GEOLOGICAL SURVEY CIRCULAR 811

Summary of the River-Quality Assessment of the Upper Chattahoochee River Basin, Georgia

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

[For use of those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below]

Multiply U.S. customary unit	*By*	*To obtain metric unit*
ft (foot)	3.048×10^{-1}	m (meter)
ft^3/s (cubic foot per second)	2.832×10^{-2}	m^3/s (cubic meter per second)
in (inch)	2.540	cm (centimeter)
	2.540×10^{-1}	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)

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ABSTRACT

The river-quality assessment of the Upper Chattahoochee River Basin included studies of (1) the impact of heat loads on river quality, (2) sediment transport and deposition, (3) magnitude and nature of point and nonpoint discharges, and (4) phytoplankton growth in the river and reservoirs.

The combined thermal effects of flow regulation and powerplants effluents resulted in mean daily river temperature downstream of the powerplants about equal to or less than computed natural temperatures. The average annual river temperature in 1976 was 14.0° Celsius just upstream of the Atkinson-McDonough thermoelectric powerplants and 16.0° Celsius just downstream from the powerplants. During a low-flow period in June 1977 the heat load from the two powerplants caused an increase in river temperatures of about 7° Celsius and a subsequent decrease in the dissolved-oxygen concentration of about 0.2 milligrams per liter. During the June low-flow period, point sources contributed 63 percent of the ultimate biochemical oxygen demand and 97 percent of ammonium as nitrogen at the Franklin station. Oxidation of ultimate biochemical demand and ammonium caused dissolved-oxygen concentrations to decrease from about 8.0 milligrams per liter at river mile 299 to about 4.5 milligrams per liter at river mile 271. Dissolved orthophosphate is the nutrient presently limiting phytoplankton growth in the West Point Lake when water temperatures are greater than about 26° Celsius.

INTRODUCTION

In 1972, the U.S. Geological Survey began a program of river-quality assessments. The objectives were (1) to define the character, interrelationships, and apparent causes of existing river-quality conditions and (2) to devise and demonstrate analytical approaches and the tools and methodology needed for developing water-quality information that would provide a sound technical basis for planners and managers to use in assessing river-quality problems and evaluating management alternatives. The river-quality assessment program involves seven steps: (1) identifying the significant problems of major importance in the basin; (2) analyzing the hydrology; (3) deciding upon assessment methods appropriate to each problem; (4) collecting data relevant to each problem by intensive investigation and synoptic surveys; (5) analyzing the data for cause-effect relationship, formulating and calibrating predictive methods by which changes in river-quality parameters can be projected, and verifying the predicted results against observed conditions; (6) forecasting the impacts in river quality of various planning alternatives; and (7) presenting the results of river-quality assessments in a manner understandable to planners and decisionmakers.

The 3-year river-quality assessment of the Upper Chattahoochee River Basin, Georgia, began April 1, 1975. The purpose of the study was to demonstrate the types of information that can be provided to guide meaningful management decisions regarding alternatives for basic development and future needs of the Upper Chattahoochee in which maintenance and improvement of water quality are requisite.

OBJECTIVES AND SCOPE

The objectives and scope of the study included (1) the development of flow and temperature models to evaluate the impact of heat loads from thermoelectric plants on stream temperature, (2) a qualitative and quantitative definition of sediment transport and deposition, (3) an assessment of the magnitudes and nature of point and nonpoint discharges to selected reaches of the river, and their effect on the DO (dissolved oxygen) regime of the river, (4) economic considerations of maintaining desired minimum concentrations of DO in the Atlanta to Franklin reach of the river, and (5) use of microbiological determinations to develop quantitative methods to estimate algae concentrations in West Point Lake.

ACKNOWLEDGMENTS

The authors acknowledge the Cobb, DeKalb, and Fulton County governments and the City of Atlanta for their assistance in the collection of data. Special thanks go to the forecasters of the National Weather Service at Atlanta and to Johnny Beckman of WSB-TV, who have provided timely weather information before and during the point and nonpoint data-collection efforts. Special thanks also go to the Georgia Power Company, and in particular to A. W. Elkins, for their efforts in maintaining steady low-flow conditions in the river during the DO data-collection studies. The authors also thank the Environmental Protection Division of the Georgia Department of Natural Resources, South Atlantic Division of the U.S. Army Corps of Engineers, Region IV of the U.S. Environmental Protection Agency, Atlanta Regional Commission, and members of the Ad Hoc Working Group on River Quality Assessment of the Advisory Committee on Water Data for Public Use for their critical review of manuscripts and many helpful suggestions relative to the types of data and methods of analyses which would be most useful in managing the Upper Chattahoochee River.

DESCRIPTION OF THE UPPER CHATTAHOOCHEE RIVER BASIN

The Upper Chattahoochee River (fig. 1) begins on the southern slopes of the Blue Ridge Mountains in northeast Georgia and flows generally southwestward through the metropolitan Atlanta area to the Georgia-Alabama State line. The drainage area of the Upper Chattahoochee River is 3,440 mi^2 (square miles) (table 1). Land-surface altitudes range from about 4,000 ft above mean sea level in the headwaters to about 635 ft above mean sea level at West Point Lake.

Rainfall in the basin averages about 54 inches per year and is greatest in the upland areas and in the southernmost part of the basin. Annual air temperature averages about 16°C (degrees Celsius), with colder temperatures occurring in the mountains and warmer temperatures in the southernmost part of the basin.

TABLE 1.—*Land use, in square miles, in the Upper Chattahoochee River Basin*

Basin upstream of—	Urban	Rural	Forest	Drainage area
Buford Dam	37	165	838	1,040
Atlanta	129	239	1,082	1,450
Fairburn	372	310	1,378	2,060
Whitesburg	396	372	1,662	2,430
West Point Dam	433	546	2,461	3,440

HYDROLOGY

The flow of the Chattahoochee River in the study reach is dependent on rainfall and operation of hydroelectric-generating facilities. The highest flows generally occur in the spring of the year, and the lowest flows occur in late autumn. The average flow at Buford Dam, based on 35 years of record, is 2,168 ft^3/s (cubic feet per second), and at Atlanta, which is about midway in the study reach, the average daily flow based on 43 years of record is 2,603 ft^3/s. A maximum flow of 59,000 ft^3/s occurred at Atlanta in 1946, and a minimum daily flow of 296 ft^3/s occurred in 1957. Average daily flow at the Atlanta station for the period 1969–77 is show in figure 2.

Flow regulation in the midriver reaches has occurred for many years because of operation of hydroelectric-generating facilities. The most pronounced changes in regulated flow have occurred since the construction and operation of Buford Dam. Figure 3 shows the flow duration of the Chattahoochee River at the Atlanta station before and after regulation by Buford Dam. The frequency of both the higher and lower flows has decreased.

Buford Dam generally does not produce peak hydroelctric power on weekends. Estimated weekend flow at the Atlanta station is about 1,200 ft^3/s.

LAND USE

Land in the Upper Chattahoochee River Basin is predominately forest (table 1). Upstream of Buford Dam, about 80 percent of the land is forested and 16 percent agricultural. Agricultural

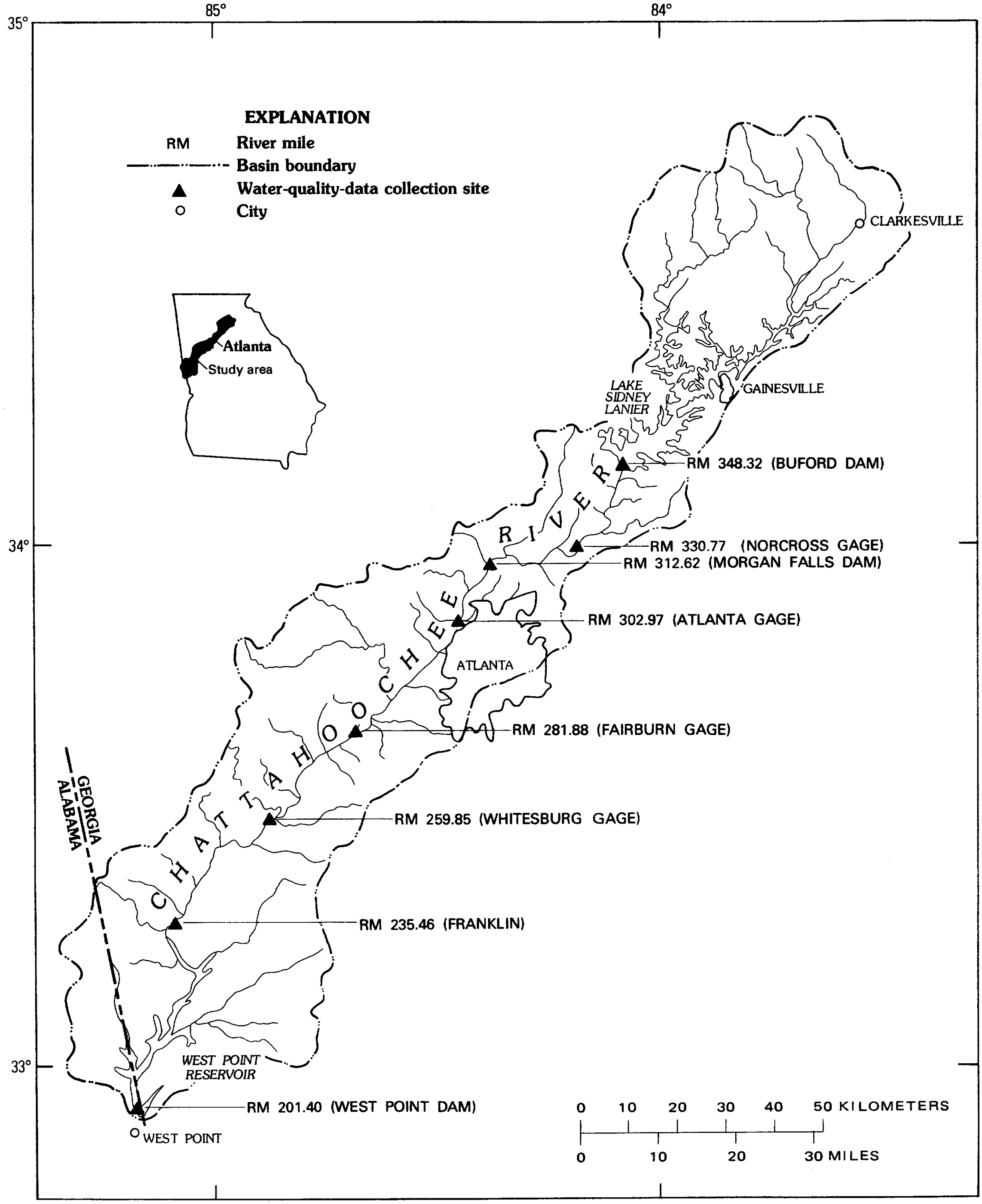


FIGURE 1.—Upper Chattahoochee River Basin, Georgia.

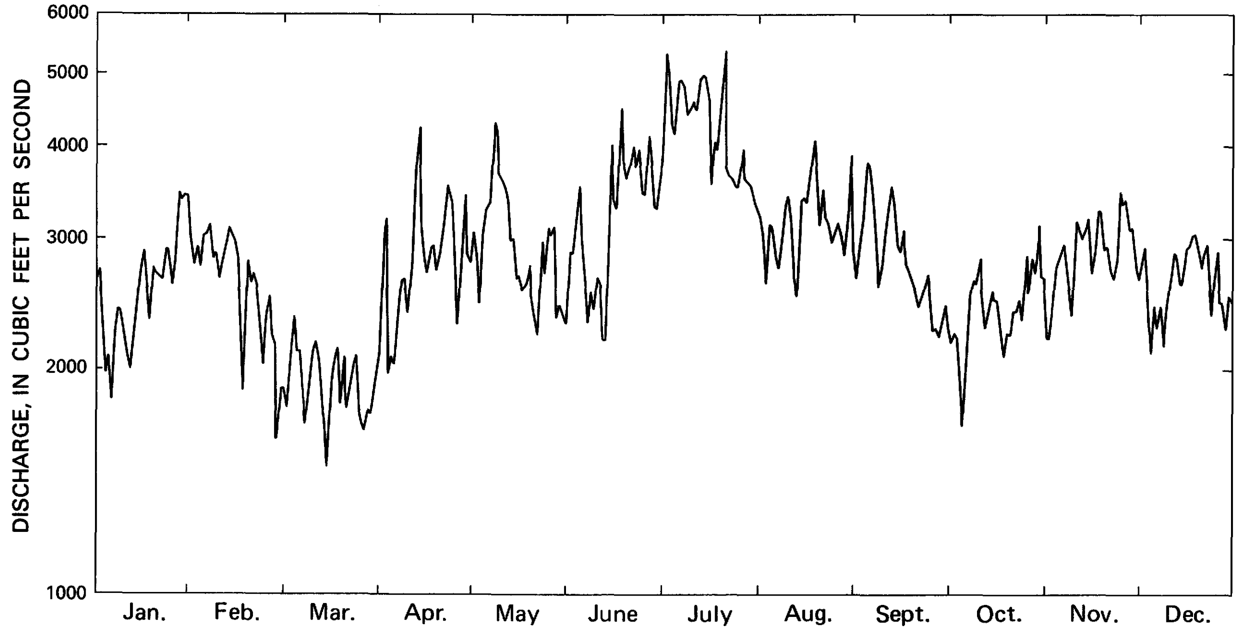


FIGURE 2.—Mean daily discharge of the Chattahoochee River at the Atlanta station for 1969–77.

activities are concentrated in the stream valleys and on the lower slopes. Crop and pastureland occupy a significant part of the agricultural land. Poultry operations, primarily broiler production, are a dominant agricultural activity. Gainesville is the largest urban complex in this part of the basin.

In the reach from Buford Dam to Atlanta, about 59 percent of the land is forested, 22 percent is urbanized, and 18 percent is farmed. About 40 percent of the agricultural land is in cropland and pasture. Corn and soybeans are the dominant crops.

The basin from Atlanta to West Point Dam includes most of Metropolitan Atlanta, the major urban complex in the basin. Land in the Atlanta area is predominantly residential, but commercial and industrial activities are significant. Some of the more important industrial activities include automobile assembly, food processing, and light manufacturing. Downstream from Atlanta, forest land is predominant. Agricultural use of the land is about the same as in the Buford Dam-to-Atlanta reach, and the types of agricultural operations are similar.

WATER USE

The water of the Chattahoochee River is utilized extensively for power generation, water supply, water-quality maintenance, and recreation.

Five electric power-generating facilities are located on the mainstem of the river and have a combined generating capacity of about 3.8 million kilowatts. Buford and Morgan Falls Dams are peak-power hydroelectric-generating facilities, and the Atkinson-McDonough, Yates, and Wansley Plants are baseload fossil-fuel thermoelectric-generating facilities. Morgan Falls is a run-of-the-river plant, utilizing hydropower-released waters from Buford Dam. The estimated average water use and generating capacity of the plants are shown in table 2.

TABLE 2.—*Estimated average water use and generating capacity of electric-generating facilities in the Upper Chattahoochee River Basin*

[From Georgia Power Co.]

River mile	Name of facility	Capacity (kw)	Average water use (ft³/s)
	Hydroelectric facilities		
348.32	Buford Dam	86,000	2,200
312.62	Morgan Falls Dam	16,800	2,500
	Thermoelectric facilities		
299.11	Plants Atkinson-McDonough	730,000	909
259.70	Plant Yates	1,250,000	1,030
249.20	Plant Wansley	1,760,000	[1]73

[1]One small unit on line in 1976.

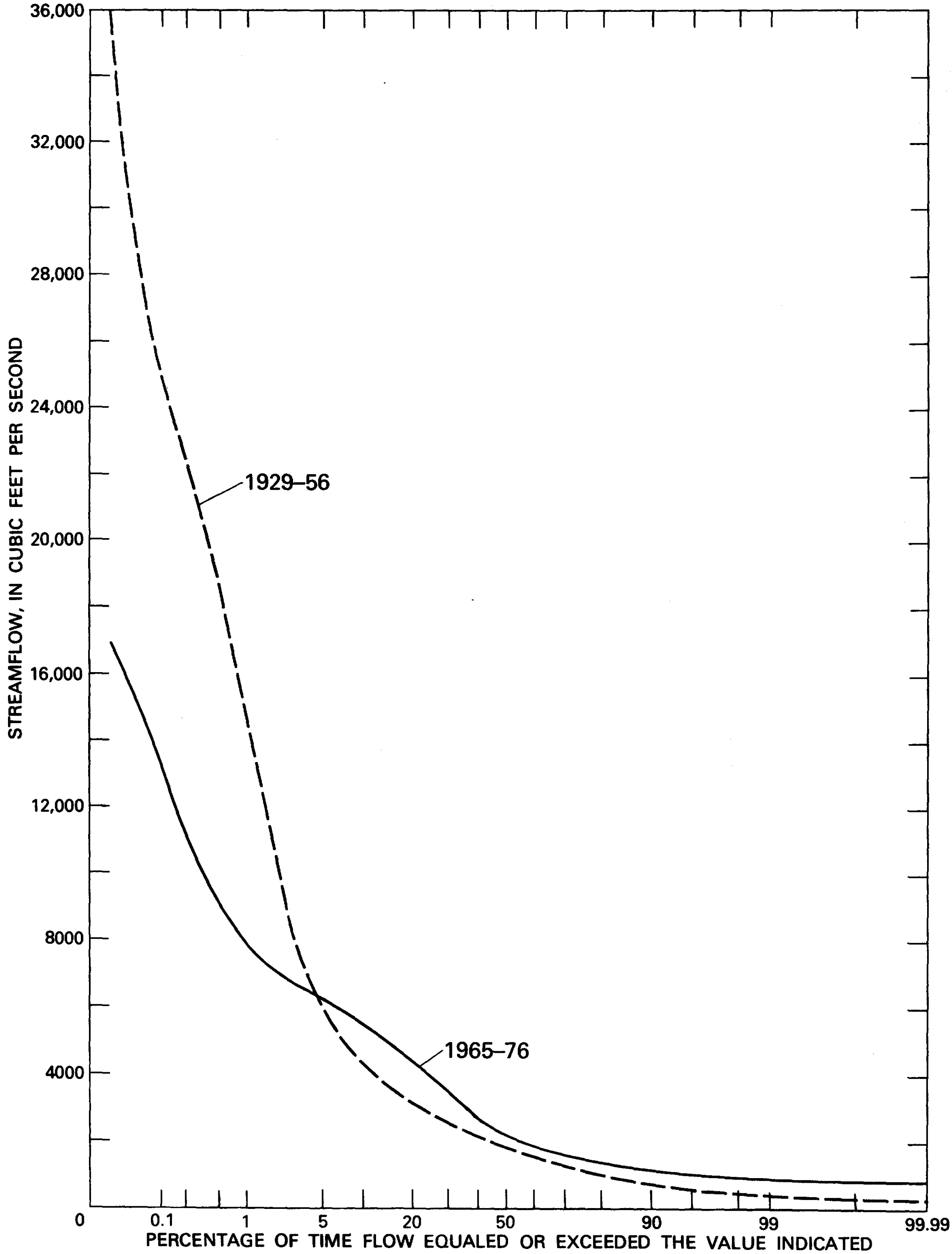


FIGURE 3.—Flow duration of the Chattahoochee River at the Atlanta gage before and after construction of Buford Dam.

At the present time (1978) public water-supply withdrawals from the Upper Chattahoochee River average about 280 ft^3/s, of which about 173 ft^3/s is withdrawn in the reach from Morgan Falls to Fairburn. Other public water supplies are withdrawn from Lake Sidney Lanier and West

Point Lake. Table 3 lists the major water users in the basin and shows the estimated 1976 and 2000 water-supply withdrawals.

Large amounts of wastewater are discharged (table 4) to the Chattahoochee River, particularly in the Atlanta area. In 1974, the Georgia Environmental Protection Division estimated that 750 ft^3/s of high-quality water would be needed downstream from Atlanta to meet water-quality standards and limited future water-supply withdrawals without equal additional flow of high-quality water to the river (Environmental Protection Divison, 1974).

Several reaches of the river are used extensively for recreation. The mountainous headwater areas are popular for trout fishing and outdoor recreation. Lake Sidney Lanier, a popular water-resort area, has numerous public access areas, boat-launching facilities, campgrounds, marinas, yacht clubs, and cottages. Lake Sidney Lanier has a higher number of annual visitor days than any other U.S. Army Corps of Engineers facility in the Nation (Metropolitan Atlanta Water Resources Study Group, 1976).

The reach from Buford Dam to Atlanta is periodically stocked with game fishes and provides recreation for fishermen, canoeists, and rafters. This reach has been designated as a National Recreation Area. The reach downstream from Morgan Falls to just upstream of the Peachtree Creek confluence, one of the most scenic reaches on the river, is the site for an annual raft race that involves thousands of participants and onlookers.

West Point Lake, a U.S. Army Corps of Engineers impoundment created by the construction of West Point Dam in 1974, is used for fishing, boating, camping, and swimming.

TABLE 3.—*Estimated water-supply withdrawals, in cubic feet per second, from the Upper Chattahoochee River for the years 1976 and 2000*

[From Metropolitan Atlanta Water Resources Study Group, 1976]

Facility	1976	2000
Hall County[1]	3.0	9
Forsyth County[1]		2
Gwinnett County[1]		68
City of Buford[1]	1	1
Gwinnett County	12	12
DeKalb County	91	188
Fulton County		243
Cobb County	39	116
City of Atlanta	134	110
Total	280	749

[1]Withdrawals upstream of Buford Dam.

TABLE 4.—*Mean daily treated wastewater returns, in cubic feet per second, for 1976 and estimated returns for the year 2000 to the Chattahoochee River and its tributaries for wastewater treatment facilities in the study area*

River Mile	Facility	[1]1976	[2]2000
	Gainesville Linwood	2.2	4.2
	Gainesville Flat Creek	5.6	9.3
	Buford	1.7	2.0
	Big Creek	4.1	17
	Crooked Creek	1.8	12
	Johns Creek	2.9	4.8
300.56	Cobb Chattahoochee	15	31
300.24	R. M. Clayton	118	161
297.50	Hollywood Road	2.3	([4])
295.13	U.S. Air Force Plant No. 6[3]	2.6	11
294.28	South Cobb Chattahoochee	13	48
291.60	Utoy Creek	21	44
288.57	Sweetwater Creek		2.6
283.54	Camp Creek	6.8	27
281.46	Anneewakee Creek		6.0
281.45	Three-river Interceptor		42
275.95	Bear Creek		7.7
	LaGrange Yellow Jacket[5]	1.5	3.0
	Total	198	433

[1]Data from monthly plant operating reports submitted to Georgia Department of Natural Resources, Environmental Protection Division.
[2]Data from Metropolitan Atlanta Water Resources Study Group (1976).
[3]Data from U.S. Environmental Protection Agency.
[4]To be eliminated by year 2000.
[5]Discharges into West Point Lake, not included in analysis.

NATURE OF THE PROBLEM

The problems associated with water quality in the Upper Chattahoochee River Basin are for the most part related to urbanization. Urbanization has created large demands on the Chattahoochee River as the major source of water supply for Atlanta and the major transporter of municipal wastes from Atlanta. In 1976 about 280 ft^3/s was withdrawn from the river upstream of Peachtree Creek (RM(river mile) 300.54) for water supply, and about 180 ft^3/s of secondary-treated wastewater was discharged into the river between the Atlanta and the Fairburn stations (RM 281.88).

During periods of high flow, direct runoff from streets, parking lots, and construction sites in the Atlanta metropolitan area can contribute large suspended-sediment and total and dissolved-constituent loads to the river and to West Point Lake.

Sedimentation during the high-flow periods inundates valuable and fertile river-bottom lands and increases peak elevation of floods. Sedimentation also reduces the useful life of dam structures and reduces the esthetic and recreational potential of reservoirs; it also can increase the cost of maintenance and water-supply operations and restrict use of water in some industrial processes.

Point sources, five WTF's (wastewater treatment facilities) and four thermoelectric plants, and nonpoint discharges contribute large nutrient loads to the Chattahoochee River and to West Point Lake.

During periods of low flow, the availability of water downstream from Buford Dam is dependent to a large extent on the operation of the dam for peak hydroelectric-power generation. Generally, peak power is not generated on weekends, and flow in the Atlanta area is about 1,200 ft^3/s.

In the 20-river-mile Atlanta-to-Fairburn reach about 130 ft^3/s of water is withdrawn from the river for water supply, and about 180 ft^3/s of treated wastewater is returned to the river from seven WTF's. The estimated net flow (including tributary inflow) at the Fairburn station during weekend low-flow periods is about 1,400 ft^3/s, of which about 13 percent is treated wastewater. In this reach two baseload thermoelectric facilities discharge (circulate) about 900 ft^3/s of heated water to the river.

The combined effects of public water-supply withdrawals, wastewater returns, and heated discharges during warm-weather low-flow periods cause low DO concentrations to occur in the river downstream from Atlanta. Table 5 shows the number of days and hours for each month during 1977 that DO concentrations were less than 5.0 mg/L in the Chattahoochee River near the Fairburn station monitor. An average daily DO concentration of 5.0 mg/L and not less than 4.0 mg/L in the reach of the river from the Peachtree Creek confluence to the Cedar Creek confluence is required at all times, unless violations occur during periods of urban storm runoff and (or) discharges from combined sewer overflows (Environmental Protection Divison, 1977). Average daily DO concentrations of less than 5.0 mg/L occurred 31 percent of the hours in the month of October 1977. Figure 4 shows the average daily DO concentrations at the Fairburn station monitor (RM 281.88) and the mean daily discharge at the Atlanta station (RM 302.97) during July 1977. Average daily DO concentrations of less than 5.0 mg/L occur at Fairburn about a day later when streamflow at Atlanta is about 1,200 ft^3/s.

