Erosion, Sediment Discharge, and Channel Morphology in the Upper Chattahoochee River Basin, Georgia

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1107

Erosion, Sediment Discharge, and Channel Morphology in the Upper Chattahoochee River Basin, Georgia

With a discussion of the Contribution of Suspended Sediment to Stream Quality

By R. E. FAYE, W. P. CAREY, J. K. STAMER, *and* R. L. KLECKNER

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1107

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, *Secretary*

GEOLOGICAL SURVEY

H. William Menard, ***Director***

Library of Congress Cataloging in Publication Data

Main entry under title:
Erosion, sediment discharge, and channel morphology in the Upper Chattahoochee River Basin, Georgia, with a discussion of the contribution of suspended sediment to stream quality.
(Geological Survey professional paper ; 1107)
"Open-file report 78-576."
Bibliography: p.
Supt. of Docs. no.: I 19.16:1107
1. Erosion—Chattahoochee River watershed. 2. Sediment transport—Chattahoochee River watershed. 3. Chattahoochee River—Channel. I. Faye, R. E. II. Series: United States. Geological Survey. Professional paper ; 1107.

QE571.E783 551.3 78-27110

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Stock Number 024-001-3305-4

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Factors for converting inch-pound units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the inch-pound.

Inch-pound	*Multiply by*	*Metric*
ft (foot)	3.048×10^{-1}	m (meter)
ft (foot)	3.048×10^{2}	mm (millimeter)
ft/s (foot per second)	3.048×10^{-1}	m/s (meter per second)
ft^3/s (cubic foot per second)	2.832×10^{-2}	m^3/s (cubic meter per second)
in. (inch)	2.540×10^{-2}	m (meter)
in. (inch)	2.540×10^{1}	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)
tons (tons, short)	9.072×10^{-1}	t (metric tons)
tons/d (tons per day)	9.072×10^{-1}	t/d (metric tons per day)
tons/ft^3 (tons per cubic foot)	3.204×10^{1}	t/m^3 (metric tons per cubic meter)
tons/yr (tons per year)	9.072×10^{-1}	t/yr (metric tons per year)
°F=9/5(°C)+32		°C=5/9(°F−32)

DEFINITION OF TERMS

Terms used in this text to describe hydrology, sediment, the erosion and transport of sediment, and the collection and analysis of water-quality data are defined below.

ALLUVIUM: A general term for all detrital deposits resulting directly or indirectly from the sediment transport of (modern) streams, thus including the sediments laid down in river beds, floodplains, lakes, fans, and estuaries.

BED LOAD: Material moving on or near the streambed by rolling, sliding, and sometimes making brief excursions into the flow a few diameters above the bed. It is not synonymous with discharge of bed material.

BEDLOAD DISCHARGE: The quantity of bedload passing a transect in a unit of time.

BED MATERIAL: The sediment mixture of which the bed is composed. Bed material particles may or may not be moved momentarily or during some future flow condition.

CHANNEL EROSION: Includes the processes of streambank erosion, streambed scour, and degradation.

COLLUVIUM: A general term applied to loose and incoherent deposits at the foot of a slope or cliff and brought there chiefly by gravity.

DRAINAGE AREA OF STREAM AT SPECIFIED LOCATION: That area, projected to and measured on a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity upstream from a specified point; synonymous with watershed.

EROSION: The detachment and movement of soil and rock fragments by water and other geological agents which results in the wearing away of the land. When water is the eroding agent, erosional processes include sheet and rill erosion, gully erosion, and channel erosion.

EROSION YIELD: The rate of erosion per unit area; generally expressed in units of tons per year per square mile ($t/yr/mi^2$).

GEOMORPHOLOGY: The observation and description of land forms and the changes that occur during land form evolution.

GROSS EROSION: The total of all sheet, gully, and channel erosion in a catchment, usually expressed in mass (tonnes), but sometimes expressed volumetrically.

GULLY EROSION: The formation of relatively deep channels that cannot be readily crossed during normal cultivation.

OVERLAND FLOW: Thin sheetlike, lateral flow across the land surface. Occurs subsequent to the beginning of surface runoff and prior to the entrance of flow into well-defined stream channels. The distance of overland flow is the true slope length of the local landscape.

PARTICLE-SIZE CLASSIFICATION OF SEDIMENT:

Class Name	*Size (mm)*
Boulders	>256
Cobbles	64–256
Gravel	2.0–64
Sand	0.062–2.0
Silt	0.004–0.062
Clay	0.00024–0.004

RILL EROSION: Land erosion forming small but well-defined incisions in the land surface, generally less than 30 cm in width and depth.

RUNOFF (Surface): The flow of water across the land surface and in stream channels. Occurs only after the local storage capacity of the landscape has been exceeded and includes both overland flow and streamflow.

RECURRENCE INTERVAL: The average number of years within which a given event will be equaled or exceeded.

SEDIMENT: (1) Particles derived from rocks or biological materials that have been transported by a fluid, (2) solid material (sludges) suspended in or settled from water.

SEDIMENT DISCHARGE: The average quantity of sediments, mass or volume, but usually mass passing a section in a unit of time. The term may be qualified as, for example, suspended-sediment discharge, bedload discharge, or total-sediment discharge; expressed in units of tons per day or tons per year (*t/d* or *t/yr*).

SEDIMENT LOAD: The sediment that is in transport. (Load is a general term that refers to material in suspension and (or) in transport. It is not synonymous with discharge.)

SEDIMENT TRANSPORT CURVE: A graph relating water discharge and sediment discharge.

SEDIMENT YIELD: The rate of sediment outflow per unit of catchment (watershed) area; expressed in tons per year per square mile [$t/yr/)mi^2$].

SHEET EROSION: The more or less uniform removal of soil from an area without the development of water channels. Included with sheet erosion, however, are the numerous but conspicuous small rills that are caused by minor concentrations of runoff.

SLOUGHING OR SLUMPING: The downward slipping and displacement of masses of bank material.

SUSPENDED SEDIMENT: Sediment that is carried in suspension by the turbulent components of the fluid or by Brownian movement.

UNMEASURED LOAD: The sum of bedload and unmeasured suspended-sediment load.

UNMEASURED SEDIMENT DISCHARGE: The difference between total-sediment discharge and measured suspended-sediment discharge.

WATERSHED: All land enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream; synonymous with drainage area.

EROSION, SEDIMENT DISCHARGE, AND CHANNEL MORPHOLOGY IN THE UPPER CHATTAHOOCHEE RIVER BASIN, GEORGIA

By R. E. Faye, W. P. Carey, J. K. Stamer, and R. L. Kleckner

ABSTRACT

The 3,550 square miles of the Upper Chattahoochee River basin is an area of diverse physiographic and land-use characteristics. The headwater areas are mountainous with steep, relatively narrow channels. Land in the headwater areas is heavily forested, but small towns and farms are common in the valleys of large streams. Downstream, the basin is characterized by low hills and wider stream channels. Land in this part of the basin is also predominantly forested; however, large agricultural and urban areas are common. Urban land use is particularly intensive within the Atlanta Metropolitan Area.

Rates of sheet erosion were computed in nine watersheds using the Universal Soil Loss Equation. The dominant land use in each watershed ranged from forested to mostly urban. Computed average annual erosion yields ranged from 900 to 6,000 [(t/yr)/mi^2]. Erosion yields were greatest in watersheds with the largest percentages of agricultural and transitional land uses. The lowest yields occurred in highly urbanized watersheds. The sensitivity of average annual sheet erosion to timber harvesting was also evaluated with the Universal Soil Loss Equation. In general, post-harvest erosion yields were several orders of magnitude greater than computed pre-harvest yields in the same areas.

Average annual suspended-sediment yields were calculated from measurements of sediment discharge from the same mine watersheds and ranged from about 300 to 800 [(t/yr)/mi^2]. Seodiment-discharges were greatest in urban water sheds and least in forested watersheds. A large part of the sediment discharged in urban streams was considered to be derived from stream-channel erosion. Unmeasured sediment discharge computed for four watersheds ranged from about 6 to 30 percent of the total annual sediment discharge.

The impact of suspended sediment on the quality of streamflows was evaluated for 14 watersheds. In general, 60 percent or more of the total annual discharge of trace metals and phosphorus was contributed by suspended sediment. Corresponding discharges of suspended nitrogen and organic carbon ranged from about 10 to 70 percent of total. Yields of suspended trace metals and nutrients from urban watersheds were consistently greater than corresponding yields from forested watersheds. Turbidity in basin streams increased with increasing concentrations of suspended sediment. Such increases, in turn, decreased the aesthetic quality of the watercourse and the depth of light penetration into the water column.

INTRODUCTION

This investigation is one part of the U.S. Geological Survey's intensive river quality assessment of the Upper Chattahoocheee River basin in Georgia (Cherry and others, 1976). In contrast to similiar studies in the Southeastern United States, this investigation examines erosion and sediment transport in large watersheds. Relations are developed, albeit imperfectly, between rates of erosion and sediment discharge and characteristic land-use, soil, topographic, and climatic parameters. Such relations, in turn, can be used by resource managers, hydrologists, and other earth scientists to better understand and accommodate the processes of erosion and sediment discharge in the study area.

ACKNOWLEDGMENTS

Much of the collection and analysis of data for this study was accomplished by field observers and hydrologic field assistants employed by the U.S. Geological Survey. The field observers were particularly dedicated and helpful, and our thanks and acknowledgements are herein extended to Charles T. Satterfield of Dahlonega, Ga., and the Steven Wells family of Whitesburg, Ga. Equally notable were the efforts of our hydrologic field assistants; especially the contributions of Douglas F. duMas, Reid C. Webb, Michael D. Holcomb, David G. Pinholster, and Ronald Boyd. The help of these personnel and others is gratefully acknowledged.

DESCRIPTION OF THE PROBLEM

The periodic occurrence of large quantities of sediment in the Chattahoochee River and its tributaries confronts the water-resource manager with a complex set of problems. Large-scale sedimentation aggrades stream channels, causing inundation of valuable bottom lands and increasing peak elevations of floods. Sediment deposition in reservoirs reduces their efficiency and useful life, and in some situations destroys the aesthetic and recreation potential of the impoundment. The sorbing capacity of sediments, especially clays and silts, provides a mechanism whereby nutrients, trace metals, and other chemical compounds are carried with the sediment into streams and reservoirs. High concentrations of suspended sediment in a water supply increase treatment costs and often restrict use of the water in certain industrial processes.

Faced with these and a host of related problems the resource manager must decide on reasonable methods to control or accommodate erosion and the discharge of sediment to basin streams. Decisions to implement control methods should be based on information of sufficient quality and quantity to permit such methods to be successful as well as economically and environmentally feasible. Unfortunately, comprehensive data relative to the processes of erosion and sediment discharge in the Upper Chattahoochee River basin have never been collected. To collect and interpret such data and to determine causal relationships between sediment discharge and the source environment are the overall objectives of this study. To accomplish these objectives, data-collection sites were established on the Chattahoochee River and on selected tributary streams. Selection of each site was based, for the most part, on physiographic location, dominant watershed land use, and availability of streamflow record. Specific study objectives at each data-collection site included:

(1) A description of sediment and sediment transport characteristics in the stream channel.
(2) A determination of average annual sediment discharge.
(3) A determination of the chemical nature of suspended sediment and its contribution to stream quality.

Study objectives relative to watersheds draining to selected data-collection sites included:

(1) An evaluation of channel and watershed morphology using Strahler (1957) stream-order analyses.
(2) A determination of average annual sheet erosion using the Universal Soil Loss Equation.
(3) The development of causal relations between stream quality, sediment discharge, land use, and other environmental factors.

UNITS OF MEASUREMENT

Data describing streamflow, lengths, and areas are defined or dimensioned in inch-pound units. Concentrations of suspended and dissolved constituents are defined in metric units and given in milligrams per liter (mg/L). Suspended- and dissolved-constituent discharges are expressed in terms of tons per year (t/yr). A list of inch-pound to metric conversions follows the "Contents" section of the report.

Symbols used in this report are defined where they first appear in the text.

DESCRIPTION OF THE STUDY AREA

The Upper Chattahoochee River basin comprises the area drained by the Chattahoochee River from its headwaters to West Point Dam (fig. 1)—a total of 3,550 square miles. The basin extends from the southern periphery of the Blue Ridge Mountains southwestward to the Alabama border, a distance of about 230 river miles. The basin is narrow compared with its length, with widths ranging from 2 to 30 miles. The width of the flood plain, in general, parallels that of the basin but seldom extends to more than 1 mile. The stream channel is well-incised within the flood plain and is characterized by steep banks and generally uniform sections. At several points in the basin, most notably downstream of Morgan Falls Dam (fig. 1), the flood plain is virtually nonexistent and channel incisement is relatively extreme. Two similar sites are occupied presently by West Point Dam and Buford Dam which impound, respectively, West Point Lake and Lake Sidney Lanier (fig. 1).

Since 1955, flow in the Chattahoochee River between Lake Lanier and West Point Lake has been regulated and, to a large extent, dominated by hydropower releases from Buford Dam. Waves generated by such releases can be observed at gaging stations along the entire reach of the river between the reservoirs.

PHYSIOGRAPHY AND TOPOGRAPHY

As described by Fenneman (1938), the Upper Chattahoochee River basin is entirely contained within the Southern Piedmont physiographic province. Within this general province, the basin occupies parts of two smaller physiographic entities—the Dahlonega and Atlanta Plateaus (fig. 1). The Dahlonega Plateau includes most of the basin upstream from Lake Sidney Lanier and contains the headwaters of the Chattahoochee River and two of its larger tributaries, the Chestatee and Soque Rivers. The area is characterized by mountains separated by deep, generally narrow valleys. Moun-

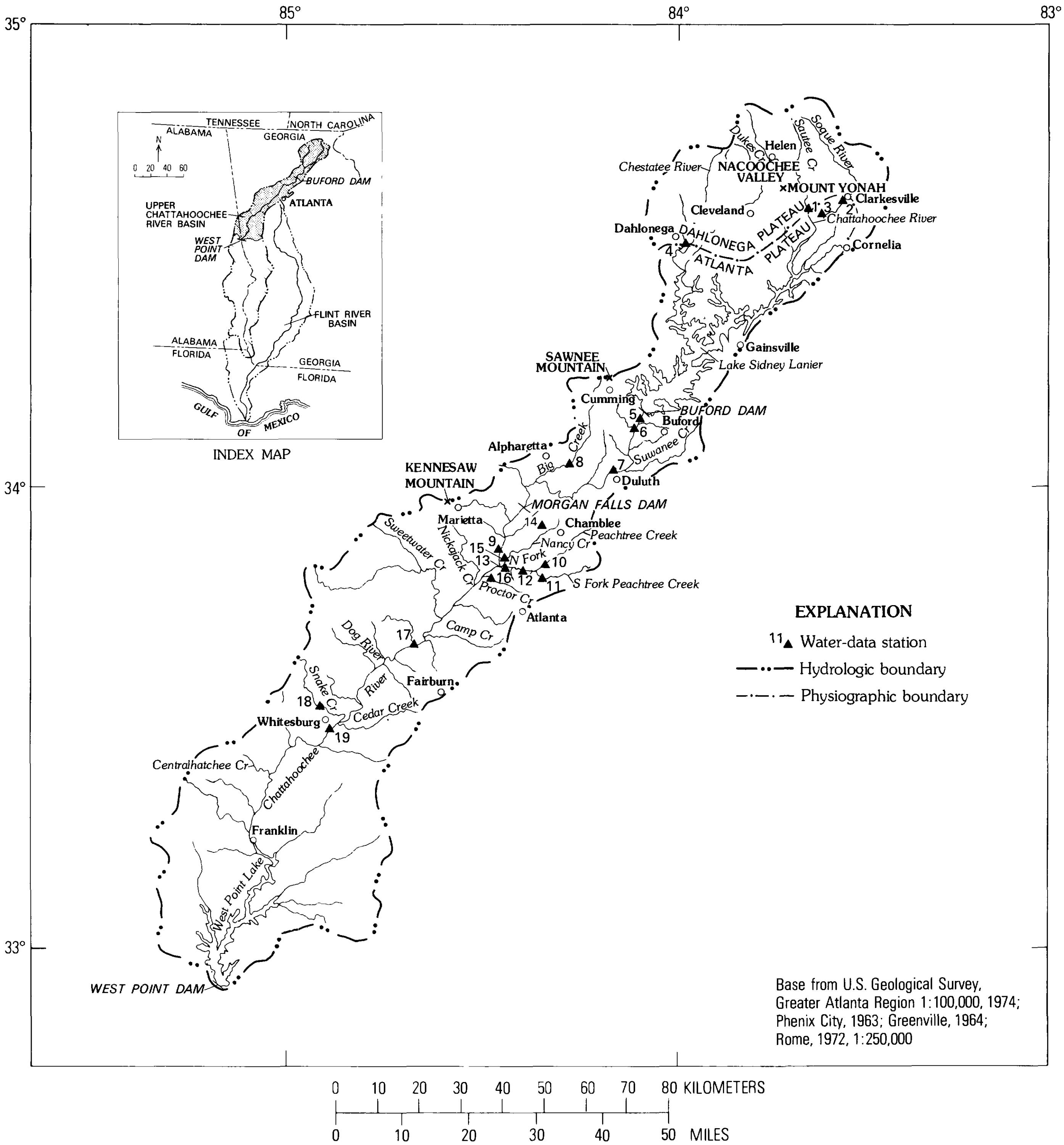


FIGURE 1.—Study area and location of water-data stations.

tain peaks in this part of the basin generally exceed 2,000 feet in altitude and at least three exceed 2,500 feet. The highest of these is Mount Yonah with a summit altitude of 3,166 feet.

The stream channel network draining the Dahlonega Plateau is generally rectangular and, for the most part, is structurally controlled. Flood plains for most streams are narrow or nonexistent. Small alluvial valleys have been formed by larger streams, however, most notably by the Chattahoochee River, south of Helen, and by the Soque River, in the vicinity of Clarkesville (fig. 1). Land and channel slopes are steep in this part of the basin. The Chattahoocheee River, in flowing across the Dahlonega Plateau, falls from altitude 2,980 feet to altitude 1,220 feet in approximately 28 river miles.

Aerial definition of the Dahlonega Plateau by Fenneman (1938) is less than precise; he places the plateau at the "high inner edge of the Piedmont in Georgia." McCallie and others (1925) provide a brief, verbal description of the plateau's boundaries and list several cities and towns located on the plateau. A small scale map delimiting the physiographic divisions of north Georgia also is provided by McCallie, but includes virtually no topographic control. By combining information from both sources, the authors have approximately defined that part of the Dahlonega Plateau drained by the Chattahoochee River and its tributaries (fig. 1). The area drained equals about 450 square miles or about 13 percent of the upper basin.

The Atlanta Plateau is discussed only briefly by Fenneman (1938) and is described as a southwestward extension of the Dahlonega Plateau. McCallie and others (1925) discuss the area in more detail and describe its major river systems. Within the Atlanta Plateau, the Chattahoochee River basin is characterized by low hills separated by narrow valleys. Alluvial bottomlands are prominant along the Chattahoochee River and its major tributaries, but generally are less than 1 mile in width. Small mountains do occur, most notably along the northern divide, and include Sawnee Mountain, northwest of Cummings, and Kennesaw Mountain, northwest of Marietta. Summit altitudes of these mountains are 1,920 feet and 1,800 feet, respectively. The stream channel network that drains the Atlanta Plateau to the Chattahoochee River is slightly more dendritic than its counterpart on the Dahlonega Plateau. The channel of the Chattahoochee River is severely controlled by structure in this part of the basin and occupies or directly parallels the trend of the Brevard Fault along most of its reach (Higgins, 1968). Major tributary streams on the Atlanta Plateau include Big, Peachtree, and Sweetwater Creeks in the vicinity of Atlanta and Snake Creek near Whitesburg (fig. 1).

Land and channel slopes on the Atlanta Plateau are generally not as steep as those on the Dahlonega Plateau. The Chattahoochee River, in flowing across the Atlanta Plateau, falls from altitude 1,220 feet to altitude 635 feet in approximately 200 river miles. The Chattahoochee River drains about 3,100 square miles of the Atlanta Plateau, which accounts for 87 percent of the study area.

CLIMATE

Climate in the study area is influenced, for the most part, by the mountainous terrain and the basin's proximity to the Gulf of Mexico (fig. 1). The higher mountains, most notably those along the northern perimeter of the basin, affect the climate most directly by serving as partial barriers to the flow of air masses. During the winter, these mountains inhibit the southerly flow of polar air into the basin, resulting in moderate winter temperatures with relatively few periods of excessively cold weather. During the summer, these same mountains serve as a barrier to north-flowing, moisture-laden winds from the Gulf. Consequently, summer convective storms are common and summertime rainfall is relatively high.

Summers on the Dahlonega Plateau are generally mild. Daytime temperatures from June through August are highest, but rarely exceed 100°F. Summer nights are cool but are seldom less than 60°F. Winters are moderately cold. Daytime temperatures are lowest from December through February and rarely exceed 55°F. Subfreezing temperatures (<32°F) occur frequently, but subzero temperatures (<0.0°F) are rare.

Average annual precipitation in this part of the basin is in excess of 60 inches. Most rainfall occurs in the winter and early spring months, but rainfall in excess of 10 inches has occurred in every month. Frozen precipitation in the form of sleet and snow is common during the winter; however, accumulations on the ground remain only a short time. During the summer, convective storms having short periods of intense rainfall are common.

A summary of precipitation and air temperature data for the city of Dahlonega is shown in table 1. Maps showing lines of equal average annual precipitation and temperature for the period 1941–70 are shown for the entire study area in figures 2 and 3, respectively.

Climatic conditions on the Atlanta Plateau are similar in most respects to those described for the Dahlonega Plateau. By comparison, the effects of altitude on rainfall and temperature are less pronounced, whereas the closer proximity to the Gulf of Mexico provides for a warmer, more humid climate. Temperature and precipitation are generally

TABLE 1.—*Summary of precipitation and air temperature data for Dahlonega, 1928–1957*

Month	Temperature (°F)				Precipitation Totals (in.)	
	Means		Extremes			
	Daily maximum	Daily minimum	Record high	Record low	Mean	Greatest daily
January	52.5	33.9	76	−1	6.8	4.30
February	55.3	34.4	76	5	6.03	3.90
March	62.3	39.4	87	9	6.71	4.50
April	72.1	47.4	92	24	5.00	4.10
May	79.9	54.6	96	34	4.38	2.67
June	86.2	62.3	100	43	3.91	2.98
July	87.9	65.6	103	50	5.78	4.18
August	86.6	64.8	100	49	5.00	4.73
September	81.5	59.9	100	36	3.89	5.44
October	71.8	49.0	92	23	3.15	4.12
November	60.4	38.9	83	3	4.37	3.51
December	52.7	33.6	74	5	6.18	3.89
Year	70.8	48.7	103	−1	60.48	5.44

a function of location. Rainfall generally decreases from the northeast to the southwest as the temperature increases (figs. 2 and 3).

Summaries of precipitation and air temperature data for the cities of Cornelia, Atlanta, and West Point are shown in tables 2 through 4, respectively.

TABLE 2.—*Summary of precipitation and air temperature data for Cornelia, 1941–1970*

Month	Temperature (°F)				Precipitation Totals (in.)	
	Means		Extremes			
	Daily maximum	Daily minimum	Record high	Record low	Mean	Greatest daily
January	51.6	31.2	80	−6	5.57	4.85
February	54.3	32.3	78	−4	5.50	3.99
March	61.2	37.8	83	7	6.44	4.70
April	71.9	46.9	90	24	5.26	3.42
May	78.8	54.1	96	30	3.85	2.65
June	84.3	61.3	100	40	4.85	4.45
July	86.4	64.3	102	50	5.71	3.64
August	86.1	63.9	99	46	4.58	3.98
September	80.0	58.4	98	30	4.02	4.55
October	71.6	47.7	92	24	3.37	4.28
November	60.9	37.7	82	7	4.01	4.54
December	52.2	31.5	76	1	5.18	2.95
Year	69.9	47.3	102	−6	58.34	4.85

TABLE 3.—*Summary of precipitation and air temperature data for Atlanta, 1941–1970*

Month	Temperature (°F)				Precipitation Totals (in.)	
	Means		Extremes			
	Daily maximum	Daily minimum	Record high	Record low	Mean	Greatest daily
January	51.4	33.4	72	−3	4.34	3.91
February	54.5	35.5	85	8	4.41	5.67
March	61.1	41.1	85	21	5.84	5.08
April	71.4	50.7	88	26	4.61	4.26
May	79.0	59.2	93	37	3.71	5.13
June	84.6	66.6	98	48	3.67	3.41
July	86.5	69.4	98	53	4.90	5.44
August	86.4	68.6	98	56	3.54	5.05
September	81.2	63.4	93	36	3.15	5.46
October	72.5	52.3	88	29	2.50	3.27
November	61.9	40.8	84	14	3.43	4.11
December	52.7	34.3	77	1	4.25	3.85
Year	70.3	51.3	98	−3	48.34	5.67

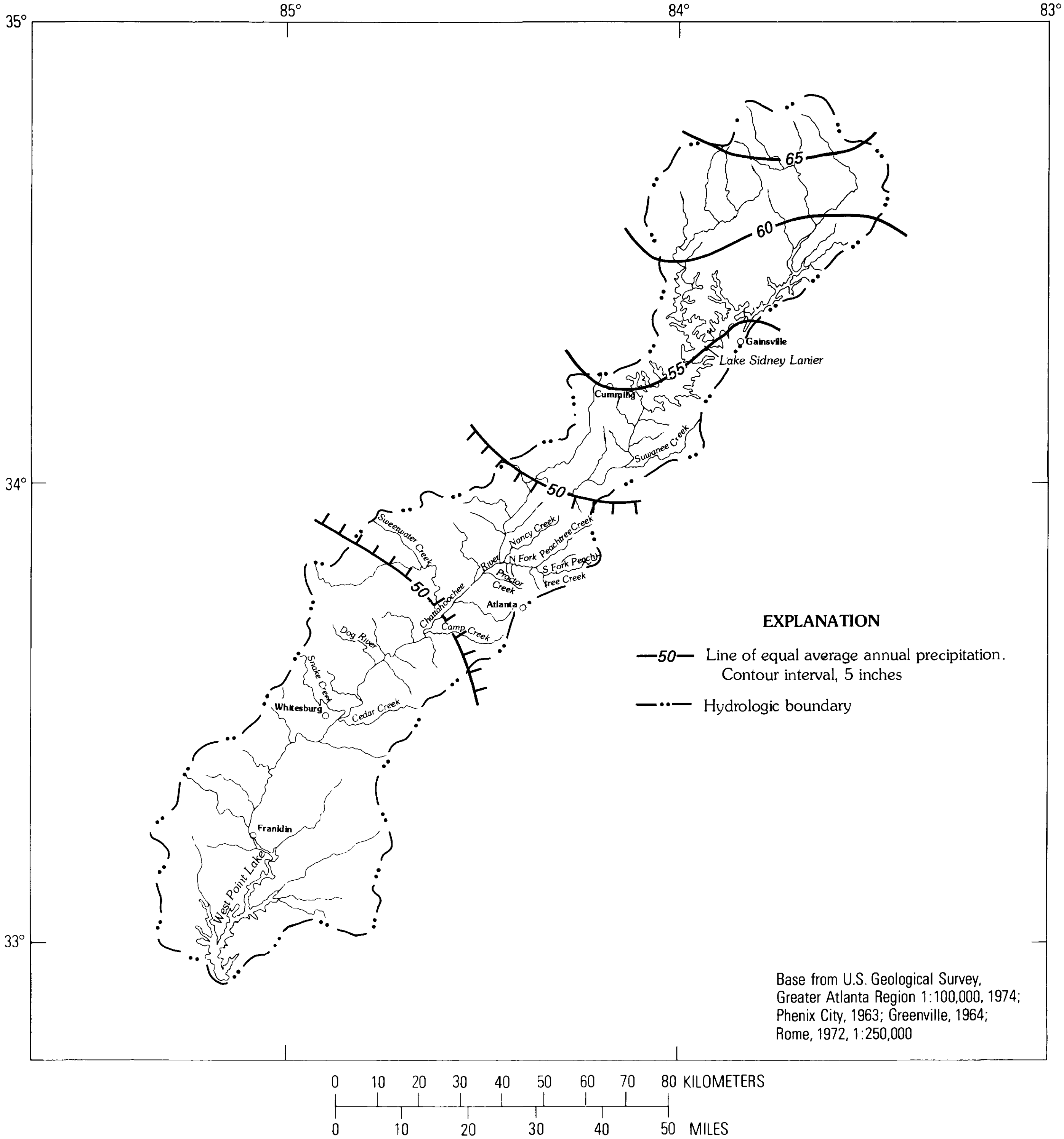


FIGURE 2.—Long-term average annual precipitation.

LAND USE AND VEGETATION

DAHLONEGA PLATEAU

The basin area within the Dahlonega Plateau is not densely populated nor is the land actively used on a large scale. In 1970, the population of the area was estimated to be about 16,000 persons (U.S. Bureau of Census, 1971), or a population density of one person per 16 acres. Ownership of land in this part of the basin is about equally divided between the Federal Government and private individuals.

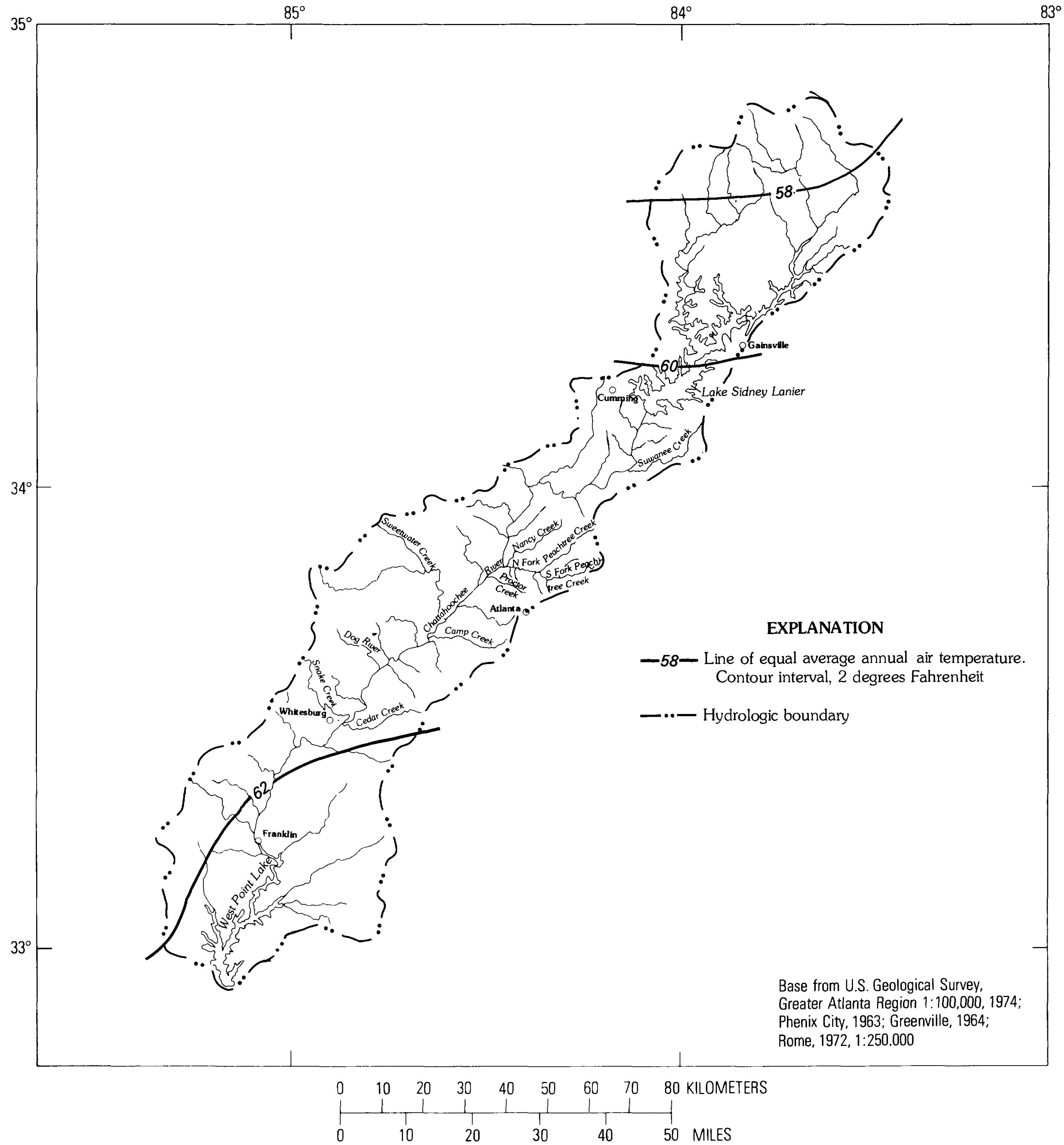


FIGURE 3.—Long-term average annual air temperature.

About 200 square miles of the basin south of the northern divide is administered by the Federal Government as part of the Chattahoochee National Forest. Except for several small State parks and some county and municipal properties, all lands south of the National Forest are held in private ownership.

At the present time (1976), active use of basin land within the Dahlonega Plateau is confined to the valleys of larger streams and is principally agricul-

TABLE 4.—*Summary of precipitation and air temperature data for West Point, 1941–1970*

Month	Temperature (°F)				Precipitation Totals (in.)	
	Means		Extremes			
	Daily maximum	Daily minimum	Record high	Record low	Mean	Greatest daily
January	58.2	34.1	80	1	4.47	2.98
February	61.2	36.1	84	8	5.16	7.18
March	67.9	41.6	88	11	6.34	5.71
April	77.6	50.1	94	27	4.89	4.75
May	84.4	57.7	99	35	3.82	3.76
June	89.5	65.5	104	43	3.81	4.69
July	90.6	68.6	105	53	5.76	3.87
August	90.3	67.8	102	52	4.08	5.02
September	85.4	62.1	101	35	3.60	6.00
October	77.3	50.1	97	24	2.47	3.00
November	66.9	39.8	87	8	3.51	7.26
December	58.9	34.2	79	1	5.08	4.60
Year	75.7	50.6	105	1	52.99	7.26

tural in nature. Grazing, row cropping, and poultry feeding account for most agricultural activities and occupy about 9 percent of the total land area. Urban and residential land use is minor and is confined to the immediate vicinities of such small towns as Helen, Cleveland, and Clarkesville.

Most basin land (90 percent) within the Dahlonega Plateau is occupied by forests and woodlands. Forested areas are characterized by mixed stands of conifer and deciduous trees dominated by pine and oak, respectively. Dominant pines include the Virginia and shortleaf varieties; common deciduous trees include white oak, red oak, and black oak. Forest undergrowth is dominated by dogwood, greenbriar, and blackberry briars. Abandoned fields are naturally seeded with broom sedge and other grasses, but are gradually overgrown by small pines, sassafras, and hardwoods. Yellow poplar is common in most areas and white pine is found at higher elevations.

Commercial logging was an important industry in this area at one time, and most forested areas have been logged at least twice. Timber is not presently logged on a large scale. Commercial stands of timber are available, however, and the potential for extensive future logging is great.

ATLANTA PLATEAU

Population density in that part of the Atlanta Plateau drained by the Chattahoochee River is much higher than in corresponding areas on the Dahlonega Plateau and active use of the land is more widespread and varied. In 1970, the population of the area was estimated to be about 1,500,000 persons (U.S. Bureau of Census, 1971), or a population density of one person per 1.3 acres. Active use of the land is characterized, for the most part, by the urbanization of forests and agricultural areas. At the present time (1976), about 12 percent of basin land on the Atlanta Plateau is urban or suburban. Corresponding percentages for agricultural lands and forests are 17 percent and 67 percent, respectively. The remaining area (4 percent) is mostly wetlands and reservoirs.

Major urban centers in this part of the basin include Atlanta, Gainesville, Marietta, Cornelia, and Alpharetta (fig. 1). Urban areas are characterized by extensive residential communities separated by commercial, industrial, and transportation centers.

Agricultural lands are located generally within the flood plains of the Chattahoochee River and its major tributaries. Grazing, row cropping, poultry feeding, and orchards constitute most of the agricultural land use. Row crops are mostly corn and hay. Apples and peaches are the most common orchard crops. Pasture lands generally are of poor quality and contain grasses such as broom sedge, crabgrass, lespedeza, and bermuda grass.

Forests in this part of the basin consist mostly of oak, pine, and hickory. Common varieties of pine are the shortleaf and loblolly. Dominant oak species are the red, black, blackjack, and white oaks. Common plants in the forest undergrowth include dogwood, greenbriar, sassafras, and blackberry briars.

Basin land on the Atlanta Plateau is nearly all privately owned. Lands administered by the Federal Government constitute the bulk of public properties and include several military reservations as well as lands adjacent to West Point Lake and Lake Lanier. The total area of public lands does not exceed 200 square miles.

Other land uses within the Atlanta Plateau include recreation, commercial logging, and sand dredging. Such activities are not areally extensive, and their impact on water quality at the present time (1977) is considered minor.

GEOLOGY AND SOILS

Metamorphic and intrusive igneous rocks underlie most of the Dahlonega and Atlanta Plateaus. A generalized geologic map designating major rock groups and formations is shown in figure 4. For

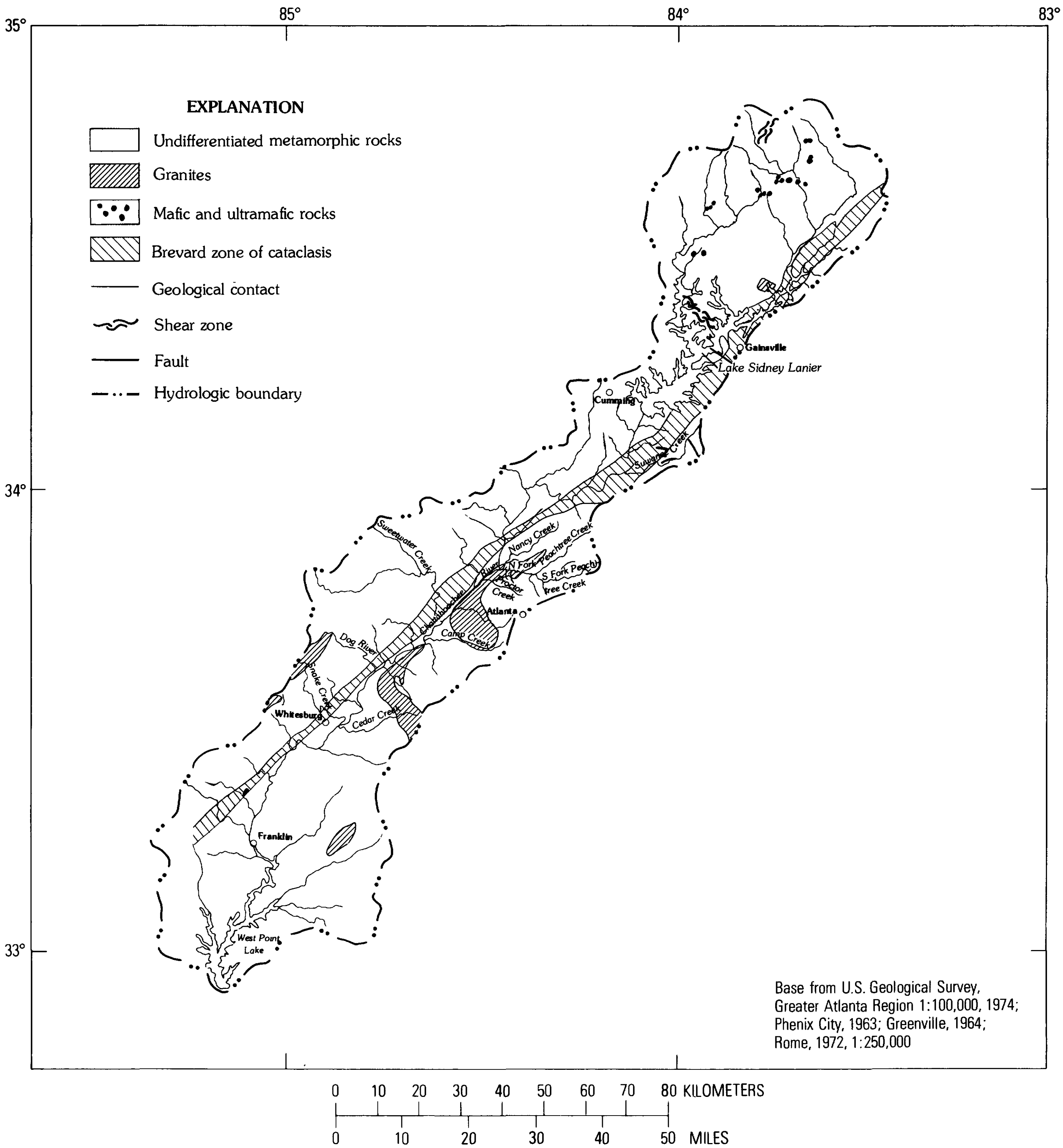


FIGURE 4.—Generalized geology of study area. Geology modified from Georgia Department of Natural Resources (1976).

the most part, the metamorphic rocks include slate, mica schist, gneiss, and quartzite. Intrusive igneous rocks include granites and ultramafics. The age of both the metamorphic and intrusive rocks is uncertain; however, Precambrian is most often cited in the literature (Crickmay, 1952; Hatcher, 1971).

Structural features of the basin include the Brevard Fault Zone and several minor faults and shear zones (fig. 4). The structure and orientation of the Brevard Fault dominate the physiographic character of the Atlanta Plateau including much of the southern half of the Upper Chattahoochee River basin.

