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STATE DIVISION OF CONSERVATION

DEPARTMENT OF MINES, MINING AND GEOLOGY

GARLAND PEYTON, Director

19 Hunter Street

Atlanta, Georgia

THE AVAILABILITY AND USE OF WATER IN GEORGIA

by

M. T. Thomson, S. M. Herrick, Eugene Brown,
and others

Prepared cooperatively by the U. S. Geological Survey

Atlanta, Jan. 15, 1957

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

Sir:

I have the honor to submit herewith Georgia Geological Survey Bulletin No. 65, "The Availability and Use of Water in Georgia" by M. T. Thomson, S. M. Herrick, Eugene Brown, and others, of the U. S. Geological Survey.

This report is published at the request of the Georgia Water Law Revision Commission, Scott Candler, Chairman to assist the Commission and the General Assembly in determining whether additional legislation is needed to promote the effective utilization of the State's water resources, and, if the answer is affirmative, in drafting practical laws and regulations.

The report contains much data, and general information on the sources, quantities, and quality of Georgia's water resources and on the present and future utilization of those waters. It serves as a progress report and general summary, as of December 1955, of the continuing cooperative investigations of water resources in the State by this Department and the U. S. Geological Survey. As such, the report will have wide application in the wise development of our water resources to meet the ever-growing demands upon them.

Very respectfully yours,

Garland Peyton

Garland Peyton
Director

PREFACE

This report summarizes the existing information on the water resources of Georgia and appraises their availability, chemical quality, and present and future utilization. It was prepared at the request of the Georgia Department of Mines, Mining and Geology, Garland Peyton, Director. That Department had been requested by the Georgia Water Law Revision Commission, Scott Candler, Chairman, to furnish a report on Georgia's water resources. The report is intended to assist the Commission and the General Assembly in determining whether additional legislation is needed to promote the effective utilization of the State's water resources, and, if the answer is affirmative, in drafting practical laws and regulations. Most of the data used in preparing the report have not been included but may be consulted in the files of the U. S. Geological Survey.

The report was prepared by the Water Resources Division of the United States Geological Survey. The Atlanta district of the Surface Water Branch, under the direction of M. T. Thomson, district engineer, prepared the section on surface water and the compilation of data on rainfall, evaporation, population, irrigation, farm ponds, crop acreages, and hydroelectric power, and part of the data on urban and industrial water supplies. The district offices of the Surface Water Branch in adjacent States supplied information on border streams. S. M. Herrick, assisted by R. L. Wait, of the Atlanta district of the Ground Water Branch, under the direction of J. T. Callahan, district geologist, prepared the section on ground water and the compilation of part of the data on urban and industrial water supplies. The Ocala district of the Quality of Water Branch under the direction of Eugene Brown, district chemist, prepared the quality-of-water discussion in the surface-water section and compiled the water analyses and temperature data for both sections.

The U. S. Geological Survey collected most of the information on water-resources in Georgia under a cooperative agreement with the Department of Mines, Mining and Geology and obtained much of the drainage-area and flood data under a cooperative agreement with the Georgia State Highway Department. Assistance in the form of funds or services was given also by the Corps of Engineers, the Soil Conservation Service, the Weather Bureau, the Fish and Wildlife Service, the Georgia Power Co., the Crisp County Power Commission, Chatham County, and the City of Savannah. The following aided by suppling information: the Forest Service, the Agricultural Extension Service, the Federal Power Commission, the Bureau of the Census, the Georgia Department of Public Health, the Georgia Department of Commerce, DeKalb County, and the cities of Atlanta, Carrollton, Dalton, East Point, Griffin, and Toccoa.

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THE AVAILABILITY AND USE OF WATER IN GEORGIA

By M. T. Thomson, S. M. Herrick, Eugene Brown, and others.

ABSTRACT

The water resources of Georgia, as a whole, are more than adequate for present uses. The rivers of the State discharged an average flow of 39,000 million gallons of water daily during the 18-year period 1937 to 1955. The underground formations of southern Georgia discharge additional undetermined quantities of water. The uses of water in Georgia in 1955 averaged about 33,000 million gallons daily.

Most of the uses of water in Georgia are nonconsumptive and in 1955 included 260 mgd for 96 urban supplies, 1,830 mgd for industry of which 1,450 mgd was for cooling at 25 steam-generating plants, and 31,000 mgd for hydroelectric power at 40 dams. Some of the water is reused as much as 20 times for nonconsumptive purposes.

Consumptive uses of water, for which the water is used only once, average about 200 mgd under dry-year conditions. In 1955 rural use averaged about 75 mgd, and in the dry year 1954 irrigation averaged about 21 mgd and net evaporation from ponds averaged about 100 mgd. The consumptive uses of water were less than one-half of one percent of the average supply of water available.

Consumptive use of water for irrigation in Georgia is estimated to increase in the future to an average of 1,200 mgd under dry-year conditions. At the maximum seasonal rate of irrigation in dry spells, this may cause withdrawals of about 11,000 mgd, which would greatly exceed the total of the minimum flows of minor streams, about 2,500 mgd, and conflicts would be expected. If irrigation water is withdrawn from streams during periods of excess flow, there may be little conflict of interest in much of the State because reductions are estimated not to exceed three percent of the average flow. However, there may be conflicts of interest in those areas where practically all of the water is used for hydroelectric power. Those areas include the Savannah River basin above Clark Hill Dam, the Chattahoochee River basin above Fort Gaines Dam, the Etowah River basin above Allatoona Dam,

and the Tennessee River basin. A legislative formula to allow irrigation from farm ponds under mutually acceptable conditions to all parties concerned poses a difficult problem.

A practical solution to this and similar water problems depends on a thorough understanding of the hydrologic factors involved, including (1) the quantity of the water resources available, (2) the reasonable requirements for conservation purposes, (3) the appraisal of water utilization for all purposes, (4) the appraisal of the quantities of water in excess of the amounts utilized, (5) the storage capacity required to impound the needed water, (6) the evaporation losses that may be expected, and (7) the need for public safety from dam failures during floods. These factors are presented in this report.

Nonconsumptive water-use data are tabulated and shown on maps, by specific sites. Proportional utilization flows and excess flows are compared to minimum and average flows at the gaging stations on the main rivers.

Consumptive water-use data per square mile are tabulated or shown on maps by counties for rural use, irrigation, and farm ponds. Comparable maps show minimum streamflows, proportional utilization flows, and excess flows.

Other State maps show average flows, flood magnitudes and frequencies, comparisons of available flows and water utilization on major rivers, single-year hardness for 17 river sites, and the geology of the State.

Streamflow varies greatly in time and place. Zero flows have occurred on rivers that drain areas as large as 110 square miles in northern Georgia and 1,150 square miles in southern Georgia. At the other extreme, flood flows have exceeded 225,000 mgd on the Savannah River at Augusta. Variations in streamflows are a result of many factors. Besides the obvious factors of rainfall and size of drainage area, regional and seasonal factors greatly influence streamflow in Georgia.

The variations in streamflow in Georgia are determined at 136 gaging stations having continuous records. These records have been summarized by 47 statistics showing historic minimum, average, and flood flows, average flows for a standard 18-year period and corresponding river stages, and nine low-flow criteria for the selection of a practical conservation flow.

The areal variation of low flows is shown by the records of 55 index gaging stations and 1,007 partial-record gaging stations, most of which are on small streams. Analysis of the low flows required division of the State into eleven regions having similar streamflow characteristics. Even within each region, there are marked variations of streamflow. At one typical gaging station draining only 134 square miles, the unit flows from parts of the drainage area varied from zero to nine times as much as the average unit flow from the total area.

Because of the great variations of natural streamflows and the even greater man-made variations expected from the increased use of water resources in the future, the establishment of water rights and the regulation of streamflow to conform to legislature requirements will be difficult unless streamflow records are available. At ungaged sites a few flow measurements made under base-flow conditions and correlated with the flow records at index gaging stations may provide reasonably accurate flow information.

There is a serious need for more water-resources information in Georgia including data on water utilization, the flow of small streams, farm ponds, and reservoirs, and a need for more scientific investigations of the inter-relationships of water resources and water utilization.

Information on the chemical and physical qualities of surface and ground waters is essential to all water users, for selection of suitable natural supplies and for the determination of the type and cost of treatment required for less suitable supplies.

Although surface waters usually vary constantly in composition, the 17 streams in Georgia for which quality data are available showed little variation during a one-year period of observation. The maximum content of dissolved solids found during this time was 130 parts per million, and the maximum hardness was 131 parts per million. Streams originating in the eastern and southern parts of the Coastal Plain are generally highly colored but contain little sediment.

No data are available to indicate the probable maximum, minimum or average concentrations of dissolved minerals or suspended solids to be expected over a long period, nor are presently available data sufficient for accurate correlation of water quality with flow, time, or water usage. Such data would be essential to the formulation and enforcement of water legislation.

Georgia is divided into four physiographic provinces on the basis of the topography. Two of these, the Blue Ridge and the Piedmont, have been combined into the Piedmont-Mountain ground water province on the basis of geology. The oldest geologic formations occur in the Piedmont-Mountain province and consist of igneous and metamorphic rocks such as granite, gneiss, schist and quartzite. The Valley and Ridge province in northwest Georgia is underlain by sedimentary rocks including sandstone, shale, limestone, dolomite, and quartzite, ranging in age from Cambrian to Pennsylvanian, that have been folded and faulted, and crop out in northeast-trending ridges and valleys. The remaining three-fifths of the State is the Coastal Plain province extending from the Fall Line to the coast and south to Florida. The geologic formations in this province consist of limestone and dolomite and alternating beds of sand, gravel, and clay which dip gently to the south and southeast.

Ground water occurs under both water-table and artesian conditions in all three provinces.

In the Piedmont-Mountain province ground water generally occurs under water-table conditions, although artesian conditions exist at a few places. Valleys provide the best sites for wells. Ground water occurs in the fractures in the rocks, and successful wells intersect one or more of these water-bearing fractures. Well yields range from 1 to 400 gpm and probably average about 20 gpm.

In the Valley and Ridge province ground water occurs mainly under artesian conditions, mostly in the limestone, sandstone, fractured quartzite, and chert. Wells range in depth from 50 to 2,100 feet and yields range from 1 to 1,500 gpm. Saline waters may be encountered if wells are located in synclines (downfolds in the rocks). Springs are common throughout this province, most of them being of the fault or the contact type. They represent a valuable potential water supply. Although the yields of these springs range from 1 to 16,000 gpm, only a few are being used for water supplies. As the springs provide a part of the low-water flow of streams, their use cannot be considered independently from that of surface water. Crawfish Spring, with a yield of about 25 mgd, is one of the largest springs in the State.

Ground water in the Coastal Plain province occurs under both artesian and water-table conditions. The Coastal Plain may be divided into three areas on the basis of the aquifers. The chemical quality of ground water is good at most places. Recharge of aquifers occurs in areas in which the aquifers are at or near the surface.

The area of the Cretaceous aquifer, which consists chiefly of sand, is in the area from the Fall Line south for a distance of 20 to 60 miles. Wells in these sands range from 100 to 1,200 feet in depth and yield from 20 to 1,100 gpm. Artesian conditions exist throughout the area, except near the Fall Line where no confining bed exists.

The area of the limestone and sand aquifer in the southwest part of the State consists of all of two and parts of seven counties. Water is obtained from both the sand and limestone. Wells range from 100 to 1,200 feet in depth and yield from 100 to 1,500 gpm.

The area of the principal artesian limestone aquifer occupies the southern and southeastern three-fifths of the Coastal Plain. It is one of the most productive aquifers known. Wells range from 100 to 1,200 feet in depth and yield from 100 to more than 4,000 gpm. Most of the industrial use of ground water in the State is from this aquifer. In coastal areas salt-water encroachment may occur if pumping lowers the piezometric surface below sea level, and in order to detect such encroachment constant observation must be maintained where water levels are now below sea level as a result of heavy pumping.

Quality of water studies are conducted as part of the ground-water program. Areas where ground water of inferior quality exists should be outlined by a water sampling program.

The hydrologic cycle and the physical laws of the occurrence of ground water should be recognized in order to provide just and equitable legal controls of ground water. A detailed knowledge of the occurrence of ground water in Georgia should be obtained to form the basis for the proper utilization and development of this resource, and for the establishment of any water laws that may be considered necessary.

INTRODUCTION

The General Assembly of Georgia in its 1955 Session adopted Resolution Act No. 46, "To create the Georgia Water Law Revision Commission . . . and for other purposes". Quotations from the Act itself make an excellent introduction to this report on the availability and use of water in Georgia:

"Whereas, the use of the streams and water within this State has greatly increased; and,

"Whereas, the conservation and proper use of the water resources of this State are important factors in the development of this State and the welfare of its people; and,

"Whereas, the conservation and proper use of the streams and surface and subterranean water within this State is vital to the growth of agriculture, the expansion of industry within this State and to the health of its people; and,

"Whereas, it is desirable to have a survey of stream and water use conditions now existing; and,

"Whereas, legislation affecting the conservation and use of streams and surface and subterranean water should be based on future growth and demand and on a study of the overall conditions within this State; and,

"Whereas, a Commission would be the best method to obtain an accurate survey and report;

"NOW THEREFORE BE IT RESOLVED BY THE GENERAL ASSEMBLY OF GEORGIA:

SECTION I

"There is hereby created a Georgia Water Law Revision Commission - - -"

During its first year of operations the Georgia Water Law Revision Commission stated in its Report to the General Assembly:

"After due consideration, - - - its primary and ultimate mission is to recommend legislation affecting the use and conservation of Georgia's water resources if it is determined that such is needed. Although the recent dry years have fairly led to the generally accepted conclusion that the State has, or is on the verge of having critical water problems, their exact nature and extent are not accurately known - - -. - - - the Commission feels that it must know accurately and definitely the Statewide situation - - -. - - - through certain investigations, surveys, and studies, which in view of the complexity of the problems and the area under consideration, cannot be completed in a relatively short time.

"Accordingly, the Commission - - - because of lack of facilities of its own for gathering much of the data and information required - - - called upon the following agencies (among others) to assist:

State Department of Mines, Mining and Geology
U. S. Geological Survey

"Most of the hydrologic data required is in the field of activity of the Department of Mines, Mining and Geology. Accordingly, the Commission obtained from the Governor funds - - - to enable the State agency to enter into a cooperative project with the U. S. Geological Survey for the purpose of obtaining the information of which they are capable - - - ."

The U. S. Geological Survey, through its cooperative surveys with the Department of Mines, Mining and Geology and other agencies, has collected much hydrologic and related geologic information concerning the availability of water in Georgia. These surveys provide information on water resources required for economical development and the best use of the Nation's water resources. The results of the surveys in Georgia have been published in the regular series of U. S. Geological Survey water-supply papers and circulars, and in publications of the Georgia Department of Mines, Mining and Geology. In this report, these data have been summarized and analyzed in relation to water use to meet the present need of the Water Law Revision Commission.

PURPOSE AND SCOPE

The purpose of this report is to describe the water-resources situation in Georgia, with respect to both the supply and the present and prospective demand, to aid in drafting water legislation. Necessarily, facts are presented only for those sites or areas where data have been obtained. At the request of the Water Law Revision Commission, the year 1970 has been chosen for prospective demands in so far as is practical.

The scope of the report is prescribed by functional limitations as well as by the amount and the nature of the information available. The subjects given broadest treatment are those within the Geological Survey's responsibilities—streamflow, ground water, the chemical quality of natural waters, all of which are interrelated, and water use. Some attention is given to rainfall and evaporation in their relation to surface water and ground water. Other allied subjects such as soil moisture, irrigation requirements, the effects of land use, sanitary quality or pollution, prospective industrial uses, and social, economic, political, and legal aspects are mainly outside the scope of this report.

Satisfactory information is available for the larger rivers of Georgia, for portions of the principal water-bearing formations of southern Georgia, for the water supplies of the larger cities, and for hydroelectric power.

Information is either inadequate or nonexistent about small streams, many water-bearing formations, industrial water use, quantities of ground water that can be safely developed from the different aquifers, watershed runoff, small water-utilization installations (such as ponds, mills, irrigation, and shallow wells), sediment, trends in water quality, and evaporation. Thus, many aspects of these subjects cannot be treated beyond the stating of general principles.

OCCURRENCE AND QUALITY OF WATER

For all practical purposes, the ultimate source of all moisture is water from the oceans. Although storage in the vast ocean reservoirs has changed substantially in the relatively recent geologic past as water has been temporarily confined in glaciers, for the present the net amount of water available to man can be considered to be constant. Through an intricate and complex pattern of evaporation, precipitation, and runoff, the same water becomes available so that it can be used again and again. This natural water cycle is commonly known as the hydrologic cycle.

In the course of the hydrologic cycle, water is evaporated from the land and vegetation as well as from the ocean and other water bodies, carried upward into the atmosphere, and later precipitated upon the earth as rain, hail, sleet, or snow.

Of the rain falling upon the land areas, part seeps into the soil and part runs off the surface into rivers to be returned to the ocean. Depending upon a variety of conditions, water seeping into the soil may follow several paths: (1), it may return to the atmosphere through evaporation almost immediately; (2), it may remain in the soil and supply the needs of plant life; (3), it may percolate downward to the zone of saturation, which is the source of water for streams during dry periods and for wells and springs. In some areas the water table, the top of the zone of saturation, intersects the land surface—for example, in marshes and at the edge of lakes and stream channels, permitting discharge of ground water by evaporation, transpiration, and flow into the surface-water bodies. Where the saturated zone is more deeply buried these losses do not occur, and the water moves laterally toward lower elevations. This movement may bring water to the land surface for discharge by springs and by evapotranspiration, or it may carry water beneath impermeable materials to be stored for long periods under artesian conditions or to be discharged by subterranean routes into the sea.

Thus, in many phases of the hydrologic cycle, water may be either ground water or surface water and may change readily from one phase to the other. Because ground water and surface water are inseparable in nature, water legislation should treat them as one resource.

During the course of the water cycle, many changes occur in the chemical character of water, depending upon the environment encountered. The principal factors affecting the quality of natural waters may be grouped under two general headings: (1), natural conditions, such as precipitation and topographic and geologic features; and (2), human activities concerned with the use of water and the disposal of waste materials.

Chemically pure water is practically unknown, owing to the ability of water to dissolve and react with other materials under a wide range of conditions. All the common forms in which water is precipitated upon the earth contain certain impurities, such as oxygen and carbon dioxide gases from the atmosphere. In some regions, such as highly industrialized, coastal, and volcanic areas, rainfall may contain large amounts of chloride and other substances.

Water flowing over the surface of the land continues to exert its solvent action, taking into solution organic as well as inorganic compounds. The amount and type of material dissolved by water depend largely upon the nature of the material contacted and the length of time in contact. Topographic features determine how fast water from the precipitation runs off the land and, therefore, the length of time that the water remains in contact with surface materials. The physical action of rapidly flowing water is able to carry sediment along in suspension or roll it to be later deposited or gradually taken into solution. On the other hand, where water passes rapidly over the surface, or contacts soluble materials only sparingly, little solution takes place, and the water is likely to be soft and low in dissolved solids.

The solvent action of water is greatly enhanced by the solution of acids from decaying vegetation. These acids are often highly colored and are also responsible for the high concentration of some heavy metals frequently found in surface waters.

Often the most significant quality characteristic of surface waters is the fluctuation shown among periods of varying flow. During periods of high flow the amount of sediment transported by most streams is likely to increase and the concentration of dissolved solids to decrease. During periods of low flow, when the ground-water contribution is likely to be large, the reverse of these conditions is usually found. The range and frequency of this variation in quality are frequently the factors upon which the usefulness of a given surface water is based.

In contrast to surface waters, the mineral content of ground water is relatively constant, though generally higher than in that of most surface waters in the same area. The long period of time required for rainwater to percolate downward to the water table and thence laterally to points of discharge tends to smooth out the fluctuations in quality common in surface waters and affords a greater opportunity for solution as well as chemical action to take place. Waters found at greater depths, or at points distant from the recharge area, are usually found to be more highly mineralized than waters near the surface or close to the intake area. Geological features, such as the type and physical structure of rock materials, determine to a large extent the amount of solution that occurs, and the rate at which it progresses. Water that has traveled even a short distance through limestone or dolomitic formations usually is high in alkalinity and is characterized by much calcium and magnesium carbonate hardness. The usually constant temperature and lack of color and suspended solids tend to make ground waters especially desirable when the mineral content is slight or can be reduced economically.

In addition to the effects of natural conditions on water quality, the activities of man may exert even more profound changes. Probably the foremost of these is the municipal and industrial use of both surface and ground waters, with subsequent return of sewage and industrial wastes to the water. Cultivation of the soil has accelerated natural erosional forces in some areas which has caused rivers and streams to be choked with sediment. In some places the construction of surface reservoirs has tended to improve water quality through settling of suspended matter in storage basins and through the mixing of dilute floodwaters with flows of higher concentration of dissolved solids. In other places reservoirs have caused a reduction of dissolved oxygen and an increase in dissolved manganese.[1]

Although the types of possible impurities in natural waters are almost unlimited, climatic, topographic, and geologic conditions generally limit the number found to a relative few types and also generally influence the concentration of each. Some of the more important chemical and physical qualities of waters, with their significance, are summarized in table 1, (p. 12).

WATER USE

Nearly all the rain that falls in Georgia, about 50 inches in an average year, has some use. Almost two-thirds of that rainfall goes into the growing of vegetation, including forests and farm crops, or is lost by evaporation directly from the soil or water surfaces. About one-third, some 17 inches on the average, runs off in the rivers or enters aquifers and provides for domestic, municipal, industrial, and hydroelectric-power needs. This water also carries away much waste matter, and serves as the home of fish and other water creatures. The salt water and the brackish water in the lower reaches of the rivers provide harbors and navigation, provide a habitat

[1]R. S. Ingols, in statement to Georgia Water Law Revision Commission, August 27, 1956.

TABLE 1. Water Quality Characteristics and Their Effects

Constituent	*Effects*
Dissolved solids	A measure of the total amount of dissolved matter, usually determined by evaporation. Excessive solids interfere in most processes and cause foaming in boilers.
Silica	Causes scale in boilers and deposits on turbine blades.
Sulfate	Excessive amounts are cathartic and unpleasant to taste. May cause scales.
Nitrate	High concentrations indicate pollution, cause methemoglobinemia in infants, help to prevent intercrystalline cracking of boiler steel.
Fluoride	Excessive concentrations cause mottled tooth enamel, small amounts lessen the incidence of tooth decay.
pH	Values below 7.0 on the pH scale indicate an acid pH range and a tendency for the water to be corrosive toward metal.
Iron and Manganese	On precipitation cause stains; unpleasant taste in drinking water; scale deposits in water lines and boilers; interfere in many processes such as dyeing and paper manufacture.
Calcium and Magnesium	Cause hardness in water.
Chloride	Unpleasant taste in high concentrations. Increases corrosive nature of water.
Sodium	Large amounts injurious to soils and crops, and humans with certain illnesses.
Hardness	Due to calcium and magnesium salts causes excessive soap consumption, scale in heat exchangers, boilers, radiators, pipes, and interferes in dyeing, textiles, food, paper and other manufacturing processes.
Alkalinity	May cause foaming in boilers and carryover of solids with steam, embrittlement of boiler steel.
Color	Stains products in process use, may cause foaming in boilers, and is unsightly in drinking water.
Suspended solids	Unsightly appearance in water. Deposit in water lines, process equipment and boilers. Reduce reservoir capacity, and plug diversion channels.

for oysters and wildfowl, and furnish recreation. This report, however, is primarily concerned with fresh water that is subject to controlled use, the flow of streams and the water of wells and springs, ponds, lakes, and reservoirs. The following discussion deals with some of the general principles of water use and includes statistics on the use of water in Georgia in 1955, and some estimates for the year 1970, or the future.

An average of 2,200 million gallons of water daily (mgd) is being withdrawn from the wells and streams of Georgia for use on farms and in homes, factories, and business establishments—enough to supply 37 cities the size of Atlanta. About 31,000 million gallons per day is used to generate hydroelectric power—enough to supply 525 such cities.

The following table compares per capita water uses in Georgia in 1955 with those in several major regions of the United States and in the Nation as a whole.

Average per capita water use in 1955[1]
(gallons per day)

Area	Combined municipal, rural and industrial uses	Irrigation use	Water power use
Georgia	610	8	5,600
Southeast[2]	740	96	9,800
Northeast[3]	930	3	7,200
West[4]	600	2,400	12,700
United States	800	680	9,100

Per capita uses of water in Georgia are somewhat less than the national averages and the averages for the Southeast. Georgia's irrigation use is at present very small. Very large water-power uses in Alabama and Tennessee, tend to make the Southeastern regional per capita uses high.

The rate of increase in water use in Georgia is striking. Eight major pulp and paper mills, for example, required in

[1]Adapted from preliminary estimates being compiled for a Geological Survey publication in preparation "Estimated use of water in the United States in 1955".

[2]Ala., Ark., Fla., Ga., Ky., La., Miss., Mo., N.C., S.C., Tenn., Va.

[3]States eastward from the line from Louisiana to Minnesota exclusive of those listed for the Southeast.

[4]States west of the line from Louisiana to Minnesota.

NOTE: Population data used in making computations for above table were provisional estimates of civilian population in 1955, prepared by U. S. Bureau of the Census.

1955 the use of fresh makeup water totalling 168 million gallons per day.[1] The Agricultural Extension Service reported in 1955 that 3,793 farm ponds were built in Georgia in 1954 compared to an average of 2,000 per year in the preceding four years and 1,300 per year in the five years 1945-49. In one year, 1954 to 1955, the number of irrigation systems in the State increased 50 percent according to the Agricultural Extension Service. Hydroelectric-power capacity of existing dams and dams under construction on Georgia rivers is more than four times as great as the capacity in 1940 according to Federal Power Commission records. Those records also show that the capacity of steam-power plants, which use enormous quantities of water, has expanded ten fold in the same period. This rapid expansion in power capacity reflects, in large measure, Georgia's industrial growth. The new and expanding industries and new hydroelectric-power dams are making heavier and heavier demands on water resources. Domestic use is being accelerated by industrial expansion. These rapid and varied increases in water use need to be classified for orderly discussion.

CLASSIFICATION

The uses of water may be classified in several ways. For example, a distinction may be made between withdrawal uses and nonwithdrawal uses.

Withdrawal Uses.—Withdrawal uses of water are those in which the water is diverted or pumped from a well, stream, or pond, even though it may later be returned to an aquifer, the parent stream, or another stream. The major withdrawal uses are rural, urban, industrial, hydroelectric-power, and irrigational.

Nonwithdrawal Uses.—Nonwithdrawal uses of water are those that do not involve diversion from the source. These include navigation, waste disposal, most recreational uses, use by fish and other forms of wildlife, and esthetic uses such as the scenic values of streams, lakes, or natural waterfalls.

Another distinction may be made between consumptive and noncomsumptive uses.

Consumptive Uses.—Consumptive uses of water are those wherein the water is withdrawn from a stream or well and

[1] G. K. Singletary in "Statement by Pulp and Paper Industry at Public Hearing of Georgia Water Law Revision Commission" at Waycross, Georgia on May 21, 1956.

not returned or made available for some additional use. The water is incorporated into a product, evaporated directly, or evaporated from vegetation.

Irrigation is an extensive consumptive use of water. Much of the water is evaporated or transpired by the vegetation. Some of the water applied for irrigation discharges into a stream or the ground, but with sprinkler irrigation, which is the most common type in Georgia, the amount of this "return flow" is small. In this report irrigation water use has been classed as entirely consumptive.

Another consumptive use of water is evaporation from pond surfaces. The monthly evaporation from small ponds often exceeds the monthly rainfall on the pond surface, particularly during the hot and dry summer and autumn months. In Georgia, the yearly rate of evaporation from small ponds, based on records from evaporation pans, often exceeds the yearly rainfall falling on the pond. Some loss of this type is inevitable from all storage reservoirs or ponds, but the percentage of stored water lost through evaporation is much higher when the ponds are shallow. Increased consumption of pond water may also take place by transpiration from a rank growth of trees and other vegetation in marshy areas surrounding the ponds.

Nonconsumptive Uses.—Nonconsumptive uses of water are those in which the water is not withdrawn or is withdrawn from a stream or well and returned to its source in essentially the same amount. Hydroelectric power is a good example of nonconsumptive use.

Most urban and industrial uses of water are classed as nonconsumptive with respect to quantity, but the quality of the water may be altered. It is generally assumed that the water returns to streams by way of the sewerage systems and waste-treatment plants. However, the watering of lawns and shrubbery is a consumptive use. Few statistics on this urban-type irrigation are available. During the extreme dry conditions which prevailed in 1954, it was found that the water pumped from the Chattahoochee River for metropolitan Atlanta was not entirely accounted for at the waste disposal plants. About 28 percent of the water was lost—some of which was used to water lawns and shrubbery.

Quantitative estimates of water use.—Quantitative estimates of water use are available only for certain types of use. Most withdrawal uses of water, whether consumptive or nonconsumptive, may be measured; for example, most urban and industrial water supplies are measured by meters. Nonwithdrawal uses of water are usually difficult to measure, especially water used for wildlife, recreation, or esthetic purposes. The amount of water used for waste disposal by dilution is also difficult to determine. Figure 1 (p. 17) shows the estimated total use of water in Georgia in 1955 for each of the five major categories of withdrawal uses discussed in this report.

GOVERNING FACTORS

Both availability and quality of water govern the quantity that may be used for beneficial purposes. Although ample, not all of the water available can be used if the chemical or physical quality of the available supply renders it unfit for some uses, or if the cost of processing or treating water is high.

Availability.—Use of water in Georgia depends to a great extent on the supply that is available at the time and place that the water is desired. Large amounts of water are taken from the principal rivers and the artesian wells of the Coastal Plain, both of which supply the so-called "wet" industries which require large quantities of water, such as steam-power production, pulp and paper production, and some forms of textile production. Recurrent periods of low streamflow restrict the use of water in some parts of Georgia; for example, there are few wet industries in the vicinity of most of the small cities in the Piedmont province. The most suitable sites for wet industries in the Piedmont province are limited to the vicinity of major rivers.

Quality.—The chemical or physical quality of a natural water supply often has an even more important bearing on the use of the water than the amount available. The oceans comprise a large part of the earth's surface, but sea water is so highly mineralized that, without extremely expensive treatment, its use for urban, agricultural, and industrial purposes is limited. On the other hand, many natural supplies contain little or no dissolved salts, and are suitable for almost any purpose. The chemical quality of a water supply is determined by chemical analysis.

Chemical analyses of water are made for many purposes. They are necessary to determine whether or not treatment of

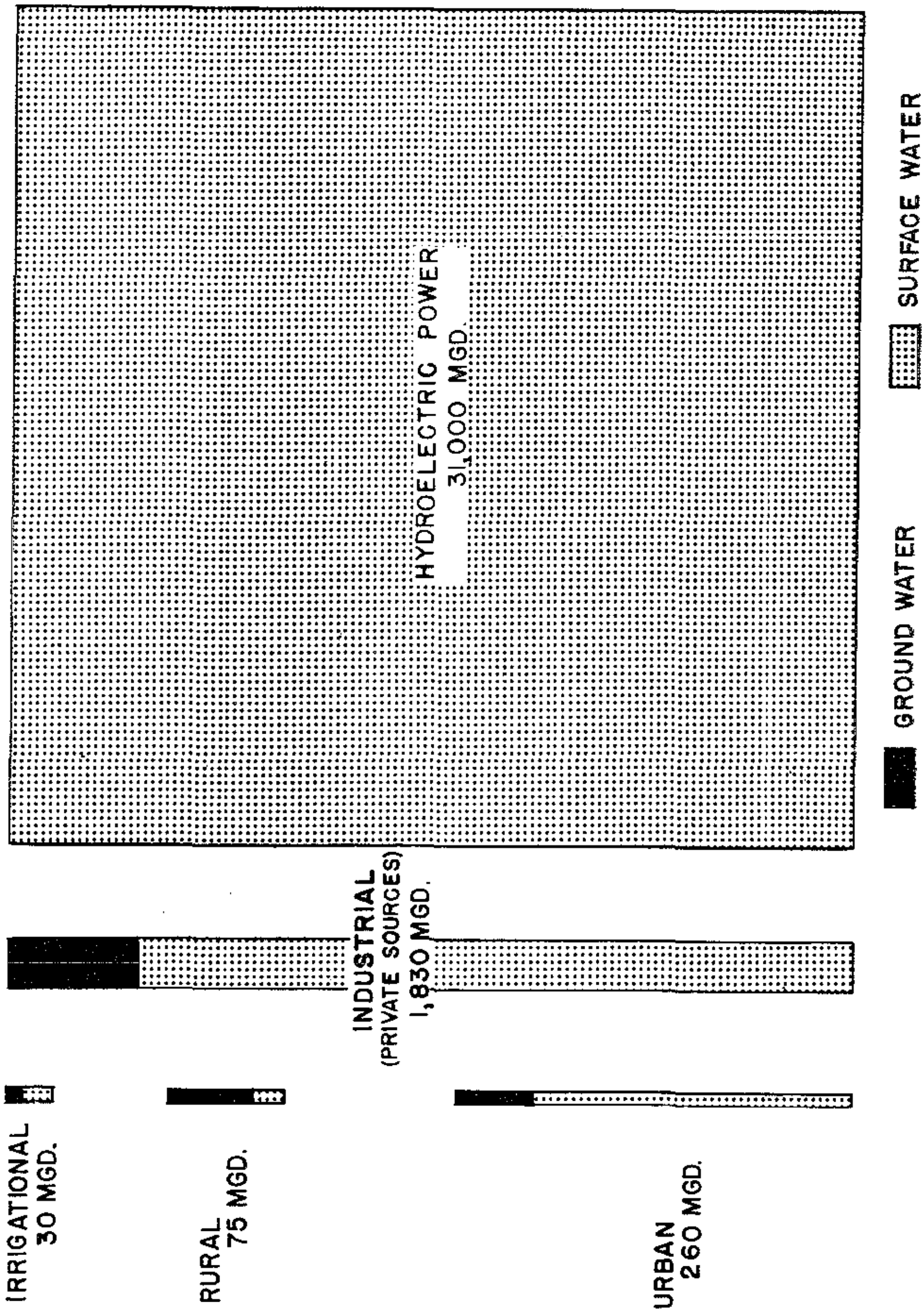


Figure 1. Water use in Georgia in 1955.

a supply is needed to meet the requirements of a prospective use and to determine the type of treatment and the probable cost.

A variety of chemical, physical, or bacteriological tests may be required. This is illustrated by the following table, which shows some of the tests commonly made to determine the suitability of a water for the general purposes indicated.

Tests commonly made for water analyses

	A	B	C	D
1. Bacteriological examinations	X			
2. Organic nitrogen	X			
3. Albuminoid nitrogen	X			
4. Ammonia nitrogen	X			
5. Nitrite	X			
6. Taste and odor	X			
7. B. O. D.	X			
8. Dissolved oxygen	X			
9. Oxygen consumed	X			
10. Turbidity	X	X		
11. Manganese	X	X		X
12. Iron	X	X		X
13. Fluoride	X	X		X
14. Color	X	X		X
15. pH	X	X	X	X
16. Nitrate	X	X	X	X
17. Chloride	X	X	X	X
18. Alkalinity or acidity	X	X	X	X
19. Dissolved solids	X	X	X	X
20. Hardness	X	X	X	X
21. Sulfate		X	X	X
22. Magnesium		X	X	X
23. Calcium		X	X	X
24. Specific conductance		X	X	X
25. Sodium		X	X	X
26. Potassium		X	X	X
27. Silica		X	X	X
28. Boron			X	X

A. Tests for determining sanitary quality of potable or polluted waters.
B. Tests for determining suitability of water for industrial uses.
C. Tests for determining the suitability of water for agricultural uses.
D. Tests for determining geological relations of natural surface and ground waters.

From this table, it is obvious that different water uses require different water qualities, with respect to the type of mineral matter contained as well as to the concentration of specific minerals. The general limiting quality requirements are discussed separately in the appropriate sections that follow.

RURAL

Rural use of water, as defined in this report, includes water for domestic purposes and livestock but does not include water used for irrigation. The water quantities have been computed from population statistics and estimates of water use per capita or per head of stock.

The estimated rural population of Georgia in 1955 was 1,561,000. This represents about 44 percent of all the people in the State. The rural population has been computed by deducting the urban population of communities of 2,500 people or more, from the total population. Thus, rural population includes both farm and non-farm groups. The populations of many small communities are included, some of which have public water supplies.

No statistics from actual surveys in Georgia are available to provide an accurate estimate of rural per capita use of water but it is much smaller than the per capita urban use because rural use includes little or no public, commercial, and industrial use. Also, the average rural use per capita for domestic purposes is generally less than the corresponding urban use largely because nearly half of the rural people in the State do not have running water in their homes. A family with running water will use much more water than one supplied by a hand pump or bucket and rope. The authors have estimated a use of 50 gallons per capita per day for that portion of the rural population served by running water and 10 gallons per capita per day for that portion without running water, to compute the domestic rural use of water in 1955, shown on figure 2. (p. 21).

Livestock use was based on the livestock population disclosed in the U. S. Department of Agriculture Marketing Service reports. The assumed per capita use of water by stock was: milk cows, 20 gallons per day; all other cattle, 10 gpd; mules and horses, 10 gpd; hogs, 3 gpd; sheep and goats, 2 gpd; chickens, 0.04 gpd; and turkeys, 0.06 gpd.

Using the above values, the rural domestic use of water in Georgia in 1955 has been estimated to be 49 mgd, most of which is obtained from wells, and the stock use 26 mgd, a total rural use in the State of 75 mgd.

Figure 2[1] (p. 21) shows the estimated comparative rural

[1]A uniform system of showing relative quantities of water used or available as streamflow on an areal basis has been employed on all of the county maps.

use of water in Georgia for the year 1955, by counties, in gallons per day per square mile (gpdsm). This concept is used to avoid the disparity in the areas of the counties and to facilitate comparisons with the flow of streams. Generally, the counties in southern Georgia have the smallest rural use in proportion to their area, and those near the larger metropolitan centers have the largest.

Estimated rural use in 1970.—The census statistics show that the rural population in many Georgia counties is either static or declining because people are leaving their farms and moving into the communities. On the basis of population projection methods employed by the Georgia Department of Public Health, the authors have estimated that the rural population in 1970 will be approximately the same as in 1955, or about 1,500,000. The trend in rural use of water per capita is expected to increase because more rural homes are expected to have running water. Assuming that all rural homes will be supplied with running water by 1970 and that the use of water by livestock will not change appreciably between now and then, the total rural use of water in 1970 is estimated to be 100 mgd, an average increase of 33 percent over the 1955 amount.

URBAN

The public water supply is essential to the very life of a modern city. The city dweller not only depends entirely on the public water supply for the water he drinks, but he must also have water to keep clean, to dispose of his wastes, and to protect his property from fire.

Essential urban uses do not necessarily extend to washing cars, cleaning streets, maintaining swimming pools and ornamental fountains, or watering shrubbery and lawns. When water is scarce, as in severe droughts, such uses are restricted, and the water is reserved for drinking and sanitary purposes.

Urban use as defined for this report includes all uses of water from water-supply systems serving municipalities of 2,500 or more people. This includes the use of water for domestic purposes (generally estimated to be about half the total), for a variety of municipal purposes, and, generally, for some commercial and industrial purposes.

Characteristics of urban use.—Water suitable for urban use must come from a relatively uncontaminated fresh water source. In order to define the suitability of water supplies for

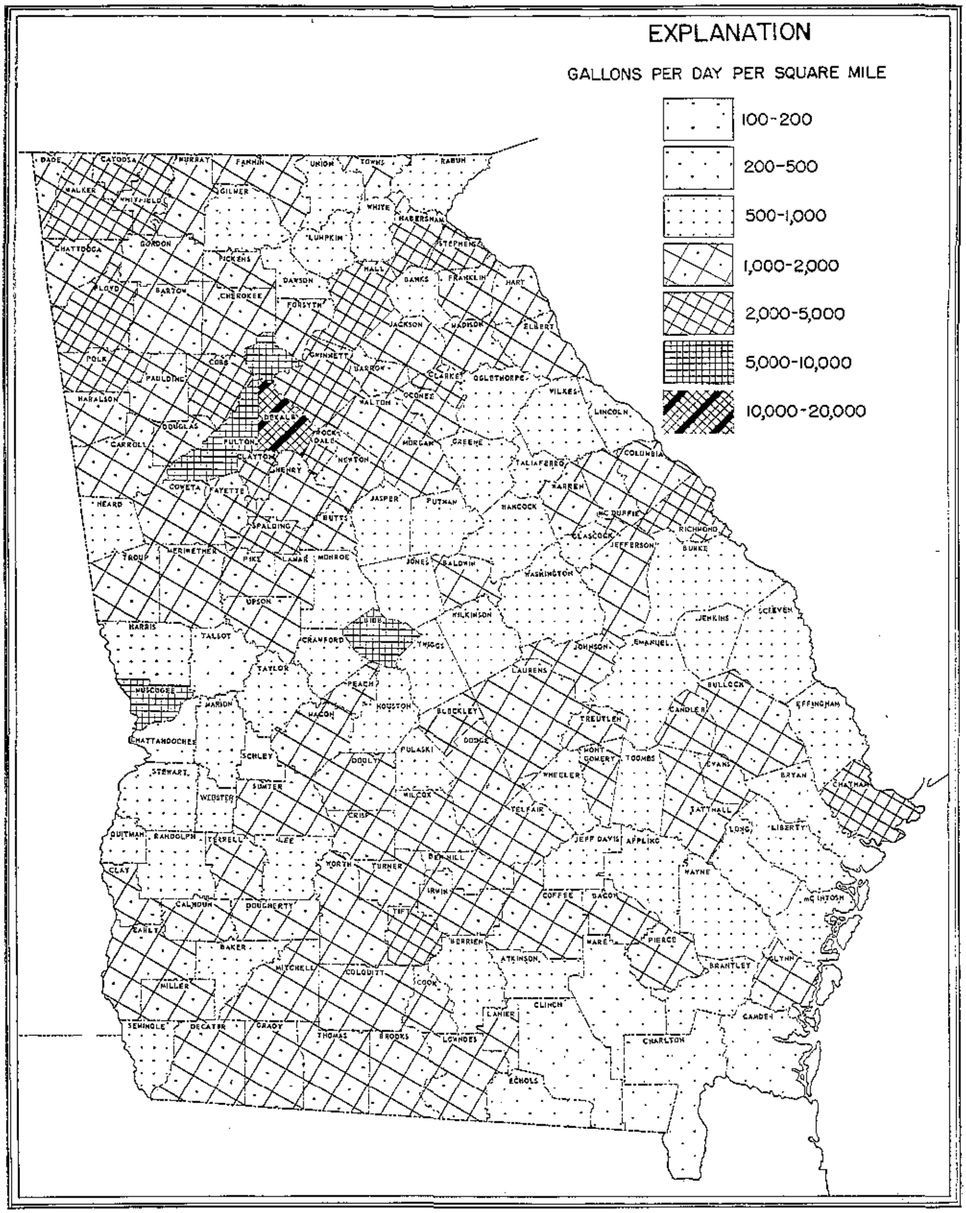


Figure 2. Map of Georgia showing estimated rural use of water by counties in 1955, in gallons per day per square mile.

human consumption, the U. S. Public Health Service many years ago stated the maximum concentrations of chemical substances permissible in water supplied on interstate carriers. These quality requirements for drinking water, as stated in the table below, have been almost universally adopted by the Health Departments of various States. In addition to being clear, colorless, odorless, of pleasant taste, and free from toxic salts, the chemical substances present in natural or treated waters to be used for drinking preferably should not exceed the following concentrations, according to the 1946 U. S. Public Health Service standards:

Constituents	Maximum Concentration (Parts per million)
Iron (Fe) and Manganese (Mn) combined	0.3
Fluoride (F)	1.5
Magnesium (Mg)	125
Chloride (Cl)	250
Sulfate (SO_4)	250
Dissolved Solids	500 (1,000 permitted)

Modern urban water supplies are usually treated. Those from wells are usually chlorinated and are sometimes treated to remove iron and manganese and to reduce excessive hardness. Those from streams are always treated to remove one or more impurities, usually by settling in raw water reservoirs, the addition of chemicals, and filtration followed by chlorination.

The capacity of the raw-water reservoir of an urban water system using streamflow depends on the relation between the supply and the requirements of the community. The reservoir provides a supplemental supply when streamflow is less than the city's requirements. The system also usually includes a comparatively small reservoir or tank in which to store treated water. This storage permits the intermittent use of the filters and also supplies the community by gravity flow or by pumps in an emergency. The finished-water reservoir is rarely large enough to maintain the supply when drought conditions reduce stream-flow below requirements.

The rate of withdrawal of urban water from streams does not vary as much as the rate of actual use of the water from the mains. The rate of use is greatest in hot weather, when lawns are watered copiously, and is usually greater during the day than at night, and greater on weekdays than on weekends. These variations are equalized to some extent by the finished-water tanks and the raw-water reservoir, so that the withdrawal rate from the streams tends to be somewhat more uniform except for the seasonal variation. Therefore, urban-use in this report is expressed in terms of mean monthly rates.

The maximum use given in this report is the highest mean monthly use for the period November 1954 to October 1955. This has been given, rather than the plant capacity, because it is more closely related to the population data on which the forecast of urban use in 1970 has been based. Plant capacities are difficult to analyze because the plants are designed on the basis of some future demand. Old plants may be used to full capacity, while recently built plants may be used only to a part of their capacity. For the 36 municipal supplies having complete records in 1955, the maximum monthly use was from 5 to 60 percent higher than the average annual use, the average being 20 percent. The average percentage was used to compute the maximum monthly rate where the municipal records did not show it.

Total urban use of water.—Good records of monthly water use for the larger cities and some smaller ones are available in the files of the Georgia Department of Public Health, from which the urban-use data in table 2 (p. 25) have been compiled. Georgia's 96 urban communities serving 2,500 or more persons used 260 million gallons of water per day on the average during the year 1955, of which 210 mgd came from streams and 50 mgd came from ground-water sources. Of the 96 urban water-supply systems in Georgia, 44 use surface-water sources, 50 use ground-water sources, and 2 use a combination of surface and ground-water.

A list of the water-supply systems in Georgia is given in table 2, together with information on population, water source, waste-disposal stream, and water use. Some of the systems supply more than one community. Where the population served differs significantly from the total population, the population served is given and so noted.

Figure 4 (p. 37) shows the comparative urban use from surface water and ground water sources in Georgia for the year 1955. Only six urban supplies exceed 10 million gallons per day, but they comprise more than half of the total urban use. Urban supplies from wells predominate in southern Georgia and supplies from streams predominate in northern Georgia.

There are 260 communities in Georgia of less than 2,500 population that have central supplies, most of them from wells or springs. These supplies have been considered part of the rural use rather than urban use because they are largely estimated, and forecasts of them for 1970 would be more conjectural than those for larger communities. Their total estimated use of water in 1955 is about 25 mgd.

Variation in per capita urban use.—The records show a considerable variation in the water use per capita, ranging from as little as 41 to as much as 732 gallons per capita per day. There are a number of factors causing variations in per capita use of urban water. Probably the principal one is the amount of water used for industrial purposes but not specifically identified in the records. Another factor may be the relative prosperity of the community—prosperous towns generally have more expensive homes, larger lawns and more shrubbery that are sprinkled more often, more cars washed, and more laundry done. Another cause of variation is the condition of the water system itself—a well built system will have relatively little loss by leakage from the water mains, but other systems may suffer relatively large losses of water between the time it is pumped from the source and the time it is delivered to the customer. Still another factor is the size of the supply or of the system itself—communities with limited sources, limited treatment plants, or limited water mains are likely to use less water than those that have abundant sources and adequate water systems. Larger communities tend to use more water per capita than smaller communities.

The authors have used 100 gallons per capita per day as the average water use in 1955 of communities that did not report the actual water supplied. Most of these communities are relatively small and are not known to have industries that use larger quantities of water.

Trends in urban use.—In 1945, the average per capita urban use of water in Georgia was 109 gallons per day[1] In 1955, it was 132 gallons per capita per day according to the records of the Georgia Department of Public Health. In 1970, the authors estimate that it will be about 140 gallons per capita per day. This trend toward increasing urban use is shown in a number of published reports on water use such as the report

[1]Langbein, W. B., Municipal Water Use in the United States, Jour. Am. Water Works Assn., November, 1949, V 41 N 11 p. 997.

Table 2.—Estimated urban use of water in Georgia

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955					1970
				Estimated population[2]	Average use[3]		Maximum monthly use[4]		Estimated percentage increase in use[5]
					Mgd	Gpc	Mgd	Gpc	
Adel	Cook	Deep well	Br. trib. to Withlacoochee River	3,100	0.2	64	[a]0.25	[a] 81	50
Albany	Dougherty	Deep well	Flint River	[b]43,000	7.5	174	[a]9.0	[a]209	60
Alma	Bacon	Deep well	Hurricane Creek	3,000	.25	83	[a].3	[a]100	60
Americus	Sumter	Deep well	Muckalee Creek	12,500	1.5	120	[a]1.8	[a]144	33
Ashburn	Turner	Deep well	Little River	3,300	.2	61	[a].25	[a] 76	50
Athens	Clark	Oconee River, Sandy Cr. (Aux.)	Oconee River	32,100	2.72	85	3.27	102	50
Atlanta	Fulton, DeKalb	Chattahoochee River	Chattahoochee R., Flint R., Intrenchment Cr., South River	[c]492,000	59	120	67	136	44
Augusta	Richmond	Savannah River	Savannah River	[b]140,000	12.5	89	14.1	101	92
Bainbridge	Decatur	Deep well	Flint River	[b]10,500	1.0	95	[a]1.2	[a]114	40
Barnesville	Lamar	Towaliga and Edie Creeks	Tobesofkee Creek	4,500	.68	151	.78	173	25
Baxley	Appling	Deep well	Branch trib. to Little Satilla River	3,700	.3	81	[a].35	[a] 95	33

See footnotes at end of table.

Table 2.—Estimated urban use of water in Georgia—Continued

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955					1970
				Estimated population[2]	Average use[3]		Maximum monthly use[4]		Estimated percentage increase in use[5]
					Mgd	Gpc	Mgd	Gpc	
Blakely	Early	Deep well	Baptist Creek to Spring Creek	3,500	0.3	86	[a]0.35	[a]100	33
Brunswick	Glynn	Deep well	St. Simons Sound and Black Banks River	19,500	[d]2.0	—	[f]2.4	—	35
Buford	Gwinnett	Shoal Creek	Trib. to Chattahoochee River	3,600	.29	80	.37	103	0
Cairo	Grady	Deep well	Br. trib. to Tired Creek	6,100	[d].6	—	[f].7	—	33
Calhoun	Gordon	Oostanaula River	Br. trib. to Oostanaula River	3,400	.76	223	1.00	290	18
Camilla	Mitchell	Deep well	Big Slough	4,400	[d].45	—	[f].55	—	56
Canton	Cherokee	Etowah River	Etowah River	2,800	.47	168	.59	211	17
Carrollton	Carroll	Little Tallapoosa River	Little Tallapoosa River	8,600	.82	95	.96	112	34
Cartersville	Bartow	Etowah River	Br. trib. to Etowah River	7,900	1.21	153	1.27	161	32
Cedartown	Polk	Spring	Cedar Creek	10,100	2.0	198	[a]2.4	[a]238	25
Cochran	Bleckley	Deep well	Br. trib. to Altamaha River	3,800	[d].4	—	[f].5	—	33
Cobb County		Chattahoochee River	Ward Creek	[b]35,000	5.64	161	7.00	200	95
Columbus	Muscogee	Chattahoochee River	Chattahoochee River	93,400	13.9	149	17.0	182	51

See footnotes at end of table.

Table 2.—Estimated urban use of water in Georgia—Continued

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955 Estimated population[2]	1955 Average use[3] Mgd	1955 Average use[3] Gpc	1955 Maximum monthly use[4] Mgd	1955 Maximum monthly use[4] Gpc	1970 Estimated percentage increase in use[5]
Commerce	Jackson	Turkey Creek, Border Creek	Trib. to Groves Creek	3,400	[d]0.35	—	[f]0.4	—	14
Cordele	Crisp	Deep well	Br. trib. to Flint River	10,300	1.25	121	[a]1.5	[a]146	36
Covington	Newton	Dry Indian Creek	Dried Indian Creek	5,900	.54	91	.63	107	48
Cuthbert	Randolph	Deep well	Br. trib. to Chattahoochee River	4,300	.3	70	[a].35	[a]81	33
Dalton	Whitfield	Mill Creek	Br. trib. to Conasauga River	[b]20,000	4.42	221	5.66	283	47
Dawson	Terrell	Deep well	Br. to Chickasawhatchee River	4,800	[d].5	—	[f].6	—	30
DeKalb County		Chattahoochee River	Br. to South River	[b]160,000	15.9	100	19.6	140	76
Donalsonville	Seminole	Deep well	Trib. to Chattahoochee River	3,000	[d].3	—	[f].35	—	50
Douglas	Coffee	Deep well	Br. trib. to 17 Mile Creek	8,600	1.0	116	[a]1.2	[a]139	50
Douglasville	Douglas	Aneewakee Creek	Br. trib. to Chattahoochee River	3,900	.27	69	.32	82	50
Dublin	Laurens	Deep well	Oconee River	[b]14,000	1.1	79	[a]1.3	[a]93	46
Eastman	Dodge	Deep well	Gum Swamp Cr. trib. to Sugar Creek	3,800	[d].4	—	[f].5	—	25

See footnotes at end of table.

Table 2.—Estimated urban use of water in Georgia—Continued

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955					1970
				Estimated population[2]	Average use[3]		Maximum monthly use[4]		Estimated percentage increase in use[5]
					Mgd	Gpc	Mgd	Gpc	
East Point	Fulton	Sweetwater Creek	Br. trib. to Chattahoochee R., South River, Chattahoochee River	[b]45,000	[e]3.3	73	[a]4.0	[a]89	36
East Thomaston	Upson	Potato Creek	Br. trib. to Flint River	3,000	2.2	732	2.4	800	0
Eatonton	Putnam	Rooty Creek	Br. trib. to Oconee River	2,900	.30	103	.39	134	17
Elberton	Elbert	Beaverdam Creek	Trib. to Savannah River	7,100	.89	125	.96	135	25
Fitzgerald	Ben Hill	Deep well	Willacoochnee River	8,500	[d].85	—	[f]1.0	—	30
Forsyth	Monroe	Tobesofkee Creek	Br. trib. to Ocmulgee River	3,500	.36	103	.39	111	40
Fort Valley	Peach	Deep well	Bay Creek	7,800	[d].8	—	[f].95	—	50
Gainesville	Hall	Chattahoochee River and Dry Creek	Chattahoochee River	[b]20,000	2.44	122	2.95	148	35
Greensboro	Greene	Town Creek	Br. trib. to Oconee River	2,800	[e].15	54	[a].2	[a]71	33
Griffin	Spalding	Flint River	Cabin Creek, Ison Branch	[b]20,000	3.00	150	3.85	192	40
Hapeville	Fulton	Deep well	Flint River, Br. to South River, South River	10,400	[d]1.05	—	[f]1.25	—	62
Hartwell	Hart	Lightwood Log Creek	Br. trib. to Savannah River	3,300	[d].3	—	[f].35	—	50

See footnotes at end of table.

Table 2.—Estimated urban use of water in Georgia—Continued

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955					1970
				Estimated population[2]	Average use[3]		Maximum monthly use[4]		Estimated percentage increase in use[5]
					Mgd	Gpc	Mgd	Gpc	
Hawkinsville	Pulaski	Deep well	Ocmulgee River	3,500	0.4	114	[a]0.5	[a]143	25
Hazlehurst	Jeff Davis	Deep well	Br. trib. to Altamaha River	3,200	.26	81	[a].3	[a]94	73
Hogansville	Troup	Flat Creek	Yellowjacket Creek	3,800	.30	79	.32	84	17
Jesup	Wayne	Deep well	Br. trib. to Penholoway Creek	5,500	[d].55	—	[f].65	—	64
LaFayette	Walker	Spring	Br. trib. to Chattooga River	5,600	[d].55	—	[f].65	—	45
LaGrange	Troup	Chattahoochee River	Blue John Cr., Br. trib. to Chattahoochee River	27,500	2.00	73	2.58	94	45
Lawrenceville	Gwinnett	Deep well	Br. trib. to Alcovy River	3,300	[d].35	—	[f].4	—	43
Lyons	Toombs	Deep well	Rocky Creek, Pendleton Creek	3,300	[d].35	—	[f].4	—	57
Macon	Bibb	Ocmulgee River	Ocmulgee River	[b]105,000	14.0	133	[a]17	[a]162	36
Manchester	Meriwether, Talbot	Springs	Pigeon Creek	4,400	[e].35	79	[a].4	[a]91	43
Milledgeville	Baldwin	Fishing Creek, Oconee River (Aux.)	Oconee River	9,900	1.05	106	1.22	124	43
Milledgeville State Hospital	Baldwin	Oconee River	Oconee River	14,000	2.10	150	2.35	168	0

See footnotes at end of table.

Table 2.—Estimated urban use of water in Georgia—Continued

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955					1970
				Estimated population[2]	Average use[3]		Maximum monthly use[4]		Estimated percentage increase in use[5]
					Mgd	Gpc	Mgd	Gpc	
Millen	Jenkins	Deep well	Buckhead Creek	3,800	[d]0.4	—	[f]0.5	—	38
Monroe	Walton	Jacks Creek	Alcovy River	5,000	.40	80	.53	106	38
Montezuma	Macon	Deep well	Flint River	3,200	[d].3	—	[f].35	—	33
Moultrie	Colquitt	Deep well	Ochlockonee River	[b]16,000	1.4	88	[a]1.7	[a]106	50
Nashville	Berrien	Deep well	Br. trib. to Withlacoochee River	3,900	[d].4	—	[f].5	—	50
Newnan	Coweta	Bolton Mill, Br., White Oak Creek (Aux.)	Mineral Springs Br., Cotton Mills Branch	8,800	1.10	125	1.37	156	27
Ocilla	Irwin	Deep well	Br. trib. to Willacoochee River	3,000	[d].3	—	[f].35	—	50
Pelham	Mitchell	Deep well	Town Br. of Little Ochlockonee River	5,100	1.0	196	[a]1.2	[a]236	50
Perry	Houston	Deep well	Indian Creek	5,100	.5	98	[a].6	[a]118	90
Porterdale	Newton	Yellow River	Yellow River	3,400	[d].3	—	[f].35	—	33
Quitman	Brooks	Deep well	Okapilco Creek	4,900	[d].5	—	[f].6	—	20
Rockmart	Polk	Curarlee Creek	Euharles Creek	4,000	[d].4	—	[f].5	—	25

See footnotes at end of table.

Table 2.—Estimated urban use of water in Georgia—Continued

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955					1970
				Estimated population[2]	Average use[3]		Maximum monthly use[4]		Estimated percentage increase in use[5]
					Mgd	Gpc	Mgd	Gpc	
Rome	Floyd	Oostanaula River, Small Creek	Coosa River, Oostanaula River, unnamed Branch	[b]40,000	4.75	119	5.59	140	37
Sandersville	Washington	Deep well	Limestone Creek	5,000	1.0	200	[a]1.2	[a]240	40
Savannah	Chatham	Deep well, Abercorn Creek	Savannah River, Tidewater, Atlantic Ocean	[b]200,000	45	225	[a]54	[a]270	31
Silvertown	Upson	Potato Creek	Potato Creek, Flint River	3,400	.5	147	.65	191	10
Statesboro	Bullock	Deep well	Br. to Lotis Creek, Br. to Ogeechee River	6,700	1.5	223	[a]1.8	[a]269	33
Summerville	Chattooga	Spring and Stream	Chattooga River	4,900	[c].2	41	[a].25	[a]51	100
Swainsboro	Emanuel	Deep well	Yamgrandee Creek	4,700	.43	91	[a].5	[a]106	40
Sylvania	Screven	Deep well	Buck Creek	3,200	.5	156	[a].6	[a]188	30
Sylvester	Worth	Deep well	Warrior Creek, Little River	2,800	.3	107	[a].35	[a]125	33
Tallapoosa	Haralson	Tallapoosa River	Tallapoosa River	3,100	.50	161	.56	181	40
Thomaston	Upson	Potato Creek	Flint River	7,400	.70	95	.82	111	43
Thomasville	Thomas	Deep well	Ochlockonee River	15,900	1.8	113	[a]2.2	[a]138	39

See footnotes at end of table.

Table 2.—Estimated urban use of water in Georgia—Continued

Urban Area[1]	County	Source of water supply	Waste-disposal stream	1955					1970
				Estimated population[2]	Average use[3]		Maximum monthly use[4]		Estimated percentage increase in use[5]
					Mgd	Gpc	Mgd	Gpc	
Thompson	McDuffie	Sweetwater Creek	Little Brier Creek	3,700	0.40	108	0.48	130	25
Tifton	Tift	Deep well	New River, Town Creek to Little River	7,700	1.7	221	[a]2.0	[a]260	41
Toccoa	Stephens	Cedar Creek	Branch to Tugaloo River	7,500	2.25	300	2.54	339	33
Trion	Chattooga	Spring	Chattooga River	3,400	[d].3	—	[f].35	—	50
Valdosta	Lowndes	Deep well	Branch of Mud Creek	[b]28,000	9.0	321	[a]11	[a]393	33
Vidalia	Toombs	Deep well	Rocky Creek	6,700	.7	104	[a].85	[a]127	43
Warner Robins	Houston	Deep well	Echeconee Creek	9,600	1.1	115	[a]1.3	[a]135	64
Washington	Wilkes	Beaverdam Creek	Rocky Creek to Little Creek	4,000	.40	100	.63	157	25
Waycross	Ware	Deep well	Satilla River	[b]16,000	2.5	156	[a]3	[a]187	88
Waynesboro	Burke	Brier Creek	Brier Creek	4,800	[c].75	156	[a].9	[a]187	27
West Point	Troup	Osaliga Creek	Chattahoochee River	4,500	.45	100	.64	142	45
Winder	Barrow	Cedar Creek	Mulberry Fork	4,900	.60	122	.69	141	25
TOTAL 96	44 Surface, 46 Deep well, 4 Spring, 1 Surface and Deep well, 1 Surface and Spring.			1,979,200	263.25		312.71 S.W.— 210.56 G.W.— 52.69		

See footnotes at end of table

Table 2. - Estimated urban use of water in Georgia—Continued

[1] Urban area is here defined as a community having a public water supply system which serves 2,500 or more persons.

[2] Estimate of population on July 1, 1955 as determined by Georgia Department of Public Health unless otherwise noted.

[3] Average pumpage for the period November 1954 to October 1955, in millions of gallons per day and gallons per capita, furnished by Georgia Department of Public Health unless otherwise noted.

[4] Maximum monthly pumpage during the period November 1954 to October 1955, in millions of gallons per day and gallons per capita, furnished by the Georgia Department of Public Health unless otherwise noted.

[5] Percentage increase applies to average and maximum monthly use in million gallons per day but not to use in gallons per capita.

[a]–Estimated on basis of average use.

[b]–Estimated population served.

[c]–Estimate of population served, furnished by Atlanta Water Works.

[d]–Computed on basis of an estimated per capita use of 100 gallons per day

[e]–Estimated on basis of incomplete records.

[f]–Computed on basis of an estimated per capita use of 120 gallons per day.

to the President by the President's Materials Policy Commission that indicated an expected increase of 10 gallons per capita between 1950 and 1975.

One of the factors that contributes to this upward trend in per capita water use for the State as a whole is that a larger part of the population in a community will be served. At the present time, many cities include fringe areas supplied by private wells; but by 1970, the cities will probably have extended their central supply systems to serve a larger proportion of the fringe areas, thus increasing the total used by a community, even with no change in population. Another factor is the increasing number of commercial and industrial establishments. Not all of those industries will add to the community population because more of the workers will live in the suburbs or in the country. Thus, the increased water use will show as an increase in per capita use for the population within the community. A third factor is the rising trend in water-using habits resulting from the increasing number of bathrooms, automatic washers, air conditioners, and other water-using appliances.

One exception to increasing per capita water use should be noted. Atlanta, Georgia's largest city, has in the past several years had a more or less constant rate of per-capita use. The trend in water use in Atlanta is shown by the graphs in figure 3 (p. 35). As indicated by the top graph on the figure, officials of the Atlanta Water Works do not expect any substantial increase in per capita use within the next 15 years.

Estimated urban use in 1970.—Urban use in 1970 has been estimated on the basis of the expected 1970 population projected, in general, by the method employed by the Georgia State Department of Health. It has been assumed in most cases that the population served will increase at least in proportion to the increase in total population. The 1955 per capita use of water in all communities but Atlanta has been increased by 10 gallons per day to obtain the estimated per capita use for 1970. The 1970 total use is estimated to be 380 mgd of which 300 mgd is expected to come from surface-water sources and 80 mgd from ground-water sources.

Table 2 (p. 25) shows the estimated percentage increase in average and maximum urban use by 1970.

A brief comment on the adequacy of present urban water-supply systems is in order here. The **Inventory of municipal**

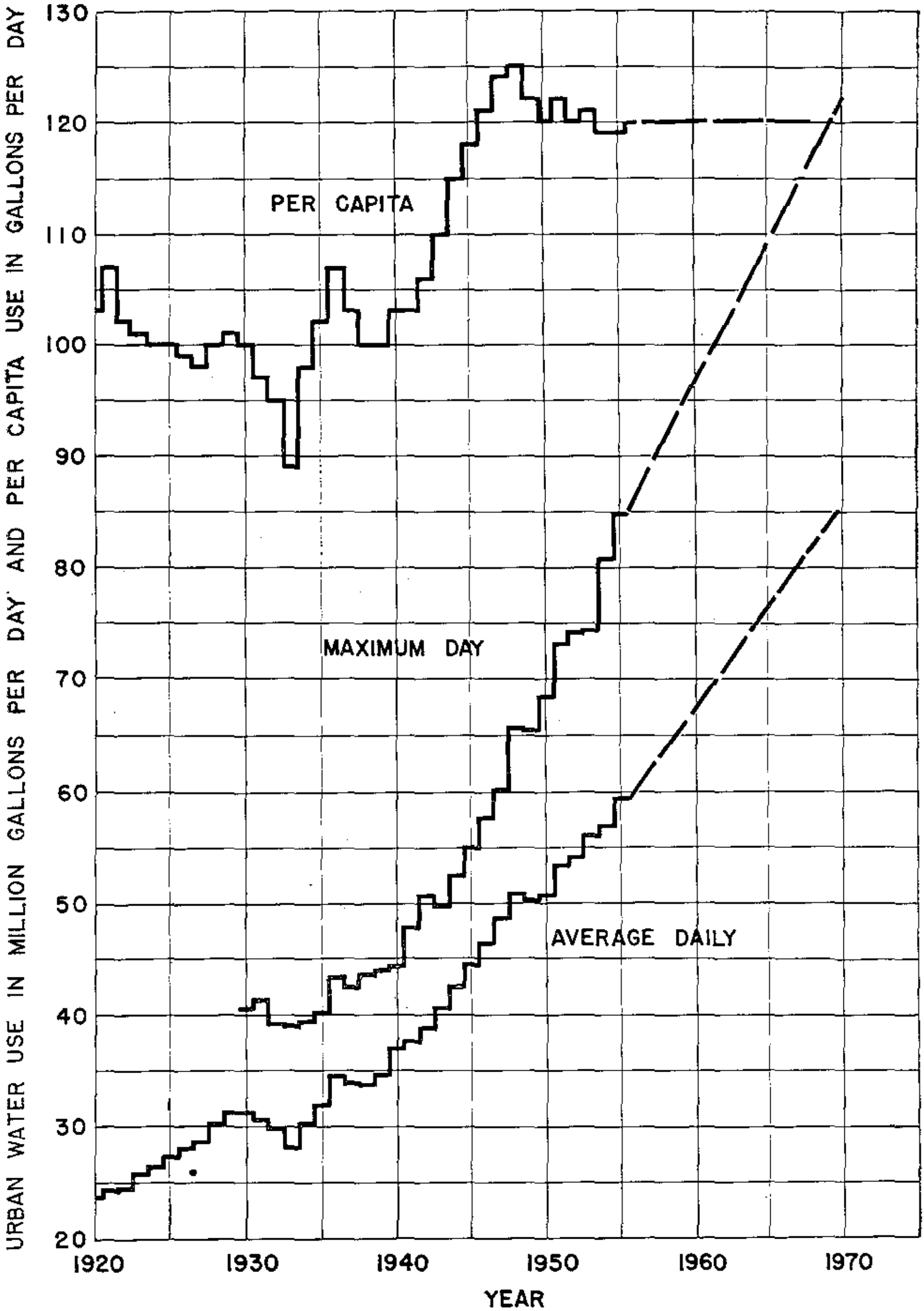


Figure 3. Past, present and probable future urban use of water in Atlanta. Reproduced by courtesy of Paul Weir, General Manager, Atlanta Department of Water Works.

water facilities for larger communities published by the U. S. Department of Health, Education, and Welfare in 1955, indicates that of 27 of the largest municipal water systems in Georgia, 16 need some form of improvement either in 1955 or in the near future. In most cases, expansion of physical facilities—for pumping, storage, treatment, or transmission—is needed rather than new sources of water. The report shows that 10 systems need increased pumping facilities, 11 need increased storage capacity, 7 need expanded treatment facilities, 7 need to extend main transmission lines, 9 need improved distribution facilities, 6 need additional ground-water sources, and 3 need additional surface-water sources. No information is available on 6 of the municipal systems, and only 5 systems are reported to need no improvement.

INDUSTRIAL

Water is used in industry as a solvent in some processes, as a raw material in others, and also is used for transportation, generation of steam, condensing and cooling, cleansing, waste treatment and disposal, and fire protection.

Quantitative information on industrial use of water in Georgia is limited to the largest users, such as the steam-power plants and some of the industrial plants in southern Georgia that use artesian wells. Some data are available from the records of the water departments of larger cities that report commercial water customers separately from domestic customers but those records do not show how much of the water is used in industrial processes. No systematic survey of industrial water use has been made in Georgia.

On the basis of the limited data available, it is estimated that the 1955 total industrial use of water in the State from private sources (sources other than public water systems) is 1,830 mgd of which 1,450 mgd is used for cooling at steam-generating plants. Manufacturing industries use about 340 mgd and non-manufacturing industries use the remaining 40 mgd. The total does not include two large users of Savannah River water located in South Carolina: Plant Urquhart which uses an average of 230 mgd, and the Savannah River Plant of the Atomic Energy Commission which uses an average of 720 mgd.

Industrial water requirements are given in many recent

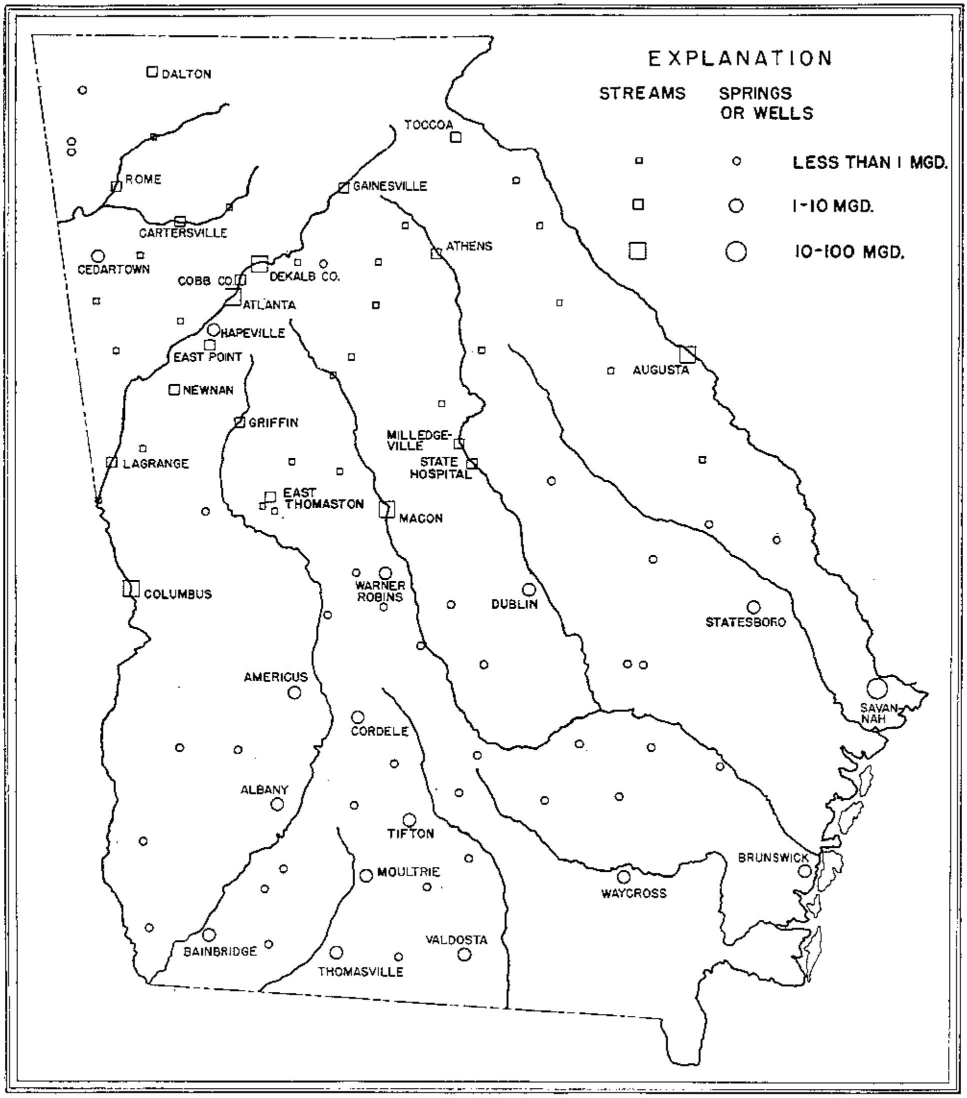


Figure 4. Map of Georgia showing estimated average urban use of water in 1955, in places of 2,500 population or more, in million gallons per day.

publications in terms of water required per unit of product. Table 3 (p. 39) gives a sample listing of these requirements.

The quality of water needed for industry is often as important as the quantity. The water uses by industry are so varied and the quality requirements so diverse that it is not possible to set up a single set of water quality tolerances that will fit all industries. Most industries have specific water quality requirements, some of which are far more exacting in certain aspects than the requirements for potable supplies. These requirements may be met by selection of a satisfactory natural water supply source, or by chemical treatment of an unsuitable supply. Limits of tolerance for chemical quality of water for some industries are shown in table 4 (p. 40). The limits given serve only to indicate certain characteristics of water that are significant in the evaluation of the suitability of water for some industrial processes. The values given in the table are only suggested guides in evaluating the suitability of water supplies and, in general, are those beyond which corrective treatment of the supply begins to be necessary.

Table 5 (p. 42) shows the estimated use of water for cooling purposes at steam generating plants in 1955, and figure 5 (p. 45) shows the location of the plants and a comparison of the amount used by each plant. The total use of water for this purpose averages about 1,450 mgd, of which the four largest plants use an average of 1,060 mgd.

The maximum rate of use is about 2,200 mgd. The maximum rate of industrial use is based on plant capacity rather than on monthly data as in the case of municipal water supply systems. Steam-power plants run at full capacity much of the time and their expansion is not adaptable to statistical projection like the population growth of cities.

POWER

The use of falling water is an important source of power in Georgia. Initially, water power was developed by small grist mills and saw mills, and until electric power became generally available most of the smaller streams of the State were dotted with small dams and water wheels. There were about 200 such small water-driven mills in the State in 1955.

The modern coordinated use of power from steam-electric and hydroelectric-power sources provides an efficient use of power resources. Steam-electric power sources are best adapted to operation over relatively long periods of time and therefore, where steam-electric and hydroelectric sources are employed together, are usually operated in the base of the power load. This leaves the hydroelectric source available for use in the rapidly changing peak portion of the load where, as a general rule, it can operate more effectively than the steam-electric supply. During the wintertime when there is a surplus of water power, hydroelectric-power plants may operate continuously, enabling the utilities to reduce the operation of steam plants and save the cost of fuel. During dry seasons, however, the hydroelectric-power plants are normally operated intermittently, sometimes for only a few hours at a time, to take care of the peak loads.

In order to fulfill peak-power needs, many hydroelectric-power plants have considerable pondage capacity. Pondage is the storing of water in the power pool at night or over week-ends so that it can be used for a few hours each week-day for

Table 3.—Industrial requirements for water[1]

Product	Unit	Water required, gal. to produce or process one unit
Alcohol	Gallon	100
Aluminum	Pound	160
Brewing (beer)	1 barrel	470
Butadiene	Pound	160
Canning	100 cases No. 2 cans	2,500- 25,000
Cement	Ton	750
Coke	Ton	3,600
Distilling:		
Grain	1,000 bu. grain mashed	600,000
Molasses	1,000 gal., 100-proof	8,400
Cooling water	1,000 gal., 100-proof	120,000
Electric power	Kilowatt	80
Gasoline	Gallon	7- 10
Iron ore (brown ore)	Ton	1,000
Meat, slaughterhouse and packing	100 hogs killed	550
Milk	1,000 raw pounds	100- 300
Oil refining	Barrel	770
Paper	Ton	5,000- 85,000
Rail freight	Ton/mile	0.1
Soap	Ton	500
Steam power	Ton of coal	60,000-120,000
Tanning	100 lbs. rawhide	800
Textiles	1,000 lbs. processed	1,000- 20,000
Rayon	1,000 lbs. produced	135,000-160,000
Woolens	1,000 lbs. finished	70,000

[1]Data reported in Journal of American Water Works Association, Vol. 38, No. 1, January 1946.

Table 4 —Suggested limits of tolerance for chemical quality of water for industrial use[a]
(Limiting values reported in parts per million)

Industry or use	Color	Hardness as $CaCO_3$	Iron as Fe	Allowable manganese as Mn	Total solids	Alkalinity as $CaCO_3$	Other requirements[b]
Baking	10	—	[c]0.2	0.2	—	—	P
Brewing							
light beer	—	—	[c] .1	.1	500	75	P. NaCl less than 275 p.p.m. (pH 6.5–7.0).
dark beer	—	—	[c] .1	.1	1,000	150	P. NaCl less than 275 p.p.m. (pH 7.0 or more).
Canning							
legumes	—	25–75	[c] .2	.2	—	—	P
general	—	—	[c] .2	.2	—	—	P
Carbonated beverages	10	250	.2 ([c].3)	.2	850	50–100	P. Organic color plus oxygen consumed less than 10 p.p.m.
Cooling	—	50	[c] .5	.5	—	—	No corrosiveness.
Food, general	—	—	[c] .2	.2	—	—	P
Ice	5	—	[c] .2	.2	—	—	P. SiO_2 less than 10 p.p.m.
Laundering	—	50	[c] .2	.2	—	—	
Paper and pulp							
groundwood	20	180	[c]1.0	.5	—	—	No grit, corrosiveness.
Kraft pulp	15	100	[c] .2	.1	300	—	
soda and sulfite	10	100	[c] .1	.05	200	—	
high-grade papers	5	50	[c] .1	.05	[c]200	—	

See footnotes at end of table.

Table 4.—Suggested limits of tolerance for chemical quality of water for industrial use[a]—Continued
(Limiting values reported in parts per million)

Industry or use	Color	Hardness as $CaCO_3$	Iron as Fe	Allowable manganese as Mn	Total solids	Alkalinity as $CaCO_3$	Other requirements[b]
Rayon (Viscose), pulp production	5	8	[c] .05	.03	100	total 50 hydroxide 8	Al_2O_3 less than 8 p.p.m., SiO_2 less than 25 p.p.m.
manufacture	—	55	.0	.0	—	—	pH 7.8 to 8.3.
Tanning	10–100	50–135	[c] .2	.2	—	total 135 hydroxide 8	
Textiles general	20	—	.25	.25	—	—	
dyeing	5–20	—	[c] .25	.25	200	—	Constant composition.

[a] Data taken from a progress report by E. W. Moore; New England Water Works Assoc., Vol. 54, p. 263, 1940.
[b] P indicates that potable water, conforming to U.S.P.H.S. standards, is necessary.
[c] Limit given applies to both iron alone, and the sum of iron and manganese.

Table 5.—Estimated cooling water use at steam generating plants in Georgia in 1955

Plant	Near	Source of water supply	Installed capacity[1] (kw)	Generation 1955[1] (million kwh)	Water use at full capacity[2] (mgd)	Average water use 1955[2] (mgd)
UTILITY						
Riverside	Savannah	Savannah River	76,000	434	120	80
Arkwright	Macon	Ocmulgee River	160,000	1,075	[a]239	[b]180
McManus	Brunswick	Turtle River	40,000	140	[a]66	[b]26
Arco	Brunswick	Turtle River	4,000	Negligible	6	Negligible
Atkinson	Atlanta	Chattahoochee River	240,000	1,517	[a]430	[b]310
Davis Street	Atlanta	Chattahoochee River (cooling pond)	6,000	Negligible	9	Negligible
Yates	Newnan	Chattahoochee River	300,000	2,011	[a]370	[b]280
Hammond	Rome	Coosa River	300,000	1,579	[a]490	[b]290
Mitchell	Albany	Flint River	45,000	139	[a]120	[b]40
Thomasville	Thomasville	Deep well	15,500	49	24	9
Waycross	Waycross	Deep well	6,750	0	11	0
INDUSTRIAL						
Bibb Mfg. Co.	Porterdale	Yellow River	4,500	0	7	0

See footnotes at end of table.

Table 5.—Estimated cooling water use at steam generating plants in Georgia in 1955—Continued

Plant	Near	Source of water supply	Installed capacity[1] (kw)	Generation 1955[1] (million kwh)	Water use at full capacity[2] (mgd)	Average water use 1955[2] (mgd)
INDUSTRIAL						
Brunswick Pulp & Paper Company	Brunswick	Salt Water River	11,000	85	17	15
Celanese Corp. of America	Rome	Oostanaula	7,000	39	11	7
Fulton Bag & Cotton Company	Atlanta	Chattahoochee River	8,500	26	13	5
Hercules Powder Co.	Brunswick	Deep well	6,000	28	10	5
Macon Kraft Co.	Macon	Ocmulgee River	17,500	108	28	19
National Container Co.	Valdosta	Deep well	15,000	110	24	20
Pepperell Mfg. Co.	Lindale	Trib. to Etowah River	6,600	28	10	5
Rayonier, Inc.	Doctortown	Deep well	10,000	54	16	10
Rome Kraft Co.	Rome	Coosa River	17,500	116	28	21
St. Marys Kraft Co.	St. Marys	St. Marys River	23,000	135	36	24
Savannah Sugar Refining Corp.	Port Wentworth	Deep well	6,000	21	10	4
Southern Paperboard Corp.	Port Wentworth	Savannah River	19,500	127	31	23
Union Bag & Paper Co.	Savannah	Savannah River	51,000	462	80	80
State Total			1,396,350	8,283	2,206	1,453
Urquhart (S. C.)	Augusta	Savannah River	250,000	1,290	390	230

See footnotes at end of table.

Table 5.—Estimated cooling water use at steam generating plants in Georgia in 1955—Continued

Plant	Near	Source of water supply	Installed capacity[1] (kw)	Generation 1955[1] (million kwh)	Water use at full capacity[2] (mgd)	Average water use 1955[2] (mgd)
INDUSTRIAL						
Savannah River Plant, AEC[c]	Augusta	Savannah River				[d]720

[1] Furnished by the Federal Power Commission.
[2] Based on a water use rate of 65 gallons per kwh unless otherwise noted.
[a] Reported by Georgia Power Company.
[b] Based on the water use at full capacity reported by the Georgia Power Company.
[c] Not a steam generating plant.
[d] Quantity used for industrial purposes; maximum use does not vary significantly from the average use; furnished by the Atomic Energy Commission.

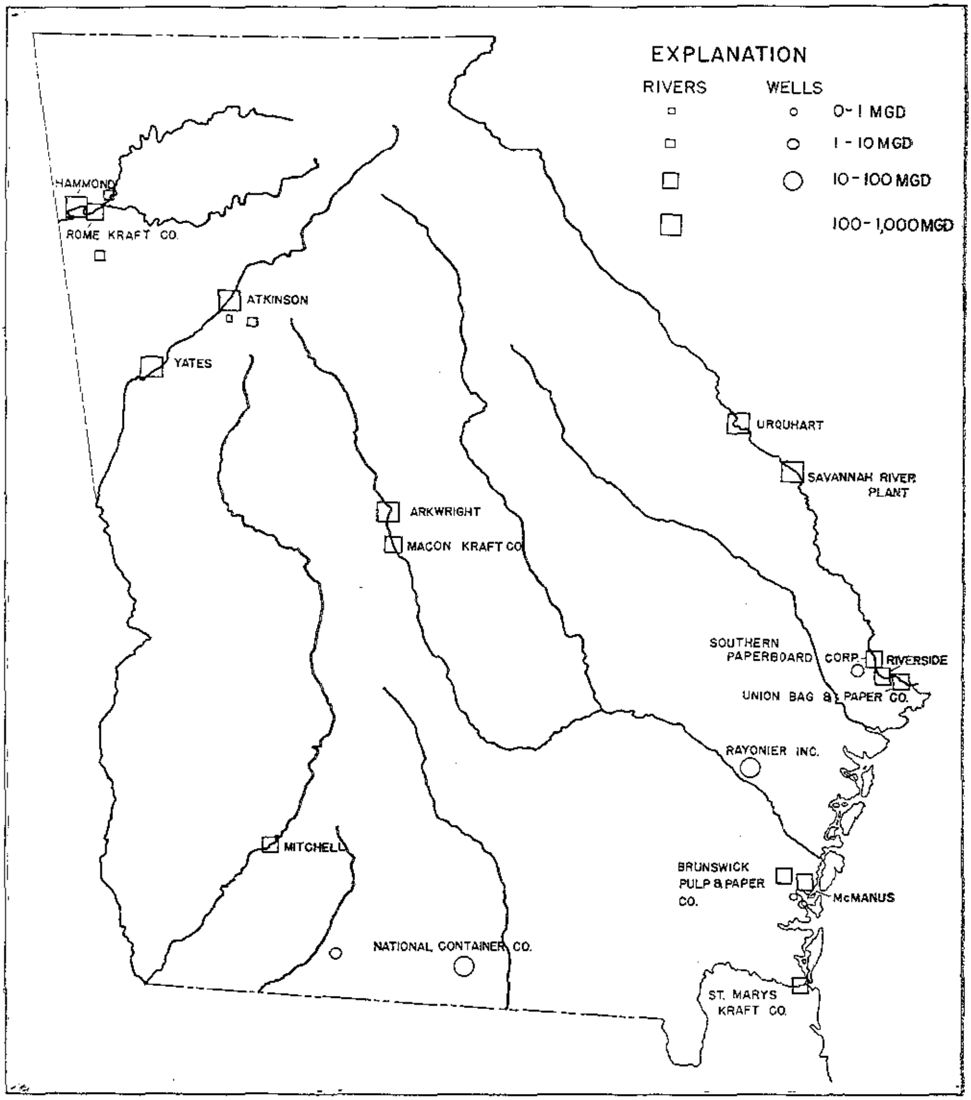


Figure 5. Map of Georgia showing estimated average water use for cooling at steam-power plants and industrial use at Savannah River Plant of the Atomic Energy Commission plant in 1955, in million gallons per day.

peak loads. Pondage is distinguished from storage by the fact that it is used primarily by the day or by the week, whereas storage is used to produce a seasonal or long-range modification of the natural flow.

