SURFACE WATER IN SOUTHWESTERN ALABAMA

GEOLOGICAL SURVEY OF ALABAMA *BULLETIN 84*

Prepared in cooperation with the
U.S. Geological Survey

GEOLOGICAL SURVEY OF ALABAMA

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DIVISION OF WATER RESOURCES

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BULLETIN 84

SURFACE WATER IN SOUTHWESTERN ALABAMA

By L. B. Peirce

With a section on

CHEMICAL QUALITY OF SURFACE WATER

By Stanley M. Rogers

Prepared in cooperation with the
United States Geological Survey

UNIVERSITY, ALABAMA

1966

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University, Alabama
February 10, 1966

Honorable George C. Wallace
Governor of Alabama
Montgomery, Alabama

Dear Governor Wallace:

I have the honor to transmit the manuscript of a report entitled "Surface Water in Southwestern Alabama" by L. B. Peirce and S. M. Rogers of the U.S. Geological Survey, with the request that it be printed as Bulletin 84 of the Geological Survey of Alabama.

Our Nation's need for water will grow enormously during the next several decades. Southwestern Alabama, with its copious water resources and singularly favorable aspects for linking sea and river transportation systems, will play an important part in supplying this coming need. Water planners bear the responsibility of developing the water resources of southwestern Alabama, not for exploitation by the few, but for the greatest benefit to all the people of the region, the State, and the Nation. In a frontier so rich in water, this is a challenging problem as well as a grave responsibility.

There is no simple formula for the orderly development and coordinated management of the region's water resources. An important factor is the social, legal, and economic framework within which those resources will be used. The basic factor is a knowledge of the water itself—the nature of its occurrence and how it varies in quantity and quality from place to place and from time to time.

Respectfully,

Philip E. LaMoreaux
State Geologist

PREFACE

This report is the fourth in a proposed series of five companion reports treating the surface-water resources and hydrology of Alabama.

Work on this series of reports was begun in 1947 by the U.S. Geological Survey in cooperation with the Geological Survey of Alabama. To allow time for the collection of supplemental data on many ungaged small streams, reports were scheduled for publication at about 5-year intervals. Earlier reports of the series, published as Special Reports of the Geological Survey of Alabama, are as follows:

Water Resources and Hydrology of Southeastern Alabama, Special Report 20, 1949.

Hydrology and Surface-Water Resources of East-Central Alabama, Special Report 22, 1955.

Surface-Water Resources and Hydrology of West-Central Alabama, Special Report 24, 1959.

In 1947, and in fact until 1960, records of streamflow in Alabama were not readily available to water planners except in the annual water supply papers of the U.S. Geological Survey. In these publications, a 20-year record of streamflow, for example, was dispersed among 20 separate volumes. Further, only the basic figures of streamflow were published, thus restricting their practical use to the relatively small group of engineers and specialists who were able to draw useful conclusions from them.

As originally conceived, therefore, the series of reports was intended to overcome to some extent these disadvantages of the annual water-supply papers for water-use planning in Alabama. The surface-water resources and hydrology of Alabama were to be covered in five companion volumes, each treating a different section of the State. Each report was to present in summarized form a compilation of all surface-water records currently available in the report area, with a discussion of the hydrologic features of the area that affect the quantity and quality of its surface waters. In addition, each report was to include representative hydrologic studies to demonstrate methods of analyzing and interpreting the basic data for the solution of various kinds of water problems.

The circumstances which led to this earlier concept of the reports no longer apply with their original force. Compilations of basic streamflow records in Alabama through September 1950 are now available as Water Supply Papers 1304 and 1306 of the U.S. Geological Survey, and Water Supply Papers 1724 and 1726 extend these compilations through September 1960. Also, various interpretive reports by State and Federal agencies, as well as previous reports of this series are now available to relieve water planners of much of the burden of analysis and interpretation.

Consequently, in this report duplication of material is avoided and perhaps a greater usefulness obtained by departing somewhat from the original scheme. That is, emphasis in compilation is shifted from basic to processed data; and in analysis, from methods to conclusions.

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SURFACE WATER IN SOUTHWESTERN ALABAMA

By L. B. Peirce

ABSTRACT

All estimates indicate that the Nation's need for water will grow enormously during the next several decades. Southwestern Alabama, with its plentiful water resources and singularly favorable aspects for linking sea and river transportation systems, can be expected to play an important part in supplying this coming need. Streams flowing from, through, or by the region discharge, on the average, about 14,000 billion gallons per year. Average annual use of surface water is now about 360 billion gallons, of which 70 percent is used only for cooling purposes.

By examining present usage of water in the light of current economic trends, the pattern of future surface-water problems in the region can be broadly outlined. Satisfactory solutions to these problems will depend upon full consideration of socio-economic factors, but more so upon a knowledge of streamflow itself—the nature of its occurrence and how it varies in quantity and quality with space and time.

As a region embracing principally only the lower basins of the Alabama and Tombigbee Rivers, southwestern Alabama is not a self-contained water-resources system. Only those streams originating in the area fully reflect the local hydrologic environment.

Streamflow in the area represents the integrated effect of numerous climatic and physiographic factors, many of which show considerable areal variation. Average annual rainfall ranges from 51 inches in the north part of the area to 65 inches in the south part. The corresponding range in average annual runoff is from 15 to 28 inches. Evapotranspiration consumes, on the average, about two-thirds of the annual rainfall. Annual lake evaporation averages about 45 inches. Rainfall and streamflow are highest during the winter and spring, but are usually adequate for all purposes the year around.

The average flow of streams in the area ranges generally from 1 to 2 cubic feet per second per square mile of surface drainage area. Low flows are considerably more variable, reflecting the diverse lithology and structure of Coastal Plain aquifers. The low flow for 7 consecutive days that occurs every other year, on the average, ranges from no flow to more than 1 cubic foot per second per square mile. Streams draining the relatively impermeable chalks of the Prairie Belt in the north part of the area have extremely low dry-weather flows, and many of them go dry nearly every year. Highest dry-weather flows are displayed by streams draining permeable sands and gravels in the coastal counties. Flow-duration data provide a useful tool for appraising the hydrologic characteristics of different watersheds. The expectancy of low flows for many streams in the area can be determined from frequency data based on streamflow records.

Floods in southwestern Alabama are an economic hazard, particularly those that occur on the major rivers during the agricultural season. Rural flood damage averages about $600,000 annually; urban flood damage is mostly limited to the cities of Montgomery, Selma, and Demopolis and averages about $185,000 annually. Floods on the major rivers can occur in any month, but are most common from February through April. In the 72 years of flood history (1892-1963) available for the Alabama and Tombigbee Rivers, no major flood has occurred in September. On the smaller streams, floods in the summer and fall are fairly common, as a result of local thunderstorms that do not much affect the larger rivers. Floods on the Alabama and Tombigbee Rivers rise and fall relatively slowly and may remain above flood stage from 1 to 3 weeks or longer. Flood expectancies for most streams of the area can be estimated from frequency graphs based on streamflow records. Flood profiles provide a useful tool for appraising the possible extent of flood inundation along the major rivers. Highest water levels along the shores of Mobile Bay are caused by tides associated with tropical hurricanes rather than by floods on the Mobile River; a tide reaching 10.8 feet above mean sea level accompanied the hurricane of July 1916.

The stream waters of southwestern Alabama are generally of good chemical quality, low in dissolved solids, and soft. With few exceptions streams of the area are of suitable quality for most industrial or domestic uses. A notable exception is Okatuppa Creek near Gilbertown (Choctaw County) which at low flow was found to have a chloride concentration of 380 parts per million, partly as a result of briny oil-field wastes discharged into the stream.

The chemical character of water in the tributary streams changes with diminishing streamflow according to the nature of ground water discharging in the basin, which in turn reflects the lithologic character of the surficial geologic formations through which the streams flow. The Alabama and Tombigbee Rivers and their tributaries contain a greater proportion of calcium and magnesium than of sodium and potassium at both high and low flow. The prevailing trend of change in chemical composition of these streams as flow decreases is an increase in bicarbonate content and a decrease in sulfate content. Below the confluence of the Alabama and Tombigbee Rivers, the chemical character of Mobile River and tributary streams reflects a geologic environment that contributes greater amounts of sodium and potassium than of calcium and magnesium to the stream waters. The waters of these streams were found to be of the sodium-chloride or sodium-bicarbonate type at both high and low flow. Escatawpa River, in contrast to other streams in the general area, was found to become a calcium-magnesium-chloride type water at low flow.

Stream temperatures vary from a low range of 38° - 44° F in January and February to a high range of 80° - 92° F in July and August. The major rivers furnish an abundant supply of water at temperatures suitable for most industrial purposes the year around.

INTRODUCTION

Southwestern Alabama is richly endowed with water resources. In the average year, surface streams of the region discharge more than 12 cubic miles of fresh water into the sea; while beneath the land surface, a volume of fresh water equivalent to many years of surface runoff lies stored in the ground-water reservoirs of the Coastal Plain. Although water use in Alabama more than doubled in the 5 years 1959 to 1963, use in southwestern Alabama was still only a small fraction of the available supply. With this high potential for future development, southwestern Alabama is truly an important segment of what has been aptly described as one of the last great frontiers of the Nation's fresh-water resources (LaMoreaux, 1960).

Public interest in water is mounting, and utilization of the largely untouched water resources of southwestern Alabama can be expected to increase rapidly with a growing public awareness and need.

As the region's water use increases, so will its water problems. The water resources of southwestern Alabama are well suited to a diversity of uses, some of which frequently lead to a conflict of interests. Water supplies for cities, agriculture and industry, navigation, hydropower, flood control, waste disposal, wildlife conservation, recreation—all of these are to some degree at cross purposes with one another. Water planners thus bear the responsibility of developing the water resources of southwestern Alabama, not for exploitation by the few, but for the greatest benefit to all the people of the region, the State, and the Nation.

In a frontier so rich, this is a challenging problem as well as a grave responsibility. There is no simple recipe for the orderly development and the coordinated management of the region's water resources. Certainly, an important ingredient in any such recipe is a thorough understanding of the social, legal, and economic framework within which those resources are to be used. But the basic ingredient is unquestionably a knowledge of the water itself—the nature of its occurrence and how it varies in quantity and quality with space and time.

PURPOSE AND SCOPE

The purpose of this report is to provide the necessary background for an understanding of the occurrence and nature of streamflow in southwestern Alabama and its potential for future use.

Because future use will be largely an extension of present uses and will seldom be dictated by hydrologic considerations alone, the report first briefly examines economic trends as related to water problems in the area and describes present and foreseeable use and control of surface water. Other sections of the report then seek to: (1) describe the hydrologic system operating in southwestern Alabama in relation to the occurrence of surface water; (2) show how, where, and to what extent basic information on surface water in southwestern Alabama has been obtained; and (3) summarize that information in a form both useful and convenient for answering the more common questions about surface water in the area.

The report is not directed toward the solution of any specific water problem; rather, it is intended to serve as a starting point for future surface-water investigations which the continuing development of water resources in the area will make necessary. Some of these investigations will require a more detailed analysis of existing data than the scope of this report permits, others will require additional data. Thus, a useful function of the present report is to inform water planners of the extent of data now available so that they can recognize areas of deficient information and better appraise future needs.

COOPERATION AND ACKNOWLEDGMENT

This report was prepared as part of the program of water investigations in Alabama conducted by the U.S. Geological Survey in cooperation with the Geological Survey of Alabama, P. E. LaMoreaux, state geologist. Cooperation between the State and Federal Geological Surveys in water-resources investigations began prior to 1900 and has been continuous since 1935.

Streamflow data summarized in the report were collected largely by the U.S. Geological Survey in cooperation with the Geological Survey of Alabama, the Alabama Highway Department, the Corps of

Engineers, and the Alabama Power Company. Climatological data were extracted from publications of the U.S. Weather Bureau. Other sources of information are acknowledged in the bibliography.

The report was assembled in the Tuscaloosa, Alabama, office of the Surface Water Branch, U.S. Geological Survey, under the direction of Lamar E. Carroon, district engineer.

DESCRIPTION OF THE AREA

GEOGRAPHY AND CLIMATE

Southwestern Alabama, as the term is used in this report, refers to the area shown in figure 1. In this area of about 12,000 square miles, roughly shaped like a funnel, are all or part of 15 of Alabama's 67 counties (table 1).

Parts of the area near the coast are drained by the Perdido River, tributaries of the Pascagoula River in Mississippi, and other small streams. Most of the area, however, is in the watersheds of the lower Alabama and Tombigbee Rivers, which converge to form the Mobile River 35 miles north of Alabama's seaport city of Mobile. Thus, not only in shape, but in drainage pattern and economic function as well, southwestern Alabama is suggestive of a huge funnel, serving to collect and carry both water and commerce from the inner regions of the State to the Gulf of Mexico.

Physiographically, all of southwestern Alabama lies in the East Gulf Coastal Plain section. Its distinguishing surface features occur in belts which cross the area from east to west, conforming to the shorelines of ancient seas. The elevation of the land surface ranges generally from 100 to 600 feet above sea level, not dropping much below 100 feet except in the marshlands near the coast and along the major rivers.

The climate is mild, with ample rain and a long growing season. Summers are long and hot, with an average July temperature of 80° F; winters are short and moderate, with an average January temperature of 50° F. Recorded extremes of temperature in the area are 109° F and -7° F. Crops may be cultivated 10 months of the year near the coast, and about 8 months in the northern counties. Average annual rainfall ranges from about 51 inches in the northern

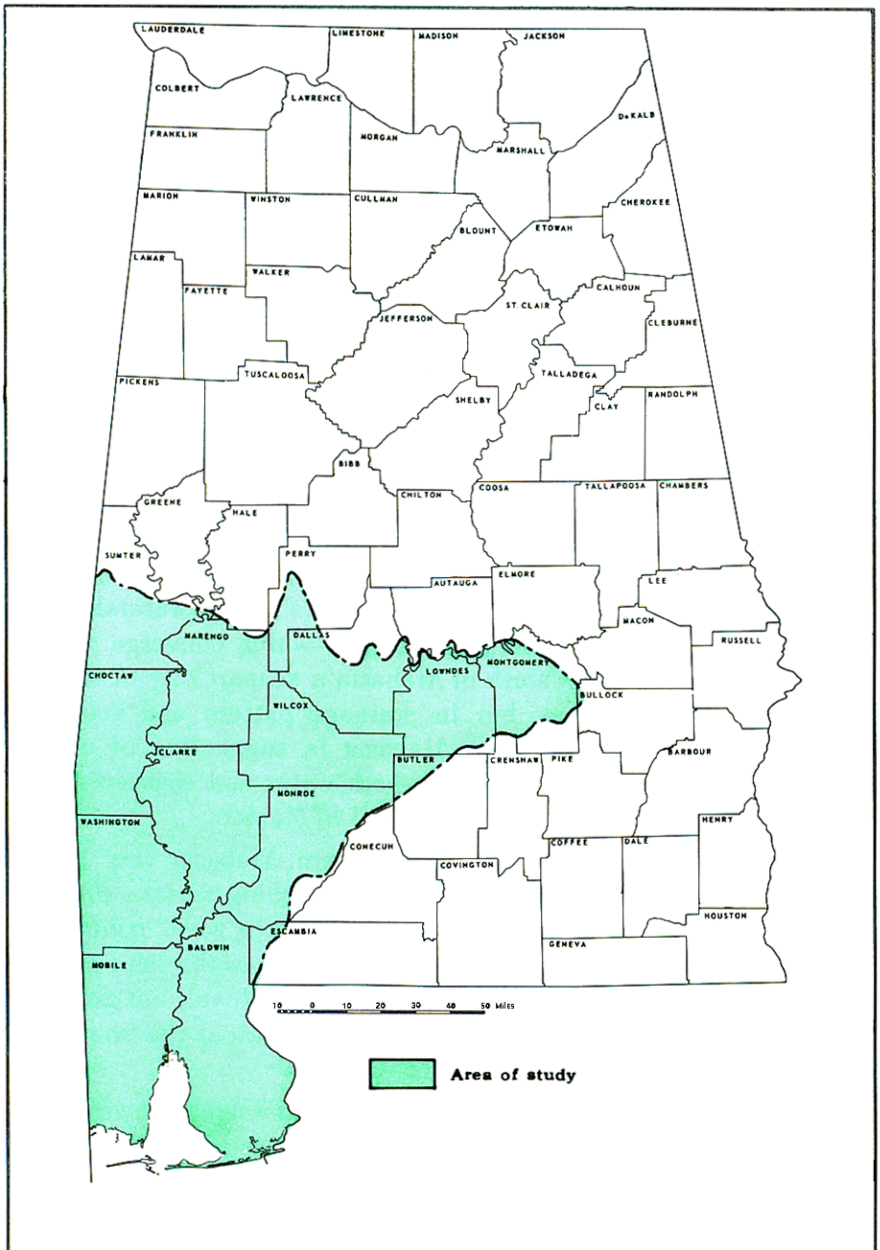


Figure 1.–Map of Alabama showing area of report.

Table 1.—*Statistical data for counties in southwestern Alabama*

County	Area (sq mi) Total	Area (sq mi) In report area	Total county population 1950	Total county population 1960	Total county population Percent change	Rank in personal income, all counties, 1960
Baldwin	1,613	1,613	40,997	49,088	+19.7	15
Butler	773	140	29,228	24,560	-16.0	36
Choctaw	918	918	19,152	17,870	- 6.7	42
Clarke	1,241	1,241	26,548	25,738	- 3.1	32
Dallas	976	707	56,270	56,667	+ .7	13
Escambia	962	91	....	....	.....	....
Lowndes	716	700	18,018	15,417	-14.4	67
Marengo	977	957	29,494	27,098	- 8.1	31
Mobile	1,242	1,242	231,105	314,301	+36.0	2
Monroe	1,035	960	25,732	22,372	-13.1	37
Montgomery	790	502	138,965	169,210	+21.8	3
Perry	734	200	20,439	17,358	-15.1	58
Sumter	911	610	23,610	20,041	-15.1	52
Washington	1,069	1,069	15,612	15,372	- 1.5	50
Wilcox	900	900	23,476	18,739	-20.2	54
Totals	.....	11,850	698,646	793,831	+13.6	....

counties to 68 inches in central Baldwin County, which is one of the wettest sections of the United States. West Indian hurricanes strike the coastal area on an average of about once in 7 years.

Land and climatic factors as related to the occurrence of surface water in southwestern Alabama are discussed in greater detail in other sections of this report.

POPULATION AND ECONOMY

In 1960, the population of southwestern Alabama was about 800,000—nearly one-fourth the population of the State. About 60 percent of the people were living in 14 urban areas having populations of 2,500 or more, the remainder in smaller towns and rural areas. Two cities and their environs—Mobile and Montgomery, the State capital—accounted for very nearly half the population of the area.

Considered individually, counties in southwestern Alabama show sharp contrasts in economy. Some, like Lowndes and Perry Counties, are essentially rural and agricultural and in total personal income rank low in comparison with other counties in Alabama. At the other extreme, Mobile and Montgomery Counties bustle with commerce and industry and in total personal income rank second and third in the State.

The economy of southwestern Alabama is well balanced between agriculture and industry. Agricultural interests are indicated by type of land use, expressed below as percentages of total area:

Land Use	Percent of total area
Forest and woodland	68
Pasture and range	13
Cropland	11
Unused land and water areas	4
Urban land	3
Federally-owned land	1

Principal agricultural products are timber and pulpwood, corn, cotton, potatoes, soybeans, livestock, and poultry.

The growth of manufacturing and industry in southwestern Alabama—as in the South generally—accelerated markedly after World War II and still continues at a rapid rate. Mobile and Montgomery are the centers of a well diversified industry that is now spreading to Selma, Demopolis, and other smaller cities and towns. The pulp and paper industry, particularly, is well established in southwestern Alabama as a result of the abundance of its two primary raw materials, pulpwood and water. Petroleum, discovered in Choctaw County in 1944, has brought another major industry almost exclusively to southwestern Alabama, for within the boundaries of the area are three of the State's four oil fields.

Principal industrial products of southwestern Alabama are pulp and paper, petroleum and coal products, lumber, wood products and naval stores, chemicals, processed meats and vegetables, seafoods, apparel, machinery and transportation equipment, clay and concrete products, feeds, and fertilizers.

ECONOMIC TRENDS AND WATER PROBLEMS

All estimates indicate that the Nation's need for water will grow enormously during the next several decades. Southwestern Alabama, with its plentiful water resources, pleasant natural environment, and singularly favorable aspects for linking sea and river transportation, can be expected to play an important part in supplying this coming need.

In addition to the basic hydrologic factors, a multitude of ecologic, social, political, and economic factors are at work shaping the future water needs and problems of the area. With respect to none of these factors can southwestern Alabama be regarded as a self-contained entity. Some of them are external to the area, operating at a distance with their effects modified more or less by local conditions. Others operate internally with strong local effects that may also be felt far beyond the boundaries of the area. For example, the facility of a seaport, which is provided by the port of Mobile, has strongly influenced economic growth and water use not only in southwestern Alabama but in the entire State.

The scope of the present report permits only a brief mention of some of these extra-hydrologic aspects of water use in southwestern Alabama. Subsequent reports aimed at the solution of specific water problems in the area will consider them more fully as the occasion demands.

Since World War II, the economy of southwestern Alabama has been shifting rapidly from its traditional dependence upon a few basic products such as lumber and cotton to a much wider range of agricultural and industrial activities. Many cotton fields in the Black Belt have been converted to pasture land, for which they are better suited; and in all parts of the area farms are becoming fewer in number and larger in size as mechanization and improved farming methods increase agricultural productivity.

The resulting surplus of farm labor has been one factor stimulating the growth and diversification of industry, which has created new opportunities for agricultural workers in manufacturing, trade, and service employments. Industry, however, has tended to concentrate near the larger towns and cities, especially the city of Mobile. Thus, one effect of the transition from agriculture to industry has been a movement of people from rural to urban areas.

The extent of this movement during the decade 1950-60 is shown by the population figures in table 1. Although the total population of the 14 counties increased more than 13 percent, the increase was the result of gains in only four counties: Mobile, Montgomery, Dallas, and Baldwin. Mobile and Montgomery Counties are predominantly urban and industrial; and Dallas County, with the rapid growth of Selma, is becoming so. Baldwin County shares in the industrial expansion of the Mobile area and further benefits from the growth of resort and recreational activity near the coast. The other 10 counties, which are predominantly rural, experienced population losses ranging up to 20 percent; but even in these counties, urban populations showed substantial gains.

There is little reason to doubt that present economic trends in southwestern Alabama will continue for the next few decades. The indications are that farms will continue to become larger and fewer, with more and more cropland giving place to pasture and woodland; that the population of the area will continue to grow as towns and cities become larger; that the demand for recreational water areas and fish and wildlife conservation will grow faster than the population; and that industry will continue to expand, both near the cities and in "industrial parks" set up in what are now rural areas favorably situated along the navigable rivers. Springboards to industrial expansion will be further improvement of the Warrior-Tombigbee Waterway, continued development of the Coosa-Alabama River system for hydropower and navigation, and eventually realization of the long-planned waterway linking the Tombigbee and Tennessee Rivers. Underpinning the entire economic structure will be the port of Mobile, where increasing volumes of raw materials and imports from foreign markets will be exchanged for the products from Alabama factories.

These economic trends set the basic pattern of future water needs and problems in southwestern Alabama. Cities and industries must look toward expanding their present water supplies or develop new sources of supply. Rural supplies, too, may need to be bolstered as more intense farming practices enlarge the need for water in agriculture, especially for irrigation. Local droughts will need to be provided for, and damaging floods guarded against.

Water laws will need to be formulated for protecting the rights of water users. The reuse of water and alternative uses of water will require closer attention. The effects of major water developments on the operation of the hydrologic system will need to be appraised and related to anticipated future uses of water. Finally, and most important of all, continued vigilance will be needed in guarding the resource itself against pollution from domestic and industrial wastes and contamination from detergents, pesticides, and radioactivity.

PRESENT USE AND CONTROL OF SURFACE WATER

PUBLIC WATER SUPPLY

In southwestern Alabama, ground water generally represents the most economical source for public water supplies of moderate demand. Of the 42 public water supplies in the area in 1963, 37 were developed from ground-water sources, mostly deep wells. Three of these supplies (Montgomery, Selma, Uniontown) were furnishing more than 1 mgd (million gallons per day). The largest ground-water supply in the area is that for Montgomery, which is pumped from a field of 63 wells having a total capacity of about 30 mgd. This system is approaching the economical limit of expansion, and the city is now developing an additional water supply from the nearby Tallapoosa River.

Surface-water supplies are presently used by five cities in southwestern Alabama. These supplies serve about half the population of the area having municipal water service (table 2).

Table 2.—*Public surface-water supplies in southwestern Alabama, 1963*

City	County	Source of supply	Population served	Plant capacity (mgd)	Maximum daily use (mgd)
Bellamy	Sumter	Sucarnoochee River[1]	500	0.158	0.118
Livingston	Sumter	Sucarnoochee River	1,500	.400	.200
Mobile	Mobile	Big Creek	250,000	30.0	28.0
Prichard	Mobile	Eight Mile Creek	62,000	8.0	5.2
York	Sumter	Toomsuba Creek	3,000	.576	.288

[1] Supplemented by shallow ground-water supply.

CITY OF MOBILE WATER SUPPLY

The Mobile public water system is the only one of the five surface-water systems that provides any substantial volume of reservoir storage. The Mobile system draws on Big Creek Lake, an impoundment created in 1952 about 18 miles west of the center of the city. The dam forming this reservoir is located on Big Creek a short distance below the mouth of Hamilton Creek, at which site it impounds runoff from a watershed of 103 square miles. At the elevation of the top of the spillway gates (110 feet above sea level), Big Creek Lake covers 3,900 acres and provides a usable capacity of 48,500 acre-feet (15.8 billion gallons).

A pumping station of 100 mgd capacity pumps water from Big Creek Lake about 9 miles through a 60-inch pipeline to a 20-million gallon reservoir at the treatment plant. This reservoir remains full as long as the pumps are running, the overflow entering a second reservoir of 54-million gallon capacity from which raw water is supplied to industrial users. The treatment plant draws from the first reservoir and has a nominal capacity of 30 mgd, but can supply as much as 40 mgd during emergencies. Two reservoirs of 10-million gallon capacity each–parts of earlier water-supply systems–are used as standing wells for the storage of treated water.

The Mobile system was designed to furnish a dependable supply of 100 mgd, which represents about 50 percent of the average natural streamflow from the watershed. Of this total supply, 30 mgd is reserved for domestic use, leaving the remainder available for industrial purposes. In 1963, average usage for domestic purposes was about 23 mgd, and for industrial purposes, about 70 mgd.

Clear Creek and Three Mile Creek, which supplied about 12 mgd to the earlier public water system, were discontinued as sources of public water supply when the Big Creek system began operating in 1952. At the same time, industries in the metropolitan area largely discontinued use of private surface-water supplies that had been furnishing about 25 mgd.

INDUSTRIAL USE OF SURFACE WATER

In 1960, industrial use of surface water in southwestern Alabama was estimated as 943 mgd. About 92 percent of this water was self-supplied by industries pumping directly from the streams, and the remainder was purchased from municipal water systems. Two major users of water—the paper industry and steam-electric generating plants—accounted for nearly all surface water withdrawn for industrial purposes, as shown by the following figures:

Industrial water user	Average daily use 1960 (mgd)	Percent of total industrial use
Paper industry	248	26
Steam-electric plants	688	73
Other users	7	1
Total	943	100

Although the above figures represent total withdrawals of surface water for industrial use, they do not indicate that the available supply was reduced by a corresponding amount. Some of this water was withdrawn, used, and returned to the river system as many as three times, and much of it was available for further downstream use. Ordinarily, only a small percentage of water used by industry is permanently removed from the hydrologic system. Practically all the water withdrawn by steam-electric plants, for example, is used for cooling purposes and is returned to the streams unchanged in quality except for an increase in temperature. In the Mobile area, however, large volumes of industrial water must be discharged after use into brackish, tidal waters near Mobile Bay. This water has completed its journey to the sea and is generally unfit for further use until freshened and returned to the land through the operation of the hydrologic cycle.

RURAL AND AGRICULTURAL USE OF SURFACE WATER

The use of surface water in rural areas of southwestern Alabama is confined mostly to livestock watering and irrigation. Water for rural domestic use is obtained from wells or springs. In 1962, the estimated usage of surface water in the area for stock watering and irrigation averaged 6 mgd.

Agriculture in southwestern Alabama is not dependent upon irrigation, as rainfall is usually adequate to bring crops to harvest. Dry periods are common during the fall months, however, and not uncommon in the important growing-season months of May and June. In most years, supplemental irrigation will produce worthwhile increases in the yields of high potential cash crops such as truck and seed crops, cotton, and pastures for dairy cattle. Most irrigating is done by portable sprinkler systems using aluminum pipe and gasoline-powered pumps drawing on streams, ponds, or wells. In 1962, about 2,300 acres were irrigated in southwestern Alabama.

NAVIGATION

Water transportation along the Alabama, Tombigbee, and Mobile Rivers dates back to Indian times. Tower (1959) mentions St. Stephens on the Tombigbee River and Claiborne on the Alabama River as being the heads of schooner navigation on those rivers during the Spanish period (1783-1813). River navigation in pioneer times was crude and uncertain. Rafts, flatboats, and keelboats loaded with farm products were steered with the current down the rain-swollen rivers to Mobile, where both craft and cargo were usually sold, the navigators then making their way back home as best they could on foot or horseback through wild, unbroken country.

WARRIOR-TOMBIGBEE WATERWAY

Demopolis was first reached by steamboat in 1819, Montgomery in 1821. It was not until 1870, however, after coal was discovered in the Black Warrior River basin, that active interest was taken in improving the lower rivers for navigation. The first project to improve the Tombigbee River was approved by the Congress in 1871 and provided for a channel 3 feet deep from Mobile to Demopolis. In 1874, a survey of the Tombigbee and Black Warrior Rivers was authorized for the purpose of planning a slack-water navigation channel 6 feet deep from Mobile to Tuscaloosa. A series of 10 locks and dams accomplishing this purpose were completed in 1895. By 1915, seven additional dams had been built extending the waterway to Port Birmingham, 20 miles west of Birmingham on the Locust Fork.

As originally planned, the waterway was intended for the operation of shallow-draft packet steamers. With the growth of industry and commerce came fleets of towboats and barges requiring a deeper channel and larger locks. This development rendered the original locks and dams obsolete and inadequate by the 1930's. In recent years the waterway has been modernized by larger structures replacing the original locks and dams as shown below:

Year opened to traffic	Name of lock and dam	River	Earlier locks eliminated
1939	Tuscaloosa	Black Warrior	Locks 10, 11, 12
1954	Demopolis	Tombigbee	Locks 4, 5, 6, 7
1957	Warrior	Black Warrior	Locks 8, 9
1960	Jackson	Tombigbee	Locks 1, 2, 3

Holt Lock and Dam, now (1964) under construction on the Black Warrior River above Tuscaloosa, will eliminate old Locks 13, 14, 15, and 16. When the current program of improvement is completed with the replacement of the small, double-lift locks at Lock 17 by a single large lock, there will be only six high-lift locks between Mobile and Port Birmingham, a distance of 400 miles. These locks (table 3) and a maintained channel of a 200-foot width and a 9-foot minimum depth will reduce the roundtrip time for large tows over the waterway from 14 days to 8 days. Commerce carried over the waterway in 1961 amounted to about 6 million tons.

ALABAMA RIVER

No navigation improvements have been made on the Alabama River except for the construction of high-level bridges and open-channel work such as snagging and dredging. The present controlling depth at low river stages is about 4 feet. Commerce carried on this river in 1961 amounted to 1.2 million tons.

Table 3.—*Physical data for locks and dams, Warrior-Tombigbee Waterway*

Item	Name of lock and dam						
	Jackson	Demopolis	Warrior	Tuscaloosa	Holt	Bankhead (Lock 17) Existing	Bankhead (Lock 17) Proposed
River miles above Mobile	119.7	216.2	269.6	346.3	355.2	373.6	373.6
Drainage area above dam (sq mi)	18,510	15,450	5,800	4,828	4,232	3,990	3,990
Reservoir							
Normal pool elevation (ft above msl)	32.5	73.5	95	123	186.5	254.5	254.5
Normal tailwater elevation (ft above msl)	1.0	32.5	73.5	95	123	186.5	186.5
Surface area at normal pool (acres)	8,500	10,000	7,800		3,270	9,200	9,200
Spillway							
Crest elevation (ft above msl)	13.0	73.0	74.9	122.9	152.5	241.5	241.5
Number of gates	8	None	6	None	14	22	b
Length of gates (ft)	60	.....	60	.....	40	a49	b
Height of gates (ft)	21	.....	21	.....	35	13.5	b
Elevation of top of gates, closed position (ft above msl)	34	.....	96	.....	187.5	255	256
Lock							
Inside chamber dimensions (ft)	110x600	110x600	110x600	95x460	110x600	52x285.5	110x600
Maximum lift (ft)	34	40	22	28	63.5	c68	d68
Power plant							
Number of generating units	None	None	None	None	1	None	1
Total generating capacity (kw)	.....	.....	.....	.....	40,000	.....	45,000

a Two gates have a length of 21.25 ft. b Under study. c. Double lift. d Single lift.

MOBILE HARBOR AND BAY

The port of Mobile, with the excellent and modern facilities to shipping provided by the Alabama State Docks, now rates among the top ten ports of the Nation. In 1962, cargoes handled by the entire port totaled 13.4 million tons. The present depth controlling entrance to Mobile harbor is 36 feet, which requires some ocean-going vessels to enter only partly loaded. In 1964, the Congress allotted funds for further improvement of the harbor, including deepening of the navigation channels in Mobile Bay and River to 40 feet.

Because of its function as a transportation link connecting the river waterways, railroads, and highway system with the Intracoastal Canal and the open sea, the port of Mobile is one of the more potent factors shaping the future development of economy and water resources in southwestern Alabama.

HYDROELECTRIC POWER AND FLOOD CONTROL

At the present time there are no major hydroelectric developments or flood-control works in southwestern Alabama.

The topography of the Coastal Plain is generally unfavorable for the development of water power. The major rivers are low in slope, and their valleys too broad and flat to permit the construction of very high dams. The Alabama River, for example, falls 106 feet in the 300 miles from Montgomery to its mouth—an average slope of only 0.35 foot per mile. In addition, foundation conditions suitable for large dams are not easily found in the unconsolidated sediments underlying most of the area. Hydroelectric plants are included, however, in plans prepared by the Corps of Engineers for navigation dams on the Alabama River at Millers Ferry and Jones Bluff (see table 6).

Floods in southwestern Alabama cause considerable damage and inconvenience to agricultural interests, highway and navigation systems, and to some cities located on the major rivers. Damage to agricultural lands along the Alabama and Tombigbee Rivers (table 4) constitutes the greatest loss (Drago, 1962). Main highways and railroads traversing the flood plains of these rivers are not subject

Table 4.—*Flooded areas and average annual rural damage along streams in southwestern Alabama* (after Drago, 1962)

Stream	Reach (miles above mouth)	Flood area (acres)	Estimated average annual flood damage
Alabama River	37-314	225,000	$345,000
Big Swamp Creek	6-38	21,000	131,000
Tombigbee River	100-220	169,000	143,000

to much damage, but county roads and bridges are sometimes damaged extensively by floods on tributary streams. Most urban flood damage occurs in Montgomery, Selma, and Demopolis, parts of which are subject to inundation by major floods (figs. 2, 3, 4). Average annual flood damage in these cities has been estimated (Drago, 1962) as: Montgomery, $107,000; Selma, $70,000; Demopolis, $10,000. A project for the protection of flood-affected areas of Montgomery was authorized by the Flood Control Act of July 3, 1958, but as yet no funds have been made available for construction. Existing dams in the upper basins of the Alabama and Tombigbee Rivers do not provide any major flood-control benefits in southwestern Alabama.

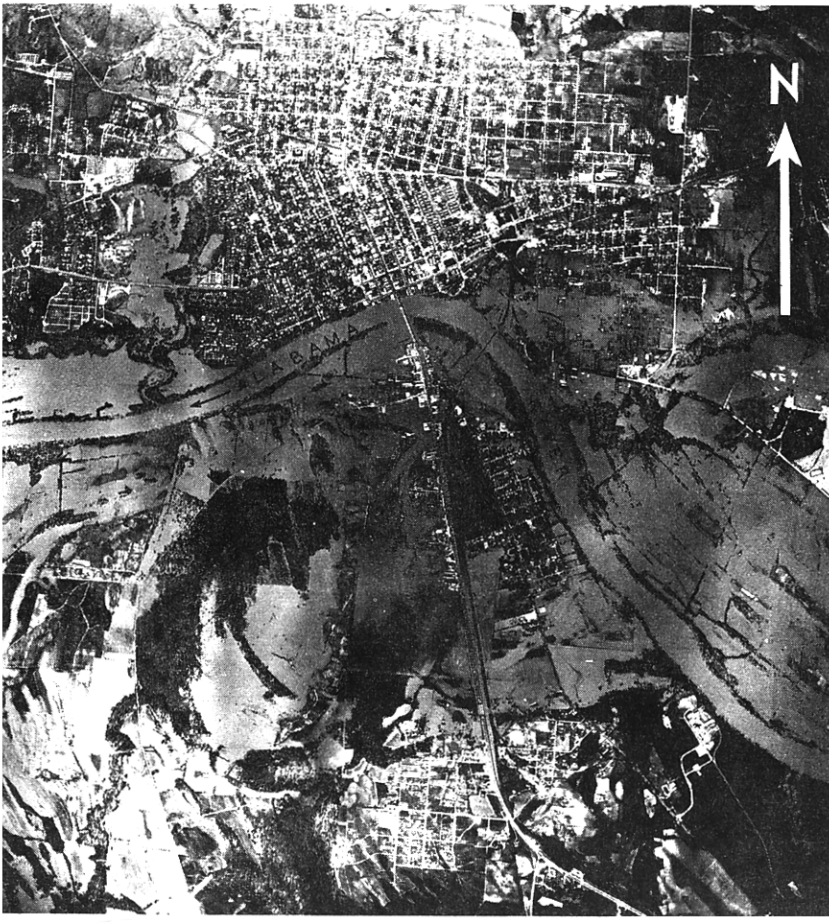
POLLUTION CONTROL

The control of water pollution in Alabama is the function of the State of Alabama Water Improvement Commission. This agency was created in 1947 for the purpose of determining the sanitary condition of the waters of the State. Further legislation in 1949 and 1953 gave the Commission regulatory powers which extend its responsibilities and authority into the general field of water use for domestic supply, industry, agriculture, seafood, and recreation.

A statewide survey of stream pollution in Alabama was completed by the Commission in 1949. In this survey, the rivers and streams of southwestern Alabama were in relatively good to excellent sanitary condition, with the principal exceptions noted as follows:

Photograph by Alabama Air National Guard

Figure 2.—Aerial view of Montgomery, Ala., showing inundation by floodwaters, February 26, 1961.



Photograph by Alabama Air National Guard

Figure 3.–Aerial view of Selma, Ala., showing inundation by floodwaters, February 26, 1961.

Photograph by Alabama Air National Guard

Figure 4.—Aerial view of Demopolis, Ala., showing inundation by floodwaters, February 28, 1961.

Catoma Creek was grossly polluted in the lower 9 miles of its length by untreated sewage and industrial waste from the city of Montgomery. The city has since remedied this condition by constructing a sewage treatment plant. Abnormally high chloride concentrations occurred in Mill Creek and Okatuppa Creek as a result of briny wastes discharged from oil-field operations in the Gilbertown area of Choctaw County. Recent efforts of the State Oil and Gas Board, supported by the Commission, have been successful in limiting further effects of these wastes. Domestic sewage from Prichard and Mobile was found to be contaminating part of Mobile Bay to the extent that the coliform count in some commercial oyster-fishing beds was greater than that permissible for the harvesting of shellfish. Since 1949, these municipalities have constructed sewage treatment plants where none existed before and are continually expanding and upgrading these facilities to care for population increases. It was also pointed out by the Commission that adequate sewage treatment would be needed to assure the continued development of the lower Perdido River as a recreational and shellfish-producing area. All Alabama municipalities within the Perdido River drainage area now provide adequate treatment of sewage.

At the present time, the lower Mobile River appears to present the principal pollution problem in southwestern Alabama. Studies by the Water Improvement Commission in 1960 indicated that Three Mile Creek was grossly polluted by partially treated sewage and untreated industrial waste. In its lower reaches this stream was completely devoid of dissolved oxygen and quite offensive in odor and appearance. Plans are underway to alleviate this situation. Chickasaw Creek was also affected in its extreme lower reaches by industrial wastes.

Below Chickasaw Creek, the Mobile River is used altogether for navigation, port facilities, and waste disposal. Water quality objectives in the harbor area are based primarily on the protection of marine shipping, prevention of nuisance, and maintenance of minimum conditions tolerable to fish while passing from Mobile Bay into the waters above Cochrane Bridge. The 1960 study indicated only a small margin of safety above the minimum water quality compatible with these objectives for Mobile River between

Cochrane Bridge and Mobile Bay. Mobile Bay waters were found to be adequately protected.

Although no pollution enters Mobile River locally above Chickasaw Creek, the river upstream from the mouth of this creek to Twelve Mile Island was affected by wastes in varying degree depending upon conditions of river discharge, wind, and tide, which can be such as to produce upstream flow. The effects on water quality in this region were not considered to be significant. Above Twelve Mile Island to McIntosh (the upstream limit of the 1960 study), Mobile River was in clean condition, the only departure from normalcy being an increase in temperature of 2° C immediately below the discharge of condenser water from the Barry steam-electric generating plant. This increase in temperature had no effect on other parameters of water quality and was dissipated within a few miles.

Sewerage improvements (table 5) have been greatly stimulated in recent years by two factors: (1) the Federal construction grant program administered by the U.S. Public Health Service, and (2) increased usage of the stabilization-lagoon method of treating sewage, which, because of its relatively low cost, makes it possible for smaller communities to meet their waste treatment responsibilities. Municipalities listed as not having sewage treatment facilities are considering improvements.

Industrial pollution subject to the authority of the Water Improvement Commission is considered by the Commission to be under control in southwestern Alabama. Undesirable conditions occasionally occur, sometimes as the result of an accident, but each case is studied by the Commission and handled in such manner as to reduce the probability of recurrence. Industries and municipalities planning to discharge wastes into Alabama waters are required to obtain permits from the Commission. This requirement applies to the expansion of existing facilities as well as to the installation of new ones.

The Commission continuously maintains surveillance over the quality of waters in the State. Southwestern Alabama has received more attention than any other area. The Commission is being actively supported in this effort by industries which prepare routine

Table 5.—*Municipal sewerage systems in southwestern Alabama, 1963*
(Information furnished by Alabama Water Improvement Commission)

Municipality	Population 1960	Population served	Method of treatment	Receiving stream
Bay Minette	5,197	3,000	Primary treatment with separate sludge digestion	Hollinger Creek
Butler	1,765	1,000	Stabilization lagoon	Branch of Wahalek Creek
Camden	1,121			Branch of Pursley Creek
Plant No. 1		300	Septic tank	
Plant No. 2		700	Stabilization lagoon	
Chickasaw	10,002	8,000	Stabilization lagoon	Chickasaw Creek
Citronelle	1,918	1,000	Imhoff tank	Puppy Creek
Demopolis	7,377	6,800	Stabilization lagoon	Tombigbee River
Fairhope	4,858	3,500	Trickling filter	Mobile Bay
Foley	2,889	1,500	Stabilization lagoon	Wolf Creek
Frisco City	1,177	900	Imhoff tank	Branch of Randons Creek
Grove Hill	1,834	1,600	Septic and Imhoff tanks	Branch of Jackson Creek
Jackson	4,959	3,200	None	Tombigbee River
Linden	2,516	1,600	Septic tanks	Branch of Chickasaw Bogue Creek
Livingston	1,544	1,500	None	Sucamoochee River
Marion	3,807	2,000	Trickling filter	Branch of Boguechitto Creek
Mobile	202,779			
McDuffie Island plant		65,000	Activated sludge process	Mobile Bay
Three Mile Creek plant		44,000	Separate sludge digestion	Three Mile Creek
Eslava Creek plant		22,000	Trickling filter	

Monroeville	3,632			
Plant No. 1		2,000	Primary treatment with combined sludge digestion	Branch of Limestone Creek
Plant No. 2		750	Septic tank	
Montgomery	134,393			
Catoma Creek plant		50,000	Bio-activation process	Catoma Creek
Outfalls		68,000	None	Alabama River
Prichard	47,371			
Plant No. 1		20,000	Primary treatment with separate sludge digestion	Three Mile Creek
Plant No. 2		10,000	Trickling filter	
Robertsdale	1,474	900	Activated sludge process	Branch of Blackwater Creek
Saraland	4,595	....	Activated sludge process	
Selma	28,385	22,000	None	Alabama River
Thomasville	3,182			
Treatment plant		750	Trickling filter	
Outfall		2,000	None	Branch of Bassett Creek

reports to the Commission on water quality below their discharges and on the characteristics of their wastes. The city of Mobile also reports to the Commission on daily operation of the municipality's sewage treatment plants.

WATERSHED CONTROL AND LAND MANAGEMENT

A projection to 1975 of land-use needs in southwestern Alabama (Alabama Soil Conservation Committee, 1961) finds that land acreage expected to be used in that year will need treatment or improvement as follows:

Land use	Expected acreage, 1975	Percentage of land needing treatment
Cropland	872,000	51
Pasture and range	1,330,000	73
Forest and woodland	5,990,000	59

The types of treatment needed include changes in land use, establishing or improving cover, rebuilding eroded or depleted soil, stabilizing runoff- and sediment-producing areas, retaining floodwaters for agricultural use and reduction of water and sediment damage, and protecting against fire, overgrazing, weeds, insects, rodents, and plant disease.

Nearly 68 percent of southwestern Alabama is covered by forests, which thus receive about two-thirds of the area's rainfall. A well managed forest cover, in addition to yielding more timber, is effective in retarding surface runoff and hence in reducing erosion of land and silting of streams. A program of forest management is conducted by the State Department of Conservation in cooperation with the U.S. Department of Agriculture. This program includes technical assistance to private woodland owners, research in forest disease and insect control, tree planting, and organized fire control. During the 1961-62 planting season, more than 23 million high quality tree seedlings were furnished at nominal cost to woodland owners in southwestern Alabama.

The U.S. Department of Agriculture, through its Soil Conservation Service, also conducts a program for the improvement of small watersheds as authorized by the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, 1954). A current and typical project in southwestern Alabama under this program is that for the watershed of Powell Creek, a tributary of Chickasaw Bogue Creek in Marengo County. Work proposed in this watershed of 66 square miles consists of land treatment and structural measures to protect eroding upland soils and minimize seasonal flooding, thereby permitting more intensive agricultural usage of the watershed. Structural measures include floodway excavation, field ditches, terraces, 20 farm ponds, and 9 flood-retarding structures.

RECREATION

Water-oriented recreation in southwestern Alabama centers about the coastal beaches and larger rivers, particularly the Tombigbee River with its navigation pools and backwater areas. All of Alabama's 204 miles of recreational salt-water shoreline–115 miles of beach and 89 miles of marshland shore–is in the report area along Mobile and Perdido Bays and the Gulf of Mexico. Most of this shoreline is privately owned. Gulf State Park, a State-operated recreational area providing both fresh-water and salt-water sporting facilities, is located on the Gulf coast in Baldwin County.