Soils in the basin are derived from the disintegration of underlying rocks and range in texture from gravelly sandy loam to clay loam. Similar soil types occur on both the Dahlonega and Atlanta Plateaus.

NETWORK DESCRIPTION

The total drainage of the Chattahoochee River basin is about 8,650 square miles; the most upstream part of which is the 3,550 square miles of study area. The Chattahoochee River is joined by the Flint River near the Georgia–Florida State line, where the combined rivers form the Appalachicola River, which, in turn, flows to the Gulf of Mexico (fig. 1).

On occasion in this section, points on the Chattahoochee River will be designated by river mile (RM). Zero river mile (RM 000.00) is defined as the confluence of the Flint and Chattahoochee Rivers.

The Chattahoochee River rises in the upland areas of the Dahlonega Plateau and flows, initially, in a southeasterly direction. About 10 miles downstream of the headwaters, the river flows through the small urban center of Helen and enters the Nacoochee Valley. Here the Chattahoochee is joined by two large tributaries, Sautee Creek at river mile 415.95 and Dukes Creek at river mile 418.08. The Chattahoochee river enters the Atlanta Plateau at about river mile 405.50 and continues on a southeasterly course to its confluence with the Soque River (RM 402.50); here the channel abruptly turns to the southwest. Several miles downstream of the Soque confluence the Chattahoochee enters the headwaters of Lake Sidney Lanier—a multipurpose reservoir impounded behind Buford Dam (RM 348.32). The Chestatee River joins the Chattahoochee within Lake Lanier at river mile 362.98.

Between Buford Dam (RM 348.32) and Morgan Falls Dam (RM 312.62), the Chattahoochee river is joined by many tributaries, most notably Suwanee Creek (RM 338.12) and Big Creek (RM 317.37).

Downstream of Morgan Falls Dam the Chattahoochee River enters the Atlanta metropolitan area and continues to flow through mostly urban areas to its confluence with Camp Creek (RM 281.79). Major tributaries in this reach include Peachtree Creek (RM 300.54), Proctor Creek (RM 297.50), Nickajack Creek (RM 295.13), Sweetwater Creek (RM 288.56), and Camp Creek (RM 283.53).

Downstream of the Atlanta metropolitan area, the Chattahoochee River continues to flow in a southwesterly direction toward West Point Lake. Major tributaries along this reach include Dog River (RM 273.50), Snake Creek (RM 261.72), Cedar Creek (RM 261.25), and Centralhatchee Creek (RM 236.52). In the vicinity of Franklin, Ga. (RM 235.46), the Chattahoochee River flows into West Point Lake and continues as West Point Lake to the terminal point of the study area at West Point Dam (RM 201.40).

COLLECTION AND ANALYSIS OF WATER DATA

WATER-DATA STATIONS

Study objectives and the paucity of relevant data required that a comprehensive water-data collection effort be established and maintained during the first year of study (Sept. 1975 to Sept. 1976). To this end, 12 locations in the basin were chosen as principal stations for periodic water-data collection and three locations were selected for miscellaneous or less-intense data collection. Primary criteria used to locate each station were land use, physiography, and length of at-site or correlative streamflow record. Continuity of data and data interpretation relative to downstream stations were also considered. Figure 1 shows the location of all water-data stations referenced in this report. Table 5 lists the stations in downstream order and keys their location to figure 1.

Principal data-collection sites on the Atlanta Plateau were located at Big Creek near Alpharetta, Peachtree Creek at Atlanta, and Snake Creek near Whitesburg. Land use within these watersheds was classified as rural, urban, and forest, respectively. In order to provide more data relative to an urban environment, several other principal data-collection sites were located within the Peachtree Creek watershed. These stations include Nancy Creek at Randall Mill Road at Atlanta, North Fork of Peachtree Creek at Buford Highway near Atlanta, and

TABLE 5.—*Station number, name, and watershed area of principal and miscellaneous water-data stations*

[C, Continuous Stage Record; P, Partial Stage Record]

Key No. (fig. 1)	U.S. Geological Survey station number	Drainage area (mi²)	Stage record	Period of record	Station name
1	02331000	150	C	1940–71	Chattahoochee River near Leaf.
2	02331250	96.0	None		Soque River near Clarkesville.
3	02331500	156	C	1906–09 1931, 1941–45	Soque River near Demorest.
4	02333500	153	C	1930–71	Chestatee River near Dahlonega.
5	02334430	1040	C	1971–76	Chattahoochee River at Buford Dam near Buford.
6	02334500	-----	C	1942–71	Chattahoochee River near Buford.
7	02334590	-----	None	-------	Chattahoochee River at State Route 120 near Duluth.
8	02335700	72.0	C	1961–76	Big Creek near Alpharetta.
9	02336000	1450	C	1930–76	Chattahoochee River at Atlanta.
10	02336120	34.1	P	1976	North Fork Peachtree Creek at Buford Highway near Atlanta.
11	02336250	29.6	P	1976	South Fork Peachtree Creek at Atlanta.
12	02336300	86.8	C	1959–76	Peachtree Creek at Atlanta.
13	02336313	3.1	P	1976	Woodall Creek at DeFoors Ferry Road at Atlanta.
14	02336339	3.2	P	1976	Nancy Creek tributary near Chamblee.
15	02336380	34.8	P	1976	Nancy Creek at Randall Mill Road at Atlanta.
16	02336526	15.5	P	1976	Proctor Creek at State Route 280 at Atlanta.
17	02337170	2060	C	1965–76	Chattahoochee River near Fairburn.
18	02337500	37.0	C	1955–76	Snake Creek near Whitesburg.
19	02338000	2430	C	1939–53, 1965–76	Chattahoochee River near Whitesburg.

South Fork of Peachtree Creek at Atlanta. The location of three principal data-collection stations on the Chattahoochee River at Atlanta, near Fairburn, and near Whitesburg provided an opportunity to compare tributary and main stream data.

Miscellaneous stations on the Atlanta Plateau were located on Proctor Creek at State Route 280 at Atlanta, on Woodall Creek at DeFoors Ferry Road at Atlanta, and on a tributary to Nancy Creek near Chamblee.

Principal data-collection stations on the Dahlonega Plateau were located on the Chattahoochee River near Leaf, on the Chestatee River near Dahlonega, and on the Soque River near Clarksville. The total flow passing these three stations includes most of the runoff from the Dahlonega Plateau. Site selection criteria in this part of the basin emphasized physiographic location and available streamflow record rather than land use.

In addition to the data-collection sites listed above, water data from several other stations were used in this study. These stations are listed in table 5 as the Soque River near Demorest, the Chattahoochee River at Buford Dam near Buford, the Chattahoochee River near Buford, and the Chattahoochee River at State Route 120 near Duluth.

For the most part, subsequent illustrations in this text refer to only a few selected water-data stations. These stations were chosen to illustrate unusual sediment-transport conditions and the range of transport and related conditions observed in the basin.

WATER-QUALITY DATA

Collection of sediment and water-quality data relative to seasonal low flows and storm runoff began in September 1975 and continued for a period of 1 year. Sampling frequency was mostly determined by the occurrence and duration of runoff events. Water data collected at each sampling site included measurements of streamflow or stage, water temperature, and water samples for chemical and suspended-sediment analyses. In addition, data used to compute bedload transport were collected at selected sites. All water samples were collected using depth-integrating techniques, as described by Guy and Norman (1970). Concentrations of suspended sand and suspended silt plus clay were determined for each water sample. Chemical analyses of each sample determined concentrations of nutrients and trace metals in both the dissolved and total phases as well as fecal contamination, pH, and specific conductance. All water-quality data collected during this study will be published by the Georgia District of the Water Resources Division, U.S. Geological Survey.

Suspended-constituent concentrations within a stream cross section commonly exhibit a high degree of spatial variation. To account for this variation, depth-integrated water samples were collected at several verticals at each cross section and composited. The suspended-constituent concentrations used in this study were derived from the composited samples. Suspended-constituent concentrations also vary with discharge and should be considered as instantaneous values and representative only of the discharge at the given time and location.

Data were collected for this study over the relatively short period of one year. Therefore, the data and interpretations presented in this report are influenced, to some degree, by prevailing climatic and land-use conditions and may not represent the true, long-term water quality of basin streams.

STREAMFLOW DATA

Direct measurement of streamflow and stage over a wide range of values defines a generally unique relation between stage (water-surface altitude) and discharge. This relation (rating) can be used to estimate instantaneous discharges when only stage values are known. Such discharges, in turn, can be used, in conjunction with other data, to compute instantaneous sediment or other water-quality constituent discharges. In addition, stage-discharge ratings permit the computation of daily mean discharge from continuous stage records. A plot of daily mean discharge against time provides the typical streamflow hydrograph. The tabulation and statistical analysis of long-term records of daily mean discharge provides standard streamflow characteristics such as flood frequency and flow duration.

During the period of data collection for this study, water-data stations described in table 5 as continuous-recording (C) and partial-record (P) were located proximate to automatic stage recorders that were routinely operated and maintained by the U.S. Geological Survey. Information such as current stage-discharge ratings and long-term daily discharge records were available for most continuous-record stations. Streamflow data for the partial-record stations consisted of a few flood-peak measurements and little or no historical record. Consequently, project efforts to collect streamflow data were concentrated at the partial-record stations and were sufficient to define valid stage-discharge relations at each site. These ratings, in turn, were used with recorded stage data to compute daily mean discharges at each partial-record station for the period January to September 1976.

THE STREAM SYSTEM

In general, a stream system is defined in terms of channel and streamflow characteristics. Channel characteristics include size and shape as well as hydraulic descriptors such as slope and channel roughness. Streamflow characteristics describe the quantity, occurrence, and temporal distribution of discharge and commonly include hydrographs, flood and drought recurrence intervals, and flow durations.

Stream system characteristics pertinent to this study include channel slope, stream-bed characteristics, streamflow hydrographs, and flow durations. Channel characteristics are presented to demonstrate the variety of channel slope, channel geometry, and streambed conditions occurring at the water-data stations. Streamflow hydrographs are presented to demonstrate the sensitivity of streamflow to rainfall and the variety of streamflow conditions that occurred during the period of data collection. Flow duration data are required to compute average annual discharges of sediment and other suspended water-quality constituents.

CHANNEL CHARACTERISTICS

Channel characteristics are described for selected water-data stations in figure 5. Each illustration shows a profile of the channel section at the station and lists the channel slope and a description of the streambed. Slope data in the vicinity of the stations were obtained by measuring the length and fall of the stream surface as depicted on 1:24,000 scale topographic maps.

Stream channel cross sections in the basin tend to be mostly rectangular to trapezoidal in shape (fig. 5). Streambeds on the Dahlonega Plateau consist of boulders, cobbles, gravel, and sand that frequently lie directly on bedrock. Streambeds on the Atlanta Plateau are similar but generally contain thicker, more extensive deposits of sand and gravel. Streambed scour and fill may be common on the Atlanta Plateau, especially where bridges or other local controls constrict the streamflow. Streambed altitudes at various discharges are shown for Big Creek near Alpharetta and Peachtree Creek at Atlanta (figs.

5*B* and 5*D*) and indicate the magnitude of scour occurring at these stations.

FLOW CHARACTERISTICS

STREAMFLOW HYDROGRAPHS

Streamflow hydrographs at selected water-data stations are shown in figure 6 for the period January through September 1976. Vertical lines at the top of each graph indicate total daily rainfall measured at a nearby rain gage. The sensitivity of streamflow to rainfall is apparent at most stations. Those streamflows showing the least sensitivity to rainfall occur at the Chattahoochee River at Atlanta. Discharge at this station and at the stations near Fairburn and Whitesburg is regulated by Buford and Morgan Falls Dams, which dampen the normal response of streamflow to all but the largest, most areally extensive rainfall events.

The recurrence of peak discharges during water year 1976 varied according to station location and rainfall distribution. For example, the three largest peaks on the Chestatee River near Dahlonega had recurrence intervals of about 5 years, 2 years, and 1.5 years, respectively. Corresponding values for Snake Creek near Whitesburg were 4 years, 3 years, and 1.3 years. Flood peaks of 4 and 5 years recurrence are not particularly rare events. Their occurrence, however, did permit the collection of sediment and other water-quality data over a greater than average range of discharges.

FLOW DURATIONS

Flow-duration data are computed from long-term streamflow records by arranging daily discharge values in order of magnitude and noting the number of days of occurrance of each value. The cumulative frequency of occurrence of each discharge defines its duration, or the percentage of time the discharge is equaled or exceeded. Duration data are generally presented in the form of a curve. Such curves represent the flow characteristics of a stream throughout a given period of record without regard to the sequence of flow events. The area defined by the duration curve equals the average daily stream discharge at the station for the given period of record.

As suggested above, flow durations can be directly computed only at stations where long-term, continuous discharge records are available. Duration data for stations where streamflow records are short-term or nonexistent can be extended to longer periods or estimated entirely from long-term records at nearby stations. Such extrapolations are generally based on the correlation of concurrent daily discharge records or the adjustment of computed durations by ratios of drainage areas.

Duration data at all principal and miscellaneous water-data stations were required for this study and were computed directly for stations with periods of record of 10 years or more (table 5). Duration data for stations with less than 10 years of record were obtained by extrapolation. Flow durations for partial-record stations in the Atlanta urban area were based on the extrapolation of durations computed from the long-term record at Peachtree Creek at Atlanta. Daily discharge values at each partial-record station were paired with concurrent values at Peachtree Creek at Atlanta and correlated by linear regression. In general, several months of these data pairs for the period January to September 1976 were used for each regression. The class discharge relative to each directly computed percentage duration at Peachtree Creek at Atlanta was then combined with the regression equations to compute corresponding discharges at the same percentage duration for the partial-record stations.

Because of the large differences in drainage area between the smaller urban watersheds and Peachtree Creek at Atlanta, the extrapolated duration data for Woodall Creek and a tributary to Nancy Creek are less representative of long-term flow conditions than are corresponding data from the larger drainages. Consequently, average daily discharges and other information based on duration data at these stations are also less representative of long-term conditions and should be treated accordingly.

The regression equations used to correlate the concurrent discharge data have the general form

$$Q_r = b_0 + b_1 Q_p$$

where

Q_r = the daily discharge at the partial-record station in cubic feet per second,

Q_p = the daily discharge at Peachtree Creek at Atlanta in cubic feet per second, and

b_0 and b_1 = regression constants.

A summary of regression data along with computed average daily discharge values at each station is listed in table 6. Use of the regression data in table 6 should be limited to the range of daily flows observed at Peachtree Creek at Atlanta during water year 1976 (16 to 8,660 cubic feet per second).

Duration data for the station on the Soque River near Clarkesville were determined by the extrapolation of durations computed from the long-term record at the Soque River near Demorest. Adjustment of the computed durations was based on the

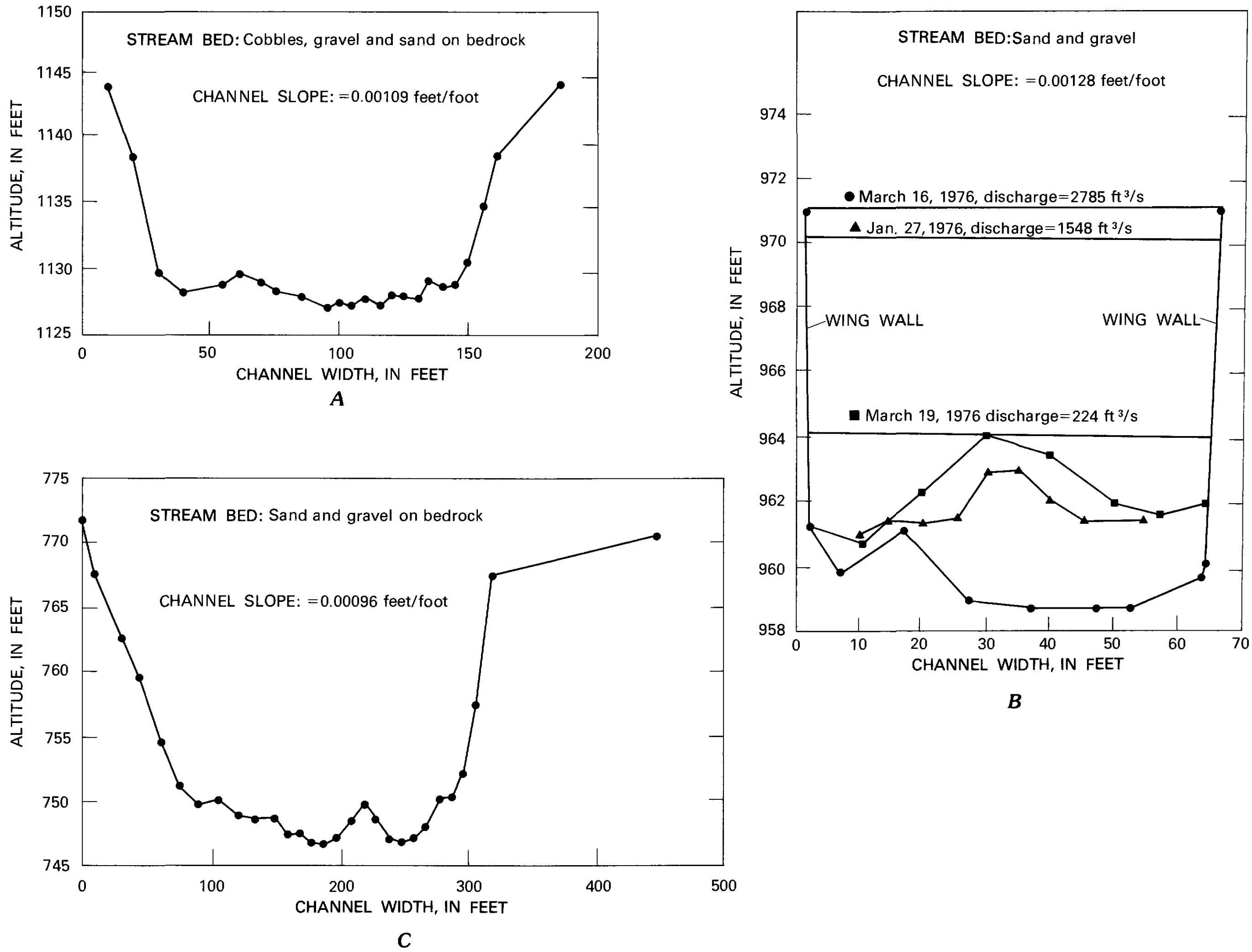


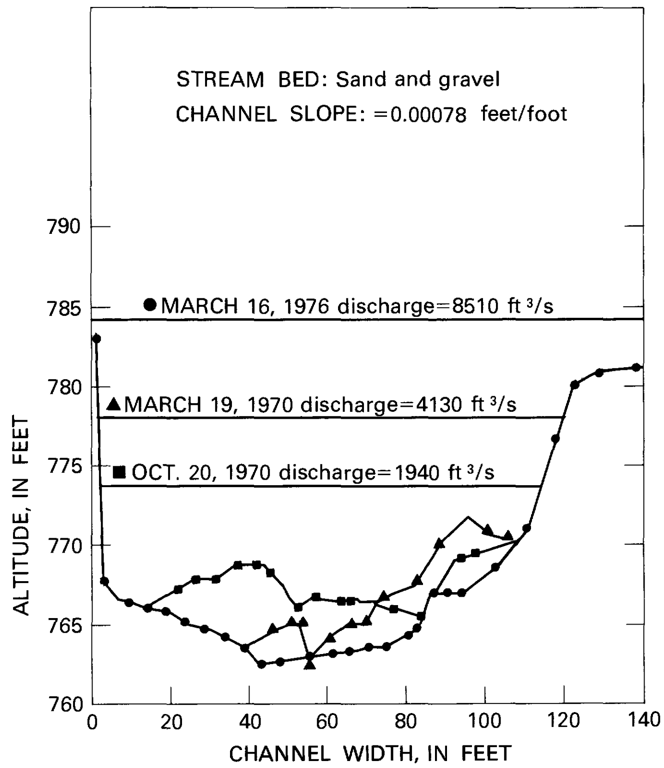
FIGURE 5.—Channel characteristics at (*A*) Chestatee River near Dahlonega, (*B*) Big Creek near Alpharetta, and (*C*) Chattahoochee River at Atlanta.

TABLE 6.—*Summary of regression data relating daily discharge at urban partial-record stations to daily discharge at Peachtree Creek at Atlanta*

Station name	b_0	b_1	Number of data pairs	Average daily discharge (ft^3/s)
N. Fork Peachtree Creek near Atlanta	−1.36	0.37	119	50
S. Fork Peachtree Creek at Atlanta	−3.12	.40	122	53
Woodall Creek at Atlanta	6.18	.092	52	19
Nancy Creek Tributary near Chamblee	1.83	.021	95	4.7
Nancy Creek at Atlanta	13.7	.377	122	67
Proctor Creek at Atlanta	10.6	.023	104	14

ratio of watershed areas drained by the two stations.

The durations of both regulated flows and intervening runoff were required for those stations on the Chattahoochee River at Atlanta, near Fairburn, and near Whitesburg. Both sets of duration data were computed using streamflow records for the period 1965–76, the longest common period of record (table 5). The occurrence of regulated flow in the reach of interest (Atlanta to near Whitesburg) is the result of hydropower production at Buford and Morgan Falls Dams. Morgan Falls Dam is a "run of the river" facility and provides only minimal regulation. Consequently, the computed streamflow durations at Buford Dam are considered equal to the durations of regulated flow at the three downstream stations. The computation of regulated flow durations used the combined streamflow



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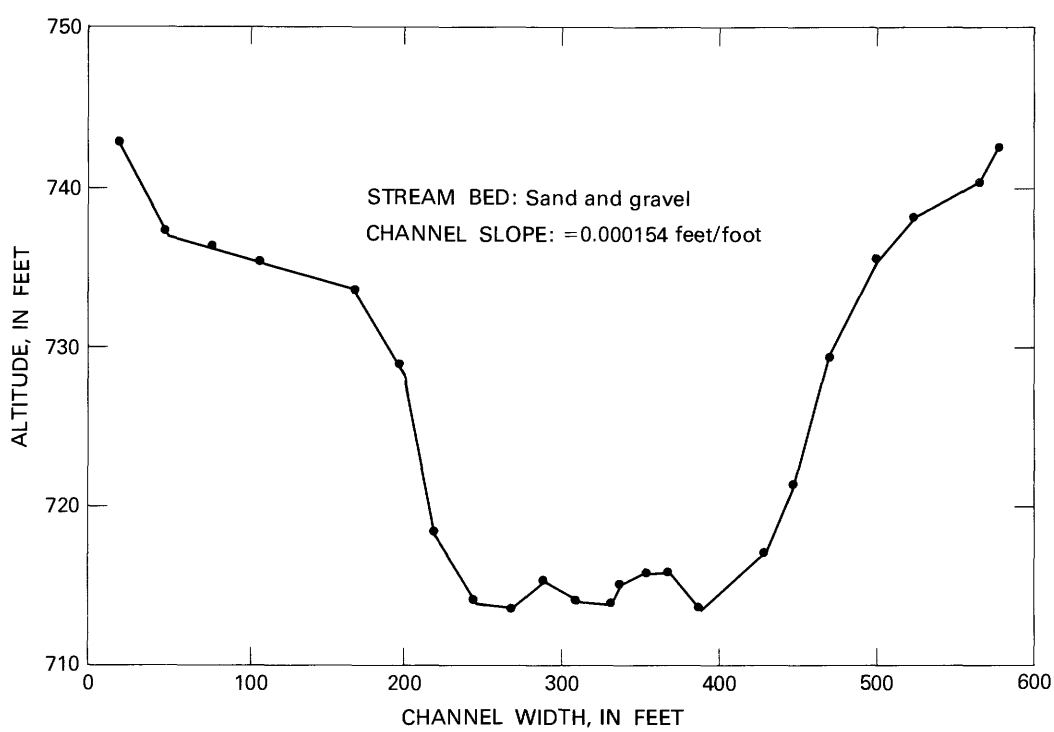

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FIGURE 5.—Continued. Channel characteristics at (*D*) Peachtree Creek at Atlanta, and (*E*) Chattahoochee River near Fairburn.

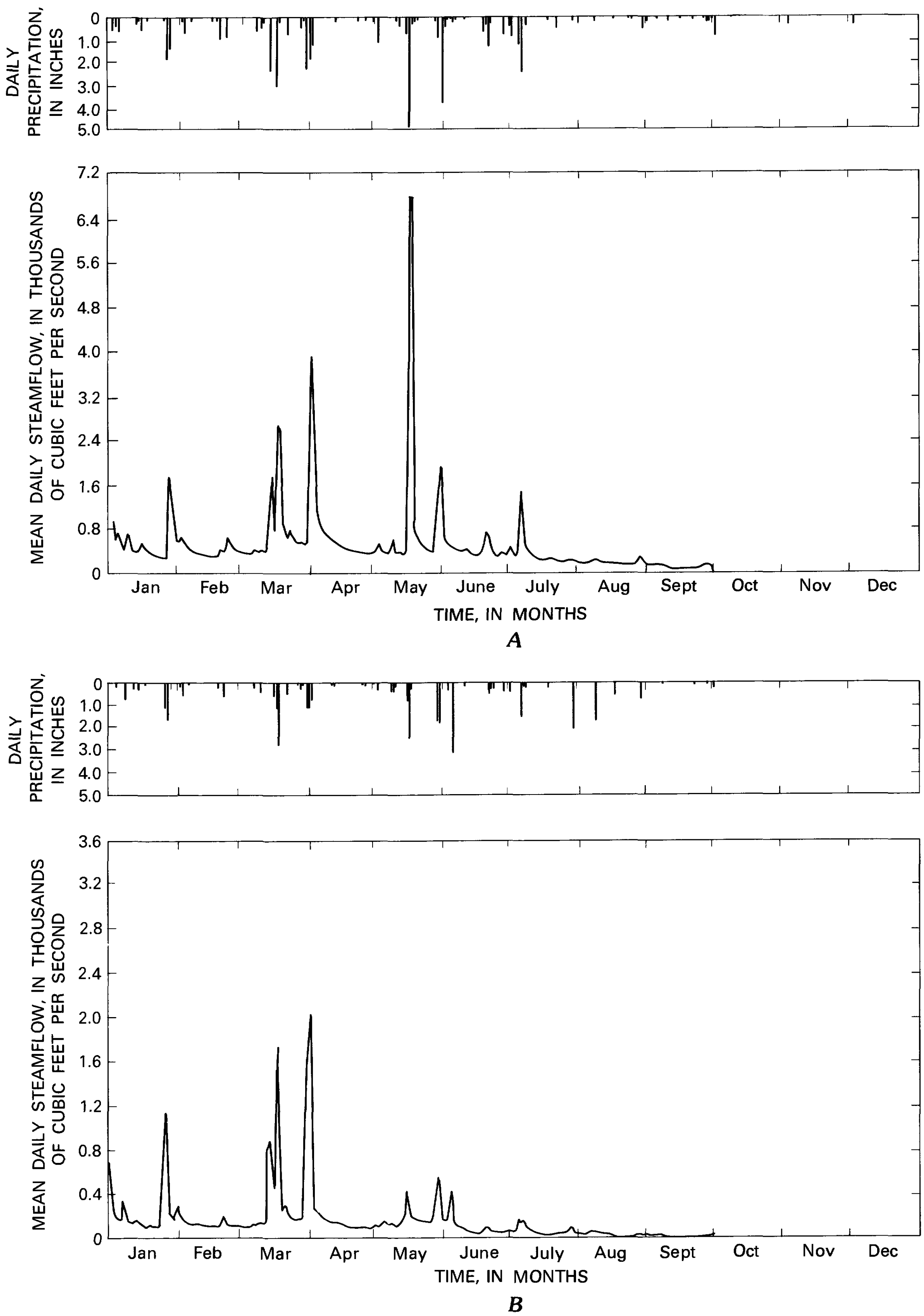


FIGURE 6.—Mean daily streamflow and daily precipitation at (*A*) Chestatee River near Dahlonega and (*B*) Big Creek near Alpharetta.

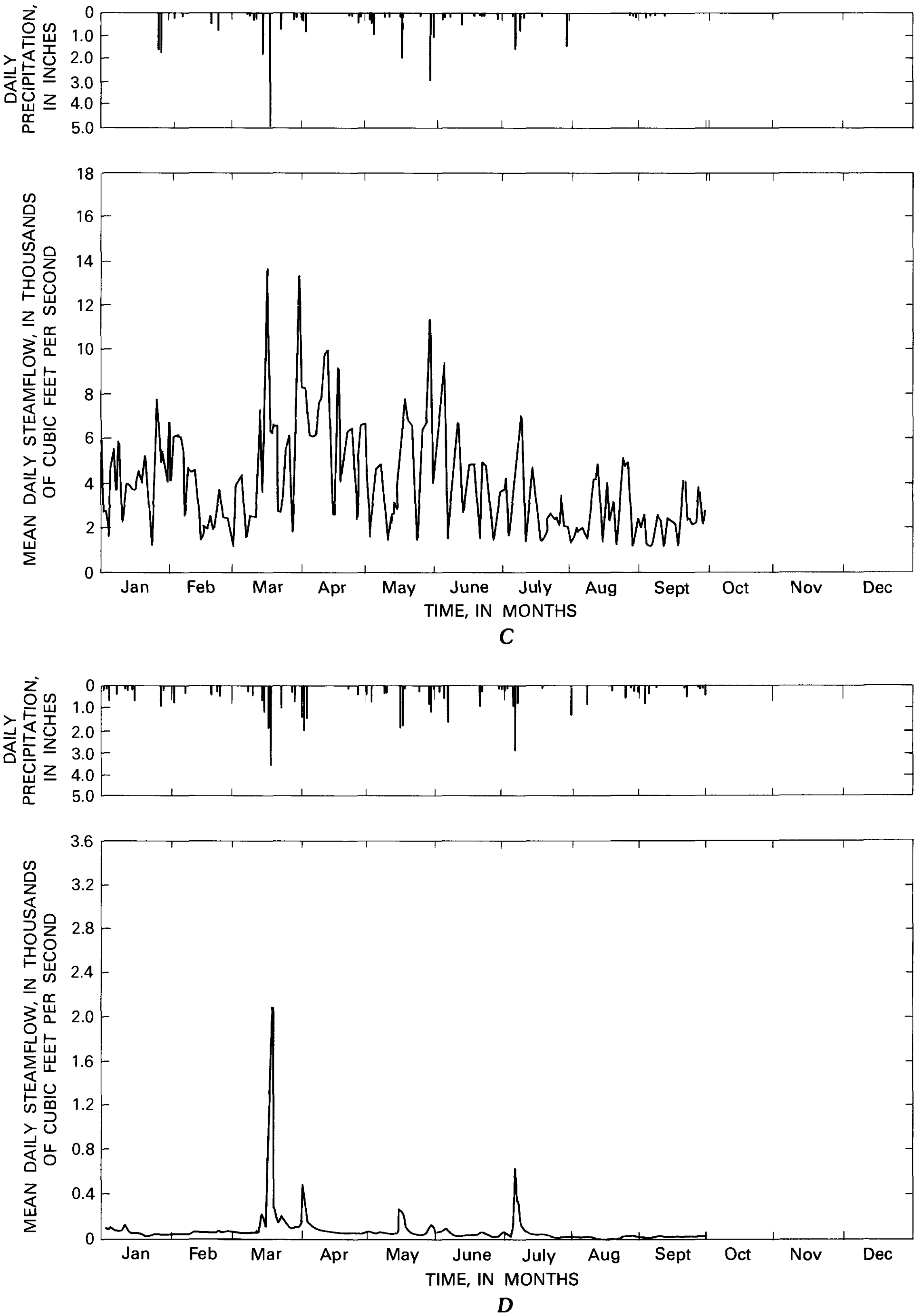


FIGURE 6.—Continued. Mean daily streamflow and daily precipitation at (*C*) Chattahoochee River at Atlanta, and (*D*) Snake Creek near Whitesburg.

TABLE 7.—*Summary of flow duration data: discharge that is equaled or exceeded during percentage of time indicated*

[Superscript *a* indicates extrapolated data]

Percentage of time	Station number					
	1000	[a]1250	1500	3500	4430 4500	5700
0.1	5990	3000	5100	5700	8400	2100
.5	2630	1720	2800	2500	7400	1300
1.0	1780	1200	2090	1700	6700	880
2	1320	860	1320	1250	6200	550
4	970	600	900	900	5700	380
6	830	490	710	800	5500	300
8	750	400	620	650	5400	260
10	630	360	590	610	5100	240
14	600	310	500	550	4600	190
18	550	290	460	500	4100	160
22	530	270	420	450	3700	140
26	460	250	390	400	3300	120
30	440	230	370	390	3000	110
35	400	210	350	360	2600	100
40	380	200	300	330	2300	90
45	340	190	280	300	2000	85
50	310	170	250	280	1700	75
55	290	160	230	270	1500	70
60	270	150	220	250	1300	65
65	250	130	215	220	1200	55
70	230	120	190	200	1100	50
75	200	110	180	190	850	45
80	190	100	170	160	800	40
85	170	95	160	140	630	35
90	150	80	140	125	590	30
95	130	75	120	105	540	26
98	110	60	90	92	530	21
99	96	50	75	79	520	18
99.5	85	45	70	70	500	16
99.9	60	32	52	60	450	14

records of stations on the Chattahoochee River at Buford Dam and near Buford. A combination of records was necessary because of the termination of one station after 1971 and the subsequent beginning of the other (table 5). Average daily flow at the two stations is nearly equivalent, however.

The durations of intervening runoff at the Chattahoochee River at Atlanta, near Fairburn, and near Whitesburg could not be computed directly from streamflow records because both runoff and regulated flows had been recorded. Division of each station's record into regulated flow and runoff was accomplished by subtracting the regulated flow recorded for a particular day at Buford Dam from the corresponding recorded daily flow at the downstream station. Adjustments for celerity were made on a whole-day basis. The difference between the daily discharge at each station and the concurrent discharge at Buford Dam was attributed to the daily runoff entering the river between the dam and the station. The sets of these differences for the period of record were used to compute the duration of intervening runoff.

A summary of flow durations for each water-data station, whether extrapolated or computed, is listed in table 7. Flow duration curves for selected water-data stations are shown in figure 7. The low-discharge parts of the runoff duration curves for the Chattahoochee River at Atlanta, near Fairburn, and near Whitesburg are poorly defined and are reported only to the limits of accuracy permitted by the data and the computation procedure discussed previously.

With the exception of stations on the Chattahoochee River downstream from Buford Dam, computed duration data were based on the entire period of record available at the station. Thus, no attempt was made to select or adjust station records relative to a common period of time. Such use of records is consistent with the treatment of daily discharge values as random-sample data and provides a better description of long-term flow expectancy in the basin.

WATERSHED AND CHANNEL MORPHOLOGY

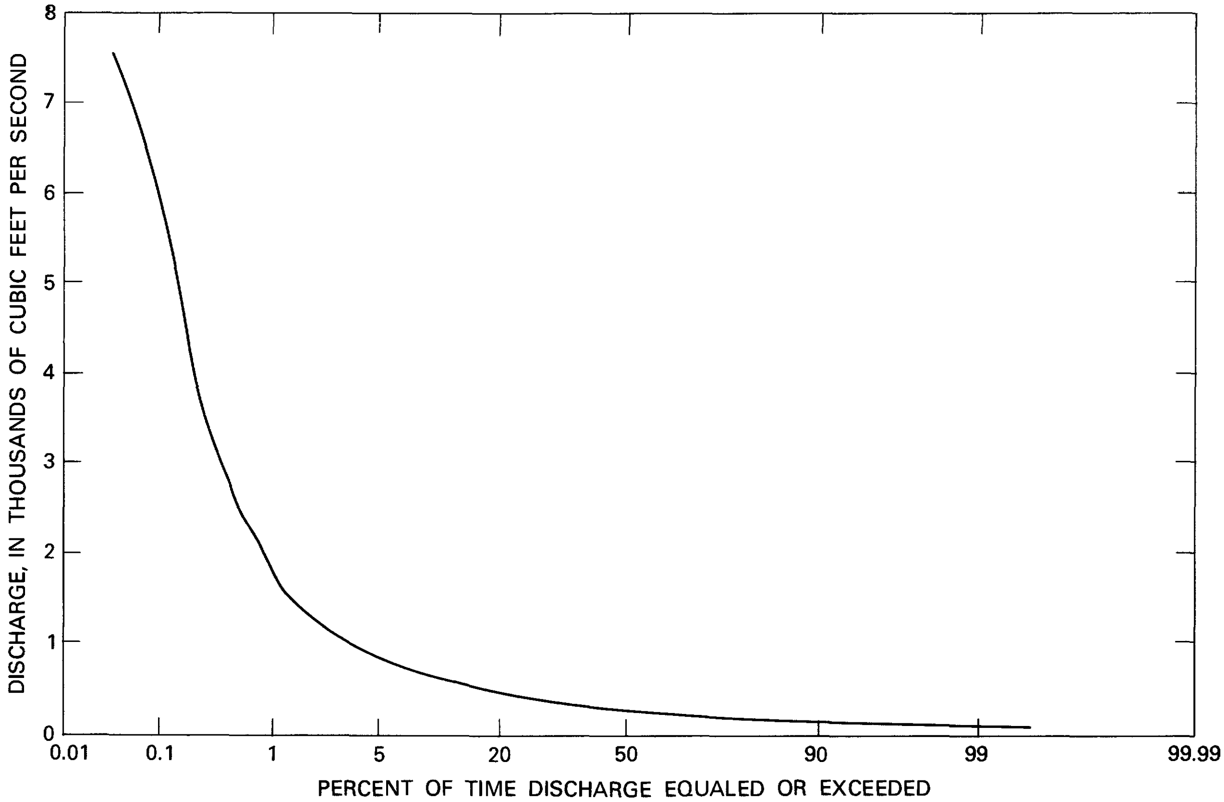
STREAM-ORDER ANALYSIS

The existing network of stream channels in the study area is the end product of all processes of erosion and sediment transport that have occurred in the basin throughout its geomorphic history. A

TABLE 7.—*Summary of flow duration data: discharge that is equaled or exceeded during percentage of time indicated*—Continued

Percentage of time	Station number						
	6000 (total flow)	6000 (runoff)	[a]6120	[a]6250	6300	[a]6313	[a]6339
0.1	13200	12000	1200	1300	3200	300	68
.5	9200	5700	700	770	1950	210	42
1.0	8100	4600	500	550	1400	135	31
2	7100	3300	360	380	970	95	22
4	6500	2300	210	230	600	61	14
6	6200	1900	150	170	430	46	11
8	5800	1700	120	125	340	36	8.9
10	5600	1500	100	106	280	31	7.5
14	5000	1200	70	75	200	25	6.2
18	4600	1000	55	58	155	20	5.0
22	4200	900	50	48	130	18	4.6
26	3800	800	41	43	115	16	4.3
30	3400	700	37	39	105	15	3.8
35	3100	625	32	33	90	14	3.7
40	2700	590	29	29	82	13	3.5
45	2500	450	26	26	74	13	3.4
50	2300	400	24	23	68	12	3.3
55	2100	350	22	21	64	12	3.1
60	1900	300	19	19	57	12	3.0
65	1800	300	15	17	52	11	2.9
70	1600	300	14	15	46	11	2.7
75	1500	300	13	14	41	10.0	2.6
80	1400	300	11	11	37	9.6	2.5
85	1300	300	10	9.6	32	9.0	2.4
90	1250	300	8.6	7.6	27	8.6	2.4
95	1100	300	6.9	5.6	22	8.0	2.3
98	980	300	5.0	3.8	18	7.9	2.2
99	960	300	4.3	2.9	15	7.7	2.1
99.5	940	300	3.4	1.9	13	7.4	2.1
99.9	920	300	2.2	.77	9.8	7.1	2.0

	[a]6380	[a]6526	7170 (total flow)	7170 (runoff)	7500	8000 (total flow)	8000 (runoff)
0.1	1200	83	27000	24000	1300	32500	32500
.5	750	54	18500	15000	610	23000	20000
1.0	540	42	12000	12000	420	19000	16000
2	375	32	11000	8900	250	14000	11000
4	238	23	9200	6200	150	10500	7500
6	176	20	8200	5000	130	9100	6200
8	145	18	7600	4100	110	8500	5000
10	120	17	7100	3900	100	7700	4400
14	89	15	6400	3000	84	6900	3600
18	72	14	5700	2500	79	6200	3200
22	62	13	5300	2300	72	5800	2700
26	57	13	4900	2000	67	5400	2500
30	52	13	4500	1800	62	5000	2300
35	49	13	4100	1400	59	4500	2000
40	46	13	3700	1300	54	4100	1800
45	43	13	3500	1200	49	3700	1600
50	40	13	3200	1100	45	3500	1400
55	38	12	2800	1000	42	3200	1300
60	35	12	2600	800	40	3000	1150
65	33	12	2500	750	38	2700	1000
70	30	12	2300	600	33	2500	750
75	29	12	2100	500	30	2400	600
80	28	12	1900	300	28	2200	450
85	26	12	1700	300	25	2000	300
90	24	11	1600	300	23	1900	300
95	22	11	1500	300	20	1700	300
98	20	11	1400	300	16	1400	300
99	19	11	1300	300	13	1200	300
99.5	18	11	1200	300	11	1100	300
99.9	17	11	1000	300	11	1050	300



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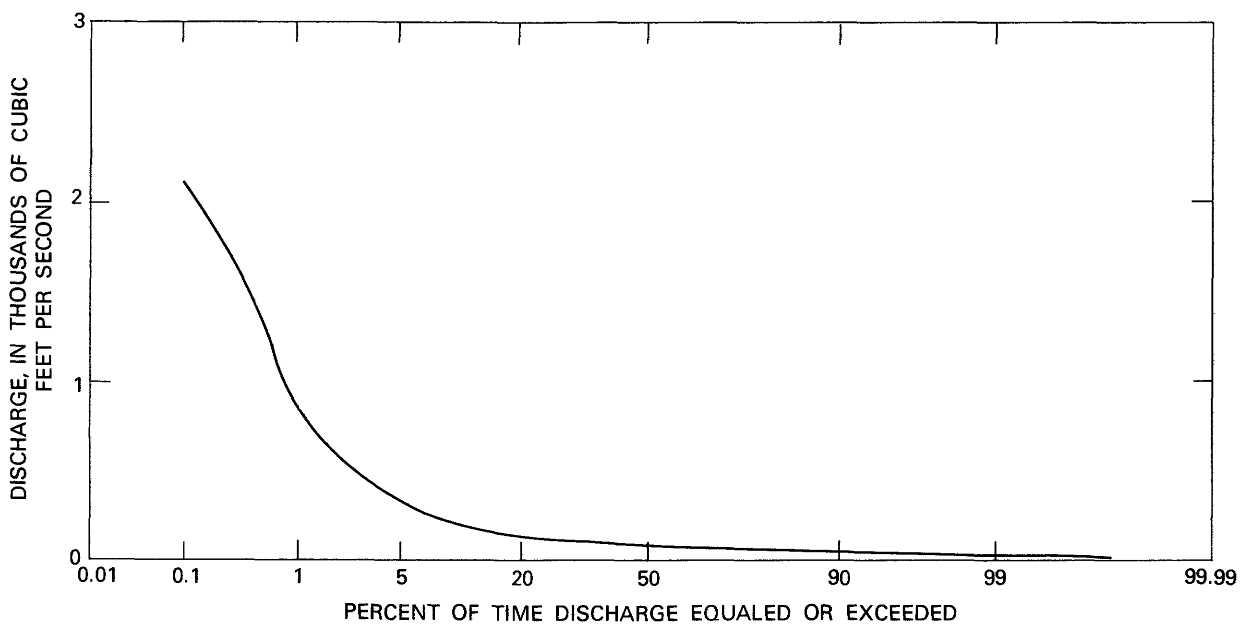
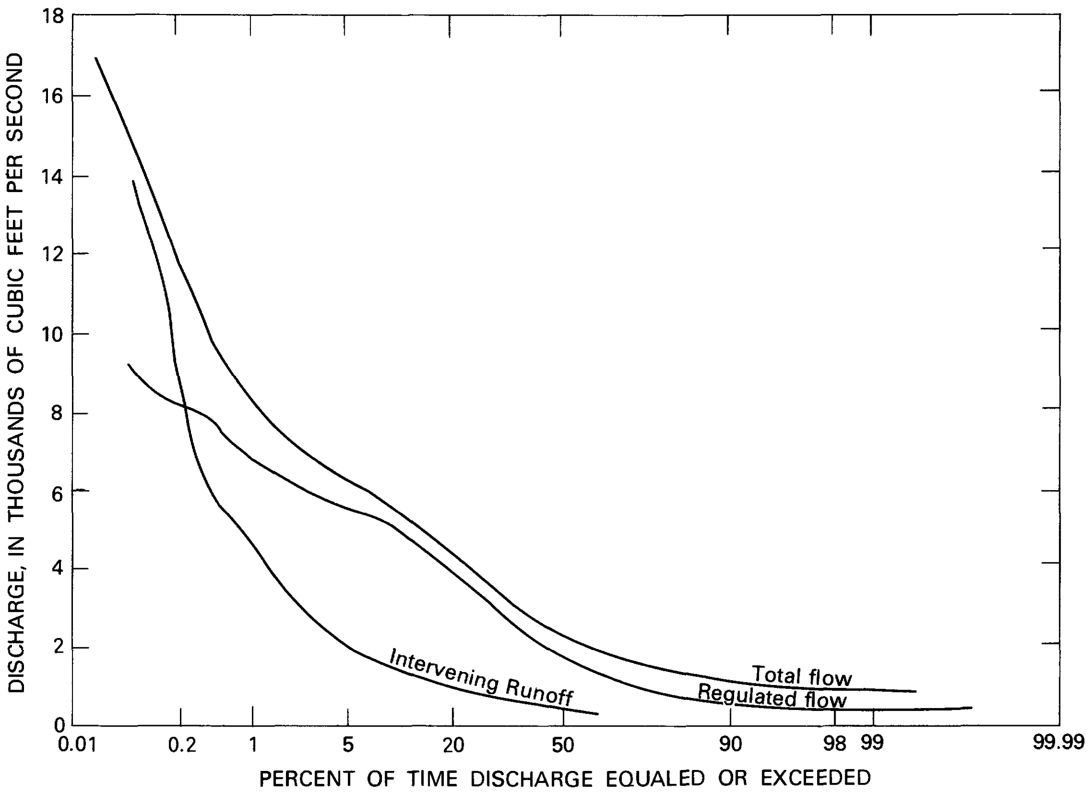


B

FIGURE 7.—Flow durations at (*A*) Chestatee River near Dahlonega and (*B*) Big Creek near Alpharetta.