TABLE 5.—*Mean monthly air temperature and number of days and hours per month during 1977 in which the DO concentration was less than 5.0 mg/L at the Chattahoochee River near Fairburn monitor*

Month	Number of days (DO <5 mg/L)	Number of hours (DO <5 mg/L)	Mean monthly air temperature[1] (°C)
January	0	0	1.5
February	0	0	5.6
March	1	4	12.9
April	0	0	17.2
May	6	56	21.1
June	9	121	25.1
July	9	130	26.4
August	9	58	25.4
September	9	74	23.1
October	16	234	15.3
November	8	159	12.4
December	1	9	5.6

[1]Data source: Climatological Data, v. 81, no. 1–12, 1977, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Ashville, N. C.

In the year 2000, public water-supply withdrawals from the river are estimated to be 667 ft^3/s. Future plans to modify the flow regime of the river to meet increasing water-supply demands include construction of a reregulation structure, dredging of the Morgan Falls reservoir (impounded by Morgan Falls Dam), and (or) changes in the hydropower releases from Buford Dam (U.S. Army Corps of Engineers, 1975). Wastewater returns in the Atlanta-to-Fairburn reach are estimated to be 538 ft^3/s. Regardless of the alternative selected, the estimated flow (1,500 ft^3/s) at the Fairburn station during weekend low-flow periods in the future will not be greatly different from today (1978).

Data and information relative to water-quality problems in the Upper Chattahoochee River Basin are presented in the following sections entitled, "Erosion and Sediment Transport," "Flow and Temperature Models," "Point and Nonpoint Discharges," and "Biological Assessment."

EROSION AND SEDIMENT TRANSPORT

Soil erosion in the Upper Chattahoochee River Basin occurs mostly in the forms of sheet and rill, gully, and channel erosion (Faye and others, 1978). Sheet erosion is the predominate process. The potential for soil erosion is principally dependent on the quantity, intensity, and frequency of precipitation, soil composition and structure, land slope and slope length, and land-use practices. The amount of eroded material that reaches a stream and is transported as sediment, in turn, depends on the size and nature of the tributary

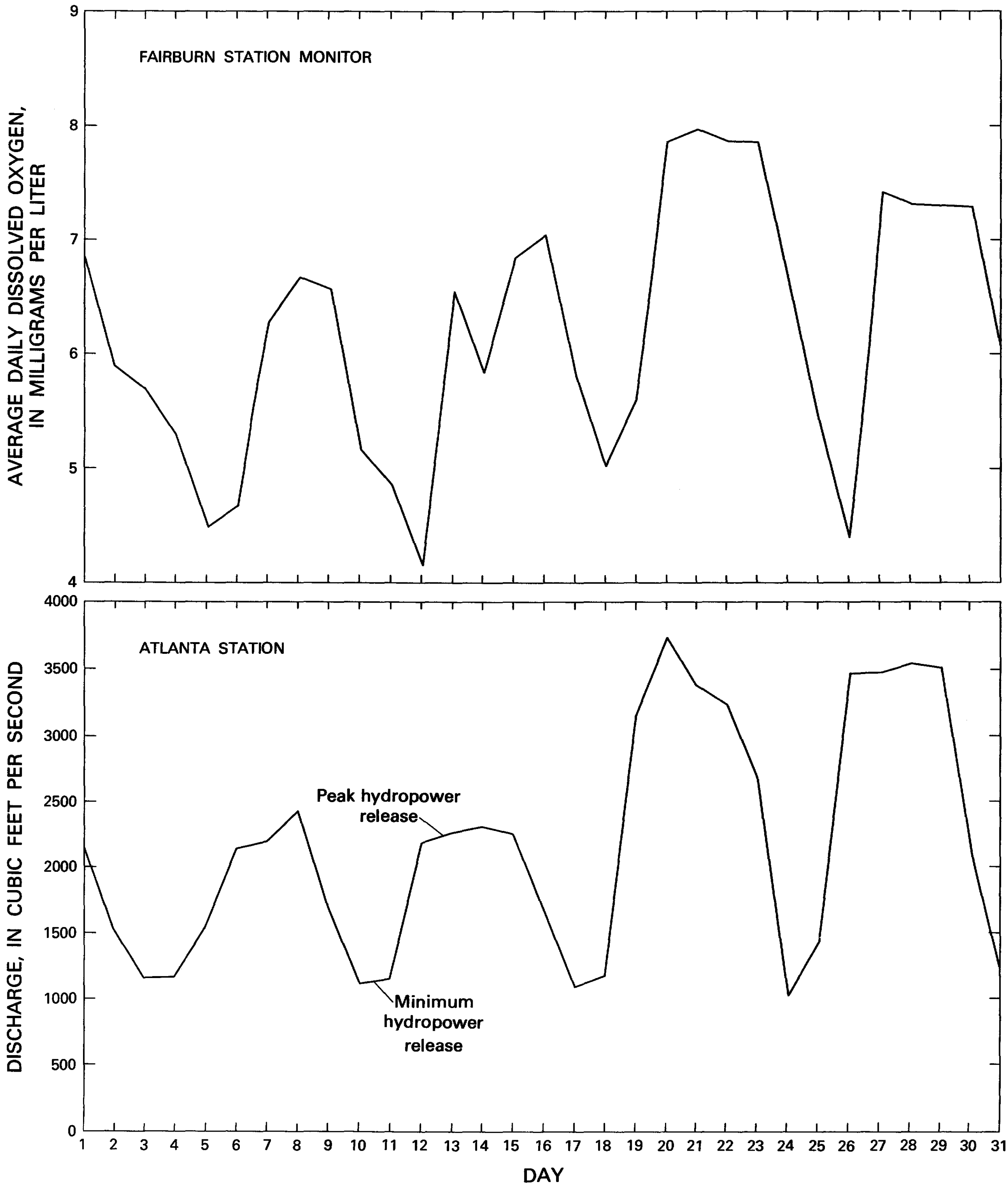


FIGURE 4.—DO concentrations at the Fairburn station monitor and mean daily discharge at the Atlanta station during July 1977.

drainage area, the rainfall intensity and frequency of occurrence, and the character of land use and erosion controls, natural or manmade.

The Universal Soil Loss equation (Wischmeier and Smith, 1965) was used to compute sheet erosion in nine selected watersheds. Land use in each watershed was predominantly urban, rural, or forested. The range of topographic and climatic conditions relative to all the watersheds is assumed characteristic of the basin as a whole. Drainage area of the watersheds ranged from about 3 to 150 mi^2. Average annual yields of erosion in the nine watersheds ranged from about 900 to 6,000 tons/mi^2/yr (tons per square mile per year). The greatest yields occurred in watershed with the largest percentages of agricultural and transitional land uses. The lowest yields occurred in highly urbanized watersheds. An evaluation of the effects of timber harvesting on average annual sheet erosion indicated that post-harvest erosion yields were several orders of magnitude greater than pre-harvest yields in the same areas.

Streams in the basin transport sediment from a variety of sources. Silt and clay are supplied mostly by overland flow. Sand and gravel are generally available from stream beds and banks. Suspended loads consist mostly of silt and clay; bed and unmeasured loads are mostly sand and gravel.

Average annual yields of suspended sediment calculated from measurements of sediment discharge at stations draining the nine watersheds for which sheet erosion was calculated ranged from about 300 to 800 tons/mi^2/yr. Sediment discharges were greatest at stations draining urban watersheds and least at stations draining predominantly forested watersheds. A large part of the sediment discharged in urban streams was considered to be derived from stream-channel erosion. Unmeasured sediment discharge at four stations ranged from about 6 to 30 percent of the total computed annual discharge of sediment.

Erosion and sediment discharge rates about 2,000 and 300 tons/mi^2/yr, respectively, at stations draining watersheds where man's impact is minimal were considered indicative of background rates in the basin.

Suspended sediment also transports significant quantities of chemical constituents in basin streams. Curves that relate the concentration of suspended chemical constituents to suspended-sediment concentration were developed at most water-data stations. In general, the suspended constituent-sediment concentration relation conformed to the geometric relation,

$$C_s = a(S_{sc})^b,$$

where C_s = the suspended chemical constituent concentration in milligrams per liter, S_{sc} = concentration of suspended silt plus clay in milligrams per liter, and a and b are constants relative to the occurrence of each constituent at individual water-data stations. A summary of the regression equations relating some suspended-constituent concentrations to silt plus clay concentrations is listed in table 6. The omission of regression information for particular constituents indicates that a functional relation could not be established.

Average annual constituent discharges were computed using the regression relations discussed previously and are listed in table 7 along with total annual constituent discharges. Suspended phosphorus ranged from about 31 to 95 percent of the total annual discharges of phosphorus and averaged about 76 percent. Suspended nitrogen discharges ranged from about 7 to 53 percent of the total annual nitrogen discharges and averaged 29 percent. Corresponding ranges for suspended organic carbon were 18 to 71 percent with an average of 43 percent. At every station, most of the trace-metal discharges were in the suspended phase.

The effects of land use on suspended-constituent discharges were determined by comparing suspended-constituent yields (table 8) at stations draining watershed with different land-use characteristics. The yields of suspended phosphorus and nitrogen from urban watersheds were greater by a factor of two than corresponding yields from forested watersheds. Similarly the yields of suspended zinc and lead from urban areas exceeded corresponding yields from forested areas by an order of magnitude. The differences in constituent yields indicate there is more opportunity in urban watersheds than in forested watersheds for nutrients and most trace metals to come into contact with sediments. The data further indicate that sediments act as a sink for nutrients and some trace metals, thus reducing the dissolved concentrations of these constituents in urban streams.

FLOW AND TEMPERATURE MODELS

Digital models of transient flow and heat transport were used to evaluate natural Chattahoochee River temperatures and analyze the impact of flow regulation at Buford Dam and ef-

TABLE 6.—*Summary of regression data relating suspended*

Station name	Suspended phosphorus as P				Suspended nitrogen as N				Suspended	
	a	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples	*a*	*b*
Chattahoochee River near Leaf	0.00274	0.746	0.97	8	0.0137	0.714	0.98	7	0.0359	0.944
Soque River near Clarkesville	.00248	.834	1.0	9	.000493	1.27	.91	8	.818	.441
Chestatee River near Dahlonega	.00132	.942	.99	11	.00167	.988	.87	10	.00255	1.51
Big Creek near Alpharetta	.00681	.639	.96	12	.0290	.528	.93	7	.0157	1.09
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	.155	.705
Nancy Creek Tributary near Chamblee	.0185	.391	.90	7	------	------	------	------	.00247	1.24
Nancy Creek at Atlanta	.00116	.909	.99	13	6.91×10^{-5}	1.49	.89	11	.201	.585
Chattahoochee River near Fairburn	.0413	.379	.61	16	------	------	------	------	.00377	1.37
Snake Creek near Whitesburg	.000911	.920	.99	7	.00530	.827	.96	6	.0446	.755
Chattahoochee River near Whitesburg	.0198	.484	.85	11	------	------	------	------	.00324	1.34

fluent discharges from the Atkinson-McDonough powerplants on river temperatures between Atlanta and Whitesburg (Faye and others, 1978).

The flow model used in a finite-difference approximation of the one-dimensional continuity and momentum equation for gradually varied flow is identical to those used by Amien and Fang (1970). Boundary conditions for the flow model were defined at the Atlanta and Whitesburg gages as discharge and stage, respectively.

The temperature model solves a finite-difference approximation of the one-dimensional equation describing the continuity of thermal energy in open channels and used observed temperatures at the Atlanta gage as boundary conditions.

Flow, temperature, and meteorological data collected during two 8-day periods beginning July 12, 1976, and August 1, 1976, were used to calibrate and verify the flow and temperature models. Examples of the results of model calibration are shown in figures 5 and 6.

Use of the models to analyze the impact on river temperatures of powerplant heat loads and bottom, cold-water releases from Buford Dam indicated that the combined effect of flow reregulation and thermal powerplant effluents resulted in mean daily river temperatures equal to or less than mean natural temperatures downstream from the powerplants. An analysis of historical river and air temperatures also provided the same basic conclusion.

The models were also used to simulate river temperature using year 2000 estimated flow conditions and meterological data collected during 1976. Except for periods of peak water-supply demand, simulated river temperatures for the year 2000 were changed little from observed, present-day (1978) temperatures.

POINT AND NONPOINT DISCHARGES

Point-source discharges, seven WTF's and the Atkinson-McDonough thermoelectric plants, occur in the Chattahoochee River or its tributaries in the Atlanta-to-Fairburn reach (Stamer and others, 1978). The mean daily flow of the WTF's in 1976 was about 180 ft³/s (table 4), or about 4 percent of the mean daily flow of 4,400 ft³/s at the Whitesburg Station.

Nonpoint sources of discharge include all sources other than the seven WTF's and the Atkinson-McDonough powerplants. The sources include runoff from urban, rural, and forested areas. Urban nonpoint discharges are characterized by the water quality of Peachtree Creek at Atlanta, rural nonpoint discharges by the water-quality characteristics of Big Creek near Alpharetta, and forested nonpoint discharges by Snake Creek near Whitesburg.

organic carbon		Suspended lead				Suspended zinc				Suspended copper			
Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples	*a*	*b*	Correlation coefficient	Number of samples
0.92	9	------	------	------	------	0.00387	0.477	0.91	8	------	------	------	------
1.0	5	------	------	------	------	.00285	.525	.93	6	0.000306	0.802	0.96	7
.93	10	0.00200	0.539	0.82	12	.00112	.701	.87	8	.000447	.900	.96	9
.69	10	.000964	.639	.82	9	------	------	------	------	------	------	------	------
------	------	.00205	.550	.67	11	.00389	.443	.95	8	.000253	.872	.92	12
------	------	.00217	.638	.94	7	.00224	.608	.80	8	------	------	------	------
------	------	.00586	.591	.94	9	.00115	.767	.97	8	.00639	.343	.85	8
------	------	.00349	.655	.93	12	.00546	.544	.91	13	.00594	.761	.82	15
.93	9	.00134	.463	.95	7	.0461	.290	.88	7	.000953	.699	.95	7
.94	7	.000346	.890	.87	4	.00319	.545	.87	4	------	------	------	------
.83	9	.000836	.789	.89	8	.000122	1.07	.92	10	.000103	.911	.97	10
.82	12	.00208	.625	.77	9	.00519	.488	.70	10	.00665	.300	.66	10
.90	5	------	------	------	------	------	------	------	------	.000313	.366	.91	5
.95	13	.00260	.610	.90	7	.00140	.728	.90	10	.00106	.622	.81	10

POINT DISCHARGES

Average annual loads and average daily concentrations of selected constituents for each of the seven WTF's are given in table 9. Table 9 indicates that (1) dissolved solids are the largest of the constituent loads, (2) 51 percent of the phosphorus load is dissolved, (3) 69 percent of the nitrogen load is dissolved, (4) the total nitrogen to total phosphorus concentration ratio is 4.6:1, and (5) trace-element concentrations are low in comparison to other constitutent concentrations.

NONPOINT DISCHARGES

Table 10 shows the average annual yields and average daily concentrations for selected constituents from urban, rural, and forested areas. Average annual yields and average daily concentrations are greatest for suspended sediment, dissolved solids, total and dissolved nitrogen, total and dissolved phosphorus, NH_4-N (ammonium as nitrogen), COD (chemical oxygen demand), BOD_u (ultimate biochemical oxygen demand), arsenic, copper, lead, and zinc in the urban area. The rural area has the greatest average annual yields and average daily concentrations for NO_3-N (nitrate as nitrogen), TOC (total organic carbon), and DOC (dissolved organic carbon). Average annual yields and average daily concentrations are smallest in the forested area.

The concentration data in table 10 indicate that (1) about 65 percent of the nitrogen is dissolved and that NO_3-N composes about 50 percent of the dissolved nitrogen, (2) about 10 percent of the phosphorus is dissolved, and (3) about 60 percent of TOC is dissolved.

RELATION OF NONPOINT CONSTITUENT YIELDS TO URBANIZATION

Average annual constituent yields from 15 subbasins in the Upper Chattahoochee Basin were related to percentage of urbanization in each of these subbasins. Generally, constituent yields increase with increasing urbanization, particularly for dissolved constituents. Strong relationships of constituent yields to percentage of urbanization were indicated for dissolved solids, BOD_u, total and dissolved phosphorus, total and dissolved nitrogen, and total lead. In contrast, COD, TOC, DOC, and suspended nitrogen and phosphorus do not appear to be significantly related to percentage of urbanization, but the yields of these constituents are generally higher in urban than in the forested areas.

The relationship of average annual yields of dissolved solids and BOD_u is shown in figure 7. The BOD_u yield from North Fork Peachtree Creek tributary (at Meadowcliff Road near Chamblee) as shown by the open circle in figure 7 was not included in the regression. Although the basin is

TABLE 7.—*Summary of average annual suspended and total constituent discharges*

Station name (tons/yr)	Organic carbon			Phosphorus as P			Nitrogen as N			Lead			Zinc		
	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)	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)	Total discharge (tons/yr)	Suspended discharge (tons/yr)	Ratio of suspended to total discharge (percent)
Chattahoochee River near Leaf	960	510	53.1	18	16	88.9	130	69	53.1	------	------	------	7.5	7.5	100
Soque River near Clarkesville	1,700	1,200	70.6	25	21	84.0	100	32	32.0	------	------	------	7.0	5.9	84.3
Chestatee River near Dahlonega	2,000	1,400	70.0	27	24	88.8	200	39	19.5	5.8	5	86.2	7.8	5.8	74.4
Big Creek near Alpharetta	1,300	500	38.5	15	14	93.3	140	31	22.1	2	2	100	------	------	------
Chattahoochee River at Atlanta	------	------	------	180	56	31.1	1,700	120	7.1	36	14	38.9	47	16	34.0
Chattahoochee River at Atlanta[1]	------	------	------	------	96	53.3	------	56	3.3	------	22	61.1	------	31	66.0
N. Fork Peachtree Creek near Atlanta	------	------	------	11	8.6	78.2	75	19	25.3	4.9	4.5	91.8	2.5	2.1	84.0
S. Fork Peachtree Creek at Atlanta	------	------	------	11	10	90.9	71	22	30.9	6.4	6.1	95.3	4.2	3.4	81.0
Peachtree Creek at Atlanta	------	------	------	32	29	90.6	200	62	31.0	16	15	93.7	16	13	81.3
Woodall Creek at Atlanta	250	46	18.4	16	5.3	33.1	46	3.7	8.0	1.8	1.5	83.0	3.4	2.7	79.4
Nancy Creek Tributary near Chamblee	38	1.9	4.8	.44	.30	68.2	------	------	------	.11	.046	38.3	.12	.096	80.0
Nancy Creek at Atlanta	670	260	38.8	11	10	90.9	77	28	36.4	4.5	3.6	80.0	3.6	3.1	86.1
Chattahoochee River near Fairburn	28,000	5,800	20.7	1,300	410	31.5	------	------	------	140	68	48.6	200	86	43.0
Chattahoochee River near Fairburn[2]	------	2,500	8.9	------	96	7.4	------	------	------	------	22	15.7	------	31	15.5
Snake Creek near Whitesburg	290	110	37.9	6	5.7	95.0	41	19	46.3	------	------	------	------	------	------
Chattahoochee River near Whitesburg	36,000	8,000	22.2	1,300	410	31.5	------	------	------	170	100	58.8	220	110	50.0
Chattahoochee River near Whitesburg[2]	------	25,000	6.9	------	96	7.4	------	------	------	------	22	12.9	------	31	8.3

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

TABLE 8.—*Annual yields of suspended constituents, in tons per square mile, from representative land-use watersheds*

	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

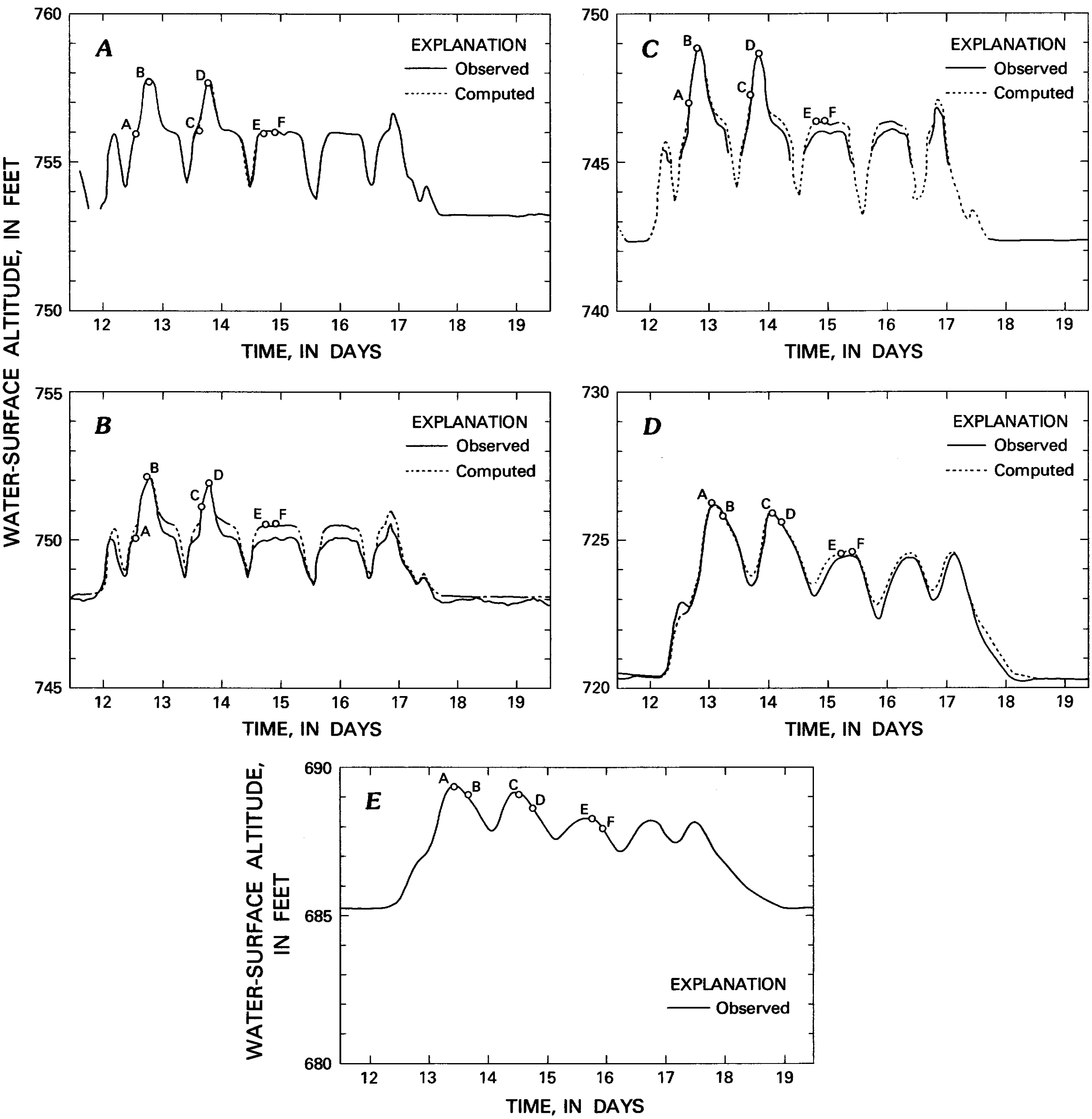


FIGURE 5.—Observed and computed stages of the Chattahoochee River during the period July 12–19, 1976. *A*, at Atlanta, *B*, at the City of Atlanta Water Works, *C*, at the plant McDonough outfall, *D*, near Fairburn, and *E*, near Whitesburg.

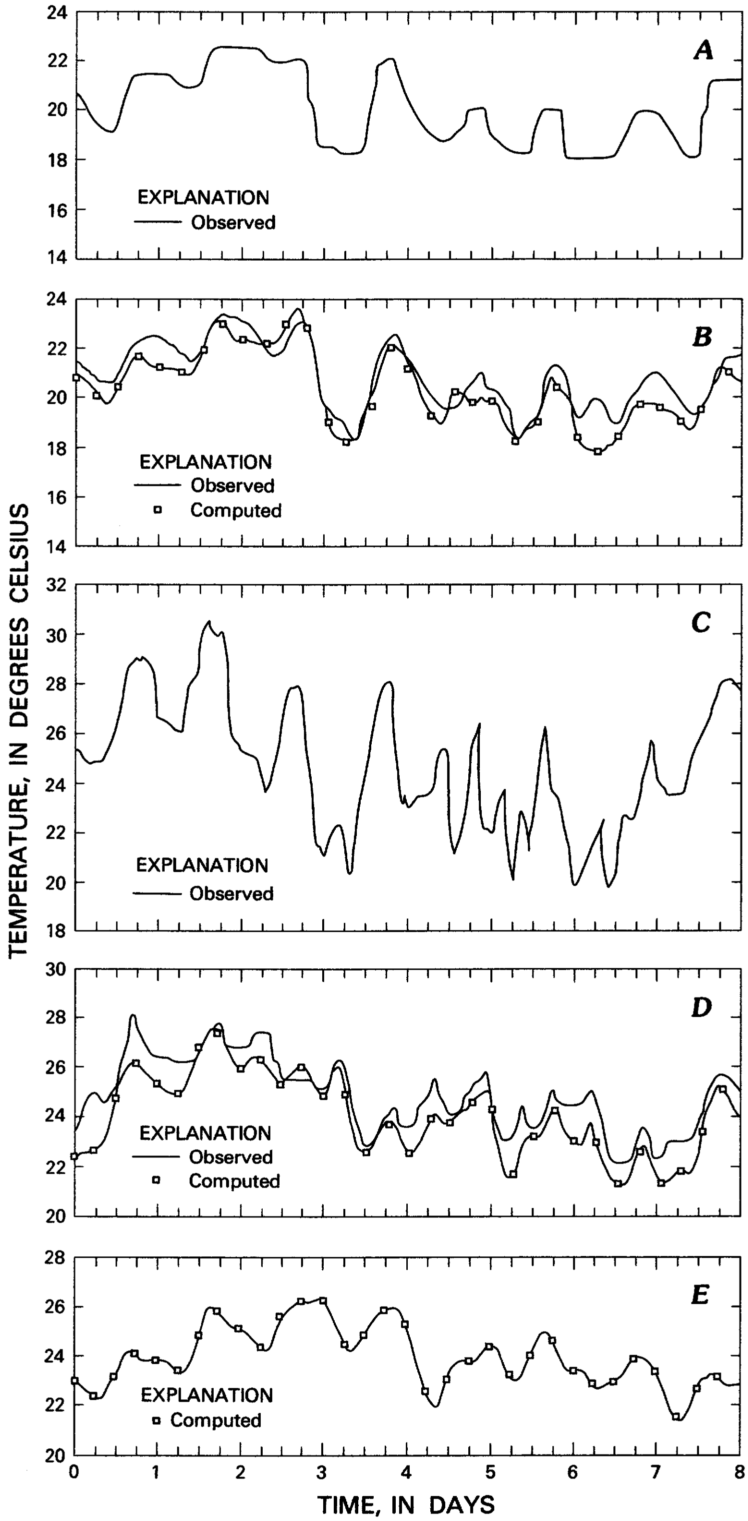


FIGURE 6.—Observed and computed temperatures of the Chattahoochee River. *A*, at Atlanta, *B*, at the plant McDonough intake, *C*, at Georgia Highway 280, *D*, near Fairburn, and *E*, near Whitesburg.