Also in the report area are two State-operated public fishing lakes–one of 100 acres in Dallas County and one of 40 acres in Marengo County. These lakes were constructed by the Alabama Department of Conservation as part of that agency's water-recreation program, which includes also the construction of public boat-launching ramps, research studies in fish and waterfowl management, and the stocking of privately owned fish ponds. By September 1962, this agency had stocked more than 5,500 fish ponds in southwestern Alabama. The average size of these ponds is about 5 acres. An important function of the Department of Conservation related to the recreational use of water is the administration of the Water Safety Patrol, which maintains patrol units on all major bodies of water for the purpose of insuring water safety through enforcement of water-safety regulations and the promotion of maximum courtesy in the multiple use of the waters.

WATER USE LAW

Alabama has few laws relating to water rights, and these relate mostly to conditions of the past that are not now important. The few conflicts that have developed at local level have been settled in courts using common-law procedures as influenced by the doctrine of riparian right.

The need for a modern water law was recognized in 1955 by a committee of representatives from all groups and agencies in Alabama interested in or concerned with water. This committee studied the subject of water law and concluded that to insure objective legislation which would best protect the interests of all water users, the State Legislature should set up a temporary "Water Resource Study Commission" to inventory water resources, study the need for legislation, and draft the necessary water laws. Such a commission was created by Legislative Act 74 in June 1959. The legislation, however, did not carry with it an appropriation; consequently, nothing was accomplished, and the act has since expired.

The outcome of this and other attempts to modernize the State's water laws indicates that the situation is not yet judged sufficiently acute to require action. This judgment may be accurate as of now, but excessive delay would appear to be unwise, for uncertainty about water rights may tend to discourage developments which could profitably be undertaken.

FUTURE SURFACE-WATER DEVELOPMENTS

A number of water-development projects that can be expected to play an important part in the future economy of southwestern Alabama are proposed or in progress, both in the report area and beyond its borders (fig. 5). One of these projects–the continued improvement of the Warrior-Tombigbee Waterway–has been mentioned. Two other projects of great economic significance to southwestern Alabama are the proposed waterway connecting the Tombigbee and Tennessee Rivers and the development of the Alabama River for navigation and hydroelectric power. The Alabama River

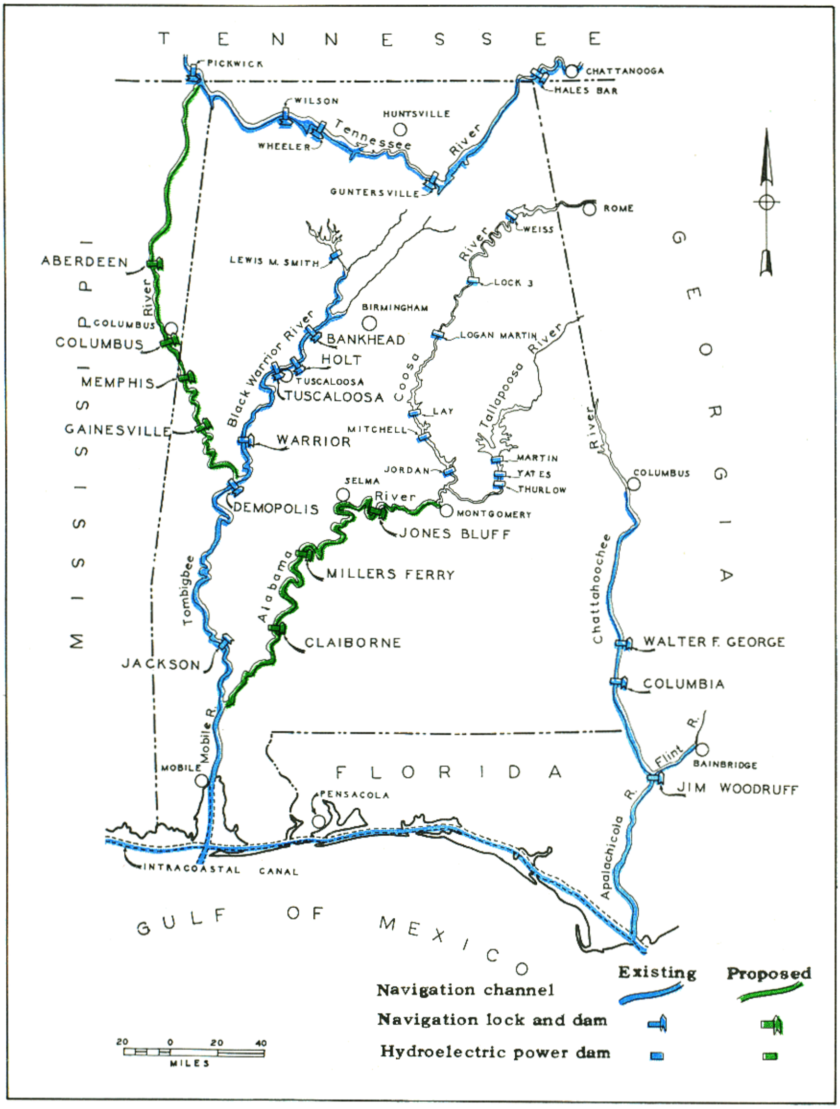


Figure 5.—Map showing major river developments affecting southwestern Alabama.

project is particularly important because the improved navigation and increased availability of electrical power will place every community along the river in a competitive position to obtain new industry.

ALABAMA-COOSA RIVER DEVELOPMENT

A project for the comprehensive development of the Alabama-Coosa River system was authorized by the Rivers and Harbors Act of March 2, 1945. Original plans for this project prepared by the Corps of Engineers called for the initial and ultimate development of the Alabama and Coosa Rivers and their tributaries for navigation, flood control, power, and other purposes. Federal authorization to develop the Coosa River was suspended in 1945 to permit the further development of that river for hydroelectric power by the Alabama Power Co.

The approved Federal plan includes dredging of the lower Alabama River and the construction of navigation locks and dams at Claiborne, Millers Ferry, and Jones Bluff to provide a 9-foot barge channel from Mobile to Montgomery. Two of these dams will include hydroelectric generating plants (table 6).

Construction of the Millers Ferry Lock and Dam began in April 1963 and is scheduled for completion in 1968. Next to be undertaken will be the Claiborne Lock and Dam, 60 miles downstream, and the channel improvements in the lower river. These works when completed will open the Alabama River to year-round barge traffic from Mobile to Selma. Last to be completed will be Jones Bluff Lock and Dam, which will extend the waterway to Montgomery.

While these navigation dams are being built on the Alabama River by the Corps of Engineers, the Alabama Power Co. will be completing its 10-year program to build three new power dams on the Coosa River and to increase generating capacity at its three old dams built on that river between 1914 and 1930.

When conditions warrant, the navigation channel can be continued to Rome, Ga., by building locks at the six Alabama Power Co. dams on Coosa River (fig. 5).

Aside from their primary functions for navigation and power,

Table 6.—*Physical data for proposed locks and dams on Alabama River*

Item	Name of Lock and Dam		
	Claiborne	Millers Ferry	Jones Bluff
Dam site, miles above mouth of Alabama River	81.8	142.3	246.8
Drainage area above dam site (sq mi)	21,490	20,700	16,285
Reservoir			
Normal pool elevation (ft above msl)	32 to 35	80	125
Normal tailwater elevation (ft above msl)	8	32 to 35	80
Surface area at normal pool (acres)	a5,850	22,500	12,000
Storage volume at normal pool (acre-ft)	a97,000	368,000	250,000
Gated spillway			
Crest elevation (ft above msl)	b15.0	46.0	91.0
Number of gates	6	17	13
Length of gates (ft)	60	50	50
Height of gates (ft)	21	35	35
Elevation of top of gates, closed position (ft above msl)	36.0	81.0	126.0
Lock			
Inside chamber dimensions (ft)	84x600	84x600	84x600
Maximum lift (ft)	27	48	45
Power plant			
Number of generating units	None	3	3
Total generating capacity (kw)	.....	75,000	68,000

a At elevation 35 ft.
b Claiborne dam to have 500 ft of ungated spillway at elevation 33.0 ft.
All figures for Jones Bluff are preliminary and subject to revision.

the dams proposed for the Alabama River will provide secondary benefits in the way of increased facilities for water-oriented recreation and wildlife conservation. The dams will not provide appreciable storage of floodwaters and should have little effect on the stages of major floods along the river. At low flows, however, river levels will be permanently raised by amounts ranging up to 27 feet at the lower end of the Claiborne reservoir and up to 50 feet or more at the lower ends of the Millers Ferry and Jones Bluff reservoirs. As a result, velocity of flow and fluctuations in water level in these navigation pools will be much less than those occurring in the river under natural conditions. Such changes in the normal regimen of the river can be expected to have significant ecologic and hydrologic effects in and along the river. For example, during low-flow periods in the summer and fall, low velocities will be accompanied by thermal stratification in the deeper navigation pools, and these conditions could affect bio-chemical relations in the pools sufficiently to influence the sanitary management of the river. Hydrologic effects of the dams can be foreseen as a result of the rise in ground-water levels that will occur upstream from the dams in the more permeable aquifers hydraulically connected to the river. Permanent saturation of the root zone in some areas of the flood plain could result, as well as increased leakage from the river to ground water, especially if the new water table is higher than previous ground-water divides.

TENNESSEE-TOMBIGBEE WATERWAY LINK

A project to connect the Tennessee and Tombigbee Rivers with a navigable waterway was approved by the Rivers and Harbors Act of July 24, 1946, but no funds have yet been made available for construction. The waterway, under present plans, would extend 253 miles from Demopolis to Pickwick reservoir on the Tennessee River by way of the East Fork of the Tombigbee River, Mackeys Creek, and Yellow Creek, in northeastern Mississippi (fig. 5). The proposed project involves the construction of 10 locks and dams and the cutting of a canal some 40 miles long through the ridge separating Mackeys and Yellow Creeks.

This waterway would provide a slack-water navigation channel from the Gulf of Mexico to the Ohio-Mississippi River system, thus making it possible for barge traffic bound for midwestern destinations to avoid the strong currents of the Mississippi River. The water route from the Tennessee River to Mobile would be shortened by about 700 miles.

Realization of the Tennessee-Tombigbee Waterway, by further stimulating industrial expansion, could be expected to lead to an increased usage of water in southwestern Alabama. No significant direct effect of the proposed waterway on the hydrologic system in the report area is foreseen. Water for lockages in the upper reaches of the waterway would be obtained from the Tennessee River, but the effect of this diversion on the flow of the lower Tombigbee River would be inconsequential.

HYDROLOGIC ENVIRONMENT

Preceding sections of this report have described, so far as the present scope will permit, the social and economic framework within which the surface-water resources of southwestern Alabama are being used. The remainder of the report is devoted to the hydrologic aspects of those resources—to the natural environment that produces surface water and to the characteristics of its occurrence.

The purpose of this section of the report is to describe the hydrologic system operating in southwestern Alabama as related to the occurrence of surface water. Following sections will summarize, for specific streams, those characteristics of streamflow most closely related to use and development.

HYDROLOGIC CYCLE

Viewed in its simplest aspect, surface water in southwestern Alabama can be regarded as representing a single phase in the highly intricate process through which water circulates continuously from the earth to the atmosphere and back to earth again (fig. 6).

Rising salt-free from the Gulf of Mexico under the vaporizing power of the sun, water is windborne across southwestern Alabama, some as invisible vapor, some as condensed droplets of clouds or fog. Part of this airborne moisture is precipitated, mostly as rain but occasionally as snow or hail, and falls either on land or directly into streams. Some of the precipitation is returned to the atmosphere by evaporation from land and water surfaces, but the remainder infiltrates into the soil or flows overland to surface streams. Much of the water that enters the soil is evaporated or returned to the atmosphere by transpiration from plant life; the remainder percolates downward to the ground-water table and enters the saturated zone, where part remains and part moves laterally to surface streams or to the Gulf of Mexico. That water which continues to move beneath or upon the land surface eventually returns to the sea, where it is again evaporated.

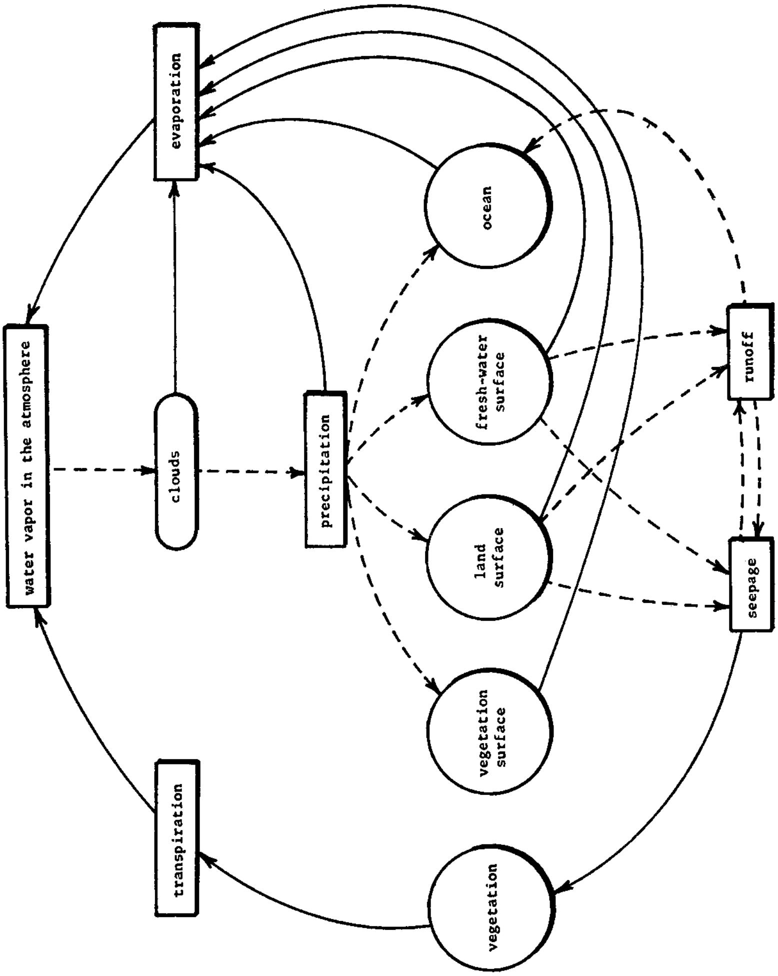


Figure 6.—Diagram of the hydrologic cycle.

FACTORS INFLUENCING STREAMFLOW

The factors that control the hydrologic cycle, though numerous, can be grouped according to their major influence on streamflow into two general classes: (1) meteorologic or climatic factors, which determine the total amount of water available for the entire process, and (2) land factors, which largely determine the proportions in which the available water reaches the streams by underground and overland routes.

Meteorologic factors, as the name denotes, operate mainly in the atmosphere, and the principal ones are precipitation, temperature, and wind. Day-by-day variations in these factors make up what is popularly spoken of as weather, whereas their average behavior over long periods of time constitutes climate.

Land factors include the physical characteristics of the land surface and the underlying rocks, as well as various topographic and cultural features of individual watersheds. The more important land factors in southwestern Alabama include rock and soil type, watershed area, shape, and slope, and land use.

Some factors governing streamflow do not fall clearly into either class. For example, the type and density of vegetation strongly influence, through the process of evapotranspiration, the amount of rainfall that becomes available to streamflow. Yet vegetation, though it grows on the surface of the land, is more closely related to climate.

None of the factors influencing streamflow acts independently, and their inter-relationships are extremely complex. Some factors exercise greater influence over high flows, some over low flows, whereas the effects of others may vary with the season or with antecedent conditions. One factor generally conditions another so that neither has a clearly recognizable effect. This interplay of meteorologic, topographic, and geologic factors in southwestern Alabama constitutes the hydrologic environment of the area.

The hydrologic environment of southwestern Alabama governs almost completely the natural streamflow characteristics of those streams which originate within the area. With respect to its major rivers, however, southwestern Alabama does not represent a self-contained hydrologic system. Although the Alabama and Tombigbee

Rivers flow through the area, nearly 80 percent of the total watershed of each of these rivers is outside the area of the report. Consequently, the streamflow characteristics of these rivers are modified, but not completely controlled, by hydrologic factors operating in southwestern Alabama. This qualification also applies, though less strongly, to Perdido River and to Escatawpa River, which have 39 percent and 17 percent, respectively, of their watersheds outside the area of the report.

The more important land and climatic factors relating to streamflow in southwestern Alabama are discussed briefly in the remainder of this section of the report.

CLIMATIC FACTORS

PRECIPITATION

Precipitation, as the basic source of all streamflow, affords a logical starting point in describing the surface-water phase of a hydrologic system. In southwestern Alabama, precipitation occurs almost entirely in the form of rain. Snow occasionally falls in the area, but so infrequently and generally in such small amounts that it is regarded more as a curiosity than as a hydrologic factor.

Most rainfall in southwestern Alabama originates in tropical maritime air masses carried inland by prevailing winds from the Gulf of Mexico. Two types of storms predominate, depending upon the season of the year. From November through April storms of the cyclonic type involving the movement of warm and cold fronts over the area are most common, and these storms may bring heavy, area-wide rainfall lasting several days. From May through October, storms of the convective type predominate. Most storms of this type occur during daylight hours and are short-lived and spotty. They range from quiet showers to cloudbursts and violent thunderstorms that may concentrate torrential rainfall over a small area in less than an hour. Convective storms also occur frequently in the frontal zones of cyclonic disturbances.

A third type of storm and one that can bring heavy, widespread rainfall to southwestern Alabama is the West Indian hurricane. These storms form in the Gulf of Mexico or the South Atlantic

Ocean, most frequently during August through October, and sometimes enter the mainland along the Gulf coast. The disastrous floods of July 1916 in Alabama, for example, were caused by a tropical hurricane that entered the United States just east of the mouth of the Mississippi River. Five-day rainfall from this storm ranged up to 22 inches at some places in southwestern Alabama, and nearly the entire State received 8 inches or more of rainfall.

AVERAGE ANNUAL RAINFALL

Areal variation in average monthly and annual rainfall in southwestern Alabama is shown in figure 7, with the corresponding variation in average annual runoff in inches. The three rainfall provinces designated in this figure as Prairie, Coastal Plain, and Gulf are those used by the U.S. Weather Bureau in compiling climatologic data. The boundaries of these provinces, though shown as following county lines, also conform reasonably well with recognized physiographic boundaries. Figure 7 serves to illustrate several interesting characteristics of average rainfall and runoff in southwestern Alabama.

Runoff is roughly proportional to rainfall, and both decrease in a northward direction away from the Gulf of Mexico–the primary source of moisture. Thus, annual rainfall in the Gulf section averages about 14 inches greater than in the Prairie section, and runoff about 13 inches greater. In all sections, however, the average monthly distribution of rainfall conforms fairly well with seasonal requirements. On the average, rainfall during the growing-season months, May through September, ranges from 39 percent of the annual total in the Prairie section to 49 percent in the Gulf section.

The greater influence of cyclonic precipitation is seen in the Prairie section, where more than half (57 percent) of the average annual rainfall occurs in the 6 months of November through April, and March is the wettest month. In contrast, convective precipitation predominates in the Gulf section, where most (53 percent) of the average annual rainfall occurs in the months May through October, and July is outstandingly the wettest month.

This preponderance of summer rainfall in the Gulf section, especially the high rainfall in July, is significant because it tends

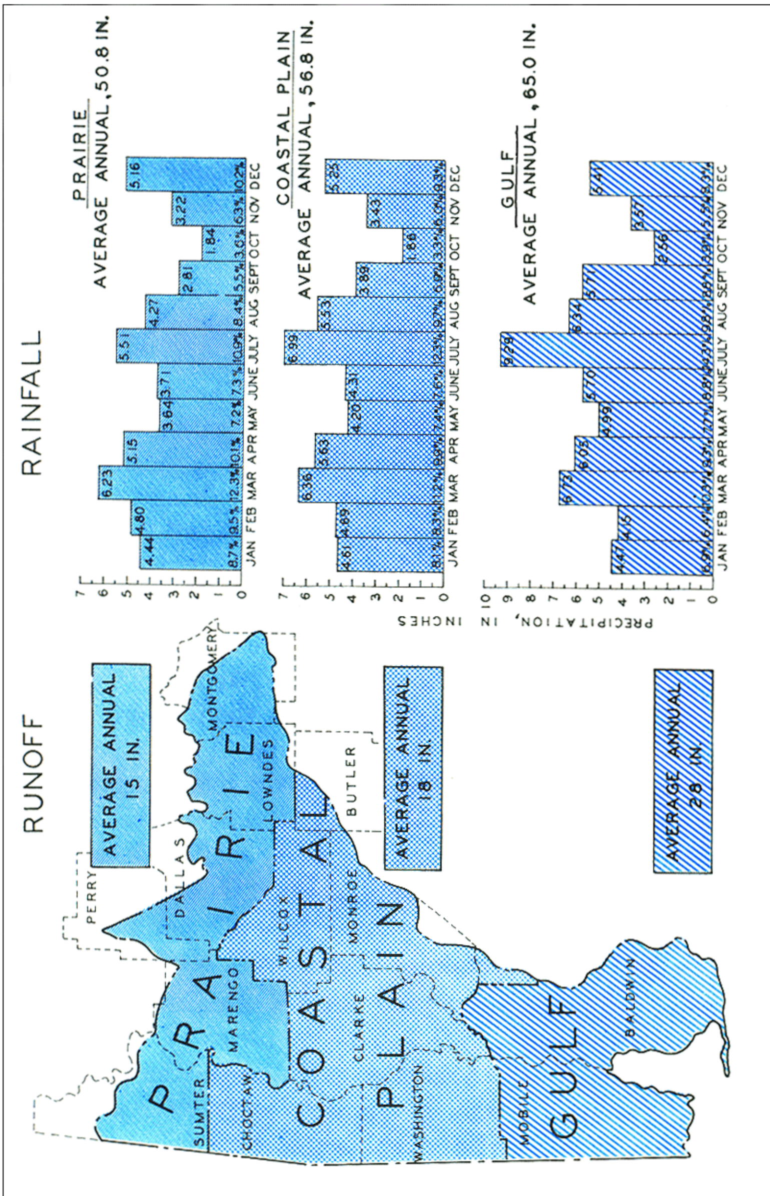


Figure 7.--Average annual rainfall and runoff in southwestern Alabama, and average distribution of rainfall by months.

to maintain ground-waterlevels during the time of year when evapotranspiration losses are greatest, thereby increasing the ground-water contribution to streamflow in the drier months of October and November when the streams are fed largely from ground-water sources. The combination of higher annual rainfall, a more effective seasonal distribution of rainfall, and favorable physiographic factors results in a higher average annual runoff in the Gulf section than in any other region of the State.

As shown in figure 7, the Coastal Plain section is intermediate in average annual rainfall and runoff to the Gulf and Prairie sections, but with characteristics more like those of the Prairie section.

VARIATION IN ANNUAL RAINFALL

Figure 7 conceals an important characteristic of annual rainfall–its variability from year to year. In any one year, the rainfall at a particular location in southwestern Alabama may differ greatly from the average value, and even over large areas considerable departures from the average are to be expected.

A typical sequence of annual rainfall in southwestern Alabama is shown in figure 8 by the annual rainfall at Montgomery for the 90 years 1873-1962. Years of high and low annual rainfall appear to occur randomly, and no regular cyclic pattern of wet or dry periods is apparent. The average annual rainfall for this period is 51.1 inches, but in particular years rainfall as high as 78.2 inches (1929) and as low as 26.8 inches (1954) has been experienced. These extreme values represent departures from the average of +53 percent and -48 percent, which departures are typical of those experienced at other localities, though not necessarily in the same years.

Annual runoff follows the same general pattern, but with even greater variation about its average value, as shown in figure 8 for the Alabama River basin upstream from Selma for the 46 years of streamflow record, 1900-12, 1929-61. From this basin of 17,100 square miles, annual runoff ranged from 32.6 inches (1929) to 9.5 inches (1904), or departures from the average of +57 percent and -54 percent. Thus, even in the major rivers, streamflow in wet

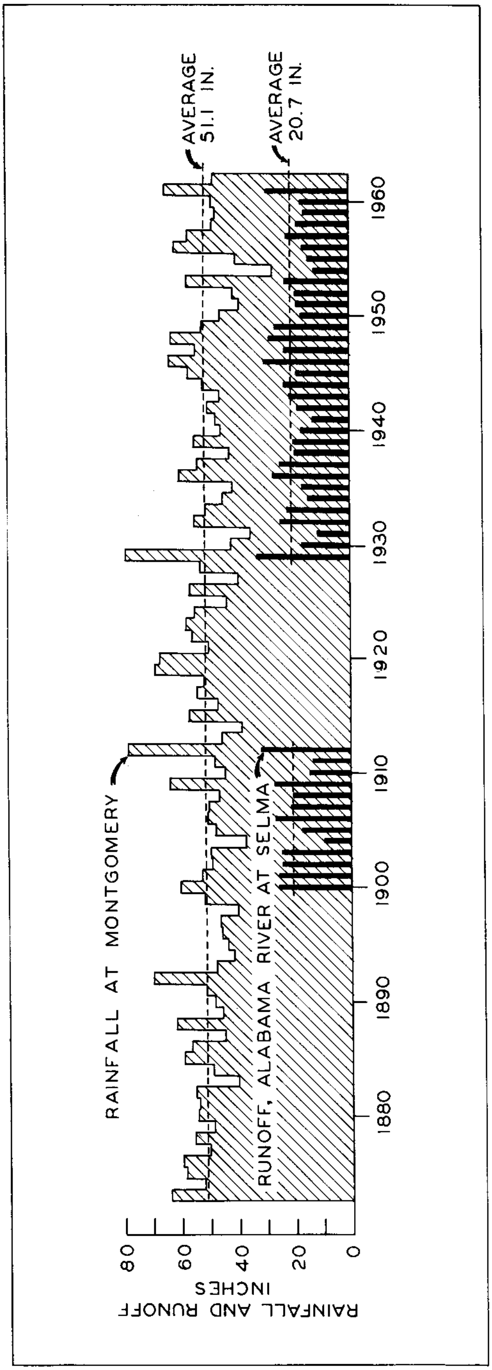


Figure 8.—Annual rainfall at Montgomery, Ala., 1873-1962, and annual runoff of Alabama River at Selma, Ala., 1900-12, 1929-61.

years may be 3 to 4 times greater than in dry years.

A knowledge of past variations in annual rainfall and streamflow is useful for appraising the water-supply characteristics of an area and for judging what variations must be expected in the future. The occasional occurrence of more extreme conditions of rainfall than have previously been experienced is a warning that as time passes even greater variations in rainfall and streamflow may occur.

STORM RAINFALL

In many kinds of water problems, figures of annual rainfall or streamflow like those shown in figure 8 have little meaning. Frequently, as in drainage or flood-control engineering, it is the upper range of streamflow rather than the average value that controls the situation. In any year, much of the streamflow in southwestern Alabama may occur as direct runoff immediately following severe storms, and it is with the characteristics of runoff from these flood-producing storms that the designer of a drainage channel, a bridge, or a spillway is chiefly concerned.

A consideration of the hydrologic cycle (fig. 6) indicates some of the factors that determine the rate and amount of surface runoff from storm rainfall. For runoff to occur, rainfall must exceed in intensity and amount what the soil, vegetation, and land surface, under a given set of conditions, will absorb or retain. Frequently these losses will consume all or most of the rainfall from light or moderate storms. In major flood-producing storms, rainfall so greatly exceeds the losses that they become of secondary importance, and the characteristics of the rainfall itself–its intensity, duration, and areal extent–become the dominant factors.

Either of the two general types of storms predominating in southwestern Alabama–the convective storm and the cyclonic storm–may produce enough rainfall to cause floods. The two types represent the extremes of flood-producing storms. The convective type, or thunderstorm, rarely produces simultaneous rainfall over large areas, but may have centers of high rainfall intensity ranging up to 10 inches per hour for a few minutes duration. Because it concentrates rainfall in both time and place, the convective storm produces flash floods in small watersheds. In contrast, the cyclonic storm usually has much lower rainfall intensities, but rain may continue with little abatement for as long as 3 or 4 days and extend over thousands of square miles, producing enormous volumes of runoff capable of flooding the largest rivers.

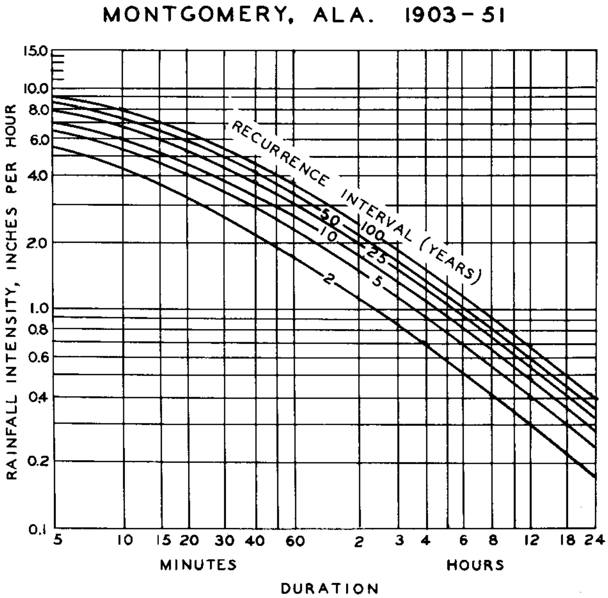
For most of the larger streams in southwestern Alabama, the characteristics of storm runoff can be determined directly from streamflow records. Unfortunately this is not the case with the small streams, for which few records of streamflow are yet available; and for watersheds smaller than about 5 square miles, the magnitude and frequency of peak rates of runoff must be estimated by more approximate methods based on a consideration of storm rainfall characteristics.

Typical relationships between intensity and duration of storm rainfall as related to frequency of occurrence are shown in figure 9 for two representative locations in southwestern Alabama (U.S. Weather Bureau, 1955). The data for Montgomery may be considered generally applicable in the Prairie and Coastal Plain sections (fig. 7), and the data for Mobile in the Gulf section.

The two relationships of figure 9 were each derived from records for only one rain gage and are strictly representative of rainfall occurring at a single point. With high rainfall intensities, the average depth of rainfall over areas as small as 1 square mile may be materially less than the high-point value. For practical engineering purposes, however, it may be assumed that the point rainfall relationships of figure 9 are applicable to drainage areas up to 1 square mile. For larger areas, intensities or depths of rainfall determined from figure 9 should be reduced by a suitable factor taken from figure 10, which shows the average area-depth relation expressed as a percentage of point rainfall for various durations.

REPRESENTATIVE STORMS OF RECORD

Of the many great storms experienced in southwestern Alabama, two will be briefly described to illustrate the nature of intense rainfall that has occurred in the area.



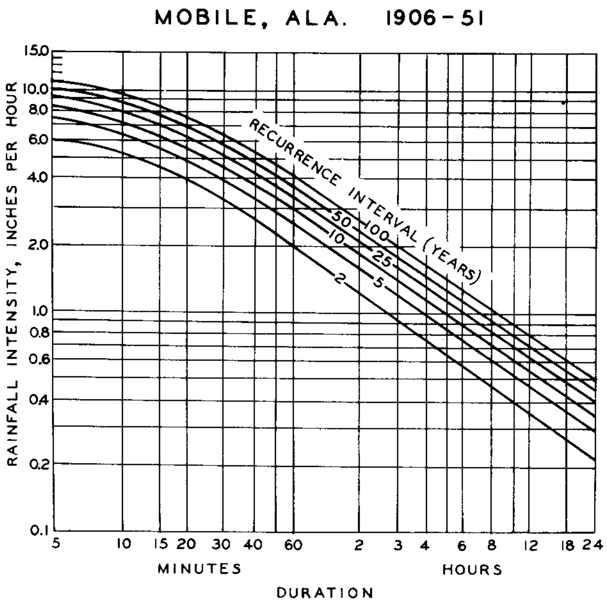


Figure 9.—Relation of intensity and duration of storm rainfall for selected recurrence intervals at two representative locations in southwestern Alabama (after U.S. Weather Bureau Technical Paper No. 25).

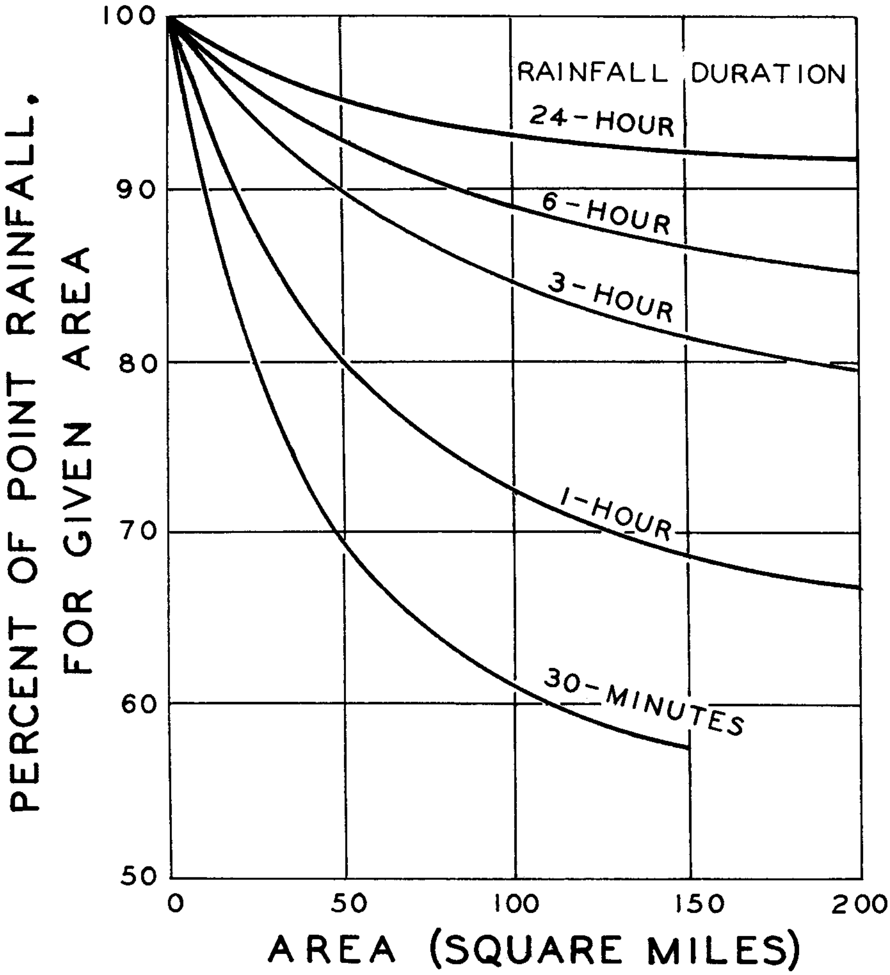


Figure 10.—Average relation of storm rainfall depth, area, and duration in southwestern Alabama (after U.S. Weather Bureau Technical Paper No. 29).

The storm of March 11-16, 1929, in Alabama and parts of Mississippi, Georgia, and Tennessee brought one of the heaviest rainfalls over a large area ever experienced in the United States. In the 4 days of the storm, all of southwestern Alabama received 10 inches or more of rainfall, with amounts ranging up to 20 inches at some places in the area. Heaviest rainfall occurred outside the report area at Elba, Ala., where 20 inches of rain fell in 24 hours, and 29.6 inches in 72 hours. The variation of rainfall depth with area and duration of rainfall during this storm is shown in table 7 (Corps of Engineers, 1945). Because the location of the storm center outside the report area was entirely fortuitous, the data of table 7 may be regarded as directly representative of the characteristics of severe storms to be expected in southwestern Alabama.

The storm of April 13, 1955, in southwestern Alabama, though much smaller in areal extent than the great storm of March 1929 and lasting only 1 day, brought some of the highest rainfall intensities ever observed in Alabama. As shown by the storm isohyetal map (fig. 11), the center of this storm was located 10 to 20 miles north of the city of Mobile in Mobile and Baldwin Counties. At Courtalds Rayon Plant, located near the storm center, total rainfall was 20.33 inches, of which 19.20 inches fell in about 16 hours. Other unofficial but apparently reliable rainfall measurements show that more than 19 inches of rain fell over an area of about 100 square miles in less than 24 hours. The highest measurement of rainfall at a Weather Bureau station was 13.36 inches at the Mobile Airport station. Of this amount, 11.56 inches fell in 4 hours—an average intensity for this duration of 2.89 inches per hour, which from figure 9 is seen to have a return period greatly in excess of 100 years.

PROBABLE MAXIMUM PRECIPITATION

Outstanding as they are, the storms of March 1929 and April 1955 still fall short of the maximum conditions of rainfall considered possible in southwestern Alabama. The greatest average depth of rainfall that can reasonably be expected to occur for a given duration and areal extent is called the probable maximum precipitation. It is determined by assuming that all meteorologic conditions conducive to great storms are maximized and combined

Table 7.—*Maximum average depth of rainfall, in inches, for selected areas and durations, storm of March 11-16, 1929, in Alabama and other southern states*

Area in square miles	Duration of rainfall, in hours 6	12	18	24	30	36	48	60	72	96
10	14.0	15.4	19.5	20.0	21.4	23.8	27.4	28.0	29.6	29.6
100	13.6	14.9	18.9	19.3	20.7	22.9	26.1	26.6	28.4	28.4
200	13.1	14.4	18.3	18.6	20.0	22.2	25.5	26.0	27.6	27.6
500	11.6	13.2	16.7	17.2	18.3	20.2	24.0	24.7	26.1	26.1
1,000	10.2	11.8	15.4	16.1	17.0	18.6	22.1	22.9	24.4	24.6
2,000	8.9	10.4	14.1	15.0	15.7	17.0	20.0	20.8	22.3	22.5
5,000	7.1	8.6	12.2	13.5	13.9	14.8	17.3	18.1	19.4	19.7
10,000	5.6	7.2	10.1	12.1	12.5	13.1	15.2	15.9	17.1	17.5
20,000	3.8	5.4	7.9	9.6	10.1	11.0	12.5	13.3	14.3	14.7
50,000	2.5	3.6	5.3	6.3	7.1	7.9	8.9	9.7	10.5	10.8
100,000	1.6	2.4	3.5	4.3	5.0	5.6	6.5	7.2	7.8	8.2

in the most effective manner.

Probable maximum precipitation in southwestern Alabama has been determined by the U.S. Weather Bureau (1956) to vary with the season of the year. Highest values occur in July and August and are summarized in table 8. Lowest values occur in January and are about 70 percent of the tabulated figures.

A knowledge of the probable maximum rainfall is necessary for the design of major dams and other hydraulic structures whose failure could result in great loss of life or property. Such structures may be designed on the basis of the probable maximum flood, which cannot be determined from a frequency analysis of existing streamflow records.

EVAPOTRANSPIRATION

Although rainfall is the basic source of runoff, most of the rain that falls in southwestern Alabama does not contribute to streamflow. Inevitably, a large part of rainfall is returned to the atmosphere, both before and after reaching the streams, by evaporation from land and water surfaces and by transpiration from plant life. Collectively, these losses in streamflow are called evapotranspiration. Because nature demands that the water requirements

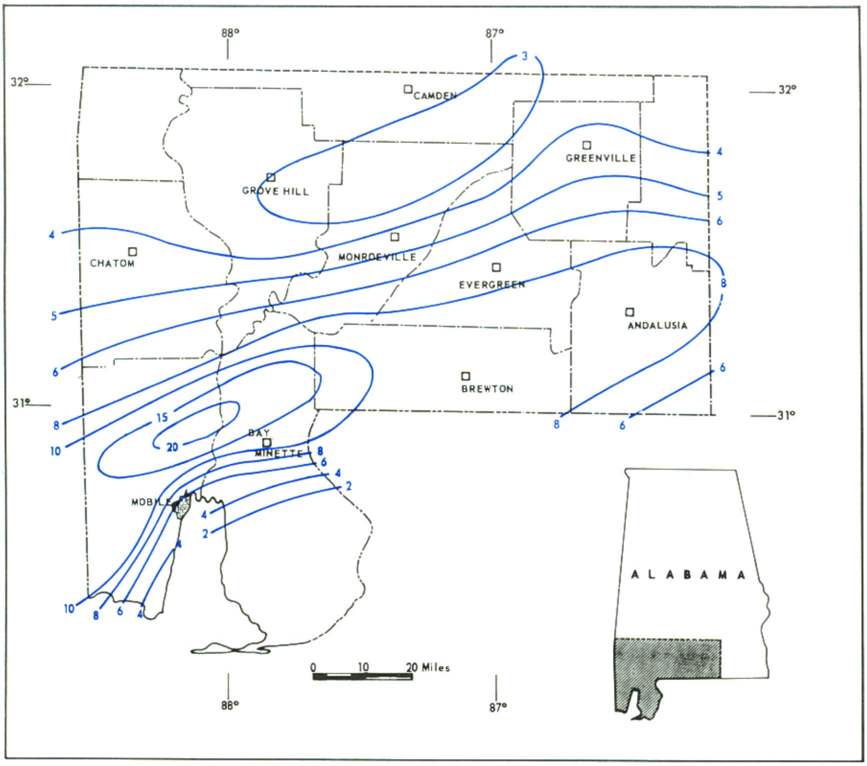


Figure 11.—Isohyetal map of total rainfall, in inches, in southwestern Alabama, storm of April 13, 1955.

Table 8.—*Probable maximum rainfall, in inches, for selected areas and durations in southwestern Alabama*

Area in square miles	Duration of rainfall, in hours			
	6	12	24	48
10	30	34	38	42
50	26	30	34	39
100	24	28	32	37
200	22	27	31	35
500	20	24	28	33
1,000	18	23	27	32

of evapotranspiration must first be met, runoff becomes a residual of rainfall after deducting evapotranspiration losses. Average annual evapotranspiration from watersheds in southwestern Alabama ranges from 36 to 39 inches, which is about two-thirds of the average annual rainfall.

The principal climatic factors controlling evapotranspiration are rainfall and temperature, which quantify the amounts of moisture and energy available for the process and also influence the type and density of native vegetation. The effects of temperature are further modified by humidity and wind.

The factors that control evapotranspiration vary greatly from season to season and from storm to storm, and their interactions are so complex that evapotranspiration from a large natural watershed defies accurate measurement over short intervals of time. Over longer periods, however, considerable simplification is possible, and on an annual basis evapotranspiration can be evaluated as total water loss (rainfall minus total runoff) with sufficient accuracy to define the general nature of the relationship between rainfall and evapotranspiration.

Figure 12, developed by this method from 13 years of rainfall and streamflow records, shows the relation between annual rainfall and average annual evapotranspiration in the Escatawpa River basin in southwestern Alabama and Mississippi. The relation is typical of similar ones for other stream basins in southwestern Alabama and may be interpreted in the following manner:

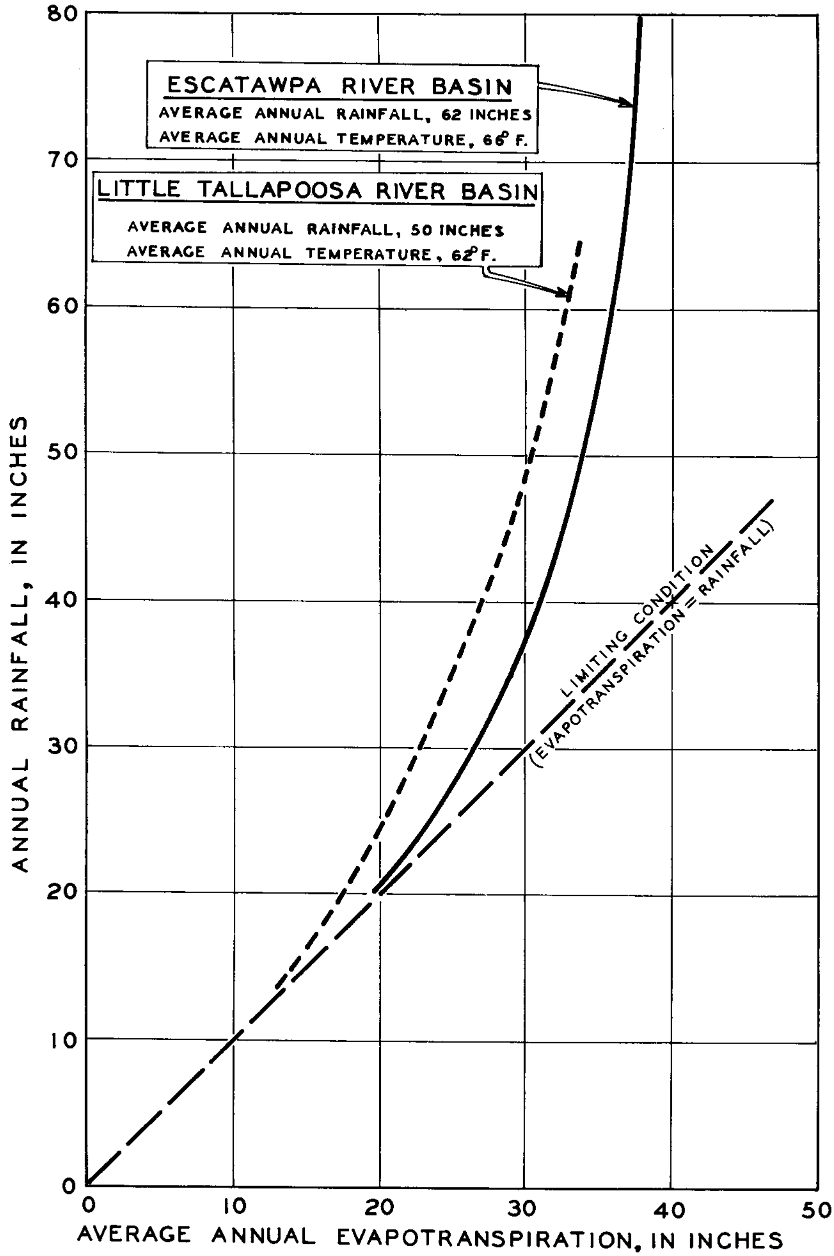


Figure 12.—Typical relationships between annual rainfall and average annual evapotranspiration for river basins in Alabama.

For those years in which annual rainfall over Escatawpa River basin is 20 inches, should such dry years occur, annual evapotranspiration would average nearly the same amount, and little runoff would take place. As annual rainfall becomes greater, average annual evapotranspiration increases, but at a decreasing rate, thus suggesting that if enough water were available to satisfy the requirements of vegetation, evapotranspiration would become chiefly a function of temperature. When annual rainfall is 60 inches, for example, evapotranspiration will average 36 inches per year; and annual runoff, as the difference between these values, will average 24 inches. For those years when annual rainfall is 80 inches, annual evapotranspiration will average about 38 inches, which represents virtually its maximum average value for climatic conditions normal to the basin.

In figure 12, a line has been drawn to represent the theoretical limiting condition in which all rainfall is consumed by evapotranspiration. The position of the relation curve for Escatawpa River basin with respect to this line is governed by the normal climate of the basin, expressed as long-term average values of annual rainfall and temperature. For Escatawpa River basin, these values are, respectively, 62 inches and 66° F. Should these parameters be substantially changed, the position of the relation curve would be shifted along the limiting line.

To illustrate this, figure 12 also shows the relation curve for a drier and colder basin—that of Little Tallapoosa River in northeastern Alabama and Georgia—for which the climatic parameters are an average annual rainfall of 50 inches and an annual temperature of about 62° F. For wetter and hotter basins, the relation curve would, of course, shift in the opposite direction toward greater evapotranspiration loss.