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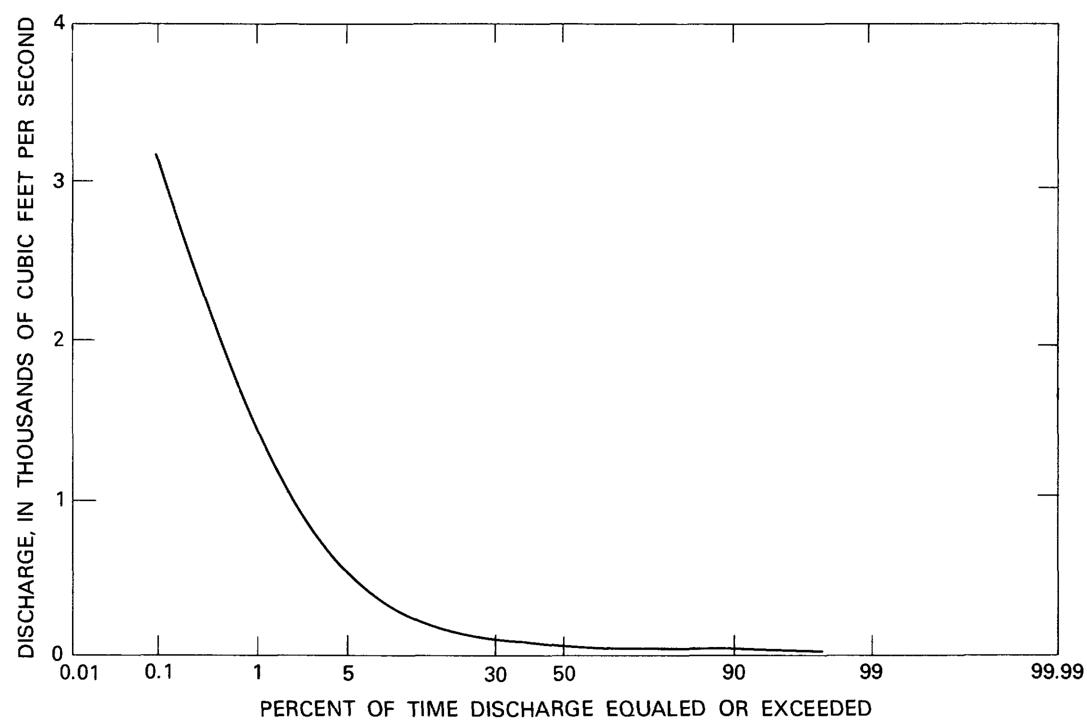


D

FIGURE 7.—Continued. Flow durations at (*C*) Chattahoochee River at Atlanta and (*D*) Peachtree Creek at Atlanta.

comprehensive treatment of erosion and sediment transport should, therefore, include a description of the channel network and its relation to basin morphology. To provide this description, stream-order analyses of the Soque River and Big Creek watersheds are presented below. Stream-order data developed for the Soque River watershed are considered representative of the channel network and channel morphology on the Dahlonega Plateau; corresponding data for the Big Creek watershed are considered typical of channels on the Atlanta Plateau.

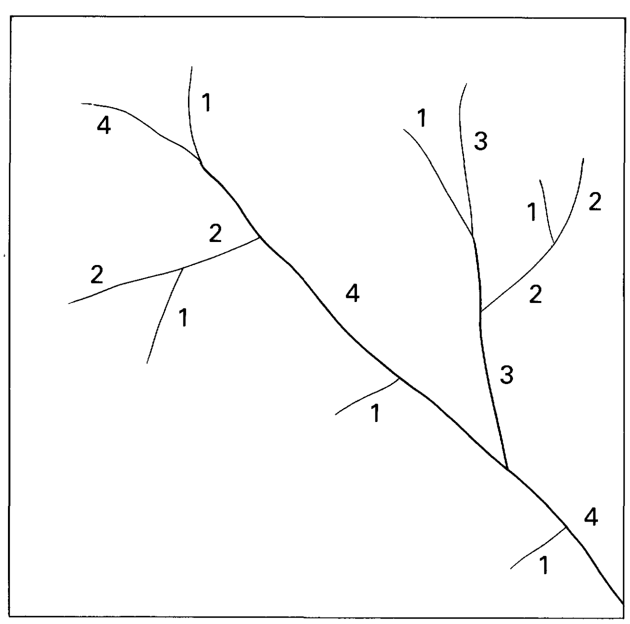
Once compiled, basic stream-order data are used to compute morphometric parameters such as drainage density and overland-flow lengths for each watershed. Drainage density is a measure of the watershed's ability to deliver the products of upland erosion to the channel network. Overland-flow length is a function of drainage density and is used later in the report in conjunction with the Universal Soil Loss Equation.

Stream-order data were computed using techniques described by Strahler (1957). A Strahler analysis considers streams with no tributaries as first-order streams. The confluence of two first-order streams marks the beginning of a second-order stream. Likewise the confluence of two second-order streams initiates a third-order stream. This process of stream order numbering continues to the most downstream point of the watershed. A Strahler analysis thus provides geomorphic data relative to channel segments of a given stream order. As shown below, the Stahler analysis differs slightly from the classical Horton (1945) analysis in which each successively higher order stream is considered to extend headward to the tip of its longest tributary.

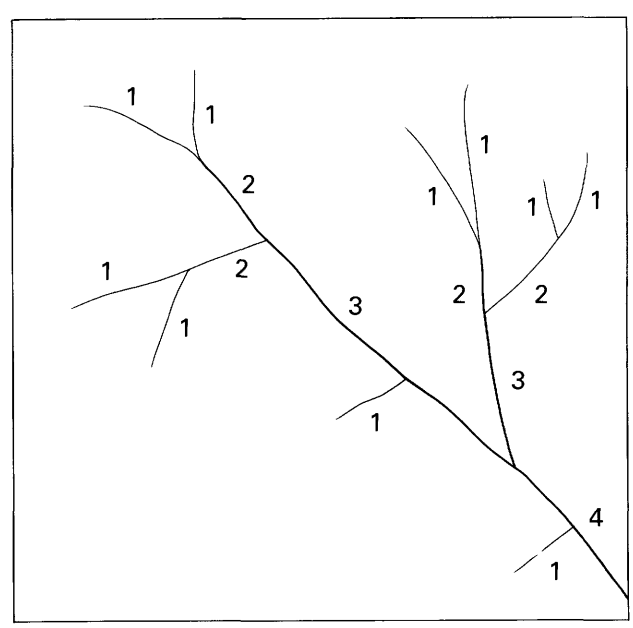
All measured stream-order data were developed from 1:24,000-scale topographic maps (Emmett, 1975) and are summarized for both watersheds in table 8. Data for stream orders one through four represent stream-channel characteristics upstream from water-data stations 2 and 8 (table 5, fig. 1). Data for the main (order five) stream of both watersheds pertain to the entire watershed down to the main streams' confluence with the Chattahoochee River.

The exponential relations of stream order to the number of channels, drainage area, average channel length, cumulative average channel length, average channel drop, cumulative average channel drop, and average channel slope are shown in figures 8 through 14. Average channel length is defined as the sum of the individual channel lengths of a given (stream) order divided by the total number of channels of that order. Average channel drop and average channel slope are similarly defined. Cumulative average channel length and cumulative average channel drop are computed by summing the respective quantities of each succeeding stream order. This cumulative process numerically duplicates the Horton methodology of extending the highest order stream to the head of its longest tributary.

The ratio of average channel drop to average channel length for each stream order defines average channel slope (fig. 14). A progressive decrease in channel slope occurs in both watersheds as



HORTON



STRAHLER

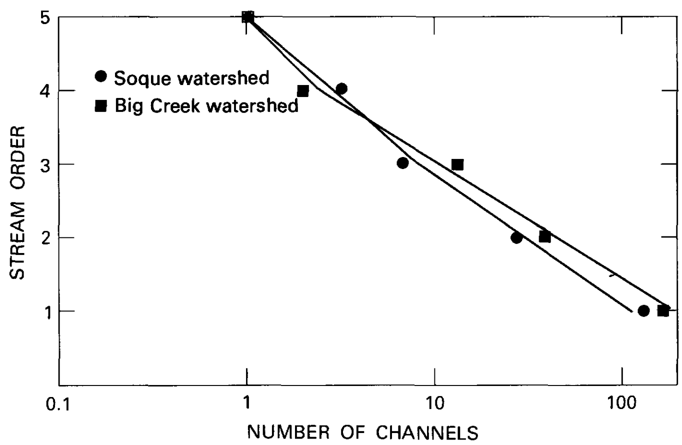


FIGURE 8.—Relation of number of channels to stream order.

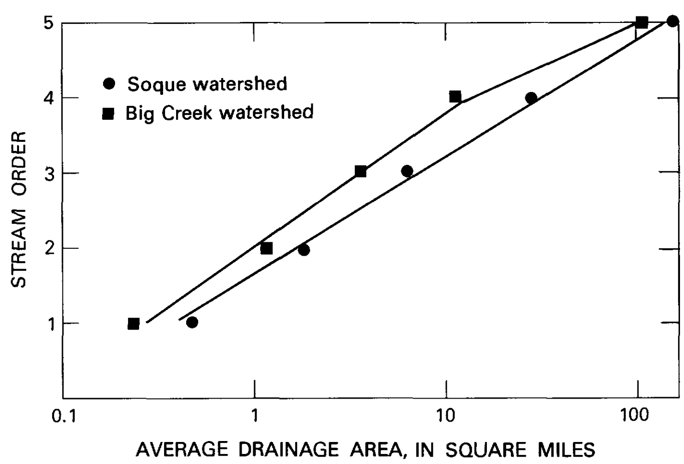


FIGURE 9.—Relation of average drainage area to stream order.

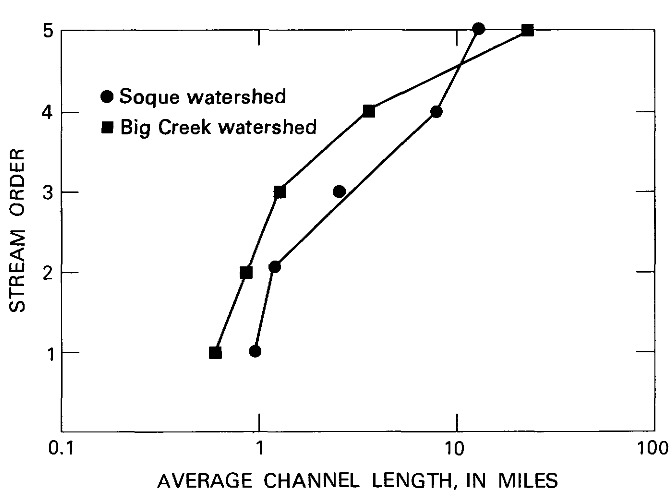


FIGURE 10.—Relation of average channel length to stream order.

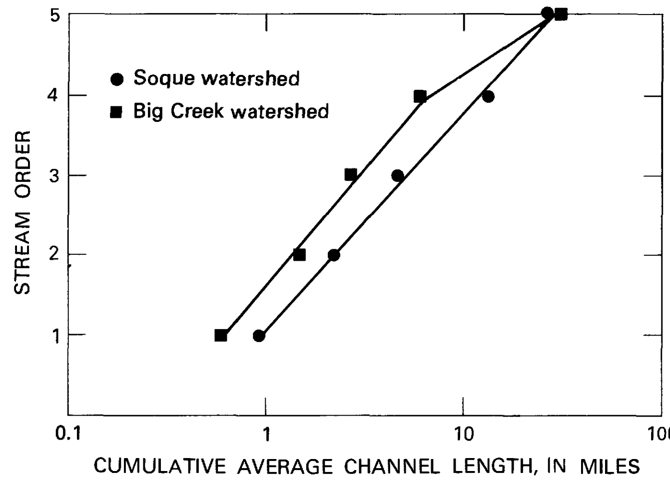


FIGURE 11.—Relation of cumulative average channel length to stream order.

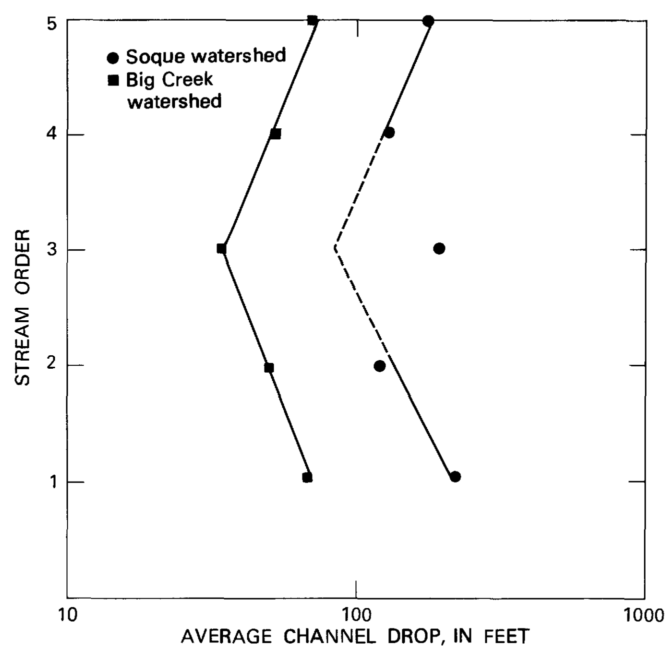


FIGURE 12.—Relation of average channel drop to stream order.

stream order increases. The rate of slope decrease for Big Creek channels is constant for the first four orders but decreases abruptly for the fifth-order stream. A similar break in the slope line for the Soque watershed occurs at the second-order level and indicates significant topographic differences between those parts of the watershed containing first- and second-order streams and those parts containing longer and flatter higher order streams.

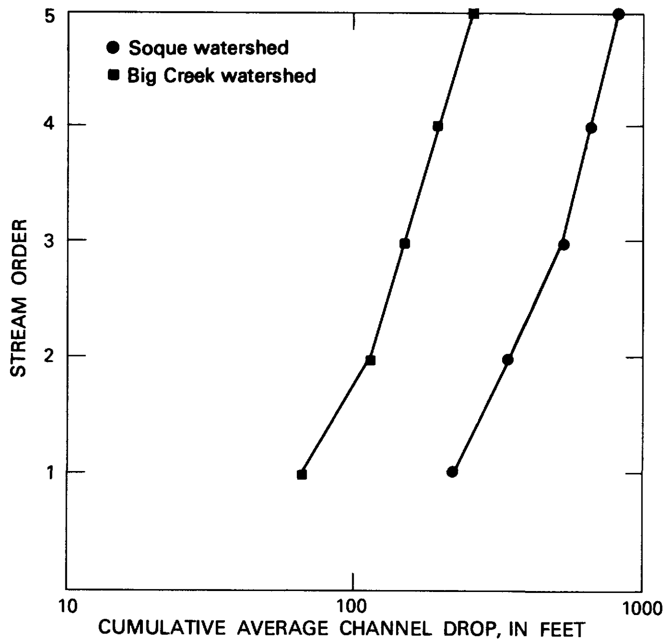


FIGURE 13.—Relation of cumulative average channel drop to stream order.

Topographic distinctions between the plateaus are graphically pointed out by the plots of cumulative average channel drop against stream order (fig. 13). These graphs show that the rate of change of cumulative channel drop in both the Big Creek

TABLE 8.—*Summary of geomorphic characteristics*

Station name	Stream order	Number of streams	Average drainage area (mi^2)	Average channel length (mi)
Big Creek near Alpharetta	1	173	0.24	0.61
	2	38	1.14	.85
	3	12	3.51	1.28
	4	2	11.4	3.50
	5	1	103	20.2
Soque River near Clarkesville	1	122	.46	.93
	2	27	1.86	1.18
	3	7	6.42	2.66
	4	3	29.8	7.71
	5	1	157	12.2

Station name	Stream order	Cumulative average channel length (mi)	Average channel drop (ft)	Cumulative average channel drop (ft)	Average channel slope (ft/ft)
Big Creek near Alpharetta	1	0.61	68	68	0.021
	2	1.46	50	118	.0110
	3	2.74	34	152	.0050
	4	6.24	52	204	.0028
	5	26.4	70	274	.00066
Soque River near Clarkesville	1	.93	224	224	.046
	2	2.11	120	344	.019
	3	4.77	197	541	.014
	4	12.5	136	677	.0033
	5	24.7	180	857	.0028

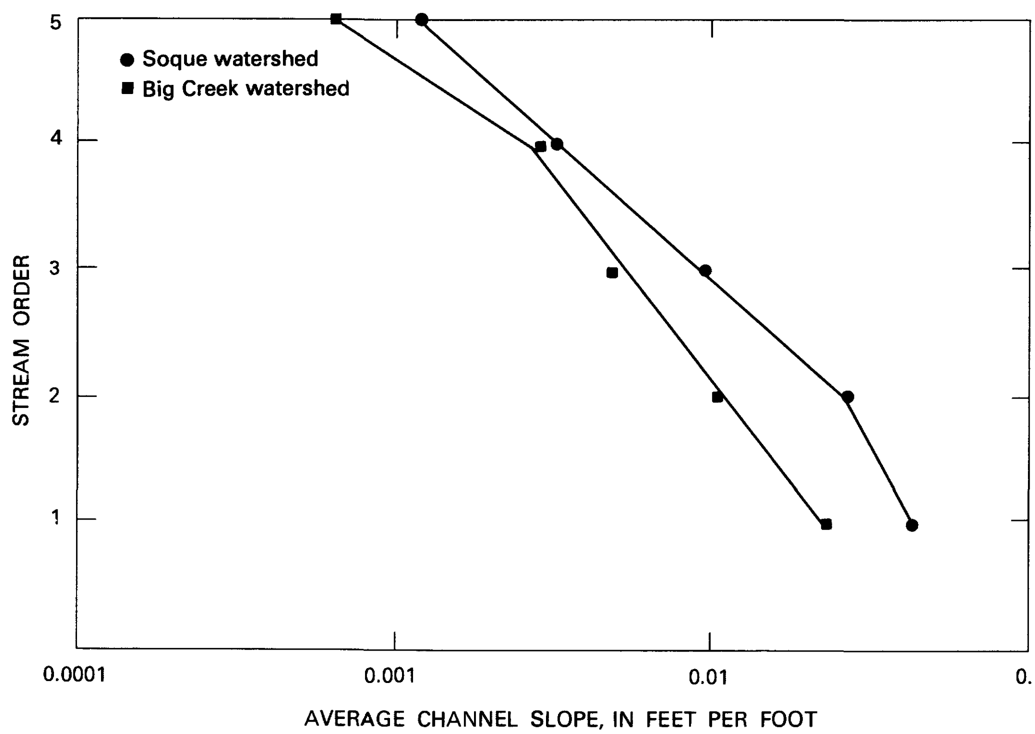


FIGURE 14.—Relation of average channel slope to stream order.

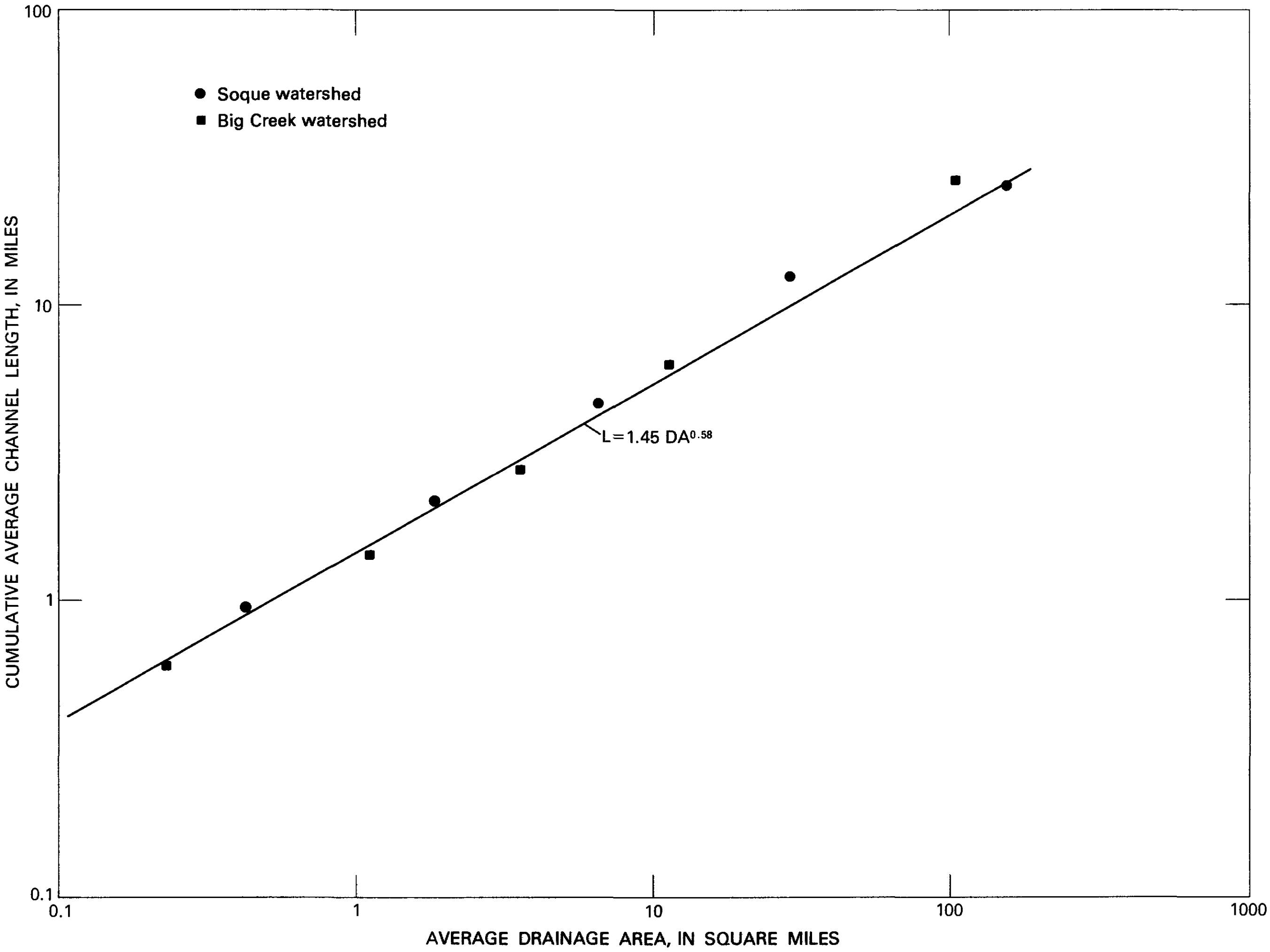


FIGURE 15.—Relation of average drainage area to cumulative average channel length.

and Soque watersheds changes abruptly from low to higher order streams. This point of change is a reflection of watershed relief and concavity and occurs at third-order streams in the Soque watershed and at second-order streams in the Big Creek watershed. The higher the order of the point of change, the greater is the watershed relief. Thus, stream-order analyses indicate greater relief and concavity for watersheds on the Dahlonega Plateau.

The relation between average drainage area and cumulative average channel length for each stream order for both the Soque and Big Creek watersheds is shown in figure 15. Geometric regression of these data resulted in the following function

$$L = 1.45 DA^{0.58}$$

where

DA = drainage area in square miles, and
L = cumulative average channel length in miles.

The exponent in this equation is indicative of the geometric development of the watershed. An exponent of 0.50 indicates that the length of the watershed has developed in the same proportion to its width. The computed exponent of 0.58 indicates that both the Big Creek and Soque River watersheds are increasing in length faster than they are increasing in width. Examination of figures 19 and 21 shows that both watersheds are indeed elongate. Studies similar to this one in different regions of the United States have yielded exponent values ranging from 0.6 to 0.7 (Leopold and others, 1964).

The coefficient of the regression equation (1.45) indicates the average length of principal stream channel supported by one square mile of watershed area. Thus, 1 square mile of land surface in either the Soque or Big Creek watersheds will support, on the average, 1.45 miles of principal channel. Leopold and others (1964) state that the coefficient of similar equations for watersheds in the Northeastern United States averages about 1.40. A similar analysis of watersheds in the Upper Salmon River basin of Idaho (Emmett, 1975) produced a coefficient of 1.50.

Drainage density is defined as the total channel length in the watershed divided by the total drainage area and indicates the average total channel length supported by each square mile of watershed. Computed drainage densities for the Soque and Big Creek watersheds are 2.07 and 2.38, respectively. These values should not be confused with the coefficient of the regression equation described previously. This coefficient refers solely to the length of the principal channel and cannot be compared to drainage density. Emmett (1975) considers drainage density to be the most useful parameter for comparing stream-channel networks of different watersheds. Horton (1945) reported that the Hiwassee River basin above Hiwassee, Ga., has a drainage density of 2.06. The Hiwassee basin is located just north of the Soque basin, which implies that there is regional consistency to drainage densities.

OVERLAND FLOW LENGTH

Representative values of overland flow lengths for both the Dahlonega and Atlanta Plateaus were required for the computation of sheet erosion using the Universal Soil Loss Equation. A method to compute such values using Strahler stream-order data is described below for those parts of the Soque and Big Creek watersheds draining to the water-data stations near Clarkesville and Alpharetta, respectively.

The length of overland flow is defined as the average distance traveled by surface runoff to the point where it enters a well-defined channel. Thus, by definition, overland-flow lengths pertain mostly to stream channels occurring on the local or microtopography and are synonomous with true field slope lengths. Stream channels relative to the microtopography are mostly true first-order streams that are rigorously defined as the shortest, unbranched channels occurring on the landscape. True first-order and other low-order streams are too small to be shown on 1:24,000-scale maps and (generally) are ignored. True-order streams are quantitatively related to overland flow length, however, through drainage density, which is defined by Leopold and others (1964) as one-half the reciprocal of the length of overland flow. Thus, data required to compute overland-flow length for a particular watershed include total drainage area along with the total number of streams and the average stream length for each stream order beginning with true order one streams.

Field observations in the Soque and Big Creek watersheds indicate that first-order streams on 1:24,000-scale maps are true fifth-order streams. Consequently, data from the Strahler analyses of stream number and cumulative average channel length (figs. 8 and 11) were replotted with adjusted ordinates beginning at the fifth-order level. The relations were then linearly extended to predict values

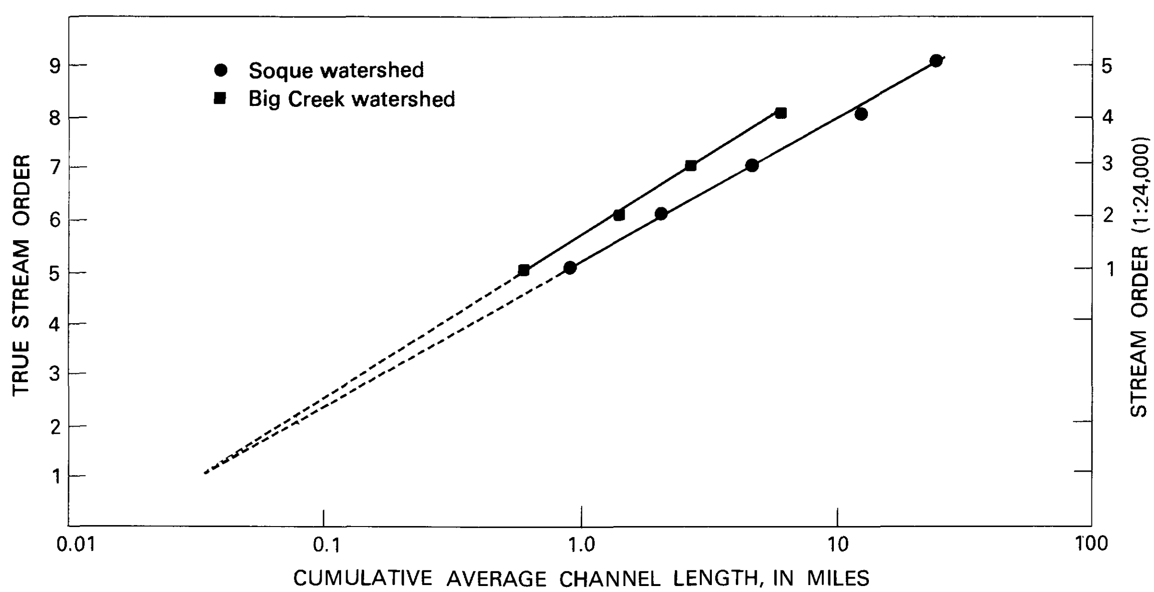


FIGURE 16.—Relation of cumulative average channel length to true stream order.

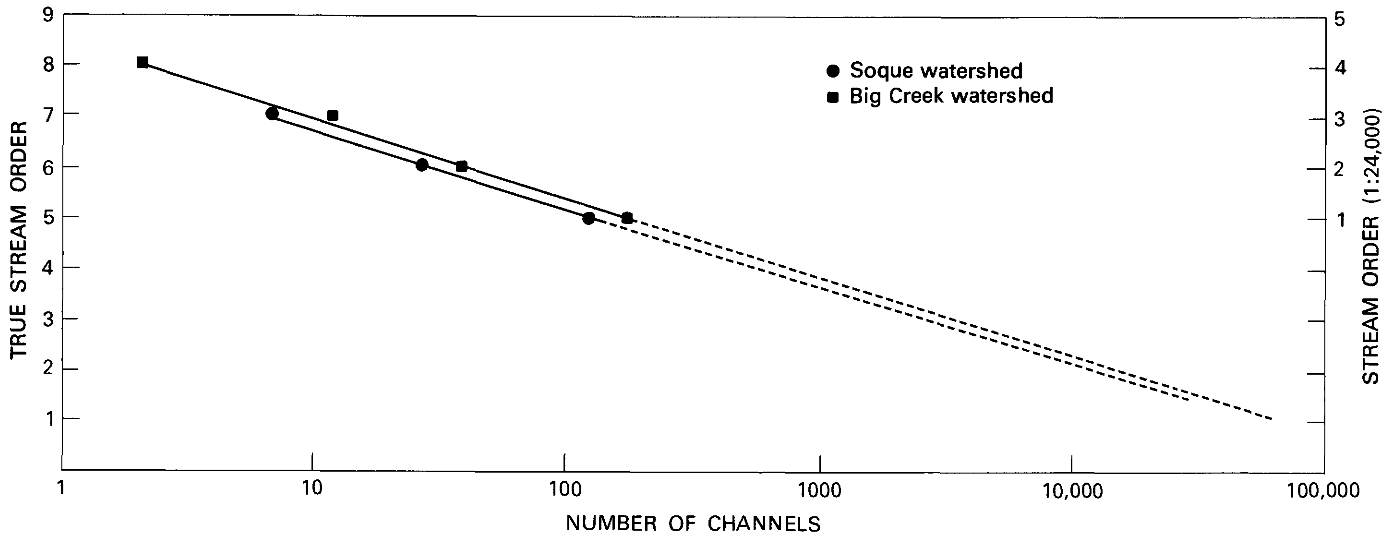


FIGURE 17.—Relation of number of channels to true stream order.

for true first- through fourth-order streams (figs. 16 and 17). Average channel length for the lower-order streams were computed from the extended cumulative average channel-length curve. A summary of stream number and average channel-length data as a function of true stream order is listed in table 9. Note that predicted lengths of true fifth-order streams are shorter than those listed for first-order streams in table 8. This decreased length indicates that unbranched channels shown on 1:24,000-scale maps are actually branching out into numerous unmapped tributaries of lower order. By extending the cumulative average channel-length curve, the headwater parts of mapped unbranched streams have been effectively assigned to lower-order streams. Thus, the actual length of true fifth-order streams is shorter than indicated on 1:24,000-scale maps and is more accurately defined by the data in table 9.

Computation of average overland-flow lengths for the Soque and Big Creek watersheds requires the products of average channel length and number of channels for each true stream order. The sum of these products provides a true total channel length in each watershed. True drainage densities can then be computed and inverted to obtain the

TABLE 9.—*Summary of overland-flow length computation using Strahler stream-order data*

Station name	Stream order (1:24,000)	True stream order	(1) Average channel length (mi)	(2) Number of streams	(1) × (2)	Overland-flow length (mi)	Overland-flow length (ft)
Big Creek near Alpharetta		1	0.031	65,000	2,015		
		2	.037	15,000	555		
		3	.074	3,350	248		
		4	.158	760	120		
	1	5	.310	173	54		
	2	6	.850	38	32		
	3	7	1.28	12	15		
	4	8	3.50	2	7		
	5	9	11.0	1	11		
		Total stream length=3,057 miles				0.012	62
Soque River near Clarkesville		1	0.033	60,000	1,980		
		2	.043	13,000	559		
		3	.099	2,800	277		
		4	.230	615	141		
	1	5	.525	122	64		
	2	6	1.18	27	32		
	3	7	2.66	7	19		
	4	8	7.71	3	23		
	5	9	4.0	1	4		
		Total stream length=3,099 miles				.015	79

average overland flow or field-slope lengths (table 9) which, for the Soque and Big Creek watersheds, are 79 feet and 62 feet, respectively.

EROSION AND SEDIMENT DISCHARGE

The erosion and transport of sediment by water in the Upper Chattahoochee River basin is affected, in part, by four major environmental factors; land use, soils, topography, and climate. These factors are interrelated and each contributes significantly to total soil loss. The impact of land use relates directly to man's activities and is most apparent in the types and distribution of land cover; whether vegetation, roads, buildings, or other facilities. In general, greater densities of land cover relate to lower rates of erosion and erosion yield. The erodibility of a soil is controlled, for the most part, by its composition and structure. For example, less cohesive soils, such as sands, are more susceptible to erosion than silts or clays, provided all other environmental factors remain the same. Silts and clays, on the other hand, are more susceptible to water transport. The topographic and climatic factors that affect erosion and the stream transport of sediment most directly include, respectively, land slope length and gradient and rainfall and rainfall intensity.

DESCRIPTION OF ENVIRONMENTAL FACTORS

Maps and tables that describe land use, soils, and topography within watersheds that drain to selected water-data stations are presented below. The impact of these factors on erosion and sediment discharge in the basin is described in succeeding sections of this report.