TABLE 9.—*Magnitude and nature of point discharges for selected constituents for the year 1976*

Facility	Total nitrogen	Dissolved nitrogen	Dissolved nitrate nitrogen	Dissolved ammonium nitrogen	Total phosphorus	Dissolved phosphorus	Dissolved orthophosphate as phosphorus	Ultimate biochemical oxygen demand	Chemical oxygen demand
Cobb Chattahoochee	330	160	4.4	130	66	27	1.1	1,200	1700
R. M. McClayton	2,300	1,500	32	1,030	440	190	17	13,000	18,000
Hollywood Road	50	37	.39	30	10	6.8	.96	220	240
U.S. Air Force Plant No. 6	14	11	9.8	.24	.80	.68	.066	17	36
South Cobb Chattahoochee	200	170	8.2	120	75	52	4.5	620	1,200
Utoy Creek	270	240	7.0	160	68	42	1.6	960	1,400
Camp Creek	76	71	60	2.4	33	29	1.0	100	250
Sum of annual loads (tons/yr)	3,200	2,200	120	1,500	690	350	26	16,000	23,000
Mean daily concentration (mg/L)[1]	18	12	0.70	8.5	3.9	2.0	0.15	90	130

TABLE 9.—*Magnitude and nature of point discharges for selected constituents for the year 1976*—Continued

Facility	Total organic carbon	Dissolved organic carbon	Suspended solids	Dissolved solids	Total arsenic	Total chromium	Total copper	Total lead	Total zinc
Cobb Chattahoochee	410	120	2,250	3,500	0.015	0.37	0.30	0.56	1.4
R. M. Clayton	5,000	1,300	9,880	28,800	.51	14	10	19	54
Hollywood Road	56	21	143	567	.0023	.046	.045	.076	.098
U.S. Air Force Plant No. 6	9.3	7.2	7.4	875	.00064	.10	.021	.044	.074
South Cobb Chattahoochee	240	110	636	3,120	.012	.24	.22	.59	1.0
Utoy Creek	520	190	564	5,120	.021	.54	.31	1.2	1.5
Camp Creek	69	38	111	1,350	.0067	.13	.061	.11	.28
Sum of annual loads (tons/yr)	6,300	1,800	13,600	43,300	0.57	15	11	22	58
Mean daily concentration (mg/L)[1]	36	10	77	245	0.003	0.09	0.06	0.12	0.33

[1]Computed from the sum of the annual loads prior to rounding.

TABLE 10.—*Average annual yields and average daily concentrations for selected constituents for urban, rural, and forested nonpoint discharges*

[Units for yield are tons per square mile per year; units for concentration are milligrams per liter]

Land use	Dissolved solids	Suspended sediment	Total nitrogen	Dissolved nitrogen	Dissolved nitrate nitrogen	Dissolved ammonium nitrogen	Total phosphorus	Dissolved phosphorus	Ultimate biochemical oxygen demand	Chemical oxygen demand	Total organic carbon	Dissolved organic carbon	Total arsenic	Total copper	Total lead	Total zinc
Urban:																
Yield	113	775	2.3	1.6	0.76	0.30	0.37	0.038	16	30	14	8.3	0.005	0.059	0.18	0.18
Average concentration	71.4	480	1.5	1.0	.48	.19	.23	.02	10	19	8.8	5.3	.003	.037	.12	.12
Rural:																
Yield	59.6	333	1.9	1.5	.83	.11	.20	.015	8	24	18	11	.003	.029	.028	.053
Average concentration	36.6	205	1.2	.94	.51	.07	.13	.01	5	14	11	6.5	.002	.018	.017	.033
Forest:																
Yield	32.2	359	1.1	.59	.26	.062	.16	.008	7.6	19	7.9	4.9	.002	.032	.041	.046
Average concentration	20.7	230	.71	.38	.17	.04	.10	.01	4.8	12	5.1	3.1	.001	.021	.025	.035

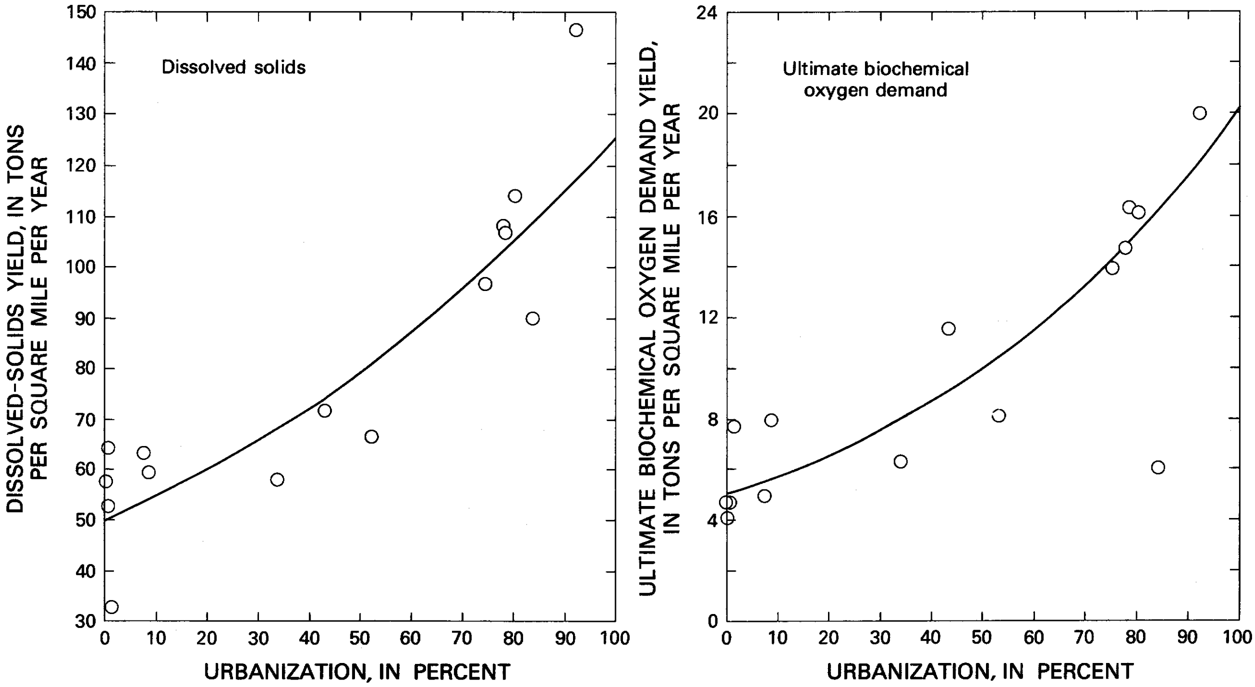


FIGURE 7.—Relationship of average annual yields of dissolved solids and BOD_u to percentage of urbanization.

84 percent urbanized, it is mostly residential. The BOD_u yield of 6.2 tons/mi²/yr from the residential area is about the same as those from forested areas. Thus, it appears that some urban land uses do not substantially increase the yields of some constituents.

AVERAGE ANNUAL URBAN, RURAL, AND FORESTED NONPOINT DISCHARGES TO THE UPPER CHATTAHOOCHEE RIVER

Urban, rural, and forested nonpoint constituent loads were computed for two reaches of the river using the following equation:

$$L = UU_y + RR_y = FF_y,$$

where,

L = nonpoint load in tons,
U = urban area in square miles (table 1),
U_y = urban constituent yield in tons per square mile per year (table 10),
R = rural area in square miles (table 1),
R_y = rural constituent yield in tons per square mile per year (table 10),
F = forested area in square miles (table 1),
F_y = forested constituent yield in tons per square mile per year (table 10).

Constituent loads computed from this equation were compared to nonpoint constituent loads computed from river measurements. Constituent loads from river measurements were computed by subtracting the point-source inputs to each reach of the river from the total inputs between the upper and lower stations in each reach.

A comparison of the nonpoint loads computed by the two methods is shown in table 11. In general, nonpoint constituent loads can be estimated from urban, rural, and forested nonpoint discharge constituent yields.

The data in table 11 indicate that on the average annual basis nonpoint loads in the reaches are as follows:

1. Atlanta to Fairburn, the upper reach (39.8, 11.7, 48.5 percent for urban, rural, and forested). Urban loads are equal to or greater than the sum of rural and forested;
2. Fairburn to Whitesburg, the lower reach (6.5, 16.8, 76.7 percent for urban, rural, and forested). Forested loads are greater than the sum of urban and rural.
3. Atlanta to Whitesburg, the inclusive reach (27.2, 13.6, 59.2 percent for urban, rural, and forested). Urban loads are the greatest and rural the least.

TABLE 11.—*Comparison of average annual nonpoint constituent loads, in tons per square mile per year, computed from urban, rural, and forested yields to nonpoint constituent loads computed from river measurements*

	Dissolved solids	Total nitrogen	Dissolved nitrogen	Dissolved inorganic nitrogen as nitrogen	Total phosphorus	Dissolved phosphorus	Total organic carbon	Total lead
Atlanta to Fairburn:								
Urban	27,400	560	390	260	90	9.2	3,400	44
Rural	4,230	130	110	67	14	1.1	1,300	2
Forest	9,550	330	170	95	47	2.4	2,300	12
Total (rounded)	41,200	1,000	670	420	150	13	7,000	58
River measurements	63,300	1,200	700	1,000	430	89	6,700	82
Fairburn to Whitesburg:								
Urban	2,720	55	39	------	8.9	.92	340	4.3
Rural	3,700	120	93	------	12	.93	1,100	1.7
Forest	9,140	310	170	------	45	2.3	2,200	12
Total (rounded)	15,600	480	300	------	66	4.1	3,600	18
River measurements	6,000	700	100	------	10	10	8,000	30
Atlanta to Whitesburg:								
Urban	30,100	620	430	------	99	10	3,700	48
Rural	7,930	250	200	------	26	2.0	2,400	3.7
Forest	18,700	640	340	------	92	4.7	4,500	24
Total (rounded)	56,700	1,500	970	------	220	17	11,000	76
River measurements	69,900	1,900	800	------	440	99	15,000	110

COMPARISON OF MAGNITUDE OF POINT AND NONPOINT DISCHARGES TO THE UPPER CHATTAHOOCHEE RIVER

Most of the average annual (fig. 8) and March 12–15, 1976, storm-constituent loads (fig. 9) at the Whitesburg station (RM 259.85) are from nonpoint discharges. On an average annual basis, nonpoint discharges contribute 78 percent of the dissolved-solids load, 48 percent of the total phosphorus load, 51 percent of the total nitrogen load, 82 percent of the TOC load, and 74 percent of total copper, lead, and zinc loads at Whitesburg. During the storm period of March 12–15, 1976, nonpoint discharges contributed 90 percent of the dissolved-solids load, 84 percent of the total phosphorus load, 79 percent of the total nitrogen load, and more than 90 percent of the arsenic and lead loads at Whitesburg (fig. 9). Most of the low-flow (June 1–2, 1977) constituent loads at the Franklin station (RM 235.46) were from point discharges (table 12). Point discharges contributed 90 percent of the total phosphorus load, 92 percent of the PO_4-P load, 78 percent of the total nitrogen load, and 80 percent of the inorganic nitrogen as nitrogen load.

A comparison of the high- and low-flow constituent loads downstream from Atlanta shows (1) high-flow loads are greater than low-flow loads, (2) most of the high-flow loads are from nonpoint discharges, and (3) constituent concentrations resulting from these loads are low. High-flow loads generally occur during the cooler months of the year, December through April. The minimum DO concentration at the Fairburn station monitor during these months was greater than 6.0 mg/L (fig. 10). The maximum phytoplankton concentration in West Point Lake was 27,000 cells/mL. Low-flow loads are mostly from point discharges, and constituent concentrations in the river resulting from these loads are large compared to constituent concentrations in the river resulting from nonpoint discharges (table 12). Point-source loads are relatively constant in comparison to non-source loads. The minimum DO concentration at the Fairburn station monitor during the period May through November 1977 was 3.6 mg/L. The maximum phytoplankton concentration in West Point Lake was 560,000 cells/mL.

PRESENT AND FUTURE EFFECTS OF POINT AND NONPOINT DISCHARGES ON THE DISSOLVED-OXYGEN REGIME OF THE UPPER CHATTAHOOCHEE RIVER

The effects of point and nonpoint discharges on the DO regime in the Atlanta (RM 302.97)-to-Franklin (RM 235.46) reach of the river were determined (Stamer and others, 1978) for two low-flow periods, August 31 to September 9, 1976, and June 1–2, 1977. Data used in the determination of these effects on the DO regime are shown in table 13. The method used in the determination was the Velz (1970) rational method of stream analysis.

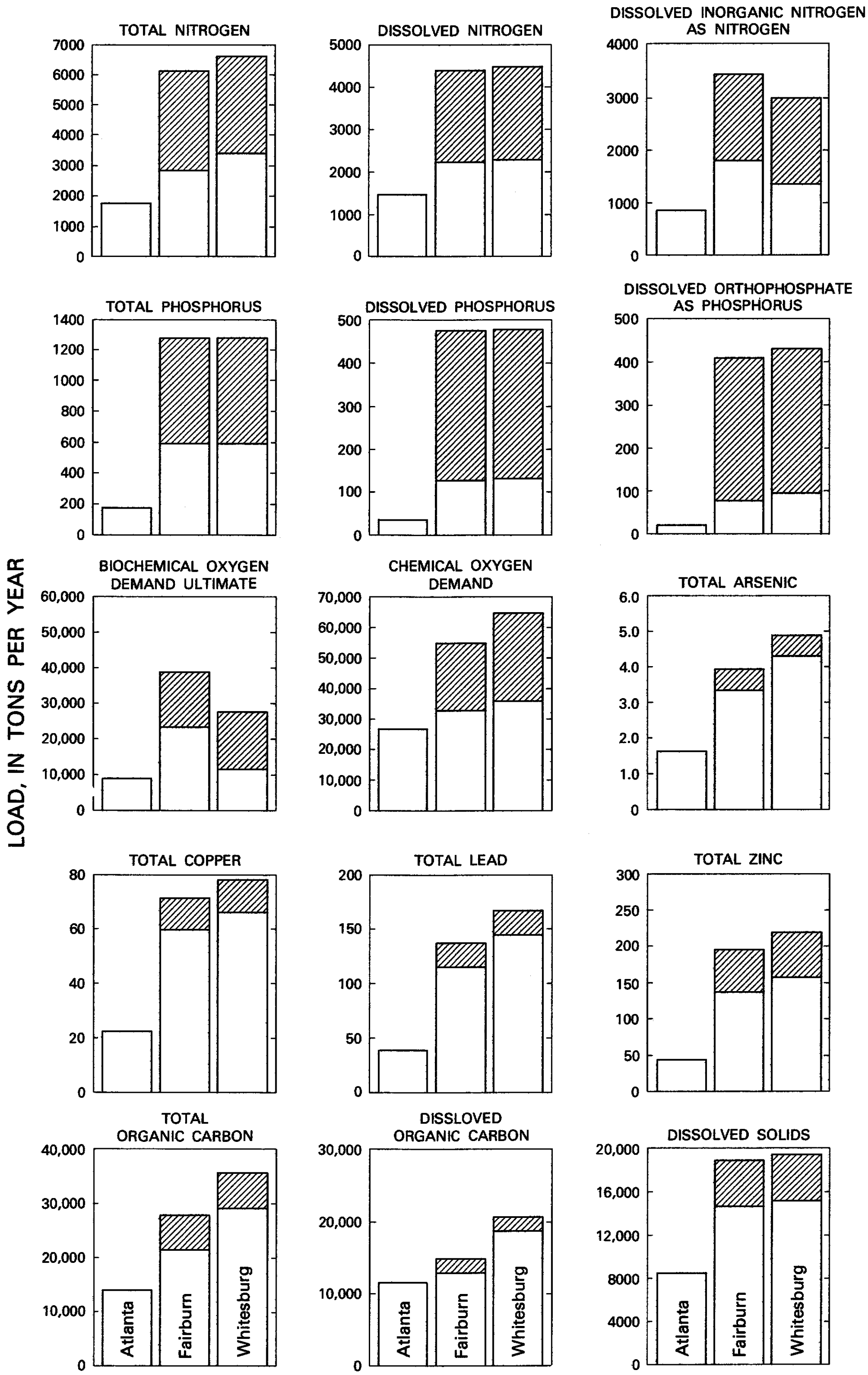


FIGURE 8.—Magnitude and nature of average annual point (crosshatched) and nonpoint (clear) loads for selected constituents at stations on the Chattahoochee River at Atlanta, Fairburn, and Whitesburg.

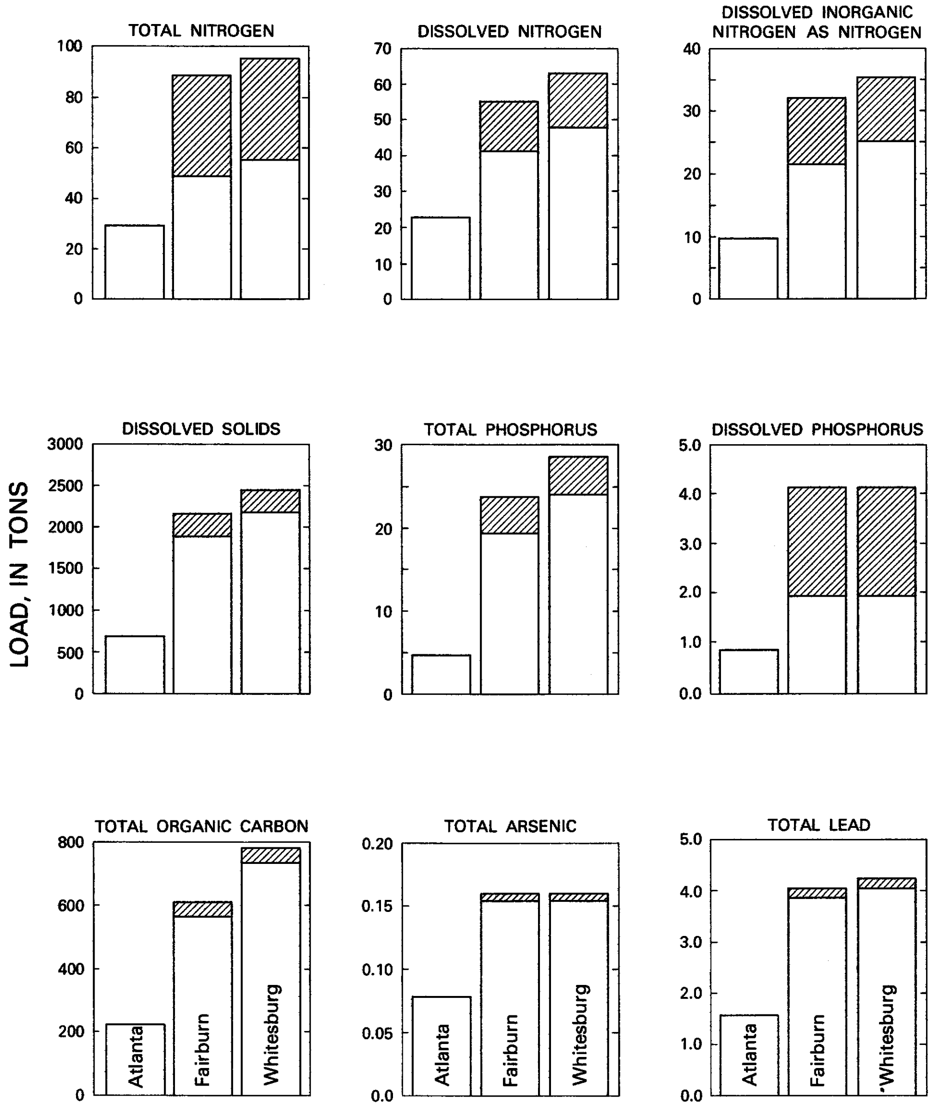


FIGURE 9.—Magnitude and nature of point (crosshatched) and nonpoint (clear) loads for selected constituents at stations on the Chattahoochee River at Atlanta, Fairburn, and Whitesburg during the storm period of March 12–15, 1976.

The DO balance is affected by deoxygenation and reoxygenation. Deoxygenation results from microbial aerobic oxidation of decomposable organic material and biological oxidation of reduced forms of nitrogen. The amount and rate of deoxygenation in the river are dependent on the magnitude and distribution of BOD_u and NH_4-N loads, the time of water passage from reach to reach, and the water temperature. Stream reoxygenation depends on the magnitude of stream-flow and increments of tributary inflow along the watercourse, and reaeration from the atmosphere. Atmospheric reaeration depends on water temperature, channel geometry, occupied channel volume, and the oxygen deficit.

Rates of deoxygenation and reoxygenation were developed from extensive analyses of river and tributary water and wastewater samples and from detailed cross-section measurements of the river channel. For this purpose, two intensive synoptic surveys, August 31 to September 9, 1976, and June 1–2, 1977, were conducted during

TABLE 12.—*Constituent loads at the Atlanta, Fairburn, Whitesburg, and Franklin stations, constituent loads from point discharges, and resulting constituent concentrations at Franklin, June 1–2, 1977*

[Results in tons per day except where indicated]

Stream station	Dissolved solids	Total phosphorus	Total orthophosphate as phosphorus	Total nitrogen	Total inorganic nitrogen as nitrogen	Flow (ft^3s)
Atlanta	99	0.11	0.075	1.46	0.93	1,150
Fairburn	308	2.69	1.82	12.07	8.04	1,610
Whitesburg	328	2.72	1.83	12.30	8.24	1,890
Franklin	334	2.72	1.83	12.44	8.34	1,990
Point discharges	148	2.46	1.69	9.7	6.65	185
Constituent concentration at Franklin (mg/L)	62.2	0.51	0.34	2.3	1.6	------
Nonpoint constituent concentration (mg/L)	38.2	0.053	0.029	0.56	0.35	------

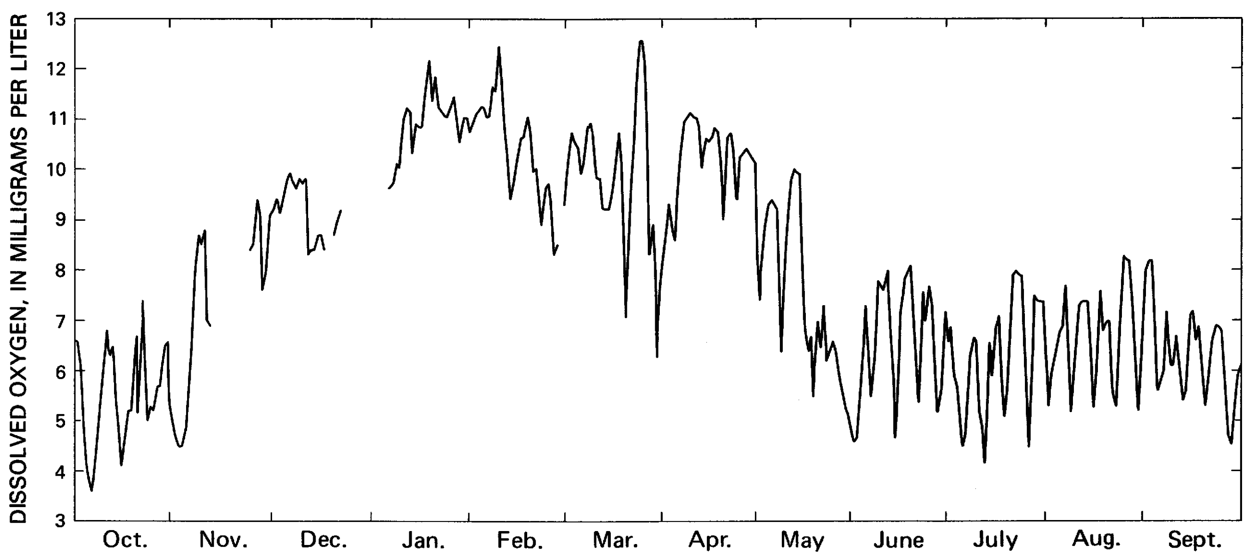


FIGURE 10.—Mean daily DO concentrations at the Chattahoochee River near Fairburn station monitor, October 1976 to September 1977.

steady-state low-flow river conditions. The June 1–2, 1977, survey was used to develop the stream self-purification factors for definition of cause-effect relationships. The August 31 to September 9, 1976, survey was used to verify the cause-effect relationships developed in June 1977.

Laboratory measurements of BOD concentrations were made at intervals during a 20-day incubation period to define the carbonaceous rate of decay, k_1, and BOD_u. A nitrification inhibitor, 1-allyl-2-thiourea, was added to water samples for BOD analysis (Hines and others, 1978). A mean k_1 of 0.07 (base 10) at 20°C was determined from laboratory BOD samples from point and nonpoint discharges and was adjusted for prevailing water temperatures in the study reach. The k_1 selected was applied to a mass-balance integration of point- and nonpoint source BOD_u loads of 36 and 21 tons/day, respectively, in the Atlanta-to-Franklin reach of the river at the prevailing time of passage as shown by curve A in figure 11. From curve A, the maximum accumulated residual BOD_u load, 49 tons/day, occurs at the Sweetwater Creek confluence (RM 288.58) and decreases to a residual of 34 tons/day at Franklin (RM 235.46).