A word of caution may be wise. The relation curves of figure 12 are intended to show the average annual evapotranspiration for all years having the same given annual rainfall. In some years, evapotranspiration may depart considerably from its average value. Consequently, figure 12 should not be used to estimate evapotranspiration or runoff on the basis of rainfall in any particular year.

SEASONAL VARIATION IN WATER LOSS

Although evapotranspiration is a continuous process, it proceeds at a much greater rate during the summer months when temperatures are higher and the demand of vegetation for water reaches its peak. On a monthly basis, however, evapotranspiration cannot be equated, even approximately, to water loss expressed as rainfall minus runoff because of the relatively great monthly changes in the total amount of water stored in the basin in stream channels, ponds and reservoirs, in the soil, and in ground-water aquifers. Some of the water loss in months of high rainfall, for example, represents water entering ground-water storage that will later be released to the streams.

The varying effectiveness of rainfall to generate streamflow throughout the year in southwestern Alabama is illustrated by figure 13, which shows 13-year averages (1950-62) of monthly rainfall, water loss, runoff, and temperature for 506 square miles of the Escatawpa River basin, most of which is in Mobile and Washington Counties. Here it can be seen that although July rainfall is almost double January rainfall, water loss in July is more than three times that in January, and runoff for the 2 months is very nearly the same.

EVAPORATION FROM FREE WATER SURFACES

Evaporation from the ocean, as the principal source of moisture for the atmosphere, is a necessary and useful phase of the hydrologic cycle. Evaporation from fresh water surfaces, on the other hand, takes its toll directly from streams and reservoirs after runoff has been concentrated or collected there, and so represents a useless and sometimes serious loss that must be taken into account in the design of every major water-storage project.

Several methods of measuring evaporation from large bodies of water have been developed (U.S. Geological Survey, 1954, 1958), but these methods are applicable only to existing lakes and reservoirs and cannot be used in the design phase. The necessity for preliminary data on evaporation in the design of reservoirs has led to the measurement of evaporation from small pans such as those used by the Weather Bureau, the theory being that evaporation

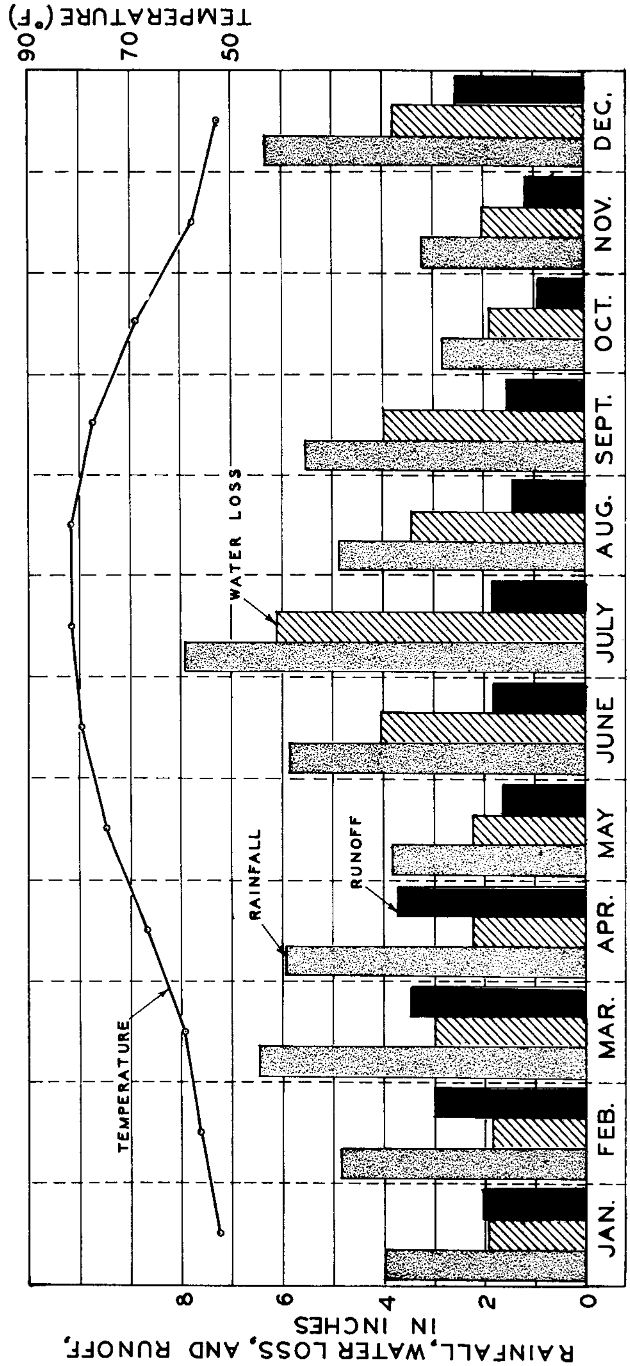


Figure 13.—Average monthly temperature, rainfall, runoff, and water loss in Escatawpa River basin, 1950-62.

from the pan can be related to that from an adjacent large water body. Experience has shown that evaporation from these small pans is usually greater than evaporation from a nearby large lake, and that the relationship of pan evaporation to lake evaporation may vary considerably throughout the year. On an annual basis, however, evaporation from a large lake or reservoir can be satisfactorily estimated by reducing annual pan evaporation by a suitable coefficient.

A coefficient of 0.77 is recommended by the Weather Bureau (1959) for reducing annual evaporation from Class-A land pans[1] in southwestern Alabama. This coefficient should not be used on a monthly basis, as such use may result in considerable error. At Lake Hefner in Oklahoma, for example, monthly pan coefficients were found to range from 0.13 to 1.32.

Weather Bureau records of evaporation from Class-A land pans in southwestern Alabama are available for Demopolis (Marengo County) and Fairhope (Baldwin County). These records are summarized in table 9. On the basis of these and other similar records outside the report area, average annual lake evaporation in southwestern Alabama has been determined by the Weather Bureau (1959) to range from 44 inches to 47 inches, as shown by figure 14. On the average, about 68 percent of the annual evaporation occurs during the 6 months May through October.

LAND FACTORS

The preceding section has shown how climatic factors in southwestern Alabama determine the amount of rainfall and largely determine the residual of that rainfall which, after evapotranspiration has taken its toll, becomes runoff. The manner in which this runoff reaches the streams—whether by overland or underground routes, and the proportions of runoff following each route—is, in turn, largely governed by the physical characteristics of the land

[1] The U.S. Weather Bureau Class-A land pan is a circular sheet-metal pan 4 feet in diameter and 10 inches deep, supported on timbers a few inches above ground, and exposed to sun and wind. The water level in the pan is maintained 2-3 inches from the top.

Table 9.—*Average evaporation, in inches, from U.S. Weather Bureau Class-A land pans in southwestern Alabama*

Month	Demopolis, Ala. 1951-53, 1956-62	Fairhope, Ala. 1948-62
January	2.41	1.81
February	2.97	2.29
March	4.14	3.89
April	5.43	5.02
May	6.24	6.55
June	6.62	6.19
July	6.64	5.90
August	6.52	5.87
September	4.97	4.58
October	3.84	3.89
November	2.68	2.35
December	2.17	1.66
Year	54.63	50.00

surface and the geologic mantle. Because the underground route is generally much slower than the overland route, land factors play an important role in regulating the time distribution of runoff, which, of all streamflow characteristics, most sensitively reflects the hydrologic nature of a drainage basin.

Land factors also are dominant in determining the chemical quality of surface water. Rain reaches the ground as relatively pure water, its mineral content usually being limited to dissolved gases, notably oxygen and carbon dioxide. Upon reaching the ground, water begins to react with the soil and rocks, dissolving mineral matter and at times transporting sand and silt or other sediments. When rainfall is intense and runoff rapid, the amount of mineral matter dissolved and carried to the streams may be small, so that the net effect may be a dilution of surface waters. But during dry weather the streams are fed mostly by ground water, which has been in contact with soil and rocks for a much longer time and, in consequence, is more highly mineralized. The amount of minerals that will be dissolved depends upon the type and solubility of the rocks, the length of time water is in contact with them,

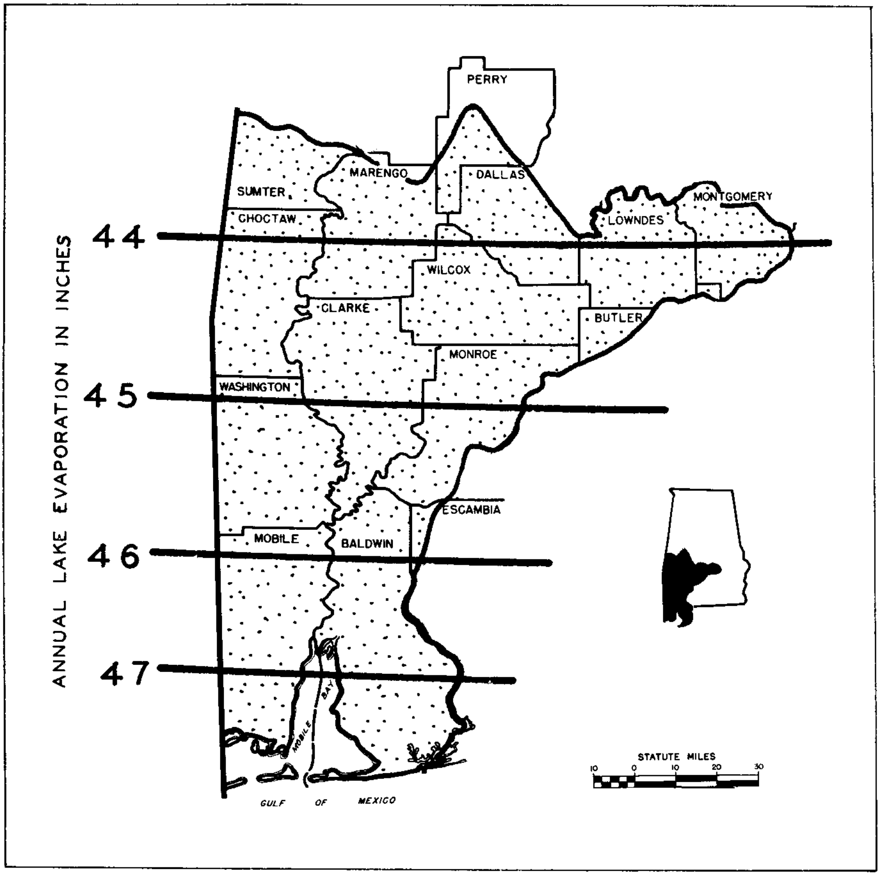


Figure 14.—Map showing average annual lake evaporation, in inches, in southwestern Alabama (after U.S. Weather Bureau).

and the chemical composition and temperature of the water itself. The chemical character of a stream may change greatly as it flows along, moving from one environment to another. Thus, land factors expressed as topography, geology, and culture affect not only the time distribution of natural streamflow, but its chemical character as well.

PHYSIOGRAPHY AND GENERAL GEOLOGY

Physiographically, all of southwestern Alabama lies in the East Gulf Coastal Plain. Rocks underlying the area are of sedimentary origin and consist of sand, gravel, and porous limestone, interbedded with chalk, marl, and clay. These strata dip southward about 40 feet to the mile, and crop out in an east-west pattern of belts. Some of these beds have greater resistance to erosion than others, and in their outcrop area have tended to develop as broad saw-tooth ridges (cuestas) sloping gently toward the south, but with a steeper north-facing slope or scarp rising perhaps several hundred feet above the lowlands. Further erosion and dissection have produced many local valleys, particularly along the steeper northward slopes, so that these belts have assumed a hilly character sometimes contrasting sharply with the adjoining lowlands.

Southwestern Alabama includes parts of eight physiographic divisions: the Black Prairie, the Chunnennuggee Hills, the Flatwoods, the Southern Red Hills, the Buhrstone Hills, the Lime Hills, the Southern Pine Hills, and flood plains, terraces, and beaches. These are shown in figure 15 and are briefly described as follows:

BLACK PRAIRIE

The Black Prairie, or Black Belt, section of southwestern Alabama is part of a great prairie of roughly 8,000 square miles extent that sweeps in a long, narrow crescent across central Alabama, through northeastern Mississippi, and into western Tennessee. In the report area it is an undulating plain of low relief, reaching altitudes of about 250 feet in areas between the streams. The Black Prairie corresponds closely with the outcrop area of certain Cretaceous chalks and marls of the Selma Group (Mooreville

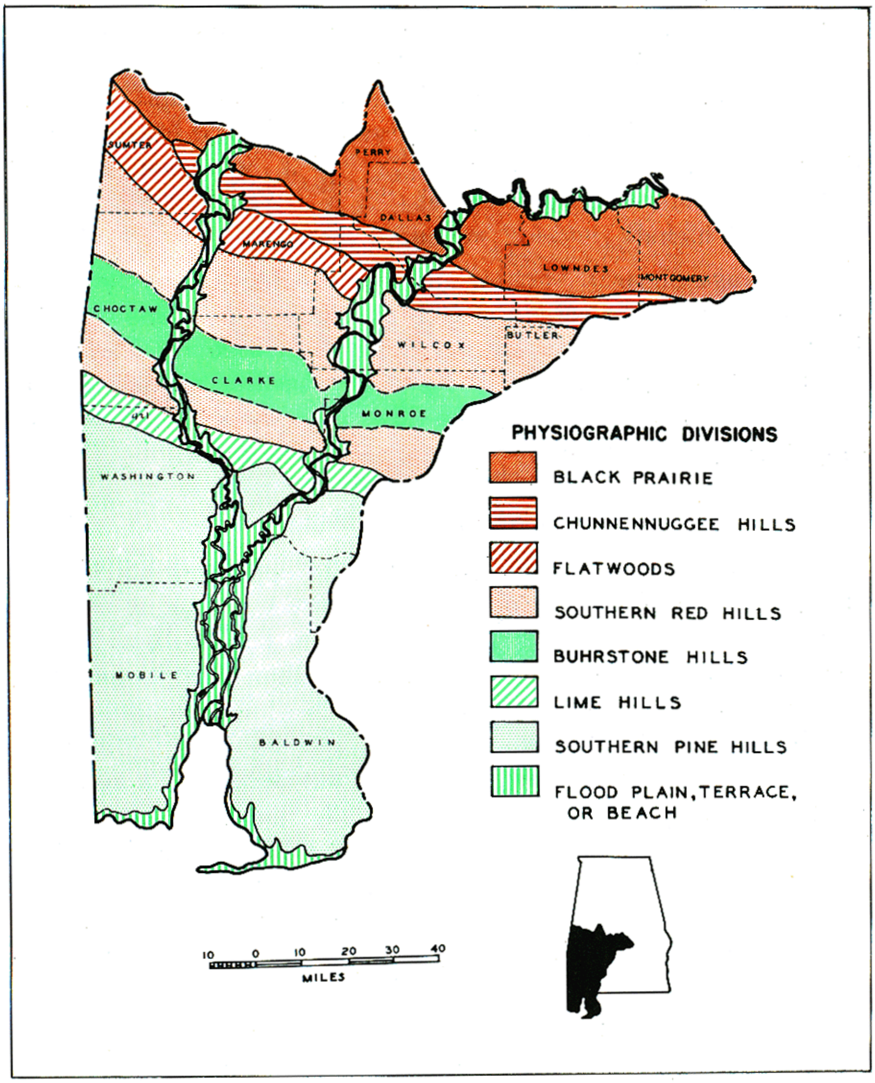


Figure 15.–Map showing physiographic divisions of southwestern Alabama.

and Demopolis Chalks). These limestones are too impure to be dissolved by percolating water so that the solution channels, caverns, and sinkholes characteristic of many limestone terrains are missing. They weather into dark-gray or black soil which is exceptionally fertile but hard to cultivate because it bakes hard in the summer and becomes a very tenacious mud when wet. The soil is thin and erodes easily on slopes, frequently exposing the underlying whitish chalk in gullies and bald spots.

Because of its thin soils and impermeable rocks, the Black Prairie represents a unique and clearly defined hydrologic region in Alabama. Its streams are noted for their high rates of flood runoff and great variability of flow. The smaller streams go dry every year, and in most years the flows of even the larger streams drop to insignificant amounts.

CHUNNENNUGGEE HILLS

The seaward dip of the Coastal Plain sediments carries the chalks of the Black Prairie beneath more resistant formations cropping out to the south (Ripley Formation, Prairie Bluff Chalk, and Clayton Formation). Lithologically, these formations show great diversity, including various gradations of silt and sand interbedded with clays, chalks, sandstones, and limestones. The more indurated beds of the Ripley Formation have developed a series of northward-facing cuestas rising 100 to 200 feet above the prairie land and sloping generally southward in a belt of smaller pine-forested sand hills. This hilly belt, sometimes called the Ripley Cuesta (Fenneman, 1938) or the Blue Marl Region (Harper, 1943), is wider and more conspicuous in Alabama east of the report area. In Sumter County, it merges with the Black Prairie, losing its topographic identity until reappearing some 50 miles northwestward in Mississippi, where it is known as Pontotoc Ridge.

The diversified rocks of this belt are, in general, more permeable than the more homogeneous chalks of the Black Prairie, but even so, are relatively poor aquifers.

FLATWOODS

South of the Chunnennuggee Hills belt and extending eastward from Mississippi through Sumter and Marengo Counties to the

Alabama River in Wilcox County, or not much beyond, is a narrow belt of little relief having about the same general elevation as the Black Prairie belt. This belt is developed largely on dark clays and marls (Porters Creek Formation) which weather in most places to stiff clayey soils that are resistant to erosion but poorly suited to cultivation. For this reason, most of this nearly level belt was densely wooded in earlier years, hence the name "flatwoods." The tough, massive clays of the Porters Creek Formation are relatively impermeable and supply little or no ground water to wells and streams (Newton and others, 1961, p. 72).

SOUTHERN RED HILLS

This hilly belt is also characterized by irregular ranges of hills of the cuesta type, having steep, serrate scarps to the north and more gentle backslopes to the south. Relief ranges up to 250 feet with summit elevations of about 550 feet along the east boundary of the report area in Bullock County, where the boundary follows the drainage divide between the Alabama and Conecuh Rivers. The northernmost range of hills is developed on the exposed edges of hard sandstones and claystones of the Nanafalia Formation and firm sand and shale beds in the underlying Naheola Formation (LaMoreaux and Toulmin, 1959, p. 4). Farther south, the underlying formations are Eocene sediments of the Wilcox and Claiborne Groups (Tuscahoma Sand, Hatchetigbee, Tallahatta, and Lisbon Formations, and Gosport Sand). These formations display a wide range in lithology, including fine to coarse sands, laminated and interbedded with clay, sandstone, and marl. In general, the more sandy beds in these formations are fair to good aquifers, whereas the more clayey beds are relatively impervious.

BUHRSTONE HILLS

Within the belt of Southern Red Hills and usually considered as part of it (Fenneman, 1938, p. 75) is a line of especially rugged hills known as the Buhrstone Hills, or Buhrstone Cuesta. Because these hills are an outstanding topographic feature of southwestern Alabama and can be so clearly related to a single geologic unit, they are shown in figure 15 as a separate division, extending through central Choctaw, Clarke, and northern Monroe Counties.

These hills are the most rugged in the entire Coastal Plain in Alabama, their rocky ridges rising as much as 200 to 300 feet above the streams and in places reaching elevations of about 600 feet above sea level.

The Buhrstone Hills have developed through the resistance to erosion of the Tallahatta Formation, which forms the upper part of the high, steep cuesta marking their northern boundary. The Tallahatta Formation is predominantly a tan-gray claystone or "buhrstone," but its lithology is varied and includes also loose sand, hard quartzite, sandstone, and clay (Toulmin and others, 1951, p. 93). The claystone of the Tallahatta Formation is relatively impermeable and supplies little ground water to streams.

LIME HILLS

This division is shown as extending in a belt 5 to 8 miles wide from southwestern Choctaw County, across northern Washington and southern Clarke Counties, into central Monroe County. Topographically, it is not well defined except at its western extremity in Mississippi near the State line, where it loses its rough character and becomes a gently rolling lowland. In southwestern Alabama, however, the general topography is hilly and in some places west of the Tombigbee River approaches the Buhrstone Hills in roughness. This is accounted for by the re-outcrop of the resistant buhrstone, which is here brought again to the surface by a conspicuous upward folding of the rocks known as the Hatchetigbee anticline. The principal rocks of this belt, however, are sands, clays, shales, and marls and a white limestone (Chickasawhay Limestone) which crop out on many of the hillsides. Although in places this limestone is soft enough to be cut by a handsaw, there is little if any solution topography (Harper, 1943, p. 170).

SOUTHERN PINE HILLS

This physiographic division of southwestern Alabama is a cuesta-like, elevated plain inclined toward the south, which has lost much of its original smooth features through erosion and stream dissection. Highest elevations range from about 400 feet above sea level near the northern boundary in Washington, Clarke, and Monroe

Counties to about 100 feet in southern Mobile and Baldwin Counties, only a few miles inland from the Gulf of Mexico. Topography is roughest in the northern half of the district, where streams draining eastward into the Tombigbee River and westward into the Alabama River descend to base level in comparatively short distances. In northwestern Baldwin County, the descent to the river flood plain is especially abrupt, as gravelly bluffs and hills here form a fairly steep westward-facing escarpment ranging up to 250 feet above sea level. In the southern half of the district, erosion is not as marked, partly because of the lower general elevation, but also because the sandy soils absorb water so readily that they are not easily erodible. Hills are smoother and more rounded; and larger, nearly level remnants of the original plain are found, especially along the major ridges extending northward through the middle of Mobile and Baldwin Counties.

Most of the northern half of the Pine Hills division is developed on estuarine deposits of Miocene age. These deposits consist of sediments ranging from clay and silt, through various gradations of sand, to fine gravel. All are fairly permeable except the clays, which are sufficiently impervious and extensive to produce artesian ground-water conditions. Generally overlying the Miocene deposits in the southern half of the district are beds of fine to coarse sand and fine to coarse gravel, with lenses of clay, of the Citronelle Formation of Pliocene age. These beds of sand and gravel are highly permeable and supply large volumes of ground water to the streams, many of which have cut their channels entirely through the Citronelle Formation to bed themselves in clays of the underlying Miocene sediments. This combination of a relatively impervious streambed with highly absorptive strata capping the interstream areas is particularly favorable to well-sustained streamflow; and it is worth noting here that streams draining the Citronelle Formation, to the extent that they have been gaged, have been found to have generally the highest low-water yields per square mile of drainage area in the entire State.

FLOOD PLAINS, TERRACES, AND BEACHES

Along the Alabama, Tombigbee, and Mobile Rivers and extending up many of their larger tributaries is an irregular belt representing the river flood plains and terraces. Only those along the major rivers are indicated in figure 15. Two topographic divisions of this belt are usually distinguishable on one bank of the stream or the other, commonly on both. These are the flood plains or first bottoms, which are overflowed more or less frequently every year; and the upper terraces or second bottoms, which are usually high enough to escape overflow except in their lower parts during especially high floods. The first bottoms are nearly level, poorly drained and often swampy, and generally wooded. The second bottoms are better drained and are generally cultivated.

The terraces are formed of alluvial deposits consisting of silt, sand, unconsolidated clay, and gravel eroded from the older rocks upstream and transported, sorted, and deposited by the streams in Quaternary times. The alluvial deposits underlying the flood plains, in places to depths of perhaps 150 feet (Toulmin and others, 1951, p. 140), are much the same type of material, but of Recent age, for alluviation is a continuing process. In an alluvial river, these sediments form the channel lining and are thus interposed between the stream and all other underlying strata. In this position, the alluvial sediments play an important hydrologic role, because the movement of ground water from the underlying rocks to the stream or from the stream to the rocks must take place through them.

Also included with river flood plains and terraces in figure 15 is a narrow coastal strip along the Gulf of Mexico and part of Mobile Bay, which represents coastal marshes and dunes and beaches of quartz sand. This coastal strip has little bearing on streamflow in the report area, but is important for recreational and economic reasons and may have its own peculiar hydrologic interests. A good example is the Shelby Lakes in Gulf State Park in Baldwin County. These lakes were originally brackish, being indirectly connected to the Gulf of Mexico through a tidal lagoon. By means of an ingenious arrangement of culverts and flap-gates which prevent the intrusion of salt water, the Alabama Department of Conservation has converted these lakes into fresh-water bodies—almost within a stone's throw of the Gulf of Mexico.

COMPONENTS OF RUNOFF

A considerable insight into the hydrologic role of the land is to be had by considering the nature of the several components of runoff that combine in the flow of a stream, and how their proportions may vary in southwestern Alabama from time to time and from one drainage basin to another of different geologic character.

Runoff following the overland route, or **direct runoff**, occurs only during or immediately following storm periods when rainfall intensity exceeds the combined rates of evaporation and seepage into the ground. It includes **surface** runoff, which reaches the stream quickly by moving over the land surface, and **interflow**, which reaches the stream almost as quickly by moving through the upper soil layers without reaching the ground-water table.

Runoff reaching the stream by the underground route, or **ground water discharge**, is water coming from subsurface storage and may sometimes be separated into two components depending upon whether it originates from basin storage or from bank storage. **Basin storage** represents ground water stored in the zone of saturation in permeable geologic formations (aquifers) as a result of rainfall infiltrating the soil and percolating downward to the water table. **Bank storage** represents water absorbed by the banks of a stream channel when the stream rises above the water table in the bank formations. This water is temporarily stored and is quickly released as the stream falls. Concurrent with ground-water discharge there may be drainage from surface storage in lakes or swamps, which, like the ground, can accumulate water in wet weather and release it slowly in dry weather. All these forms of delayed runoff are referred to collectively as **base flow**.

In a perennial stream, the basin-storage component of base flow is continuous, increasing somewhat in wet weather and declining in dry weather. Discharge from bank storage takes place only when the stream is below the level of its saturated banks. At any one time, the amount of bank storage may be considerably less than that of basin storage. But during the course of a year, the entire bank-storage reservoir may be filled and emptied several times, while only a part of the basin-storage reservoir is used.

SEPARATION OF RUNOFF COMPONENTS

A precise quantitative separation of these various components of runoff is not possible; however, approximate methods of flow separation (Kunkle, 1962) are useful for making qualitative comparisons between different streams. This has been done in figure 16, which shows hydrographs of daily discharge for two streams of southwestern Alabama in which the components of streamflow from surface runoff, basin storage, and bank storage have been segregated for a period of 1 water year (October 1 to September 30). The streams compared in figure 16 were chosen because they illustrate nearly the extreme difference in streamflow composition in southwestern Alabama. These streams drain watersheds of the same size, 123 square miles; and to further the comparison, water years were selected in which the volumes of runoff for the two streams were approximately equal.

Chickasaw Creek, in the Southern Pine Hills district in Mobile County, drains a highly absorptive and retentive basin underlain mostly by permeable sands and gravels. Figure 16 shows that during the 1957 water year the daily flow of this stream ranged from 5,140 cfs (cubic feet per second) to 40 cfs, and the total volume of runoff was equivalent to an average depth of 30.6 inches over the drainage basin. Of this total runoff, an estimated 63 percent was derived from surface runoff, 24 percent from basin storage, and 13 percent from bank storage.

This is in marked contrast to the performance of Big Swamp Creek, in Lowndes County, which drains a basin underlain by relatively impermeable chalk and marl of the Black Prairie. Figure 16 shows that during the 1946 water year the total runoff of this stream amounted to 29.6 inches, and daily flows ranged from 8,820 cfs to less than 1 cfs. The minimum flow could not be shown on the logarithmic scale used in the figure because on 51 days of this year the stream had no flow. Nearly all, or 95 percent, of the year's streamflow is estimated to have come from surface runoff, and the remainder from bank storage. In this drainage basin, discharge from basin storage appears to be virtually nonexistent.

The hydrographs of figure 16 illustrate the great diversity in runoff characteristics that can occur in southwestern Alabama.

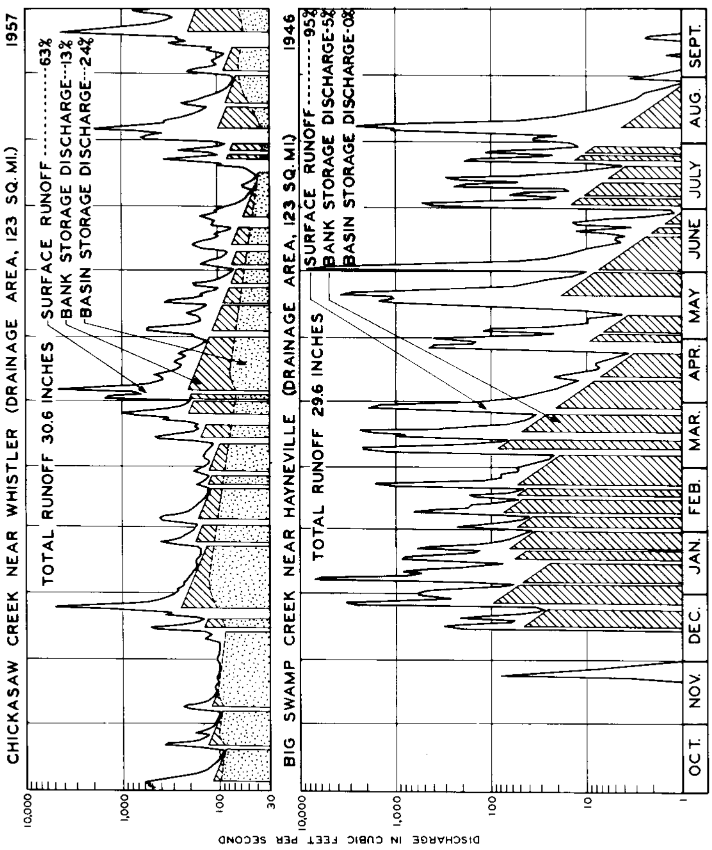


Figure 16.—Hydrographs of daily discharge for two streams of southwestern Alabama, showing approximate separation of runoff components.

Some streams, like Big Swamp Creek, drain watersheds in which a shallow soil mantle is underlain by relatively impermeable rocks. Such streams react strongly to rainfall with sharply concentrated flood peaks, but having little ground-water storage to sustain them, recede quickly to low flows and may even cease to flow during dry weather. Other streams, like Chickasaw Creek, drain watersheds in which the soil mantle and underlying geologic formations have a large capacity for accepting and storing rainfall as ground water, which is released to the stream at a relatively steady rate. These streams react less strongly to rainfall and generally have well sustained flows throughout the year, even during long periods of dry weather.

The most influential factor determining the variability of natural streamflow is thus seen to be the source of supply. If the principal source is from surface runoff, streamflow tends to be widely fluctuating, with high rates of flood runoff and low rates of fair-weather flow. Ground-water storage tends to stabilize streamflow both by increasing low flows and by decreasing high flows—for ground water can be stored only at the expense of surface runoff.

WATERSHED CHARACTERISTICS AFFECTING RUNOFF

Numerous physical characteristics of watersheds have been recognized by hydrologists as affecting the quantitative composition of runoff. Topographic features considered by Langbein (1947) to be important in relation to flood flow include: watershed area, shape, and altitude; land and stream slopes; length and pattern of stream channels; and water-surface area of streams, lakes, and swamps. Benson (1962) found that watershed area and channel slope were the most effective determinants of flood flow in New England. Geologic features mentioned by Speer and others (1963) as the more important factors influencing the base flow of streams in the Mississippi Embayment in Mississippi and Alabama include: permeability and porosity of geologic units incised by the stream; the interrelation of the base of these units, the water table, and the water surface in the stream; and the water-table gradient toward the stream. To these could be added, in southwestern Alabama, the effects of streambed alluvium on ground-water flow to and from the streams, watershed and artesian leakage, and streamflow accretion from uncapped flowing wells.

The effects of these many watershed characteristics in proportioning the components of runoff are interdependent and, in general, cannot be isolated and evaluated in southwestern Alabama without considerably more hydrogeologic exploration and research. Existing streamflow records in the area, however, do make possible a crude appraisal of the overall effect.

EFFECTS OF WATERSHED CHARACTERISTICS ON STREAMFLOW

If all watersheds in a humid region like southwestern Alabama were hydrologically alike except for size, one could expect any selected parameter of streamflow for the various watersheds to have an exponential relationship with watershed size, or drainage area. This is more understandably expressed in mathematical terms as $Q \propto A^x$, where Q is the streamflow parameter selected, A is the drainage area of the watershed, and x is the exponent. For example, if Q is taken to represent either the total volume of runoff or the average rate of flow, the value of x would be unity because both of these parameters would be directly proportional to drainage area. Or again, if Q is taken to represent the peak rate of flow from the various watersheds for floods of a particular frequency of occurrence, the value of x would be less than unity because of the longer time required for floodwaters to concentrate and drain from larger watersheds.

In figure 17, three parameters of streamflow are shown related to drainage area, using data for gaged watersheds in southwestern Alabama. One of these parameters is average discharge. The other two parameters are defined elsewhere in this report, but at the moment their precise meaning is not important. It is sufficient to know that one (mean annual flood) is representative of flood flow or surface runoff, and the other (median 7-day low flow) is representative of base flow or ground-water discharge. It is also interesting, though not essential, to know that in the logarithmic form of plotting used for figure 17, the slope of a line of relation represents the exponential value, x.

For none of these streamflow parameters do the plotted points representing the different watersheds define a unified relationship

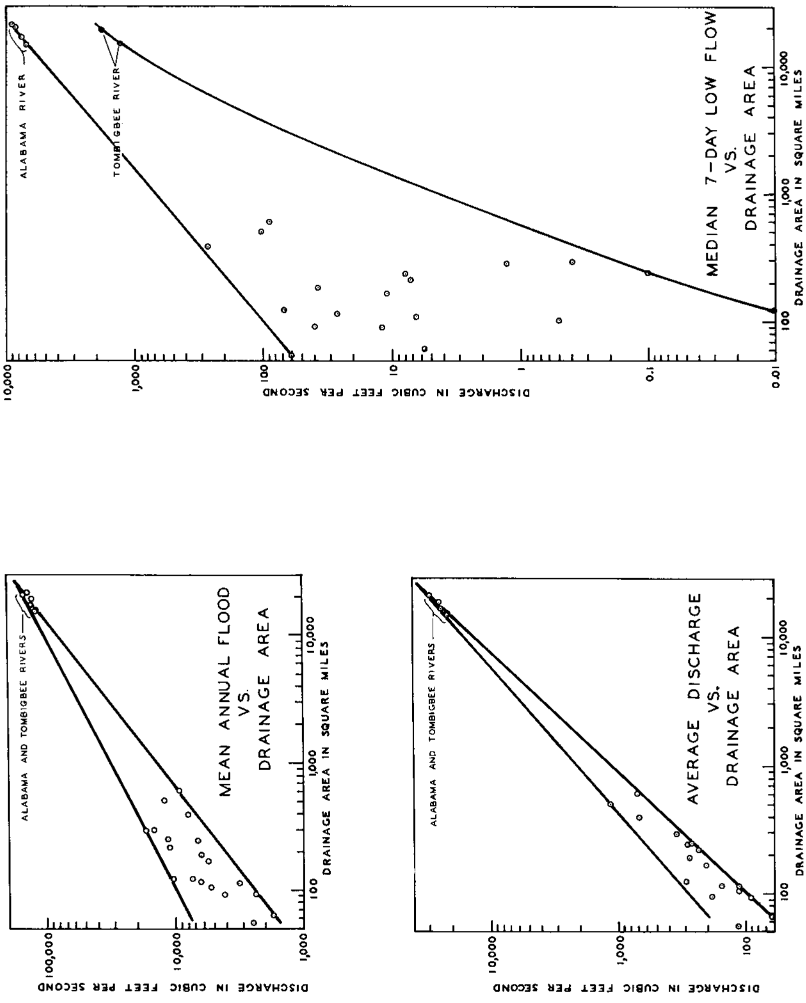


Figure 17.—Relation of drainage area to flood flow, average flow, and low flow of streams in southwestern Alabama.

with drainage area. In each case, the points scatter considerably, indicating only the broad, general relationships outlined by the enveloping curves shown. The scatter of the points indicates that watershed characteristics other than drainage area are affecting the relationships, and that these secondary characteristics have their greatest influence on low flow, less on flood flow, and comparatively little on average flow, in which opposite effects tend to cancel each other.

No clue is given as to what these secondary factors may be. It might be inferred that those affecting the flood-flow parameter are mostly surficial or topographic, whereas those affecting the low-flow parameter are subsurficial or geologic, but such inference is not always sound. For example, an impermeable basin produces low rates of base flow, but also high rates of surface runoff to which the system of stream channels must necessarily adjust itself. Hence, an extensive and efficient surface-drainage system, which is distinctly a topographic feature related to flood runoff, may be merely the reflection of geologic or subsurface features (Carlston, 1963).

The convergent trend of the enveloping curves in figure 17 shows that the effect of secondary watershed characteristics becomes smaller, percentagewise, as drainage area increases. This must necessarily result when the smaller watersheds are sub-basins of the larger ones, because the whole watershed integrates the peculiarities of its separate parts and can exhibit no greater extremes than any of them. The trend toward convergence is greatest for floods, when climatic factors (depth, area, and duration of rainfall) are such as to reduce or overpower the effects of land factors on runoff. Thus, in figure 17 the points representing the major watersheds of the Alabama and Tombigbee Rivers plot as a close group on the flood parameter relationship. In the low-flow relationship, however, complete convergence is not attained by these major watersheds because as streamflow declines, individual watershed differences emerge, becoming more and more pronounced as streamflow approaches minimum flow. As shown in the figure, this is especially true of the smaller basins in which the effect of some singular hydrologic feature is more likely to predominate.

WATERSHED LEAKAGE

The low-flow relation of figure 17 shows clearly that surface area of the watershed is not a dependable basis for appraising the low-flow characteristics of streams in southwestern Alabama. The principal reason for this is that the surface drainage area of the watershed may have little or no relation to the areal extent and productivity of ground-water aquifers supplying the base flow of the stream.

Most of southwestern Alabama is underlain by unconsolidated sediments. In these porous and permeable deposits, the ground-water table is not a fixed surface nor usually a level one. Rather, it is a subdued reflection of surface topography and rises and falls in accordance with rainfall. Thus, while the topographic divide is a fixed and permanent feature of the terrain, the ground-water divide may be unstable, shifting both horizontally and vertically in wet and dry weather. When the two divides do not coincide, **watershed leakage** occurs from the area between them (fig. 18).

STREAM GAGING

As brought out in the preceding section, surface water in southwestern Alabama, both in quantity and chemical character, is a highly variable resource produced by the interaction of numerous meteorologic, topographic, geologic, and biologic factors. For the most part, these factors are beyond man's control and are so intricately related that he can scarcely measure, let alone predict, their individual effects on runoff. Fortunately, this piecemeal approach to the determination of runoff is unnecessary. For runoff occupies a unique place in the hydrologic cycle: nowhere else in this vast, diffuse process are the circulating waters of the earth collected in discrete channels where they can be tangibly perceived and measured. Furthermore, the flow of a stream at any time represents the integrated effect of all factors influencing runoff, so that gaging the flow of streams provides at once the simplest and best basis for estimating present and future parameters of streamflow.

Basic records of streamflow in Alabama are compiled and published for each water year (October 1 to September 30) by the U.S. Geological Survey in the annual bulletin **Surface Water Records**

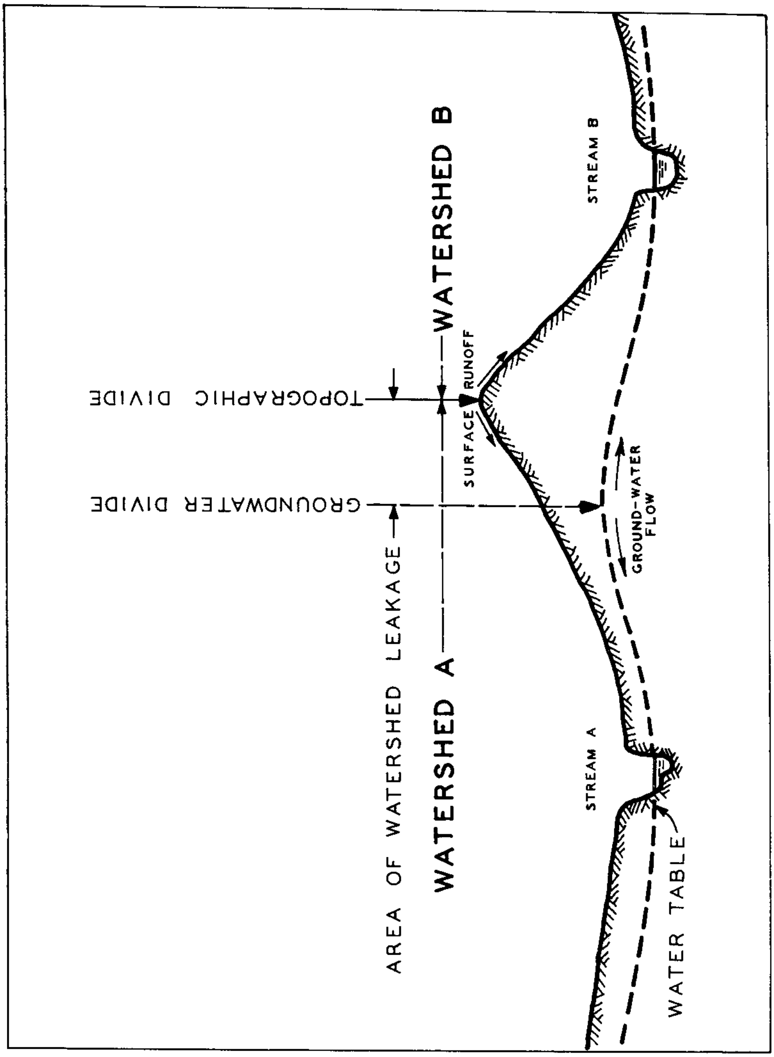


Figure 18.—Diagram illustrating watershed leakage from watershed A to watershed B.

of Alabama. Prior to the 1961 water year, records of streamflow for southwestern Alabama were published annually in the U.S. Geological Survey Water Supply Papers, Part 2-B (South Atlantic Slope and Eastern Gulf of Mexico Basins, Ogeechee River to Pearl River).

PARTIAL-RECORD STATIONS

Many important surface-water problems deal with the extremes of flow—that is, flow during times of flood or during times of drought. For example, the hydraulic design of bridges, culverts, and spillways depends upon a knowledge of the magnitude and frequency of floods, whereas the design of water supplies requires a knowledge of the duration and frequency of low flows. Thus, much of the value of streamflow records lies in the information they provide regarding high and low flow. For many streams, a great deal of useful information regarding the extremes of flow can be obtained without the expense of collecting a continuous record of stage and discharge.

A location where selective stream gaging is done for the purpose of defining only the high-flow or low-flow regimen of a stream is called a partial-record station. During the special data-collection phase of this report, 22 low-flow partial-record stations were operated in southwestern Alabama for a period of 3 years. At these stations, the discharge was measured periodically during dry weather when the flow of the streams was largely or wholly from ground-water sources. In themselves, these discharge measurements are not especially informative, but when correlated with the concurrent discharge of a primary or secondary station, they make possible reliable estimates of low-flow parameters for a much longer period.