LAND USE

Land-use data were collected, assembled, and interpreted by the Land Information and Analysis Branch of the U.S. Geological Survey. Original data were collected as high-altitude, remote-sensor imagery during the period 1971–75. Classification of the imagery into land-use categories was accomplished according to criteria developed by Anderson and others (1976). These land-use categories are listed on p. 30 along with respective imagery widths and areas. Image data whose width or area config-

TABLE 10.—*Summary of land-use data by category*

Station name	Residential		Commercial and services		Industrial	
	Area (mi^2)	Percent of total area	Area (mi^2)	Percent of total area	Area (mi^2)	Percent of total area
Chattachooche River near Leaf	0.58	0.39	0.003	0.002		
Soque River near Clarkesville	.39	.41	.03	.03		
Chestatee River near Dahlonega	.04	.03	.005	.003		
Big Creek near Alpharetta	2.98	4.14	.31	.43		
N. Fork Peachtree Creek near Atlanta	14.84	43.54	2.88	8.45	0.61	1.79
S. Fork Peachtree Creek at Atlanta	16.45	55.57	2.47	8.34	.41	1.39
Peachtree Creek at Atlanta	44.02	50.71	9.65	11.12	1.37	1.58
Woodall Creek at Atlanta	.50	16.08	.12	3.86		
Nancy Creek tributary near Chamblee	.86	26.46	.32	9.85		
Nancy Creek at Atlanta	18.17	57.59	2.22	7.04	.31	.98
Snake Creek near Whitesburg	.32	.86				

Station name	Transportation, communication, and utilities		Industrial and commercial complexes		Other urban or built-up land	
	Area (mi^2)	Percent of total area	Area (mi^2)	Percent of total area	Area (mi^2)	Percent of total area
Chattahoochee River near Leaf						
Soque River near Clarkesville	0.11	0.11				
Chestatee River near Dahlonega						
Big Creek near Alpharetta	1.60	2.22			0.69	0.96
N. Fork Peachtree Creek near Atlanta	1.84	5.40	3.37	9.89	.57	1.67
S. Fork Peachtree Creek at Atlanta	.72	2.43	1.46	4.93	.96	3.24
Peachtree Creek at Atlanta	3.22	3.71	6.82	7.86	2.64	3.04
Woodall Creek at Atlanta	.42	13.50	1.62	52.09	.19	6.11
Nancy Creek tributary near Chamblee	.33	10.15				
Nancy Creek at Atlanta	.49	1.55	1.79	5.67	1.06	3.36
Snake Creek near Whitesburg						

TABLE 10.—*Summary of land-use data by category*—Continued

	Cropland and pasture		Orchards	
	Area (mi²)	Percent of total area	Area (mi²)	Percent of total area
Chattachoochee River	8.03	5.51		
Soque River near Clarkesville	10.36	10.79	0.13	0.14
Chestatee River near Dahlonega	15.71	10.27		
Big Creek near Alpharetta	25.18	34.97	.05	.07
N. Fork Peachtree Creek near Atlanta	0.04	.12		
S. Fork Peachtree Creek at Atlanta	.05	.17		
Peachtree Creek at Atlanta	.09	.10		
Woodall Creek at Atlanta				
Nancy Creek tributary near Chamblee	.031	.95		
Nancy Creek at Atlanta	.25	.79		
Snake Creek near Whitesburg	5.73	15.49		

	Confined feeding operations		Deciduous forest		Conifer forest	
	Area (mi²)	Percent of total area	Area (mi²)	Percent of total area	Area (mi²)	Percent of total area
Chattahoochee River near Leaf	0.26	0.17	0.38	0.25	1.44	0.96
Soque River near Clarkesville	.26	.27			.73	.76
Chestatee River near Dahlonega			.025	.02	4.65	3.04
Big Creek near Alpharetta	.86	1.19	8.29	11.51	8.74	12.14
N. Fork Peachtree Creek near Atlanta			1.02	2.99	1.66	4.87
S. Fork Peachtree Creek at Atlanta			1.57	5.30	1.20	4.05
Peachtree Creek at Atlanta			3.31	3.81	2.91	3.35
Woodall Creek at Atlanta			.18	5.79		
Nancy Creek tributary near Chamblee			.01	.31	.76	2.34
Nancy Creek at Atlanta			1.43	4.53	1.22	3.87
Snake Creek near Whitesburg	.02	.05	8.96	24.22	7.84	21.19

	Mixed forest		Reservoirs		Quarries and gravel pits	
	Area (mi²)	Percent of total area	Area (mi²)	Percent of total area	Area (mi²)	Percent of total area
Chattahoochee River near Leaf	139.25	92.67	0.06	0.04		
Soque River near Clarkesville	83.77	87.26	.22	.23		
Chestatee River near Dahlonega	132.31	86.48	.21	.14		
Big Creek near Alpharetta	22.88	31.78	.06	.08	0.12	0.17
N. Fork Peachtree Creek near Atlanta	5.90	17.31	.18	.53		
S. Fork Peachtree Creek at Atlanta	3.90	13.18	.04	.14	.01	.03
Peachtree Creek at Atlanta	11.0	12.67	.23	.27	.01	.01
Woodall Creek at Atlanta	.08	2.57				
Nancy Creek tributary near Chamblee	1.42	43.60				
Nancy Creek at Atlanta	3.81	12.08	.32	1.01		
Snake Creek near Whitesburg	13.92	37.62	.13	.35		

Station name	Transitional areas		Ratio of cropland area to pasture area
	Area (mi²)	Percent of total area	(percent)
Chattahoochee River near Leaf			26
Soque River near Clarkesville			24
Chestatee River near Dahlonega			43
Big Creek near Alpharetta	0.24	0.33	11
N. Fork Peachtree Creek near Atlanta	1.16	3.40	
S. Fork Peachtree Creek at Atlanta	.38	1.28	
Peachtree Creek at Atlanta	1.54	1.77	
Woodall Creek at Atlanta			
Nancy Creek tributary near Chamblee	.21	6.34	
Nancy Creek at Atlanta	.48	1.52	
Snake Creek near Whitesburg	.08	.22	30

uration was less than the minimum were not mapped.

Land-use conditions in 1976, when most water-quality data were collected, are considered equivalent to those mapped for the period 1971–75.

Land use in watersheds draining to 11 water-data stations is shown in figures 18 through 23. Included in figure 22 is land use in watersheds draining to North Fork of Peachtree Creek near Atlanta, South Fork of Peachtree Creek at Atlanta, Nancy Creek at Atlanta, Nancy Creek tributary near Chamblee, and Woodall Creek at Atlanta. Land-use data are listed, by station and category, in table 10. Cropland-area to pasture-area ratios obtained from the U.S. Department of Agriculture (1970) are also listed where appropriate. Forested lands account, respectively, for about 94, 88, and 90 percent of the areas draining to the Chattahoochee River near Leaf, the Soque River near Clarksville, and the Chestatee River near Dahlonega. The drainage of the Soque River is the most heavily urbanized and the most intensely farmed of the watersheds on the Dahlonega Plateau.

A greater land-use diversity is shown for drainages on the Atlanta Plateau. For example, the watersheds, of Big Creek near Alpharetta, Peachtree Creek at Atlanta, and Snake Creek near Whitesburg contain, respectively, about 55, 20, and 83 percent forest lands. Conversely, the same drainages contain about 8, 78, and 1 percent urban areas, respectively. Photographs of typical basin landscapes are shown in figure 24.

SOILS AND TOPOGRAPHY

Soil associations in those watersheds for which land-use maps have been previously discussed are shown in figures 25 through 30. Included in figure 29 are soil associations in watersheds draining to North Fork of Peachtree Creek near Atlanta, South Fork of Peachtree Creek at Atlanta, Nancy Creek at Atlanta, Nancy Creek tributary near Chamblee, and Woodall Creek at Atlanta. Descriptions of individual soil associations are also listed on each figure. Summaries of pertinent soil and topographic data are listed in tables 11 to 19. Individual county soils reports (see Selected References) provided the general soils maps from which the various delineations of soil associations were made. Also provided in these reports were soil descriptions and area and slope data relative to each of the soil types that comprise a soil association. Soil erodibility values for each soil type were obtained from the Georgia State Soil and Water Conservation Committee (1977).

Land use category	Minimum width (ft)	Minimum area (acres)
Residential	660	10
Commercial and services	660	10
Industrial	660	10
Transportation, communications, and utilities	660	10
Industrial and commercial complexes	660	10
Mixed urban or built-up land	660	10
Other urban or built-up land	660	10
Cropland and pasture	1,320	40
Orchards, groves, vineyards, nurseries, and ornamental horticultural areas	1,320	40
Confined feeding operations	660	10
Deciduous forest land	1,320	40
Conifer forest land	1,320	40
Mixed forest land	1,320	40
Streams and canals	660	10
Lakes	660	10
Reservoirs	660	10
Forested wetlands	1,320	40
Nonforested wetlands	1,320	40
Strip mines, quarries, and gravel pits	660	10
Transitional areas	1,320	40

TABLE 11.—*Summary of soil and topographic data for the watershed draining to the Chattahoochee River near Leaf*

Soil Association	Area (mi^2)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Cartecay-Toccoa-Congaree	8.8	1.0	0.18	0.12
Hayesville-Fanin-Wickham	1.0	13	.28	1.74
Hayesville-Rabun-Hiwassee	.2	17	.24	2.77
Haysville-Fanin-Edneyville	37.8	17	.23	2.84
Tallapoosa-Musella	46.2	26	.29	5.52
Edneyville-Porters-Ashe	54.0	30	.24	6.91
Rabun-Hayesville-Hiwassee	2.0	14	.25	2.13
Weighted mean (watershed)	---	23	.25	4.95

TABLE 12.—*Summary of soil and topographic data for the watershed draining to the Soque River near Clarkesville*

Soil Association	Area (mi^2)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Porters-Ashe	14.4	47	0.24	14.30
Madison-Halewood	20.1	23	.32	4.46
Cecil-Madison	47.8	22	.32	4.11
Clifton-Davidson	4.3	40	.30	11.3
Congaree-Chewacla-Buncomb	9.1	1.8	.32	.18
Louisa-Chandler	.3	41	.27	11.5
Weighted mean (watershed)	---	25	.30	5.68

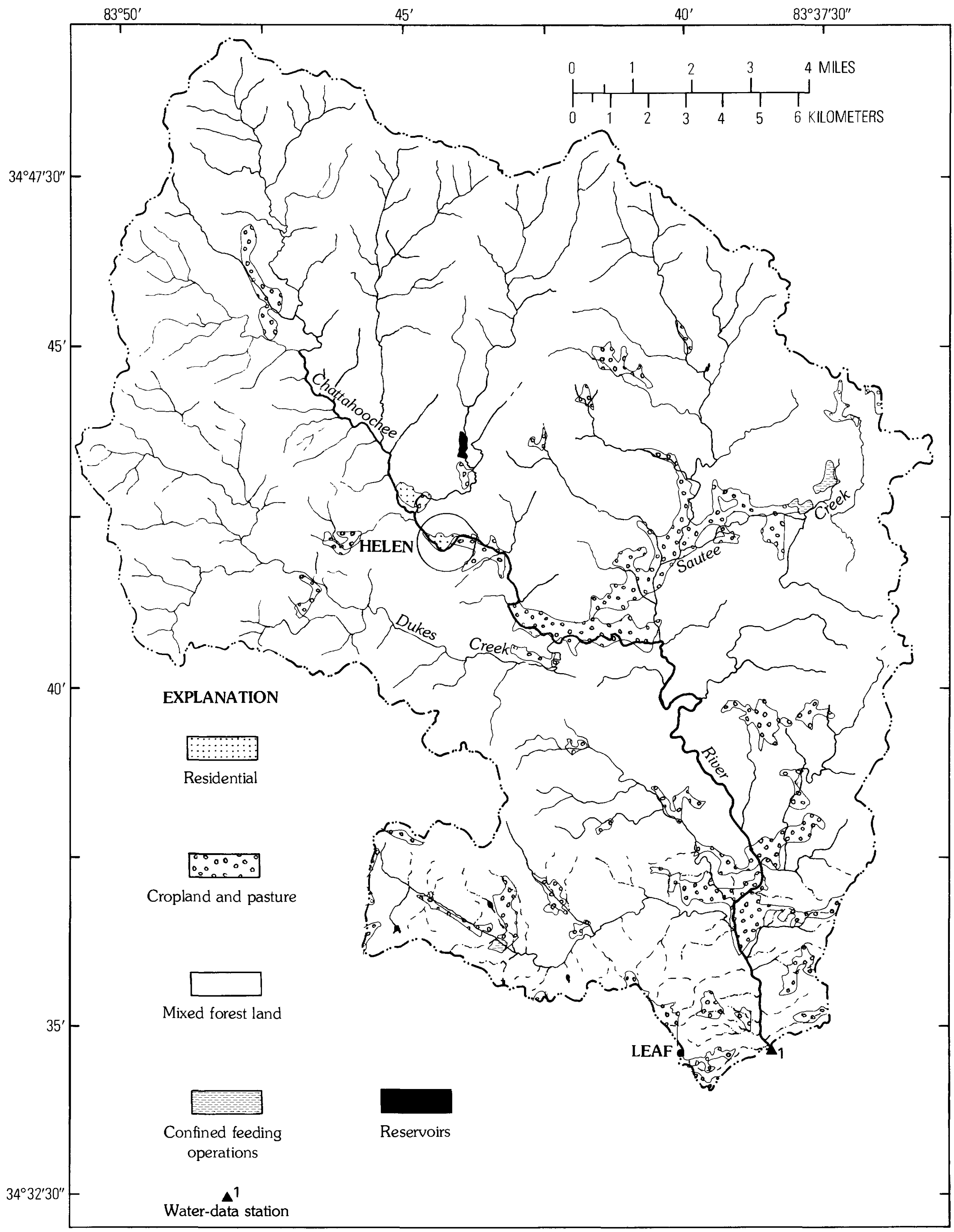


FIGURE 18.—Land use in the watershed draining to the Chattahoochee River near Leaf.

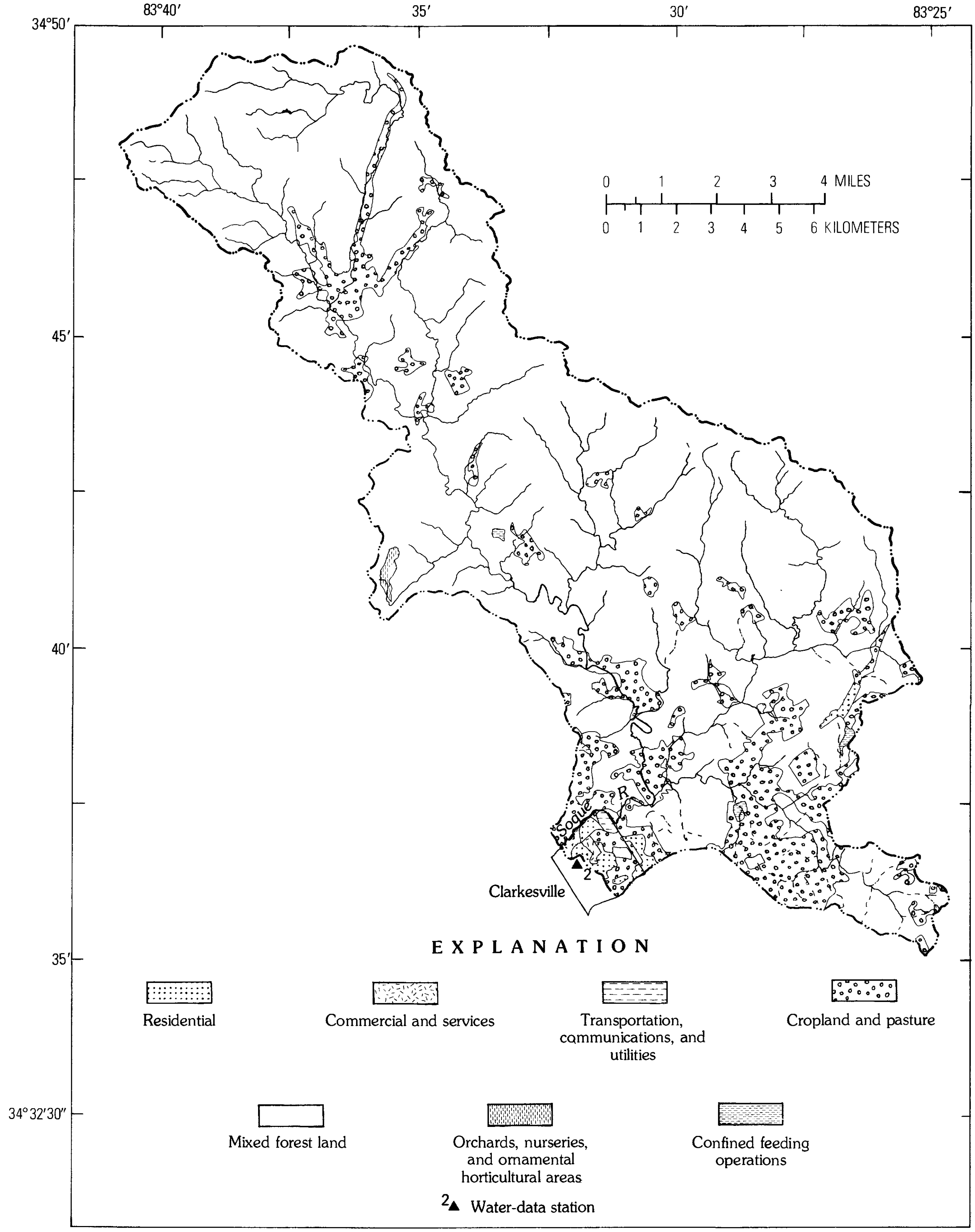


FIGURE 19.—Land use in the watershed draining to the Soque River near Clarkesville.

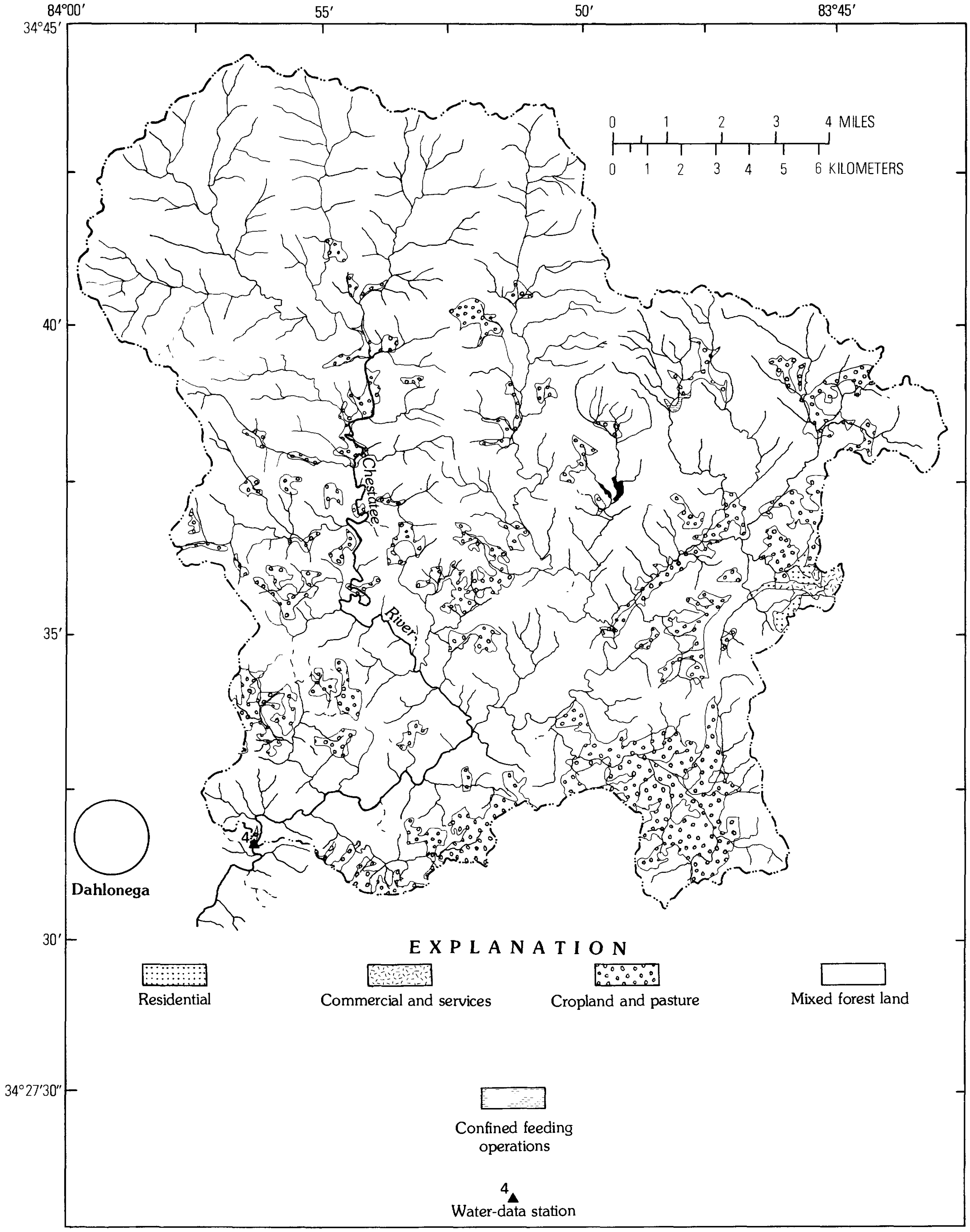


FIGURE 20.—Land use in the watershed draining to the Chestatee River near Dahlonega.

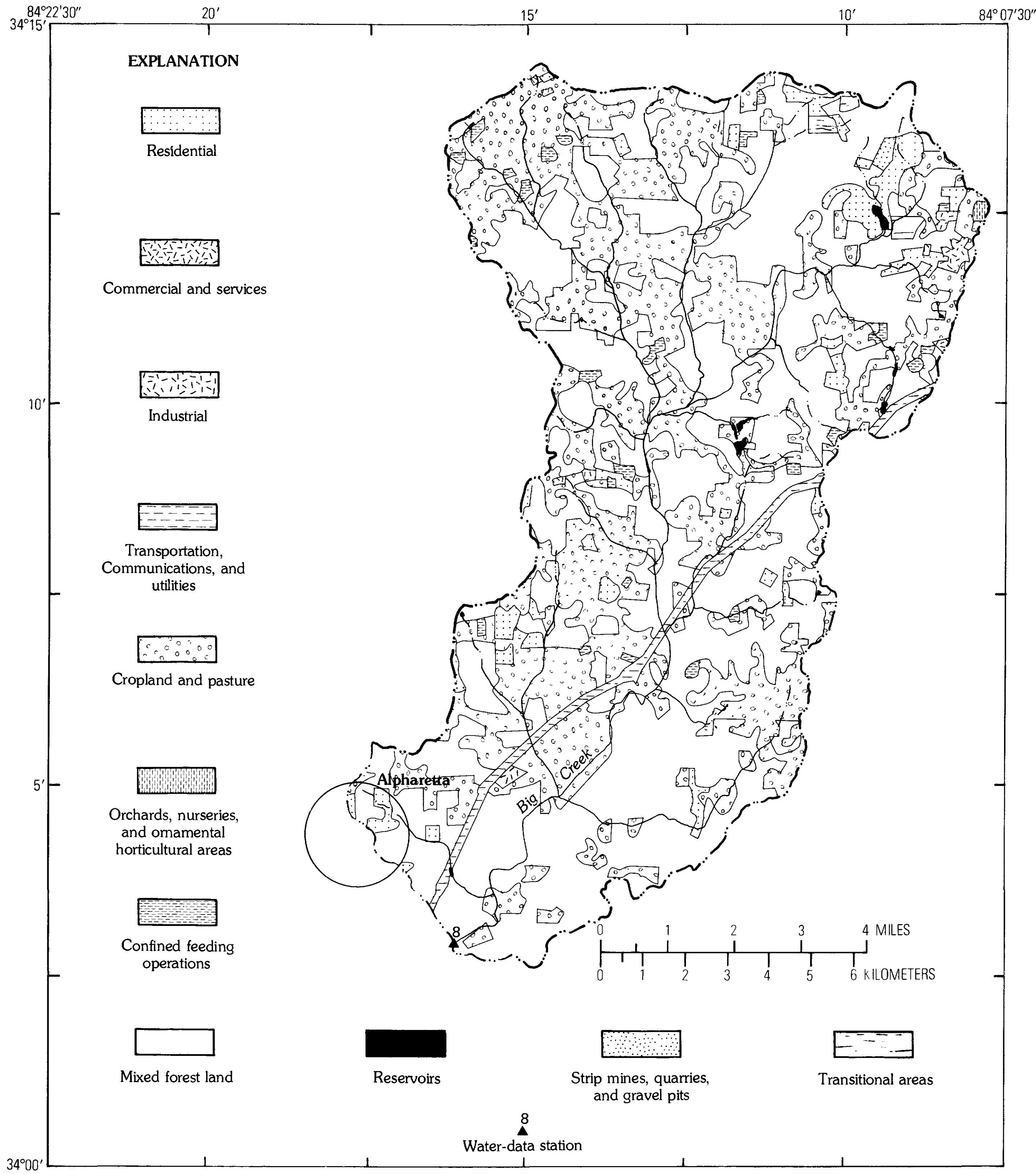


FIGURE 21.—Land use in the watershed draining to Big Creek near Alpharetta.

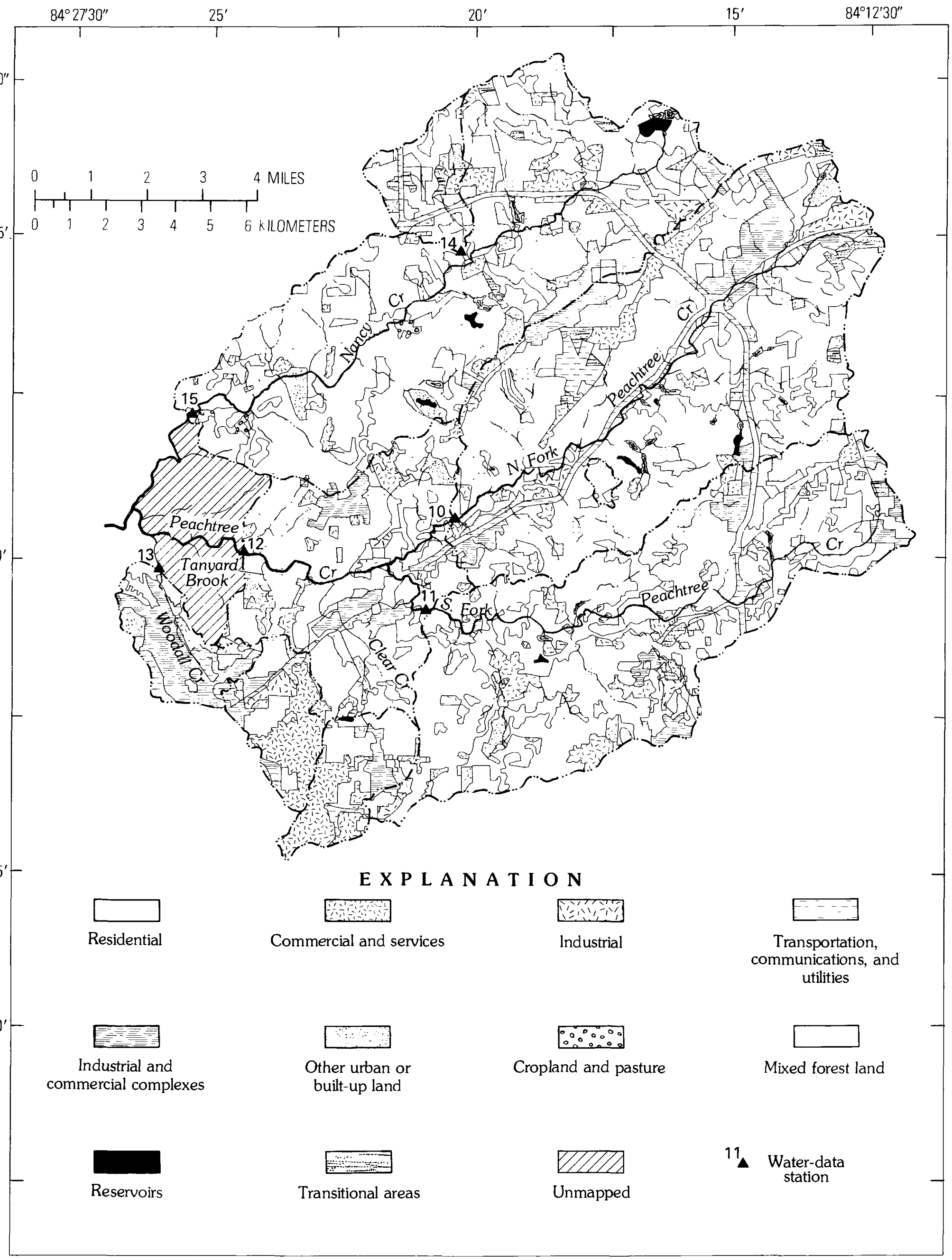


Figure 22.—Land use in the watersheds draining to Peachtree Creek at Atlanta, Nancy Creek at Atlanta, and Woodall Creek at Atlanta.

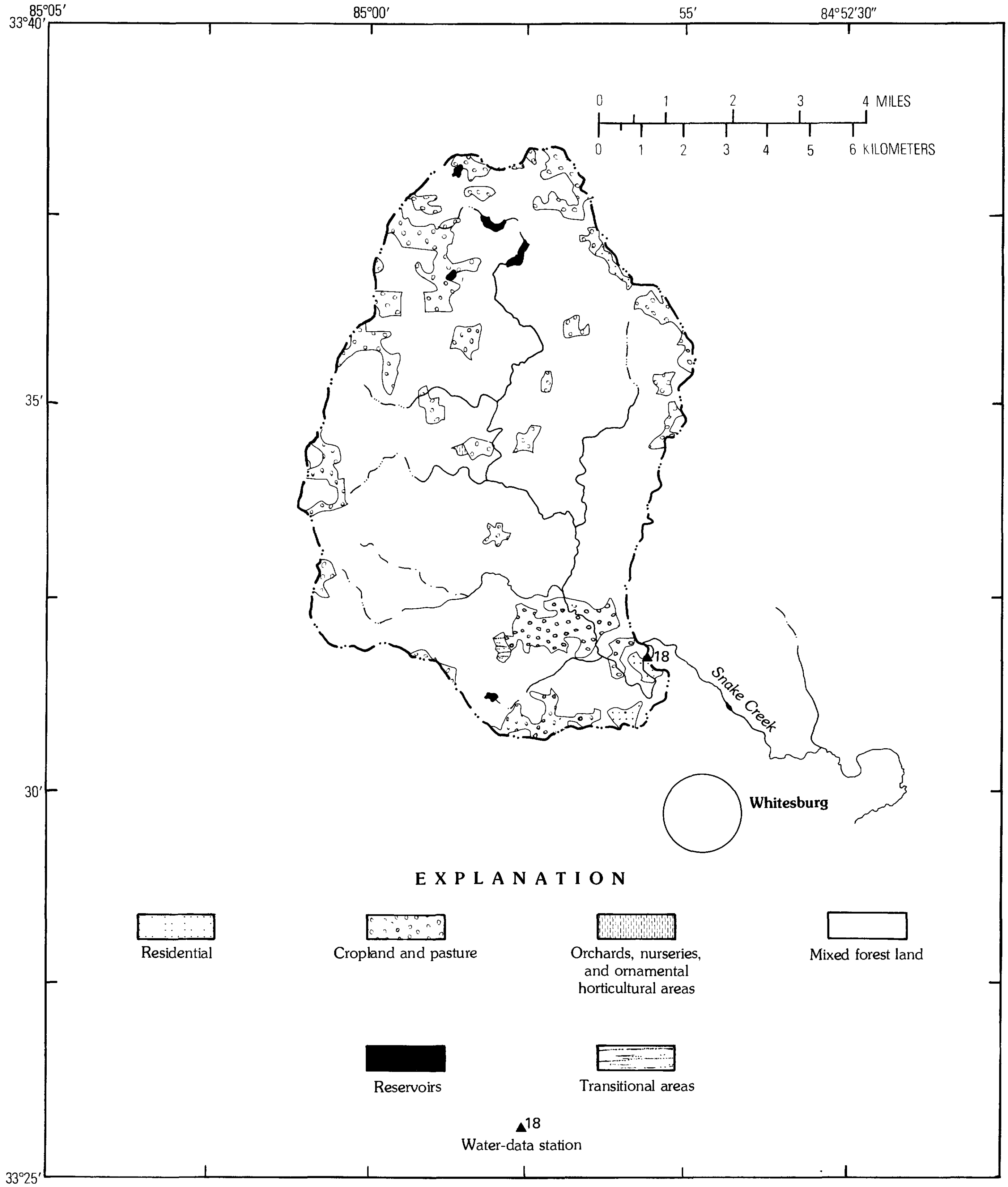


FIGURE 23.—Land use in the watershed draining to Snake Creek near Whitesburg.

FIGURE 24.—Typical basin land use. (*A*) Farmstead on the Dahlonega Plateau. (Continued on p. 38.)

TABLE 13.—*Summary of soil and topographic data for the watershed draining to the Chestatee River near Dahlonega*

Soil association	Area	Mean slope (percent)	Soil erodibility	Slope length and gradient factor
Cartecay-Toccoa-Congaree	8.1	1.0	0.18	0.12
Hayesville-Fanin-Wickham	7.1	13	.28	1.74
Hayesville-Rabun-Hiwassee	.1	17	.24	2.77
Hayesville-Fanin-Edneyville	50.4	17	.23	2.84
Tallapoosa-Musella	45.0	26	.29	5.52
Edneyville-Porters-Ashe	37.3	30	.24	6.91
Rabun-Hayesville-Hiwassee	5.0	14	.25	2.13
Weighted mean (watershed)	---	22	.25	4.40

The values of slope and soil erodibility for each association listed in tables 11 to 19 are area-weighted means based on the component soil-type data.

As might be expected, land slopes on the Dahlonega Plateau are about twice as steep as slopes on the Atlanta Plateau. Soil erodibility factors, on the other hand, range from only 0.25 to 0.32 for all of the watersheds studied.

TABLE 14.—*Summary of soil and topographic data for the watershed draining to Big Creek near Alpharetta*

Soil association	Area (mi^2)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Cecil-Habersham	7.8	7.8	0.32	0.75
Cecil-Madison	64.2	9.8	.32	1.05
Weighted mean (watershed)	---	9.6	.32	1.02

EROSION

Erosion by water in the Upper Chattahoochee River basin occurs as sheet and rill erosion, gully erosion, and channel erosion. Riil erosion is considered a minor form of sheet erosion and subsequent reference in this text to sheet erosion is understood to include both processes. With the exception of intensely urbanized areas, sheet erosion occurs

FIGURE 24.—Continued. Typical basin land use. (*B*) Cultivated field in the floodplain of the Soque River near Clarkesville.

TABLE 15.—*Summary of soil and topographic data for the watershed draining to North fork of Peachtree Creek near Atlanta*

Soil Association	Area (mi²)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Chewacla-Wehadkee	5.24	1.0	0.28	0.11
Madison-Pacolet-Gwinnett (flood plains)	10.56	6.4	.32	.58
Madison-Pacolet-Gwinnett (hills and ridges)	.14	16	.32	2.21
Louisburg-Weedowee-Pacolet	2.59	18	.29	2.73
Pacolet-Gwinnett-Louisberg	11.50	18	.31	2.73
Appling-Pacolet-Gwinnett	2.23	6.4	.32	.55
Made land	1.82	18	.30	2.73
Weighted mean (watershed)	---	11	.31	1.52

TABLE 16.—*Summary of soil and topographic data for the watershed draining to South fork of Peachtree Creek at Atlanta*

Soil Association	Area (mi²)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Chewacla-Wehadkee	4.57	1.0	0.28	0.11
Madison-Pacolet-Gwinnett (flood plains)	11.29	6.4	.32	.58
Madison-Pacolet-Gwinnett (hills and ridges)	9.87	16	.32	2.21
Pacolet-Gwinnett-Louisberg	.35	18	.31	2.73
Unclassified	3.37	10	.31	1.14
Made land	.15	10	.31	1.14
Weighted mean (watershed)	---	9.3	.31	1.14

FIGURE 24.—Continued. Typical basin land use. (*C*) Confined feeding operation in the floodplain of the Chattahoochee River near Duluth. (Continued on p. 40.)

TABLE 17.—*Summary of soil and topographic data for the watershed draining to Peachtree Creek at Atlanta*

Soil Association	Area (mi^2)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Chewacla-Wehadkee	10.99	1.0	0.28	0.11
Madison-Pacolet-Gwinnett (flood plains)	25.44	6.4	.32	.58
Madison-Pacolet-Gwinnett (hills and ridges)	10.43	16	.32	2.21
Pacolet-Gwinnett-Louisberg	14.20	18	.31	2.73
Appling-Pacolet-Gwinnett	2.23	6.4	.32	.58
Louisberg-Weedowee-Pacolet	2.59	18	.29	2.73
Unclassified	18.92	11	.31	1.26
Made land	1.97	18	.30	2.73
Weighted mean (watershed)	---	10	.31	1.32

TABLE 18.—*Summary of soil and topographic data for the watershed draining to Nancy Creek at Atlanta*

Soil Association	Area (mi^2)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Chewacla-Wehadkee	4.40	1.0	0.28	0.11
Madison-Louisa-Pacolet	.91	23	.31	4.16
Madison-Pacolet-Gwinnett (flood plains)	13.30	6.4	.32	.58
Madison-Pacolet-Gwinnett (hills and ridges)	2.59	16	.32	2.21
Gwinnett-Pacolet-Musella	.27	18	.31	2.73
Gwinnett-Davison-Musella	1.55	6.2	.31	.55
Louisberg-Weedowee-Pacolet	.33	18	.29	2.73
Appling-Louisberg-Pacolet	.23	6.6	.30	.60
Pacolet-Gwinnett-Louisberg	9.08	18	.31	2.73
Appling-Pacolet-Gwinnett	.09	6.4	.32	.58
Made Land	.81	12	.31	1.42
Unclassified	1.22	12	.31	1.42
Weighted mean (watershed)	---	11	.31	1.38

FIGURE 24.—Continued. Typical basin land use. (*D*) High density housing along the Chattahoochee River near Atlanta.

TABLE 19.—*Summary of soil and topographic data for the watershed draining to Snake Creek near Whitesburg*

Soil Association	Area (mi^2)	Mean slope (percent)	Soil erodibility factor	Slope length and gradient factor
Congaree-Buncomb	1.4	1.2	0.34	0.12
Madison-Tallapoosa	16.1	3.8	.31	.31
Madison-Louisa-Tallapoosa	19.5	18	.31	2.73
Weighted mean (watershed)	---	11	.31	1.58

throughout the basin and is, by far, the predominant erosional process. Gully erosion occurs mostly in transitional areas where vegetation has been recently stripped from the land surface. Land-use data (table 10) indicate that transitional lands occupy only about 1 percent of the basin area. Thus, the contribution of gully erosion to total erosion in the basin is considered small. Channel erosion occurs mostly in the form of streambank erosion and was qualitatively evaluated through field reconnaissances during the period 1975–77. The relative stability of channel dimensions was assessed by noting the occurrence of bank sloughing and channel debris and the abundance and type of bank vegetation. These assessments indicated that relatively severe bank erosion had occurred in the headwaters of Nancy Creek and South Fork of Peachtree Creek, in downstream parts of Peachtree Creek, and along the Chattahoochee River downstream of Buford Dam. Local erosion of stream banks was also noted in reaches where the landscape had been recently disturbed or where flow velocities were unusually high. Bank erosion in the remainder of the stream system was observed to be relatively minor.

Average annual sheet erosion within each of the watersheds shown in figures 18 through 23 was quantitatively evaluated using the Universal Soil Loss Equation. As developed by Wischmeier and

FIGURE 24.—Continued. Typical basin land use. (*E*) Residential park in the Peachtree Creek watershed. (Continued on p. 42.)

Smith (1965), the Universal Soil Loss Equation has the general form

$$E = R \times K \times LS \times C \times P$$

where

E = average annual sheet erosion in tons per acre,
R = rainfall factor,
K = soil erodibility,
LS = slope length and gradient factor,
C = crop management factor, and
P = conservation practice factor.

The rainfall factor (R) expresses the erosion potential of long-term, average annual rainfall. Rainstorm characteristics used to derive the factor are the total kinetic energy of the storm and its maximum 30-minute rainfall intensity. Values of rainfall factor for watersheds discussed in this report were derived from Wischmeier and Smith (1965) and are listed below by water-data station.

Station name	Rainfall factor
Chattahoochee River near Leaf	280
Soque River near Clarkesville	340
Chestatee River near Dahlonega	300
Big Creek near Alpharetta	270
North Fork Peachtree Creek at Atlanta	300
South Fork Peachtree Creek at Atlanta	300
Peachtree Creek at Atlanta	300
Nancy Creek at Atlanta	300
Snake Creek near Whitesburg	325

The soil erodibility factor (K) represents the average annual sheet erosion for a particular soil in tons per acre per unit of rainfall factor (R). Values of K for this study were obtained from literature sources but were originally determined from field measurements where erosion of various soil types was observed under standard topographic, cropping, and conservation conditions.

Wischmeier and Smith (1965) define slope length as the distance from the point of origin of overland

FIGURE 24.—Continued. Typical basin land use. (*F*) Fossil fuel powerplant adjacent to the Chattahoochee River at Atlanta.

flow to (1) the point where the slope decreases to the extent that deposition begins or (2) the point where runoff enters a well-defined channel. For this study the slope lengths of 79 feet and 62 feet computed from the extrapolation of stream-order data were used, respectively, for all areas on the Dahlonega and Atlanta Plateaus. The slope length and gradient factor (*LS*) is used to adjust the estimate of sheet erosion to specific landscapes. Each factor represents a function of slope steepness and length relative to sheet erosion measured on a standard soil plot constructed with a slope length of 72.6 feet and a land slope of 9 percent. The factor value for a specific slope length and land slope is computed by the formula

$$LS=\frac{(\lambda)^{0.5}}{72.6}\times\frac{430x^2+30x+0.43}{6.57}$$

where

λ=true slope length (79 or 62 feet), and

x=the sine function of the angle of land slope in degrees.

LS factors for the various soil associations in the basin were computed using this function and the given slope lengths and area-weighted land slopes discussed previously (tables 11 to 19). The computed *LS* factors are listed, according to soil association, in tables 11 to 19.