The use of water for peak power at hydroelectric-power plants is complicated by the need for large, constant amounts of water for cooling purposes at steam-power plants. The present trend is toward large steam turbines—those recently installed in Georgia have as much as 125,000 kilowatts capacity. The trend is toward large plants also—a plant with a capacity of a million kilowatts is to be built on the Coosa River in Alabama to supply power for Georgia. Such a plant requires a constant supply of water so large that no river in northern Georgia could furnish it without a storage reservoir large enough to equalize the flow throughout the year. To do this would conflict with peak hydroelectric-power production at the dam. The use of nuclear fuels at steam-power plants will not resolve this conflict for the steam turbines would still be most efficient when operated at constant loads and would still require a large, constant supply of water.

Excellent data on the use of hydroelectric power are available in the records of the Federal Power Commission that show the trend in power use to be upward in recent years, averaging about a 9 per cent increase every year. Power use has been increasing in Georgia at this rate since 1941 and there is no indication of any tapering off before 1970. The increased industrial demands, the extension of power to rural homes, the increase in the use of electrical appliances and air conditioning, and the general prosperity and growth of the State have caused this steady upward trend.

The map in figure 6 (p. 47) shows the estimated average use of water by the hydroelectric-power plants on Georgia rivers that were built or under construction in 1955. For these plants table 6 (p. 48), shows the installed capacity, the average annual energy production, and the estimated quantity of water used for full capacity and for average production. The water quantities were computed by the methods used by the Federal Power Commission, employing average efficiency rates.

The plants listed in table 6 are those in Georgia or on interstate streams that use water from Georgia. The basin and State totals are the totals of the amounts listed for each plant.

Net totals include only a portion of each of the amounts given for Federal interstate projects. For example, only one-half of each of the amounts given for Hartwell and Clark Hill are included in the net totals for the Savannah River basin.

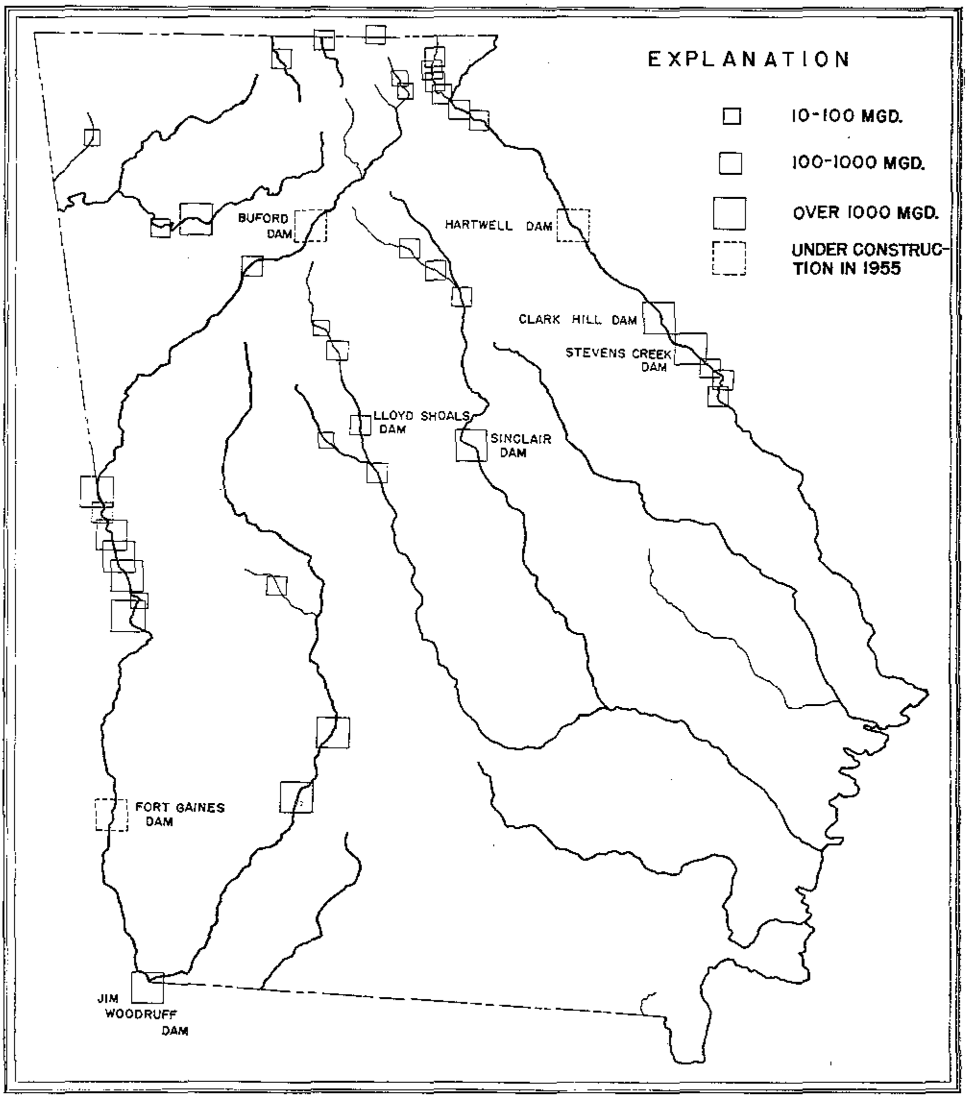


Figure 6. Map of Georgia showing estimated average hydroelectric-power use of water, at dams built or under construction in 1955, in million gallons per day.

Table 6.—The estimated use of water for hydroelectric power in Georgia at plants built or under construction in 1955[a]

Plant	River	Drainage area (sq. mi.)	Design head[d] (ft.)	Installed capacity[d] (kw)	Average Ann. generation[d] (million kwh)	Water use at full capacity[e] (mgd)	Average annual water use[f] (mgd)	Reservoir[g]	
								Surface area (acres)	Usable storage (mg)
SAVANNAH RIVER BASIN									
Burton	Tallulah	118	116	6,120	20	[k]620	190	2,775	34,500
Nacoochee	Tallulah	136	60	4,800	14	780	260	—	800
Terrora	Tallulah	151	180	16,000	46	[k]880	280	834	7,500
Tallulah	Tallulah	186	600	72,000	171	[k]1,100	310	—	460
Tugalo	Tugaloo	464	150	45,000	108	[k]3,100	790	597	3,700
Yonah	Tugaloo	470	72	22,500	51	[k]3,300	780	—	1,100
Hartwell	Savannah	2,088	185	300,000	453	16,000	2,700	57,000	465,000
Clark Hill	Savannah	6,140	136	280,000	698	20,000	5,700	78,500	563,000
Stephens Creek	Savannah	7,260	27	18,800	90	6,800	3,700	4,300	4,900
Kings Mill	Augusta Canal	7,260	32	[i]2,300	[i]7	700	240	—	—
Enterprise	Augusta Canal	7,260	[h]30	1,200	6.2	390	230	—	—
Sibley	Augusta Canal	7,260	[h]30	2,100	11	680	400	—	—
Basin Total				770,820	1,675.2	54,350	15,580	144,006	1,080,960
Net Basin Total[c]				480,820	1,100.2	36,350	11,380	76,256	566,960

See footnotes at end of table.

Table 6.—The estimated use of water for hydroelectric power in Georgia at plants built or under construction in 1955[a]—Continued

Plant	River	Drainage area (sq. mi.)	Design head[d] (ft.)	Installed capacity[d] (kw)	Average Ann. generation[d] (million kwh)	Water use at full capacity[e] (mgd)	Average annual water use[f] (mgd)	Reservoir[g] Surface area (acres)	Reservoir[g] Usable storage (mg)
ALTAMAHA RIVER BASIN									
Milstead	Yellow	248	44	800	2.9	180	70	—	—
Porterdale	Yellow	400	62	1,500	8.2	230	150	—	—
Lloyd Shoals	Ocmulgee	1,400	104	14,400	67	[k]1,800	710	4,750	25,400
High Falls	Towaliga	128	108	3,680	8	330	80	—	—
Juliette	Ocmulgee	1,960	16	[i]670	[i]2	400	140	—	—
Tallassee	Middle Fork Oconee	364	40	1,500	4.4	360	120	—	—
Mitchell Bridge	Middle Fork Oconee	390	23	500	2.2	210	110	—	—
Barnett Shoals	Oconee	835	50	2,800	15	540	330	—	—
Sinclair	Oconee	2,840	92	45,000	138	[k]4,700	1,600	15,400	69,700
Basin Total				70,850	247.7	8,750	3,310	20,150	95,100

See footnotes at end of table.

Table 6.—The estimated use of water for hydroelectric power in Georgia at plants built or under construction in 1955[a]—Continued

Plant	River	Drainage area (sq. mi.)	Design head[d] (ft.)	Installed capacity[d] (kw)	Average Ann. generation[d] (million kwh)	Water use at full capacity[e] (mgd)	Average annual water use[f] (mgd)	Reservoir[g]	
								Surface area (acres)	Usable storage (mg)
APALACHICOLA RIVER BASIN									
Hodges Shoals	Soque	148	26	[j]300	[j]1	110	40	—	—
Porter Shoals	Soque	114	90	[j]1,300	[j]4	140	50	—	—
Buford	Chattahoochee	1,046	136	86,000	170	6,100	1,310	55,400	548,000
Morgan Falls	Chattahoochee	1,340	48	16,800	43	[k]3,100	980	—	—
Langdale	Chattahoochee	3,600	16	4,010	20	2,400	1,400	—	—
Riverview	Chattahoochee	3,600	15	480	2.7	310	200	—	—
Bartlett's Ferry	Chattahoochee	4,200	112	65,000	291	[k]6,800	2,900	5,600	44,300
Goat Rock	Chattahoochee	4,250	70	26,000	170	[k]4,800	2,700	1,000	1,600
North Highlands	Chattahoochee	4,662	40	6,900	45	[k]2,400	1,200	—	—
City Mills	Chattahoochee	4,664	10	180	.3	170	30	—	—
Eagle & Phenix Mills	Chattahoochee	4,666	26	4,100	25	1,500	1,100	—	—
Fort Gaines	Chattahoochee	7,507	75	130,000	436	17,000	6,400	46,000	68,400
Whitewater	Whitewater	237	10	360	1.1	350	120	—	—

See footnotes at end of table.

Table 6.—The estimated use of water for hydroelectric power in Georgia at plants built or under construction in 1955[a]—Continued

Plant	River	Drainage area (sq. mi.)	Design head[d] (ft.)	Installed capacity[d] (kw)	Average Ann. generation[d] (million kwh)	Water use at full capacity[e] (mgd)	Average annual water use[f] (mgd)	Reservoir[g]	
								Surface area (acres)	Usable storage (mg)
				APALACHICOLA RIVER BASIN—Continued					
Crisp County	Flint	3,500	30	11,200	53	3,600	1,900	7,000	11,400
Flint River	Flint	5,150	24	5,400	47	[k]2,400	2,200	2,500	2,400
Jim Woodruff	Apalachicola	17,100	26	30,000	226	11,000	9,500	37,500	12,100
Basin Total				388,030	1,535.1	62,180	32,030	155,000	688,200
Net basin total[c]				308,030	1,204.1	48,180	24,080	122,600	651,000
				MOBILE RIVER BASIN					
Allatoona	Etowah	1,110	135	74,000	169	5,300	1,400	19,200	191,000
Thompson-Weinman Co.	Etowah	1,120	13	625	3.5	470	300	—	—
The Trion Co.	Chattooga	160	18	272	.1	150	60	—	—
Basin total				74,897	172.6	5,920	1,760	19,200	196,000

See footnotes at end of table.

Table 6.—The estimated use of water for hydroelectric power in Georgia at plants built or under construction in 1955[a]—Continued

Plant	River	Drainage area (sq. mi.)	Design head[d] (ft.)	Installed capacity[d] (kw)	Average Ann. generation[d] (million kwh)	Water use at full capacity[e] (mgd)	Average annual water use[f] (mgd)	Reservoir[g]	
								Surface area (acres)	Usable storage (mg)
TENNESSEE RIVER BASIN									
Chatuge	Hiwassee	189	124	10,000	31	780	270	7,150	74,700
Nottely	Nottely	214	169	15,000	37	860	240	4,290	55,700
Blue Ridge	Toccoa	232	147	20,000	35	1,300	260	3,320	60,700
Basin Total				45,000	103	2,940	770	19,760	191,000
Net basin total[c]				35,000	72	2,160	500	11,180	116,400
STATE TOTAL				1,349,597	3,640.9	134,140	53,450	353,116	2,246,360
NET STATE TOTAL[c]				969,597	2,796.6	101,360	41,030	249,386	1,620,460
PLANTS OUTSIDE OF GEORGIA AFFECTING GEORGIA RIVERS									
Jackson Bluff	Ochlockonee	1,660	35	8,800	20	2,400	630	10,000	22,000
Lay	Coosa	9,087	82	177,000	580	20,900	7,780	——	14,700
Martin	Tallapoosa	3,000	146	154,000	367	10,000	2,800	38,300	423,000

See footnotes at end of table.

Table 6.—The estimated use of water for hydroelectric power in Georgia at plants built or under construction in 1955[a]—Continued

[a] Two minor plants in operation in 1955 but due to be submerged by plants under construction are not indicated.
[c] Net total after deducting proportional quantities at federal interstate projects.
[d] Obtained from Federal Power Commission records or the plant operator unless otherwise noted.
[e] Based on installed name-plate capacity assuming a wheel efficiency of 80% unless otherwise noted.
[f] Based on average annual generation assuming a wheel efficiency of 80%.
[g] Reported in "Reservoirs in the United States", U. S. Geological Survey Water-Supply Paper 1360-A or obtained from the Federal Power Commission records.
[h] Gross head.
[j] Estimated.
[k] Based on water use per kilowatt at full station load under most favorable conditions, as reported by the Georgia Power Company.

IRRIGATION

Recent agricultural research has demonstrated the benefits of irrigation for tobacco and certain vegetable crops in Georgia. It has also been found profitable for many other crops, including cotton.

Rates of water use.—No records of water use for irrigation in Georgia are available but the quantity has been estimated from the acreage irrigated and recommended rates of application. The U. S. Census of Agriculture for 1954 gives the number of irrigation systems and the number of acres irrigated in each county. The Soil Conservation Service has prepared irrigation handbooks which show the optimum amount of water needed and the recommended rates of application for different types of crops and soils. Most of the acreage under irrigation in Georgia is expected to need in a dry year 1.0 acre-foot of water per acre which includes an allowance for wastage in application. By applying that rate of water use to the acreage under irrigation, the average use of water for irrigation in 1954 in the State has been estimated to be 21 mgd.

The usual rate of application of water during the summer months, when irrigation is needed most, is 0.3 inch per day Actually, the water is applied an inch or two at a time at intervals of 5 to 10 days, depending on the weather and type of soil and crop. The maximum rate of application of 0.3 inch per day is 9 times the average annual rate of 1 acre-foot per year.

Irrigation-water requirements in a dry year are quantitatively stated in two ways in this report. The average rate per day is obtained by dividing the estimated annual application of 1.0 acre-foot per acre by the number of days in the year and converting to gallons per day. This may be compared with the supply of water available on an annual basis. (Over a long period of years, the average rate should be less than that for a dry year, but no data are available with which to estimate long-term average irrigation use.) The peak rate per day during the irrigation season is determined by converting the estimated application rate of 0.3 inch per day into gallons per day. This may be compared with the water supply available in dry periods.

Table 7 (p. 56) shows by counties for the dry year, 1954, the number of farms using irrigation, the acres irrigated, the estimated use at the average annual rate, and the average rate in thousand gallons per day per square mile.

Figure 7 (p. 62) shows the estimated average annual use of water for irrigation in Georgia in the dry year 1954 by counties. The rate is expressed in gallons per day per square mile to avoid the effect of the different areas of the counties, and to facilitate comparisons.

Irrigation trends.—The authors have found no basis for predicting the rate at which irrigation systems are likely to be installed on Georgia farms. The drought of 1954 gave a tremendous impetus to irrigation because of the proven benefits, particularly to tobacco crops, during that year. Also, farmers have approached an economic status that enables them to invest in capital improvements so that they can finance the initial costs of irrigation equipment and the essential water supplies in the form of either ponds or wells.

If the current period of deficient rainfall continues there will be a continuing rapid increase in the number of irrigation systems in the State. If, however, there should be a series of wet years, the number of irrigation systems will increase more slowly.

The irrigation specialists of the Soil Conservation Service and the Agricultural Research Service have estimated that about 10 percent of Georgia's present acreage in cotton, corn, and pasture and about 50 percent of the present acreage in legumes, tobacco, and truck crops can be irrigated economically. A much greater annual increase in the acreage under irrigation than took place in the past two years will have to occur if this estimate is to be reached by 1970. However, if not in 1970, it may be reached in the next few decades, and the problems resulting therefrom may as well be recognized for 1970.

Assuming that future irrigated acreage reaches the above percentages of present acreage under cultivation, the annual average irrigation use of water under dry-year conditions, computed at the rate of 1 acre-foot per acre, will total about 1,200 mgd for the State. The annual average use during many years will be considerably less than 1,200 mgd. However, the maximum rate of use during an irrigation season may reach 11,000 mgd.

Table 7.—Irrigation use of water in Georgia in 1954

County	Number of farms using irrigation[1]	Number of acres irrigated[1]	Estimated average annual water use[2]	
			Mgd	Thousand gpsdm
Appling	9	90	0.08	0.2
Atkinson	7	32	.03	.1
Bacon	2	56	.05	.2
Baker	2	72	.06	.2
Baldwin	1	17	.02	.1
Banks	2	40	.04	.2
Barrow	1	14	.02	.1
Bartow	4	37	.03	.1
Ben Hill	2	6	.01	0
Berrien	14	248	.22	.4
Bibb	9	184	.16	.6
Bleckley	1	12	.01	.1
Brantley	3	10	.01	0
Brooks	26	668	.59	1.2
Bryan	0	0	0	0
Bulloch	92	505	.45	.6
Burke	0	0	0	0
Butts	3	34	.03	.2
Calhoun	1	35	.03	.1
Camden	4	610	.55	.8
Candler	38	259	.23	.9
Carroll	2	39	.04	.1
Catoosa	4	39	.04	.2
Charlton	0	0	0	0
Chatham	4	101	.09	.2
Chattahoochee	0	0	0	0
Chattooga	0	0	0	0

See footnotes at end of table.

Table 7.—Irrigation use of water in Georgia in 1954—Continued

County	Number of farms using irrigation[1]	Number of acres irrigated[1]	Estimated average annual water use[2]	
			Mgd	Thousand gpdsm
Cherokee	1	155	.14	.4
Clarke	8	134	.12	1.0
Clay	0	0	0	0
Clayton	9	198	.18	1.2
Clinch	0	0	0	0
Cobb	11	261	.23	.7
Coffee	58	459	.41	.6
Colquitt	90	1,162	1.04	1.9
Columbia	0	0	0	0
Cook	46	526	.47	2.1
Coweta	5	202	.18	.4
Crawford	2	8	.01	0
Crisp	1	7	.01	0
Dade	6	139	.12	.7
Dawson	1	3	.002	0
Decatur	26	683	.61	1.0
DeKalb	8	206	.18	.7
Dodge	3	54	.05	.1
Dooly	1	200	.18	.4
Dougherty	3	93	.08	.3
Douglas	3	13	.01	.1
Early	19	842	.75	1.4
Echols	2	11	.01	0
Effingham	0	0	0	0
Elbert	7	23	.02	.1
Emanuel	7	45	.04	.1
Evans	33	688	.62	3.3

See footnotes at end of table.

Table 7.—Irrigation use of water in Georgia in 1954—Continued

County	Number of farms using irrigation[1]	Number of acres irrigated[1]	Estimated average annual water use[2]	
			Mgd	Thousand gpdsm
Fannin	0	0	0	0
Fayette	10	190	.17	.9
Floyd	11	145	.13	.3
Forsyth	5	35	.03	.1
Franklin	6	30	.02	.1
Fulton	42	408	.36	.7
Gilmer	5	21	.02	0
Glascock	0	0	0	0
Glynn	6	187	.17	.4
Gordon	1	50	.05	.1
Grady	60	675	.60	1.3
Greene	7	576	.52	1.3
Gwinnett	6	141	.12	.3
Habersham	7	329	.29	1.1
Hall	4	93	.06	.2
Hancock	0	0	0	0
Haralson	7	67	.06	.2
Harris	4	60	.05	.1
Hart	10	305	.27	1.1
Heard	2	81	.07	.3
Henry	7	258	.23	.7
Houston	2	160	.15	.4
Irwin	4	344	.31	.8
Jackson	7	146	.13	.4
Jasper	6	147	.13	.4
Jeff Davis	7	20	.02	.1
Jefferson	2	25	.02	0
Jenkins	0	0	0	0

See footnotes at end of table.

Table 7.—Irrigation use of water in Georgia in 1954—Continued

County	Number of farms using irrigation[1]	Number of acres irrigated[1]	Estimated average annual water use[2]	
			Mgd	Thousand gpdsm
Johnson	0	0	0	0
Jones	2	17	.02	0
Lamar	1	60	.05	.3
Lanier	13	127	.12	.7
Laurens	6	310	.28	.4
Lee	7	294	.27	.7
Liberty	0	0	0	0
Lincoln	0	0	0	0
Long	1	3	.003	0
Lowndes	82	884	.79	1.5
Lumpkin	5	10	.01	0
McDuffie	5	252	.22	.9
McIntosh	0	0	0	0
Macon	1	1	.001	0
Madison	3	68	.06	.2
Marion	3	101	.09	.3
Meriwether	6	210	.18	.4
Miller	1	4	.003	0
Mitchell	15	261	.23	.4
Monroe	7	225	.20	.5
Montgomery	4	42	.04	.2
Morgan	3	205	.18	.5
Murray	0	0	0	0
Muscogee	2	85	.08	.4
Newton	10	298	.27	1.0
Oconee	6	38	.03	.2
Oglethorpe	6	216	.19	.4

See footnotes at end of table.

Table 7.—Irrigation use of water in Georgia in 1954—Continued

County	Number of farms using irrigation[1]	Number of acres irrigated[1]	Estimated average annual water use[3]	
			Mgd	Thousand gpdsm
Paulding	1	225	.20	.6
Peach	0	0	0	0
Pickens	0	0	0	0
Pierce	9	137	.12	.4
Pike	8	131	.12	.5
Polk	4	129	.12	.4
Pulaski	0	0	0	0
Putnam	0	0	0	0
Quitman	0	0	0	0
Rabun	3	34	.03	.1
Randolph	0	0	0	0
Richmond	4	142	.12	.4
Rockdale	0	0	0	0
Schley	1	50	.05	.3
Screven	1	50	.05	.1
Seminole	1	15	.02	0
Spalding	8	127	.12	.5
Stephens	4	18	.02	.1
Stewart	1	5	.01	0
Sumter	4	65	.06	.1
Talbot	2	11	.01	0
Taliaferro	1	80	.07	.4
Tattnall	45	883	.78	1.6
Taylor	0	0	0	0
Telfair	2	140	.12	.3
Terrell	2	11	.01	0
Thomas	13	330	.29	.5

See footnotes at end of table.

Table 7.—Irrigation use of water in Georgia in 1954—Continued

County	Number of farms using irrigation[1]	Number of acres irrigated[1]	Estimated average annual water use[2]	
			Mgd	Thousand gpdsm
Tift	44	1,233	1.10	4.2
Toombs	49	394	.35	1.0
Towns	2	3	.003	0
Treutlen	1	60	.05	.3
Troup	5	102	.09	.2
Turner	1	20	.02	.1
Twiggs	0	0	0	0
Union	1	1	0	0
Upson	2	57	.05	.2
Walker	11	344	.31	.7
Walton	4	97	.08	.3
Ware	5	28	.02	0
Warren	0	0	0	0
Washington	7	953	.85	1.3
Wayne	1	3	.003	0
Webster	1	125	.12	.5
Wheeler	4	236	.21	.7
White	1	7	.01	0
Whitfield	5	38	.03	.1
Wilcox	3	43	.04	.2
Wilkes	2	78	.07	.2
Wilkinson	0	0	0	0
Worth	7	144	.14	.2
Total	1,268	23,973	21.40	.4

[1] Reported in 1954 Census of Agriculture—Preliminary.
[2] Based on use of 1.00 acre-feet per acre per year, the yearly rate during a dry year.

Note: The maximum rate of use per day based on an application rate of 0.3″ per day is 9 times the rate of use per year shown in the last two columns of this table.

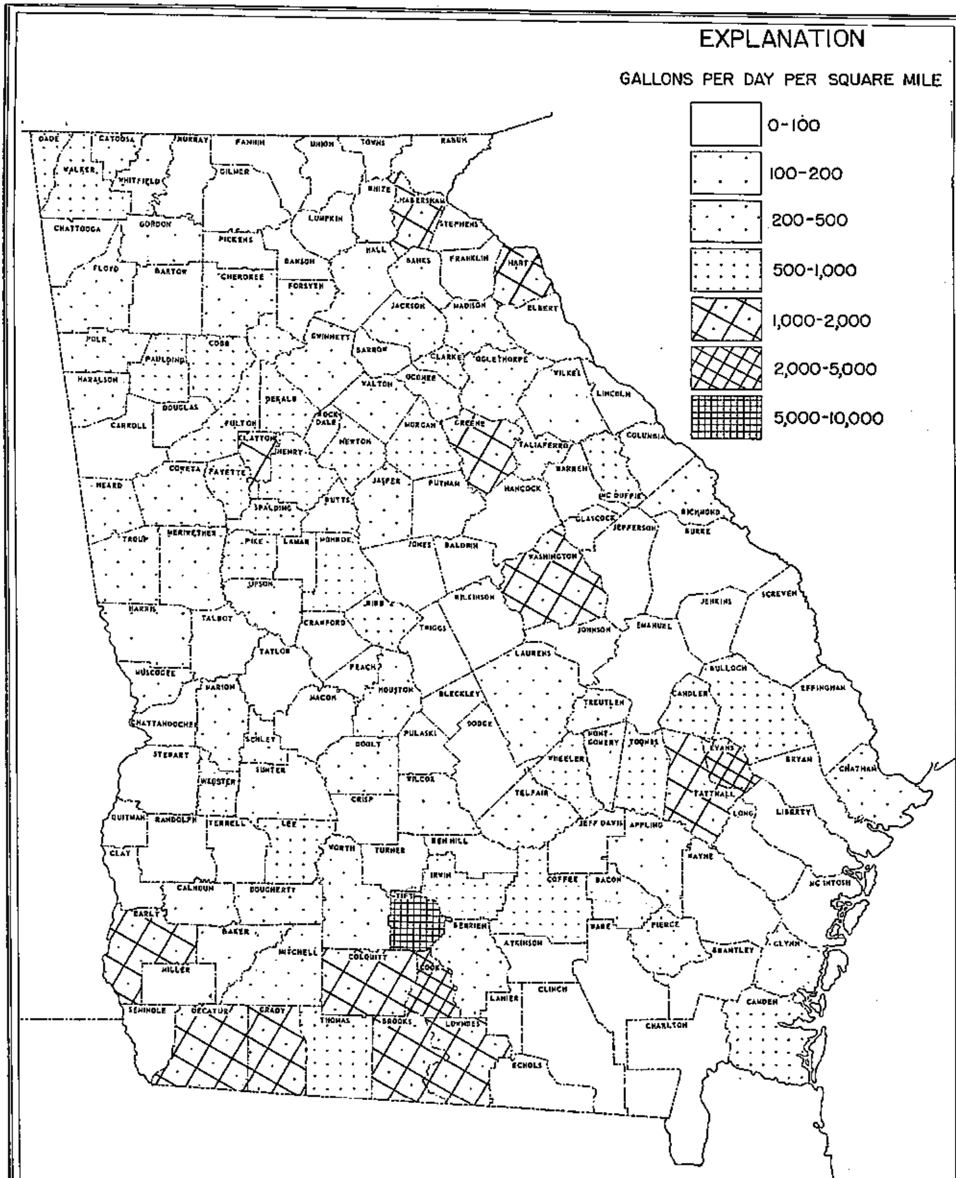


Figure 7. Map of Georgia showing estimated use of water for irrigation in 1954, by counties, expressed as an average rate of flow in gallons per day per square mile.

A study of the irrigation use in 1954, the cropland under cultivation in 1954, and the acreage of class I and II lands[1] estimated by the Soil Conservation Service in 1955 permits the general conclusion that the future annual average rate of irrigation use may be between 10,000 and 40,000 gallons per day per square mile in most counties of the State, with a use of less than 10,000 gallons per day per square mile in the mountain counties and in about twelve counties near the coast.

Water-quality requirements.—Although the quality requirements for water in agriculture are in general less exacting than those for either municipal or industrial use, no single quality standard has as yet been devised that is applicable to all agricultural areas. The suitability of water for irrigation must take into account not only the chemical and physical composition of the water itself, but also that of the soil to which it will be applied. In addition, consideration must also be given to the physical nature of the soil, drainage conditions, climate, the quantity of water applied and frequency of application, and the salt tolerance of the crops irrigated.

SURFACE WATER

Surface-water resources include the water in rivers, smaller streams, lakes, ponds, and man-made reservoirs. The most distinguishing characteristic of surface waters is their dynamic nature. Surface waters are usually in a state of change and subject to great variation in quantity and in quality. Even lakes and ponds are affected by rainfall, evaporation, wind and temperature differences, as well as inflow and outflow. Surface-water reservoirs usually are drawn down and refilled annually. These dynamic characteristics of surface waters make it necessary to treat surface-water resources largely in terms of rate of flow.

The fact that streams do flow distinguishes problems of water use and water rights from those of constant natural resources. The water in the stream is only temporarily in the possession of, or available for the use of, the owner on whose property the stream is located. The owner has certain rights to the water as it flows by, limited by the equal rights of other

[1]Land capability classes used by the Soil Conservation Service to classify land according to its ability to produce. Class I land is considered "very good" and class II land is considered "good". (A manual on conservation of soil and water: 1954, U. S. Soil Conservation Service, Agriculture handbook no. 61.)

riparian land owners some of whom may live many miles upstream or downstream from him.

Like their flow, the chemical and physical quality of streams varies from day to day and from year to year. For most streams the concentration of dissolved solids is inversely related to the flow—being greatest during low-flow periods, and least during high-flow periods. The sediment concentration, on the other hand, is directly related to flow and usually is a maximum during and immediately following storms.

The fluctuation in quality of water with variations in flow requires the analysis of many samples, extended over a period of time in order to determine maximum and minimum quality characteristics and to effectively evaluate the pattern of variation. Inasmuch as the doctrine of riparian water rights gives all riparian owners a right to water unimpaired in quality by other owners, it becomes necessary to accurately establish the natural and man-made variation in quality of surface waters under all conditions of flow and usage.

LEGISLATIVE CONSIDERATIONS

The authors do not propose to give a comprehensive discussion of water law or to suggest any legislation. However, in order to aid those who will consider water legislation, the surface-water section of this report has been prepared on the assumption that information on the following subjects will be required:

1. **Rural Use.**—The use of water for rural domestic and stock purposes, but not including irrigation, by its very nature has a high priority and would be difficult to regulate. The quantities of water involved are small in comparison to most other surface-water uses and are generally obtained from wells or ponds before the water reaches the streams. As rural use in Georgia is relatively small in proportion to streamflow, and as it has been fairly constant since streamflow records began, its effect on streamflow is not apparent. However, any substantial increment in future rural use will probably cause a corresponding decrease in future streamflows because most of the rural use is consumptive.

2. **Conservation Flow.**—A rate of streamflow of acceptable chemical and physical quality to satisfy the "reasonable" water rights of riparian land owners, to provide water for rural domestic and livestock use, and to furnish water for the

conservation of fish and wildlife and possibly recreational and esthetic values is called a conservation flow in this report. Such conservation flow need not necessarily be adequate for urban or industrial supplies, for waste disposal, for hydroelectric power, or for irrigation and is distinguished from the flows so utilized. When a utilization flow exceeds the conservation flow, the conservation flow would be provided by the passage of the utilization flow. Presumably the conservation flow would be specified by legal regulations, possibly as a minimum natural flow or, a larger rate defined by one of a number of possible criteria based on records of natural streamflow. A number of criteria for rates of flow available without storage that may be considered in drafting a suitable definition of a conservation flow are given.

3. **Utilization Flow.**—A rate of flow that provides water for existing nonconsumptive uses such as urban, industrial, and power uses is called a utilization flow in this report. Water used for these purposes is generally returned to a stream only slightly diminished in quantity and thus may be used again by each successive downstream user as long as the water quality remains suitable. A user of water for a process that does not consume the water may utilize the water day by day as it flows by his establishment, or he may store the water in a reservoir during periods of high flow for use during periods when the natural flow would be below his requirements. Having used the flow of a stream in either way over a period of time and having made investments based on an assumption of the continued availability of the water at the accustomed rates of flow, the user may claim to have a vested right to the perpetual availability of those rates of flow. The propriety of such claims is not within the scope of this report. However, pertinent water facts are presented to indicate the general magnitude of such water uses and their relation to the quantity of water available for use. Utilization flow also includes the use of water for waste disposal, but it has not been included in this report for lack of satisfactory techniques for its determination. The term does not include the consumptive use of water for irrigation which is classified separately from the nonconsumptive utilization flows.

Flows now utilized or to be utilized by developments now under construction are included in the report. Authorized, proposed, or potential projects are not included.

As any decrease of these utilization flows would infringe to some extent on established usage downstream, acceptable legislation pertaining to appropriation of these flows by upstream users would be difficult to draft.

4. **Excess Flow.**—A stream flow in excess of a conservation flow or utilization flow is called an excess flow in this report. Excess flows must be determined on the basis of streamflow records. In general, excess flows could be made subject to appropriation without detriment to existing uses.

5. **Irrigation Use.**—As irrigation use is generally consumptive, it reduces streamflow when the water used is taken from sources which contribute to streamflow. Streamflow for irrigation use is distinguished in this report from that for nonconsumptive uses of water, which are grouped under utilization flows.

6. **Storage required.**—The storage required in a reservoir to impound some flow during floods or high-water periods and store it until the water is needed at a later time is pertinent to any plan for the utilization of streamflow in excess of the minimum flow.

7. **Evaporation loss.**—Evaporation losses that affect the storage capacity of reservoirs are pertinent to the consideration of farm ponds and larger reservoirs when evaporation losses may be a large part of, or even exceed, the amounts of water utilized for beneficial purposes.

8. **Flood flow.**—Reservoir spillways need to be adequate for public safety from floods. A brief summary of data from a recent flood report is included in this report.

9. **Data requirements.**—The adequacy and accuracy of specific types of water information that may be used as the basis for the establishment of broad water policies and as the basis for the administration of water regulations are enumerated at several places in the report.

DESCRIPTION OF GEORGIA

Georgia has an area of 58,518 square miles. From north to south its length is 320 miles and its maximum width is 250 miles. Great variations in surface-water resources are to be expected in such a large area because of weather and physiographic factors.

Physiographic Provinces

Georgia lies in four physiographic provinces, the Blue Ridge province, the Valley and Ridge province, the Piedmont province, and the Coastal Plain (Fenneman, 1946). The characteristics of streams differ among the provinces, and within the Coastal Plain great differences in runoff characteristics make it desirable, for surface water investigations, to consider the Coastal Plain in two sections that are designated as the upper Coastal Plain and the lower Coastal Plain. These divisions of the State are shown in figure 8 (p. 68).

Blue Ridge province.—The mountainous region in northeastern Georgia, known as the Blue Ridge province, has an average annual rainfall ranging from 53 to 70 inches. The average runoff ranges from 27 to 37 inches. The terrain is characterized by forest-covered mountains separated by narrow valleys in which the towns and most of the cropland lie. The mountains reach altitudes as high as 4,000 to 5,000 feet above mean sea level. The rivers generally have small drainage areas but relatively high water yields. They have steep, rocky channels and flow swiftly over many rapids and waterfalls. There are no large cities and few industrial plants in the province, but there are many water-power and reservoir sites. The power reservoirs have helped make the area popular for recreation. Springs supply most of the towns with water. The surface waters are generally soft.

Valley and Ridge province.—The Valley and Ridge province in northwestern Georgia has an average annual rainfall ranging from 49 to 58 inches. The annual runoff ranges from 18 to 24 inches. The terrain is characterized by wide cultivated valleys, ranging in altitude from 550 to 800 feet above sea level, separated by narrow, steep, wooded ridges ranging in altitude from 1,600 to 2,000 feet above sea level. Practically all of the towns and much of the cropland are in the valleys. The rivers generally flow in deep channels meandering in wide flood plains. Where they cut through the ridges in water gaps, they are shallow and swift with many rapids. The major rivers have a few low-head water-power sites but few practical large-reservoir sites because of the agricultural land that would be submerged. Many small dam sites in the water gaps are suitable for minor power development or small reservoirs. Rivers and springs are the principal sources of

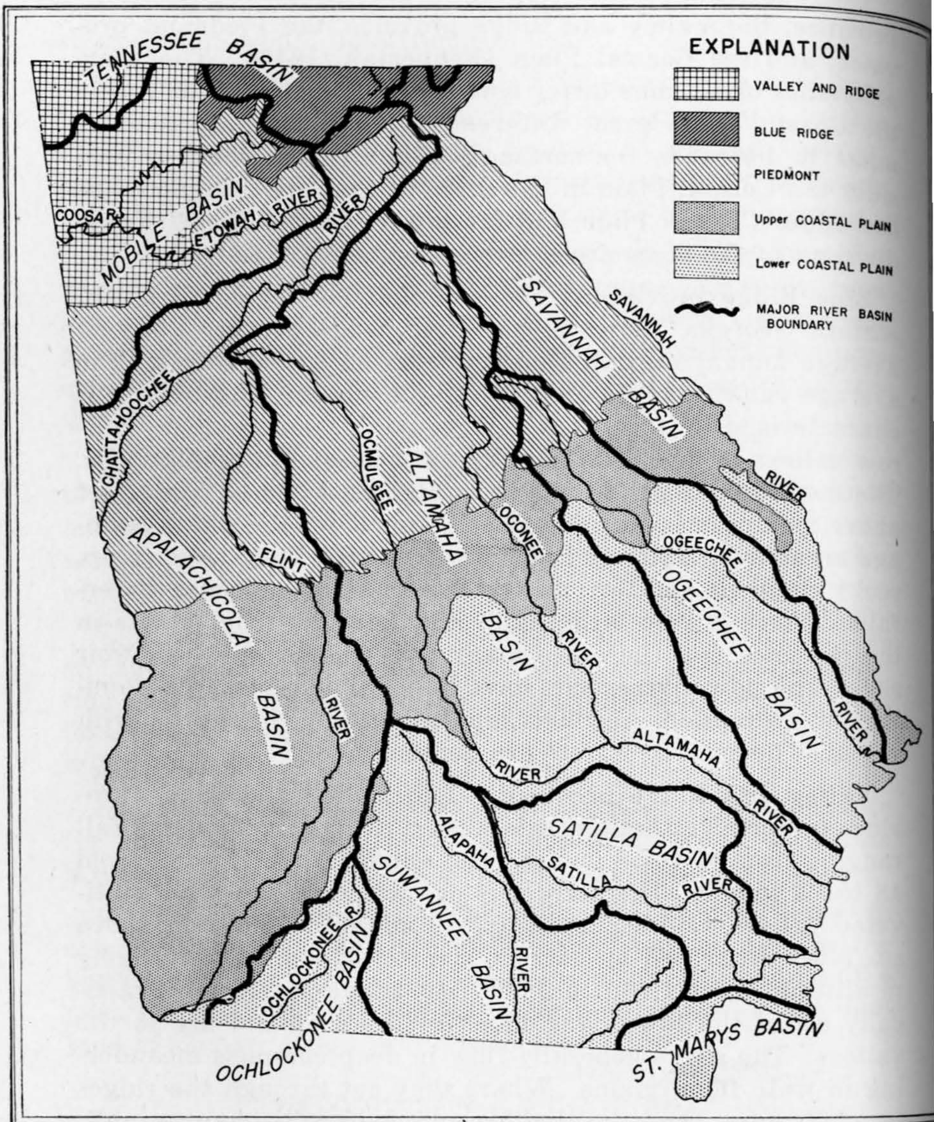


Figure 8. Map of Georgia showing physiographic provinces and major river basins.

municipal and industrial water. The surface waters are generally soft to moderately hard.

Piedmont province.—The Piedmont province has an average annual rainfall ranging from 44 to 59 inches. The average annual runoff ranges from 10 to 39 inches. The region ranges in altitude from 300 to 1,500 feet above sea level and is characterized by both narrow and broad ridges separated by relatively narrow valleys. Nearly all the towns, highways, railroads, and farmlands are on the ridges. The steep hillsides and most of the river valleys are wooded, but there are stretches of cultivated bottom lands along the larger rivers. The streams generally have moderate slopes interrupted by occasional rapids and waterfalls, and flow in well-defined channels within valleys of varying widths. Streambeds are usually composed of silt or gravel overlying bedrock. There are many water-power and reservoir sites. Small streams and rivers are the principal sources of water for the larger cities and industries, but wells are used by many small towns. The river water is soft.

Fall Line.—The boundary between the Piedmont province and the Coastal Plain is called the Fall Line because of the steep fall of rivers as they cross the boundary. It is sometimes called the fall zone because the boundary is discontinuous and both the Coastal Plain sediments and the crystalline rocks of the Piedmont may be exposed in a zone several miles in width. The Fall Line is commonly the head of navigation of large rivers and the site of water-power dams as at Augusta, Milledgeville and Columbus.

Upper Coastal Plain.—The upper Coastal Plain has an average annual rainfall ranging from 43 to 55 inches. The average annual runoff of the larger streams ranges from 12 to 28 inches. Their flow is relatively uniform because of the small storm runoff and high yields due to ground-water inflow. The very small streams commonly have very little runoff because the pervious soil absorbs rain water rapidly and the channels do not cut deeply enough to intercept ground-water flow. The streams are generally sluggish, flowing in deep, meandering, low-banked, tree-choked channels. They are bordered by wide, swampy, densely wooded valleys. The ridges are generally broad with gentle slopes. Most of the cropland, transportation lines, and towns are on the ridges. The region has some low-head water-power sites on larger streams. It has few reservoir sites because of the flat terrain and pervious soil. River water is used for steam-power plants and some manufacturing, but artesian wells supply all but one of the towns and many of the industries. The surface water is soft except in southwestern Georgia where it is moderately hard.

Lower Coastal Plain.—The lower Coastal Plain has an average annual rainfall ranging from 45 to 53 inches. The average annual runoff ranges from 9 to 14 inches. This region generally has the least runoff of any part of Georgia, partly because of higher temperatures and low flow-producing land characteristics, and possibly because of the high consumptive demands for water by the dense vegetation in the swamps. The terrain consists of very wide and very low flat ridges separated by very wide, swampy, heavily wooded valleys. Practically all of the towns and cropland are on the broad ridgetops. There are few reservoir and low-head water power sites. The lower reaches of the rivers are affected by tides and may contain brackish or salt water during low-flow seasons. River water is used for steam-power plants and for waste disposal. Practically all of the cities and industries other than large steam-power plants obtain water supplies from artesian wells. A few large water users take water from the larger rivers. The surface waters are generally soft and are often highly colored and some may be acid.

PRINCIPLES OF OCCURRENCE

The occurrence of water in streams is the result of a combination of many natural phenomena. The total supply of water in the world is essentially constant, but the amount of water available to the people of Georgia in their rivers and small streams is highly variable. The rainfall in Georgia ranges from very intense storms with 20 inches or more of rain falling in limited areas within a few days to extended droughts when little or no rain falls for periods up to several months and in areas covering a large part of the State. This great variation in rainfall results in great variations in soil moisture and is the principal cause of great floods and droughts.

Air Movement.—The wind transports the water supply of Georgia from the ocean to the land and returns approximately two-thirds of that water to the ocean.

Most of the rainfall in Georgia is associated with cyclonic storms which draw warm moist air over the State principally from the Gulf of Mexico and, to a lesser extent, from the Atlantic Ocean. In the course of that movement, some of the moisture condenses and falls as rain or snow.

At times the cyclonic storms have very low pressure centers accompanied by strong winds over a wide area. At times, also, these intense storms seem to stagnate so that the "front" between the warm moist air and the cool dry air stays in the same general area. This results in intense rainfall in great quantity in that area, which is the common cause of severe floods.

Following the passage of the center of the cyclonic storm the winds come from the north and west bringing cool dry continental air, which tends to evaporate moisture from the vegetation and wet surface of the ground. That moisture does not fall again on Georgia but is carried out over the ocean by the general movement of the air masses.

Hurricanes are a violent type of cyclonic storm with winds over 75 miles per hour, that originate in the tropical area of the Gulf of Mexico, Carribean Sea, or Atlantic Ocean during the late summer and early autumn months. They usually move northward along the coast, with easterly winds in advance of the storm carrying moist air over the coastal areas. As a result of the hurricanes, the eastern part of Georgia may receive a number of heavy storms from August to October, that cause a pronounced increase in streamflows and occasionally cause floods.

Rainfall.—The moisture brought over the State of Georgia from the Gulf of Mexico, and to a lesser extent from the Atlantic Ocean, precipitates from three major causes.

The first of these is the difference in the air temperatures between the ocean air masses and the continental air masses. This tends to create a band of high rainfall and streamflow along the Gulf Coast.

The second cause of precipitation is the high mountains of northeastern Georgia which deflect the warm moist air upward into cool air where the moisture is condensed. As a result rainfall is heavy on the southern and eastern face of the mountains. Somewhat less rain is released on the leeward side of the mountains.

Figure 9 (p. 73) shows the above variation in annual rainfall over Georgia.

The third cause of precipitation is the hot summer climate. The updraft of warm, moist air reaches cooler air in high altitudes resulting in the familiar short, violent thunderstorm. The intense rainfall during thunderstorms is the common cause of floods on very small streams, but is rarely a cause of major floods on large rivers.

The rainfall in Georgia is somewhat heavier in the winter and spring months and in the mid-summer months than it is in May and June or in the rather dry months of October and November. This seasonal variation of rainfall is somewhat more pronounced in southeastern Georgia than in other parts of the State.

Infiltration.—The process of infiltration has attracted much attention in recent years as conservationists have emphasized the advantages of forest cover and crop rotation over row crops. The bare land surface that results from row-crop practices suffers compaction and puddling from raindrops and forms a relatively impervious surface. This causes more rain to run off the land surface, resulting in erosion, and permits less water to get into the soil where it can benefit crops.

Steep gullied hillsides where the top soil has been removed and where the exposed sub-soil has a low infiltration capacity have high runoff rates. Where such areas have been abandoned and allowed to grow up into pasture and forest, or have been converted into fields of kudzu, lespedeza, or other cover crops, the cover tends to reduce flood runoff by increasing the infiltration capacity. In a number of decades tree roots pervade the soil, which with the assistance of earthworms and burrowing animals, increases the infiltration capacity of the soil and causes it to receive a considerable amount of water that might otherwise become surface runoff. This, in the long run, may be of considerable benefit in reducing flood damage, but it may not substantially increase the low flows of streams because much or all of the additional water that infiltrates may be consumed by the additional vegetation.

Although certain land-use practices do increase the infiltration of water into the land in local areas, the percentage of the land so affected is usually small in relation to the total land area. The benefits to streamflow may be primarily local

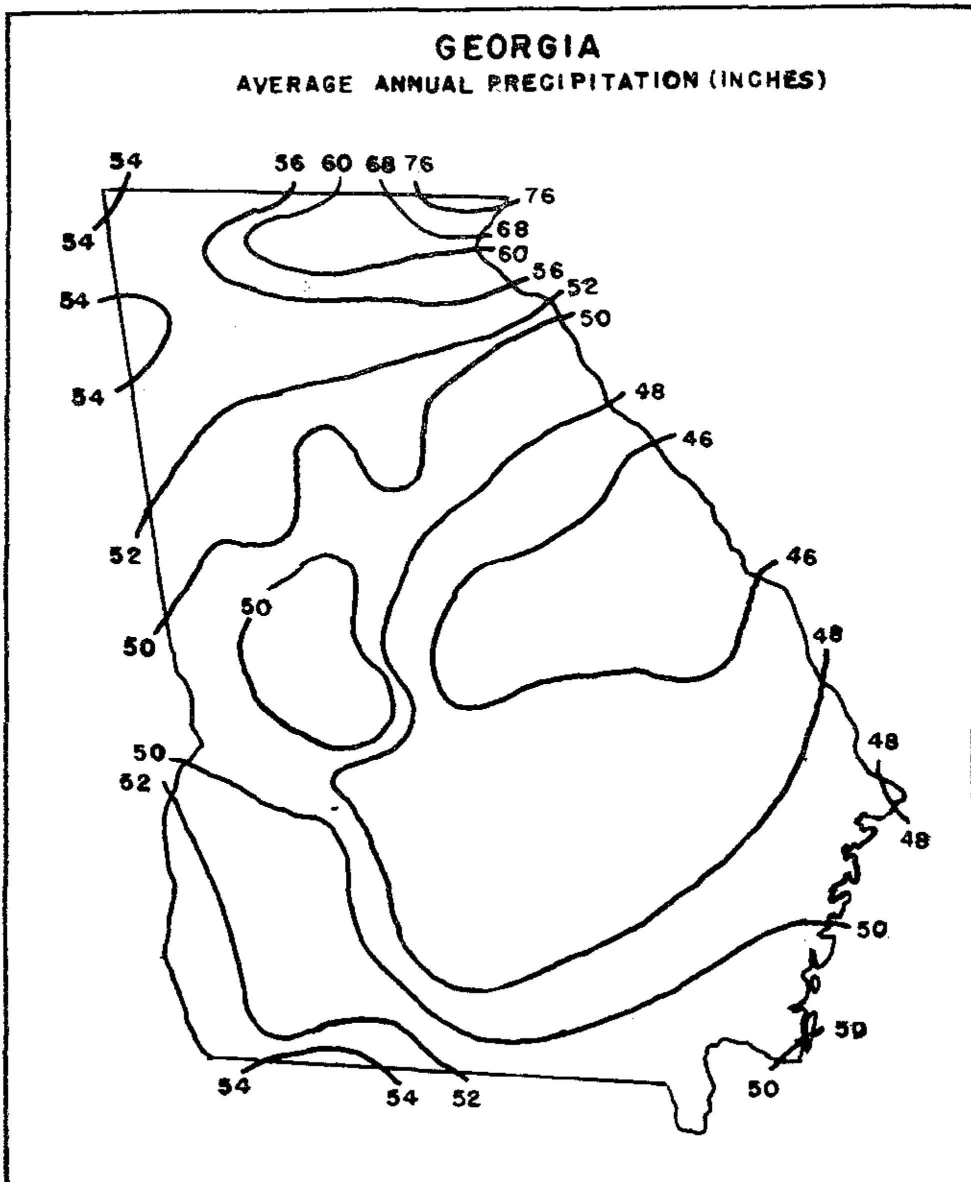


Figure 9. Map showing average annual preciptation in Georgia (Climate and Man, 1941 Yearbook of Agriculture, p. 827).

because increased infiltration may be very nearly balanced by increased transpiration of local vegetation. This factor of local effect, together with the probability that the ratio of managed to unmanaged lands is not likely to change greatly, makes it unlikely that land-use changes will materially alter the usable water supply in Georgia in the foreseeable future.

Paved surfaces in urban communities shed much of the rain falling on those surfaces and cause additional runoff in the streams, much of it in the form of local floods which may be damaging if sufficient provision has not been made to carry off or store the additional water and if damageable property is located on the flood plain. Ordinarily, paved surfaces, even in urban areas, are only a few percent of the total land surface—about 10 to 20 percent in highly developed residential areas. The remaining land area may not be greatly affected, so that dry-season flows may not be changed seriously by urbanization except where the sewer systems intercept ground water flows and prevent them from reaching the streams.

Thus, there are two influences of infiltration on water resources that may have opposite effects locally but little effect over large areas. Reforestation and cover crops will tend to decrease floods, while urbanization will tend to increase floods. Neither is likely to alter greatly the low flows of streams.

Evapotranspiration.—Evapotranspiration is a term used to describe the combination of two closely related water phenomena—evaporation and transpiration. It includes the water evaporated from plant, land, and water surfaces. Evapotranspiration is not readily measured. It is usually estimated by empirical formulas or by computing the difference between rainfall and runoff — the difference being approximately equivalent to evapotranspiration — approximately, because some of the precipitation may be disposed of in other ways, as by replenishment of ground-water reservoirs that discharge into the ocean instead of the streams. Evapotranspiration is closely related to sunlight and temperature, so that it is greatest in summertime and usually is greater in daytime than at night.

Knowledge of evapotranspiration is still very limited; but the subject is potentially significant to the conservation and wise use of water resources because more of the water delivered by the rainfall is consumed by evapotranspiration than becomes available as streamflow or ground water resources. In Georgia, annual evapotranspiration averages twice the annual runoff. Thus, a given change in annual evapotranspiration rates may cause up to twice as much change in annual runoff. In parts of the lower Coastal Plain, annual evapotranspiration rates are as much as five times the annual runoff. Because the area has protracted periods of severe low flows, research in controlling evapotranspiration rates may be highly desirable in that part of Georgia.

Research on evapotranspiration losses has been undertaken in western States where the water laws have permitted the appropriation of all of the water available under natural conditions. The objective of the research is to provide additional water for beneficial use by reducing nonbeneficial evapotranspiration losses.

Soil Moisture.—Soil moisture plays an important role in the transition of water from rainfall to streamflow. Soil moisture is the water that is present in the top few inches or feet of the soil, where the roots of trees and other vegetation are most dense, and is the source of most of the water transpired by vegetation.

Soil moisture is recharged to some extent during each rain and pumped out by vegetation or evaporated directly from the land surface during fair weather. The recharge of soil moisture has first toll of rain water, penetration to the water table occurring only after soil moisture is substantially replenished. Soil moisture changes reflect the variations in rainfall and, to some degree, changes in land use. The amount of water held as soil moisture is dependent on the depth and nature of the soil itself, as well as on the rainfall.

Soil moisture is subject to seasonal variations that are highly significant to streamflow in Georgia. The two principal seasons are the dormant season, extending from the first killing frost of winter to the last one in the spring, and the growing, or frost-free, season.

In the dormant season, most plant life is not growing vigorously; the deciduous trees, the pasture grasses, and most other vegetation transpire but little moisture. As a result, the rainfall that percolates into the soil horizon to become soil moisture is exhausted less rapidly, and as the soil moisture approaches field capacity, retention of infiltrated water as soil moisture becomes small. Thus, during the dormant season a larger portion of the percolating water passes through the soil and reaches the water table, creating greater ground-water contributions to streamflow than during the growing season. Also, as soil moisture nears saturation, smaller proportions of the rainfall percolate into the ground, and larger proportions of the rainfall run off into the streams.

In the growing season the deciduous foliage has a rank growth and stays green. The foliage gives off moisture through transpiration which withdraws soil moisture at a rapid rate causing the soil to become dry. As a result, more rain-water can percolate into the soil and be retained by the soil horizon and less water will be rejected as overland storm runoff. The nearly continuous deficiency in soil moisture during the growing season causes much of the rain that infiltrates into the soil to be retained and transpired, leaving little moisture to percolate down to the water table. The result is that falling water tables are typical of the growing season. As the water table lowers, the ground-water contributions to streamflow also diminish.

Streamflow.—The water that collects in streams and flows to the sea, represents that portion of the rain that falls on the earth that is excess to Nature's needs under the climatic conditions typical of the area. The annual requirements for water to satisfy the needs of Nature's plants is relatively constant from year to year. Except for changes in ground or surface storage, the volume of water appearing as streamflow in each year is the difference between the rainfall in that year and the nearly constant volumes of water transpired by plants or evaporated from land or water surfaces. Thus, the residual that appears as streamflow varies more from year to year than does the annual rainfall. Streamflow for short periods within the year may be zero during extended periods of drought when there is little or no rainfall; or, it may be very great when heavy rains fall on saturated soil.

In addition to the variations due to amount and intensity of rainfall, there are pronounced seasonal trends in streamflow in Georgia. During the growing season, from about April to November, streamflow generally decreases. Superimposed upon this falling trend is a relatively small amount of storm runoff from time to time, depending on the intensity and amount of the rainfall and the prior conditions of the land. At the end of the growing season, it is common for streams in southern Georgia to be dry. High evapotranspiration losses in the broad swampy bottomlands in southern Georgia may also accentuate the low streamflows.

During the dormant season, December to March, there is a tendency for streamflows to increase, though generally with a lag of a few weeks because the soil moisture must first be restored. At the end of the dormant season, generally in March, streams tend to flow rather full, and much runoff results from storms. Floods are most common during the dormant season. Near the end of the dormant season in southern Georgia, the bottomlands may be flooded for weeks at a time and the swamps may extend from hillside to hillside.

Summary. The interrelationship of air movements, temperature, rainfall, infiltration, soil moisture, and ground water result in a complex pattern of streamflow. The naturally variable streamflow pattern is further complicated by man-made factors such as reservoirs, power-plant operations, diversions, and land-use changes. Consequently, the quantitative determination of surface-water resources for wise use and orderly development and for legislative regulation is a complex and specialized process which requires a large number of continuous records of streamflow. The analysis of records of streamflow requires many techniques to express the variable nature of the flow, especially the low-flows which are important for agricultural and industrial development and which are the main concern of existing and proposed water laws.

TYPICAL STREAMFLOW AND UTILIZATION DATA

The nature and utilization of streamflow data are discussed by using one typical gaging-station record, that for the Yellow River near Snellville, in Gwinnett County, for an example. No discussion of water quality has been included in this section as no quality data are available for the Yellow River at this gaging station.

A gaging station, or, more precisely, a streamflow-measurement station, is a site on a stream where a record of the flow is obtained by means of a record of the stage, or water level on the gage, and a rating which defines the stage-flow relation. When the stage record is continuous for a considerable period—generally a year or more—and the rating is defined throughout the period, the station is termed a continuous-record station. A partial-record station is a station where

Figure 10. Typical stream gaging station. Water measurement being made at station on South River near McDonough, Georgia.

there is no continuous record of stage, or where the stage-flow relation is not defined.

The records of stage at a continuous-record gaging station are obtained either from direct readings of the gage by a local observer or from a water-stage recorder, operated by clockwork and floats, that traces on a chart a continuous record of water-level fluctuations. Frequent measurements of the flow are made by engineers with a current meter or a portable weir. The general methods used by the U. S. Geological Survey on the basis of experience in stream gaging since 1888 are described in Water-Supply Paper 888.

The records obtained at continuous-record gaging stations are published annually in the Water-Supply Papers of the U. S. Geological Survey. The data given include a description of the gaging station, its location, type of gage and its datum, drainage area, period of record, average flow, maximum and minimum flow for the current "water year" (October 1 to September 30) and for the period of record, the accuracy of the data, other pertinent remarks, and a table of the daily flow in cubic feet per second (cfs) for the water year. The water year is used rather than the calendar year because most rivers in the United States usually have their lowest flow about September 30 and the runoff for the year ending on that date is more readily comparable with rainfall and with the flows at other sites. The annual data end with a summary of the monthly flow and runoff in inches, and both the water-year and calendar-year mean flow and total runoff.

In this report the average and low-flow data have been expressed in millions of gallons per day (mgd), rather than in cubic feet per second which is the usual unit for expressing the rate of streamflow. This was done to be consistent with the ground-water information which is given in gallon units—gallons per minute (gpm) for small flows and million gallons per day (mgd) for large flows—except that flows per square mile are frequently given in thousands of gallons or in gallons rather than in millions of gallons to avoid using decimal places. These units are preferable to gallon-per-minute terms because an inconvenient coefficient (0.00144) is required to convert the latter to million gallons per day. Most ground-water developments in Georgia are for domestic, municipal, and industrial purposes. Engineers in those fields usually prefer to express quantities in gallons rather than in cubic feet.

The latter unit, used only in the discussion of flood flows in this report, is preferred by most hydraulic engineers who deal with large quantities of water, as in connection with water power, large dams, flood control, bridges, and irrigation.

The calendar year has been shown in this report for illustrations and tables but the average flows have been computed for water years.

Average Flow

The average flow of a stream at a particular site is an important statistic in the analysis of other streamflow quantities, but it has limited direct value in the utilization of a stream. It is an important clue to other statistics, such as excess flows, and is helpful in correlation studies. It represents the long-term total amount of water that the stream produces and thus is the limit on the amount of water available for use. However, the natural variation of streamflow is so great that the entire runoff can be used at the rate of the average flow only if sufficient storage is provided to sustain the demand over the greatest drought deficiency. This ideal is never achieved—even the largest reservoirs have spillways to release surplus water during extraordinary floods, and evaporation reduces the total flow available from reservoirs below the average flow under natural conditions.

Average Flow for Standard Period

Ideally, the average flow of a stream should be the average for an infinite period of years, but no streamflow records in Georgia from which the averages would be computed were obtained prior to 1893, and rainfall records began only a few years earlier. Most of the streamflow records in Georgia began in 1937 and 1938 when the present cooperative water-resources investigations were started. After considering a number of alternatives, the authors have adopted the 18-year period from October 1, 1937 to September 30, 1955 as a standard period. It represents the optimum combination of usefulness and expediency for the determination of average flows for the State as a whole. The average flow of the Yellow River near Snellville for the standard period is 101 mgd.

The Hydrograph

The daily flow at a river site for a year when plotted on a chart is called the annual hydrograph. Figure 11 (p. 82) shows an example of a hydrograph for a "typical" year in which there were neither excessive floods nor unusual droughts. The year 1945, selected for the typical year, is the one in which conditions for each calendar month most nearly approached the average for that month during the past 18 years.

The daily rainfall at the Norcross gage of the U. S. Weather Bureau is also plotted to show a comparison of rainfall and runoff. The rainfall and the flow hydrograph are plotted to a common scale in inches of daily rainfall and runoff and a common scale in terms of the water flowing at the gage in million gallons per day. Both scales are shown. (One inch of water in 24 hours from the drainage basin of 134 square miles equals 2,325 mgd.)

The Norcross gage is the only rain gage near the drainage basin of the Yellow River near Snellville. A close correlation between one rain gage on the edge of a drainage basin of 134 square miles and the runoff from that basin cannot be expected. The average of several rain gages evenly distributed over the area would be needed to provide a good comparison of rainfall and runoff, but there are few small river basins in Georgia with enough rain gages to provide good rainfall-runoff comparisons.

Even though the data are not strictly comparable, the figure shows that the rate that water is received from rainfall greatly exceeds the rate with which it runs off. Also, the winter and spring rains produced higher peak flows than the summer rains. For example, the rainfall of April 23-25 of 3.2 inches produced a peak of 0.65 inch per day whereas the rainfall of September 13-17 of 4.59 inches produced two small peaks, the highest of which was only 0.09 inch per day. The April rain occurred shortly after the end of the dormant season and the September rain occurred near the end of the growing season.

Hydrograph of monthly runoff.—The presentation of monthly rainfall and runoff, as in figure 12 (p. 84), is much simpler than the daily rainfall-runoff comparison in figure 11. Figure 12 shows the much greater monthly runoff in proportion to the rainfall during the dormant season than during the growing season. It also shows the much greater consumptive effect of evapotranspiration losses in the growing season by the greater difference between the monthly rainfall and monthly runoff. In April and September, for example, the

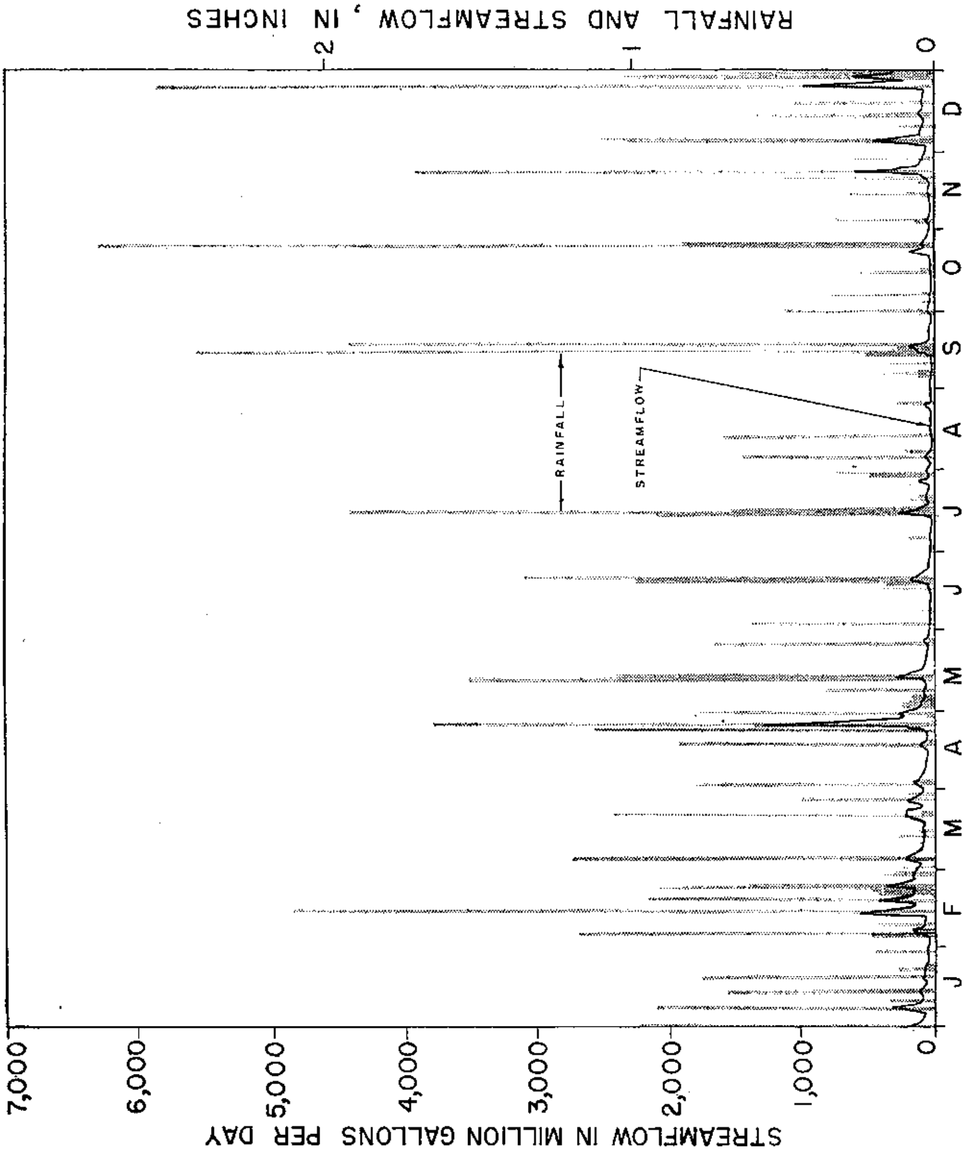


Figure 11. Hydrograph of daily flow of Yellow River near Snellville and bar graph of daily rainfall at Norcross, 1945, a typical year.

rainfall was nearly the same, 5.86 inches and 5.72 inches respectively, but the runoff was 2.40 inches in April and only 0.48 inch in September.

Monthly streamflow data (average flows for each calendar month) are useful for many purposes involving large volumes of water, sustained uses, or storage computations. The monthly data are much less cumbersome and for many purposes give essentially the same results as daily data except for the details of extreme high or low flows.

Daily Flow in a Typical Year.—Daily flow data are usually preferred in studies of extreme low flows for such purposes as urban and industrial uses. The daily hydrograph in figure 13 (p. 85) shows the same flow data as that in figure 11 (p. 82) except that the flow scale has been expanded to better show the low flows. The flood flows would project far above the top of the figure. This hydrograph shows the irregularity of stream flow caused by frequent rains in a typical year and the short duration of the surface runoff from the rains, that can be expected on small rivers in the Piedmont Region.

It also shows, more clearly than the monthly hydrograph, the relatively high sustained flows between peaks during the dormant season, the low flows between the peaks during the growing season, and the gradual increases in the sustained flow after the end of the growing season.

Daily Flow in a Dry Year.—The daily hydrograph in the dry year of 1954 is shown in figure 14 (p. 86). The same general pattern is discernible as in the typical year except that the sustained flow between the small rises caused by rains during the summer became progressively lower in 1954, reaching its lowest levels at the end of the growing season in October. About the middle of October, when evapotranspiration losses began to diminish rapidly, streamflow began to increase, even without the benefit of appreciable rainfall.

Flow Frequency

Future flow conditions are often forecast by computing the statistical frequency of historic events. The probable occurrences in the future are expressed as recurrence intervals. A flow having a 20-year recurrence interval, for example, is the flow for which there is one chance in twenty that it will not be available in any year, or, as it is most commonly stated,

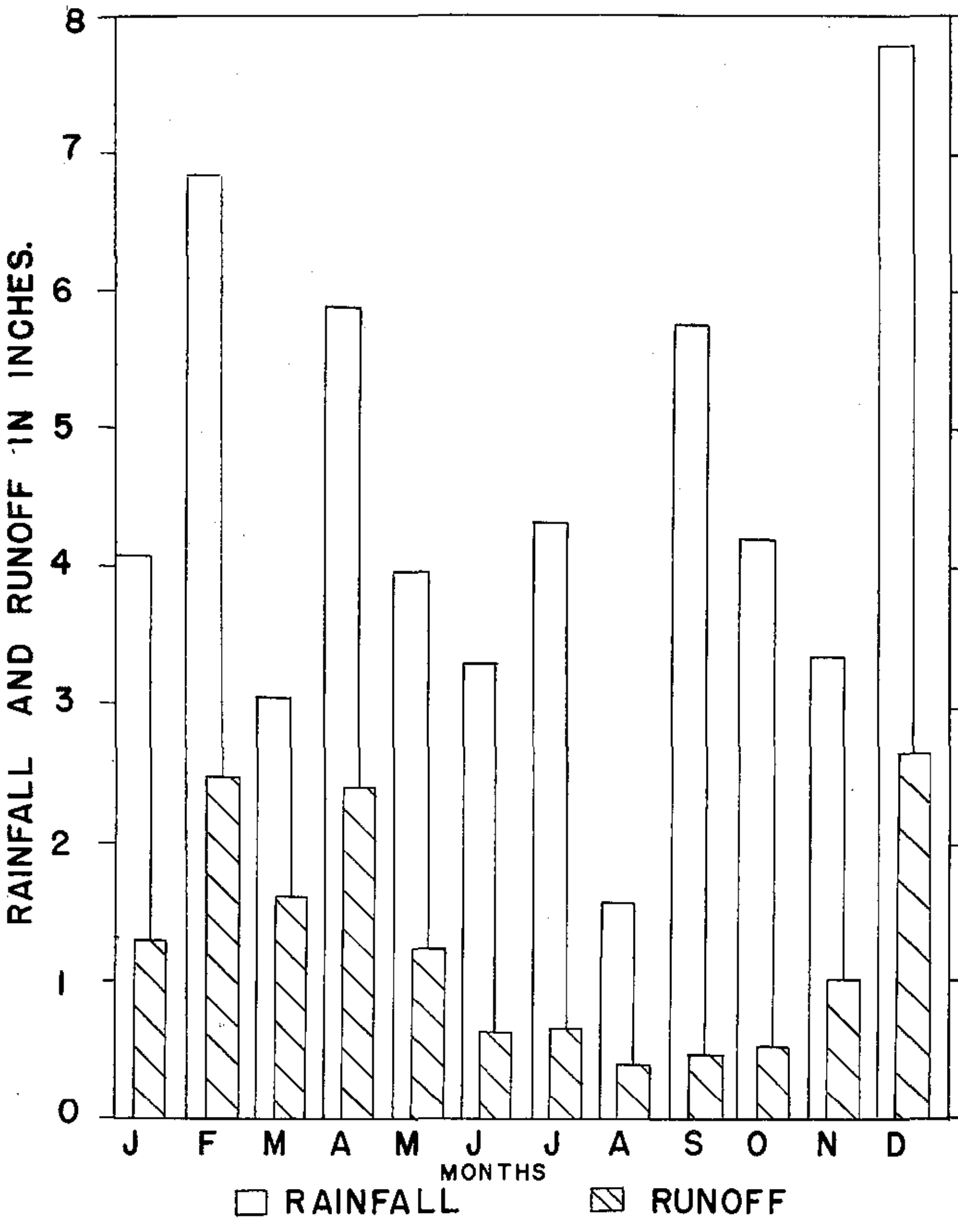


Figure 12. Monthly flow of Yellow River near Snellville and rainfall at Norcross, 1945.

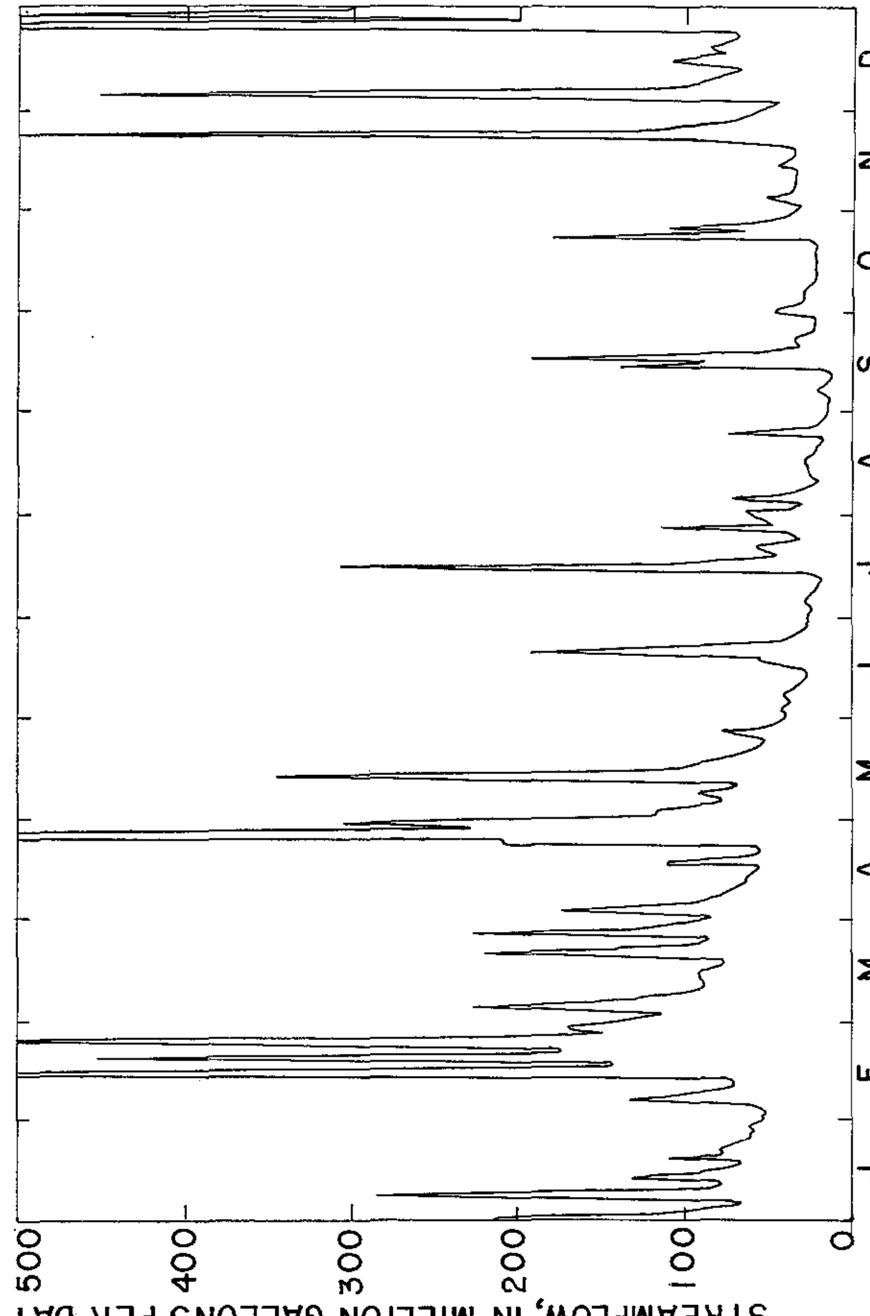


Figure 13. Hydrograph of daily flow of Yellow River near Snellville showing flows less than 500 million gallons per day during a typical year.

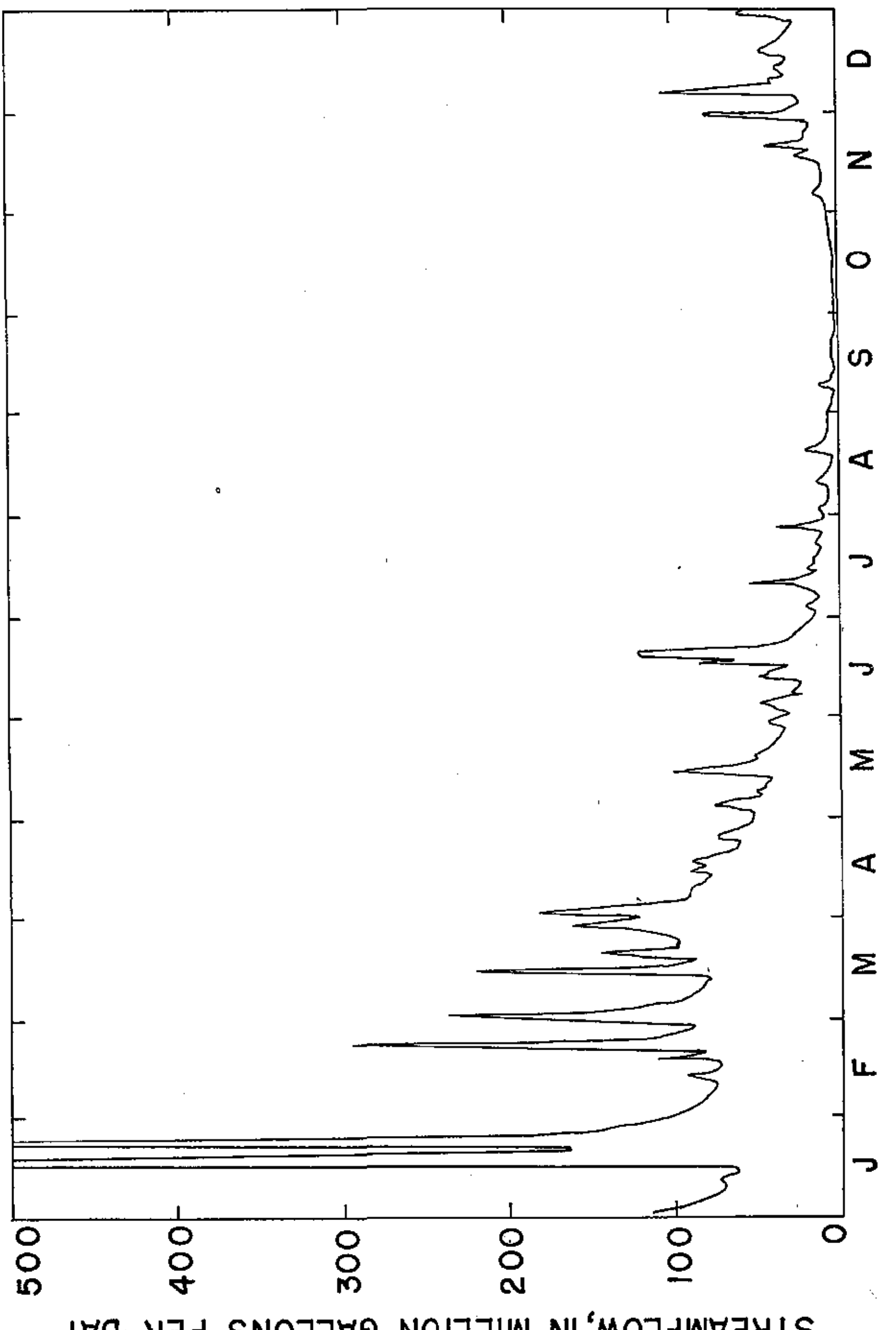


Figure 14. Hydrograph of daily flow of Yellow River near Snellville, showing flows less than 500 million gallons per day during 1954, a dry year.

the flow that will fail to occur one year in twenty years on the average. The 2-year recurrence-interval flow is the median amount, meaning that half the future events will probably be greater than that amount and half will probably be smaller.

In computing the frequency of flow shown in this report, the flow events are treated as an annual series in which only the lowest event or highest event in each year is used. Thus, the frequency of minimum daily flow represents the frequency with which a given flow can be expected to occur as an annual minimum. Recurrence intervals of low-water events were computed for this report by using the formula $(N + 1)/M$, where N equals the total number of events and M is the order of magnitude, with number 1 being the smallest or most severe event. Thus, the lowest annual event in the list of 19 events receives the recurrence interval of 20 years, the second lowest event receives the recurrence interval of 10 years, and the median event, 2 years.

In this report the flood frequency is based on a regional analysis that gives a more reliable indication of the frequency of future events than do the records for any one station. Low-flow frequency data in this report are based on the record for each station during the period 1937-55. When these low-flow frequency data are analyzed more thoroughly, on a regional basis, considerable change in the flows may be expected for some stations, particularly in the smaller and rarer flows such as the 20-year-recurrence-interval amounts.

Low Flows

Low-flow data are generally used more frequently in Georgia than average or intermediate flow data. Average streamflows are generally abundant and are rarely used to their full extent except for hydroelectric-power production. When streamflows are low the supply for urban and industrial utilization or for irrigation may become deficient locally and the value of the available water increases accordingly. When competition for the use of low flows becomes acute, controversies ensue and accurate low-flow data become important in the solution of those controversies.

There are a variety of ways of describing low-flow conditions, the significance of which is dependent on the use of the water. The quantity of flow may be sufficient for urban water supply, for example, long after the flow has become inadequate for waste-disposal, industrial, or power needs. The length of low-flow periods is also significant—a reservoir may suffice for a few days deficiency but may be inadequate for a shortage of several months. Another factor is the frequency of low-flow conditions—a community or industry may adapt itself to occasional water shortages in rare droughts but may find conditions intolerable if the shortages happen too frequently. Thus low flows need to be defined by three elements, the quantity of the flow, the duration of the low-flow period and the frequency of recurrence. The variety of low-flow requirements for different water uses makes it desirable to discuss low-flow quantities in terms of averages for several periods of time and several frequencies of recurrence.

A hydrograph of the flow during the period June through November for the typical year and the average flow for various low-flow periods shown in figure 15 (p. 89) demonstrate the significance of several low-flow criteria used in discussing conservation flows. Figure 16 (p. 90) shows the frequency of recurrence of the minimum daily flow of the Yellow River near Snellville.

Minimum Daily Flow.—The minimum daily flow known is the streamflow statistic that is most widely employed in Georgia today. Engineers employ it in the design of municipal and industrial water supplies and waste-treatment plants. Important water rights may be based on that statistic. It may be determined readily at sites where there are long-term gaging station records, or it may be computed with some reliability by correlation of low-flow measurements at other sites with the record for a suitable complete-record gaging station. A distinction is made between the minimum daily flow which is the mean flow between midnight and midnight, and the minimum flow, which is the instantaneous minimum.

Minimum Flow.—The instantaneous minimum flow is generally not much less than the minimum daily flow on a fairly large stream having natural runoff conditions. Evapotranspiration fluctuations are not usually severe on such streams during the dry autumn seasons when the minimums usually occur. The minimum flow may be much less than the minimum daily flow under regulated conditions, as shown in figure 17 (p. 92).

7-Day Minimum Flow.—The mean flow for the minimum

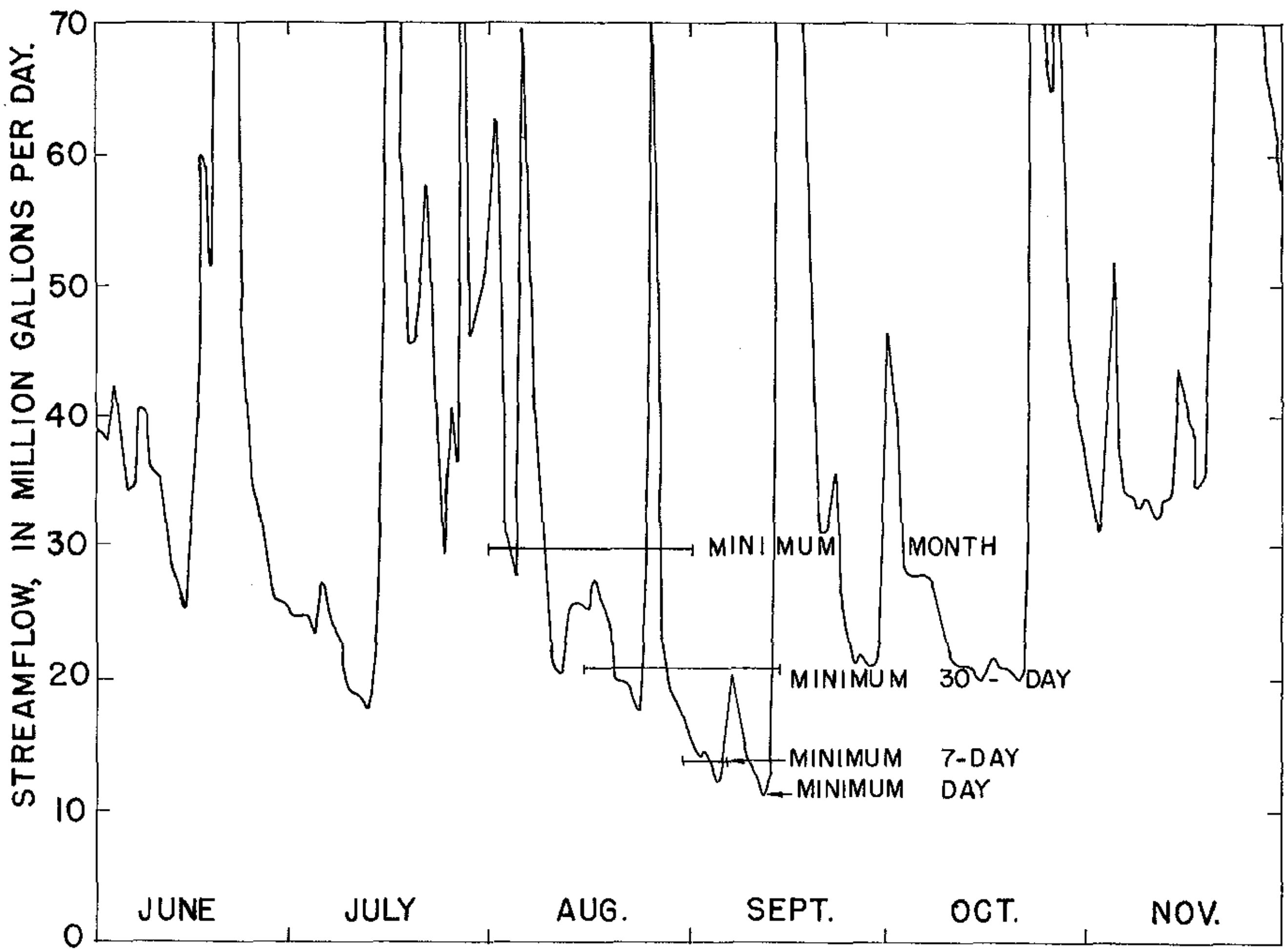


Figure 15. Hydrograph of daily flow less than 70 million gallons per day of Yellow River near Snellville during June through November in a typical year, showing occurrence of minimum mean rates of flow for several periods of time.