DESCRIPTIONS OF GAGING STATIONS AND PARTIAL-RECORD STATIONS

Gaging stations and partial-record stations in southwestern Alabama for which significant records of streamflow are available are listed in table 10. The bar chart shows the period of record at each station. The station number shown in the first column is used

Table 10.—*Gaging stations in southwestern Alabama*

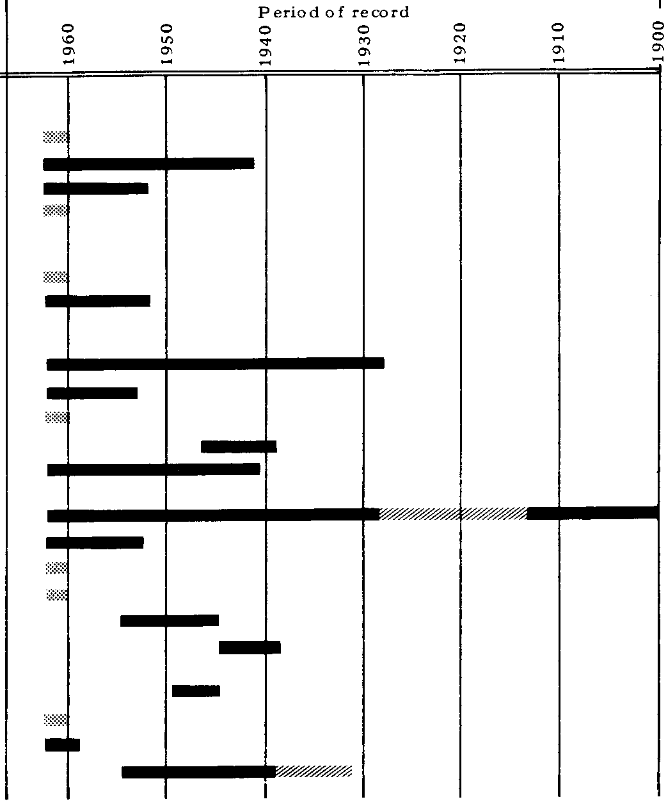
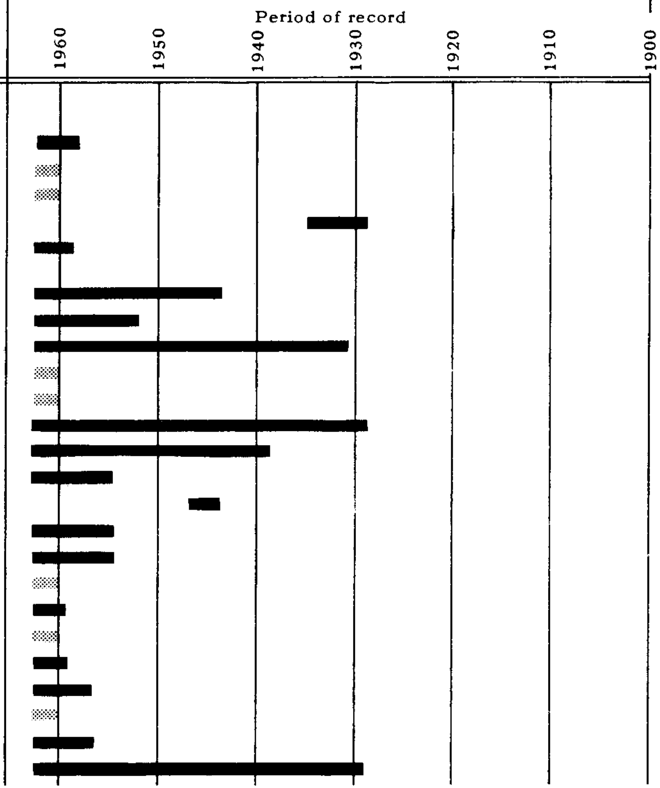
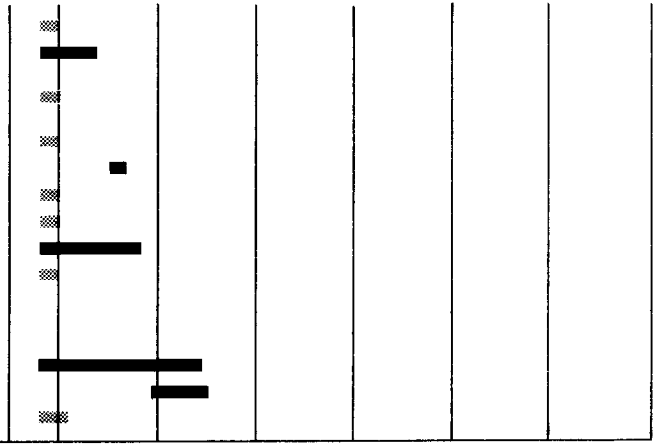
Station no.	Stream and location	Class of station	Drainage area (sq mi)	Period of record
	Perdido River Basin			
3762.40	Dyas Creek near Dyas, Ala.	PR	57.3	
3765.00	Perdido River at Barrineau Park, Fla.	C	394	
3775.00	Styx River near Loxley, Ala.	C	93.2	
3779.75	Blackwater River above Seminole, Ala.	PR	115	
	Fish River Basin			
3784.10	Fish River near Daphne, Ala.	PR	30.7	
3785.00	Fish River near Silverhill, Ala.	C	55.1	
	Mobile River Basin			
4200.00	Alabama River near Montgomery, Ala.	C	15,100	
4210.00	Catoma Creek near Montgomery, Ala.	C	298	
4211.75	Pintlala Creek near Montgomery, Ala.	PR	257	
4215.00	Big Swamp Creek near Hayneville, Ala.	C	123	
4220.00	Big Swamp Creek near Lowndesboro, Ala.	C	247	
4230.00	Alabama River at Selma, Ala.	C	17,100	
4255.00	Cedar Creek at Minter, Ala.	C	217	
4255.95	Cedar Creek near Berlin, Ala.	PR	382	
4256.55	Mush Creek near Selma, Ala.	PR	45.4	
4260.00	Boguechitto Creek near Browns, Ala.	PR	104	
4265.00	Boguechitto Creek at Boguechitto near Orrville, Ala.	C	197	
4270.00	Boguechitto Creek near Orrville, Ala.	C	292	
4272.50	Pine Barren Creek near Snow Hill, Ala.	PR	263	
4273.00	Prairie Creek near Oak Hill, Ala.	C	9.7	
4275.00	Alabama River near Millers Ferry, Ala.	C	20,700	

Table 10.—*Gaging stations in southwestern Alabama*—Continued

Station no.	Stream and location	Class of station	Drainage area (sq mi)
	Mobile River Basin—Continued		
4277.00	Turkey Creek at Kimbrough, Ala.	C	114
4277.50	Beaver Creek near Pine Hill, Ala.	PR	36.8
4278.65	Pursley Creek above Camden, Ala.	PR	40.8
4280.00	Alabama River at Coy, Ala.	C	21,200
4283.00	Tallatchee Creek near Vredenburgh, Ala.	C	14.6
4285.00	Flat Creek at Fountain, Ala.	C	245
4290.00	Limestone Creek at Monroeville, Ala.	C	117
4295.00	Alabama River at Claiborne, Ala.	C	22,000
4296.05	Little River near Little River, Ala.	PR	140
4296.50	Majors Creek near Tensaw, Ala.	PR	44.7
4670.00	Tombigbee River near Coatopa, Ala.	C	15,400
4675.00	Sucarnoochee River at Livingston, Ala.	C	606
4680.00	Alamuchee Creek near Cuba, Ala.	C	63
4685.00	Chickasaw Bogue near Linden, Ala.	C	258
4690.00	Kinterbish Creek near York, Ala.	C	91.4
4695.00	Tuckabum Creek near Butler, Ala.	C	112
4695.20	Yantley Creek near Jachin, Ala.	PR	95.3
4695.50	Horse Creek near Sweetwater, Ala.	C	52.8
4695.75	Wahalak Creek near Butler, Ala.	PR	22.8
4696.00	Bashi Creek near Campbell, Ala.	C	86.3
4697.00	Okatuppa Creek at Gilbertown, Ala.	C	151
4697.75	Santa Bogue Creek near Frankville, Ala.	PR	168
4698.00	Satilpa Creek near Coffeeville, Ala.	C	166
4700.00	Tombigbee River near Leroy, Ala.	C	19,100



4700.75	East Bassetts Creek near Dickinson, Ala.	PR	39.9
4701.00	East Bassetts Creek at Walker Springs, Ala.	C	188
4702.05	West Bassetts Creek at Bassetts Creek, Ala.	PR	128
4703.40	Bates Creek near Malcolm, Ala.	PR	74.4
4705.00	Mobile River at Mt. Vernon, Ala.	C	43,000
4706.15	Cedar Creek near Mt. Vernon, Ala.	PR	86.0
4709.25	Chickasaw Creek at Chunchula, Ala.	PR	45.4
4710.00	Chickasaw Creek near Whistler, Ala.	C	123
4710.75	Halls Mill Creek near Theodore, Ala.	PR	27.2
	Pascagoula River Basin		
4794.25	Escatawpa River at Deer Park, Ala.	PR	190
4795.00	Escatawpa River near Wilmer, Ala.	C	506
4800.00	Big Creek near Mobile, Ala.	C	84
4801.50	Franklin Creek near Grand Bay, Ala.	PR	16.4



Gage heights only (U.S. Weather Bureau)

Discharge measurements only

Gage heights and daily discharge

C Continuous record station

PR Partial-record station

to identify the station on plate 1 and elsewhere in this report. This same number has been used since 1958 to identify the station in publications of the U.S. Geological Survey. The station numbers constitute a nationwide coding system, and their sequence conforms to the downstream order of listing used in Water-Supply Papers.

Detailed descriptions and streamflow summaries for gaging stations and partial-record stations are given in Appendix A.

DEFINITION OF TERMS AND CONVERSION OF UNITS

The units in which hydrologic data are given in this report are defined as follows:

Acre-foot (ac-ft) is a unit of volume for expressing reservoir storage. One acre-foot is the volume of water required to cover 1 acre to a depth of 1 foot. A discharge of 1 cubic foot per second for 24 hours is equivalent to 1.9835 acre-feet, or 2 acre-feet, with an error of less than 1 percent.

Climatic year is the 12-month period April 1 to March 31. The climatic year is designated by the calendar year in which it begins. The climatic year is commonly used as the annual time unit for the analysis and presentation of low-flow data because it does not separate the annual low-flow seasons.

Cubic foot per second (cfs) is the unit rate of discharge. One cubic foot per second is the rate of discharge of a stream having a cross sectional area of 1 square foot and an average velocity of 1 foot per second.

1 cfs = 7.48 U.S. gallons per second
= 449 U.S. gallons per minute
= 0.646 Millions of U.S. gallons per day

Cubic foot per second per square mile (cfsm) is the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that the runoff is distributed uniformly with regard to time and area. Cubic foot per second per square mile is computed by dividing the discharge in cubic feet per second by the drainage area in square miles. It is a useful unit for comparing the discharges of streams draining basins of unequal size because it reduces, in effect, all basins to the same size, i.e., 1 square mile.

Hydrogen-ion concentration (pH) indicates the degree of acidity or alkalinity of water. Numbers on the pH scale represent the negative logarithm of the hydrogen-ion concentration in moles per liter. Water with a pH value of 7.0 is neutral—that is, neither acidic nor alkaline. Progressively lower pH values below 7.0 denote increasing acidity, and progressively higher pH values above 7.0 denote increasing alkalinity.

Parts per million (ppm) is the unit for expressing the concentration of the dissolved constituent in a million unit weights of water. In units of the metric system, which is used in chemical analyses, one part per million represents one milligram of the dissolved substance in one kilogram of water. A useful equivalence is:

$$10{,}000 \text{ ppm} = 1 \text{ percent (by weight)}$$

Runoff, in inches, is the depth to which an area would be covered if all the water draining from it in a given period were uniformly distributed over its surface. This term is useful for comparing runoff with rainfall, which is also expressed in inches of depth.

Specific conductance (micromhos per centimeter at 25° C) is a measure of the ability of water to conduct an electrical current. Specific conductance varies with the temperature of the water and with the concentration and degree of ionization of the different minerals in solution. It does not, however, indicate the relative quantities of different minerals in solution.

Water year is the 12-month period from October 1 to September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1960, is called the "1960 water year." The water year is a convenient time unit for some forms of hydrologic or statistical analysis of annual streamflow data because it begins and ends in the fall when streamflow and natural basin storage are ordinarily lowest.

STREAMFLOW CHARACTERISTICS

A knowledge of the hydrologic regime of a watershed is basic to the design and operation of most hydraulic engineering projects. The mean annual streamflow at a project site, the seasonal and long-term distribution of runoff, and the magnitude and frequency of floods and low flows are essential data for planning and design. When these data are dependable, all other aspects being favorable, a satisfactory and economical project is possible.

The purpose of this section of the report is to summarize information on streamflow in southwestern Alabama in a convenient form for use by water planners and managers, or the general public, in the solution of water problems. The presentation of basic data available elsewhere has been avoided. Methods of analyzing the data follow recognized procedures and are not dwelt upon except as thought necessary to make the results clear and usable to the reader.

AVERAGE DISCHARGE

The long-term average discharge of a stream, though it tells nothing about streamflow variability, is a useful statistic in the preliminary planning of water supplies because it represents the theoretical upper limit of the stream's capability for development. If the total flow of a stream could be conserved for use, the maximum continuous draft rate obtainable would correspond to the average flow of the stream. Practically, a complete utilization of streamflow in this manner cannot be accomplished. Many stream valleys in southwestern Alabama are not well suited topographically to the development of the large volumes of storage that would be required. In addition, some water is inevitably lost from a reservoir through evaporation and seepage, so that the economical limit of development for streams in southwestern Alabama is nearer to 50 to 60 percent of the average flow. At this level of development, a reservoir will fill every year, and variations in annual runoff are not of primary significance.

The average flow of a stream as determined from the comparatively short time represented by gaging station records is only a statistical estimate of the average flow for a much longer period.

In general, the longer the sampling period used to determine average flow, the better that estimate can be expected to be, provided the normal hydrologic regime of the stream remains unchanged. A 20-year average flow would ordinarily reflect a reasonable balance of wet and dry years and would be considered adequate for most purposes. A 5-year average flow, on the other hand, might be significantly above or below the long-term average as the result of an outstandingly wet or dry year during the period considered. Short-term averages can often be improved by correlation with nearby streams for which longer streamflow records are available (Matalas and Jacobs, 1964). Adjustments so made are generally more reliable than similar ones based on rainfall-runoff relationships.

The average flows at gaging stations in southwestern Alabama having five or more years of streamflow records are listed in the last two lines of table 11, both as discharge in cubic feet per second (cfs) and as unit runoff in cubic feet per second per square mile (cfsm). The figures of unit runoff are useful for quickly comparing the hydrologic behavior of different streams. In southwestern Alabama, average unit runoff ranges from a little more than 1 cfsm to nearly 3 cfsm.

SEASONAL DISTRIBUTION OF STREAMFLOW

The seasonal distribution of streamflow for representative streams in southwestern Alabama is illustrated by figure 19, which shows the average percentage of annual flow for each month of the year during the 19-year period 1944-62.

The major rivers are represented by Alabama River at Selma and Tombigbee River at Demopolis (upper half of figure). It will be noticed that the Alabama River displays a more uniform annual distribution of flow, with lower percentages for winter and spring months and higher percentages for summer and fall months, than the Tombigbee River. This is due partly, if not mostly, to flow regulation by reservoirs on the Coosa and Tallapoosa Rivers and other headwater tributaries of the Alabama River. Regulation of the Alabama River began in 1914 with the completion of Lay Dam on Coosa River and has progressively increased through the years with the completion of Mitchell Dam (1923), Jordan Dam (1929),

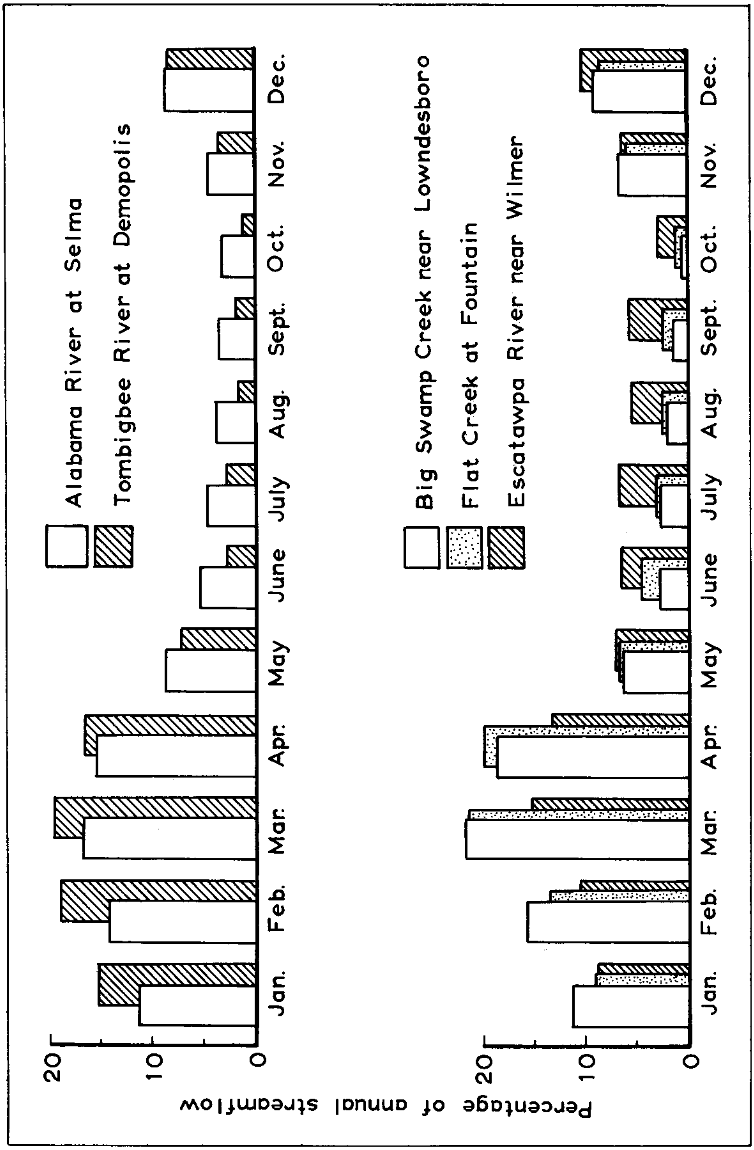


Figure 19.—Average distribution of streamflow by months, 1944-62.

and Weiss Dam (1961) on Coosa River; Martin Dam (1926) on Tallapoosa River; and Allatoona Reservoir (1949) on Etowah River in Georgia. Additional dams are now under construction. In contrast, the only major reservoir affecting the Tombigbee River is Lewis Smith Reservoir, which was completed in 1960 in the headwaters of the Black Warrior River. Thus, for the Tombigbee River, the data of figure 19 substantially represent natural flow, and within certain statistical limits can be presumed to represent future natural conditions. Data shown for the Alabama River, however, are strictly valid only for the period they represent and, because of the continuing development of that river, should not be extrapolated into the future.

The data for tributary streams (lower half of figure) represent natural conditions of runoff. Here it will be noticed that Big Swamp Creek and Flat Creek do not differ much in average seasonal distribution of flow. Escatawpa River, as a result of greater groundwater reserves and more favorable conditions of rainfall, shows a more uniform pattern of monthly flow than the other two streams.

FLOW-DURATION CHARACTERISTICS

One of the most effective devices for appraising streamflow variability is the flow-duration curve. A flow-duration curve is a cumulative frequency curve showing the percentage of time during which specified discharges were equaled or exceeded in a given period. It condenses many years of streamflow data into a compact graphic arrangement that quickly reveals the general character of the stream. For this reason, the flow-duration curve is especially useful for comparing the runoff characteristics of different streams. If streamflow during the period represented by the curve is typical of the long-term behavior of the stream, the flow-duration curve can be regarded as representing the long-term average distribution of future streamflow for water power, water supply, and waste disposal (Searcy, 1959).

Because streamflow represents the integrated effect of climate, geology, and topography on runoff, the shape of the flow-duration curve is determined by these characteristics of a drainage basin. The slope of the lower end of the duration curve is a good index of the natural storage in the basin, including ground-water storage. A flat slope indicates a large amount of storage and a steep slope, a negligible amount. This is illustrated in figure 20, which shows the duration of daily flows in cubic feet per second per square mile (cfsm) for three minor streams of southwestern Alabama for the same 10-year period (1953-62).

An obvious difference in the three curves of figure 20 is their general slope. The slope of the duration curve for Catoma Creek is steep throughout, indicating a stream of highly variable flow fed almost entirely from surface runoff. This characteristic is to be expected of Catoma Creek, which drains mostly from an outcrop area of relatively impermeable chalk.

In contrast, the lower ends of the flow-duration curves for Fish River and Chickasaw Creek are relatively flat, reflecting the presence in these watersheds of underground storage that tends to equalize flow. Both of these streams drain permeable sands and gravels of the Citronelle Formation, whose excellent water-bearing properties have already been noted.

For Catoma Creek, the largest of the three watersheds, the duration curve is so steep that it could not be shown conveniently in figure 20 for flows under 0.01 cfsm, which flow is seen to have been equaled or exceeded for 80 percent of the time. That is, for 20 percent of the time the flow of Catoma Creek was less than 0.01 cfsm, which represents a flow of only 3 cubic feet per second from the entire watershed of 298 square miles. In fact, for 2 percent of the time during the period considered this stream ceased flowing altogether. Fish River, the smallest of the three watersheds, is also the least variable in flow; as shown by figure 20, the flow of this stream was 0.69 cfsm (38 cfs) or greater for 99.9 percent of the time.

Flow-duration data for the period of record at gaging stations in southwestern Alabama that have been operated for 5 or more years are shown in table 11. Data shown for the Alabama River reflect the pattern of regulation during the period considered and are otherwise applicable only as long as that pattern remains unchanged. New sources of regulation or changes in the type of regulation from existing developments will alter flow-duration characteristics.

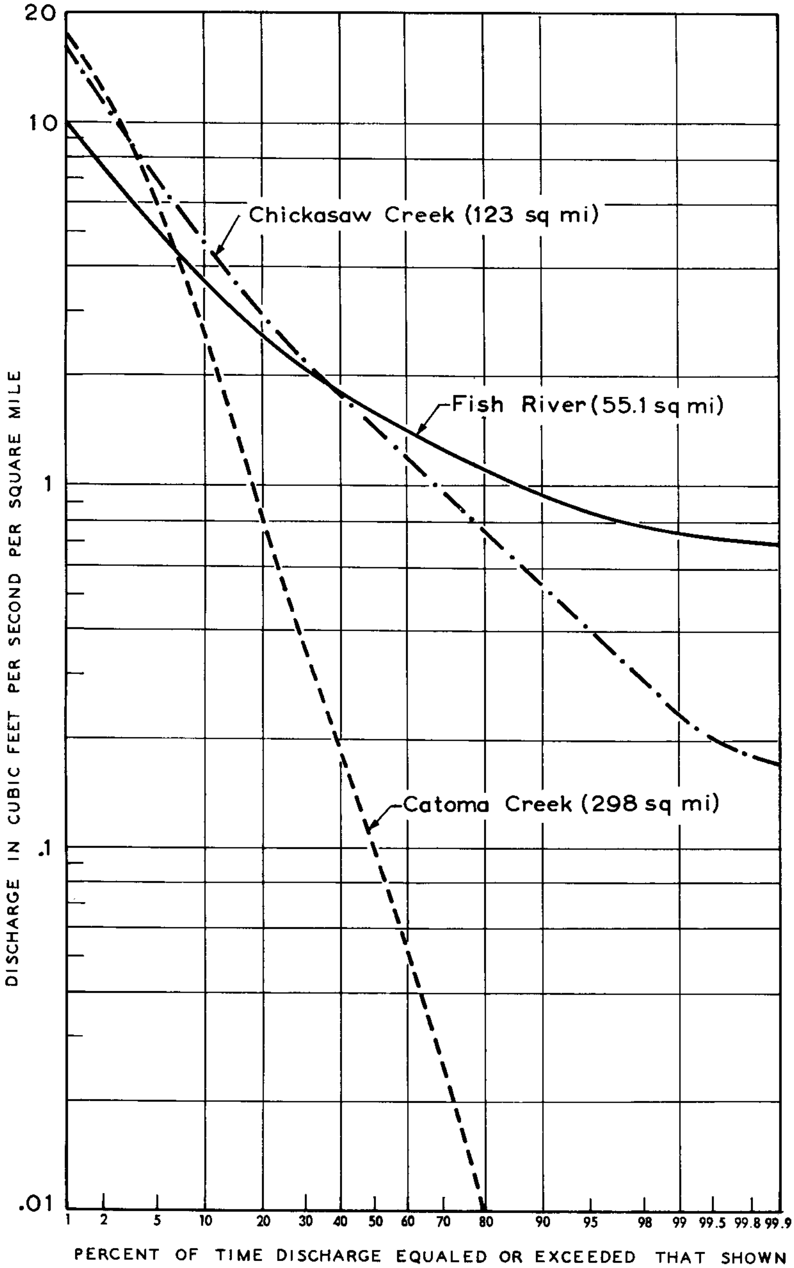


Figure 20.—Flow-duration curves for three streams of southwestern Alabama for period 1953-62.

Table 11.—*Duration of daily flow and average discharge at gaging stations in southwestern Alabama*

Percent of time	Discharge, in cubic feet per second, which was equaled or exceeded for indicated percentage of time													
	3765.00	3775.00	3785.00	4200.00	4210.00	4215.00	4220.00	4230.00	4255.00	4260.00	4265.00	4270.00	4275.00	4285.00
	Perdido River at Barrineau Park, Fla. (1942-62)	Styx River near Loxley, Ala. (1952-62)	Fish River near Silverhill, Ala. (1954-62)	Alabama River near Montgomery, Ala. (1928-62)	Catoma Creek near Montgomery, Ala. (1953-62)	Big Swamp Creek near Hayneville, Ala. (1940-46)	Big Swamp Creek near Lowndesboro, Ala. (1941-62)	Alabama River at Selma, Ala. (1929-62)	Cedar Creek at Minter, Ala. (1953-62)	Boguechitto Creek near Browns, Ala. (1945-53)	Boguechitto Creek at Boguechitto near Orrville, Ala. (1939-43)	Boguechitto Creek near Orrville, Ala. (1945-49)	Alabama River near Millers Ferry, Ala. (1938-54)	Flat Creek at Fountain, Ala. (1944-62)
1	4,500	1,300	550	120,000	5,200	3,000	4,500	140,000	3,600	1,700	4,200	6,500	160,000	3,800
2	3,300	970	400	100,000	3,700	2,000	2,800	120,000	2,200	1,200	3,100	4,600	130,000	2,600
5	2,200	580	270	73,000	1,700	750	1,400	84,000	1,000	660	1,300	2,800	98,000	1,500
10	1,400	400	200	50,000	820	340	780	58,000	420	330	500	1,300	72,000	770
20	970	250	140	31,000	220	110	280	35,000	200	140	150	420	42,000	350
30	740	170	110	23,000	110	49	110	25,000	120	82	88	210	30,000	200
40	600	130	100	18,000	57	28	48	19,000	82	53	59	120	24,000	120
50	510	97	90	14,000	27	11	20	15,000	50	34	39	79	19,000	75
60	440	76	81	12,000	15	2.9	6.9	13,000	33	20	27	49	15,000	47
70	380	62	70	11,000	7.6	.4	2.7	12,000	22	11	17	28	13,000	31
80	330	49	61	9,200	2.6	.1	1.1	10,000	15	5.4	9.4	14	11,000	20
90	290	36	52	7,600	.4	0	.4	8,500	7.5	1.2	3.0	6.0	9,800	9.6
95	260	30	47	6,600	.1	....	.1	7,400	3.5	.2	1.7	4.2	8,600	6.1
98	250	24	44	5,600	0	....	0	6,200	.8	0	.7	2.1	7,200	3.9
99	240	23	42	5,000	....	....	....	5,600	.6	....	.5	1.3	6,400	2.4
99.5	230	21	40	4,600	....	....	....	5,400	.4	....	.4	.9	5,900	1.6
99.9	210	19	38	3,700	....	....	....	4,700	.2	....	.2	.5	5,400	.4
Average discharge (cfs)	773	181	119	23,250	348	168	310	25,730	237	141	262	500	30,330	317
(cfsm)	1.96	1.94	2.16	1.54	1.17	1.37	1.26	1.52	1.09	1.36	1.33	1.71	1.47	1.29

Percent of time	Discharge, in cubic feet per second, which was equaled or exceeded for indicated percentage of time													
	4290.00	4295.00	4670.00	4675.00	4680.00	4690.00	4695.00	4697.00	4698.00	4700.00	4701.00	4710.00	4795.00	4800.00
	Limestone Creek near Monroeville, Ala. (1953-62)	Alabama River at Claiborne, Ala. (1931-62)	Tombigbee River near Coatopa, Ala. (1929-62)	Sucarnoochee River at Livingston, Ala. (1939-62)	Alamuchee Creek near Cuba, Ala. (1955-62)	Kinterbish Creek near York, Ala. (1955-62)	Tuckabum Creek near Butler, Ala. (1955-62)	Okatuppa Creek at Gilbertown, Ala. (1957-62)	Satilpa Creek near Coffeeville, Ala. (1957-62)	Tombigbee River near Leroy, Ala. (1929-53, 1955-60)	East Bassett Creek at Walker Springs, Ala. (1957-62)	Chickasaw Creek near Whistler, Ala. (1952-62)	Escatawpa River near Wilmer, Ala. (1946-62)	Big Creek near Mobile, Ala. (1946-50)
1	1,200	160,000	130,000	6,100	780	1,300	1,800	2,400	2,700	140,000	2,500	1,900	8,400	1,200
2	890	140,000	110,000	4,400	580	730	1,100	1,600	1,700	120,000	1,800	1,400	6,000	960
5	480	100,000	87,000	3,000	270	360	460	790	910	94,000	1,100	800	3,700	600
10	310	74,000	65,000	2,100	140	200	250	470	520	76,000	720	550	2,500	440
20	200	45,000	39,000	990	70	110	130	280	310	48,000	440	350	1,400	310
30	140	31,000	23,000	600	45	74	74	200	220	31,000	330	260	960	240
40	110	23,000	14,000	420	29	53	45	140	160	19,000	260	210	680	210
50	82	19,000	8,400	310	20	38	31	93	110	11,000	190	170	500	180
60	63	16,000	5,700	230	14	28	22	66	73	7,400	150	140	360	160
70	49	13,000	4,100	180	11	22	14	46	51	5,300	120	120	250	140
80	38	12,000	2,800	140	7.8	16	9.3	29	35	3,700	91	92	180	120
90	27	9,600	1,900	110	5.3	9.9	5.0	15	22	2,600	63	62	130	100
95	21	8,400	1,500	91	3.9	6.4	3.2	7.8	17	2,000	49	48	100	88
98	16	7,200	1,200	72	3.2	4.4	2.2	3.0	12	1,500	39	37	72	76
99	14	6,700	980	62	2.9	3.4	1.9	1.8	10	1,300	33	29	60	72
99.5	13	6,300	840	58	2.5	2.8	1.7	1.4	8.4	1,200	31	25	49	69
99.9	12	5,600	600	53	1.9	2.2	1.0	1.0	6.7	960	28	23	40	66
Average discharge (cfs)	158	31,760	22,070	775	69.1	104	122	218	260	26,230	348	285	1,041	242
(cfsm)	1.35	1.44	1.43	1.28	1.10	1.14	1.09	1.44	1.57	1.37	1.85	2.32	2.06	2.88

LOW FLOW

Because water, like other commodities, increases in value as it becomes less plentiful, the ability of a watershed to sustain streamflow during dry weather may be an asset of considerable importance. Low flow is the critical design quantity for small water supplies that provide no storage, for such supplies are limited to the amount nature will provide. When streamflows are low, local water shortages are possible, and competition for the use of available water may develop. An equitable solution to controversies which thus arise is hardly to be expected unless accurate low-flow data are at hand.

Low-flow conditions may be described in a variety of ways, the significance of which depends upon the nature of water use. Streamflow may be sufficient for urban water supply, for example, long after it has become inadequate for industrial use, waste disposal, or power generation. The length of low-flow periods is also important—a reservoir that suffices to carry over a few weeks deficiency may be inadequate for a shortage lasting several months. Finally, the frequency of low-flow conditions must be considered, for a community or industry may be able to adapt to occasional water shortage but find the frequent occurrence of such conditions intolerable. Thus, low flows need to be defined not only in rates of discharge, but also in duration and frequency of occurrence.

MINIMUM FLOW

A convenient and useful method of describing low flows is in terms of averages for periods of various length. For this report, the lowest average flow was determined at gaging stations in the report area for periods of 1, 7, 15, 30, 60, 120, and 183 days during each climatic year of streamflow record. For each gaging station this procedure results in an array of yearly lowest average flows for each of the selected durations. For example, from 20 years of streamflow record there would result an array of twenty daily (1-day) flows, each representing the lowest daily flow in a particular year. Similarly, there would be an array of twenty 7-day average flows, each representing the average for the seven lowest consecutive daily flows in a particular year—and so on, for each selected duration. These arrays form the basis for determining the frequency distribution of low flows as later described.

The lowest item in each array and the year of its occurrence are listed for the various gaging stations in table 12. Thus, this table shows the minimum average flow for each selected duration that has occurred at each gaging station during the indicated period of record.

Similar information cannot be furnished to the same extent for the partial-record stations for which only occasional measurements of base flow are available. However, by correlating these measured flows with concurrent flow at a gaging station it was found possible in most cases to estimate the minimum 7-day flow for the partial-record station that occurred during the period of record at the gaging station. Generally these estimates represent 7-day low flows that occurred in the outstanding drought year 1954. This distinction between observed and estimated data appearing in table 12 is pointed out because the latter are subject to greater possible error.

FREQUENCY OF LOW FLOWS

Though showing the minimum flows of record for gaged streams in southwestern Alabama, table 12 gives no clue as to how often those flows can be expected to occur. It has been mentioned that the climatic year 1954 was outstandingly dry in the report area, and table 12 does indeed show that many of the streams for which longer records are available reached their minimum flows in that year. But were the low flows of 1954 really exceptional? If so, how unusual are they—do they represent flows to be expected, say, four times in a century or perhaps only once? Questions like these are answered by the low-flow frequency curve, which relates the lowest average discharge for various durations to its recurrence interval.

As used here, the recurrence interval of a specified low flow is the average number of years between occurrences of an equal or smaller flow. Mathematically, the recurrence interval is the reciprocal of the probability of occurrence. For example, an event having a 50-percent chance of occurrence in any given year has a recurrence interval of 1/0.50 or 2 years; similarly, a 4-percent chance of occurrence is equivalent to a recurrence interval of 1/0.04 or

Table 12.—*Minimum average flows and median 7-day low flows of gaged streams in southwestern Alabama*

Station no.	Stream and location	Drainage area (sq mi)	Period of record (climatic years)	Lowest mean flow, in cfs, for indicated number of consecutive days during period of record								Estimated median 7-day low flow, 1939-61	
				1	7	15	30	60	120	183	Year of occurrence	cfs	cfsm
3762.40	Dyas Creek near Dyas, Ala.	57.3	....	....	5	....	....	....	....	....	1954	9.6	0.17
3765.00	Perdido River at Barrineau Park, Fla.	394	1942-61	209	211	212	220	228	238	271	1954	275	.70
3775.00	Styx River near Loxley, Ala.	93.2	1952-61	a 16	a 17.1	a 19.9	b 21.9	b 25	b 28.6	b 34.7	a1955 b1954	40	.43
3779.75	Blackwater River above Seminole, Ala.	115	....	....	46	....	....	....	....	....	1955	70	.61
3784.10	Fish River near Daphne, Ala.	30.7	....	....	19	....	....	....	....	....	1955	32	1.04
3785.00	Fish River near Silverhill, Ala.	55.1	1954-61	37	38	39.4	41	46.7	48.9	53.9	1955	61	1.11
4200.00	Alabama River near Montgomery, Ala.	15,100	1928-61	a2,420	a4,480	a4,840	a5,320	b5,460	b5,740	b6,120	a1941 b1954	7,000	.46
4210.00	Catoma Creek near Montgomery, Ala.	298	1953-61	a 0	a 0	b 0	b 0	b 0	b 0	b .8	aSeveral b1954	.4	.0013
4211.75	Pintlala Creek near Montgomery, Ala.	257	....	....	0	....	....	....	....	....	1954	.6	.0023
4215.00	Big Swamp Creek near Hayneville, Ala.	123	1939-45	a 0	a 0	a 0	0	0	b 0	c 7.6	aAll b1940 c1945	0	0
4220.00	Big Swamp Creek near Lowndesboro, Ala.	247	1941-61	a 0	a 0	a 0	a 0	b 0	b 0	b 0	aSeveral b1954	.1	.0004
4230.00	Alabama River at Selma, Ala.	17,100	1900-12 1929-61	a3,300	a3,300	a3,300	a3,340	a3,630	a5,220	b6,610	a1904 b1954	7,700	.45

4255.00	Cedar Creek at Minter, Ala.	217	1953-61	.1	.3	.4	.6	.7	2.7	5.9	1954	7.3	.034
4255.95	Cedar Creek near Berlin, Ala.	382	...	...	...	...	...	...	...	...	...	10	.026
4256.55	Mush Creek near Selma, Ala.	45.4	...	...	...	...	...	...	...	...	...	1.0	.022
4260.00	Boguechitto Creek near Browns, Ala.	104	1944-53	a 0	a 0	a 0	b 0	b .2	b .7	b 2.7	aSeveral b1952	.5	.0048
4265.00	Boguechitto Creek at Boguechitto near Orrville, Ala.	197	1939-43	a 0	a 0	b 0	b .9	b 2.1	b 10.1	b 39.2	aSeveral b1941	.9	.0046
4270.00	Boguechitto Creek near Orrville, Ala.	292	1944-48	a .4	a .9	a 1.1	a 2.2	a 3.7	b 19.7	a 32.0	a1945 b1948	1.3	.0045
4272.50	Pine Barren Creek near Snow Hill, Ala.	263	...	...	...	...	...	...	...	...	...	27	.10
4273.00	Prairie Creek near Oakhill, Ala.	9.7	1960-61	a 0	a 0	a 0	a 0	a .1	a .6	b 2.4	a1961 b1960	0	0
4275.00	Alabama River near Millers Ferry, Ala.	20,700	1938-53	a4,890	b6,350	b6,380	b6,860	b7,610	c9,700	c10,400	a1951 b1941 c1952	8,500	.41
4277.00	Turkey Creek at Kimbrough, Ala.	114	1959-61	a 3.2	a 3.6	b 6.2	a 9.3	a 13.3	a 25.8	b 42.2	a1959 b1960	2.0	.018
4277.50	Beaver Creek near Pine Hill, Ala.	36.8	...	...	0	...	...	...	...	...	1954	.7	.019
4278.65	Pursley Creek above Camden, Ala.	40.8	...	...	0	...	...	...	...	...	1954	.2	.0049
4283.00	Tallatchee Creek near Vredenburgh, Ala.	14.6	1959-61	0	0	0	.1	.1	.5	2.8	1961	0	0
4285.00	Flat Creek at Fountain, Ala.	245	1944-61	.2	.3	.4	.6	1.7	3.4	6.3	1954	8.0	.033
4290.00	Limestone Creek at Monroeville, Ala.	117	1952-61	a 11	b 12.1	b 12.4	b 14.2	b 15.3	b 19.3	b 23.8	a1956 b1954	27	.23
4295.00	Alabama River at Claiborne, Ala.	22,000	1930-61	4,840	5,570	6,000	6,090	6,420	6,870	7,250	1954	8,900	.40

Table 12.—*Minimum average flows and median 7-day low flows of gaged streams in southwestern Alabama*—Continued

Station no.	Stream and location	Drainage area (sq mi)	Period of record (climatic years)	Lowest mean flow, in cfs, for indicated number of consecutive days during period of record: 1	7	15	30	60	120	183	Year of occurrence	Estimated median 7-day low flow, 1939-61: cfs	cfsm
4296.05	Little River near Little River, Ala.	140	....	....	68	....	....	....	....	....	1954	92	0.66
4296.50	Majors Creek near Tensaw, Ala.	44.7	....	....	13	....	....	....	....	....	1954	21	.47
4670.00	Tombigbee River near Coatopa, Ala.	15,400	1929-61	50	51	83.9	614	715	951	1,350	[1]1954	1,300	.084
4675.00	Sucarnoochee River at Livingston, Ala.	606	1939-61	a 50	b 52.3	b 53.3	b 54.9	b 58.5	b 66.7	b 81	a1957 b1954	92	.15
4680.00	Alamuchee Creek near Cuba, Ala.	63	1955-61	a 1.8	a 2.1	a 2.2	a 2.8	a 4.0	b 5.2	b 8.1	a1957 b1956	5.7	.090
4685.00	Chickasaw Bogue near Linden, Ala.	258	1944-45	a .3	a .5	b .9	b 1.2	b 1.3	b 3.1	b 7.9	a1944 b1945	.6	.0023
4690.00	Kinterbish Creek near York, Ala.	91.4	1954-61	a 1.8	a 2.1	a 2.6	a 3.4	a 4.3	a 5.7	b 11.4	a1954 b1956	12	.13
4695.00	Tuckabum Creek near Butler, Ala.	112	1954-61	a .7	a .9	a .9	a 1.3	a 2.2	a 3.1	b 5.9	a1954 b1956	6.7	.060
4695.20	Yantley Creek near Jachin, Ala.	95.3	....	....	5	....	....	....	....	....	1954	12	.13
4695.50	Horse Creek near Sweetwater, Ala.	52.8	1959-61	a 2.1	a 3.9	b 5.2	b 8.8	b 9.4	c 21.1	a 43.6	a1960 b1959 c1961	2.0	.038
4695.75	Wahalak Creek near Butler, Ala.	22.8	....	....	....	....	....	....	....	....	....	2.0	.088
4696.00	Bashi Creek near Campbell, Ala.	86.3	1959-61	a 2.6	a 3.0	a 3.2	a 3.6	a 7.0	b 22.9	a 48.0	a1961 b1959	1.0	.012

4697.00	Okatuppa Creek at Gilbertown, Ala.	151	1957-61	a .8	a 1.1	a 1.3	a 2.0	a 7.1	a 15.1	b 63.9	a1957 b1960	11	.073
4697.75	Santa Bogue Creek near Frankville, Ala.	168	....	....	1.5	....	....	....	....	....	1954	12	.071
4698.00	Satilpa Creek near Coffeeville, Ala.	166	1957-61	a 7.3	a 7.8	a 9.1	a 10.0	a 21	b 58.8	b 69.4	a1957 b1958	11	.066
4700.00	Tombigbee River near Leroy, Ala.	19,100	1929-59	534	639	646	721	796	1,070	1,700	[1]1954	1,800	.094
4700.75	East Bassett Creek near Dickinson, Ala.	39.9	....	....	.1	....	....	....	....	....	1954	1.2	.030
4701.00	East Bassett Creek at Walker Springs, Ala.	188	1957-61	a 30.0	a 32.9	a 40.6	a 50.4	b 60.2	b 83.6	b 95.6	a1957 b1958	38	.20
4702.05	West Bassett Creek at Bassett Creek, Ala.	128	....	....	3	....	....	....	....	....	1954	12	.094
4703.40	Bates Creek near Malcolm, Ala.	74.4	....	....	.2	....	....	....	....	....	1954	2.0	.027
4705.00	Mobile River at Mt. Vernon, Ala.	43,000	1954	4,310	7,140	8,740	9,300	9,560	9,870	10,300	1954	12,000	.28
4706.15	Cedar Creek near Mt. Vernon, Ala.	86.0	....	....	5	....	....	....	....	....	1954	28	.32
4709.25	Chickasaw Creek at Chunchula, Ala.	45.4	....	....	7	....	....	....	....	....	1954	25	.55
4710.00	Chickasaw Creek near Whistler, Ala.	123	1952-61	19.0	19.4	20.6	23.3	28.8	37.6	45.0	1954	69	.56
4794.25	Escatawpa River at Deer Park, Ala.	190	....	....	0	....	....	....	....	....	1954	.1	.0005
4795.00	Escatawpa River near Wilmer, Ala.	506	1946-61	38.0	38.3	41.4	45.0	52.1	71.5	91.4	1954	103	.20
4800.00	Big Creek near Mobile, Ala.	84	1945-49	65.0	66.3	71.6	77.4	82.6	92.8	109	1945	76	.90
4801.50	Franklin Creek near Grand Bay, Ala.	16.4	....	....	....	....	....	....	....	....	....	13	.79

[1] Minimum flows of Tombigbee River occurring in 1954 were abnormally low as a result of closure of navigation lock and dam at Demopolis and storage of water upstream.

25 years. This concept of a recurrence interval does not imply any regularity of occurrence; a low flow of 25-year recurrence interval might occur several times, or not at all, in a given 25-year period.

The analysis of low-flow frequency for tributary streams in southwestern Alabama is based on the 23-year period 1939-61. Low-flow arrays for some gaging stations having shorter records were extended to the full period by correlation with gaging stations having complete record. To take advantage of the longer records available for the Alabama and Tombigbee Rivers, the frequency analysis for these streams is based on the 32-year period 1929-60. Low flows of the Tombigbee River in 1954 were not used in the frequency study because those flows were unnaturally low as a result of closure of the navigation dam at Demopolis and the storage of water upstream during that year.

To illustrate the graphical form of the low-flow frequency curve, a family of such curves is shown in figure 21 for Sucarnoochee River at Livingston (Station 4675.00). Each of the curves represents a different duration from 1 day to 120 consecutive days, as indicated. The scale at the left of the figure shows the average discharge in cubic feet per second for any of these durations. The scale at the bottom shows the recurrence interval, in years, at which average discharges not exceeding those shown can be expected to occur as an annual minimum. Reading directly from figure 21 to illustrate its interpretation: at intervals averaging 25 years, the lowest 30-day average flow of the year can be expected to be no more than 58 cfs; or again, about every 10 years, on the average, the annual minimum flow for 120 days can be expected to average 90 cfs or less.

Although figure 21 makes it possible to read discharge and recurrence interval as continuous variables, it is not well suited for reading discharge for durations other than those for which a curve is drawn. Another arrangement of the data, which allows duration to be read as a continuous variable, is shown in figure 22. In this figure, the different curves represent recurrence intervals of 2, 5, 10, and 25 years. The discharge scale at the left remains unchanged, but the bottom scale now shows the number of consecutive days for durations of any length up to 120 days. Reading from this diagram allows statements of the following kind in

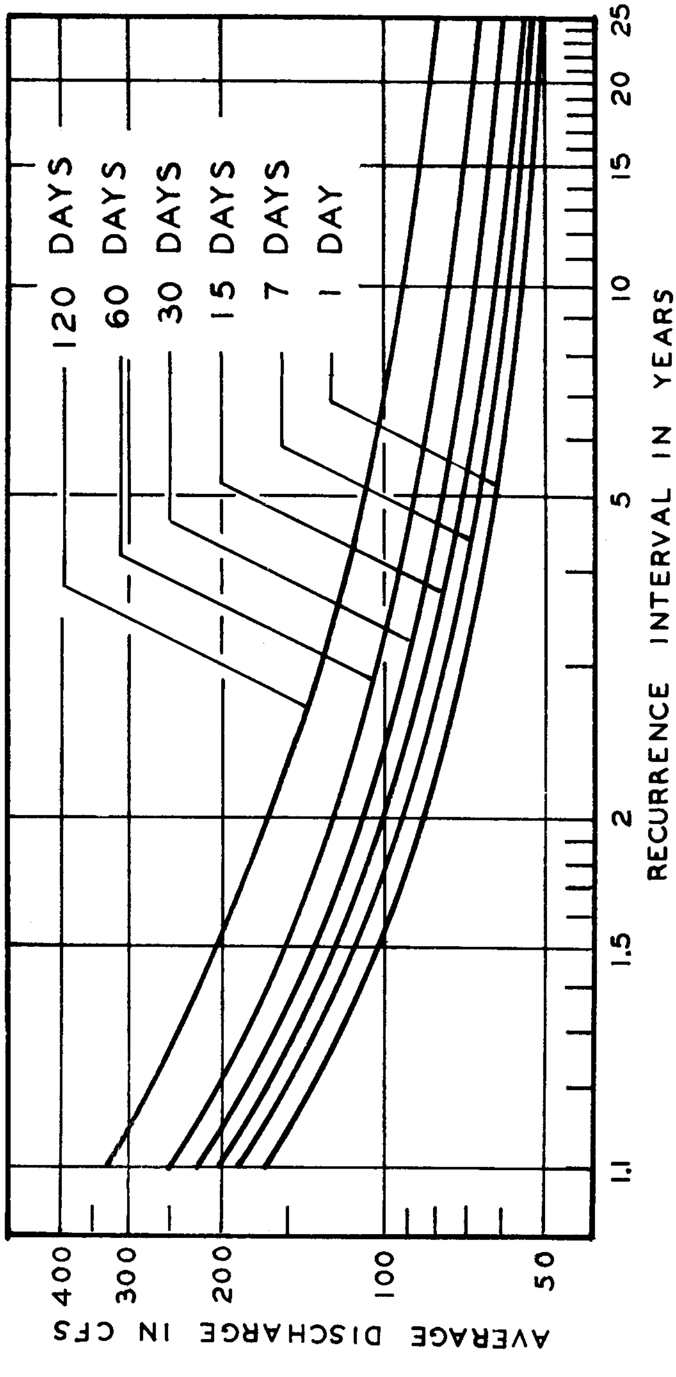


Figure 21.–Discharge and recurrence intervals of annual low flows, Sucarnoochee River at Livingston, Ala.

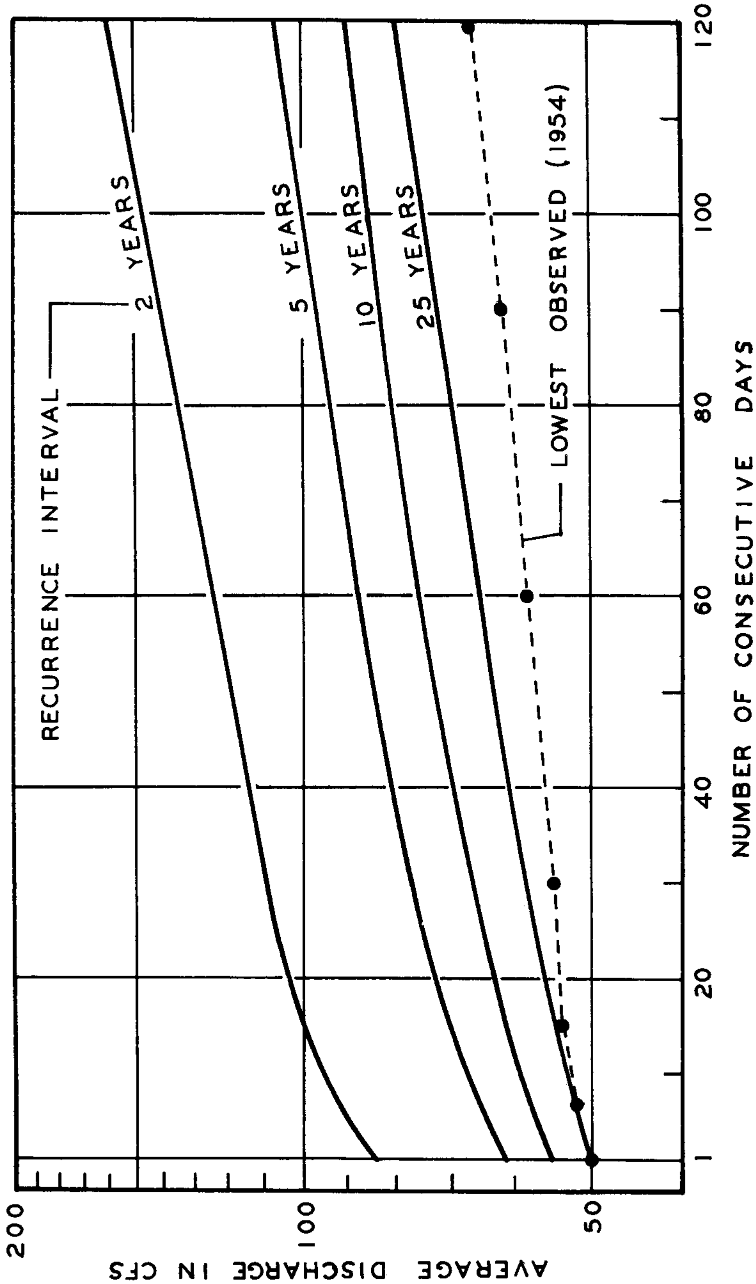


Figure 22.–Expected duration of lowest average discharge for selected recurrence intervals, Sucamoochee River at Livingston, Ala.

regard to Sucarnoochee River: an average flow of 100 cfs can be expected to extend over a 100-day period as an annual minimum at intervals averaging 5 years in length; or again, 60-day periods during which the average flow does not exceed 65 cfs can be expected to occur with an average return period of 25 years.