The cropping management factor (*C*) was originially defined by Wischmeier and Smith (1965) as the ratio of (1) sheet erosion measured from standard soil plots with specified cropping conditions to (2) the erosion measured from identical plots under conditions of clean-tilled, continuous fallow. Other *C* factors have been recently developed for various uses such as row crops, forest, pasture, and cropped woodland and are listed in publications of the Georgia Soil and Water Conservation Committee (1977) and the U.S. Department of Agriculture (1977). Cropping management factors

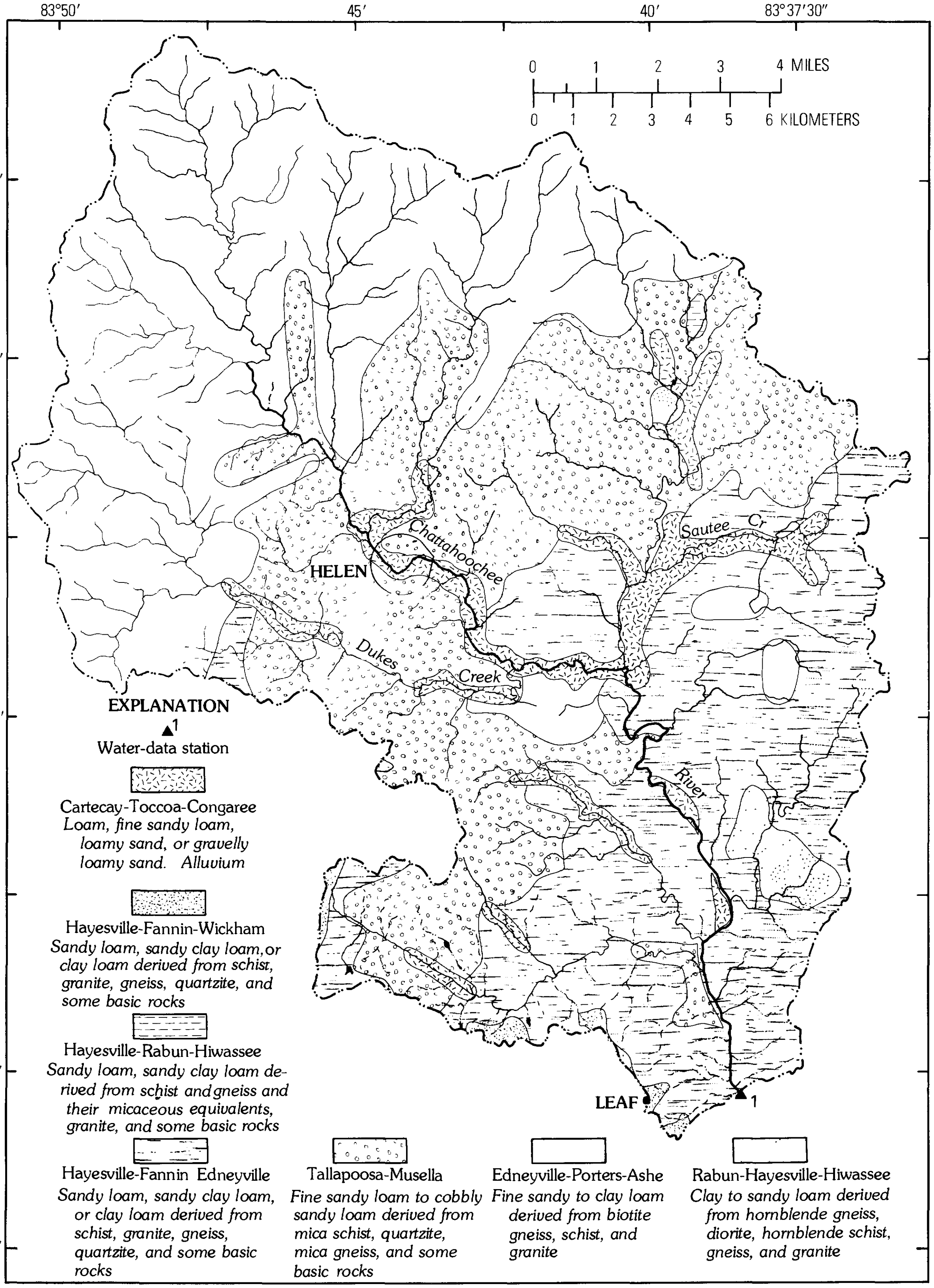


FIGURE 25.—Soil associations in the watershed draining to the Chattahoochee River near Leaf.

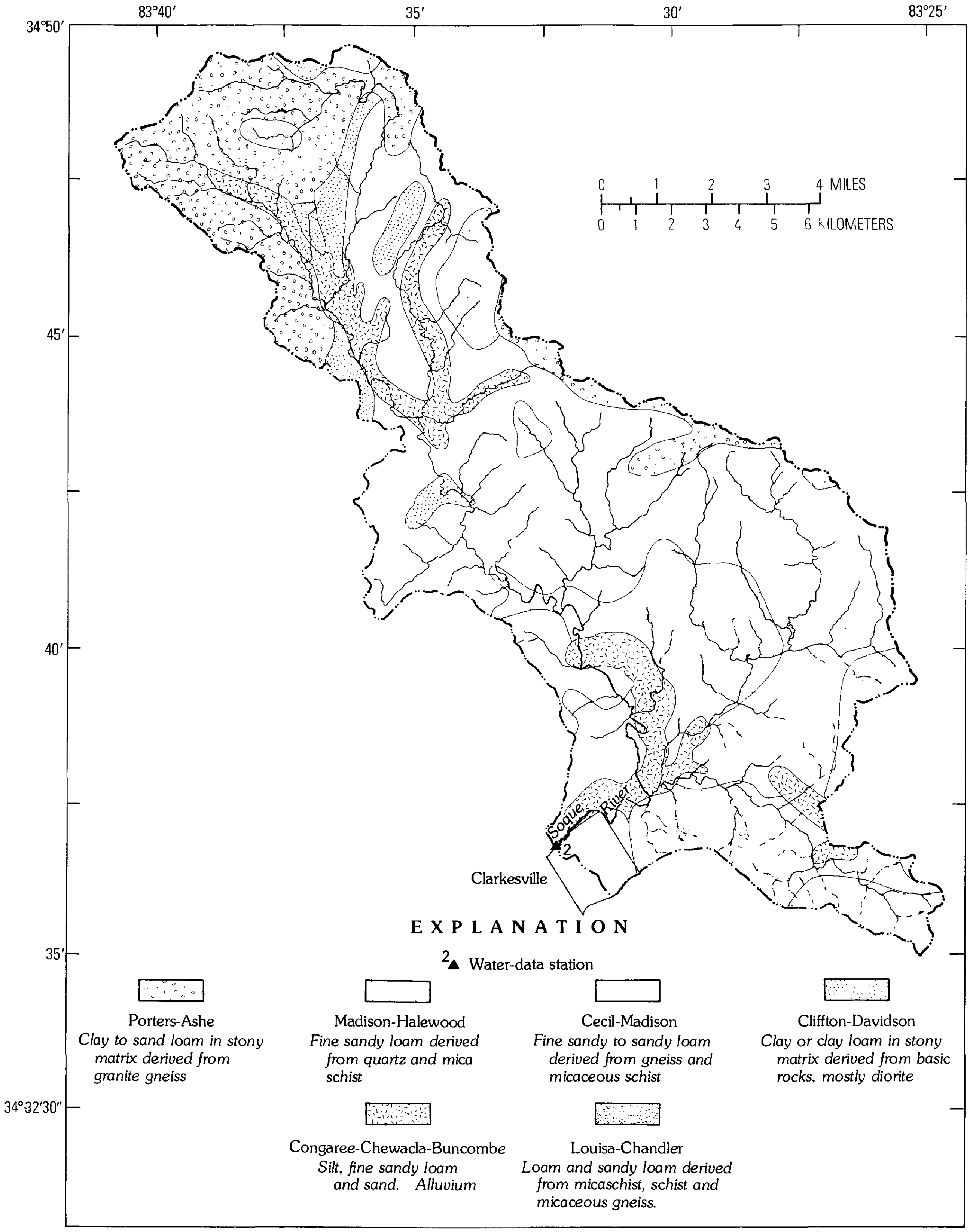


FIGURE 26.—Soil associations in the watershed draining to the Soque River near Clarkesville.

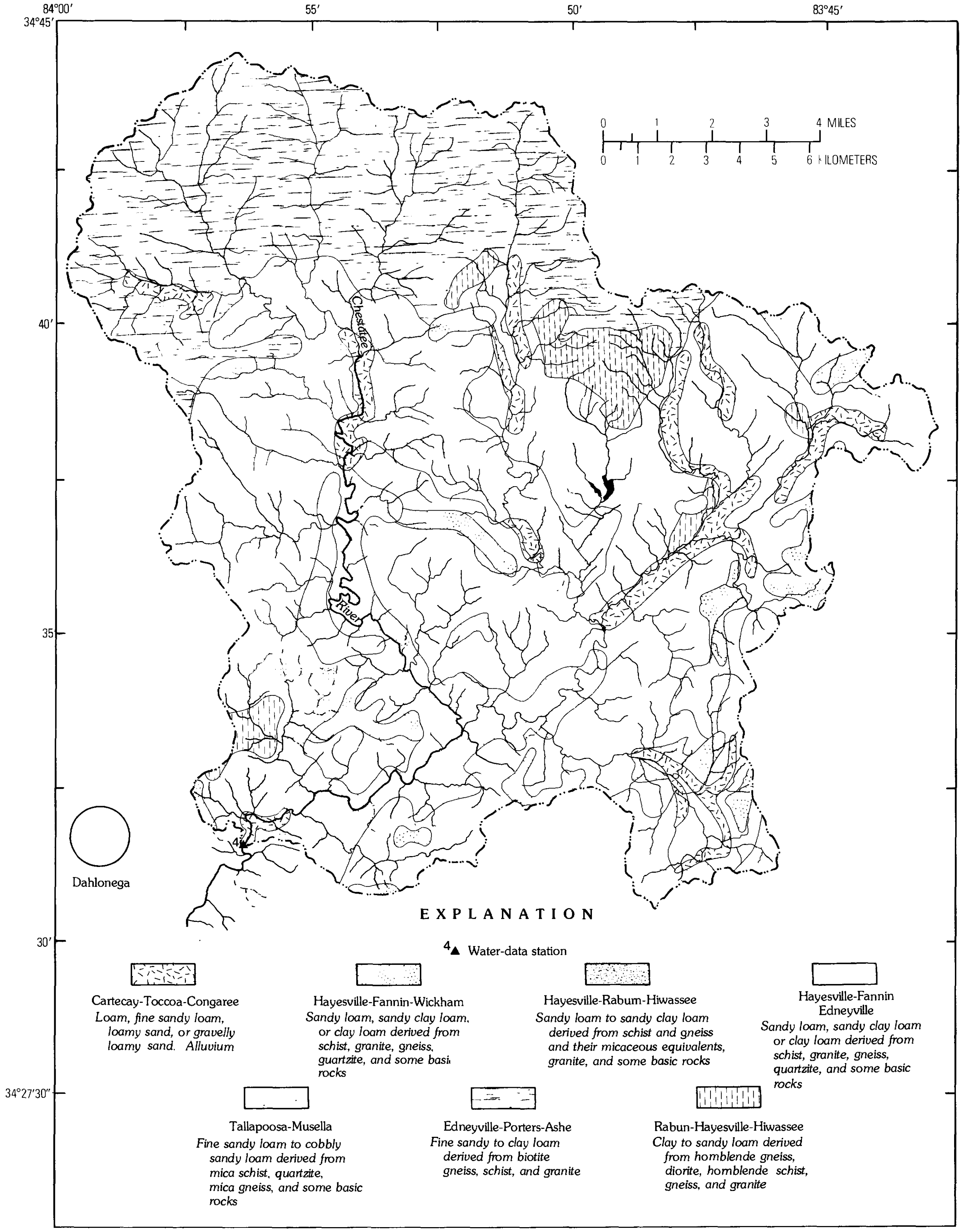


FIGURE 27.—Soil associations in the watershed draining to the Chestatee River near Dahlonega.

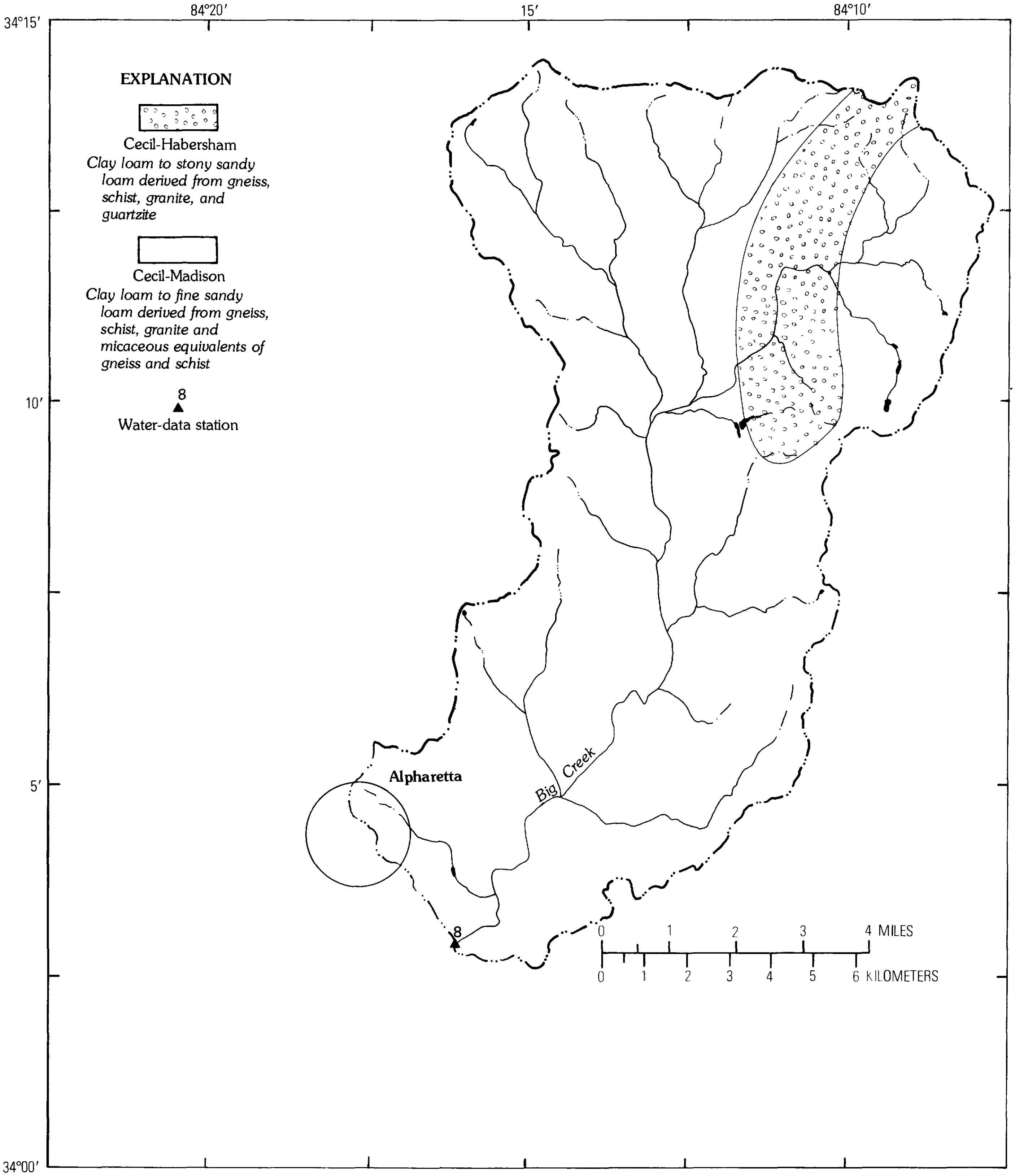


FIGURE 28.—Soil associations in the watershed draining to Big Creek near Alpharetta.

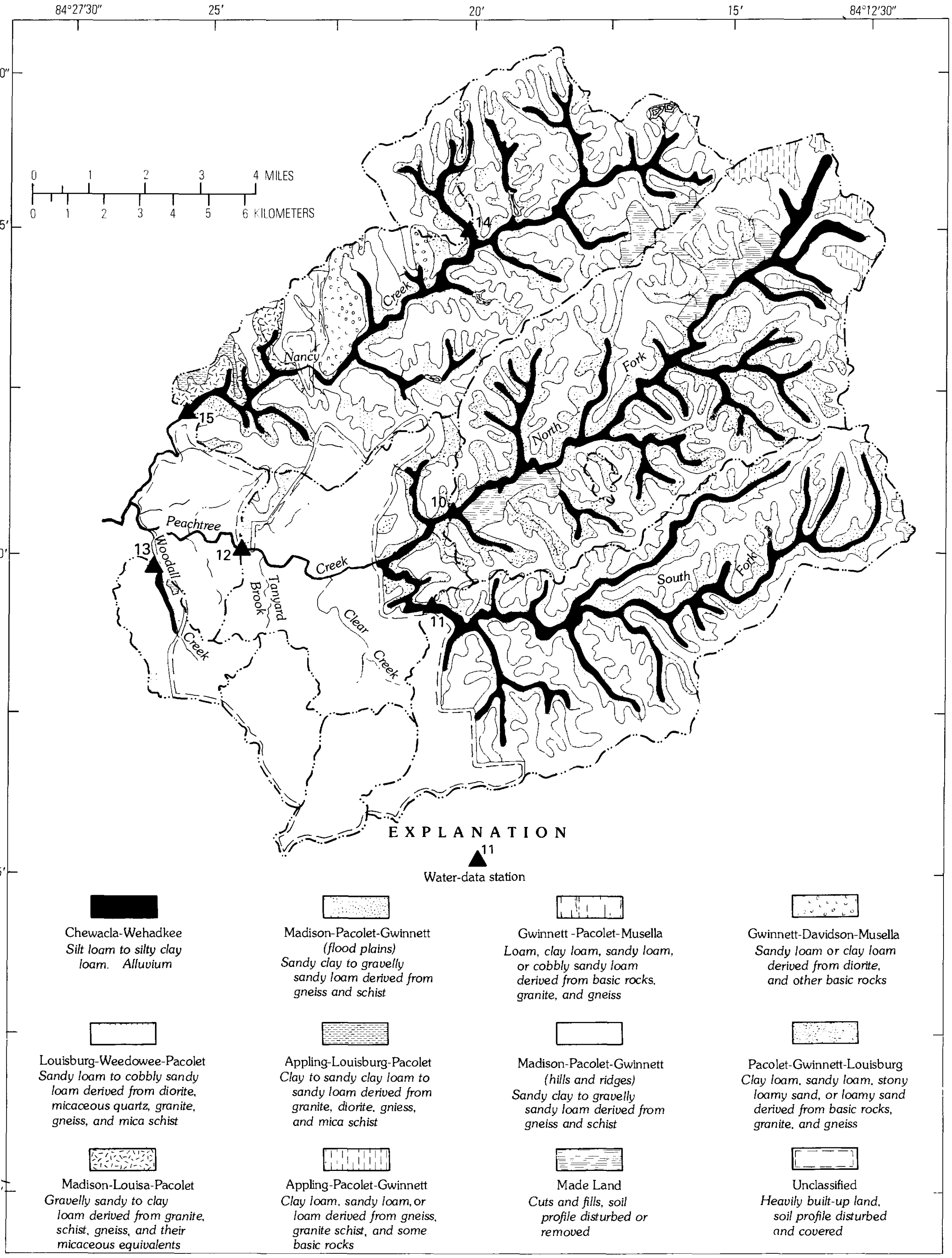


FIGURE 29.—Soil associations in the watersheds draining to Peachtree Creek at Atlanta, Nancy Creek at Atlanta, and Woodall Creek at Atlanta.

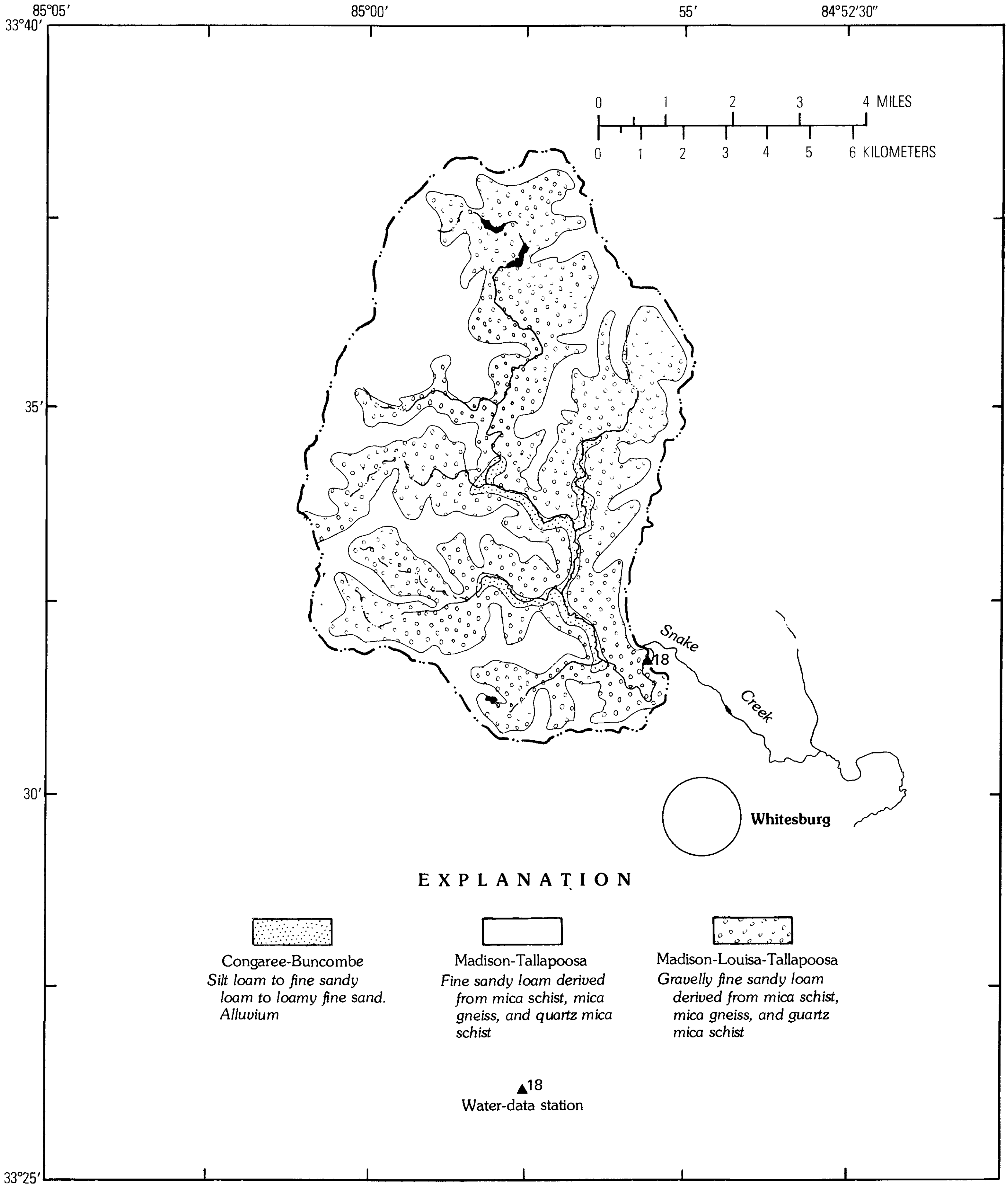


FIGURE 30.—Soil associations in the watershed draining to Snake Creek near Whitesburg.

used in this study were obtained mostly from these sources and are listed below by land-use activity.

C factor	Land use
0.52	Row crop
.07	Pasture
.0005	Undisturbed forest
.30	Orchards
.01	Confined feeding operations
.01	Residential
.00	Industrial and transportation
.05	Other urban
.50	Transitional areas
.34	Cropped woodland

The assignment of a C factor to a particular land use was based, in part, on a concept of the general character of that use throughout the basin. The C factor for croplands (0.52), for example, was based on the planting and harvesting of corn, the annual reseeding of cornfields, and the turn plowing of crop residues into the field after harvest. The C factor assigned to pasture lands (0.07) is representative of cleared land with no appreciable canopy and a 60-percent cover of weeds and grasses. Forested areas were considered managed with a tree canopy of about 80 percent and a 90-percent cover of forest litter on the soil surface (C factor = 0.0005). The C factors assigned to transitional areas and cropped woodlands (0.50 and 0.34) are typical of land that has undergone a recent and large-scale disturbance.

Cropping management factors for residential, confined feeding, and other land uses such as parks and golf courses were not available from literature sources. Cropping management factors were developed for these categories by treating them as pasture land with varying degrees of canopy and ground cover.

Structures and other impervious areas associated with commercial, industrial, and transportation land uses cover the land surface so extensively that soil erosion is effectively inhibited. A C factor of zero was assigned to these areas.

The conservation practice factor (P) accounts for control practices such as contour plowing or terracing that reduce the erosion potential of runoff by influencing drainage patterns, runoff concentration, and runoff velocity. The P factor applies only to cultivated areas and relates a particular practice to land slope. Contour plowing is widely practiced in the basin and was the only conservation practice considered in this study. Listed below are the pertinent P factors for various ranges of land slope. The P factor for land uses other than cropland equals 1.0.

Land slope (percent)	P factor
1.1 to 2	0.4
2.1 to 7	.5
7.1 to 12	.6
12.1 to 18	.8
18.1 to 24	.9

To compute sheet erosion (E) using the Universal Soil Loss Equation the land use and soil maps for each watershed (figs. 18–23 and 25–30) were divided into ¼-square mile areas or nodes. The various equation factors listed above were applied to each node according to the location of the area, the land use, the soil association, and the land slope pertinent to the node. Because cropland and pasture were mapped as a single unit (figs. 18–23), the designation of cropland or pasture at particular nodes was random and based on the ratio of cropland to pasture area listed in table 10. Average annual sheet erosion at each node was computed as the product of the assigned factors. Total sheet erosion in each watershed was computed as the sum of all nodal values for that watershed. Table 20 lists the computed average annual sheet erosion and erosion yields.

The impact of future timber harvesting on sheet erosion was also estimated using the Universal Soil Loss Equation. Cropping management factors were converted from 0.0005 to 0.34 for a 2-square mile area in the Chattahoochee near Leaf watershed

TABLE 20.—*Sheet erosion and erosion yields computed by the Universal Soil Loss Equation*

Station name	Drainage area (mi^2)	Average annual sheet erosion (tons/yr)	Erosion yield (tons/yr/mi^2)
Chattahoochee River near Leaf	150	305,000	2,030
Soque River near Clarkesville	96.0	613,000	6,390
Chestatee River near Dahlonega	153	482,000	3,150
Big Creek near Alpharetta	72.0	199,000	2,760
N. Fork Peachtree near Atlanta	34.1	41,800	1,230
S. Fork Peachtree at Atlanta	29.6	25,600	860
Peachtree Creek at Atlanta	86.8	80,500	930
Nancy Creek at Atlanta	34.8	30,500	880
Snake Creek near Whitesburg	37.0	70,300	1,900

TABLE 21.—*Summary of regression data relating suspended-sediment concentrations to stream discharge*

Station name	Suspended sediment			
	a	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	0.00129	1.61	0.94	14
Soque River near Clarkesville	.568	.950	.95	16
Chestatee River near Dahlonega	.00119	1.66	.93	36
[1] Big Creek near Alpharetta	.0145	1.74	.99	5
[2] Big Creek near Alpharetta	5.61	.457	.84	15
[3] Chattahoochee River at Atlanta	.000820	1.27	.81	31
[4] Chattahoochee River at Atlanta	.000598	1.61	.93	9
N. Fork Peachtree Creek near Atlanta	.155	1.33	.94	15
S. Fork Peachtree Creek at Atlanta	.202	1.34	.99	15
Peachtree Creek at Atlanta	.573	1.03	.89	39
Woodal Creek at Atlanta	14.0	.399	.96	7
Nancy Creek tributary near Chamblee	1.85	1.32	.99	7
Nancy Creek at Atlanta	.384	1.20	.97	9
Proctor Creek at Atlanta	12.6	.787	.98	6
[4] Chattahoochee River near Fairburn	.105	.884	.86	9
Snake Creek near Whitesburg	.569	1.12	.81	37
[4] Chattahoochee River near Whitesburg	.00492	1.21	.91	15
	Suspended silt + clay			
	a	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	0.00780	1.27	0.89	14
Soque River near Clarkesville	1.20	.701	.80	19
Chestatee River near Dahlonega	.00135	1.55	.93	36
[1] Big Creek near Alpharetta	.0249	1.61	.97	5
[2] Big Creek near Alpharetta	9.99	.302	.85	16
[3] Chattahoochee River at Atlanta	.00964	.923	.68	31
[4] Chattahoochee River at Atlanta	.00110	1.49	.87	10
N. Fork Peachtree Creek near Atlanta	.279	1.15	.93	16
S. Fork Peachtree Creek at Atlanta	.350	1.14	.97	16
Peachtree Creek at Atlanta	.517	.945	.89	15
Woodall Creek at Atlanta	12.3	.400	.97	7
Nancy Creek tributary near Chamblee	1.61	1.30	.98	7
Nancy Creek at Atlanta	.396	1.16	.96	12
Proctor Creek at Atlanta	6.76	.867	.96	8
[4] Chattahoochee River near Fairburn	.0780	.878	.90	7
Snake Creek near Whitesburg	.517	1.09	.74	33
[4] Chattahoochee River near Whitesburg	.00594	1.16	.94	15

[1] rise
[2] peak and recession
[3] regulated flow
[4] intervening runoff

(fig. 18) and a 1-square mile area in the Snake Creek drainage near Whitesburg (fig. 23). As a result, computed average annual sheet erosion increased from 305,000 tons per year to 536,000 tons per year in the Chattahoochee River drainage and from 70,300 tons per year to 111,000 tons per year in the Snake Creek drainage. Thus, in both watersheds the hypothetical disturbance of a relatively small area greatly increased the total computed sheet erosion.

Comparison of erosion yields in table 20 with the environmental factors discussed previously provides some insight into the relations between environmental factors and erosion. Erosion yields were greater in watersheds with relatively large LS and rainfall factors. Relatively large yields also occurred in those watersheds containing large percentages of agricultural and transitional land uses.

SEDIMENT DISCHARGE

Sediment discharge is defined as the rate at which sediment passes a section of a stream and is generally reported in tons per day or tons per year. When expressed in tons per day, the instantaneous suspended-sediment discharge is calculated as the product of stream discharge in cubic feet per second (ft^3/s), suspended-sediment concentration in milligrams per liter (mg/L), and the conversion factor 0.0027.

For this study, both instantaneous and average annual discharges of total-, suspended-, bed-, and unmeasured-sediment discharges are considered. Total-sediment discharge is defined as the sum of the suspended-sediment and unmeasured-sediment discharges. Unmeasured-sediment discharge is defined as the sum of the bed- and the suspended-sediment discharges transported in the water column below a distance of about 0.3 foot above the stream bed. Sediments suspended in this part of the water column cannot be measured by depth-integrating samplers, hence the term unmeasured discharge. Unmeasured- and bed-sediment discharges listed in this report were computed using techniques developed by Colby and Hembree (1955) and Einstein (1950).

SUSPENDED SEDIMENT

Regression relations describing suspended-sediment and suspended silt plus clay concentrations as a function of instantaneous stream discharge were developed for each water-data station. At most stations these transport relations were satisfactorily explained by the general geometric function

$$C = aQ_i^b$$

where

C = suspended-sediment concentration in milligrams per liter,

Q_i = instantaneous stream discharge in cubic feet per second, and

a and b = regression constants.

A summary of the regression analyses for each water-data station is listed in table 21. Correlation coefficients for all regressions ranged from 0.68 to 0.99 and were 0.85 or greater for 28 relations. The minimum data base for any relation was 5 samples; 17 relations were developed using 14 samples or more.

Concentration versus discharge curves for selected water-data stations are shown in figures 31 to 35. The specific data points from which the curves were plotted are also shown and indicate whether the water sample was collected on the rise, peak, or recession of a flow event. With the exception of one

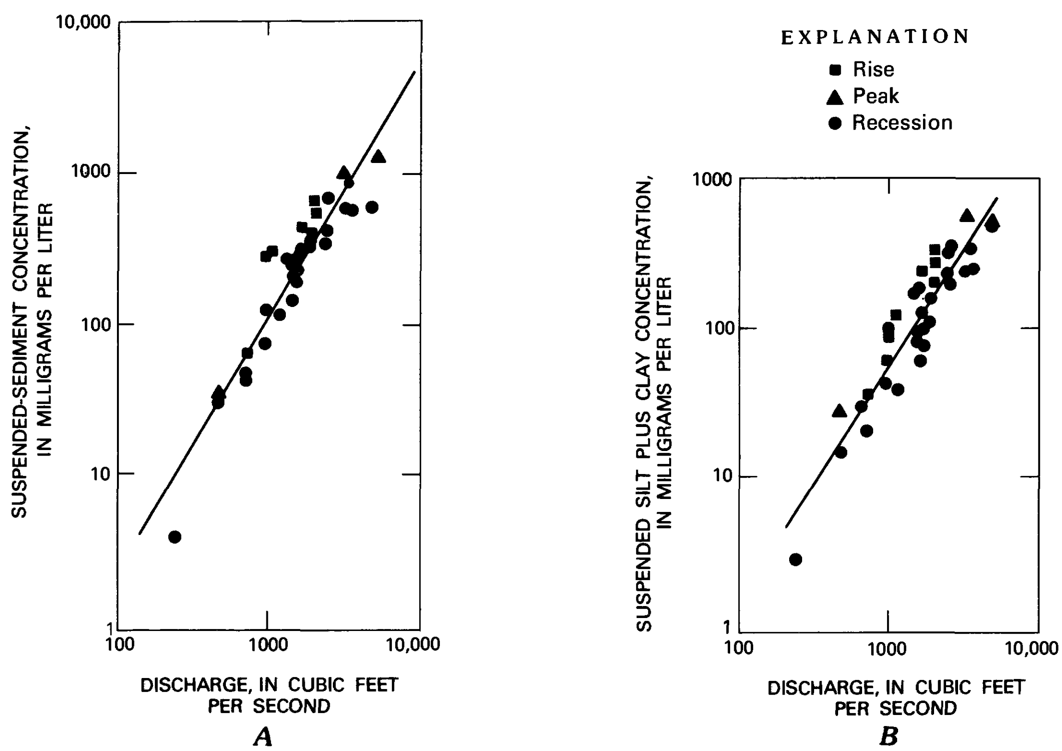


FIGURE 31.—Relation of suspended-sediment concentrations to stream discharge at the Chestatee River near Dahlonega.

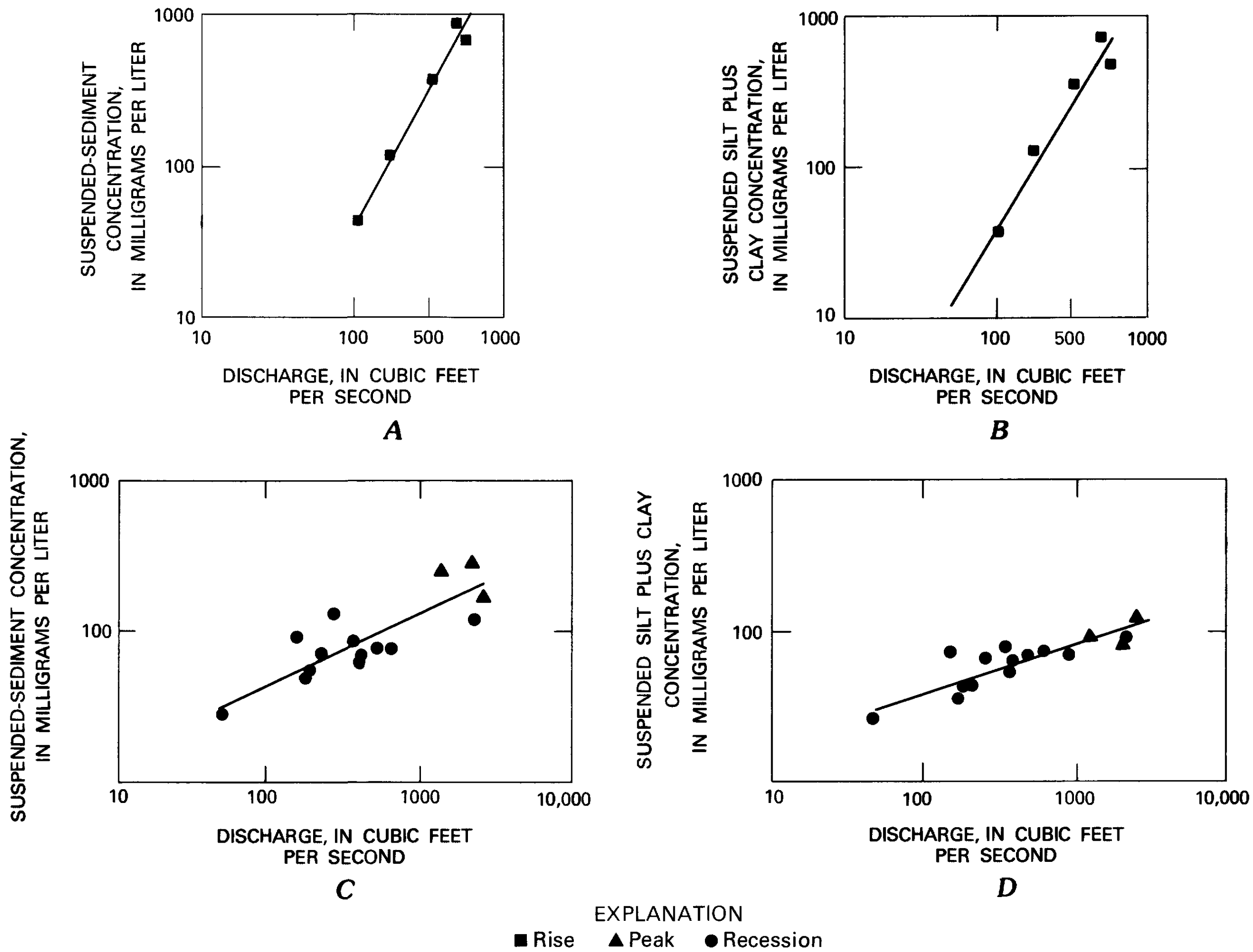


FIGURE 32.—Relation of suspended-sediment concentrations to stream discharge at Big Creek near Alpharetta.

station, the relations were not sensitive to river-stage direction. At the excepted station, Big Creek near Alpharetta, the concentrations of suspended sediment transported during periods of rising stage were significantly higher than corresponding concentration transported at the same discharge during periods of peak stage or recession.

At the Chattahoochee River at Atlanta, the concentration of suspended sediment was observed to be sensitive to the source of water in the channel. The concentrations of suspended sediment transported by regulated flows were significantly lower than sediment concentrations related to intervening runoff at the same discharge (fig. 33). The concentration versus discharge relations pertaining to regulated flows were developed from data collected during the late spring and summer of 1976 when tributary contributions to the Chattahoochee River between Buford Dam and Atlanta were minimal. Sediment data relative to runoff were collected during basin-wide rainfall events when river flows at Atlanta were comprised mostly of surface runoff.

Similar, though less pronounced, concentration differences were observed at the Chattahoochee River near Fairburn and near Whitesburg. Suspended-sediment data listed for these two stations, however, were collected mostly during runoff events and are not representative of regulated flows (fig. 35).

AVERAGE ANNUAL SUSPENDED-SEDIMENT DISCHARGE

Average annual suspended-sediment discharges were computed by a modified version of the sediment-transport, flow-duration curve method described by Colby (1956) and Miller (1951). For each water-data station this method combines discharges and corresponding percentages of time from the flow-duration curve with corresponding suspended-sediment concentrations from the concentration-discharge curve. Instantaneous suspended-sediment discharges for each river discharge at each flow duration are computed and weighted by the corresponding percentage of time. The sum of the

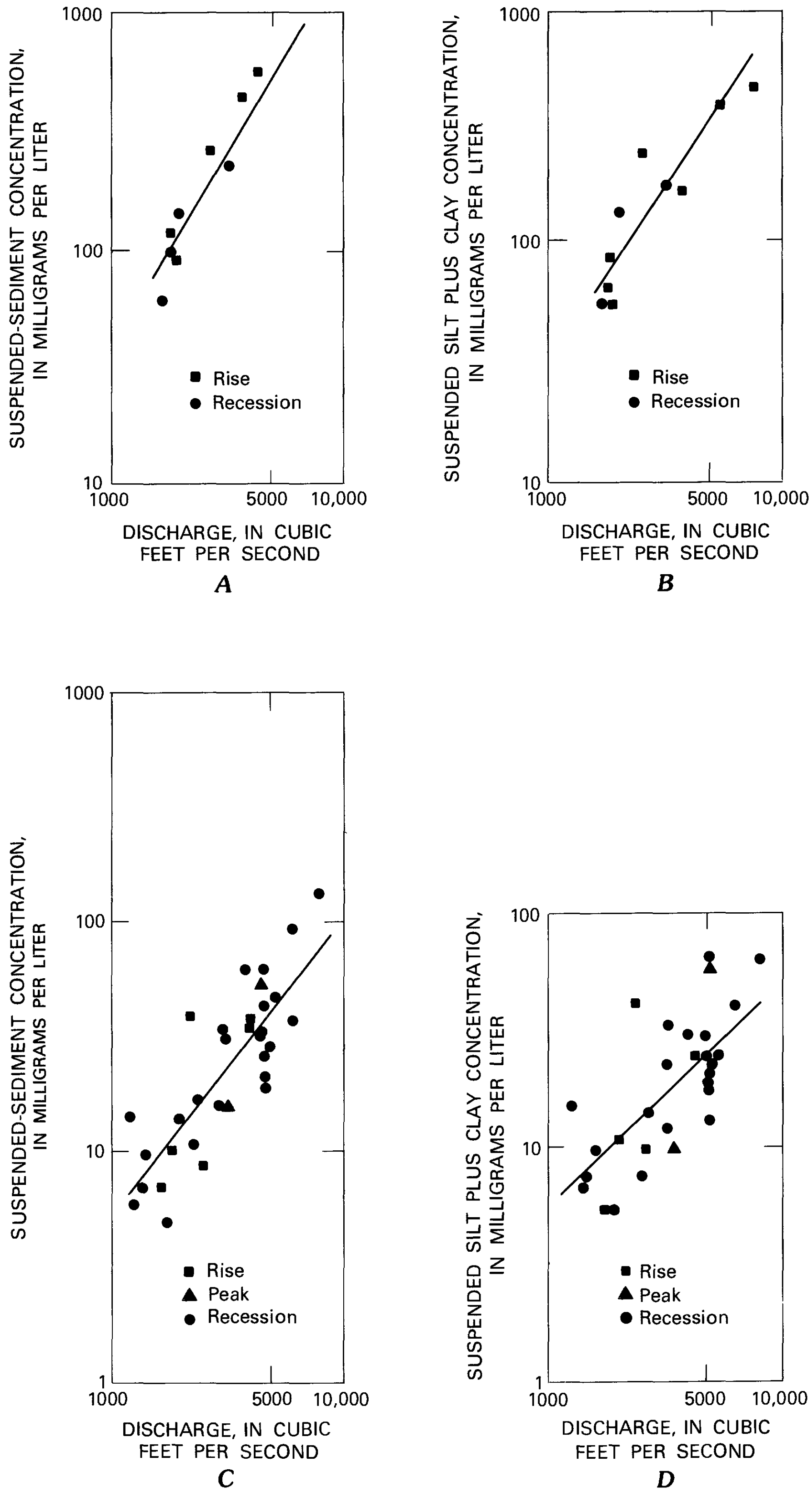


FIGURE 33.—Relation of suspended-sediment concentrations to stream discharge at the Chattahoochee River at Atlanta.