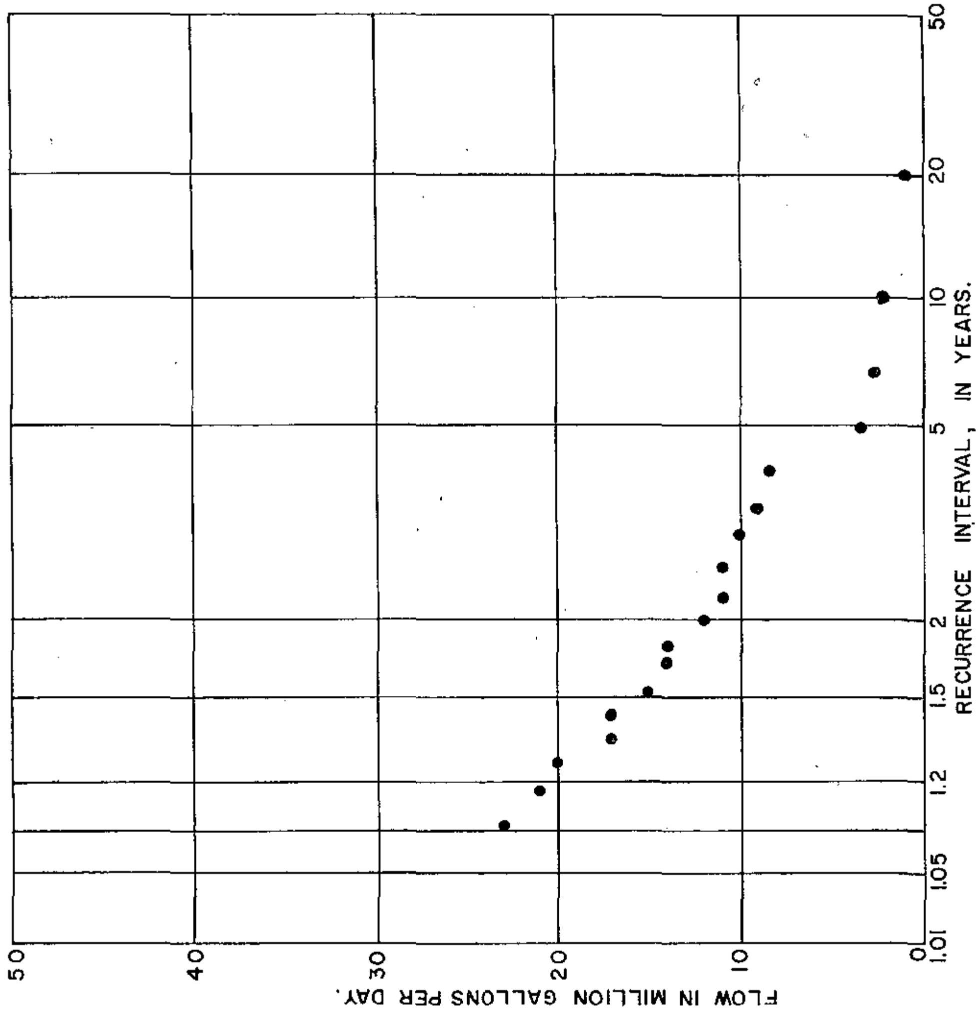


Figure 16. Frequency of minimum daily flows, 1937-55, Yellow River near Snellville, Ga.

7-day period is another important low-flow statistic. It is employed in some States as a basis for the design of waste-treatment plants. The 7-day minimum flow usually is not much greater than the minimum daily flow on streams having natural runoff conditions. It may be much greater on streams that are regulated for hydroelectric-power purposes because of weekend pondage operations.

The severity of regulation on many rivers is illustrated by the hourly hydrographs for selected 14-day periods shown in figures 17 and 18. The periods selected are not necessarily the periods of lowest flow but, rather, are typical 14-day periods. The effect of weekend pondage appears prominently in figure 18 (p. 93). Because most pondage regulation is on a weekly basis, a minimum 7-day flow has more significance than, say a minimum 5-day, or minimum 10-day flow.

30-Day Minimum Flow.—The mean flow for the minimum 30-day period is a useful statistic for the computation of storage requirements for very low flows. It requires special computation, using daily-flow data and generally has not been computed in published records. The 30-day minimum flow is available for the drought year 1954 for Georgia gaging stations because of the special studies that have been made of that unusual event but has not been compiled for other years.

Minimum Monthly Flow.—The minimum monthly flow is the mean flow for the minimum calendar month. It is usually larger than the 30-day minimum flow. It has less significance than the minimum daily flow or the minimum seven-day flow for most water-supply and waste-treatment purposes. As a streamflow statistic the minimum monthly rate has the advantage that it is generally available, or can be readily computed, at sites where the flow is affected by seasonal storage operations at reservoirs. The change in contents of major reservoirs is usually available on a monthly basis and is usually a reliable statistic for adjusting regulated flow data to show natural flows. In contrast, data on daily or weekly change of contents are often not available or not reliable for so adjusting daily or weekly streamflow data. Records of diversions and other operational data at water works and waste treatment plants are also more generally available on a monthly basis than on a daily or weekly basis. In the future, when most streams in Georgia will be affected by storage operations, not only at large reservoirs but also from a multitude of irri-

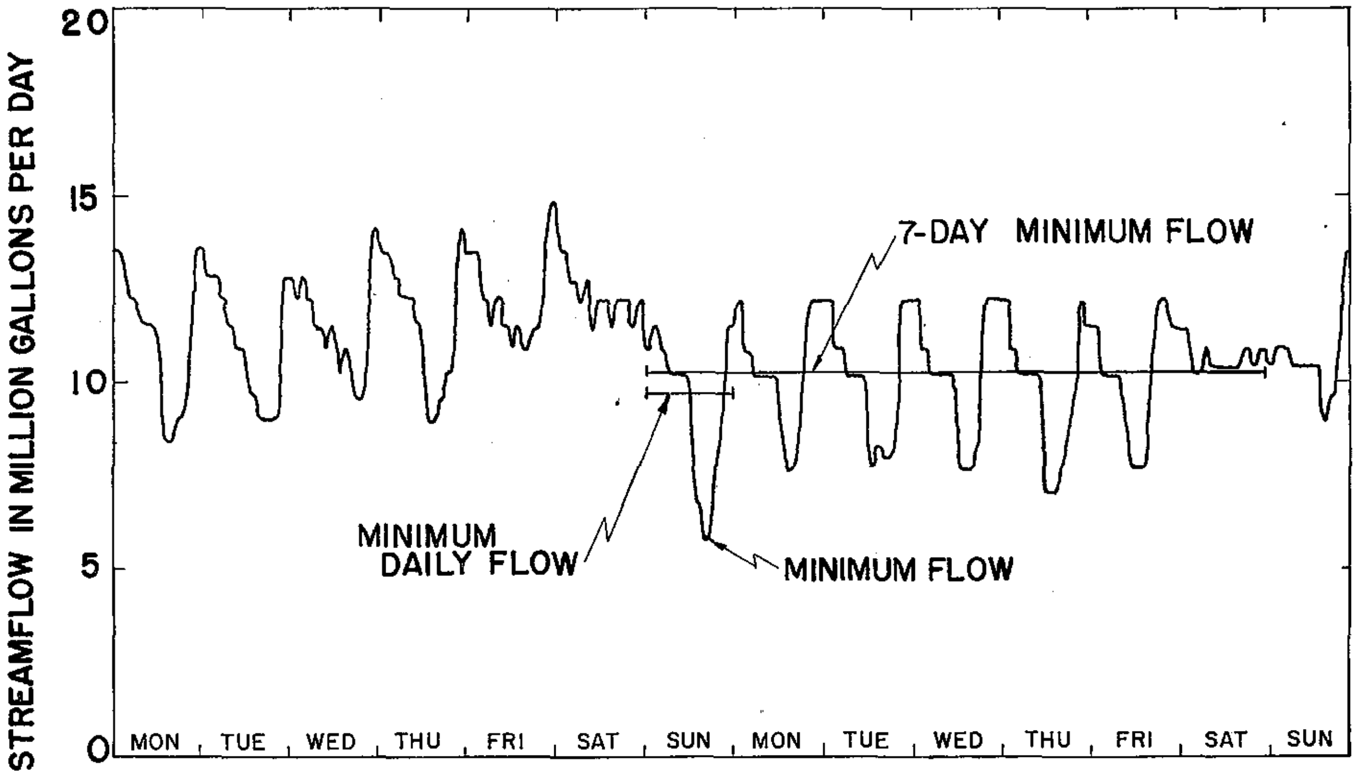


Figure 17. Hydrograph of hourly flow of Mill Creek near Dalton during a typical 14-day period of regulation.

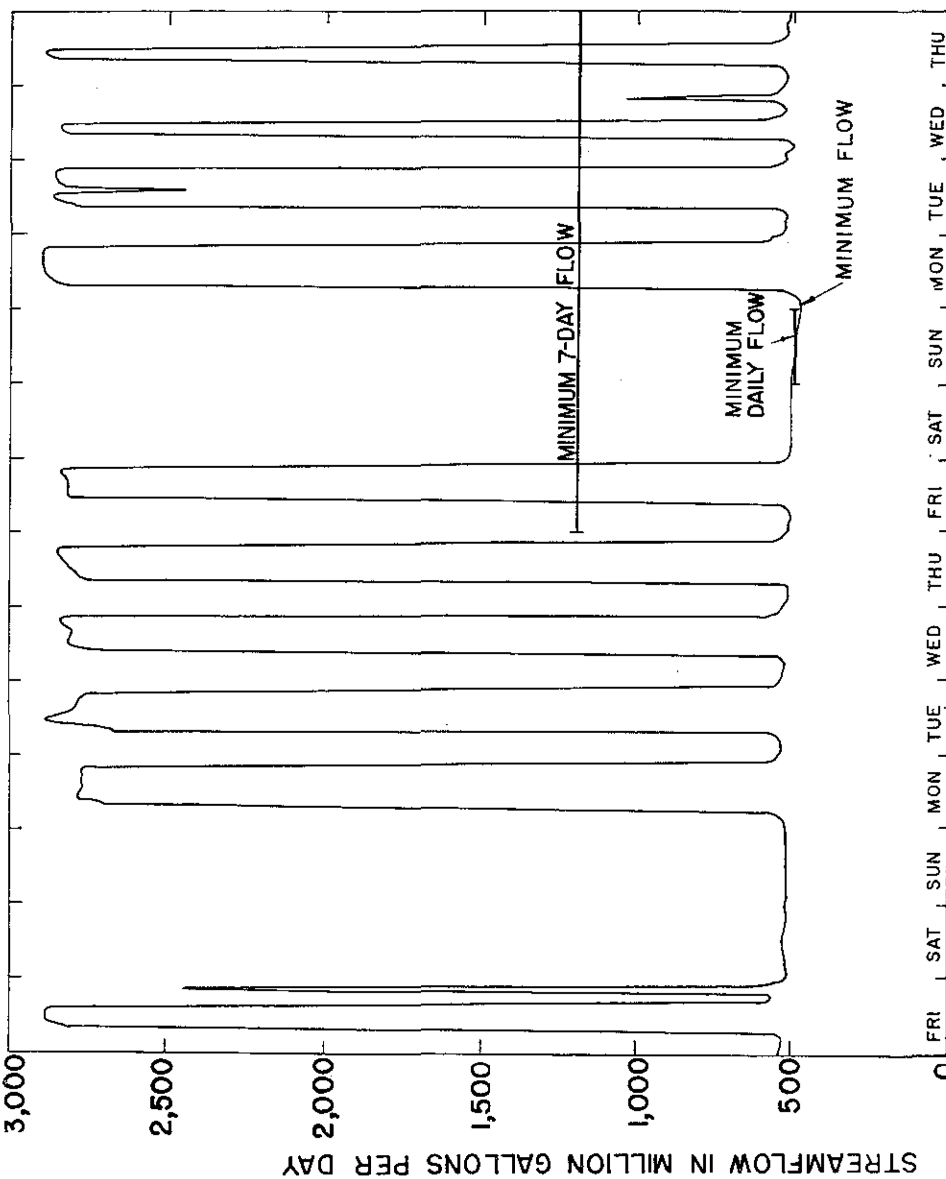


Figure 18. Hydrograph of hourly flow of Ocmulgee River near Jackson during a typical 14-day period of regulation.

gation ponds, monthly operations may be recorded or estimated but daily and weekly operations can hardly be expected to be available for adjustment of observed daily flows, or of 7-day periods or 30-day periods that do not coincide with calendar periods. Then too, the compilation and study of monthly statistics is a much less onerous task than for shorter periods.

Rural-Use Flow

Rural-use flow, as defined in this report, refers to the consumption of water for domestic and livestock purposes expressed as a rate of flow from the drainage basin. It has been estimated to be an average rate of use of 0.46 mgd in 1955, and an average rate of 0.64 mgd in the future, for the drainage area of 134 square miles above Snellville. The rural-use flows for 1955 and the future are both less than the minimum daily flow observed during the period of record. The increment of rural use, 0.18 mgd, should reduce the future flows by about that amount.

Conservation Flow

Conservation flow as defined in this report is the flow that might be specified as being required to satisfy reasonable riparian rights and conservation needs. So long as the natural flow equals or exceeds the conservation flow, upstream users would be required to release that amount. If the natural flow is less than the conservation flow, it would not be incumbent on water users to maintain that amount. Similar provisions are incorporated in a number of Federal Power Commission licenses for hydroelectric-power dams.

One of the objectives of water-law studies is a satisfactory general definition of a conservation flow which would satisfy most "reasonable" uses of a stream, provide for wildlife conservation, and be readily determined at a specific site. Such a flow might be of any order of magnitude established by statute or by a jury, but presumably it would be related in some way to the natural flow during low-water periods.

A conservation flow for a stream might be related to minimum flows that have occurred, such as the worst known drought; or some selected drought, such as that of 1954; or an average of several selected droughts (as was proposed in the South Carolina Water Law and adopted in the Mississippi

Water Law); or an average of all known annual minimum flows. However, the difficulty of determining drought flows that occurred in the past on ungaged streams might suggest that conservation flows be designated by specifying some probable frequency of low flow such as the 2-, 10-, or 20-year recurrence interval.

All these probable frequency criteria are based on actual streamflow records, but in Georgia, records are too short to determine a long-term minimum. The 20-year, 10-year, and 2-year recurrence interval events, the unusual 1954 drought event, and several other serious drought events, can be fairly well established from records for the 18-years-and-three-months period (October 1, 1937 to December 31, 1955) summarized in this report. The period includes 19 low-flow periods which statistically permit the designation of the lowest event as a 20-year recurrence interval, although it is not too well defined. The 10-year recurrence interval event is better defined. It should be recognized that the amount of flow for a given recurrence interval at a particular site depends somewhat on the method of computation. To minimize controversy, a water law that defines a flow on the basis of a recurrence interval should state how such a flow would be determined.

The authors have compiled an assortment of practical criteria for the definition of a conservation flow that could be considered in drafting water legislation. In general, the smallest quantities are the most significant and also are the most difficult to determine accurately at ungaged sites. Higher quantities are more readily determined but are less significant. These criteria for the example site (Yellow River near Snellville) are given in million gallons per day in the following table based on records for the 19 annual low-flow periods of 1937 to 1955.

Frequency (recurrence interval)	Min. 1-day	Min. 7-day	Min. Month
2-year (median)	12	14	23
10-year	2.3	3.4	6.1
20-year	1.0	1.2	2.5

If one of the smaller quantities were stipulated for the conservation flow, it would permit the appropriation for irrigation or other diversion of somewhat larger quantities than one of the larger conservation flows would permit. The following table shows the excess flows of the Yellow River that are available at Snellville for each of the conservation-flow criteria.

The amounts are for the average excess flow available, in million gallons per day.

Frequency	Min. 1-day	Min. 7-day	Min. Month
2-year	90	88	80
10-year	98.7	97.6	94.9
20-Year	100.0	99.8	98.5

It should be noted that the average excess flows in the above table for the larger criteria for conservation flows are not the difference between the conservation flows in the preceding table and the average flow. See page 103 for further discussion of excess flow.

Utilization Flows

A utilization flow, as the term is employed in this report, is the flow equal to the use, or capacity to use, water for nonconsumptive purposes, as for cities, industries and hydroelectric-power plants. The term has not been applied to the flows for consumptive uses such as rural or irrigation uses.

A utilization flow is based on the actual capacity or use of water and not on the supply of water available. However, a utilization flow may be limited by the available supply of water.

A utilization flow is not necessarily available all of the time. For example, many hydroelectric power plants have utilization capacities much greater than the average flow. They use more than the average flow during high-flow periods but have to reduce their use of water to less than the average flow during low-flow periods.

A utilization flow at a site on a stream depends on the amount of water withdrawn for use at that point. However, the streamflow at the site comes from the drainage basin upstream from that site. The portion of a utilization flow that comes from any given point upstream from the site of use is called the proportional utilization flow for that point. Streamflow records are used to compute proportional utilization flows from the utilization flows determined by actual use of the water.

The flow of the Yellow River near Snellville is used at a number of places downstream for a variety of purposes such as urban supply at Macon, navigation below Doctortown, industrial supply at Plant Arkwright and hydroelectric power at Milstead and Lloyd Shoals Dam. The map in figure 19 (p. 98) shows the gaging stations on the Yellow, Ocmulgee, and Altamaha Rivers and some of the sites where water is used below Snellville, for which the determination of proportional utilization flows at the Snellville gaging station will be demonstrated.

Municipal

The municipal water supply for the city of Macon is withdrawn from the Ocmulgee River at the upstream city limits. Macon had a population of 77,200 in 1955, and its water supply system served 105,000 people at an average rate of 14 mgd and at a maximum monthly rate of 17 mgd.

The flow of the Ocmulgee River at Macon is measured by a gaging station. The drainage area is 2,240 square miles. The average flow for the standard period, 1937-55, is 1,573 mgd, and the minimum daily flow for the period is 83 mgd. The average and maximum utilization flows for municipal supply at Macon are only about one percent of the average flow and 17 percent and 20 percent respectively of the minimum daily flow.

The minimum daily flow of the Yellow River near Snellville for the standard period is 1.0 mgd. If computed by the same percentage-of-the-minimum relationship as exists at Macon, the proportional utilization flow at Snellville would be 0.17 mgd at the average-use rate and 0.20 mgd at the maximum monthly-use rate.

The relation between the low flows at Snellville and Macon differs from that between the respective drainage areas. The minimum flow at the Snellville gaging station is 1.2 percent of that at Macon, but the drainage area at Snellville is 4.5 percent of that at Macon. A considerable error in the proportional utilization flow would be introduced if the drainage area proportion were employed. The relation between the low flows also differs from that between the average flows. The average flow at Snellville is 6.4 percent of that at Macon, more than 5 times the percentage ratio of the minimum flows.

The simple percentage calculation is not always applicable to the computation of proportional utilization flows. For example, the effect of storage reservoirs, power operations, and diversions may need to be considered as well as the variable relationship between corresponding flows. Usually it is desirable to correlate the flows at the upstream site with those

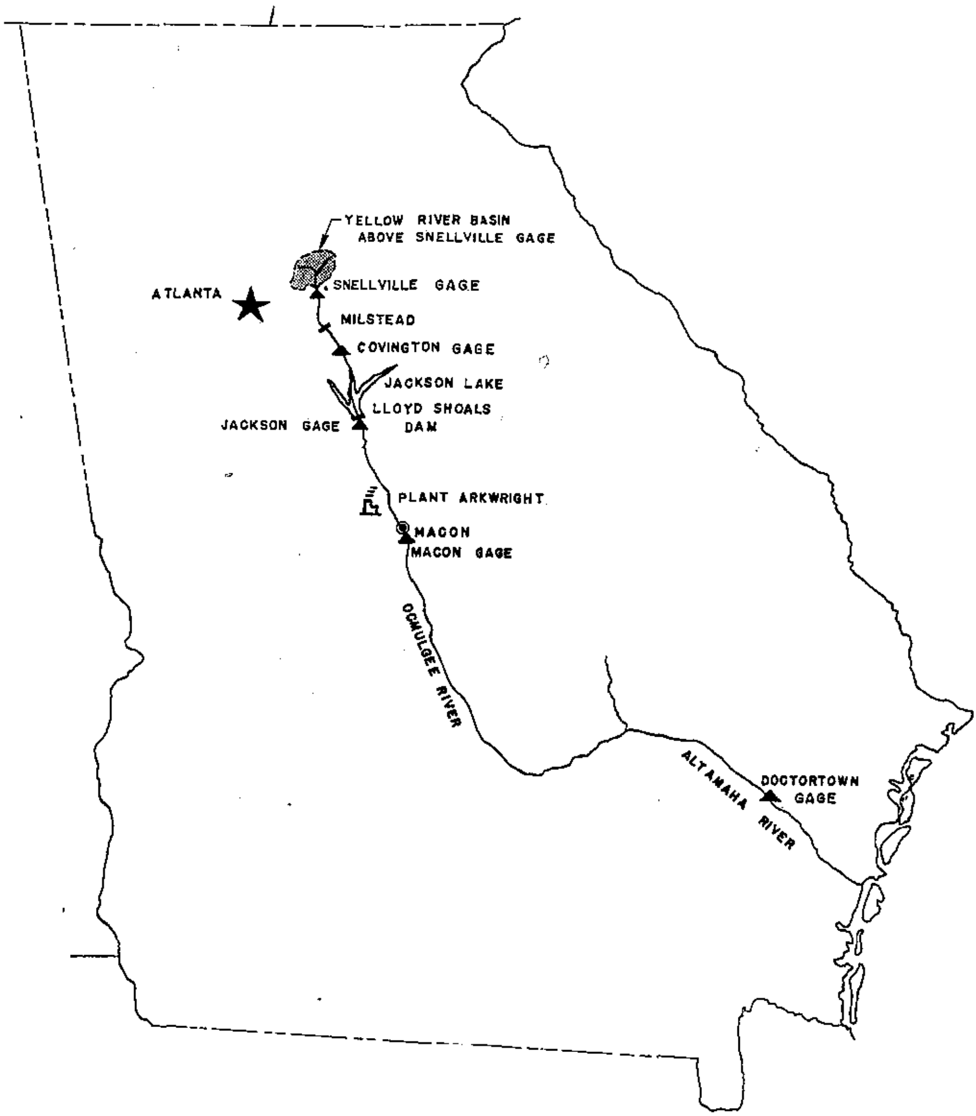


Figure 19. Principal water utilization and gaging stations downstream from basin of Yellow River near Snellville.

at the site where the utilization takes place in order to make allowances for unusual conditions. This was done to determine the proportional utilization flows at Snellville in preference to simple percentages. By the correlation method the average and maximum proportional utilization flows at the Snellville gaging station for the municipal use at Macon were computed to be 0.42 mgd and 0.54 mgd. The methods of making correlations are discussed on pages 176 to 187.

Navigation

There is an existing navigation project on the Altamaha River from Doctortown to its mouth which provides a channel depth of three feet. This requires a flow at Doctortown of 1,300 mgd, not much more than the minimum daily flow of 924 mgd for the standard period, as shown by the Doctortown gaging-station record. The proportional flow at Snellville, determined by a correlation study, is only 1.4 mgd.

Industrial

Plant Arkwright is a steam-power plant which withdraws water for cooling purposes from the Ocmulgee River seven miles north of Macon. It has an installed capacity of 160,000 kw and a reported average annual energy production of 1,075 million kwh. It uses 239 mgd at maximum capacity and 180 mgd as an annual average. The corresponding proportional utilization flows at the Snellville gaging station, determined by a correlation study, are 12 mgd and 9 mgd.

These proportional utilization flows are considerably more than the minimum flow at the Snellville gaging station and more than the conservation flows defined by some of the smaller criteria. If there were no reservoirs between Snellville and Plant Arkwright, whenever the flow is 12 mgd or less all of the flow could be used at Plant Arkwright. If water is withdrawn from the Yellow River above Snellville when the natural flow is 12 mgd or less, and the water withdrawn is consumed for irrigation, or stored in a reservoir, or otherwise not returned to the river, Plant Arkwright will be deprived of the quantity of flow so withdrawn and not returned. On the other hand, whenever the flow at Snellville exceeds 12 mgd, water in excess of that amount that is withdrawn does not affect the usable proportion of the flow at Plant Arkwright that comes from Snellville. The maximum rate of utilization flow is more significant than the average rate when no storage reservoirs are available to adjust the natural flow to the rate that the water is to be used.

As a storage reservoir, Jackson Lake, is available above Plant Arkwright, the average utilization flow of 9 mgd is more significant than the maximum utilization flow. The flow of 9 mgd represents the average quantity of the flow from Snellville that is used at Plant Arkwright. So long as the flow passing Snellville averages this amount, the reservoir presumably could adjust the flow in such a way as not to deprive Plant Arkwright of the flow from Snellville that would have been available under natural conditions. As a matter of fact Jackson Lake is operated, in part, to provide sufficient flow for the Plant.

Hydroelectric Power

The Milstead development is a small run-of-river hydroelectric power dam on the Yellow River 20 miles downstream from the Snellville gaging station. It has a 16-foot dam and a 1,600-foot head race that provides a head of 44 feet at the turbine. The drainage area at the site is 248 square miles. The turbine capacity is reported to be 800 kw and the average annual energy production is reported to be 2.9 million kwh. The estimated maximum and average utilization flows are 180 mgd and 70 mgd.

By correlations between the Snellville and Covington gaging station records and the estimated flows at Milstead, which is located between them, the proportional utilization flows from Snellville for hydro-power purposes at Milstead have been computed to be a maximum of 100 mgd and an average of 39 mgd. The maximum proportional utilization flow is a substantial proportion of the flow at the Snellville gaging station, nearly equal to the average flow. The natural flow at Snellville was less than 100 mgd 55 percent of the time during the standard period, 1937 to 1955.

Any withdrawal of water from the Yellow River near Snellville that is not returned, when the flow is 100 mgd or less will deprive the Milstead development of water that could be used for power production. The Milstead development cannot use any flow from above Snellville in excess of 100 mgd because there is no storage capacity above the small dam with which to detain the excess flow.

If there were storage available, the average proportional utilization flow of 39 mgd at Snellville for the power utilization at Milstead would represent the average flow that would have to pass Snellville to provide for the reported average use of water at the Milstead development. However, if storage were available the average use of water at Milstead would probably be considerably greater than the present average use under natural flow conditions. (See table on page 105).

Hydroelectric Power and Reservoir Storage

Utilization flows for hydroelectric power plants that have reservoir storage are more complicated than those for run-of-river plants. An example is Lloyd Shoals Dam on the Ocmulgee River. Lloyd Shoals Dam is 100 feet high and Jackson Lake, impounded by the Dam, provides 25,400 million gallons of usable storage. The turbines can use water at a maximum rate of 1,800 mgd as shown by records at the Jackson gaging station immediately downstream from the Dam. The drainage area at the Dam and gaging station is 1,420 square miles, and the average flow for the standard period is 1,017 mgd.

Correlations show that the maximum proportional utilization flow at the Snellville gaging station is 220 mgd, considerably more than the average flow of 101 mgd. If there were no storage reservoir available, no water could be withdrawn and consumed at Snellville when the flow there is less than 220 mgd without depriving Lloyd Shoals Dam of flow that could be used. Flows at Snellville were less than 220 mgd 84 percent of the time during the standard period 1937 to 1955.

Because there actually is a storage reservoir at Lloyd Shoals Dam the maximum proportional utilization flow of 220 mgd at Snellville loses some of its significance as a limit on the flow needed for use at Lloyd Shoals Dam. The reservoir is operated, like most power reservoirs, so as to store water during the winter and spring months, maintain a full head during the summer, and release the stored water during the autumn months when natural streamflows are normally low. The reservoir is full for only three or four months of the year. When the reservoir is not full, Lloyd Shoals Dam can use not only the 220 mgd through the turbines, but additional flows that are stored in the reservoir for later use.

The storing of flood waters at Jackson Lake and their use at Lloyd Shoals Dam does not necessarily use all of the flow. The average annual energy production at the Dam is 67 million kwh, equivalent to an average annual utilization flow of 710 mgd. The proportional average annual utilization flow at the Snellville gaging station is 86 mgd, based on correlations. This would leave an average annual excess flow of 15 mgd which might be diverted or consumed for irrigation without reducing the flow used at Lloyd Shoals Dam, provided the withdrawal took place at times when it would not interfere with storage at Jackson Lake or power use at the Dam.

Summary of Utilization Flows

The above five utilization flows illustrate some of the problems involved in the use and reuse of the flow of a river at different places. In each case the utilization flow was determined by the actual use at the site. The proportional utilization of the flow of the Yellow River at the Snellville gaging station was computed by correlations of the records of flow of the appropriate gaging stations. Maximum rates of utilization flow are significant when there are no storage reservoirs. Average rates are significant when storage reservoirs are involved. The proportional utilization flow need provide only for the largest downstream use when the water used is returned to the stream.

The several maximum and average proportional utilization flows at Snellville are compared with the average flow and the several criteria for conservation flow in the following table, in million gallons per day:

Average flow for standard period 1937-55	101	
Maximum proportional utilization flows		
Lloyd Shoals Dam (power and storage)	220	plus flood flow until reservoir is full
Milstead (power without storage)	100	
Plant Arkwright (industrial)	12	
Navigation	1.4	
Macon (municipal)	.54	
Average proportional utilization flows		
Lloyd Shoals Dam	86	
Milstead	39	
Plant Arkwright	9	
Navigation	1.4	
Macon	.42	
Criteria for conservation flow		
2-yr. minimum month	23	
2-yr. minimum 7-day	14	

2-yr. minimum day	12
10-yr. minimum month	6.1
10-yr. minimum 7-day	3.4
10-yr. minimum day	2.3
20-yr. minimum month	2.5
20-yr. minimum 7-day	1.2
20-yr. minimum day	1.0

Excess Flow

Flows in excess of those reserved for conservation or for non-consumptive utilization are termed "excess flows" in this report. They may be withdrawn without reducing the conservation or utilization flows, provided the withdrawals take place during excess-flow periods.

Flows in excess of small conservation or small utilization flows are available nearly all of the time. There is no excess flow during periods when the natural flow is equal to or less than the conservation or utilization flow. When utilization flows are very large, the excess flows may occur only during a few floods and may be highly irregular.

Because of the wide range of conditions governing excess flows and because storage reservoirs are frequently maintained to capture and use excess flows, it is convenient to express the excess flow as an average annual flow.

The average annual excess flow at a gaging station where the streamflow record is available may be computed by a number of methods. One method is to deduct the reserved flow from the natural flow on those days when the natural flow exceeds the reserved flow, add the remainders and divide by the total number of days in the period. (When the natural flow is less than the reserved flow the excess flow is zero and not a negative amount.) If this is done for a number of flows of varying magnitudes, the resulting average annual excess flows may be plotted against the corresponding reserved flows to define an excess-flow curve like that for the Yellow River near Snellville in figure 20 (p. 104). The reserved flow is shown on a logarithmic scale because of the great range of natural flows. The excess flow cannot exceed the average flow and may be conveniently shown on an arithmetic scale.

The computation process described above is laborious and not usually used. Short-cut methods of computing excess flow curves which do not warrant description here have been used in the preparation of this report.

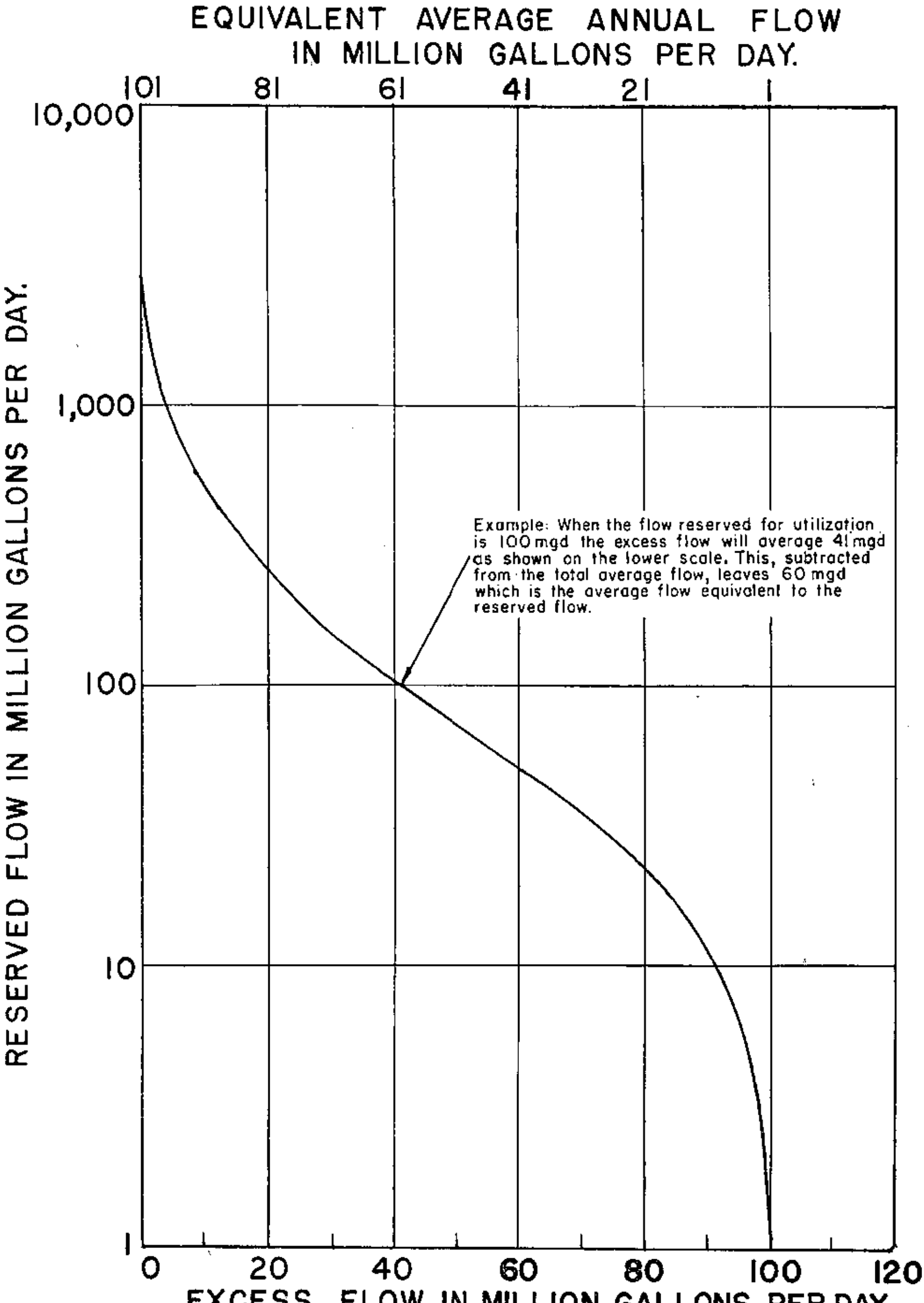


Figure 20. Excess flow curve for Yellow River near Snellville, showing excess flow and equivalent average flow.

The annual volume of reserved flow can be computed and expressed as an equivalent average flow as shown by the scale at the top of figure 20 (p. 104). This flow is less than the reserved flow shown by the scale at the left of figure 20 because only the natural flow is counted whenever it is less than the reserved flow. When this equivalent average flow is subtracted from the average annual flow (101 mgd at Snellville), the difference is the excess flow as shown by the bottom scale of figure 20.

When a given maximum utilization flow based on plant capacity is used as the reserve flow, the excess flow shown by the curve in figure 20 is the flow in excess of that which could have been used had the plant at all times used the available flow up to the limit of its capacity. The amount that could have been used by the plant is the equivalent average annual flow shown by the scale at the top of figure 20, and is called the potential utilization flow. Usually a plant does not operate so as to use all of the potential utilization flow so that the amount actually used in the past, called the average utilization flow, is less.

The following table shows the potential utilization flow and the average utilization flow on the Yellow River at the Snellville gaging station for its proportional share of the five uses which have been described. The columns based on maximum use reported show the maximum use or the maximum utilization flow based on plant capacity and show the corresponding potential utilization flow and potential excess flows from figure 20. The columns based on average use reported show the average use or the average annual utilization flow and show the corresponding excess flow (average flow minus average use).

Proportional Utilization Flows and Excess Flows
(Average annual flow expressed in million gallons per day)

	Based on max. use reported			Based on avg. use reported	
	maximum use reported	potential utilization flow	potential excess flow	average use reported	average excess flow
Macon	0.54	0.42	100.58	0.42	100.58
Navigation	1.4	1.4	99.6	1.4	99.6
Plant Arkwright	12	11	90	9	92
Milstead	100	60	41	39	62
Lloyd Shoals Dam*	200+	79+	22—	86	15

*The amounts for Lloyd Shoals Dam are plus or minus flood flows as indicated, until the reservoir is full.

Irrigation use.—The present irrigation use in the Yellow River Basin above Snellville is negligible, but a different picture appears when the flow in a dry year is compared to estimated future irrigation use. Future irrigation use under dry-year conditions in the basin is estimated to be at an average annual rate of 2.8 mgd and a maximum rate of 25 mgd.

The estimated future maximum rate of irrigation use exceeds the flow of the river at Snellville that occurred during the minimum flow period in September and October of 1954. However, it is during July and August that the largest irrigation needs must be met. If all of the irrigation water were applied during these two months, the average daily use would be 16 mgd. This amounts to 95 percent of the July flow in a dry year, such as 1954, and greatly exceeds the August flow. During a normal year, irrigation use at the rate of 16 mgd would require 32 percent of the average monthly flow at Snellville during July and 52 percent during August. Thus, irrigation at the future maximum rate, directly from the streams without the use of storage facilities, would cause severe interference with the use of water downstream. Therefore, storage during highwater is imperative if irrigation uses and other uses are to be compatible.

Comparison of excess flow and future irrigation use.—The estimated future use of water for irrigation under dry-year conditions, an average annual rate of 2.8 mgd, is a small part of the average annual flow and of the average annual excess flows for the several conservation flows or for municipal, navigation, and industrial utilization. It is only 4.5 percent of the average annual excess flow for the power development at Milstead based on reported average power production and 6.8 percent of the excess flow based on the potential plant capacity. It is 19 percent of the average annual excess flow for the hydroelectric power and reservoir development at Lloyd Shoals Dam based on the reported average power production.

Storage

Storage is the impounding of water in a reservoir in order to have it available for later use when the natural stream-flow may not be adequate to meet the draft rate. In this report, storage is expressed as a volume in millions of gallons and the draft rate is expressed in millions of gallons per day.

Storage required for 30-day minimum flow.—The computation of the storage required to maintain a continuous flow equal to the mean flow for a minimum 30-day period is illustrated on figure 21 (p. 108). The hydrograph is an enlargement of the September and October flow for 1954 that was shown in figure 14 (p. 86). The bar shows the mean flow for the minimum 30-day period. The shaded area below the bar and above the hydrograph represents the deficiency in water that must be supplied from storage if the mean flow is to be maintained. As each days' deficiency is in million gallons, the total storage required is obtained by simply adding up the daily deficiencies and subtracting any daily excess which occurs during the deficiency period such as on Sept. 27 and Oct. 14 and 15. This gives the storage required in million gallons.

The stored water must be obtained from the flow in excess of the mean 30-day minimum flow prior to the deficiency period, and it will be replaced in the reservoir from the excess flow after the period.

This same general principle is used to compute the storage required for any draft rate up to the long-term average flow which represents the maximum rate of water that the stream will furnish over a long period of time.

These computations do not take into account the water lost by evaporation from the reservoir surface, by leakage, or by loss of reservoir capacity resulting from sedimentation. These factors that depend on the character of the reservoir site, the construction of the dam, and the amount of area flooded must, of course, be considered when a project reaches the design stage.

The storage curve.—The storage curve (fig. 22 p. 109) shows the relation between any average draft rate during periods between spills and the storage capacity required to maintain that rate for the gaging station on Yellow River near Snellville. The curve is derived from the record of streamflow using the principles discussed above for the 30-day minimum flow and through the use of the mass-curve technique that need not be explained here. Mean monthly flow data are generally adequate for computation of the storage curve. The storage required for the minimum 30-day flow and the point of zero storage requirement (at the minimum flow) define the low end of the curve.

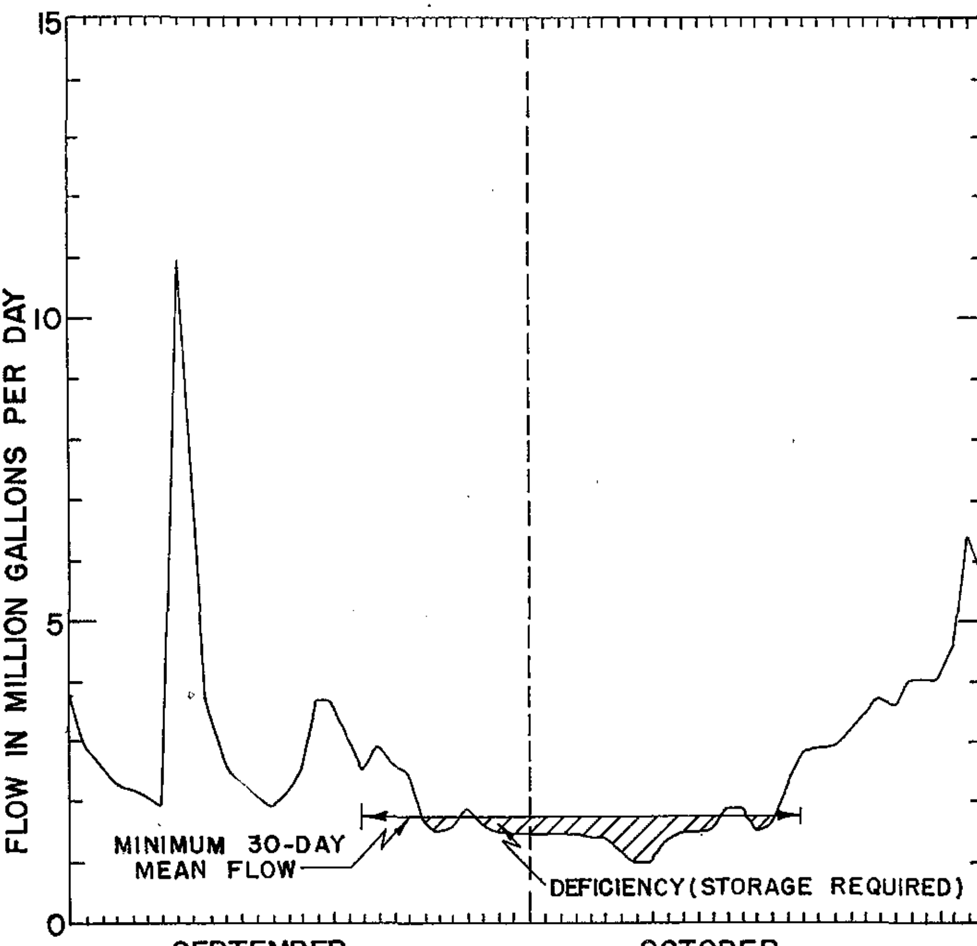


Figure 21. Graphical illustration of a method used to determine storage requirements.

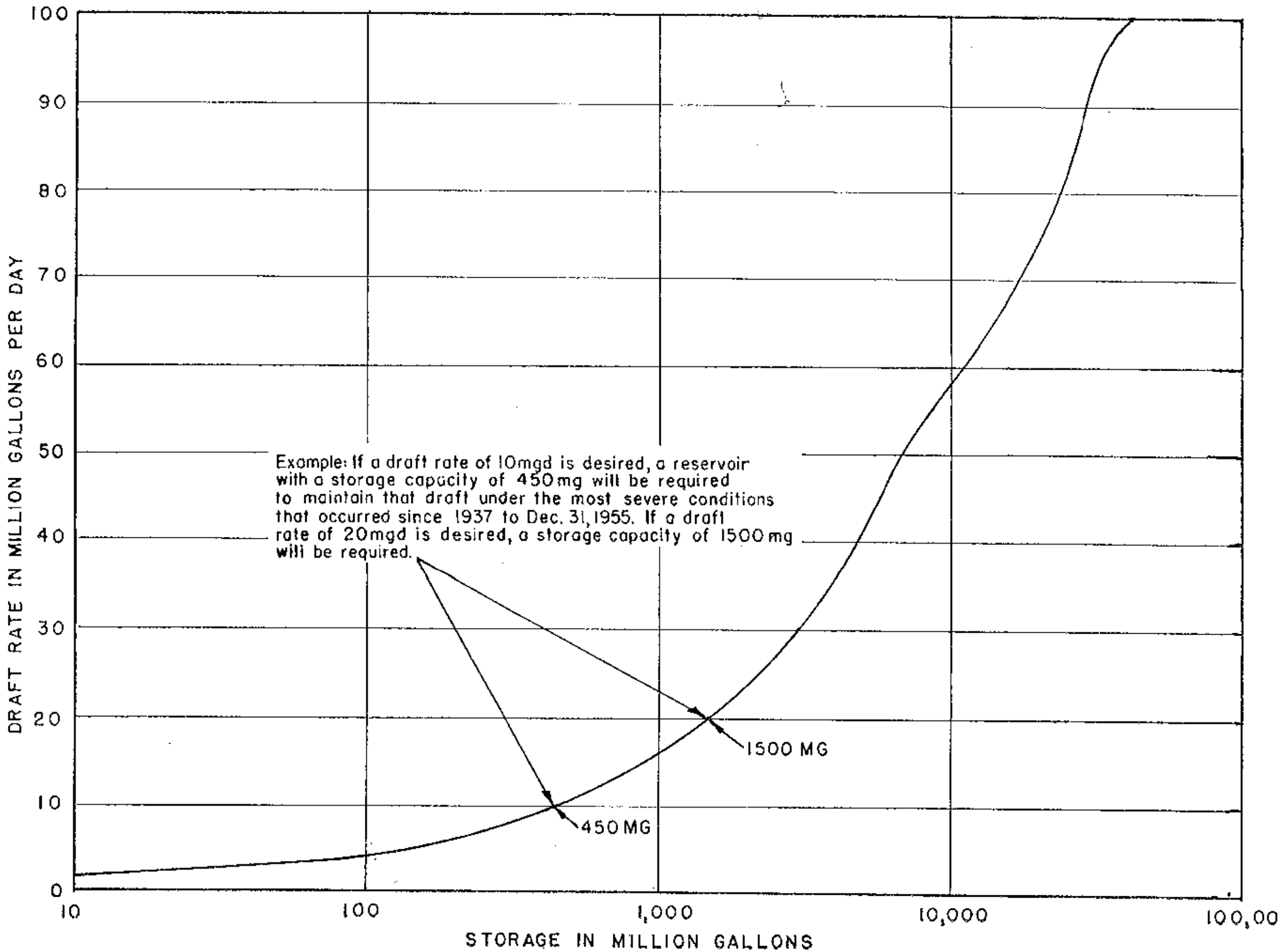


Figure 22. Storage curve for Yellow River near Snellville.

The storage curve shows the storage required to maintain the indicated average draft rate under the most adverse flow conditions that occurred during the period and is an enveloping curve for all of the years of record, possibly defined in one part by a severe drought of short duration and in another part by a less severe drought of longer duration.

Use of the storage curve.—The storage curve for a site on a stream presents graphically the estimated volume of storage required to yield any given average draft rate, usually up to the natural average annual flow of the stream at the site. Since the storage curve is based on streamflow data, it may readily be determined for sites at which gaging stations have been maintained. It is also possible to develop storage curves for other sites where limited streamflow data are available by correlations with data of gaging station sites.

The following discussion of the use of the storage curve pertains to flow requirements of a continuous nature such as for municipal, industrial, and power supplies. Storage for irrigation in Georgia, which probably will involve principally farm ponds rather than large streams, is discussed on page 192.

Purely for illustrative purposes, let us assume that consideration is being given to an industry at the Snellville site that will need two million gallons of water per day. As the minimum flow is only one million gallons a day, a reservoir will obviously be required. From the storage curve in figure 22 (p. 109), the storage required to provide a draft rate of 2 mgd is 10 million gallons. The actual height of dam and size of lake required to provide this storage depends on the topography of the dam and reservoir site. This storage requirement is based on the assumption that all of the flow is to be returned to the river near the site, as is usually the case with an industrial supply or a run-of-river power plant.

If the flow were to be diverted from the Yellow River into some other river (a common situation with urban use) or were to be consumed, as it would be if used for irrigation, provision would have to be made to pass a specified flow for downstream use. In order to provide for a 20-year daily minimum conservation flow of 1.0 mgd under these conditions, the total storage requirement for a 2 mgd rate of use would be that for a draft of 3 mgd which, from figure 22, is 40 mg. Thus, about four times as much storage capacity would be needed in order to avoid reducing the small conservation flow. If the conservation flow were that defined by the Mississippi Water Law, 3.5 mgd, the total storage requirement would be that for a draft rate of 5.5 mgd less the storage required for 3.5 mgd which, from figure 22 (p. 109), is 170 mg less 60 mg, or 110 mg. Eleven times as much storage capacity would be needed because of the larger conservation flow. These comparisons indicate that when the water used is not to be returned to the stream from which it was taken, larger conservation flows require greater storage facilities. The reason for this increase in storage requirements is that if there were no conservation-flow requirements, runoff from current rainfall during the low-flow period could be counted on to supplement the amount of water stored, but when a conservation flow is required, some of this runoff has to be passed through the reservoir leaving less gain to reservoir storage. Obviously, the higher the conservation flow, the less gain there would be to storage and the larger the reservoir that would be required.

Evaporation

Evaporation losses are normally a minor part of the water used at a power reservoir such as Jackson Lake. At full pond level the reservoir has an area of 4,750 acres, or 7.4 square miles. The drainage area at the Dam is about 1,420 square miles so that the maximum reservoir surface is only 0.5 percent of the total area that supplies water to the Dam. The average annual rainfall at two rainfall stations in the vicinity, for the 18-year period 1937 to 1955, is 45.54 inches. The average annual evaporation measured in an evaporation pan at Experiment is 58.01 inches. It is customary to use 70 percent of the land pan evaporation as the evaporation from a large lake surface. Applying 70 percent to the pan evaporation measured at Experiment gives an estimate of 40.61 inches for the average annual evaporation loss from the reservoir which is less than the average annual rainfall.

However, there is another factor to be taken into account. This is the difference between the runoff that would have occurred from the land surface that becomes inundated by the reservoir and the 100 percent runoff from precipitation on the water surface. In the case of Jackson Lake the runoff from the land surface amounts to an average of 15.07 inches per year for the standard 18 year period, assuming that the runoff from the inundated area is at the same rate as that from the entire drainage area. The average net change, then, resulting from a proposed reservoir is the rainfall on the reservoir less the evaporation and less the runoff that would have come from the inundated area. For Jackson Lake this becomes 45.54 — 40.61 — 15.07 = — 10.14 inches. The minus sign indicates a net loss. This loss applied to the maximum reservoir area of 4,750 acres gives an average loss from Jackson Lake equivalent to an average flow of 3.6 mgd, or only 0.35 percent of the average flow from the drainage basin. In the very dry year, 1954, the net loss, computed in a similar manner, was 1.6 percent. The net evaporation loss from a large reservoir, such as Jackson Lake is much less in proportion to the volume stored than the evaporation from farm ponds. Evaporation from farm ponds is discussed on page 192.

Floods

The design of flood spillways is complex and a detailed discussion of the subject is not believed necessary to this report. Briefly, the procedure involves the study of intense storm rainfall, maximum runoff conditions, and factors of safety based on the risk involved. Spillways of large dams are generally designed to pass floods much greater than the maximum flood of record.

The design of bridges and other structures that do not involve loss of life or great property loss in the event of failure is based on much smaller floods than spillway-design floods. Consideration is given to economic factors and the design flood is usually related to them on the basis of the expected frequency of recurrence of the flood flow. A report entitled **Floods in Georgia, Magnitude and Frequency** by R. W. Carter was published in 1951 as USGS Circular 100. It gives information for rivers that drain 30 square miles or more above the Fall Line, and 300 square miles or more below the Fall Line, and for frequencies up to 50 years.

Bankful stage at the gaging station on the Yellow River near Snellville is 13 feet and the flow is 4,000 cubic feet per second. The data in **Floods in Georgia** indicate that this flow will probably be exceeded two to three times a year on the average.

The maximum flood of record for the Yellow River at Snellville was 9,500 cfs on November 29, 1948. Other rivers in the Piedmont province of Georgia have had even more severe floods from other storms equivalent to a flood of about 20,000 cfs at Snellville. The mean annnual flood at Snellville is 3,280 cfs; the 10-year flood is 1.85 times as great or 6,000 cfs; and the 50-year flood is 2.7 times as great, or 8,900 cfs. The maximum flood of record, that of 1948, 9,500 cfs, is 2.9 times the mean annual flood and has a recurrence interval of 60 to 70 years. A 20,000 cfs flood at Snellville would be 6 times the mean annual flood and would be an exceedingly rare event.

With such large flows involved in spillway design it is apparent that this subject is one to be considered for each individual project by competent hydraulic engineers, and rigidly controlled by public authority in the cause of public safety.

Data Requirements

Nearly all of the above discussion has been based on the Snellville gaging station records and the other gaging stations at Covington, Jackson, Macon, and Doctortown, from which the utilization flows and correlations were computed.

The procedures have been described to illustrate some of the problems of fact involved in questions concerning water development and water use but they have not been sufficiently detailed for actual design, operation and regulation purposes. There are some deficiencies in the data available, such as the lack of nearby rain and evaporation gages, quality of water information, and the short records at the stream-gaging stations; but on the whole, the quantitative facts pertaining to the availability of water at the Snellville site were obtained within usable degrees of accuracy.

The accuracy of the daily records at the Snellville gaging station in general is believed to be within 10 percent. The monthly and yearly averages are subject to smaller errors.

GAGING STATION DATA

Streamflow data are available from 126 continuous-record gaging stations in Georgia (see fig. 23 p. 115). These data cover periods of from one year to as much as 63 years, providing a total of more than 1,800 station-years of records. Records are also available for gaging stations in other States near the Georgia boundaries. A summary of the basic data and of the results of analyses of those data is presented in tables 8A, 8B, and 8C (pp. 119-143).

Table 8 lists data for all of the continuous-record gaging stations in operation in 1955 and discontinued stations of 5 or more years of continuous record since 1937, when the standard period began. The table consists of 50 columns and, because of its magnitude, is shown in three sections: Table 8A (p. 119), the basic data from the observed records at the gaging stations; Table 8B (p. 128), the average flow for the standard period, and flood-flow information for various recurrence intervals; and Table 8C (p. 135), the information on low-flow rates that may be employed in defining a conservation flow. The average-flow and low-flow data are given in million gallons daily (mgd) and in million gallons daily per square mile (mgdsm).

There are a number of gaps in the data reported in Table 8 caused by the lack of data for the particular statistic. Numerous footnotes add supplemental information or remark on pertinent characteristics of the data as given where they differ significantly from the general description.

Some stage data are given for low, average, and flood flows to provide the reader with a general relationship between stage and flow at the gaging station sites. The authors did not attempt to analyze these relationships as the channel geometry will vary considerably from site to site on most streams. However, the stage data furnished will give the reader a rough idea of the range of stage that he might expect in the vicinity of the gaging stations. For practical purposes, a field investigation at the site by competent engineers is desirable when stage problems are involved.

An explanation of the data included in table 8A (p. 119) is given in the following paragraphs:

Map number.—The map number in column 1 is given for each section of the table in order to assist the reader in identifying the location of the station on the general location map in figure 23 (p. 115). The same identification number is used for the station throughout this report.

Station identification.—The gaging-station identification in column 2 gives the name of the river and the nearest locality which can be identified on the ground or on the usual maps of the area. A more precise description is given in the annual water-supply papers of the U. S. Geological Survey on the surface water supply for the area.

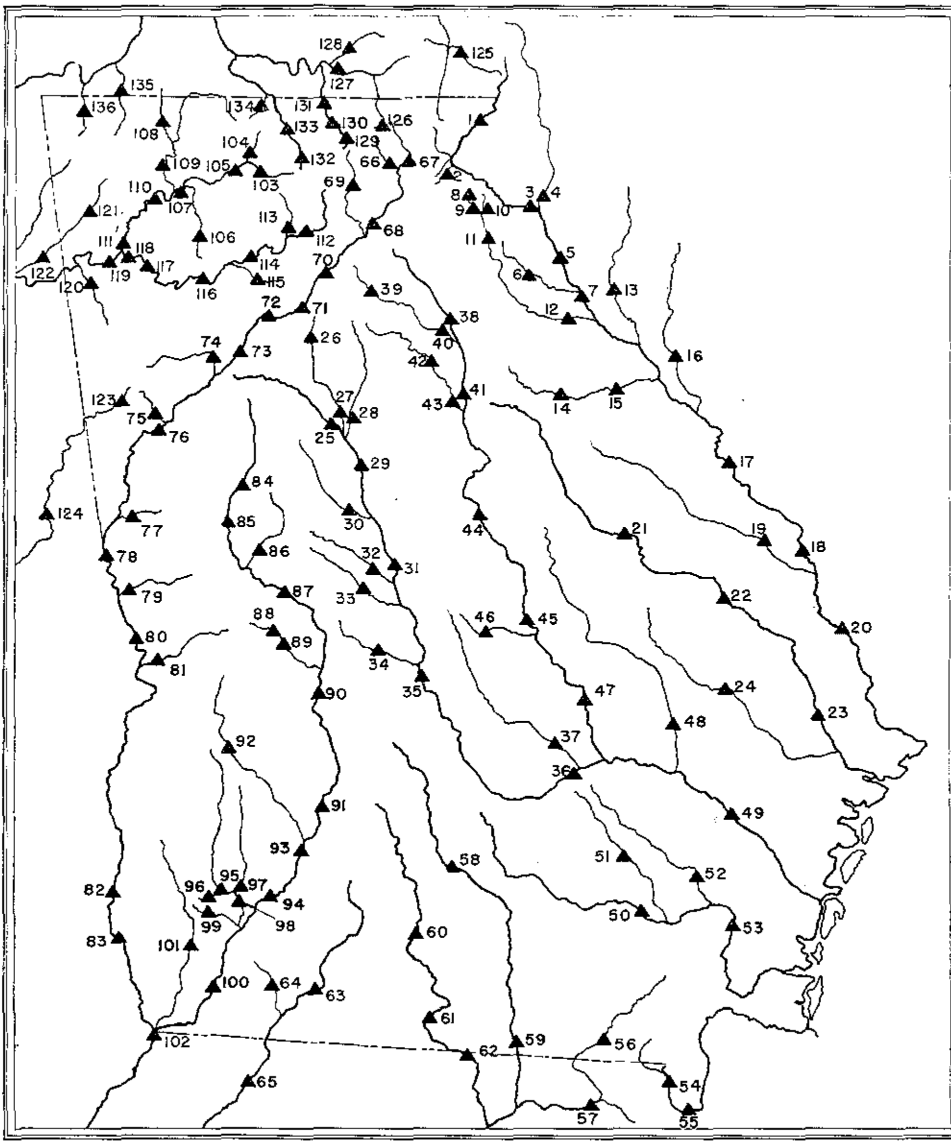


Figure 23. Map of Georgia showing location of stream-gaging stations. (Numbers refer to tables 8A, 8B, 8C).

Drainage area.—The drainage area in column 3 is the area in the drainage basin above the gaging station from which the water discharges past the gaging station.

Datum.—The datum in column 4 is the altitude of the zero of the gage in feet above mean sea level. When the datum is given to the nearest tenth of a foot it has been adjusted to the general adjustment of 1929, supplemental southeastern adjustment of 1936. When the altitude is given only to the nearest foot it has been determined by altimeter or from a topographic map and is not as accurate as the elevations determined by leveling to benchmarks.

Period of record.—Column 5 gives the period of years during which the gaging station was in operation. The first and last year given may be incomplete, and in some cases, there may be gaps within the period of record. Gaps of less than a 12-month period are not indicated.

Average flow.—Column 6 lists the average flow for the number of complete years of record given in column 7.

Number of years.—Column 7 shows the number of complete years of record within the period of record shown in column 5.

Maximum known floodflow.—The maximum flow in column 8 is the maximum known flow of flood peaks within the period of record or for historical floods prior to the period of record for which the flow has been determined. The data given are not necessarily the highest floods that have occurred, but are the highest of which the authors have knowledge.

The stage in column 9 generally corresponds to the maximum discharge in the preceding column. At a few stations, as noted, the maximum stage occurred at a different time and date than the maximum flow. Also, there are a few places where the maximum stage for a historic flood is known but the corresponding discharge has not been determined.

The date in column 10 is that on which the maximum known floodflow occurred.

Minimum flow.—The minimum daily flow in column 11 is the minimum flow for a day from midnight to midnight within the period of record shown in column 5.

The stage in column 12 corresponds to the preceding minimum daily flow at the time it was observed. At many gaging stations with unstable streambeds the stage at the time of the lowest historical drought may be different from what it would be at a different period should a similar flow recur.

The date of the minimum daily flow is given in column 13.

The instantaneous minimum flow is shown in column 14. Due to diurnal regulation it occasionally happens that the instantaneous minimum flow during the day is less than the minimum daily flow given in column 11.

The stage corresponding to the instantaneous minimum flow is listed in column 15.

The date on which the minimum instantaneous flow occurred is given in column 16.

The first 16 columns of table 9A complete the basic data. Table 8B (p. 128) begins by repeating columns 1, 2, and 3 in order to identify the station for which the succeeding information is given.

Average flow for 18-year standard period, 1937-55.—The average flow for the standard period in column 17 is based on observed record when available. When the gaging-station record does not cover the entire standard period the missing monthly flows were estimated from correlations with other gaging stations.

The stage in column 18 corresponds to the flow in the preceding column. It is an average stage and is not necessarily applicable throughout the entire period of record at gaging stations that have unstable streambeds.

The average flow in column 19 is the average number of million gallons of water flowing per day from each square mile of the area shown in column 3, assuming that the runoff is distributed uniformly in time and area.

The average flow, in inches per year, in column 20 is the depth to which the area in column 3 would be covered if all the water draining from it in the average year were uniformly distributed on its surface. Expressing volumes of runoff in inches permits easy comparison with rainfall and evapotranspiration, which are usually measured in inches.

Floodflow.—The flow at bankfull stage in column 21 has been determined from the gaging-station rating curve, and a field determination or a cross-section in the vicinity of the gaging station. It is the flow at the stage when the river is about to break into the flood plain in the vicinity of the gaging station site.

The stage in column 22 is the average stage that corresponds to the flow in the preceding column.

The bankfull flow in column 23 is the floodflow in column 21 divided by the drainage area in column 3.

The mean annual flood in column 24 is the average of the annual floods, from U. S. Geological Survey Circular 100, **Floods in Georgia.**

The stage in column 25 is taken from the average rating curve of the gaging station, and corresponds to the flow in the preceding column.

The mean annual flood in column 26 is the flow in column 24 divided by the drainage area in column 3.

In column 27, the rate of floodflow recurring an average of once every 10 years is that for which there is a ten-to-one chance that it might occur in any year. (These data were taken from Circular 100.)

The floodstage in column 28 corresponds to the floodflow in the preceding column.

The floodflow in column 29 is the floodflow in column 27 divided by the drainage area in column 3.

The 50-year recurrence-interval floodflow in column 30, is that for which there is a 50-to-1 chance that it might occur in any year. (From Circular 100).

The stage in column 31 corresponds to the floodflow in the preceding column.

The floodflow in column 32 is the floodflow in column 30 divided by the drainage area in column 3.

Low-flow frequency.—The remaining columns, in table 8C (p. 135), give flow criteria that might be used in the designation of conservation flows, in units of flow at the site and in terms of flow per square mile.

Columns 33-38 list the minimum-monthly mean flows during the standard period for 2-year, 10-year and 20-year recurrence intervals. Columns 39-44 give similar data for the minimum 7-day mean flow and columns 45-50 give similar data for the minimum daily flows.

These data are based largely on flow observed at the site during the period 1937-55, and as such are an expression of

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	SAVANNAH RIVER BASIN														
1	Chattooga River near Clayton, Ga.	207	1,165.6	1907–08; 1939–55	386	16	29,000	13.8	Aug. 1940	57	0.7	Oct. 1954	*	*	*
2	Panther Creek near Toccoa, Ga.[1]	32.5	673.5	1943–55	46.0	12	15,100	18.0	June 1949	6.5	1.4	Sept. 1955	6.5	1.4	Sept. 1954-55
3	Tugaloo River near Hartwell, Ga.[2]	909	570	1925–27; 1940–55	1,270	17	28,600	10.8	Aug. 1940	122	1.5	Oct. 1954	118	1.5	Oct. 1954
4	Seneca River near Anderson, S. C.[3]	1,026	520	1928–55	1,310	27	77,000	25	Aug. 1928	139	2.4	Sept. 1954	58	[b]	Nov. 1934
5	Savannah River near Iva, S. C.[2]	2,231	432.3	1950–55	2,450	5	54,400	12.7	Mar. 1952	349	[b]	Oct. 1954	308	1.8	Oct. 1954
6	South Beaverdam Creek at Dewy Rose, Ga.	35.8	581.1	1942–55	32.4	13	2,600	13.4	Jan. 1943	.65	.8	Sept., Oct. '54	0.5	.8	Sept. 1954
7	Savannah River near Calhoun Falls, S. C.[2]	2,876	363.5	1896–1900; 1903; 1930–32; 1938–55	3,150	17	96,500	[e]11.5	Aug. 1940	411	.5	Oct. 1954	318	.4	Oct. 1953
8	North Fork Broad River near Toccoa, Ga.	19.3	750.4	1954–55	——	—	1,060	8.3	Feb. 1955	3.4	.1	Sept. 1955	3.1	1.0	Sept. 1955
9	North Fork Broad River near Lavonia, Ga.	42.0	680.4	1954–55	——	—	1,500	11.8	Feb. 1955	4.9	5.5	Sept. 1955	4.7	5.5	Sept. 1955
10	Toms Creek near Martin, Ga.	10.3	681.7	1954–55	——	—	700	8.4	Feb. 1955	1.3	4.5	Sept. 1954, 55	1.0	4.5	Sept. 1955
11	North Fork Broad River near Carnesville, Ga.	119	600.3	1942–44; 1954–55	——	—	4,700	7.6	Mar. 1944 Jan. 1943	11	1.9	Oct. 1954	10	1.9	Oct. 1954
12	Broad River near Bell, Ga.	1,430	357.2	1926–32; 1937–55	1,100	24	79,400	34.8	Oct. 1929	71	2.2	Oct. 1954	70	2.2	Oct. 1954
13	Little River near Mt. Carmel, S. C.	217	354.0	1939–55	132	15	20,800	29.6	Aug. 1940	.65	.4	Oct. 1954	.45	.4	Oct. 1954
14	Little River near Washington, Ga.	291	360	1949–55	118	6	13,100	27.6	Mar. 1952	.21	1.6	Oct. 1954	*	*	*
15	Little River near Lincolnton, Ga.	574	271.7	1943–51	331	7	54,000	[g]44.3	Sept. 1929	9.7	1.0	Oct. 1944	9.0	1.0	Oct. 1944
16	Stevens Creek near Modoc, S. C.[4]	545	197.3	1940–55	228	15	35,100	[f]41.1	Aug. 1940	0	—	Oct., Nov. '54	*	*	*
17	Savannah River at Augusta, Ga.[2]	7,508	97.0	1884–91; 1898–06; 1925–55	6,720	45	360,000	[f]40	1796	672	[b]	Oct. 1927	419	.4	Sept. 1939
18	Savannah River at Burton's Ferry Bridge near Millhaven, Ga.[2]	8,650	52.4	1939–55	6,530	16	141,000	[g]27.0	Aug. 1940	1,370	1.5	Sept. 1951	*	*	*

See footnotes at end of table.

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	SAVANNAH RIVER BASIN—continued														
19	Brier Creek at Millhaven, Ga.[4]	646	95.9	1937–55	412	19	64,000	[h]25.1	Sept. or Oct. 1929	41	.0	Sept. 1954	[b]	[b]	[b]
20	Savannah River near Clyo, Ga.[2]	9,850	13.4	1937–55	7,140	18	128,000	[j]23.6	Aug. 1940	1,830	1.6	Oct. 1941	1,770	1.5	Oct. 1941
	OGEECHEE RIVER BASIN														
21	Ogeechee River near Louisville, Ga.[3]	800	199.2	1937–49	561	12	46,000	[g]21.3	Oct. 1929	56	2.2	June 1945	54	2.1	June 1945
22	Ogeechee River at Scarboro, Ga.	1,940	111.8	1937–55	1,040	18	24,600	[k]12.8	Aug. 1940 Mar. 1944	78	—.9	Sept. 1954	[b]	[b]	[b]
23	Ogeechee River near Eden, Ga.	2,650	19.6	1937–55	1,370	18	26,300	[m]14.7	Mar. 1944	85	.0	Sept. 1954	*	*	*
24	Canoochee River near Claxton, Ga.	555	80.5	1937–55	262	18	12,100	13.9	Apr. 1948	0.56	1.2	Sept., Oct. '54	*	*	*
	ALTAMAHA RIVER BASIN														
25	South River near McDonough, Ga.[5]	436	565.0	1939–55	361	16	34,500	24.7	Jan. 1946	35	2.1	Oct. 1954	30	2.0	Oct. 1954
26	Yellow River near Snellville, Ga.	134	810	1942–55	107	13	9,500	19.4	Nov. 1948	1.0	.4	Oct. 1954	.97	.4	Oct. 1954
27	Yellow River near Covington, Ga.[3,4]	396	617.0	1944–55	289	11	16,200	20.3	Nov. 1948	6.5	.5	Oct. 1954	5.7	.5	Oct. 1954
28	Alcovy River below Covington, Ga.	251	605	1944–49	238	5	12,400	27.2	July 1887	28	.7	Oct. 1947	39	.7	Oct. 1947
29	Ocmulgee River near Jackson, Ga.	1,420	419.3	1906–15; 1939–55	[c]1,120	25	69,000	26.8	Dec. 1919	45	3.5	[10]Nov. 1954	*	*	*
30	Towaliga River near Forsyth, Ga.[2]	315	410	1944–49	273	5	15,900	[b]	Mar. 1929	21	[b]	Sept. 1945	21	0.4	July-Sept. '45
31	Ocmulgee River at Macon, Ga.[3]	2,240	269.8	1893–1913; 1931–55	1,750	42	83,500	28.0	Nov. 1948	83	2.0	Oct. 1954	79	1.9	Oct. 1954
32	Tobesofkee Creek near Macon, Ga.	182	310.0	1937–55	120	18	9,830	23.2	Mar. 1944	1.4	2.1	Oct. 1954	*	*	*
33	Echeconnee Creek near Macon, Ga.	100	[b]	1937–43	86.6	6	8,760	12.8	Mar. 1942	2.6	.2	Oct. 1938	*	*	*
34	Big Indian Creek at Perry, Ga.	108	279.4	1943–55	51.6	12	3,000	8.6	Mar.-Apr. '44	14	.2	Sept. 1951 Aug. 1955	13	.1	Aug. 1955
35	Ocmulgee River at Hawkinsville, Ga.[2]	3,800	189.6	1944–55	2,540	11	79,000	36.5	Jan. 1925	271	.3	Oct. 1954	*	*	*

See footnotes at end of table.

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	ALTAMAHA RIVER BASIN—continued														
36	Ocmulgee River at Lumber City, Ga.[2]	5,180	87.5	1936–55	3,460	19	98,400	26.3	Jan. 1925	522	—.9	Oct., Nov. '54	522	—.9	Nov. 1954
37	Little Ocmulgee River at Towns, Ga.	363	108.1	1937–46	171	9	20,000	20.4	Jan. 1925	1.4	2.0	June 1941	1.3	2.0	June 1941
38	Oconee River at Athens, Ga.[6]	283	580	1944–49	279	5	9,000	23.0	Mar. 1929	27	[b]	Sept. 1947	7.8	2.3	June, July '45
39	Allen Creek at Talmo, Ga.	17.3	784.4	1951–55	——	—	1,150	11.5	Mar. 1952	1.3	.6	Sept. 1954	1.2	.6	Oct. 1954
40	Middle Oconee River near Athens, Ga.[3, 4]	398	555.7	1901–02; 1929–32; 1937–55	304	18	19,600	[a]25.5	Feb. 1902	18	.4	Oct. 1954	17	.4	Oct. 1954
41	Oconee River near Greensboro, Ga.[3, 4]	1,090	409.8	1903–31; 1937–55	874	46	66,800	35.4	Aug. 1908	38	—.1	Oct. 1954	36	—.1	Oct. 1954
42	Apalachee River near Bostwick, Ga.[6]	176	540	1944–49	180	5	8,500	8.9	Jan. 1946	25	1.4	Oct. 1947	16	1.2	Sept. 1947
43	Apalachee River near Buckhead, Ga.[4]	436	424.1	1901–08; 1937–55	359	25	[p]	[p]27.5	Aug. 1908	10	.3	Oct. 1954	9.0	.3	Oct. 1954
44	Oconee River at Milledgeville, Ga.[2]	2,950	230.8	1903–23; 1937–55	[d]2,180	40	95,000	38.7	Aug. 1928	58	[b]	Aug., Sept. '25 Apr. 1955	[b]	[b]	[b]
45	Oconee River at Dublin, Ga.[2]	4,400	149.1	1898–1913; 1931–55	3,140	38	96,700	33.0	Apr. 1936	226	.5	Sept. 1951	215	0.5	Sept. 1951
46	Rocky Creek near Dudley, Ga.	62.9	260	1951–55	——	—	2,390	9.4	May 1953	.24	.8	Oct. 1954	0.15	0.8	Oct. 1954
47	Oconee River near Mt. Vernon, Ga.[2]	5,110	103.3	1937–55	3,220	18	66,300	22.6	Dec. 1948	304	1.2	Oct. 1954	*	*	*
48	Ohoopee River near Reidsville, Ga.	1,110	73.8	1903–07; 1937–55	586	22	47,000	[h]28.4	Jan. 1925	12	.7	Sept. 1954	*	*	*
49	Altamaha River at Doctortown, Ga.	13,600	28.5	1931–55	8,170	24	300,000	14.6	Jan. 1925	924	—3.6	Oct., Nov. '54	898	—3.6	Oct. 1954
	SATILLA RIVER BASIN														
50	Satilla River near Waycross, Ga.	1,300	66.4	1937–55	564	18	39,000	22.4	Apr. 1948	4.0	2.5	Nov. 1954	3.9	2.5	Nov. 1954
51	Hurricane Creek near Alma, Ga.	150	136.4	1951–55	——	—	4,450	9.4	Sept. 1953	0	[b]	Most years	*	*	*
52	Little Satilla River near Offerman, Ga.	646	59.0	1951–55	——	—	17,200	13.5	Sept. 1953	0	[b]	Oct., Nov. '54	*	*	*
53	Satilla River at Atkinson, Ga.	2,880	14.8	1931–55	1,290	24	110,000	[q]27.2	Sept. 1928	2.9	1.9	Nov. 1931	*	*	*

See footnotes at end of table.

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	ST. MARYS RIVER BASIN														
54	North Prong St. Marys River at Moniac, Ga.	[a]160	89.4	1921–23; 1927–30; 1932–34; 1950–55	96.3	10	6,060	19.9	Sept. 1928	0	[b]	Most years	*	*	*
55	St. Marys River near Macclenny, Fla.	[a]720	40.0	1926–55	422	29	28,100	22.3	Sept. 1947	7.8	.7	May 1932	*	*	*
	SUWANEE RIVER BASIN														
56	Suwanee River at Fargo, Ga.	[a]1,260	91.9	1921–23; 1927–31; 1937–55	698	22	13,800	19.5	Oct. 1928	0	[b]	1931, 1943, 1954	*	*	*
57	Suwanee River at White Springs, Fla.	[a]1,990	48.5	1906–08; 1927–55	1,107	30	28,500	[c]36.6	Apr. 1948	3.1	—	Nov. 1931	*	*	*
58	Alapaha River near Alapaha, Ga.	644	209.3	1937–55	301	18	16,000	18.0	1928	0	[b]	July, Sept., Oct. 1954	*	*	*
59	Alapaha River at Statenville, Ga.	1,400	76.8	1921; 1931–55	599	23	27,300	29.8	Apr. 1948	11	.8	Nov. 1954	10	.8	Nov. 1954
60	Little River near Adel, Ga.	547	171.1	1940–55	308	15	38,800	21.0	Apr. 1948	0.16	1.0	Oct. 1954	*	*	*
61	Withlacoochee River near Quitman, Ga.	1,560	84.3	1920–21; 1928–31; 1937–48	786	14	66,000	31.7	Apr. 1948	4.4	[b]	Nov., Dec. '40 Dec. 1941	3.8	1.8	Nov. 1940
62	Withlacoochee River near Pinetta, Fla.	2,220	47.2	1931–55	926	24	79,400	38.6	Apr. 1948	47	6.3	Aug. 1955	45	6.3	Aug. 1955
	OCHLOCKONEE RIVER BASIN														
63	Ochlockonee River near Thomasville, Ga.	550	133.6	1937–55	287	18	72,000	29.1	Apr. 1948	1.7	.7	Oct. 1938	*	*	*
64	Tired Creek near Cairo, Ga.	55	159.0	1943–55	41.5	12	28,100	16.3	Apr. 1948	.06	.0	June 1955	*	*	*
65	Ochlockonee River near Havana, Fla.	1,020	59.2	1928–55	604	27	55,900	35.1	Apr. 1948	11	10.8	Oct., Nov. '54	*	*	*
	APALACHICOLA RIVER BASIN														
66	Chattahoochee River near Leaf, Ga.[4]	150	1,219.5	1940–55	252	15	14,100	13.6	Jan. 1946	47	1.3	Oct. 1941	46	1.3	Oct. 1954
67	Soque River near Demorest, Ga.[2]	156	1,152.2	1904–09; 1929–31; 1940–51	229	17	21,000	28.5	June 1949	12	.9	Oct. 1931	5	.7	Oct. 1931
68	Chattahoochee River near Gainesville, Ga.[3]	559	975.0	1901–03; 1937–55	753	18	45,800	26.2	Jan. 1946	134	1.2	Oct. 1954	*	*	*

See footnotes at end of table.

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	APALACHICOLA RIVER BASIN —continued														
69	Chestatee River near Dahlonega, Ga.[7]	153	1,128.6	1929-31; 1940-55	218	17	15,300	[g]22.1	Jan. 1946	32	[b]	Oct. 1931 Oct. 1941	28	.9	Oct. 1931
70	Chattahoochee River near Buford, Ga.[3]	1,060	905.2	1942–55	1,400	13	55,000	32.6	Jan. 1946	235	3.3	Sept. 1951	221	3.2	Sept. 1951
71	Chattahoochee River near Norcross, Ga.[8]	1,170	878.1	1903–46	1,460	43	55,000	27.7	Jan. 1946	85	.5	Aug. 1925	*	*	*
72	Chattahoochee River near Roswell, Ga.[3]	1,230	849.5	1941–55	1,510	14	56,000	23.4	Jan. 1946	212	1.4	Oct. 1954	208	1.4	Oct. 1954
73	Chattahoochee River at Atlanta, Ga.[6]	1,450	750.1	1928–31; 1936–55	1,640	21	59,000	28.0	Jan. 1946	220	1.7	Oct. 1954	191	1.6	Sept. 1954
74	Sweetwater Creek near Austell, Ga.	246	857.0	1904–05; 1913; 1937–55	193	18	8,980	[g]20.0	July 1916	1.4	—.7	Oct. 1954	[b]	[b]	[b]
75	Snake Creek near Whitesburg, Ga.[7]	37	770	1954–55	—	—	1,200	5.8	Feb. 1955	1.5	1.6	Oct. 1954	1.5	1.6	Sept.-Oct. '54
76	Chattahoochee River near Whitesburg, Ga.[8]	2,430	684.1	1938–54	2,420	15	59,000	25.1	Jan. 1946	302	1.0	Oct. 1941	290	1.0	Oct. 1941
77	Yellowjacket Creek near LaGrange, Ga.	182	601	1951–55	—	—	6,870	11.3	Mar. 1952	3.4	.7	Oct. 1954	3.0	.7	Oct. 1954
78	Chattahoochee River at West Point, Ga.[19]	3,550	551.7	1896–1910; 1912–55	3,630	59	134,000	30.0	Dec. 1919	145	1.6	Sept. 1925	*	*	*
79	Mountain Creek near Hamilton, Ga.	61.7	550	1943–55	52.2	11	11,800	16.6	July 1948	3.6	1.4	Oct. 1954	3.4	1.4	Oct. 1954
80	Chattahoochee River at Columbus, Ga.[2]	4,670	185.1	1912; 1929–55	[c]4,190	26	198,000	53.2	Mar. 1929	310	.5	Oct. 1931	190	.1	Oct. 1931
81	Upatoi Creek at Fort Benning, Ga.[14]	447	189.7	1942–47	432	5	[b]	31.3	Mar. 1943	74	5.4	Oct. 1943	[b]	[b]	[b]
82	Chattahoochee River at Columbia, Ala.[22]	8,040	72.2	1928–55	6,960	27	203,000	56.0	Mar. 1929	782	2.5	Oct. 1954	750	2.4	Oct. 1954
83	Chattahoochee River at Alaga, Ala.[2]	8,340	62.7	1938–44	6,570	7	207,000	46.0	Mar. 1929	918	1.1	Oct., Nov. '41	*	*	*
84	Flint River near Griffin, Ga.[10]	272	711.4	1937–55	207	18	15,300	[g]17.9	Mar. 1929	1.6	1.2	Oct. 1954	*	*	*
85	Flint River near Molena, Ga.	990	646.8	1898; 1945–53	876	6	38,400	17.1	Dec. 1919	33	5.0	Sept. 1951	30	5.0	Sept. 1951
86	Potato Creek near Thomaston, Ga.[11]	186	600	1938–55	140	17	9,240	8.8	Nov. 1948	.50	2.1	Oct. 1954	.43	2.1	Oct. 1954

See footnotes at end of table.

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	APALACHICOLA RIVER BASIN —continued														
87	Flint River near Culloden, Ga.	1,890	334.5	1911–23; 1928–31; 1937–55	1,540	32	92,000	38.4	Mar. 1929	63	.9	Oct. 1931	61	.9	Oct. 1931
88	Whitewater Creek near Butler, Ga.	75	365.8	1943–51	101	8	1,340	6.5	Mar. 1944	63	1.7	June 1945	61	1.6	June 1945
89	Whitewater Creek below Rambulette Creek near Butler, Ga.	93.4	365.8	1951–55	—	—	1,120	5.5	May 1953	72	b	Oct. 1951, '52	68	1.1	Oct. 1952
90	Flint River at Montezuma, Ga.[8]	2,900	255.8	1905–09; 1911–12; 1930–33; 1934–55	2,310	28	92,300	[g]27.4	Mar. 1929	378	b	Oct. 1941	b	b	b
91	Flint River at Oakfield, Ga.[2]	3,860	193.3	1930–33; 1934–55	2,880	23	90,000	35.1	Jan. 1925	98	b	June 1941	69	.5	Oct., Nov. '54
92	Kinchafoonee Creek at Preston, Ga.	197	337.7	1951–55	—	—	6,000	8.8	May 1953	20	1.6	June 1955	19	1.5	June 1955
93	Flint River at Albany, Ga.[2]	5,230	150.0	1902–21; 1929–55	4,060	44	92,000	37.8	Jan. 1925	275	b	Aug. 1930	b	b	b
94	Flint River at Newton, Ga.[2]	5,740	110.2	1938–45; 1946–47	4,300	8	94,000	41.1	Jan. 1925	543	3.0	Oct. 1940	511	2.9	Oct., Nov. '40
95	Ichawaynochaway Creek near Milford, Ga.[3]	620	150.3	1905–07; 1939–55	515	16	15,500	17.2	——, 1916	78	.8	Sept. 1954	76	.8	Sept. 1954
96	Alligator Creek near Milford, Ga.	b	167.2	1942–52	7.24	9	b	4.4	Mar. 1944	0	b	Most years	*	*	*
97	Chickasawhatchee Creek at Elmodel, Ga.	320	b	1939–49	245	10	3,630	11.9	Mar., Apr. 48	3.4	.8	Oct., Nov. '43	*	*	*
98	Ichawaynochaway Creek near Newton, Ga.[3]	1,000	113.8	1937–47	757	9	26,000	35	——, 1916	132	.5	Sept. 1941	*	*	*
99	Big Cypress Creek near Milford, Ga.	b	210.6	1942–49	2.11	7	105	2.8	Apr. 1948	0	b	Most years	*	*	*
100	Flint River at Bainbridge, Ga.[3]	7,350	58.1	1908–13; 1928–55	5,420	31	101,000	40.9	Jan. 1925	1,230	7.9	Dec. 1955	1,200	3.5	Nov. 1954
101	Spring Creek near Iron City, Ga.	520	85.7	1920–21; 1937–55	311	18	12,600	19.9	Apr. 1948	5.9	1.0	Oct., Nov. '54	*	*	*
102	Apalachicola River at Chattahoochee, Fla.[2]	17,100	45.6	1928–55	[c]14,000	27	293,000	34.0	Mar. 1929	3,240	—2.2	Oct., Nov. '54	3,200	—2.2	Oct. 1954
	MOBILE RIVER BASIN														
103	Cartecay River near Ellijay, Ga.[12]	135	1,255.4	1937–55	172	18	20,000	13.0	Apr. 1938	41	1.1	Oct. 1941	38	1.1	Oct. 1941

See footnotes at end of table.