The broken line in figure 22 shows the lowest average flows observed in Sucarnoochee River during the period of stream gaging (1939-61). The lowest 1-day flow occurred in 1957; but for all longer durations, lowest average flows occurred in 1954. Hence, for durations longer than 1 day, the position of the broken line with respect to the frequency curves indicates the relative severity of the 1954 drought on Sucarnoochee River. For durations under 15 days, the low flows of 1954 are seen to represent a recurrence interval of about 25 years. For periods longer than 15 days, they represent events of increasing rarity, and for 120 days the flow was so unusually low that its recurrence interval cannot be reliably determined from the period of record available. It is evident, however, that the recurrence interval for the 120-day flow was much in excess of 25 years, perhaps as much as 100 years. Thus, in the Sucarnoochee River basin, and generally elsewhere in the report area, the severity of the 1954 drought as expressed in terms of streamflow lay not so much in the low flows reached but in the length of time those flows persisted.

Low-flow frequency data similar to that shown graphically in figures 21 and 22 are given in table 13 for other gaged streams in southwestern Alabama and may be plotted if the graphical form is desired. The low-flow expectancies shown in this table are based on the assumption that factors controlling low flows of the past will continue to operate without significant change in the future. Known developments in progress on the Alabama River and its headwaters may soon render inapplicable the data shown in table 13 for that river; however, the data may be of future use for comparative purposes in appraising the effects of these developments on low flows and are, therefore, included.

Table 13.—*Average flow expected as an annual minimum, for selected durations and recurrence intervals*

Station no.	Stream and location	Drainage area (sq mi)	Recurrence interval (years)	Lowest average discharge, in cfs, for number of consecutive days indicated					
				1	7	15	30	60	120
3765.00	Perdido River at Barrineau Park, Fla.	394	2	255	275	290	315	355	445
			5	237	241	250	265	290	340
			10	220	226	230	240	260	300
			25	205	210	214	224	240	275
3775.00	Styx River near Loxley, Ala.	93.2	2	34	40	47	59	80	115
			5	24	27	31	38	49	70
			10	20	22	24	29	37	51
			25	16	17	18	21	26	35
3785.00	Fish River near Silverhill, Ala.	55.1	2	56	61	65	72	80	90
			5	45	48	51	56	60	66
			10	41	43	45	49	52	57
			25	37	38	39	41	45	49
4200.00	Alabama River near Montgomery, Ala.	15,100	2	5,800	7,000	7,700	8,100	8,800	10,000
			5	4,100	5,900	6,500	6,800	7,300	8,200
			10	3,300	5,200	5,700	6,000	6,400	7,200
			25	2,600	4,500	4,900	5,200	5,500	6,200
4220.00	Big Swamp Creek near Lowndesboro, Ala.	247	2	0	.1	.2	.4	1.2	7.0
			5	0	0	0	.1	.3	1.4
			10	0	0	0	0	.1	.5
			25	0	0	0	0	0	.1
4230.00	Alabama River at Selma, Ala.	17,100	2	6,700	7,700	8,300	8,900	9,600	11,000
			5	5,200	6,400	6,900	7,400	7,900	9,000
			10	4,300	5,700	6,200	6,500	7,000	8,000
			25	3,500	5,000	5,400	5,700	6,000	6,700
4255.00	Cedar Creek at Minter, Ala.	217	2	5.8	7.3	9.3	12	16	27
			5	1.9	2.6	3.7	5.0	7.0	12
			10	.8	1.2	1.8	2.5	3.8	7.0
			25	.2	.4	.6	.9	1.4	2.7
4260.00	Boguechitto Creek near Browns, Ala.	104	2	.3	.5	.8	1.5	3.0	11
			5	0	.1	.1	.2	.4	2.0
			10	0	0	0	.1	.1	.6
			25	0	0	0	0	0	.1

4275.00	Alabama River near Millers Ferry, Ala.	20,700	2	7,700	8,500	9,000	9,500	10,300	11,800
			5	6,300	7,100	7,400	7,800	8,300	9,500
			10	5,500	6,400	6,600	6,800	7,300	8,200
			25	4,600	5,400	5,600	5,800	6,100	6,800
4285.00	Flat Creek at Fountain, Ala.	245	2	6.4	8.0	10	12	16	28
			5	2.4	3.2	3.9	5.0	7.0	12
			10	1.3	1.8	2.3	3.0	4.2	7.4
			25	.5	.7	.9	1.3	2.2	4.3
4290.00	Limestone Creek near Monroeville, Ala.	117	2	24	27	30	33	38	48
			5	16	18	20	22	26	33
			10	13	15	16	18	21	26
			25	10	11	12	14	17	21
4295.00	Alabama River at Claiborne, Ala.	22,000	2	8,200	8,900	9,600	10,400	11,200	12,600
			5	6,700	7,400	8,000	8,500	9,000	10,100
			10	5,900	6,600	7,100	7,400	7,800	8,700
			25	5,000	5,700	6,100	6,300	6,600	7,300
4670.00	Tombigbee River at Demopolis lock and dam near Coatopa, Ala.	15,400	2	1,200	1,300	1,500	1,700	2,100	3,100
			5	800	920	1,000	1,200	1,400	2,000
			10	620	720	790	900	1,100	1,700
			25	450	530	570	660	830	1,300
4675.00	Sucarnoochee River at Livingston, Ala.	606	2	83	92	100	109	125	160
			5	61	65	70	77	87	107
			10	55	58	61	66	75	90
			25	50	52	54	58	65	80
4680.00	Alamuchee Creek near Cuba, Ala.	63	2	5.1	5.7	6.4	7.3	8.7	12
			5	2.9	3.4	3.8	4.2	5.0	7.0
			10	2.3	2.6	2.9	3.2	3.9	5.3
			25	1.8	2.0	2.2	2.5	3.0	4.0
4690.00	Kinterbish Creek near York, Ala.	91.4	2	10	12	14	17	21	24
			5	4.2	5.1	5.9	7.2	9.0	11
			10	2.8	3.2	3.7	4.6	6.0	7.9
			25	1.8	2.1	2.4	2.9	3.8	5.6
4695.00	Tuckabum Creek near Butler, Ala.	112	2	5.7	6.7	7.7	9.0	11.5	18
			5	2.5	2.8	3.2	3.9	5.1	8.0
			10	1.6	1.9	2.2	2.6	3.3	5.0
			25	.9	1.1	1.3	1.7	2.2	3.1

Table 13.—*Average flow expected as an annual minimum, for selected durations and recurrence intervals*—Continued

Station no.	Stream and location	Drainage area (sq mi)	Recurrence interval (years)	Lowest average discharge, in cfs, for number of consecutive days indicated					
				1	7	15	30	60	120
4697.00	Okatuppa Creek at Gilbertown, Ala.	151	2	8.8	11	13	18	25	43
			5	1.7	2.4	3.0	4.2	6.7	15
			10	.5	.7	1.0	1.5	2.9	7.0
			25	.1	.1	.2	.4	1.0	3.0
4700.00	Tombigbee River near Leroy, Ala.	19,100	2	1,600	1,800	1,900	2,200	2,800	4,100
			5	1,000	1,200	1,400	1,600	2,000	2,700
			10	800	1,000	1,100	1,400	1,700	2,300
			25	630	820	1,000	1,200	1,500	2,000
4701.00	East Bassett Creek at Walker Springs, Ala.	188	2	33	38	44	55	72	92
			5	23	26	30	37	48	60
			10	19	22	24	29	37	49
			25	15	17	19	22	28	38
4710.00	Chickasaw Creek near Whistler, Ala.	123	2	62	69	75	85	103	140
			5	43	48	52	60	73	105
			10	34	38	41	46	57	88
			25	25	28	31	34	43	66
4795.00	Escatawpa River near Wilmer, Ala.	506	2	93	103	120	155	210	300
			5	66	72	82	102	135	190
			10	54	58	64	76	100	146
			25	42	44	48	55	70	100

LOW-FLOW INDEX

A reference discharge that will serve as an index of low flow for quickly appraising the normal dry-weather capability of a stream to dilute pollutional wastes has been found useful in Alabama (Peirce, 1959). To serve this purpose, the index flow chosen should meet the following requirements:

(1) It should not reflect an appreciable amount of surface runoff; that is, it should be largely base flow or ground-water discharge.

(2) It should represent flow largely available without storage.

(3) It should be a flow having the same recurrence interval for all streams considered, which recurrence interval should represent average or normal rather than extreme low-water conditions.

(4) It should be computed from, or adjusted to represent, the same common period of years for all streams.

A streamflow parameter that meets these requirements reasonably well is the median value of the annual 7-day low flows. For streams that are not regularly gaged, this parameter can be satisfactorily determined from a relatively small amount of streamflow data. As a median value, it is a fairly stable parameter, being the average only of position in an array of items and hence unaffected by extreme values. Also as a median, it is a good measure of "normal" conditions. The recurrence interval for the median value in a series of annual events is always known, being 2 years in any form of frequency distribution. Finally, the 7-day period of low flow is short enough to represent both base flow and flow that is available for the most part without storage. Yet the 7-day period is long enough to suppress the effects of abnormally low transient flows of little hydrologic significance that might result from occasional regulation or from natural causes of an accidental nature.

Median annual 7-day low flows for streams in southwestern Alabama are listed in the last two columns of table 12, both in cubic feet per second and as cubic feet per second per square mile of drainage area. All have been adjusted to represent a common 23-year period, 1939-61, so as to be directly comparable.

AREAL VARIATION IN LOW FLOW

The areal variation of index low flows in southwestern Alabama is shown in figure 23. In this figure, the watersheds of 43 tributary streams have been outlined on a map of the report area, with their respective low-flow indices in cubic feet per second per square mile of drainage area. These watersheds range in area from 16.4 to 382 square miles, the median value being 114 square miles. On this basis, several broad regions have been delineated in which the low-flow indices display some degree of similarity on the arbitrary scale of values indicated.

Figure 23 serves to illustrate a notable hydrologic feature of southwestern Alabama: the great difference in low-flow characteristics of streams in the northern and southern parts of the area. Compared generally, unit index low flows for watersheds in Mobile and Baldwin Counties are about 250 times greater than those for watersheds along the northern boundary of the report area.

LOW FLOW AND GEOLOGY

Each of the geologic units forming the surface and subsurface of southwestern Alabama has certain physical properties that determine its ability to function as an aquifer—that is, to store and transmit ground water to wells and streams. Since the low-flow index has been chosen to represent flow from ground-water aquifers, it might be supposed that index flows for various watersheds, when plotted on a map as in figure 23, would display some areal conformity with the outcrops of geologic units through which the streams flow. To a certain extent this is true in southwestern Alabama, although some watersheds depart considerably in index flow from the areal pattern that might be expected.

In some of the regions indicated in figure 23, the correlation between low flow and geology is clear enough; in others it is not so readily apparent. For example, the very poor index flows of watersheds along the north boundary of the report area can be ascribed to the low permeability of the chalks and marls of the Prairie Belt. Low basin permeability, however, does not suffice to explain the equally poor index low flow of the watershed touching the west-central boundary of the report area in figure 23. This watershed is

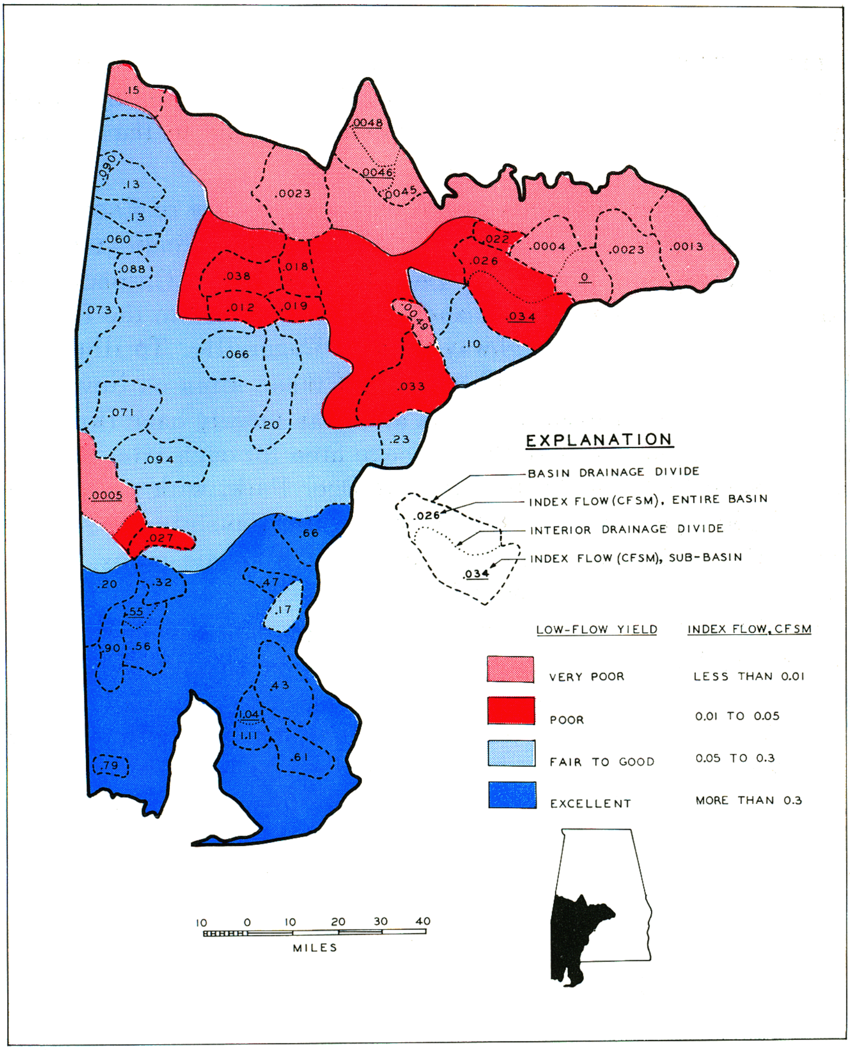


Figure 23.—Map showing areal variation of index low flow in southwestern Alabama.

the upper Escatawpa River basin, which is underlain by fairly permeable deposits.

The Escatawpa River basin above the gaging station at U.S. Highway 98 near Wilmer is sketched in figure 24, with part of Bassetts Creek basin (tributary to Tombigbee River) lying to the east, and part of Chickasawhay River basin lying to the west in Mississippi.

Repeated measurements of the dry-weather flow of Escatawpa River at different locations along the stream have indicated disproportionately low flows near Deer Park and near Citronelle as compared to flow near Wilmer, and also as compared to the flow of Bassetts Creek at U.S. Highway 43 near Wagarville. To illustrate the situation, flows measured at each of these sites on November 6, 1962, when all streamflow in the area was largely base flow, are indicated in figure 24, with the drainage area for each site. Here, it can be seen that Escatawpa River at Deer Park, with a drainage area of 190 square miles, had no flow; while Bassetts Creek near Wagarville, with a drainage area of only 128 square miles, had a substantial base flow of nearly 19 cfs. This contrast in flow is especially conspicuous because the geologic map (MacNeil, 1946) shows that both streams above the points of measurement drain from the same geologic formation. Although most geologic formations of the area are not lithologically uniform, this difference in flow is too great to be reasonably ascribed to basin-wide differences of permeability in the same geologic formation. Instead, the explanation may be a form of watershed leakage, induced largely by topographic features but favored perhaps by the structural attitude of aquifers feeding the streams.

The topographic influence is illustrated by the upper part of figure 24, which shows a ground-surface profile along the east-west line A - B, extending from Chickasawhay River through Chatom to the Tombigbee River. This profile crosses Escatawpa River and intersects Bassetts Creek at three different locations.

It is evident from the profile that Escatawpa River basin here occupies an upland valley in which the stream channel is elevated some 100 feet above Chickasawhay River to the west and nearly 200 feet above Tombigbee River to the east. In this situation,

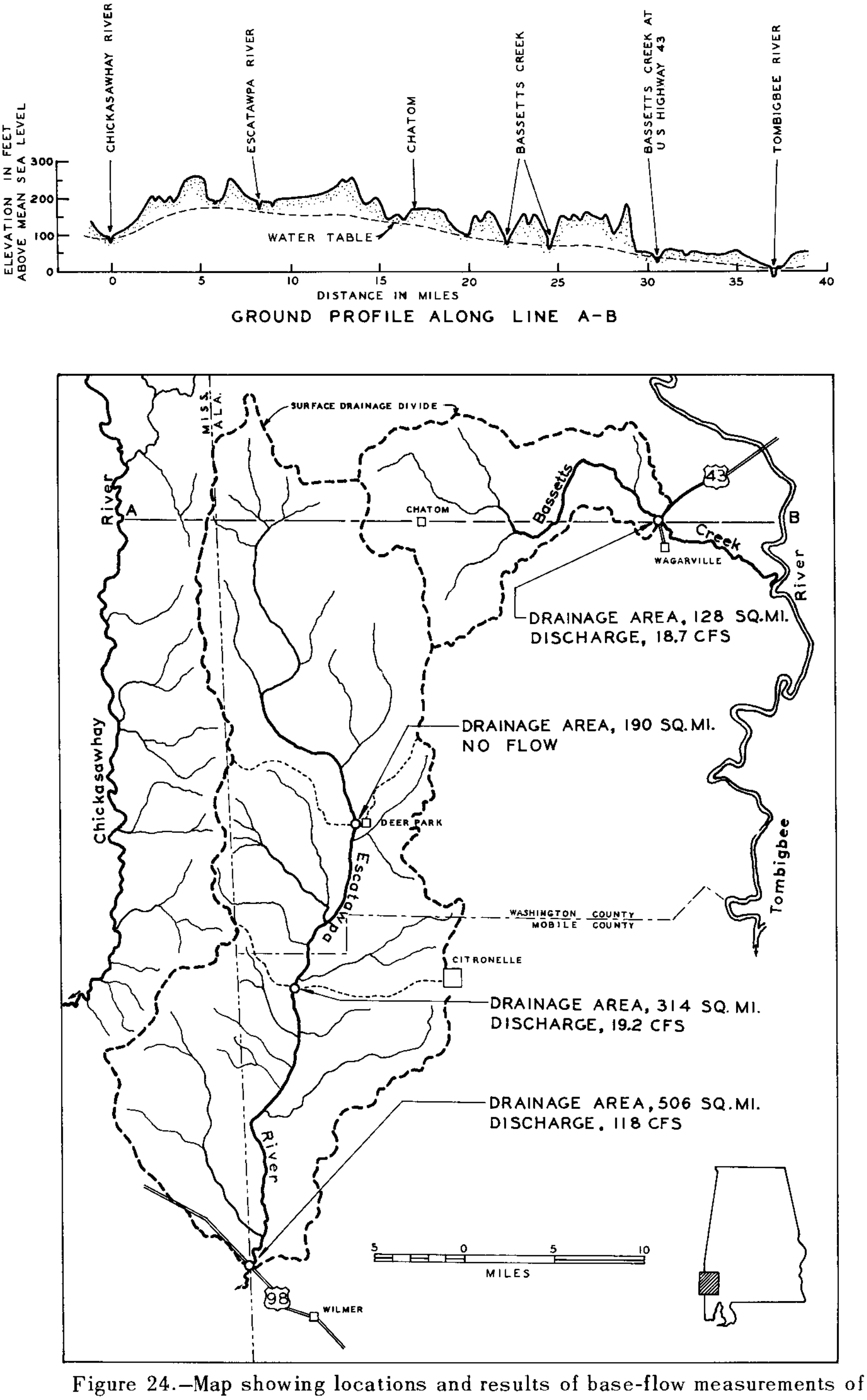


Figure 24.—Map showing locations and results of base-flow measurements of Escatawpa River and Bassetts Creek in November 1962.

ground water under water-table conditions would be free to drain both east and west toward the Tombigbee and Chickasawhay Rivers, and, as shown by the hypothetical water table sketched, could continue to feed those rivers and their tributaries, such as Bassetts Creek, even after declining below the streambed of Escatawpa River, which would then cease to flow.

The watersheds of Bassetts Creek and the upper Escatawpa River lie in the outcrop area of sedimentary deposits of Miocene age consisting of sand, sandstone, and clay. These beds have a regional dip to the southwest of 15 to 25 feet per mile, and ground water in them can occur under artesian conditions (Robinson and others, 1956). There is thus a possibility that ground water not reaching Escatawpa River above Deer Park may reach the stream as artesian leakage below Citronelle, which could partly account for the increased low-water yield of the stream observed near Wilmer.

The foregoing example serves very well to show that a similarity in low-flow index does not necessarily indicate a similarity in surface geology. There are two principal reasons why this is so, both stemming from inadequacies of the low-flow index.

In the first place, the low-flow behavior of different streams cannot be compared on the basis of a low-flow index unless that index takes into account the difference in size of the flow-contributing areas. Expressing index flow on a unit area (per square mile) basis, as in figure 23, represents an attempt to eliminate the size factor. Unfortunately, the results may have little meaning because the surface drainage area—which of necessity has been used to compute the unit index flow—may be greatly different from the undetermined subsurface area that actually supplies the low flow of the stream. Moreover, the subsurface drainage system may not have a fixed area, even for a selected rate of streamflow, because streams are commonly fed by several aquifers, each having different characteristics and possibly being in different stages of recharge at different times.

Secondly, the low-flow index does not necessarily reflect the total capacity of an aquifer to supply water, but only its ability to supply water to surface streams. Water deep in the ground can be reached by drilling wells, whereas for a surface stream to intercept ground water, its channel must be lower than the water table—a condition that does not always exist, even in areas of copious ground-water supply. Some streams may be so lightly entrenched that they do not benefit from an aquifer that yields abundantly to more deeply incised streams. On the other hand, some streams in the report area—for example, Chickasaw Bogue and Horse Creek in Marengo County (Newton and others, 1961)—benefit at low flow from uncapped artesian wells tapping deep aquifers that normally would supply no water to those streams.

Only a few of the simpler aspects of the complex relationship between ground water and surface water in southwestern Alabama have been mentioned. But these should be sufficient to show that maps like figure 23, which seek to generalize low streamflow characteristics on an areal basis, are dependable only to the extent that the streamflows have been determined by actual measurement. Inferences regarding the low flow of ungaged streams based solely on geologic evidence may be useful in preliminary studies, but they should always be verified by measurements of stream discharge under various conditions of base flow before any major development is undertaken.

FLOODS

From the hydrologist's viewpoint, any relatively high streamflow overtopping the banks in some reach of a stream can be classed as a flood. By this very broad definition, most minor floods pass unnoticed by the general public and are of interest to the hydrologist mainly as a statistical background for the comparatively few great floods that compel general attention. To most people a "flood" suggests at the very least some measure of inconvenience to human activities, if not an outright threat to life and property. The definition of a flood once proffered by some hydrologic wit as "a river stage high enough to wet someones pocketbook" has much to recommend it. Essentially the same idea is expressed by the Weather Bureau's definition of **flood stage** as the stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the elevation is measured.

By this definition, flood stage does not represent a definite statistical concept, but is instead a culturally defined elevation that is subject to change as flood plain occupancy and use vary with time and season. For flood-warning purposes, or for comparing different floods at the same location, this concept of a flood is quite useful; however, for comparing the same flood at different locations along a stream, it is sometimes misleading because local conditions may dictate the choice of flood stages that represent relatively greater or smaller floods at some places than at others.

FLOODS ON MAJOR RIVERS

The economic aspects of floods in southwestern Alabama have been mentioned. Because of their area-wide influence and greater potential for damage, floods on the Alabama and Tombigbee Rivers merit first and closest attention. Practical questions to be answered are: When do such floods occur and how often? How high do they reach, and how long do they last? What is their peak rate of flow, and how fast does the flood peak travel?

For the purpose of illustration, figure 25 shows how some of these questions can be answered for a particular flood. In this example, stage hydrographs for the moderate flood of April 1951 are shown for four locations along the Alabama River, proceeding in a downstream direction from Montgomery to Claiborne.

Flood stage as defined and currently used by the U.S. Weather Bureau is shown on the hydrograph for each location. At Montgomery, for example, it has been determined that a river stage of 35 feet, as read on the Weather Bureau's gage, will overflow wide areas of lowland along and near the river, with the incipient threat of damage to agricultural interests. At Selma, where the river banks are higher or steeper and the lowlands less extensively used, the danger line is relatively higher than at Montgomery, and flood stage is considered to be 45 feet as read on the Selma gage. Similarly, a flood stage of 40 feet is considered appropriate for Millers Ferry and Claiborne. As figure 25 shows, the 1951 flood exceeded flood stage by various amounts at all four places, but by the smallest amount at Selma where flood stage is relatively highest.

Another useful concept in dealing with floods is that of **flood-to-peak interval**, which is defined as the time interval between the

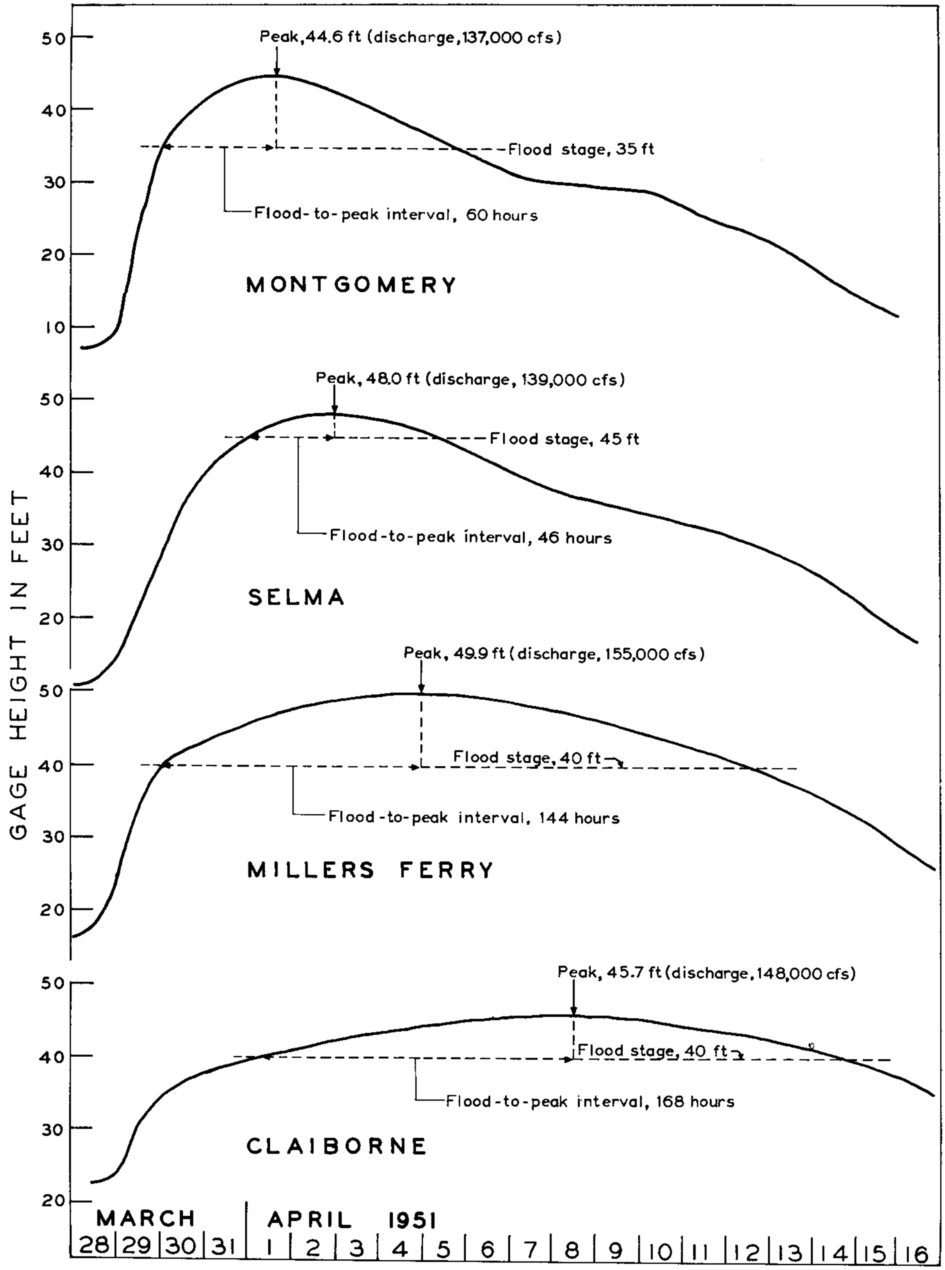


Figure 25.—Stage hydrographs for flood of April 1951 at four locations along Alabama River.

occurrence of flood stage and the flood peak. Empirical evidence shows that people generally do not show much concern over flooding until flood stage is reached (Sheaffer, 1961). Thus the occurrence of flood stage usually corresponds with the beginning of preparations to meet the oncoming inundation. The flood-to-peak interval therefore represents the time available for people to adjust their occupancy of the flood plain so as to minimize damage from the coming flood.

Like flood stage, flood-to-peak interval is an empirical rather than a theoretical concept. It represents no definite time interval at a given location, even for floods of the same peak magnitude, because of the erratic and unpredictable nature of storm rainfall and the resulting variability of flood hydrographs. In spite of this, the flood-to-peak interval displays enough consistency at places along the Alabama and Tombigbee Rivers to be of real value in appraising the characteristics of major floods on those streams. As indicated in figure 25, the flood-to-peak interval for the flood of April 1951 on the Alabama River ranged from 46 hours at Selma to 168 hours at Claiborne.

If flood duration is taken to be the length of time flood stage is exceeded, it can be seen from figure 25 that the duration of the 1951 flood ranged from 4.3 days at Selma to 13.5 days at Claiborne. The shorter duration at Selma than at Montgomery is again the result of the relatively high flood stage designated for Selma. The broadening and flattening of the hydrograph as the flood moved downstream is quite evident in the figure and is characteristic of floods on both the Alabama and the Tombigbee Rivers.

It will be noted that peak discharge increased only slightly between Montgomery and Selma. The substantial increase in peak discharge between Selma and Millers Ferry was caused by inflow from Cahaba River, the only major tributary of the Alabama River, which enters 17 miles below Selma. Between Millers Ferry and Claiborne, peak discharge decreased appreciably as a result of valley storage and the lack of substantial inflow from tributaries, which had discharged the bulk of their flood runoff prior to the arrival of the flood peak on the main river.

From figure 25, the time of travel of the 1951 flood peak from

Montgomery to Claiborne can be determined as 6.7 days, which represents an average rate of movement of 33 miles per day if the distance is measured along the low-water channel. For other major floods on the Alabama River, the travel time of the peak from Montgomery to Claiborne has ranged from 6 to 8 days; and on the Tombigbee River from Demopolis to Leroy (or Jackson) has averaged about 5 days.

Characteristics of known major floods on the Alabama and Tombigbee Rivers in southwestern Alabama are shown in table 14. Records of river stage collected by the U.S. Geological Survey, the U.S. Weather Bureau, and the Corps of Engineers were consulted in the preparation of this table. At some locations where more than one of these agencies used the same gaging station, inconsequential differences in the reported peak stage for some floods may be noted.

SEASONALITY OF FLOODS

Floods can occur in southwestern Alabama in any season of the year, but they are much more likely to occur in winter and early spring. This seasonal distribution of floods is especially important to agriculture because it reduces the risk of crop damage by floods during the growing season.

Most flood studies are prompted by the design needs of engineering structures. Once these structures are completed, it matters little whether they are subjected to floods in one season or in another. During the period of construction, however, when the river may need to be diverted by cofferdams or other means, the occurrence of an uncontrollable flood may be disastrous. Construction costs and risks can often be reduced by considering the seasonality of floods and scheduling critical operations during the low-water season.

The seasonality of floods on the Alabama and Tombigbee Rivers has been appraised from daily observations of river stage made by the U.S. Weather Bureau during the period 1892-1961 at Selma and Demopolis. At both of these places, the seasonal distribution of river stages exceeding a selected reference flood level

Table 14.—*Stage characteristics of major floods on Alabama and Tombigbee Rivers*

River	Location	Flood stage[1]		Date of flood crest	Peak stage		Flood-to-peak interval (days)	Duration above flood stage (days)
		Gage height (ft)	Elevation (ft, msl)		Gage height (ft)	Elevation (ft, msl)		
Alabama	Montgomery[2]	35.0	138.3	Apr. 1, 1886	59.7	163.0	....	....
				Mar. 30, 1888	57.7	161.0	....	....
				Dec. 11, 1919	57.1	160.4	2.2	9.0
				Mar. 17, 1929	56.9	160.2	2.4	15.5
				Nov. 30, 1948	56.0	159.3	4.0	15.0
				Feb. 27, 1961	58.0	161.3	5.5	18.3
Alabama	Selma	45.0	106.8	Apr. 8, 1886	57.0	118.8	....	....
				Dec. 14, 1919	55.9	117.7	3.5	8.8
				Mar. 19, 1929	55.5	117.3	4.0	15.5
				Dec. 3, 1948	56.0	117.8	5.4	13.2
				Mar. 1, 1961	58.0	119.8	6.0	16.4
Alabama	Millers Ferry	40.0	66.8	March 1929	56.8	83.6	....	....
				Apr. 14, 1938	56.6	83.4	12.6	22.0
				Dec. 5, 1948	56.2	83.0	10.4	21.0
				Mar. 3, 1961	60.0	86.8	11.3	28.4
Alabama	Claiborne	40.0	40.4	Mar. 25, 1929	54.6	55.0	....	....
				Apr. 17, 1938	52.2	52.6	12.8	22.0
				Dec. 9, 1948	52.0	52.4	12.5	22.0
				Mar. 7, 1961	55.2	55.6	12.7	28.6

Tombigbee	Demopolis	48.0	68.0	Apr. 18, 1874	[3]70.4	93.5	....	....
				Apr. 22, 1900	[3]73.1	96.2	6.0	20.6
				Apr. 3, 1902	[3]68.9	92.0	6.8	22.2
				July 15, 1916	[3]66.2	89.3	1.9	9.7
				Apr. 5, 1951	[3]66.9	90.0	8.0	19.0
				Feb. 28, 1961	71.1	91.1	7.2	20.5
Tombigbee	Former Lock 1 near Leroy	31.0	23.1	April 1874	51.8	44.5	....	....
				Apr. 27, 1900	50.6	43.3	....	....
				July 23, 1916	46.8	39.5	....	....
				Apr. 11, 1951	45.8	38.5	21.0	44.0
				Mar. 4,5, 1961	48.2	40.9	....	....

[1] Flood stages are those currently used by U.S. Weather Bureau.
[2] Flood stages and elevations for Montgomery are referred to U.S. Weather Bureau gage at foot of Commerce Street.
[3] At site and datum then in use.

was determined. The reference flood level selected for the Tombigbee River at Demopolis is flood stage (48 feet) in current use by the Weather Bureau. At Selma, on the Alabama River, the reference flood level (30 feet) is lower than Weather Bureau flood stage, but is comparable in frequency of occurrence to the reference level used for Demopolis.

During the 70-year period, the exceedence of reference flood level was tallied separately for each of the 12 months. Figure 26 shows, for each month of the year, the percentage of the total number of months during which reference flood level was exceeded. To the extent that the 70-year period considered is representative of a much longer period, the monthly percentages can be interpreted as monthly probabilities of occurrence of reference level floods. For example, figure 26 shows that at Demopolis flood stage can be expected to occur in 7 out of 10 months of March; or to put it another way, the chances of flood stage occurring in any particular March are 7 in 10. By the same interpretation, figure 26 would show that the probability of flood stage at Selma and Demopolis during September is zero. This is not to say that floods cannot occur in September; it means simply that no floods above the reference level did occur in that month during the 70 years, 1892-1961.

Flooding during the summer months is more frequent in smaller streams than in the major rivers as a result of intense but localized thunderstorms that do not much affect the major rivers. This is illustrated by figure 27, which shows the seasonality of bankfull stage in a watershed of 245 sq mi (Flat Creek) and in one of only 5.3 sq mi (Sofkahatchee Creek). The lengths of record available for these streams are 19 years and 11 years, respectively. Sofkahatchee Creek is located north of Montgomery about 20 miles outside the report area, but is the nearest small watershed for which records of significant length are available. Watersheds of comparable size in the southern part of the report area could be expected to show an even greater prevalence of summer floods.

MAXIMUM KNOWN FLOODS

Data on the greatest known floods at gaging stations in southwestern Alabama are given in table 15. Information on the maximum

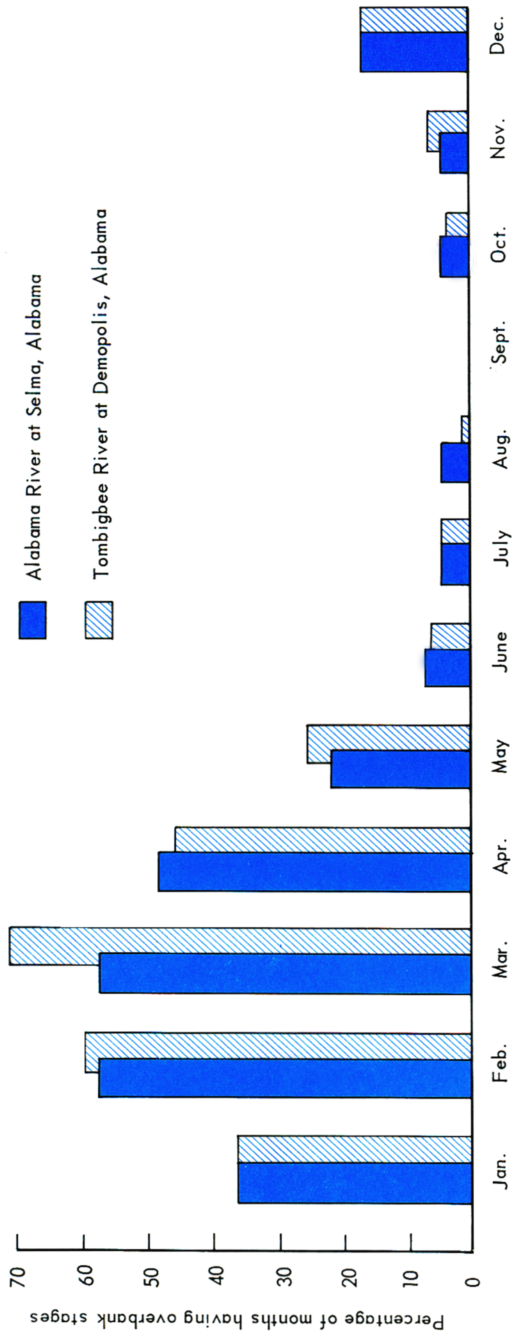


Figure 26.—Seasonality of floods on Alabama and Tombigbee Rivers.

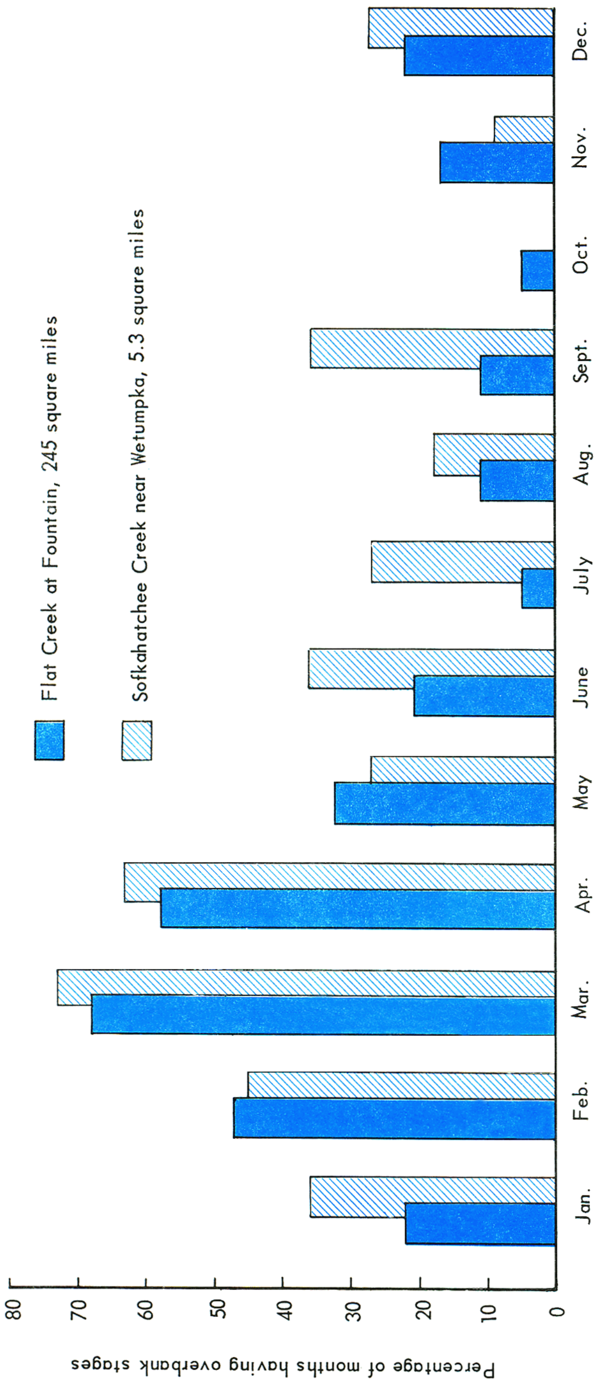


Figure 27.—Seasonality of floods on representative minor streams of southwestern Alabama.

flood occurring during the period of record at each gaging station is shown first and is followed by information believed to be reliable on major floods that have occurred outside the period of record.

Similar data for outstanding floods at miscellaneous sites other than gaging stations are given in table 16. Peak discharges shown in this table were computed from surveys of flood marks and channel characteristics made shortly after the flood.

FREQUENCY OF ANNUAL FLOODS

Because they represent the upper limit of documented flood experience in southwestern Alabama, the floods listed in tables 15 and 16 are of considerable historical interest. They do not, however, provide a logical basis for the hydraulic design of engineering projects. The knowledge that a particular flood is the greatest known does not, in itself, afford any clue as to how often that flood may be equaled or exceeded. If the period of known floods extends over many years, it might reasonably be supposed that the greatest flood during that period represents an event of considerable rarity, though the precise degree of rarity remains undefined. If the period of known floods covers only a few years, the greatest flood during the period is likely to represent a fairly common occurrence, but the possibility cannot be excluded that even a short period of record may fortuitously include an outstanding flood.

