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MAGNITUDES, NATURE, AND EFFECTS OF POINT AND NONPOINT DISCHARGES IN THE CHATTAHOOCHEE RIVER BASIN, ATLANTA TO WEST POINT DAM, GEORGIA

by

J. K. Stamer, R. N. Cherry, R. E. Faye, and R. L. Kleckner

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River Quality Assessment of the Upper Chattahoochee River Basin, Georgia

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than U.S. Customary 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 (feet)	3.048 x 10	m (meters)
ft^3/s (cubic feet per second)	2.832 x 10	m^3/s (cubic meters per second)
in, (inches)	2.540	cm (centimeters)
	2.540 x 10	mm (millimeters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)
acres	4.047 x 10	km (square kilometers)
ton (short, 2000 pounds)	9.072 x 10	t (metric ton)
$(tons/mi^2)/yr$ (tons per square mile per year)	3.503 x 10	$(t/km^2)/yr$ (tons per square kilometers per year)

MAGNITUDES, NATURE, AND EFFECTS OF POINT AND NONPOINT DISCHARGES IN THE CHATTAHOOCHEE RIVER BASIN, ATLANTA TO WEST POINT DAM, GEORGIA

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ABSTRACT

During the period April 1975 to June 1978, the U.S. Geological Survey conducted a river-quality assessment of the Upper Chattahoochee River basin in Georgia. One objective of the study was to assess the magnitudes, nature, and effects of point and nonpoint discharges in the Chattahooche River basin from Atlanta to the West Point Dam.

On an average annual basis and during the storm period of March 12-15, 1976, nonpoint-source loads for most constituents analyzed were larger than point-source loads at the Whitesburg station, located on the Chattahoochee River about 40 river miles downstream of Atlanta. Most of the nonpoint-source constituent loads in the Atlanta-to-Whitesburg reach were from urban areas. 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 Whitesburg.

During weekends, power generation at the upstream Buford Dam hydroelectric facility is minimal. Streamflow at the Atlanta station during dry-weather weekends is estimated to be about 1,200 ft^3/s (cubic feet per second). Average daily dissolved-oxygen concentrations of less than 5.0 mg/L (milligrams per liter) occurred often in the river, about 20 river miles downstream from Atlanta during these periods from May to November.

During a low-flow period, June 1-2, 1977, five municipal point sources contributed 63 percent of the ultimate biochemical oxygen demand, 97 percent of the ammonium nitrogen, 78 percent of the total nitrogen, and 90 percent of the total phosphorus loads at the Franklin station, at the upstream end of West Point Lake. Average daily concentrations of 13 mg/L of ultimate biochemical oxygen demand and 1.8 mg/L of ammonium nitrogen were observed about 2 river miles downstream from two of the municipal point sources. Carbonaceous and nitrogenous oxygen demands caused dissolved-oxygen concentrations between 4.1 and 5.0 mg/L to occur in a 22-mile reach of the river downstream from Atlanta. Nitrogenous oxygen demands were greater than carbonaceous oxygen demands in the reach from river mile 303 to 271, and carbonaceous demands were greater from river mile 271 to 235. The heat load from the Atkinson-McDonough thermoelectric powerplants caused a decrease in the dissolved-oxygen concentrations of about 0.2 mg/L.

During a critical low-flow period, a streamflow at Atlanta of about 1,800 ft^3/s, with present (1977) point-source flows of 185 ft^3/s containing concentrations of 45 mg/L of ultimate biochemical oxygen demand and 15 mg/L of ammonium nitrogen, results in a computed minimum dissolved-oxygen concentration of 4.7 mg/L in the river downstream from Atlanta. In the year 2000, a streamflow at Atlanta of about 1,800 ft^3/s with point-source flows of 373 ft^3/s containing concentrations of 45 mg/L of ultimate biochemical oxygen

demand and 5.0 mg/L of ammonium nitrogen, will result in a computed minimum dissolved-oxygen concentration of 5.0 mg/L. A streamflow of about 1,050 ft^3/s at Atlanta in the year 2000 will result in a dissolved-oxygen concentration of 5.0 mg/L if point-source flows contain concentrations of 15 mg/L of ultimate biochemical oxygen demand and 5.0 mg/L of ammonium nitrogen.