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	MOBILE RIVER BASIN—continued														
104	Ellijay River at Ellijay, Ga.	90	1,242.3	1907; 1918–21; 1953–55	—	—	7,940	16.3	Jan. 1954	18	2.2	Sept. 1954	17	2.2	Sept. 1954
105	Coosawattee River near Ellijay, Ga.[9]	238	1,216.0	1938–49	299	11	13,000	14.3	Feb. 1946 Jan. 1947	67	1.2	Oct. 1941	65	1.2	Oct. 1941
106	Rock Creek near Fairmount, Ga.	5.61	759.0	1951–55	—	—	820	4.2	Jan. 1954	.50	.4	Sept., Oct. '54	.40	.4	Sept. 1954
107	Coosawattee River at Pine Chapel, Ga.[7]	856	616.2	1938–55	909	17	40,200	30.8	Mar. 1951	142	1.0	Oct. 1941	141	1.3	Oct. 1954
108	Mill Creek at Dalton, Ga.[7]	37	695.4	1943–55	45.5	12	[b]	8.4	Mar. 1951	7.8	[b]	Oct. 1954	5.8	1.4	Sept. 1955
109	Conasauga River at Tilton, Ga.	682	622.3	1937–55	734	18	29,000	[t]30.2	Mar. 1951	44	2.3	Oct. 1954	*	*	*
110	Oostanaula River at Resaca, Ga.	1,610	604.1	1896–55	1,800	54	68,600	[a]36.3	Apr. 1886	116	.5	Sept. 1925	*	*	*
111	Oostanaula River near Rome, Ga.	2,120	561.7	1939–55	2,220	16	47,000	35.1	Jan. 1947	264	4.1	Oct. 1954	[b]	[b]	[b]
112	Etowah River near Dawsonville, Ga.[3]	103	1,050	1940–55	159	15	4,780	15.8	Jan. 1946	32	.8	Oct. 1954	*	*	*
113	Amicalola Creek near Dawsonville, Ga.[3]	84.7	1,203.9	1939–52	139	12	7,450	7.0	Feb. 1942	33	.4	Sept. 1951	[b]	[b]	[b]
114	Etowah River at Canton, Ga.	605	844.6	1896–1905; 1937–55	743	24	36,700	[a]25.0	Jan. 1892	115	1.0	Sept. 1954	*	*	*
115	Little River near Roswell, Ga.	60.5	897.8	1947–55	50.7	8	3,200	14.0	Nov. 1948	1.4	—.4	Sept. 1955	1.2	—0.4	Sept. 1955
116	Etowah River at Allatoona Dam above Cartersville, Ga.[2]	1,110	686.9	1938–55	[d]1,093	17	40,400	20.8	Jan. 1946	134	[b]	May 1953	[b]	[b]	[b]
117	Etowah River near Kingston, Ga.[2]	1,630	610.0	1928–31; 1936–55	[e]1,503	21	52,000	[g]31	Dec. 1919	173	2.9	Oct. 1931	130	2.8	Oct. 1931
118	Etowah River at Rome, Ga.[2]	1,810	561.7	1904–21; 1939–55	1,890	32	55,000	[w]	Dec. 1919	233	[b]	Oct. 1904	[b]	[b]	[b]
119	Coosa River near Rome, Ga.[2]	4,040	553.0	1897–1903; 1928–31; 1937–55	4,250	27	100,000	[a]40.3	Apr. 1886	562	[b]	Oct. 1931 Sept. 1955	870	—0.5	Oct. 1931
120	Cedar Creek near Cedartown, Ga.[3]	109	724.7	1942–55	102	13	12,500	16.4	Nov. 1948	17	.9	Oct., Nov. '54	[b]	[b]	[b]

See footnotes at end of table.

Table 8A.—Gaging station information; maximum, average, and minimum flow for period of record—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Datum (ft. above msl)	Period of record	Average flow		Maximum flood-flow			Minimum flow					
										Daily			Instantaneous		
					Mgd	No. years	Cfs	Stage (ft.)	Date	Mgd	Stage (ft.)	Date	Mgd	Stage (ft.)	Date
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	MOBILE RIVER BASIN—continued														
121	Chattooga River at Summerville, Ga.[13]	193	613.5	1937–55	222	18	24,500	21.0	Mar. 1951	25	[b]	Oct. 1937 Nov. 1939	23	1.5	Nov. 1939
122	Chattooga River at Gaylesville, Ala.[3]	377	549.6	1937–55	429	18	33,700	25.2	Mar. 1951	48	3.6	Oct. 1940	*	*	*
123	Little Tallapoosa River at Carrollton, Ga.	89	971.2	1937–55	84.7	18	6,010	19.3	Nov. 1948	.17	2.5	Oct. 1954	[b]	[b]	[b]
124	Tallapoosa River at Wadley, Ala.[3]	1,660	601.3	1923–55	1,563	32	52,800	27.9	Feb. 1936	29	2.3	Oct. 1954	*	*	*
	TENNESSEE RIVER BASIN														
125	Cullasaja River at Cullasaja, N. C.[15]	86.5	2,023.4	1907–09; 1921–55	144	37	16,500	20.8	Aug. 1940	12	[b]	Sept. 1925	12	[b]	Sept. 1925 Jan. 1940
126	Hiwassee River at Presley, Ga.	45.5	1,932.7	1941–55	84.0	13	5,700	15.2	Mar. 1952	15	1.6	Sept., Oct. '54	14	1.6	Oct. 1954
127	Hiwassee River above Murphy, N. C.[2]	406	1,538.2	1897–1917; 1918–55	588	55	23,100	[a]18.4	Mar. 1899	40	1.9	Oct. 1952[17]	[b]	[b]	[b]
128	Valley River at Tomotla, N. C.	104	1,556.5	1904–09; 1914–17; 1918–55	162	43	9,030	17.3	Nov. 1906	7.8	.5	Aug. 1925	7.8	.5	Aug., Sept. '25
129	Nottely River near Blairsville, Ga.[4]	74.8	1,812.5	1942–55	112	13	8,500	16.8	Mar. 1952	18	[b]	Oct. 1947	17	1.8	Sept., Oct. '47
130	Nottely River near Ivy Log, Ga.	191	1,680.5	1936–42	206	6	11,500	12.2	July 1938	51	[b]	June 1941	46	1.3	June 1941
131	Nottely River at Nottely Dam, near Ivy Log, Ga.	215	1,599.2	1942–55	261	13	2,830	6.34	May 1944	.1	.2	Sept., Oct. '54	.06	.2	Sept. 1954
132	Toccoa River near Dial, Ga.	177	1,782.1	1913–55	313	43	10,800	11.2	Mar. 1952	39	.4	Sept. 1925	*	*	*
133	Toccoa River near Blue Ridge, Ga.[2]	233	1,538.8	1913–55	378	43	13,900	13.0	July 1916	0	[b]	[18]	*	*	*
134	Fightingtown Creek at McCaysville, Ga.[3]	70.9	1,449.8	1942–55	127	12	5,420	11.9	Mar. 1951	24	1.4	Sept., Oct. '54	24	1.4	Nov. 1953 Sept., Oct. '54
135	South Chickamauga Creek near Chickamauga, Tenn.	428	651.1	1928–55	450	27	27,600	20.7	Mar. 1951	41	.5	Oct. 1954	39	.5	Oct. 1941 Oct. 1954
136	Chattanooga Creek near Flintstone, Ga.	50.6	649.2	1950–55	—	—	6,140	12.9	Mar. 1951	.84	.2	Sept. 1954	.65	.2	Sept. 1954

See footnotes at end of table.

Footnotes to Table 8A

[1] Diversion above station at times for municipal supply of Toccoa.
[2] Flow regulated by powerplant and/or reservoir.
[3] Some regulation and/or diurnal fluctuation at low flow by powerplant or mill.
[4] Slight diurnal fluctuation at low flow caused by mills.
[5] Flow figures include diversion from Chattahoochee River (averaging about 7.7 mgd) for Atlanta municipal supply.
[6] Diurnal fluctuation caused by mill or powerplant.
[7] Moderate diurnal fluctuation at times caused by mill.
[8] Moderate diurnal fluctuation caused by powerplant.
[9] Slight diurnal fluctuation or regulation caused by powerplant or mill.
[10] Some diurnal fluctuation at low flow. City of Griffin diverts an average of about 1.6 mgd from the river upstream, to the Towaliga River and Potato Creek.
[11] Some regulation at low flow caused by diversion for municipal and industrial supplies at Thomaston.
[12] Some diurnal fluctuation caused by mill.
[13] Low and medium flow regulated by powerplant.
[14] About 5.2 mgd diverted above station for Fort Benning water supply.
[15] Slight regulation at low flow by reservoir.
[16] Minimum daily flow of 12 mgd occurred November 1910, caused by closing of dam upstream.
[17] Minimum daily flow of 6.5 mgd occurred December 1924, caused by freeze-up and filling of reservoir upstream.
[18] Occurred December 1930 to March 1931, caused by closing of dam upstream.
[*] Same as minimum daily flow, columns 11-13.
[a] Approximate; includes part of watershed in Okefenokee Swamp which is indeterminate.
[b] Not determined.
[c] Not adjusted for storage in reservoir.
[d] Adjusted for storage in reservoir.
[e] Maximum stage known, 28.2 ft. Aug. 25, 1908, original site and datum, from records of U. S. Weather Bureau; flow not determined.
[f] Stage at Fifth Street gage site furnished by local residents; datum, 102.1 ft. above msl.
[g] Flood of October 1929 reached a stage of 30.8 ft., from information by Corps of Engineers; flow not determined.
[h] From information by Georgia State Highway Department.
[j] Maximum stage since 1921, 29.7 ft. in October 1929, from records of U. S. Weather Bureau; flow not determined.
[k] Maximum stage known, 17.0 ft. in October 1929, from information by local residents; flow not determined.
[m] Maximum stage known, 20.0 ft. in October 1929, from data furnished by Central of Georgia Railway Co.
[n] At gage site 1 mile upstream from present site and at unknown datum.
[p] Flow and datum not determined. Flood of November 1948 reached a stage of 26.8 ft. (flow, 23,800 cfs).
[q] From information by local residents.
[r] Flood of August 1907 reached a stage of about 25 ft., from information by local resident. Flow increased by failure of dam above station.
[s] From records of U. S. Weather Bureau.
[t] Maximum stage; occurred at time different from maximum flow.
[v] Flood of April 1886, reached a stage of 40.3 ft. at Fifth Avenue bridge gage sties, from records of U. S. Weather Bureau.
[w] In excess of 28 ft. at Freeman's Ferry gage site which is 5 miles upstream from present site and datum not determined.
[x] At Fifth Avenue gage site at Rome, 7½ miles upstream from present site and at datum 575.8 ft. above msl. According to stage relation graph this flood would have had an equivalent stage of about 43 ft. at present site.
[y] From information by Central of Georgia Railway Co.
[z] At gage site 2.8 miles downstream from present site and at datum 1507.8 ft. above msl.

Table 8B.—Gaging station information; average flow for standard period, 1937–55, and flood flow statistics.

Map no.	Gaging Station	Drainage area (sq. mi.)	Average flow, 1937–55				Flood-flow											
			Mgd	Stage (ft.)	Mgdsm	Inches	Bankfull			Mean Annual			10-Year R. I.			50-Year R. I.		
							Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm
(1)	(2)	(3)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	SAVANNAH RIVER BASIN																	
1	Chattooga River near Clayton, Ga.	207	385	1.8	1.86	38.96	—	—	—	7,600	6.1	36.7	14,600	9.0	70.5	22,600	11.8	109
2	Panther Creek near Toccoa, Ga.	32.5	45.6	2.0	1.40	29.46	4,800	10	148	3,450	8.4	106	6,620	11.8	204	10,200	14.8	314
3	Tugaloo River near Hartwell, Ga.	909	1,285	3.6	1.41	29.73	—	12	—	18,200	8.8	20.0	34,900	11.2	38.4	54,000	—	59.4
4	Seneca River near Anderson, S. C.	1,026	1,223	4.3	1.19	25.11	15,900	11	15.5	—	—	—	—	—	—	—	—	—
5	Savannah River near Iva, S. C.	2,231	2,800	—	1.26	26.20	56,800	13	25.5	—	—	—	—	—	—	—	—	—
6	South Beaverdam Creek at Dewy Rose, Ga.	35.8	30.5	1.7	.85	17.92	—	—	—	—	—	—	—	—	—	—	—	—
7	Savannah River near Calhoun Falls, S. C.	2,876	3,135	—	1.09	22.94	51,200	8.0	17.8	46,500	—	16.2	89,400	—	31.1	138,000	—	48.0
12	Broad River near Bell, Ga.	1,430	1,053	5.5	.74	15.48	8,200	13	5.7	25,200	23.5	17.6	48,300	30.0	33.8	74,800	34.0	52.3
13	Little River near Mt. Carmel, S. C.	217	127	1.9	.58	12.34	—	—	—	—	—	—	—	—	—	—	—	—
15	Little River near Lincolnton, Ga.	574	282	2.6	.49	10.32	6,350	15	11.1	9,290	19.5	16.2	17,900	27.0	31.2	27,600	—	48.1
16	Stevens Creek near Modoc, S. C.	545	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	Savannah River at Augusta, Ga.[1]	7,508	5,849	8.5	.78	16.42	95,000	30	12.7	104,000	—	14.4	200,000	—	27.6	310,000	—	42.8
18	Savannah River at Burton's Ferry Bridge near Millhaven, Ga.[1]	8,650	6,476	9.7	.75	15.75	16,600	14	1.9	71,200	—	8.2	136,000	—	15.7	211,000	—	24.4
19	Brier Creek at Millhaven, Ga.[1]	646	403	4.6	.62	13.03	1,600	7.5	2.5	4,370	11.2	6.86	8,400	13.3	13.0	13,000	14.8	20.1
20	Savannah River near Clyo, Ga.[1]	9,850	7,142	9.0	.73	15.20	14,500	11	1.5	68,400	—	6.9	130,000	—	13.2	202,000	—	20.5
	OGEECHEE RIVER BASIN																	
21	Ogeechee River near Louisville, Ga.	800	483	7.4	.60	12.76	1,860	11	2.3	11,000	15.8	13.8	21,200	17.7	26.5	32,800	—	41.0
22	Ogeechee River at Scarboro, Ga.	1,940	1,039	6.1	.54	11.27	1,550	6.0	0.8	14,600	11.2	7.5	27,900	13.4	14.4	43,300	—	22.3
23	Ogeechee River near Eden, Ga.	2,650	1,367	5.8	.52	10.86	4,980	8.0	1.9	15,200	12.4	5.7	28,900	14.0	10.9	44,800	—	16.9
24	Canoochee River near Claxton, Ga.	555	262	3.3	.47	9.91	1,740	9.0	3.1	5,620	12.3	10.1	10,800	13.6	19.5	16,600	—	29.9

See footnotes at end of table.

Table 8B.—Gaging station information; average flow for standard period, 1937–55, and flood flow statistics—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Average flow, 1937–55: Mgd	Average flow, 1937–55: Stage (ft.)	Average flow, 1937–55: Mgdsm	Average flow, 1937–55: Inches	Flood-flow: Bankfull: Cfs	Flood-flow: Bankfull: Stage (ft.)	Flood-flow: Bankfull: cfsm	Flood-flow: Mean Annual: Cfs	Flood-flow: Mean Annual: Stage (ft.)	Flood-flow: Mean Annual: cfsm	Flood-flow: 10-Year R. I.: Cfs	Flood-flow: 10-Year R. I.: Stage (ft.)	Flood-flow: 10-Year R. I.: cfsm	Flood-flow: 50-Year R. I.: Cfs	Flood-flow: 50-Year R. I.: Stage (ft.)	Flood-flow: 50-Year R. I.: cfsm
(1)	(2)	(3)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	ALTAMAHA RIVER BASIN																	
25	South River near McDonough, Ga.	436	359	4.4	.82	17.38	5,000	13	11.5	15,100	19.5	34.6	28,100	23.0	64.4	40,700	—	93.3
26	Yellow River near Snellville, Ga.	134	101	1.7	.75	15.75	4,000	13	29.9	3,280	11.0	24.5	6,100	18.5	45.5	8,860	—	66.1
27	Yellow River near Covington, Ga.	396	284	3.1	.72	15.07	1,350	6.0	3.4	7,820	16.0	19.7	14,600	19.8	36.9	21,200	—	53.5
28	Alcovy River below Covington, Ga.	251	186	2.4	.74	15.61	2,400	10	9.6	4,420	14.8	17.6	8,210	21.2	32.7	11,900	—	47.4
29	Ocmulgee River near Jackson, Ga.	1,420	1,053	5.1	.74	15.61	24,000	14	16.9	29,300	15.8	20.6	54,400	23.3	38.3	79,000	30	55.6
30	Towaliga River near Forsyth, Ga.	315	227	1.6	.72	15.07	5,100	13	16.2	6,660	15.1	21.1	12,300	—	39.0	18,000	—	57.1
31	Ocmulgee River at Macon, Ga.	2,240	1,573	4.4	.70	14.80	14,800	18	6.6	36,500	22.4	16.3	67,900	26.5	30.3	98,600	—	44.0
32	Tobesofkee Creek near Macon, Ga.	182	120	3.5	.66	13.85	5,040	17	27.7	4,320	15.6	23.7	8,030	21.2	44.1	11,600	—	3.7
33	Echeconnee Creek near Macon, Ga.	100	87.9	1.9	.88	18.46	800	5.0	8.0	—	—	—	—	—	—	—	—	—
34	Big Indian Creek at Perry, Ga.	108	51.7	1.4	.48	10.04	148	2.5	1.5	—	—	—	—	—	—	—	—	—
35	Ocmulgee River at Hawkinsville, Ga.	3,800	2,556	6.4	.67	14.12	8,100	12	2.1	33,200	26.1	8.74	61,600	33.1	16.2	89,300	—	23.5
36	Ocmulgee River at Lumber City, Ga.	5,180	3,415	5.9	.66	13.85	24,100	15	4.7	34,300	16.8	6.62	63,700	20.9	12.3	92,200	—	17.8
37	Little Ocmulgee River at Towns, Ga.	363	185	—	.51	10.72	514	6.5	1.4	3,850	13.9	10.6	7,150	16.0	19.7	10,400	—	28.7
38	Oconee River at Athens, Ga.	283	219	4.4	.77	16.29	—	—	—	5,150	17.3	18.2	9,590	—	33.9	13,900	—	49.1
40	Middle Oconee River near Athens, Ga.	398	304	1.7	.76	16.02	6,350	12	16.0	7,000	12.9	17.6	13,000	18.8	32.7	18,900	—	47.5
41	Oconee River near Greensboro, Ga.	1,090	799	4.0	.73	15.34	3,990	10	3.7	17,200	21.8	15.8	32,000	27.5	29.4	47,500	31	42.7
42	Apalachee River near Bostwick, Ga.	176	139	2.3	.79	16.56	5,650	7.0	32.1	4,980	6.6	28.3	8,940	—	50.8	13,400	—	76.1
43	Apalachee River near Buckhead, Ga.	436	336	3.6	.77	16.15	1,350	7.0	3.1	12,400	20.5	28.4	23,000	26.4	52.8	33,400	31	76.6
44	Oconee River at Milledgeville, Ga.	2,950	1,929	9.3	.65	13.71	10,200	16	3.5	43,500	30.0	14.7	81,100	37.3	27.5	118,000	—	40.0
45	Oconee River at Dublin, Ga.	4,400	2,824	6.8	.64	13.44	23,600	20	5.4	42,000	25.0	9.55	78,800	31.0	17.9	114,000	—	25.9

See footnotes at end of table.

Table 8B.—Gaging station information; average flow for standard period, 1937–55, and flood flow statistics—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Average flow, 1937–55				Flood-flow											
			Mgd	Stage (ft.)	Mgdsm	Inches	Bankfull			Mean Annual			10-Year R. I.			50-Year R. I.		
							Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm
(1)	(2)	(3)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	ALTAMAHA RIVER BASIN—continued																	
47	Oconee River near Mount Vernon, Ga.	5,110	3,218	8.0	.63	13.17	13,800	14	2.7	39,600	19.4	7.75	74,100	23.5	14.5	108,000	—	21.1
48	Ohoopee River near Reidsville, Ga.	1,110	580	5.4	.52	11.00	3,190	11	2.9	8,900	16.6	8.02	17,100	21	15.4	26,400	24	23.8
49	Altamaha River at Doctortown, Ga.	13,600	8,105	4.9	.60	12.49	13,100	5.0	1.0	76,000	9.4	5.59	147,000	11.5	10.8	226,000	13.3	16.6
	SATILLA RIVER BASIN																	
50	Satilla River near Waycross, Ga.	1,300	564	7.9	.43	9.10	2,420	12	1.9	8,200	16.4	6.31	19,000	19.4	14.6	31,700	21.6	24.4
53	Satilla River at Atkinson, Ga.	2,880	1,335	9.3	.46	9.77	5,520	13	1.9	16,000	16.7	5.56	37,400	20.2	13.0	62,500	23.3	21.7
	ST. MARYS RIVER BASIN																	
54	North Prong St. Marys at Moniac, Ga.	[a]160	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
55	St. Marys River at Macclenny, Fla.	[a]720	427	6.4	.593	12.45	5,600	15	7.8	7,600	16.2	10.6	17,600	20.0	24.4	29,400	—	40.8
	SUWANEE RIVER BASIN																	
56	Suwanee River at Fargo, Ga.	1,260	598	7.8	.47	9.91	1,710	9.8	1.4	5,000	14.0	3.97	11,600	19.3	9.21	19,400	—	15.4
57	Suwanee River at White Springs, Fla.	[a]1,990	1,079	7.9	.542	11.39	14,000	32	7.0	8,600	26.8	4.3	20,000	34.6	10.0	33,300	—	16.7
58	Alapaha River near Alapaha, Ga.	644	301	6.2	.47	9.77	2,400	11	3.7	4,500	12.7	6.99	10,400	15.8	16.1	17,500	18.4	27.2
59	Alapaha River at Statenville, Ga.	1,400	598	6.6	.43	8.96	6,600	24	4.7	6,000	22.4	4.29	14,000	27.6	10.0	23,200	29.3	16.6
60	Little River near Adel, Ga.	547	284	6.1	.52	10.86	4,690	16	8.6	6,000	16.6	11.0	13,900	18.3	25.4	23,300	19.5	42.6
61	Withlacoochee River near Quitman, Ga.	1,560	613	5.0	.39	8.28	7,600	19	4.9	9,600	20.7	6.15	22,500	26.0	14.4	37,400	28.5	24.0
62	Withlacoochee River near Pinetta, Fla.	2,220	926	9.2	.417	8.76	20,000	32	9.0	10,000	22.0	4.5	23,200	33.5	10.4	38,700	35.5	17.4
	OCHLOCKONEE RIVER BASIN																	
63	Ochlockonee River near Thomasville, Ga.	550	287	5.4	.52	11.00	1,280	9.0	2.3	5,800	16.0	10.5	13,400	19.1	24.4	22,600	21.6	41.1
64	Tired Creek near Cairo, Ga.	55	38.1	2.9	.69	14.52	141	4.5	2.6	3,800	8.8	69.1	8,800	11.1	160	14,700	130	267
65	Ochlockonee River near Havana, Fla.	1,020	579	16.4	.568	11.92	2,300	22	2.3	7,500	27.3	7.4	17,400	30.8	17.1	29,000	32.8	28.4

See footnotes at end of table.

Table 8B.—Gaging station information; average flow for standard period, 1937–55, and flood flow statistics—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Average flow, 1937–55				Flood-flow											
			Mgd	Stage (ft.)	Mgdsm	Inches	Bankfull			Mean Annual			10-Year R. I.			50-Year R. I.		
							Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm
(1)	(2)	(3)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	APALACHICOLA RIVER BASIN																	
66	Chattahoochee River near Leaf, Ga.	150	244	2.3	1.63	34.21	8,400	10	56.0	8,000	9.7	53.3	14,900	14.1	99.3	21,600	17	144
67	Soque River near Demorest, Ga.	156	213	2.2	1.37	28.78	4,400	10	28.2	6,900	13.5	4.42	12,800	21.0	82.1	18,600	26.6	119
68	Chattahoochee River near Gainesville, Ga.[2]	659	753	2.4	1.35	28.24	13,000	12	23.3	22,500	—	40.3	41,800	—	74.8	60,400	—	108
69	Chestatee River near Dahlonega, Ga.	153	214	1.9	1.40	29.32	7,700	15	50.3	7,990	15.4	52.2	14,900	21.7	97.4	21,600	—	141
70	Chattahoochee River near Buford, Ga.[2]	1,060	1,305	6.2	1.23	25.79	12,200	17	11.5	21,700	22.8	20.5	40,400	29	38.1	58,700	—	55.4
71	Chattahoochee River near Norcross, Ga.[2]	1,170	1,371	3.6	1.17	24.57	12,200	11	10.4	19,200	16.7	16.4	35,700	22.2	30.5	51,800	26.8	44.3
72	Chattahoochee River near Roswell, Ga.[2]	1,230	1,433	4.1	1.17	24.43	15,100	13	12.3	—	—	—	—	—	—	—	—	—
73	Chattahoochee River at Atlanta, Ga.[2]	1,450	1,607	4.0	1.11	23.21	18,900	15	13.0	22,400	17.1	15.4	35,200	21.9	24.3	48,300	25.6	33.3
74	Sweetwater Creek near Austell, Ga.	246	193	1.8	.78	16.56	3,310	10	13.5	4,160	11.8	16.9	7,720	18.0	31.4	11,200	—	45.5
76	Chattahoochee River near Whitesburg, Ga.[2]	2,430	2,329	2.8	.96	20.09	31,800	18	13.1	28,200	16.7	11.6	44,500	23.2	18.3	61,000	29	25.1
77	Yellowjacket Creek near LaGrange, Ga.	182	138	3.9	.76	16.02	675	6.5	3.7	—	—	—	—	—	—	—	—	—
78	Chattahoochee River at West Point, Ga.	3,550	3,266	4.9	.92	19.28	17,500	11	4.9	48,000	19.8	13.5	75,600	24	21.3	104,000	27	29.3
79	Mountain Creek near Hamilton, Ga.	61.7	52.4	2.1	.85	17.78	920	4.0	14.9	3,840	7.7	62.2	7,160	11.7	116	104,000	15.2	168
80	Chattahoochee River at Columbus, Ga.	4,670	4,091	4.6	.88	18.46	32,000	20	6.9	66,800	33.0	14.3	106,000	42.0	22.7	144,000	49.0	30.8
81	Upatoi Creek at Fort Benning, Ga.	447	401	6.4	.90	18.87	—	—	—	—	—	—	—	—	—	—	—	—
82	Chattahoochee River at Columbia, Ala.	8,040	6,819	11.5	.85	17.78	88,000	45	10.9	78,500	42.6	9.76	125,000	51.0	15.5	170,000	—	21.1
83	Chattahoochee River at Alaga, Ala.	8,340	6,954	9.6	.83	17.51	52,000	32	6.2	77,500	—	9.29	123,000	—	14.7	168,000	—	20.1
84	Flint River near Griffin, Ga.	272	207	6.0	.76	16.02	990	9.0	3.6	6,300	13.8	23.2	11,800	16.4	43.4	17,000	18.5	62.5
85	Flint River near Molena, Ga.	990	769	6.9	.78	16.29	9,400	14	9.5	18,200	20.0	18.4	33,900	26	34.2	49,200	—	49.7

See footnotes at end of table.

Table 8B.—Gaging station information; average flow for standard period, 1937–55, and flood flow statistics—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Average flow, 1937–55				Flood-flow											
			Mgd	Stage (ft.)	Mgdsm	Inches	Bankfull			Mean Annual			10-Year R. I.			50-Year R. I.		
							Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm
(1)	(2)	(3)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	APALACHICOLA RIVER BASIN—continued																	
86	Potato Creek near Thomaston, Ga.	186	139	3.5	.75	15.75	3,060	6.0	16.5	3,960	6.5	21.3	7,370	8.1	39.6	10,600	—	57.0
87	Flint River near Culloden, Ga.	1,890	1,380	4.9	.73	15.34	17,000	18	9.0	32,200	25.8	17.0	59,700	36.0	31.6	86,800	—	45.9
88	Whitewater Creek near Butler, Ga.	75	96.3	2.0	1.28	27.01	325	3.2	4.3	409	4.1	5.4	750	5.3	10.0	1,100	6.1	14.6
90	Flint River at Montezuma, Ga.	2,900	2,314	6.0	.80	16.70	5,980	9	2.1	32,700	20.1	11.3	60,900	24.3	21.0	88,400	27.1	30.5
91	Flint River at Oakfield, Ga.	3,860	2,894	5.5	.75	15.75	23,100	18	6.0	31,300	22.2	8.1	58,300	29.7	15.1	112,000	—	29.1
93	Flint River at Albany, Ga.	5,230	3,880	6.4	.74	15.61	32,200	23	6.2	37,000	24.9	7.1	69,000	32.0	13.2	100,000	—	19.2
94	Flint River at Newton, Ga.	5,740	4,282	8.8	.75	15.61	36,100	24	6.3	35,400	24.2	6.2	66,000	—	11.5	95,900	—	16.7
95	Ichawaynochaway Creek near Milford, Ga.	620	514	2.2	.83	17.38	3,380	7.0	5.5	6,640	10.8	10.7	12,300	—	19.8	17,900	—	28.9
97	Chickasawhatchee Creek at Elmodel, Ga.	320	184	2.8	.58	12.08	620	4.6	1.9	2,200	9.7	6.9	4,100	12.4	12.8	5,950	—	18.6
98	Ichawaynochaway Creek near Newton, Ga.	1,000	730	2.7	.73	15.34	3,510	7.0	3.5	7,770	14.7	7.8	14,500	—	14.5	21,100	—	21.1
100	Flint River at Bainbridge, Ga.	7,350	5,480	10.6	.75	15.61	19,700	18	2.7	36,300	26.4	4.9	66,900	—	9.1	97,000	—	13.2
101	Spring Creek near Iron City, Ga.	520	311	6.1	.60	12.49	563	6.6	1.1	5,700	16.3	11.0	10,700	19.0	20.5	15,400	21	29.6
102	Apalachicola River at Chattahoochee, Fla.[3]	17,100	13,770	5.9	.805	24.84	—	—	—	94,500	21.5	5.5	176,000	28.0	10.3	255,000	32.5	14.9
	MOBILE RIVER BASIN																	
103	Cartecay River near Ellijay, Ga.	135	172	2.0	1.27	26.74	3,750	6.0	27.8	3,600	5.9	26.7	5,700	7.4	42.2	7,790	8.5	57.7
105	Coosawattee River near Ellijay, Ga.	238	302	2.1	1.27	26.61	5,590	8.0	23.5	6,680	9.1	28.1	10,600	12.5	44.5	14,400	15.4	60.5
107	Coosawattee River at Pine Chapel, Ga.	856	913	4.7	1.07	22.26	10,400	20	12.1	15,500	24.3	18.1	24,500	26.8	28.6	33,500	28.7	39.1
108	Mill Creek at Dalton, Ga.	37	42.1	2.7	1.14	23.89	390	6.0	10.5	1,510	6.9	40.8	2,390	7.1	64.6	4,140	7.4	11.2
109	Conasauga River at Tilton, Ga.	682	734	5.3	1.08	22.67	8,650	19	12.7	13,400	22.3	19.6	21,100	25.8	30.9	28,800	28.8	42.2
110	Oostanaula River at Resaca, Ga.	1,610	1,704	6.1	1.06	22.26	11,100	16	6.9	21,800	25.5	13.5	34,300	31.2	21.3	47,000	34.0	29.2

See footnotes at end of table.

Table 8B.—Gaging station information; average flow for standard period, 1937–55, and flood flow statistics—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Average flow, 1937–55				Flood-flow											
			Mgd	Stage (ft.)	Mgdsm	Inches	Bankfull			Mean Annual			10-Year R. I.			50-Year R. I.		
							Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm
(1)	(2)	(3)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	MOBILE RIVER BASIN—continued																	
111	Oostanaula River near (at) Rome, Ga.	2,120	2,212	9.0	1.04	21.86	18,000	19	8.5	26,500	28.1	12.5	42,000	35.0	19.8	57,200	—	27.0
112	Etowah River near Dawsonville, Ga.	103	154	1.8	1.50	31.49	2,730	11	26.5	3,200	12.3	31.1	5,950	—	57.8	8,650	—	84.0
113	Amicalola Creek near Dawsonville, Ga.	84.7	138	.9	1.63	34.34	—	—	—	4,640	5.2	54.8	8,640	—	102	12,500	—	148
114	Etowah River at Canton, Ga.	605	694	3.6	1.15	24.16	7,720	15	12.8	11,800	19.6	19.5	18,600	23.0	30.7	25,500	25.3	42.1
115	Little River near Roswell, Ga.	60.5	47.8	1.0	.79	16.56	—	—	—	—	—	—	—	—	—	—	—	—
116	Etowah River at Allatoona Dam above Cartersville, Ga.[4]	1,110	1,094	1.8	.99	20.63	11,000	10	9.9	19,300	14.0	17.4	30,500	18.2	27.5	41,700	—	37.6
117	Etowah River near Kingston, Ga.[4]	1,630	1,485	5.6	.91	19.14	6,450	14	4.0	27,000	20.7	16.6	42,700	27.7	26.2	58,500	—	35.9
118	Etowah River at Rome, Ga.[4]	1,810	1,627	7.9	.90	18.87	20,000	30	11.0	27,000	—	14.9	42,500	—	23.5	58,300	—	32.2
119	Coosa River near Rome, Ga.[4]	4,040	3,968	5.4	.98	20.63	38,500	30	9.5	41,500	31.2	10.3	65,900	37.2	16.3	89,700	—	22.2
120	Cedar Creek near Cedartown, Ga.	109	93.7	1.4	.86	18.05	2,200	7.0	20.2	4,930	10.8	45.2	7,780	13.4	71.4	10,600	15.3	97.2
121	Chattooga River at Summerville, Ga.	193	222	3.8	1.15	24.16	3,290	13	17.0	8,730	16.7	45.2	13,800	18.4	71.5	18,800	19.7	97.4
122	Chattooga River at Gaylesville, Ala.	377	429	6.9	1.14	23.89	—	—	—	12,800	—	34.0	23,000	—	61.0	32,900	—	87.3
123	Little Tallapoosa River at Carrollton, Ga.	89	84.7	5.6	.95	19.95	159	6.0	1.8	2,950	13.2	33.2	4,670	16.7	52.5	6,380	—	71.7
124	Tallapoosa River at Wadley, Ala.	1,660	1,512	4.5	.911	19.14	—	—	—	32,600	—	19.6	58,700	—	35.4	83,800	—	50.5
	TENNESSEE RIVER BASIN																	
125	Cullasaja River at Cullasaja, N. C.	86.5	138	1.9	1.60	33.53	3,300	11	3.8	—	—	—	—	—	—	—	—	—
126	Hiwassee River at Presley, Ga.	45.5	80.8	2.4	1.78	37.33	1,300	7.0	28.6	1,640	—	36.0	2,590	—	56.9	3,540	—	77.8
127	Hiwassee River above Murphy, N. C.	406	518	3.4	1.28	26.88	16,300	13	40.1	—	—	—	—	—	—	—	—	—
128	Valley River at Tomotla, N. C.	104	146	2.6	1.40	29.46	4,500	12	43.3	3,950	10.8	38.0	6,240	14.3	60.0	8,530	16.8	82.0

See footnotes at end of table.

Table 8B.—Gaging station information; average flow for standard period, 1937–55, and flood flow statistics—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Average flow, 1937–55				Flood-flow											
			Mgd	Stage (ft.)	Mgdsm	Inches	Bankfull			Mean Annual			10-Year R. I.			50-Year R. I.		
							Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm	Cfs	Stage (ft.)	cfsm
(1)	(2)	(3)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
	TENNESSEE RIVER BASIN—continued																	
129	Nottely River near Blairsville, Ga.	74.6	105	2.7	1.41	29.46	2,450	8.0	32.8	2,500	—	33.4	3,950	—	52.8	5,390	—	72.1
132	Toccoa River near Dial, Ga.	177	293	1.8	1.66	34.75	7,000	8.5	39.5	4,600	—	26.0	7,270	—	41.1	9,950	—	56.2
133	Toccoa River near Blue Ridge, Ga.	233	356	2.8	1.53	32.04	—	—	—	—	—	—	—	—	—	—	—	—
134	Fightingtown Creek at McCaysville, Ga.	70.9	120	2.2	1.69	35.43	—	—	—	—	—	—	—	—	—	—	—	—
135	South Chickamauga Creek near Chickamauga, Tenn.	428	442	2.7	1.03	21.72	4,500	11	10.5	14,200	—	33.2	22,400	—	52.3	30,700	—	71.7
136	Chattanooga Creek near Flintstone, Ga.	50.6	53.1	2.9	1.05	21.99	—	—	—	—	—	—	—	—	—	—	—	—

[1] Columns 24–32 based on records obtained prior to operation of Clark Hill Reservoir.
[3] Columns 24–32 based on records obtained prior to operation of Jim Woodruff Reservoir.
[4] Columns 24–32 based on records obtained prior to operation of Allatoona Reservoir.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937-55						Minimum 7-day average flow, 1937-55						Minimum 1-day average flow, 1937-55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd (33)	Mgdsm (34)	Mgd (35)	Mgdsm (36)	Mgd (37)	Mgdsm (38)	Mgd (39)	Mgdsm (40)	Mgd (41)	Mgdsm (42)	Mgd (43)	Mgdsm (44)	Mgd (45)	Mgdsm (46)	Mgd (47)	Mgdsm (48)	Mgd (49)	Mgdsm (50)
(1)	(2)	(3)																		
	SAVANNAH RIVER BASIN																			
1	Chattooga River near Clayton, Ga.	207	155	.749	105	.507	63.7	.308	114	.551	82	.40	58	.28	109	.527	79	.38	57	.28
2	Panther Creek near Toccoa, Ga.[1]	32.5	20	.61	13	.40	9.9	.30	16	.49	9.7	.30	8.4	.26	16	.49	9.7	.30	7.8	.24
3	Tugaloo River near Hartwell, Ga.	909	630	.693	472	.519	271	.298	472	.519	312	.343	203	.223	235	.259	122	.134	122	.134
3	Tugaloo River near Hartwell, Ga.[2]	909	516	.568	346	.381	218	.240	—	—	—	—	—	—	—	—	—	—	—	—
4	Seneca River near Anderson, S. C.	1,026	509	.496	319	.311	199	.194	420	.409	254	.248	167	.163	387	.377	211	.206	139	.135
5	Savannah River near Iva, S. C.	2,231	1,310	.586	941	.422	573	.257	1,100	.493	776	.348	464	.208	724	.325	435	.195	349	.156
5	Savannah River near Iva, S. C.[2]	2,231	1,174	.526	798	.357	519	.233	—	—	—	—	—	—	—	—	—	—	—	—
6	South Beaverdam Creek at Dewy Rose, Ga.	35.8	10	.28	5.2	.144	1.34	.037	7.8	.22	3.5	.098	.90	.025	7.1	.20	3.0	.084	.65	.018
7	Savannah River near Calhoun Falls, S. C.[3]	2,876	1,489	.518	1,070	.372	632	.220	1,282[4]	.446	875	.304	522	.182	835	.297	546	.190	411	.143
7	Savannah River near Calhoun Falls, S. C.[3]	2,876	1,301	.452	955	.332	578	.201	—	—	—	—	—	—	—	—	—	—	—	—
12	Broad River near Bell, Ga.	1,430	363	.254	154	.108	96	.067	286	.200	101	.071	77	.054	265	.185	92	.065	71	.050
13	Little River near Mount Carmel, S. C.	217	30	.138	12	.055	2.9	.013	18	.083	6.7	.031	.78	.004	16	.074	6.2	.029	.65	.003
15	Little River near Lincolnton, Ga.	574	30	.052	7.1	.012	1.4	.002	18	.032	2.3	.0040	1.1	.0019	14	.024	1.2	.002	1.1	.002
16	Stevens Creek near Modoc, S. C.	545	—	—	6.7	.012	0	.000	—	—	3.1	.006	0	.000	—	—	.3	.0006	0	.000
17	Savannah River at Augusta, Ga.	7,508	2,520	.336	1,730	.230	1,500	.200	1,939	.258	1,351	.180	1,325	.176	1,670	.222	898	.120	866	.115
17	Savannah River at Augusta, Ga.[2]	7,508	1,739	.232	1,266	.169	563	.075	—	—	—	—	—	—	—	—	—	—	—	—
18	Savannah River at Burton's Ferry Bridge near Millhaven, Ga.	8,650	3,152	.364	2,309	.267	1,929	.223	2,420	.280	1,660	.192	1,610	.18	2,220	.257	1,450	.167	1,370	.158

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937–55						Minimum 7-day average flow, 1937–55						Minimum 1-day average flow, 1937–55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm
(1)	(2)	(3)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
	SAVANNAH RIVER BASIN—continued																			
18	Savannah River at Burton's Ferry Bridge near Millhaven, Ga.[2]	8,650	2,534	.293	1,555	.180	688	.077	—	—	—	—	—	—	—	—	—	—	—	—
19	Brier Creek at Millhaven, Ga.	646	153	.236	99	.15	61	.094	109	.169	76	.12	41	.063	97	.15	71.1	.11	41	.063
20	Savannah River near Clyo, Ga.	9,850	3,333	.339	2,719	.276	2,218	.225	2,640	.268	2,020	.205	1,940	.197	2,420	.246	1,850	.188	1,830	.186
20	Savannah River near Clyo, Ga.[2]	9,850	2,764	.281	1,937	.197	765	.078	—	—	—	—	—	—	—	—	—	—	—	—
	OGEECHEE RIVER BASIN																			
21	Ogeechee River near Louisville, Ga.	800	123	.154	78	.097	43	.054	81	.101	58	.072	36	.045	74	.092	56	.070	36	.045
22	Ogeechee River at Scarboro, Ga.	1,940	248	.128	173	.089	92	.047	.191	.098	120	.062	78	.040	162	.084	100	.052	78	.040
23	Ogeechee River near Eden, Ga.	2,650	308	.116	231	.087	123	.046	234	.088	171	.065	89	.034	228	.086	149	.056	85	.032
24	Canoochee River near Claxton, Ga.	555	8.1	.015	2.5	.005	.79	.001	2.9	.005	.97	.002	.56	.001	2.1	.004	.84	.002	.56	.001
	ALTAMAHA RIVER BASIN																			
25	South River near McDonough, Ga.	436	121	.278	56	.13	43	.099	101	.231	47	.108	37	.085	94	.216	45	.103	35	.080
25	South River near McDonough, Ga.[3]	436	—	—	—	—	25	.057	—	—	—	—	19	.044	—	—	—	—	17	.039
26	Yellow River near Snellville, Ga.	134	23	.17	6.1	.046	2.5	.019	14	.104	3.4	.025	1.2	.009	12	.090	2.3	.017	1.0	.007
27	Yellow River near Covington, Ga.	396	71	.18	35	.088	12	.030	55	.139	16	.040	7.8	.020	49	.124	10	.025	6.5	.016
28	Alcovy River below Covington, Ga.	251	45	.18	23	.092	7.8	.031	34	.135	13	.052	4.9	.020	31	.12	10	.04	4.5	.018
29	Ocmulgee River near Jackson, Ga.	1,420	378	.266	238	.168	64	.045	337	.237	222	.156	48	.034	301	.212	199	.140	45	.032
29	Ocmulgee River near Jackson, Ga.[2]	1,420	279	.196	67	.047	56	.039	—	—	—	—	—	—	—	—	—	—	—	—
30	Towaliga River near Forsyth, Ga.	315	28	.089	3.9	.012	1.4	.004	16	.051	1.1	.003	.32	.002	14	.044	.90	.003	.21	.0007

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937–55						Minimum 7-day average flow, 1937–55						Minimum 1-day average flow, 1937–55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm
(1)	(2)	(3)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
	ALTAMAHA RIVER BASIN —continued																			
31	Ocmulgee River at Macon, Ga.	2,240	535	.239	317	.142	107	.048	423	.189	284	.127	90	.040	394	.176	213	.095	83	.037
31	Ocmulgee River at Macon, Ga.[2]	2,240	413	.184	139	.062	72	.032	—	—	—	—	—	—	—	—	—	—	—	—
32	Tobesofkee Creek near Macon, Ga.	182	22	.12	7.8	.043	3.6	.020	17	.093	3.7	.020	1.8	.010	6	.088	3.3	.018	1.4	.008
33	Echeconnee Creek near Macon, Ga.	100	11	.11	3.1	.03	1.2	.012	7.8	.078	1.2	.012	.51	.005	7.1	.071	1.1	.011	—	—
34	Big Indian Creek at Perry, Ga.	108	26	.24	18	.17	18	.17	21	.194	14	.130	13	.12	20	.19	14	.13	11	.10
35	Ocmulgee River at Hawkinsville, Ga.	3,800	905	.238	536	.141	289	.076	698	.184	491	.129	271	.071	646	.170	355	.093	271	.071
35	Ocmulgee River at Hawkinsville, Ga.[2]	3,800	850	.224	358	.094	270	.071	—	—	—	—	—	—	—	—	—	—	—	—
36	Ocmulgee River at Lumber City, Ga.	5,180	1,250	.241	928	.179	573	.111	1,140	.22	877	.169	525	.101	1,100	.212	866	.167	522	.101
36	Ocmulgee River at Lumber City, Ga.[2]	5,180	1,152	.222	750	.145	555	.107	—	—	—	—	—	—	—	—	—	—	—	—
37	Little Ocmulgee River at Towns, Ga.	363	7.1	.020	2.0	.006	.65	.002	3.0	.008	1.6	.004	.61	.002	2.5	.007	1.4	.0037	.56	.002
38	Oconee River at Athens, Ga.	283	78	.28	24	.085	19	.067	59	.208	17	.060	14	.049	53	.197	15	.053	13	.046
40	Middle Oconee River near Athens, Ga.	398	103	.259	34	.085	27	.068	83	.209	25	.063	21	.053	69	.17	21	.053	18	.045
41	Oconee River near Greensboro, Ga.	1,090	282	.259	89	.082	56	.051	207	.190	58	.053	42	.039	184	.169	48	.094	38	.035
42	Apalachee River near Bostwick, Ga.	176	42	.24	23	.13	9.0	.051	33	.187	15	.085	6.5	.037	31	.176	12	.068	6.1	.035
43	Apalachee River near Buckhead, Ga.	436	89	.20	46	.11	16	.037	67	.15	28	.064	12	.028	63	.144	23	.053	10	.023

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937–55						Minimum 7-day average flow, 1937–55						Minimum 1-day average flow, 1937–55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm
(1)	(2)	(3)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
	ALTAMAHA RIVER BASIN—continued																			
44	Oconee River at Milledgeville, Ga.[4]	2,950	500	.169	259	.089	222	.075	412	.140	145	.049	94	.032	380	.129	59	.020	58	.020
45	Oconee River at Dublin, Ga.[4]	4,400	706	.160	434	.099	303	.069	579	.132	253	.057	237	.054	543	.123	227	.052	226	.051
47	Oconee River near Mount Vernon, Ga.[4]	5,110	939	.184	552	.108	391	.076	730	.143	379	.074	308	.060	672	.132	367	.072	291	.057
48	Ohoopee River near Reidsville, Ga.	1,110	59	.053	31	.028	13	.012	32	.029	20	.018	13	.012	29	.026	18	.016	12	.011
49	Altamaha River at Doctortown, Ga.	13,600	2,560	.188	1,800	.132	1,130	.083	1,980	.146	1,510	.111	944	.069	1,890	.139	1,450	.107	924	.068
	SATILLA RIVER BASIN																			
50	Satilla River near Waycross, Ga.	1,300	23	.018	9.7	.007	4.9	.004	17	.013	7.8	.006	4.1	.003	14	.011	7.8	.006	4.0	.003
53	Satilla River at Atkinson, Ga.	2,880	79	.027	30	.010	16	.005	57	.020	24	.008	14	.005	52	.018	23	.008	14	.005
	ST. MARYS RIVER BASIN																			
55	St. Marys River near Macclenny, Fla.	[a]720	21	.029	15	.021	13	.018	17	.024	11	.015	11	.015	16	.022	10	.014	10	.014
	SUWANNEE RIVER BASIN																			
56	Suwannee River at Fargo, Ga.	1,260	25	.020	.81	.0006	.08	.0006	13	.010	0	0	0	0	12	.010	0	0	0	0
57	Suwannee River at White Springs, Fla.	[a]1,990	47	.024	8.3	.004	7.8	.004	37	.019	6.7	.003	5.6	.003	28	.014	5.6	.003	4.8	.002
58	Alapaha River near Alapaha, Ga.	644	4.7	.007	.39	.0006	0	0	.84	.001	.13	.0002	0	0	.4	.0006	.06	.00009	0	0
59	Alapaha River at Statenville, Ga.	1,400	48	.034	22	.016	14	.01	37	.026	15	.011	12	.009	34	.024	14	.010	11	.008
60	Little River near Adel, Ga.	547	5.6	.01	.63	.0012	.39	.0007	—	—	—	—	—	—	—	—	—	—	.16	.0003
61	Withlacoochee River near Quitman, Ga.	1,560	16	.01	4.6	.003	3.6	.002	9.0	.006	3.4	.002	3.4	.002	8.4	.005	3.4	.002	3.0	.002
62	Withlacoochee River near Pinetta, Fla.	2,220	100	.045	57	.026	50	.023	85	.038	50	.023	50	.023	81	.036	50	.023	47	.021

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937–55						Minimum 7-day average flow, 1937–55						Minimum 1-day average flow, 1937–55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm
(1)	(2)	(3)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
	OCHLOCKONEE RIVER BASIN																			
63	Ochlockonee River near Thomasville, Ga.	550	16	.029	3.7	.007	3.0	.005	5.0	.009	2.6	.005	2.5	.005	4.7	.009	2.3	.004	1.7	.003
64	Tired Creek near Cairo, Ga.	55	6.7	.12	1.9	.034	.81	.015	2.7	.049	.84	.015	.2	.004	2.6	.047	.71	.013	.06	.001
65	Ochlockonee River near Havana, Fla.	1,020	72	.071	25	.025	14	.014	41	.040	21	.021	11	.011	39	.038	25	.025	11	.011
	APALACHICOLA RIVER BASIN																			
66	Chattahoochee River near Leaf, Ga.	150	92	.61	56	.37	54	.36	79	.53	52	.35	49	.33	76	.507	50	.333	47	.313
67	Soque River near Demorest, Ga.	156	97	.62	55	.35	50	.32	78	.50	51	.33	48	.31	61	.39	33	.212	17	.108
68	Chattahoochee River near Gainesville, Ga.	559	344	.615	181	.324	178	.318	291	.521	171	.306	164	.293	255	.456	156	.279	134	.240
69	Chestatee River near Dahlonega, Ga.	153	79	.52	45	.29	43	.28	65	.42	39	.25	36	.24	63	.412	39	.255	32	.209
70	Chattahoochee River near Buford, Ga.	1,060	513	.484	290	.274	271	.256	454	.428	268	.253	246	.232	427	.403	235	.222	230	.217
71	Chattahoochee River near Norcross, Ga.	1,170	546	.467	288	.246	265	.226	453	.387	257	.220	239	.204	438	.374	247	.211	210	.180
72	Chattahoochee River near Roswell, Ga.	1,230	549	.446	285	.232	272	.221	458	.372	259	.211	248	.202	437	.355	251	.204	212	.172
72	Chattahoochee River near Roswell, Ga.[5]	1,230	—	—	—	—	290	.236	—	—	—	—	267	.217	—	—	—	—	230	.187
73	Chattahoochee River at Atlanta, Ga.	1,450	628	.433	319	.220	279	.192	486	.335	285	.197	253	.174	461	.318	273	.188	220	.152
73	Chattahoochee River at Atlanta, Ga.[5]	1,450	—	—	—	—	297	.235	—	—	—	—	272	.188	—	—	—	—	237	.163

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937–55						Minimum 7-day average flow, 1937–55						Minimum 1-day average flow, 1937–55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm
(1)	(2)	(3)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
	APALACHICOLA RIVER BASIN—continued																			
74	Sweetwater Creek near Austell, Ga.	246	43	.17	10	.041	2.8	.012	30	.12	8.4	.034	1.5	.006	26	.11	7.8	.032	1.4	.006
76	Chattahoochee River near Whitesburg, Ga.	2,430	853	.351	365	.15	317	.13	618	.254	322	.133	250	.103	595	.245	302	.124	205	.084
77	Yellowjacket Creek near LaGrange, Ga.	182	30	.16	9.0	.05	6.4	.035	17	.093	7.1	.039	3.7	.020	15	.082	5.7	.031	3.4	.019
78	Chattahoochee River at West Point, Ga.	3,550	1,120	.315	421	.119	330	.093	801	.226	368	.104	279	.079	776	.219	344	.097	235	.066
79	Mountain Creek near Hamilton, Ga.	61.7	13	.21	5.4	.088	4.3	.070	11	.18	4.3	.070	3.7	.060	10	.16	4.1	.066	3.6	.058
80	Chattahoochee River at Columbus, Ga.	4,670	1,420	.304	706	.151	453	.097	1,170	.251	564	.121	414	.089	866	.185	543	.116	388	.083
80	Chattahoochee River at Columbus, Ga.[2]	4,670	1,382	0.296	503	0.108	356	0.076	—	—	—	—	—	—	—	—	—	—	—	—
81	Upatoi Creek at Fort Benning, Ga.	447	123	.275	44	.098	23	.051	83	.19	24	.054	13	.029	74	.17	21	.047	11	.025
82	Chattahoochee River at Columbia, Ala.	8,040	2,330	.289	1,260	.157	886	.110	2,050	.255	1,070	.133	840	.104	1,890	.236	1,050	.131	782	.097
82	Chattahoochee River at Columbia, Ala.[2]	8,040	2,227	.277	1,045	.130	782	.097	—	—	—	—	—	—	—	—	—	—	—	—
83	Chattahoochee River at Alaga, Ala.	8,340	2,420	.290	1,290	.155	905	.109	2,130	.255	1,100	.132	840	.101	1,940	.233	918	.110	776	.093
83	Chattahoochee River at Alaga, Ala.[2]	8,340	2,283	.274	1,044	.125	784	.094	—	—	—	—	—	—	—	—	—	—	—	—
84	Flint River near Griffin, Ga.	272	45	.165	14	.051	3.9	.014	26	.096	10	.037	2.1	.008	23	.085	8.4	.031	1.6	.006
84	Flint River near Griffin, Ga.[6]	272	46.2	.170	15.8	.058	6.5	.024	—	—	—	—	4.5	.017	—	—	—	—	4.2	.015

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937-55						Minimum 7-day average flow, 1937-55						Minimum 1-day average flow, 1937-55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm
(1)	(2)	(3)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
	APALACHICOLA RIVER BASIN—continued																			
85	Flint River near Molena, Ga.	990	172	.174	44	.044	27	.027	97	.098	30	.030	25	.025	84	.085	25	.025	24	.024
86	Potato Creek near Thomaston, Ga.	186	25	.13	9.1	.049	1.6	.0086	16	.086	2.6	.014	1.2	.006	12	.065	1.8	.010	.50	.003
87	Flint River near Culloden, Ga.	1,890	377	.199	107	.057	70	.37	218	.115	76	.040	64	.034	199	.105	63	.033	63	.033
88	Whitewater Creek near Butler, Ga.	75	78	1.04	64	.85	62	.83	71	.95	62	.83	59	.79	71	.95	59	.79	58	.77
90	Flint River at Montezuma, Ga.	2,900	867	.299	520	.180	413	.142	704	.243	430	.148	399	.138	653	.225	388	.134	378	.130
91	Flint River at Oakfield, Ga.	3,860	1,040	.269	558	.145	555	.144	853	.224	517	.134	479	.134	479	.124	233	.028	98	.025
93	Flint River at Albany, Ga.	6,230	1,320	.252	867	.166	759	.145	1,120	.214	698	.133	546	.104	559	.107	386	.074	299	.057
94	Flint River at Newton, Ga.	5,740	1,710	.298	1,230	.214	1,100	.191	1,490	.260	1,030	.179	905	.158	1,030	.179	711	.124	543	.095
95	Ichawaynochaway Creek near Milford, Ga.	620	194	.313	116	.187	94	.15	158	.255	76	.123	83	.134	143	.231	79	.13	78	.13
97	Chickasawhatchee Creek at Elmodel, Ga.	320	15	.047	2.0	.0062	.78	.0024	12	.038	1.3	.004	.61	.002	11	.034	1.2	.0051	.59	.002
98	Ichawaynochaway Creek near Newton, Ga.	1,000	253	.253	110	.110	78	.078	211	.211	97	.097	71	.071	204	.204	90	.090	71	.071
100	Flint River at Bainbridge, Ga.	7,350	2,390	.325	1,590	.216	1,430	.195	2,230	.303	1,420	.193	1,390	.189	2,120	.288	1,250	.170	1,230	.167
101	Spring Creek near Iron City, Ga.	520	48	.092	13	.025	7.0	.013	41	.079	9	.019	6	.012	37	.071	9	.017	5.9	.011
102	Apalachicola River at Chattahoochee, Fla.	17,100	5,899	.345	3,554	.208	3,438	.201	5,744	.336	3,447	.202	3,336	.195	5,558	.325	3,335	.195	3,238	.189
	MOBILE RIVER BASIN																			
103	Cartecay River near Ellijay, Ga.	135	74	.55	59	.44	50	.37	63	.47	47	.35	44	.33	61	.45	45	.33	41	.30
105	Coosawattee River near Ellijay, Ga.	238	116	.487	92	.39	65	.27	94	.39	72	.30	65	.27	90	.38	67	.28	63	.26

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937–55						Minimum 7-day average flow, 1937–55						Minimum 1-day average flow, 1937–55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm	Mgd	Mgdsm
(1)	(2)	(3)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)
	MOBILE RIVER BASIN—continued																			
107	Coosawattee River at Pine Chapel, Ga.	856	264	.308	207	.242	159	.186	229	.268	154	.180	148	.173	215	.251	143	.167	142	.166
108	Mill Creek at Dalton, Ga.	37	12	.32	10	.27	8.9	.24	11	.30	9.7	.26	8.4	.23	10	.27	9	.24	7.8	.21
109	Conasauga River at Tilton, Ga.	682	89	.131	69	.10	54	.079	74	.11	56	.082	47	.069	72	.11	54	.079	44	.065
110	Oostanaula River at Resaca, Ga.	1,610	358	0.22	273	0.170	226	0.140	326	0.202	218	0.135	202	0.125	305	0.189	206	0.128	194	0.120
111	Oostanula River near (at) Rome, Ga.	2,120	452	.213	352	.166	326	.154	394	.186	305	.144	287	.135	388	.183	282	.133	264	.125
112	Etowah River near Dawsonville, Ga.	103	59	.57	43	.42	35	.34	52	.50	38	.36	32	.31	52	.50	36	.35	32	.31
113	Amicalola Creek near Dawsonville, Ga.	84.7	54	.64	44	.52	35	.41	43	.51	36	.43	34	.40	43	.51	33	.39	32	.38
114	Etowah River at Canton, Ga.	605	248	.410	162	.268	138	.228	208	.344	144	.238	125	.207	205	.339	136	.225	115	.190
115	Little River near Roswell, Ga.	60.5	13	.21	3.7	.061	3.6	.060	7.8	.13	2.3	.038	1.6	.026	7.8	.13	2.0	.033	1.4	.023
116	Etowah River at Allatoona Dam above Cartersville, Ga.	1,110	450	.405	224	.202	215	.194	286	.258	171	.154	152	.137	262	.236	135	.122	134	.121
116	Etowah River at Allatoona Dam above Cartersville, Ga.[2]	1,110	324	.292	189	.170	179	.161	—	—	—	—	—	—	—	—	—	—	—	—
117	Etowah River near Kingston, Ga.	1,630	574	.352	375	.230	315	.193	418	.256	279	.171	273	.167	362	.222	246	.151	236	.145
117	Etowah River near Kingston, Ga.[2]	1,630	483	.296	315	.193	246	.151	—	—	—	—	—	—	—	—	—	—	—	—
118	Etowah River at (near) Rome, Ga.	1,810	646	.357	405	.224	377	.208	468	.259	332	.183	318	.176	401	.222	295	.163	249	.138
118	Etowah River at Rome, Ga.[2]	1,810	559	.309	376	.208	301	.166	—	—	—	—	—	—	—	—	—	—	—	—
119	Coosa River near (at) Rome, Ga.	4,040	1,200	.297	834	.206	755	.187	982	.243	672	.166	621	.154	827	.205	604	.150	562	.139
119	Coosa River near Rome, Ga.[2]	4,040	1,050	.260	634	.157	611	.151	—	—	—	—	—	—	—	—	—	—	—	—

See footnotes at end of table.

Table 8C.—Gaging station information; frequency of occurrence of several low rates of flow—continued

Map no.	Gaging Station	Drainage area (sq. mi.)	Minimum monthly average flow 1937–55						Minimum 7-day average flow, 1937–55						Minimum 1-day average flow, 1937–55					
			2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.		2-year R. I.		10-year R. I.		20-year R. I.	
			Mgd (33)	Mgdsm (34)	Mgd (35)	Mgdsm (36)	Mgd (37)	Mgdsm (38)	Mgd (39)	Mgdsm (40)	Mgd (41)	Mgdsm (42)	Mgd (43)	Mgdsm (44)	Mgd (45)	Mgdsm (46)	Mgd (47)	Mgdsm (48)	Mgd (49)	Mgdsm (50)
(1)	(2)	(3)																		
	MOBILE RIVER BASIN—continued																			
120	Cedar Creek near Cedartown, Ga.	109	26	.24	23	.21	19	.17	24	.22	20	.18	.18	.002	19	.17	14	.13	14	.13
121	Chattooga River near Summerville, Ga.	193	52	.27	44	.23	38	.20	47	.24	38	.20	37	.19	34	.18	25	.13	25	.13
123	Little Tallapoosa River at Carrollton, Ga.	89	19	.21	5.7	.064	.89	.010	12	.13	2.5	.028	.43	.005	9.0	.10	1.3	.015	.17	.002
	TENNESSEE RIVER BASIN																			
125	Cullasaja River at Cullasaja, N. C.	86.5	47	.54	28	.32	23	.26	37	.43	23	.27	19	.22	34	.39	22	.25	18	.21
126	Hiwassee River at Presley, Ga.	45.5	29	.64	19	.42	16	.35	23	.51	17	.37	15	.33	22	.48	16	.35	15	.33
127	Hiwassee River above Murphy, N. C.	406	136	.335	67	.16	64	.16	86	.21	54	.13	52	.13	72	.18	41	.10	40	.099
128	Valley River at Tomotla, N. C.	104	40	.385	24	.231	16	.154	28	.269	19	.183	14	.135	26	.250	17	.163	14	.135
129	Nottely River near Blairsville, Ga.	74.8	35	.47	26	.35	20	.27	31	.41	19	.25	19	.25	28	.37	19	.25	18	.24
132	Toccoa River near Dial, Ga.	177	115	.650	89	.50	77	.43	103	.582	81	.46	71	.40	98	.55	76	.43	70	.40
133	Toccoa River near Blue Ridge, Ga.	233	100	.43	3.7	.16	3.0	.13	5.2	.022	.71	.003	.65	.003	23	.01	.5	.002	.5	.002
134	Fightingtown Creek at McCaysville, Ga.	70.9	41	.58	31	.44	30	.42	36	.51	25	.35	25	.35	34	.48	25	.35	25	.35
135	South Chickamauga Creek near Chickamauga, Tenn.	428	78	.18	59	.14	53	.12	69	.16	50	.12	46	.11	64	.15	43	.10	41	.096
136	Chattanooga Creek near Flintstone, Ga.	50.6	3.2	.063	1.8	.036	1.5	.030	2.5	.049	1.4	.028	.90	.018	2.1	.04	.97	.019	.84	.017

[1] Adjusted for diversion by City of Toccoa.
[2] Adjusted for change in contents of reservoir above station. Change in contents data necessary to adjust columns 39–50 not available.
[3] Adjusted for diversion from Chattahoochee River. Diversion data necessary to adjust columns 33–36, 39–42 and 45–58 not available.
[4] Observed; not adjusted for change in contents of reservoir above station. Change in contents data necessary for adjustment not available.
[5] Adjusted for diversion (DeKalb County) above station. Diversion data necessary to adjust columns 33–36, 39–42, and 45–48 not available.
[6] Adjusted for diversion (City of Griffin) above station. Diversion data necessary to adjust columns 39–42 and 45–48 not available.

the frequency of past occurrences. A more reliable estimate of future occurrences would require a regional low-flow analysis in which this period of record would be related to a longer period. However, it is believed that the data presented will serve a useful purpose pending the making of a regional analysis.

REGIONAL FLOW CHARACTERISTICS

Flow characteristics are shown for specific sites by the gaging station records but many of the characteristics are subject to some degree of regional generalization. Regional flow characteristics are useful in extending gaging-station data to ungaged sites where streamflow information may be needed for such purposes as the determination of water rights, the optimum development of water resources, or the equitable distribution of the water. Generalizations might be made for the entire State, for each county, for each river basin, or for some other geographic area or region. Regardless of the areal unit chosen, regional characteristics of streamflow need to be determined and described on a per-unit-of-drainage-area basis. Generally the flow per square mile is given in this report, in preference to runoff in inches or flow per acre.

Figure 24 (p. 145) shows the flood-flow, average-flow, and low-flow characteristics of the gaging stations in Georgia with respect to their drainage areas. The flow scale is shown both in million gallons per day and cubic feet per second.

The average flow data have a general slope of 45° which indicates that the average flow tends to be generally proportional to the drainage area. The average flows range from 0.40 mgdsm to 1.86 mgdsm.

The flood-flow data show a general trend that is somewhat flatter than a 45° angle. This indicates that the maximum floods tend to vary with about the 8/10 power of the drainage area rather than in direct proportion to it. The flood flows range from about 10 cfsm up to about 300 cfsm, more than 7 times the range for average flows. It is also evident that a proportionally greater range of flood flows has been experienced at the few gaging stations having drainage areas less than 100 square miles than at the gaging stations on larger streams. This is to be expected because intense storm rainfall covering an entire drainage area is much more likely to be experienced over a small area than over a large area. Also, the

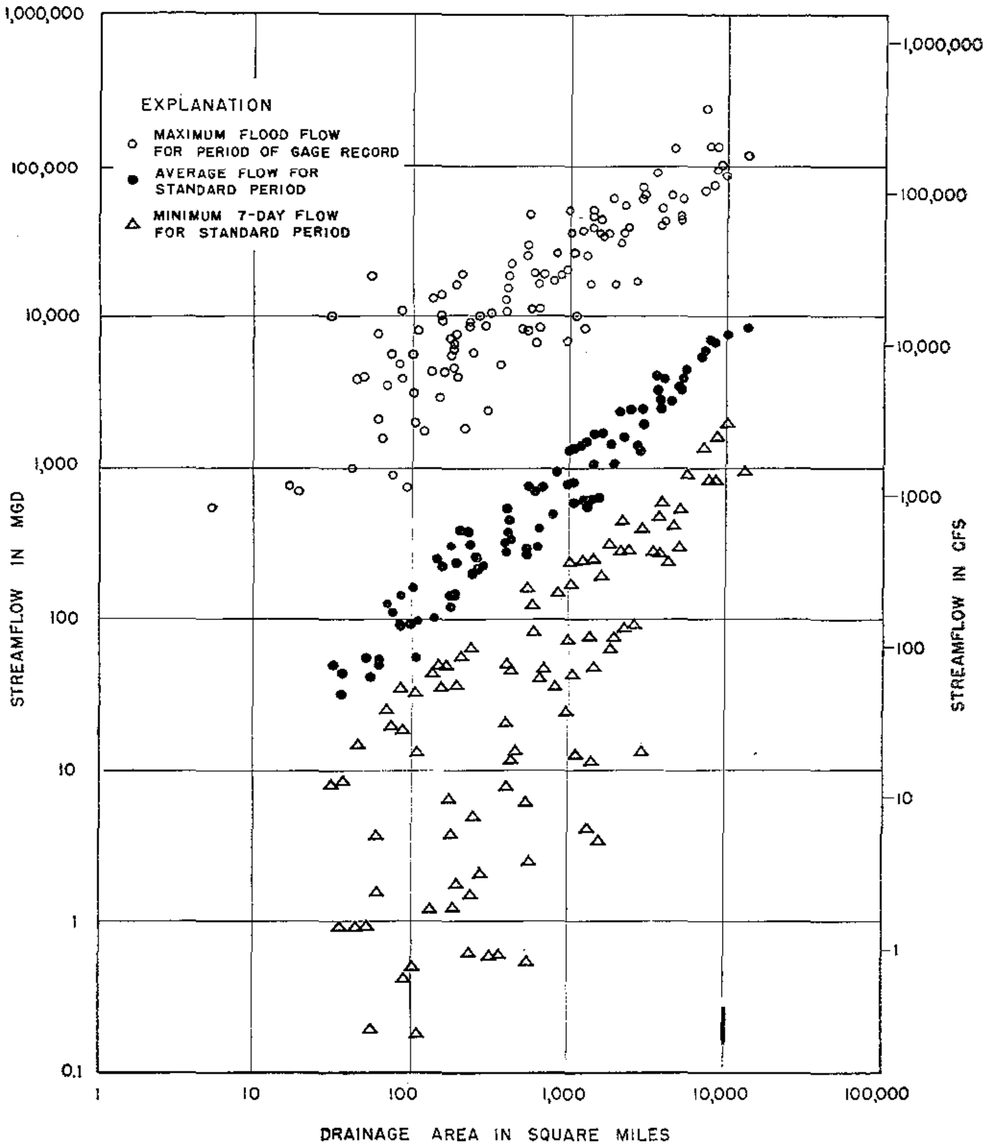


Figure 24. Relation of flood flow, average flow and minimum 7-day flow to size of drainage area for gaging stations in Georgia.

basin characteristics of small areas can be radically different from each other, whereas the characteristics of large drainage basins tend to be more nearly alike, though not necessarily homogeneous.

The scatter of the minimum 7-day flow data, is much greater than the scatter of either the flood data or the average-flow data. The general trend of the minimum 7-day flow data is only vaguely proportional to the drainage area. Thus, the drainage area is a poor indicator of low flows even for large rivers. The minimum flows range from zero to 0.40 mgdsm.

A State-wide generalization of streamflow characteristics has little value because of the great scatter of the data, particularly for low flows. Some improvement may be obtained by consideration of smaller regions in which the factors that affect streamflow are more nearly uniform.

No comprehensive study of regional water quality is practical, as records of water quality include data for a period of only 1 year at just 17 locations in all of Georgia. This small amount of record does not permit determination of maximum or minimum mineral concentration, nor does it allow the establishment of water quality criteria required for definition of riparian rights. It is impractical to attempt extension of these data by correlation methods to other streams for which no analyses are available. A general discussion of surface-water quality is presented on pages 225 to 236.

Streamflow Regions

It has been found that the low-flow characteristics of streams in Georgia are different for the four major physiographic provinces and vary considerably within those provinces. Therefore, the low-flow data in this report have been organized by streamflow regions based on the studies made for a report on the 1954 drought (Thomson and Carter, 1955).

Minimum-flow data, collected for the 1954 drought at 1,007 partial-record station sites and 53 complete-record stations on small unregulated streams, were studied to determine if they defined relatively homogeneous regions having stream-flow characteristics significantly similar within a region and different from those in other regions.

In making this study, the stations within each of the principal physiographic provinces were grouped into small areas containing equal number of sites having measured flow. The areas were defined by the boundaries of the provinces and county lines wherever possible. Various combinations of the area data were grouped and statistical tests applied for evidence of similarity. The actual test used was a simplified graphical method which produced results in agreement with those obtained by analysis of variance. Areas with similar characteristics were incorporated into eleven streamflow regions. Region boundaries follow county lines within each physiographic province, as shown in figure 25 (p. 148).

The low flows at the sites within a streamflow region are not necessarily all close to the average. The magnitude of the low flow is only one element in the determination of the regions. The other element is the degree of variation among the low flows. The range of the low flows within any part of the region may be about as broad as the range of low flows within the entire region. Thus, the low flows within a region are not uniform, but rather, they vary in a similar way.

Index stations.—An index station is a continuous-record gaging station having its drainage basin entirely or almost entirely within a streamflow region. Records from an index station are representative of the natural flows to be expected of other streams within its region. In some instances, the actual location of the station is just outside, but most of its drainage basin lies within the region. The symbol on the map in figure 25 (p. 148) is located at the center of the drainage area.

Some of the index gaging stations have only a brief period of record. If the station was in operation in 1954, its low-flow record was employed for some analyses, but its average flow was not computed unless there were at least five years of record available since the beginning of the standard 18-year period, October 1, 1937.

Regional variations.—The regional variations in low and average streamflows are summarized in table 9 (p. 150). The number of gaging stations in each region is shown to provide a basis for judging the significance of the range of the data. A large number of stations tends to make the range of the data more significant. The averages and ranges of flows are presented in thousands of gallons per day per square mile to facilitate comparisons. For the partial-record stations, the table shows for each region the average and range of the 1954 minimum daily flow and the maximum drainage area

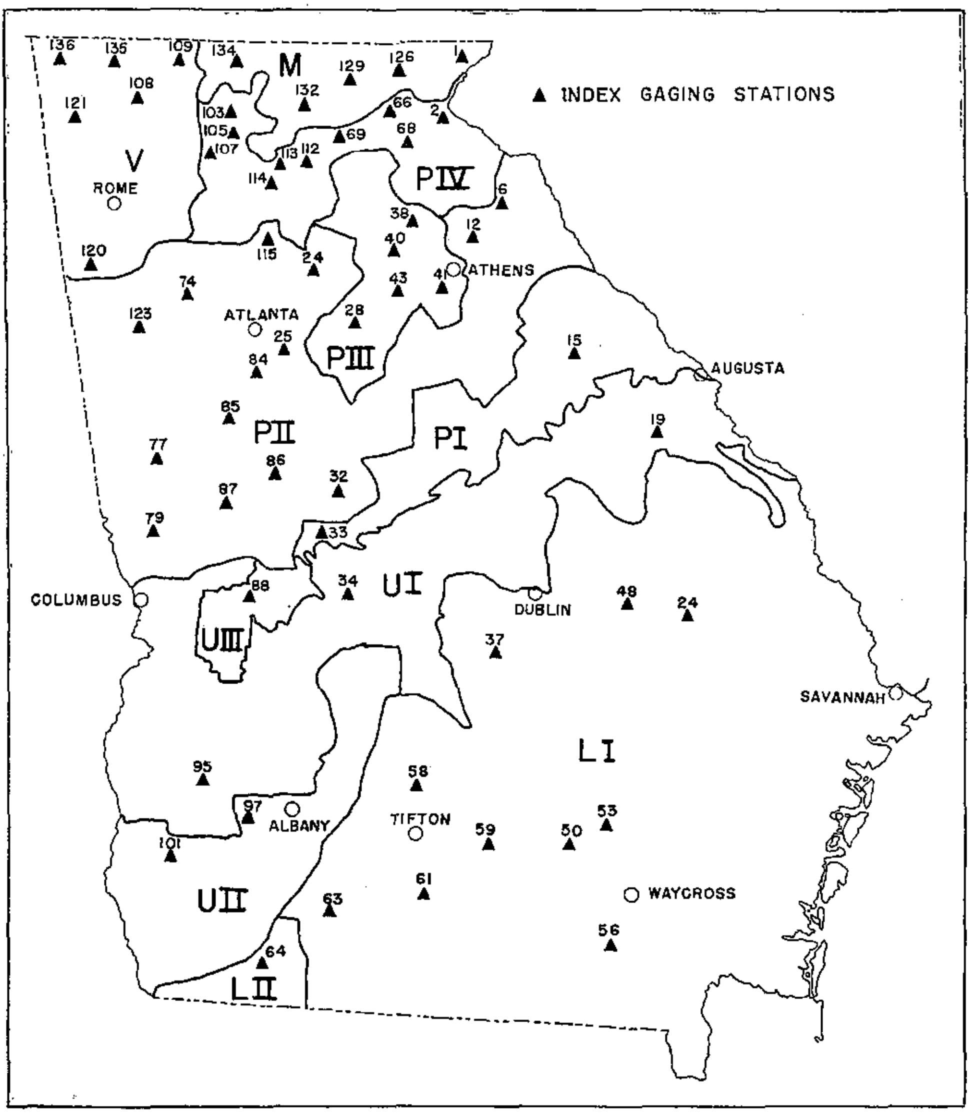


Figure 25. Map of Georgia showing streamflow regions and location of index gaging stations.

for which zero flows were observed during the drought of 1954. For the index gaging stations, the table shows for each region the average and the range of the 20-year minimum 1-day flow (which did not necessarily occur in 1954) and the range of the average flow for the standard 18-year period.

The ranges of minimum flows at the 1,007 partial-record sites for the 1954 drought are much greater than those of the 20-year 1-day minimum flows at the index gaging stations. The 1954 partial-record station data include the flow of many more small streams than are measured by the index gaging stations. Yet, some of the index stations experienced lower 20-year 1-day minimums at times other than 1954. If investigations of low flows at partial-record stations had been made throughout the period since 1937, as they were in 1954, the ranges of minimum flows would probably be even greater than those shown in the table.

Zero flows were found in six of the regions in 1954, from drainage areas up to 110 square miles in northern Georgia and 1,150 square miles in southern Georgia. This is a clear warning that investigation of the flow of small streams is needed before making investments that depend on a continuous flow of water.

The minimum flow data for 1954 in table 9 are shown graphically in the bar chart in figure 26 (p. 151).

Rural-Use Flows

Most of the water for rural use comes from wells or springs and does not get into the streams. Consequently, only changes in rural-use affect the measured streamflow. Decreases in rural use in some areas between 1955 and 1970 would have a negligible effect on streamflows. Expected increases in other areas would probably cause less than a five percent reduction of minimum flows of local streams except that in some areas of unusual increase in rural use, the reductions may be on the order of 10 to 20 percent. In those areas where minimum streamflows have been zero, any increase in rural needs will probably be supplied from wells which, in the long run, may reduce streamflows by the increased amount of water used. Thus, with increased rural use, those streams that go dry under present conditions would be dry for somewhat longer periods.

Table 9.—Regional streamflow averages and ranges
(thousand gallons per day per square mile)

Region	Partial record stations, 1954				Index gaging stations			
	No. of stations	Minimum 1-day flow		Maximum drainage area having no flow (sq. mi.)	No. of stations	20-yr. 1-day minimum		18-yr. average
		Average (thousand gpdsm)	Range (thousand gpdsm)			Average (thousand gpdsm)	Range (thousand gpdsm)	Range (thousand gpdsm)
M	13	200	150–460	less than 3	5	320	240–400	1,410–1,860
V	70	120	0–740	14	6	110	17–210	860–1,150
PI	58	2	0– 18	110	2	3	2– 4	490– 880
PII	314	24	0–460	84	*10	25	6– 58	660– 850
PIII	43	60	4–240	less than .6	5	31	18– 46	730– 770
PIV	84	230	.1–600	less than .4	10	260	170–380	1,070–1,630
UI	136	79	0–600	110	3	98	63–130	480– 830
UII	33	7	0–120	310	2	6	2– 11	580– 600
UIII	4	420	130–830	less than 15	1	770	——	1,290
L-I	244	.3	0– 14	1,150	10	3.5	0– 11	390– 520
L-II	8	30	0– 84	20	1	1	——	69

* Stations with low flow appreciably affected by diversion were not used in this tabulation.

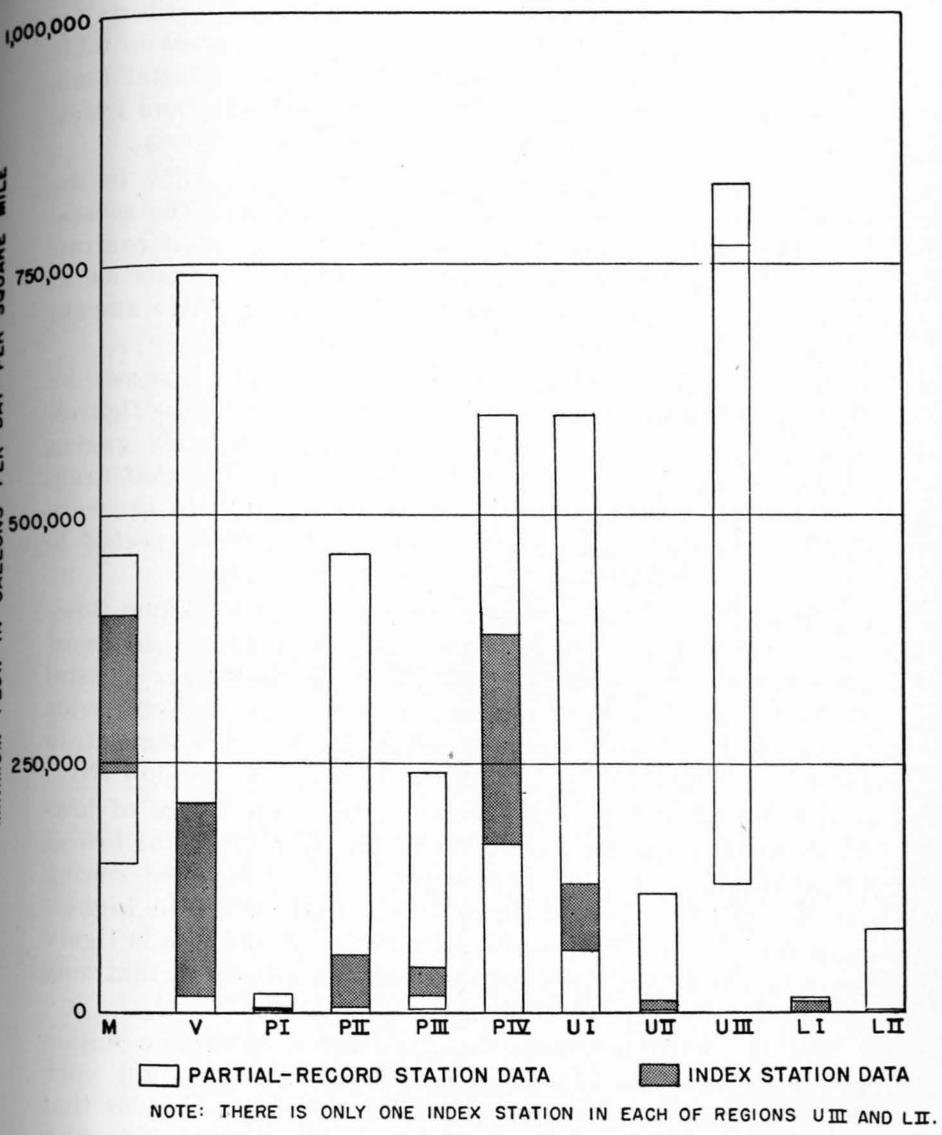


Figure 26. Range of minimum flows per square mile in Georgia, by streamflow regions.

Conservation Flows

The average and range of the flows per square mile at the index stations corresponding to nine low-flow criteria for conservation are summarized by streamflow regions in table 10 (p. 153). The yields are highest in upper Coastal Plain region III, second greatest in the Mountain region, and lowest in lower Coastal Plain region I, by any of the criteria.

The relation of the 20-year minimum 1-day flow to the average flow for representative index stations in the several regions is shown in figure 27 (p. 155). The greatest contrast among the regions is readily apparent in both the relation of the minimum flow to the average and in the relative amount of the minimum flow.

The average and range of the 1954 low flows is shown by regions in figures 28, 29, and 30 (pp. 156-158). These figures, based on 1,007 partial-record stations and 53 index gaging stations, represent the minimum flows for streams that drain several square miles or more and do not apply to the very small ephemeral streams in any region that are expected to have no flow in dry weather.

Figure 28 (p. 156) shows the average of the minimum flows of the streams in each region. The lowest yields are most prevalent in the lower Coastal Plain, in the upper Coastal Plain region II, and Piedmont region I. The highest yields are most prevalent in the Blue Ridge province (M region), in Piedmont region IV, and in upper Coastal Plain region III.

Figures 29 and 30 together show the wide range of low-flows within each region. Figure 29 (p. 157) shows the lowest minimum flow in each region that was determined during the drought of 1954 and figure 30 (p. 158) shows the highest minimum flow. The categories are the same as those in figure 28. Figures 29 and 30 show the range of low flows that may reasonably be expected in any region.

The ranges of minimum flows on different streams within the same region as shown by figures 29 and 30 should warn the reader not to apply average low-flow data, such as that shown by figure 28, to specific sites. The only satisfactory evidence of the low flow of a small stream is actual measurement under certain conditions explained on pages 179-185, and correlations with the systematic records at index gaging stations made by qualified engineers.

Table 10.—Regional averages and ranges of daily, 7-day and monthly minimum flows of index gaging stations in Georgia (thousand gallons per day per square mile)

Region	No. of Stations	2-yr. R. I.*		10-yr. R. I.*		20-yr. R. I.*	
		Average	Range	Average	Range	Average	Range
Minimum monthly flows							
M	5	620	470– 750	440	350–510	360	270–430
V	6	200	63– 320	160	36–270	140	30–240
PI	2	81	52– 110	21	12– 30	7	2– 12
PII	**10	190	120– 280	68	41–140	38	12– 70
PIII	5	230	180– 280	90	82–110	48	31– 67
PIV	10	540	310– 640	360	240–520	310	190–410
UI	3	260	240– 310	170	150–190	140	94–170
UII	2	70	47– 92	15	6– 25	8	2– 13
UIII	1	1,000	——	850	——	830	——
L I	10	23	7– 120	8	1– 28	4	0– 12
L II	1	120	——	34	——	15	——
State	**55		7–1,000		1–850		0–830
Minimum 7-day mean flows							
M	5	510	410– 580	370	250–460	320	250–400
V	6	160	49– 300	140	28–260	130	18–230
PI	2	55	32– 78	8	4– 12	3	2– 5
PII	**10	120	93– 200	46	20– 98	27	6– 60
PIII	5	170	130– 210	58	52– 64	35	20– 49
PIV	10	450	270– 530	300	180–430	280	170–400
UI	3	200	170– 250	120	120–130	110	63–130
UII	2	58	38– 79	12	4– 19	7	2– 12
UIII	1	950	——	830	——	790	——
L I	10	13	1– 29	6	0– 18	4	0– 12
L II	1	49	——	15	——	4	——
State	**55		1– 950		0–830		0–790

See footnotes at end of table.

Table 10.—Regional averages and ranges of daily, 7-day and monthly minimum flows of index gaging stations in Georgia—Continued (thousand gallons per day per square mile)

Region	No. of Stations	2-yr. R. I.*		10-yr. R. I.*		20-yr. R. I.*	
		Average	Range	Average	Range	Average	Range
Minimum 1-day mean flow							
M	5	480	370–550	330	250–430	320	240–400
V	6	150	40–270	120	19–240	110	17–210
PI	2	48	24– 71	6	2– 11	3	2– 4
PII	**10	100	82–190	40	16– 84	25	6– 58
PIII	5	160	120–200	59	40– 94	31	18– 46
PIV	10	430	250–510	290	170–390	260	170–380
UI	3	190	150–230	120	110–130	98	63–130
UII	2	52	34– 71	11	5– 17	6	2– 11
UIII	1	950	——	790	——	770	——
L I	10	11	1– 26	5	0– 16	3	0– 11
L II	1	47	——	13	——	1	——
State	**55		1–950		0–790		0–770

* Recurrence interval.
** Stations with low flow appreciably affected by diversions not used in this tabulation.