In the hydraulic design of bridges, dams, embankments, and other structures to be situated in river flood plains, the first consideration is the frequency of the greatest flood the structure should survive or safely control. The design of the structure on any basis other than the maximum probable flood must be assumed to involve some risk of damage or destruction by floodwaters. For this reason, large dams or other important structures whose failure would result in loss of human life or great property damage are designed to withstand the greatest flood likely to occur. However, when the failure of a structure would involve only temporary inconvenience and nominal loss, it is desirable from an economic viewpoint to include an element of risk in the design. By considering the probable frequency of floods, that risk can be evaluated for any severity of flooding and weighed against the cost of providing

Table 15.—*Maximum known stages and discharges at gaging stations in southwestern Alabama*

Station no.	Stream and location	Drainage area (sq mi)	Period of record	Date of flood	Gage height (ft)	Elevation above mean sea level (ft)	Discharge cfs	Discharge cfsm
3765.00	Perdido River at Barrineau Park, Fla.	394	1941-62	Apr. 15, 1955	23.9	49.7	39,000	99.0
				Mar. 15, 1929	[1]25.7	51.5	....	.....
3775.00	Styx River near Loxley, Ala.	93.2	1951-62	Dec. 6, 1953	19.7	[2] 59	14,000	150
				Sept. 1926	[3]22.2	[2] 61	....	.....
3785.00	Fish River near Silverhill, Ala.	55.1	1953-62	Dec. 6, 1953	17.0	....	8,570	156
4200.00	Alabama River near Montgomery, Ala.	15,100	1927-62	Feb. 26, 1961	60.6	158.6	283,000	18.7
				Apr. 1, 1886	[4]62.7	160.6	322,000	21.3
4210.00	Catoma Creek near Montgomery, Ala.	298	1952-62	Feb. 25, 1961	28.6	179.7	48,600	163
				Nov. 28, 1948	27.5	178.5	....	.....
4215.00	Big Swamp Creek near Hayneville, Ala.	123	1939-46	Mar. 23, 1944	12.1	176.4	19,100	155
				Nov. 27, 1948	14.7	179.0	39,000	317
4220.00	Big Swamp Creek near Lowndesboro, Ala.	247	1940-62	Nov. 27, 1948	21.3	149.2	37,000	150
4230.00	Alabama River at Selma, Ala.	17,100	1900-13	Mar. 1, 1961	58.0	119.8	284,000	16.6
			1928-62	Apr. 8, 1886	57.0	118.8	248,000	14.5
4255.00	Cedar Creek at Minter, Ala.	217	1952-62	Feb. 25, 1961	24.6	148.1	45,600	210
4260.00	Boguechitto Creek near Browns, Ala.	104	1944-62	Mar. 29, 1951	19.0	148.4	14,200	137
				Dec. 28, 1942	[4]20.7	150.1	19,000	183
4270.00	Boguechitto Creek near Orrville, Ala.	292	1944-49	Apr. 27, 1944	26.6	117.7	32,400	111
				Dec. 29, 1942	[4]29.4	120.5	47,000	161
4273.00	Prairie Creek near Oak Hill, Ala.	9.7	1959-62	Feb. 24, 1961	14.2	....	1,690	174
4275.00	Alabama River near Millers Ferry, Ala.	20,700	1937-54	Apr. 14, 1938	56.6	83.4	237,000	11.4
				Mar. 3, 1961	60.0	86.8	284,000	13.7
4277.00	Turkey Creek at Kimbrough, Ala.	114	1958-62	Dec. 10, 1961	25.0	83.8	39,600	347

4280.00	Alabama River near Coy, Ala.	21,200	1928-34	Mar. 23, 1929	55.8	73.2	269,000	12.7
4283.00	Tallatchee Creek near Vredenburgh, Ala.	14.6	1958-62	Mar. 6, 1961	11.7	121.4	2,950	202
4285.00	Flat Creek at Fountain, Ala.	245	1943-62	Nov. 27, 1948	23.2	68.6	26,000	106
4290.00	Limestone Creek at Monroeville, Ala.	117	1951-62	Feb. 25, 1961	16.3	121.2	30,600	262
				March 1929	[1]22	126.9	....	.....
4295.00	Alabama River at Claiborne, Ala.	22,000	1930-62	Mar. 7, 1961	55.2	55.6	267,000	12.1
4670.00	Tombigbee River at Demopolis, Ala.	15,400	1928-62	Feb. 28, 1961	35.7	91.7	250,000	16.2
4675.00	Sucarnoochee River at Livingston, Ala.	606	1938-62	Feb. 22, 1961	29.4	119.4	31,500	52.0
4680.00	Alamuchee Creek near Cuba, Ala.	63	1954-62	Feb. 22, 1961	18.0	179.5	12,000	190
4685.00	Chickasaw Bogue near Linden, Ala.	258	1944-46	Mar. 26, 1945	30.3	99.3	33,000	128
4690.00	Kinterbish Creek near York, Ala.	91.4	1954-62	Feb. 22, 1961	22.2	[2]142	14,400	158
4695.00	Tuckabum Creek near Butler, Ala.	112	1954-62	Feb. 22, 1961	20.1	....	6,830	61.0
4695.50	Horse Creek near Sweetwater, Ala.	52.8	1959-62	Dec. 10, 1961	17.5	....	25,800	489
4696.00	Bashi Creek near Campbell, Ala.	86.3	1959-62	Dec. 10, 1961	25.9	....	20,600	239
4698.00	Satilpa Creek near Coffeeville, Ala.	166	1956-62	July 8, 1956	18.4	....	25,600	154
4700.00	Tombigbee River near Leroy, Ala.	19,100	1928-62	Mar. 4,5, 1961	48.2	41.0	252,000	13.2
				May 1874	[3]51.8	44.5	280,000	14.7
				April 1900	[3]50.6	43.3	269,000	14.1
4701.00	East Bassett Creek at Walker Springs, Ala.	188	1956-62	July 8, 1956	12.2	72.2	19,300	103
4705.00	Mobile River at Mt. Vernon, Ala.	43,000	1953-54	Feb. 1,2, 1954	11.4	9.4	143,000	3.3
				Mar. 9, 1961	[3]20.6	18.6	539,000	12.5
4710.00	Chickasaw Creek near Whistler, Ala.	123	1951-62	Apr. 13, 1955	[4]25.4	....	42,000	341
4795.00	Escatawpa River near Wilmer, Ala.	506	1945-62	June 2, 1959	24.7	....	30,000	59.3
4800.00	Big Creek near Mobile, Ala.	84	1945-50	July 12, 1950	17.5	76.1	3,460	41.2

[1] From information by local residents
[2] By barometer
[3] From information by Corps of Engineers
[4] From floodmarks

Table 16.—*Outstanding flood-crest elevations and discharges at miscellaneous locations in southwestern Alabama*

Stream and location	Drainage area (sq mi)	Date of flood	Crest elevation (ft, msl)	Discharge	
				cfs	cfsm
Clark County					
Bush Creek at U.S. Highway 84, ½ mi east of Gosport	4.5	July 8, 1956	....	4,050	900
Jackson Creek in E½ sec. 25, T. 8 N., R. 1 E., 2 mi southwest of Winn	42.7	July 8, 1956	....	34,000	796
Pigeon Creek at U.S. Highway 84, 1 mi west of Gosport	22.6	July 8, 1956	....	18,800	832
Ulkinask Creek, 2 mi northwest of Coffeeville on road to West Bend	31.1	July 8, 1956	....	25,500	820
Dallas County					
Mush Creek at State Highway 41, 3 mi south of Sardis	45.4	Dec. 13, 1961	....	19,100	421
Lowndes County					
Big Swamp Creek at County Highway 37, 3 mi southwest of Letohatchee	43.7	Feb. 24, 1961	....	29,500	675
Pintlala Creek at County Highway 32, 1 mi downstream from L & N RR bridge and 11 mi northeast of Hayneville	189	Feb. 21, 1961	185.4	......	.....
Pintlala Creek at U.S. Highway 80, 7 mi east of Lowndesboro	257	Feb. 21, 1961	165.0	54,300	211
Marengo County					
Chickasaw Bogue at St L & SF RR bridge, 3 mi northwest of Linden	268	Mar. 26, 1945	89.1	......	.....
Montgomery County					
Baldwin Slough (branch of) at U.S. Highway 231, 3 mi southeast of Montgomery	1.12	Aug. 31, 1961	210.0	2,000	1,790

Mobile County					
Bayou Sara at U.S. Highway 43, at Saraland	23.4	Apr. 13, 1955	....	15,000	641
Big Creek at Big Creek Reservoir	103	Apr. 13, 1955	....	[1]25,800	250
Cold Creek at U.S. Highway 43, 3 mi north of Axis	16.2	Apr. 13, 1955	....	5,160	319
Norton Creek at U.S. Highway 43, ½ mi south of Saraland	4.15	Apr. 13, 1955	....	6,030	1,450
Sister Creek at U.S. Highway 43, 6 mi south of Mt. Vernon	4.11	Apr. 13, 1955	....	4,110	1,000
Wilcox County					
Bokok Creek at State Highway 5, 1 mi southwest of Lamison	5.57	Dec. 10, 1961	111.1	2,970	533
Graham (Mud) Creek at State Highway 5, 1 mi northeast of Lamison	7.89	Dec. 10, 1961	126.2	6,940	880
Martin and Goose Creeks at State Highway 5, 2 mi southwest of Lamison	[2] 26.0	Dec. 10, 1961	108.3	[2]10,800	415
Pine Barren Creek at State Highway 41, 8 mi northeast of Camden	345	Nov. 1948	103.2	......	.....
Pursley Creek at State Highway 41, 4 mi southwest of Camden	60.2	Mar. 31, 1961	....	11,400	189

[1] Figure of peak flow over spillway furnished by J. B. Converse & Co., Mobile, Ala.
[2] Both streams combined

additional protection, thereby establishing the most economical design.

When a long record of floods is available, as at some gaging stations, the process of relating the magnitude and frequency of floods is relatively simple. Commonly, only the annual floods are considered, an **annual flood** being defined as the highest peak discharge during a water year. In the method currently used by the U.S. Geological Survey (Dalrymple, 1960), the annual floods are arrayed and numbered in descending order of discharge, beginning with the greatest flood as number 1. The recurrence interval for each flood is then computed as $(n + 1)/m$, where n is the number of annual floods in the array, and m is the order number. The annual floods are then plotted, with discharges as ordinates and recurrence intervals as abscissae, on a special graph paper designed to make the plotted data approach a straight line, and a curve is fitted by eye.

An example of a flood-frequency curve developed by this method is given in figure 28, which shows recurrence intervals for annual floods of the Alabama River at Selma (Station 4230). The annual floods plotted in this figure are those for the water years 1892-1961.

Recurrence interval, as used here with reference to floods, is defined as the average number of years between annual floods equaling or exceeding a specified discharge. Otherwise, the term has the same mathematical interpretation as previously explained in connection with the frequency of low flows. The 5-year flood, for example, is the discharge that can be expected to be equaled or exceeded 20 times in 100 years. Again, no regularity of occurrence is implied; the 5-year flood might be experienced several times, or not at all, in a given 5-year period. The probability, P, of a flood of any recurrence interval, T, being exceeded in any specific period of n years is readily computed from the formula:

$$P = 1 - (1 - 1/T)^n$$

The table on page 122 shows computed probabilities of exceedence for floods of selected recurrence interval in various periods of years. Thus, reading from this table, the probability that a 5-year flood will be exceeded in a specific 5-year period is 0.67 (67

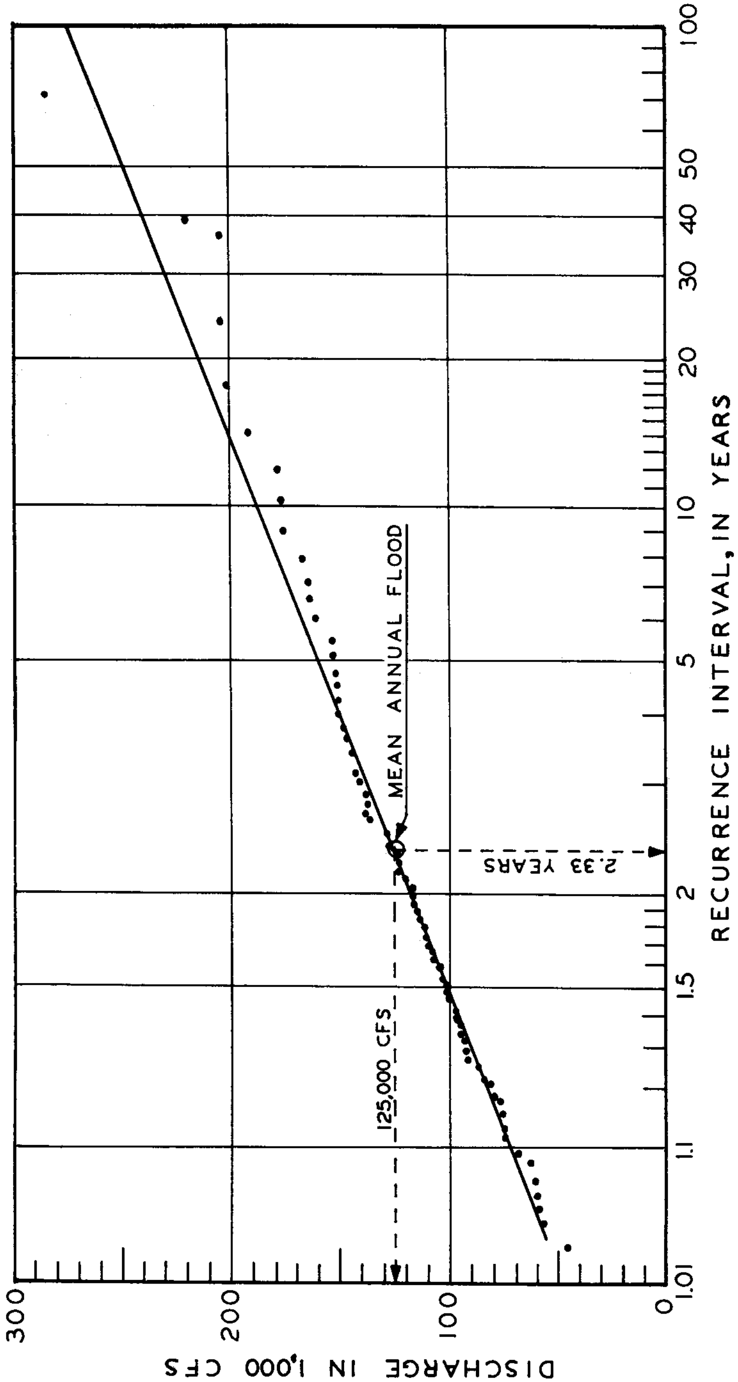


Figure 28.–Frequency of annual floods of Alabama River at Selma, Ala., period 1892-1961.

chances in 100), whereas the probability of this flood being exceeded in a 100-year period is 0.99999+ or a near certainty (1.00).

Recurrence interval of flood (years)	Probability of exceedence during period of years indicated				
	5	10	25	50	100
5	0.67	0.89	0.9962	0.99999	0.99999+
10	.41	.65	.928	.9948	.99997
25	.18	.34	.64	.87	.983
50	.10	.18	.40	.64	.87
100	.05	.10	.22	.40	.63

MEAN ANNUAL FLOOD

For appraising the relative flood potentials of different streams it is convenient to select for comparison an index flood of some particular frequency. A commonly used index flood is the average of the annual floods for each stream. This flood is referred to as the **mean annual flood**; according to statistical theory (Gumbel, 1958), when determined from a large number of annual floods, it has a recurrence interval of 2.33 years. When determined from relatively few annual floods (for example, a typical streamflow record), the mean annual flood is subject to the inherent errors of small samples, but it can be estimated within certain statistical limits if determined graphically from the flood-frequency curve as the discharge having a recurrence interval of 2.33 years. Thus, figure 28 indicates the mean annual flood of the Alabama River at Selma is 125,000 cfs.

Mean annual floods determined by this method for 19 gaging stations in southwestern Alabama are listed in table 17.

REGIONAL FLOOD FREQUENCY

Flood frequency curves for different streams can be directly compared if the discharge values are expressed in dimensionless

Table 17.—*Mean annual floods at gaging stations on tributary streams in southwestern Alabama, period 1929-61*

Station no.	Stream and location	Drainage area (sq mi)	Mean annual flood (cfs)
3765	Perdido River at Barrineau Park	394	7,950
3775	Styx River near Loxley	93.2	4,120
3785	Fish River near Silverhill	55.1	2,480
4210	Catoma Creek near Montgomery	298	14,400
4215	Big Swamp Creek near Hayneville	123	10,400
4220	Big Swamp Creek near Lowndesboro	247	11,500
4255	Cedar Creek at Minter	217	11,100
4260	Boguechitto Creek near Browns	104	5,300
4270	Boguechitto Creek near Orrville	292	17,000
4285	Flat Creek at Fountain	245	6,790
4290	Limestone Creek near Monroeville	117	6,400
4675	Sucarnoochee River near Livingston	606	9,440
4680	Alamuchee Creek near Cuba	63	1,730
4690	Kinterbish Creek near York	91.4	2,380
4695	Tuckabum Creek near Butler	112	3,200
4698	Satilpa Creek near Coffeeville	166	5,780
4701	East Bassett Creek at Walker Springs	188	6,400
4710	Chickasaw Creek near Whistler	123	7,310
4795	Escatawpa River near Wilmer	506	12,300

terms as ratios to the mean annual flood. When this is done for a number of gaged streams in a given locale, and for the same period, it is commonly found that a similarity in shape and slope of the individual frequency curves exists over broad geographic regions. Experience has shown that by combining the closely related curves it is practicable to develop an average or composite frequency curve that is generally applicable to all streams in each homogeneous region.

Studies of flood frequency in the southeastern States (Barnes and Golden, in press) show that a single composite flood-frequency curve can be used for all tributary streams in southwestern Alabama. This curve (fig. 29) shows the ratio to the mean annual flood for floods of other recurrence intervals up to 50 years. The curve does not apply to the main stems of the Alabama, Tombigbee, and Mobile Rivers, and its applicability to streams draining watersheds smaller than 10 square miles has not been verified.

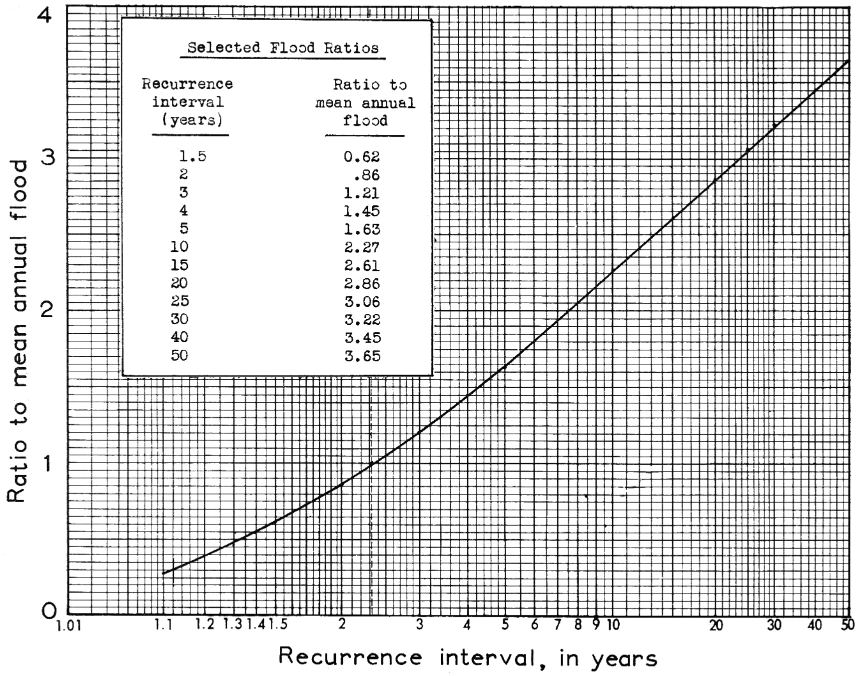


Figure 29.—Composite flood-frequency curve for tributary streams of southwestern Alabama.

The composite frequency curve of figure 29 can be used in conjunction with table 17 to determine floods of any recurrence interval up to 50 years at the gaging stations listed in the table. The procedure is to multiply the mean annual flood for the gaging station shown in table 17 by the flood ratio for the desired recurrence interval taken from figure 29. For example, the 50-year flood for Station 4675, Sucarnoochee River at Livingston, is determined by multiplying 9,440 cfs (mean annual flood from table 17) by 3.65 (ratio of 50-year flood to mean annual flood from figure 29). The product 34,456 cfs is the desired 50-year flood discharge; for practical purposes, this could be rounded to 34,500 cfs.

HYDROLOGIC AREAS

Use of the composite frequency curve as described above is not restricted to the gaging stations listed in table 17. The curve may be applied in the same manner to other locations on gaged streams and to sites on ungaged streams throughout the report area. The only requirement is that the mean annual flood at the point of interest must be known.

It has been mentioned that area of the watershed is the dominant topographic factor influencing mean annual floods in southwestern Alabama. As was shown by figure 17, the area-wide relationship between mean annual flood and drainage area is too general to allow reliable estimates of mean annual flood from a single curve of relation. If several relation curves are drawn, however, each averaging the data for a group of physiographically related streams, the error in estimating mean annual flood can be much reduced. Further, the physiographic feature relating the gaged streams in each group then serves as a basis for extending the relationship to ungaged streams of similar physiographic character. In this way, **hydrologic areas** can be delineated in which the mean annual flood for any stream, gaged or ungaged, can be estimated with some assurance from a knowledge of drainage area alone. Because the relation curve for each hydrologic area averages the data for gaged streams in the area, it may be regarded as the most likely relation for ungaged streams.

Hydrologic areas of southwestern Alabama, as delineated and numbered by Barnes and Golden (in press), are outlined on the map of figure 30. The variation of mean annual flood with drainage area in each hydrologic area is shown by figure 31 within the range defined by data for the period 1929-61.

USE OF REGIONAL FLOOD-FREQUENCY RELATIONSHIPS

Within the range of the relation curves, figures 29, 30, and 31 provide a means for estimating floods of any recurrence interval up to 50 years at any location on a tributary stream in southwestern Alabama. The procedure is:

1. Determine the drainage area in square miles upstream from the point of interest.

2. From figure 30, determine the hydrologic area in which the watershed is located.

3. From figure 31, using the appropriate relation curve for the hydrologic area, determine the mean annual flood corresponding to the drainage area of the watershed.

4. From figure 29, determine the flood ratio for the desired recurrence interval. (Flood ratios for commonly used recurrence intervals are tabulated in the figure.)

5. Multiply the mean annual flood by the flood ratio to obtain the desired discharge in cubic feet per second.

If desired, a complete flood-frequency curve may be defined by plotting discharges determined in the above manner for a number of different recurrence intervals.

FLOOD FREQUENCY ON MAJOR RIVERS

The larger the watershed the greater is the likelihood that some part of it will experience flood-producing rainfall during any particular year. This characteristic tends to increase the relative magnitude of the smaller annual floods with respect to the larger ones. Also, major floods are subject to relatively greater attenuation in large watersheds than in small ones because they are spread over a much longer period of time. This characteristic of large watersheds tends to reduce the relative magnitude of the larger annual floods with respect to the smaller ones. Though stated

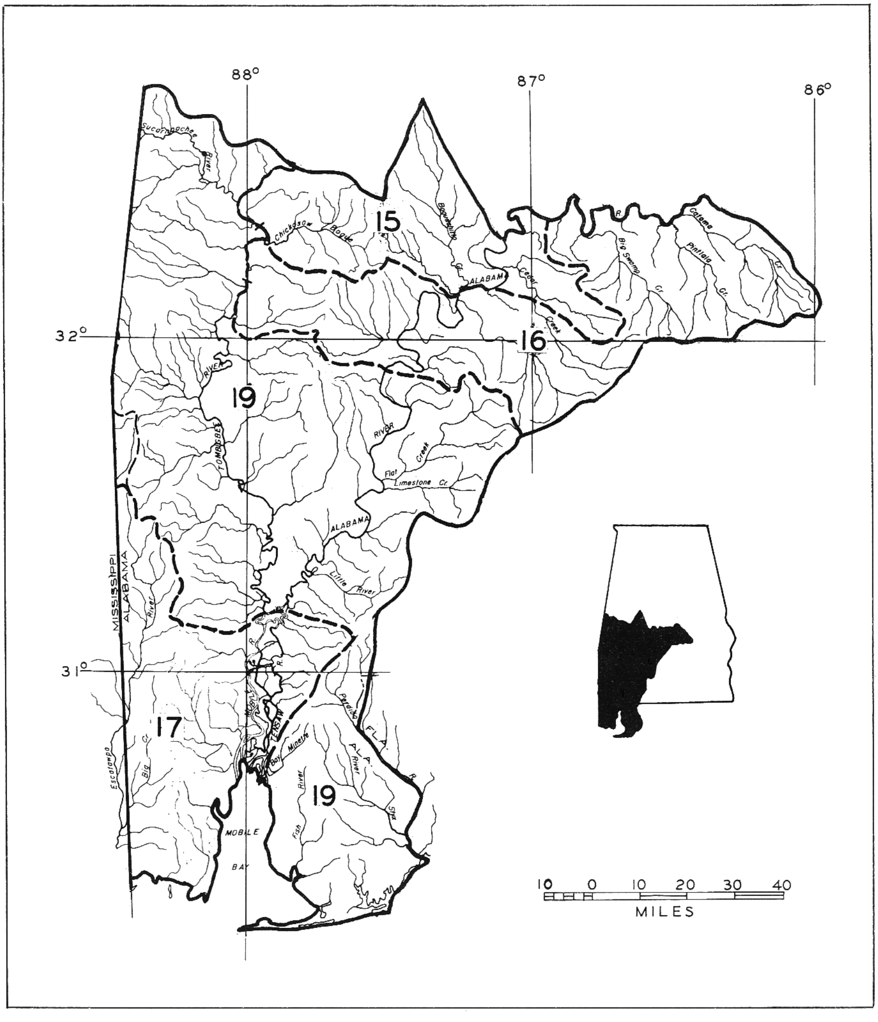


Figure 30.—Map showing hydrologic areas for estimating flood frequency in southwestern Alabama.

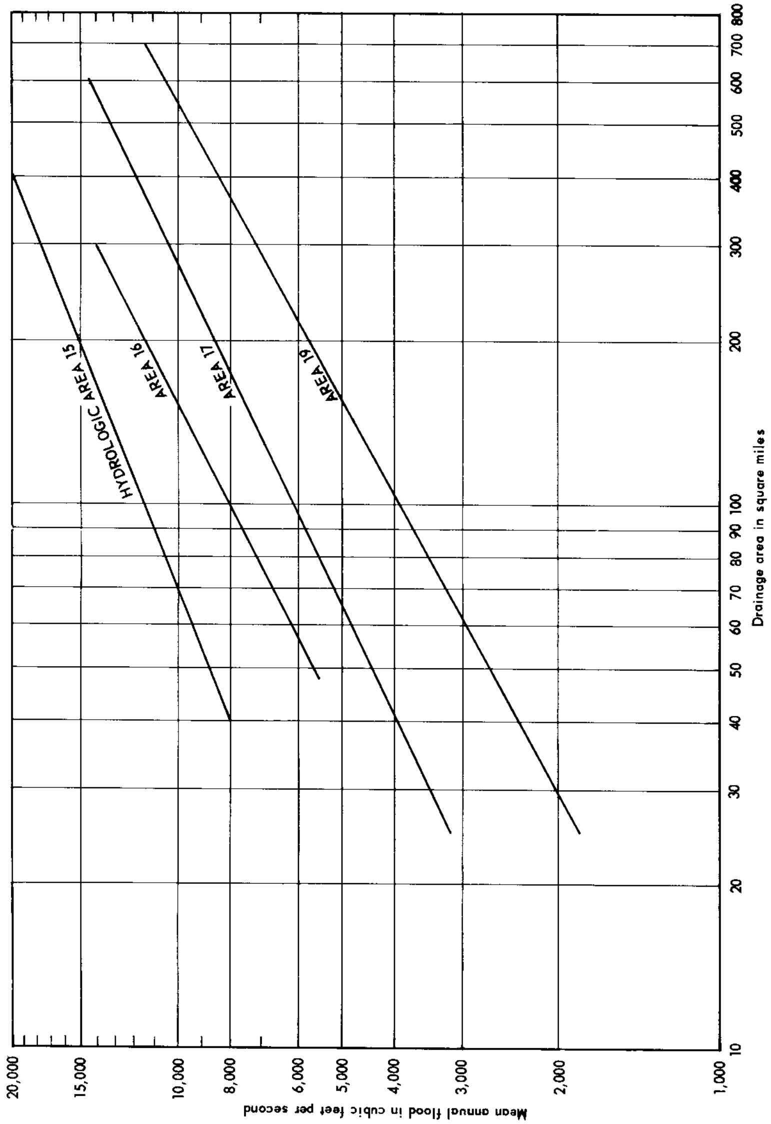


Figure 31.—Variation of mean annual flood with drainage area in hydrologic areas of southwestern Alabama.

differently, both tendencies lead to the same result, which is a flood-frequency curve of flatter slope for large watersheds. To illustrate, the 50-year flood ratio ranges from a median value of 3.65 for tributary streams in the report area to about 2.00 for the Alabama and lower Tombigbee Rivers. For this reason, a composite frequency curve has not been found practicable in Alabama for watersheds greater than about 3,000 square miles (Peirce, 1954, p. 18). Flood-frequency relations along the major rivers are therefore best determined from frequency curves for the individual gaging stations, interpolating between stations.

ALABAMA AND TOMBIGBEE RIVERS

Flood discharge for selected recurrence intervals at any location on the Alabama River can be read from figure 32, using the variation of drainage area along the river as a parameter. This diagram is based on frequency curves for four gaging stations (Nos. 4200, 4230, 4275, and 4295) for the period 1892-1961.

A similar diagram for the Tombigbee River downstream from Demopolis is shown in figure 33. It is based on frequency curves for two gaging stations (Nos. 4670 and 4700) for the period 1892-1961.

MOBILE RIVER

The Mobile River, formed by the union of the Alabama and Tombigbee Rivers, flows in a single low-water channel for a distance of only about 5 miles immediately downstream from the confluence of these two streams. The river then enters an old deltaic flood plain where it branches into three major distributary streams and numerous smaller ones. This complex network of braided channels extends southward for about 35 miles to Mobile Bay (pl. 1). The entire system of channels is usually referred to collectively as Mobile River; specifically, this name applies only to the largest and most westerly channel. The principal distributary is Tensaw River, which forms the east channel and is also continuous from the point of division to Mobile Bay. Between the Mobile and Tensaw Rivers is a maze of channels, lakes, and bayous separated by thickly wooded river flats, swamps, and tidal marshes. At times of

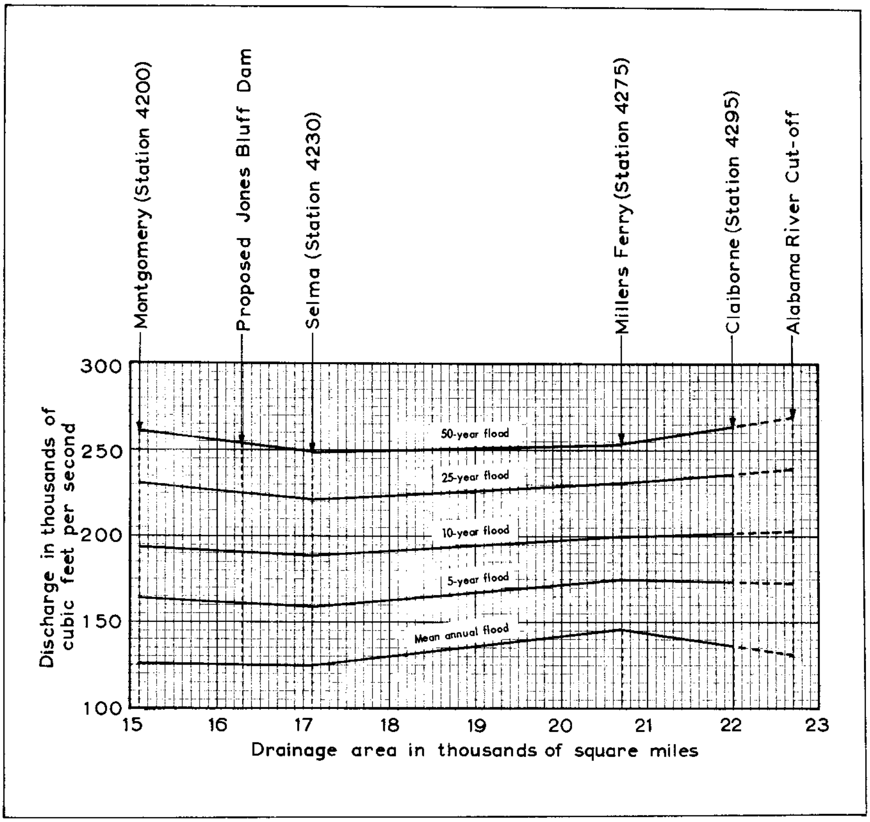


Figure 32.—Variation of flood discharge with drainage area, for selected recurrence intervals, Alabama River.

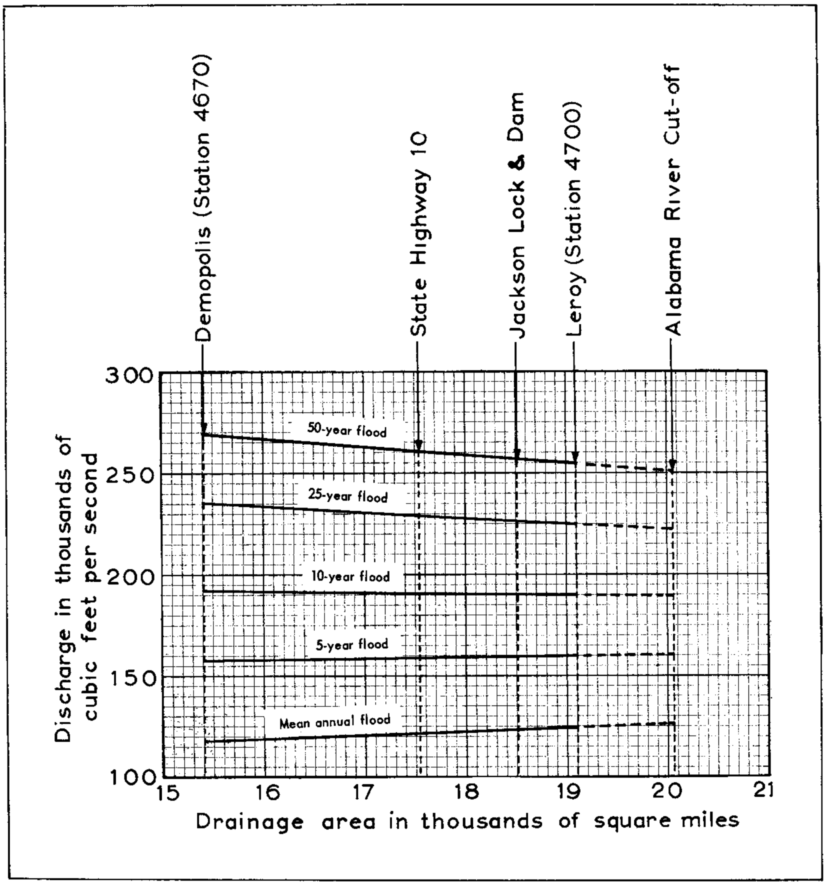


Figure 33.—Variation of flood discharge with drainage area, for selected recurrence intervals, Tombigbee River.

flood, all of this low-lying interior terrain is overflowed, and the river occupies the entire width of the flood plain, which ranges from 5½ to 9 miles.

Floods in Mobile River are caused by flooding of either or both the Alabama River and the Tombigbee River. Commonly both streams are in flood at the same time but to a different degree, depending upon storm characteristics over their respective watersheds.

A gaging station on Mobile River at Mt. Vernon (Station 4705) was operated for only 1 year. Longer records, however, are available for the Alabama River at Claiborne (Station 4295) and for the Tombigbee River at Lock 1 (Station 4700). Together, these stations gage runoff from 41,100 square miles, or about 95 percent of the Mobile River basin above Mt. Vernon. Streamflow records at Claiborne and Lock 1 are available concurrently for the water years 1931-61 and provide a basis for estimating annual floods in Mobile River for the 31-year period. As a statistical sample, this period is not long enough to yield a very dependable appraisal of flood frequency; however, the appraisal can be much strengthened by including information available on floods outside the period of record.

Historically, there are references to unusual floods in the lower Alabama and Tombigbee Rivers occurring in May 1874, April 1886, April 1900, July 1916, and April 1929. Factual information regarding these floods is varied and includes high-water elevations at one or more places along the rivers, statements by local residents as to relative flood magnitudes, and rainfall records. Based on this information, peak discharges for these five historic floods have been estimated for inclusion in the frequency study.

The resulting flood-frequency curve for Mobile River is shown in figure 34. It is applicable to any location on the river below the confluence of the Alabama and Tombigbee Rivers.

FLOOD PROFILES

When circumstances permit, the simplest and most effective method of protecting against floodwaters is to remain beyond their reach. A useful device for appraising the elevation necessary to provide security against floods is the flood profile, which is constructed by drawing lines between known flood-crest elevations

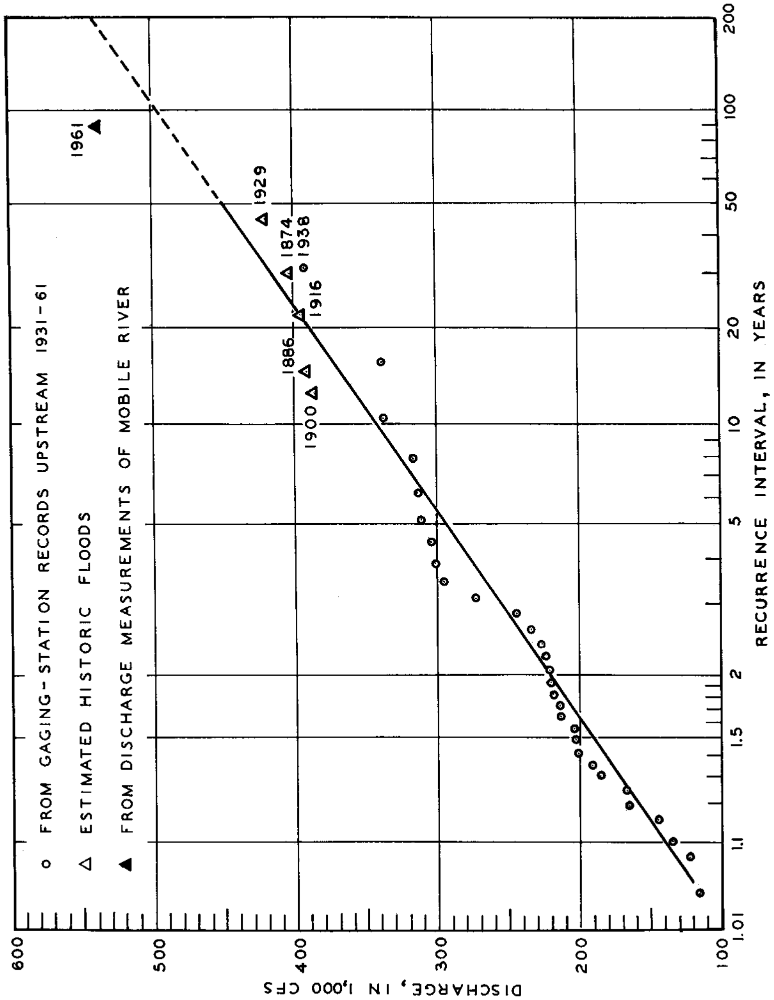


Figure 34.—Frequency of annual floods of Mobile River.

plotted in their respective locations along the stream. Although the resulting profile does not properly represent the instantaneous slope of the water surface over long reaches of the stream, it does closely indicate the highest elevation reached by a particular flood at any location. The flood profile may be used in conjunction with a map showing ground elevations to appraise the possibility or extent of inundation at a particular locality along the stream.

Profiles for the flood of February-March 1961 are shown in figure 35 for the Alabama River and in figure 36 for the Mobile and Tombigbee Rivers.

The flood of 1961 was selected for this purpose because of its excellent documentation (Barnes and Somers, 1961; Corps of Engineers, 1963) and its unusual magnitude. It is the greatest flood known on the Mobile River, with an estimated recurrence interval of about 200 years. It is also the greatest flood known on the Alabama River downstream from Selma, with estimated recurrence intervals of over 100 years at Selma, 85 years at Millers Ferry, and 60 years at Claiborne. On the Tombigbee River from Demopolis downstream, the flood of 1961 is the third highest known, with estimated recurrence intervals of 35 years at Demopolis and 50 years at Lock 1. Table 14 compares crest elevations of the 1961 flood with those of other known major floods at important locations on the Alabama and Tombigbee Rivers.

FLOOD ELEVATIONS IN MOBILE BAY

The flood profile of figure 36 shows that the flood of 1961—the greatest known in Mobile River—produced a crest elevation of only about 2 feet above mean sea level near the mouth of the river and the head of Mobile Bay. Considerably higher water levels along the shores of Mobile Bay have been caused by unusual tidal effects, independently of floods in Mobile River. Unusually high tides in Mobile Bay are occasionally produced by strong winds associated with tropical hurricanes, especially when these winds are from the south. Some of the highest hurricane tides at Mobile reported by the U.S. Weather Bureau are as follows:

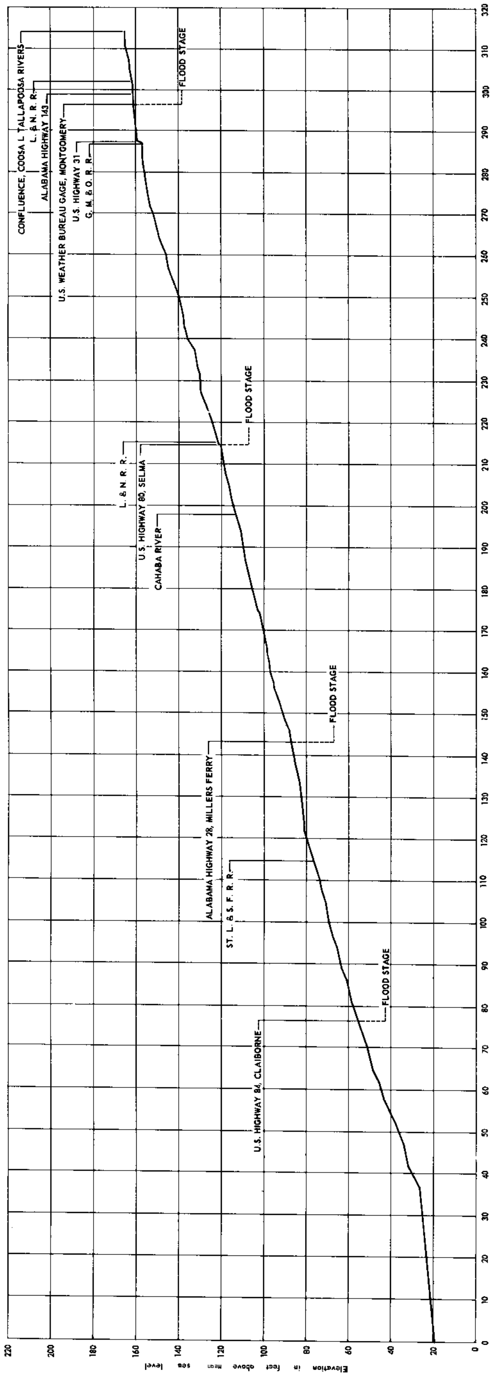


Figure 35.--Flood profile of Alabama River for flood of February-March 1961.

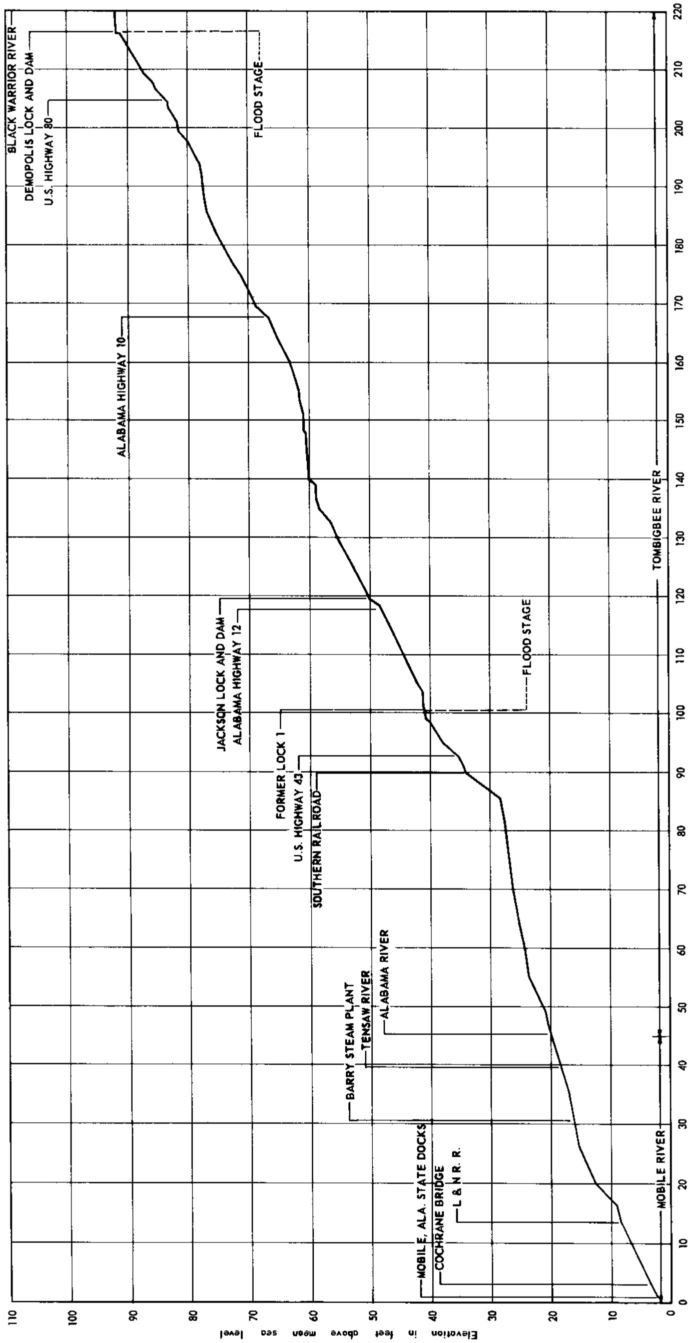


Figure 36.—Flood profile of Mobile and Tombigbee Rivers for flood of February-March 1961.

Date	High tide elevation (feet above msl)
July 5, 1916	10.8
Sept. 27, 1906	9.1
Oct. 2, 1893	8.4
1852	8.0
Aug. 15, 1901	7.4

WATER QUALITY OF SELECTED STREAMS IN SOUTHWESTERN ALABAMA

By Stanley M. Rogers

Whenever water contacts the dusts of the air or soils and rocks on the earth's surface or under the ground, the usual result is dissolution of these earth materials with an increase in the mineral content of the water. The earth's crust varies in chemical composition over its expanse and contributes mineralization to the water that corresponds with the varied composition of the earth's crust. The earth's water follows an unceasing cycle in its movement from the atmosphere to the earth's surface, on ocean or land, and back to the atmosphere. A part of the water that falls as rain or snow onto the earth's land surface follows a varied path on its journey to the sea. A part of the water enters the ground where it may be delayed in its journey to the sea for many years. Where the ground is saturated or the water cannot rapidly penetrate the ground surface, streams and rivers are formed to flow over the earth's surface and traverse many kinds of rocks before reaching the sea. Ground water contacts a greater quantity of minerals and for a longer time than surface water and therefore is usually more mineralized. During extended periods of time when the rain or snow does not sustain the flow of the rivers and streams, the amount of ground water in the streams increases in proportion to the amount of surface water. Where the ground water is highly mineralized or contains undesirable minerals, the water may be limited in use to man.

Long ago, man used his senses of taste and smell to determine the suitability of water in the rivers, lakes, and springs for his use, and frequently named certain localities according to the quality of the water to be found there—Goodwater, Badwater, Sweetwater, Bittersprings, and the like. However, modern methods of chemical and physical analysis identify and determine the quantity of most minerals in the water in parts chemical constituent per million parts water. Man has learned, from past experience, the identity and quantities of chemicals that may be tolerated in water for certain uses. The criteria for water quality for any use are determined by this past experience. As man finds new uses for water, the suitability of any stream water for these uses will depend upon its range in chemical composition. The chemical composition and character of stream water usually changes with streamflow or from the introduction of natural or man-made contaminants.

SCOPE AND PURPOSE OF SAMPLING PROGRAM

The sampling program provides stream discharge, stream temperature, and chemical analysis data of selected streams from the Mobile, Perdido, Fish, and Pascagoula River basins within southwestern Alabama. Tombigbee River and eight tributary streams, Alabama River and seven tributary streams, Mobile River and two tributary streams, Perdido River and one tributary stream, Fish River, and Escatawpa River—a tributary of the Pascagoula River—were included in the sampling program or represented by streamflow, stream temperature, and chemical analysis data of record.

All sampling sites are near U.S. Geological Survey stream gaging stations and the gaging station numbers and titles describe the programmed sampling sites. Sampling site locations are identified by gaging station numbers on plates 1 and 2 and are described in Appendix A.

The sampling program data describe (1) the chemical composition of stream waters at high flow and low flow (table 18), (2) the chemical character as a water type at high and low flows, (3) the high flow-low flow trend of change in water type, (4) the chemical character of the ground water predominantly influencing base flow of some streams, and (5) the quality of streams at high and low flow. The chemical composition of the streams as represented by the sampling program are given in table 18. The chemical character of the waters shown on plate 2 are after Piper (1944).

CHEMICAL COMPOSITION AND CHARACTER OF STREAM WATERS AT HIGH AND LOW FLOW

PERDIDO RIVER AND TRIBUTARIES

3765. PERDIDO RIVER NEAR BARRINEAU PARK, FLA.

The index low flow (median annual 7-day low flow) of Perdido River at this location is 275 cfs, which is exceeded as a daily flow about 93 percent of the time. The stream was sampled at a discharge of 1,640 cfs, which is exceeded 8 percent of the time, and at that discharge contained a sodium chloride type water.

3775. STYX RIVER NEAR LOXLEY, ALA.

The index low flow of Styx River at this location is 40 cfs, which is exceeded about 87 percent of the time. Samples of stream water were taken at a high flow of 740 cfs (exceeded 2 percent of the time) and at a low flow of 42 cfs (exceeded 86 percent of the time). The stream water at high flow and low flow is a sodium chloride type water with a trend toward a sodium bicarbonate type water at low flow. Significant changes in chemical composition are the increase in sodium and bicarbonate contents with diminished flow that is accompanied by a decreased sulfate content.