A comparison of the observed and computed river BOD_u loads converted to concentrations in milligrams per liter is shown in figure 12. The

TABLE 13—*Chemical, physical, and flow data used to comute DO profiles in the Atlanta-to-Franklin reach of the river for the years 1977 and 2000*

Station name	River mile	Water temperature (°C) September 1976	Water temperature (°C) June 1977	Flow (ft^3/s) June 1977	Flow (ft^3/s) September 1976	Flow (ft^3/s) 7Q10	Flow (ft^3/s) 2000	Ultimate biochemical oxygen demand (mg/L) September 1976	Ultimate biochemical oxygen demand (mg/L) June 1977	Ammonium nitrogen (mg/L) September 1976	Ammonium nitrogen (mg/L) June 1977	Dissolved oxygen (mg/L) September 1976	Dissolved oxygen (mg/L) June 1977
Chattahoochee River at Atlanta	302.97	20.5	20.8	1,150	1,081	1,150	1,193	2.4	4.0	0.01	0.02	9.0	9.2
Chattahoochee River (Atlanta Intake) at Atlanta	300.62	------	21	−110	−110	------	−109	------	------	------	------	------	------
Cobb Chattahooche WTF near Atlanta	300.56	27	22	16	16	------	31	76	67	12	10.4	3.0	.7
Peachtree Creek at Atlanta	300.52	23	22	84	37	15	------	3	7	.09	.12	8.0	6.7
R. M. Clayton WTF at Atlanta	300.24	27	24	130	128	------	161	40	81	12	14.5	3.3	1.2
Proctor Creek at SR 280 at Atlanta	297.50	22	22	7.4	6.1	1.5	------	21	50	6.7	2.9	3.8	4.0
Nickajack Creek at Cooper Lake Road near Mableton	295.13	22	22	21	13	2.4	------	2.4	.68	.01	.04	8.4	8.5
South Cobb Chattahoochee WTF near Mableton	294.28	29	21	14	13	------	48	54	86	5.0	13.2	7.4	.7
Utoy Creek WTF near Atlanta	291.60	29	23	18	19	------	44	33	27	13	14	2.4	3.1
Utoy Creek at SR 70 near Atlanta	291.57	23	22	16.5	10	2	------	9	6	.42	.16	5.0	7.5
Sweetwater Creek near Austell	288.58	23	22	214	130	15	------	2.6	5	.05	.05	6.4	7.7
Sweetwater Creek WTF near Austell	288.57	------	------	------	------	------	3	------	------	------	------	------	------
Camp Creek WTF near Atlanta	283.78	26	22	7.3	6	------	27	45	11	.02	5.8	3.1	3.8
Camp Creek at Enon Road near Atlanta	283.54	24	21	19	10	4	------	1.8	4	.01	.08	6.8	8.0
Deep Creek at SR 70 near Tell	283.77	23	20	21	10	3	------	1.0	4	.01	.01	6.6	8.6
Anneewakee Creek at SR 166 at Douglasville	281.47	24	21	26	17	4	------	1.6	4	.02	.02	6.9	8.8
Anneewakee Creek WTF near Douglasville	281.46	------	------	------	------	------	6	------	------	------	------	------	------
Three-river interceptor	281.45	------	------	------	------	------	42	------	------	------	------	------	------
Pea Creek at SR 70 near Palmetto	277.40	21	------	------	4	------	------	0.8	------	------	------	6.9	------
Bear Creek at SR 166 near Douglasville	275.95	22	20	40	11	5	------	1.0	4	.01	.02	8.2	9.2
Bear Creek (SR 166) WTF near Douglasville	275.94	------	------	------	------	------	8	------	------	------	------	------	------
Bear Creek at SR 70 near Rico	274.49	23	21	16.5	6	.5	------	1.8	4	.01	.01	6.6	8.4
Dog River at SR 166 near Fairplay	273.46	24	21	95	42	6	------	2.3	4	.00	.02	9.1	9.0
Wolf Creek at SR 5 near Banning	267.34	21	21	19	13	15	------	1.3	4	.01	.02	8.9	8.6
Snake Creek near Whitesburg	261.72	22	21	52	46	9	------	2.3	4	.00	.02	9.0	8.8
Cedar Creek at SR 70 near Roscoe	261.25	22	22	30	14	7	------	1.3	4	.02	.06	4.6	8.2
Wahoo Creek at Arnco Mills	259.85	22	22	27	2.2	4	------	7.8	------	------	.02	5.2	8.9
Whooping Creek near Lowell	250.87	22	22	27	23	4	------	1.5	3	------	.03	8.3	8.8
Pink Creek near Centralhatchee	244.89	22	21	10	4	1	------	1.8	4	------	.01	7.5	8.4
Centralhatchee Creek at US 27 near Franklin	236.51	22	22	65	26	13	------	1.0	3	------	------	------	------

overall close agreement between the independently observed and the computed river concentrations supports the adoption of the BOD_u decay rate of 0.07 (at 20°C). The lowest BOD_u concentrations, 3.6 to 5.2 mg/L, were observed at the Atlanta station, and the highest, about 10 to 18 mg/L, at SR (State Route) 139. The high BOD_u concentrations at SR 280 were due to the addition of 32 tons/day of BOD_u from point discharges.

The computed BOD_u concentrations decreased from a maximum of 12.8 mg/L at SR 280 to 6.3 mg/L at Franklin, or about 50 percent (fig. 10). In the same reach the BOD_u load decreased from 44 to 34 tons/day, or about 23 percent.

A nitrogenous rate of oxidation, k_3, of 0.19 (base 10) was determined from observed NH_4-N concentration changes in the river, with consideration of effects due to dilution during the June 1977 survey. The k_3 selected was applied to a mass-balance integration of point- and nonpoint-source NH_4-N loads, 6.8 and 0.21 tons/day, respectively in the Atlanta-to-Franklin reach of the river at the prevailing time of passage as shown by curve B in figure 11. The maximum accumulation of unoxidized NH_4-N of 6.5 tons/day occurs at RM 288.58 and decreases to a residual of 2.2 tons/day at RM 235.46. The NO_3-N load (curve C in figure 11) increased from 3.1 tons/day at RM 288.58 to 7.4 tons/day at RM 235.46.

A comparison of the observed and computed river NH_4-N loads converted to concentrations in milligrams per liter is shown in figure 13. The overall close agreement between the independently observed and computed river concentrations supports the adoption of the NH_4-N decay rate of 0.19. The lowest NH_4-N concentrations,

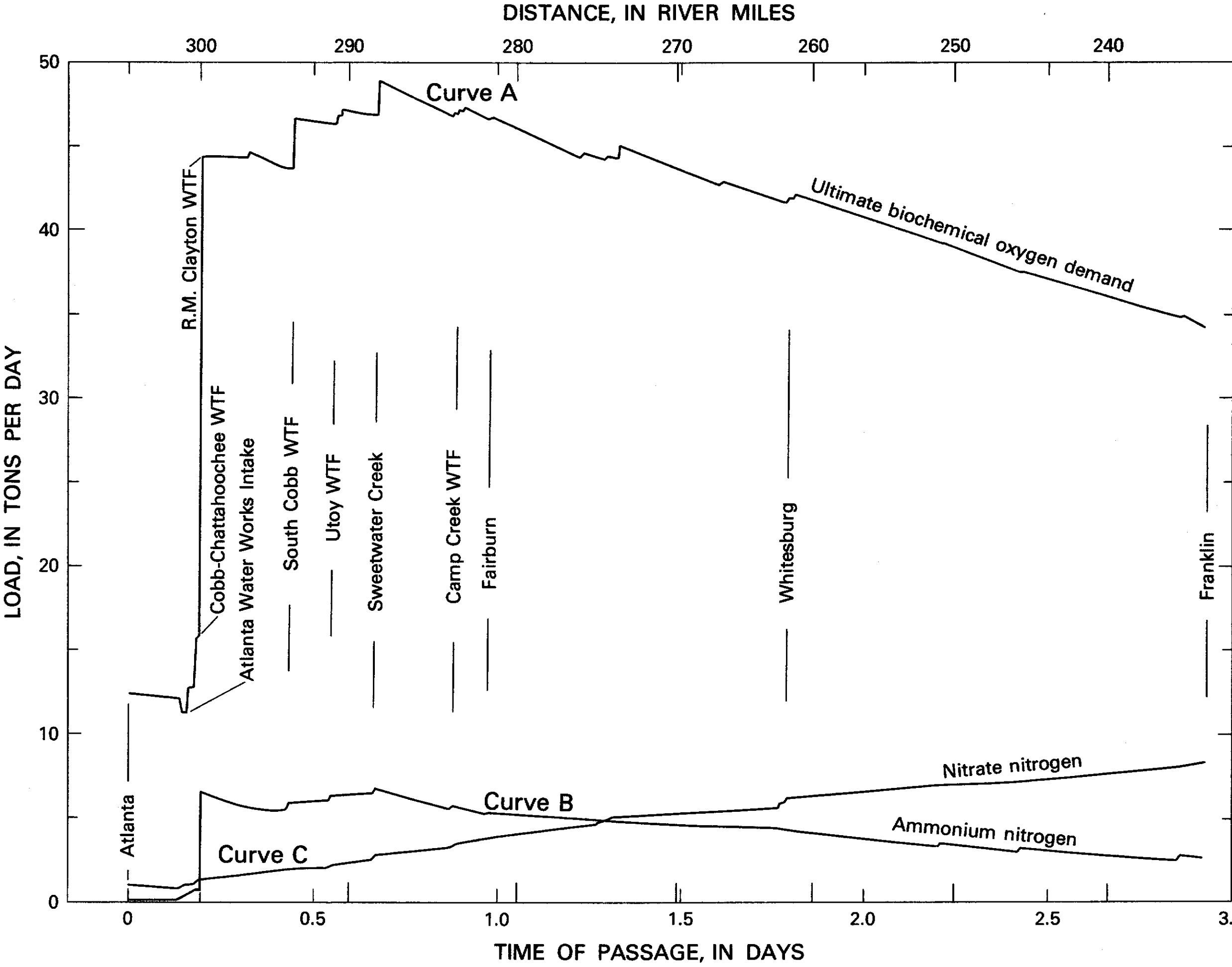


FIGURE 11.—Magnitude of point- and nonpoint-source BOD, ammonium nitrogen, and nitrate nitrogen loads in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.

0.00 to 0.04 mg/L, were observed at the Atlanta station and the highest, 1.2 to 2.4 mg/L, at SR 280 (RM 298.77). The computed NH_4-N concentrations decreased from 1.7 mg/L at SR 280 to 0.40 mg/L at Franklin. The lack of agreement (about 0.15 mg/L) between the observed and computed NH_4-N concentrations at Bush Head Shoals (RM 246.93) and at Franklin may be due, in part, to NH_4-N assimilation by extensive periphytic growth on the shoals in this reach of the river.

A comparison of the independently observed and computed conversion of river NH_4-N to NO_3-N concentrations is shown in figure 14. The overall close agreement indicates that the formation of NO_3-N was mostly due to the oxidation of NH_4-N at a k_3 of 0.19. The lowest NO_3-N concentrations, 0.25 to 0.31 mg/L, were observed at the Atlanta station, and the highest, 1.2 to 1.4 mg/L, at Franklin.

An overall confirmation of the self-purification factors adopted (k_1 = 0.07 at 20°C and k_3 = 0.19) is shown by the comparison of the observed and computed river DO concentrations in figure 15 for the June 1–2, 1977, intensive synoptic survey. The highest DO concentrations, 8.1 to 10.8 mg/L, were observed at the Atlanta station. Point-source NH_4-N and BOD_u discharges and the heat load from the thermal powerplants cause the observed DO concentrations to decrease to 4.4 mg/L just upstream of the Capps Ferry Bridge (RM 271.19). DO concentrations less than 5.0 mg/L were observed in a 22-mile reach of the river from Fairburn (RM 281.88) to Whitesburg (RM 259.85). The DO concentrations gradually in-

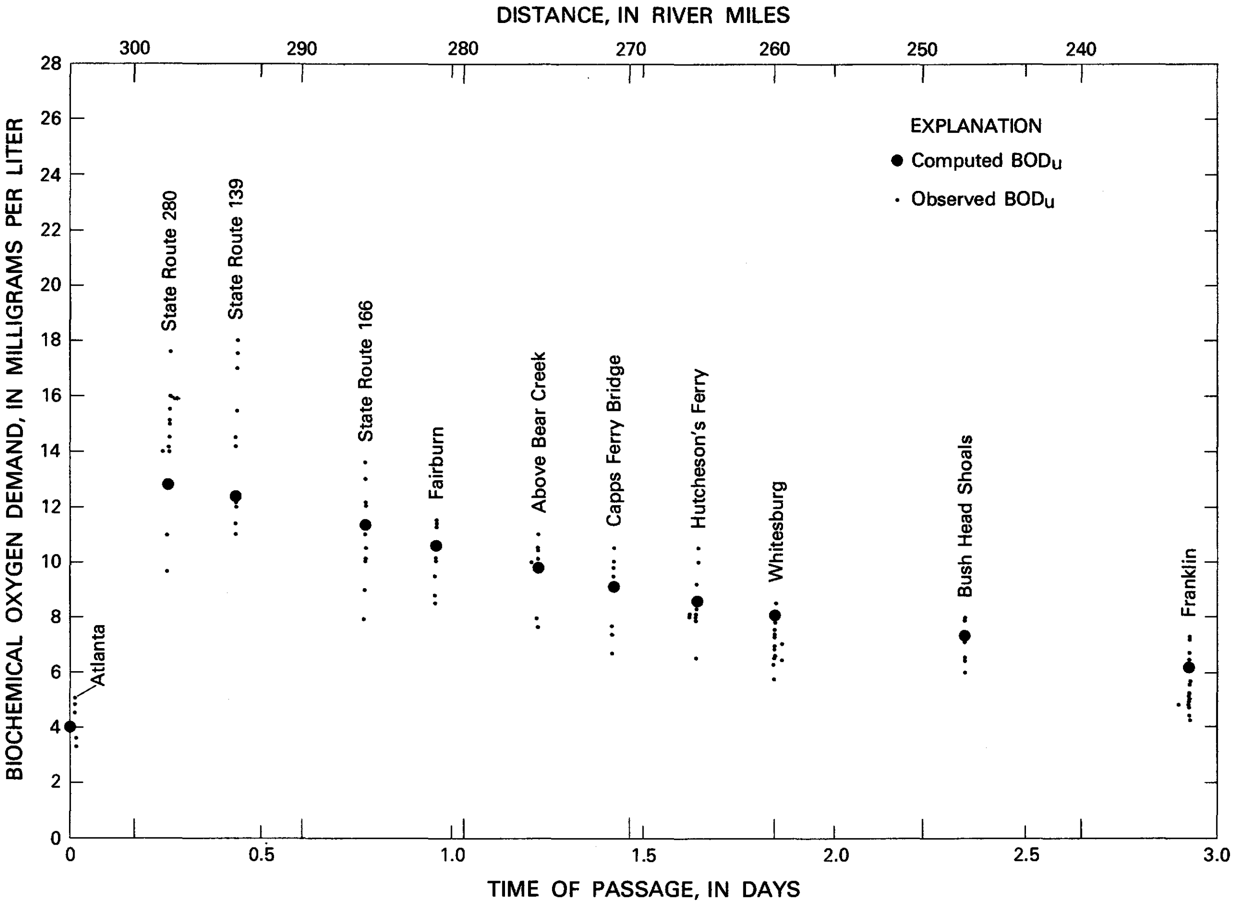


FIGURE 12.—Comparison of observed and computed BOD_u concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.

creased from 4.4 mg/L just upstream of the Capps Ferry Bridge to an observed concentration of 7.2 mg/L at Franklin.

DO concentrations in the river for the June 1–2, 1977, survey are decreased about equally by carbonaceous (52 percent) and nitrogeneous (48 percent) oxygen demands. The computed effect of carbonaceous demands only (k_1 – 0.07 at 20°C) on DO concentrations is shown in figure 16, and the effect of nitrogenous demands only (k_3 – 0.19) is shown in figure 17. In the upper reach of the river (RM 302.97 to RM 271.19), 48 percent of the carbonaceous oxygen demands and 58 percent of the nitrogenous oxygen demands are exerted, because the nitrogenous demands occur at a higher rate than do the carbonaceous demands. The computed minimum DO concentration exceeds 6.0 mg/L in figures 16 and 17.

Average observed water temperatures in the Atlanta-to-Franklin reach are shown in figure 18. The lowest average water temperature, 20.8°C, occurred at the Atlanta station, and the highest average water temperature, 27.1°C, occurred just downstream (RM 298.77) from the Atkinson-McDonough powerplants. Downstream from the Atkinson-McDonough plants, the lowest average temperature, 24.0°C, occurred at Hutcheson's Ferry (RM 255.66). The observed average water temperature at Whitesburg was 25°C and was the equilibrium temperature without the thermal discharges from the Atkinson-McDonough plants. The average water temperature at Franklin was 26.7°C.

An analysis of the effect of the heat load from the Atkinson-McDonough plants on the DO and BOD regimes for the period June 1–2, 1977, indicates that the DO concentrations are about 0.2 mg/L less with the heat load than without. With the heat load, 34 tons/day of BOD_u reached the lake, and without the heat load 35 tons/day of

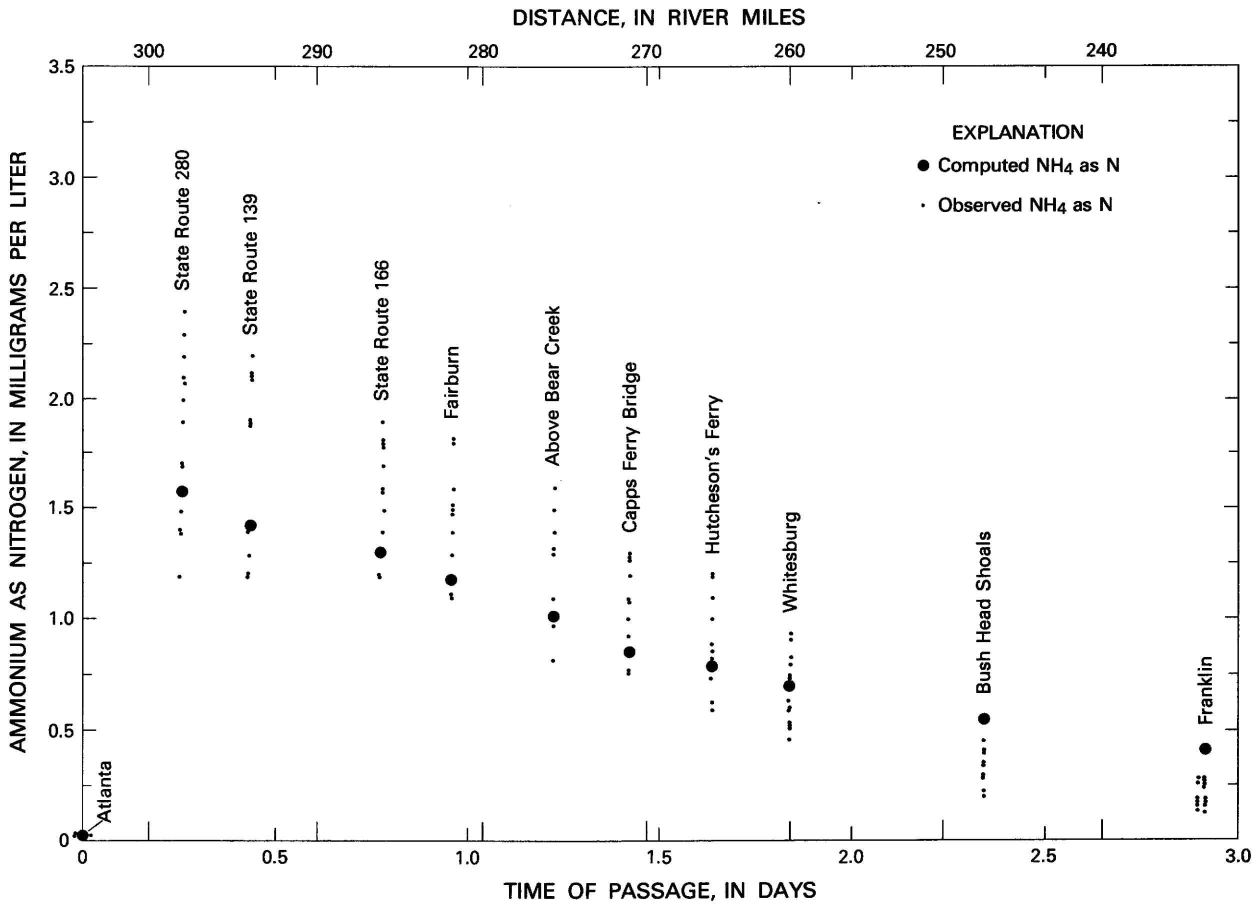


FIGURE 13.—Comparison of observed and computed ammonium nitrogen concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.

BOD_u reached the lake. The difference in the BOD residual loads at Franklin relative to the heat load was about 3 percent. Therefore, the net effect of the Atkinson-McDonough plant heat loads on the DO and BOD regimes appears to be negligible.

The computed DO profile from data collected during the low-flow period of August 31 to September 9, 1976, (table 13) is shown in figure 19. A 0.07 k_1 and a 0.19 k_3 (the same as those in June 1977) were used in the DO computations. The flows at the Atlanta station and tributaries and the nonpoint-source BOD_u and point-source BOD_u and NH_4-N loads (21.3 and 5.51 tons/day) were less in September 1976 than in June 1977. The lesser flows and loads in September 1976 resulted in a DO profile similar to that observed in June 1977.

The close agreement between the computed and observed DO profiles permit projection of results from wastewater management alternatives.

ECONOMIC CONSIDERATIONS OF WASTEWATER MANAGEMENT ALTERNATIVES

Schefter and Hirsch (1979) evaluated the cost of four alternatives for maintaining a minimum DO concentration of 3, 4, or 5 mg/L in the river for the years 1980, 1990, and 2000. All wastewater from the WTF's was assumed to receive at least secondary treatment (45 mg/L BOD_u, 15 mg/L NH_4-N).

The alternatives evaluated were:

1. The least-cost combination of nitrification (27 mg/L BOD_u, 3 mg/L NH_4-N) of a percentage of the total wastewater discharge and

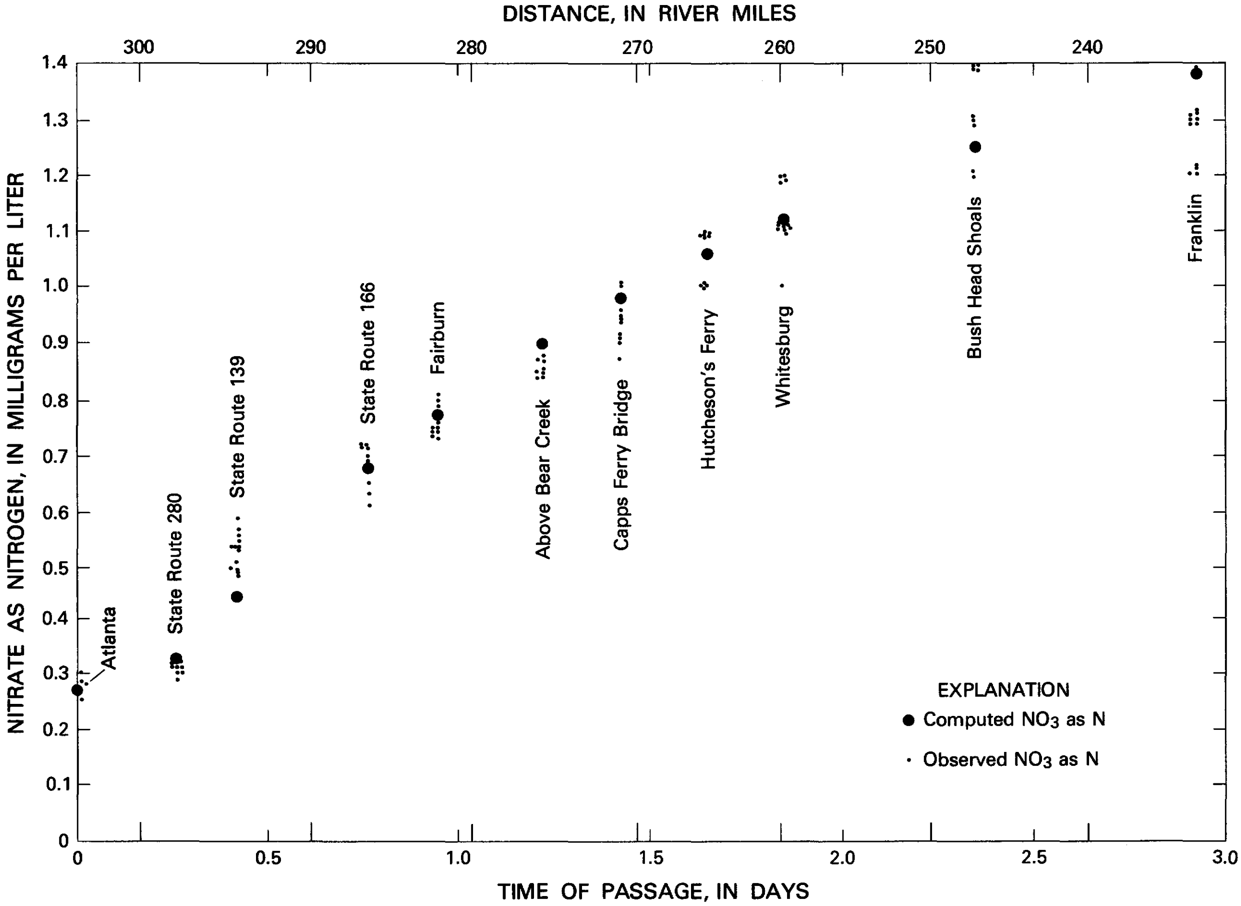


FIGURE 14.—Comparison of observed and computed nitrate nitrogen concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.

modification of the present hydropower generation pattern at Buford Dam.