Phytoplankton concentrations in West Point Lake, about 70 river miles downstream from Atlanta, could exceed 3 million cells per milliliter during extended low-flow periods in the summer with present point- and nonpoint-source nitrogen and phosphorus loads. In the year 2000, phytoplankton concentrations in West Point Lake are not likely to exceed 700,000 cells per milliliter during extended low-flow periods in the summer, if phosphorus concentrations do not exceed 1.0 mg/L in point-source discharges.

INTRODUCTION

The traditional approach to improving stream-water quality has been to identify the point sources of discharge and require that the discharge from these sources meet specified standards. The approach has been modified by the passage of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), which requires the implementation of wastewater treatment plans for the control of constituent loads from both point and nonpoint sources on an areawide basis.

Studies have indicated that storm runoff from nonpoint sources may contain organic wastes, nitrogen, phosphorus, trace metals, and sediment in sufficient quantities to be a significant contributor to the degradation of water quality in the receiving stream. The BOD (biochemical oxygen demand) load from urban runoff in a Durham, North Carolina, basin was estimated by Bryan (1970) to be equal to the BOD load from the basin's WTF (wastewater treatment facility), which operated at secondary treatment levels. Bryan (1974) also reported that 0.74 $(tons/mi^2)/yr$ (tons per square mile per year) of lead were discharged into the 1.67 mi^2 (square mile) urban basin in Durham, North Carolina, and that the lead was associated with the suspended solids.

Whipple (1970), in a study of three New Jersey river basins, reported that less than 39 percent of the total organic loading, as measured by BOD, was from known point sources. Whipple and others (1974) indicated that it is unrealistic to attempt to control algae blooms by controlling point-source nutrient loads for rivers which receive high nutrient loadings from urban runoff.

Kluesener and Lee (1974) indicated that about 80 percent of the total phosphorus and 35 percent of the annual total nitrogen loads discharging into a small lake in Madison, Wisconsin, resulted from urban runoff. Wilber and Hunter (1975) indicated that stormwater runoff contributes a greater proportion of heavy metals than does a secondary WTF on a unit-volume basis. Lead was the predominant metal in the urban runoff. Colston (1974), in a Durham, North Carolina, study, reported that urban storm runoff dominated downstream water quality about 20 percent of the time.

Correll and others (1975) reported that annual nitrogen and phosphorus yields from forested lands are low. Disturbances to a forested watershed, which include clear cutting and improper harvesting techniques, result in higher nutrient yields (Corbett and others, 1975). Correll and others (1975) have also reported than nonpoint nitrogen and phosphorus yields from cultivated cropland and confined animal feed-lot operations rank second only to urban runoff.

Although indications are that waste loads from both point and nonpoint sources can cause degradation of stream-water quality, the Ad Hoc Working Group on River-Quality Assessment of the Advisory Committee on Water Data for Public Use recommended that river-quality assessments be conducted in basins before costly areawide wastewater treatment plans are implemented (U.S. Department of the Interior, 1975, 1976). A series of studies are thus being conducted by the U.S. Geological Survey to assess the water resources of some of the Nation's major rivers. The purpose of the studies is to provide demonstration products containing information to guide management decisions regarding basin development and future uses of rivers in which maintenance and improvement of water quality are prime requisites. A 3-year study of the Upper Chattahoochee River basin, which began April 1, 1975, is one of the demonstration studies. The study is comprised of four work elements and is described by Cherry and others (1978a).