Geologic units considered to influence the base flow of the river are the Citronelle Formation and Miocene sediments.

FISH RIVER

3785. FISH RIVER NEAR SILVER HILL, ALA.

The index low flow of Fish River at this location is 61 cfs, which flow is exceeded about 80 percent of the time. The river was sampled at a high flow of 160 cfs (exceeded 15 percent of the time) and at a discharge of 62 cfs (exceeded 79 percent of the time). The river is a sodium chloride type water at both high and low flows

Table 18.—*Chemical composition of selected streams in southwestern Alabama*

(Chemical constituents are in parts per million. Analyses are by U.S. Geological Survey unless otherwise indicated.)

Date of collection	Laboratory number	Discharge (cfs)	Approximate percent of time discharge is exceeded	Silica (SiO_2)	Iron (Fe)	Iron in solution (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	Temperature (°F)
																Residue on evaporation (180° C)	Sum of determined constituents	Calcium, magnesium	Noncarbonate			
							PERDIDO RIVER BASIN															
						2-3765. Perdido River at Barrineau Park, Fla.																
5- 7-53	0-565	1,640	08	5.5	....	0.28	0.6	0.4	1.8	0.2	3	1.0	3.0	0.0	0.1	34	...	3	..	20	5.3	..
						2-3775. Styx River near Loxley, Ala.																
4- 2-62	Ala. 482	740	03	3.2	....	.08	.5	.2	1.4	.3	1	.4	2.8	.0	.3	30	10	2	1	20	5.0	61
11- 6-62	Ala. 617	42.0	86	6.5	....	.07	1.0	.1	3.0	.8	6	.0	3.8	.1	.2	20	19	3	0	21	6.6	..
							FISH RIVER BASIN															
						2-3785. Fish River near Silver Hill, Ala.																
4- 2-62	Ala. 472	160	15	5.5	....	.07	.0	.5	2.3	1.1	2	.6	4.1	.0	.3	25	16	2	0	23	5.2	61
11- 6-62	Ala. 607	62.0	79	6.2	....	.07	.8	.2	4.8	.8	7	1.6	5.0	.0	.6	26	23	3	0	22	7.1	57
							MOBILE RIVER BASIN															
						2-4200. Alabama River near Montgomery, Ala.																
12- 1-52	....	5,000	99	7.6	0.28	.05	13	4.5	6.3	1.2	58	8.6	5.8	.1	.9	77	...	51	3	126	7.3	..
4- 2-62	Ala. 485	60,400	07	4.7	....	.04	9.4	1.6	3.2	1.1	33	5.2	4.0	.1	.3	51	46	30	3	77	6.1	..
11- 7-62	Ala. 604	8,090	87	2.9	....	.03	19	3.5	20	2.3	57	37	16	.3	.2	149	129	62	15	225	6.8	62
						2-4210. Catoma Creek near Montgomery, Ala.																
4- 2-62	Ala. 477	5,290	01	4.3	....	.14	16	.5	1.8	1.2	50	1.4	3.0	.1	.3	74	54	42	1	97	6.3	..
11- 5-62	Ala. 622	.06	97	.7	....	.02	54	1.7	3.7	2.5	164	7.6	4.7	.2	.1	167	156	142	7	274	7.3	..

2-4220. Big Swamp Creek near Lowndesboro, Ala.																						
4- 2-62	Ala. 479	2,940	02	3.9	....	.21	19	.6	1.6	.8	60	1.6	2.0	.1	.3	93	60	50	1	111	6.5	..
11- 5-62	Ala. 605	.3	92	2.5	....	.05	44	.8	6.7	2.7	141	.0	10	.2	.2	152	136	113	0	247	7.3	54
2-4225. Mulberry Creek at Jones, Ala.																						
2- 1-49	2125	555	15	7.8	....	.11	1.4	.8	2.3	.4	4	2.7	4.0	0	.7	28	23	7	4	26	7.1	..
9-21-49	2999	170	51	8.9	....	.15	1.8	1.3	2.0	.8	6	3.3	4.5	.1	1.4	33	28	10	5	28	7.0	..
2-4230. Alabama River at Selma, Ala.																						
4- 2-62	Ala. 476	63,000	09	6.3	....	.03	11	1.6	3.2	1.3	38	5.4	3.3	.3	.3	56	52	34	3	83	6.2	..
11- 7-62	Ala. 601	7,100	96	3.6	....	.02	10	2.4	7.4	1.3	46	4.2	7.2	.1	.5	66	60	35	0	104	6.8	58
2-4250. Cahaba River near Marion Junction, Ala.																						
2- 1-49	2126	6,850	08	8.2	....	.02	7.8	3.0	3.9	.6	32	9.5	3.0	0	.9	59	54	32	6	81	7.7	..
9-21-49	2988	1,090	55	6.9	....	.01	18	7.0	2.6	.5	76	8.1	3.5	0	1.4	86	86	74	11	149	7.4	..
2-4272.50. Pine Barren Creek near Snow Hill, Ala.																						
4- 2-62	Ala. 474	3,860	..	7.5	....	.32	7.0	.4	1.8	1.5	21	4.6	2.1	.1	.3	61	36	19	2	50	6.1	60
11- 6-62	Ala. 599	32.0	..	5.4	....	.14	7.0	.4	2.5	.7	24	.0	4.0	.0	.2	44	32	19	0	52	6.8	52
2-4277. Turkey Creek at Kimbrough, Ala.																						
4- 3-62	Ala. 487	137	..	13	....	.15	9.9	2.3	5.8	.9	28	17	5.0	.1	.2	86	68	34	11	101	6.2	..
11- 5-62	Ala. 619	5.0	..	8.3	....	.18	9.0	2.3	7.1	1.6	40	4.8	7.6	.1	.3	63	61	32	0	99	7.2	..
2-4285. Flat Creek at Fountain, Ala.																						
4- 2-62	Ala. 473	4,090	01	8.3	....	.49	3.0	.4	1.8	1.2	8	4.6	1.9	.0	.3	70	62	9	2	33	6.2	62
11- 5-62	Ala. 620	9.7	90	9.4	....	.34	12	1.9	4.8	1.6	49	4.6	3.1	.1	.3	65	62	38	0	102	7.1	..
2-4295. Alabama River at Claiborne, Ala.																						
10- 4-53	1964	19,900	50	5.4	.53	.23	9.8	1.8	3.1	1.6	37	5.5	2.4	.2	.4	72	...	32	..	85	7.1	..
2-4296.50. Majors Creek near Tensaw, Ala.																						
4- 2-62	Ala. 470	234	..	5.5	....	.13	1.2	.0	1.4	.9	3	.8	2.5	.0	.3	34	14	3	1	17	5.3	61
11- 7-62	Ala. 606	23.4	..	5.8	....	.16	2.0	.0	2.5	.5	7	.0	4.0	.0	.2	27	18	5	3	18	7.2	51
2-4670. Tombigbee River at Demopolis lock and dam, near Coatopa, Ala.																						
4- 3-62	Ala. 488	63,200	11	4.7	....	.02	12	2.0	5.5	1.1	38	13	4.9	.1	.1	69	62	38	7	107	6.0	..
11- 6-62	Ala. 600	2,320	85	3.6	....	.02	9.8	2.6	6.7	1.2	42	7.6	5.0	.1	.0	65	58	35	0	102	6.7	64
2-4675. Sucarnoochee River at Livingston, Ala.																						
4- 3-62	Ala. 484	3,040	05	7.5	....	.16	4.8	1.0	2.3	1.2	15	7.2	1.5	.1	.3	54	33	16	4	51	5.8	..
11- 6-62	Ala. 598	131	82	7.3	....	.27	3.5	.3	4.1	1.1	17	.0	4.5	.0	.2	49	29	10	0	45	6.5	52
2-4680. Alamuchee Creek near Cuba, Ala.																						
11- 4-59	28323	12.5	65	11	....	.00	4.8	1.8	4.4	1.9	21	9.2	3.5	.0	.0	65	47	20	2	64	6.4	..
6-13-60	28913	10	72	10	....	.01	6.0	2.2	5.2	1.2	31	7.2	3.5	.1	.7	68	51	24	0	75	7.0	..

Table 18.—*Chemical composition of selected streams in southwestern Alabama*—Continued

Date of collection	Laboratory number	Discharge (cfs)	Approximate percent of time discharge is exceeded	Silica (SiO_2)	Iron (Fe)	Iron in solution (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids: Residue on evaporation (180° C)	Dissolved solids: Sum of determined constituents	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Temperature (° F)
MOBILE RIVER BASIN—Continued																						
2-4690. Kinterbish Creek near York, Ala.																						
11- 4-59	28322	57	38	4.5	....	0.00	2.9	1.1	2.5	1.1	13	5.0	3.0	0.0	0.1	46	27	12	1	41	6.3	..
6-13-60	28907	17	78	8.6	....	.24	3.1	1.7	2.9	.8	18	3.4	2.0	.1	1.7	44	33	14	0	45	6.8	..
2-4695. Tuckabum Creek near Butler, Ala.																						
4- 3-62	Ala. 483	259	09	13	....	.18	3.0	1.1	3.7	1.1	10	8.2	3.4	.1	.2	57	39	12	4	48	5.8	..
11- 6-62	Ala. 602	5.0	90	15	....	.64	9.1	2.2	15	2.0	63	5.0	6.3	.1	.4	100	87	32	0	129	6.9	57
2-4695.5. Horse Creek near Sweetwater, Ala.																						
4- 3-62	Ala. 475	76	..	13	....	.26	5.5	1.5	4.1	1.3	15	12	4.5	.0	.3	62	50	20	8	68	6.0	..
11- 5-62	Ala. 596	3.7	..	9.4	....	.28	2.5	.4	4.6	1.1	12	.0	6.9	.0	.4	45	32	8	0	37	6.0	..
2-4697. Okatuppa Creek at Gilbertown, Ala.																						
4- 3-62	Ala. 489	336	16	15	....	.10	17	2.3	12	1.2	49	10	21	.1	.1	124	103	52	12	175	6.5	..
11- 6-62	Ala. 623	16.5	87	12	....	.03	53	7.7	214	2.9	90	17	380	.2	.2	793	731	164	90	1,340	7.3	..
2-4698. Satilpa Creek near Coffeeville, Ala.																						
4- 3-62	Ala. 486	390	15	14	....	.13	10	1.7	3.4	.8	36	5.6	3.0	.1	.2	71	57	32	2	78	6.3	..
11- 5-62	Ala. 603	14	96	7.3	....	.33	24	1.2	2.8	.6	76	.0	5.5	.1	.2	90	79	65	3	135	7.1	53
2-4700. Tombigbee River near Leroy, Ala.																						
10- 4-53	1962	1,840	96	.7	0.24	.01	21	2.1	18	1.4	68	16	24	.1	.1	120	...	61	..	222	7.4	..
4- 3-62	Ala. 478	66,000	13	5.9	....	.01	14	1.2	4.6	1.4	44	8.8	4.1	.1	.3	78	62	40	5	103	6.4	63
11- 7-62	Ala. 621	....	..	3.6	....	.06	20	2.7	23	2.2	58	25	30	.3	.1	161	136	61	13	237	6.9	..

						2-4702.05. West Bassett Creek at Bassett Creek, Ala.																
4- 3-62	Ala. 481	1,140	. .	4.3	. . . .	.07	.6	.1	1.4	.2	2	.8	1.5	.1	.3	31	10	2	0	20	5.0	59
11- 5-62	Ala. 618	19	. .	7.3	. . . .	.19	1.0	.1	2.3	.5	5	.0	3.0	.1	.3	20	17	3	0	21	6.1	. .
						2-4705. Mobile River near Mt. Vernon, Ala.[1]																
2-10-54	. . . .	[2]119,000	11	7.4	. . . .	.07	9.7	1.4	3.8	1.5	29	10	3.5	.1	1.1	81	. . .	30	6	90	7.3	. .
8-10-54	. . . .	[2]8,170	98	9.8	. . . .	.08	12	3.8	8.3	1.2	56	7.8	9.0	.1	.5	80	. . .	46	0	139	7.2	. .
						2-4710. Chickasaw Creek near Whistler, Ala.																
10- 3-53	1963	87	82	7.1	.40	.23	.4	.6	2.5	.2	4	2.5	2.8	.1	.1	33	. . .	3	. .	20	5.9	. .
4- 3-62	Ala. 471	645	07	5.9	. . . .	.08	1.2	.0	1.6	1.2	5	.4	2.5	.0	.3	25	15	3	0	18	5.3	. .
11- 6-62	Ala. 616	95	79	5.8	. . . .	.14	1.0	.1	2.8	.6	6	.0	3.1	.1	.2	23	17	3	0	19	6.3	. .
						PASCAGOULA RIVER BASIN																
						2-4795. Escatawpa River near Wilmer, Ala.																
10- 3-53	1961	110	94	7.9	.51	.24	.6	.4	2.5	.2	4	2.0	3.2	.1	.2	30	. . .	3	. .	22	6.1	. .
4- 3-62	Ala. 480	4,060	04	3.5	. . . .	.07	.5	.2	2.3	.2	4	.8	2.0	.1	.3	31	12	2	0	18	5.5	59
11- 6-62	Ala. 597	118	92	8.0	. . . .	.12	2.4	.5	3.4	.4	3	.0	9.6	.0	.3	31	26	8	6	37	5.8	51

[1] Analyses reprinted from Robinson and others, 1956.
[2] 10-day average discharge for composited sample.

but trends toward a sodium bicarbonate type water with lessened flow. Significant changes in chemical composition are the increase in sodium and bicarbonate content of the river with diminished streamflow that is accompanied by a slight increase in sulfate content.

Geologic units of significance in their effect on the base flow of the stream are the Citronelle Formation and Miocene sands.

PASCAGOULA RIVER TRIBUTARIES

4795. ESCATAWPA RIVER NEAR WILMER, ALA.

The index low flow of Escatawpa River at this location is 103 cfs, which flow is exceeded about 95 percent of the time. The river was sampled at a high flow of 4,060 cfs (exceeded 4 percent of the time) and again at a low flow of 118 cfs (exceeded 92 percent of the time). Significant changes in chemical composition are the increase in calcium, sodium, and chloride contents with diminished streamflow that is accompanied by a decrease in bicarbonate and sulfate contents. The river contains a sodium chloride type water at high flow and a calcium chloride type water at low flow. The trend of change in water type for this river is an exception for the streams adjacent to the river basin and below the confluence of the Tombigbee and Alabama Rivers.

SUMMARY: PERDIDO, FISH, AND PASCAGOULA RIVER BASINS

The selected tributary streams in river basins south of the confluence of the Tombigbee and Alabama Rivers, as well as Majors Creek and West Bassett Creek, contain a sodium chloride or sodium bicarbonate type water at high flow and become sodium bicarbonate or trend toward sodium bicarbonate type waters at low flow. The Escatawpa River is the one exception in its high flow-low flow trend of change in water types. West Bassett Creek and the Escatawpa River contain water of very similar chemical character during high flow stages but exhibit dissimilar trends in water type at low flow discharges. Headwaters of both streams drain the same geologic formation with West Bassett Creek showing a trend of change in water type at low flow discharge that is very similar to other streams in the group. Chloride concentrations above the normal for Puppy Creek and Beaver Pond Branch, tributaries to the

Escatawpa, have been noted (Powell and others, 1963, p. 42). The chloride content of these tributaries may be the reason for the reversal in trend for the Escatawpa River at low flow.

ALABAMA RIVER AND TRIBUTARIES

4200. ALABAMA RIVER NEAR MONTGOMERY, ALA.

The Alabama River near Montgomery was sampled at a high-flow discharge of 60,400 cfs (exceeded 7 percent of the time) and a low-flow discharge of 8,090 cfs (exceeded 87 percent of the time). The river water increased in concentration for all constituents except silica and iron from high to low flow. Significant increases in calcium, sodium, and sulfate content of the river water changes the chemical character from a calcium magnesium bicarbonate type water at high flow to a calcium magnesium sulfate chloride type at low flow. The high flow-low flow trend of change in water type is toward a sodium sulfate chloride type water (pl. 2, table 18).

4210. CATOMA CREEK NEAR MONTGOMERY, ALA.

The index low flow of Catoma Creek at the sampling site is 0.4 cfs, which discharge is exceeded about 90 percent of the time. The basin contains very few flowing wells and is not an area of abundant ground-water discharge (Knowles and others, 1960, pl. 1). The stream was sampled at a high-flow discharge of 5,290 cfs (exceeded 1 percent of the time) and at a low-flow discharge of 0.06 cfs (exceeded 97 percent of the time). The stream water increases in content for all chemical constituents with the exception of iron and silica (table 18). The dissolved solids content increases from 74 ppm to 167 ppm with diminished streamflow. The chemical character of the stream waters remains a calcium magnesium bicarbonate type and varies only slightly in chemical composition over a rather wide range of streamflow variation (pl. 2).

The basin lies wholly within the Black Prairie belt which is characterized by the presence of a thin soil overlying rather impermeable rock. The very low basin yield per unit area during periods of low flow and the uniformity in chemical character for extremes in streamflow indicate either very little ground-water contribution by the geologic formations or a remarkable uniformity in the effect of the surficial geologic formations on the character of the stream's base flow.

4220. BIG SWAMP CREEK NEAR LOWNDESBORO, ALA.

Big Swamp Creek has the lowest yield during low flow periods of any of the streams considered in the study. The index low flow is 0.1 cfs, which is exceeded 95 percent of the time. Discharge at high flow sampling was 2,940 cfs (exceeded 2 percent of the time) and at low flow was 0.3 cfs (exceeded 92 percent of the time). The stream increases in calcium, magnesium, sodium, potassium, bicarbonate, chloride, and in dissolved solids content with diminishing streamflow. The sulfate content of the water decreases. The stream changes in chemical character very little over a wide range in streamflow and remains a calcium magnesium bicarbonate type water at high and low flow.

Geologic units traversed by the stream are the Eutaw and Ripley Formations and Recent alluvium that are underlain by the Selma Group. The Mooreville and Demopolis Chalks crop out in the basin and probably contribute abundant calcium and magnesium. There is no evidence to indicate that ground waters of high chloride concentrations are discharging into the surface stream (Scott, 1957, pl. 3).

4225. MULBERRY CREEK AT JONES, ALA.

Mulberry Creek is outside the project area but shows a significant influence on the Alabama River and for this reason it is included in the discussion of the tributary streams of the Alabama. The index low flow of the Mulberry Creek is 65 cfs, which flow is exceeded about 94 percent of the time. The stream was sampled at a high-flow discharge of 555 cfs (exceeded 15 percent of the time) and at a discharge of 170 cfs (exceeded 51 percent of the time). The variation in discharge of streamflow does not constitute a normal range for high and low flow sampling, but the river shows enough variation in chemical composition to establish a trend of change in water type. The river increases in calcium, magnesium, potassium, bicarbonate, sulfate, chloride, and dissolved solids contents with diminishing discharge. The dissolved solids content of this stream is low in comparison with the tributaries previously considered. The stream water is a calcium magnesium chloride type water in the range of discharge sampled. The significant changes in chemical composition are the increase in calcium, magnesium, bicarbonate, and sulfate content of the river.

4230. ALABAMA RIVER AT SELMA, ALA.

The Alabama River at Selma was sampled at a high-flow discharge of 63,000 cfs (exceeded 9 percent of the time) and at a low-flow discharge of 7,100 cfs (exceeded 96 percent of the time). The river is a calcium magnesium bicarbonate type water at high- and low-flow discharges. However, the trend of change in chemical character is toward a sodium bicarbonate type water. The sodium, bicarbonate, chloride, and dissolved solids content of the river increases with diminished streamflow that is accompanied by a decrease in calcium and sulfate content (pl. 2, table 18).

A significant decrease in the dissolved solids content of the river water occurs in the reach between Montgomery and Selma during low-flow periods. Presumably, well-sustained streams of low dissolved solids content, such as Mulberry Creek, have a greater influence on the river than poorly sustained streams containing higher concentrations of dissolved solids such as Catoma and Big Swamp Creeks. This reach of the Alabama River is paralleled by the fall line that divides the upland regions from the Coastal Plain of Alabama.

4250. CAHABA RIVER NEAR MARION JUNCTION, ALA.

The Cahaba River at this location has an index low flow of 400 cfs, which flow is exceeded about 93 percent of the time. The river was sampled at a discharge of 6,850 cfs (exceeded 8 percent of the time) and again at a discharge of 1,090 cfs (exceeded 55 percent of the time). The stream water increases in calcium, magnesium, bicarbonate, chloride, and dissolved solids content with diminishing discharge that is accompanied by a decrease in sodium, potassium, and sulfate content. The stream is a calcium magnesium bicarbonate type water at high and low flow with a significant increase in calcium, magnesium, and bicarbonate content at low flow.

The Cahaba River is another tributary of the Alabama River outside the report area that contributes significantly to the chemical composition of the Alabama River. Geologic formations influencing streamflow are the Coker and Gordo (Monroe, 1941, pl. 1).

4272.5. PINE BARREN CREEK NEAR SNOW HILL, ALA.

The index low flow of Pine Barren Creek at this location is 27 cfs. The stream was sampled at 3,860 cfs and again at 32.0 cfs discharge. The water remains calcium magnesium bicarbonate type water at high and low flow. The significant changes in chemical composition are the increase in sodium and bicarbonate content accompanied by a decrease in sulfate with lessened streamflow.

Geologic formations thought to influence the character of the stream at base flow are the Nanafalia and Clayton (MacNeil, 1946).

4277. TURKEY CREEK AT KIMBROUGH, ALA.

The index low flow of Turkey Creek at this location is 2 cfs. Samples of stream water were obtained at discharges of 137 and 5 cfs. Sodium, potassium, bicarbonate, and chloride content of the stream increased with lessened streamflow that was accompanied by a decrease in calcium, sulfate, and dissolved solids. The increase in bicarbonate accompanied by a decrease in sulfate content changes the chemical character of the water from a calcium magnesium chloride type at high flow to a calcium magnesium bicarbonate type water at low flow (pl. 2, table 18).

Geologic formations considered to contribute mineralization to low flow of the stream are the Nanafalia and the Tuscahoma that crop out adjacent to the stream basin. The trend of change in chemical character is not toward the composition of ground waters in the Nanafalia or Tuscahoma that are available from record (LaMoreaux and Toulmin, 1959, table 3). The chemical character is very near that of water in the alluvium of an adjacent stream valley

(Horse Creek) whose headwaters drain the same geologic environment. The Horse Creek basin is an area of artesian ground-water discharge (Newton and others, 1961, pl. 2), where the base flow of the stream is influenced by the discharge from flowing artesian wells. In contrast, the Turkey Creek basin is not an artesian area and the chemical character of the stream's base flow is unrelated to ground waters selected from the underlying formations. The dissolved solids content of streams in both basins increases with streamflow which indicates that runoff and bank storage waters contact a more readily leached geologic formation than the underlying formations. The chemical character of the high-flow samples for both basins are very similar but that of the low-flow samples are very dissimilar. The character of ground water in the Nanafalia Formation and Tuscahoma Sand in the outcrop area may differ from that of the well waters in the Horse Creek basin. It is quite possible that the stream is influenced during base flow by the outcrop area of these formations and not by the alluvium of Turkey Creek basin.

4285. FLAT CREEK AT FOUNTAIN, ALA.

The index low flow of Flat Creek at this location is 8 cfs, which flow is exceeded about 92 percent of the time. The stream was sampled at a high-flow discharge of 4,090 cfs and at a low-flow discharge of 9.7 cfs. The higher discharge is exceeded only 1 percent of the time and the lower discharge is exceeded 90 percent of the time. The chemical character of the stream water at high flow is calcium magnesium chloride type but at low flow is a calcium magnesium bicarbonate type water (pl. 2, table 18). Significant changes in chemical composition are increases in calcium, magnesium, and bicarbonate content of the stream water. The sulfate content remains unchanged and the dissolved solids content changes very little with diminished streamflow.

Geologic units within the stream basin are the Tuscahoma Sand, Lisbon Formation, and Recent terraces.

4295. ALABAMA RIVER AT CLAIBORNE, ALA.

The Alabama River at Claiborne was sampled at a discharge of 19,900 cfs, which flow is exceeded about 50 percent of the time.

At this discharge, the river at Claiborne contains a calcium magnesium bicarbonate type water that is very similar to that at Montgomery and Selma during high-flow discharges (pl. 2, table 18).

SUMMARY: ALABAMA RIVER AND TRIBUTARIES

At high flow, the Alabama River contains a calcium magnesium bicarbonate type water near Montgomery, at Selma, and at Claiborne (pl. 2). The chemical characters of the water at these three sampling sites are very similar and comparable with the chemical character of the Mobile River near Mt. Vernon during periods of high flow in the Mobile River. A significant decrease in dissolved solids content of the Alabama River occurs between Montgomery and Selma. The well-sustained yield of dilute water by southward-flowing tributaries affects the dissolved solids content of the Alabama River more than does the poorly sustained yield of more concentrated water by northward-flowing tributaries. The net result is a more dilute river water at Selma than at Montgomery. The high-low flow trend of water types differs at the Montgomery and Selma sampling sites. These differing trends may result from impoundment of the river above Montgomery or from differing geologic environment above and below the Fall Line.

Four of the eight tributaries of the Alabama River discharge a calcium magnesium bicarbonate type water at both high and low flows. Two streams discharge a calcium magnesium sulfate chloride type water at high flow and a calcium magnesium bicarbonate at low-flow discharges. Mulberry Creek discharges a calcium magnesium chloride sulfate type water at both high and low flow discharges.

One stream, Turkey Creek at Kimbrough, discharges from a nonartesian area and the character of the stream's base flow is unrelated to that of waters in the underlying geologic formations. The evidence available indicates that the base flow is influenced primarily by ground water very similar to water from the alluvium in an adjacent stream (Horse Creek).

TOMBIGBEE RIVER AND TRIBUTARIES

4670. TOMBIGBEE RIVER AT DEMOPOLIS LOCK AND DAM NEAR COATOPA, ALA.

The Tombigbee River at this station was sampled at a high-flow discharge of 63,200 cfs and a low-flow discharge of 2,320 cfs. The high-flow discharge is exceeded only 11 percent of the time and the low flow is exceeded 85 percent of the time. The magnesium, sodium, and bicarbonate content of the river water increases with diminished discharge accompanied by a decrease of calcium and sulfate. Potassium and chloride content remain approximately the same and dissolved solids content decreases slightly. The river is a calcium magnesium bicarbonate type water at high and low flow. Significant changes in chemical composition are the increase in sodium and bicarbonate content accompanied by a decrease in sulfate content.

4675. SUCARNOOCHEE RIVER AT LIVINGSTON, ALA.

The index low flow of Sucarnoochee River at this location is 92 cfs, which flow is exceeded about 95 percent of the time. The stream was sampled at a high-flow discharge of 3,040 cfs (exceeded 5 percent of the time) and resampled at a low-flow discharge of 131 cfs (exceeded 82 percent of the time).

Geologic units traversed by the stream within the project area are the Ripley and Nanafalia Formations, Tuscahoma Sand, and Recent terraces. Analyses of ground waters discharging into the stream are unavailable for comparison with the chemical composition of the stream base flow. The stream water at high flow is characterized by its chemical composition as a calcium magnesium bicarbonate type water (pl. 2, table 18). The stream decreases in calcium, magnesium, and in sulfate content with diminished flow and increases in sodium, bicarbonate, and chloride content. The stream is a sodium bicarbonate type water at low flow. The mineral content of the stream water decreases with lessened streamflow.

4680. ALAMUCHEE CREEK NEAR CUBA, ALA.

The index low flow of Alamuchee Creek at this site is 5.7 cfs, which flow is exceeded about 89 percent of the time.

Although the stream was sampled only at moderately low flows of 12.5 cfs and 10 cfs, the chemical character of the stream water shows some change (pl. 2, table 18). Stream water increases in calcium, magnesium, sodium, bicarbonate, and dissolved solids content with diminished discharge while potassium and sulfate decrease in content. The chloride content remains the same. The change in chemical composition does not change classification of the stream water as a water type. The most significant changes are the increases in calcium and bicarbonate with the loss in sulfate content. The principal geologic units influencing the chemical character of the base flow are the Nanafalia Formation and Tuscahoma Sand and possibly the alluvium of the river valley (oral communication, J. G. Newton, 1964).

4690. KINTERBISH CREEK NEAR YORK, ALA.

The index low flow of Kinterbish Creek at this site is 12 cfs, which flow is exceeded about 87 percent of the time. The stream was sampled at a discharge of 57 cfs (exceeded 38 percent of the time) and again at a discharge of 17 cfs (exceeded 78 percent of the time). Water in the stream at these discharges is a calcium magnesium bicarbonate type. Stream water increases in calcium, magnesium, and sodium content with diminished flow and decreases in sulfate and chloride content (pl. 2, table 18). Significant changes in composition are increase in calcium and bicarbonate content with a decrease in sulfate content.

The geologic units considered to influence the chemical character of the stream at base flow are the Nanafalia Formation, Tuscahoma Sand, and Recent alluvium. The similarity in the chemical composition of Alamuchee and Kinterbish Creeks at both high and low flows should be noted and the similarity in the trend of change in chemical composition for both streams. Headwaters of the streams are adjacent and the principal geologic formations exposed or underlying the basins are the same. Analyses of ground waters that discharge into the stream basin are unavailable for consideration of their effect upon the base flow of the stream. The basin is not shown to contain areas of artesian discharge (Toulmin and others, 1951, pl. 2).

4695. TUCKABUM CREEK NEAR BUTLER, ALA.

The index low flow of Tuckabum Creek at this site is 6.7 cfs, which flow is exceeded about 86 percent of the time. Tuckabum Creek was sampled at a high flow of 259 cfs (exceeded 9 percent of the time) and again at a low flow of 5.0 cfs (exceeded 90 percent of the time). At high flow the stream is a calcium magnesium chloride type water and at low flow is a sodium bicarbonate type water. The calcium, magnesium, potassium, bicarbonate, chloride, and dissolved solids content of the stream water increase with diminished flow of the stream whereas the sulfate content decreases. The significant changes in chemical composition affecting the chemical character of the water are the increase in sodium and bicarbonate content with a decrease in sulfate content.

Geologic units discharging water into the stream basin are the Tuscahoma Sand, Hatchetigbee Formation, and Recent terraces. Artesian discharge from these formations occur in the stream basin (Toulmin and others, 1951, pl. 2).

4695.5. HORSE CREEK NEAR SWEETWATER, ALA.

The index low flow of Horse Creek at this location is 2 cfs. The stream was sampled at a medium flow of 76 cfs discharge and again at a low-flow discharge of 3.7 cfs. The character of the stream at medium flow is calcium magnesium chloride type water and at low flow is a sodium chloride type. The chemical composition of the water places it very near the sodium bicarbonate type water (pl. 2, table 18). Stream water increases in sodium and chloride content, accompanied by a decrease in calcium, magnesium, potassium, bicarbonate, sulfate, and dissolved solids content with diminishing streamflow. Significant changes are the increase in sodium and chloride accompanied by a complete loss of sulfate content at low flow.

The geologic units considered to discharge ground water into the stream basin are the Nanafalia Formation, Tuscahoma Sand, and Recent alluvium. Analyses of ground water from these formations that were sampled within the basin are of record (Newton and others, 1961, table 4). The Nanafalia Formation is represented by chemical analysis of water from wells numbered BB-9 and DD-29, the Tuscahoma Sand by well numbered JJ-3, and the Recent alluvium by well numbered EE-15 in table 4. Extension of the trend line of change in chemical character from medium flow to low flow indicates that ground water discharging from the Nanafalia Formation exerts the major influence on the base flow of Horse Creek (pl. 2).

4697. OKATUPPA CREEK AT GILBERTOWN, ALA.

The index low flow of Okatuppa Creek at this site is 11 cfs, which flow is exceeded about 93 percent of the time. Stream samples were obtained at a high-flow discharge of 336 cfs (exceeded 16 percent of the time) and at a low-flow discharge of 16.5 cfs (exceeded 87 percent of the time). Stream water at high flow is calcium magnesium chloride type water and at low flow is sodium chloride type water. The stream water increases in content for all chemical constituents with the exception of iron and silica. The greatest increase is in sodium and chloride content. The dissolved solids content increases from 124 ppm to 793 ppm with diminishing streamflow. Okatuppa Creek has the greatest increase in dissolved solids for any stream considered in the southwestern Alabama area. The geologic formations discharging ground water within the basin area are the Hatchetigbee, Gosport, and Lisbon (Toulmin and others, 1951, pl. 2, table 1; wells numbered 102, 120, 124, 127, and 134). All ground waters discharging from wells listed above in this basin are sodium bicarbonate type waters (pl. 2, table 18). The change in chemical composition with diminished discharge toward a sodium chloride type water of 380 ppm chloride and a dissolved solids content of 793 ppm is unaccountable on the basis of water discharging from surficial geologic formations. Introduction of oilfield brine waters into the Okatuppa Creek basin is the probable cause of a sodium chloride type water at low flow (Powell and others, 1963, p. 24-32).

4698. SATILPA CREEK NEAR COFFEEVILLE, ALA.

The index low flow of Satilpa Creek at this site is 11 cfs, which flow is exceeded about 98 percent of the time. The stream was sampled at a high discharge of 390 cfs (exceeded 15 percent of the time) and again at a discharge of 14 cfs (exceeded 96 percent of the time). The stream remains a calcium magnesium bicarbonate type water at high and low flow (pl. 2, table 18). The stream increases in calcium, bicarbonate, chloride, and dissolved solids content with diminished discharge that was accompanied by a decrease in magnesium, sodium, and sulfate content. The significant changes in composition are the increase in calcium and bicarbonate contents accompanied by a decrease in sulfate content.

Geologic units exposed within the area are the Tallahatta, Lisbon, and Miocene sands (MacNeil, 1946).

4700. TOMBIGBEE RIVER NEAR LEROY, ALA.

The Tombigbee River at this station was sampled at a high discharge of 66,000 cfs, which is exceeded 13 percent of the time and at a low flow of undetermined discharge. River water at high-flow discharge is a calcium magnesium bicarbonate type, which changes to a calcium magnesium chloride type with diminished streamflow. The greater increases are in sodium and chloride content, but the content of all constituents increases with decrease in streamflow except silica and iron. The trend of change is toward a sodium chloride type water.

4702.05. WEST BASSETT CREEK AT BASSETT CREEK, ALA.

The index low flow of West Bassett Creek at this site is 12 cfs. Stream water samples were obtained at discharges of 1,140 and 19 cfs. A sodium chloride type water occurs at high flow and a sodium bicarbonate type water at low flow. The stream increases in calcium, sodium, potassium, bicarbonate, and in chloride content with diminished streamflow that is accompanied by a decrease in sulfate content. There is an apparent decrease in dissolved solids content. Significant changes in composition are the increase in sodium and bicarbonate content accompanied by a decrease in sulfate. The indicated trend in chemical character is toward a sodium bicarbonate type ground water as shown in the diagram for the Okatuppa Creek basin (pl. 2, table 18).

The geologic units believed to influence the trend toward a sodium bicarbonate type water at low flow are the Miocene sands and the Recent alluvium (MacNeil, 1946).

SUMMARY: TOMBIGBEE RIVER AND TRIBUTARIES

The high flow-low flow trend of change in chemical character is approximately the same for Okatuppa Creek and for the Tombigbee River near Leroy (pl. 2). The trend evidenced by these streams is not apparent for any other station on the Tombigbee River or for any of its tributary streams. The trend for the Tombigbee River near Coatopa, and for its distributary, the Mobile River near Mt. Vernon, is very similar. The chemical character of the Tombigbee River and its distributary at low flow remains that of a calcium magnesium bicarbonate type water with one exception—near Leroy, Ala. The low-flow discharge sample at this station is a calcium magnesium chloride type water trending toward a sodium chloride type water.

Five of the tributary streams are calcium magnesium bicarbonate type waters at high-flow discharges, two are calcium magnesium chloride type waters, and one is a sodium chloride type water. At low-flow discharges, four of the tributary streams trend in chemical character toward a sodium bicarbonate type water, three remain unchanged in water type, and one becomes a sodium chloride type water. For one of the tributary streams where a reliable relationship could be surmised between sources of discharging ground water and the basin area, the trend in change of chemical composition with diminished streamflow was extended toward that of a ground water discharging from a geologic formation. For another tributary stream, the high flow-low flow trend of change in chemical character could not be correlated with the character of ground waters known to be discharging into the stream basin from surficial geologic formations. The presence of concentrated brine waters are known to be influencing the nature of Okatuppa Creek's base flow (Powell and others, 1963).

MOBILE RIVER AND TRIBUTARIES

4296.5. MAJORS CREEK NEAR TENSAW, ALA.

The index low flow for Majors Creek at this site is 21 cfs. The stream was sampled at a high flow of 234 cfs and again at a low flow of 23.4 cfs. The stream increases in calcium, sodium, bicarbonate, and chloride content with diminishing streamflow that is accompanied by a decrease in potassium and dissolved solids content. Significant increases in calcium and bicarbonate content, accompanied by a decrease in sulfate content, change the chemical character of the stream water from a sodium chloride type at high flow to a sodium bicarbonate type at low-flow discharge (pl. 2, table 18). Geologic units believed to influence the base flow of the stream are the Citronelle Formation and Miocene sands. The chemical character of this stream at both high and low flow is similar to West Bassett Creek.

4705. MOBILE RIVER NEAR MT. VERNON, ALA.

The composition and quality of the Mobile River near Mt. Vernon has been considered on the basis of daily samples composited for 10-day periods (Robinson and others, 1956). Analysis of river water for a 10-day average discharge of 119,000 cfs was chosen to represent the river at high flow and analysis of the river water for a 10-day average discharge of 8,170 cfs was chosen to represent the river at low flow (Robinson and others, 1956, table 4). The character of the river water at both high and low flow is a calcium magnesium bicarbonate type. At low flow, the river increases in most chemical constituents except sulfate and nitrate, which decrease significantly in concentration. At low flow, the composition and character of the Mobile River near Mt. Vernon is very similar to that of the Tombigbee and Alabama Rivers but with increased flow the composition of the Mobile River is more like the Tombigbee River than the Alabama River.

4710. CHICKASAW CREEK NEAR WHISTLER, ALA.

The index low flow of Chickasaw Creek at this location is 69 cfs, which flow is exceeded about 88 percent of the time. The stream was sampled at a high discharge of 645 cfs (exceeded 7 percent of the time) and again at 95 cfs (exceeded 79 percent of the time). The stream increases in sodium, bicarbonate, and chloride content with diminished flow and decreases in calcium and sulfate content (pl. 2, table 18). The water is a sodium bicarbonate type at both high and low flow. Ground-water analyses are of record (Robinson and others, 1956, table 7) that represent formation waters believed to influence the character of the stream during base flow. Water from well numbered 41 represents ground water in the alluvium of the stream basin; well numbered 29 represents the terrace deposits; and well numbered 34 represents Miocene sands. The character of the base flow is influenced more by the terrace deposits and the underlying Miocene sands than by the alluvium. The character of the ground water in the alluvium of this basin differs considerably in composition and character from the ground water in the alluvium for Horse Creek basin. The high index low flow of this basin per unit area indicates an abundance of ground-water discharge at both high- and low-flow discharges. The character of the streamflow at both high and low flow does not vary greatly toward either the underlying sands or toward the alluvium, but is more nearly akin to the water to be found in the terrace deposits.

SUMMARY: MOBILE RIVER AND TRIBUTARIES

The streams tributary to the Mobile River that have not been included in previous summation are Majors Creek and Chickasaw Creek. These streams join the Mobile River below the confluence of the Tombigbee and the Alabama Rivers. The differences in composition and chemical character of these streams, as compared to the tributaries above the confluence of Tombigbee and Alabama, reflect a difference in the chemical nature of the underlying formations. Majors Creek and Chickasaw Creek water contain a greater proportion of sodium and chloride or sodium and bicarbonate than the other tributaries. The composition and changes in composition and character are more nearly like streams in the other river basins below the confluence of the Tombigbee and Alabama Rivers than the tributaries above it.

CHEMICAL COMPOSITION AND CHARACTER OF SELECTED STREAMS - SUMMARY

Two rather broad areas that reflect differences in geologic formations are apparent in the chemical composition and character of the selected streams in southwestern Alabama.

The Tombigbee and Alabama Rivers, and their tributary streams above the Mobile River, contain a greater proportion of calcium and magnesium than of sodium and potassium at both high and low flows. A consistent trend of change in chemical composition with diminished streamflow is an increase in bicarbonate accompanied by a decrease in the sulfate content of the stream. The prevailing trends are toward a calcium magnesium bicarbonate type water or a sodium bicarbonate type water at low discharges. One exception to the prevailing trends is noted for the Tombigbee River and for two streams entering the southwestern Alabama area from the upland regions—the Alabama River near Montgomery and Mulberry Creek. The presence of oilfield brines in the Okatuppa Creek basin could be responsible for the divergent trends shown by Okatuppa Creek and the Tombigbee River near Leroy. The reasons for the divergent trend shown by the Alabama River near Montgomery, and Mulberry Creek are unknown. Both streams show significant increases in sulfate content with diminished streamflow and drain areas above the fall line. The chemical character of water in the individual tributary streams changes with diminished flow according to the nature of ground water discharging in the basin or according to the lithologic character of the exposed geologic formations within nonartesian basins. The Tombigbee and Alabama Rivers waters are the summation of the chemical characters of waters in their respective tributaries but both exhibit the effect of individual tributaries during periods of low flow—local changes in chemical character or in the dissolved solids contents.

Below the confluence of the Tombigbee and Alabama Rivers, the chemical character of the rivers and tributary streams reflects a geologic environment that contributes greater amounts of sodium and potassium than calcium and magnesium to the stream waters. The stream waters within this area are sodium chloride or sodium bicarbonate at both high and low flow—one stream excepted. The Escatawpa River reverses this trend to become a calcium magnesium chloride type water at low flow. The reason for this exception is not known with certainty.

The low-flow yield of a stream basin does not determine the chemical character of the stream water during base-flow periods. Ground water from geologic units of varied lithology may change the chemical character of the stream water at varying streamflows. In nonartesian basins incised into monolithologic geologic units, the character of the stream water may not change over a very wide range of streamflow. However, the chemical character and the low-flow yield of tributary streams do influence the composition and character of our rivers. Control of tributary streams, by diversion or impoundment of their water, may affect the water quality of our major streams.

QUALITY OF STREAM WATER AS RELATED TO CHEMICAL COMPOSITION

SILICA CONTENT

The silica content of the streams in southwestern Alabama ranges from 0.7 ppm in Catoma Creek during high-flow periods to 15 ppm in Tuckabum Creek at low flow, and Okatuppa Creek at high flow (table 18). The arithmetic average of silica content is 7.1 ppm. Silica constitutes a large proportion of the mineral content of some streams but is considerably lower than the 25 or 30 parts found in many natural waters in areas of high precipitation (Hem, 1959, p. 51). The low silica content qualifies these streams for use in the majority of industrial and domestic applications provided other constituents are not present in objectionable quantities (Peirce and Geurin, 1959, table 19).

CHLORIDE CONTENT

The chloride content of the streams, excluding Okatuppa Creek and the Tombigbee River near Leroy, ranges from 1.5 ppm in the Sucarnoochee River and West Bassett Creek to 16 ppm in the Alabama River near Montgomery. With noted exceptions, the arithmetic average of the chloride concentrations is 4.3 ppm. A high chloride concentration of 380 ppm occurs in the Okatuppa Creek during low-flow discharge. This chloride concentration disqualifies stream use in all industrial applications listed in table 19 (Peirce and Geurin, 1959) and is in excess of concentrations as recommended by the U.S. Public Health Service for use on interstate carriers. The other streams qualify for use in the majority of industrial and domestic applications.

NITRATE CONTENT

The nitrate content of the streams ranges from 0.0 in the

Tombigbee River near Demopolis and Alamuchee Creek to 1.7 ppm in the Kinterbish Creek (table 18). The average nitrate content for all streams is 0.4 ppm. Nitrate content in streams not subject to pollution from sewage or other sources seldom is as high as 5 ppm and often is less than 1 ppm (Hem, 1959, p. 117). The streams considered in this sampling program gave little indication of pollution on the basis of the nitrate content.

DISSOLVED SOLIDS CONTENT

Dissolved solids content (residue on evaporation) of the streams ranged from 20 ppm in West Bassett Creek to 167 ppm in Catoma Creek at low flow. One exception is a dissolved solids content of 793 ppm in Okatuppa Creek at low flow. With the noted exception, the average of the dissolved solids content for the streams is 63 ppm. The majority of the streams may be classified as dilute stream waters and should be acceptable for most industrial and domestic uses (Peirce and Geurin, 1959, table 19).

HARDNESS

The hardness of stream waters ranges from 2 ppm in West Bassett Creek, Satilpa Creek, Styx River, and Fish River to 164 ppm in Okatuppa Creek at low flow. The average of hardness for the streams is 30 ppm. Hardness of water does not become particularly objectionable for use in ordinary domestic purposes until it reaches 100 ppm (Hem, 1959, p. 147). The soft water contained in most streams can be used for most industrial and domestic applications.

For streams containing soft water, the streams in southwestern Alabama contain a significant amount of noncarbonate hardness. Noncarbonate hardness is generally attributed to the calcium and magnesium salts of sulfates and chlorides. Generally, the streams in southwestern Alabama that decrease in sulfate with diminished streamflow also decrease in noncarbonate hardness and those streams that increase in sulfate with diminished streamflow increase in noncarbonate hardness. In those instances where the decrease in sulfate content is not paralleled by a decrease in noncarbonate hardness, the chloride content increases.

HYDROGEN ION CONCENTRATION - pH

The hydrogen ion concentration of a water is an expression of the overall balance of the relation between dissolved substances in the water causing acid reactions (hydrogen ions in the water) and those causing basic reactions (hydroxyl ions in the water). Water without any substances dissolved in it, either solid or gas, has an equal number of hydrogen ions and hydroxyl ions and is neither acidic or basic–a neutral pH - 7.0. Where the hydrogen ions outnumber the hydroxyl ions, the water is acid to that extent, and the pH value shifts from 7.0 toward 1.0 or less than 1.0 on the pH scale. The converse is true when hydroxyl ions outnumber hydrogen ions and the pH shifts from 7.0 toward 14.0 on the pH scale.

The pH value for most natural ground waters ranges from 5.5 to 8 with the pH of most surface waters between 7 and 8. In humid regions, the pH of surface waters is slightly below 7 (Hem, 1959, p. 48).

The pH of the streams in southwestern Alabama ranged from 5.0 for the Styx River to 7.7 for the Cahaba River. Approximately 66 percent of the pH values were less than 7.0 or on the acid side of the pH scale. Twenty-one of the 25 streams showing significant changes in pH from high to low flow increase in pH with diminished flow.

Waters with pH on the acid side of the scale are generally more aggressive in their contact with solid materials and therefore tend to erode materials. Commonly, these waters are treated to increase the pH above 7.0 before industrial use or distribution for domestic use.

TEMPERATURE

The temperature of the surface streams in southwestern Alabama varied from a minimum of 38° F to 44° F during the months of January and February to a high of 80° F to 92° F during the months of July and August. Extreme stream temperatures occur for streams of very low flow during the hot summer months and during the cold winter months. The larger streams do not show the variation in water temperature exhibited by their tributary streams.