2. Nitrification of some percentage of the total wastewater discharge without modifying power generation patterns at Buford Dam.
3. Nitrification of the total wastewater discharge without modifying present power generation patterns at Buford Dam.
4. The least-cost combination of nitrification of some percentage of total wastewater discharge without modifying the present power generation pattern at Buford Dam, and assuming the storage capacity of Morgan Falls reservoir is increased and a reregulation structure is built downstream from Buford Dam.

Computations of minimum DO concentrations are based on the following conditions: (1) point-source discharges from Atlanta to Franklin of 250, 314, and 370 ft^3/s in the years 1980, 1990, and 2000, respectively, (2) point-source discharges containing concentrations of 45 and 27 mg/L BOD_u and 15 and 3 mg/L NH_4-N, (3) tributary inflows of 93 ft^3/s from Atlanta to Franklin (lowest consecutive 7-day mean flow that occurs once in 10 years) and (4) minimum sustained streamflow at the Atlanta station ranging from 860 to 1,800 ft^3/s. The computed minimum DO for various combinations of wastewater treatment (expressed in percentage of total wastewater treatment discharge receiving nitrification) and flow at the Atlanta station are summarized in figure 20. To attain a minimum DO concentration of 4.0 mg/L in the Atlanta-to-Franklin reach with a streamflow of 1,500 ft^3/s at the Atlanta station would require nitification of 22 percent (55 ft^3/s) of

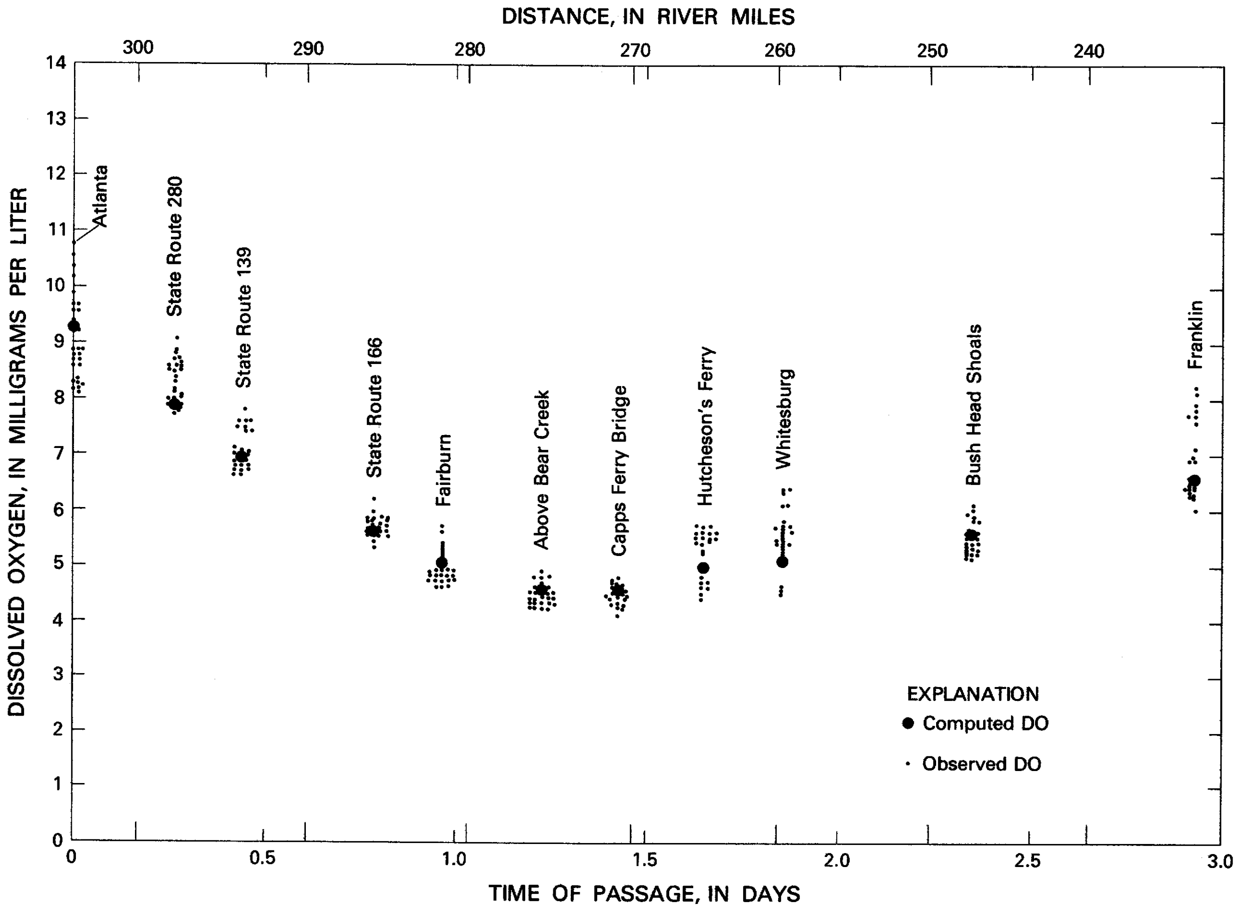


FIGURE 15.—Comparison of observed and computed DO concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.

the wastewater discharge in 1980, 36 percent (113 ft^3/s) in 1990, and 48 percent (179 ft^3/s) in the year 2000.

COST OF WASTEWATER TREATMENT

The additional cost of nitrification for each of the WTF's in the Atlanta-to-Franklin reach was estimated using information provided in the Atlanta Regional Commission's wastewater management plans and Giffels and others (1977).

Annual operating costs attributable to upgrading the facilities were added to annualized capital cost to determine the total annual cost of nitrification. The estimated cost and flow for each facility are shown in table 14. Annual costs were related to the percentage of the total point-source load receiving nitrification in the years 1980, 1990, and 2000 (fig. 21). The figure shows that in 1980, if 50 percent of the wastewater was nitrified rather than treated at secondary levels, the additional cost would be $1.6 million per year. The additional cost for 1990 would be $2.0 million per year, and for the year 2000, $2.5 million per year.

COST OF CHANGING RELEASE PATTERN FROM BUFORD DAM

The U.S. Army Corps of Engineers (1975) in a study of the Buford Dam/Lake Sidney Lanier project estimated that 74 percent of the average annual benefits consist of recreation benefits, 17 percent consist of benefits from hydroelectric power, and the remainder, 9 percent, are from flood control, navigation (in the Apalachicola Waterway), water supply (for the Atlanta Met-

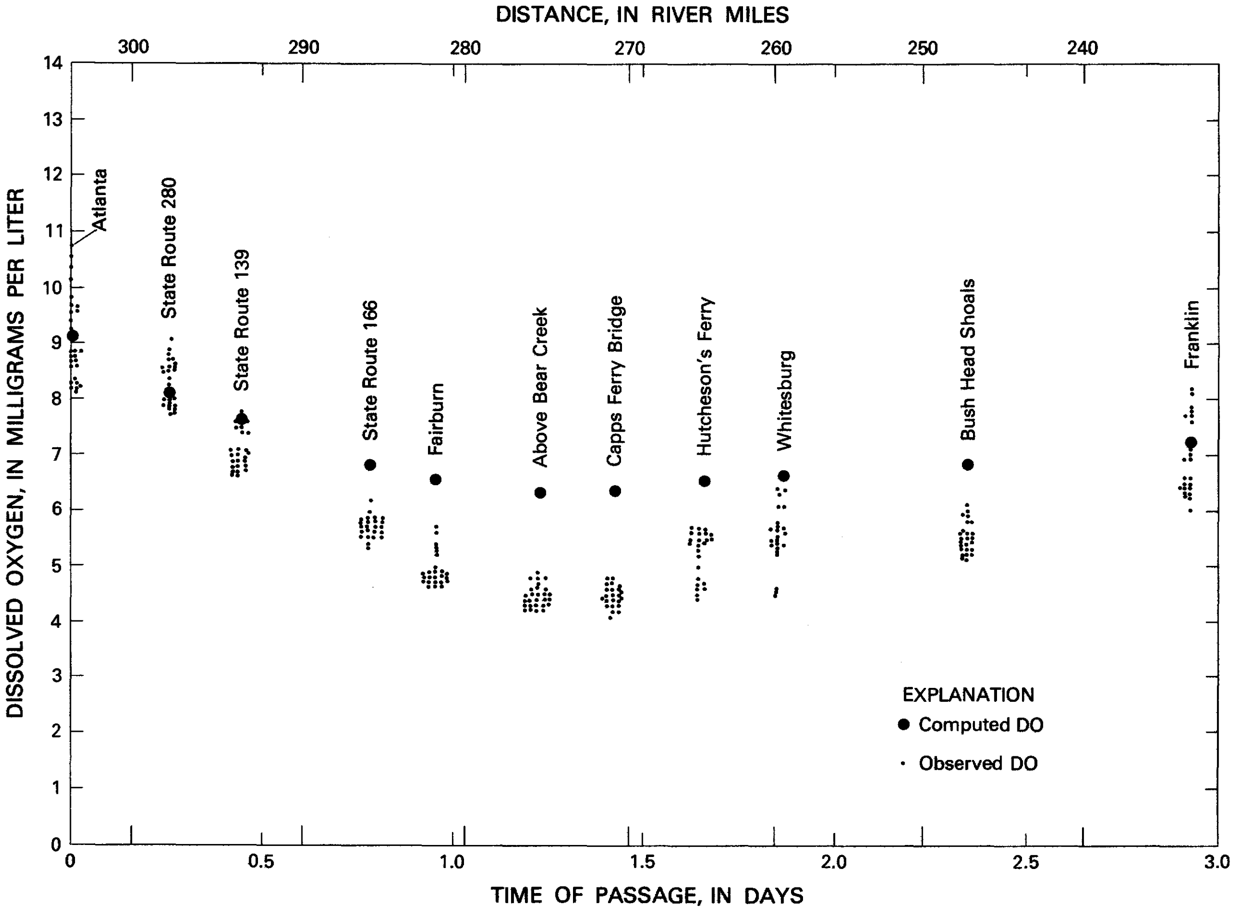


FIGURE 16.—DO concentrations observed and DO concentration profile due only to carbonaceous oxygen demands in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.

TABLE 14.—*Average daily flow of waste treatment plants discharging to the Chattahoochee River between Atlanta and Whitesburg and the annualized cost of converting the plants from secondary to advanced levels of treatment (nitrification)*

[Costs in first quarter 1976 dollars]

Plant Name	River mile	1980		1990		2000	
		Average flow (ft^3/s)	Annual cost ($1,000)	Average flow (ft^3/s)	Annual cost ($1,000)	Average flow (ft^3/s)	Annual cost ($1,000)
Cobb-Chattahoochee	300.56	24.0	458.40	28.9	518.27	30.7	538.85
R. M. Clayton	300.24	131.1	1,704.19	150.0	1,932.45	161.3	2,069.03
South Cobb	294.78	38.1	694.43	51.1	851.60	48.5	819.79
Utoy Creek	291.60	42.0	722.43	46.0	771.07	44.0	746.75
Sweetwater Creek	288.57	------	------	2.9	147.69	2.6	143.95
Camp Creek	283.78	15.0	359.82	22.0	444.02	27.2	507.63
Anneewakee Creek	281.46	------	------	6.0	193.84	6.0	193.84
Regional Interceptor	281.45	------	------	------	------	42.4	726.14
Bear Creek	274.48	------	------	7.0	207.34	7.7	216.69

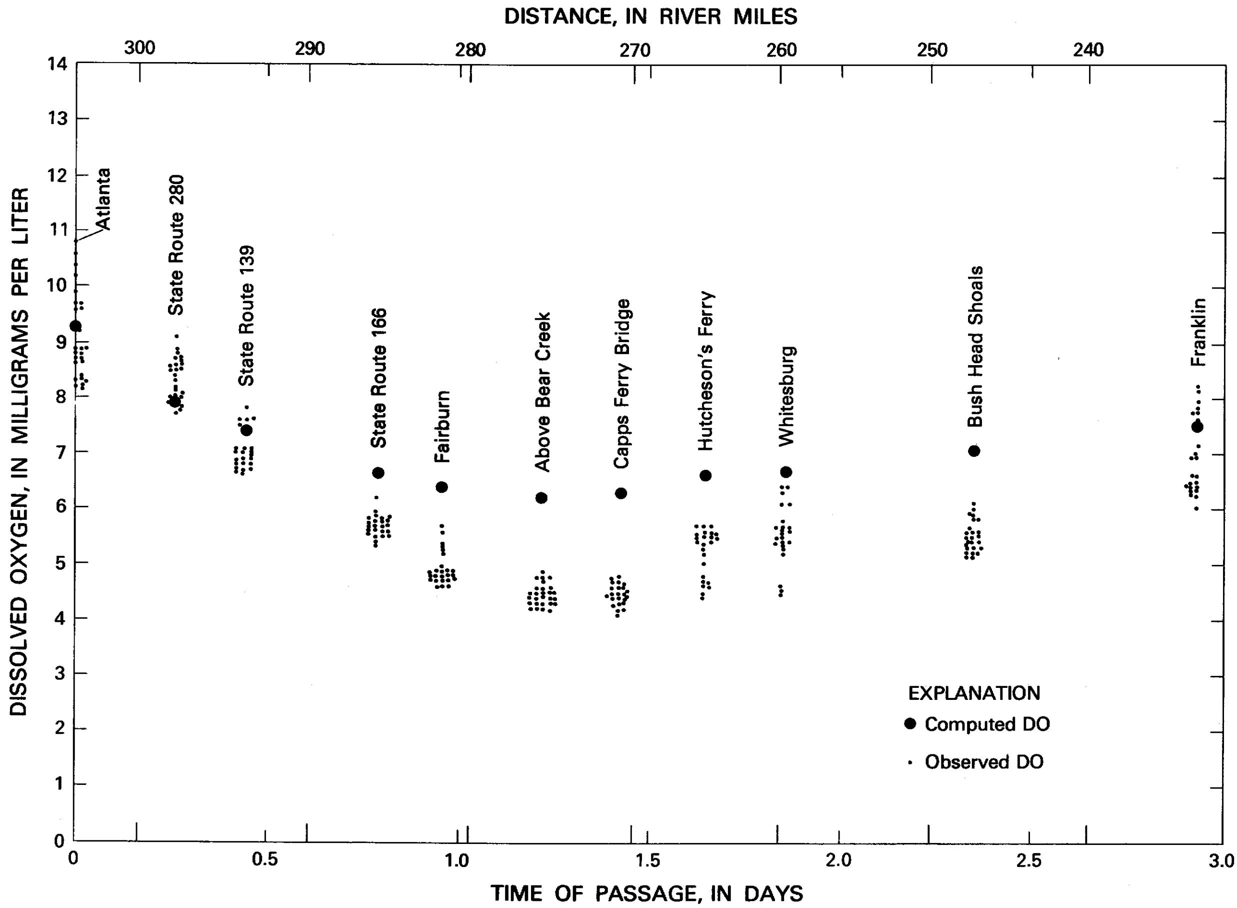


FIGURE 17.—DO concentrations observed and DO concentration profile due only to nitrogenous oxygen demands in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.

ropolitan Area), and low-flow water-quality maintenance (for the Chattahoochee River from Atlanta to West Point Lake). Hydroelectric power benefits may be subdivided into three types: benefits of energy production in peak demand hours, benefits of energy production in nonpeak demand hours, and dependable peaking capacity benefits.

The changes in the pattern of release for Buford Dam considered by Schefter and Hirsch (1979) result in almost no change in benefits except for dependable peak hydropower capacity. To sustain higher minimum flows at the Atlanta station, the release of water during peak periods of electricity demands must be decreased in low-flow years, causing a corresponding decrease in the dependable peak power capacity. It is assumed that the dependable peaking capacity lost at Buford Dam could be replaced by the construction of a facility comparable in cost ($23.34 kW/yr) to Georgia Power Company's Rocky Mountain pump-storage project. The annual benefits foregone are the losses in dependable peaking capacity times this $23.34 kW/yr.

Figure 22 shows the relationship between flow at the Atlanta station and the annual benefits foregone at Buford Dam for the years 1980, 1990, and 2000. The differences in flow at the Atlanta station are due to increases in water-supply withdrawals from Lake Sidney Lanier and from the Chattahoochee River from an annual average of about 170 ft^3/s in 1980, 240 ft^3/s in 1990, to 610 ft^3/s in 2000.

FIGURE 19.—Comparison of observed and computed DO concentrations in the Atlanta-to-Franklin reach of the river during ▶ low-flow period, August 31 to September 9, 1976.

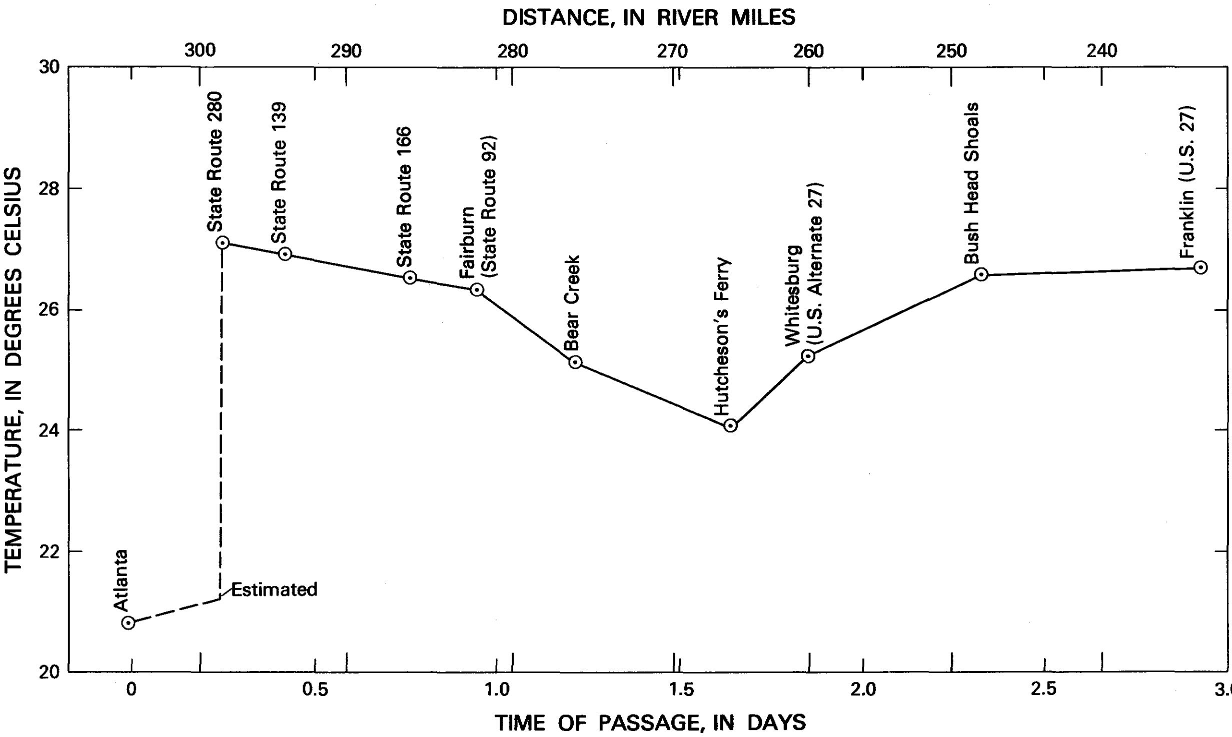
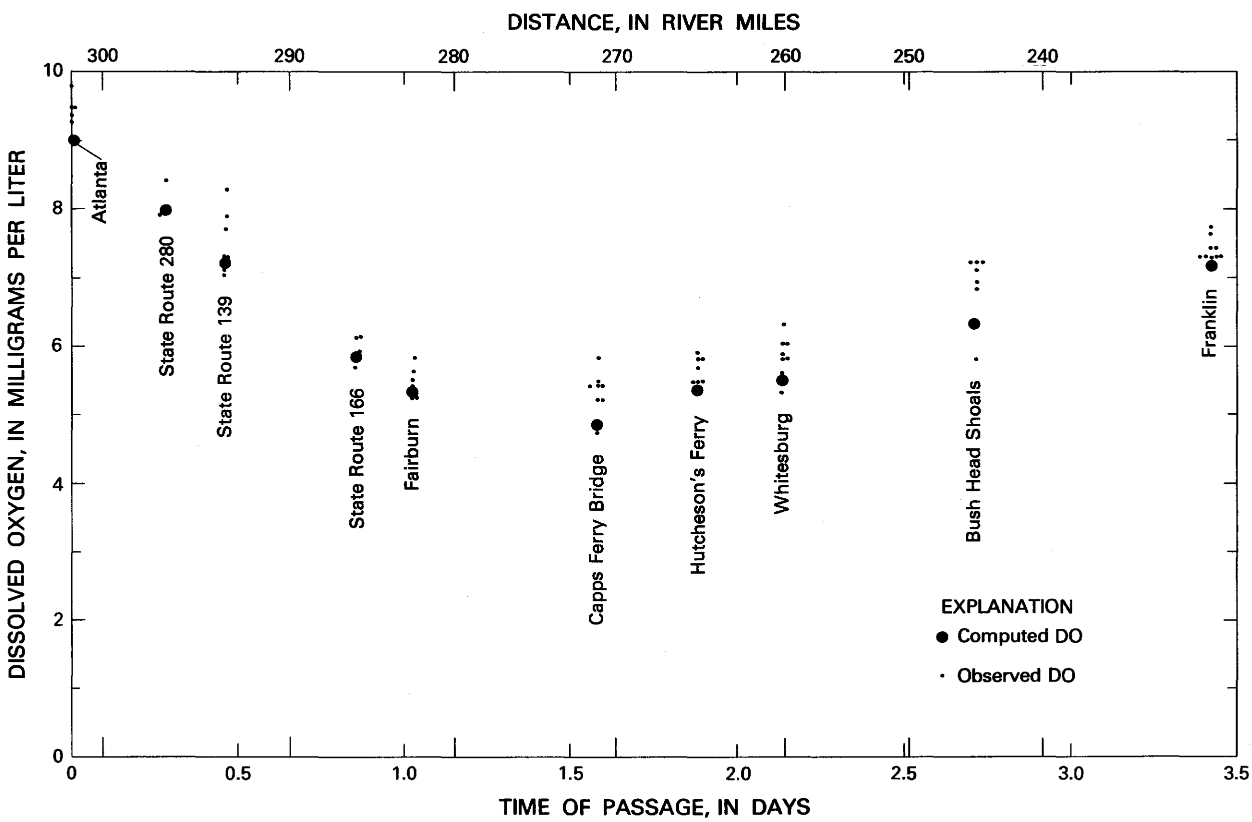


FIGURE 18.—Temperature of river water in the Atlanta-to-Franklin reach of the river during low-flow period, June 1–2, 1977.



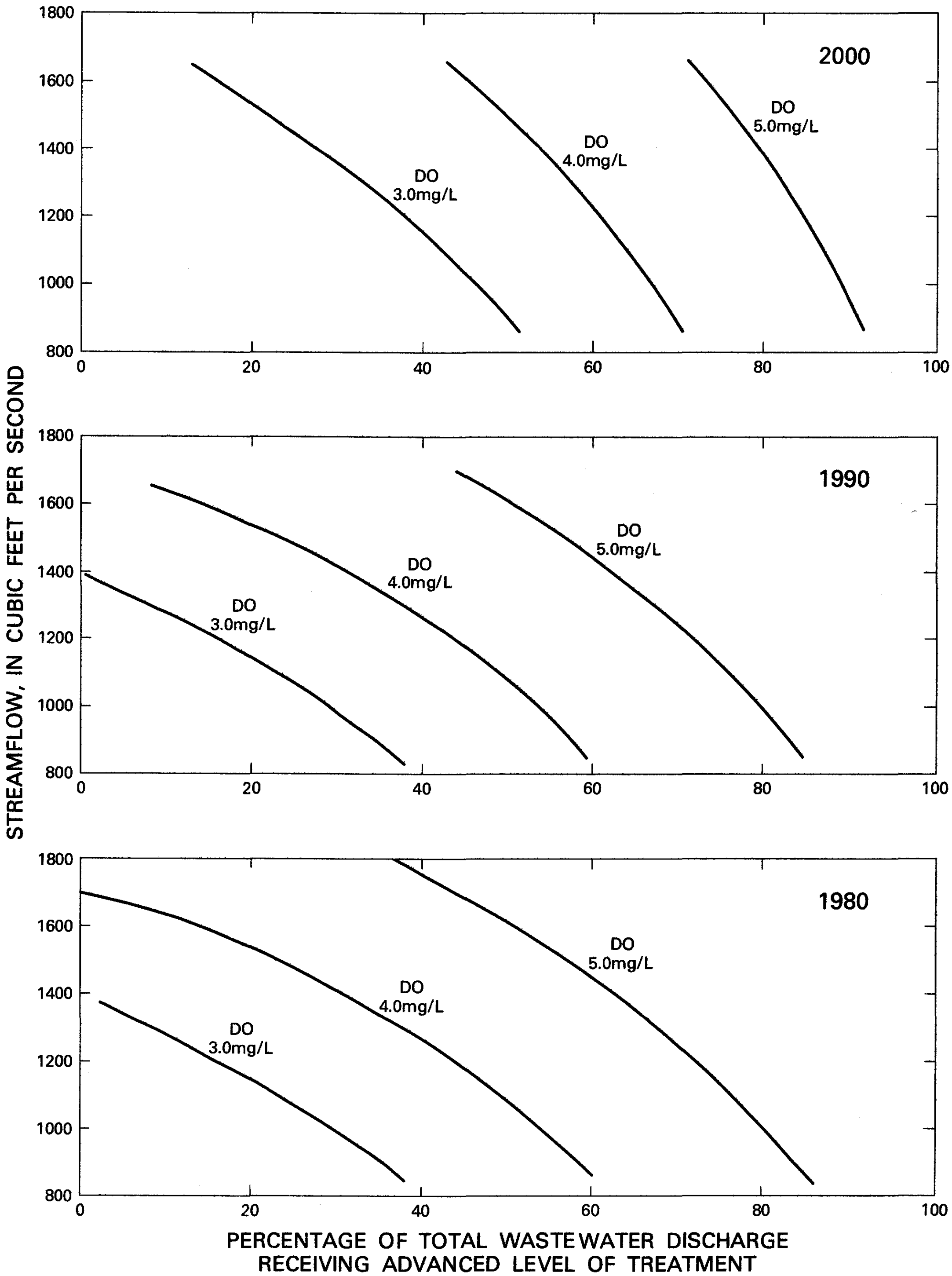


FIGURE 20.—Relationship of minimum DO concentration to streamflow at Atlanta station and percentage of total wastewater discharge nitrified for years 1980, 1990, and 2000.