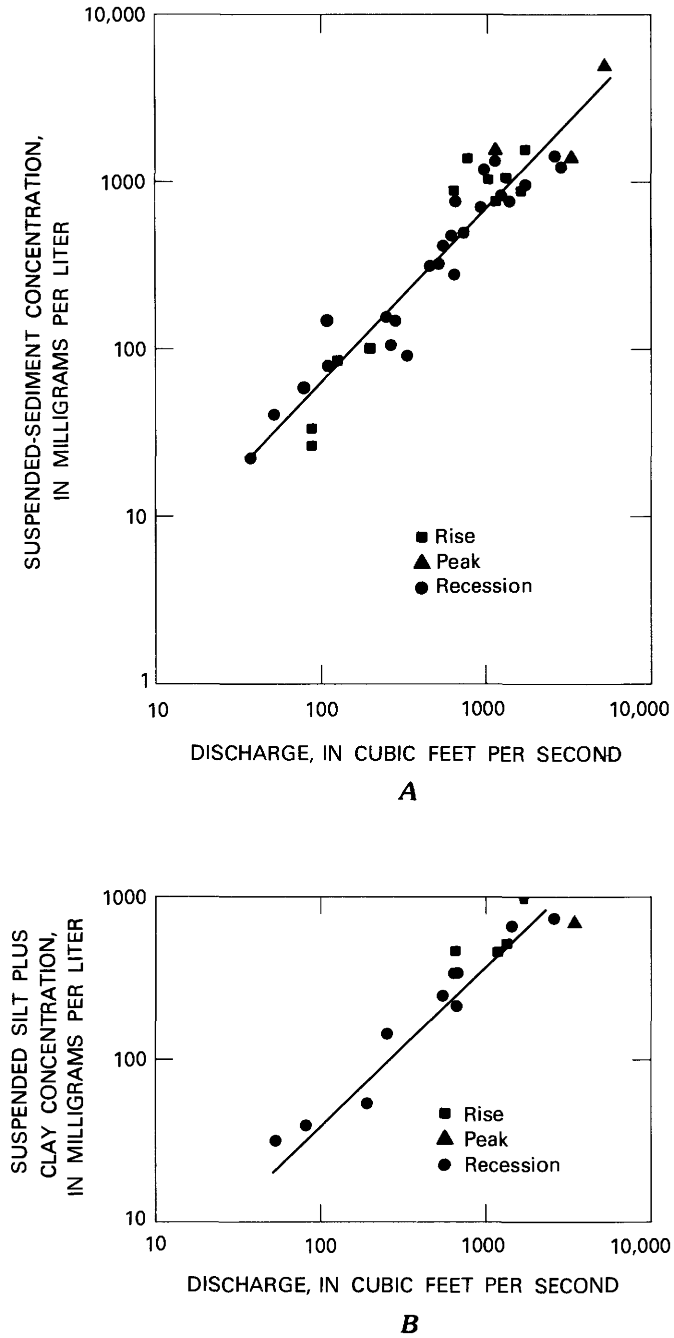


FIGURE 34.—Relation of suspended-sediment concentrations to stream discharge at Peachtree Creek at Atlanta.

weighted values is the average annual suspended-sediment discharge at the station. The flow duration and concentration-discharge relations used in these computations are considered representative of long-term conditions in the basin. Average annual discharges of suspended sediment and suspended silt plus clay were computed at each water-data station and are listed in table 22.

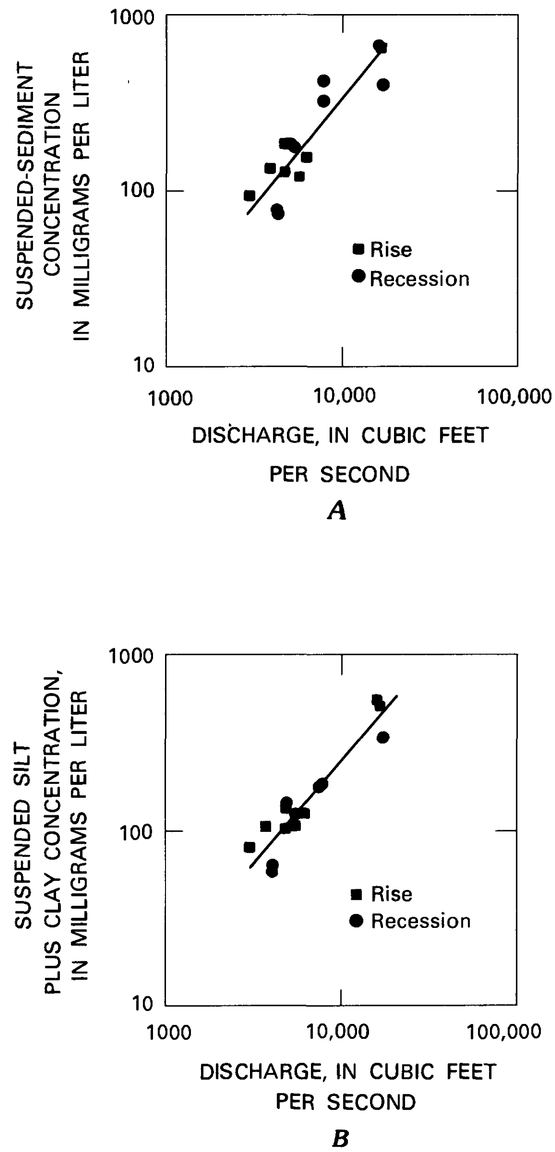


FIGURE 35.—Relation of suspended-sediment concentrations to stream discharge at the Chattahoochee River near Whitesburg.

Suspended-sediment discharges for Big Creek near Alpharetta were computed using the concentration-discharge curves for both rising stage and peak and receding stages. These discharges were then weighted according to the amount of time the daily streamflow at the station was reported to be rising (25 percent) and receding (75 percent) during the period of record. The sums of the weighted discharges are the values listed in table 22.

Annual suspended-sediment discharge at the Chattahoochee River at Atlanta was computed for both regulated flows and intervening runoff. Computed annual suspended-sediment discharges at the Chat-

TABLE 22.—*Average annual suspended-sediment discharge and yield*

Station name	Suspended-sediment discharge (tons/yr)	Suspended-sediment yield (tons/yr/mi²)	Suspended silt plus clay discharge (tons/yr)	Suspended silt plus clay yield (tons/yr/mi²)
Chattahoochee River near Leaf	43,000	287	18,800	125
Soque River near Clarkesville	43,200	450	17,900	186
Chestatee River near Dahlonega	52,300	342	24,700	161
Big Creek near Alpharetta	24,000	333	17,800	247
Chattahoochee River at Atlanta	108,000	415	75,300	283
[1] Chattahoochee River at Atlanta	62,300	---	41,000	---
N. Fork Peachtree Creek near Atlanta	15,100	443	8,820	259
S. Fork Peachtree Creek at Atlanta	25,400	858	12,200	412
Peachtree Creek at Atlanta	65,500	755	32,500	374
Woodall Creek at Atlanta	1,230	397	960	310
Nancy Creek tributary near Chamblee	275	86	224	70
Nancy Creek at Atlanta	19,800	569	16,000	460
Proctor Creek at Atlanta	1,540	99	1,040	67
Chattahoochee River near Fairburn	311,000	366	220,000	256
[2] Chattahoochee River near Fairburn	62,300	---	41,000	---
Snake Creek near Whitesburg	13,300	359	10,000	270
Chattahoochee River near Whitesburg	449,000	368	340,000	274
[2] Chattahoochee River near Whitesburg	62,300	---	41,000	---

[1] Discharge attributed to regulated flow.
[2] Discharge attributed to regulated flow. Equals computed discharge at the Chattahoochee River at Atlanta.

tahoochee River near Fairburn and near Whitesburg pertain only to intervening runoff. The suspended-sediment discharges contributed by regulated flow to the stations near Fairburn and Whitesburg were considered equal to the annual discharge computed for the upstream station at Atlanta. Yields of suspended sediment for stations on the Chattahoochee River downstream of Buford Dam were computed for intervening runoff only using the drainage area between the dam and the particular station rather than the total drainage area at the station. Sediment transported by regulated flows was considered to be derived entirely from the river channel.

MECHANICS OF SUSPENDED-SEDIMENT TRANSPORT

Although stream discharge has been shown to be the primary determinant of suspended-sediment concentrations at the various water-data stations, other factors such as channel and streambed characteristics, stream velocity, and depth of flow also influence the quantity and distribution of sediment carried in suspension, especially with respect to the sand-size particles.

Typical channel and streambed characteristics in the basin have been summarized previously in figure 5. In general, suspended-sediment concentrations are most sensitive to those channel characteristics that tend to produce or increase turbulence. Consequently, streamflow along rock beds or beds containing large rocks and boulders tends to transport larger quantities of suspended sediment per unit volume of water than streamflow across a sand and gravel bed. Similarly, channel constrictions such as debris or bridge piers also tend to increase suspended-sediment concentrations. A major constriction of the channel can cause scour of the streambed as noted at Big Creek near Alpharetta and Peachtree Creek at Atlanta (figs. 5*B* and 5*D*).

Lateral distributions of suspended-sediment concentration, mean velocity, and depth of flow are shown for several water-data stations in figures 36 to 40. Also shown are sediment sizes indicating the size (D_{50}) which was larger than 50 percent, by weight, of the sampled bed material. The date and discharge relative to the measurements are also listed. These data represent measurements made at a limited number of discrete, vertical lines and should not be construed as a complete description of lateral parameter distribution across the various sections.

The sensitivity of suspended-sediment concentration to flow parameters is shown to vary not only with the station but with different flow conditions at the same station. For example, lateral distribution of suspended sediment at the North Fork of Peachtree Creek and at Snake Creek near Whitesburg were, respectively, directly and inversely related to corresponding distributions of flow velocity and depth (figs. 38 and 40). At the Chestatee River near Dahlonega (fig. 36), the lateral distribution of suspended sediment varied directly with velocity and depth at a discharge of 3,200 cubic feet per second and varied inversely with velocity at a discharge of 7,280 cubic feet per second.

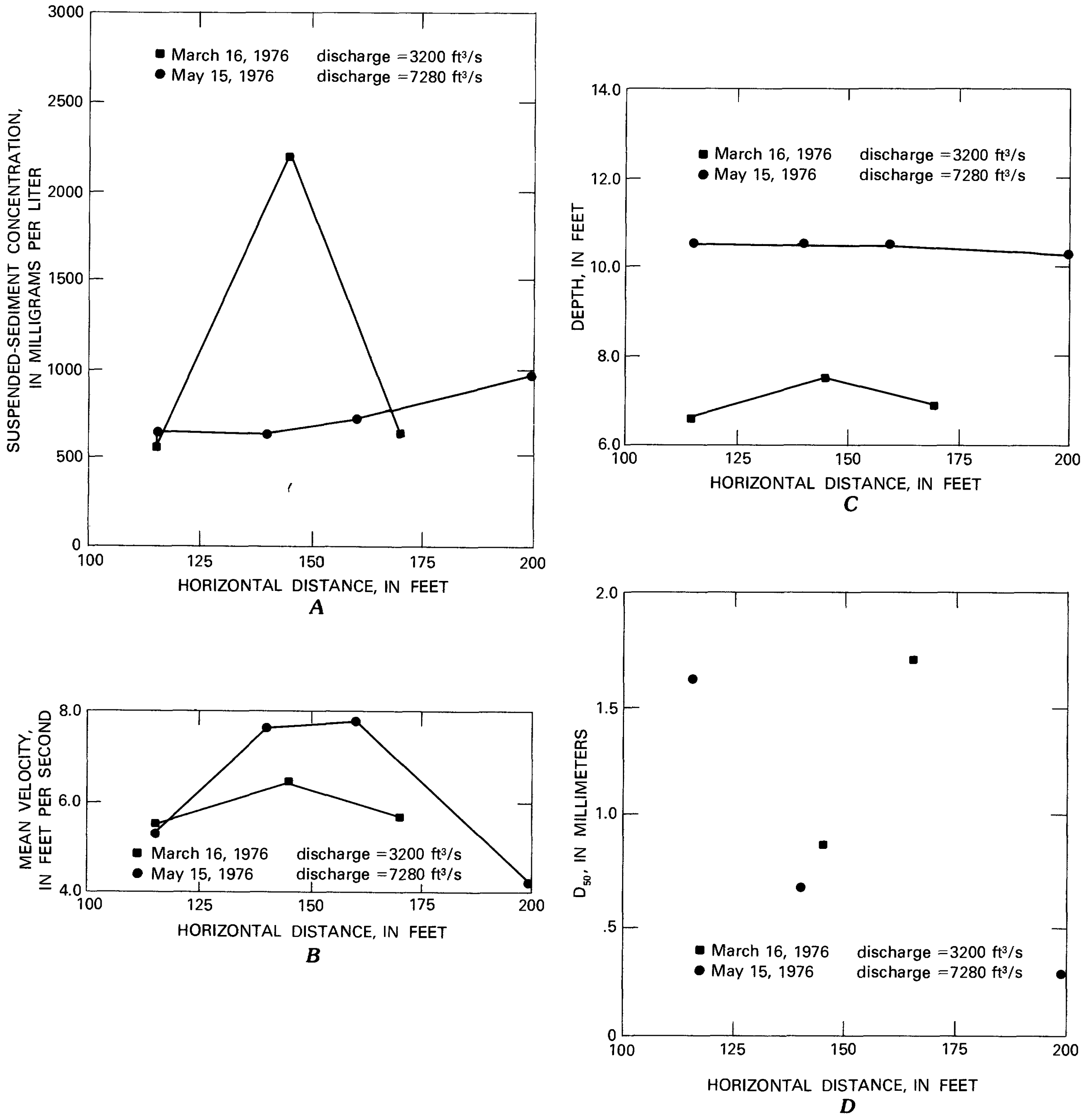


FIGURE 36.—Lateral distributions of suspended-sediment concentration, flow velocity, flow depth, and size of bed material at the Chestatee River near Dahlonega.

The effect of suspended-sediment concentration and flow parameters on bed-sediment size can be illustrated with data from Big Creek near Alpharetta (fig. 37). At a discharge of 576 cubic feet per second the size of bed material across the channel varied directly with suspended-sediment concentration, velocity, and depth. An inverse relation between the same parameters occurred at a discharge of 1,330 cubic feet per second. Such examples illustrate the uncertainty experienced in relating flow parameters to sediment transport. In general, however, the data presented (figs. 36–40) indicate that concentrations of suspended sediment in basin streams are proportional to stream velocities. Sedi-

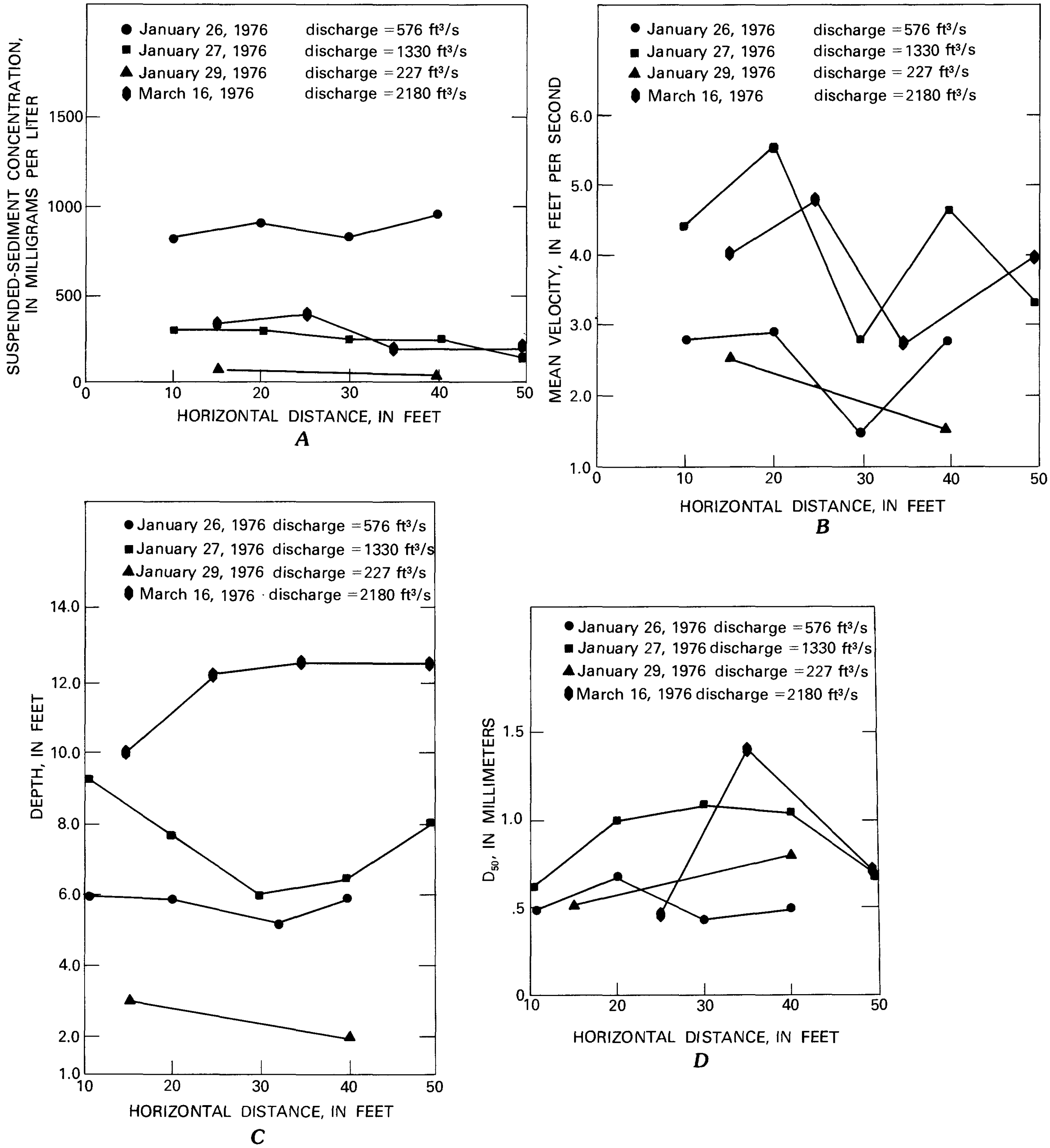


FIGURE 37.—Lateral distributions of suspended-sediment concentration, flow velocity, flow depth, and size of bed material at Big Creek near Alpharetta.

ment-transport relations to depth and sediment size could not be determined with available data.

The quantity and temporal distribution of suspended sediment discharged during runoff events is illustrated in figure 41. Values of instantaneous suspended-sediment discharge and river stage were plotted against time for selected runoff periods. A suspended-sediment discharge hydrograph for the

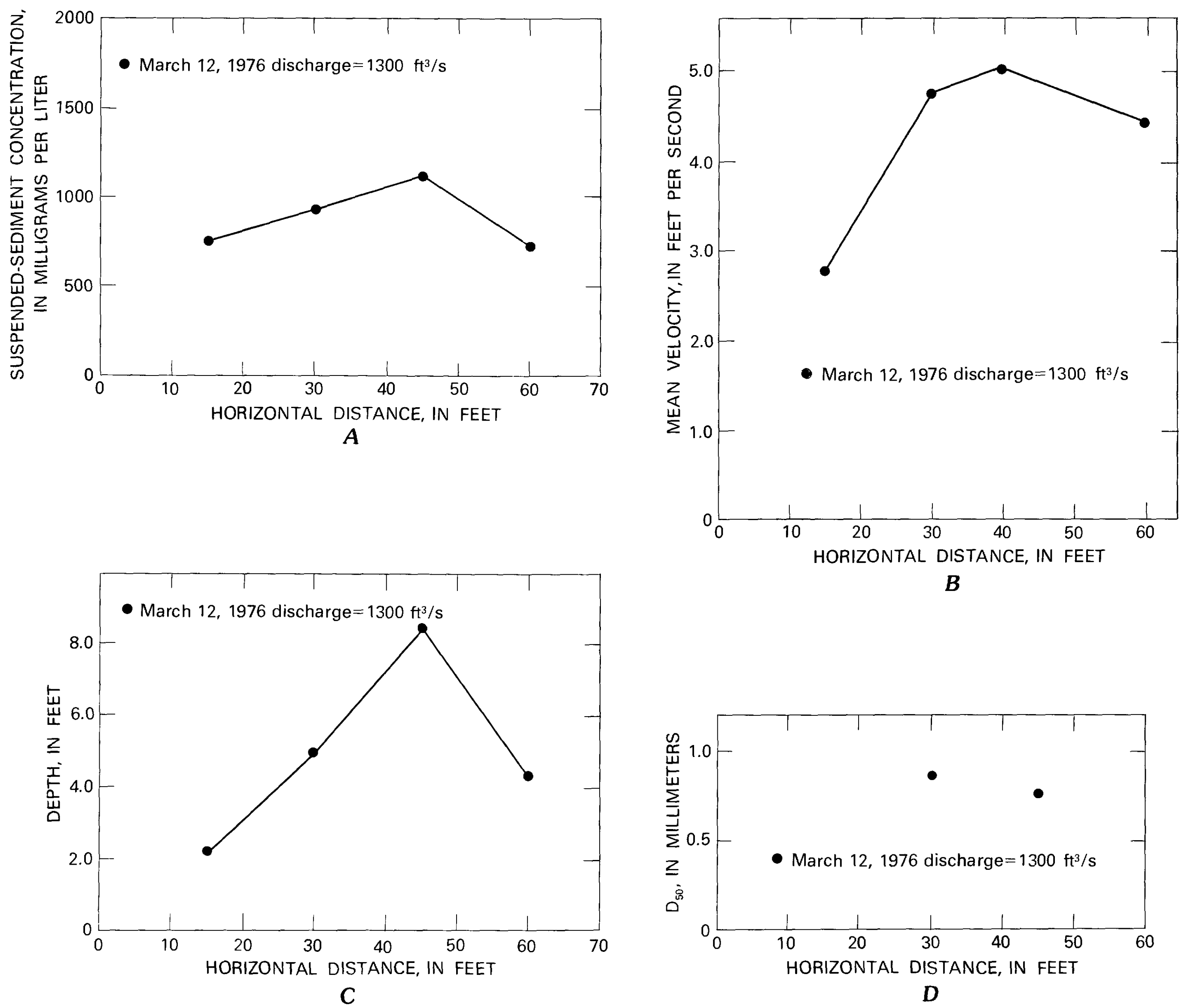


FIGURE 38.—Lateral distributions of suspended-sediment concentration, flow velocity, flow depth, and size of bed material at North Fork of Peachtree Creek near Atlanta.

storm was developed by interpolating between the instantaneous discharge measurements. At most stations, the sediment-discharge and stream hydrograph were in phase or nearly in phase and peaked at approximately the same time. At Big Creek near Alpharetta, however, most of the sediment load significantly preceded the water load from the storm. Integration of the sediment-discharge hydrographs provided the storm discharge of suspended sediment. The computed storm load is listed on each figure and, in most cases, amounts to a significant part of the average annual suspended-sediment discharge (table 22).

UNMEASURED AND BED SEDIMENT

DESCRIPTION AND SOURCE

Streams in the Upper Chattahoochee River basin transport a variety of sediment from several sources. Silts and clays are supplied mostly by overland flows; sand and gravel are generally available from the streambed and bank storage. During transport, the coarser materials (sand and gravel) are transported along or just above the bed and constitute most of the unmeasured load. Sediment concentrations and particle-size distributions in the unmeasured zone, therefore, are governed by the amount and size of material available for transport and by the capacity of the stream to transport this material.

Streambeds on the Dahlonega Plateau consist of discontinuous deposits of sand, gravel, and boulders on a bedrock base. Sand deposits occur in isolated patches or in stringers of varying thickness and area. Coarse gravels and cobbles occur sporadically and do not form a continuous gradation with the finer sediments. Bed material samples collected on the Dahlonega Plateau indicate that coarser materials (large gravel and cobbles) are transported only when flow velocities are extremely high and that sand and fine gravel constitute the vast majority of unmeasured loads. In addition, a considerable quantity of sand is stored on the sides and banks of stream channels during low-flow periods and becomes available for transport as stream stage increases.

Streambeds on the Atlanta Plateau consist mostly of sand and fine gravel; however, bedrock sections are not uncommon. Channel deposits are generally a foot thick or more and are continuous throughout the bed. Such channels are by definition alluvial because their beds consist of material that is readily available for transport (Einstein, 1950, p. 6; Vanoni ed., 1975, p. 114). Deposits of sand on channel banks in the Atlanta Plateau are common and frequently large and may contribute to unmeasured loads at high flows. Other sources of material that could be transported as unmeasured load are derived from channel or gully erosion and, as such, may be of local importance.

Photographs of typical streambed and stream-channel conditions on the Dahlonega (*A* and *B*) and Atlanta (*C* and *D*) Plateaus are shown in figure 42.

COMPUTATION

Instantaneous unmeasured and bed-sediment discharges were computed using the modified Einstein method developed by Colby and Hembree (1955). The computation of sediment discharge using the modified Einstein method requires data describing the particle-size distribution of both suspended sediments in transport and bed sediments assumed to be available for transport at the time of sampling. Other data required include instantaneous suspended-sediment concentrations, stream discharge, stream top width, water temperature, and average flow depth. Results of the modified Einstein computations are listed in table 23. Computation of unmeasured discharge using the modified Einstein procedure is terminated when computed bed discharge is zero. Such occurrences are noted by a dash in the unmeasured discharge column of table 23 and indicate that the discharge of course sediments in the unmeasured zone is considered nil. Unmeasured- and bed-sediment discharges listed for the Chattahoochee River stations at Atlanta and near Whitesburg relate, for the most part, to regulated flow.

TRANSPORT CURVES

Instantaneous sediment-discharge data in table 23 were sufficiently complete at several water-data stations to permit the development of transport curves (fig. 43). Regression relations based on these curves were computed using the general geometric equations

$$Q_{su} \text{ or } Q_{sb} = aQ_i^b$$

where

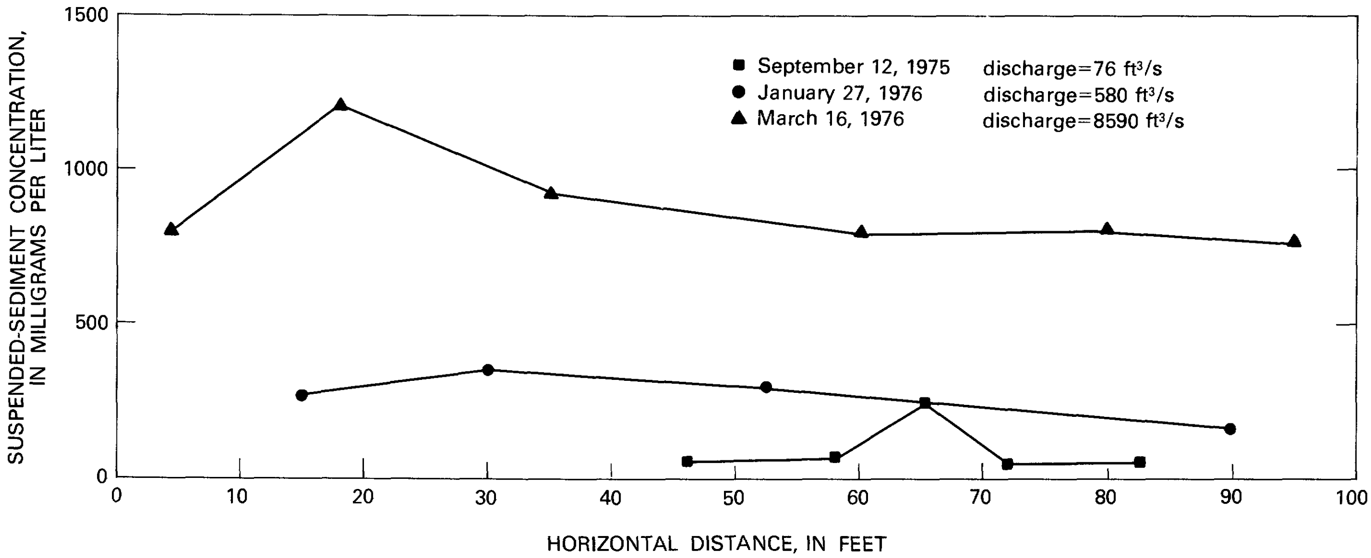
Q_{su} and Q_{sb} = unmeasured- and bed-sediment discharge, respectively,

Q_i = instantaneous stream discharge in cubic feet per second, and

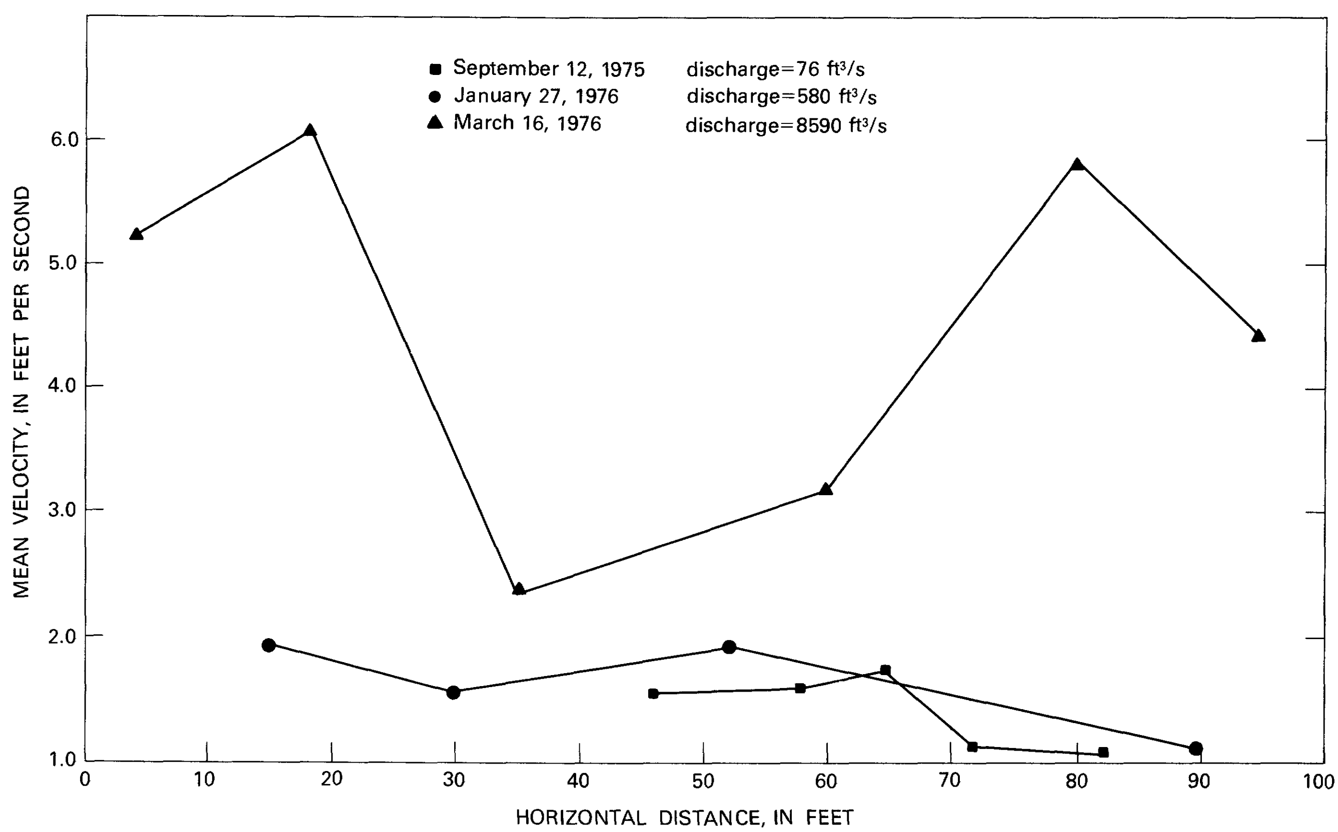
a and b = regression constants.

A summary of the regression analyses is listed in table 24.

The sensitivity of unmeasured- and bed-sediment discharges to stream discharge points out some interesting aspects of sediment transport in the study area. Examination of the unmeasured-sediment discharge data for the Chestatee River near Dahlonega (table 23 and fig. 43*B*) indicates that the quantity of unmeasured and bed loads in the river is limited by the supply of coarse sediments. Notice in table 23 that unmeasured- and bed-sediment discharges always occurred on the receding limb of the hydrograph. If the occurrence of such discharges is governed solely by the stream's transporting ability, then computations based on sample data collected on the rising limb should also indicate the presence of unmeasured and bed sediments in transport. Instead, computed total-sediment discharge equaled measured suspended-sediment discharge. Such an occurrence does not indicate an absence of sediment in the unmeasured zone. It does indicate, however, that bed-sediment discharge was minimal during the initial part of the runoff event and that the river's capacity to transport course material equaled or exceeded its supply. Typically, then, as the stream continues to rise, more and more course sediment is supplied to it, particularly from bank storage. Eventually the supply exceeds the trans-

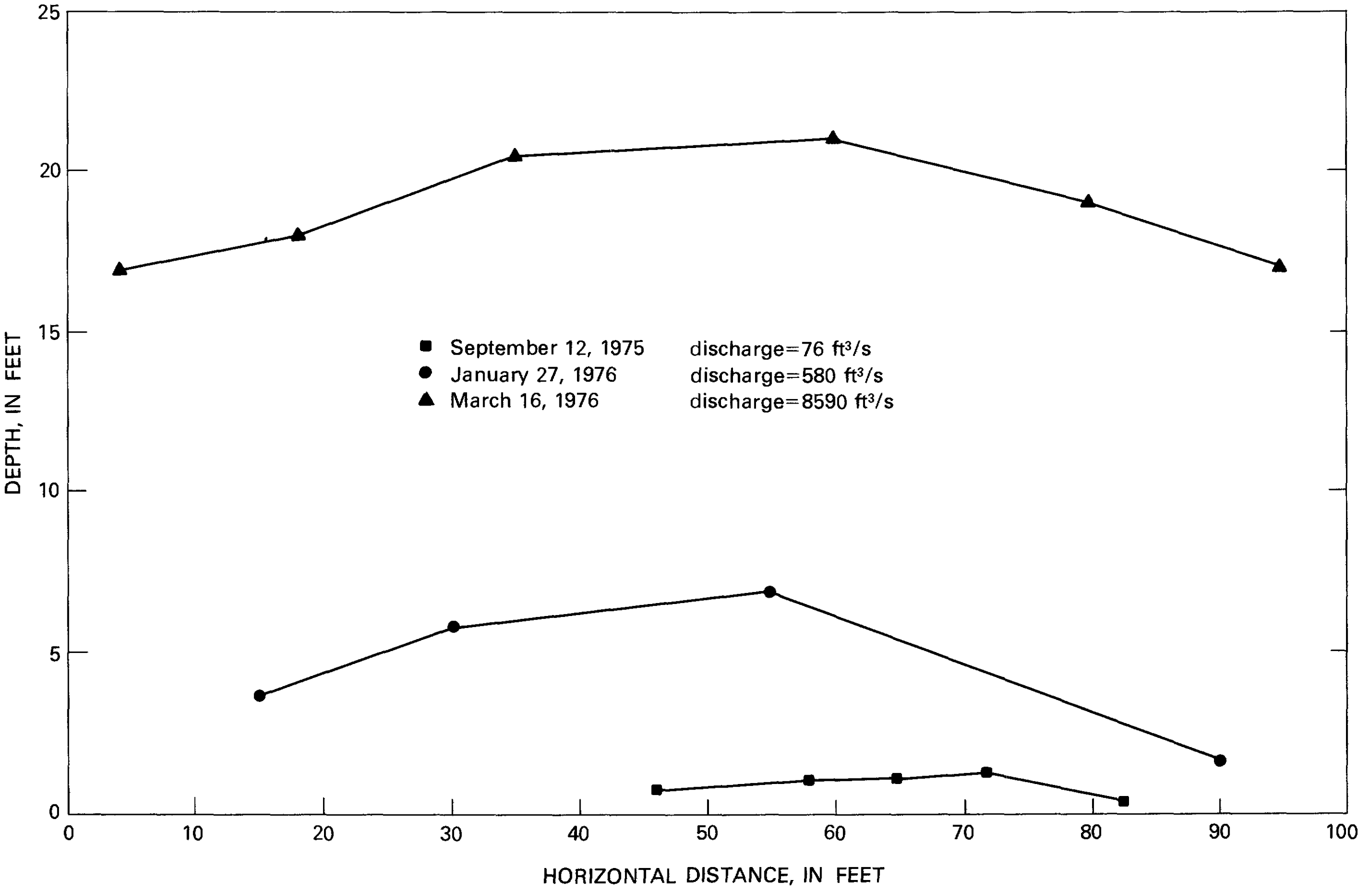


A

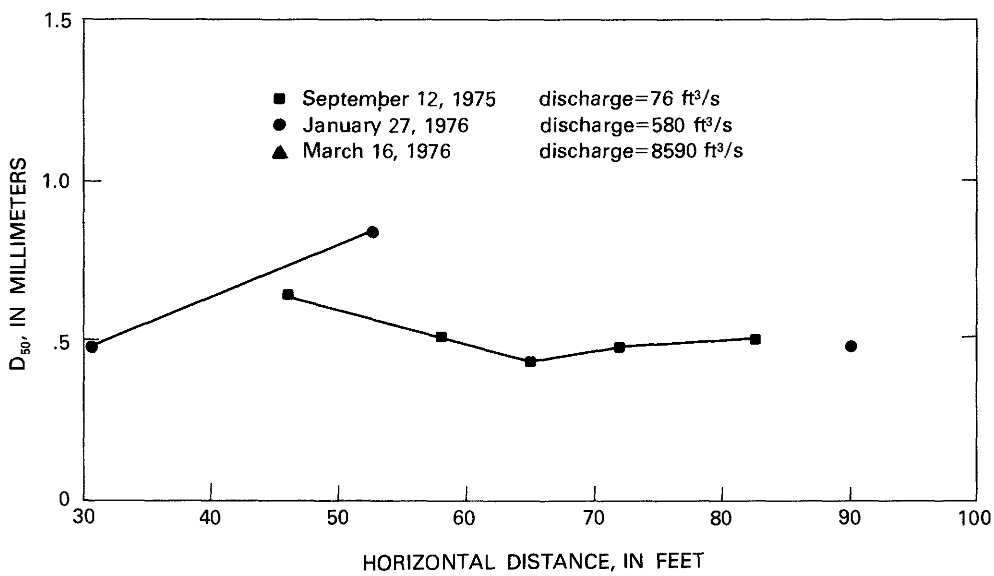


B

FIGURE 39.—Lateral distributions of suspended-sediment concentration, flow velocity, flow depth, and size of bed material at Peachtree Creek at Atlanta.



C



D

FIGURE 39.—Continued.