Objectives and Scope

The objective of this work element was to assess the magnitudes, nature, and effects of point and nonpoint discharges on the water quality of the Chattahoochee River. The scope includes determination of (1) the magnitudes and nature of point and nonpoint discharges in the Chattahoochee River basin from Atlanta to the West Point Dam (fig. 1), (2) the effects of point and nonpoint discharges on DO (dissolved oxygen) concentrations in the Atlanta-to-Franklin reach of the river, and (3) the effects of point and nonpoint discharges on phytoplankton concentrations in West Point Lake.

Acknowledgments

The authors wish to 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 efforts. The authors also wish to thank the Environmental Protection Division of the Georgia Department of Natural Resources, the South Atlantic Division of the U.S. Army Corps of Engineers, Region IV of the U.S. Environmental Protection Agency, the Atlanta Regional Commission, and the members of the Ad Hoc Working Group on River-Quality Assessment of the Advisory Committee on Water Data for Public Use for their many helpful suggestions relative to the types of data which would be most useful in managing the Chattahoochee River.

DESCRIPTION OF THE STUDY AREA

The study area includes the 1,990 mi^2 area of the Chattahoochee River basin from the Atlanta station to the West Point Dam. Figure 1 shows the location of data-collection sites in the Chattahoochee River basin, and table 1 lists the corresponding map reference numbers, station names, and the river miles of these data-collection sites.

The city of Atlanta, at the upstream end of the study area, has a population of 1,500,000 and comprises about 10 percent of the drainage area. West Point Lake is about 70 mi downstream from Atlanta. The 29,500-acre lake is impounded by the West Point Dam, which was completed by the U.S. Army Corps of Engineers in 1974. The purposes of the dam and lake are hydroelectric power generation, flood control, and recreation.

Land-surface altitudes in the study area range from about 1,000 ft above msl (mean sea level) in the Atlanta area to about 635 ft above msl at West Point Lake. Rainfall averages about 50 in. per year and annual air temperature averages about 16°C (Celsius).

Land Use

Land in the study area is about 70 percent forested, 15 percent rural, and 15 percent urban (table 2). Forested land includes deciduous and coniferous forests, wetlands, and water. Rural land includes small communities, cropland, pastureland, and confined feed-lot operations. Urban land includes residential, commercial, and industrial activities.

The Atlanta-to-Fairburn reach contains most of the Atlanta Metropolitan Area where the land 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. Land use of selected tributary basins is shown in table 3.

Water Use

The waters of the Chattahoochee River are utilized extensively for power generation, water supply, wastewater assimilation, water-quality maintenance, and recreation.

Five electric power-generating facilities are on the Chattahoochee River and have a combined generating capacity of about 3.8 million kw (kilowatts). Atkinson-McDonough, Yates, and Wansley are fossil-fuel thermoelectric powerplants. Buford and Morgan Falls Dams, upstream of the study area, are peak-power hydroelectric-generating facilities. The generating capacity and the estimated mean water use for each of the five facilities are shown in table 4.

Mean daily municipal water-supply withdrawals at the present time (1976) in the study area principally for the city of Atlanta are 134 ft^3/s (cubic feet per second), all of which is withdrawn in the Atlanta-to-Fairburn reach.