The maximum sustainable flow at the Atlanta station after water supply demands are met is 1,670 ft^3/s in 1980, 1,600 ft^3/s in 1990, and 1,230 ft^3/s in 2000. Benefits foregone do not decrease for flow at the Atlanta station less than 1,380 ft^3/s in 1980, 1,290 ft^3/s in 1990, and 870 ft^3/s in 2000.

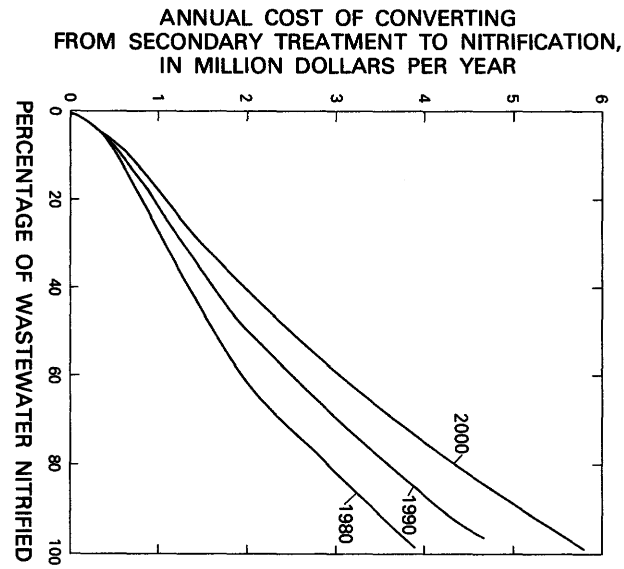


FIGURE 21.—Relationship of annual cost of converting from secondary treatment to nitrification to percentage of total waste discharge nitrified for years 1980, 1990, and 2000.

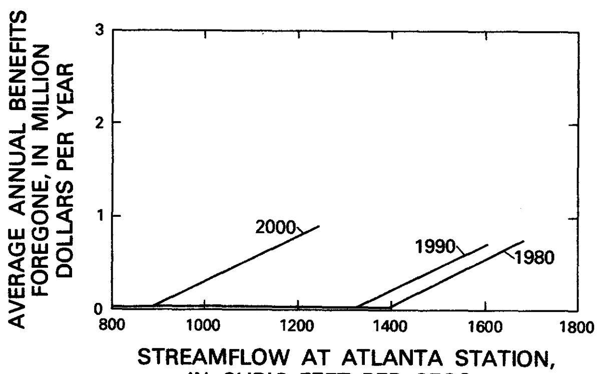


FIGURE 22.—Relationship of average annual benefits foregone at Buford Dam to streamflow at Atlanta station for years 1980, 1990, and 2000.

COST OF REREGULATION OF CHATTAHOOCHEE RIVER FLOWS

A minimum flow of about 1,600 ft^3/s at the Atlanta station could be maintained, and peak power and water-supply demands satisfied, at least through 1990, by constructing a reregulation structure with a water storage volume of 8,400 acre-ft just downstream of Buford Dam and increasing the capacity of Morgan Falls reservoir, by dredging, to a storage volume of 8,500 acre-ft. According to the U.S. Army Corps of Engineers, Lake Sidney Lanier restudy (1975), the capital cost of the reregulation structure would be $11.5 million; operation and maintenance costs would be $65,800 per year. Using a discount rate of 10 percent and a life of 100 years, the annualized cost of the reregulation structure is $1.2 million. The Corps of Engineers reports that the initial cost of dredging Morgan Falls reservoir would be $1.6 million and the annual maintenance cost $15,000 per year. Using a 10-percent discount rate and a 100-year life, the annualized cost of increasing the storage capacity of Morgan Falls Reservoir is $180,000 per year. Thus, the combined annual cost of constructing and operating the reregulation structure and Morgan Falls reservoir would be $1.4 million per year.

COST OF WASTEWATER MANAGEMENT ALTERNATIVES

Assuming a minimum DO concentration of 5 mg/L for the year 1990, the least costly plan would be: nitrification of 63 percent of the total wastewater flow and maintenance of a minimum flow of 1,600 ft^3/s at the Atlanta station. The additional treatment cost is estimated to be $2.72 million per year, and the benefits foregone due to the loss of dependable peaking capacity are estimated to be $0.75 million per year. The total cost (in benefits foregone plus additional treatment cost) is estimated to be $3.47 million per year (table 15, alternative 1).

Without modification of the Buford Dam release pattern, about 92 percent of the wastewater discharge would have to be nitrified in 1990. The estimated cost of the additional treatment would be $4.30 million per year, but no dependable peaking capacity benefits would be foregone (table 15, alternative 2).

The additional cost for nitrification of the total wastewater discharge in 1990 would be $5.05 million per year, or $1.59 million per year more than the least-cost plan (table 15, alternative 3).

The least-cost plan with Morgan Falls reservoir dredged and construction of a reregulation structure would be $4.23 million per year. This cost would include $2.72 million per year for additional treatment cost, $0.10 million per year dependable peaking capacity benefits foregone,

TABLE 15.—*Summary of economic considerations of wastewater management alternatives for years 1980, 1990, and 2000*

Alternative	Minimum dissolved oxygen (mg/L) 1980: 3	1980: 4	1980: 5	1990: 3	1990: 4	1990: 5	2000: 3	2000: 4	2000: 5
1. Treating a proportion of total waste discharge at advanced level and modification of present Buford Dam release pattern:									
Minimum streamflow at Atlanta station in cubic feet per second	1,380	1,670	1,380	1,430	1,600	1,600	870	870	870
Proportion of waste nitrified in percent	0	0	62	0	24	63	52	70	90
Cost:									
Additional cost for nitrification in million dollars per year	0.00	0.00	2.03	0.0	1.08	2.72	2.58	3.76	5.10
Dependable peaking capacity benefits foregone in million dollars per year	.00	.71	.00	.34	.75	.75	.00	.00	.00
Total	.00	.71	1.62	.34	1.83	3.47	2.50	3.74	5.10
2. Nitrifying a proportion of total waste discharge without modification of present Buford Dam release pattern:									
Minimum streamflow at Atlanta station in cubic feet per second	860	860	860	860	860	860	860	860	860
Proportion of waste nitrified in percent	39	59	84	52	72	92	52	70	90
Cost:									
Additional cost for nitrification in million dollars per year	1.35	1.91	3.12	2.10	3.20	4.30	2.58	3.76	5.10
Dependable peaking capacity benefits foregone in million dollars per year	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	1.35	1.91	3.12	2.10	3.20	4.30	2.58	3.76	5.10
3. Nitrifying total waste discharge without modification of plant Buford Dam release pattern:									
Minimum streamflow at Atlanta station in cubic feet per second	860	860	860	860	860	860	860	860	860
Proportion of waste nitrified in percent	100	100	100	100	100	100	100	100	100
Cost:									
Additional cost for nitrification in million dollars per year	3.95	3.95	3.95	5.05	5.05	5.05	5.95	5.95	5.95
Dependable peaking capacity benefits foregone in million dollars per year	.00	.00	.00	.00	.00	.00	.00	.00	.00
Total	3.95	3.95	3.95	5.05	5.05	5.05	5.95	5.95	5.95
4. Nitrifying a proportion of total waste discharge and dredging of Morgan Falls reservoir and constructing a regulation without modification of present Buford Dam release pattern:									
Minimum streamflow at Atlanta station in cubic feet per second	1,640	1,640	1,640	1,560	1,600	1,600	1,230	1,230	1,230
Proportion of waste nitrified in percent	0	0	46	0	24	63	36	58	82
Cost:									
Additional cost for nitrification in million dollars per year	0.00	0.00	1.54	0.00	1.09	2.72	1.77	2.92	4.50
Dependable peaking capacity benefits foregone in million dollars per year	−.01	.20	−.01	−.01	.11	.11	.07	.07	.07
Cost of dredging Morgan Falls and construction of regulation station	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Total	1.39	1.60	2.93	1.39	2.60	4.23	3.24	4.39	5.97

and $1.4 million per year for construction and operation of the facilities (table 15, alternative 4).

The data in table 15 summarize the relative cost of various alternatives. The data indicate that the least-cost plans for 1980 and 1990 require a minimum flow at the Atlanta station of about 1,600 ft^3/s. For the year 2000, however, at least 92 percent of the total wastewater discharge would require nitrification, because a minimum flow greater than about 1,230 ft^3/s could not be maintained at the Atlanta station if water-supply demands are met during drought conditions similar to those in 1954–56.

BIOLOGICAL ASSESSMENT

Studies were conducted to (1) assess the amount and rate of nitrification in the Atlanta-to-Franklin reach of the Chattahoochee River, (2) relate the nutrient concentration to AGP (algal growth potential), and (3) determine the effect of nutrient concentration as measured by AGP on algal growth in the West Point Lake.

NITRIFICATION

Nitrification can be an important factor affecting the DO balance in streams. DO concentration decreases in the river were due to a combination of nitrogenous and carbonaceous oxygen demands. Nitrogenous demands (nitrification) caused approximately 50 percent of the DO decreases in the Atlanta-to-Franklin reach of the river. Figure 23 shows the decreases in DO concentration resulting from nitrification and the total decreases in DO concentration during the low-flow period of June 1–2, 1977.

Nitrification, oxidation of NH_4-N to NO_3-N, proceeds in two steps catalyzed by the chemoautotrophic bacteria, *Nitrosomonas* and *Nitrobacter* (Alexander, 1965):

$$NH_4 + 1\tfrac{1}{2}\, O_2 \; \textit{Nitrosomonas} \; NO_2^- + 2H^+ + H_2O$$
$$NO_2^- + \tfrac{1}{2}\, O_2 \; \textit{Nitrobacter} \; NO_3^-$$

Studies by Ehlke (1978) indicate that the concentration of *Nitrobacter* in the benthic sediment, shown in figure 24, ranged from about 10^2 to 10^3/g in the reach from Atlanta to Franklin. *Nitrobacter* was less abundant in the water column than in the benthic sediment throughout the reach, generally less than 10 bacteria/mL. Compared with findings in studies elsewhere (Tuffey and others, 1974; Curtis and others, 1975), the concentration of *Nitrobacter* and *Nitrosomonas* in the Chattahoochee River was very low. The concentration of *Nitrosomonas* in Chattahoochee River water and benthic sediment (fig. 25) was greater than corresponding *Nitrobacter* concentrations.

The observed NH_4-N, NO_2-N, and NO_3-N concentrations in the Chattahoochee River from RM 302.97 to RM 235.46 are shown in figure 26. The concentrations of NH_4-N, NO_2-N, and NO_3-N were lowest near Atlanta (RM 302.97), which is upstream from the Metropolitan Atlanta WTF's. The NH_4-N concentration was maximum at RM 298.99, which is just downstream of the major WTF's. Oxidation of NH_4-N to NO_3-N by bacterial

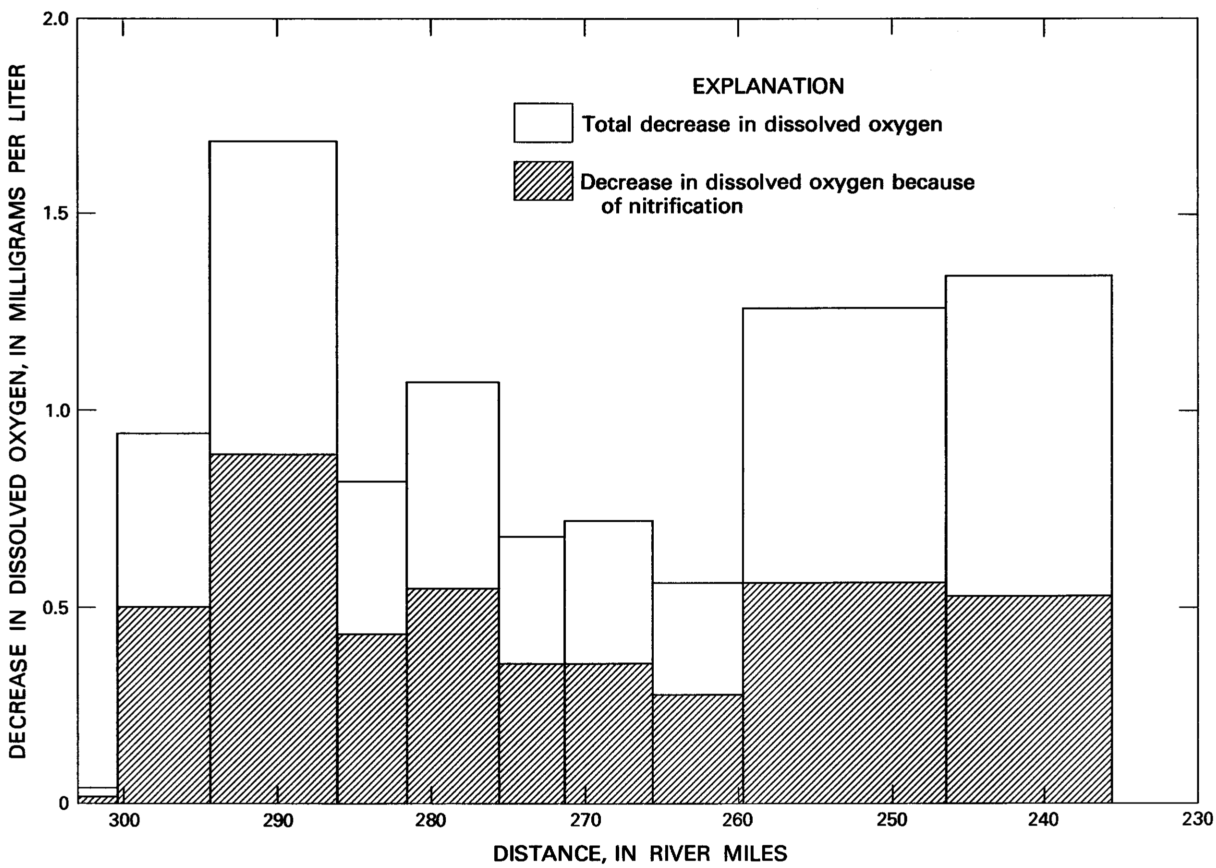


FIGURE 23.—Comparison of decreases in DO resulting from nitrification to total decrease in DO in the Atlanta-to-Franklin reach during low-flow period, June 1–2, 1977.

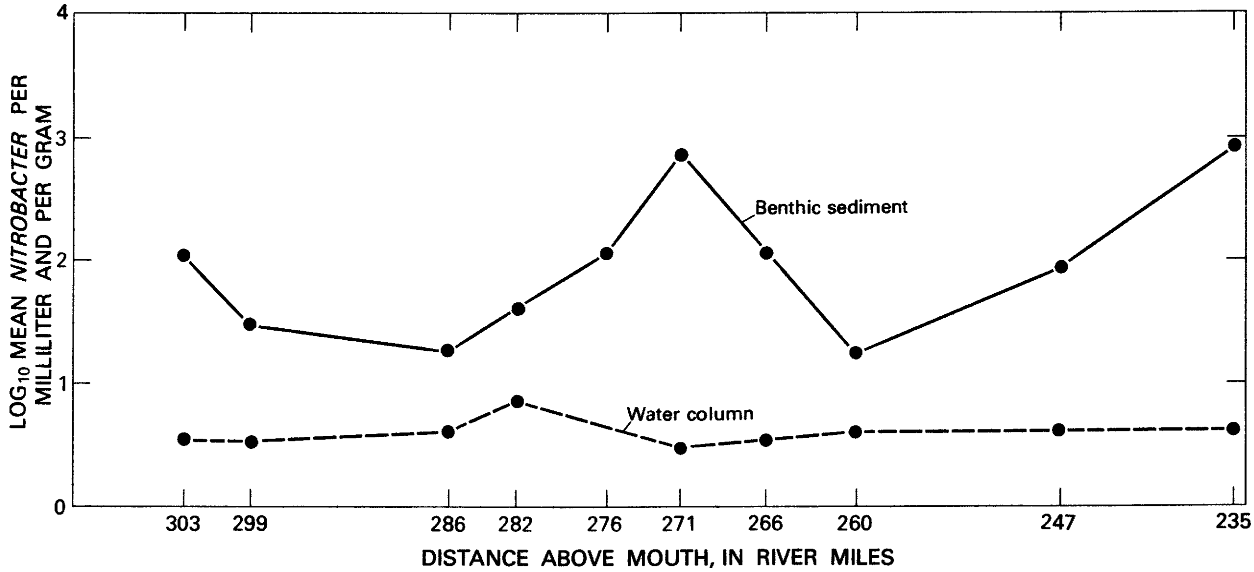


FIGURE 24.—*Nitrobacter* population in Chattahoochee River water and benthic sediment during June 1–2, 1977.

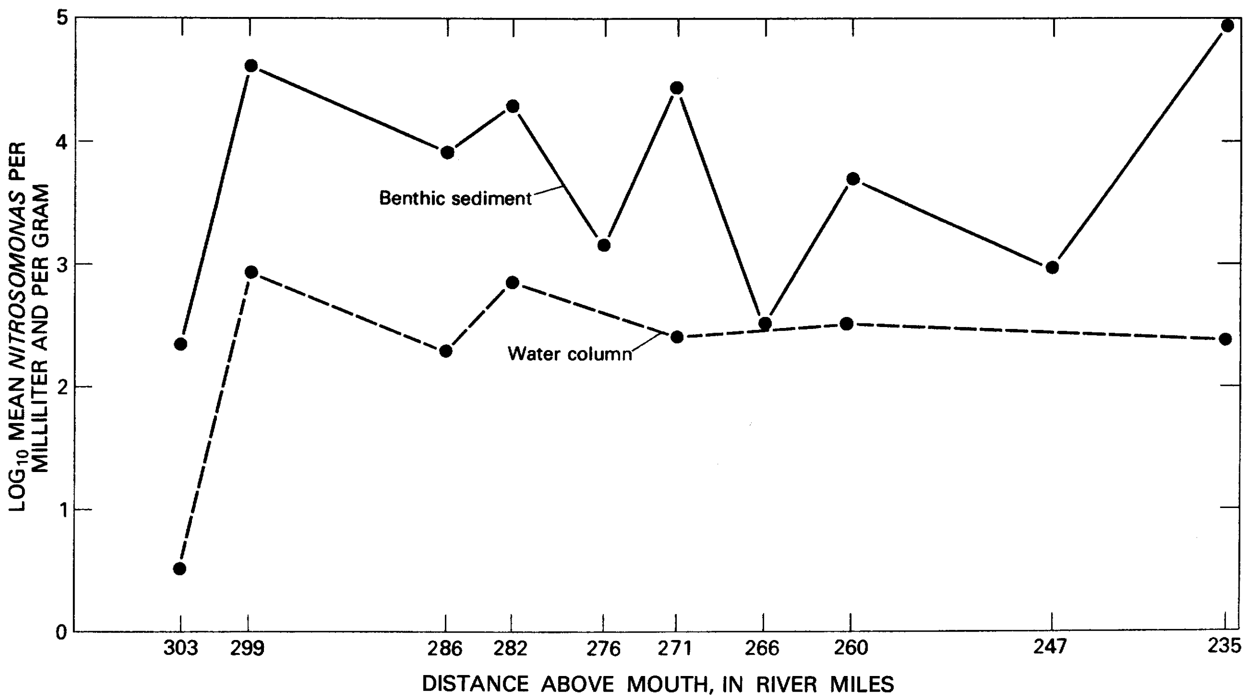


FIGURE 25.—*Nitrosomonas* population in Chattahoochee River water and benthic sediment during June 1–2, 1977.

nitification occurred nearly linearly from RM 298.99 to RM 235.46. The maximum concentration of NO_3-N, which is the end product of nitification, occurred near the downstream end of the study reach.

The concentration of NH_4-N decreased at almost a constant rate of 0.02 mg/L/h (milligrams per liter per hour) during June 1–2, 1977, from RM 298.77 to RM 235.46, on the basis of a traveltime of about 65 h and a change in concentration of NH_4-N from 1.8 to 0.2 mg/L (fig. 22).

The concentrations of NO_3-N increased at al-

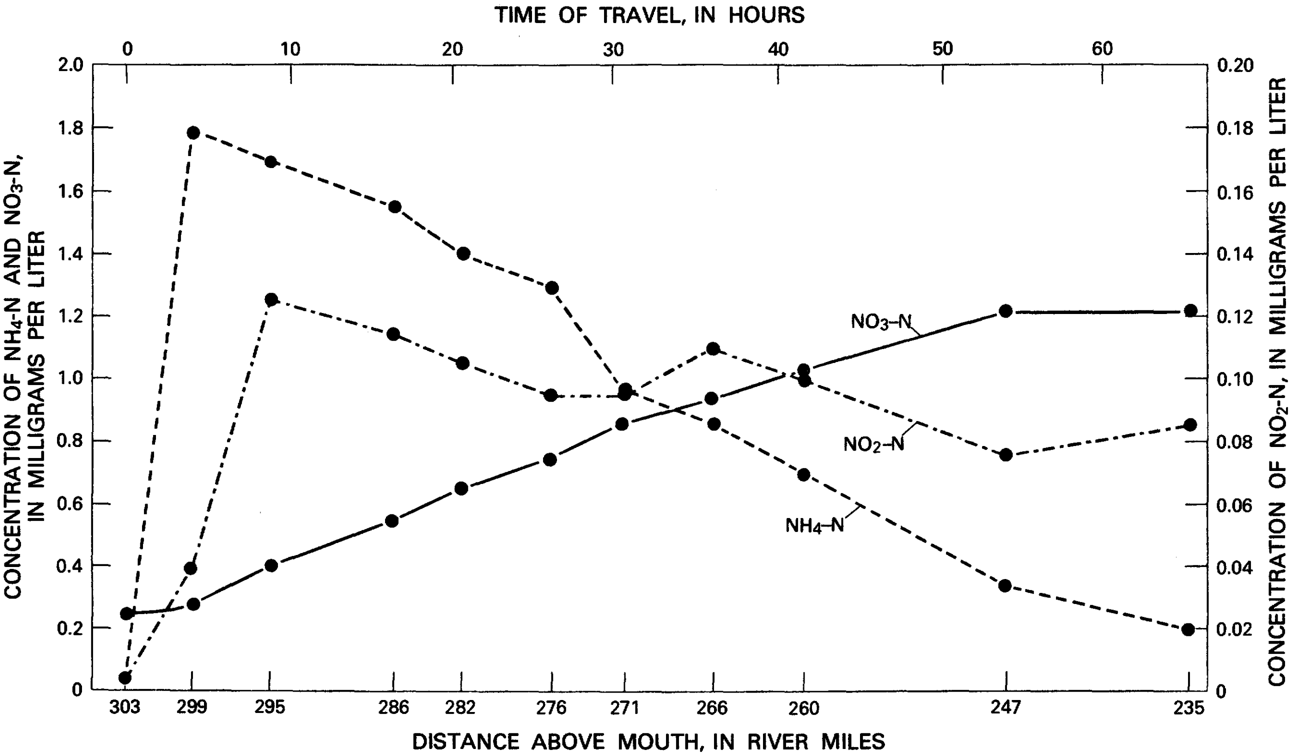


FIGURE 26.—Mean concentrations of ammonium, nitrite, and nitrate as nitrogen in the Chattahoochee River during June 1–2, 1977.

most a constant rate of 0.02 mg/L/h during the period of June 1–2, 1977, from RM 302.97 to RM 246.93. The increase in NH_4-N concentration was approximately equal to the decrease in the NO_3-N concentration during the period of June 1–2, 1977.

Generally, the greater concentration of nitrifying bacteria in river-bed sediments compared with that in the water column has led many investigators to conclude that most nitrifying bacteria activity probably occurs in benthic sediments, not in the water column (Tuffey and others, 1974; Matulewich and Finstein, 1978).

All sampling for nitrifying bacteria was done when the flow of the Chattahoochee River was near 1,150 ft^3/s and the mean depth from RM 302.97 to RM 258.63 was about 4.7 ft. Using the data of figures 24 and 25, the relative concentrations of *Nitrosomonas* and *Nitrobacter* can be calculated in a 4.7 ft water column and 0.4 in benthic sediment column. Averaging the data, 53 percent of the *Nitrosomonas* are calculated to be in the water column, and 47 percent in the top 0.4 in of benthic sediment. Similarly, 72 percent of the *Nitrobacter* were present in the water column, and 28 percent in the benthic sediment. This indicates that, during the study period, most nitrifying bacterial activity occurred in the water column, not in the benthic sediment.

PHYTOPLANKTON

Concentrations of phytoplankton (diatoms, green algae, and blue-green algae) were generally higher downstream from Atlanta than upstream of Atlanta (Lium and others, 1978). Concentrations of phytoplankton were higher in Lake Sidney Lanier and West Point Lake than in the river and tributaries, with maximum concentrations occurring in West Point Lake downstream from Franklin.