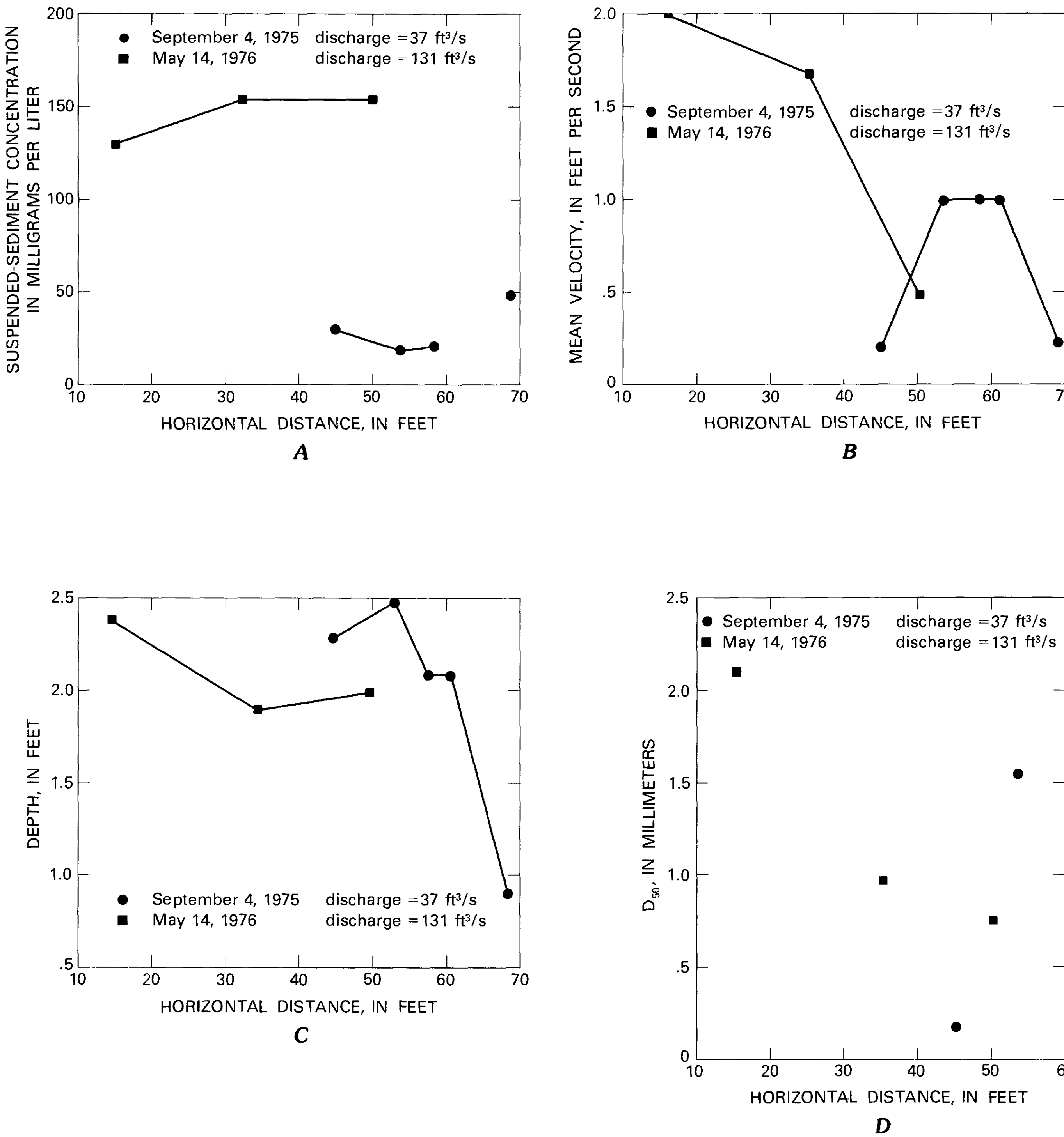


FIGURE 40.—Lateral distributions of suspended-sediment concentration, flow velocity, flow depth, and size of bed material at Snake Creek near Whitesburg.

port capacity of the stream and course sediments begin to settle to the bottom and move as bedload. During recession, supplies of course sediment from outside the channel are progressively reduced and sediment deposition on the channel banks takes place. Material previously deposited on the bed now serves as the major supply of bedload and suspendable sands. The stream always attempts to transport as much suspended sediment as it can. Consequently, the bed-sediment transport rate declines

TABLE 23.—*Summary of unmeasured- and bed-sediment discharge computations*

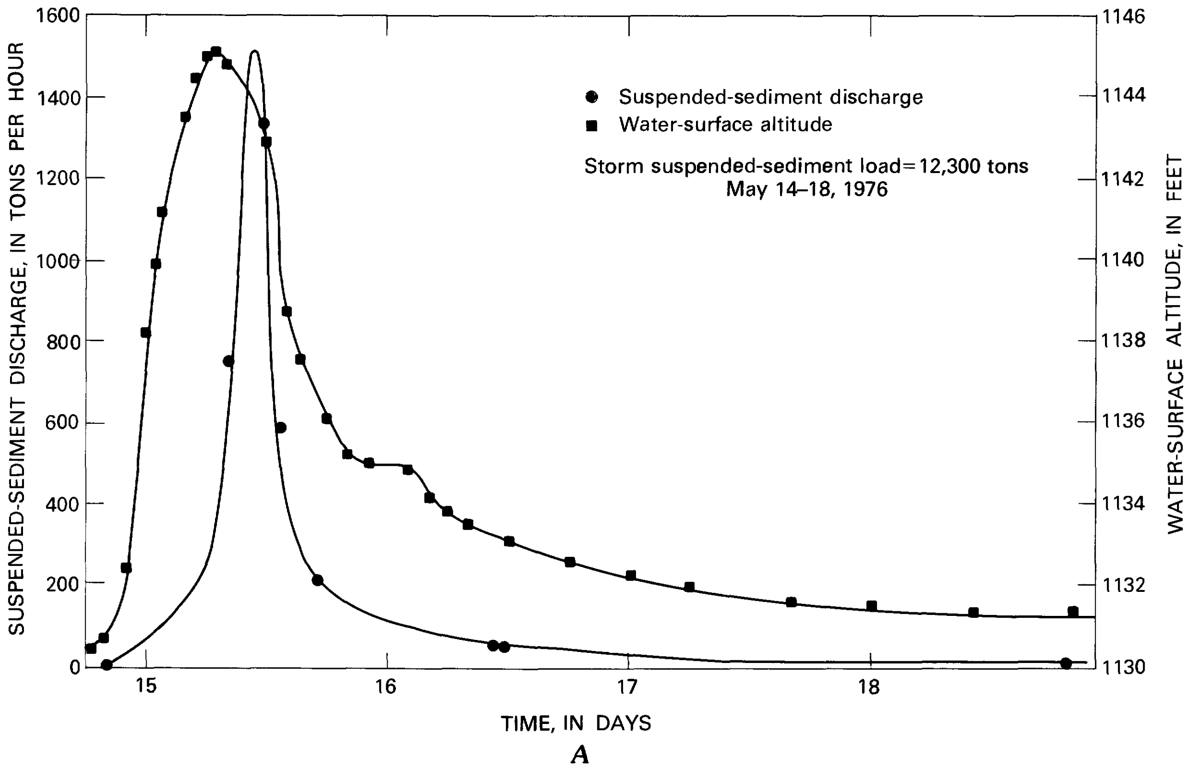
Station name	Date	Time	Stream discharge (ft^3/s)	Bed discharge (tons/day)	Unmeasured discharge (tons/day)	Ratio of bed to unmeasured discharge (percent)	Stage direction
Chattahoochee River near Leaf	9–23–75	1355	880	0.17	65.5	0.26	Falling
	3–16–76	1335	2800	460	1810	5	Falling
	5–28–76	1405	4440	614	5690	11	Rising
Soque River near Clarkesville	9–22–75	1620	163	0.0	—	—	Rising
	3–16–76	1015	2380	221	1280	17	Rising
	5–15–76	1650	3180	158	428	7	Falling
Chestatee River near Dahlonega	9–24–75	0910	825	3.84	154	2.5	Falling
	3–16–76	1610	3200	101	1250	8.1	Falling
	3–16–76	2300	1700	27.8	415	6.7	Falling
	5–15–76	1230	8180	1290	5280	24	Falling
	5–28–76	1105	970	0.0	—	—	Rising
Chattahoochee River near Buford	7–22–76	1400	530	0.0	—	—	Rising
	7–22–76	1505	8900	248	984	25	Rising
	7–22–76	1640	11700	114	474	24	Peak
	7–22–76	2000	4300	22.6	156	14	Falling
Chattahoochee River near Duluth	7–22–76	1650	700	0.0	—	—	Rising
	7–22–76	1809	1800	0.0	—	—	Rising
	7–22–76	1859	5400	131.0	716	18	Rising
	7–22–76	2151	7300	191	872	22	Rising
Big Creek near Alpharetta	9–22–75	1030	42	0.0	—	—	Falling
	12–31–75	1400	672	5.1	43.3	12	Peak
	1–26–76	0920	498	1.31	139	.94	Rising
	1–26–76	1405	764	6.11	76.5	8.0	Rising
	1–27–76	1440	1320	43.4	253	17	Peak
	1–29–76	1420	227	0.45	6.40	7.0	Falling
	3–16–76	1915	2180	80.8	494	16	Rising
	3–18–76	1445	393	0.0	—	—	Falling
Chattahoochee River at Atlanta	5–27–76	0850	8120	123	635	19	Falling
	4–14–77	1400	7970	126	766	16	Peak
	4–25–77	1200	6060	41	226	18	Falling
	5–28–77	1030	1200	3.7	3.7	~100	Falling
N. Fork Peachtree Creek near Atlanta	3–12–76	2245	1410	395	1580	25	Falling
	5–11–76	1000	30	0.0	—	—	Steady
S. Fork Peachtree Creek at Atlanta	5–11–76	1100	25	0.0	—	—	Steady
	3– 9–76	1048	212	3.18	43.2	7.4	Falling
	3–13–76	0035	1200	75.7	768	9.9	Rising
Peachtree Creek at Atlanta	9–12–75	1130	69	0.67	6.9	9.7	Falling
	1–27–76	1000	580	1.86	46.3	4.0	Falling
	3–16–76	1145	8510	375	2280	16	Peak
Nancy Creek tributary near Chamblee	5–27–76	2125	89	148	352	42	Rising
Nancy Creek at Atlanta	5–12–76	1130	30	0.0	—	—	Steady
Chattahoochee River near Fairburn	4–14–77	1255	9900	96.0	703	14	Rising
Snake Creek near Whitesburg	9– 4–75	1120	37	0.0	—	—	Steady
	4–14–76	1850	145	.53	.53	~100	
Chattahoochee River near Whitesburg	5–14–76	1530	4080	59.9	59.9	~100	Falling
	4–14–77	1125	9605	113	368	31	Peak
	6– 2–77	1300	1880	18.3	18.3	~100	Steady

rapidly as the bed-sediment supply goes into suspension. Such a decline is manifest in the slope of the bed-sediment transport curve shown in figure 43B. Streambed deposits continue to supply sediment to bedload and suspension until they are depleted. Field observations indicate that similar bed-transport processes occur at the other water-data stations on the Dahlonega Plateau.

Unmeasured- and bed-sediment transport curves for Big Creek near Alpharetta are shown in figure 43c. Notice that these curves are not as divergent at the lower discharges as those developed for the Chestatee River near Dahlonega. Big Creek is largely an alluvial-channel stream, and it is expected that sufficient bed material is available most of the time to satisfy the stream's transport capacity. Thus, the nature of the unmeasured- and bed-sediment transport curves should be governed more by the stream's ability to transport sediment than by the amount of sediment in supply.

AVERAGE ANNUAL DISCHARGE

The average annual discharge of bed and unmeasured sediments was computed using each trans-



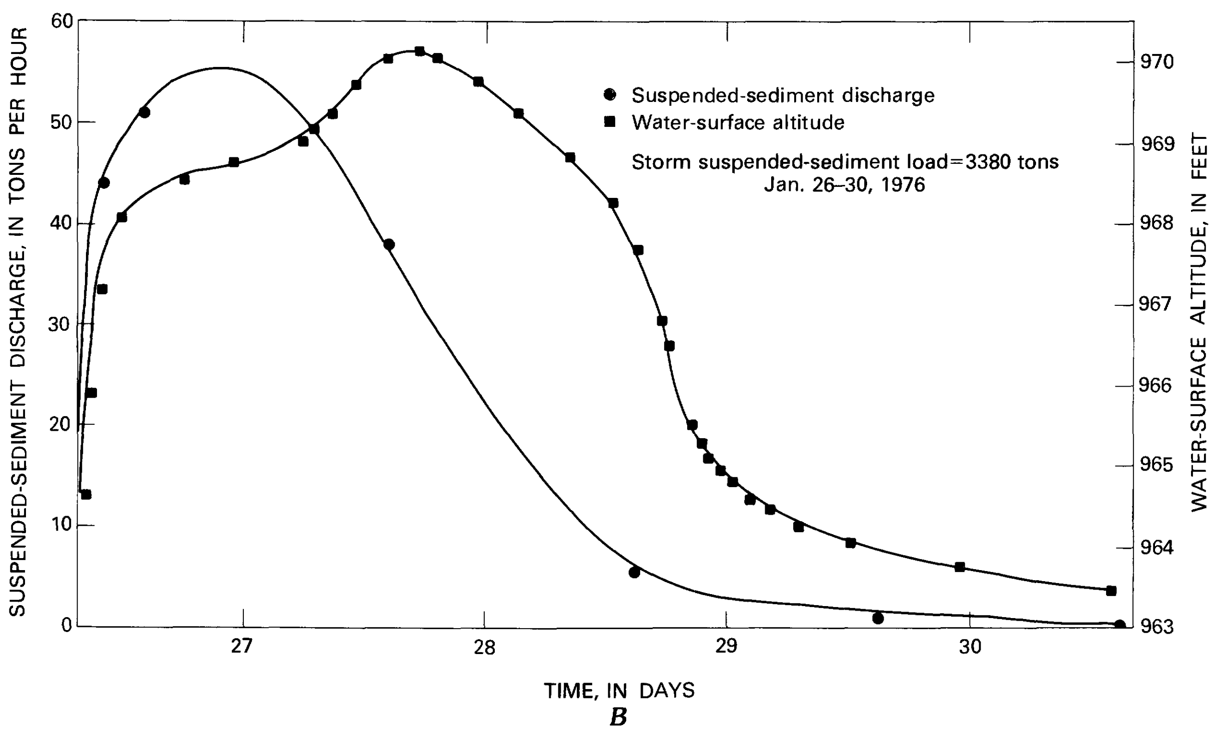
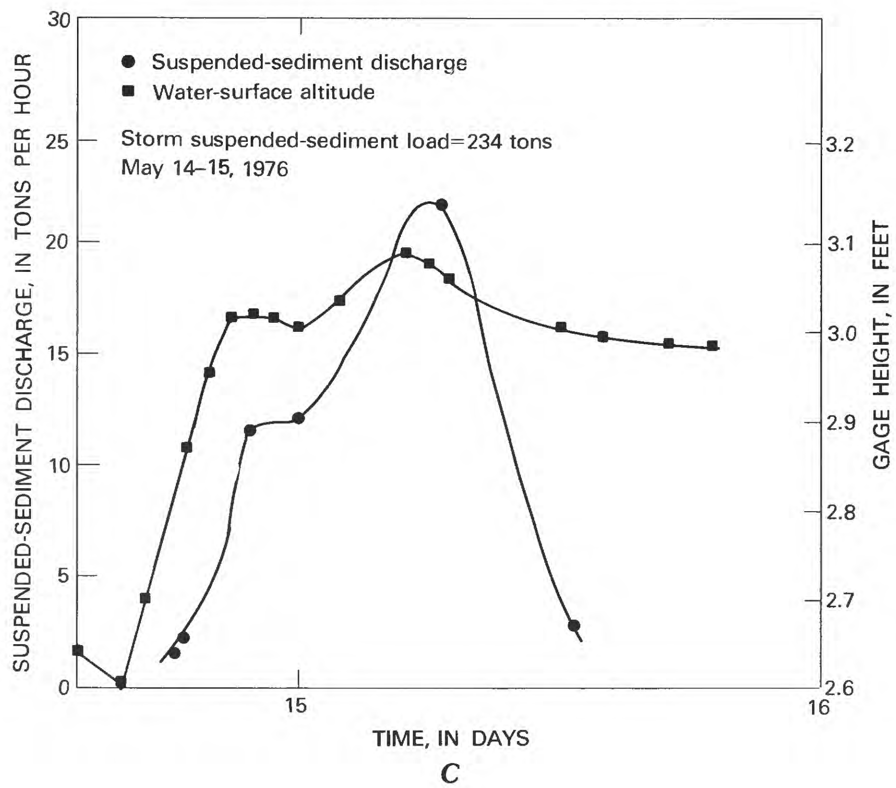


FIGURE 41.—Storm loading of suspended sediment at (*A*) Chestatee River near Dahlonega and (*B*) Big Creek near Alpharetta.



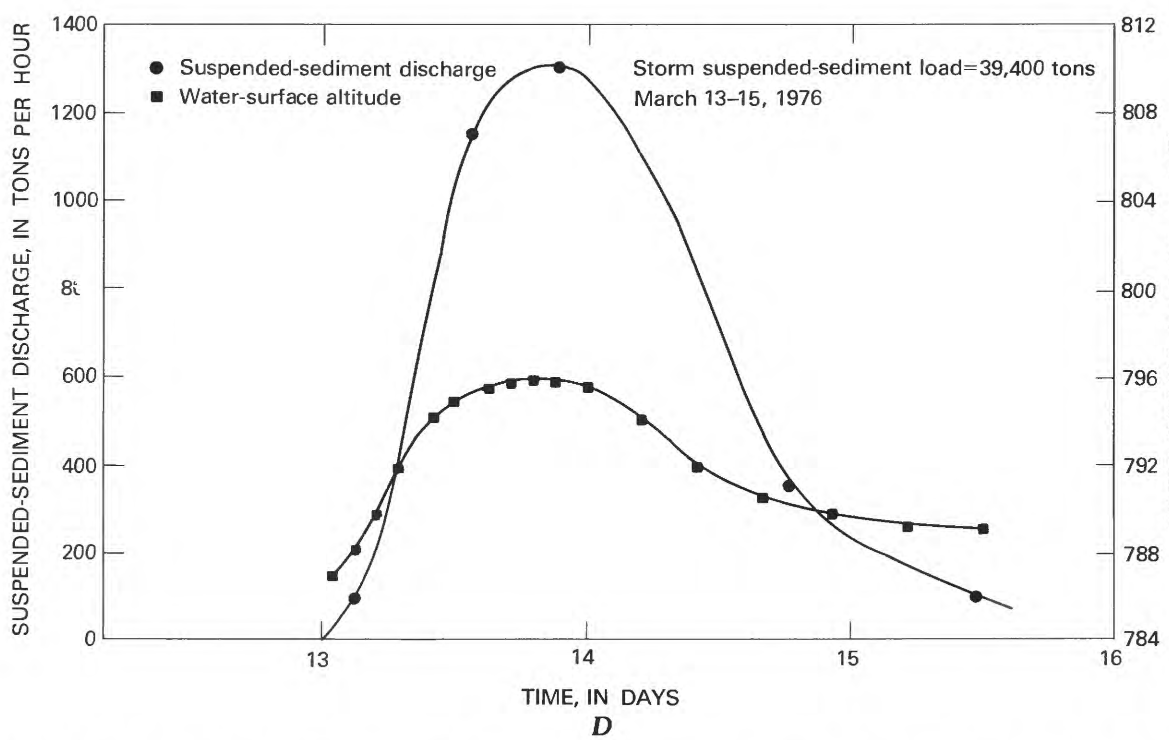


FIGURE 41.—Continued. Storm loading of suspended sediment at (*C*) Snake Creek near Whitesburg and (*D*) Chattahoochee River near Whitesburg.

FIGURE 42.—Typical streambeds and stream channels on the Dahlonega and Atlanta Plateaus—(*A*) Chattahoochee River upstream of Helen.

TABLE 24.—*Summary of regression data relating unmeasured- and bed-sediment discharges to stream discharge*

Station name	Discharge	*a*	*b*
Chattahoochee River near Leaf	Unmeasured	4.42×10^{-7}	2.78
Chestatee River near Dahlonega	Unmeasured	4.29×10^{-3}	1.56
	bed	$.02 \times 10^{-7}$	2.50
Big Creek near Alpharetta	unmeasured	1.25×10^{-4}	1.99
	bed	4.54×10^{-7}	2.49
Chattahoochee River at Atlanta	Bed	1.11×10^{-5}	1.78
Peachtree Creek at Atlanta	Unmeasured	3.14×10^{-2}	1.22
	bed	1.18×10^{-3}	1.34
Chattahoochee River near Whitesburg	Bed	4.89×10^{-3}	1.11

port relation listed in table 24 and the basic discharge computation techniques described previously for suspended sediment. Computed annual discharges are listed in table 25. Average annual total-sediment discharge was computed as the sum of the average annual unmeasured-sediment and suspended-sediment discharges.

DELIVERY RATIOS

The quantity of sediment transported at a stream station depends on the rate of gross erosion in the watershed and on the various factors that affect the routing, deposition, and transport of sediment. Only a part of the material eroded from upland areas is transported to streams and out of the watershed. The remaining material is deposited wherever the entraining characteristics of runoff waters are no longer sufficient to maintain transport. Consequently, the magnitude of sediment discharge is highly variable with respect to location. A measure of this variability is the delivery ratio, which is defined as the ratio of the quantity of sediment delivered to a stream station to the total amount of material in transport in the watershed (gross erosion). This relation is presented below as

FIGURE 42.—Continued. Typical streambeds and stream channels on Dahlonega and Atlanta Plateaus—(*B*) Soque River upstream of Clarkesville. (Continued on p. 68.)

TABLE 25.—*Average annual total-, unmeasured- and bed-sediment discharge*

Station name	Average annual total discharge (tons/yr)	Average annual unmeasured discharge (tons/yr)	Average annual bed discharge (tons/yr)	Ratio of unmeasured to total discharge (percent)	Ratio of bed to total discharge (percent)
Chattahoochee River near Leaf	64,200	21,200	----	33	---
Chestatee River near Dahlonega	73,600	21,300	945	29	1.3
Big Creek near Alpharetta	25,600	1,630	160	6.4	.62
Chattahoochee River at Atlanta	-----	-----	5,630	---	---
Peachtree Creek at Atlanta	71,400	5,890	464	8.2	.62
Chattahoochee River near Whitesburg	-----	-----	9,960	---	---

$$D=\frac{S_t}{E_G}$$

where

D=delivery ratio,

S_t=total average annual sediment discharge at a stream station, and

E_G=average annual gross erosion in the watershed draining to the station.

For this study, total-sediment discharge at a station is the sum of the average annual suspended- and unmeasured-sediment discharges (table 25). Gross erosion in the watershed is considered equivalent to the sheet erosion computed by the Universal Soil Loss Equation. Delivery ratios at four water-data stations can be computed and are listed below.

FIGURE 42.—Continued. Typical streambeds and stream channels on the Dahlonega and Atlanta Plateaus—(*C*) Tributary to the Chattahoochee River downstream of Buford Dam.

Station name	Delivery ratio
Chattahoochee River near Leaf	0.21
Chestatee River near Dahlonega	.15
Big Creek near Alpharetta	.13
Peachtree Creek at Atlanta	.89

The high delivery ratio for the Peachtree Creek station may indicate that a large part of the sediment delivered to that station originated within the channel. With the exception of the high ratio noted above, the delivery ratios computed for this study compare favorably with ratios developed by Roehl (1962) from field investigations of reservoir sedimentation in the southeastern Piedmont. Roehl's ratio data range from 0.037 to 0.594 and were collected from watersheds ranging in area from 0.61 to 166 square miles.

The reader should note that both the erosion and unmeasured-sediment discharge data used to compute the delivery ratios are somewhat subjective and should use the ratios accordingly.

MANAGEMENT IMPLICATIONS OF EROSION AND SEDIMENT DISCHARGE DATA

Information of importance to water resource managers includes the definition of background or natural sediment and erosion yields and changes in these yields caused by land use. Data from watersheds where land cover has been totally unaffected by man were not available from this study. Of the drainages studied, however, those contributing to the Chattahoochee River near Leaf and Snake Creek near Whitesburg were the least affected by man's activities. Sediment-yield data from these watersheds indicate a background rate of sediment yield in the basin in excess of 200 tons per year per square mile. Computed sheet erosion data indicate background erosion yields are about 2,000 tons per year per square mile.

FIGURE 42.—Continued. Typical streambeds and channels on the Dahlonega and Atlanta Plateaus—(*D*) Snake Creek near Whitesburg.

The effect of land use on erosion and sediment yield is most apparent for watersheds on the Dahlonega Plateau. Man's influence, though small, is most pronounced in the drainage of the Soque River near Clarkesville and decreases progressively in the watersheds of the Chestatee and Chattahoochee Rivers (figs. 18–20). Computed erosion and sediment yields follow this trend exactly, being greatest in the Soque drainage and least in the watershed of the Chattahoochee River near Leaf.

On the Dahlonega Plateau, the effect of changes in land use on erosion is best demonstrated by use of the Universal Soil Loss Equation. As discussed previously, computed average annual sheet erosion in the watershed of the Chattahoochee River near Leaf increased from 305,000 tons per year to 536,000 tons per year after a hypothetical timber harvest covering 2 square miles. Thus, a disturbance of the land cover over 1.3 percent of the total drainage area caused a 76-percent increase in computed annual sheet erosion for the entire watershed.

The effect of large-scale urbanization on erosion and sediment yields is not clearly defined by the data presented in this report. On the one hand, computed sheet-erosion yields for those areas draining to Peachtree Creek and its tributaries are the lowest in the basin (table 20). Conversely, the greatest yields of stream sediment are recorded for several of the same watersheds (table 22). One explanation for this apparent dichotomy lies in the nature of urban land cover. Typical use of land in the Atlanta urban area includes large tracts covered with buildings, homes, streets, roads, parking lots, and runways. Even open areas such as yards, parks, and golf courses are generally landscaped and planted with grass. The net effect of such land cover is to reduce both the opportunity and occurrence of sheet erosion. At the same time, however, rates of storm runoff to urban streams have increased in proportion to increases in impervious areas. Such increases frequently overload the channel capacity of Peachtree Creek and its tributaries causing channel ero-

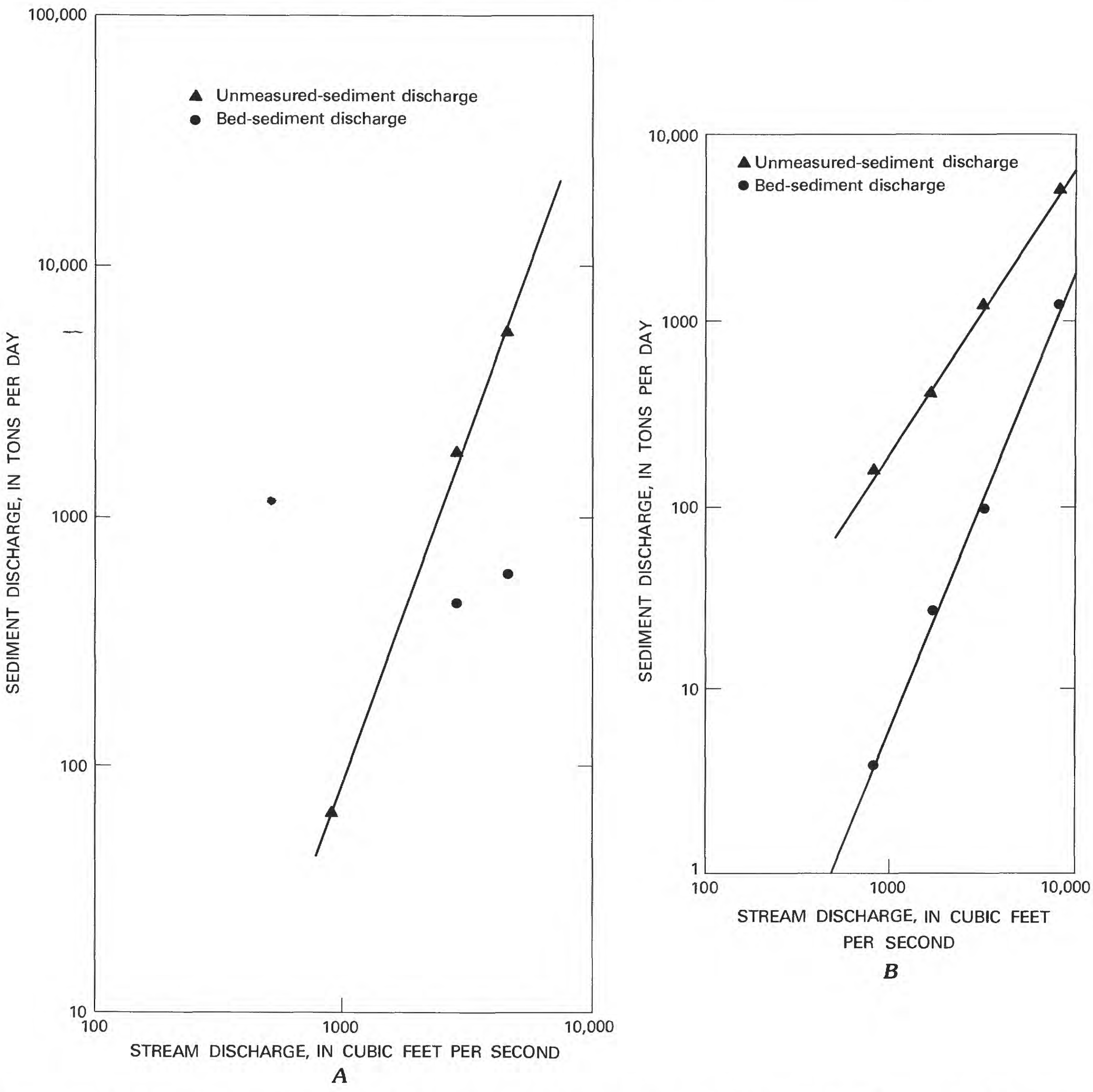


FIGURE 43.—Relation of unmeasured- and bed-sediment discharge to stream discharge at (*A*) Chattahoochee River near Leaf and (*B*) Chestatee River near Dahlonega.

sion which, in turn, is measured as sediment discharge. Thus, sheet erosion in the Peachtree Creek drainage can be relatively low, while, at the same time, the sediment yield from Peachtree Creek and its tributaries, supplemented by channel erosion, is high.

When urbanization in a particular watershed is complete, the dimensions of channels draining the watershed will eventually enlarge to accomodate the greater runoff rates. After this adjustment, erosion of the channels will diminish and sediment yields from the channels will reflect the lower rates

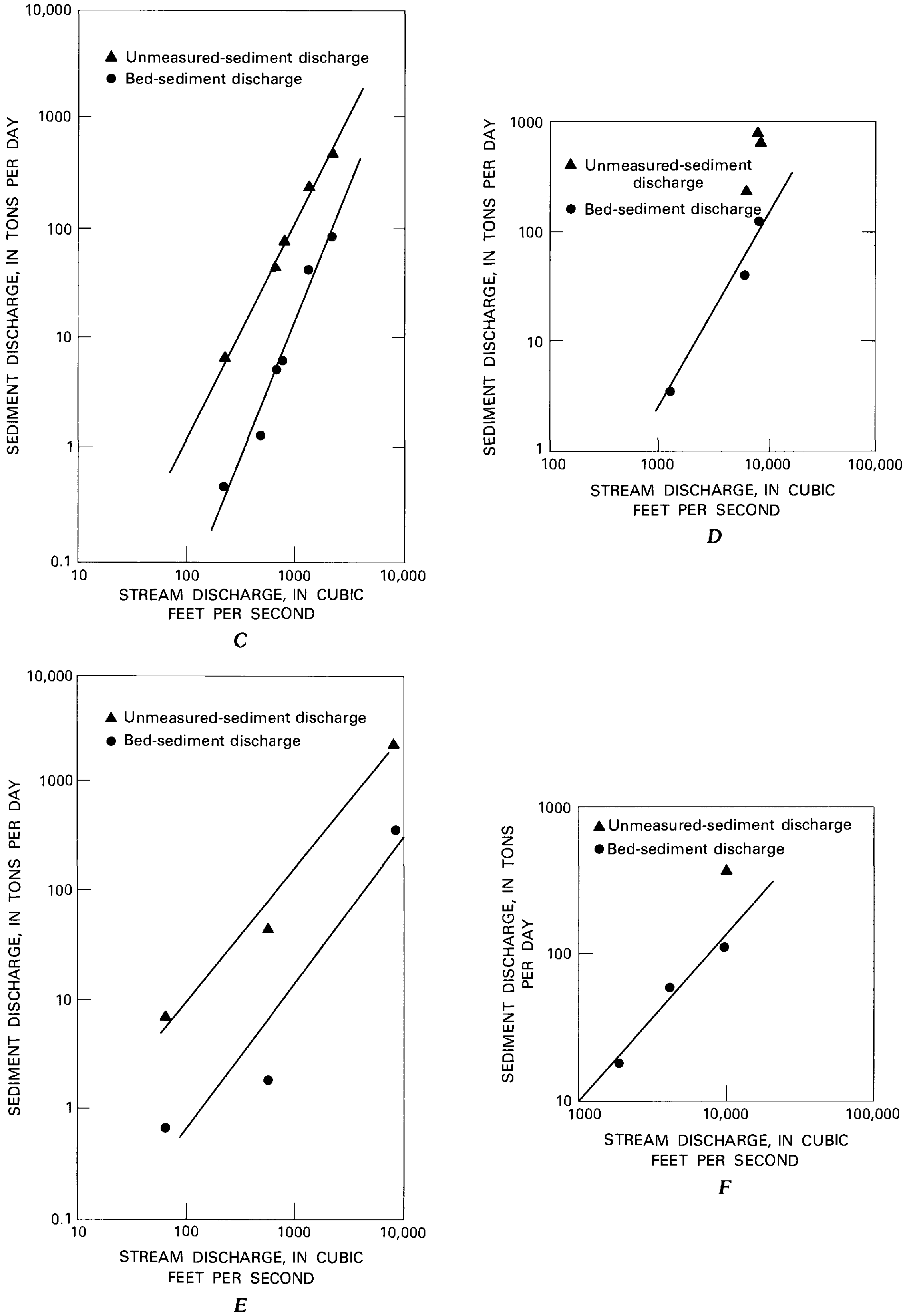


FIGURE 43.—Continued. Relation of unmeasured- and bed-sediment discharge to stream discharge at (*C*) Big Creek near Alpharetta, (*D*) Chattahoochee River at Atlanta, (*E*) Peachtree Creek at Atlanta, and (*F*) Chattahoochee River near Whitesburg.

of sheet erosion caused by urbanization. The areas draining to Proctor Creek and tributary to Nancy Creek are probably indicative of urban watersheds in which urbanization is nearly complete and channel dimensions have adjusted to increased runoff. The annual sediment yields from these watersheds were the lowest recorded of any watershed in this study (table 22).

CONTRIBUTION OF SUSPENDED SEDIMENT TO STREAM QUALITY

The impact of suspended sediment on stream quality is both aesthetic and chemical. For this study, the aesthetic consequences are measured in terms of turbidity; chemical consequences are evaluated by comparing average annual suspended and total discharges of chemical constituents and by noting the relation of suspended-constituent concentrations to corresponding concentrations of suspended sediment.

TURBIDITY

Turbidity is generally defined as a reduction in the transparency of water caused by suspended particulate matter. The particulate matter may consist of sediment particles as well as organic matter or microscopic organisms. In general, an increase in stream turbidity reduces the visual appeal of the water, the aesthetic value of the water course, and decreases the depth to which light can penetrate the water column. The unit of turbidity measurement used in this report is defined by Brown and others (1970) as the Jackson Turbidity Unit (JTU).

Curves of sample turbidity plotted against corresponding concentrations of suspended silt plus clay are shown for selected water-data stations in figure 44. Regression relations based on these curves were computed using the general geometric equation

$$T = aS_{sc}^{b}$$

where

T = turbidity in JTU's,

S_{sc} = suspended silt plus clay concentration in milligrams per liter, and

a and b = regression constants.

A summary of regression data relating suspended silt plus clay concentration to turbidity at most water-data stations is listed in table 26. Correlation coefficients for the 14 stations ranged from 0.80 to 0.99 with coefficients for 12 stations at 0.90 or higher. Note that two regression equations are listed for the station at Big Creek near Alpharetta. The silt plus clay concentration versus turbidity relation is distinctly different at this station depending on the stage direction at the time of sampling (fig. 44*B*). The turbidity - suspended-sediment relation for the Chattahoochee River at Atlanta includes data from samples collected during regulated flow and intervening runoff. The turbidity data plotted along the lower part of the curve are relative to regulated flow and are not as sensitive to silt plus clay concentrations as the higher turbidity values that relate to samples collected during storm runoff. The regressions listed for the Chattahoochee River near Fairburn and near Whitesburg relate only to intervening runoff.

At each water-data station, increases in suspended-sediment concentration resulted in corresponding increases in turbidity. Such increases, in turn, decreased the aesthetic appeal of the water-

TABLE 26.—*Summary of regression data relating turbidity to concentrations of suspended silt plus clay*

Station name	a	b	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	0.783	0.907	0.96	14
Soque River near Clarkesville	.217	1.14	.93	18
Chestatee River near Dahlonega	.686	.915	.95	42
[1] Big Creek near Alpharetta	.029	1.80	.95	10
[2] Big Creek near Alpharetta	.882	.902	.89	11
Chattahoochee River at Atlanta	1.41	.746	.84	40
N. Fork Peachtree Creek near Atlanta	2.50	.714	.90	17
S. Fork Peachtree Creek at Atlanta	.933	.868	.96	17
Peachtree Creek at Atlanta	.825	.906	.99	29
Woodall Creek at Atlanta	1.87	.739	.95	14
Nancy Creek Tributary near Chamblee	2.60	.739	.96	15
Nancy Creek at Atlanta	.990	.849	.95	21
Chattahoochee River near Fairburn	1.34	.830	.93	21
Snake Creek near Whitesburg	1.42	.835	.94	36
Chattahoochee River near Whitesburg	3.19	.699	.80	19

[1] Recession samples.
[2] Rise and peak samples.

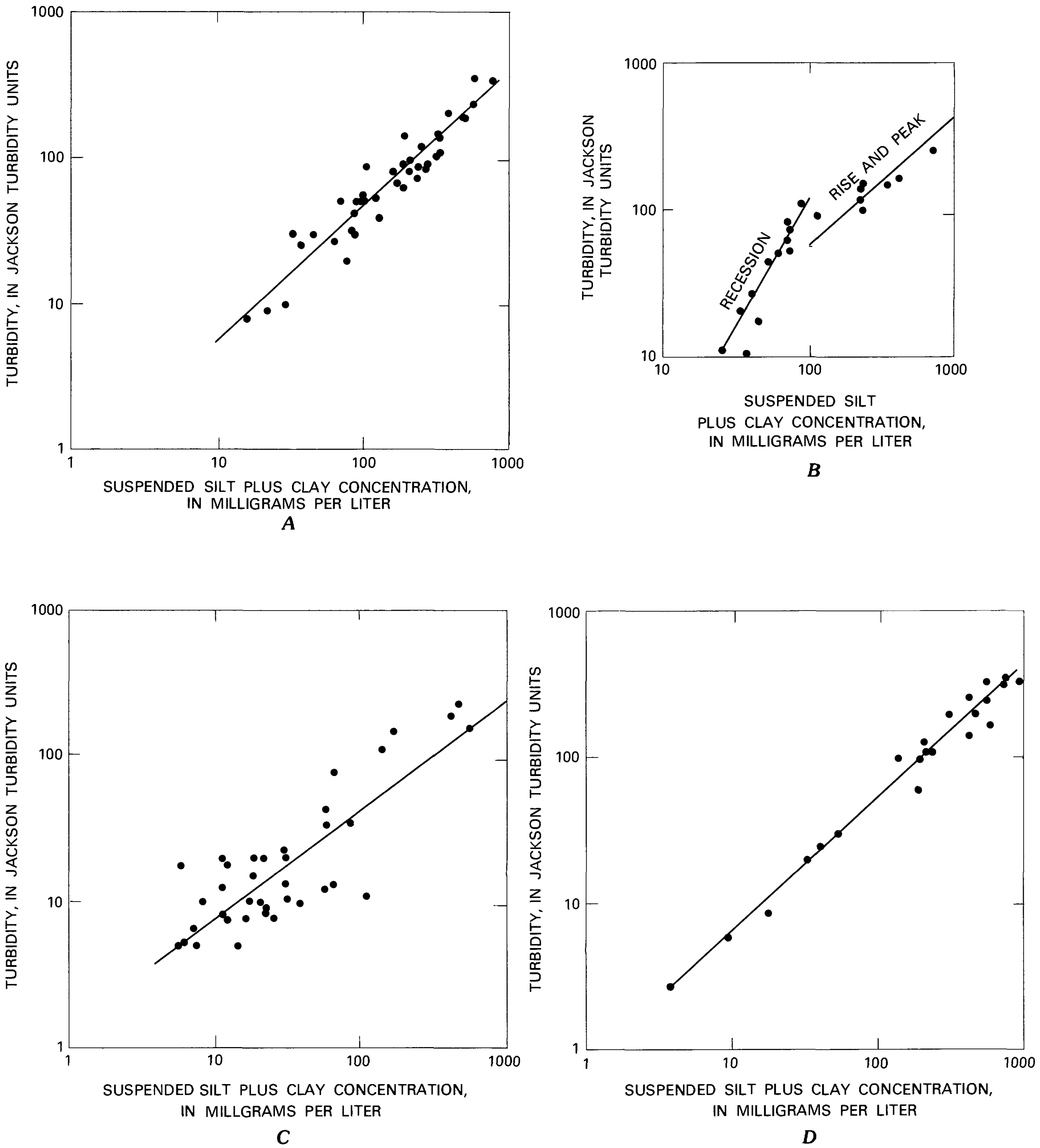


FIGURE 44.—Relation of turbidity to suspended silt plus clay concentration at (*A*) Chestatee River near Dahlonega, (*B*) Big Creek near Alpharetta, (*C*) Chattahoochee River at Atlanta, and (*D*) Peachtree Creek at Atlanta.