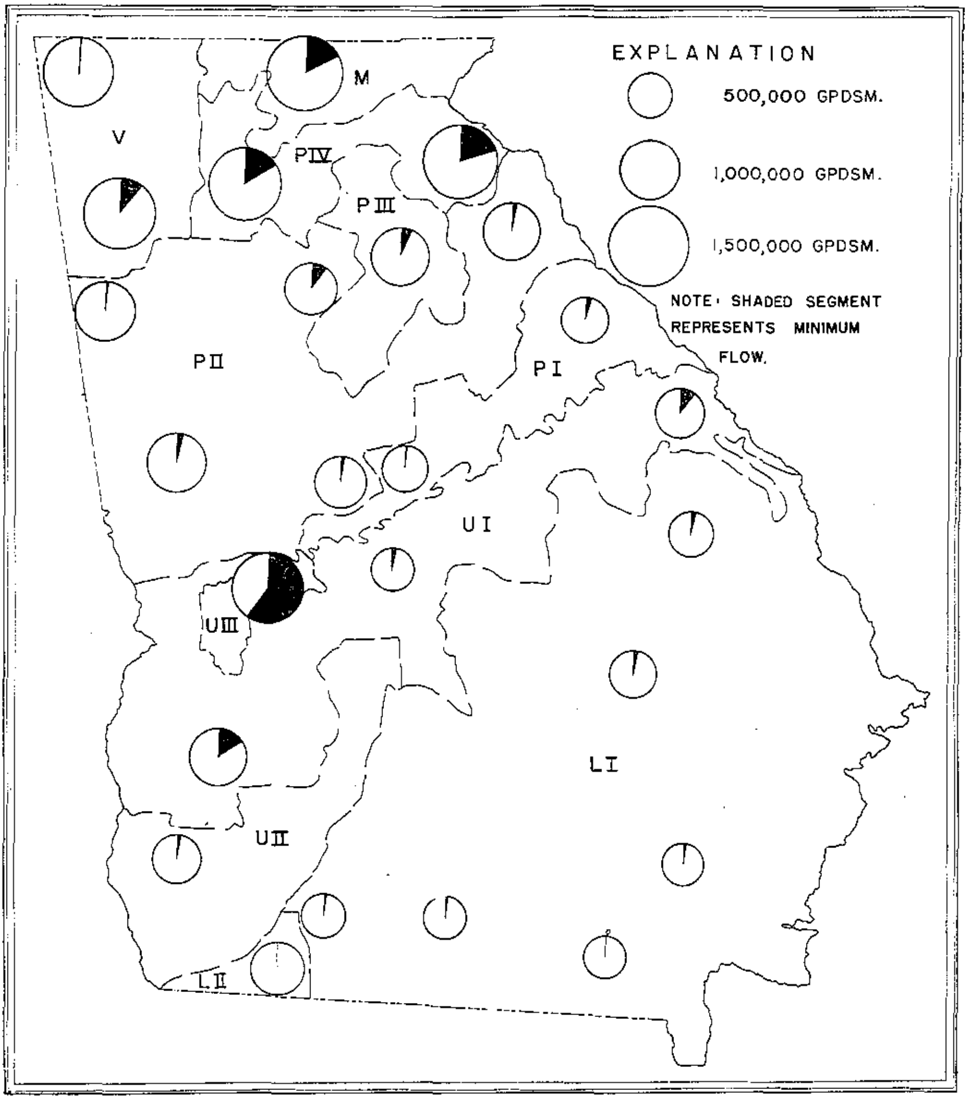


Figure 27. Map of Georgia showing average flow and 20-year 1-day minimum flow at representative gaging stations.

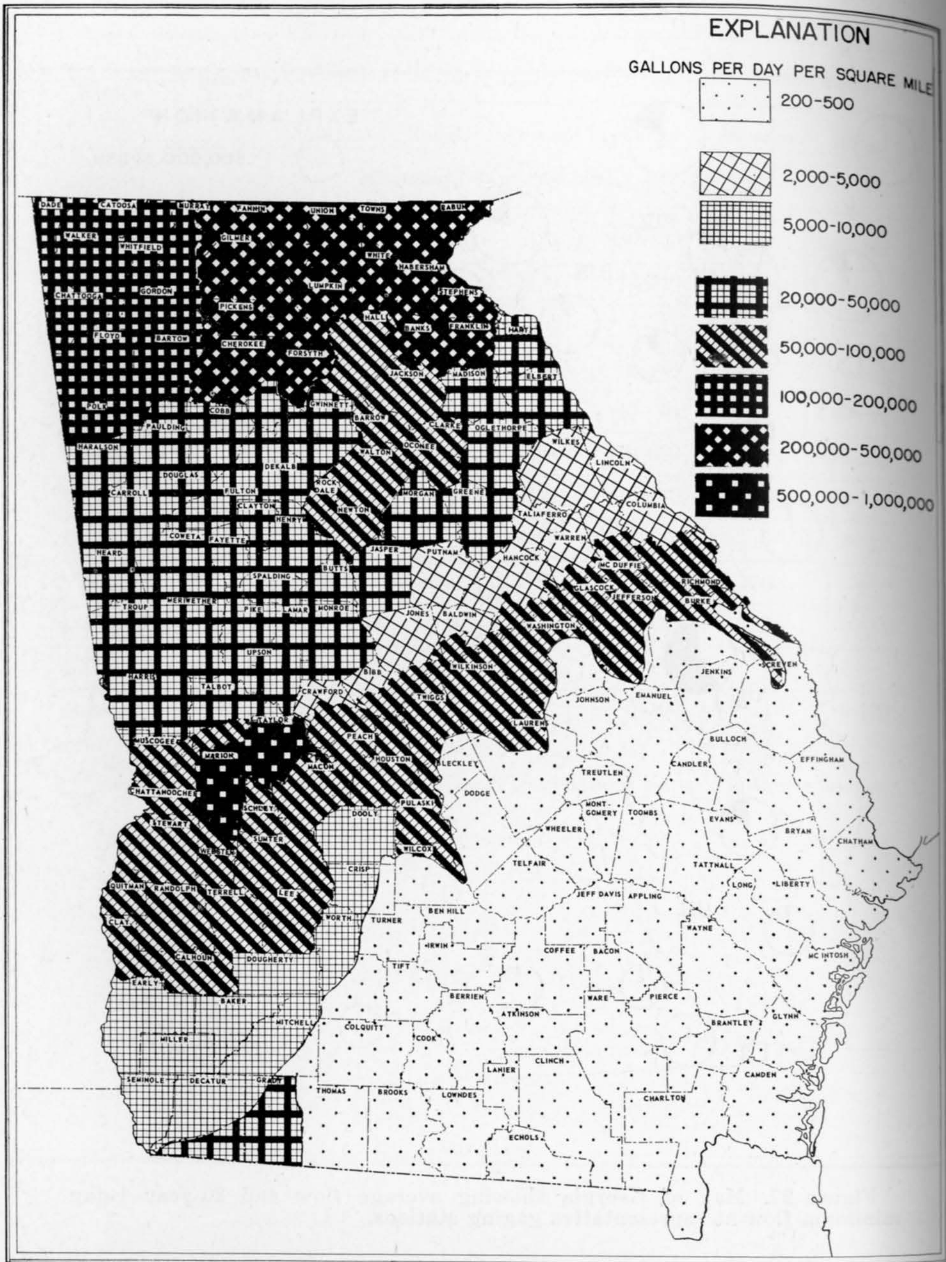


Figure 28. Map of Georgia showing the average of the minimum flows per square mile determined in each region for 1954.

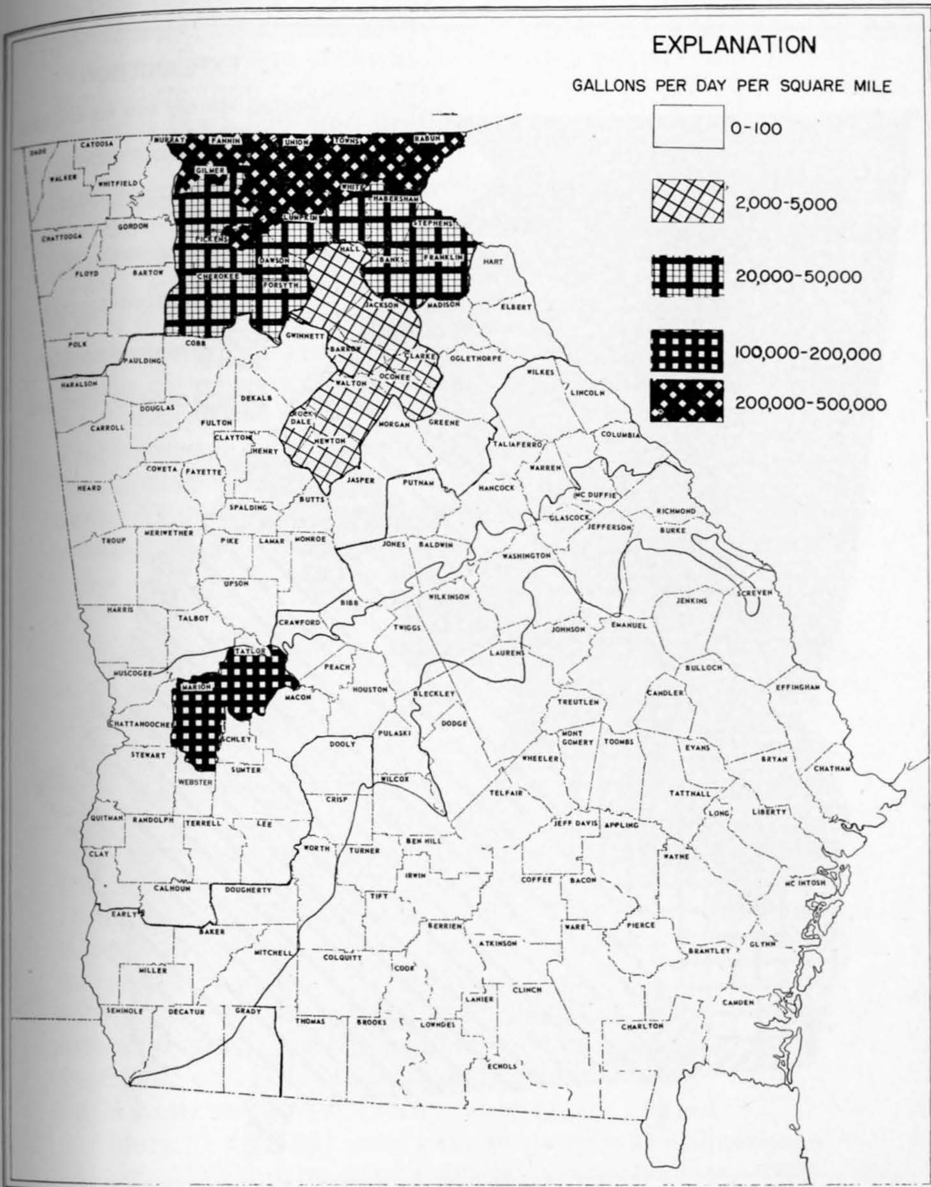


Figure 29. Map of Georgia showing lowest minimum flow per square mile determined in each region for 1954.

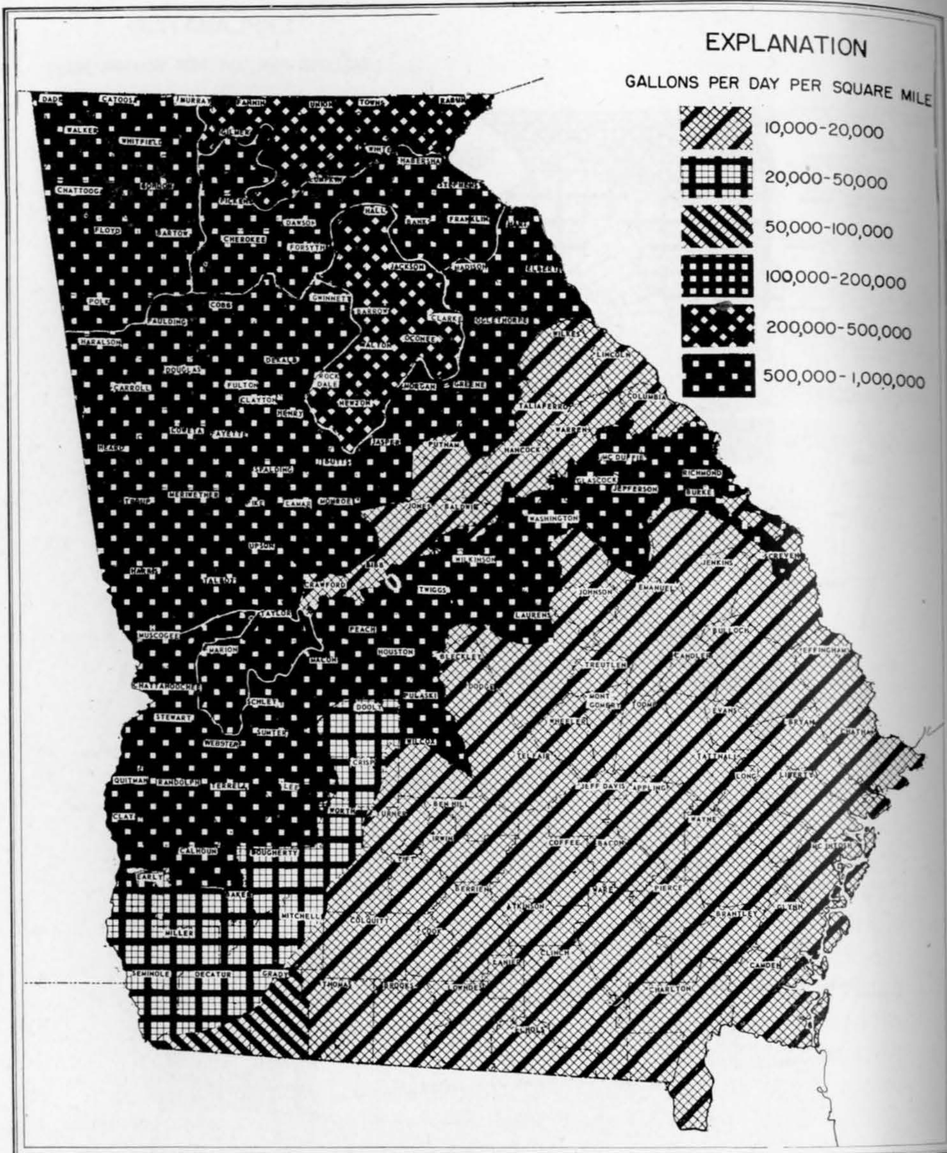


Figure 30. Map of Georgia showing highest minimum flow per square mile determined in each region for 1954.

The total of the minimum flows of all the minor streams in Georgia during the 1954 drought has been estimated to be 2,500 mgd. The corresponding total of the minimum flows of the major rivers of the State has been estimated to be 5,400 mgd, more than twice as great. The flow of the major rivers includes the 2,500 mgd draining from the minor streams and 2,900 mgd additional most of which comes from ground-water contributions directly into the major rivers in the Coastal Plain, notably into the Flint River, and by releases of stored water from major reservoirs.

The sum of the minimum flows of the minor streams in 1954, 2,500 mgd, represents the total streamflow available without storage reservoirs to supply and carry away the wastes of the many small cities and industries and to irrigate most of the crop lands that are not convenient to major rivers. The estimated future maximum rate of use of water for irrigation during the irrigation season under dry-year conditions is about 11,000 mgd, over four times the streamflow available without storage that would be most likely to be used.

Utilization Flows

Utilization flows are not adaptable to regional analysis; they must be considered separately for each river basin. Utilization flows are established by the use of the water by cities, industries, and power dams, none of which tend to have regional uniformity. The flow from the tributaries of the Ocmulgee River basin above Lloyd Shoals Dam, for example, is utilized to a great extent for hydroelectric power, but that from most of the tributaries downstream from the Dam is not used for power at all. The proportional utilization flows for power purposes above Lloyd Shoals Dam may be computed and, thus, may be analyzed, but by river basins, rather than by the streamflow regions. In order to show the effect of utilization flows at the index gaging stations, proportional utilization flows have been computed on a river-basin basis and are shown in table 11 (p. 161).

Figure 31 (p. 169) shows the proportional utilization of the average flow in the major drainage basins of the State. In all but a few instances, the average utilization flow is for power purposes. Four categories are shown by the shading. The heaviest shading indicates the areas where practically all of the flow was utilized in 1955 or will be utilized by projects under construction in 1955. These include the Savannah River basin above Clark Hill Dam, the Chattahoochee River basin above Fort Gaines Dam, the Etowah River basin above Allatoona Dam, and the Tennessee River basin. The medium shading indicates the areas where 50 to 100 percent of the average flow was utilized. These include the Savannah River basin below Clark Hill (for navigation), the Oconee River basin above Sinclair Dam, the Ocmulgee River basin above Lloyd Shoals Dam, the Ochlockonee River basin above Jackson Bluff Dam in Florida, the Flint River basin and the Chattahoochee River basin above Jim Woodruff Dam and below Fort Gaines Dam, the Tallapoosa River basin above Martin Dam in Alabama, and the Coosa River basin above Lay Dam in Alabama and below Allatoona Dam. The light shading indicates the areas where less than 50 percent of the flow was utilized, which includes the Altamaha River and tributaries below Sinclair Dam and Lloyd Shoals Dam (for navigation on the Altamaha River). The unshaded portion of the map represents the area where there is no major utilization of the flow.

Excess Flows

In table 11 (p. 161), the difference between the 18-year (1937-55) average flow and the highest of the average utilization flows during 1955 is shown in the column headed "excess flow". This excess flow is available to supply increases in utilization flows and for future irrigation without decreasing the flow now used.

Irrigation requirements.—The future annual average irrigation requirements under dry year conditions have been estimated to average from 10,000 to 40,000 gallons per square mile per day in most Georgia counties, with averages of less than 10,000 gallons per day square mile in the mountain counties and coastal counties. These quantities are generally small in proportion to the annual flow of streams. The total future estimated irrigation requirement of 1,200 mgd is only three percent of the average annual flow of all of Georgia's rivers and less than 10 percent of the annual flow during a dry year. However, the annual average irrigation requirement is concentrated in a few months, at a time when the streamflow is far below average.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia (thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Utilization flow: Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[1]	Estimated future average irrigation use
	SAVANNAH RIVER BASIN											
1	Chattooga River near Clayton, Ga.	207	1,860	280	2.9	3.6	150	150	1,860	730	0	6
2	Panther Creek near Toccoa, Ga.	32.5	1,400	240	25.	98.	130	130	1,450	620	0	14
6	South Beaverdam Creek at Dewy Rose, Ga.	35.8	850	18	10	11	14	14	850	61	0	20
12	Broad River near Bell, Ga.	1,430	740	50	.5	.6	29	29	740	140	0	20
15	Little River near Lincolnton, Ga.	574	490	2	.02	.02	1.0	1.0	490	4.9	0	25
19	Brier Creek at Millhaven, Ga.	646	620	63	.6	.8	2.5	3.7	0	160	460	20
	OGEECHEE RIVER BASIN											
24	Canoochee River near Claxton, Ga.	555	470	1	0	0	0	0	0	0	470	30

[1] Based on the largest of the reported average utilization flows.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia—Continued
(thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Utilization flow										
		Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[1]	Estimated future average irrigation use
	ALTAMAHA RIVER BASIN											
25	South River near McDonough, Ga.	436	820	*69	8.5	10	110	150	550	56	270	20
26	Yellow River near Snellville, Ga.	134	700	7	1.7	2.1	22	30	510	10	190	20
28	Alcovy River below Covington, Ga.	251	740	18	4.0	4.8	48	64	500	25	240	30
32	Tobesofkee Creek near Macon, Ga.	182	660	8	0	0	0	0	0	11	650	20
33	Echeconnee Creek near Macon, Ga.	100	880	4	0	0	0	0	0	7.0	870	25
34	Big Indian Creek at Perry, Ga.	108	480	100	0	0	0	0	0	140	340	20
37	Little Ocmulgee River at Towns, Ga.	363	510	2	0	0	0	0	0	2.2	510	30
38	Oconee River at Athens, Ga.	283	770	46	9.5	12	0	0	630	64	140	30
40	Middle Oconee River at Athens, Ga.	398	760	45	2.5	2.7	0	0	620	73	140	30

*Minimum flow affected by diversion upstream.
[1] Based on the largest of the reported average utilization flows.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia—Continued (thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Utilization flow										
		Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[1]	Estimated future average irrigation use
	ALTAMAHA RIVER BASIN (Cont.)											
41	Oconee River near Greensboro, Ga.	1,090	730	35	1.9	2.2	0	0	600	53	130	30
43	Apalachee River near Buckhead, Ga.	436	770	23	1.3	1.4	0	0	640	32	110	30
48	Ohoopee River near Reidsville, Ga.	1,110	520	11	0	0	0	0	10	15	500	30
	SATILLA RIVER BASIN											
50	Satilla River near Waycross, Ga.	1,300	430	3	0	0	.7	.8	0	0	430	30
53	Satilla River at Atkinson, Ga.	2,880	460	5	0	0	0	0	0	0	460	10
	SUWANNEE RIVER BASIN											
56	Suwannee River at Fargo, Ga.	1,260	470	0	0	0	0	0	0	0	470	10
58	Alapaha River near Alapaha, Ga.	644	470	0	0	0	0	0	0	0	470	30

[1] Based on the largest of the reported average utilization flows.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia—Continued
(thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Utilization flow										
		Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[1]	Estimated future average irrigation use
	SUWANNEE RIVER BASIN (Cont.)											
59	Alapaha River at Statenville, Ga.	1,400	430	8	0	0	0	0	0	0	430	30
61	Withlacoochee River near Quitman, Ga.	1,560	390	2	0	0	0	0	0	0	390	30
	OCHLOCKONEE RIVER BASIN											
63	Ochlockonee River near Thomasville, Ga.	550	520	3	0	0	0	0	310	0	210	30
64	Tired Creek near Cairo, Ga.	55	690	1	0	0	0	0	410	0	280	30
	APALACHICOLA RIVER BASIN											
66	Chattahoochee River near Leaf, Ga.	150	1,630	313	100	110	410	570	1,630	970	0	14
68	Chattahoochee River near Gainesville, Ga.	559	1,350	240	75	88	310	430	1,350	750	0	14
69	Chestatee River near Dahlonega, Ga.	153	1,400	209	65	78	270	380	1,400	650	0	14

[1] Based on the largest of the reported average utilization flows.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia—Continued
(thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Utilization flow										
		Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[1]	Estimated future average irrigation use
	APALACHICOLA RIVER BASIN (Cont.)											
74	Sweetwater Creek near Austell, Ga.	246	780	6	13	16	5.3	7.3	780	18	0	20
77	Yellowjacket Creek near LaGrange, Ga.	182	760	19	.7	.8	**	**	760	60	0	20
79	Mountain Creek near Hamilton, Ga.	61.7	850	58	2.1	2.6	**	**	850	180	0	20
84	Flint River near Griffin, Ga.	272	760	*6	11	14	1.2	3.6	520	23	240	20
85	Flint River near Molena, Ga.	990	780	24	0	0	1.8	5.6	550	34	230	20
86	Potato Creek near Thomaston, Ga.	186	750	*3	18	21	.5	1.4	530	8.6	220	20
87	Flint River near Culloden, Ga.	1,890	730	33	0	0	2.5	7.4	510	46	220	20
88	Whitewater Creek near Butler, Ga.	75	1,280	770	0	0	57	170	880	1,080	200	20

*Minimum flow affected by diversion upstream.
** Data not available.
[1] Based on the largest of the reported average utilization flows.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia—Continued
(thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Utilization flow										
		Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[1]	Estimated future average irrigation use
	APALACHICOLA RIVER BASIN (Cont.)											
95	Ichawaynochaway Creek near Milford, Ga.	620	830	130	0	0	0	0	580	180	250	20
97	Chickasawhatchee Creek at Elmodel, Ga.	320	580	2	0	0	0	0	400	2.6	180	30
101	Spring Creek near Iron City, Ga.	520	600	11	0	0	0	0	420	16	180	30
	MOBILE RIVER BASIN											
103	Cartecay River near Ellijay, Ga.	135	1,270	300	5.5	6.4	160	270	1,030	300	240	14
105	Coosawattee River near Ellijay, Ga.	238	1,270	260	4.6	5.5	130	230	1,050	260	220	14
107	Coosawattee River at Pine Chapel, Ga.	856	1,070	166	3.0	3.5	85	140	880	170	190	14
108	Mill Creek at Dalton, Ga.	37	1,140	210	120	150	110	180	930	210	210	20
109	Conasauga River at Tilton, Ga.	682	1,080	65	1.2	1.4	34	56	880	65	200	20

[1] Based on the largest of the reported average utilization flows.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia—Continued
(thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Utilization flow										
		Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[f]	Estimated future average irrigation use
	MOBILE RIVER BASIN (Cont.)											
112	Etowah River near Dawsonville, Ga.	103	1,500	310	2.4	2.6	160	270	1,500	310	0	14
113	Amicolola Creek near Dawsonville, Ga.	84.7	1,630	380	3.2	3.3	190	330	1,630	380	0	14
114	Etowah River at Canton, Ga.	605	1,150	190	1.7	1.7	98	170	1,150	190	0	14
115	Little River near Roswell, Ga.	60.5	790	23	.2	.2	12	20	790	23	0	20
120	Cedar Creek near Cedartown, Ga.	109	860	130	a	a	a	a	700	130	160	20
121	Chattooga River at Summerville, Ga.	193	1,150	130	a	a	a	a	940	130	210	20
123	Little Tallapoosa River at Carrollton, Ga.	89	950	*2	9.2	11	a	a	950	a	0	20

a Utilization data not computed for some sites outside of Georgia.
[f] Based on the largest of the reported average utilization flows.

Table 11.—Availability and estimated proportional utilization flows of index gaging stations in Georgia—Continued
(thousands of gallons per day per square mile of drainage area)

Map no.	Gaging station	Utilization flow										
		Drainage area, (sq. mi.)	18-year average flow, 1937–55	Minimum daily flow, 20-year R. I.	Average urban	Maximum urban	Average industrial	Maximum industrial	Average power	Average navigation	Average excess flow[1]	Estimated future average irrigation use
	TENNESSEE RIVER BASIN											
126	Hiwassee River at Presley, Ga.	45.5	1,780	330	a	a	a	a	1,780	a	0	6
129	Nottely River near Blairsville, Ga.	74.6	1,410	240	a	a	a	a	1,410	a	0	6
132	Toccoa River near Dial, Ga.	177	1,660	400	a	a	a	a	1,660	a	0	6
134	Fightingtown Creek at McCaysville, Ga.	70.9	1,690	350	a	a	a	a	1,690	a	0	6
135	South Chickamauga Creek near Chickamauga, Tenn.	428	1,030	96	a	a	a	a	1,030	a	0	20
136	Chattanooga Creek near Flintstone, Ga.	50.6	1,050	17	a	a	a	a	1,050	a	0	20

* Minimum flow affected by diversion upstream.
a Utilization data not computed for some sites outside of Georgia.
[1] Based on the largest of the reported average utilization flows.

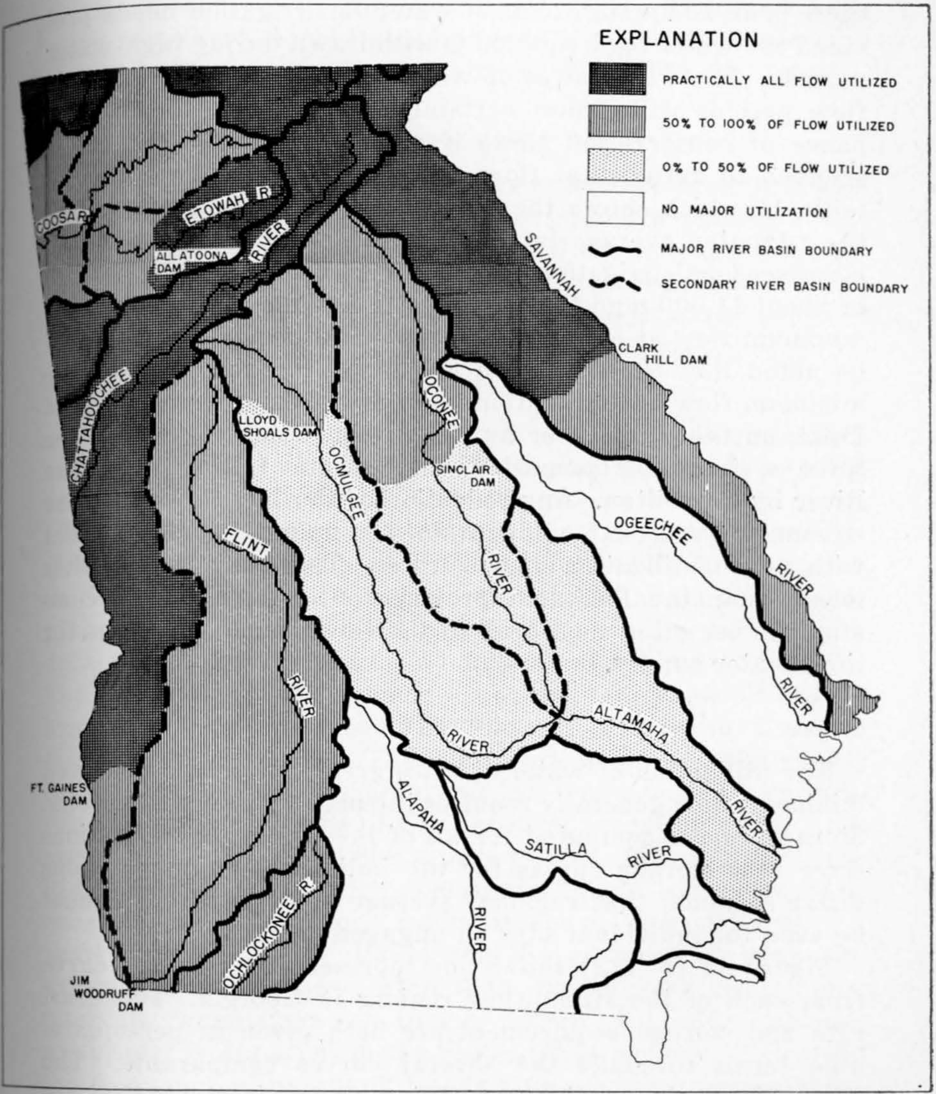


Figure 31. Map of Georgia showing relation of proportional utilization flows to average flow by river basins.

Irrigation requirements will conflict with other uses of water in areas shown in figure 31 (p. 169) where practically all of the flow is now utilized. In all other areas of the State, there is an adequate excess of water for irrigation needs provided the water for irrigation is withdrawn during high-water periods. The withdrawal of water for irrigation during low-flow periods will almost certainly conflict with the maintenance of conservation flows if one of the lesser criteria is selected to define that flow. This is readily apparent from table 11 which shows the 20-year minimum 1-day flow and the estimated average future irrigation water use. The maximum seasonal irrigation rate is nine times the average rate or about 11,000 mgd for the State as a whole and exceeds the minimum flow at most of the gaging stations. Also, it should be noted that the maximum urban use already exceeds the minimum flow at four stations—on Sweetwater Creek by East Point, on the Flint River by Griffin, on Potato Creek by the three systems at Thomaston, and on the Little Tallapoosa River by Carrollton. Any reduction of the low flows of these streams by seasonal withdrawals for irrigation will conflict with urban utilization of the water. There are many other localities in the Piedmont province of Georgia where communities use all or nearly all of the flow of small streams for their water supply.

Storage

The utilization of water at rates greater than the observed minimum flow generally requires the use of storage reservoirs. Storage curves computed for all of the index gaging stations show that storage curves for the individual gaging stations differ so much that regional average storage curves cannot be used for individual sites on ungaged streams.

Figure 32 (p. 172) shows one representative storage curve from each of the streamflow regions in Georgia. The draft rate and storage requirement are both given in per-square-mile terms to make the several curves comparable. The figure shows the great range of storage requirements that are needed to produce a given draft rate. For example, an average annual draft rate of 200,000 gallons per day per square mile requires no storage at the stations in the Blue Ridge province, upper Coastal Plain region III, and Piedmont region IV (because the minimum flow in those regions exceeds that draft rate), requires 1,600,000 gallons per square mile at the station in the Valley and Ridge province, and requires 90,000,000 gallons per square mile at the station in the lower Coastal Plain! Even within a single region, there are such wide ranges of storage requirements that storage reservoirs should be designed only on the basis of specific-site data.

Evaporation

As evaporation varies with reservoir surface area, it is necessary to compute evaporation losses for each specific reservoir. In middle and southern Georgia, the average evaporation loss per acre of reservoir surface exceeds the average rainfall on the reservoir by over 150,000 gallons per year.

Floods

The frequency of bankfull floods in Georgia is quite variable, the average number at some gaging stations is as often as ten times a year and at others as rare as once in six years (recurrence intervals range from 0.1 to 6.5 years). Bankfull stages and flows have been determined for most of the gaging stations in Georgia from field surveys, channel and floodplain cross sections, and the gaging-station rating curves. The data are shown in columns 21 and 22 of table 8B (p. 128). The frequency with which floods exceed bankfull stages has been computed from the data in **Floods in Georgia.** (Carter, R. W., 1951) There appears to be no relation between size of drainage area and the frequency of overbank floods within the limits of the drainage areas for which data are available (31 to 13,600 square miles). Rivers in the Blue Ridge province generally experience floods less often than once a year (recurrence intervals range from 0.78 to 4.0 years). Rivers in the Valley and Ridge province generally experience floods more often than once a year (recurrence intervals range from 0.3 to 0.8 years). No other regional uniformity is apparent in the State. Thus in most of Georgia the frequency of overbank floods appears to be primarily influenced by local conditions.

Most of the gaging stations in Georgia have frequencies of overbank floods ranging from about three times a year to once in two years (recurrence intervals of 0.3 to 2.0 years). This limiting range may not be applicable to small streams

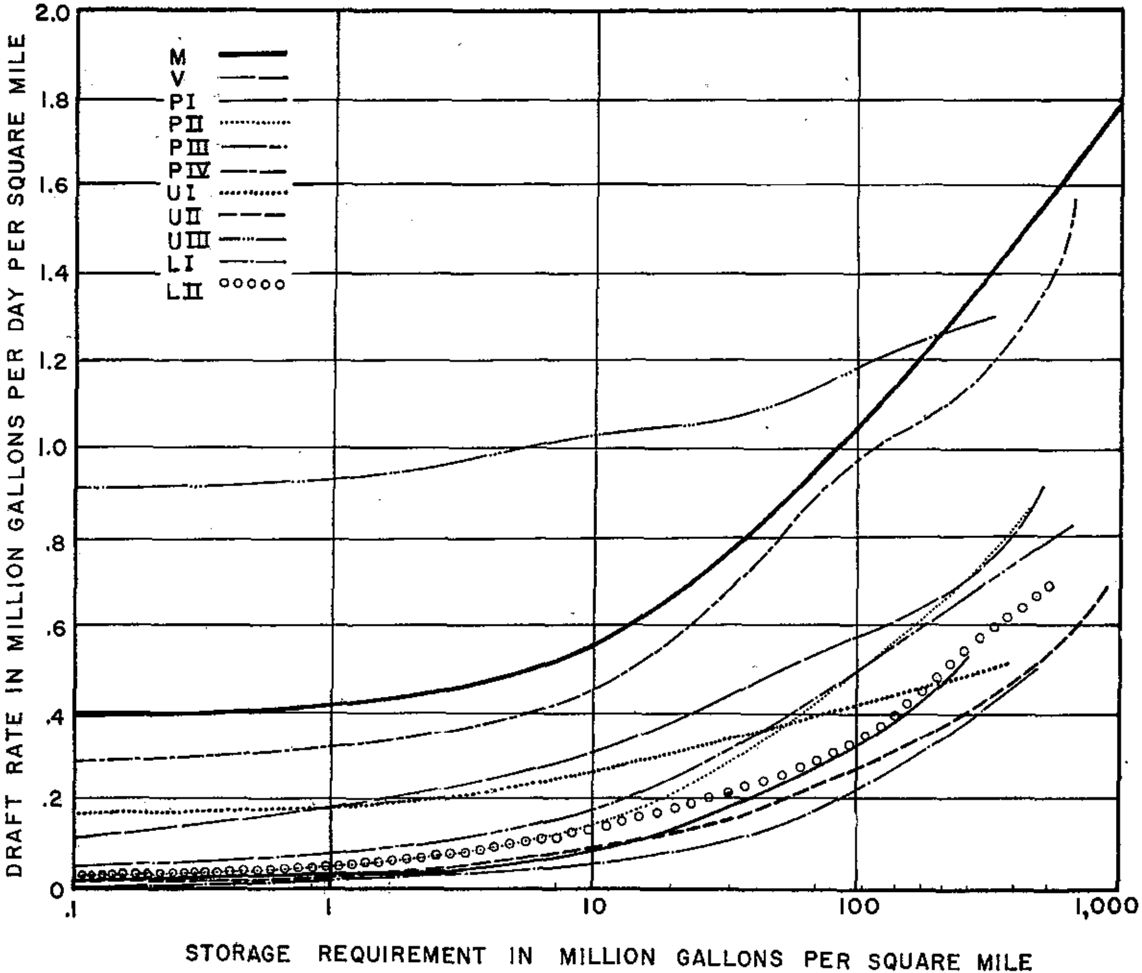


Figure 32. Representative regional storage curves.

having drainage areas less than 30 square miles, or to streams in swampy terrain. Flood data on small streams are practically nonexistant and gaging stations are rarely located in swampy reaches of the rivers.

Regional maps and curves of annual flood magnitudes and frequencies from **Floods in Georgia** have been reproduced in this report in figures 33 to 36 (pp. 174, 175) for general information. It should be noted that the regions used for flood analyses do not conform with those used for low-flow analyses. Flood characteristics are greatly influenced by storm patterns which have very little influence on low-flow characteristics.

The curves show average values for the several regions and are considered to be more significant than the limited information generally available at a specific site. The scatter of the gaging station data used to define the mean curves of figure 34 (p. 174) is indicated by the following percentages. There are approximately two chances out of three that the mean annual flood flow at a particular site will be within the indicated percentage of the average-curve value.

Region 1	20%
Region 2	10%
Region 3	16%
Region 5	18%
Region 6	19%
Region 7	6%

Regions 4 and 8 do not have enough stations in them for the scatter to be computed statistically.

The magnitude of a flood flow with a frequency of 50 years or less at an ungaged site on a tributary stream may be determined from the figures in the following manner:

(1) Determine the size of the drainage area above the site in square miles.

(2) Determine from figure 33 (p. 174) the hydrologic region in which the stream lies. (These tend to conform to the physiographic provinces.)

(3) Determine the mean annual flood flow corresponding to the drainage area from the curve for that region in figure 34 (p. 174). (Most of the flood flows vary with the .8 power of the drainage area.)

(4) Determine from figure 35 (p. 175) the area in which

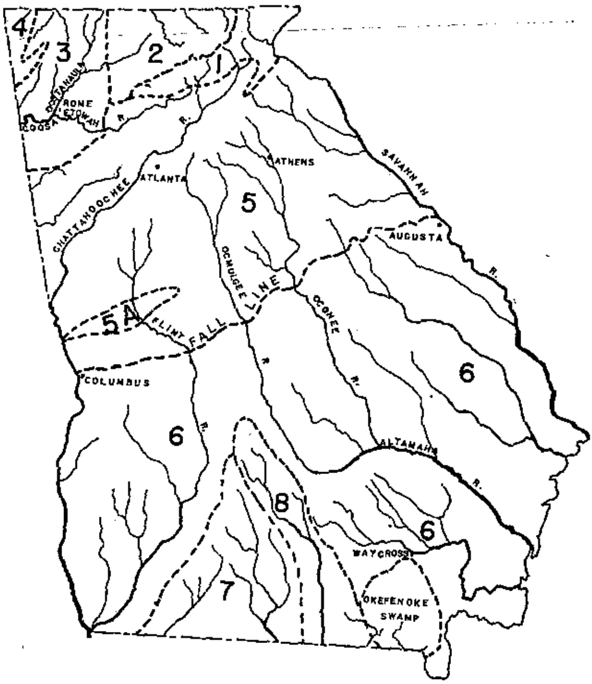


Figure 33. Map of Georgia showing hydrologic regions for determination of mean annual flood.

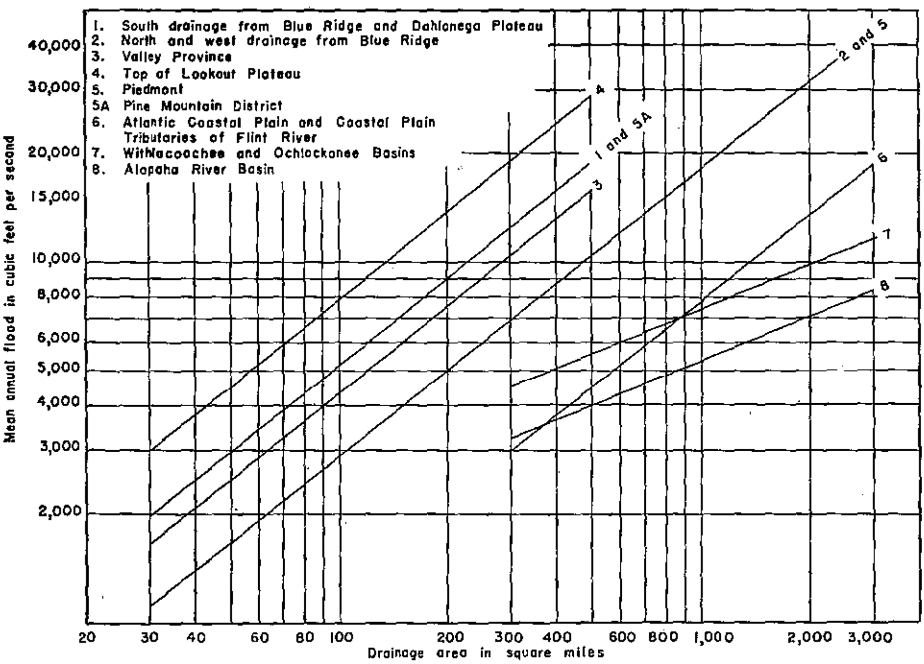


Figure 34. Variation of mean annual flood with drainage area for Georgia streams. (Summary).

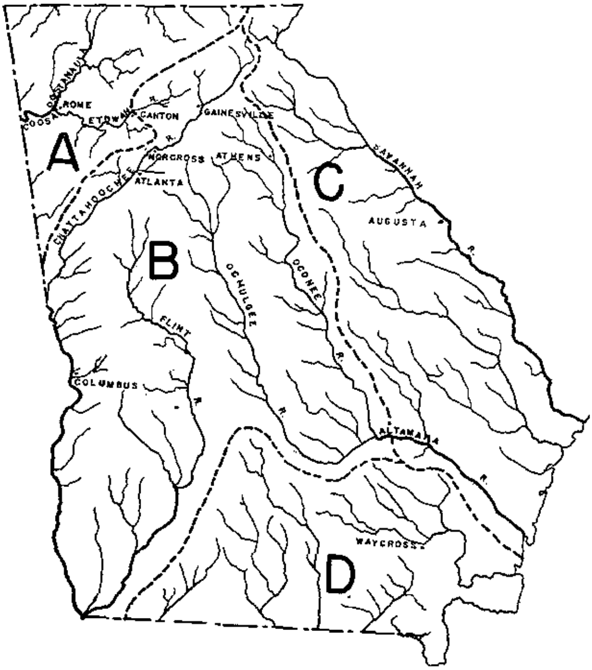


Figure 35. Map of Georgia showing areas to which regional flood frequency curves apply.

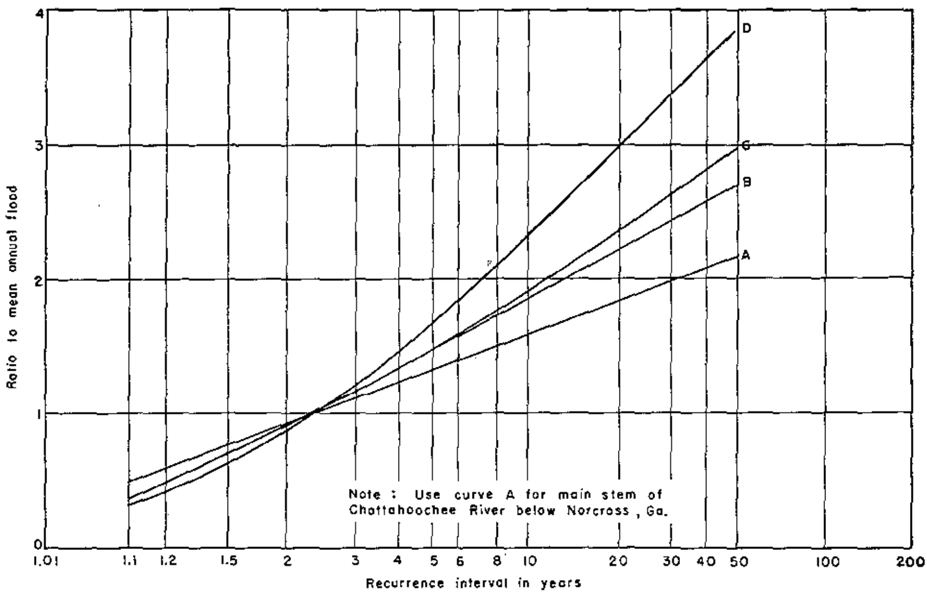


Figure 36. Frequency of annual floods, areas A, B, C, D, period 1892-1949.

the stream lies. (These areas reflect a climatic pattern rather than physiographic influences.)

(5) From the curve for that area in figure 36 (p. 175) determine the flood ratio for the desired frequency.

(6) Multiply the mean annual flood flow (3) by the flood ratio (5) to obtain the desired flood flow.

If desired, a complete frequency-magnitude graph for the site may be defined by plotting flood flows determined in the above manner for a number of different frequencies.

FLOW CORRELATION

If Georgia should adopt a new water law that requires the reservation of a conservation flow or utilization flow and permits the appropriation of excess flows for irrigation or other consumptive purposes, how could a property owner on a stream know how much water he may use and how much he must release? The studies of regional flows have shown that wide ranges of flow values exist in every region so that he would have no general values of any flow statistic to guide him. If there is a gaging station at the site, as on the Yellow River near Snellville, the station records will provide practically all of the information he would need. If there is no such gaging station at or near his site he must rely on flow correlations to obtain the needed information.

Flow correlations are comparisons of the flows at two or more sites. They are made generally to permit the extension of flow information from a gaged site to another site where there is little flow information.

Before there were many streamflow records available, correlations were based largely on rainfall data. If the runoff from a given drainage basin were known, it was related to the rainfall over the drainage basin. The rainfall-runoff relation was then applied to the rainfall over the drainage basin above the ungaged site and its runoff estimated. Similarly the rainfall-runoff relation for a short period might be applied to the rainfall over a long period to estimate the long-term runoff. The method has some merit in the estimation of average flow but it has limited value in the estimation of low flows.

Now that many streamflow records are available, more reliable estimates can be secured with streamflow records alone. The streamflow records reflect not only the differences in rainfall between two drainage basins but also the differences caused by land characteristics which may be much greater than differences due to rainfall. Correlations with the streamflow records at a gaged site may provide reliable information for a wide range of flow statistics from only a small amount of flow data at the site where the information is desired.

The simplest flow correlations are those based on the relative size of the drainage areas. If two sites are in the same general region and receive similar rainfall over their drainage basins it is logical to assume that the average streamflows will be proportional to the respective drainage areas. Drainage-area correlations are frequently made and streamflow data are published with the flow-per-square-mile given to aid in making them. They are reasonably reliable within a streamflow region for average or near-average flows on streams draining similar sized areas. Results may be subject to large errors for extreme flow conditions, such as drought flows and flood flows, and when the flow of small streams is estimated from the flow of large streams. The greatest usefulness of a drainage-area correlation is in the determination of average flows.

Average Flow

The natural average flow at a site, that is the flow provided by Nature unaffected by manmade regulation or diversions, can be estimated from the drainage area at the site and the average flow per square mile at nearby unregulated gaging stations. The natural average flow in million gallons per day per square mile for the standard 18-year period, 1937-55, is shown for the index gaging stations on perennial streams on the map in figure 37 (p. 178). The natural average flow per square mile may be estimated within reasonable limits for perennial streams by interpolation from this map except in the areas indicated as doubtful. No data exist in those areas with which to estimate reliably the natural average flow.

The natural average flow cannot be interpolated satisfactorily from this map for very small ephemeral streams, for streams which receive a large portion of their flow from springs, or for streams which are affected by unmeasured

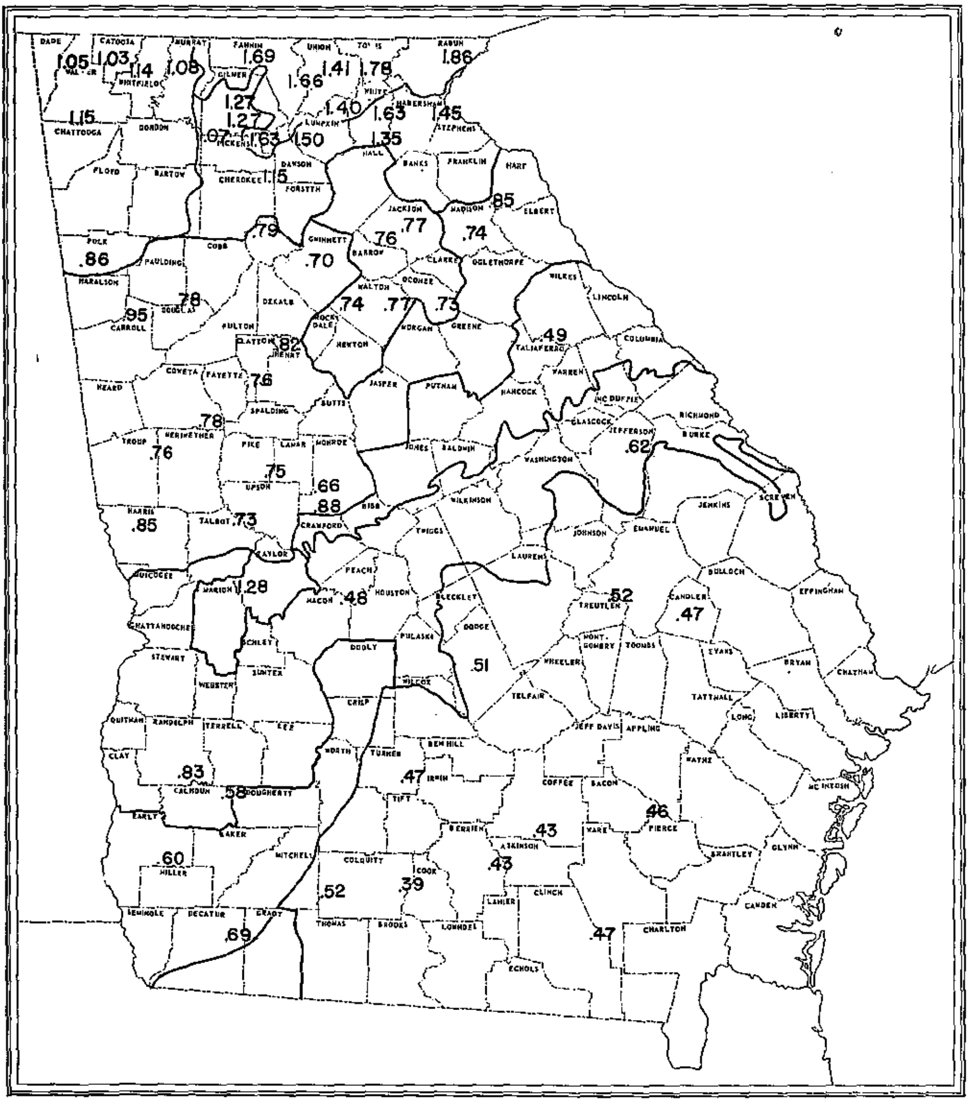


Figure 37. Map showing average flow in million gallons per day per square mile, for 18-year period, 1937-55, for index areas in Georgia.

NOTE: Interpolations of average flow will be doubtful for 16 coastal counties and in areas where adjacent figures are greatly different or are far apart.

storage operations or diversions. If a large proportion of the drainage area contains farm ponds, natural lime sinks, or natural lakes and swamps, it may not be possible to estimate the average flow on the basis of existing streamflow information. For such sites, a site investigation and some streamflow records at the site would be necessary.

It is likely that there will be so much regulation and water storage in the future that estimates of the natural average flow will no longer be reliable from drainage-area comparisons with the present gaging-station information without additional streamflow records and records of diversions, storage, and evaporation with which to relate the natural average flow to the actual conditions at the site. When those difficulties are anticipated, provisions should be made to secure the supplemental information well in advance of the need.

Low Flow

Measurements of low flow at 1,060 sites during the 1954 drought showed that low flows of small streams cannot be estimated accurately from drainage-area comparisons, even under natural conditions.

Some of the variations in low flows of small streams that may be expected within a small area are illustrated in figure 38 (p. 180). It shows the results of low-flow measurements at 40 sites in the Yellow River basin above the Snellville gaging station which were correlated with the gaging-station record to determine the minimum daily flow during the 1954 drought. The drainage area is only 134 square miles and is only 16 miles in its longest dimension, but the flows per unit of area range from zero to as much as nine times the unit flow at the gaging-station.

Examination of figure 38 shows that large unit flows tend to predominate in the southeastern part of the area and low unit flows in the northwestern part. There may be a physical reason for this trend, but careful examination of the drainage basin has not yielded evidence of recognizable physical features that would enable an engineer to predict the flows that are defined by the actual stream-flow measurements.

A gaging-station record at the site may be the only satisfactory means to secure the information required for large water supplies and water uses and for the information required in areas where water conflicts occur. In other areas,

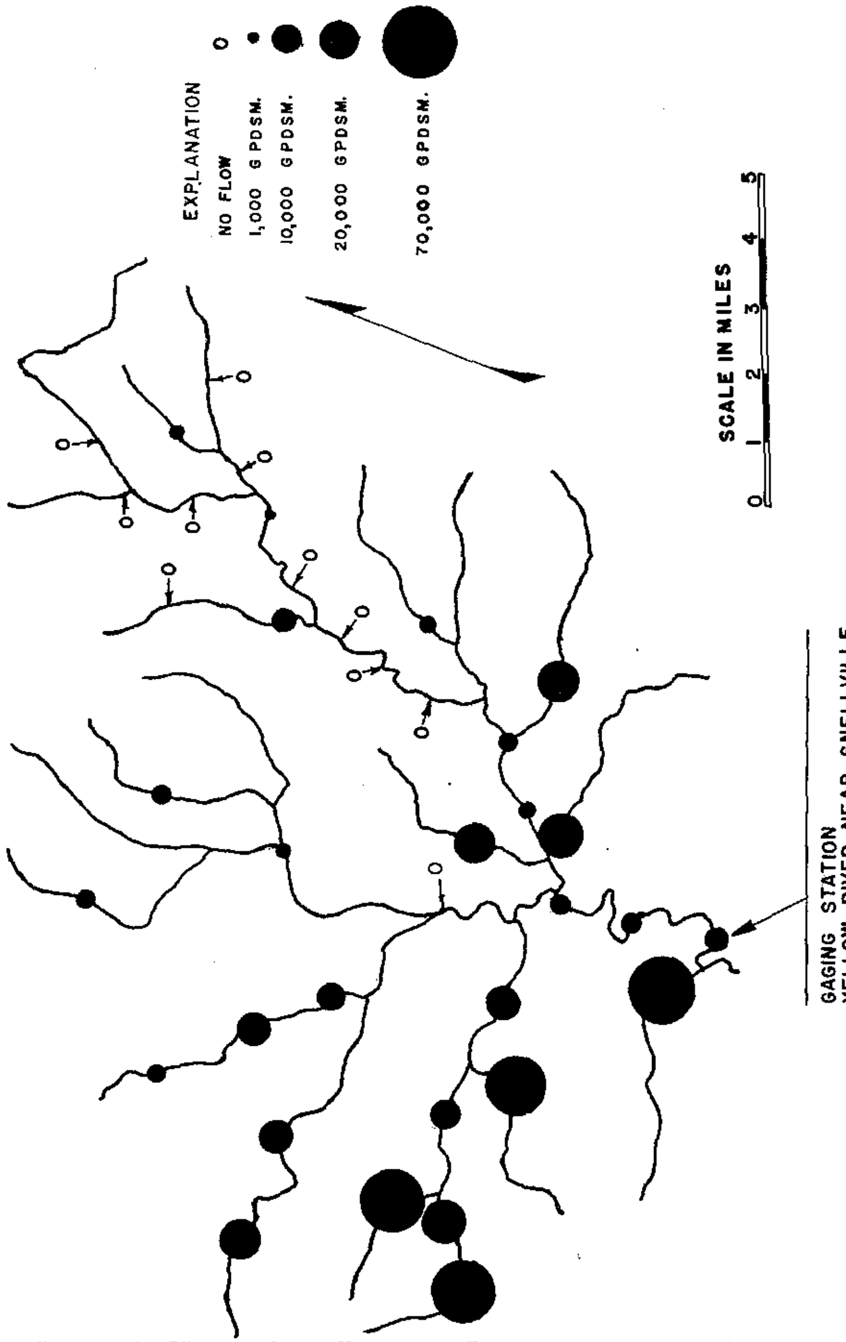


Figure 38. Map of the Yellow River Basin showing the minimum flow during the 1954 drought at selected sites in the basin in gallons per day per square mile.

a correlation between gaging station records and a few low-flow measurements at or close to the site may provide reasonably reliable information for most purposes.

The low-flow measurements need not necessarily be made at a time of extremely low flow, but they must be made during base-flow conditions. The methods of making correlations of low flows are described in the following sections.

Gaging Stations

It has long been recognized that two gaging stations at sites close together on the same stream and having nearly the same sized drainage areas should have practically the same flows per square mile of drainage area, day by day, month by month, and year by year so long as there are no man-made or unusual natural reasons for a difference and so long as the whole drainage basin involved is in a reasonably homogenous area. The differences in flow caused by local rainfall variations should average out over a short period of time. If, however, the two gaging stations are located a considerable distance apart their flows will tend to differ and if the two stations are on different streams the difference in the day-by-day flows will become greater as the opportunities for differences in rainfall and basin characteristics increase.

These differences, however, may not be entirely random or accidental. There is a strong tendency for corresponding flows to be related to each other though not always in proportion to their drainage areas. The correlation is generally best when long-term average flows are compared. The correlation for a wide range of conditions, from low flows to high flows cannot be determined, however, from a relationship based on average flows alone.

Correlations between two gaging station records are most satisfactorily determined by comparison of the monthly mean flows for the whole period for which records at both stations are available. This subject is discussed more fully by Langbein and Hardison in the publication, **Extending Stream Flow Data,** Proceedings American Society Civil Engineers, Paper No. 826.

Correlation techniques have wide application to the establishment of conservation and utilization flows. They were employed, for example, in the computation of the proportional utilization flows on Yellow River for the water used at downstream cities and power plants. The correlations, shown in figure 39 (p. 183) were made between the flow record at the Snellville gaging station and that for each of the downstream gaging stations where the water was being used. For the given utilization flow at each downstream site, the correlation curve was employed to determine the corresponding flow at Snellville.

Similar correlations have been computed for 60 pairs of gaging stations in Georgia in order to estimate some of the data for the 18-year standard period that are listed in table 8 (pp. 119-143).

Partial-Record Stations

Correlation curves between gaging-station records generally show certain common characteristics. The low-water portion of the curves usually plots as a straight line on logarithmic paper, and the higher portion of the curve generally shows nearly the same flow per square mile at flows above about one-and-a-half times the average flow. Using these characteristics, a curve may be estimated for the correlation between the flow at a site at which low-flow measurements have been made and the flow at a nearby index gaging station. An example of how such a correlation curve may be estimated is given in figure 40 (p. 184). After having drawn a correlation curve, it may be entered with any desired low-flow amount at the gaging station, such as the conservation or a utilization flow, and the corresponding flow for the ungaged site may be read from the curve.

The validity of this estimate can be determined best by the consistency of the relationship as shown by measurements under different low-flow conditions, preferably in different years. If the resulting correlations are in close agreement, an average curve may be employed with some confidence. If they differ considerably, the relationship between the flows at the two sites should be viewed with suspicion and the most conservative flow employed. A number of observations ought to be made before the estimate may be considered valid, the number depending on the consistency with which the data correlate and the permissible risk involved. A large investment that is highly dependent on a continuous supply of water requires better data than a small investment that will not be harmed by water shortages.

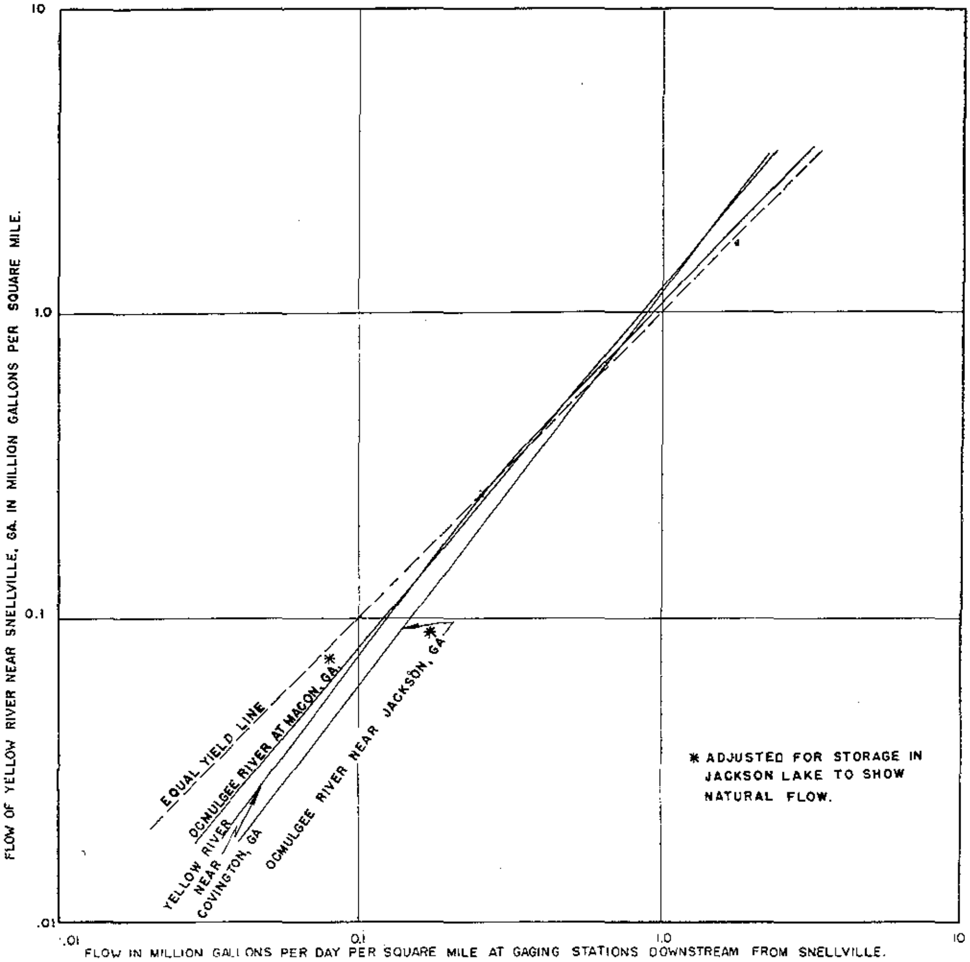


Figure 39. Correlation curves between the flow of Yellow River near Snellville and the flow at downstream gaging stations.

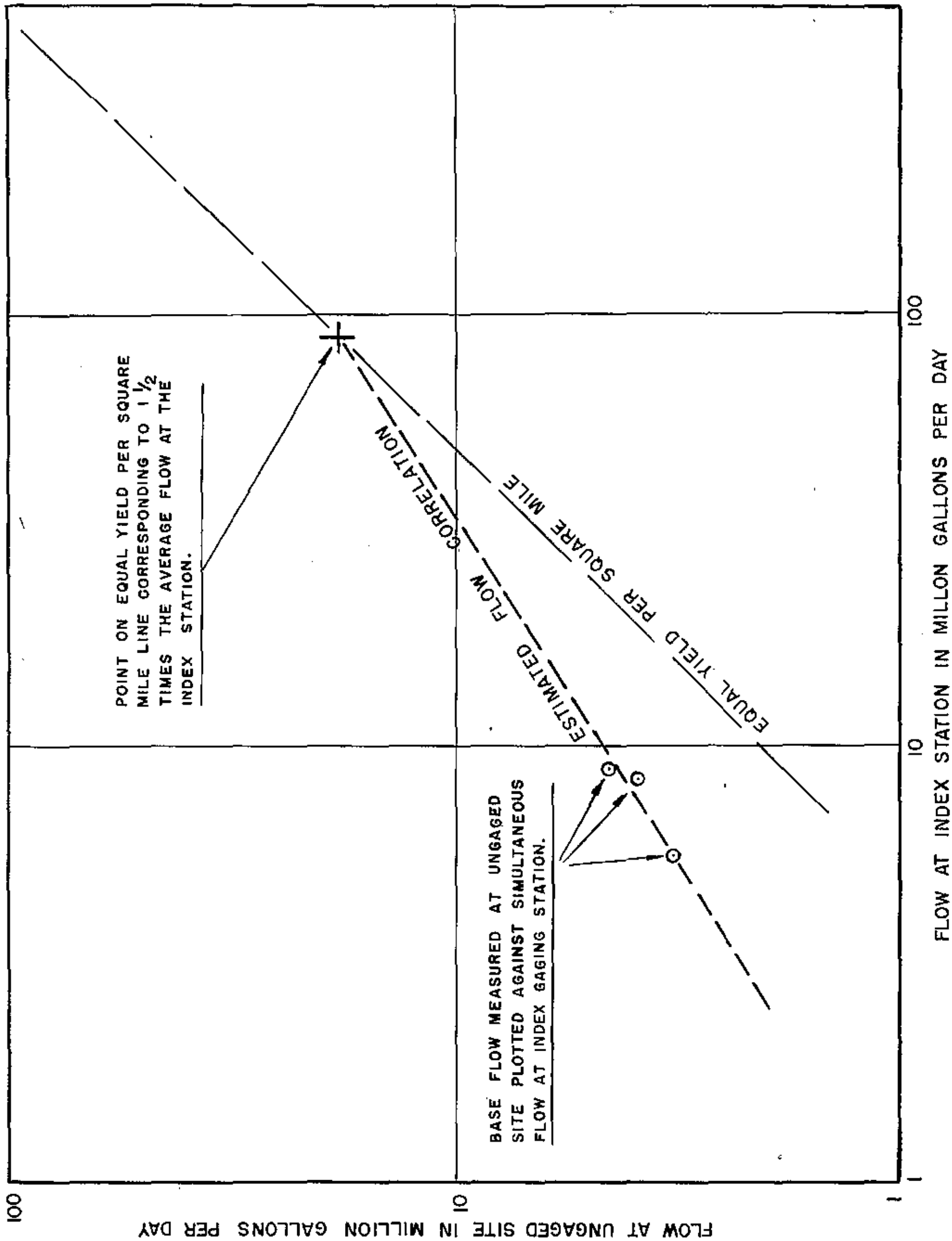


Figure 40. Illustrations of a method of estimating a curve of relation between the flow of a gaged and an ungaged stream.

Application to Specific Sites

A property owner could estimate any desired flow at a site by use of a correlation curve between the flow at his site and the flow at the nearest index gaging station or partial-record gaging station. First he would need one or more flow measurements made during base-flow conditions and would need to know the drainage area at his site. Then he would obtain from the U. S. Geological Survey office the simultaneous flow, and the average flow at the appropriate index station. (If he uses a partial-record station he would need a simultaneous measurement at the partial-record station also, because there will be no record being currently obtained.) Then he would prepare a correlation curve as described above. To compute the conservation flow or utilization flow at his site he would obtain definition of the conservation flow or utilization flow for the gaging station from the proper State water agency and transpose this to his site through use of the relation curve. Having determined the conservation flow or utilization flow at his site, the property owner could then provide for the release of the required flow through gates or valves if his development includes a dam across the channel.

If a farmer plans merely to pump from the channel when the flow is in excess of the flow reserved for other uses, he would need to know when there is excess flow at his site. Although gaging stations are used to measure and control diversions in the West and could be justified for major developments in Georgia, the expense for an individual farm would probably exceed the benefits from the use of the water. Furthermore, it would be impractical for him to measure the flow whenever he expects to pump. Thus, some other procedure is needed to indicate when excess water is available.

One procedure for indicating excess flows would be to have a mark set by a competent hydraulic engineer to show the level corresponding to the flow that must be passed. Unfortunately, there are few stable channels in Georgia and a mark set in one season might represent a greatly different flow after the next high water.

Another procedure would be to equip a number of index gaging stations with telephone devices with which any one can call up the nearest station and receive a signal which indicates the stage. From the stage he can derive the flow at that time and its relation to regulation flows. This could indicate, as a general guide, when diversions are permissible on nearby streams.

Regardless of how elaborate a system was devised, conflicts among a number of people all of whom might wish to pump at the same time could hardly be avoided. It would seem that the services of a water master would serve the needs of all the users in an irrigation district better than any system under which many persons would attempt to interpret individually the complexities of streamflows.

Water masters serve in irrigation districts in the West to allocate water among the property owners who have water rights. The water masters also measure diversions and pumping and sometimes help the parties to reach agreement over conflicting water claims.

It appears unlikely that there could be much irrigation in Georgia supplied by pumping water directly from flowing streams during low flow periods without conflict with other utilization, particularly north of the Fall Line.

Excess Flow

Excess-flow curves are derived from duration curves which show the percent of time the flow was equal to or greater than given rates of flow. The excess flow is indicated by the area under the duration curve and above the conservation or utilization flow and may be converted readily to an average rate of excess flow. Duration curves are readily derived by use of correlation studies, and excess-flow curves, in turn, may be derived from the duration curves.

The authors have studied excess-flow curves on a regional basis and have concluded that the variations within the streamflow regions are too great to warrant the use of regional average curves. Until further research discloses better means, excess flows should be determined on the basis of studies for the specific sites.

Storage

The determination of storage curves at ungaged sites by correlation is not as direct and simple as the determination of low-flow rates. Storage is a volume that is computed by summation of the difference between the daily flow rates and the draft rate. The volume of storage required depends largely on the sequence of the flows on the hydrograph. If high and low flows alternate, the storage volume will be very small in comparison with that required for a long sequence of high flows followed by a long sequence of low flows. Thus, a flashy stream may have different storage requirements than one with more uniform flow, even though there may be a good correlation between their monthly flows. Therefore, the correlation curve cannot be applied directly to transpose a storage curve except in very favorable circumstances such as at two nearby sites on the same stream where the storm runoff as well as the base flows are comparable. Unless further research discloses satisfactory regional criteria for estimates of storage requirements they should be determined on the basis of individual studies for the specific sites. Those studies will need to be made by competent engineers.

Data and Study Requirements

Regional streamflow studies in Georgia on which both future development and possible public regulation of water use will depend are seriously handicapped by the lack of:

1. Base-flow measurements of small streams in all parts of the State.
2. Index gaging stations in many parts of the State.
3. Topographic maps.
4. Information on existing water-use installations to show utilization, storage, and regulation.
5. Research on regional excess curves and storage curves.
6. Index stations for chemical quality on major streams.
7. Partial-record stations for chemical quality on minor streams.
8. Representative complete-record sediment stations on selected major streams.
9. Partial-record sediment stations on other streams, where sediment is or may become a problem.
10. A sufficient amount of record on the above stations for determination of ten-year minimum and maximum concentration values and quality characteristics—including correlation with discharge and conservation water quality criteria.

FARM PONDS

The term "farm pond" is applied generally to almost any small body of water. The Census of Agriculture includes in their tabulations, "artificial ponds, small reservoirs, and earth tanks". Some of these may be natural ponds, or reservoirs created by substantial dams on small streams; others may be more on the order of mill ponds created by small dams on fairly large streams; still others may be "off-channel" ponds fed by diversion dams and ditches. These types generally depend on surface runoff from definite drainage areas for their supply of water. Another type of farm pond is a large pit supplied by rainwater and groundwater seepage, or even by water pumped from wells for which the drainage area has no significance because the surface-water contributions are negligible.

The following discussion of farm ponds is limited primarily to small reservoirs on ephemeral streams, the flows of which are derived from direct surface runoff (sometimes vaguely called "diffused surface waters"). The term "ephemeral" is applied to streams that flow only during rainstorms, or which continue to flow for only a short period thereafter—only as long as it takes for the water to drain off the surface of the drainage basin. An ephemeral stream does not necessarily have a permanent, clearly defined channel. The limitation of the discussion of farm ponds to small reservoirs on ephemeral streams is desirable in order to differentiate their characteristics clearly from those of reservoirs on perennial streams.

The flow characteristics of ephemeral streams differ from those of perennial streams principally in that ephemeral streams have no base flow, which usually constitutes a considerable part of the total runoff of perennial streams. Thus, annual runoff of ephemeral streams is usually less than that of perennial streams.

The flow of ephemeral streams is highly susceptible to modification resulting from land-use changes. The flood-control and conservation benefits of land management are primarily effective on the flow of ephemeral streams. Several studies have been made of the effects of forest cover and land management on ephemeral streams or on very small perennial streams. Among them is a striking example of the effect of forest cover on runoff demonstrated at the Coweeta Hydrologic Laboratory of the U. S. Forest Service: an average increase in runoff of 17 inches a year resulted from the clearing of forest trees on a small 19-acre drainage basin (Hoover, 1944).

Another series of experiments on land management at the U. S. Southeastern Piedmont Experiment Station near Watkinsville, Ga., achieved excellent results of storm-runoff modification on little plots measuring 1/40 of an acre.

On one 19-acre area at Watkinsville, the annual storm runoff was reduced from an average of six inches to an average of less than one inch by changing from row crops to continuous-cover crops (Hendrickson, 1949). The average annual runoff of perennial streams in the vicinity of Watkinsville is 16 inches. Thus, the annual runoff of 6 inches from the 19-acre area suggests that in the Piedmont province the average direct runoff of an ephemeral stream under normal row-crop practices is about 40 percent of that of a perennial stream. Under continuous-cover cropping practices, the direct runoff of the ephemeral stream was apparently reduced to less than 6 percent of that of a perennial stream.

The Watkinsville experiments did not include within their scope the determination of what part of the increased infiltration of surface water penetrated to the water table and thence, eventually became streamflow.

Except for the limited information of these experiment stations, there are no records in Georgia on ephemeral streams or farm ponds.

Water Supply of Ponds on Ephemeral Streams

Because of the lack of records on ephemeral streams or farm ponds with which to analyze their water supply, the direct runoff of the Yellow River near Snellville computed from flow hydrographs has been used in the following analysis. It may be assumed that this direct runoff is roughly equivalent to the runoff of an ephemeral stream in the Yellow River basin.

Figure 41 (p. 190) shows the hydrograph for a typical year and figure 42 (p. 191) shows that for the low year 1954 on the Yellow River near Snellville, plotted on logarithmic scales. On each figure a dotted line has been drawn which represents the base flow. The flows above the base-flow line rep-

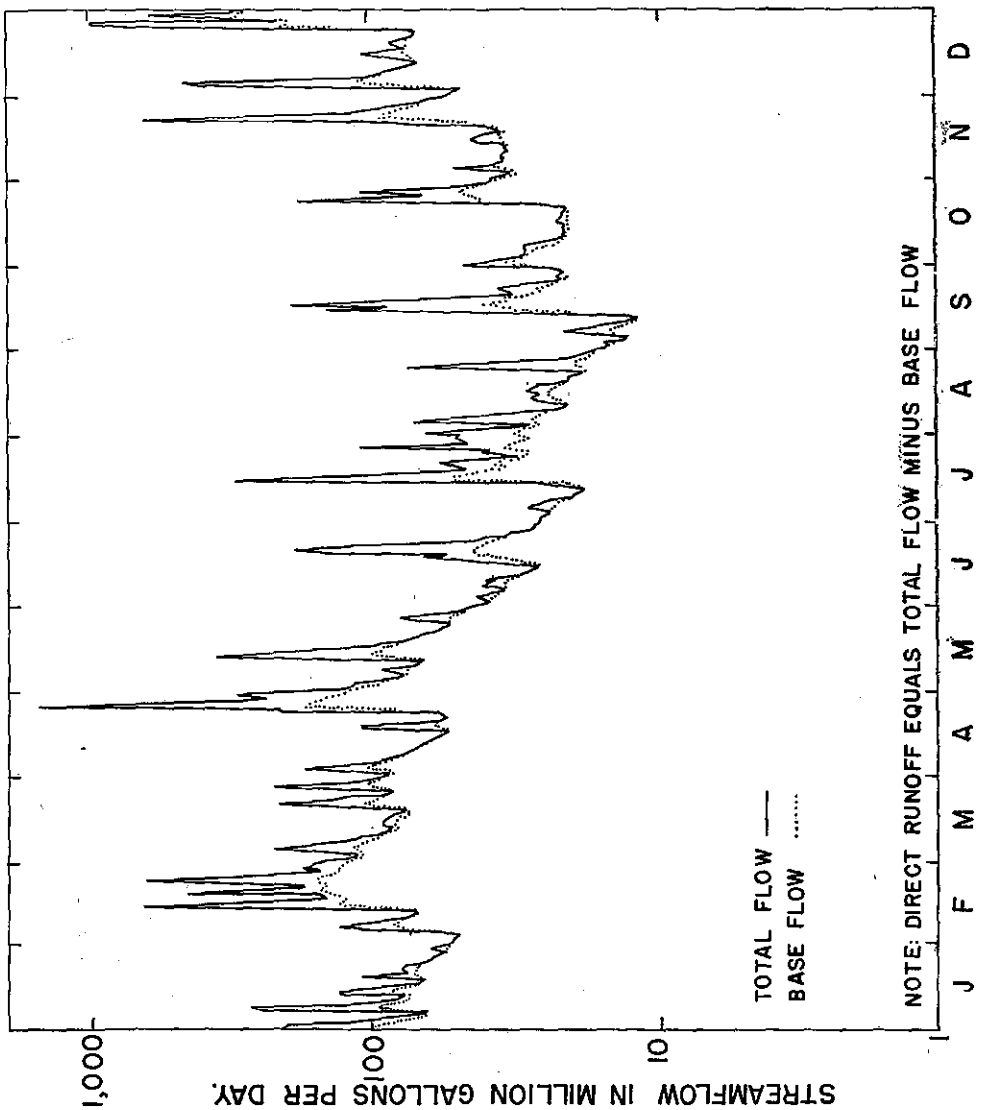


Figure 41. Hydrograph of daily flow of Yellow River near Snellville for a typical year showing total flow, base flow, and direct runoff.

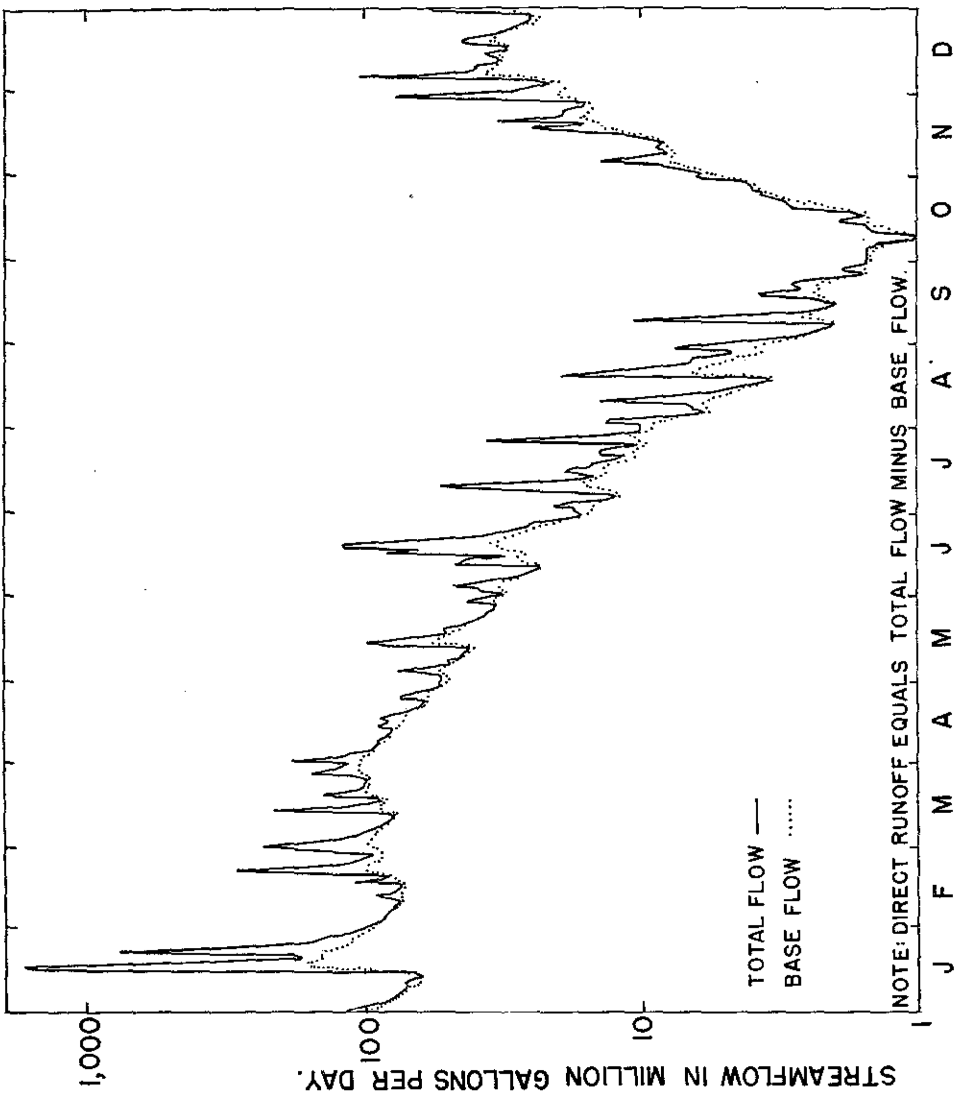


Figure 42. Hydrograph of daily flow of Yellow River near Snellville for the year 1954 showing total flow, base flow, and direct runoff.

resent the direct runoff. The direct runoff becomes streamflow immediately after a rain storm and, thus, provides a basis for estimating runoff to be expected in ephemeral streams. At the Yellow River at Snellville, direct runoff constituted about 40 percent of the total runoff for the standard period 1937-55, the same percentage found for row-crop practices at Watkinsville. The techniques for determining base flows are still largely experimental and subject to personal opinion. Consequently this method of estimating direct runoff for any specific site on an ephemeral stream would have little value. Moreover a specific site would probably have characteristics that differ considerably from the average as the Watkinsville experiments demonstrated. However, a precise determination of the direct runoff is not necessary for this discussion of an average farm pond on an ephemeral stream.

The average farm pond in the Piedmont region has a maximum depth of 9 feet, a surface area of 2.25 acres, and a volume of 2.7 millions of gallons. The curves of volume and surface area of the pond in figure 43 (p. 193) were computed (with modification to give volume in gallon terms) from the equation used by the Soil Conservation Service for small ponds: $V = .4\ AD$, in which V is volume in acre-feet, A is surface area in acres, and D is depth in feet.

If a properly designed pond is built it will contain water most of the time. Rain that falls on the water surface will run off when the pond is full or will be added to the pond's content when the pond level is below the outlet. On the other hand, the presence of the pond will result in a loss of water through evaporation.

To determine the net volume of water available in the average pond during any period, it is necessary to consider the runoff from its drainage area and the rainfall and evaporation from the pond surface. Using direct runoff rates per square mile based on a hydrograph analysis such as shown on figure 42 (p. 191) and adjusting for rainfall and evaporation within the pond area for the replenishment period following the drought of 1954, it was found that a drainage area of 45 acres would have been necessary to fill a pond of average size during the replenishment period November 1, 1954 to March 31, 1955.

Having determined the minimum drainage area of the

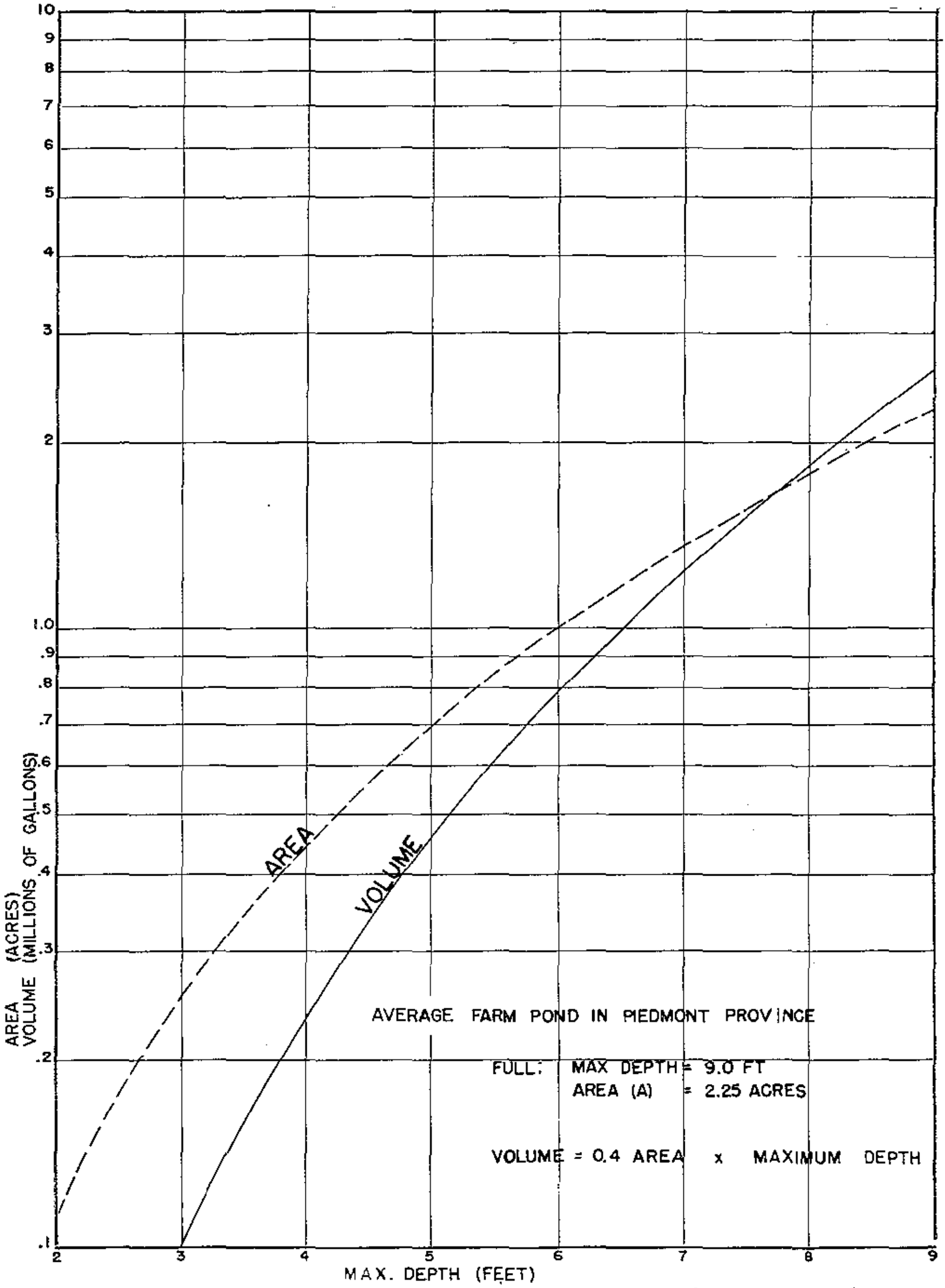


Figure 43. Area-volume-depth relations of an average farm pond in the Yellow River basin.

average pond, the volume of water that would have been available in the pond during the critical deficiency period, 1954-55, and the typical year, was computed. This was done by assuming that the pond was full at the beginning of each period and adding or subtracting the runoff from the drainage area and the rainfall and evaporation on the pond surface on a monthly basis.

The resulting monthly hydrographs in figure 44 (p. 195) show the supply of water that would have been available during a typical year and during the dry period of 1954-55 in an average Piedmont pond having the minimum drainage area to replenish it during the critical period of 1954-55. During the typical year the net evaporation loss was slight; in only two months was the pond volume reduced by evaporation. Net evaporation loss for the typical year was only 0.6 percent of the runoff of 6.6 mg, a negligible loss. During 1954, the net evaporation loss was equal to about 43 percent of the runoff of 3.5 mg.

