 square miles.

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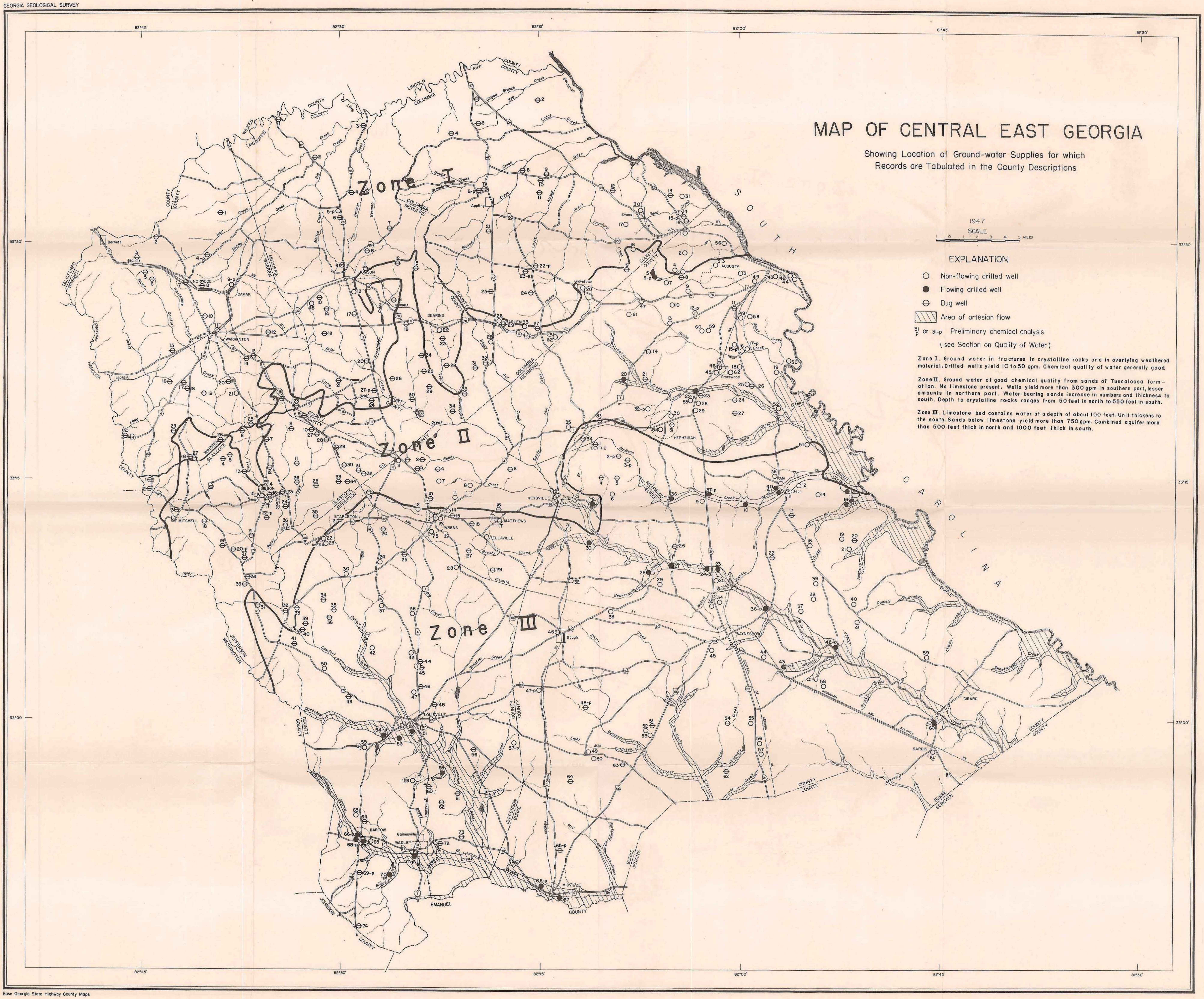
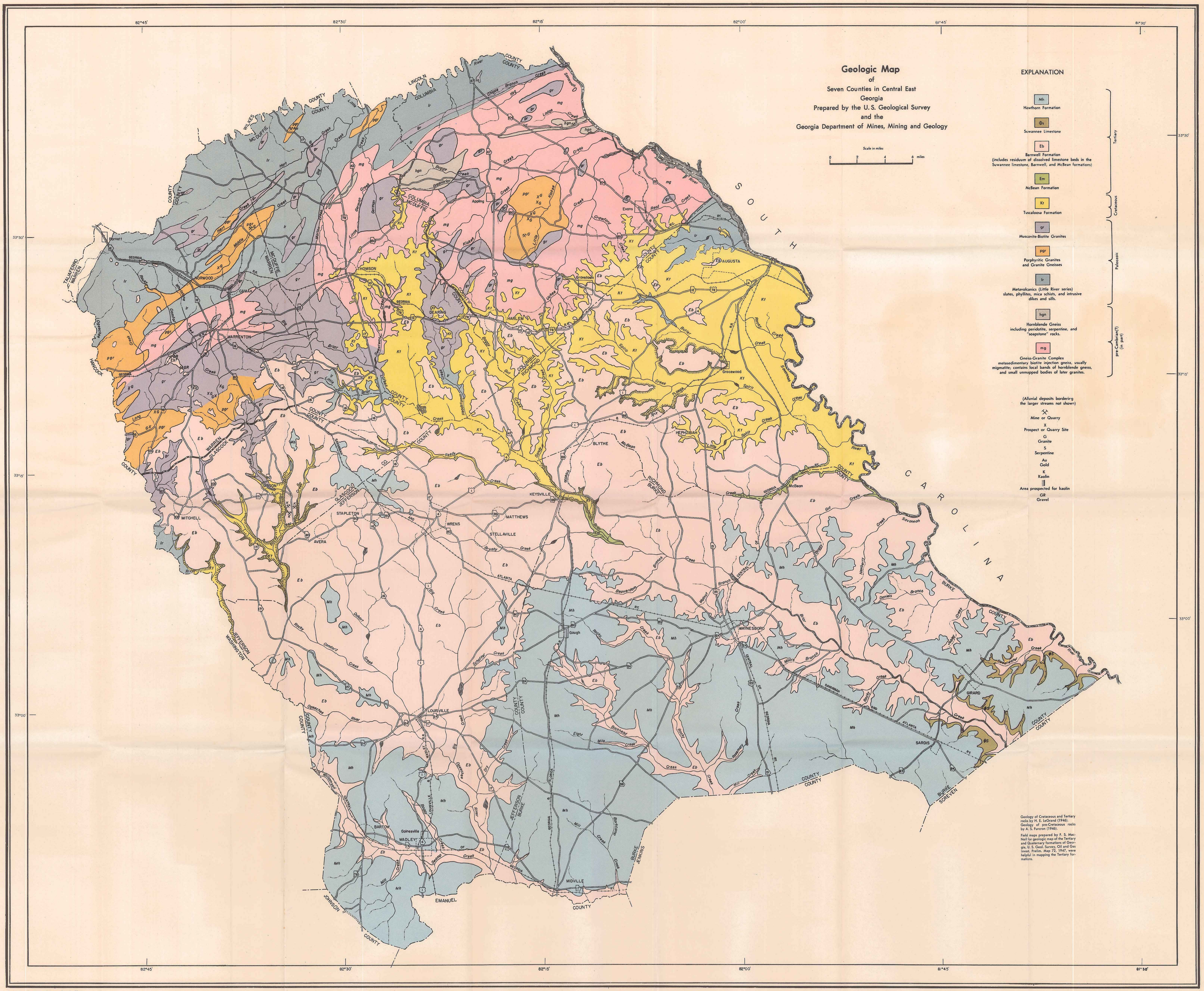

MAP OF CENTRAL EAST GEORGIA
Showing Location of Ground-water Supplies for which Records are Tabulated in the County Descriptions
1947
SCALE
EXPLANATION
Non-flowing drilled well
Flowing drilled well
Dug well
Area of artesian flow
31 p or 31-p Preliminary chemical analysis
(see Section on Quality of Water)
Zone I. Ground water in fractures in crystalline rocks and in overlying weathered material. Drilled wells yield 10 to 50 gpm. Chemical quality of water generally good.
Zone II. Ground water of good chemical quality from sands of Tuscaloosa formation. No limestone present. Wells yield more than 300 gpm in southern part, lesser amounts in northern part. Water-bearing sands increase in numbers and thickness to south. Depth to crystalline rocks ranges from 50 feet in north to 550 feet in south.
Zone III. Limestone bed contains water at a depth of about 100 feet. Unit thickens to the south. Sands below limestone yield more than 750 gpm. Combined aquifer more than 500 feet thick in north and 1000 feet thick in south.
Zone I
Zone II
Zone III
SOUTH CAROLINA
AUGUSTA
WAYNESBORO
LOUISVILLE
THOMSON
WARRENTON
WRENS
EMANUEL



Base Georgia State Highway County Maps