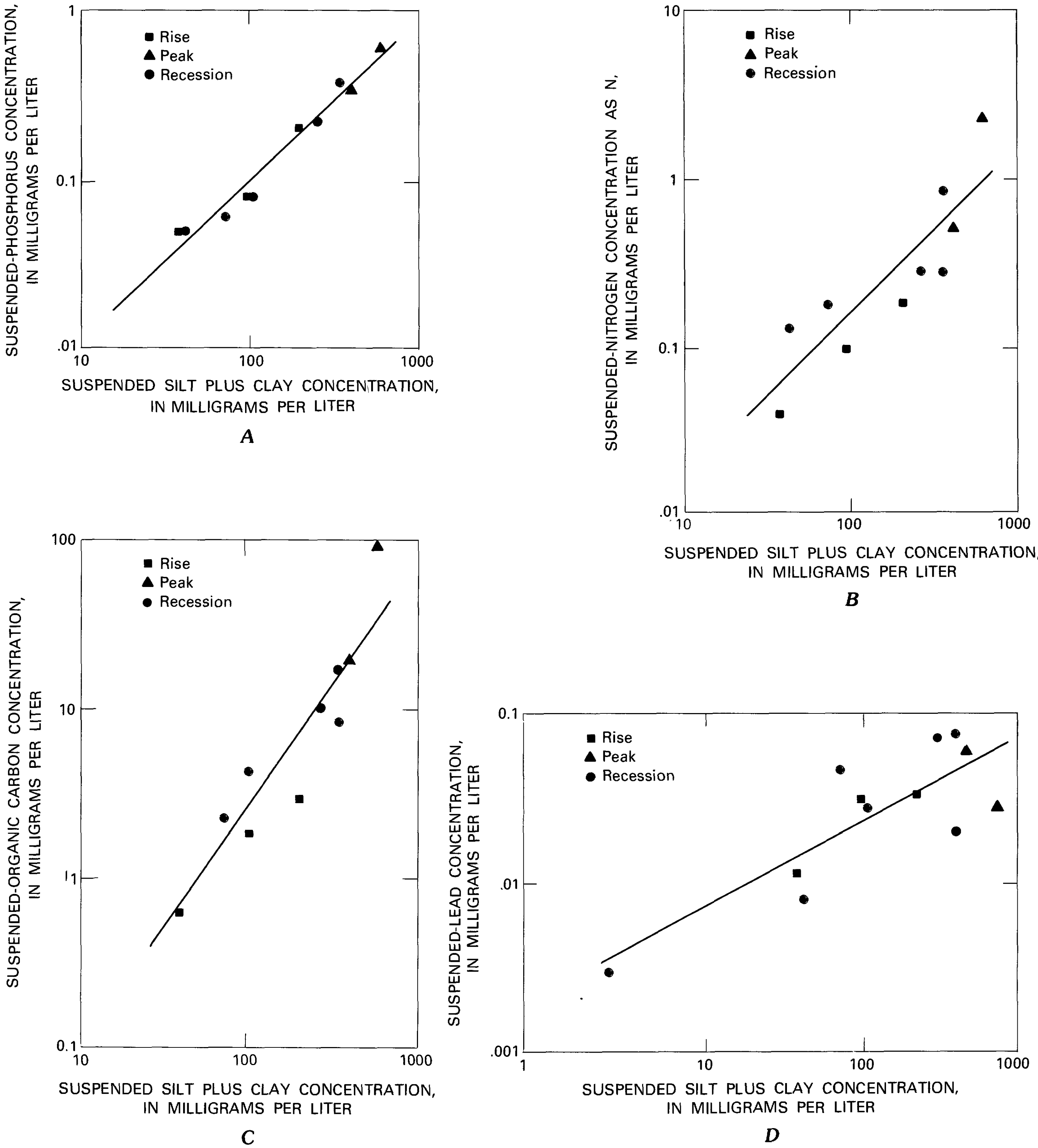


FIGURE 45.—Relation of suspended-constituent concentrations to concentrations of suspended silt plus clay at the Chestatee River near Dahlonega.

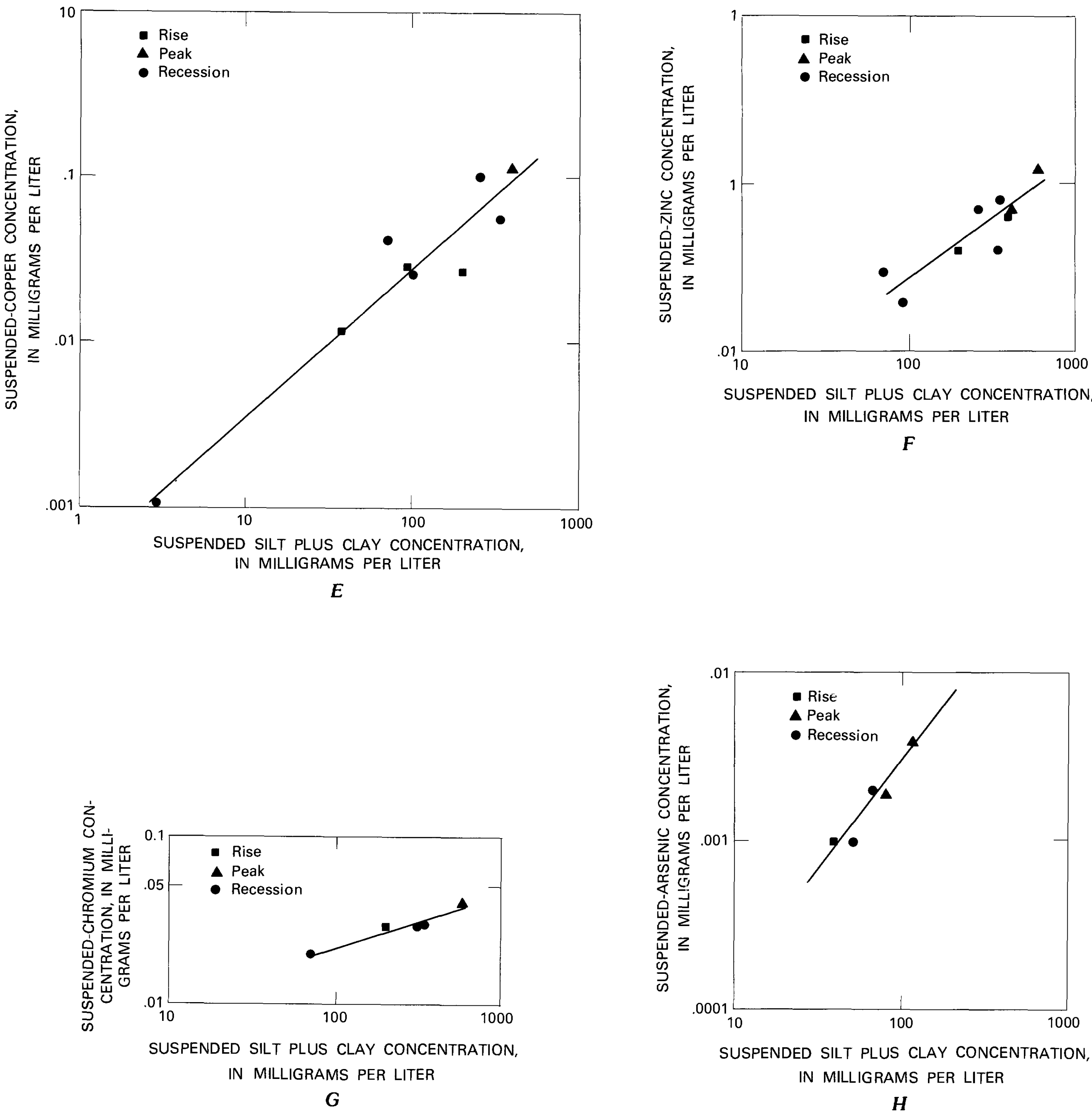


FIGURE 45.—Continued.

course and the depth of light-penetration into the water.

The reader should note that the measurement of turbidity is, by definition, somewhat subjective. Consequently, turbidity values should not be used to quantitatively determine suspended-sediment concentrations.

CHEMICAL QUALITY

The effect of suspended sediment on the chemical quality of a stream is mostly a function of (1) the water-quality constituents of interest, (2) the relation of the concentration of these constituents to the concentrations of suspended sediment, and (3) the constituent loads transported by the stream. The

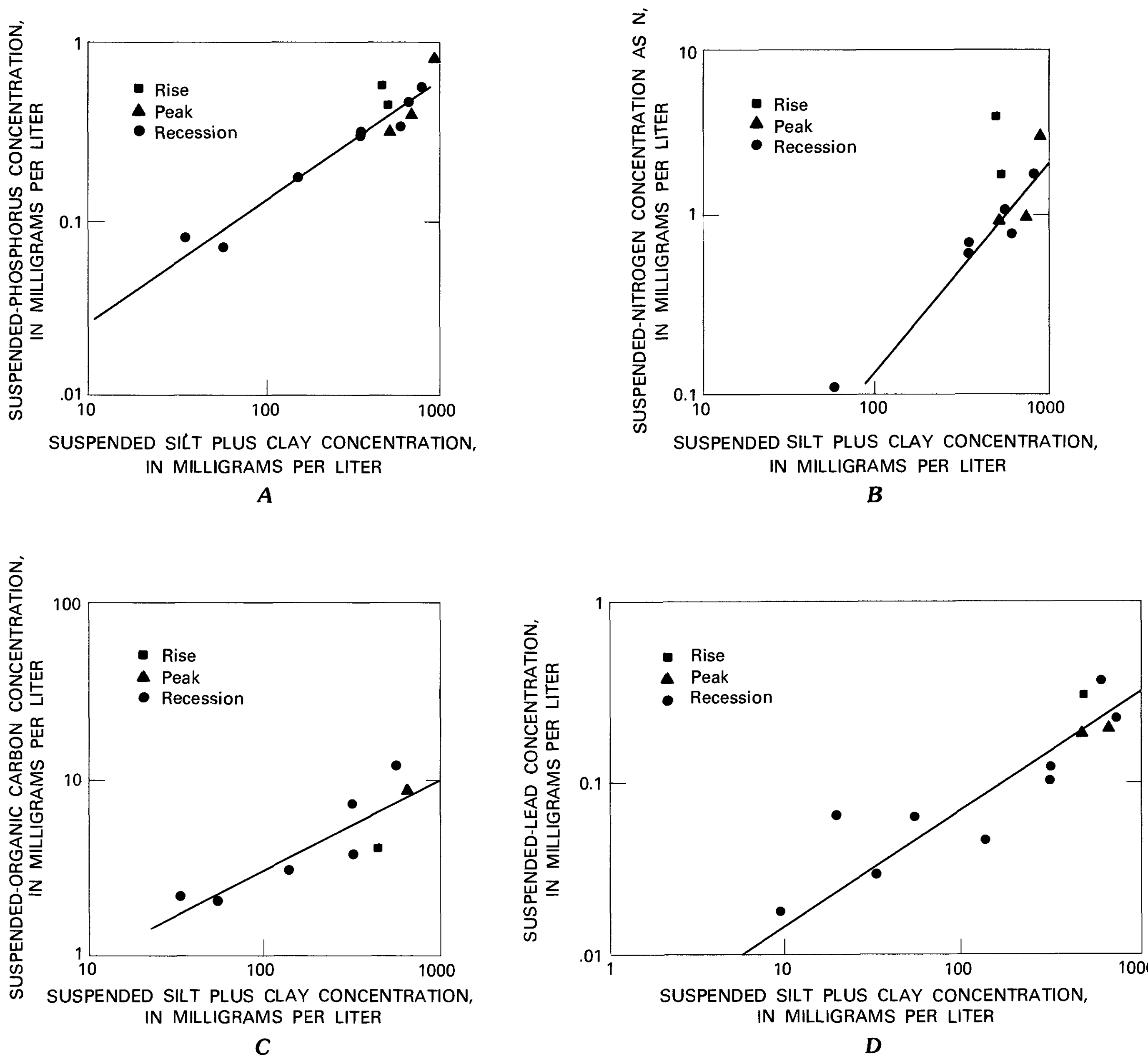


FIGURE 46.—Relation of suspended-constitutent concentrations to concentrations of suspended silt plus clay at Peachtree Creek at Atlanta.

chemical constituents of interest to this study were phosphorus, nitrogen, organic carbon, lead, zinc, copper, chromium, and arsenic. Curves relating the concentrations of these constituents in the suspended phase to the corresponding concentrations of suspended silt plus clay have been established at most water-data stations. Curves for selected stations are shown in figures 45 and 46, and represent, respectively, relations at the Chestatee River near Dahlonega and at Peachtree Creek at Atlanta. Such curves indicate that the various constituent-sediment concentrations are generally related by the geometric function

$$C_s = aS_{sc}^b$$

where

C_s=chemical constituent concentration in the suspended phase in milligrams per liter,

S_{sc}=concentration of suspended silt plus clay in milligrams per liter, and

a and b=regression constants.

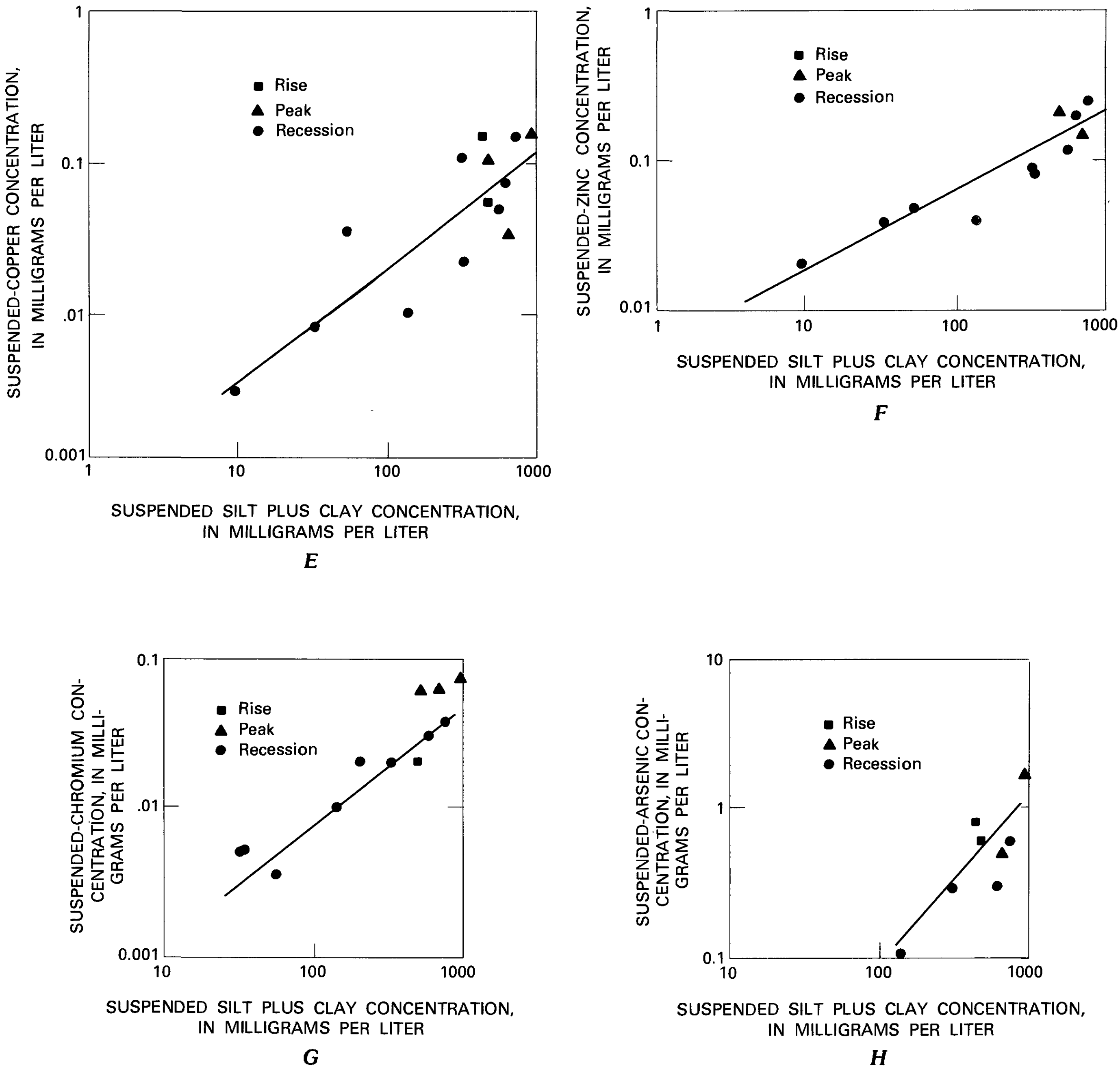


FIGURE 46.—Continued.

A summary of the regression equations relating suspended-constituent concentrations to silt plus clay concentrations at most water-data stations is listed in table 27. Also listed are correlation coefficients and the number of data pairs used in each regression. The omission of regression information for a particular constituent indicates that a functional relation could not be established.

In general, suspended concentrations of the constituents of interest correlate well with concentrations of suspended silt plus clay (table 27). Of the nutrients studied, the degree of correlation was highest for phosphorus and lowest for organic carbon.

Average annual suspended-constituent discharges were computed using the regression data in table 27 and the flow-duration data in table 7. For each water-data station, the flow duration of a suspended-constituent concentration was determined by relating the corresponding concentration of suspended

TABLE 27.—*Summary of regression data relating suspended-constituent concentrations to concentrations of suspended silt plus clay*

Station name	Suspended phosphorus as P				Suspended nitrogen as N			
	a	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	0.00274	0.746	0.97	8	0.0137	0.714	0.98	7
Soque River near Clarkesville	.00248	.834	1.0	9	.000493	1.27	.91	8
Chestatee River near Dahlonega	.00132	.942	.99	11	.00167	.988	.87	10
Big Creek near Alpharetta	.00681	.639	.96	12	.0290	.528	.93	7
Chattahoochee River at Atlanta	.0103	.500	.91	15	.00116	1.06	.87	9
N. Fork Peachtree Creek near Atlanta	.00161	.504	.96	12	.000600	1.21	.66	9
S. Fork Peachtree Creek at Atlanta	.00330	.781	.99	12	.00203	.983	.90	11
Peachtree Creek at Atlanta	.00703	.646	.98	12	.000454	1.23	.93	12
Woodall Creek at Atlanta	.0665	.372	.91	7	.0163	.641	.96	6
Nancy Creek tributary near Chamblee	.0185	.391	.90	7	-------	----	---	--
Nancy Creek at Atlanta	.00116	.909	.99	13	.0000691	1.49	.89	11
Chattahoochee River near Fairburn	.0413	.379	.61	16	-------	----	---	--
Snake Creek near Whitesburg	.000911	.920	.99	7	.00530	.827	.96	6
Chattahoochee River near Whitesburg	.0198	.484	.85	11	-------	----	---	--

Station name	Suspended organic carbon				Suspended lead			
	a	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	0.0359	0.944	0.92	9	-------	----	---	--
Soque River near Clarkesville	.818	.441	.99	5	-------	----	---	--
Chestatee River near Dahlonega	.00255	1.51	.93	10	0.00200	0.539	0.82	12
Big Creek near Alpharetta	.0157	1.09	.69	10	.000964	.639	.82	9
Chattahoochee River at Atlanta	-------	----	---	--	.00205	.550	.67	11
N. Fork Peachtree Creek near Atlanta	-------	----	---	--	.00217	.638	.94	7
S. Fork Peachtree Creek at Atlanta	-------	----	---	--	.00586	.591	.94	9
Peachtree Creek at Atlanta	-------	----	---	--	.00349	.655	.93	12
Woodall Creek at Atlanta	.155	.705	.93	9	.00134	.463	.95	7
Nancy Creek tributary near Chamblee	.00247	1.24	.94	7	.000346	.890	.87	4
Nancy Creek at Atlanta	.201	.585	.83	9	.000836	.789	.89	8
Chattahoochee River near Fairburn	.00377	1.37	.82	12	.00208	.625	.77	9
Snake Creek near Whitesburg	.0446	.755	.90	5	-------	----	---	--
Chattahoochee River near Whitesburg	.00324	1.34	.95	13	.00260	.610	.90	7

silt plus clay to a stream discharge (tables 27 to 21 to 7). The average annual discharge of the chemical constituent was then computed using the technique described previously for the computation of suspended-sediment discharges. Computed suspended-constituent discharges are listed by water-data station in table 30. Computed suspended-constituent discharges contributed by regulated flow to the Chattahoochee River at Atlanta are considered transported, without loss, to the stations near Fairburn and near Whitesburg.

Average annual dissolved constituent discharges were computed on the basis of the relation of the constituent concentration to stream discharge. At those stations where the dissolved constituent concentrations did not significantly change with stream discharge, the average annual constituent discharge was computed using the relation

$$Y_d = 0.0027 \times Q_a \times C_{dm} \times 365$$

where

Y_d = the average annual dissolved-constituent discharge in tons per year,

Q_a = the mean daily stream discharge in cubic feet per second, and

C_{dm} = the mean dissolved-constituent concentration in milligrams per liter for all samples at a station.

TABLE 27.—*Summary of regression data relating suspended-constituent concentrations to concentrations of suspended silt plus clay*—Continued

Station name	Suspended zinc				Suspended copper			
	a	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	0.00387	0.477	0.91	8	-------	----	---	--
Soque River near Clarkesville	.00285	.525	.93	6	0.000306	0.802	0.96	7
Chestatee River near Dahlonega	.00112	.701	.87	8	.000447	.900	.96	9
Big Creek near Alpharetta	-------	----	---	--	-------	----	---	--
Chattahoochee River at Atlanta	.00389	.443	.95	8	.000253	.872	.92	12
N. Fork Peachtree Creek near Atlanta	.00224	.608	.80	8	-------	----	---	--
S. Fork Peachtree Creek at Atlanta	.00115	.767	.97	8	.00639	.343	.85	8
Peachtree Creek at Atlanta	.00546	.544	.91	13	.000594	.761	.82	15
Woodall Creek at Atlanta	.0461	.290	.88	7	.000953	.699	.95	7
Nancy Creek tributary near Chamblee	.00319	.545	.87	4	-------	----	---	--
Nancy Creek at Atlanta	.000122	1.07	.92	10	.000103	.911	.97	10
Chattahoochee River near Fairburn	.00519	.488	.70	10	.00665	.300	.66	10
Snake Creek near Whitesburg	-------	----	---	--	.000313	.366	.91	5
Chattahoochee River near Whitesburg	.00140	.728	.90	10	.00106	.622	.81	10

Station name	Suspended chromium				Suspended arsenic			
	a	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	0.00330	0.388	0.88	5	-------	----	---	--
Soque River near Clarkesville	2.9×10^{-6}	1.57	.97	6	-------	----	---	--
Chestatee River near Dahlonega	.00579	.295	.96	5	7.24×10^{-7}	1.34	0.97	5
Big Creek near Alpharetta	-------	----	---	--	6.85×10^{-7}	1.39	.85	4
Chattahoochee River at Atlanta	.000654	.705	.88	5	6.58×10^{-5}	.654	.99	7
N. Fork Peachtree Creek near Atlanta	-------	----	---	--	3.02×10^{-5}	.775	.92	5
S. Fork Peachtree Creek at Atlanta	.00242	.403	.93	8	2.10×10^{-6}	1.22	.94	5
Peachtree Creek at Atlanta	.000198	.796	.85	11	4.81×10^{-6}	1.12	.86	10
Woodall Creek at Atlanta	.000475	.643	.93	6	0.000145	.666	.93	6
Nancy Creek tributary near Chamblee	.00137	.352	.78	5	-------	----	---	--
Nancy Creek at Atlanta	3.57×10^{-6}	1.37	.96	4	5.40×10^{-8}	1.10	.98	10
Chattahoochee River near Fairburn	-------	----	---	--	4.48×10^{-5}	.747	.89	10
Snake Creek near Whitesburg	-------	----	---	--	3.53×10^{-5}	.728	.98	4
Chattahoochee River near Whitesburg	-------	----	---	--	6.19×10^{-5}	.679	.84	11

The mean concentrations used for these computations are listed in table 28 along with the average daily stream discharge. Mean concentrations are listed only for those parameters for which average annual suspended-constituent discharges were calculated (table 27).

At those stations where dissolved-constituent concentrations changed significantly with stream discharge, the concentration-discharge relation was best described by the geometric function

$$C_d = aQ_i^b$$

where

C_d = the instantaneous dissolved-constituent concentration in milligrams per liter,

Q_i = the instantaneous stream discharge in cubic feet per second, and

a and b = regression constants.

A summary of regression equations relating dissolved-constituent concentrations to stream discharge is listed in table 29. Of particular interest are the positive relations between dissolved-nutrient concentrations and stream discharge noted at water-data stations on the Dahlonega Plateau and at Snake Creek near Whitesburg. Such relations indicate that dissolved nutrient concentrations increase with increases in stream discharge and that substantial

TABLE 28.—*Mean concentrations of dissolved constituents used to compute average annual dissolved-constituent discharges*
[*a*, regression relation (see table 29)]

Station name	Mean daily discharge (ft³/s)	Dissolved phosphorus as P: Mean concentration (mg/L)	Dissolved phosphorus as P: Number of samples	Dissolved nitrogen as N: Mean concentration (mg/L)	Dissolved nitrogen as N: Number of samples
Chattahoochee River near Leaf	402	0.0044	9	*a*	--
Soque River near Clarkesville	219	.019	10	*a*	--
Chestatee River near Dahlonega	370	.0086	21	0.45	19
Big Creek near Alpharetta	119	.0090	21	.97	21
Chattahoochee River at Atlanta	2890	.011	24	.54	21
N. Fork Peachtree Creek near Atlanta	50.1	.023	12	1.1	13
S. Fork Peachtree Creek at Atlanta	52.6	*a*	--	.94	13
Peachtree Creek at Atlanta	137	.025	23	1.0	23
Woodall Creek at Atlanta	19.1	.83	10	2.3	10
Nancy Creek tributary near Chamblee	4.74	.030	7	---	--
Nancy Creek at Atlanta	66.7	.022	14	.74	14
Chattahoochee River near Fairburn	3930	*a*	--	---	--
Snake Creek near Whitesburg	58.2	.0053	19	*a*	--
Chattahoochee River near Whitesburg	4419	*a*	--	---	--

Station name	Dissolved organic carbon: Mean concentration (mg/L)	Dissolved organic carbon: Number of samples	Dissolved lead: Mean concentration (mg/L)	Dissolved lead: Number of samples
Chattahoochee River near Leaf	1.9	9	-----	--
Soque River near Clarkesville	3.5	10	-----	--
Chestatee River near Dahlonega	*a*	--	0.0023	9
Big Creek near Alpharetta	6.4	12	trace	9
Chattahoochee River at Atlanta	-----	--	.0034	12
N. Fork Peachtree Creek near Atlanta	-----	--	.0090	9
S. Fork Peachtree Creek at Atlanta	-----	--	.0057	9
Peachtree Creek at Atlanta	-----	--	.011	18
Woodall Creek at Atlanta	10	10	.016	9
Nancy Creek tributary near Chamblee	-----	--	.014	5
Nancy Creek at Atlanta	6.2	14	.014	11
Chattahoochee River near Fairburn	3.9	24	.0095	13
Snake Creek near Whitesburg	*a*	--	-----	--
Chattahoochee River near Whitesburg	*a*	--	.0072	11

quantities of dissolved nutrients are contributed to basin streams by runoff from forested areas. The average annual discharge of dissolved constituents whose concentrations varied with stream discharge was computed using the procedure described previously for computing the annual discharge of suspended sediment.

The sum of the suspended- and dissolved-constituent discharges is considered the total average annual constituent discharge at the station. The total and suspended discharges computed for the constituents of interest at each station are listed in table 30 along with the percentage of total constituent discharge contributed by suspended sediment. Of the nutrients studied, the contribution of suspended phosphorus at all stations ranged from about 31 to 95 percent of total annual phosphorus discharge and averaged about 76 percent. Corresponding ranges for suspended nitrogen and organic carbon were 7 to 53 percent and 18 to 71 percent, respectively. The average contribution of suspended nitrogen and organic carbon to total annual constituent discharge at all stations was 29 and 43 percent, respectively. Trace metal discharges contributed by suspended sediment constitute a large percentage of the total annual metal discharge at every station. Suspended lead, for example, contributed about 38 to 100 percent of total lead discharge and averaged 84 percent for all stations.

MANAGEMENT IMPLICATIONS OF CHEMICAL QUALITY DATA

With respect to the impact of sediment on stream quality, water resource managers are concerned

TABLE 28.—*Mean concentrations of dissolved constituents used to compute average annual dissolved-constituent discharges* —Continued

Station name	Dissolved zinc		Dissolved copper	
	Mean concentration (mg/L)	Number of samples	Mean concentration (mg/L)	Number of samples
Chattahoochee River near Leaf	trace	9	-----	--
Soque River near Clarkesville	0.0050	8	0.0023	8
Chestatee River near Dahlonega	.0054	11	.0032	11
Big Creek near Alpharetta	-----	--	-----	--
Chattahoochee River at Atlanta	trace	12	.0021	12
N. Fork Peachtree Creek near Atlanta	.0089	9	-----	--
S. Fork Peachtree Creek at Atlanta	.014	9	*a*	--
Peachtree Creek at Atlanta	.021	18	.0039	14
Woodall Creek at Atlanta	.037	9	.0050	9
Nancy Creek tributary near Chamblee	.0060	5	-----	--
Nancy Creek at Atlanta	.0073	11	.0034	11
Chattahoochee River near Fairburn	.012	13	.0041	13
Snake Creek near Whitesburg	-----	--	.0030	10
Chattahoochee River near Whitesburg	.0075	12	.0035	12

Station name	Dissolved chromium		Dissolved arsenic	
	Mean concentration (mg/L)	Number of samples	Mean concentration (mg/L)	Number of samples
Chattahoochee River near Leaf	trace	9	-----	--
Soque River near Clarkesville	0.004	8	-----	--
Chestatee River near Dahlonega	trace	11	trace	11
Big Creek near Alpharetta	-----	--	trace	9
Chattahoochee River at Atlanta	0.0002	11	trace	12
N. Fork Peachtree Creek near Atlanta	-----	--	trace	9
S. Fork Peachtree Creek at Atlanta	trace	9	trace	9
Peachtree Creek at Atlanta	.00083	18	0.00061	18
Woodall Creek at Atlanta	.0015	8	.040	9
Nancy Creek tributary near Chamblee	trace	5	-----	--
Nancy Creek at Atlanta	trace	11	.00054	11
Chattahoochee River near Fairburn	-----	--	.00031	13
Snake Creek near Whitesburg	-----	--	none	10
Chattahoochee River near Whitesburg	-----	--	.00025	12

with the response of stream quality to increasing concentrations of sediment. The relative contribution of sediment to nonpoint pollution and the effect of land use on suspended-constituent discharges are also cause for concern.

The effects of sediment concentration on the chemical quality of basin streams has been demonstrated (figs. 45 and 46, table 27). At every station, the suspended concentration of nutrients and trace metals increased with increasing concentrations of suspended silt plus clay. Similar relations between turbidity and suspended sediment (fig. 44, table 26) indicate a progressive decrease in the aesthetic and light-transmitting quality of streams with increasing concentrations of suspended sediment.

Sediment is commonly considered a nonpoint pollutant. As such, computed suspended-constituent discharges indicate the minimum nonpoint contribution to stream quality at stream stations receiving loads from both point and non-point sources. Five large municipal wastewater-treatment facilities discharge treated effluents to the Chattahoochee River between the stations at Atlanta and near Fairburn. Comparison of suspended and total nutrient discharges at the Fairburn station (table 28) indicates that at least 32 percent of the phosphorus transported in the Chattahoochee River downstream of the wastewater-treatment facilities is non-point in origin.

The effect of land use on suspended-constituent discharges can be determined by comparing suspended-constituent yields from watersheds with different land-use characteristics. Table 30 lists the yields of suspended constituents from watersheds

TABLE 30.—*Annual yields of suspended constituents from representative land use watersheds*

	Suspended-constituent yield, in tons/yr/mi^2							
	Phosphorus	Nitrogen	Organic carbon	Lead	Zinc	Copper	Chromium	Arsenic
Forest	0.15	0.36	7.4	0.033	0.048	0.034	0.027	0.0011
Urban	.33	.71	8.1	.16	.13	.050	.023	.0038
Rural	.19	.43	6.9	.028	----	----	----	.0028

TABLE 29.—*Summary of regression data relating dissolved-constituent concentrations to stream discharge*

Station name	Dissolved phosphorous as P				Dissolved nitrogen as N			
	a	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	--------	----	---	--	0.00428	0.551	0.92	15
Soque River near Clarkesville	--------	----	---	--	.0336	.385	.83	10
Chestatee River near Dahlonega	--------	----	---	--	--------	----	---	--
S. Fork Peachtree Creek at Atlanta	0.00350	0.361	0.92	9	--------	----	---	--
Peachtree Creek at Atlanta	--------	----	---	--	--------	----	---	--
Nancy Creek tributary near Chamblee	--------	----	---	--	--------	----	---	--
Chattahoochee River near Fairburn	253	−0.923	.89	20	--------	----	---	--
Snake Creek near Whitesburg	--------	----	---	--	.0458	.427	.74	16
Chattahoochee River near Whitesburg	389	−0.972	.91	23	--------	----	---	--

Station name	Dissolved organic carbon				Dissolved copper			
	a	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples
Chattahoochee River near Leaf	--------	----	---	--	--------	----	---	--
Soque River near Clarkesville	--------	----	---	--	--------	----	---	--
Chestatee River near Dahlonega	0.192	0.333	0.94	9	--------	----	---	--
S. Fork Peachtree Creek at Atlanta	--------	----	---	--	0.0368	−0.466	0.76	8
Peachtree Creek at Atlanta	--------	----	---	--	--------	----	---	--
Nancy Creek tributary near Chamblee	--------	----	---	--	--------	----	---	--
Chattahoochee River near Fairburn	--------	----	---	--	--------	----	---	--
Snake Creek near Whitesburg	.0853	.704	.77	8	--------	----	---	--
Chattahoochee River near Whitesburg	.140	.410	.74	19	--------	----	---	--

where land use is predominantly forest, urban, or rural. Yield data were computed as the sum of average annual suspended-constituent discharges from representative watersheds divided by the sum of the watershed drainage areas. Representative forested watersheds were selected as areas draining to the Chattahoochee River near Leaf, the Chestatee River near Dahlonega, the Soque River near Clarkesville, and Snake Creek near Whitesburg. Corresponding urban watersheds included the areas draining to Peachtree Creek at Atlanta, North Fork of Peachtree Creek near Atlanta, South Fork of Peachtree Creek at Atlanta, Woodall Creek at Atlanta, tributary to Nancy Creek near Chamblee, and Nancy Creek at Atlanta. The area draining to Big Creek near Alpharetta was considered most representative of a rural watershed. Note that annual suspended-constituent discharges were not available for every constituent of interest at every watershed listed above (table 31). Thus average yield data were computed, for the most part, with different numbers of watersheds.

The impact of urban land use on average annual suspended-constituent yields is clearly indicated. The yields of suspended phosphorus and nitrogen from urban watersheds, for example, are greater by a factor of two than corresponding yields from forested watersheds. Similarly, the average yields of suspended lead and zinc from urban areas exceed corresponding yields from forested areas by an order of magnitude. These differences in yield between urban and forested areas indicate that sediments in urban watersheds contact nutrients and most trace metals with greater frequency than sediments found in mostly forested watersheds. These data further indicate that sediments act as sinks for nutrients and some trace metals, thus reducing the dissolved concentrations of these constituents in urban streams.

Suspended-constituent yields from the designated rural watershed were slightly greater or about equal to corresponding yields from the forested watersheds.

SUMMARY

Land-use, soils and other environmental data were used in conjunction with the Universal Soil Loss Equation to compute sheet erosion in nine large watersheds of the Upper Chattahoochee River basin.

TABLE 31.—*Summary of average annual suspended- and total-constituent discharges*

Station name	Phosphorus as P			Nitrogen as N		
	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)
Chattahoochee River near Leaf	18	16	88.9	130	69	53.1
Soque River near Clarkesville	25	21	84.0	100	32	32.0
Chestatee River near Dahlonega	27	24	88.8	200	39	19.5
Big Creek near Alpharetta	15	14	93.3	140	31	22.1
Chattahoochee River at Atlanta	180	56	31.1	1,700	120	7.1
[1] Chattahoochee River at Atlanta	---------	96	53.3	---------	56	3.3
N. Fork Peachtree Creek near Atlanta	11	8.6	78.2	75	19	25.3
S. Fork Peachtree Creek at Atlanta	11	10	90.9	71	22	30.9
Peachtree Creek at Atlanta	32	29	90.6	200	62	31
Woodall Creek at Atlanta	16	5.3	33.1	46	3.7	8.0
Nancy Creek tributary near Chamblee	.44	.30	68.2	---------	---------	----
Nancy Creek at Atlanta	11	10	90.9	77	28	36.4
Chattahoochee River near Fairburn	1,300	410	31.5	---------	---------	----
[2] Chattahoochee River near Fairburn	---------	96	7.4	---------	---------	----
Snake Creek near Whitesburg	6.0	5.7	95.0	41	19	46.3
Chattahoochee River near Whitesburg	1.300	410	31.5	---------	---------	----
[2] Chattahoochee River near Whitesburg	---------	96	7.4	---------	---------	----

Station name	Organic carbon			Chromium		
	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)
Chattahoochee River near Leaf	960	510	53.1	4.6	4.6	100
Soque River near Clarkesville	1,700	1,200	70.6	.74	.65	88
Chestatee River near Dahlonega	2,000	1,400	70.0	5.6	5.6	100
Big Creek near Alpharetta	1,300	500	38.5	---------	---------	----
Chattahoochee River at Atlanta	---------	---------	----	21	10	47.6
[1] Chattahoochee River at Atlanta	---------	---------	----	---------	11	52.4
N. Fork Peachtree Creek near Atlanta	---------	---------	----	---------	---------	----
S. Fork Peachtree Creek at Atlanta	---------	---------	----	.9	.9	100
Peachtree Creek at Atlanta	---------	---------	----	2.0	1.9	95
Woodall Creek at Atlanta	250	46	18.4	.14	.11	78.6
Nancy Creek tributary near Chamblee	38	1.9	4.8	---------	---------	----
Nancy Creek at Atlanta	670	260	38.8	.64	.64	100
Chattahoochee River near Fairburn	28,000	5,800	20.7	---------	---------	----
[2] Chattahoochee River near Fairburn	---------	2,500	8.9	---------	---------	----
Snake Creek near Whitesburg	290	110	37.9	---------	---------	----
Chattahoochee River near Whitesburg	36,000	8,000	22.2	---------	---------	----
[2] Chattahoochee River near Whitesburg	---------	2,500	6.9	---------	---------	----

See footnotes at end of table.

Average annual erosion yields ranged from about 900 to 6,000 tons per square mile per year. Erosion yields were large in those watersheds with relatively high percentages of agricultural and transitional land uses and were lowest in predominantly urban watersheds. The Universal Soil Loss Equation was also used to determine the sensitivity of annual sheet erosion to timber harvesting. Computed post-harvest erosion yields were several orders of magnitude greater than pre-harvest yields in the same areas.

Average yields of suspended sediment from the same nine watersheds ranged from about 300 to 800 tons per square mile per year. Yields of sediment were greatest from predominantly urban watersheds and least from mostly forested watersheds. A large part of the sediment discharged from urban streams was considered to be derived from channel erosion. Average annual unmeasured-sediment discharge computed at four stations ranged from about 6 to 30 percent of the total annual sediment discharge.

The contribution of suspended sediment to stream quality was evaluated by comparing annual suspended and total constituent discharges at 14 stations. In general, 60 percent or more of the annual discharge of phosphorus and trace metals was contributed by suspended sediment. Suspended discharges of nitrogen and organic carbon ranged from about 10 to 70 percent of total, respectively. Yields of nutrients and trace metals in suspension were greater from urban watersheds than from forested drainages.

TABLE 31.—*Summary of average annual suspended- and total-constituent discharges*—Continued

Station name	Zinc			Copper		
	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)
Chattahoochee River near Leaf	7.5	7.5	100	---------	---------	----
Soque River near Clarkesville	7.0	5.9	84.3	2.7	2.2	81.5
Chestatee River near Dahlonega	7.8	5.8	74.4	7.6	6.4	84.2
Big Creek near Alpharetta	---------	---------	----	---------	---------	----
Chattahoochee River at Atlanta	47	16	34.0	22	9.3	42.3
[1] Chattahoochee River at Atlanta	---------	31	66.0	---------	7.0	31.8
N. Fork Peachtree Creek near Atlanta	2.5	2.1	84.0	---------	---------	----
S. Fork Peachtree Creek at Atlanta	4.2	3.4	81.0	2.0	1.7	85.0
Peachtree Creek at Atlanta	16	13	81.3	5.1	4.6	90.2
Woodall Creek at Atlanta	3.4	2.7	79.4	.36	.27	75.0
Nancy Creek tributary near Chamblee	.12	.096	80.0	---------	---------	----
Nancy Creek at Atlanta	3.6	3.1	86.1	1.1	.94	85.5
Chattahoochee River near Fairburn	200	86	43.0	73	45	61.6
[2] Chattahoochee River near Fairburn	---------	31	15.5	---------	7.0	9.6
Snake Creek near Whitesburg	---------	---------	----	1.2	1.0	83.3
Chattahoochee River near Whitesburg	220	110	50.0	78	46	59.0
[2] Chattahoochee River near Whitesburg	---------	31	8.3	---------	7.0	9.0

Station name	Arsenic			Lead		
	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge
Chattahoochee River near Leaf	---------	---------	----	---------	---------	----
Soque River near Clarkesville	---------	---------	----	---------	---------	----
Chestatee River near Dahlonega	0.14	0.14	100	5.8	5.0	86.2
Big Creek near Alpharetta	.20	.20	100	2	2	100
Chattahoochee River at Atlanta	1.70	.77	44.5	36	14	38.9
[1] Chattahoochee River at Atlanta	---------	.96	55.5	---------	22	61.1
N. Fork Peachtree Creek near Atlanta	.071	.071	100	4.9	4.5	91.8
S. Fork Peachtree Creek at Atlanta	.10	.10	100	6.4	6.1	95.3
Peachtree Creek at Atlanta	.33	.33	100	16	15	93.7
Woodall Creek at Atlanta	.79	.037	4.7	1.8	1.5	83
Nancy Creek tributary near Chamblee	---------	---------	----	.11	.046	38.3
Nancy Creek at Atlanta	.20	.16	80.0	4.5	3.6	80.0
Chattahoochee River near Fairburn	4.1	2.7	65.9	140	68	48.6
[2] Chattahoochee River near Fairburn	---------	.96	23.4	---------	22	15.7
Snake Creek near Whitesburg	.074	.074	100	---------	---------	----
Chattahoochee River near Whitesburg	5.0	3.6	72.0	170	100	58.8
[2] Chattahoochee River near Whitesburg	---------	.96	19.2	---------	22	12.9

[1] Discharge attributed to regulated flow.
[2] Discharge attributed to regulated flow. Equals computed discharge at the Chattahoochee River at Atlanta.

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