Although no allowance has been made in the computations for seepage, it is recognized that it would reduce still further the supply of water available.

Water Utilization from Small Ponds

How much land could be irrigated with water available in an average farm pond of 2.7 mg capacity? The hydrographs in figure 44 (p. 195) shows that in a dry year water is more plentiful for early-season irrigation than for late-season irrigation. Many crops raised in Georgia require irrigation water during July and August. If all of the water available from the average pond during July and August of the typical year were applied in the amount of 0.5 acre-ft (0.163 mg) per acre per month for the two-month period, a total of about 8 acres could be irrigated. (If the 1.0 acre-ft per year was applied over an earlier period than July and August, somewhat more than 8 acres could be irrigated because less of the water would have had a chance to evaporate.) Including 0.1 mg evaporation loss, irrigation of the 8 acres would have used 2.7 mg, or 0.35 mg per acre per year. At the rate of 0.35 mg per acre per year, the estimated future average irrigation use for the Yellow River basin above Snellville during an average year would be 1,060 mg if the water were ob-

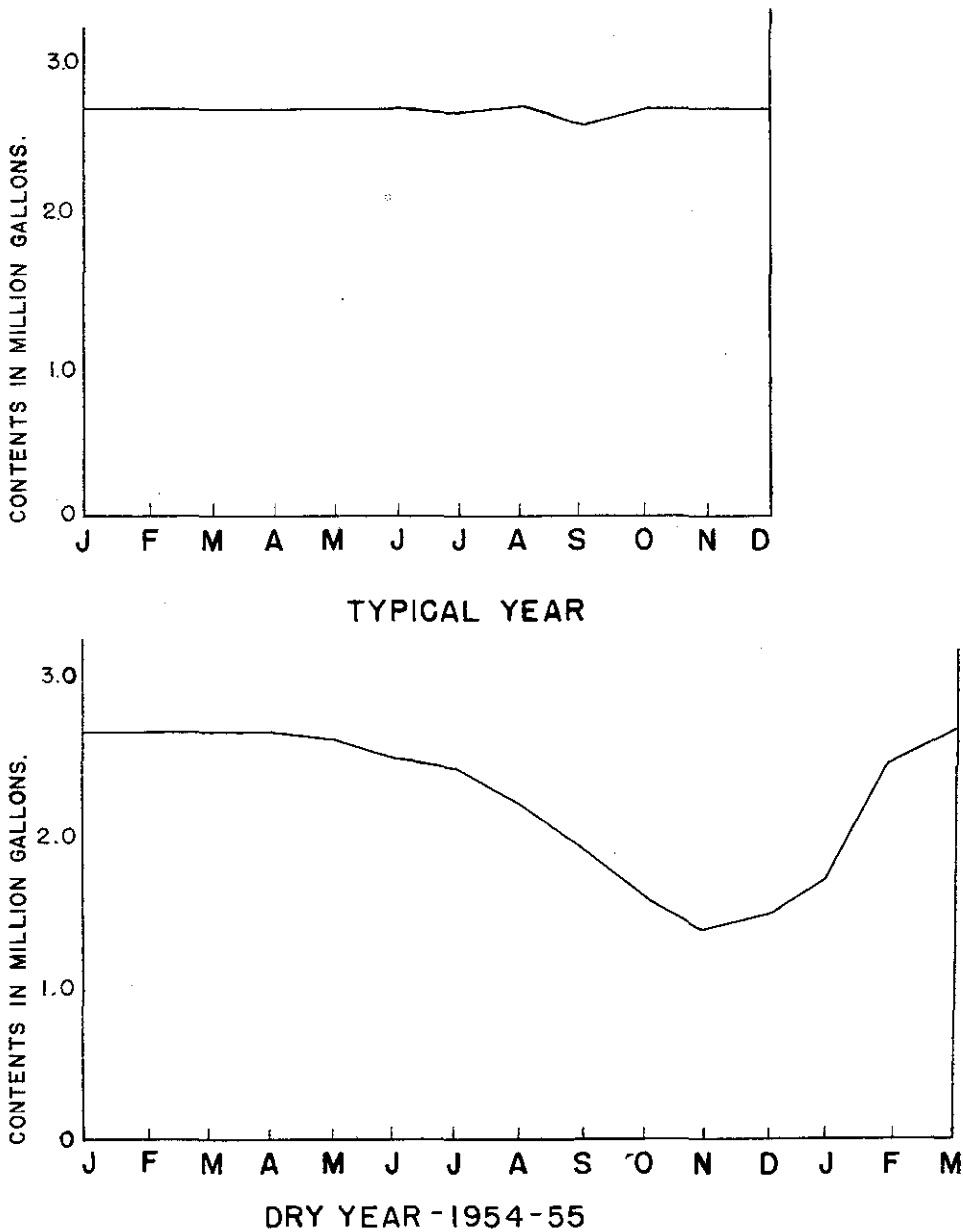


Figure 44. Estimated month-end contents of an average farm pond in the Yellow River basin, assuming no withdrawal for irrigation.

tained from average-size ponds. This is equivalent to 2.9 mgd flowing an entire year.

Six acres could have been irrigated by the average pond in the dry 1954 season. Irrigation of the 6 acres would have taken about 3.3 mg (0.55 mg per acre per year) including 1.4 mg evaporation loss. At the rate of 0.55 mg per acre per year, the estimated future irrigation use for the Yellow River basin above Snellville during a dry year would be 1,700 mg or the equivalent of 4.7 mgd flowing the entire year.

Comparison of Evaporation Losses Between an Average Small Pond and a Large Reservoir

The comparative efficiencies of the average small pond in the Yellow River basin above Snellville and Jackson Lake, the reservoir at Lloyd Shoals, with respect to evaporation losses for a typical year and the dry year 1954 are shown in the following table. Figures are based on the data used in the preparation of figure 44 (p. 195) and the data used in the discussion of evaporation at Jackson Lake on page 111. Estimated evaporation losses, expressed as percentages of the runoff from the drainage area for the year, are as follows:

	1945 percent	1954 percent
Average farm pond (2.25 acres)— no withdrawal of water	0.6	43
Average farm pond (2.25 acres)— used for irrigation in July and August	0	39
Jackson Lake (4,750 acres)— used for power	0	1.6

From this table it may be seen that in a typical year, such as 1945, little or no net evaporation loss takes place from either a small pond or a reservoir. However, during an especially dry year, such as 1954, the large reservoir loses much less water in proportion to the runoff of its drainage basin than the average farm pond.

Effect of Ponds on Downstream Flows

The estimated future average irrigation use of water in the Yellow River basin above Snellville of 4.7 mgd including the evaporation losses under severely dry conditions if all the water were obtained from average sized farm ponds is less than a third of the average annual excess flow corresponding to average power production at Lloyd Shoals Dam. This would indicate that there are sufficient water resources to supply anticipated irrigation needs and the existing utilization flows.

However, an important time element is involved. Lloyd Shoals Dam uses the entire flow from the Yellow River basin including flood flows when the reservoir is not full. In the critical replenishment period of 1954-55, for example, no water was wasted over the spillway at Lloyd Shoals Dam, and consequently, any water withdrawn by the operators of upstream ponds during this period would have reduced the quantity available for power generation at Lloyd Shoals Dam.

If the farmers replenished their irrigation ponds during a critical low winter like that of 1954-55 as soon as runoff became available, without making allowances for downstream utilization, about 1,450 million gallons would be withdrawn from the Yellow River basin. This would result in a loss of about one percent of the potential energy of the flow from the Yellow River Basin at Lloyd Shoals Dam in 1955.

Farm Ponds in Georgia by Counties

Table 12 (p. 198) shows the number of farm ponds (artificial ponds, small reservoirs, and earth tanks) enumerated in the 1954 Census of Agriculture and the average area and average maximum depth of farm ponds estimated by the Agricultural Extension Service in 1955 for the State by counties. It also shows the total capacity of farm ponds in each county estimated from those data. These ponds are not limited to those on ephemeral streams.

Figure 45 (p. 204) shows the general pattern of farm pond density over the State, generally averaging one pond within an area of one to ten square miles. There is a notably greater density in a band of counties in southern Georgia and in a smaller group of counties in northwestern Georgia. There are relatively few ponds in the mountains, close to the coast, and in a band of counties in the upper Coastal Plain.

The 27,061 farm ponds in Georgia in 1954 had an estimated total area of about 86,000 acres and a total capacity of about 79,000 million gallons. In comparison, the 22 power reservoirs built or under construction in 1955 have a total area of about 250,000 acres within the State boundaries and a usable capacity of 1,620,000 million gallons. The average

Table 12.—Farm ponds in Georgia in 1954

County	Land Area (sq. mi.)	Number of ponds[1]	Average area of ponds[2] (nearest acre)	Average max. depth of ponds[2] (nearest foot)	Total capacity of all ponds in county[3] (mg)
Appling	514	145	3	5	280
Atkinson	318	252	2	5	330
Bacon	293	89	7	9	730
Baker	355	13	8	4	54
Baldwin	265	57	3	5	110
Banks	231	47	2	20	240
Barrow	171	63	2	9	150
Bartow	476	358	2	6	4,200
Ben Hill	255	189	2	5	250
Berrien	466	411	2	5	540
Bibb	251	112	4	9	530
Bleckley	219	144	3	7	390
Brantley	447	31	2	3	30
Brooks	492	316	4	6	860
Bryan	439	4	3	3	5
Bulloch	684	654	4	7	2,400
Burke	832	89	4	5	230
Butts	185	35	2	10	110
Calhoun	289	56	2	6	88
Camden	656	2	4	7	7
Candler	251	487	4	6	1,600
Carroll	495	221	2	10	580
Catoosa	167	240	1	6	140
Charlton	799	[2] 6	1	6	3
Chatham	441	59	2	8	150
Chattahoochee	253	12	4	8	50
Chattooga	317	300	2	6	470

See footnotes at end of table.

Table 12.—Farm ponds in Georgia in 1954—Continued

County	Land Area (sq. mi.)	Number of ponds[1]	Average area of ponds[2] (nearest acre)	Average max. depth of ponds[2] (nearest foot)	Total capacity of all ponds in county[3] (mg)
Cherokee	428	109	2	10	210
Clarke	125	92	4	8	380
Clay	224	32	1	7	35
Clayton	149	114	4	12	620
Clinch	796	13	25	3	130
Cobb	348	230	5	12	1,800
Coffee	613	1,024	6	4	3,300
Colquitt	563	1,351	4	6	4,200
Columbia	306	171	3	5	330
Cook	226	256	3	4	400
Coweta	443	172	3	8	570
Crawford	313	57	2	8	120
Crisp	296	238	2	5	390
Dade	165	138	*	10	36
Dawson	213	30	2	12	62
Decatur	612	153	2	5	250
De Kalb	269	115	2	6	180
Dodge	499	470	4	7	1,700
Dooly	394	81	3	6	190
Dougherty	326	31	2	5	40
Douglas	201	35	5	12	270
Early	526	226	2	8	590
Echols	425	4	8	5	20
Effingham	480	46	7	14	590
Elbert	362	224	2	4	180
Emanuel	686	422	5	7	1,900
Evans	186	222	5	7	1,000

See footnotes at end of table.

Table 12.—Farm ponds in Georgia in 1954—Continued

County	Land Area (sq. mi.)	Number of ponds[1]	Average area of ponds[2] (nearest acre)	Average max. depth of ponds[2] (nearest foot)	Total capacity of all ponds in county[3] (mg)
Fannin	396	15	3	12	70
Fayette	199	69	3	8	230
Floyd	514	427	3	5	830
Forsyth	243	95	4	12	590
Franklin	269	114	2	7	160
Fulton	523	198	3	8	660
Gilmer	439	37	2	11	130
Glascock	142	19	2	9	40
Glynn	423	14	2	10	40
Gordon	358	451	3	10	1,500
Grady	467	399	2	10	780
Greene	404	102	1	8	110
Gwinnett	437	199	2	11	700
Habersham	283	82	2	8	170
Hall	426	119	1	10	160
Hancock	485	108	3	5	210
Haralson	285	126	2	12	300
Harris	465	140	5		550
Hart	257	151	1	5	79
Heard	301	50	2	9	88
Henry	331	99	6	10	770
Houston	379	48	4	10	250
Irwin	372	482	4	7	1,800
Jackson	337	175	4	9	720
Jasper	373	91	2	5	150
Jeff Davis	331	176	3	7	480
Jefferson	532	173	7	10	1,600

See footnotes at end of table.

Table 12.—Farm ponds in Georgia in 1954—Continued

County	Land Area (sq. mi.)	Number of ponds[1]	Average area of ponds[2] (nearest acre)	Average max. depth of ponds[2] (nearest foot)	Total capacity of all ponds in county[3] (mg)
Jenkins	351	82	4	6	220
Johnson	313	291	5	5	950
Jones	402	113	4	5	330
Lamar	181	120	2	10	390
Lanier	167	53	3	7	150
Laurens	811	680	3	8	2,100
Lee	355	40	6	6	190
Liberty	510	18	4	7	66
Lincoln	253	104	1	6	81
Long	403	16	5	12	120
Lowndes	506	375	4	6	1,000
Lumpkin	292	50	4	15	410
McDuffie	263	223	2	6	350
McIntosh	431	1	1	6	1
Macon	399	63	3	9	220
Madison	281	76	2	11	163
Marion	365	65	4	5	190
Meriwether	499	102	2	7	140
Miller	287	58	2	5	95
Mitchell	511	243	2	5	400
Monroe	399	133	2	9	310
Montgomery	235	173	4	6	470
Morgan	356	125	3	9	440
Murray	342	210	1	7	190
Muscogee	220	135	4	6	370
Newton	273	119	4	10	620
Oconee	186	60	3	11	260

See footnotes at end of table.

Table 12.—Farm ponds in Georgia in 1954—Continued

County	Land Area (sq. mi.)	Number of ponds[1]	Average area of ponds[2] (nearest acre)	Average max. depth of ponds[2] (nearest foot)	Total capacity of all ponds in county[3] (mg)
Oglethorpe	432	81	2	10	210
Paulding	318	67	3	6	160
Peach	151	22	3	10	86
Pickens	225	31	3	7	85
Pierce	342	66	4	8	270
Pike	230	117	3	8	390
Polk	312	495	1	5	260
Pulaski	254	83	5	7	380
Putnam	350	31	3	5	61
Quitman	170	30	2	8	63
Rabun	369	25	1	8	26
Randolph	436	53	3	8	170
Richmond	325	86	2	15	340
Rockdale	128	38	2	9	110
Schley	162	49	2	9	110
Screven	651	232	7	5	1,100
Seminole	274	75	3	4	120
Spalding	201	142	4	4	300
Stephens	180	10	2	12	31
Stewart	463	88	4	9	410
Sumter	491	62	5	6	240
Talbot	390	53	5	10	350
Taliaferro	195	25	2	9	44
Tattnall	493	444	3	6	1,000
Taylor	400	78	4	5	230
Telfair	440	239	2	4	250
Terrell	329	66	7	9	540

See footnotes at end of table.

Table 12.—Farm ponds in Georgia in 1954—Continued

County	Land Area (sq. mi.)	Number of ponds[1]	Average area of ponds[2] (nearest acre)	Average max. depth of ponds[2] (nearest foot)	Total capacity of all ponds in county[3] (mg)
Thomas	540	572	4	6	1,600
Tift	266	669	4	6	1,800
Toombs	369	422	5	5	1,400
Towns	172	11	2	9	26
Treutlen	194	223	2	8	460
Troup	447	85	4	8	350
Turner	293	390	4	8	1,500
Twiggs	365	67	2	6	100
Union	319	6	3	9	21
Upson	333	77	3	8	260
Walker	448	762	*	3	90
Walton	330	176	4	9	720
Ware	912	105	2	4	150
Warren	284	184	3	3	200
Washington	674	235	4	8	1,100
Wayne	646	118	4	7	430
Webster	195	92	5	8	480
Wheeler	306	262	3	9	920
White	243	46	2	15	130
Whitfield	281	548	1	6	430
Wilcox	383	187	3	8	580
Wilkes	472	153	3	3	180
Wilkinson	458	42	4	8	180
Worth	580	516	2	8	1,100
State	58,518	27,061			79,000

[1] Data from 1954 Census of Agriculture.
[2] Data from Agricultural Extension Service files.
[3] Computed on basis of formula: Volume (in acre–feet) = .4 x Area (in acres) x Depth (in feet).
* Less than 0.5 acre.

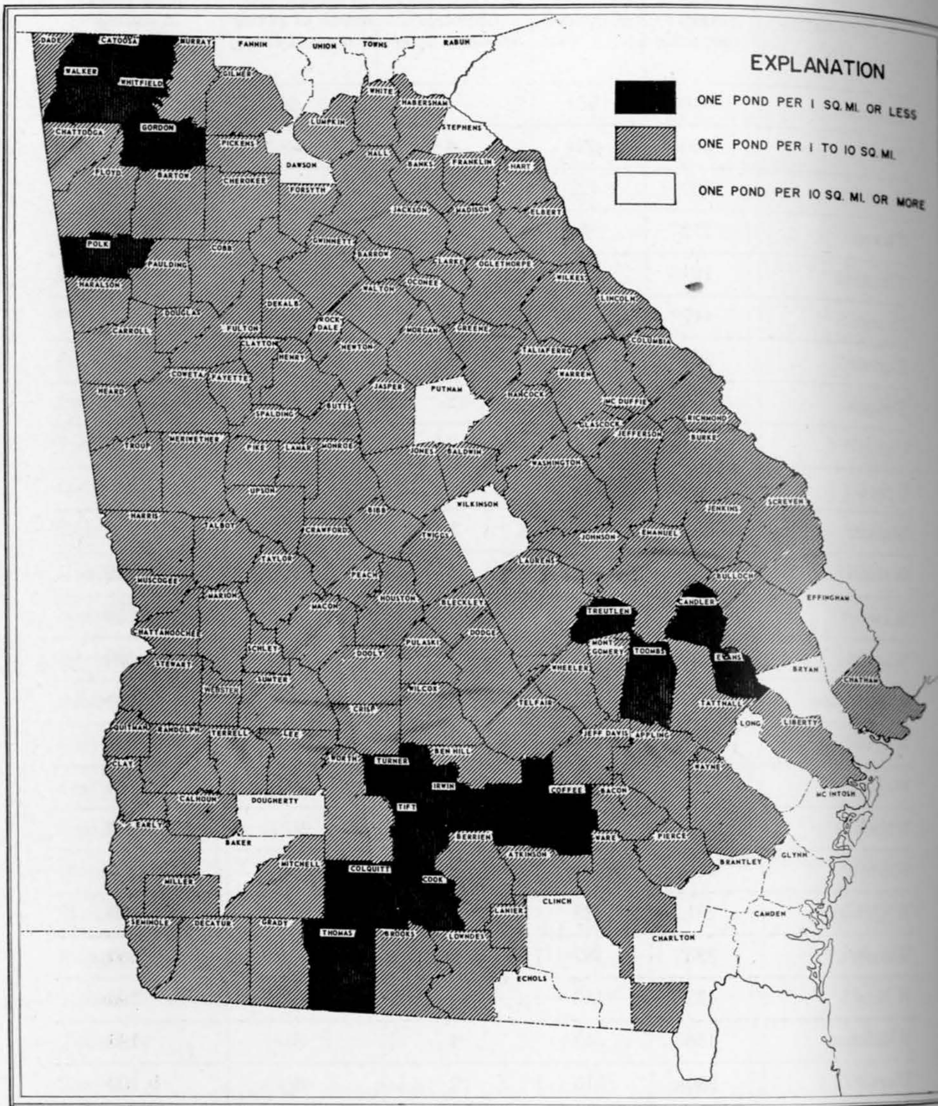


Figure 45. Map of Georgia showing average density of farm ponds in 1954 by counties, in square miles of county area per pond.

capacity of farm ponds is about 0.9 million gallons per acre of water surface while that of the power reservoirs is about 6.5 million gallons per acre. These comparisons are significant when evaporation losses from ponds and reservoirs are considered.

Evaporation from Farm Ponds in Georgia

Estimates of the net evaporation loss from farm ponds have been made by counties with the statistics in table 12 (p. 198) and precipitation and evaporation records of the U. S. Weather Bureau.

Statistics on pond areas compiled by the Agricultural Extension Service are not necessarily based on the same number of ponds that were counted by the Census of Agriculture. Also, not all of the 27,061 ponds listed in the Census were completed and full of water at the beginning of the year 1954. After making allowances for those factors, the net evaporation loss from all farm ponds in the State in 1954 was computed to be about 100 mgd.

Figure 46 (p. 206) shows the estimated average evaporation loss from farm ponds by counties during the year 1954. The loss is shown in gallons per day per square mile in order to make the amounts comparable for the counties of varying areas. The loss was generally within the range of 100 to 5,000 gallons per day per square mile. In two groups of counties in southern Georgia the evaporation loss from ponds generally exceeded 5,000 gallons per day per square mile. In those areas, many of the farm ponds are large and had high evaporation rates and low rainfall rates in 1954. Evaporation losses were notably low in the extreme northern counties where the rainfall in 1954 equaled or exceeded the evaporation. The counties near the coast also had generally low evaporation losses, due principally to the small number of ponds in the area.

Data Requirements on Ephemeral Streams and Farm Ponds

Except for the data at the two experiment stations and some work initiated in 1956 on pilot watersheds by the U. S. Geological Survey in cooperation with the Soil Conservation Service, there are no data applicable to Georgia's ephemeral

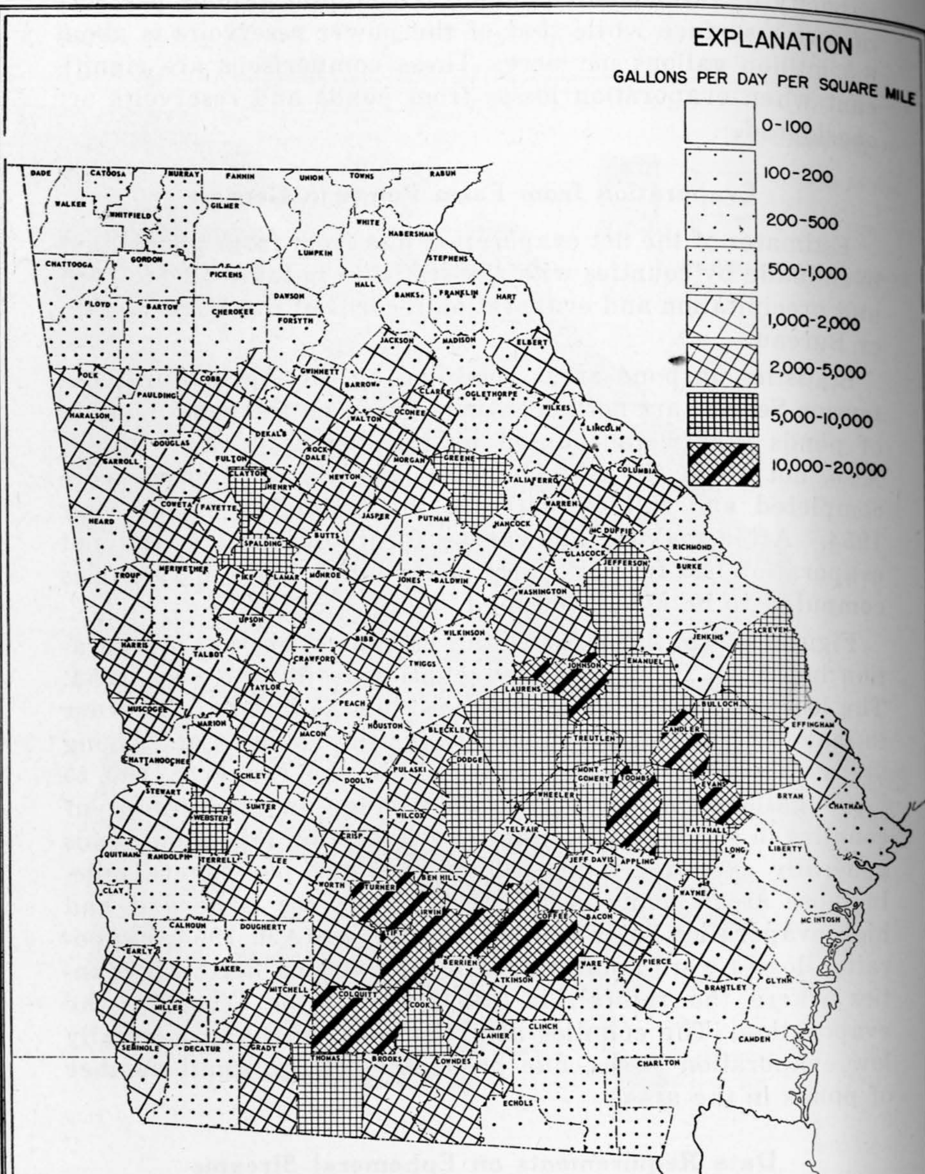


Figure 46. Map of Georgia showing average annual net evaporation loss from farm ponds in 1954, by counties, in gallons per day per square mile of county area.

streams and farm ponds. The preceding computations based on the separation of direct surface runoff by deducting base flows from the flows of a perennial stream are useful only for very broad estimates. Data are needed on the flow of ephemeral streams, the number and dimensions of farm ponds, the water evaporated from ponds, the water used from ponds for irrigation, the effect of ponds on water tables, the seepage from ponds, and the effect of ponds on storm runoff of ephemeral streams. These data are needed to evaluate the need for regulation of ponds and to provide sound bases for their design.

MAJOR RIVER SYSTEMS

The major rivers of Georgia each drain from two or more streamflow regions. Consequently, the regional characteristics shown by the index gaging stations seldom apply to the major rivers. Rather, the flow of a major river blends the regional flow characteristics as the river progresses through successive regions. Moreover, most of the major rivers are highly regulated by storage reservoirs and hydropower plants. Thus, major rivers are best treated by individual river basins rather than by regions.

The relation between available streamflow and average annual water use on the major rivers of Georgia is shown in table 13 (p. 208). The table lists the gaging stations in downstream order on all of the main stems of the rivers and for each station shows the drainage area, the estimated future maximum irrigation rate of water use, the smallest and the largest of the nine criteria for conservation flows, the largest proportional utilization flows for urban and industrial purposes at the maximum rate in 1955, and for urban, industrial, power and navigation purposes at average rates for 1955, the corresponding average excess flows, the estimated future average irrigation use, and the average flow for the standard period.

The estimated future maximum rate of irrigation use, if withdrawn from the rivers and their tributaries during the low-flow season would exceed the minimum flow of the rivers except in and adjacent to the Blue Ridge province where the irrigation requirements are small and the minimum river flows are large in proportion to the drainage areas.

Table 13.—Availability and estimated proportional utilization flows on the major rivers of Georgia
(million gallons per day)

Map no.	Gaging station	Drainage area sq. mi.	Estimated future maximum irrigation use	[1]Conservation flow		Proportional utilization flow in 1955						Average excess flow						Estimated future average irrigation use	18-year Average flow 1937–55
						Maximum		Average											
				Minimum daily 20-year R. I.	Minimum monthly 2-year R. I.	Urban	Industrial	Urban	Industrial	Hydroelectric power	Navigation	[1]Daily 20-year R. I.	[1]Monthly 2-year R. I	Urban	Industrial	Hydroelectric power	Navigation		
	SAVANNAH RIVER BASIN																		
1	Chattooga River near Clayton, Ga.	207	8	57	155	1	32	1	32	380	150	330	230	380	350	0	240	1	385
3	Tugaloo River near Hartwell, Ga.	909	96	122	630	3	110	2	110	1,280	540	1,160	650	1,280	1,180	0	740	11	1,285
5	Savannah River near Iva, S. C.	2,231	510	349	1,310	6	250	5	250	2,800	1,200	2,450	1,490	2,790	2,550	0	1,600	56	2,800
7	Savannah River near Calhoun Falls, S. C.	2,876	730	411	1,490	6	280	5	280	3,130	1,350	2,720	1,640	3,130	2,860	0	1,780	80	3,135
17	Savannah River at Augusta, Ga.	7,508	1,600	**	**	16	720	13	720	1,000	3,420	**	**	5,840	5,130	4,850	2,430	180	5,849
18	Savannah River at Burton's Ferry Bridge near Millhaven, Ga.	8,650	1,800	**	**	19	90	16	62	0	4,300	**	**	6,460	6,410	6,470	2,180	200	6,476
20	Savannah River at Clyo, Ga.	9,850	2,000	**	**	23	110	20	75	0	5,000	**	**	7,120	7,070	7,140	2,140	220	7,142
	OGEECHEE RIVER BASIN																		
21	Ogeechee River near Louisville, Ga.	800	26	36	123	0	0	0	0	0	0	450	360	480	480	480	480	3	483

See footnotes at end of table.

Table 13.—Availability and estimated proportional utilization flows on the major rivers of Georgia—Continued
(million gallons per day)

Map no.	Gaging station	Drainage area sq. mi.	Estimated future maximum irrigation use	[1]Conservation flow: Minimum daily 20-year R. I.	[1]Conservation flow: Minimum monthly 2-year R. I.	Proportional utilization flow in 1955, Maximum: Urban	Proportional utilization flow in 1955, Maximum: Industrial	Proportional utilization flow in 1955, Average: Urban	Proportional utilization flow in 1955, Average: Industrial	Proportional utilization flow in 1955, Average: Hydroelectric power	Proportional utilization flow in 1955, Average: Navigation	Average excess flow: [1]Daily 20-year R. I.	Average excess flow: [1]Monthly 2-year R. I.	Average excess flow: Urban	Average excess flow: Industrial	Average excess flow: Hydroelectric power	Average excess flow: Navigation	Estimated future average irrigation use	18-year Average flow 1937–55
	OGEECHEE RIVER BASIN (Cont.)																		
22	Ogeechee River at Scarboro, Ga.	1,940	69	78	248	0	0	0	0	0	0	960	790	1,030	1,030	1,030	1,030	8	1,039
23	Ogeechee River near Eden, Ga.	2,650	90	85	308	0	0	0	0	0	0	1,280	1,060	1,360	1,360	1,360	1,360	10	1,367
	ALTAMAHA RIVER BASIN																		
25	South River near McDonough, Ga.	436	64	35	121	4	63	4	48	240	25	320	240	350	310	120	330	7	359
29	Ocmulgee River near Jackson, Ga.	1,420	300	45	378	11	160	9	120	710	66	1,010	680	1,040	930	340	990	33	1,053
31	Ocmulgee River at Macon, Ga.	2,240	480	83	535	17	240	14	180	0	99	1,490	1,030	1,500	1,390	1,570	1,470	52	1,573
35	Ocmulgee River at Hawkinsville, Ga.	3,800	760	271	1,020	0	0	0	0	0	370	2,280	1,540	2,550	2,550	2,550	2,190	83	2,556
36	Ocmulgee River at Lumber City, Ga.	5,180	1,060	522	1,250	0	0	0	0	0	720	2,890	2,160	3,410	3,410	3,410	2,700	116	3,415
40	Middle Oconee River near Athens, Ga.	283	67	18	103	1	0	1	0	250	29	290	200	300	300	50	280	7	304
41	Oconee River near Greensboro, Ga.	1,090	270	38	282	3	0	2	0	660	58	760	520	780	790	140	740	30	799

See footnotes at end of table.

Table 13.—Availability and estimated proportional utilization flows on the major rivers of Georgia—Continued
(million gallons per day)

Map no.	Gaging station	Drainage area sq. mi.	Estimated future maximum irrigation use	Conservation flow[1]		Proportional utilization flow in 1955						Average excess flow						Estimated future average irrigation use	18-year Average flow 1937–55
						Maximum		Average											
				Minimum daily 20-year R. I.	Minimum monthly 2-year R. I.	Urban	Industrial	Urban	Industrial	Hydroelectric power	Navigation	Daily[1] 20-year R. I.	Monthly[1] 2-year R. I.	Urban	Industrial	Hydroelectric power	Navigation		
	ALTAMAHA RIVER BASIN (Cont.)																		
44	Oconee River at Milledgeville, Ga.	2,950	800	58	500	4	0	3	0	1,600	80	1,870	1,430	1,920	1,920	330	1,850	75	1,929
45	Oconee River at Dublin, Ga.	4,400	950	226	706	0	0	0	0	0	330	2,600	2,120	2,820	2,820	2,820	2,490	104	2,824
47	Oconee River near Mt. Vernon, Ga.	5,110	1,100	291	939	0	0	0	0	0	420	2,930	2,280	3,210	3,210	3,210	2,800	124	3,218
49	Altamaha River at Doctortown, Ga.	13,600	3,000	924	2,560	0	0	0	0	0	1,300	7,180	5,540	8,100	8,100	8,100	6,800	328	8,105
	SATILLA RIVER BASIN																		
50	Satilla River near Waycross, Ga.	1,300	70	4	23	0	1	0	1	0	0	560	540	560	560	560	560	8	564
53	Satilla River at Atkinson, Ga.	2,880	100	14	79	0	0	0	0	0	0	1,320	1,260	1,330	1,330	1,330	1,330	11	1,335
	SUWANNEE RIVER BASIN																		
58	Alapaha River near Alapaha, Ga.	644	26	0	5	0	0	0	0	0	0	300	300	300	300	300	300	3	301
59	Alapaha River at Statenville, Ga.	1,400	67	11	48	0	0	0	0	0	0	590	550	590	590	590	590	7	598

See footnotes at end of table.

Table 13.—Availability and estimated proportional utilization flows on the major rivers of Georgia—Continued
(million gallons per day)

Map no.	Gaging station	Drainage area sq. mi.	Estimated future maximum irrigation use	[1]Conservation flow		Proportional utilization flow in 1955						Average excess flow						Estimated future average irrigation use	18-year average flow 1937–55
						Maximum		Average											
				Minimum daily 20-year R. I.	Minimum monthly 2-year R. I.	Urban	Industrial	Urban	Industrial	Hydroelectric power	Navigation	[1]Daily 20-year R. I.	[1]Monthly 2-year R. I.	Urban	Industrial	Hydroelectric power	Navigation		
	OCHLOCKONEE RIVER BASIN																		
63	Ochlockonee River near Thomasville, Ga.	550	40	2	16	0	0	0	0	170	0	280	270	280	280	120	280	4	287
	APALACHICOLA RIVER BASIN																		
66	Chattahoochee River near Leaf, Ga.	150	12	47	92	17	85	15	61	240	150	200	150	230	180	0	90	1	244
68	Chattahoochee River near Gainesville, Ga.	559	60	134	344	49	240	42	180	750	420	620	410	710	470	0	330	6	753
70	Chattahoochee River near Buford, Ga.	1,060	100	230	513	84	420	72	300	1,300	700	1,080	790	1,230	1,000	0	600	11	1,305
71	Chattahoochee River near Norcross, Ga.	1,170	120	210	546	84	420	72	300	1,370	700	1,160	820	1,300	1,070	0	670	13	1,371
72	Chattahoochee River near Roswell, Ga.	1,230	130	212	549	85	420	73	300	1,430	710	1,220	880	1,360	1,130	0	720	15	1,433
73	Chattahoochee River at Atlanta, Ga.	1,450	160	220	628	87	430	75	310	1,600	740	1,390	980	1,530	1,300	0	870	18	1,607
76	Chattahoochee River near Whitesburg, Ga.	2,430	310	205	853	13	370	11	280	2,320	910	2,120	1,480	2,320	2,050	0	1,420	34	2,329

See footnotes at end of table

Table 13.—Availability and estimated proportional utilization flows on the major rivers of Georgia—Continued
(million gallons per day)

Map no.	Gaging station	Drainage area sq. mi.	Estimated future maximum irrigation use	[1]Conservation flow		Proportional utilization flow in 1955						Average excess flow						Estimated future average irrigation use	18-year average flow 1937–55
						Maximum		Average											
				Minimum daily 20-year R. I.	Minimum monthly 2-year R. I.	Urban	Industrial	Urban	Industrial	Hydroelectric power	Navigation	[1]Daily 20-year R. I.	[1]Monthly 2-year R. I.	Urban	Industrial	Hydroelectric power	Navigation		
	APALACHICOLA RIVER BASIN (Continued)																		
78	Chattahoochee River at West Point, Ga.	3,550	460	235	1,120	14	*	12	*	3,260	1,000	3,030	2,150	3,250	*	0	2,270	50	3,266
80	Chattahoochee River at Columbus, Ga.	4,670	640	388	1,420	17	*	14	*	4,090	1,200	3,700	2,670	4,080	*	0	2,890	70	4,091
82	Chattahoochee River at Columbia, Ala.	8,040	1,080	782	2,330	0	0	0	0	4,600	2,400	6,040	4,490	6,810	6,810	2,220	4,420	120	6,819
83	Chattahoochee River at Alaga, Ala.	8,340	1,100	775	2,420	0	0	0	0	4,700	2,400	6,180	4,530	6,950	6,950	2,250	4,550	120	6,954
84	Flint River near Griffin, Ga.	272	54	2	45	4	1	3	1	140	6	200	160	200	200	70	200	6	207
85	Flint River near Molena, Ga.	990	200	24	172	0	6	0	2	540	34	740	600	760	760	230	740	24	769
87	Flint River near Culloden, Ga.	1,890	390	63	377	0	14	0	5	970	88	1,320	1,000	1,380	1,370	410	1,290	43	1,380
90	Flint River at Montezuma, Ga.	2,900	590	378	867	0	88	0	29	1,600	550	1,940	1,450	2,310	2,280	710	1,760	64	2,314
91	Flint River at Oakfield, Ga.	3,860	810	98	1,040	0	105	0	35	2,000	660	2,800	1,850	2,890	2,860	890	2,230	89	2,894

See footnotes at end of table

Table 13.—Availability and estimated proportional utilization flows on the major rivers of Georgia—Continued
(million gallons per day)

Map no.	Gaging station	Drainage area sq. mi.	Estimated future maximum irrigation use	[1]Conservation flow		Proportional utilization flow in 1955						Average excess flow						Estimated future average irrigation use	18-year average flow 1937–55
						Maximum		Average											
				Minimum daily 20-year R. I.	Minimum monthly 2-year R. I.	Urban	Industrial	Urban	Industrial	Hydroelectric power	Navigation	[1]Daily 20-year R. I.	[1]Monthly 2-year R. I.	Urban	Industrial	Hydroelectric power	Navigation		
	APALACHICOLA RIVER BASIN (Continued)																		
93	Flint River at Albany, Ga.	5,230	1,100	299	1,320	0	120	0	40	2,700	750	3,580	2,560	3,880	3,840	1,180	3,130	120	3,880
94	Flint River at Newton, Ga.	5,740	1,300	543	1,710	0	0	0	0	2,950	1,200	3,740	2,570	4,280	4,280	1,330	3,080	150	4,282
100	Flint River at Bainbridge, Ga.	7,350	1,500	1,230	2,390	0	0	0	0	3,800	1,900	4,250	3,090	5,480	5,480	1,680	3,580	170	5,480
	MOBILE RIVER BASIN																		
103	Cartecay River near Ellijay, Ga.	135	8	41	74	1	36	1	21	140	40	130	98	170	150	30	130	1	172
105	Coosawattee River near Ellijay, Ga.	238	15	63	116	1	55	1	32	250	60	240	190	300	270	50	240	2	302
107	Coosawattee River at Pine Chapel, Ga.	855	90	142	264	3	120	3	75	750	140	770	650	910	840	160	770	10	913
110	Oostanaula River at Resaca, Ga.	1,610	210	194	383	4	170	4	100	1,400	190	1,510	1,320	1,700	1,600	300	1,510	23	1,704
111	Oostanaula River near Rome, Ga.	2,120	310	264	452	6	230	5	140	1,800	260	1,950	1,760	2,210	2,070	410	1,950	34	2,212
112	Etowah River near Dawsonville, Ga.	103	6	32	59	0	28	0	16	150	30	120	95	150	140	0	120	1	154

See footnotes at end of table.

Table 13.—Availability and estimated proportional utilization flows on the major rivers of Georgia—Continued
(million gallons per day)

Map no.	Gaging station	Drainage area sq. mi.	Estimated future maximum irrigation use	[f]Conservation flow		Proportional utilization flow in 1955						Average excess flow						Estimated future average irrigation use	18-year average flow 1937–55
						Maximum		Average											
				Minimum daily 20-year R. I.	Minimum monthly 2-year R. I.	Urban	Industrial	Urban	Industrial	Hydroelectric power	Navigation	[f]Daily 20-year R. I.	[f]Monthly 2-year R. I.	Urban	Industrial	Hydroelectric power	Navigation		
	MOBILE RIVER BASIN (Cont.)																		
114	Etowah Eiver at Canton, Ga.	605	60	115	248	1	100	1	60	690	110	580	450	690	630	0	580	7	694
116	Etowah River at Allatoona Dam above Cartersville, Ga.	1,110	130	134	450	1	120	1	70	1,090	130	960	640	1,090	1,020	0	960	14	1,094
117	Etowah River near Kingston, Ga.	1,630	220	236	574	0	210	0	120	1,200	240	1,250	910	1,480	1,360	280	1,240	24	1,485
118	Etowah River at Rome, Ga.	1,810	250	249	646	0	220	0	130	1,300	250	1,380	980	1,620	1,500	330	1,380	28	1,627
119	Coosa River near Rome, Ga.	4,040	580	562	1,200	0	490	0	290	3,300	560	3,410	2,770	3,960	3,680	670	3,410	64	3,968

* Data not available. ** Recurrence interval data not available because of regulation below Clark Hill Dam.

[f] Conservation flow data computed on basis of observed flows during period 1937–55. Not adjusted for regulation or diversions existing in 1955 or to be expected when dams under construction in 1955 are completed.

The 20-year 1-day minimum flow of the major rivers of Georgia is relatively large in proportion to the average flow of those rivers that rise in the Blue Ridge province, and on the Flint River which lies mostly in the upper Coastal Plain. The low flow is very small in proportion to the average flow of the rivers that lie entirely in the lower Coastal Plain.

The 2-year minimum monthly flow is generally two to five times the 20-year 1-day minimum flow except where the 20-year 1-day minimum flow is very low due to lack of sustained inflow from parts of the Piedmont province or due to regulation by power plants, in which cases the 2-year minimum monthly flow may be ten to twenty times as large as the smaller flow.

The 20-year 1-day minimum flow of the major rivers and the maximum rates of the larger urban and industrial utilizations are compared in figure 47 (p. 216). The abrupt increase in minimum flow on the Savannah River is caused by the re-regulation of the flows from Clark Hill Dam at Stevens Creek Dam above Augusta for navigation purposes. The increase in minimum flow shown on the Chattahoochee River is that expected from the operation of Buford Dam which presumably will affect the minimum flow down to Jim Woodruff Dam at the Florida State line. Actually the effect below Bartlett's Ferry Dam will depend on operations there and at the dams already built and under construction below it. The abrupt decrease in minimum flow on the Flint River is caused by power-plant operations at Crisp County Dam. The rapid increase in minimum flow on the lower Flint River is caused by springs and seepage from the limestone formations in that area. The figure shows that the maximum urban water-supply requirements are generally small with respect to the minimum flow of the major rivers. Industrial requirements (for steam-power plants) are larger and at Plant Arkwright on the Ocmulgee River and Plant Atkinson and Plant Yates on the Chattahoochee River exceed the 20-year 1-day minimum flow.

Figure 48 (p. 217) compares proportional utilization flows for hydroelectric-power and navigation purposes and excess flows with the flow of the major rivers on an average annual basis. The entire flow of the Savannah River from above Clark Hill Dam is utilized for power purposes, as is that of the Chattahoochee River above Fort Gaines Dam and that of the Eto-

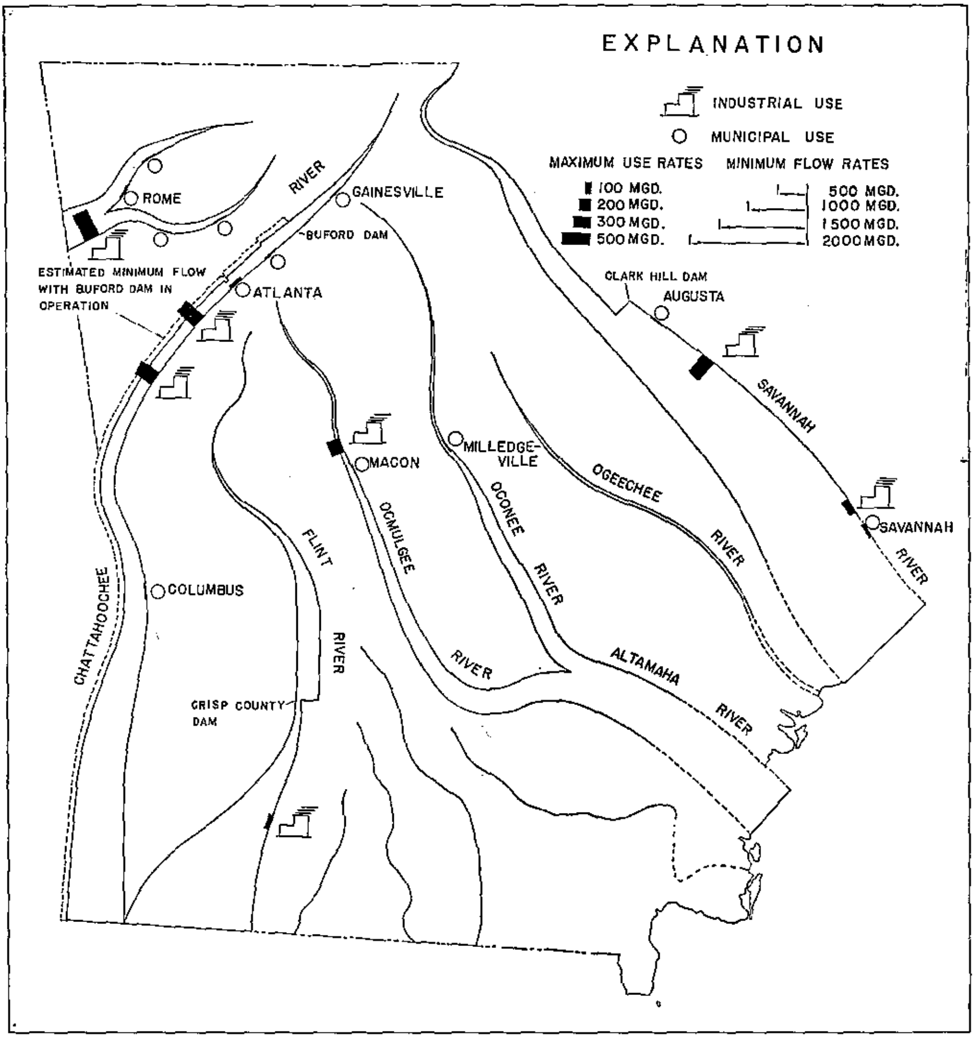


Figure 47. Diagram of the minimum 20-year 1-day flows and present maximum urban and industrial utilization on the major rivers of Georgia, in million gallons per day.

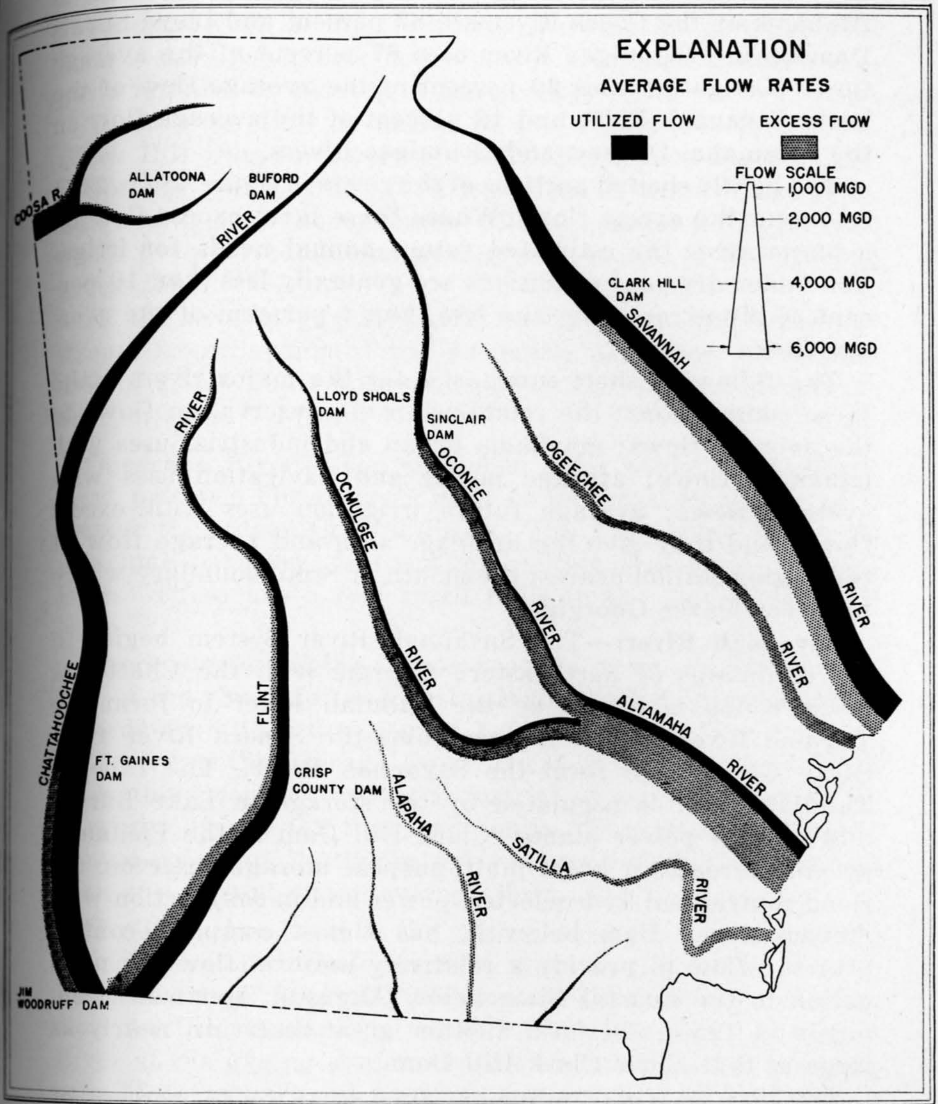


Figure 48. Diagram of the average flow, average utilization flow and average excess flow on the major rivers of Georgia, in million gallons per day.

wah River above Allatoona Dam. Jim Woodruff Dam uses 68 percent of the average flow of the Chattahoochee and Flint Rivers. Sinclair Dam on the Oconee River and Lay Dam in Alabama on the Coosa River use 83 percent and Lloyd Shoals Dam on the Ocmulgee River uses 67 percent of the average flow. Navigation uses 60 percent of the average flow of the lower Savannah River and 16 percent of the average flow on the Altamaha, Oconee, and Ocmulgee Rivers.

The lightly shaded portions of the rivers in figure 48 (p. 217) represent the excess flow. Where there is an excess flow on a major river the estimated future annual needs for irrigation under dry-year conditions are generally less than 10 percent of the excess flow and less than 4 per cent of the average flow.

The following short summaries for the major rivers make these comparisons: the relationship of conservation flows to the average flows; maximum urban and industrial uses with minimum flows; average power and navigation uses with average flows; average future irrigation uses with excess flows; and they give the drainage area and average flow at the gaging station nearest the mouth or State boundary where the river leaves Georgia.

Savannah River.—The Savannah River System begins in the mountains of northeastern Georgia with the Chattooga River which is joined by the Tallulah River to form the Tugaloo River, which in turn joins the Seneca River from South Carolina to form the Savannah River. The flow of Tallulah River is regulated by the storage in Lake Burton and by four power plants. Clark Hill Dam in the Piedmont province creates a great multi-purpose storage reservoir for flood control and hydroelectric power and in conjunction with Stevens Creek Dam below it, has almost complete control over the flow to provide a relatively uniform flow for navigation in the Coastal Plain below Augusta. Hartwell Dam, begun in 1955, will form another great reservoir, nearly as large as that above Clark Hill Dam.

The 20-year 1-day minimum flow is 10 to 15 percent of the average flow above Clark Hill Dam. It is 21 to 25 percent of the average flow below Augusta, an unusually high percentage caused by the reregulation at Stevens Creek Dam.

The largest urban use in proportion to the minimum flow, at Augusta, is only two percent of the minimum flow. The largest industrial use, at the Savannah River Plant of the Atomic Energy Commission, uses 720 mgd, 20 percent of the regulated minimum flow.

Practically all of the flow from the area above Clark Hill Dam is used for hydroelectric power. Navigation below Augusta requires 60 percent of the average flow.

There is no flow in excess of the utilization flow above Clark Hill Dam to supply the estimated future average irrigation use which is less than 3 percent of the average flow. Below Augusta, the estimated future annual irrigation use under dry-year conditions averages 8 percent of the average excess flow.

At the nearest gaging station to its mouth (50 miles upstream from Savannah) the Savannah River has a drainage area of 9,850 square miles and an average flow for the standard period of 7,142 mgd.

Ogeechee River.—The Ogeechee River begins in the Piedmont province but receives most of its dry-season flow as it crosses the upper Coastal Plain. The Canoochee River, its principal tributary, lies entirely within the lower Coastal Plain. There are a few small mills in the Ogeechee River basin.

There are no gaging-station records in the Piedmont portion of the river. In the Coastal Plain portion, gaging-station records show that the 20-year 1-day minimum flow is about 7 percent of the average flow. There is no water utilization from the river for urban, industrial, power, or navigation purposes except for the small mills. The estimated future annual irrigation use under dry-year conditions averages less than one percent of the average flow.

The Ogeechee River at the gaging station nearest its mouth (which does not include the flow from the Canoochee River) has a drainage area of 2,650 square miles and an average flow for the standard period of 1,367 mgd. The Canoochee River at the gaging station nearest its mouth has a drainage area of 555 square miles and an average flow of 262 mgd.

Altamaha River.—The Altamaha River System is formed by two major branches, the Ocmulgee and Oconee Rivers, which rise in the Piedmont province and receive substantial increments of flow in dry seasons as they cross the upper Coastal Plain. South River, the head of the Ocmulgee River, receives a substantial part of its low flow from the Chattahoochee River through the Atlanta and DeKalb County water works and sewer systems. Lloyd Shoals Dam and Jackson Lake regulate the low flow of the Ocmulgee River. The Oconee River has minor regulation below Barnett Shoals Dam and severe regulation below Sinclair Dam at Milledgeville. The regulation from Sinclair Dam is discernible in low-water periods down to Doctortown on the Altamaha River. The Altamaha River is navigable up to Doctortown for vessels with a three-foot draft.

The 20-year, 1-day minimum flow of the South River is 10 percent of the average flow, a relatively high proportion caused by the diversion from the Chattahoochee River. It is 3 to 5 per cent at other stations in the Piedmont portions of the Ocmulgee and Oconee Rivers. In the Coastal Plain, it increases to 15 percent on the Ocmulgee River and 9 percent on the Oconee River, and is 11 percent on the Altamaha River.

The largest utilization for urban purposes in the system, at Macon, requires 3 percent of the minimum flow of the Ocmulgee River. The largest urban use on the Oconee River, at Milledgeville, is 5 percent of the minimum flow.

The largest utilization for industrial purposes, at Plant Arkwright on the Ocmulgee River, exceeds the minimum flow and is 15 percent of the average flow. The flow is usually regulated by Jackson Lake to provide sufficient water for Plant Arkwright.

The largest average utilization for hydroelectric power on the Oconee River, at Sinclair Dam, is 83 percent of the average flow. The largest average use for hydroelectric power on the Ocmulgee River, at Lloyd Shoals Dam, is 67 percent of the average flow. Navigation below Doctortown requires 16 percent of the average flow.

The estimated future annual irrigation use under dry-year conditions averages 6 to 10 percent of the excess flow of the Ocmulgee River above Lloyd Shoals Dam, 14 to 23 percent of the excess flow above Sinclair Dam and 4 to 5 percent of the excess flow downstream from those Dams.

The Ocmulgee River at the downstream gaging station 12 miles upstream from the confluence with the Oconee River, has a drainage area of 5,180 square miles and an average flow for the standard period of 3,415 mgd. The Oconee River at its lowest gaging station, 29 miles above the confluence has a drainage area of 5,110 square miles and an average flow for the standard period of 3,218 mgd. The Altamaha River at the Doctortown gaging station, 59 miles above the mouth, has a drainage area of 13,600 square miles and an average flow of 8,105 mgd. It has the largest flow of any river system within the State.

Lower Coastal Plain rivers.—The Satilla River, the St. Marys River, the Suwannee River system including the Alapaha River and the Little River-Withlacoochee River system, and the Ochlockonee River, all lie within the lower Coastal Plain and have no regulation within Georgia except from small mills and recreation ponds. The Okefenokee Swamp drains into the St. Marys and Suwannee Rivers.

The 20-year 1-day minimum flow of the lower Coastal Plain rivers ranges from zero to about 2 percent of the average flow. Urban and industrial use of water generally comes from deep wells and has little effect on the low flows of the rivers but there may be local increases in streamflow from the waste water. The only hydroelectric power developed on these rivers, in Florida on the Ochlockonee River, uses 60 percent of its average flow. The estimated future annual irrigation use under dry-year conditions averages about 1 percent of the excess flow except in the Ochlockonee River Basin where it is about 4 percent.

The Satilla River at the downstream gaging station at Atkinson has a drainage area of 2,880 square miles and an average flow for the standard period of 1,335 mgd. The St. Marys River at the gaging station near Macclenny, Florida which is far upstream from the mouth, has a drainage area of 720 square miles and an average flow for the standard period of 427 mgd. The Suwannee River at Fargo, the nearest gaging station to the Florida State line, has a drainage area of 1,260 square miles and an average flow for the standard period of 598 mgd. The Alapaha River at Statenville, the nearest gaging station to the Florida State line, has a drainage area of 1,400 square miles and an average flow for the standard period of 598 mgd. The Withlacoochee River near Pinetta, Florida, the nearest station to the State line has a drainage area of 2,220 square miles and an average flow for the standard period of 926 mgd. The Ochlockonee River near

Thomasville, the nearest gaging station to the Florida State line, has a drainage area of 550 square miles and an average flow for the standard period of 287 mgd.

Chattahoochee River.—The Chattahoochee River is the longest river in Georgia—436 miles from its source in northeastern Georgia to the Florida line. There is a little regulation from small mills on the headwater streams in the Blue Ridge province and on tributaries in the Piedmont province. Before Buford dam on the upper river went into operation, the hydroelectric-power plant on the Soque River at Habersham Mills affected the weekly distribution of low flows as far downstream as West Point. Buford Dam which was placed in operation on February 1, 1956, will have a major effect on the river flow below it. Below West Point a series of seven power dams regulate the flow. Oliver Dam, near Columbus, being planned in 1956, will add another dam to this series. Jim Woodruff Dam, nearing completion, and Fort Gaines Dam begun in 1955, will regulate the river in the upper Coastal Plain and provide for navigation up to Columbus.

The 20-year 1-day minimum flow decreases below Buford because of the diversions for urban water supplies in the Atlanta metropolitan area. It is 18 percent of the average flow above Buford, 7 percent at West Point and 11 percent below Columbus. Buford Dam will increase the 20-year 1-day minimum flow by 90 mgd down to West Point. Below that point, the dams now under construction will probably greatly alter the minimum flows. The 2-year minimum monthly flow is about double the 20-year 1-day minimum flow in the headwaters, and as much as four times as great in the lower river.

Urban use of water in 1970 in the systems withdrawing water between Buford Dam and Atlanta is estimated to be about 150 mgd at the maximum summer rate, which will be about 45 percent of the sum of the flow released from Buford Dam and the minimum flow from the drainage area between Buford Dam and Atlanta. The average urban use for the four systems will be about 8 percent of the average flow at Atlanta.

The largest industrial use, at Plant Atkinson near Atlanta, has a maximum rate of 430 mgd, more than double the present 20-year minimum daily flow and about 65 percent more than the expected 20-year minimum daily flow after Buford

Dam is in operation, assuming that the minimum release from the dam will be 500 cfs and that about 50 percent of the water diverted for urban supplies will not be returned to the river above Plant Atkinson.

Plant Yates near Newnan will supersede Plant Atkinson as the largest industrial water user when expansion plans, announced in 1956, are completed. The capacity is to be increased from 300,000 kw to 550,000 kw by the addition of two units. The future maximum capacity to use water for cooling is estimated to be 680 mgd and the average use is estimated to be 510 mgd.

Hydroelectric power will use practically all of the flow above Fort Gaines Dam and 68 percent of the flow between Fort Gaines Dam and Jim Woodruff Dam at the Florida State line.

The estimated future average irrigation use of water under dry-year conditions will not exceed 1 percent of the average flow above Atlanta or 2 percent below Atlanta but there will be no flow available in excess of the hydropower utilization above Fort Gaines Dam. Below Fort Gaines Dam the average irrigation need will be about 9 percent of the excess flow available.

At Alaga, Ala., 34 miles above the Florida State line the Chattahoochee River has a drainage area of 8,340 square miles and an average flow (adjusted to the standard period) of 6,954 mgd.

Flint River.—The Flint River begins in the Piedmont province and has no regulation except from small mills until it is well into the upper Coastal Plain. Below the Fall Line this river lies entirely within the upper Coastal Plain and in dry seasons receives a large percentage of its flow from groundwater. The flow is regulated by power plants near Cordele and at Albany. At the Florida State line the Flint River joins the Chattahoochee River in the pool of Jim Woodruff Dam to form the Apalachicola River.

The 20-year 1-day minimum flow is 2 to 5 percent of the average flow in the Piedmont region and 16 to 22 percent in the Coastal Plain except at Crisp County Dam and Albany where it is reduced to 3 percent by power-plant operations.

The largest urban use of the river water, at Griffin, has taken all of the minimum flow. The largest urban water supply in the river basin, from deep wells at Albany averages 7.5 mgd. The largest industrial use of the river water, at Plant Mitchell below Albany, at the maximum rate is 40 percent of the minimum river flow and averages 10 percent of the average river flow.

The largest utilization of the river flow, for hydroelectric-power purposes at Jim Woodruff Dam, is 68 percent of the average flow.

The estimated future annual irrigation use of water under dry-year conditions averages 5 percent of the excess flow in the Piedmont region and 6 to 9 percent in the Coastal Plain. The largest use is expected in the lower reaches where some of the irrigation water in the lower basin of the Flint River probably will be obtained from deep wells.

At Bainbridge 29 miles above the Florida State line the Flint River has a drainage area of 7,350 square miles and an average flow of 5,480 mgd for the standard period.

Coosa River.—The Coosa River System begins with the Cartecay River which joins the Ellijay River in the Blue Ridge province to form the Coosawattee River. In the Valley and Ridge province the Coosawattee River and the Conasauga River meet to form the Oostanaula River. At Rome the Oostanaula River and the Etowah River form the Coosa River. The Etowah River rises in the mountains and flows through the Piedmont and Valley and Ridge provinces. The lower Etowah River and the Coosa River are regulated by Allatoona Reservoir. There are many small mills on the tributaries.

The 20-year 1-day minimum flow is 21 to 24 percent of the average flow in the Blue Ridge province and diminishes to 11 to 14 percent in the Valley and Ridge province.

The largest urban use, at Rome, is less than 1 percent of the minimum flow of the Oostanaula River. The largest industrial use, at Plant Hammond and the Rome Kraft Plant on the Coosa River, averages 8 percent of the average river flow and the maximum use is 71 percent of the minimum river flow.

The largest hydroelectric-power use, at Allatoona Dam uses practically all of the average flow of the Etowah River.

Under dry-year conditions the estimated future annual irrigation use above Allatoona Dam averaging about 1 percent of the average flow would practically all be taken from water that could be used at the Dam. Elsewhere, the estimated future irrigation use will be 3 to 4 percent of the excess flow in the mountain headwaters of the Coosawattee River and 6 to 10 percent in the Valley and Ridge province.

At the gaging station near Rome, 22 miles above the Alabama State line, the Coosa River has a drainage area of 4,040 square miles and an average flow of 3,968 mgd.

QUALITY OF SURFACE WATERS

The evaluation of the surface water resources of an area requires the determination of factual data on two basic factors—the quality and quantity of water available. Both are of great consequence in the selection of a water supply for most purposes. Consideration of the cost of utilizing surface water also requires a knowledge of its sedimentation characteristics.

Factors that go into the evaluation of streamflow, such as time and place variations, are equally necessary in a study of water quality. Accurate conclusions can not be drawn from the results of daily chemical analysis of a stream for a period of one year any more than they can be obtained from the daily measurement of the flow of the same stream for the same period.

Yet it is upon the results of such data that the following discussion of the chemical quality of Georgia's surface waters must be based, for there are no better data available. There is no long-term quality record for even one location in the entire State of Georgia. Records for a one-year period are available for only 17 locations.

It is, therefore, impossible to present facts accurately indicating the effect of streamflow and water use on water quality in Georgia that might be considered in effecting water legislation.

Investigations to determine the general chemical and physical character of surface waters in Georgia were made during the period 1937-1947, and included 911 analyses from 239 locations throughout the State. Daily samples were obtained from 17 locations on 13 major streams and composited in ten-day intervals for analysis. The average chemical composition at the 17 daily sampling stations is shown in table 14 (p. 226). Daily temperatures obtained at these locations are shown graphically in figure 49.

Table 14.—Single-year average chemical composition of selected surface waters in Georgia

Chemical analyses, in parts per million, by U. S. Geological Survey

Source and Location	Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color
															Calcium, magnesium	Non-carbonate			
Altamaha River at Doctortown	1937–38	10,330	12	0.10	7.2	1.6	4.1	1.2	31	3.2	3.2	0.0	0.5	54	25				19
Chattahoochee River at Columbus	1940–41	3,704	11	.05	3.9	1.3	5.2	1.5	21	4.7	3.5	.1	1.1	44	15				9
Chattahoochee River near Hilton	1940–41	5,700	10	.03	5.6	1.3	4.8	1.4	23	5.4	4.1	.1	1.0	47	19				7
Chattahoochee River near Vinings	1937–38	2,220	11	.04	2.4	1.1	3.3	1.1	16	2.7	1.9	.0	.4	33	11				9
Chattooga River at Trion	1946–47	385	7.1	.04	26	6.5	1.9		109	3.0	2.2	.1	1.1	101	92			7.5	9
Conasauga River at Tilton	1942–43	1,231	7.1	.04	15	4.3	2.6	1.0	63	4.2	2.6	.0	.6	69	55				9
Etowah River near Cartersville	1938–39	1,389	11	.03	4.0	1.3	2.8	1.0	22	3.2	1.5	.0	.2	36	15				6
Flint River at Bainbridge	1941–42	9,547	8.7	.05	17	1.0	2.7	.8	54	3.2	2.7	.1	.6	68	46				14
Flint River at Montezuma	1943–44	4,463	9.8	.07	2.4	1.0	3.6		14	2.5	2.2	.0	.6	34	10				13

Table 14.—Single-year average chemical composition of selected surface waters in Georgia—Continued

Chemical analyses, in parts per million, by U. S. Geological Survey

Source and Location	Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
Ichawaynochaway Creek near Newton	1944–45	856	7.4	0.12	16	0.9	2.4		53	1.4	3.0	0.0	0.6	67	44				23
Ocmulgee River at Lumber City	1945–46	7,395	11	.07	8.2	1.4	4.2		32	3.2	3.5	.2	.6	55	26			7.0	15
Ocmulgee River at Macon	1937–38	2,573	12	.06	3.6	1.6	4.6	1.6	22	3.9	2.9	.0	1.0	44	16				9
Oconee River at Milledgeville	1937–38	2,863	16	.05	4.1	1.8	5.1	1.7	27	2.9	3.2	.0	1.2	51	18				8
Ogeechee River near Eden	1937–38	1,844	11	.27	7.5	1.2	3.7	.8	27	2.5	4.3	.0	.2	59	24				50
Oostanaula River at Rome	1941–42	2,734	7.5	.03	12	2.8	2.3	1.1	47	4.4	1.9	.1	.7	56	41				7
Satilla River near Waycross	1937–38	457	5.8	.08	1.6	1.0	3.8	.7	6	2.0	6.1	.0	.1	49	8			6.1	90
Savannah River near Clyo	1933–39	11,240	11	.05	4.3	1.3	3.4	1.2	22	3.0	2.4	.0	.3	41	16		50		13

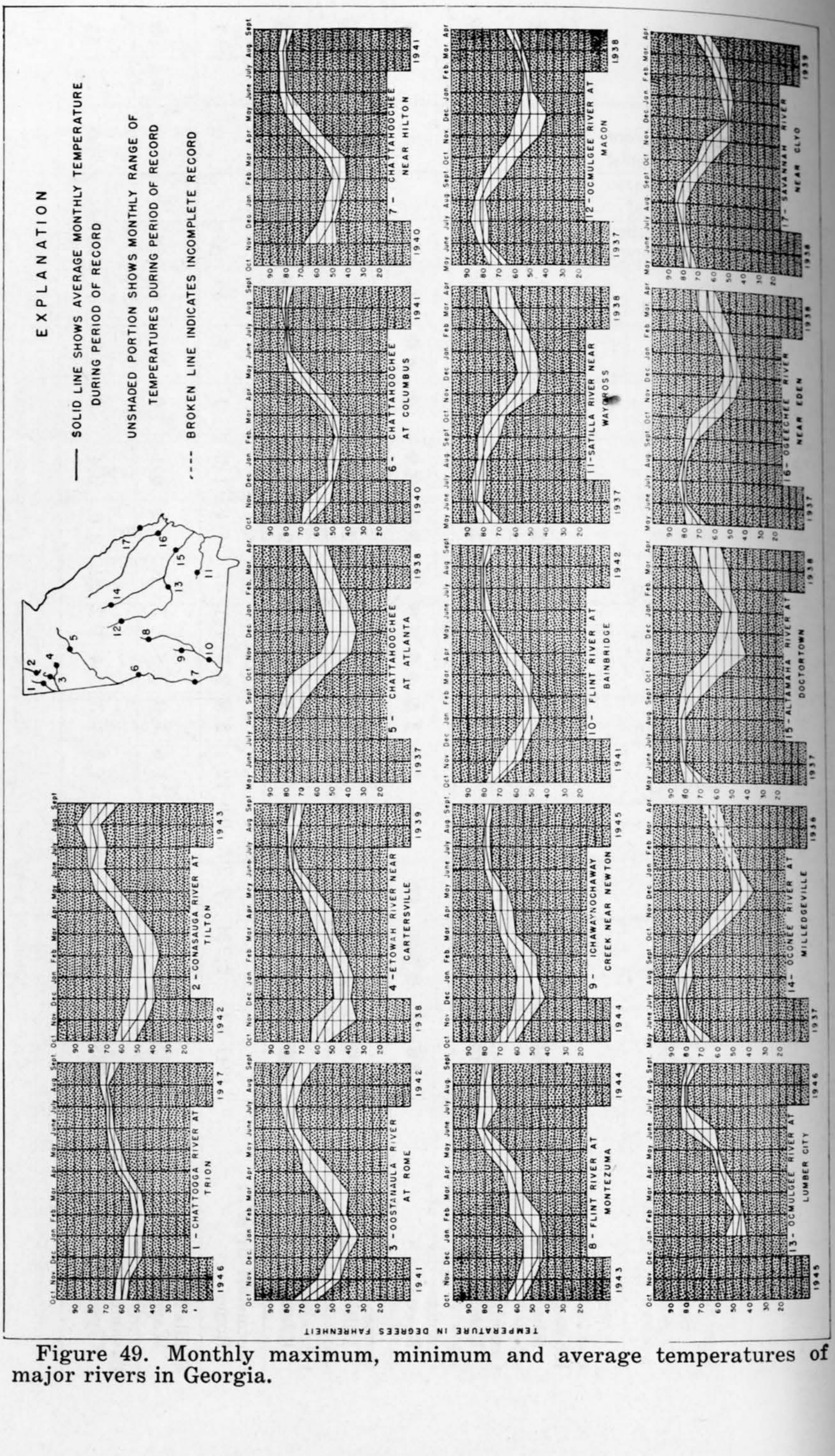


Figure 49. Monthly maximum, minimum and average temperatures of major rivers in Georgia.

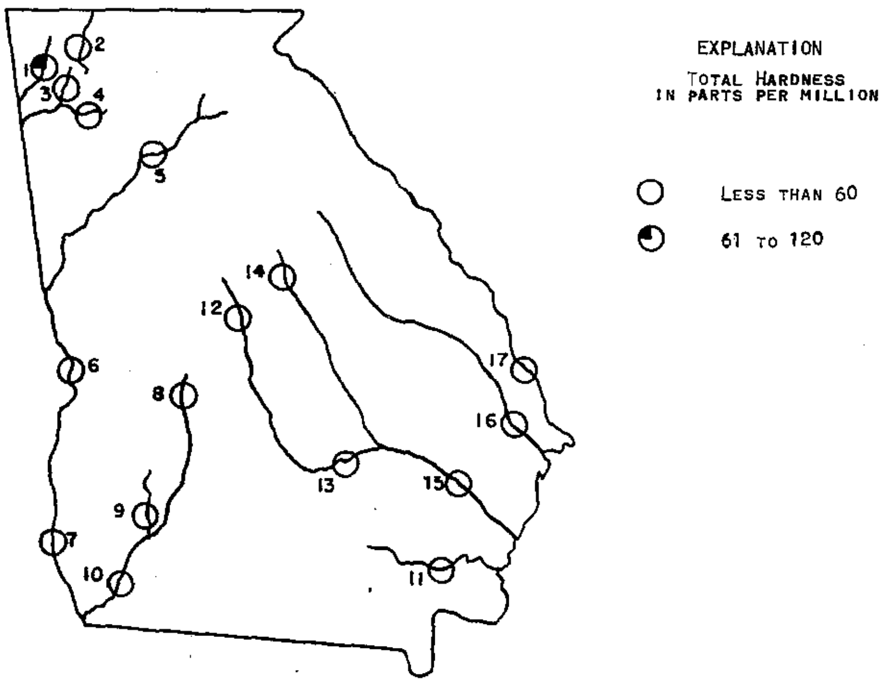
Analyses were also made on 305 miscellaneous samples including samples from 33 springs and samples of raw and treated surface water used for 32 municipal supplies.

The results of these analyses show the waters to be quite soft and low in mineral content during the period observed at the selected sampling locations, with but little range in mineral concentration. Figure 50, (p. 230), showing single year averages of total hardness values for the 17 daily stations, illustrates the relatively soft water conditions that prevail throughout the State.

Surface waters vary in composition from one location to another, and, over a period of time, reflect seasonal variations in streamflow, including periods of floods and drought. During the period of sample collection few serious floods or extreme droughts ocurred, a condition reflected in the rather uniform mineral content of the waters examined.

The greatest range in concentration of the various chemical constituents contained was observed to be in bicarbonate and hardness. The range in these constituents for the Chattooga River at Trion was observed to be from 47 to 142 ppm in bicarbonate and from 42 to 118 ppm in hardness. Maximum concentration of bicarbonate was observed to be 157 ppm at Indian Springs near Albany, and maximum hardness, 145 ppm at Blue Springs near Quitman. Very few samples exhibited values in excess of 10 ppm of sulfate, magnesium or chloride. The low nitrate values did not indicate any serious animal waste pollution during the sampling period. The one instance in which a possibility was indicated was the Chattahoochee River near Whitesburg, where nitrate was found to be 12 ppm. Many of the surface streams originating in the southern and eastern parts of the Coastal Plain were highly colored, but carried little suspended matter. Spot samples from scattered locations represent conditions existing only at the time of sampling, and are inadequate for evaluating the variations that occur in chemical composition of a water for any given period.

During the course of its runoff to the sea, a surface stream is subject to many changing conditions, such as evaporation, inflow, aeration, etc., all of which tend to alter the chemical quality. These conditions generally result in a fairly regular increase in mineral content in the downstream direction. Such increases were found by analysis of samples from various loca-



1 CHATTOOGA RIVER AT TRION
2 CONASAUGA RIVER AT TILTON
3 OOSTANAULA RIVER AT ROME
4 ETOWAH RIVER NEAR CARTERSVILLE
5 CHATTAHOOCHEE RIVER NEAR VININGS
6 CHATTAHOOCHEE RIVER AT COLUMBUS
7 CHATTAHOOCHEE RIVER NEAR HILTON
8 FLINT RIVER AT MONTEZUMA
9 ICHAWAYNOCHAWAY CREEK NEAR NEWTON
10 FLINT RIVER AT BAINBRIDGE
11 SATILLA RIVER NEAR WAYCROSS
12 OCMULGEE RIVER AT MACON
13 OCMULGEE RIVER AT LUMBER CITY
14 OCONEE RIVER AT MILLEDGEVILLE
15 ALTAMAHA RIVER AT DOCTORTOWN
16 OGEECHEE RIVER NEAR EDEN
17 SAVANNAH RIVER NEAR CLYO

Figure 50. Map of Georgia showing single-year average values of total hardness for 17 surface water stations.

tions on the Chattahoochee River system, as shown in figure 51 (p. 232).

The mineral concentration of surface waters at a site normally varies inversely with flow. During periods of high runoff surface waters are high in suspended solids but they have little time for actual contact with soluble mineral formations and, as a result, tend to be low in dissolved solids. On the other hand, during periods of base flow there are lower sediment concentrations but more time is available for solution of rock and other materials, resulting in higher mineral content. A good example of the inverse relationship often observed between mineral concentration and streamflow may be seen in figure 52 (p. 233), which shows the concentration of dissolved solids at various discharge rates for the Flint River at Bainbridge.

Flow-concentration relationships are not always as clearly defined as in the above example, as shown in figures 53 (p. 234) 54 (p. 235) for the Altamaha River at Doctortown and the Chattahoochee River near Hilton, respectively. It is apparent that other factors may have a considerable effect on this relationship. Continued chemical build-up of soil solutions occurs in agricultural areas and high concentrations are often returned to a stream during the first heavy rainfall, to increase temporarily the mineral content of that particular waterway. In such a case, the increase in concentration of dissolved solids parallels, to some extent, the increase in flow. After the initial leaching of the soils, continued rainfall brings about a return to the normal inverse ratio between concentration and flow. Seasonal variations such as the water-retention tendencies of the soils during the dormant season and the rapid absorption of rainfall during the growing season also alter these conditions.

Rather minute changes in calcium concentration shown in figures 53 and 54 for the Altamaha and Chattahoochee Rivers might have resulted from any one of a number of conditions. From the short period of record available it is impossible to single out any one condition to account for such small changes in concentration.

Although the range and variation in mineral concentration observed during the sampling period were not sufficiently large to cause much concern, it must be noted, that, in general, these streams are as yet little-used for industrial waste dis-

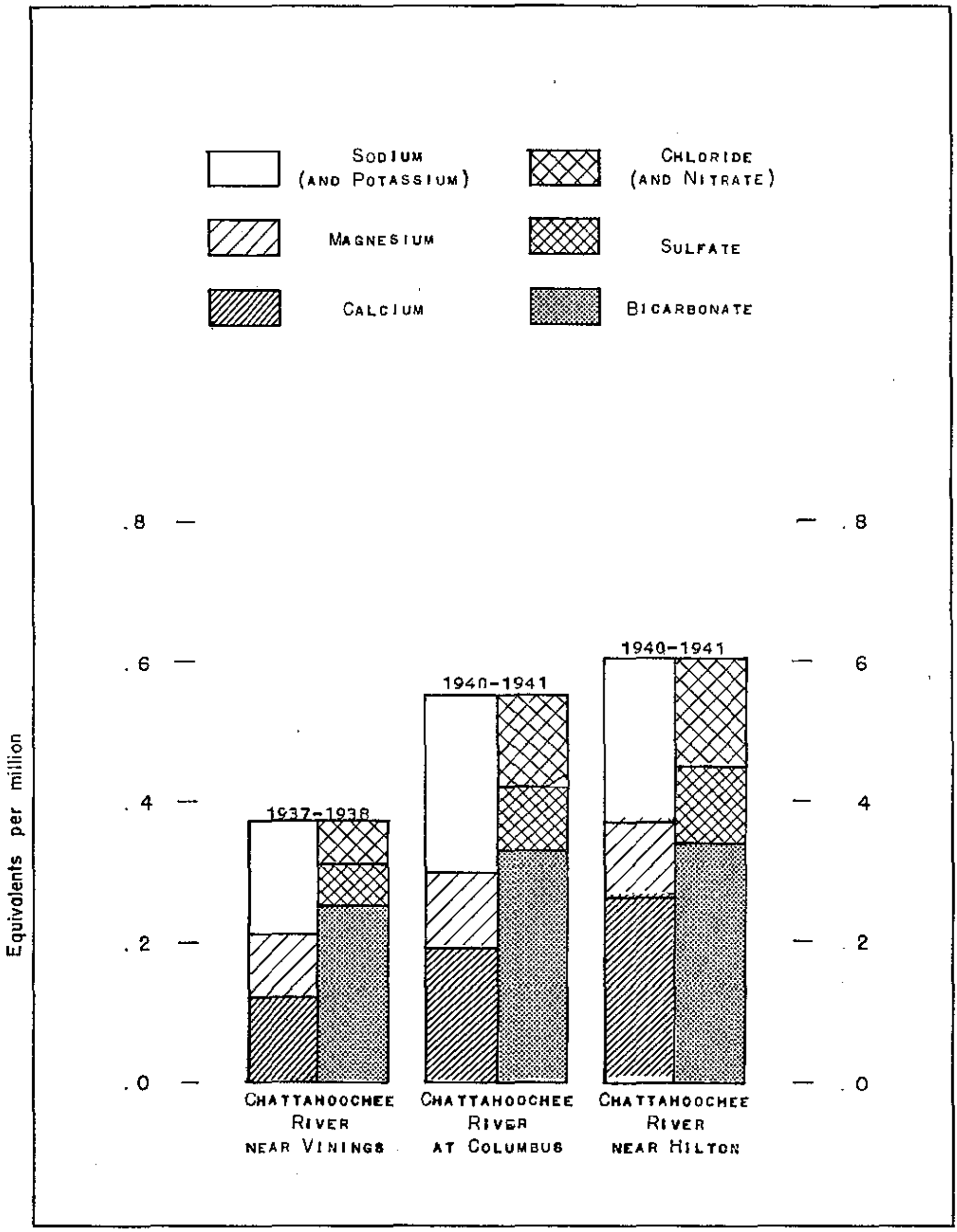


Figure 51. Single-year averages of chemical composition of water in Chattahoochee River, Georgia during period May 1937 to September 1941.

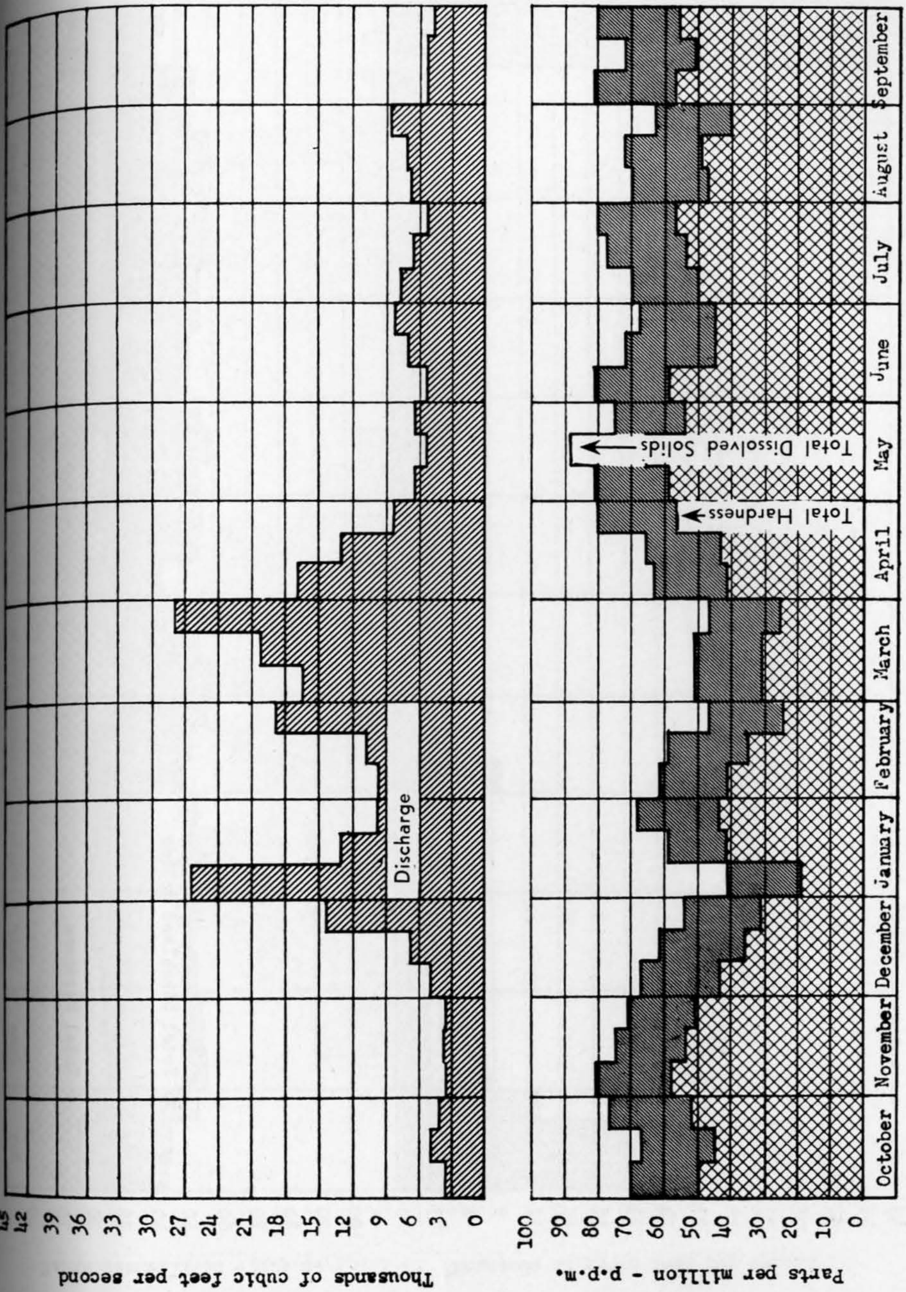


Figure 52. Relation of dissolved solids to discharge for Flint River at Bainbridge, Georgia, 1941-42.

Figure 53. Relation of dissolved solids to discharge for Altamaha River at Doctortown, Ga., 1937-38.