Figure 27 shows a comparison of phytoplankton concentrations from the headwaters of the Chattahoochee River to the West Point Dam during August 1976. The highest concentration (mostly blue-green algae) occurred in West Point Lake. The lowest concentration occurred near Norcross. Figures 28, 29, and 30 show the monthly variation in average concentrations of the various

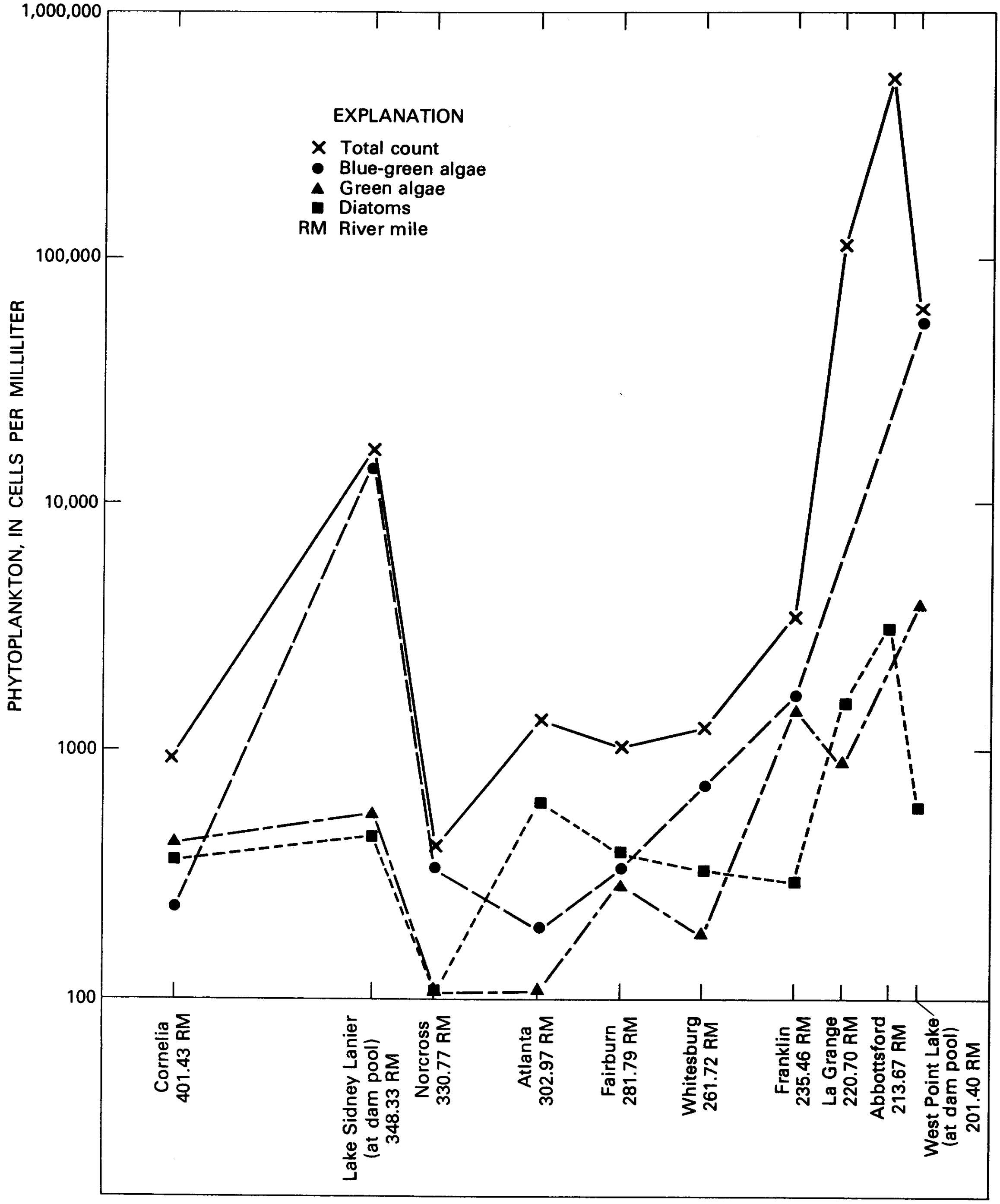


FIGURE 27.—Concentration of phytoplankton by river mile for August 1976.

phytoplankton genera in Lake Sidney Lanier and West Point Lake. Average concentrations of blue-green (fig. 28) and green algae (fig. 29) were highest in West Point Lake. In the spring, monthly concentrations of diatoms (fig. 30) were highest at Lake Sidney Lanier. The spring diatom increase as shown in figure 30 did not occur in West Point Lake. The blue-green algae were dominant in both lakes, and concentrations were highest during the summer months. Diatom concentrations generally exceeded the green algae concentrations in both lakes.

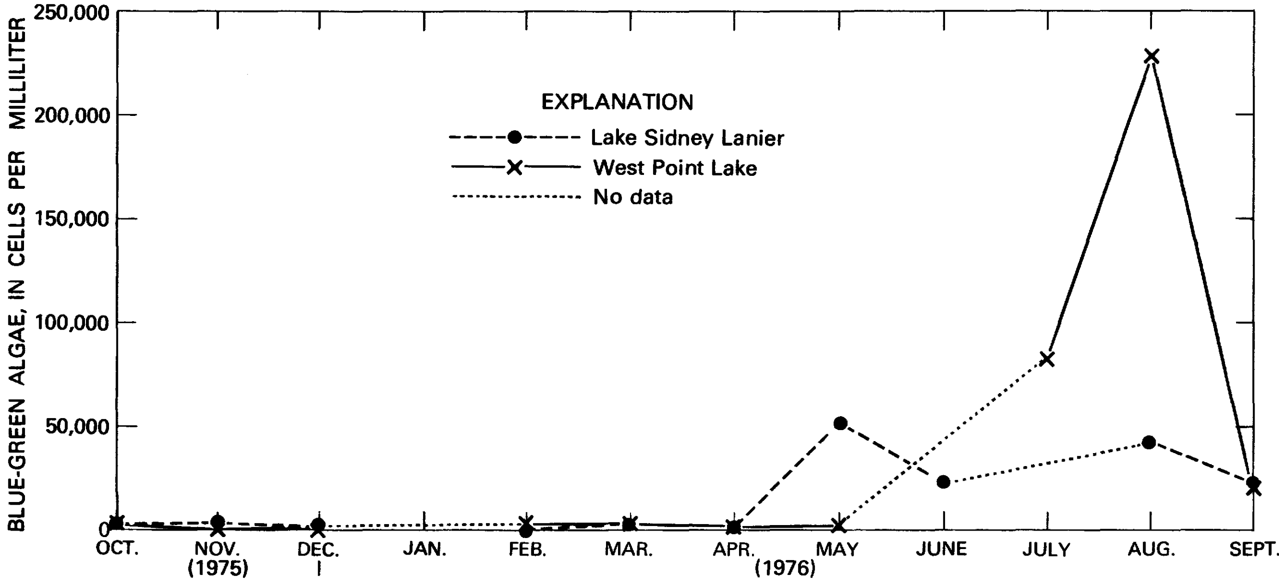


FIGURE 28.—Average concentration of blue-green algae by month in Lake Sidney Lanier and West Point Lake.

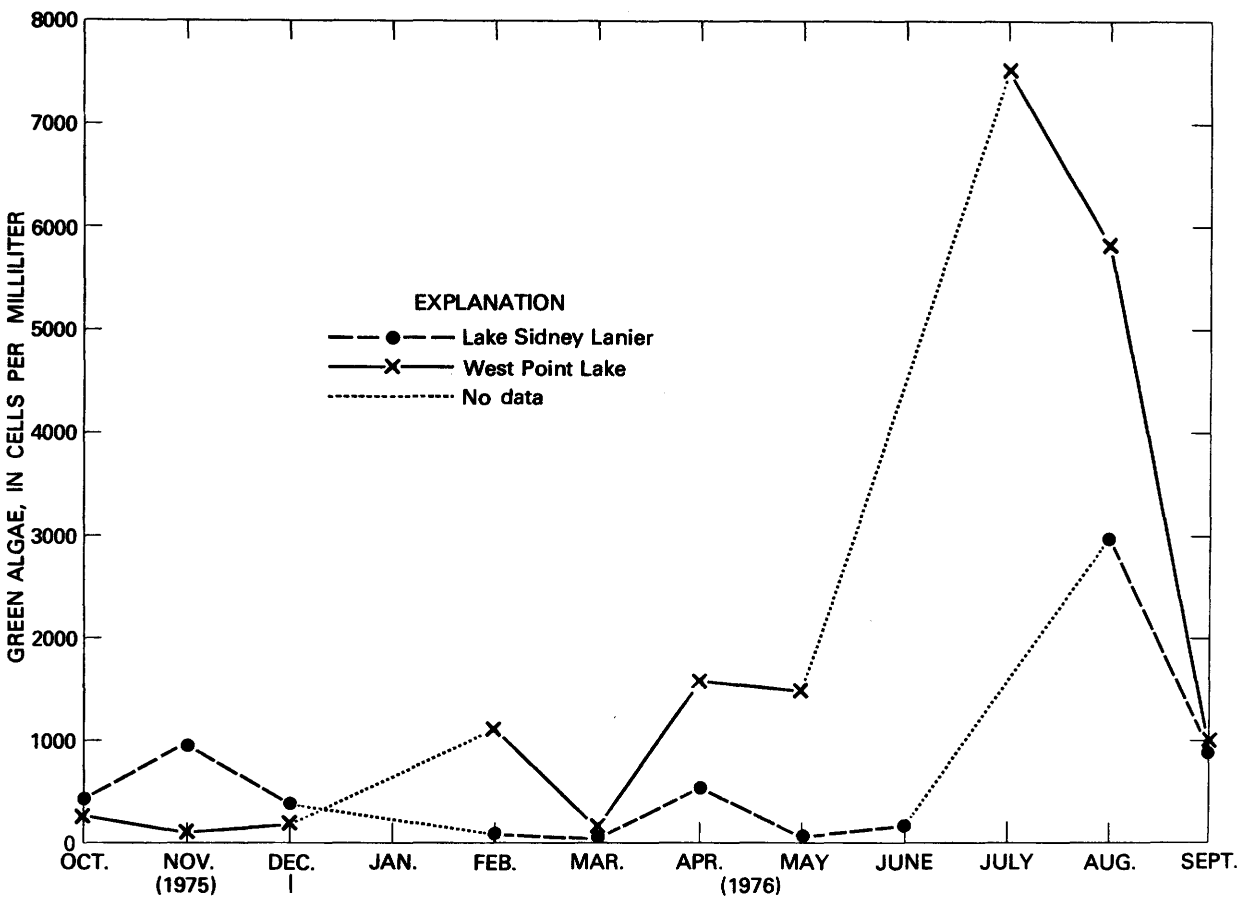


FIGURE 29.—Average concentration of green algae by month in Lake Sidney Lanier and West Point Lake.

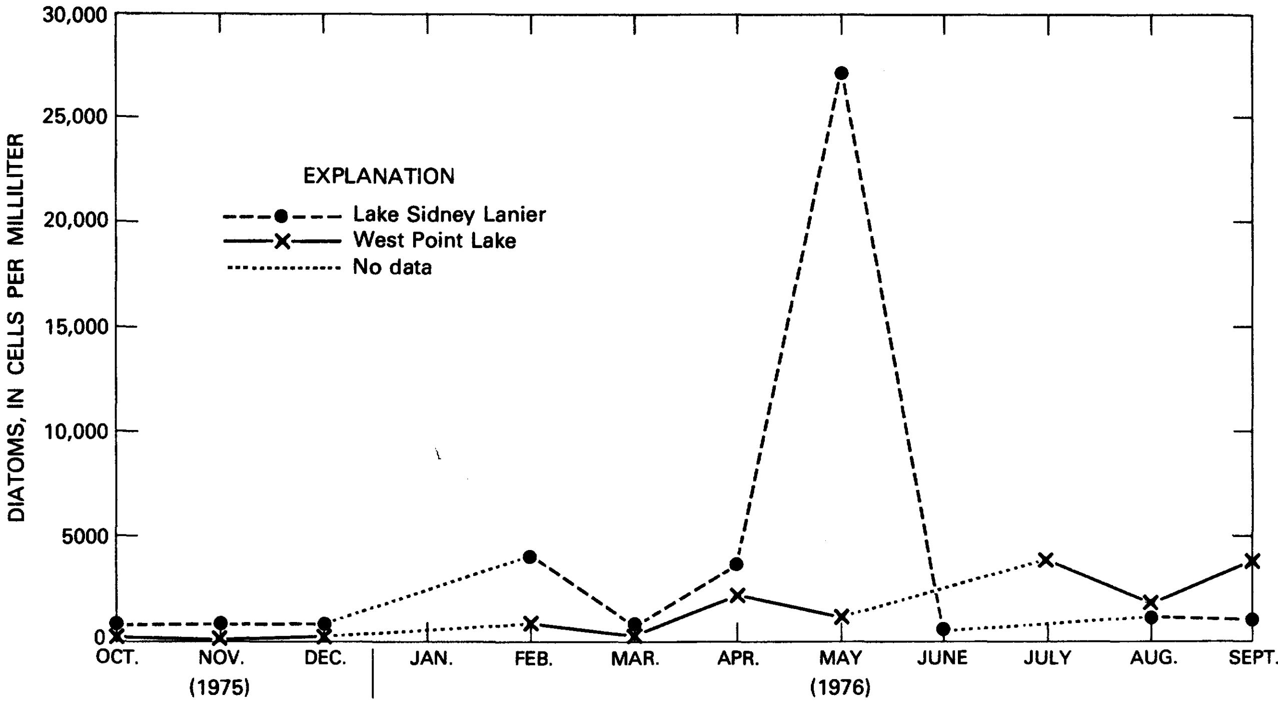


FIGURE 30.—Average concentration of diatoms by month in Lake Sidney Lanier and West Point Lake.

Figure 31 shows mean annual concentrations of total phytoplankton, dissolved PO_4-P (orthophosphate as phosphorus), and NO_2 + NO_3-N (nitrite plus nitrate as nitrogen) from the upper reaches of the Chattahoochee River to the West Point Dam. Phytoplankton concentrations upstream of Lake Sidney Lanier were less than 1,000 cells/mL, and in Lake Sidney Lanier they were about 10,000 cells/mL. Concentrations downstream from Lake Sidney Lanier to the upstream end of West Point Lake at Franklin were less than 4,000 cells/mL. Maximum concentrations in West Point Lake were about 90,000 cells/mL.

The dissolved PO_4-P and NO_2 + NO_3 concentrations were highest in the river reaches and the upper parts of the two lakes and lowest in the dam pools of both lakes. The high NO_2 + NO_3-N concentrations downstream from Atlanta were primarily a result of nitrification of treated sewage effluent by the *Nitrosomonas* and *Nitrobacter* bacteria (Ehlke, 1978).

ALGAL GROWTH POTENTIAL

Oswald and Golueke (1966) first used the term "algal growth potential" (AGP) and defined it as "the dry weight of algae which will grow in a given water sample in the laboratory when no factor other than dissolved nutrients in the sample is limiting to growth."

Algal assays are sometimes utilized to determine the effects of nutrients from municipal, industrial, or agricultural wastewater effluents on phytoplankton growth in natural waters (Maloney and others, 1972; Green and others, 1975, 1976; Miller and others, 1976). The AGP determination used in this study is measured in a filtered water sample and, therefore, measures the potential for additional phytoplankton growth based on the nutrients that are biologically available.

Figure 32 shows the mean annual concentrations of AGP, dissolved PO_4-P, and NO_2 + NO_3-N from the upper to lower reaches of the study area. The AGP and nutrient concentrations were less than 10 and 0.4 mg/L, respectively, upstream of Atlanta. AGP decreased from about 25 mg/L at Franklin to about 1 mg/L at the West Point dam pool. Dissolved PO_4-P decreased from 0.1 mg/L at Franklin to less than 0.01 mg/L at the West Point dam pool, and dissolved NO_2 + NO_3-N decreased from 0.6 mg/L at Franklin to about 0.1 mg/L at the dam pool.

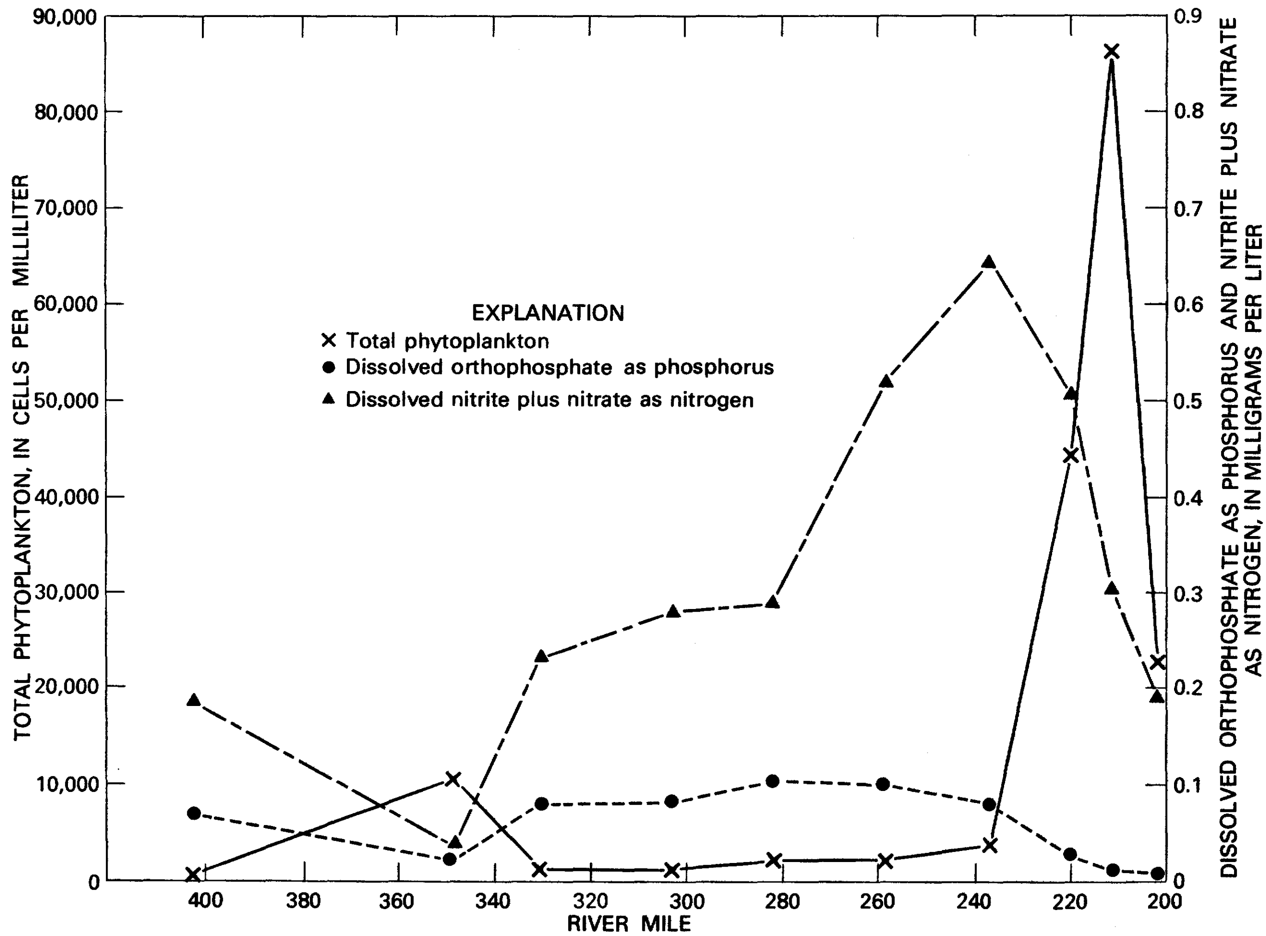


FIGURE 31.—Mean annual concentration of total phytoplankton, dissolved orthophosphate, and nitrite plus nitrate by river mile.

RELATION OF ALGAL GROWTH POTENTIAL TO NUTRIENTS IN WEST POINT LAKE

Several regression equations were developed and used to evaluate the relation of dissolved concentrations of NH_4-N, NO_2-N, NO_3-N, PO_4-P, and SiO_2 (silica) to AGP in the West Point Lake. The equation (Cherry and others, 1978) determined from the regression of available data is:

$$\text{AGP (mg/L)} = 211\ (PO_4\text{-P, mg/L}) + 13.4\ (NO_3\text{-N, mg/L}) - 0.8.$$

The multiple correlation coefficient and standard error of estimate are 0.96 and 3.7 mg/L. Concentrations of dissolved PO_4-P were more significantly related to AGP than corresponding concentrations of dissolved NO_3-N.

RELATION OF PHYTOPLANKTON GROWTH TO ALGAL GROWTH POTENTIAL IN WEST POINT LAKE

Plots relating AGP and phytoplankton concentration to river mile downstream of Franklin at various temperatures are shown in figures 33 and 34. A linear relation between miles downstream from Franklin and AGP and phytoplankton concentrations occurred during all sampling periods when AGP was greater than about 0.5 mg/L. Where AGP was less than about 0.5 mg/L, a decrease in the phytoplankton concentration occurred downstream. Therefore the availability of nutrients, as indicated by the AGP, appears to be limiting phytoplankton growth in the downstream reaches of the West Point Lake.

The relationship between the rate of change of AGP with river mile from 10° to 30°C is defined by the following equation:

$$A_1 = -(0.0673T - 0.625),$$

where

A_1 = rate of change of AGP per river mile in milligrams per liter per river mile, and

T = average water temperature, in degrees Celsius.

Similarly, for phytoplankton the rate of change is defined by the following equation:

$$P_1 = 0.0084T - 0.066,$$

where

P_1 = rate of change of phytoplankton concentration per river mile, in ($\log_e$) cells per milliliter per river mile, and

T = average water temperature, in degrees Celsius.

Therefore, knowing the AGP at Franklin and the water temperature of the lake, the AGP and phytoplankton concentration can be estimated at downstream sites in the lake using the following equations:

$$C_{ar} = -(A_1R) + C_{ai},$$

where

C_{ar} = AGP in milligrams per liter at river mile R, downstream from Franklin,

A_1 = rate of change of AGP, in milligrams per liter per river mile,

R = river mile downstream from Franklin, and

C_{ai} = AGP, in milligrams per liter at Franklin;

$$C_{pr} = P_1R + C_{pi},$$

where

C_{pr} = phytoplankton concentration in ($\log_e$) cells per milliliter at river mile R, downstream from Franklin,

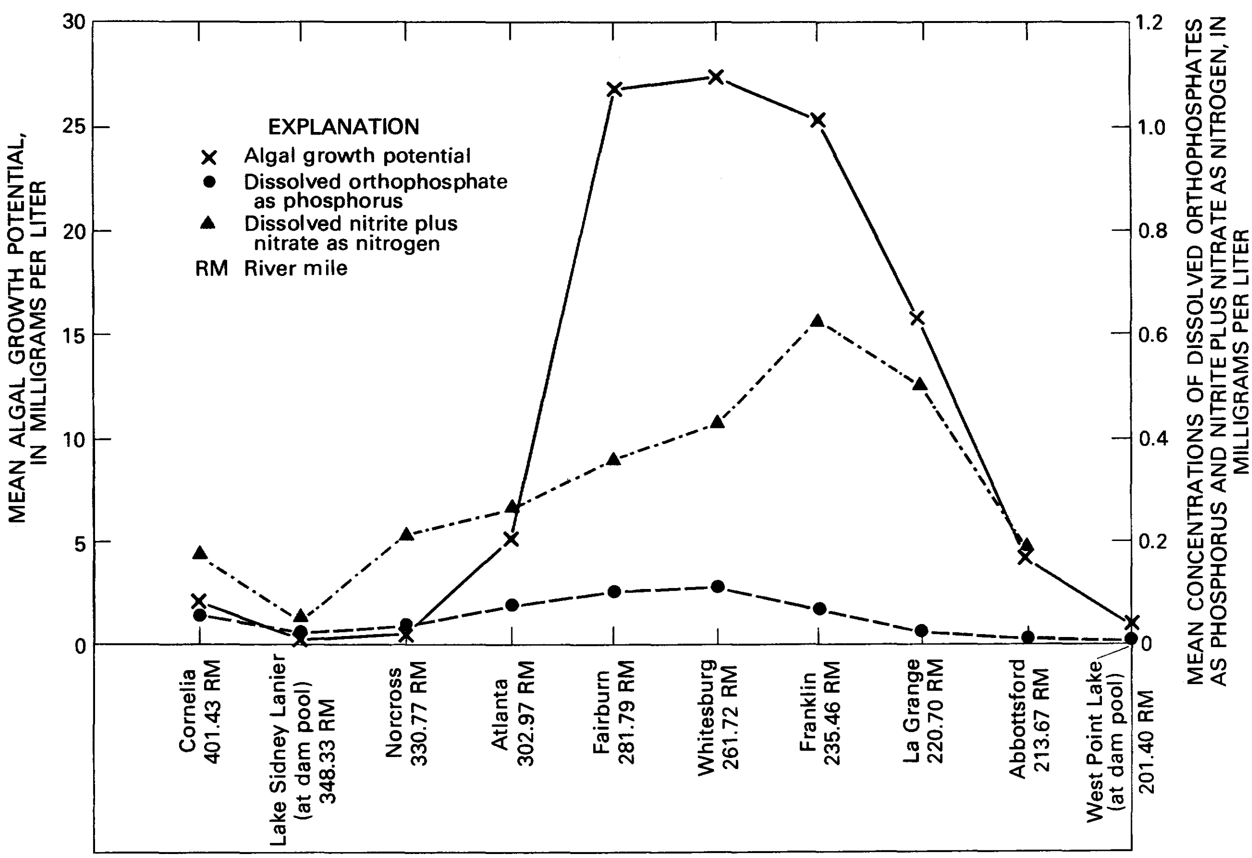


FIGURE 32.—Mean annual concentration of AGP, dissolved orthophosphate, and nitrite plus nitrate by river mile.

P_1 = rate of increase of phytoplankton concentrations, in ($\log_e$) cells per milliliter per river mile,

R = river mile downstream from Franklin, and

C_{pi} = phytoplankton concentration in ($\log_e$) cells per milliliter at Franklin.