SELECTED REFERENCES

Alabama Business Research Council, 1960, Water and economic growth - a study of Alabama and the Southeast: Tuscaloosa, Ala., University of Alabama School of Commerce and Business Administration, 45 p.
Alabama Department of Conservation, 1962, Report for fiscal year October 1, 1961, to September 30, 1962: Montgomery, Ala., 128 p.
Alabama Soil Conservation Committee, 1961, Alabama soil and water conservation needs inventory: 144 p.
Alabama State Chamber of Commerce, 1962, Selected comparative statistics: Montgomery, Ala., 28 p.
Alabama State Department of Public Health, 1963, Public water supplies on record January 1, 1963: Montgomery, Ala., 18 p.
Alabama Water Improvement Advisory Commission, 1949, Studies of pollution in streams of Alabama: Montgomery, Ala., 298 p.
Alabama Water Improvement Commission, 1960, Report of study, Mobile-Tombigbee River system, September-October 1960: Montgomery, Ala., 32 p.
——— 1960, Progress report 1959-60: Montgomery, Ala., 53 p.
Barnes, H. H., Jr., and Somers, W. P., 1961, Floods of February-March 1961 in the Southeastern States: U.S. Geol. Survey Circ. 452, 21 p.
Barnes, H. H., Jr., and Golden, H. G., Magnitude and frequency of floods in the United States, Part 2-B: U.S. Geol. Survey Water Supply Paper 1674 (in press).
Benson, M. A., 1962, Factors influencing the occurrence of floods in a humid region of diverse terrain: U.S. Geol. Survey Water Supply Paper 1580-B, 64 p.
Bidgood, Lee, 1962, Transition in Alabama: University of Alabama Press, Alabama Business Research Council, 106 p.
Carlston, Charles W., 1963, Drainage density and streamflow: U.S. Geol. Survey Prof. Paper 422-C, 8 p.
Corps of Engineers, 1945, Storm rainfall in the United States, depth, area, duration data: Mobile, Ala., U.S. Army Engineers District, 26 p.
——— 1963, Report on the flood of February-March 1961 in the Mobile District: Mobile, Ala., U.S. Army Engineers District, 26 p.
Dalrymple, Tate, 1960, Flood-frequency analysis: U.S. Geol. Survey Water Supply Paper 1543-A, 80 p.
Drago, Emanual A., 1962, Flood problems in Alabama: Auburn, Ala., Water Resources Committee, Alabama section ASCE, 50 p.
Fenneman, N. M., 1938, Physiography of eastern United States: New York and London, McGraw-Hill Book Co., 714 p.
Garrett, John A., 1962, Water use law: Auburn, Ala., Water Resources Committee, Alabama section ASCE, 50 p.
Gumbel, E. J., 1958, Statistics of extremes: New York, Columbia Univ. Press, 375 p.
Harper, R. M., 1943, Forests of Alabama: Alabama Geol. Survey Mon. 10, 230 p.
Hawley, M. H., 1960, Income and population in Alabama: University of Alabama, School of Commerce and Business Adm., Bur. of Business Research, No. 27, 27 p.
Hem, J. D., 1959, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water Supply Paper 1473, 268 p.

Knowles, D. B., Reade, H. L., Jr., and Scott, J. C., 1960, Geology and ground-water resources of Montgomery County, Alabama, with special reference to the Montgomery area: Alabama Geol. Survey Bull. 68, pt. B, 493 p.

Kunkle, G. R., 1962, The baseflow-duration curve, a technique for the study of ground water discharge from a drainage basin: Am. Geophysical Union Jour., v. 67, no. 4, p. 1543-1544.

LaMoreaux, P. E., 1960, Ground-water resources of the South—a frontier of the Nation's water supply: U.S. Geol. Survey Circ. 441, 9 p.

LaMoreaux, P. E., and Toulmin, L. D., 1959, Geology and ground-water resources of Wilcox County, Alabama: Alabama Geol. Survey County Rept. 4, 280 p.

Langbein, W. B., 1947, Topographic characteristics of drainage basins: U.S. Geol. Survey Water Supply Paper 968-C, 28 p.

Langbein, W. B., and others, 1949, Annual runoff in the United States: U.S. Geol. Survey Circ. 52, 14 p.

Matalas, N. C., and Jacobs, Barbara, 1964, A correlation procedure for augmenting hydrologic data: U.S. Geol. Survey administrative report.

MacNeil, F. S., 1946, Geologic map of the Tertiary formations of Alabama: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 45.

Monroe, W. H., 1941, Notes on deposits of Selma and Ripley age in Alabama: Alabama Geol. Survey Bull. 48, 150 p.

Newton, J. G., Sutcliffe, Horace, Jr., and LaMoreaux, P. E., 1961, Geology and ground-water resources of Marengo County, Alabama: Alabama Geol. Survey County Rept. 5, 443 p.

Peirce, L. B., 1954, Floods in Alabama, magnitude and frequency: U.S. Geol. Survey Circ. 342, 105 p.

——— 1959, Low-flow and flow-duration data for Alabama streams: Montgomery, Ala., Alabama Water Improvement Commission, 168 p.

Peirce, L. B., and Geurin, J. W., 1959, Surface-water resources and hydrology of west-central Alabama: Alabama Geol. Survey Spec. Rept. 24, 236 p.

Piper, A. M., 1944, A graphic procedure in the geochemical interpretation of water analyses: Am. Geophys. Union Trans., v. 25, p. 914-923.

Powell, W. J., Carroon, L. E., and Avrett, J. R., 1963, Water problems associated with oil production in Alabama: Alabama Geol. Survey Circ. 22, 63 p.

Robinson, W. H., Powell, W. J., and Brown, Eugene, 1956, Water resources of the Mobile area, Alabama: U.S. Geol. Survey Circ. 373, 45 p.

Searcy, J. K., 1959, Flow-duration curves: U.S. Geol. Survey Water Supply Paper 1542-A, 33 p.

Scott, J. C., 1957, Ground-water resources of Lowndes County, Alabama: Alabama Geol. Survey Inf. Ser. 6, 80 p.

Sheaffer, John R., 1961, Flood-to-peak interval, chap. VII *of* Papers on flood problems: Chicago, Ill., University of Chicago Press, 228 p.

Speer, Paul R., Golden, Harold G., and Patterson, James F., 1963, Low-flow characteristics of streams in the Mississippi Embayment in Mississippi and Alabama: U.S. Geol. Survey open-file report, 159 p.

Swindel, G. W., Jr., Williams, M. R., Geurin, J. W., 1963, Water in Alabama: U.S. Geol. Survey Water Supply Paper 1765, 89 p.

Toulmin, L. D., LaMoreaux, P. E., and Lanphere, C. R., 1951, Geology and ground-water resources of Choctaw County, Alabama: Alabama Geol. Survey Spec. Rept. 21 and County Rept. 2, 197 p.

Tower, J. A., 1959, The shaping of Alabama: University of Alabama Press, The Alabama Review.

U.S. Department of Health, Education, and Welfare, 1962, Municipal water facilities, communities of 25,000 population and over, as of January 1, 1962: Public Health Service, 108 p.

U.S. Geological Survey, 1954, Water-loss investigations: Lake Hefner studies, technical report: U.S. Geol. Survey Prof. Paper 269, 158 p.

______ 1958, Water-loss investigations, Lake Mead studies: U.S. Geol. Survey Prof. Paper 298, 100 p.

U.S. Weather Bureau, 1892-1961, Daily river stages (published annually).

______ 1955, Rainfall intensity-duration-frequency curves for selected stations in the United States, Hawaiian Islands, and Puerto Rico: U.S. Weather Bureau Tech. Paper 25, 53 p.

______ 1956, Seasonal variation of the probable maximum precipitation east of the 105th meridian for areas from 10 to 1,000 square miles and durations of 6, 12, 24, and 48 hours: U.S. Weather Bureau Hydrometeorological Rept. 33, 58 p.

______ 1958, Rainfall intensity-frequency regime, pt. 2—Southeastern United States: U.S. Weather Bureau Tech. Paper 29, 31 p.

______ 1959, Evaporation maps for the United States: U.S. Weather Bureau Tech. Paper 37, 13 p.

APPENDIX

DESCRIPTIONS OF GAGING STATIONS AND PARTIAL-RECORD STATIONS

For the gaging stations, the following descriptions give the location, drainage area, data available, average discharge, extremes of discharge, and general remarks. When known, the datum of the gage is also given. Descriptions of the partial-record stations are limited to the first three items.

The location and drainage area are determined from the most accurate maps available.

The datum of the gage (elevation of zero on the gage above mean sea level) is shown when it has been determined accurately by differential leveling; acknowledgment is made when this work was done by others.

Under **Data available** are shown the type of information available and the period during which it was obtained.

Average discharge for the gaging stations is shown for the period of streamflow record.

Under **Extremes** are given the maximum discharge and gage height and the minimum discharge during the period of record. This is followed by information believed to be reliable concerning major floods that have occurred outside the period of record.

Unnatural conditions that affect the flow of the stream are noted under **Remarks**.

PERDIDO RIVER BASIN

3762.40 DYAS CREEK NEAR DYAS, ALA.

Location.—In NE¼ sec. 29, T. 1 S., R. 4 E., at bridge on U.S. Highway 31, 2 mi south of Dyas, and 7 mi northeast of Bay Minette, Baldwin County.
Drainage area.—57.3 sq mi.
Data available.—12 base-flow measurements, 1960-63.

3765.00 PERDIDO RIVER AT BARRINEAU PARK, FLA.

Location.—In sec. 15, T. 2 N., R. 32 W., on right bank 25 ft downstream from county highway bridge, 1,000 ft downstream from Alligator Creek, and half a mile southwest of Barrineau Park, Escambia County, Fla.
Drainage area.—394 sq mi.
Datum of gage.—25.77 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: June 1941 to date of report; chemical analysis: 1953.

Average discharge.—21 years (1941-62), 773 cfs.

Extremes.—1941-62: Maximum discharge, 39,000 cfs Apr. 15, 1955 (gage height, 23.94 ft), from rating curve extended above 8,500 cfs; minimum, 207 cfs Sept. 15, 1954 (gage height, 1.29 ft).

Maximum stage known, 25.7 ft Mar. 15, 1929, from information by local resident.

3775.00 STYX RIVER NEAR LOXLEY, ALA.

Location.—In S½ sec. 26, T. 4 S., R. 4 E., near right bank on downstream side of pier of bridge on county road, 2 mi upstream from Hollinger Creek, and 7 mi northeast of Loxley, Baldwin County.

Drainage area.—93.2 sq mi.

Data available.—Daily gage heights and discharges: October 1951 to date of report; 2 chemical analyses: 1962.

Average discharge.—11 years (1951-62), 181 cfs.

Extremes.—1951-62: Maximum discharge, 14,000 cfs Dec. 6, 1953 (gage height, 19.73 ft), from rating curve extended above 6,600 cfs on basis of slope-area measurement of peak flow; minimum, 16 cfs June 22, 1955.

Flood in September 1926 reached a stage of 22.2 ft, from information by Corps of Engineers.

3779.75 BLACKWATER RIVER ABOVE SEMINOLE, ALA.

Location.—In NW¼ sec. 19, T. 6 S., R. 6 E., at bridge on county road 2¼ mi west of Seminole, Baldwin County.

Drainage area.—115 sq mi.

Data available.—10 base-flow measurements, 1960-63.

FISH RIVER BASIN

3784.10 FISH RIVER NEAR DAPHNE, ALA.

Location.—On W½ of line between secs. 18 and 19, T. 5 S., R. 3 E., at bridge on Baldwin County Highway 64, 5 mi east of Daphne, Baldwin County.

Drainage area.—30.7 sq mi.

Data available.—11 base-flow measurements, 1960-63.

3785.00 FISH RIVER NEAR SILVER HILL, ALA.

Location.—On line between secs. 5 and 8, T. 6 S., R. 3 E., near midchannel on upstream side of bridge on State Highway 104, a quarter of a mile downstream from Caney Branch, half a mile upstream from Perone Branch, 2¾ mi west of Silver Hill, Baldwin County, and 12 mi upstream from mouth.

Drainage area.—55.1 sq mi.

Data available.—Daily gage heights and discharges: July 1953 to date of report; 2 chemical analyses: 1962.

Average discharge.—9 years (1953-62), 119 cfs.

Extremes.—1953-62: Maximum discharge, 8,570 cfs Dec. 6, 1953 (gage height, 17.04 ft); minimum, 37 cfs June 20, 21, 1955.

MOBILE RIVER BASIN

4200.00 ALABAMA RIVER NEAR MONTGOMERY, ALA.

Location.—In NW¼ sec. 31, T. 17 N., R. 17 E., at midstream pier of bridge on west land of U.S. Highway 31, 4 mi upstream from Autauga Creek, and 6 mi northwest of Montgomery, Montgomery County.

Drainage area.—15,100 sq mi, approximately.

Datum of gage.—97.90 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: October 1927 to date of report; chemical analyses: 1952, 1962 (2); gage-height records collected at Montgomery since December 1890 are contained in reports of U.S. Weather Bureau.

Average discharge.—35 years (1927-62), 23,250 cfs.

Extremes.—1927-62: Maximum discharge, 283,000 cfs Feb. 26, 1961; maximum stage, 60.65 ft Feb. 27, 1961; minimum discharge, 2,180 cfs Nov. 24, 1941; minimum daily, 2,420 cfs Nov. 24, 1941; minimum gage height, -2.2 ft Sept. 26, 1954.

Maximum stage known, 62.7 ft Apr. 1, 1886, from floodmarks (discharge, 322,000 cfs from rating curve extended above 276,000 cfs). Flood of Mar. 30, 1888, reached a stage of 60.6 ft, from floodmarks (discharge, 283,000 cfs). Elevation of floodmarks of both floods referred to U.S. Weather Bureau gage 9.3 mi upstream and transferred to present site by gage-height relation curve.

Remarks.—Flow regulated by upstream reservoirs in Coosa and Tallapoosa River basins.

4210.00 CATOMA CREEK NEAR MONTGOMERY, ALA.

Location.—In center of sec. 6, T. 15 N., R. 18 E., on right bank on downstream side of bridge on U.S. Highway 331, 5 mi south of Montgomery, Montgomery County.

Drainage area.—298 sq mi.

Datum of gage.—151.02 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: June 1952 to date of report; 2 chemical analyses, 1962.

Average discharge.—10 years (1952-62), 348 cfs.

Extremes.—1952-62: Maximum discharge, 48,600 cfs Feb. 25, 1961 (gage height, 28.65 ft); no flow for many days in some years.

Flood of Nov. 28, 1948, reached a stage of 27.5 ft.

4211.75 PINTLALA CREEK NEAR MONTGOMERY, ALA.

Location.—In NW¼ sec. 17, T. 15 N., R. 16 E., at bridge on U.S. Highway 80, 12 mi southwest of Montgomery, Montgomery County.

Drainage area.—257 sq mi.

Data available.—13 base-flow measurements, 1960-63.

4215.00 BIG SWAMP CREEK NEAR HAYNEVILLE, ALA.

Location.—In sec. 19, T. 14 N., R. 15 E., at bridge on State Highway 21, 1 mi downstream from Fort Deposit Creek, and 1½ mi southwest of Hayneville, Lowndes County.

Drainage area.—123 sq mi.
Datum of gage.—164.25 ft above mean sea level, datum of 1929.
Data available.—Daily gage heights and discharge, January 1939 to September 1946.
Average discharge.—7 years (1939-46), 168 cfs.
Extremes.—1938-46: Maximum discharge, 19,100 cfs Mar. 23, 1944 (gage height, 12.1 ft); no flow at times in each year.

Flood of Nov. 27, 1948, reached a stage of 14.7 ft, from floodmarks (discharge, 39,000 cfs, from rating curve extended above 10,000 cfs on basis of contracted-opening measurement of peak flow).

4220.00 BIG SWAMP CREEK NEAR LOWNDESBORO, ALA.

Location.—In NE¼ sec. 19, T. 15 N., R. 14 E., at upstream side of right-bank pier of bridge on U.S. Highway 80, 1 mi downstream from Panther Creek, 5 mi west of Lowndesboro, Lowndes County, and 12 mi upstream from mouth.
Drainage area.—247 sq mi.
Datum of gage.—127.95 ft above mean sea level, datum of 1929 (levels by Corps of Engineers).
Data available.—Daily gage heights and discharge, December 1937 to April 1938, October 1940 to date of report; 2 chemical analyses, 1962.
Average discharge.—22 years (1940-62), 310 cfs.
Extremes.—1937-38, 1940-62: Maximum discharge, 37,000 cfs Nov. 27, 1948 (gage height, 21.3 ft, from floodmark), from rating curve extended above 25,000 cfs; no flow at times.

4230.00 ALABAMA RIVER AT SELMA, ALA.

Location.—In SE¼ sec. 36, T. 17 N., R. 10 E., in first pier from right bank of Edmund Pettus Bridge on U.S. Highway 80 in Selma, Dallas County, and 1 mi upstream from Valley Creek.
Drainage area.—17,100 sq mi, approximately.
Datum of gage.—61.80 ft above mean sea level, datum of 1929.
Data available.—Daily gage heights and discharge: January 1900 to December 1913, June 1928 to date of report; daily water temperature: October 1955 to November 1956; 2 chemical analyses: 1962. Gage-height records since December 1890 are contained in reports of U.S. Weather Bureau.
Average discharge.—47 years (1900-13, 1928-62), 26,070 cfs.
Extremes.—1900-13, 1928-62: Maximum discharge, 284,000 cfs Mar. 1, 1961 (gage height, 57.97 ft); minimum discharge observed, 2,660 cfs Nov. 1, 1904 (gage height, -2.20 ft).

The flood of Apr. 8, 1886, reached a stage of 57.0 ft (discharge, 248,000 cfs), from floodmarks recovered by Corps of Engineers.

Remarks.—Flow regulated by upstream reservoirs in Coosa and Tallapoosa River basins.

4255.00 CEDAR CREEK AT MINTER, ALA.

Location.—In SE¼ sec. 20, T. 13 N., R. 11 E., on right bank on downstream side of bridge on County Highway 16, 0.2 mi downstream from Snake Creek, 0.5 mi east of Minter, Dallas County, and 4 mi upstream from Dry Cedar Creek.

Drainage area.—217 sq mi.
Datum of gage.—123.50 ft above mean sea level, datum of 1929.
Data available.—Daily gage heights and discharge: June 1952 to date of report.
Average discharge.—10 years (1952-62), 237 cfs.
Extremes.—1952-62: Maximum discharge, 45,600 cfs Feb. 25, 1961 (gage height, 24.58 ft); minimum daily, 0.1 cfs Aug. 12, Sept. 15, 1954.

4255.95 CEDAR CREEK NEAR BERLIN, ALA.

Location.—In NE¼ sec. 14, T. 14 N., R. 10 E., at bridge on State Highway 41, 5 mi southeast of Berlin, Dallas County, 7 mi south of Sardis, and 16 mi south of Selma.
Drainage area.—382 sq mi.
Data available.—13 base-flow measurements, 1960-63.

4256.55 MUSH CREEK NEAR SELMA, ALA.

Location.—In SW¼ sec. 29, T. 15 N., R. 11 E., at bridge on State Highway 41, 1 mi southeast of Berlin, 3 mi south of Sardis, and 12 mi south of Selma, Dallas County.
Drainage area.—45.4 sq mi.
Data available.—Annual peak stages and discharges, 1951-62; 12 base-flow measurements, 1960-63.

4260.00 BOGUECHITTO CREEK NEAR BROWNS, ALA.

Location.—In NW¼ sec. 24, T. 17 N., R. 7 E., 300 ft downstream from bridge on U.S. Highway 80, a third of a mile upstream from Southern Railway bridge, 2 mi east of Browns, Dallas County, and 2½ mi downstream from Washington Creek.
Drainage area.—104 sq mi.
Datum of gage.—129.39 ft above mean sea level, datum of 1929 (levels by Corps of Engineers).
Data available.—Daily gage heights and discharge: October 1943 to June 1954; annual peak stage and discharge: 1954-58, 1960-62.
Average discharge.—11 years (1943-54), 137 cfs.
Extremes.—1943-62: Maximum discharge, 14,200 cfs Mar. 29, 1951 (gage height, 19.0 ft); no flow for many days in some years.

Flood of Dec. 28, 1942, reached a stage of 20.7 ft, from floodmarks (discharge, 19,000 cfs, from rating curve extended above 14,000 cfs).

4265.00 BOGUECHITTO CREEK AT BOGUE CHITTO NEAR ORRVILLE, ALA.

Location.—In NE¼ sec. 19, T. 16 N., R. 8 E., at Southern Railway bridge, 1 mi southwest of Bogue Chitto, Dallas County, 1½ mi upstream from Dry Creek, and 5 mi northwest of Orrville.
Drainage area.—197 sq mi.
Datum of gage.—100.05 ft above mean sea level, datum of 1929 (levels by Corps of Engineers).
Data available.—Daily gage heights and discharge: September 1938 to April 1944.

Average discharge.—5 years (1938-43), 262 cfs.

Extremes.—1938-44: Maximum discharge, 31,800 cfs Aug. 16, 1939 (gage height, 31.2 ft, from graph based on gage readings), from rating curve extended above 8,400 cfs; no flow on many days.

4270.00 BOGUECHITTO CREEK NEAR ORRVILLE, ALA.

Location.—In NW¼ sec. 4, T. 15 N., R. 8 E., at bridge on State Highway 22, 300 ft downstream from Louisville & Nashville Railroad bridge, three-quarters of a mile downstream from Tatum Creek, and 2 mi west of Orrville, Dallas County.

Drainage area.—292 sq mi.

Datum of gage.—91.09 ft above mean sea level, datum of 1929 (levels by Corps of Engineers).

Data available.—Daily gage heights and discharge: February 1944 to September 1949.

Extremes.—1944-49: Maximum discharge, 32,400 cfs Apr. 27, 1944 (gage height, 26.6 ft, from graph based on gage readings); minimum observed, 0.3 cfs Sept. 5, 1945 (gage height, 2.49 ft).

Flood of Dec. 29, 1942, reached a stage of 29.4 ft, from floodmarks (discharge 47,000 cfs, from rating curve extended above 24,000 cfs). A discharge of 0.1 cfs was measured Oct. 22, 1941.

4272.50 PINE BARREN CREEK NEAR SNOW HILL, ALA.

Location.—In SE¼ sec. 21, T. 12 N., R. 10 E., at bridge on State Highway 21, 4 mi west of Snow Hill, Wilcox County.

Drainage area.—263 sq mi.

Data available.—12 base-flow measurements, 1960-63; 2 chemical analyses, 1962.

4273.00 PRAIRIE CREEK NEAR OAK HILL, ALA.

Location.—In N½ sec. 18, T. 11 N., R. 10 E., on right bank at downstream end of pier of bridge on State Highway 10, 1.4 mi west of Oak Hill, Wilcox County, and about 6 mi upstream from mouth.

Drainage area.—9.73 sq mi.

Data available.—Daily gage height and discharge: July 1959 to date of report.

Extremes.—1959-62: Maximum discharge, 1,690 cfs Feb. 24, 1961 (gage height, 14.15 ft); no flow on many days.

4275.00 ALABAMA RIVER NEAR MILLERS FERRY, ALA.

Location.—In NW¼ sec. 8, T. 13 N., R. 7 E., near midspan on downstream side of bridge on State Highway 28, just downstream from Prairie Creek, and 2¼ mi northwest of Millers Ferry, Wilcox County.

Drainage area.—20,700 sq mi, approximately.

Datum of gage.—26.82 ft above mean sea level, datum of 1929 (levels by Corps of Engineers).

Data available.—Daily gage heights and discharge: October 1937 to September 1954. Gage-height records since 1931 are contained in reports of U.S. Weather Bureau.

Average discharge.—17 years (1937-54), 30,330 cfs.

Extremes.—1937-54: Maximum discharge, 237,000 cfs Apr. 14, 1938 (gage height, 56.6 ft); minimum daily, 3,700 cfs Sept. 29, 1954.

Flood in March 1929 reached a stage of 56.8 ft, from floodmarks (discharge, 238,000 cfs). Flood in April 1886 reached a stage 1 to 5 ft higher than that of March 1929. Flood of March 3, 1961 reached a stage of 60.0 ft (284,000 cfs).

Remarks.—Flow regulated by upstream reservoirs in Coosa and Tallapoosa River basins.

4277.00 TURKEY CREEK AT KIMBROUGH, ALA.

Location.—In SE¼ sec. 10, T. 12 N., R. 5 E., on right bank on upstream side of pier of bridge on county road, 0.3 mi upstream from Southern Railway bridge, 0.6 mi downstream from State Highway 5, 1 mi south of Kimbrough, Wilcox County, and 2 mi upstream from mouth.

Drainage area.—114 sq mi.

Datum of gage.—58.78 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: August 1958 to date of report; 2 chemical analyses, 1962.

Average discharge.—4 years (1952-62), 185 cfs.

Extremes.—1958-62: Maximum discharge, 39,600 cfs Dec. 10, 1961 (gage height, 25.02 ft); minimum, 2.4 cfs Aug. 13, 1961.

4277.50 BEAVER CREEK NEAR PINE HILL, ALA.

Location.—In NE¼ sec. 33, T. 12 N., R. 5 E., at bridge on Wilcox County Highway 18, 1 mi southeast of Pine Hill, Wilcox County.

Drainage area.—36.8 sq mi.

Data available.—12 base-flow measurements, 1960-63.

4278.65 PURSLEY CREEK ABOVE CAMDEN, ALA.

Location.—In SE¼ sec. 29, T. 12 N., R. 8 E., at bridge on Wilcox County Highway 39, 1 mi southeast of Camden, Wilcox County.

Drainage area.—40.8 sq mi.

Data available.— 13 base-flow measurements, 1960-63.

4280.00 ALABAMA RIVER NEAR COY, ALA.

Location.—In NE¼ sec. 17, T. 11 N., R. 6 E., at St. Louis-San Francisco Railway bridge, 3 mi north of Coy, Wilcox County.

Drainage area.—21,200 sq mi, approximately.

Datum of gage.—17.37 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: July 1928 to September 1934.

Average discharge.—6 years (1928-34), 30,480 cfs.

Extremes.—1928-34: Maximum discharge, 269,000 cfs Mar. 23, 1929 (gage height, 55.83 ft); minimum, 5,800 cfs Nov. 3, 4, 1931 (gage height, 2.00 ft).

Remarks.—Flow regulated by upstream reservoirs in Coosa and Tallapoosa River basins.

4283.00 TALLATCHEE CREEK NEAR VREDENBURGH, ALA.

Location.—In N½ sec. 31, T. 10 N., R. 8 E., near midstream on downstream side of bridge on Monroe County Highway 56, 0.8 mi upstream from St. Louis-San Francisco Railway bridge, 1 mi upstream from small tributary, 1.1 mi southeast of Vredenburgh, Monroe County, and about 10 mi upstream from mouth.

Drainage area.—14.6 sq mi.

Datum of gage.—109.73 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: October 1958 to date of report.

Average discharge.—4 years (1959-62), 19.3 cfs.

Extremes.—1959-62: Maximum discharge, 2,950 cfs Mar. 6, 1961 (gage height, 11.70 ft); no flow many days each year.

4285.00 FLAT CREEK AT FOUNTAIN, ALA.

Location.—In SE¼ sec. 36, T. 8 N., R. 6 E., on downstream side of midchannel pier of bridge on State Highway 41, three-fourths mi downstream from St. Louis-San Francisco Railway bridge, 1 mi northwest of Fountain, Monroe County, 2 mi upstream from Bradley Mill Creek, 8 mi upstream from mouth, and 8 mi northwest of Monroeville.

Drainage area.—245 sq mi.

Datum of gage.—45.43 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: October 1943 to date of report; 2 chemical analyses, 1962.

Average discharge.—19 years (1943-62), 317 cfs.

Extremes.—1944-62: Maximum discharge, 26,000 cfs Nov. 27, 1948 (gage height, 23.2 ft), from rating curve extended above 20,000 cfs; minimum, 0.2 cfs Sept. 13, 14, 1954.

4290.00 LIMESTONE CREEK AT MONROEVILLE, ALA.

Location.—In NE¼ sec. 22, T. 7 N., R. 7 E., near left bank on downstream side of pier of bridge on State Highway 41, 3 mi northwest of Monroeville, Monroe County, and 10 mi upstream from mouth.

Drainage area.—117 sq mi.

Datum of gage.—104.88 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: December 1951 to date of report.

Average discharge.—10 years (1952-62), 158 cfs.

Extremes.—1951-62: Maximum discharge, 30,600 cfs Feb. 25, 1961 (gage height, 16.28 ft); minimum, 10 cfs June 10, 1956.

Flood of March 1929 reached a stage of about 22 ft, from information by local resident.

4295.00 ALABAMA RIVER AT CLAIBORNE, ALA.

Location.—In sec. 25, T. 7 N., R. 5 E., near left bank on downstream side of pier of bridge on U.S. Highway 84 at Claiborne, Monroe County, half a mile downstream from Limestone Creek, and 12 mi west of Monroeville.

Drainage area.—22,000 sq mi, approximately.

Datum of gage.—0.4 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: April 1930 to date of report; 2 chemical analyses, 1953-54.

Average discharge.—32 years (1930-62), 31,760 cfs.

Extremes.—1930-62: Maximum discharge, 267,000 cfs Mar. 7, 1961; maximum gage height, 55.15 ft Mar. 7, 1961; minimum discharge, 4,450 cfs Oct. 1, 1954.

Remarks.—Flow regulated by upstream reservoirs in Coosa and Tallapoosa River basins.

4296.05 LITTLE RIVER NEAR LITTLE RIVER, ALA.

Location.—In W½ sec. 19, T. 4 N., R. 4 E., at bridge on State Highway 59, 3 mi north of Little River, Baldwin County.

Drainage area.—140 sq mi.

Data available.—13 base-flow measurements, 1960-63.

4296.50 MAJORS CREEK NEAR TENSAW, ALA.

Location.—In SW¼ sec. 18, T. 2 N., R. 3 E., at bridge on State Highway 59, 2 mi southwest of Tensaw, Baldwin County.

Drainage area.—44.7 sq mi.

Data available.—13 base-flow measurements, 1960-63; 2 chemical analyses, 1962.

4670.00 TOMBIGBEE RIVER AT DEMOPOLIS LOCK & DAM, NEAR COATOPA, ALA.

Location.—In NW¼ sec. 22, T. 18 N., R. 2 E., on left bank, 100 ft upstream from lock and dam, half a mile downstream from Foscue Creek, 2½ mi west of Demopolis, 3.6 mi downstream from Black Warrior River, and 13 mi east of Coatopa, Sumter County. Prior to Sept. 30, 1955, gage was located at Moscow Memorial Bridge on U.S. Highway 80, 11 mi downstream from present site.

Drainage area.—15,400 sq mi, approximately.

Datum of gage.—56.00 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: August 1928 to date of report; 2 chemical analyses, 1962.

Average discharge.—34 years (1928-62), 22,070 cfs.

Extremes.—1928-62: Maximum discharge, 250,000 cfs Feb. 28, 1961 (gage height, 35.66 ft); minimum daily, 50 cfs Aug. 1-6, 1954 (result of closure of dam during construction and storage of water upstream).

Remarks.—Some regulation at low flow by lock below gage.

4675.00 SUCARNOOCHEE RIVER AT LIVINGSTON, ALA.

Location.—In SW¼ sec. 33, T. 19 N., R. 2 W., on right bank at downstream side of pier of main span of bridge on U.S. Highway 11, 500 ft upstream from Southern Railway bridge three-fourths mi southwest of Livingston, Sumter County, and 9 mi upstream from Alamuchee Creek.

Drainage area.—606 sq mi.

Datum of gage.—90.04 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: October 1938 to date of report; 2 chemical analyses, 1962.

Average discharge.—24 years (1938-62), 775 cfs.

Extremes.—1938-62: Maximum discharge, 31,500 cfs Feb. 22, 1961 (gage height, 29.35 ft); minimum, 49 cfs Sept. 11, 1957.

4680.00 ALAMUCHEE CREEK NEAR CUBA, ALA.

Location.—In NE¼ sec. 24, T. 17 N., R. 4 W., on right bank on downstream side of bridge on U.S. Highway 80, 2½ mi northeast of Cuba, Sumter County, and 4 mi upstream from Toomsuba Creek.

Drainage area.—63 sq mi, approximately.

Datum of gage.—161.50 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: July 1954 to date of report; 2 chemical analyses, 1959-60.

Average discharge.—8 years (1954-62), 69.1 cfs.

Extremes.—1954-62: Maximum discharge, 12,000 cfs Feb. 22, 1961 (gage height, 18.03 ft); minimum daily, 1.8 cfs Aug. 30, Sept. 9, 1957.

4685.00 CHICKASAW BOGUE NEAR LINDEN, ALA.

Location.—In SW¼ sec. 28, T. 16 N., R. 3 E., at bridge on U.S. Highway 43, 1½ mi north of Linden, Marengo County, 2 mi downstream from Atkins Creek, and 11 mi upstream from mouth.

Drainage area.—258 sq mi.

Datum of gage.—68.96 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: January 1944 to September 1946.

Average discharge.—2 years (1944-46), 326 cfs.

Extremes.—1944-46: Maximum discharge, 33,000 cfs Mar. 26, 1945 (gage height, 30.33 ft); minimum observed, 0.3 cfs June 27-29, 1944.

4690.00 KINTERBISH CREEK NEAR YORK, ALA.

Location.—In NE¼ sec. 33, T. 16 N., R. 2 W., near left bank on downstream side of pier of bridge on State Highway 17, half a mile downstream from small tributary, three-fourths mi north of Choctaw County line, 5½ mi downstream from Little Kinterbish Creek, and 14 mi southeast of York, Sumter County.

Drainage area.—91.4 sq mi.

Data available.—Daily gage heights and discharge: July 1954 to date of report; 2 chemical analyses, 1959-60.

Average discharge.—8 years (1954-62), 104 cfs.

Extremes.—1954-62: Maximum discharge, 14,400 cfs Feb. 22, 1961 (gage height, 22.23 ft); minimum, 1.8 cfs Aug. 15, Oct. 8, 1954.

4695.00 TUCKABUM CREEK NEAR BUTLER, ALA.

Location.—In S½ sec. 15, T. 14 N., R. 2 W., on left bank 150 ft upstream from bridge on State Highway 17, 2½ mi upstream from Yantley Creek, 4 mi downstream from Boguechitto Creek, and 7 mi northeast of Butler, Choctaw County.

Drainage area.—112 sq mi.

Data available.—Daily gage heights and discharge: August 1954 to date of report; 2 chemical analyses, 1962.

Average discharge.—8 years (1954-62), 122 cfs.

Extremes.—1954-62: Maximum discharge, 6,830 cfs Feb. 22, 1961 (gage height, 20.13 ft); minimum, 0.7 cfs Sept. 21-23, 30, Oct. 6, 1954 (gage height, 0.19 ft).

4695.20 YANTLEY CREEK NEAR JACHIN, ALA.

Location.—In N½ sec. 3, T. 14 N., R. 2 W., at bridge on State Highway 17, 1 mi south of Jachin, Choctaw County, and 9 mi north of Butler.

Drainage area.—95.3 sq mi.

Data available.—12 base-flow measurements, 1960-63.

4695.50 HORSE CREEK NEAR SWEETWATER, ALA.

Location.—In SW¼ sec. 34, T. 13 N., R. 2 E., near right bank on downstream end of pier of bridge on Marengo County Highway 25, half a mile downstream from Mill Creek, 3 mi upstream from Sweetwater Creek, and 3½ mi south of Sweetwater, Marengo County.

Drainage area.—52.8 sq mi.

Data available.—Daily gage heights and discharge: July 1959 to date of report; 2 chemical analyses, 1962.

Average discharge.—3 years (1959-62), 127 cfs.

Extremes.—1959-62: Maximum discharge, 25,800 cfs Dec. 10, 1961 (gage height, 17.5 ft, from floodmarks); minimum, 2.1 cfs Sept. 24, 1960.

4695.75 WAHALAK CREEK NEAR BUTLER, ALA.

Location.—In W½ sec. 30, T. 13 N., R. 2 W., at bridge on State Highway 17, 1 mi south of Butler, Choctaw County.

Drainage area.—22.8 sq mi.

Data available.—12 base-flow measurements, 1960-63.

4696.00 BASHI CREEK NEAR CAMPBELL, ALA.

Location.—In NW¼ sec. 9, T. 11 N., R. 1 E., near left bank on downstream end of pier of bridge on State Highway 69, half a mile downstream from Trawick Creek, half a mile upstream from Tallahatta Creek, and 1.6 mi north of Campbell, Clarke County.

Drainage area.—86.3 sq mi.

Data available.—Daily gage heights and discharge: June 1959 to date of report.

Average discharge.—3 years (1956-62), 145 cfs.

Extremes.—1959-62: Maximum discharge, 20,600 cfs Dec. 10, 1961 (gage height, 25.94 ft); minimum, 0.5 cfs Sept. 26-30, 1962.

4697.00 OKATUPPA CREEK AT GILBERTOWN, ALA.

Location.—In SE¼ sec. 30, T. 11 N., R. 3 W., near left bank on downstream side of bridge on State Highway 17, 300 ft downstream from Alabama, Tennessee, and Northern Railroad bridge, 550 ft upstream from small unnamed tributary, three-fourths mi northeast of Gilbertown, Choctaw County, and 1½ mi upstream from Bogueloosa Creek.

Drainage area.—151 sq mi.

Datum of gage.—59.41 ft above mean sea level, datum of 1929.

Data available.—Daily gage heights and discharge: June 1956 to date of report; 3 chemical analyses, 1960, 1962.
Average discharge.—6 years (1956-62), 218 cfs.
Extremes.—1956-62: Maximum discharge, Feb. 21, 1961, not determined; maximum daily, 4,200 cfs Feb. 22, 1961; minimum daily, 0.8 cfs, Aug. 28, 29, Sept. 7, 8, 1957.

4697.75 SANTA BOGUE CREEK NEAR FRANKVILLE, ALA.

Location.—In NW¼ sec. 14, T. 8 N., R. 2 W., at bridge on Washington County Highway 31, 1½ mi north of Frankville, Washington County.
Drainage area.—168 sq mi.
Data available.—12 base-flow measurements, 1960-63.

4698.00 SATILPA CREEK NEAR COFFEEVILLE, ALA.

Location.—In SE¼ sec. 13, T. 9 N., R. 1 W., near left bank on downstream side of bridge on State Highway 12, a quarter of a mile upstream from unnamed tributary, 3 mi downstream from Harris Creek, and 3¾ mi east of Coffeeville, Clarke County.
Drainage area.—166 sq mi.
Data available.—Daily gage heights and discharge: June 1956 to date of report; 2 chemical analyses, 1962.
Average discharge.—6 years (1956-62), 260 cfs.
Extremes.—1956-62: Maximum discharge, 25,600 cfs July 8, 1956 (gage height, 18.37 ft); minimum, 7.0 cfs Aug. 29, 1957.

4700.00 TOMBIGBEE RIVER NEAR LEROY, ALA.

Location.—In sec. 13, T. 7 N., R. 1 W., at former navigation lock and dam no. 1, 4 mi upstream from Jackson Creek, 5 mi northwest of Leroy, Washington County, and 18 mi downstream from Jackson Lock & Dam.
Drainage area.—19,100 sq mi, approximately.
Datum of gage.—7.28 ft below mean sea level, datum of 1929 (levels by Corps of Engineers).
Data available.—Daily gage heights: October 1928 to date of report; daily discharge: October 1928 to September 1960 (since October 1960, discharges above 40,000 cfs only); 3 chemical analyses, 1953, 1962.
Average discharge.—32 years (1928-60), 26,230 cfs.
Extremes.—1928-62: Maximum discharge, 252,000 cfs Mar. 4, 5, 1961 (gage height, 48.24 ft); minimum daily prior to Oct. 1, 1960, 500 cfs Sept. 2, 1929 (result of storage above dam from installation of flashboards).

Floods in May 1874 and April 1900 reached stages of 51.8 ft (discharge, 280,000 cfs), and 50.6 ft (discharge, 269,000 cfs), respectively, from information by Corps of Engineers.

Remarks.—Some regulation at low flow by navigation locks and dams.

4700.75 EAST BASSETTS CREEK NEAR DICKINSON, ALA.

Location.—In NW¼ sec. 7, T. 9 N., R. 4 E., at bridge on Clarke County Highway 27, half a mile northwest of Dickinson, Clarke County, and 6 mi northeast of Grove Hill.

Drainage area.—39.9 sq mi.
Data available.—12 base-flow measurements, 1960-63.

4701.00 EAST BASSETTS CREEK AT WALKER SPRINGS, ALA.

Location.—In NE¼ sec. 32, T. 7 N., R. 3 E., near right bank on downstream side of bridge on county road, 0.2 mi southeast of Walker Springs, Clarke County, and 2¾ mi upstream from Rabbit Creek.
Drainage area.—188 sq mi.
Datum of gage.—60.02 ft above mean sea level, datum of 1929.
Data available.—Daily gage heights and discharge: June 1956 to date of report.
Average discharge.—6 years (1956-62), 348 cfs.
Extremes.—1956-62: Maximum discharge, 19,300 cfs July 8, 1956 (gage height, 12.25 ft); minimum, 20 cfs Sept. 22, 1956.

4702.05 WEST BASSETTS CREEK AT BASSETTS CREEK, ALA.

Location.—In N½ sec. 25, T. 6 N., R. 1 W., at bridge on U.S. Highway 43 at Bassetts Creek, Washington County, 1½ mi north of Wagarville.
Drainage area.—128 sq mi.
Data available.—19 base-flow measurements, 1953-54, 1960-63; 2 chemical analyses, 1962.

4703.40 BATES CREEK NEAR MALCOLM, ALA.

Location.—In S½ sec. 46, T. 3 N., R. 1 E., at bridge on U.S. Highway 43, 1 mi north of Malcolm, Washington County.
Drainage area.—74.4 sq mi.
Data available.—18 base-flow measurements, 1953-54, 1960-63.

4705.00 MOBILE RIVER NEAR MT. VERNON, ALA.

Location.—In SE¼ sec. 41, T. 2 N., R. 1 E., at boat pier on west bank of David Lake, half a mile upstream from lake outlet to Mobile River, 2½ mi northeast of Mt. Vernon, Mobile County, and at mile 41.3 from Mobile.
Drainage area.—43,000 sq mi, approximately.
Data available.—Daily gage heights and discharge: October 1953 to September 1954; chemical analyses of composited 10-day samples, 1953-54.
Average discharge.—1 year (1954), 38,150 cfs.
Extremes.—1953-54: Maximum discharge, 143,000 cfs Feb. 1, 2, 1954; maximum gage height, 11.40 ft Feb. 2, 1954; minimum daily discharge, 4,310 cfs Sept. 24, 1954.

Flood of Mar. 9, 1961, reached a stage of 20.6 ft, from floodmarks (discharge, 539,000 cfs).

Remarks.—Low and medium stage affected by tide. Flow regulated by upstream reservoirs in Alabama River basin and to some extent at low flows by navigation locks and dams on Tombigbee and Black Warrior Rivers.

4706.15 CEDAR CREEK NEAR MT. VERNON, ALA.

Location.—In E½ sec. 1, T. 1 N., R. 1 W., at bridge on U.S. Highway 43, three-fourths mile south of Mt. Vernon, Mobile County.

Drainage area.—86.0 sq mi.
Data available.—14 base-flow measurements, 1953-54, 1960-61.
Remarks.—Stage affected by tide.

4709.25 CHICKASAW CREEK AT CHUNCHULA, ALA.

Location.—In NE¼ sec. 32, T. 1 S., R. 2 W., at bridge on Mobile County Highway 63, half a mile east of Chunchula, Mobile County.
Drainage area.—45.4 sq mi.
Data available.—11 base-flow measurements, 1960-63.

4710.00 CHICKASAW CREEK NEAR WHISTLER, ALA.

Location.—In NW¼ sec. 2, T. 3 S., R. 2 W., on downstream side of right pier of bridge on county road, 2 mi upstream from Seabury Creek, 5 mi northwest of Whistler, Mobile County, and 8 mi northwest of Mobile.
Drainage area.—123 sq mi.
Data available.—Daily gage heights and discharge: October 1951 to date of report; 2 chemical analyses, 1953-54.
Average discharge.—11 years (1951-62), 285 cfs.
Extremes.—1951-62: Maximum discharge, 42,000 cfs Apr. 13, 1955 (gage height, 25.4 ft, from floodmarks), from rating curve extended above 10,600 cfs on basis of slope-area measurement of peak flow; minimum, 18 cfs Sept. 3, 4, 1954 (gage height, 0.41 ft).

4710.75 HALLS MILL CREEK NEAR THEODORE, ALA.

Location.—In sec. 38, T. 5 S., R. 2 W., at bridge on U.S. Highway 90, 4 mi north of Theodore, Mobile County, and 8 mi southwest of Mobile.
Drainage area.—27.2 sq mi.
Data available.—6 base-flow measurements, 1960-62.
Remarks.—Stage affected by tide.

PASCAGOULA RIVER BASIN

4794.25 ESCATAWPA RIVER AT DEER PARK, ALA.

Location.—On and about center of line between secs. 18 and 19, T. 3 N., R. 3 W., at bridge on Washington County Highway 8, half a mile west of Deer Park, Washington County.
Drainage area.—190 sq mi.
Data available.—11 base-flow measurements, 1960-63.

4795.00 ESCATAWPA RIVER NEAR WILMER, ALA.

Location.—In NW¼ sec. 19, T. 2 S., R. 4 W., on downstream side of center main-channel pier of bridge on State Highway 42, at Alabama-Mississippi State line, a quarter of a mile downstream from Gulf, Mobile & Ohio Railroad bridge, half a mile upstream from Rocky Creek, and 4 mi northwest of Wilmer, Mobile County.
Drainage area.—506 sq mi.
Data available.—Daily gage heights and discharge: August 1945 to date of report; 3 chemical analyses, 1953, 1962.

Average discharge.—17 years (1945-62), 1,041 cfs.

Extremes.—1945-62: Maximum discharge, 30,000 cfs June 2, 1959 (gage height, 24.66 ft); minimum, 37 cfs Sept. 2-4, 1954.

4800.00 BIG CREEK NEAR MOBILE, ALA.

Location.—In NW¼ sec. 1, T. 4 S., R. 4 W., at bridge on county highway, 1 mi upstream from Hamilton Creek, 6 mi downstream from Gulf, Mobile & Ohio Railroad bridge, and 19 mi west of Mobile, Mobile County.

Drainage area.—84 sq mi.

Datum of gage.—58.60 ft above mean sea level, datum of 1929 (levels by Corps of Engineers).

Data available.—Daily gage heights and discharge: December 1944 to September 1950; chemical analysis, 1951.

Average discharge.—5 years (1945-50), 242 cfs.

Extremes.—1944-50: Maximum discharge, 3,460 cfs July 12, 1950 (gage height, 17.5 ft); minimum observed, 65 cfs Oct. 18-21, 1945, June 30, July 1, 2, 1950.

Remarks.—Site of gaging station now submerged by Big Creek Lake.

4801.50 FRANKLIN CREEK NEAR GRAND BAY, ALA.

Location.—In NW¼ sec. 4, T. 7 S., R. 4 W., St. Stephens meridian, at bridge on county highway, 0.9 mi east of Alabama-Mississippi State line, 2.6 mi west of Grand Bay, Mobile County, and 3.1 mi upstream from mouth.

Drainage area.—16.4 sq mi.

Data available.—14 base-flow measurements, 1958-61.