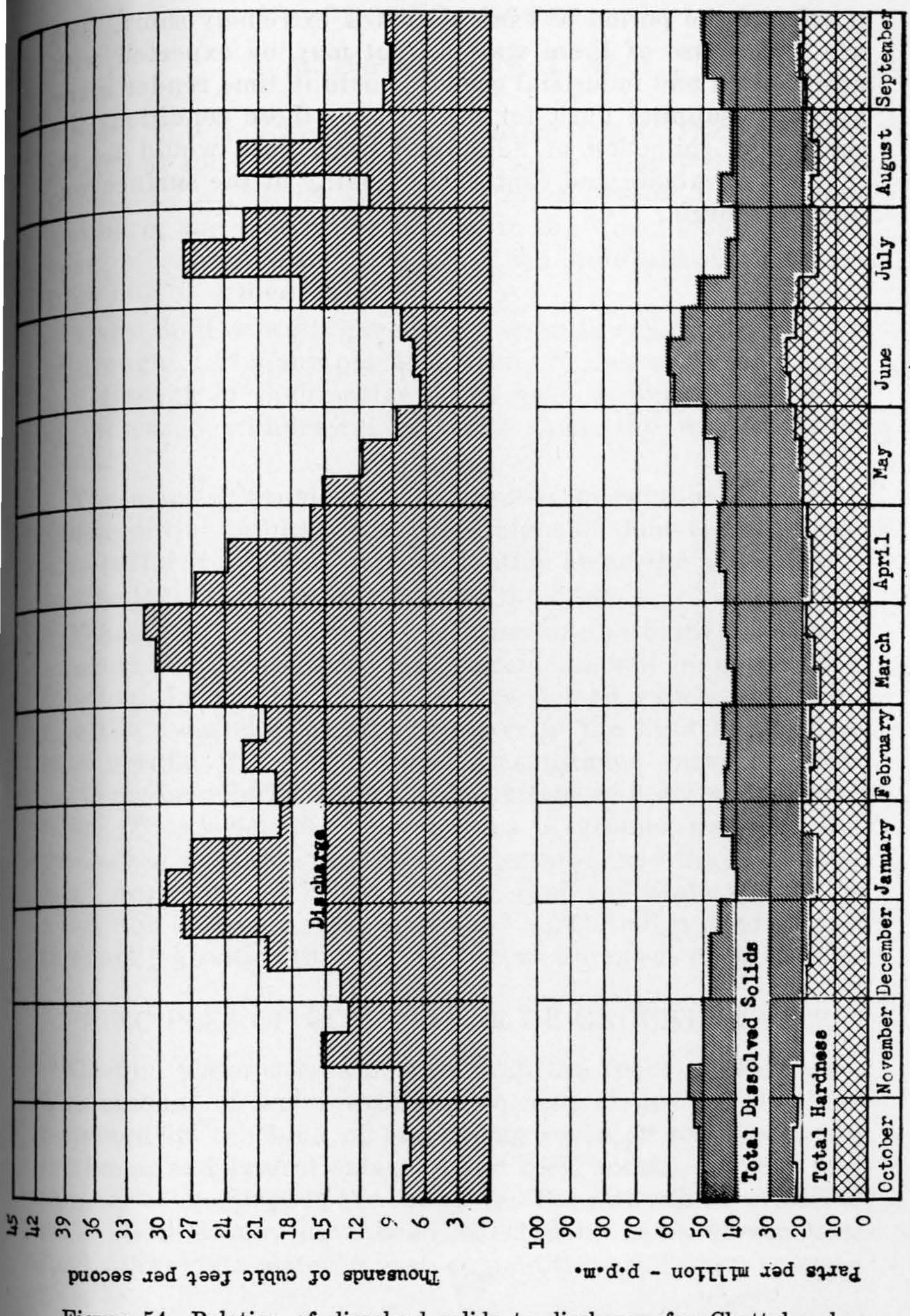


Figure 54. Relation of dissolved solids to discharge for Chattahoochee River near Hilton, Ga., 1940-41.

posal and the period of examination is extremely short. The use and re-use of these waters, that may be expected with agricultural and industrial growth, could in time render many available supplies unfit for use. Under those conditions the continuing collection of additional basic data would be essential to evaluate and control the quality of the surface waters of Georgia.

GROUND WATER

S. M. Herrick and R. L. Wait

Some of the post-Columbian settlements of Georgia were located at springs, and some early settlers dug wells in order to obtain a supply of water that was accessible to the house and barn, and that would be cool in the warm months of the year. Most of the rural dwellers of the State still obtain water from dug or drilled wells.

Many shallow wells have been known to fail during periods of drought. At many places deeper artesian wells have stopped flowing or their water levels have declined as a result of increased withdrawal of water from the water-bearing rocks.

These water problems have created speculation about the causes of the problems and what might be done to help those who suffer from them, and speculation about the need of protective legislation for all water in the State.

When the ground-water resources of the State have been measured and described, many problems will be closer to a solution. Legislation might then be passed which would define the ownership of ground water in the light of the fact that ground water is a transient substance, moving across property boundaries according to certain well-defined natural laws. Thus when the relationships of ground water to the geology of the State are better understood, and the individual local problems are better defined, then the State will be in a position to decide what additional legislation is needed, and to enact legislation that will best serve the needs of its people.

PRINCIPLES OF OCCURRENCE OF GROUND WATER

Ground water occurs in nearly all the rocks of the earth. The amount of water available to man at any place is determined by the kind of underlying rocks or sediments, the thickness and lateral extent of the rock bodies, the size and number of openings in the rocks, and the attitude of stratified rocks as they may have been affected by earth movements. Rocks that yield water in usable quantities are known as aquifers.

The State of Georiga lies mainly in three geologic provinces (Stephenson and Veatch, 1915, p. 52) : The Valley and Ridge province, the Piedmont-Mountain province, and the Coastal Plain (pl. 1). The northwestern corner of the State is in the Cumberland Plateau province, but for convenience that area is included in the Valley and Ridge province in this report, as the area is small and the rocks are similar to those in the Valley and Ridge province. The rock types are different in the three principal provinces. The size and number of the openings in the rocks differ from one province to another, and, likewise, the amount of water that can be obtained from wells in these provinces differs.

Ground water occurs in the rock openings in the zone of saturation. The zone of saturation is that part of the earth below the surface in which all the pore spaces are filled with water under hydrostatic pressure. The thickness of the zone of saturation differs from one kind of rock to another, and from one region to another. For practical purposes it extends no deeper than 500 or 600 feet in most rocks in the Piedmont-Mountain province, but it may be several thousand feet thick in the Valley and Ridge and Coastal Plain provinces.

The size and number of the rock openings determine the amount of water that can be stored and recovered and the rate at which it can be recovered. Extremely dense rocks such as granite, schist, gneiss, shale, and cemented sandstone have little void space and therefore contain relatively minor amounts of water. The void spaces in these consolidated rocks consist mainly of fractures, including faults and joints, and partings along bedding planes. Limestone may be cavernous because of solution of the rock by circulating ground water. Carlsbad Cavern in New Mexico and Mammoth Cave in Kentucky are extreme examples of caverns formed in this way. Gravel, sand, and cavernous limestone have a much greater amount of void space than the dense rocks mentioned previously, and more water can be stored in these rocks and recovered from them.

Ground water moves in response to gravity just as surface water does, though more slowly because of the loss of energy by friction as the water moves through the small openings in the rocks. It is possible to determine the direction of movement by constructing maps of the water table. The direction of movement of ground water is down the hydraulic gradient toward the point of lowest level in any given area. In artesian aquifers, where the water is confined between impervious layers, the direction of flow may be upward at some places, as water flows upward in pipes under pressure, but the direction of movement is always down the hydraulic gradient.

The pumping of water from wells influences ground-water movement. When a well is pumped, water is withdrawn from the aquifer and the water table or piezometric surface is lowered, causing a cone of depression to be developed around the well (fig. 55). Water moves toward the well from all directions within this cone of depression, the radius of which is determined by the rate of pumping, the length of time the well is pumped, and the ability of the formation to transmit water. As pumping continues, this cone broadens and deepens until enough water is diverted from its previous point or points of discharge to supply the well. Opportunities for discharge, such as at springs or by leakage through adjacent rocks, and structures like faults and folds are among the factors that influence the rate and direction of the movement of ground water in any given aquifer.

Water-Table Conditions

Ground water that is in contact with the atmosphere through the soil zone is known as free or unconfined water and is said to occur under water-table conditions. Ground water in the Piedmont-Mountain province of Georgia is largely unconfined. The position of the water table at any place is a resultant of the local balance of the forces that tend to build it up and draw it down. Thus the water level is affected by the amount of rainfall, the storm intensity or rate at which the rain falls, the permeability and previous moisture content of the soil, the thickness and permeability of the water-bearing material, the opportunity for natural discharge in which the topographic location is an important factor, and the rate of artificial withdrawal, if any. Records obtained from observation wells in areas of shallow water table in Georgia indicate that the water table generally responds to rainfall within 12 hours after a rain commences and continues to rise after the rain ceases until the water that has infiltrated in excess of the moisture-holding capacity of the soil has drained downward to the water table. (See fig. 56.)

A lack of precipitation is accompanied by a decline of the water table. Obviously, if no precipitation occurs to recharge the ground-water body, the water table must decline as water

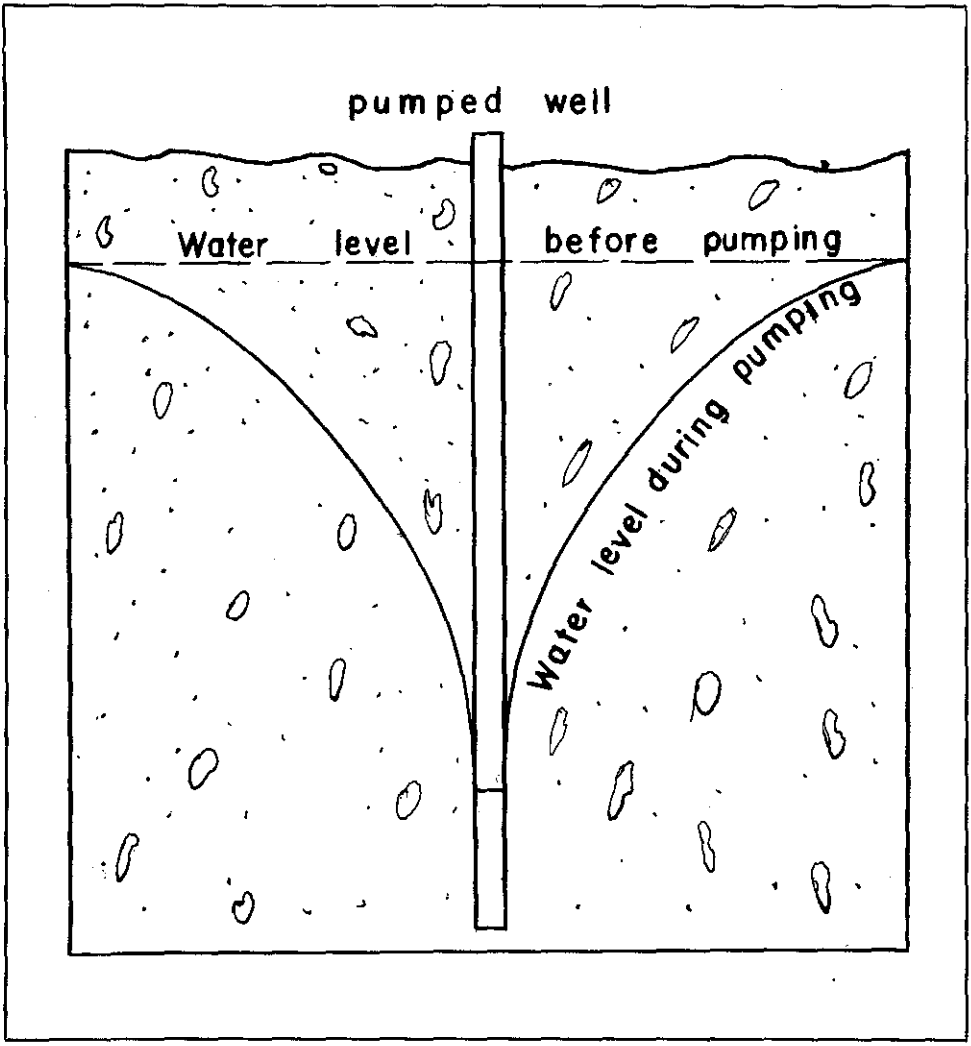


Figure 55. Diagramatic section illustrating cone of depression caused by pumping under water table conditions.

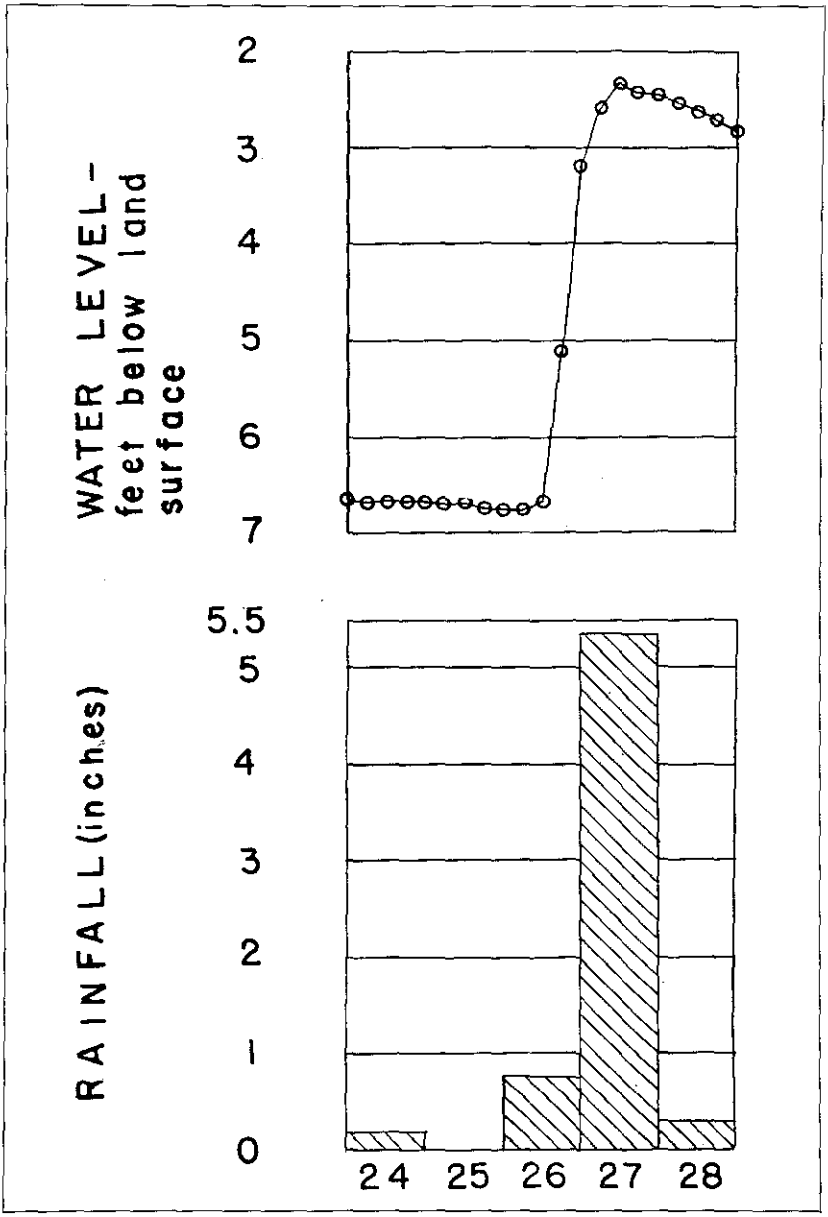


Figure 56. Graph showing effect of rainfall in July 1953 on Well 343, a dug well which penetrates Pleistocene sands.

drains out of the rocks into the surface streams, or is evaporated and transpired.

Artesian Conditions

Artesian water is ground water, confined between strata of low permeability, that is under sufficient pressure to rise above the level at which it is encountered by a well, whether or not it rises to or above the surface of the ground. Ordinarily, water enters an artesian aquifer in its outcrop area and moves downward and in the direction of the hydraulic gradient until it passes beneath the upper confining bed. Recharge to the aquifer takes place mostly in the outcrop area but may occur also at other places, as will be explained later.

Artesian conditions prevail throughout the Coastal Plain of Georgia except in the outcrop areas of the individual aquifers. The principal artesian aquifer, consisting of limestone, is one of the most extensive and productive aquifers in the United States.

The water levels in artesian wells define a pressure-head-indicating surface (piezometric surface) which is analogous to the water table but which may be either above or below the land surface, depending on the relation between the artesian head and the surface elevation at any given point. If water is removed from the artesian aquifer a cone of depression or pressure relief is created. (See fig. 57 for a map of the cone in the Savannah area.) If pumping is heavy and long enough, the piezometric surface may be lowered below the top confining bed creating water-table conditions. However, if pumping is reduced, the water level begins to recover immediately and artesian conditions may be restored.

Aquifers have elastic properties and expand and contract in response to changes in head and to outside forces. In coastal areas the weight of water on top of the aquifer changes from high to low tide, and this is reflected by the water level in wells near the ocean. In the Savannah area these tidal effects may amount to as much as 4 feet. Figure 58 shows the effect of typical spring and neap tides. Trains passing near an observation well may cause temporary loading, forcing the water level higher in the well. Changes in barometric pressure cause fluctuations of the water levels, as do earthquakes and explosions.

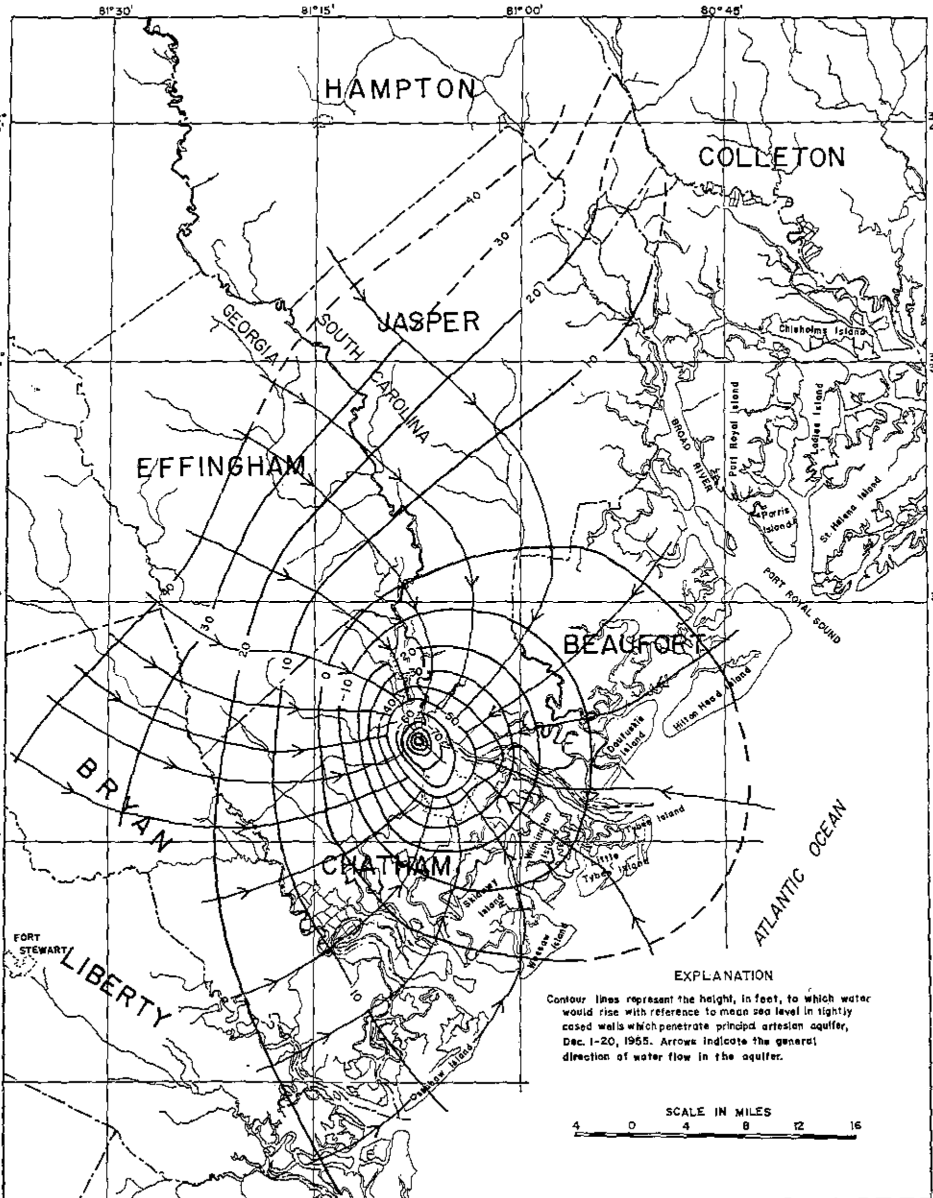


Figure 57. Piezometric surface of artesian water, Savannah and vicinity, 1955.

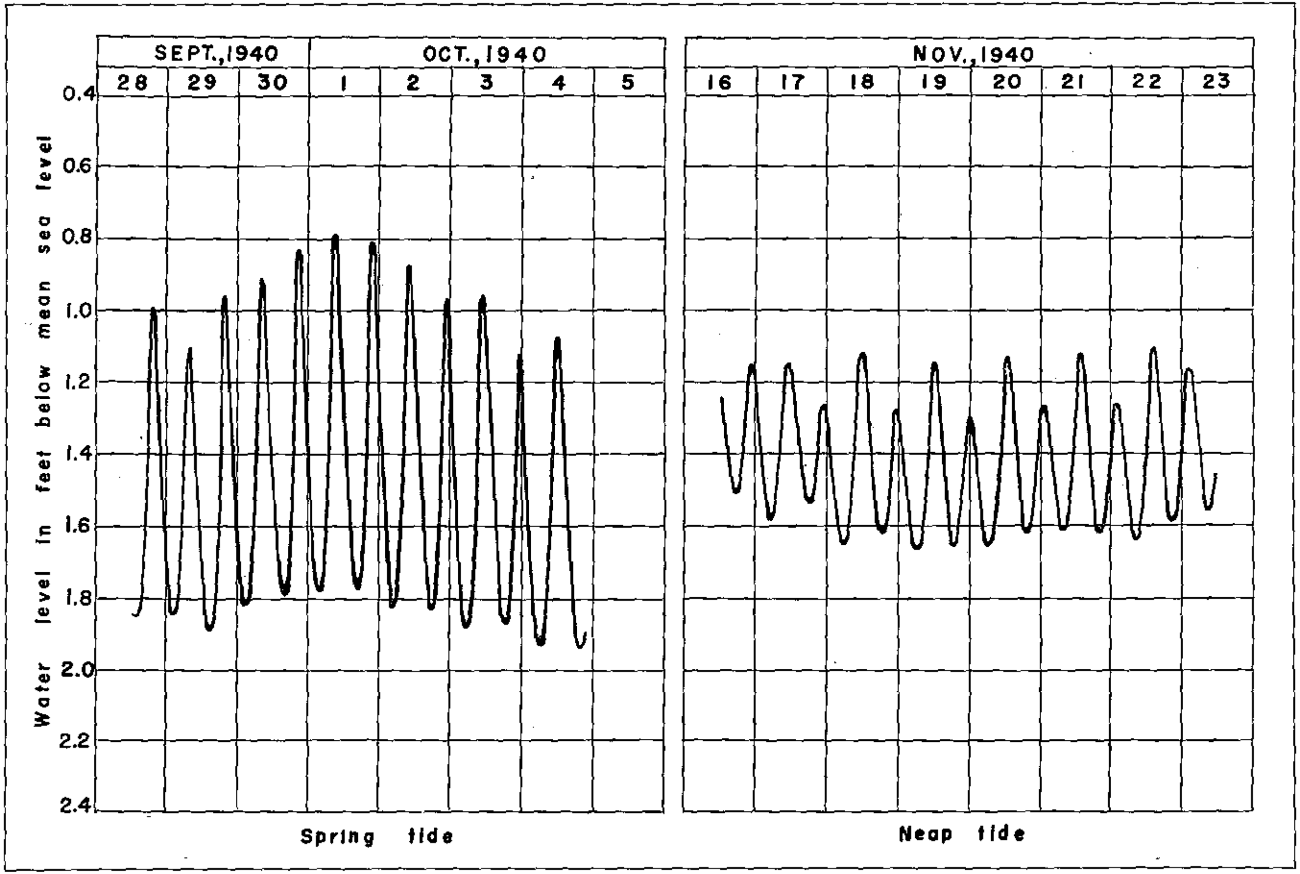


Figure 58. Tidal effect in a well near Savannah, Georgia
(After M. A. Warren, 1944)

If a cone of depression or pressure relief is created and maintained for a period of years, a subsidence of the land surface may occur. The land settles in response to the lowering of pressure and the consequent compaction of the aquifer and associated beds. Noticeable subsidence has occurred in places in Texas and California, among others (Tolman, 1937, p. 341. Recent leveling by the U. S. Coast and Geodetic Survey in the Savannah area indicates that the land surface there may have subsided about 0.1 foot, possibly as a result of the pumping of artesian water.

Water must not contain excessive amounts of certain chemical constituents if it is to be usable by man for domestic, irrigation, or industrial supply. The chemical quality of ground water in Georgia is good at most places. Some areas have problems with excessive hardness or iron content, and some coastal areas have problems of excessive salinity.

LEGISLATIVE CONSIDERATIONS

In the past the legislative bodies of many other states, in attempting to devise effective means of controlling the use of water, have regarded surface water and ground water as separate and unrelated resources, whereas actually the two are closely related. Past legislation has generally recognized the obvious fact that surface water flows across property lines, but they have assumed ground water to be a static part of the property. Successful legislation must recognize that ground water, like surface water, is in motion, en route to the sea. Water is transported from the sea to the land area as vapor. Once it falls as precipitation, it is once again on its way back to the sea. It may flow over or beneath the surface, or both at different times, but ultimately it will return to the sea if its journey is not interrupted by evaporation or transpiration.

The growing demand for ground-water supplies has raised the question of ownership of ground water and also the problem of administering any laws that might be formulated pertaining to regulation of use of ground water. Before there can be laws that will equitably apportion this resource to its users, there must be an understanding of the physical principles that govern its occurrence. It remains the responsibility of the ground-water geologists and hydrologists to obtain the necessary physical data on which effective legislation can be based.

Thompson and Fiedler (1932) have appropriately stated the aspects of this fundamental relationship. A portion of their paper follows:

"In the beginning it is necessary to distinguish between water-table conditions and artesian conditions, for there may be notable differences in the effects of pumping as one or the other of these conditions exists. A water table is the upper surface of the zone of saturation beneath the earth's surface, except where such upper surface is formed by an impermeable body. If the permeable water-bearing bed lies beneath an impermeable bed, it is completely saturated. The water is under hydrostatic pressure, so that, when penetrated by a well, it will rise above the elevation at which it is first encountered. The water may be said to be under artesian pressure, and artesian conditions exist.

"Practically all ground water occurring in sufficient quantities or of good enough quality to be useful to man has its ultimate source in the precipitation that falls upon the land. It is not an inexhaustible supply, but, depending upon conditions of precipitation and the geologic conditions that effect its movement and recovery, it is a resource that within some limit is being more or less continually renewed. To this extent it differs from oil and gas which in some other respects have properties in common with those of ground water. Where water table conditions exist, recharge of the water-bearing formations—that is, renewal of the supply—may occur at least in part by downward percolation in the area where the water is withdrawn through wells. Where artesian conditions occur, there can be no direct downward percolation to the water-bearing formations through the impermeable bed. The water that supplies the wells must move into the area from some points at a greater or less distance where the impermeable bed is absent. The movement of water under artesian conditions is comparable to the movement of water in pipe lines, and the rate at which water can be withdrawn from the system is determined primarily by certain characteristics of the system which involve the element of friction.

"Also, practically all ground water that is useful to man on any large scale is moving, continually but slowly, from some point of recharge to some point of natural discharge or of artificial withdrawal. The direction of flow of the ground water under either water table or artesian conditions may be determined fairly accurately by determining differences in the elevation of the water levels in a series of wells.

"An important consideration arising from these facts, the significance of which will become more apparent in the discussion that follows, is that, except in areas where the ground water is essentially stagnant—in which case it is likely not to be a very valuable resource—the water that a person pumps from his well is actually not a permanent part of his land, but, like the wind that passes over it, moves from beneath the land of another to his land and passes on to more distant points. Furthermore, in the case of water moving in an artesian formation, shut off from the surface by an overlying confining bed, the contribution of water from the precipitation on the land of a well owner by direct downward percolation is essentially nil. Under water-table conditions, however, there may be measurable contribution to a well from precipitation on the overlying surface by direct downward percolation * * *."

"It should be noted that the water that is moving underground is not merely maintaining the supply of ground water, but generally, except for loss by transpiration and evaporation or by artificial withdrawal, it is moving toward an outlet, in some stream the flow of which it helps to maintain or toward the ocean.

"When water is drawn from a well, either by pumping or by natural artesian flow, the head of the water immediately drops in the well and also in the formation surrounding it. The decline of head is greatest in the discharging well and decreases with the distance from the well, until at some distance there is very slight decline or none at all. However, it has become increasingly clear in the past few years, that in the course of time the area of influence of a pumped or flowing well may expand until it reaches the bordering limit of the formation. When the well is pumped or discharges by natural flow, the rate of decline in head is at first rapid but becomes slower and slower until finally, if the rate of discharge exceeds the rate of recharge, the drop in head will continue until eventually it is no longer possible to withdraw water at the original rate. The ultimate effect of pumping in some areas can not be determined merely by observations during a pumping test of a few hours, days, or even weeks, but may require careful observations extending over a period of at least a year or two.

"Long time observations in a few parts of the country have shown a more or less continuous decline of the water table or artesian pressure, perhaps interrupted for a few months each year or for a period of two or three years when there was exceptional precipitation or decrease in rate of pumpage. Such decline suggests, but does not necessarily prove, that the draft of the water-bearing formations has been in excess of average annual recharge. According to principles of hydraulics involved, it is necessary to lower the head on the water—that is, to produce a drawdown—in order to cause the water to flow toward the well from which it is being withdrawn. Therefore, under some conditions a considerable drop in head when water is withdrawn from a formation is no more serious than the drop in head experienced at times of peak load in a water-distribution system which has an adequate supply available. This fact must be recognized in any program of legal control that is to be fair to all users of ground water.

"An essential point to be recognized in the consideration of questions of legal control is that, generally it is impossible for one land owner to pump water from beneath his land at an appreciable rate without affecting the water level or artesian pressure beneath the land of his neighbors and perhaps also beneath land at a distance of several miles from his own property."

The ground-water section of this report is designed to explain what is known about the occurrence of ground water in the State of Georgia, to point out where more information is needed, and, in general, to provide a basis of factual information from which the State can decide whether legislation affecting the use of ground water is needed at this time.

GEOLOGY

Georgia is divided into three geologic provinces (Stephenson and Veatch, 1915, p. 52), the Piedmont-Mountain province, the Valley and Ridge province, and the Coastal Plain province. The division of the State by geologic provinces is based on the rock types of each province and conforms to the physiographic provinces (See p. 67) except that the Blue Ridge and Piedmont physiographic provinces are combined in the Piedmont-

Mountain geologic province. The Coastal Plain, which covers an area of 35,000 square miles, or three-fifths of the total area of the State, is the largest of the three provinces. (See pl. 1.)

Piedmont-Mountain Province

The Piedmont-Mountain province is underlain by metamorphic and igneous rocks, commonly known as crystalline rocks. The metamorphic rocks constitute the older igneous and sedimentary rocks into which younger igneous rocks have been intruded. The metamorphic rocks are the most extensive in the province and cross the State in well-defined northeast-trending belts. These rocks include biotite gneiss, muscovite schist, slate, quartzite, and marble. The igneous rocks are composed chiefly of granite and, less extensively but in appreciable amounts, of the more basic types such as hornblende and diorite gneiss, pyroxenite, gabbro, dolerite, and basalt. The crystalline rocks are the oldest rocks in Georgia, ranging in age from Precambrian to Triassic.

As a result of repeated profound deformations, the metamorphic rocks exhibit extremely complex structures, including close folding, overthrust faulting, and igneous intrusion.

The deformations have produced primary structural planes that are important to the circulation of ground water in these rocks. Fault planes, shear zones (groups of fault planes), planes of schistosity resulting from close folding, intrusive contacts around the margins of large intrusive bodies, and joints are prominent structural features. Horizontal joint planes in granites and granite-like rocks have produced horizontally concentric sheets—similar to the layers around an onion — that are convex-upward beneath hills and uplands and concave-upward beneath valleys and lowlands. This type of joint pattern is conducive to the accumulation and storage of ground water in the valleys and to drainage of water from beneath hills. The planes of schistosity are important structural planes, in partings along which ground water may occur. They are followed in order of importance by contact joints connected with intrusive bodies, tension and shear joints in metamorphic rocks, and fault planes.

Above the solid rock is a mantle of weathered soil or residuum. Water occurs in this material as it does in sedimentary bodies of sand and clay, and the material serves both as an aquifer to shallow wells and as a medium for absorbing and storing water from precipitation and feeding it into cracks in the underlying rock.

Valley and Ridge Province

The Valley and Ridge province consists of 10 counties in the extreme northwest corner of the State. The province is underlain by folded consolidated sedimentary rocks including shale, slate, dolomite, limestone, quartzite, and sandstone and minor amounts of conglomerate, marble, and coal. These rocks range in age from Cambrian to Pennsylvanian.

Rocks of the Valley and Ridge province are composed of sediments derived from long-continued erosion of the crystalline rocks of the Piedmont-Mountain province to the southeast and east and subsequently deposited in an ancient interior sea whose eastern margin covered this part of Georgia. After the deposition and consolidation of the rocks, compressive forces from the southeast pushed these rocks toward the northwest, causing them to buckle and fold much as a rug does when pushed from opposite ends. As a result, the strata were thrown into parallel southwest-trending folds called anticlines and synclines. Some of the individual folds can be traced for more than a hundred miles. Continuation of the compressive force from the southeast resulted in additional metamorphism which produced schistosity having a regional southeasterly dip. Some fractures developed into overthrust faults which caused considerable horizontal displacement of rocks over much of the area. The effects of the folding and faulting were not of the same magnitude over the entire area but decreased progressively in a northwesterly direction, amounting to little more than simple vertical uplift in the extreme northwest corner of this province in Georgia. Lookout, Pigeon, and Little Sand Mountains are made up of such undisturbed strata and they constitute the easternmost extensions of the Cumberland Plateau in Georgia. Since the deformation, which took place many millions of years ago during late Paleozoic time, these rocks have remained as dry land and have been subjected to weathering.

Thus the most recent chapter in the geologic history of this area has been one of extensive erosion, as a result of which the anticlines—broad, archlike structures—have been eroded and occupy valleys, while their counterparts, the synclines, or basinlike structures, now stand as topographic ridges. The reason for preferential erosion of the anticlines is that the rocks in them were cracked where they were stretched over the crests of the folds, making them comparatively easy to erode; whereas the rocks in the synclines were compressed by the folding and thus were made more resistant to erosion.

The structures in the underlying rocks that are important to the occurrence of ground water are mostly secondary and include the schistosity, fault and shear zones, bedding and joint planes, and in limestone and dolomite, the solution cavities. The only primary structure of importance is the openings between the individual sand grains in sandstone.

Residuum or weathered rock is present in this province as in the Piedmont-Mountain province, and it contains ground water. The residuum varies in thickness and composition throughout the area, depending on local rock types. In general, these weathered materials are probably thickest in valleys and other topographic depressions and thinnest on the tops of hills and ridges. In composition, the mantle rock ranges from tight clay overlying limestone and shale to loose, porous, sandy material covering areas underlain by dolomite and sandstone. The residuum is important because it acts as a giant sponge, absorbing and storing precipitation and feeding the water slowly downward to the joints and other openings in the underlying rocks.

Coastal Plain Province

The Coastal Plain province is underlain by stratified sediments consisting of alternating beds of unconsolidated and semiconsolidated clay, silt, sand, limestone, and dolomite (see plate 1). These sediments form a southeastward- and southward-thickening wedge which overlies the crystalline basement rocks. The basement rocks are the extension of the rocks of the Piedmont-Mountain province to the north. At the Fall Line, the boundary between the Piedmont-Mountain and Coastal Plain provinces, the irregular, eroded surface of the crystalline complex slopes coastward beneath the stratified sediments of the Coastal Plain. These sedimentary formations crop out at the surface in parallel belts trending northeasterly across the Coastal Plain and dip toward the coast at low angles. The blanket of stratified rocks thickens progressively from a featheredge at the Fall Line to somewhat more than 7,000 feet in southwestern Georgia, where the maximum thickness apparently is attained. Geologically, these strata are the youngest in the State, ranging in age from Late Cretaceous to Recent. (See pl. 1.)

The slope of the land surface of the Coastal Plain is approximately 3 feet per mile from the Fall Line to the Georgia coast. The older Cretaceous beds dip to the southeast and south about 30 to 40 feet per mile, the strata of Eocene age 12 to 15 feet per mile. Strata of Miocene age and younger have dips of less than 8 feet per mile. (See pl. 1.) The coastward slope of the underlying basement complex is much steeper than that of the overlying sediments, being steepest in the Chattahoochee River and Talbot-Crawford County area where dips ranging from 60 to more than 125 feet per mile have been recorded, East of Crawford County, however, the slope of the basement rocks apparently becomes progressively gentler, as in Washington County where dips of 55 feet per mile or less have been noted. The importance of the basement dip is that the water-bearing sediments thicken in shorter distances and occupy a greater volume of the earth where the dips are steepest.

Earth movements which create folding and faulting have been absent in the Coastal Plain except locally. In the Andersonville bauxite district, Sumter County, are east-west faults which have maximum displacements of 80 feet. Subsurface data and surface features indicate that such deformation was confined to the lower Tertiary and that the underlying Cretaceous formations were unaffected. The cause of such faulting is not known, but subsidence due to solution of the rocks by circulating ground water may account for displacements as great as those observed. In this area the Clayton formation of Paleocene age is close to the surface and lies within relatively easy reach of descending ground water. In addition to the faulting, relatively gentle anticlines and synclines occur at some places in the Coastal Plain province.

OCCURRENCE OF GROUND WATER

Ground water occurs at depths ranging from a few feet to several thousand feet. The occurrence of ground water is relatively simple in broad outline, although complex in detail, and it seems to be mysterious to many people. There are many popular misconceptions about ground water. There are, for example, the erroneous beliefs that ground water is found only in underground rivers and the superstition that a forked stick in the hands of a water witch will find good water, even where scientific methods have failed. Common sense tells us, however, that the occurrence of ground water everywhere is controlled by the local geology and hydrology, and that only if the geology and the hydrology are studied thoroughly will an adequate understanding of ground-water conditions come about.

Piedmont-Mountain Province

The Piedmont-Mountain province includes the portion of Georgia which lies north of the Fall Line, except for ten counties in the northwest corner of the State. The rocks exposed in the Piedmont-Mountain province are schist, gneiss, granite, quartzite and other metamorphic rocks which have been intruded by a series of granites. They are the oldest known rocks in the State.

The metamorphic rocks are weathered and have a mantle of decayed rock ranging in thickness from 5 to 80 feet, and perhaps more in places. This mantle of decayed rock serves as a giant sponge, absorbing ground water during wet seasons and allowing it to percolate slowly downward into the cracks of the bedrock below. The amount and depth of residuum depends upon the type of rock, as some rocks are more resistant to weathering than others. The residuum varies in thickness from place to place, usually being thickest in valleys and thinnest on hilltops. Usually erosion removes most of the residuum from the hilltops.

Ground water in the Piedmont-Mountain area occurs largely under water-table conditions. The amount of ground water available depends on the type of rocks, the amount, distribution and intensity of rainfall, the thickness and permeability of the residuum, and the extent of fracturing of the underlying bedrock.

Ground water is stored in the residuum and in the fractures in the underlying bedrock. Recharge to the ground-water body occurs from rain falling on the ground in the immediate area and moving downward to join the ground-water body. The water table responds rapidly to recharge. Water in excess of the amount capable of being infiltrated and stored flows off at the surface or through wet-weather springs as rejected recharge. Wet-weather springs are common throughout the Piedmont-Mountain area.

The structure of rocks in the Piedmont-Mountain province is a controlling factor for movement and storage. The granites of the area hold but a small amount of water in storage, as the fracture system in a granite represents only a very small percentage of the total volume of the rock. Schist and gneiss are made up of many layers of minerals, and partings along the spaces between layers may contain water. These rocks may contain also a system of fracture like those in granite. Where the schistosity is vertical and the parting planes are exposed, water is taken into the ground quite rapidly, but where the schistosity dips, even slightly, less water is absorbed by the rocks.

Faults may act either as ground-water barriers or as conduits. At Warm Springs, the Towiliga fault has cut off the Hollis quartzite of Precambrian age and acts as a ground-water barrier. Likewise, in the areas of schist and gneiss, small faults tend to act as barriers, preventing water from moving freely along the lines of schistosity.

Water-table conditions

Block diagrams of a typical valley in the Piedmont-Mountain area of Georgia are shown in figure 59. Figure 59 shows the water table at the highest annual level, which is in the spring after the winter rains have recharged the ground-water body and water levels are at their peak for the year. The stream is flowing bank full, and the wet-weather springs on the hillside are flowing.

Figure 59 also shows the same valley after an extended drought. The water levels are very low. No rain has occurred to recharge the ground-water body and the river, which is fed by ground-water runoff during the periods between rains, has dried up. The springs on the hillside have also ceased to flow.

Possible well sites are shown in both figures. Location "A" shows a drilled well that penetrates the greatest thickness of residuum and enters the bedrock below. This well is cased to the bedrock. The open hole below the casing intersects water-bearing fractures and will continue to be productive even during a drought.

Two sites labeled "B" are shown. The dug well will produce water during the early part of the year, but as the dry

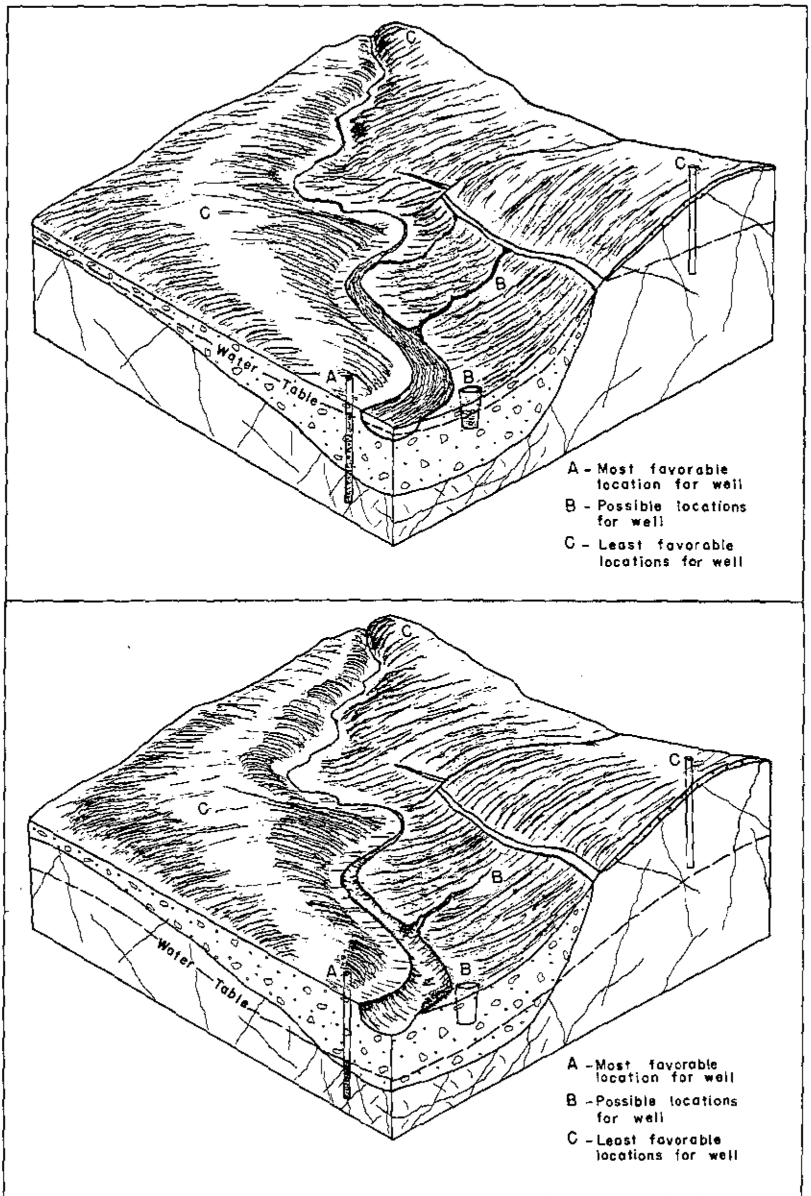


Figure 59. Block diagrams illustrating the occurrence of ground water in the Piedmont-Mountain province of Georgia. Upper diagram shows position of water table under average conditions; lower diagram shows position of water table after extended drought. Note that dug well B is dry after the drought.

season goes on the water table declines and the well goes dry when the water table falls below its bottom. Dug wells are usually shallow, penetrating only the upper few feet of the zone of saturation. The other site labeled "B" is near the wet-weather spring. A drilled well at either of these sites would usually be successful.

Sites labelled "C" are in the least favorable locations to obtain water. All are located on hilltops or high ground. The residuum is thin or absent and the fracture system in the underlying bedrock is not as well developed as in the valley. Accordingly, rain falling here runs off rapidly because there is little residuum to hold it, and, as there are fewer fractures in the bedrock, a much smaller amount of water can be stored. The well shown at location "C" (right) yields no water. Even though it penetrates to a depth below the water table no water-bearing fractures were encountered and water does not enter the well. Neither dug nor drilled wells in such hilltop sites are likely to yield much water.

Figure 60 is a hydrograph of Fulton County 26, a drilled well 350 feet deep and 10 inches in diameter on which a recorder has been installed since 1944. The hydrograph covers the period March 1 to 31, 1956, and shows the water-level fluctuations and amount of rainfall for this period. On March 15 and 16 rainfall amounting to 3.53 inches occurred. Daily noon readings indicate a water-level rise of 0.46 foot during the 48-hour period, and a continued rise from noon on March 16 to noon March 31 of an additional 0.41 foot, a total rise of 0.87 foot. Recharge began shortly after rainfall commenced and continued until a large part of the water absorbed by the residuum had reached the water table.

Figure 61 is a long-term hydrograph of Fulton County 26. Average monthly water levels have been plotted against monthly rainfall. This hydrograph illustrates the seasonal fluctuation of water levels as well as long-term fluctuation during periods of deficient and excessive rainfall.

Artesian conditions

Artesian conditions occur in only a few places in the Piedmont-Mountain province of Georgia. Wells that intersect water-bearing fractures in the underlying bedrock may be artesian in that water rises in the casing above the point at which the water-bearing fracture was encountered during

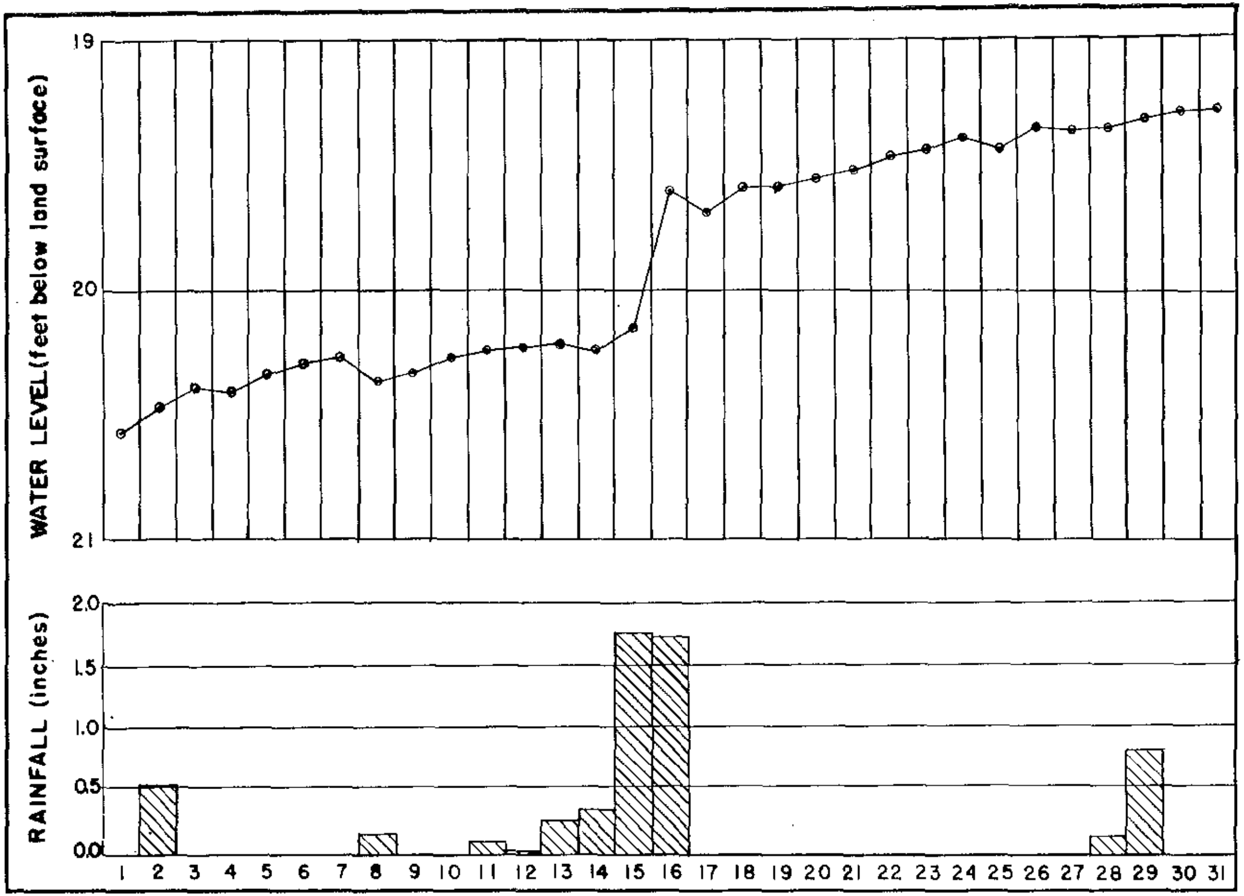


Figure 60. Graph showing effect of rainfall on Fulton 26, a drilled water-table well, March, 1956.

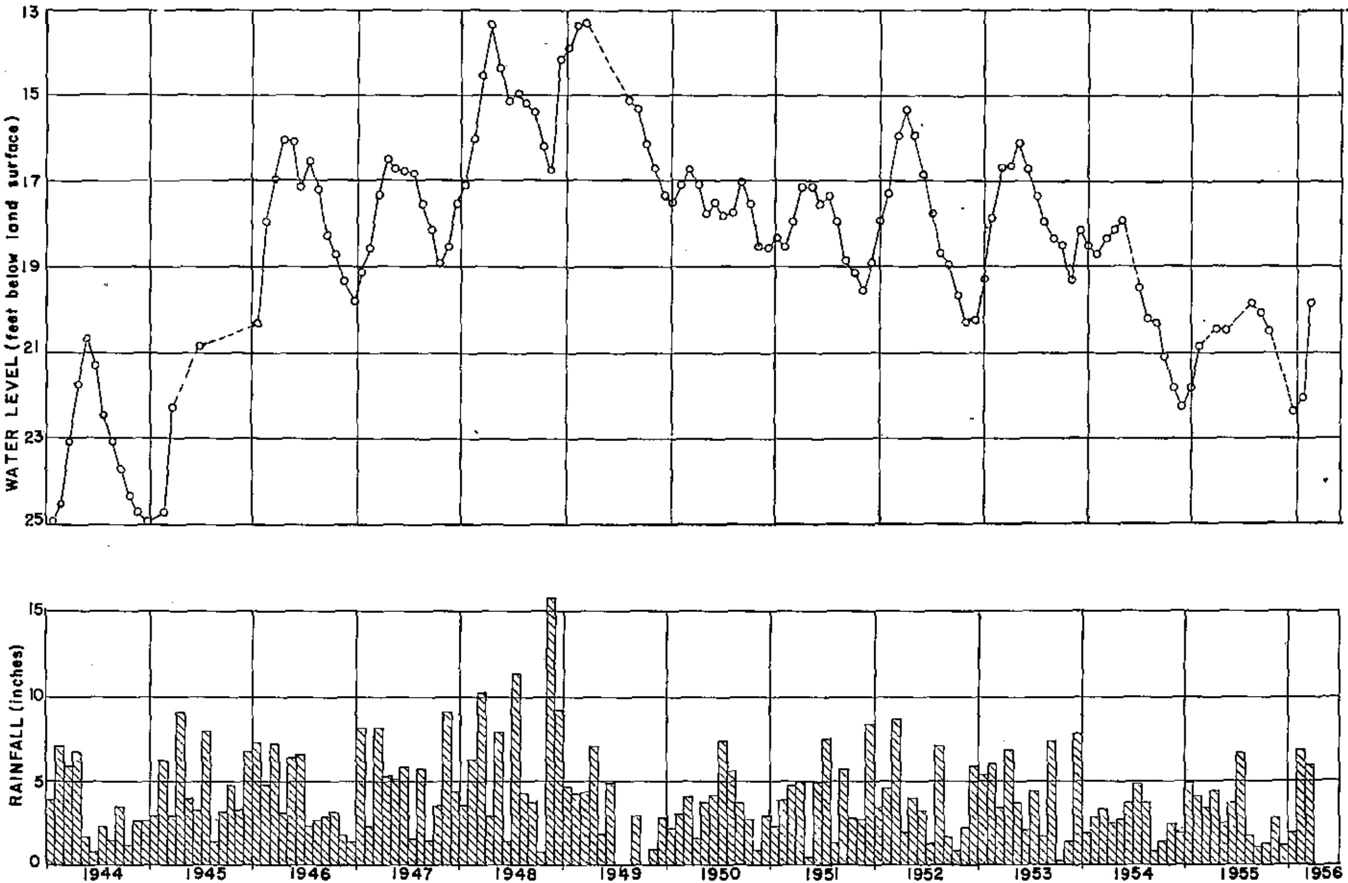


Figure 61.—Long term hydrograph of Fulton County Well 26.

drilling. An occasional such well may flow, especially one located near the bottom of a valley.

An example of artesian conditions in the Piedmont-Mountain province is in the Pine Mountain area, near Warm Springs (see Hewett and Crickmay, 1937), where the Hollis quartzite has been folded and faulted. Erosion has removed the cover from this aquifer and it is exposed on the top of Pine Mountain south of Warm Springs, but the bed remains deeply buried north of Pine Mountain. Water enters the aquifer where it is exposed on top of the mountain and moves northward toward Warm Springs, which is at a lower elevation. Wells intersecting this aquifer at depth are known to be artesian, and some have flowed.

Wells

Dug wells and drilled wells are used for water supplies in the Piedmont-Mountain province. Drilled wells are used principally for municipal and industrial supply and dug wells supply the majority of the rural inhabitants of the province.

Dug wells range in depth from 30 to 90 feet and in diameter from 3 to 4 feet and are constructed by hand. Dug wells are mostly uncased, but a few are cased with concrete or tile or shored with wood. Their depths depend upon the thickness of the residuum and the depth of the water table. The well is dug to a point below the top of the water table so that water can seep into the bottom of the well. Yields of 1 to 10 gpm (gallons per minute) are obtained from dug wells. This amount is usually sufficient for domestic and farm needs.

Drilled wells are used predominantly as sources of water for smaller towns and cities and small industrial plants. They range in depth from about 100 feet to more than 1,000 feet and probably average about 200 feet in depth. Their diameters range from 4 to 12 inches. These wells are cased only to the top of the hard rock, the hole below the casing being left open.

Yields ranging from less than 1 gallon per minute to as much as 400 gpm have been obtained from drilled wells in the Piedmont-Mountain province, the average yield being about 20 gpm.

Location of wells.—One of the most important factors influencing the yield of a well in the Piedmont-Mountain province is its location with respect to topography. Three considerations make the valleys the more favorable sites for wells: the direction of movement of ground water, the amount of residuum available for its storage, and the long-time drainage from high to low ground. Ground water flows from upland areas to lowland areas, and hence tends to accumulate in the valleys. Furthermore, the thickness of residuum available for storage of ground water usually is considerably more in the valleys, as erosion is less active there than on the hilltops. As an extreme example, a well drilled on a hilltop site at Ben Hill in Fulton County reached a depth of 500 feet without producing any appreciable quantity of water; but a second well, only a short distance away in a lowland site, yielded 144 gpm at a depth of only 15 feet (Herrick and LeGrand, 1949). The valleys are subject to recharge from the upland residuum for long periods of time after a rain. Wells in valleys continue to yield water long after many of those on highland areas have gone dry.

In areas underlain by granite, weathering produces concentric layers of rock much like the layers of an onion. Water enters the tops of hills and ridges and flows through cracks toward lowland areas at a relatively rapid rate. Wells on hills or ridges may be dry after relatively short periods of drought, while wells in valleys and lowlands areas are still productive.

Wells drilled in areas underlain by schist or gneiss are most apt to be successful if located according to the local pattern of schistosity and fractures. According to Herrick and Le Grand (1949), "A successful well is one whose intake area contributes considerable water to it. If the strata comprising the intake area for a well crop out on a steep hill where runoff is great and where the influent seepage is, therefore, relatively small, the well will, in all probability, be a small producer." Conversely, if the rocks crop out in flat areas, runoff will be less rapid, more recharge can take place, and wells will be more successful.

Springs

Springs are common throughout the Piedmont-Mountain province of Georgia. Most of these springs are of the seepage type—that is, water percolates to the land surface through pervious material. Gravity springs develop along the sides of hills where the rock containing water is exposed and water moving downward through the rock issues from fractures. This type of spring usually produces a small amount of water but may be of sufficient capacity to furnish water for domestic needs. Many gravity springs occur on the flanks of Stone Mountain.

Artesian springs are those which flow under artesian pressure. They result when the confining bed is breached, as by erosion, and water escapes to the surface. Perhaps the best known artesian springs in the Piedmont-Mountain province in Georgia are those at Warm Springs in Meriwether County. The aquifer is the Hollis quartzite, a much fractured rock which has permeable zones at the top and bottom and a rather impervious zone in the middle. This formation is exposed on Pine Mountain and the high areas to the south of Warm Springs and dips to the northwest where it is intersected by the northeast-trending Towiliga fault about a mile and half northwest of the town of Warm Springs. Hewett and Crickmay (1937) on the basis of hydrologic and geologic studies concluded that water entering the bottom of the Hollis quartzite travels downgradient to the Towiliga fault where it is forced upward into the porous zone in the top of the quartzite, whence it is discharged along the crest of a minor anticline in the vicinity of the town of Warm Springs. According to a temperature-gradient study, the Hollis quartzite is buried to a depth of about 3,800 feet in the vicinity of the Towiliga fault.

Quality of Water

Ground water varies more in chemical quality in the Piedmont-Mountain province than in any other area in the State. The variation in rock type accounts for this variation in quality, each type of rock producing a water whose chemical characteristics are due to the chemical composition of the host rock. The light-colored or "acid" rocks, such as granite and quartzite, usually produce water of good quality low in dissolved solids. The dark-colored or "basic" rocks, such as hornblende gneiss, peridotite, and basaltic rocks, yield more highly mineralized water that contains objectionable quantities of iron. The iron content may be 2.0 ppm, or even more. These basic rocks may produce water that is high also in calcium and magnesium and, therefore, is hard. Water from the Little River series is high in calcium and sulfate and very hard. Hardness may range between 18 and 1,000 ppm. Sodium and potassium usually are present in small quantities, rarely exceeding 10 ppm. Sulfate, chloride, and nitrate are present in minor amounts.

Near Austell in southern Cobb County several wells and springs produce highly mineralized water high in sodium chloride. Water from one well contained more than 6,000 ppm of dissolved solids. The source of this mineralization is not known but may be from a highly soluble basic rock that is not exposed anywhere. Fluoride occurs in concentrations of no more than 0.1 ppm.

Utilization

Most rural and domestic water supplies are obtained from wells, either dug or drilled. Many of the smaller towns and the industries derive their supplies from wells. It is estimated that in 1956 1.3 mgd of ground water was withdrawn for rural domestic and stock use and 6.6 mgd for urban domestic and industrial use.

Valley and Ridge Province

The principal types of rocks in the Valley and Ridge province are limestone, dolomite, marble, shale, schist, sandstone, quartzite, and chert. The best potential sources of ground-water supplies in rocks of this area are limestone, sandstone, fractured quartzite and chert, and dolomite. The poorest water producers are shale and schist, both of which are extremely tight, except along bedding and joint planes and planes of schistosity.

Not only the bedrock but also the surficial residuum exerts a control on ground-water supplies. The openings between the particles of residuum feed rainwater downward to the underlying aquifers. The physical nature of the residuum is most important in determining the amount of recharge that reaches the water table.

Artesian aquifers in this province include sandstone, fractured quartzite and chert, limestone and dolomite, all of Paleozoic age.

In the structural basins flowing artesian wells may be obtained. Although artesian wells are not common, several have been drilled along the eastern slopes of Horn Mountain, in western Gordon County, and White Oak Ridge, Catoosa County.

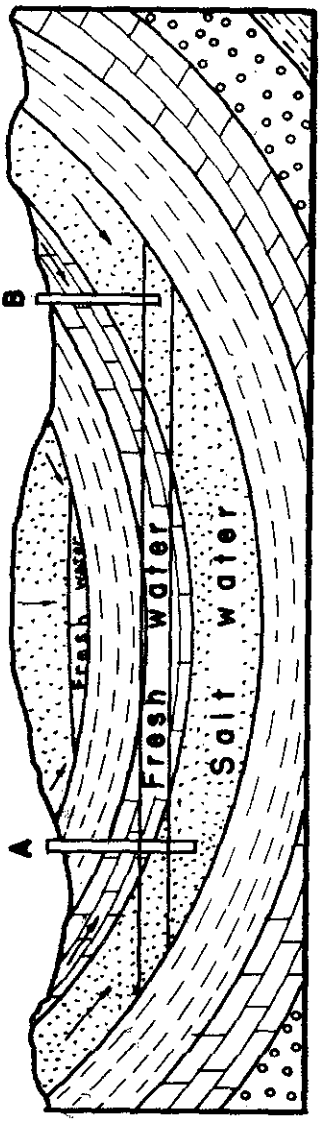


Figure 62. Diagramatic section showing fresh and salt water relationship in synclinal basin.

A. Well will yield salt water.

B. Well will yield fresh water.

Folds are probably the most important structures controlling ground-water movement and storage. Figure 62 shows how ground water finds its way from the surface of the ground down into the upturned edges of a pervious bed (or series of pervious beds), how it migrates because of gravity down the hydraulic gradient toward the center of the synclinal basin, which forms a natural underground reservoir from which large amounts of water are generally recoverable by means of wells.

In addition to acting as underground artesian reservoirs these structural basins may inhibit the circulation of ground water, causing it to become mineralized. Mineralized ground water has been obtained from wells penetrating synclinal basins situated between Rome and Lavender Mountain, Floyd County, and in the Subligna-Gore area, in eastern Chattooga County. In some places salt water may have been incorporated in the rocks during their deposition and has never been flushed out because of lack of ground-water circulation.

Thrust faults border many of the folded structures and exercise considerable control over the movement of ground water. Owing to the low angle of inclination of the faults with respect to land surface, the overthrust blocks may tend to "smother" the fault zones and prevent ground water from discharging as springs. The practical effect of such faults is to localize ground-water movement and prevent downdip movement of ground water on a regional scale. Another effect of some of these faults is to decrease the circulation of ground water to the extent that it becomes mineralized locally.

Fault zones are beneficial to ground-water circulation at some places, as they include shattered rocks which may store considerable water and yield it freely. In order to obtain sufficient water from wells, it is generally necessary to drill into the fractures. Some faults are the sites of large springs.

Planes of schistosity represent parting planes in some metamorphic rocks. Openings that form along such planes constitute the storage space for ground water in these rocks. Shale and slate act as confining beds for the more permeable rocks such as sandstone and limestone.

In limestone, openings along bedding planes and joints may be enlarged by solution. At some places solution has gone so far as to produce subsurface caverns which, when filled with water, constitute potentially large sources of ground water.

The Rock Spring-Kensington area, Walker County, and the valley occupying central Dade County are areas where cavernous limestones exist.

Wells

Ground water is obtained from dug and drilled wells and springs in the Valley and Ridge province. Dug wells generally range from 3 to 4 feet in diameter and from 15 to more than 100 feet in depth. These wells derive their water from the unconsolidated surficial residuum, whose character varies according to the underlying bedrock from which it was derived. Most of these wells are protected from "caving" through the use of wooden curbs, but some are lined with brick, limestone, sandstone, chert, or concrete. Many dug wells in shale or limestone are not curbed, as the surficial residuum of these rocks will stand without caving. In areas underlain by dolomite of the Knox group, however, the surficial residuum is extremely porous, loose, and gravelly. Moreover, weathering is extremely deep, at some places extending as deep as 200 feet. The construction of successful dug wells here is hazardous and time consuming because of the danger of caving. The area between Cartersville and Rome is underlain by dolomite of the Knox. Yields from dug wells are low, not exceeding a gallon or two a minute at most places. In spite of their low yields these wells are widely used, particularly in rural areas, as a source of domestic water supply.

Drilled wells range in diameter from 3 to 12 inches and in depth from 50 to more than 2,100 feet, averaging 100 to 150 feet in depth. Wells are cased to the top of the bedrock and the remainder of the well is left as an open hole.

The potential yields from wells depends upon the total number of openings intersected by the wells (see fig. 63). The number of openings will depend on local geologic conditions, chiefly on the type of rock.

The average number of drilled wells per county is between 250 and 300 throughout the province. Drilled wells yield from 1 gpm to more than 1,500 gpm, depending on the aquifer, the largest yields coming from cavernous limestone and dolomite.

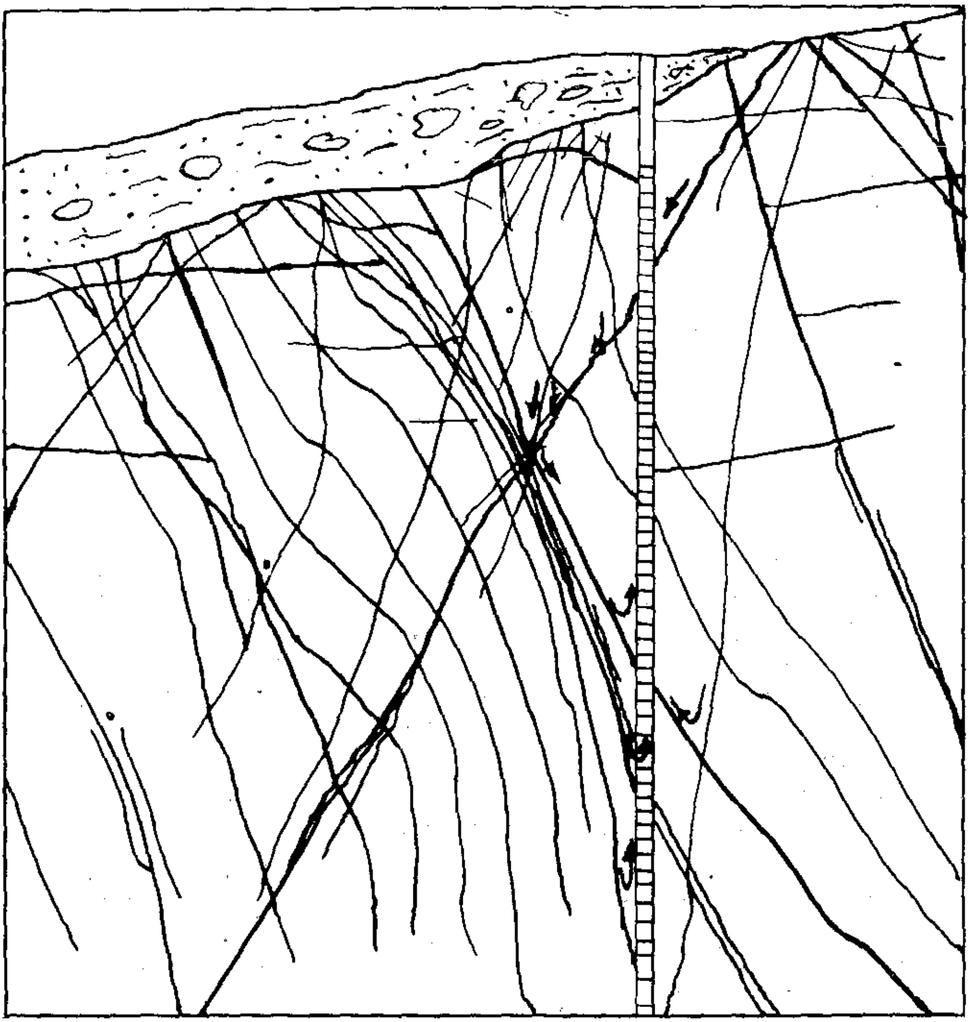


Figure 63. Diagram showing how a well may obtain water by cutting joints. (After E. E. Ellis).

Springs.

Springs, though little used, yield large quantities of ground water in the Valley and Ridge province. Some of them are only small seeps, but others are the principal sources of rivers. The geologic structure is most important in the occurrence of springs, which, in this province, either are of the contact-gravity type or issue along fault lines. Both types are abundant. Examples of contact-gravity springs are Chickamauga Spring, Cedartown Spring, and Dews Pond, which are along the western base of Taylor Ridge. Examples of fault-line springs are Buzzard Roost Spring, Cleghorn Spring, and Cave Spring.

Contact springs occur where the land surface intersects the contact between a relatively permeable water-bearing formation and an underlying relatively impermeable formation. Chickamauga Spring, Walker County, is an example of a contact spring in a synclinal basin. This spring is situated on the western limb of a basin where the formations have an easterly dip. Two lithologically different formations of the Knox group, the water-bearing dolomite and the Newala limestone, which here is of low permeability, are in contact with one another. Cedartown Spring, Polk County, is another spring originating under similar geologic conditions.

Fault-line springs occur where formations having different lithologic characteristics have been moved into contact with one another. Water moving down gradient through the porous water-bearing formation encounters the relatively impervious fault zone and is deflected along it to the surface of the ground.

The flow of individual springs in the Valley and Ridge province ranges from less than 1 gpm to more than 15,000 gpm. Every county contains at least 10 springs having flows of more than 200,000 gallons a day. Some of these springs furnish entire municipal water supplies and others a part of such supplies.

Utilization

The principal uses of ground water in the Valley and Ridge province are domestic, municipal, and industrial. Little use is being made of ground water for irrigation. In 1950 the estimated use of ground water in this area for domestic and municipal purposes was 5 mgd. An estimate made in 1955 showed that both domestic and municipal use had increased.

Municipal and industrial

Ground-water supplies for municipal and industrial purposes come chiefly from drilled wells and springs or a combination of the two. The various ways in which these two types of developments are combined and utilized in this area are worth noting. In some places municipal supplies were derived originally from springs, and as the towns grew, additional supplies were obtained from deep wells. In other places wells were used from the first. Industries were established in some urban areas where houses had individual water supplies, from either dug wells or springs, and later, when a municipal water-supply system was needed, arrangements were made for the industry to furnish water to the town.

Municipal and industrial wells yield from 10 to more than 300 gpm. A recently drilled oil-test well a few miles west of Lafayette, Ga., is reported to have yielded 1,500 gpm from a limestone. The largest spring in the province is Crawfish Spring in Walker County, which flows more than 15,000 gpm.

Rural supplies

Nearly all the rural dwellings in the province get their water from wells and springs. Dug wells range in diameter from 3 to 4 feet and in depth from 25 to more than 100 feet. Drilled wells range in diameter from 3 to 8 inches and in depth from 50 to 300 feet, averaging about 100 feet. Yields of at least 2 gpm, which is satisfactory for a domestic supply, may be obtained almost anywhere in the area. Springs ranging from seeps to those having yields of 500,000 gpd are used as sources of domestic supply. Ground water is used very little for irrigation in this province.

As the name Valley and Ridge implies, the surface topography in this area consists of linear, flat-bottomed valleys separated by well-defined, prominent ridges. The bulk of the better farmland is in the valleys. Water for irrigation has been obtained from surface streams rather than from drilled wells. Most of the valleys are underlain by limestone units which are the largest producers of ground water in this part of the State. It is probable that ground water adequate for irrigation may be developed in certain parts of this area.

Quality of water

The dissolved solids in ground waters of this province are ordinarily between 100 and 400 ppm but are as high as 1,200 ppm in some areas where the ground-water circulation is poor. Usually 300 ppm of dissolved solids is considered high for this area.

Most of the province is underlain by limestone or dolomite; hence, much of the available ground water is hard. The total hardness of water ranges between 100 and 160 ppm in dolomite of the Knox group, between 132 and 188 ppm in the Newala limestone of the Knox group, which is essentially a dolomite, and between 165 and 229 ppm in the Conasauga formation, Lowville and Moccasin limestones and the Floyd shale.

Except in the shale, sandy shale, and sandstone of the Red Mountain formation, most of the ground water contains only minor amounts of sulfate. In a deep well drilled near Ringgold, Ga., water derived from the Red Mountain formation contained 237 ppm of sulfate.

The silica in ground waters from this province ranges from 2 to 22 ppm. The highest silica content is in water from the Lookout sandstone.

Sodium and potassium are dissolved in small quantities from nearly all rocks. When these elements are present in large amounts they are practically always derived from salts and brines contained in sediments of marine origin. Most ground waters in this province contain sodium and potassium in small amounts, from a trace up to 9 ppm. Waters derived from limestones of the Conasauga, Newala, Lowville, Moccasin, and Floyd formations and dolomite of the Knox group contain these elements in amounts ranging from a trace up to 1.7 ppm. Water from a deep well penetrating the Red Mountain formation had a combined sodium and potassium content of 240 ppm. In another well penetrating much of the Lowville and Moccasin limestones sodium and potassium content amounted to 2,390 ppm. This water contained 4,260 ppm of chloride.

Chloride and fluoride are present in minor amounts in ground waters of this region. Ground waters derived from the

Lookout sandstone or the Red Mountain formation contain less than 1 ppm of fluoride.

Iron is dissolved from practically all soils and rocks. Next to hardness iron is the most objectionable constituent in the ground waters of the province. At some places ground waters derived from shales of the Rome, Conasauga, and Red Mountain formations and from the Lookout sandstone contains iron in objectionable quantities. The iron may be removed by aeration, coagulation, and filtration, but to do so is not always practical for domestic use.

Coastal Plain Province

The Coastal Plain province in Georgia extends from the Fall Line on the north to Florida on the south and from the Savannah River on the east to the Chattahoochee River on the west.

The Coastal Plain sediments consist of alternating beds of unconsolidated gravel, sand, clay and silt, and limestone and dolomite that dip in a general southeast direction.

The Coastal Plain may be subdivided into three areas (fig. 64) on the basis of the most important aquifers of the province. Along the Fall Line and for a distance of 30 to 60 miles south of it, sand and gravel of Cretaceous age constitute the important aquifer. These sand and gravel deposits are designated in this report as the Cretaceous aquifer. In the southwestern part of the Coastal Plain, in all of Calhoun and Early Counties and parts of Clay, Randolph, Terrell, Seminole, Miller, Baker, and Dougherty Counties, limestone of the Midway group and sand of the Wilcox group forming the so-called limestone-sand aquifer, furnish most of the water. These rocks are known as the Paleocene and Eocene aquifers. In the remaining two-thirds of the Coastal Plain, water is obtained from limestone ranging in age from middle Eocene to early Miocene. These limestones constitute the principal artesian aquifer, one of the most productive aquifers in the United States. The three aquifer areas will be discussed in the order of the importance of the aquifers.

Table 15 lists the principal formations present in the Coastal Plain and describes their water-bearing properties.

Plate 2 is a fence diagram of the artesian aquifers of the Coastal Plain. The principal artesian aquifer is thickest along the coast and in the southern part of Georgia. It thins to the

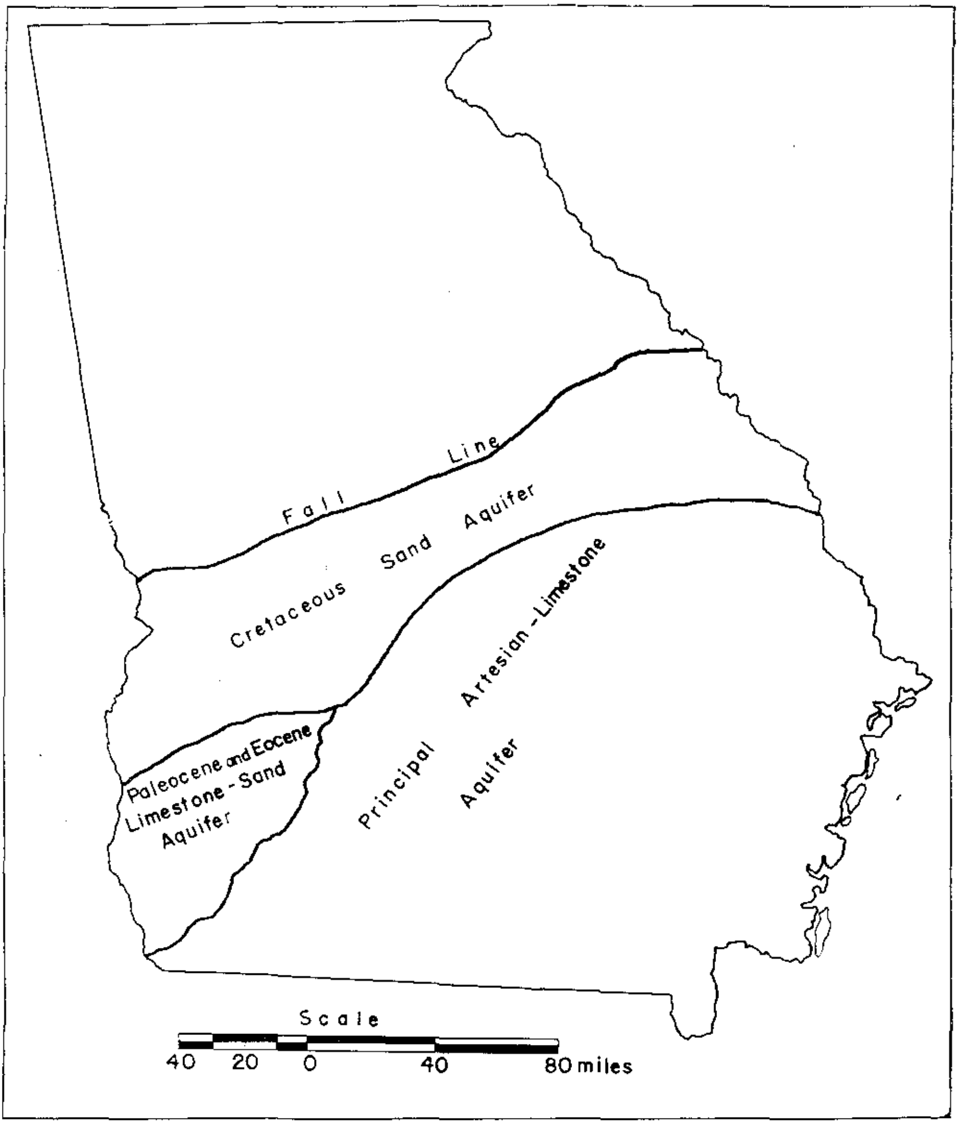


Figure 64. Chief aquifers of the Coastal Plain of Georgia.

Table 15—Generalized table of deposits underlying the Coastal Plain of Georgia

System	Series	Stratigraphic Unit	Thickness (feet)	Lithology	Water-bearing properties
Quaternary and Tertiary	Recent to Pliocene, undifferentiated.		0–120	Chiefly gray to dark-green silty clay and some fine to coarse-grained sand and gravel.	Unconsolidated sand and gravel yield water of good quality in the coastal area and westward as far as Long, Wayne, and Brantley Counties. Pleistocene deposits in river valleys usually not water bearing.
	Miocene	Hawthorn formation and Tampa limestone.	50–320	Pale- to dark-green phosphatic sandy clay, phosphatic sand, and phosphatic sandy limestone.	Yields up to 200 gpm ± from sands of Hawthorn in McIntosh, Glynn, and Camden Counties in coastal area. These sands are little used and represent an important potential source of water where present. Tampa limestone, a part of the principal artesian aquifer, yields up to 200 gpm.
Tertiary	Oligocene, undifferentiated.	Includes Suwannee limestone.	10–85	Limestone, ranging from soft, chalky, and fossiliferous to dense, calcitized, saccharoidal, and unfossiliferous.	Suwannee limestone yields up to 500 gpm in the area of the principal artesian aquifer.
	Eocene	Jackson group (Includes, among other Units, Ocala limestone and Barnwell formation).	78–400	White to cream much calcitized, recrystallized saccharoidal limestone; sandy, sparsely glauconitic limestone at bottom of section.	Ocala limestone in combination with Tampa and Suwannee limestones will yield 500 to 4,000 gpm. In Albany area yields up to 1,000 gpm. This aquifer is one of the most productive known. Transmissibility ranges from 250,000 gpd per foot in Savannah area to 1,000,000 at Brunswick, Jesup, and St. Marys.

Table 15—Generalized table of deposits underlying the Coastal Plain of Georgia—Continued

System	Series	Stratigraphic Unit	Thickness (feet)	Lithology	Water-bearing properties
Tertiary	Eocene	Claiborne group (Gosport sand, McBean, Lisbon, and Tallahatta formations.)	500–800	Dense light-gray sandy, sparsely glauconitic limestone; some bluish clay, dark-brown sandy, cherty, dolomitic limestone, and light-gray glauconitic marl.	Sands yield up to 300 gpm in area of limestone-sand aquifer. Limestones along coast and south tier of counties contain connate water of inferior quality.
		Wilcox group (Bashi marl member of Hatchetigbee formation, Tuscahoma sand, and Nanafalia formation.)	200	Alternating micaceous lignitic clay and sand with minor amounts of gray crystalline glauconitic limestone.	Tuscahoma sand will yield up to 500 gpm in area of limestone-sand aquifer.
	Paleocene	Midway group (Clayton formation).	200	Mostly gray crystalline glauconitic limestone and minor amounts of clay and sand.	Limestone of Clayton formation yields up to 600 gpm in area of limestone-sand aquifer. Aquifer important in the southwestern part of State for both municipal and irrigation supplies.
Cretaceous	Upper Cretaceous	Includes Providence sand, Ripley formation, Cusseta sand, Blufftown and Eutaw formations undifferentiated, and Tuscaloosa formation.	2,000	Alternating green, red, and purple micaceous clay and fine to coarse-grained sand, and minor amounts of sandy limestone.	Yields from sands of the Providence, Cusseta, and Tuscaloosa formations range from 50 to 1,200 gpm. Water may contain iron in objectionable quantities.

north and west and pinches out to the north near the Fall Line and east of the Chattahoochee River. The aquifer is buried by about 200 feet of younger sediments near Savannah, and by 400 to 600 feet of sediments in the southern part of the State. Westward and northwestward from the coast the aquifer is closer to the land surface and is at the land surface in the Dougherty plain. The aquifer is recharged where it is exposed at the land surface.

In the southwestern part of the State, between the Chattahoochee and Flint Rivers in the area of the Paleocene and Eocene limestone-sand aquifer, the Clayton formation of the Midway group and the Tuscahoma sand of the Wilcox group are artesian aquifers. Many wells are constructed so as to obtain water from both aquifers and are known as multiple-aquifer wells.

In that part of the State between Augusta and Columbus and southward to Fort Gaines the Cretaceous sands are the important water-bearing units. Some of these aquifers are under water-table conditions in the area where they crop out but become artesian downgradient where the sands are covered by clays.

Table 16 lists the key wells used in the fence diagram, describes their location, and lists the depth and altitude above mean sea level of the wells. Well numbers on the plate refer to Georgia Geological Survey (GGS) numbers in the left column of the table.

Figure 65 shows the areas where heavy pumping is taking place in the Coastal Plain. More ground water is withdrawn in the seven coastal counties and the adjacent counties than in all the rest of the Coastal Plain counties.

The use of ground water for irrigation has become important in the past few years. Streams, sink holes, and other ponds went dry during the 1954-55 drought, but deep wells in the Coastal Plain continued to produce water in undiminished quantity. Many farmers and inhabitants of rural communities who depended for their domestic or irrigation supply on dug wells, ponds, or streams had to haul water from towns whose water supply was derived from the deeper artesian aquifers. Those farmers who owned wells penetrating the artesian aquifers had a steady supply of water and were able to irrigate crops and take advantage of the favorable

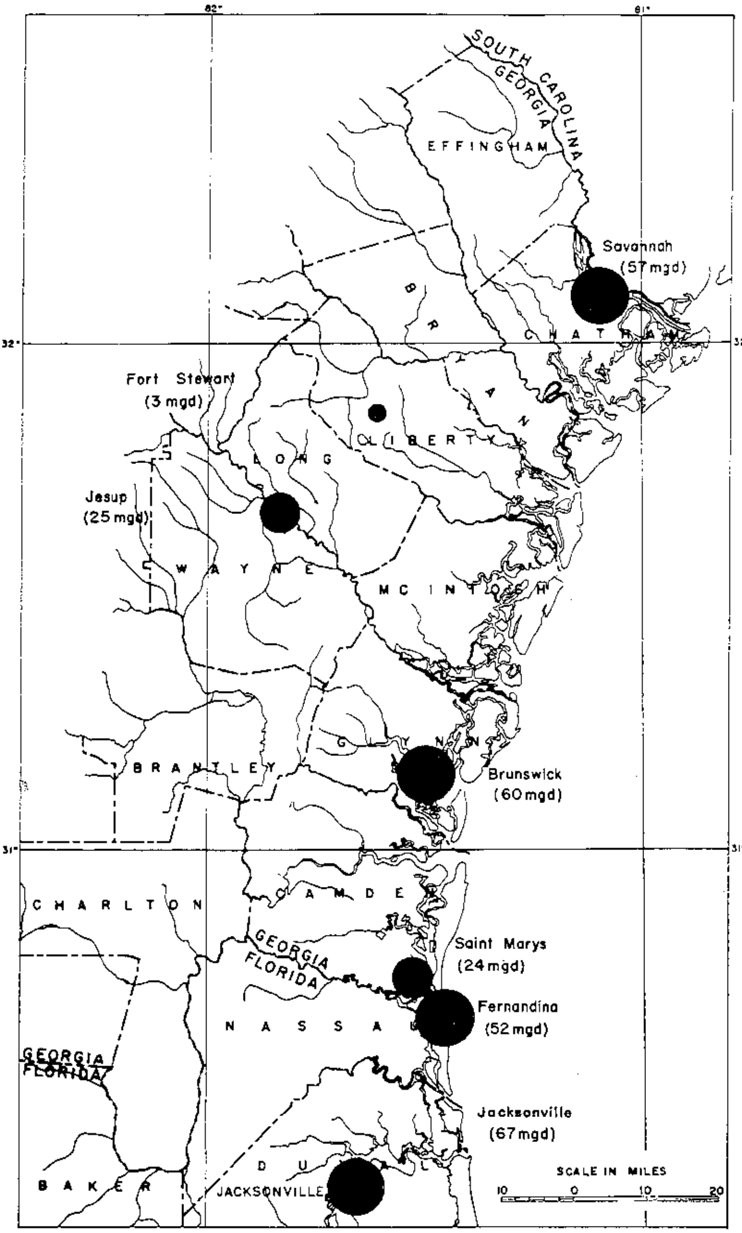


Figure 65. Principal centers of withdrawal of artesian water in eastern Georgia and northeastern Florida in 1955.