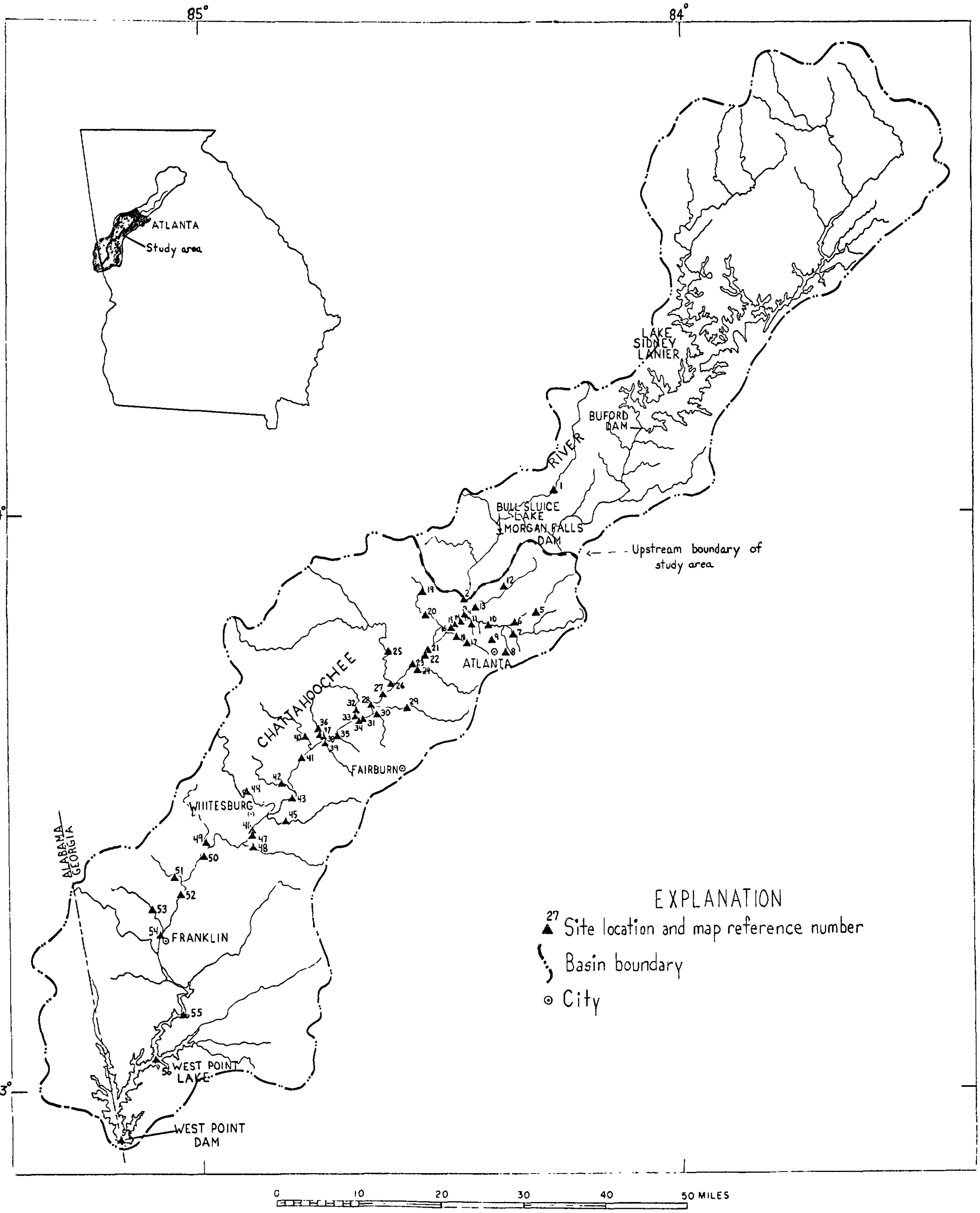

Figure 1.-- Data-collection sites in the Chattahoochee River basin.

Table 1.--Map reference number, station name, and river mile above mouth of data collection sites in the Chattahoochee River basin