AGP at Franklin (C_{ai}) can be estimated from the relationship between AGP and nutrient concentrations at the Whitesburg station (following equation), because AGP at Whitesburg and Franklin is about the same (fig. 35). The Chattahoochee River at the Whitesburg Station is free flowing, which allows for development of nutrient concentration and flow relationships as shown in figure 36. The relationship between AGP and nutrient concentrations at the Whitesburg station was determined (Stamer and others, 1978) from a multiple linear regression analysis (correlation coefficient is 0.97) and is defined by:

$$C_{aw} = 8.10 + 137.5\ (PO_4\text{-}P) + 4.61\ (NO_3\text{-}N),$$

where

C_{aw} = AGP in milligrams per liter, at Whitesburg,

PO_4-P = dissolved orthophosphate (as phosphorus) concentration, in milligrams per liter, at Whitesburg, and

NO_3-N = nitrate (as nitrogen) concentration, in milligrams per liter, at Whitesburg.

PRESENT AND FUTURE EFFECTS OF POINT AND NONPOINT DISCHARGES ON ALGAL GROWTH IN WEST POINT LAKE

The effects of PO_4-P and NO_3-N concentrations, as measured by AGP, from point and nonpoint

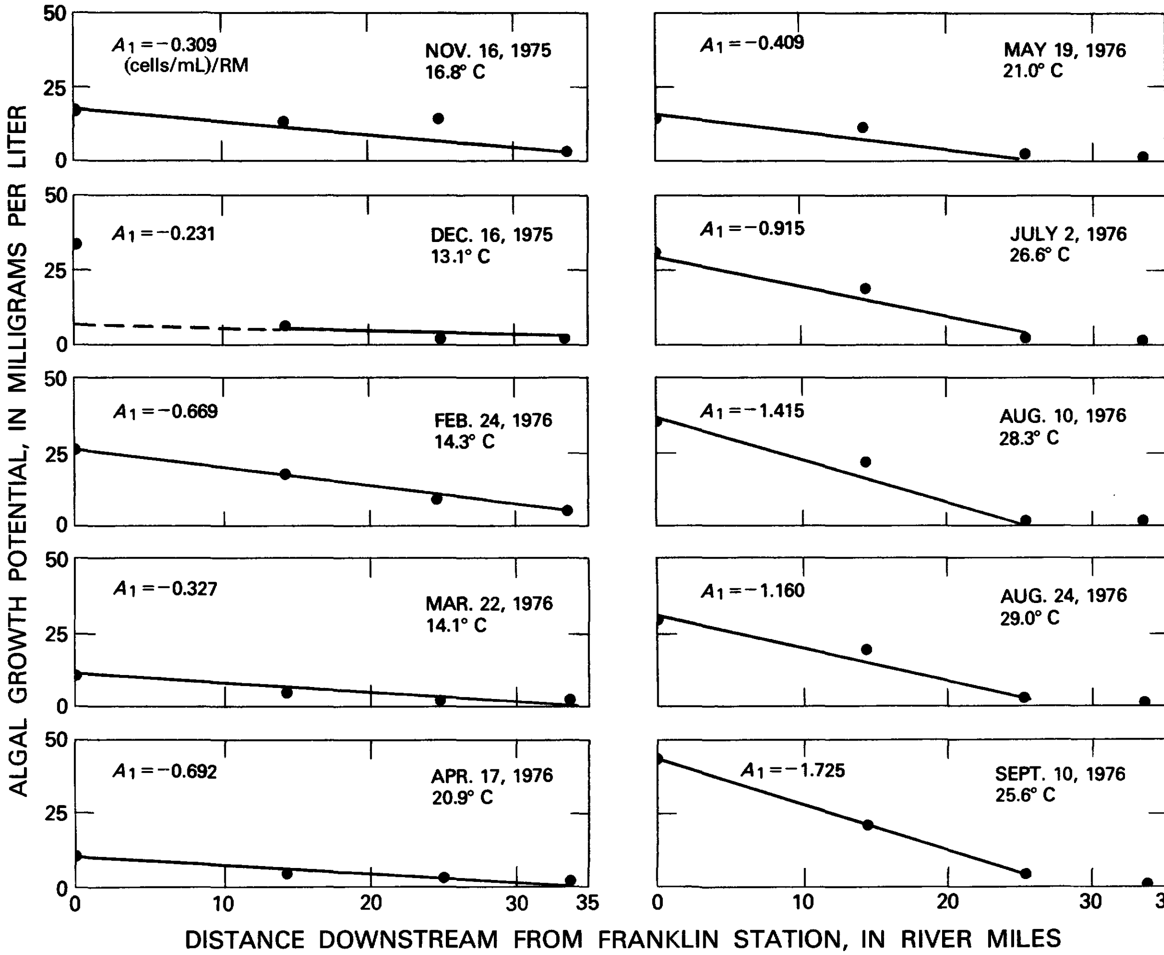


FIGURE 33.—Observed AGP by river mile downstream from Franklin station.

discharges on phytoplankton concentrations in West Point Lake were estimated for lake water temperatures of 30°C for the following conditions:

1. Average daily point-source PO_4-P and NO_3-N loads, average daily nonpoint-source PO_4-P and NO_3-N loads, and July mean monthly flow (3,490 ft³/s) at Whitesburg.
2. Average daily point-source PO_4-P load based on phosphorus concentration of 1.0 mg/L and NO_3-N load, average daily nonpoint PO_4-P and NO_3-N loads, and July mean monthly flow at Whitesburg.
3. Observed June 1977 point-source PO_4-P and NO_3-N loads, observed June 1977 nonpoint-source PO_4-P and NO_3-N loads, and observed June 1977 flow (1,990 ft³/s) at Whitesburg, and,
4. Average daily point-source load based on phosphorus concentration of 1.0 mg/L, observed June 1977 point-source NO_3-N load, observed June 1977 nonpoint-source PO_4-P and NO_3-N loads, and observed June 1977 flow at Whitesburg.

A summary of the conditions and effects is shown in table 16. PO_4-P and NO_3-N concentrations at Whitesburg for condition 1 were determined from the concentration-flow relationships in figure 36. PO_4-P and NO_3-N concentrations at Whitesburg for conditions 2, 3, and 4 were determined by converting the PO_4-P and NO_3-N loads at Whitesburg to concentrations based on the flow at Whitesburg. These analyses assumed that 50 percent of the phosphorus concentration in point discharges for conditions 2 and 4 is dissolved PO_4-P and that the point-source NH_4-H and NO_2-N concentrations are as NO_3-N.

The data indicate that with present (1978) PO_4-P and NO_3-N loads from point and nonpoint

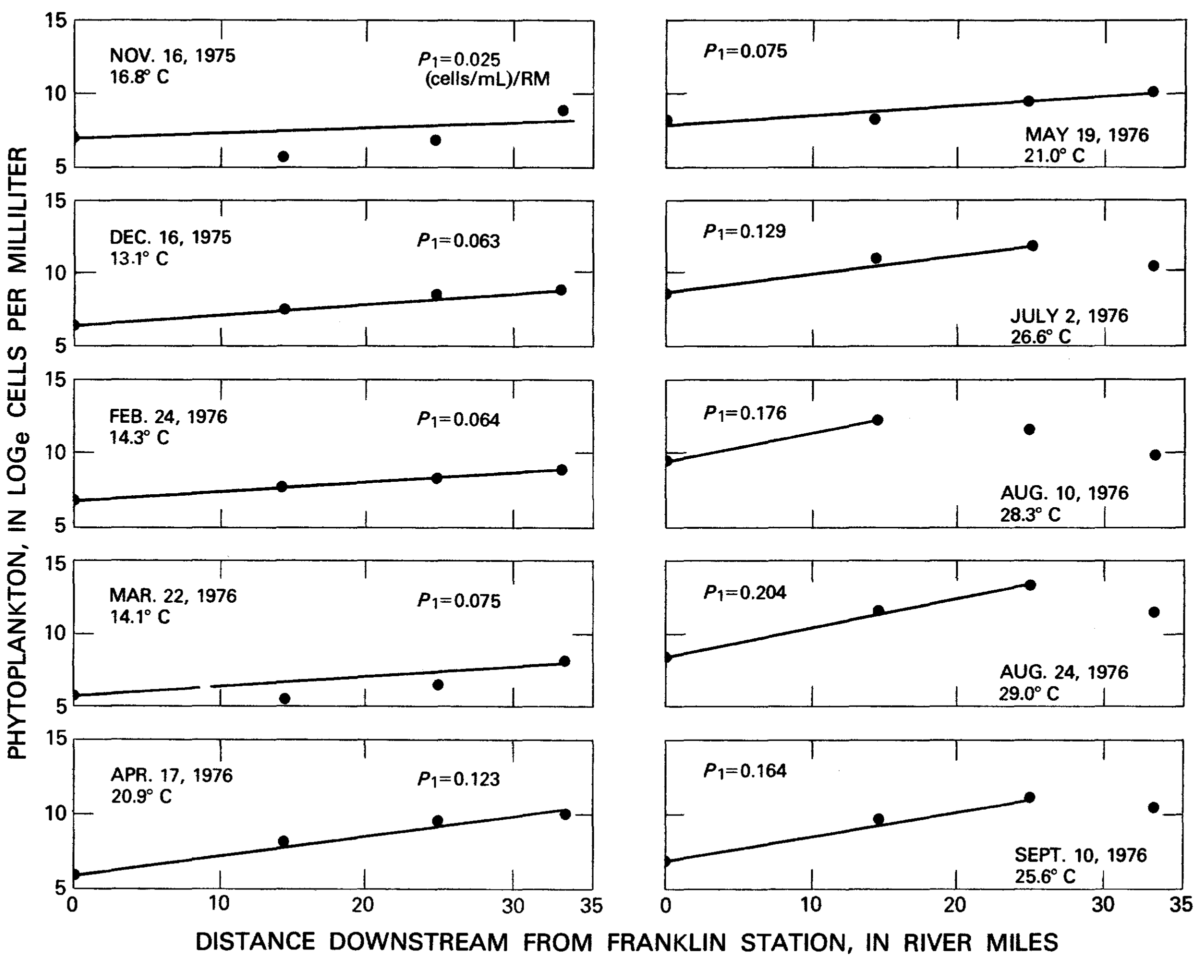


FIGURE 34.—Observed phytoplankton concentrations by river mile downstream from Franklin station.

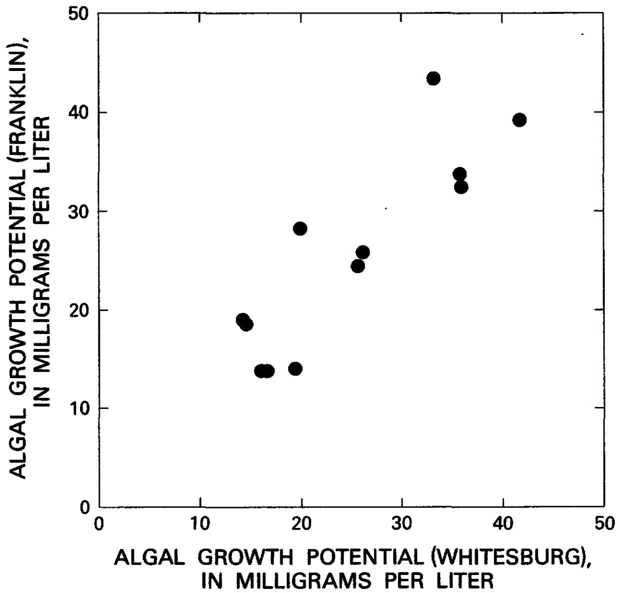


FIGURE 35.—Algal growth potential at Franklin versus algal growth potential at Whitesburg.

sources and mean monthly July flows (3,490 ft^3/s) at Whitesburg the maximum phytoplankton concentration would be 2.6×10^5 cells/mL 19 river miles downstream from Franklin (RM 216) in West Point Lake. Phytoplankton concentrations could reach 3.6×10^6 cells/mL at the dam pool with present point and nonpoint loads during an extended low-flow period such as the flow (1,990 ft^3/s) observed at Whitesburg in June 1977. At the same Whitesburg flow, the maximum phytoplankton concentration in the lake would be 1.2×10^5 cells/mL 15 river miles downstream from Franklin (RM 220.71) with a concentration of 1.0 mg/L of phosphorus in point discharges.

Point-source discharges are estimated to increase from about 180 ft^3/s in 1976 to about 370 ft^3/s in the Atlanta-to-Whitesburg reach by the year 2000. The future effects of PO_4-P and NO_3-N concentrations, as measured by AGP, from point and nonpoint discharges on phytoplankton concentrations in West Point Lake were estimated for lake water temperatures of 30°C for the following conditions:

1. Average daily point-source PO_4-P and NO_3-N loads with present levels of wastewater treatment, present average daily nonpoint-source PO_4-P and NO_3-N loads and July mean monthly flow (3,490 ft^3/s) at Whitesburg,
2. Average daily point-source PO_4-P load based on a phosphorus concentration of 1.0 mg/L and NO_3-N load, present nonpoint-source PO_4-P and NO_3-N loads, and July mean monthly flows at Whitesburg,
3. Average daily point-source PO_4-P load based on phosphorus concentration of 1.0 mg/L and NO_3-N load, nonpoint-source PO_4-P and NO_3-N loads based on an increase of 100 percent urbanization in the Atlanta-to-Whitesburg reach, and July mean monthly flows at Whitesburg,
4. Average daily point-source PO_4-P and NO_3-N loads with present levels of wastewater treatment, present average daily nonpoint-source PO_4-P and NO_3-N loads, and observed June 1977 flows (1,990 ft^3/s) at Whitesburg, and
5. Average daily point-source PO_4-P load based on phosphorus concentration of 1.0 mg/L and NO_3-N load, present average daily nonpoint-source PO_4-P and NO_3-N loads, and observed June 1977 flows at Whitesburg.

The data in table 16 show that with present wastewater treatment levels in the year 2000 with flows at Whitesburg of 1,990 ft^3/s and 3,490 ft^3/s, the maximum phytoplankton concentrations in West Point Lake will be 3.6 million cells/mL at the dam pool and 2.4 million cells/mL about 2 river miles upstream of the dam pool. Point-source discharges containing 1.0 mg/L phosphorus and flows of 1,990 ft^3/s and 3,490 ft^3/s at the Whitesburg station would result in the maximum phytoplankton concentrations of 6.3×10^5 cells/mL at about the Abbottsford station and 1.1×10^5 cells/mL at about the LaGrange station.

The analysis of the present and future effects of point and nonpoint discharges on phytoplankton concentrations in West Point Lake at 30°C indicates that phytoplankton concentrations are dependent mostly on point discharges of phosphorus. Phytoplankton concentrations at 30°C could exceed 3×10^6 cells/mL during extended low flow (about 2,500 ft^3/s at Whitesburg) with present average daily point-source PO_4-P loads. In the year 2000, phytoplankton concentrations, at 30°C, could reach 2×10^6 cells/mL with July mean monthly flows (3,490 ft^3/s at Whitesburg) and with future daily point-source PO_4-P and NO_3-N loads.

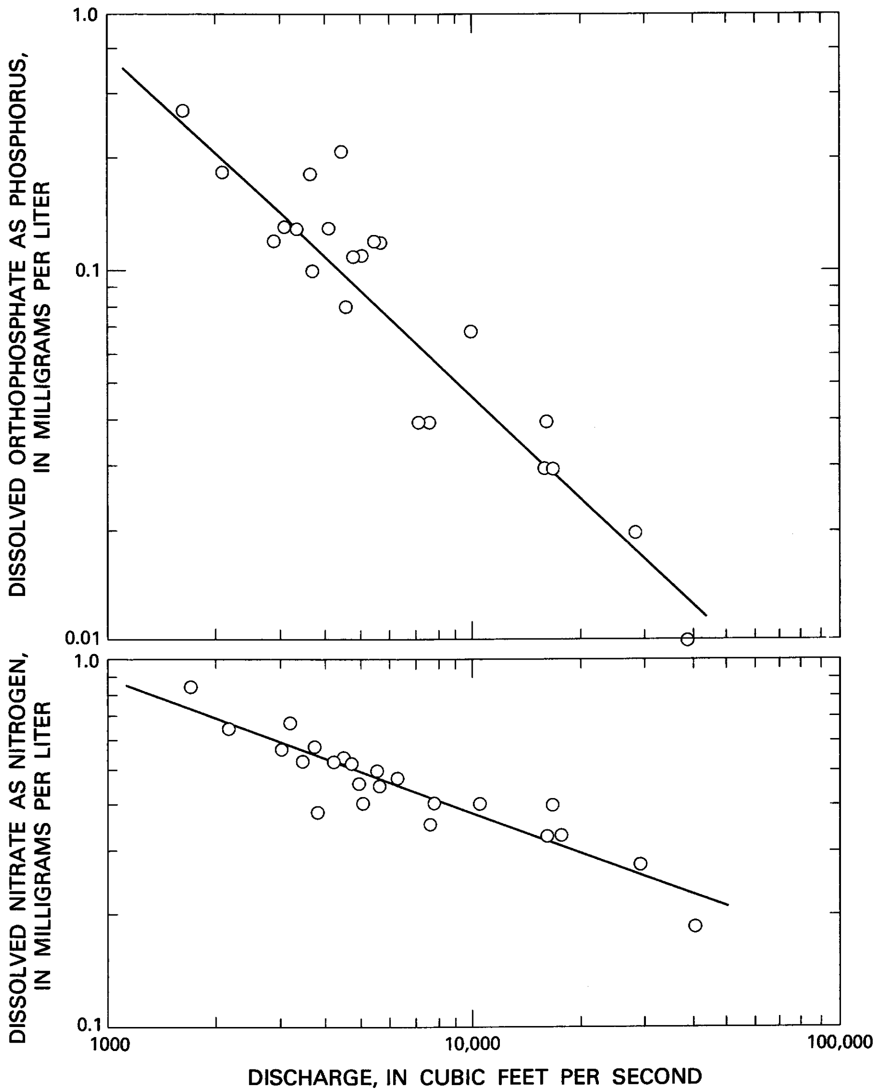


FIGURE 36.—Relationship of dissolved orthophosphate and dissolved nitrate concentrations to water discharge in the Chattahoochee River near Whitesburg.

SUMMARY

During the period April 1975 to June 1978, the U.S. Geological Survey conducted a river-quality assessment of the Upper Chattahoochee River Basin to Georgia. Five objectives of the study were to:

1. Evaluate the impact of heat loads from thermoelectric plants on stream temperature through the development of flow and temperature models.
2. Assess the amounts of sediment transport and deposition.
3. Assess the magnitudes and nature of point and nonpoint discharges to selected reaches of the river and their effect on the DO regime of the river.
4. Evaluate the economic considerations of maintaining desired minimum concentrations of DO in the Atlanta-to-Franklin reach of the river.
5. Use microbiological determinations to develop quantitative methods to estimate algae concentrations in West Point Lake.

Significant results of the study are:

1. The combined thermal effects of flow regulation and powerplant effluents resulted in mean daily river temperatures downstream of the powerplants about equal to or

TABLE 16.—*Summary of present (1978) and future (year 2000) effects of point and nonpoint phosphorus and nitrogen discharges on phytoplankton concentrations in West Point Lake*

[Concentrations are in milligrams per liter except for phytoplankton, in cells per milliliter, and flow, in cubic feet per second]

Condition	Level of wastewater treatment	Whitesburg				West Point Lake	
		Flow	Dissolved orthophosphate as phosphorus	Dissolved nitrate nitrogen	Algal growth potential	River mile[1]	Phytoplankton[2] concentration
		1976					
1	Present	3,490	0.12	0.56	27	19.06	260,000
2	Modified present[3]	3,490	.03	.56	15	10.43	53,000
3	Observed June 1977[4]	1,990	.34	1.0	.59	[5]33.10	3,600,000
4	Modified observed June 1977	1,990	.06	1.0	21	14.75	120,000
		2000					
1	Present	3,490	0.22	1.1	43	30.94	2,400,000
2	Modified present	3,490	.05	1.1	20	14.39	110,000
3	Modified present	3,490	.06	1.2	22	15.83	140,000
4	Present	1,990	.39	2.7	74	[6]3.10	3,600,000
5	Modified present	1,990	.09	2.7	33	23.74	630,000

[1]River mile downstream of Franklin where AGP is 0.5 mg/L.
[2]Phytoplankton concentration at river mile where AGP is 0.5 mg/L.
[3]Point PO_4-P load based on 1.0 mg/L phosphorus concentration in discharge.
[4]Concentrations of nitrogen and phosphorus were not determined on filtered water samples. During low-flow conditions, dissolved and total values are nearly the same.
[5]AGP at RM 33.10 is 13 mg/L.
[6]AGP at RM 33.10 is 28 mg/L.

less than computed natural temperatures. An independent analysis of historical river and air temperature data provided the same basic conclusions.

2. Except for periods of peak water-supply demand, simulated year 2000 river temperatures were little changed from observed, present-day (1978) temperatures.
3. Average annual erosion yields ranged from about 900 to 6,000 tons per square mile per year. The greatest erosion yields occurred in those watersheds having large percentages of agricultural and transitional land uses. Erosion yields were lowest in urban watersheds.
4. Timber harvesting increases annual sheet erosion by several orders of magnitude.
5. Average yields of suspended sediment transported by streams ranged from 300 to 800 tons per square mile per year. Yields of sediment were highest from urban watersheds and lowest from forested watersheds. A large part of the sediment discharged in urban streams was considered to be derived from channel erosion.
6. Average annual unmeasured-sediment discharge ranged from about 6 to 30 percent of the total annual sediment discharge transported by streams.
7. Sixty percent or more of the annual load of phosphorus and trace metals was associated with suspended sediment. Suspended discharges of nitrogen and organic carbon ranged from about 10 to 70 percent of total, respectively. Yields of suspended nutrients and trace metals were highest from urban watersheds and lowest from forested areas.
8. Average annual yields and daily concentrations for most constituents were largest in streams draining urban areas and smallest in streams draining forested and residential areas.
9. On an average annual basis and during storm periods, nonpoint-source loads for most constituents were larger than point-source loads.
10. Average annual point-source discharges accounted for about 50 percent of the dissolved nitrogen, total nitrogen, and total phosphorus loads and about 70 percent of the dissolved phosphorus loads at a station about 40 river miles downstream from Atlanta.
11. Low DO concentrations in the river downstream from Atlanta occur during periods of warm weather when peak hydroelectric power is not generated at the upstream Buford Dam.

12. Average daily concentrations of DO of less than 5.0 mg/L in the river, about 20 river miles downstream from Atlanta, occurred about 27 percent of the days from May 15, 1977, to November 15, 1977. Minimum daily concentrations of DO of about 3 mg/L occurred during this period.
13. During a low-flow period, five municipal point sources contributed 63 percent of the BOD_u, 97 percent of the ammonium as nitrogen, 78 percent of the total nitrogen, and 90 percent of the total phosphorus loads at Franklin. Average daily concentrations of 13 mg/L of BOD_u and 1.8 mg/L of ammonium as nitrogen were observed in the river about 2 river miles downstream from the R. M. Clayton and Cobb Chattahoochee wastewater treatment facilities. Oxidation of the high concentration of BOD_u and ammonium as nitrogen caused DO concentrations to decrease from about 8.0 mg/L at RM 299 to about 4.5 mg/L at RM 271. Nirogenous oxygen demands (k_3 = 0.19 to the base 10) accounted for about 52 percent of the decrease in DO concentrations in the upper reach of the river (RM 303 to RM 271) and about 42 percent in the lower reach (RM 271 to RM 235). Carbonaceous oxygen demands were exerted at a k_1 equal to 0.07 to the base 10 at 20° Celsius.
14. During a critical low-flow period, a streamflow at Atlanta of about 1,800 ft^3/s (cubic feet per second) and point-source flows of 185 ft^3/s containing concentrations of 45 mg/L of BOD_u and 15 mg/L ammonium as nitrogen result in a computed DO concentration of 4.7 mg/L downstream from Atlanta. With point-source concentrations of 45 mg/L of BOD_u and 10 mg/L of ammonium as nitrogen, present point-source flows, and a streamflow of about 1,500 ft^3/s at Atlanta, the computed minimum DO concentration is 5.0 mg/L. With 45 mg/L of BOD_u, 5 mg/L of ammonium as nitrogen, and a streamflow of about 900 ft^3/s, the minimum DO concentration is 5.5 mg/L.
15. During a critical low-flow period in the year 2000, point-source flows of 373 ft^3/s, and concentrations of 15 mg/L BOD_u and 5.0 mg/L of ammonium as nitrogen, and a streamflow of about 1,000 ft^3/s, result in a minimum DO concentration of 5.0 mg/L. Point-source flows containing BOD_u and ammonium as nitrogen concentrations of 45 and 5 mg/L, respectively, require a streamflow of about 1,800 ft^3/s to meet the DO concentration standard (average daily DO concentrations of 5.0 mg/L and not less than 4.0 mg/L) by the State of Georgia.
16. The average annual river temperature in 1976 was 14.0°C just upstream of the Atkinson-McDonough thermoelectric powerplants and 16.0°C just downstream from the powerplants. The highest temperatures and the greatest differences in temperature occurred during the summer months when streamflow is generally the lowest. During the June 1977 low-flow period, the heat load from the two powerplants caused an increase in river temperature of about 7°C and a subsequent decrease in the DO concentrations of about 0.2 mg/L.
17. Analysis of wastewater management alternatives based on economic efficiency indicated that low-flow augmentation can be substituted for nitrification of wastewater to maintain minimum DO concentrations of 3.0 mg/L downstream from Atlanta between the years 1977 and 2000. The savings in waste treatment cost will more than offset the benefits foregone by the loss of peak-generating capacity at Buford Dam. Maintenance of a minimum DO concentration of 5.0 mg/L will require nitrification of wastewater after about 1990.
18. The lower concentration of the nutrient dissolved orthophosphate as phosphorus is presently limiting phytoplankton growth in West Point Lake when water temperatures are greater than about 26°C. Estimated phytoplankton concentrations for 1977 could exceed 3 million cells/mL at 30°C, in West Point Lake if the algal growth potential at Whitesburg (Franklin) is about 50 mg/L during extended low flow (1,990 ft^3/s at Whitesburg) in June 1977. In the year 2000, phytoplankton concentrations in West Point Lake are not likely to exceed 700,000 cells/mL during extended low-flow periods in the summer if point-source concentrations of phosphorus are not greater than about 1 mg/L.

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