Table 16.—Key wells used in fence diagram, Plate 2

Well Number Georgia Geological Survey	Location and Owner	Altitude in feet above Mean Sea Level	Depth of well in feet below land surface
7	Bibb County—Cochran Flying Field, 7 miles south of Macon, Ga.	358	509
15	Lowndes County—U. S. Engineers, Test Well No. 1.	236	425
84	McIntosh County—Blackbeard Island.	10	711
94	Washington County—City of Sandersville.	465	872
108	Crisp County—1½ miles west of Arabi.	364	1005
131	Burke County—near McBean.	129	620
133	Jefferson County near Wrens.	445	549
170	Colquitt County—D. G. Arrington LL 270, LD 8.	270	4902
176	Emanuel County—City of Swainsboro.	310	873
190	Montgomery County—Lonnie Wilkes.	287	600
194	Houston County—H. B. Gilbert.	364	1693
211	Effingham County—City of Springfield.	47	400
228	Decatur County—City of Bainbridge.	135	445
295	Screven County—City of Sylvania.	202	490
331	Calhoun County—City of Morgan.	252	667
341	Chattahoochee County—City of Cusseta.	550	1205
364	Camden County—St. Marys Kraft Co.	11	1190
366	Ware County—City of Waycross.	140	775
381	Chatham County—U. S. Geological Survey.	6	740
435	Clay County—City of Fort Gaines.	396	455
453	Charlton County—Folkston High School.	72	650
487	Marion County—Lee Oil and Gas Co.	650 Approximate	1770

market prices. It is estimated that about 400 irrigation wells have been drilled in the Coastal Plain in the past few years.

Area of the Principal Artesian Aquifer

The principal artesian aquifer underlies about two-thirds of the Coastal Plain (see fig. 64) and furnishes nearly 70 percent of the ground water used in Georgia. The formations composing this aquifer are, in ascending order, the Ocala limestone of late Eocene age, the Suwannee limestone of Oligocene age, and the Tampa limestone of Miocene age. These three limestones generally act as a single hydrologic unit. Above and below the aquifer are beds of low permeability that confine the water in the limestones. The upper confining bed is clay of the Hawthorn formation of Miocene age, which extends from the coastal area westward to the Flint River. The lower confining bed consists of clay and limestone of the McBean formation of middle Eocene age. The McBean underlies the principal artesian aquifer throughout the area of confinement (see pl. 1.)

The regional dip of the principal artesian aquifer is toward the southeast. Structural highs occur in western Camden and eastern Charlton Counties, in eastern Brantley and western Glynn Counties, and in Long and western McIntosh Counties. The limestone appears to form a syncline in eastern Glynn County and lies about 600 feet below the surface in the vicinity of Darien in McIntosh County. Beginning at Savannah the limestone rises toward the northeast to within 80 feet of the surface at Parris Island and Hilton Head Island, S. C.

The outcrop areas serve as the recharge areas for the limestones that make up the principal artesian aquifer. The Ocala limestone crops out in the Dougherty Plain area (see fig. 66) and in a narrow northeast-trending belt as far east as Effingham County. Parts of Brooks and Lowndes Counties on the Georgia-Florida line and Jenkins County in east-central Georgia also are recharge areas. Recharge occurs downward through the exposed rock and from the sink holes in the limestone. To the south and parallel to the Fall Zone where the limestone is underlain and overlain by sands, recharge takes place upward and downward from these sand units.

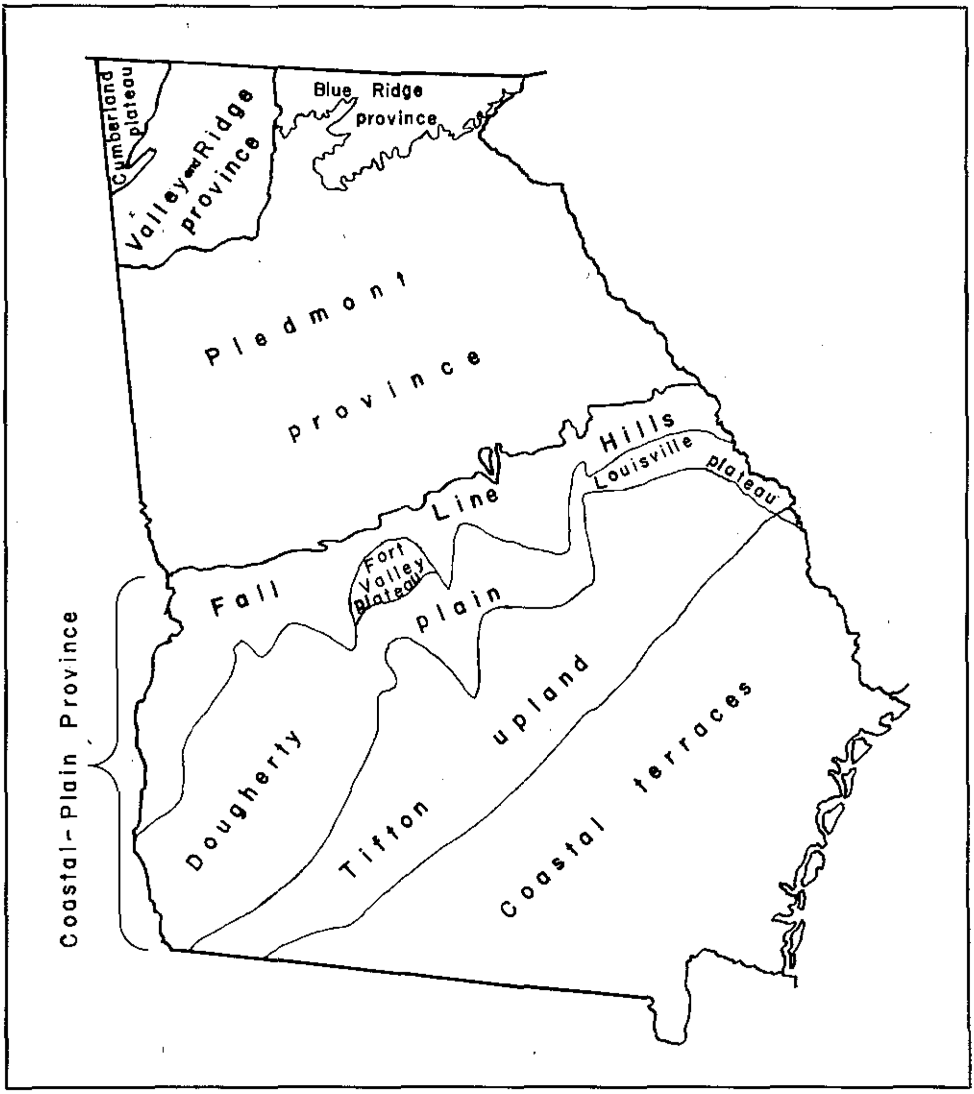


Figure 66. Physiographic provinces of Georgia.
(After S. W. McCallie, 1925)

Water-table conditions

Water-table conditions occur in the overlying sediments, insofar as they are water bearing, throughout the area of the principal artesian aquifer. The residuum furnishes water to dug wells and is the principal source of water in rural areas. Shallow-lying sands furnish water to shallow drilled wells and to driven wells. Along the coast and in the southeastern counties near the Georgia-Florida border, sand and gravel of Pliocene to Recent age are capable of furnishing water in moderate quantities. Sands of the upper part of the Hawthorn formation also yield water to wells. These water-table aquifers yield water that is softer than water from the limestone and is more suitable for use in boilers and for other industrial uses, and they are an important source of soft domestic water. The sands are highly porous and permeable and readily absorb rainfall. Figure 56 is a hydrograph of well Chatham 343, a well dug 15 feet into Pleistocene sands at the U. S. Department of Agriculture's Plant Introduction Station south of Savannah. This hydrograph shows that 6.11 inches of rainfall during July 26th and 27th caused the water level to rise 4.40 feet during the 48-hour period.

Artesian conditions

In 1884 the first flowing well was drilled in Georgia near Albany by Col. John Fort. At that time the piezometric surface was higher than the land surface in nearly all the artesian area. The original city wells at Savannah flowed. In the remainder of the coastal area southward to the Georgia-Florida border and inland below an altitude of about 70 feet, wells flowed at the land surface. Flowing wells could be constructed for many miles inland along the river valleys. Flowing wells could be obtained along the major streams in Baker and Mitchell Counties, eastern Calhoun and western Dougherty County, most of Lee County, and parts of Terrell and Crisp Counties. By 1955 most wells in this area had stopped flowing. Wells have stopped flowing in Chatham County and most of Bryan County. At St. Marys in Camden County a small nonflowing area has developed. A canvass of wells in Dougherty County revealed no flowing wells from the principal artesian aquifer, although several flowing wells tap deeper water-bearing zones.

Because the ground water in the principal artesian aquifer is confined between beds of low permeability and is under hydraulic pressure, withdrawal of water causes a rapid decline of pressure and quickly creates a cone of depression in the piezometric surface around the pumping well. If the pumping rate is increased, the cone of depression expands.

In the Savannah area, pumping has produced a large cone of depression, in which water moves toward the center. Similar cones of depression have been developed at Brunswick and St. Marys, but data are not available to determine how deep or extensive they are.

Barometric fluctuations are observed in artesian wells. When barometric pressure decreases water levels rise; when the pressure increases water levels decline.

Loading of the aquifer also causes water levels to fluctuate. An increased load causes the water to rise in the well. The effects of tidal loading have been observed in wells in the Savannah area, where water levels fluctuate as much as 4 feet, rising as the tide moves in and declining as the tide moves out. This tidal effect dies out a short distance inland. Figure 58 shows the effect of spring and neap tides in a well in Chatham County.

Piezometric surface.—Figure 67 is a piezometric map of the principal artesian aquifer in 1942, showing the direction of movement of ground water. Water entered the principal artesian aquifer in the recharge area and moved south or southeast. In Jenkins, Screven, and Bulloch Counties and part of Effingham County, the direction of movement of water was nearly due east toward South Carolina. In the area between Candler County and western Turner County the movement was southeasterly; beyond, in the area extending southwest to the corner of the State, the movement was southerly toward Florida. The ground-water high in Brooks and Lowndes Counties represents a recharge area, from which water moves away in every direction.

Figure 68 shows the piezometric surface in southeast Georgia approximately as it was before withdrawal began. Movement in the coastal region was generally east and, especially in the area around Savannah, northeast, and the piezometric surface was above the land surface throughout the six coastal counties, ranging from more than 60 feet above sea level in

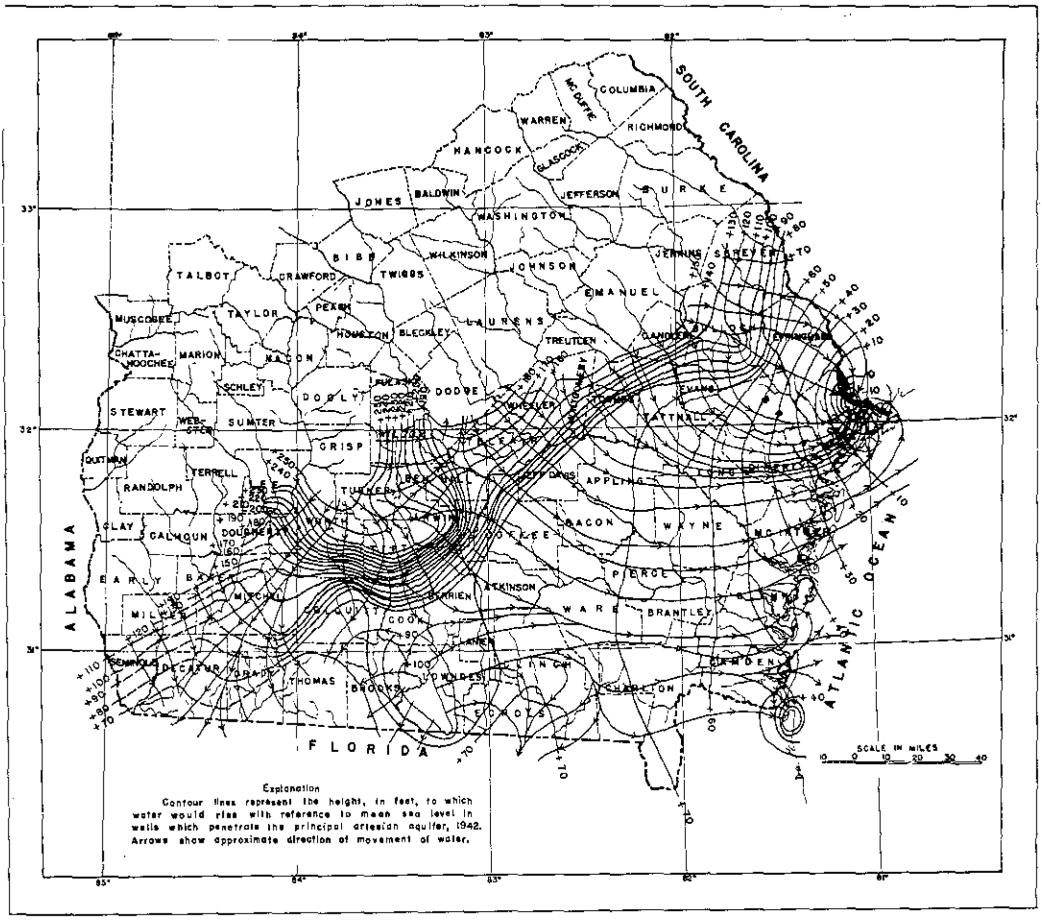


Figure 67. Piezometric surface of principal artesian aquifer, 1942
(After Warren, 1944)

Camden County to more than 40 feet above sea level in Chatham County.

The cone of depression at Savannah by 1942 was then more than 40 feet below sea level at the deepest point. The map of this piezometric surface in 1955 (see fig. 57) shows that the diameter of the cone of depression has been enlarged to about 35 miles, that the cone extends to more than 100 feet below sea level, and that the water is moving southwestward toward Savannah from the vicinity of Parris Island, S. C. The map of the original piezometric surface (see fig. 68) shows that the water once moved toward the Parris Island area, which was then an area of natural discharge, but which may now be one of recharge from the sea.

Figure 69 is a map showing the decline of the piezometric surface in the Savannah area up to the year 1956. A system of observation wells to record the fluctuations of the piezometric surface has been established, and heads at these wells have been measured periodically for about 17 years. Declines ranging from 30 to more than 100 feet have been registered in Chatham County and declines of 20 to 30 feet in Bryan and Liberty Counties. Water levels are affected within a radius of about 25 to 30 miles from the center of pumping. In the coastal area from Bryan County south to the St. Marys River, two other large cones of depression have been created by the pumping of large quantities of artesian water. In the Brunswick area water levels have declined as much as 40 feet and in the St. Marys area as much as 70 feet.

Salt-water encroachment

Along the coast where ground-water withdrawals are large and water levels are depressed below sea level there is the possibility of salt-water encroachment into the fresh-water aquifers. The large lowering of the piezometric surface in the Savannah area may allow salt water from the ocean to enter the fresh-water-bearing limestones if those limestones are in direct contact with sea water or if salt water is present in overlying permeable materials and the confining bed is thin or absent. Such conditions may exist at the area of outcrop on the ocean floor and in coastal channels where dredging has thinned or removed the upper confining bed. The aquifer crops out on the ocean floor at an unknown distance east of Savannah and the coast. It probably is exposed also

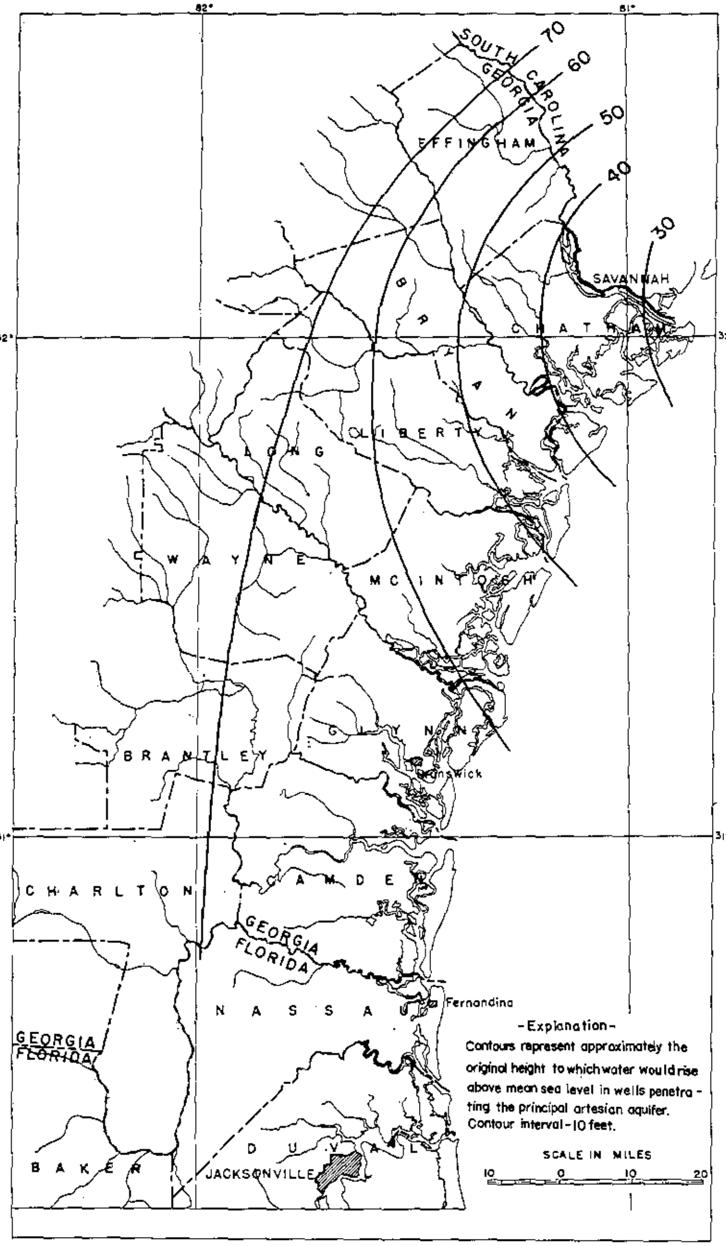


Figure 68. Map of the original piezometric surface of artesian water in the principal artesian aquifer in southeastern Georgia. (After Warren, 1944).

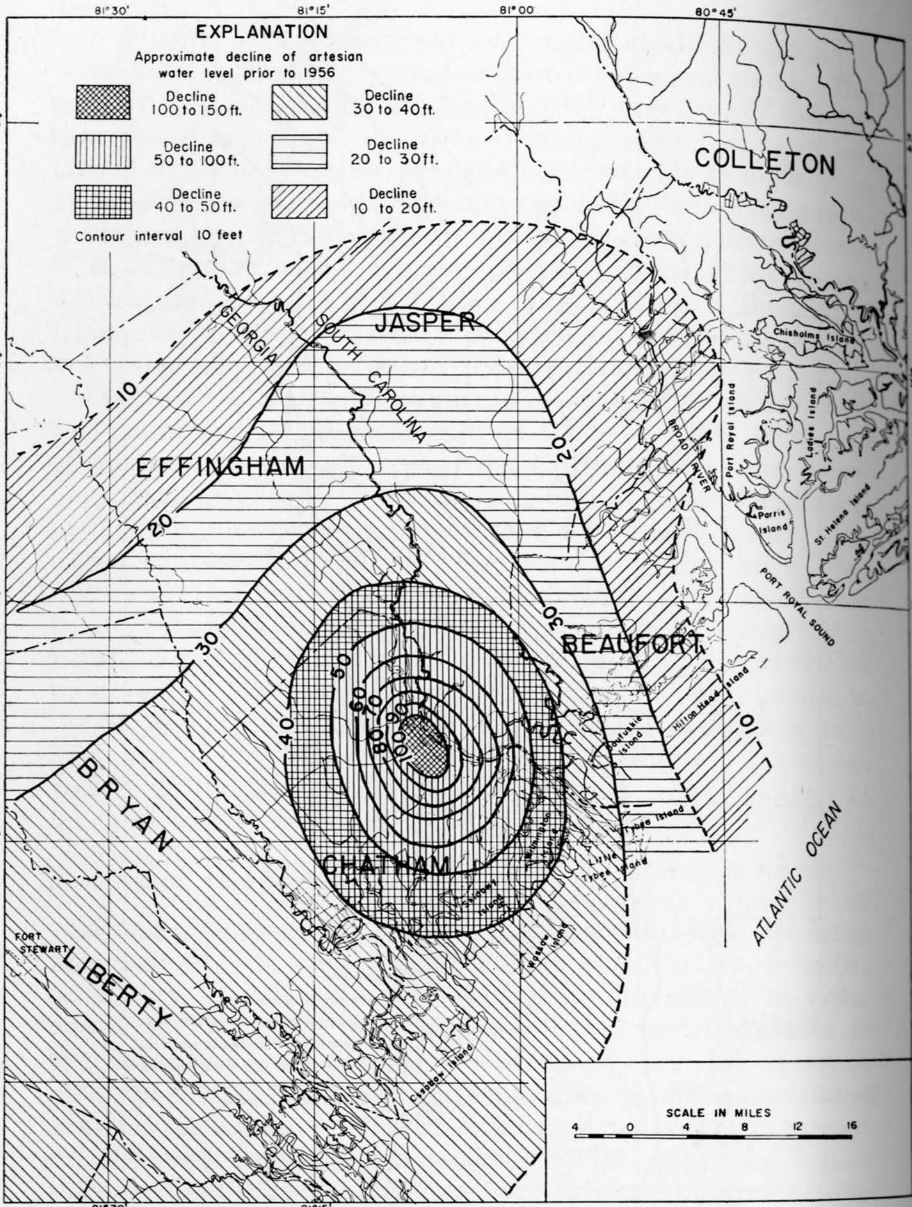


Figure 69. The decline of artesian water levels, Savannah and vicinity, prior to 1956.

at the bottom of the coastal channels near Hilton Head Island and Parris Island, S. C.

The aquifer is underlain by other rocks which may contain salt water. Deep test drilling has shown that salt water is present below the aquifer near St. Marys and at Parris Island, S. C., and it probably is present along the entire coast of Georgia.

Studies are being made to determine if salt water is moving into the aquifer at Savannah. Work was started in this area in 1939, and in 1944 Geological Survey of Georgia Bulletins 49 and 49a reported conditions as they existed at that time. From 1944 to 1954, determinations of the chloride content of water in selected wells were made periodically as a means of detecting any changes in salinity, and these have been presented in open file reports. In May 1954 two outpost wells were drilled to determine the quality of water at various depths and to determine the character and thickness of the aquifer and the confining clay beds. In October 1954 an area office was established in Savannah to resume the studies.

Wells

Drilled wells supply most of the water used in the area of the principal artesian aquifer. These range from less than 100 to as much as 1,200 feet in depth and from 3 to 20 inches in diameter. Dug wells which supply some dwellings range from 30 feet to 70 feet in depth.

The construction of drilled wells is of the simplest type. The casing is usually extended into the limestone and either driven or cemented into place, and the remainder of the hole drilled in the limestone is left uncased. It is important that the casing be extended into the limestone. Should the casing be extended only into the top of the Miocene clays above the limestone, the clays may cave into the well and cause it to fail. Also, whenever the artesian pressure in the aquifer is greater than that in the Miocene sands and clays, inadequate casing may allow water to leak from the principal aquifer, causing a loss in head.

Figure 70 (Warren, 1945) is a contour map of the top of the principal limestone aquifer and shows the altitude of the top of the limestone bed with reference to sea level. The amount of casing needed in a well may be approximated by

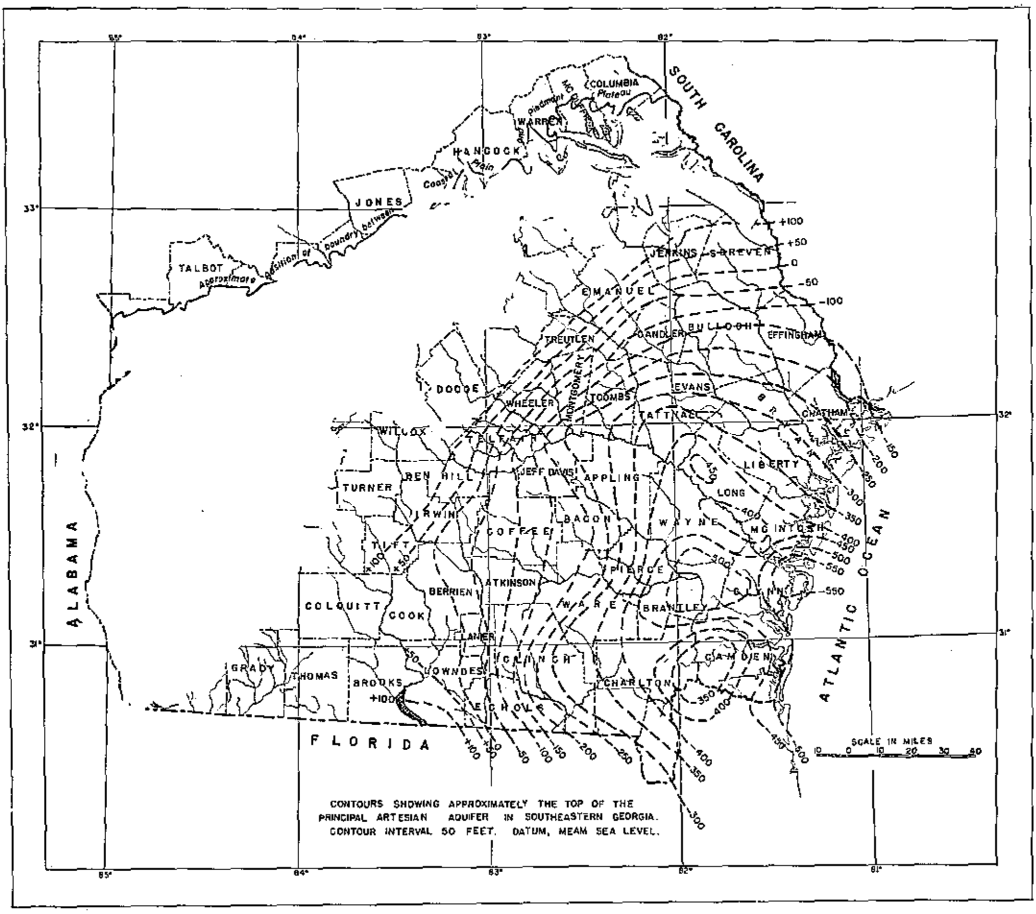


Figure 70. Structural contour map of the top of the principal artesian aquifer in southeastern Georgia. (After Warren, 1944).

determining the difference in elevation between the land surface at the well site and the top of the limestone bed.

Wells that draw from the principal aquifer have maximum yields ranging from about 100 gpm to more than 4,000 gpm. In the area near the outcrop, yields are generally less than elsewhere. In the Savannah area, yields range from 500 to about 2,000 gpm. In the Jesup area and in the Brunswick area and south to St. Marys, yields of as much as 4,000 gpm may be obtained.

Springs

Few springs issue from the principal artesian aquifer, as the aquifer is covered almost everywhere by a thick blanket of sand and clay. Most springs in the area occur around the edges where this blanket is thin. Blue or Russell Spring in Decatur County, Radium Springs near Albany, Rock Springs in Laurens County, and Magnolia Spring in Jenkins County are examples. Other small springs of minor importance doubtless occur, especially near rivers where downcutting has exposed minor aquifers in the Miocene deposits. There probably are many submarine springs where the aquifer is exposed on the ocean floor.

Quality of water

Water from the principal artesian aquifer is of generally good quality, low in silica, iron, and dissolved solids, and ranges from soft to very hard (see table 17). The dissolved solids are lowest in the area of recharge. The hardness and dissolved solids increase with the distance from the area of recharge. Plate 3 shows the hardness of water from the aquifers in various parts of the State. Near the area of recharge the water ranges in hardness from soft to moderately hard. In the southern counties and along the coast the hardness is as high as 300 ppm. The increase in hardness is probably due to the fact that water that has moved long distances through the aquifer has had more time to dissolve the limestone.

Deep wells at the Thomasville airfield yielded water containing 7,300 ppm of chloride from a reported depth of 1,635 feet. These wells are in the Tallahassee syncline, and the high mineralization may be the result of poor ground-water circulation.

Table 17.—Analyses of water from principal artesian aquifier

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

County number and owner	Amount of casing (feet)	Total depth (feet)	Date of collection	Temperature (degrees F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
Appling #13 City of Baxley	564	849	3-17-43	77	215	45	0.09	34	13	15	2.5	153	3.0	22	9.6	0.4	0.0	138
Camden #94 City of Kingsland	446	548	3-21-40		528	35	.32	77	38	22	2.1	201	0	117	34	.5	.10	348
Chatham #19 City of Savannah	255	603	2-9-38	73	176	53	.01	26	10	10	1.4	134	2.0	6.8	5.8	.0	.0	106
Chatham #117 U. S. Government	125	602			347	40	.02	28	20	56	4.2	145	0	85	52	.6	.25	152
Chatham #345 U. S. Navy	352	535	7-27-43	75	260	40	.01	18	16	48		149		23	48	.8	.0	111
Effingham #7 Central of Georgia. R. R.	273	431	3-12-40		186	56	.03	29	6.6	11	2.0	120	7.9	7.0	4.6	.2	.10	100
Evans #2 City of Claxton	600	662	3-4-43	75	160	46	.06	23	9.1	11	2.6	125	3.0	4.2	3.5	.4	.1	95
Glynn #152 Sea Island Co.	540	812	1-23-41		317	38	.08	40	25	22	2.1	144	0	94	22	.5	.0	202
Liberty #161 U. S. Government (Fort Stewart)	451	816	1-21-41	75	152	36	.02	19	9.4	16	2.6	133	0	8.4	3.6	.4	.0	86

Table 17.—Analyses of water from principal artesian aquifier—Continued

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

County number and owner	Amount of casing (feet)	Total depth (feet)	Date of collection	Temperature (degrees F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
Screven #2 City of Sylvania	150	301	5–21–43	70	193	36	0.06	49	5.1	4.4	1.1	166	0	8.6	2.8	0.2	0.0	143
Tattnall #1 City of Reidsville	560	713	3–5–43	72	155	33	.31	24	8.2	13	3.4	139	0	5.2	4.1	.4	.0	94
Ware #9 City of Waycross	572	931	5–28–41	74	224	46	.21	34	14	16	2.4	159	0	29	14	.4	.15	142
Wayne #2 City of Jesup	480	675	1–21–41		215	40	.03	29	16	17	2.4	155	0	36	8.0	.5	.0	138
Bacon #1 (Alma) City of Alma	363	626	5–28–41	76	203	46	.01	29	14	15	2.9	160	0	21	7.6	.4	.05	130

Figure 71 shows typical analyses of ground waters from the principal artesian aquifer.

Area of the Cretaceous Aquifer

The Cretaceous rocks in Georgia consist, in ascending order, of the following formations: the Tuscaloosa formation, the Eutaw and Blufftown formations, (not differentiated in this report), the Cusseta sand, the Ripley formation, and the Providence sand. The Tuscaloosa formation, the Cusseta sand, and the Providence sand are aquifers in this area. The Cretaceous rocks are exposed in a northeast-trending belt southeast of the Fall Line. They are covered by younger sediments at some places and crop out in a belt as much as 50 miles wide at others. Along the Chattahoochee River this belt extends from Columbus southward to Fort Gaines, in the central portion of the State from Macon southward to Cochran and Dublin, and in the eastern part of the State from Augusta southward to Sylvania.

Water under both artesian and water-table conditions occurs in the Cretaceous aquifers. Water-table conditions occur in the outcrop area of the sands. As ground water moves down the dip it becomes confined between clay beds above and the bedrock or clay beds below and thus becomes artesian. Recharge is derived from local precipitation and from influent streams that cross the recharge area.

Water-table conditions

The residuum developed on the outcrop belt of the Cretaceous rocks yields water to both dug and drilled wells. In the area of exposure of the Cusseta sand in Chattahoochee, Marion, and Stewart Counties beds of clay or fine sandy clay act as confining beds. Water moves downward until it reaches these impermeable beds and then moves laterally. Springs emerge where the contact between the sands and the impermeable beds are exposed in road cuts or on hillsides.

The local relief at some places is as much as 400 feet. Erosion has exposed the water-bearing sands over wide areas, and leakage from them is the source of the base flow of many of the streams. Sands that lie above the bottoms of the stream valleys are drained at many places.

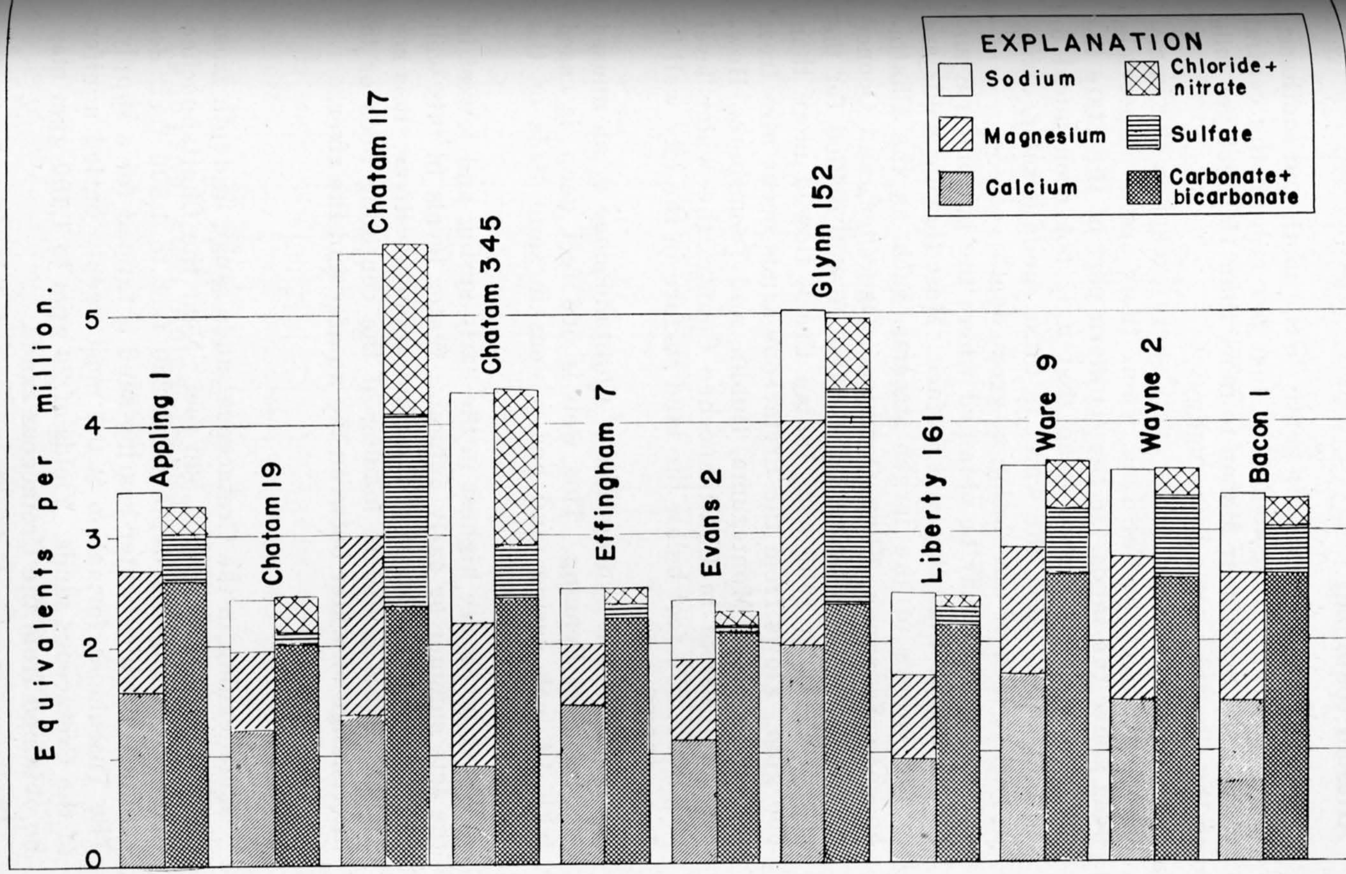


Figure 71. Quality of water from principal artesian aquifer.

Artesian conditions

The Cretaceous strata dip gently to the south and southeast. The dips range from about 100 feet per mile in the central part of the State near Macon to more than 150 feet per mile in the Chattahoochee River valley.

Artesian conditions occur everywhere except in the immediate vicinity of the Fall Line, where there are no impervious beds above the sands. In the southern part of the State the Cretaceous sands are so deep that it is not economical to develop them. Also, the water in these sands is salty, owing in part to lack of circulation at great depth.

Flowing wells may be obtained where the piezometric surface is higher than the land surface. Most flowing wells are in the valleys of the larger streams, such as the Chattahoochee, Savannah, Flint, Ocmulgee, Ogeechee, and Oconee Rivers and their principal tributaries. A well drilled for the city of Perry in 1955 near Indian Creek flowed more than 600 gpm. Flows from the Cretaceous sands occur also from the city wells at Montezuma, Dublin, and Toomsboro. However, at Cusseta in Chattahoochee County, the water level was about 270 feet below the land surface in the city well in June 1953.

Figure 72 is a hydrograph of Chattahoochee 9, an unused well at Fort Benning. This well is 568 feet deep, is cased with 12 inch casing, and has screens in sand beds of the Tuscaloosa formation.

Water levels are highest in the early spring and lowest in the late summer or early autumn. Water levels in this well fluctuate with the stage of the Chattahoochee River. It is not known if this is due to loading of the confining beds or to interchange of water between the aquifer and the river.

Wells

Wells ending in the Cretaceous sands range in depth from about 100 to more than 1,500 feet. Near the Chattahoochee River they range in depth from 250 feet to 1,500 feet, depending on which water-bearing sand is tapped for a supply. The Tuscaloosa formation is the most deeply buried aquifer of the Cretaceous sands. Yields of 20 gpm to 1,100 gpm may be obtained from the Cretaceous sands.

Wells are constructed with screens or slotted pipe opposite

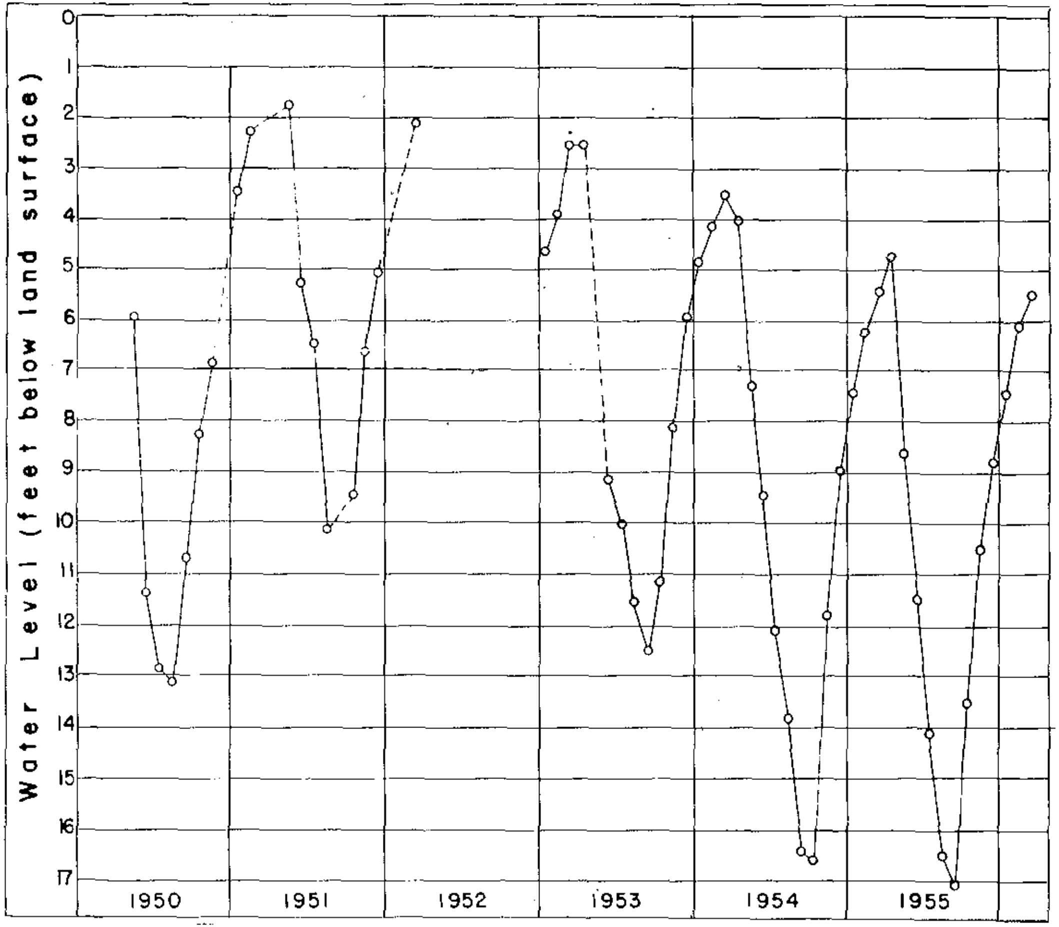


Figure 72. Chattahoochee County Well 9.

the water-bearing sands. The size of the screen used must be carefully chosen, or sand will be pumped through the openings of the screen into the well. Some wells are gravel packed.

In developing wells near deep canyons, such as Providence Canyon, a water-bearing sand that lies below the bottom of the canyon must be penetrated if a year-round water supply is to be obtained, because sands exposed in the sides of the canyons are drained except during wet weather.

Springs

Few large springs are known to issue from the Cretaceous rocks. Springs have been developed by small communities for municipal supply and by individual landowners for domestic supply. Prior to 1953 the town of Cusseta obtained its water supply from several springs that issued from the Cusseta sand. In rural areas some farmers utilize springs for domestic and stock water. In the Fort Benning area several springs produce enough water to maintain large ponds throughout the year. A spring that supplies the swimming pool at Fort Benning was flowing 237 gpm when measured in December 1952.

Quality of water

Water from the Cretaceous sands is generally soft and low in dissolved solids. The hardness ranges from 5 to 157 ppm (see table 18). According to LaMoreaux (1946), some of the waters that are slightly harder than usual are derived from a calcareous facies. Waters having a hardness of as much as 124 ppm in east-central Georgia, reported by LeGrand (1956), are derived from limestone in the Barnwell formation of Eocene age. The hardness and dissolved solids increase in a southeastward direction from the Fall Line, and with depth.

Iron is present in objectionable quantities in waters from the Cretaceous aquifer at some places. Fluoride occurs in the waters in amounts of as much as 0.4 ppm. Figure 73 shows the chemical analyses of waters typical of the Cretaceous sands.

Table 18.—Analyses of water from Cretaceous Sands

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

County number and owner	Amount of casing (feet)	Total depth (feet)	Date of collection	Temperature (degrees F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
Twiggs #17 Ga. Kaolin Co.	240	291	11–9–44	65	68	18	0.02	15	1.1	1.1		45	0	3.1	2.1	0.1	1.1	42
Twiggs #40 City of Jeffersonville	533	533	11–9–44	66	197	24	.06	60	1.7	2.7		178	0	9.4	4.6	.1	.1	157
Twiggs #72 Miller Hendrick	360	360	11–9–44	68	27	10	.43	1.1	.5	2.9		0	0	8.9	1.2	.1	.0	5
Washington #51 City of Sandersville	760	760	8–6–44	64	80	22	.87	16	1.5	4.4		54	0	7.7	2.4	.0	.0	46
Washington #126 Edgar Bros'.	120	123	9–12–44	65	66	9.4	.63	13	1.0	9.1		53	0	9.5	1.9	.1	.1	37
Chattahoochee #13 City of Cusseta	1140	1140	6–30–53	77.5	143	54	.83	12	1.0	15	2.2	58	0	9.0	11	.2	.0	34

Area of the Paleocene and Eocene Limestone-Sand Aquifer

The composite limestone-sand aquifer consists of the Tuscahoma sand of early Eocene age above and limestone of the Clayton formation of Paleocene age below.

This composite aquifer is present in southwestern Georgia in Calhoun and Early Counties and parts of Clay, Randolph, Terrell, Seminole, Miller, Baker, and Dougherty Counties (see fig. 64).

Ground water occurs under both water-table and artesian conditions throughout this area. Recharge to the artesian aquifers occurs mainly where the aquifers crop out at the land surface.

The lower Eocene sands crop out from central Clay County on the west to Twiggs County on the east. The limestone of the Clayton formation crops out from Quitman and Clay Counties on the west to Schley and Sumter Counties on the east.

The Tuscahoma sand and Clayton formation are recharged principally in the outcrop areas. However, some recharge may occur from the underlying Cretaceous sands to the limestone of the Clayton. The water in the Cretaceous sands is known to be under a higher artesian pressure than the water in the limestone, and discharges to it by upward flow through wells that tap both aquifers.

Water-table conditions

Water-table conditions occur throughout the area in the residuum developed at the land surface and in the limestone and sand aquifers where they are unconfined. Shallow bored or dug wells obtain water from the residuum and yield up to 10 gpm. Although only small quantities of water are obtained from the residuum, its importance cannot be denied, for it continues to be the main source of water for much of the rural population.

Artesian conditions

Artesian conditions occur throughout this area. The head ranges from more than 100 feet below the land surface to about 10 feet above the land surface, depending upon the location of the wells.

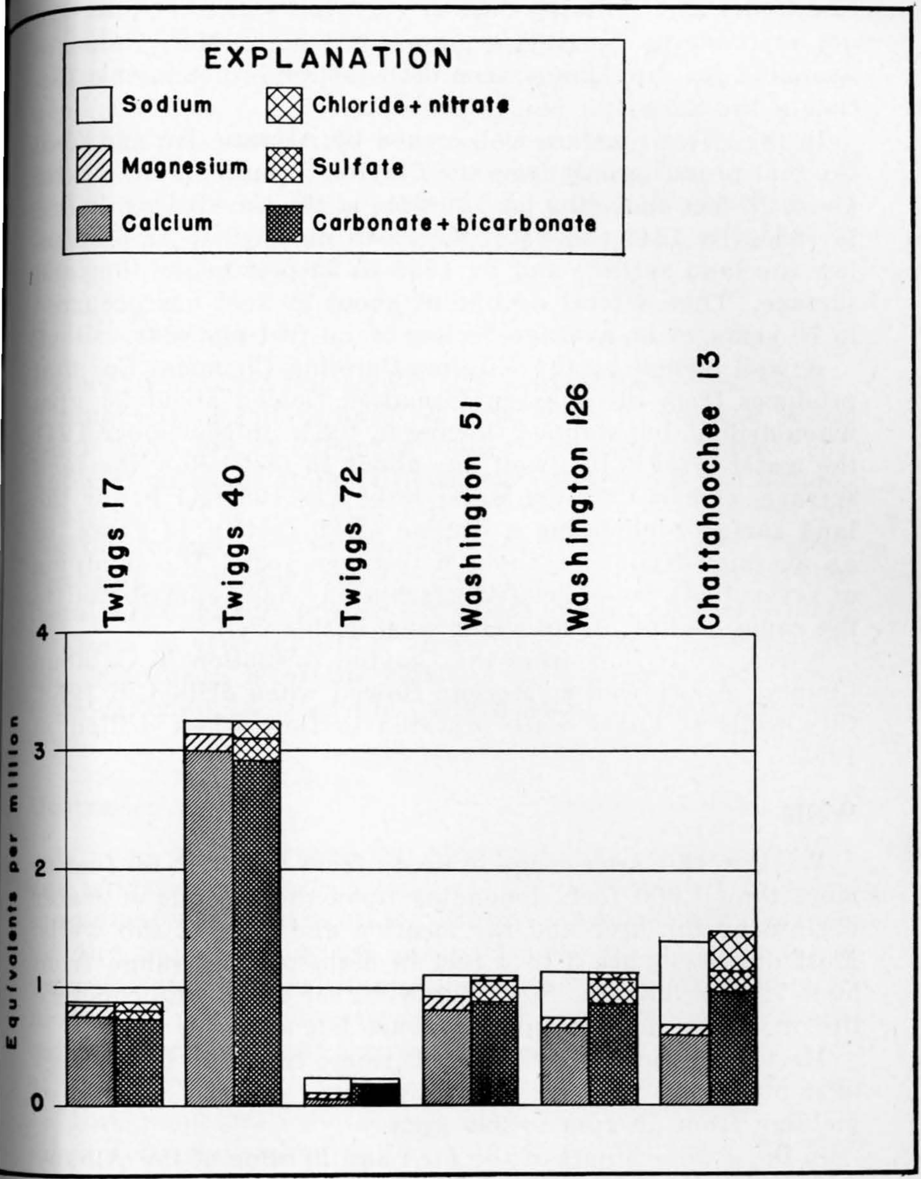


Figure 73. Quality of water from Cretaceous sands.

Data indicate that ground-water movement in these aquifers is from the area of recharge toward the south and southeast under the confining beds of clay, but sufficient data are not available to construct a piezometric map. More data are available for the Albany area than for any other in this section of the State.

In the Albany area a well owned by Atlantic Ice and Coal Co. that produces only from the Clayton formation had a head about 26 feet above the land surface at the time it was drilled in 1885. By 1941 the water level had dropped to 48 feet below the land surface and by 1955 to 74 feet below the land surface. Thus a total decline of about 99 feet has occurred in 70 years, or an average decline of 1.4 feet per year.

A well owned by the Virginia-Carolina Chemical Co. that produces from the Clayton formation flowed about 55 gpm when drilled, but stopped flowing in 1931. In November 1941 the water level in this well was about 16 feet below the land surface, and in 1955 the water level was 105 feet below the land surface, indicating a decline of 89 feet in 14 years, or an average decline of about 6 feet per year. The pumping of several city wells located nearby may have contributed to the rapid decline of the water level in this well.

A few wells flow from the Clayton formation in Calhoun County. A city well at Morgan flowed when drilled in 1953. City wells at Leary were reported to flow when drilled in 1953.

Wells

Wells in this area range in depth from less than 50 feet to more than 1,000 feet, depending upon the amount of water desired by the user and the location and type of the wells. Most dug wells are 3 to 4 feet in diameter and range from 50 to 70 feet in depth. Some dug wells are cased with concrete tile or wooden boards and others are left uncased.

Most domestic and drilled wells range from 100 to 150 feet in depth, are 3 to 6 inches in diameter, and are capable of yielding from 50 gpm to 900 gpm.

In the southern part of the area and in some of the Albany city wells and those at the Marine Corps Supply Depot the Tuscahoma sand is tapped by municipal wells. This sand is present at depths of 200 to 600 feet in the Albany area and at slightly greater depths at the Marine Depot. A few wells in Albany use only the Clayton formation. In the Albany area the daily pumpage was about 8 mgd (million gallons per day) in 1955, and water levels in wells were more than 80 feet below the land surface.

The towns of Edison in Calhoun County, Dawson, Brownwood and Sasser in Terrell County, and Fort Gaines in Clay County obtain municipal supplies from the Clayton formation. Several irrigation wells in Dougherty and Calhoun Counties and wells at Jakin, Damascus, and Kolomokee State Park also obtain water from the Clayton, and yields up to 900 gpm have been obtained.

Quality of water

Ground water in this area is of good quality at most places. It ranges from soft to hard (see table 19). Dissolved solids range from 108 to 218 ppm. The iron content is low. The water from some of the Cretaceous sands is of the sodium bicarbonate type, and that from the Tuscahoma sand and the Clayton formation is of the calcium bicarbonate type. Figure 74 shows graphically the analyses listed in table 19. Water from wells Early 2 and Dougherty 7 is of the sodium bicarbonate type, and that from wells Decatur 12, Early 8, and Mitchell 8 is of the calcium bicarbonate type. Water from Mitchell 13 is of the calcium magnesium bicarbonate type.

Utilization

Ground water is used for industrial, municipal, domestic, and irrigation purposes throughout the area of the limestone-sand aquifer, as it is in all the Coastal Plain province. Nearly all the cities and towns derive their water supply from ground-water sources, as do the industries. Most of the municipal supplies require no treatment, but some systems add chlorine for purification and some add fluoride for reduction of tooth decay in children.

Most municipal water-supply systems are based on one or more wells, depending on the yield of the wells and the size of the town. Many towns pump the water directly from the wells into the mains. Pressure is maintained by elevated storage tanks.

Irrigation supplies have been developed from ground-water

Table 19.—Analyses of water from limestone-sand aquifier

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

County number and owner	Amount of casing (feet)	Total depth (feet)	Date of collection	Temperature (degrees F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
Decatur #12 U. S. Government	408	1037	11–1–51		108	6.8	0.9	36	2	1.1		109	0	1.0	6.0	0.0	2.0	98
Dougherty #7 City of Albany	1027	1027		76	202	24	.01	21	5.2	43	2.3	194	0	8.3	2.9	.2	.09	74
Early #2 City of Blakely		809	5–16–46	77	218	16	.06	5.8	2.7	74		191	0	16	8.8	.4	.5	26
Early #8 Kestler School			2–3–54		131	5.7	.36	45	.7	2.4	.2	140	0	.2	2.8	.0	1.6	115
Mitchell #13 City of Pelham	153	728	2–4–38		186	28	.02	37	18	4.1	2.0	204	0	4.7	3.6	.0	.05	166
Mitchell #8 City of Camilla	396	396	5–27–43		137	7.4	.08	47	1.6	2.2	.3	145	0	1.6	2.1	.0	1.2	124

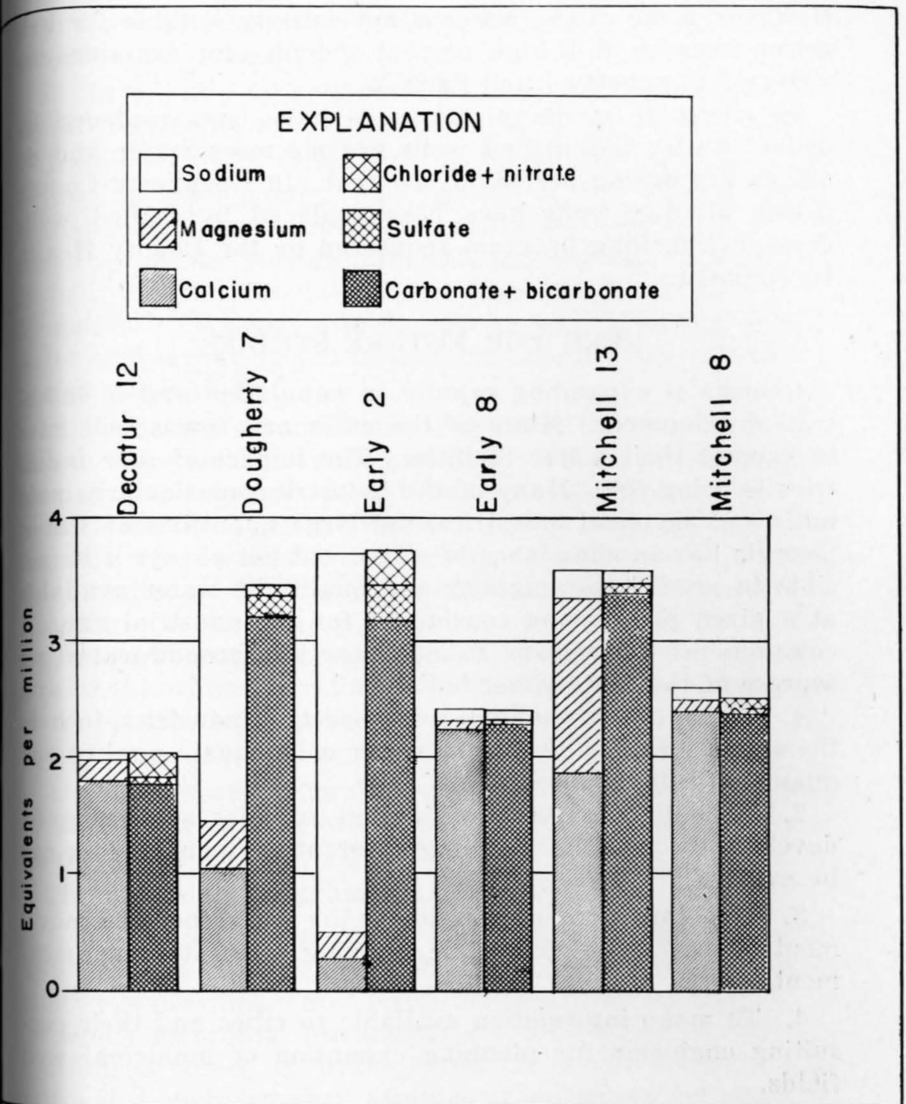


Figure 74. Quality of water from the limestone-sand aquifer.

sources on an increasing scale in recent years, and most crops in this area are no more than 500 to 1,000 feet—vertically—from a water supply of constant quality and temperature. However, some of the water is not entirely suitable for irrigation because of a high percent sodium—for example, the water of Dougherty 7 and Early 2.

In recent years many dug wells have been replaced by drilled wells. The drilled wells provide more water and do not go dry during periods of drought. In Dougherty County nearly all dug wells have been replaced by drilled wells through a drilling program sponsored by the County Health Department.

NEED FOR FUTURE STUDIES

Georgia is expanding rapidly in population and in industrial development. Many of the cities and towns will have to expand their water facilities. The impact of new industries is being felt. Many of the industries, particularly pulp mills and chemical industries, use large quantities of water. Georgia has an abundance of water, but not always is it possible to predict the quantity and quality of water available at a given point being considered for an industrial site. A comprehensive program to appraise the ground-water resources of the State is needed:

1. To supply information to prospective industries, to help them find locations that have water of adequate quality and quantity for their purpose.

2. To delineate areas of limited supplies so that overdevelopment and the resulting substantial financial loss can be avoided.

3. To obtain more information on the occurrence and movement of salt water, to enable averting salt-water encroachment.

4. To make information available to cities and their consulting engineers for planning expansion of municipal well fields.

5. To provide information on supplies available for irrigation.

6. To provide general factual information needed in determining water rights.

7. To provide basic geologic and hydrologic information

needed for the solution of problems involving ground-water pollution, drainage, and artificial recharge.

8. To make basic data available to Federal, State, and local agencies engaged in water-management and water-conservation activities.

9. To provide ground-water data needed to evaluate the overall hydrology and water resources of the State.

Ground-water investigations are made for the purpose of evaluating the quantity and quality of the ground water available for use, to provide for orderly development of this resource, and to provide information for proper planning so as to avoid interference, waste, and overdevelopment. Information is necessary also in order to solve problems of salt-water encroachment and to protect supplies from contamination of other kinds.

In evaluating ground-water supplies it is necessary to define the location, thickness, and lateral extent of each water-bearing formation; to describe its water-bearing properties; to evaluate the quantity of water stored in it; to determine the area where water enters it from streams or from rainfall, the direction of ground-water movement, and the points of discharge; to map the piezometric surface or water table; to obtain information on the chemical properties and temperature of the water; to estimate the recharge and discharge so as to be able to appraise the quantities available for use; and to record changes in water levels and quality.

A well-balanced program includes the following: collection of basic data, interpretation and research, and publication of results.

The basic-data program is of two types.

1. Collection of records of factors that change with time. This program includes the operation of a network of observation wells in which water levels are measured periodically or on which recording instruments are maintained to obtain a continuous record of water levels. In areas threatened by salt-water encroachment, samples of water are collected periodically and analyzed for chloride content to provide a record of any changes in salinity. Records of other such factors such as precipitation, temperature of water, spring and stream flow, elevation of surface-water bodies, barometric changes, ocean tides, pumpage, and quantities of water arti-

ficially recharged are collected in connection with specific area studies.

Continuing records are collected to meet certain needs. The basic network of observation wells should be continued indefinitely. Long-term records are needed to evaluate the effects of droughts and wet periods on the availability of water, to evaluate the long-term effects of pumping on the water levels, to provide a basis for evaluating the effects of water-management and conservation programs, and in general to provide information for planning efficient use of the available supplies.

2. Collection of data on factors that do not change with time. This part of the program includes collecting and assembling records of wells and borings, making observations of rock outcrops and of rock cuttings from wells, collecting water samples for analysis, and other routine operations resulting in the accumulation of raw data for further study. These facts are usually assembled on an areal basis. A specific study may include only a small area to meet a specific problem, may be countywide, or may include several counties or a drainage basin. The program may be of a reconnaissance type, perhaps a year per county, or may be comprehensive, in which case several years may be required to cover a single county. Data on surface water are collected as necessary.

Interpretation and research follow and accompany the collection of the basic data. They provide the transition between raw, meaningless data and a report which makes the results of the investigation available to and usable by others. They result in preparation of geologic maps; maps of the thickness, extent, and attitude of water-bearing and non-water-bearing formations; appraisals of the water-transmitting and storing ability of the aquifers; estimates of areas and quantities of recharge and discharge and of quantities of water available for development; interpretation of chemical analyses in terms of source and movement of the water, usability for different purposes, and effects on quality of various patterns of groundwater development, land management, etc.

Research on special problems commonly is necessary, to provide answers to problems involving geologic and hydrologic situations that are unique to an area and that must be worked out before the hydrology can be evaluated. To date, in Georgia, salt-water encroachment is the only such problem on which more than a bare start on the necessary research has been made. Problems to be worked on in the future are: correlation of rainfall and temperature with water levels as a means of evaluating recharge and as a method of predicting water levels; correlation of water levels and streamflow; study of the relation of ground-water levels and lake levels; study of upward and downward leakage in aquifers and effects of pumping wells in stratified formations; and effects of jointing and faulting on the movement and quality of ground water.

Results of the investigations are released to the public in formal reports and in open-file releases. Basic data are placed in the open file as soon as they can be checked carefully and are available on request. Records of water levels are published annually. Project or area-type studies terminate in a report which includes tables of basic data; geologic maps and maps showing water levels and water quality; and an interpretive text analyzing the data and expressing conclusions as to the availability and quality of water and the conditions affecting future development and conservation of the supply.

SUMMARY

This report presents a summary and analysis of the availability of water in Georgia, the use of water in 1955, and some projections of water use to 1970.

Water circulates constantly from the oceans through the air to the land. There, it becomes soil moisture, ground water, or surface water, and may transfer readily from one phase to another. About two-thirds of Georgia's average annual rainfall returns to the air by evaporation and transpiration. The remainder returns to the oceans by way of the rivers and underground aquifers and comprises the water available for controlled use.

Water uses are classified as withdrawal or nonwithdrawal uses, and consumptive or nonconsumptive uses. Withdrawal uses, for such purposes as urban and industrial supplies, hydroelectric power, and irrigation are usually measurable, and therefore readily adaptable to regulation. Nonwithdrawal uses, for such purposes as conservation, recreation, and waste disposal are difficult to measure, and therefore difficult to regulate or control. Consumptive uses include rural use, evaporation from ponds, and irrigation use. Nonconsumptive uses include most urban use, industrial use, hydroelectric-power use and navigation use.

Rural use of water in Georgia for domestic and stock-water supplies is estimated to average 75 mgd in 1955, and to increase to about 100 mgd by 1970. The counties near the metropolitan areas generally have the highest rural use.

Urban use of water in Georgia in areas supplied by the 96 municipal and county systems serving 2,500 or more people is estimated to average 260 mgd in 1955, and to increase to 380 mgd by 1970. The six largest systems furnish more than half of the total urban supply of water. Maximum monthly rates of urban use range from 5 to 60 percent more than the average monthly rates. Urban use is usually nonconsumptive but the quality of the water is impaired.

Industrial use of water in Georgia is estimated to average 1,830 mgd in 1955. In addition, two industrial plants in South Carolina use 950 mgd from the Savannah River. The largest industrial use in Georgia, for cooling at the 27 steam-power plants, averages about 1,450 mgd, of which the four largest plants use 1,060 mgd. Industrial use is generally nonconsump-

tive, but the quality of the water may be impaired and the temperature of cooling water is raised.

Hydroelectric-power use of water, by far the largest use in Georgia, averages about 41,000 mgd for the 43 plants built or under construction in 1955. Hydroelectric-power use involves large storage reservoirs to equalize streamflow seasonally, and pondage operations which generally release large flows during work days when the plants operate at full capacity and reduce the flows drastically at night and over week-ends to conserve water. At full capacity, the hydroelectric-power plants in Georgia use 101,000 mgd. Power reservoirs have a total surface area of about 250,000 acres and a total usable capacity of about 1,600,000 million gallons. These quantities do not include the share for the adjacent States in Federal developments on the border rivers. Large storage reservoirs may affect the quality and temperature of the water released from them.

Irrigation use of water in Georgia is estimated to have averaged about 21 mgd in the dry year 1954. The maximum rate of application is generally about nine times the average annual rate. The future use of water for irrigation under dry-year conditions is estimated to average about 1,200 mgd. The future maximum rate of use for irrigation, 11,000 mgd, could occur in many years when there are dry spells during the summer. This would cause serious conflicts with other water uses.

Net evaporation loss from the 27,061 farm ponds in Georgia under the dry conditions that existed in 1954 is estimated to have averaged about 100 mgd. The ponds are estimated to have a total area of about 86,000 acres and a total capacity of about 79,000 million gallons—34 percent of the area of the power reservoirs in the State but only 5 percent of their usable capacity. Farm ponds are more common in northwestern Georgia and in a band of counties in southern Georgia than in the rest of the State. The average annual evaporation rate from ponds is greater in the central part of the Coastal Plain than in the rest of the State and less in the northern counties and coastal counties.

Because surface water and ground water are inseparable in nature, water legislation should provide for both phases. However, it is more convenient, and clearer, to discuss the availability and quality of surface waters and ground waters separately.

Surface-water resources in Georgia consist mostly of the flow of streams, modified by reservoirs. The quantity of streamflow is highly variable with respect to time and place and is the result of many natural factors. Besides the obvious factors of rainfall and size of drainage area, seasonal factors have a dominant effect on streamflow in Georgia. Streamflow must be evaluated for a specific place rather than in a general area, and not only in terms of magnitude, but also in terms of time periods, and in terms of frequency. Streamflows for various magnitudes, periods, and frequencies are determined quantitatively at gaging stations, a large number of which are required to define streamflows in all parts of the State and from areas of different sizes. Because quantities of flow are closely related to drainage areas, streamflows are frequently expressed as flows per square mile of drainage area to facilitate comparisons at different sites. Thus, information concerning the availability of surface-water resources is based largely on gaging-station records, is mostly quantitative, and is frequently related to drainage area.

Records of streamflow are employed in many ways that pertain to water legislation, some of which are: to derive minimum, average, and flood flows for various periods and frequencies; to define practical criteria for conservation flows; to compute proportional utilization flows, excess flows, and storage-requirements; and to relate available streamflow with its present or proposed utilization.

Streamflow records are available for more than 1,800 station-years at 126 gaging stations in the State. These records are summarized in one tabulation of 47 statistics of flow and stage for each site.

Streamflow characteristics in Georgia as shown by the records are too varied for satisfactory analysis on a statewide basis. They differ among the four physiographic provinces: the Blue Ridge province, the Valley and Ridge province, the Piedmont province, and the Coastal Plain. Within the latter province, they differ considerably between the upper and lower parts. In order to improve low-flow analyses, several of the provinces are subdivided, making eleven streamflow regions in the State. The regional streamflow information is derived from the records at 55 of the gaging stations called index stations and 1,007 partial-record stations.

The average flow for the standard 18-year period, 1937-55, ranges from 400,000 to 1,860,000 gpdsm in Georgia. The highest average yields occur in the Blue Ridge province and upper Coastal Plain region III, and the smallest yields occur in lower Coastal Plain region I.

The increase in rural use by 1970 will have little effect on low flows of streams.

The smallest of nine practical criteria for a conservation flow, the 20-year, 1-day minimum flow, ranges from 0 to 780,000 gpdsm in Georgia. The highest yield is in the upper Coastal Plain region III. The next highest yields occur in the Blue Ridge province and range from 240,000 to 400,000 gpdsm. The lowest yields occur in the lower Coastal Plain region I, where most of the local streams have zero flow at times.

The largest of the practical criteria for conservation flow, the median minimum monthly flow, ranges from 7,100 to 1,030,000 gpdsm in Georgia, the largest yield being nearly 150 times as much as the smallest yield.

Utilization flows for urban, industrial, and power purposes are determined by actual use or capacity at the site, but the utilization flow at the site depends on proportional flows from all parts of the drainage basin upstream from the site.

Utilization flows for urban water supplies are generally not large in proportion to average river flows, but they are large in proportion to minimum flows of the Chattahoochee River in the Atlanta metropolitan area and at a number of the small cities in the Piedmont province. Most of the urban water supplies in northern Georgia come from streams but in southern Georgia nearly all of the urban water supplies come from wells.

Utilization flows for cooling purposes at steam-power plants are more than the 20-year 1-day minimum flow at Plant Arkwright on the Ocmulgee River and at Plant Atkinson and Plant Yates on the Chattahoochee River.

Utilization for hydroelectric-power at Clark Hill Dam on the Savannah River, Fort Gaines Dam on the Chattahoochee River, Allatoona Dam on the Etowah River, and the upper Tennessee Valley Authority dams use practically all of the flow. Future withdrawal of water for irrigation from the drainage areas above those dams will reduce power production by a small percentage, estimated not to exceed 3 percent.

In other parts of the State there appears to be sufficient streamflow for all present utilization and the future estimated use of water for irrigation under dry-year conditions, provided irrigation water is withdrawn during high-water periods.

The total of the minimum flows of all minor streams in Georgia in 1954 is estimated to be 2,500 mgd. This represents the total streamflow available without storage reservoirs to supply many of the small cities and industries and carry away their wastes, and to irrigate crop lands because many of the small cities and industries and croplands are not convenient to major rivers and are dependent on small streams. The estimated future maximum rate of use of water for irrigation during dry spells is about 11,000 mgd in the irrigation season. This is over four times the flow of minor streams available without storage. Thus, withdrawals for irrigation during low-flow periods would probably conflict with other uses of streamflow.

The average frequency of overbank floods at gaging stations in Georgia ranges from ten per year to one in six years. At most stations the range is from about three per year to one in two years. Floods in the Blue Ridge province average less often than one per year. Those in the Valley and Ridge province in general average more often than one per year. In the rest of the State the frequency of overbank floods appears to be governed mostly by local conditions.

Flow correlations from gaging-station data are needed to estimate streamflows at ungaged sites. Streamflow estimates based on rainfall and drainage areas have some reliability for average flows but little or no reliability for low flows. For example, in one small river basin draining 134 square miles where the low flow is at the rate of 7,500 gpdsm, low flows within the basin vary from 0 to 65,000 gpdsm. Reliable low-flow estimates at an ungaged site require base-flow measurements.

The evaporation from farm ponds in proportion to the runoff from the contributing drainage area is relatively large when compared to that from power reservoirs. In average years the net evaporation is negligible from both. In the dry year 1954 an average sized farm pond in the Piedmont region would have lost 43 percent of the annual runoff from the smallest drainage area that would refill it in the winter of 1954-55 when used for recreation, or 39 percent if the water were used for irrigation. In contrast, a large power reservoir lost only about 1.6 percent of the runoff from its drainage area in 1954.

The appraisal of the availability and use of water in Georgia is handicapped by the lack of factual information. Water uses for irrigation, rural, and recreational purposes are largely conjectural. The effect on streamflows of many hydrologic factors such as reforestation and other land-use practices, farm ponds, paved surfaces, and channel improvements, are largely unknown. Factual data on direct runoff, the flow of small streams, and the water supply for farm ponds are almost totally lacking. Practical water regulations are difficult to prepare because of the highly variable nature of surface-water resources and of most water utilization. Any regulation deemed necessary over consumptive uses of water and the determination of water rights will be gravely handicapped unless steps are taken, well in advance of the need, to collect systematic water-use data, streamflow data, reservoir and pond data, and quality of water data, and to make concurrent scientific studies of streamflow data with which to appraise their relation to the rapidly increasing utilization of water in Georgia.

Information on the chemical and physical qualities of surface and ground waters is essential to all water users, for the selection of suitable natural supplies and for the determination of the type and cost of treatment required for less suitable supplies.

Although surface waters vary constantly in composition, the 17 streams in Georgia for which quality data are available showed little variation during a one-year period of observation. The maximum content of dissolved solids found during this time was 130 parts per million, and the maximum hardness was 131 parts per million. Streams originating in the eastern and southern parts of the Coastal Plain are generally highly colored but contain little sediment.

No data are available to indicate the probable maximum, minimum or average concentrations of dissolved minerals or suspended solids to be expected over a long period, nor are presently available data sufficient for accurate correlation of water quality with flow, time, or water usage. Such data would be essential to the formulation and enforcement of water legislation.

The State of Georgia has large ground-water resources. At some places in the State this resource has been developed and at others it is almost undeveloped.

Of the three geologic provinces of the State, the Coastal Plain has the most abundant ground-water supplies, especially in the area underlain by the principal artesian aquifer. Nearly all municipal and industrial supplies in the Coastal Plain are obtained from this aquifer. Individual wells yield as much as 4,000 gpm. In 1955 pumpage at four coastal cities totalled 141 million gallons per day. Irrigation from groundwater sources, recently begun in Georgia, may ultimately use millions of gallons per day during the growing season.

Present day pumpage in the Coastal Plain has caused a decline in water levels in the areas of pumpage and in the surrounding countryside. The water level at Savannah has been lowered about 140 feet, and wells in the surrounding area have stopped flowing. The water level has been lowered also in the vicinity of Brunswick, St. Marys, and Jesup, but the extent of lowering in the surrounding area is not known. A decline of the piezometric surface below sea level in coastal areas could result in the encroachment of salt water into the aquifer. This problem is now being studied in the Savannah area.

Wild-flowing artesian wells in the Coastal Plain cause a serious loss of water which could be saved if the wells were properly cased and the flow controlled. Warren (1944) estimated that about 30 million gallons per day was lost through uncontrolled flowing wells in the 10 coastal counties in the year 1943.

The Valley and Ridge province has abundant ground-water supplies, most of which are undeveloped. Many large springs of this area are utilized by industries, municipalities, and homes. However, many more of them could be developed.

Ample supplies of ground water for domestic purposes can be developed in the Piedmont-Mountain province. The occurrence of ground water is largely dependent on topographic location in this province, so that well sites must be carefully selected to insure that an adequate supply is obtained. The water table fluctuates seasonally with precipitation, and, in times of drought over-pumping may result in dry wells locally.

Although many data have been accumulated, much more information is needed in order to define completely the ground-water resources of Georgia. Topographic maps are needed throughout the State. Of the 58,518 square miles in Georgia, 15,640 square miles are covered by published topographic maps considered modern and adequate for engineering studies. In 1956 a total of 19,431 square miles of mapping was in progress by the Geological Survey. Adequate topographic maps are fundamental and necessary for groundwater studies.

A network of observation wells has been established in the coastal area. The network is close knit in the Savannah study area but more widespread in the rest of the coastal counties. An observation-well network is one of the basic parts of ground-water studies, and also, provides water level data that may be needed in possible future litigation. To provide basic data for future studies, additional coverage is needed throughout the entire State, first in the Coastal Plain where it is needed most, and second in the remainder of the State.

Additional subsurface geologic data are needed throughout the State to determine the position, thickness, and areal extent of the aquifers. The ground-water study program in the State needs to be increased if this resource is to be defined in the foreseeable future.

In formulating laws and regulations relating to the utilization of ground water, the physical principles of the occurrence of ground water must be considered. Water law should recognize the inter-connection between ground and surface water.

Any regulation of water use is most effective when done largely through voluntary cooperation of water users and the public in general, based upon adequate understanding of the facts. As in all other phases of regulation of human conduct, a law whose purpose is not freely and plainly understood is not easy to enforce. Public recognition of the need for equitable and effective control is the first prerequisite. It can be achieved by adequate investigation of our water resources and free dissemination of the results and implications. Given such understanding, only a minimum amount of restrictive legislation will be needed.

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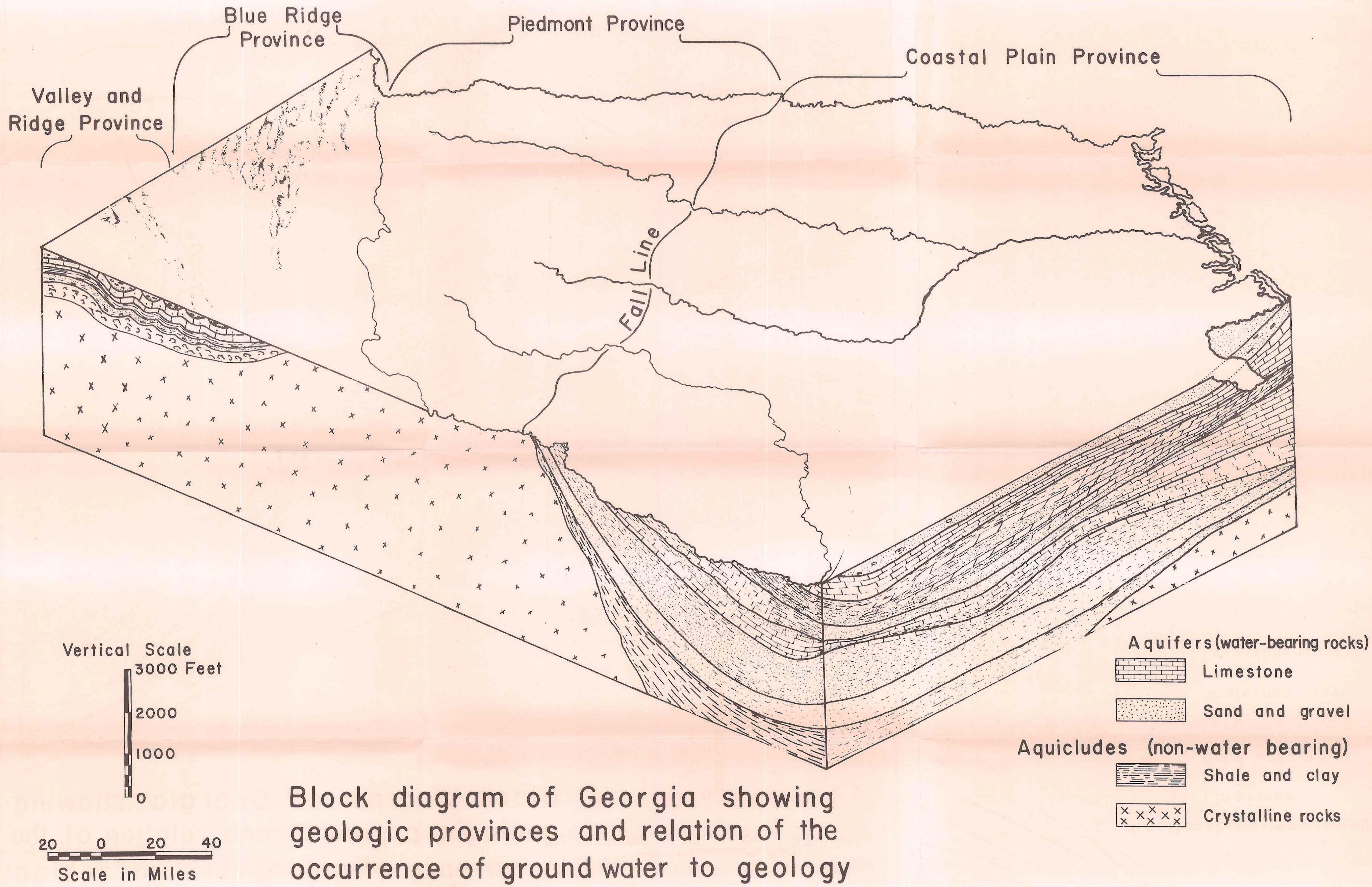
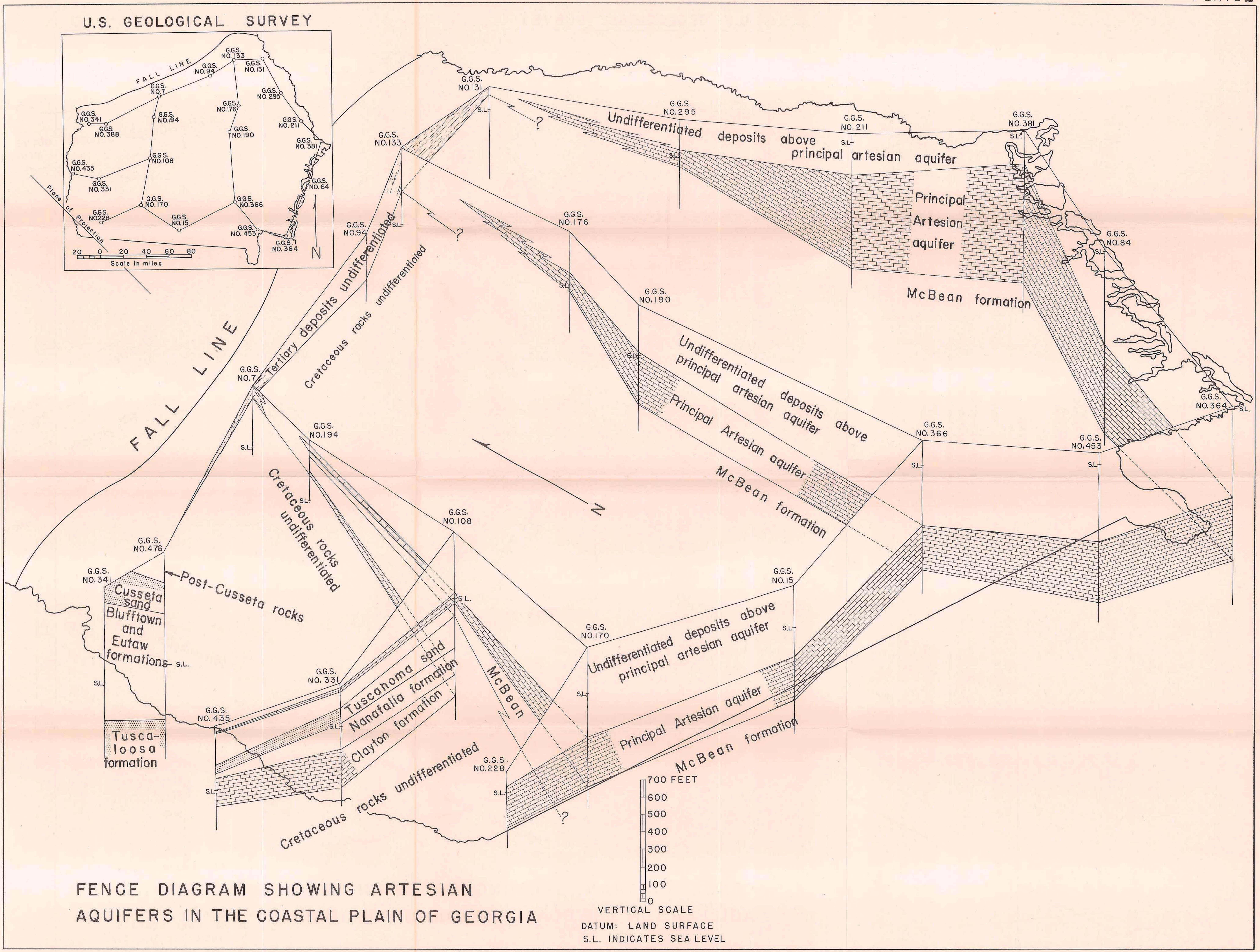
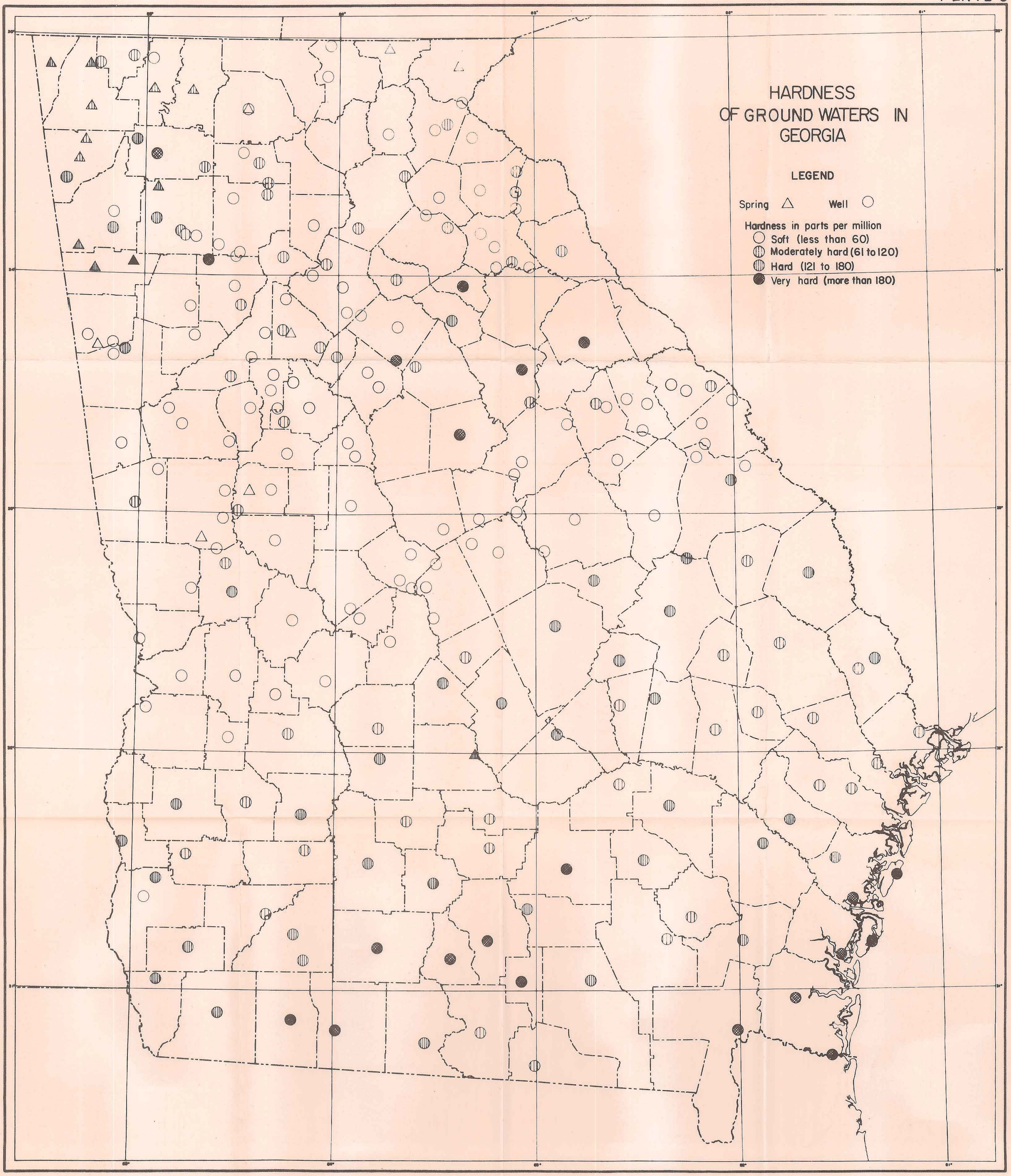


Block diagram of Georgia showing geologic provinces and relation of the occurrence of ground water to geology



FENCE DIAGRAM SHOWING ARTESIAN AQUIFERS IN THE COASTAL PLAIN OF GEORGIA


HARDNESS
OF GROUND WATERS IN
GEORGIA
LEGEND
Spring
Well
Hardness in parts per million
Soft (less than 60)
Moderately hard (61 to 120)
Hard (121 to 180)
Very hard (more than 180)