Map Reference Number	Station Name	River Mile
1	Big Creek near Alpharetta	317.37
2	Chattahoochee River at Atlanta	302.97
3	Chattahoochee River (Atlanta Intake) at Atlanta	300.62
4	Cobb Chattahoochee WTF near Atlanta	300.56
5	North Fork Peachtree Creek Tributary (Meadowcliff Drive) near Chamblee	
6	North Fork Peachtree Creek at Buford Highway near Atlanta	
7	South Fork Peachtree Creek at Atlanta	
8	Clear Creek at Piedmont Park at Atlanta	
9	Tanyard Branch at 26th Street extension at Atlanta	
10	Peachtree Creek at Atlanta	300.52
11	Woodall Creek at DeFoors Ferry Road at Atlanta	
12	Nancy Creek Tributary near Chamblee	
13	Nancy Creek at Randall Mill Road at Atlanta	
14	R. M. Clayton WTF at Atlanta	300.24
15	Plants Atkinson-McDonough at Atlanta	299.11
16	Chattahoochee River at SR 280 at Atlanta	298.77
17	Hollywood Road WTF at Atlanta	
18	Proctor Creek at SR 280 at Atlanta	297.50
19	Nickajack Creek (USAF Plant 6 outfall) near Smyrna	
20	Nickajack Creek at Cooper Lake Road near Mableton	295.13
21	Chattahoochee River at SR 139 near Mableton	294.65
22	South Cobb Chattahoochee WTF near Mableton	294.28
23	Utoy Creek WTF near Atlanta	291.60
24	Utoy Creek at SR 70 near Atlanta	291.57
25	Sweetwater Creek near Austell	288.58
26	Sweetwater Creek WTF near Austell	288.57
27	Chattahoochee River (SR 166) near Ben Hill	286.07
28	Camp Creek WTF near Atlanta	283.78
29	Camp Creek at Enon Road near Atlanta	283.54
30	Deep Creek at SR 70 near Tell	283.27
31	Chattahoochee River (SR 92) near Fairburn	281.88
32	Anneewakee Creek at SR 166 near Douglasville	281.47
33	Anneewakee Creek WTF near Douglasville	281.46
34	Three-river interceptor	281.45
35	Pea Creek at SR 70 near Palmetto	277.40
36	Bear Creek at SR 166 near Douglasville	275.95
37	Bear Creek (SR 166) WTF near Douglasville	275.94
38	Chattahoochee River (above Bear Creek) near Rico	275.81
39	Bear Creek at SR 70 near Rico	274.49
40	Dog River at SR 166 near Fairplay	273.46
41	Chattahoochee River (Capps Ferry Bridge) near Rico	271.19
42	Wolf Creek at SR 5 near Banning	267.34
43	Chattahoochee River at Hutcheson's Ferry near Rico	265.66
44	Snake Creek near Whitesburg	261.72
45	Cedar Creek at SR 70 near Roscoe	261.25
46	Chattahoochee River (U.S. Alt. 27) near Whitesburg	259.85
47	Plant Yates	259.70
48	Wahoo Creek at Arnco Mills	256.55
49	Whooping Creek near Lowell	250.87
50	Plant Wansley	249.20
51	Chattahoochee River at Bush Head Shoals near Franklin	246.93
52	Pink Creek near Centralhatchee	244.89
53	Centralhatchee Creek at U.S. 27 near Franklin	236.51
54	Chattahoochee River at U.S. 27 at Franklin	235.46
55	Chattahoochee River at SR 219 near LaGrange	221.26
56	Chattahoochee River at SR 109 near Abbottsford	210.67
57	West Point Lake at dam pool near West Point	202.36

Table 2.--Land use in the study area

Basin between:	Urban (mi^2)	Urban percent	Rural (mi^2)	Rural percent	Forest (mi^2)	Forest percent	Drainage area (mi^2)
Atlanta to Fairburn	243	39.8	70.9	11.7	296	48.5	610
Fairburn to Whitesburg	24.1	6.5	62.0	16.8	284	76.7	370
Whitesburg to West Point Dam	37.5	3.7	174	17.2	799	79.1	1,010
Atlanta to West Point Dam	304	15.3	307	15.4	1,380	69.3	1,990

Table 3.--Land use of selected tributary basins in the study area

Map reference number (fig. 1)	Tributary	Land use: Urban (mi^2)	Urban Percent	Rural (mi^2)	Rural Percent	Forest (mi^2)	Forest Percent	Drainage area (mi^2)
1	Big Creek near Alpharetta[a]	5.94	8.0	26.1	36.0	40.0	56.0	72.4
5	North Fork Peachtree Creek Tributary (Meadowcliff Drive) near Chamblee	.27	84.0	.00	.0	.05	16.0	0.32
6	North Fork Peachtree Creek at Buford Highway near Atlanta	25.3	74.0	.04	.1	8.76	25.9	34.1
7	South Fork Peachtree Creek at Atlanta	22.9	77.1	.05	.2	6.71	22.7	29.6
8	Clear Creek at Piedmont Park at Atlanta	3.74	100.	.00	.0	.00	.0	3.74
9	Tanyard Branch at 26th Street extension at Atlanta	3.47	99.1	.00	.0	.03	.9	3.50
10	Peachtree Creek at Atlanta	69.5	80.0	.09	.01	17.2	19.9	86.8
11	Woodall Creek at DeFoors Ferry Road at Atlanta	2.85	91.6	.00	.0	.26	8.4	3.11
12	Nancy Creek Tributary near Chamblee	1.72	52.9	.03	.9	1.50	46.2	3.25
13	Nancy Creek at Randall Mill Road at Atlanta	26.2	75.4	.28	.8	8.28	23.8	34.8
44	Snake Creek near Whitesburg	.40	1.1	5.75	15.5	30.8	83.4	37

[a]Station not in study area but included to represent quality characteristics of discharge from rural areas.

Table 4.--Generating capacity and mean daily water use for five electric generating facilities

Map reference number (fig. 1)	River Mile	Facility	Capacity (kw)	Average water use (ft^3/s)
			Hydroelectric	
	348.32	Buford Dam	86,000	2,200
	312.62	Morgan Falls Dam	16,800	2,500
			Thermoelectric	
15	299.11	Plants Atkinson-McDonough	730,000	909
47	259.70	Plant Yates	1,250,000	1,030
50	249.20	Plant Wansley	1,760,000	[a]73

[a]One small unit on line in 1976.

Combined mean daily municipal water-supply withdrawals upstream of the study area are 146 ft^3/s. Water-supply withdrawals for 1976 and estimated withdrawals for the year 2000 are shown in table 5.

Mean daily treated wastewater returns at the present time in the study area are 179 ft^3/s, all of which is returned in the Atlanta-to-Fairburn reach. Wastewater returns to the Chattahoochee River and its tributaries for 1976 and estimated returns for the year 2000 are shown in table 6. In 1974, the Georgia EPD (Environmental Protection Division) estimated that 750 ft^3/s of high-quality water would be needed at the Peachtree Creek confluence to meet water-quality standards. An average daily DO concentration of 5.0 mg/L (milligrams per liter) and no 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 CSO's (combined-sewer overflows) into the river (Environmental Protection Division, 1977).

The newly impounded West Point Lake occupies about 29,500 acres and is becoming a popular resort and fishing area. The lake has public access areas, boat launching facilities, campgrounds, and marinas.

Hydrology

The flow of the Chattahoochee River in the study area is dependent upon rainfall and regulation by the Buford, Morgan Falls, and West Point Dams. The highest flows generally occur in the spring and lowest flows in late autumn. The mean daily discharge for the Atlanta station for the period 1969-77 is shown in figure 2. Drainage area and mean daily discharge for stations in the study area are shown in table 7.

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

NATURE OF THE PROBLEM

The problems associated with water quality in the study area are for the most part related to urbanization in the Atlanta Metropolitan Area. The urbanization has created large demands on the Chattahoochee River as the major water supply for Atlanta and the major transporter of muncipal wastes from Atlanta. Estimated weekend flow at the Atlanta station during dry weather is about 1,200 ft^3/s, because Buford Dam does not ordinarily produce peak hydro- electric power on weekends. In the Atlanta-to-Fairburn reach, about 20 RM (river miles) in length, about 130 ft^3/s is withdrawn from the river for water supply and about 180 ft^3/s of treated wastewater is returned

Table 5.--Mean daily municipal water-supply withdrawals for 1976 and estimated withdrawals for the year 2000 from the Chattahoochee River
(from Metropolitan Atlanta Water Resources Study Group, 1976)

Facility	Withdrawals (ft^3/s)	
	1976	2000
	Average	Average
Hall County[a]	3	9
Forsyth County[a]		2
Gwinnett County[a]		68
City of Buford	1	1
Gwinnett County	12	12
DeKalb County	91	187
Atlanta-Fulton County		243
Cobb County	39	117
City of Atlanta	134	110
Total withdrawal	280	749

[a]Withdrawals upstream of Buford Dam.

Table 6.--Mean daily-treated wastewater returns for 1976 and estimated returns for the year 2000 to the Chattahoochee River and its tributaries for wastewater treatment facilities in the study area

Map reference number	Facility	Discharge (ft^3/s)	
		[a]1976	[b]2000
	Gainesville Linwood[d]	2.2	4.2
	Gainesville Flat Creek[d]	5.6	9.3
	Buford[d]	1.7	2.0
	Big Creek[d]	4.1	17
	Crooked Creek[d]	1.8	12
	Johns Creek[d]	2.9	4.8
4	Cobb Chattahoochee	15	31
14	R. M. Clayton	118	161
17	Hollywood Road	2.3	e
19	[c]U.S. Air Force Plant No. 6	2.6	11
22	South Cobb Chattahoochee	13	48
23	Utoy Creek	21	44
26	Sweetwater Creek		2.6
28	Camp Creek	6.8	27
33	Anneewakee Creek		6.0
34	Three-river Interceptor		42
37	Bear Creek		7.7
	LaGrange Yellow Jacket[f]	1.5	3.0
Total discharge		198	433

[a]Data from monthly plant operating reports submitted to Georgia Department of Natural Resources, Environmental Protection Division

[b]Data from Metropolitan Atlanta Water Resources Study Group, 1976

[c]Data from Environmental Protection Agency

[d]Upstream of study area

[e]To be eliminated by year 2000

[f]Discharges into West Point Lake, not included in analysis

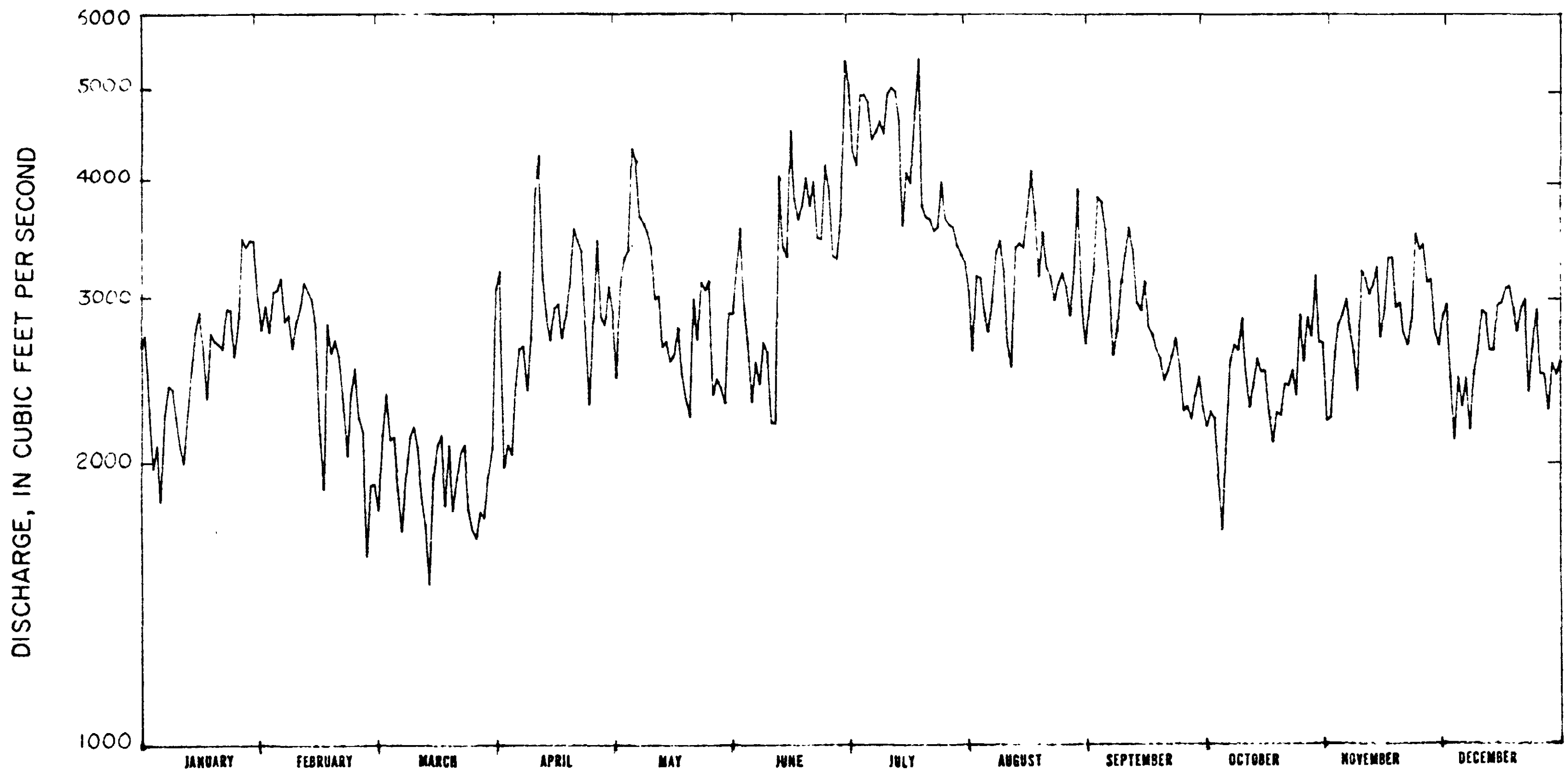

Figure 2.--Mean daily discharge at the Atlanta station for 1969-77.

Table 7.--Drainage area, mean daily discharge, and period of record for stream stations in the study area

Map reference number	Station name	Drainage (mi^2)	Mean daily discharge (ft^3/s)	Period of record	Stage record
[a]1	Big Creek near Alpharetta	72	119	1960-76	Continuous
[b]2	Chattahoochee River at Atlanta	1,450	2,888	[d]1965-76	Continuous
5	North Fork Peachtree Creek tributary (Meadowcliff Drive) near Chamblee	0.32	0.53	1973-76	Partial
6	North Fork Peachtree Creek at Buford Highway near Atlanta	34.08	50.0	1976	Partial
7	South Fork Peachtree Creek at Atlanta	29.6	52.6	1976	Partial
8	Clear Creek at Piedmont Park at Atlanta	3.74	c	1976	Partial
9	Tanyard Branch at 26th Street extension at Atlanta	3.50	c	1976	Partial
10	Peachtree Creek at Atlanta	86.8	139	1959-76	Continuous
11	Woodall Creek at DeFoors Ferry Road at Atlanta	3.11	19.1	1976	Partial
12	Nancy Creek Tributary near Chamblee	3.25	4.7	1976	Partial
13	Nancy Creek at Randall Mill Road at Atlanta	34.8	66.7	1976	Partial
[b]31	Chattahoochee River near Fairburn	2,060	3,930	1965-76	Continuous
44	Snake Creek near Whitesburg	37	58.2	1955-76	Continuous
[b]46	Chattahoochee River near Whitesburg	2,430	4,419	[d]1965-76	Continuous

[a]Upstream of study area, but included to represent quality characteristics at discharge from rural areas.
[b]Regulated flow.
[c]No value, stage records of poor quality.
[d]Because map reference number 31 was established in 1965, only the 1965-76 period of record for map reference numbers 2 and 46 was used for comparability purposes in the study.

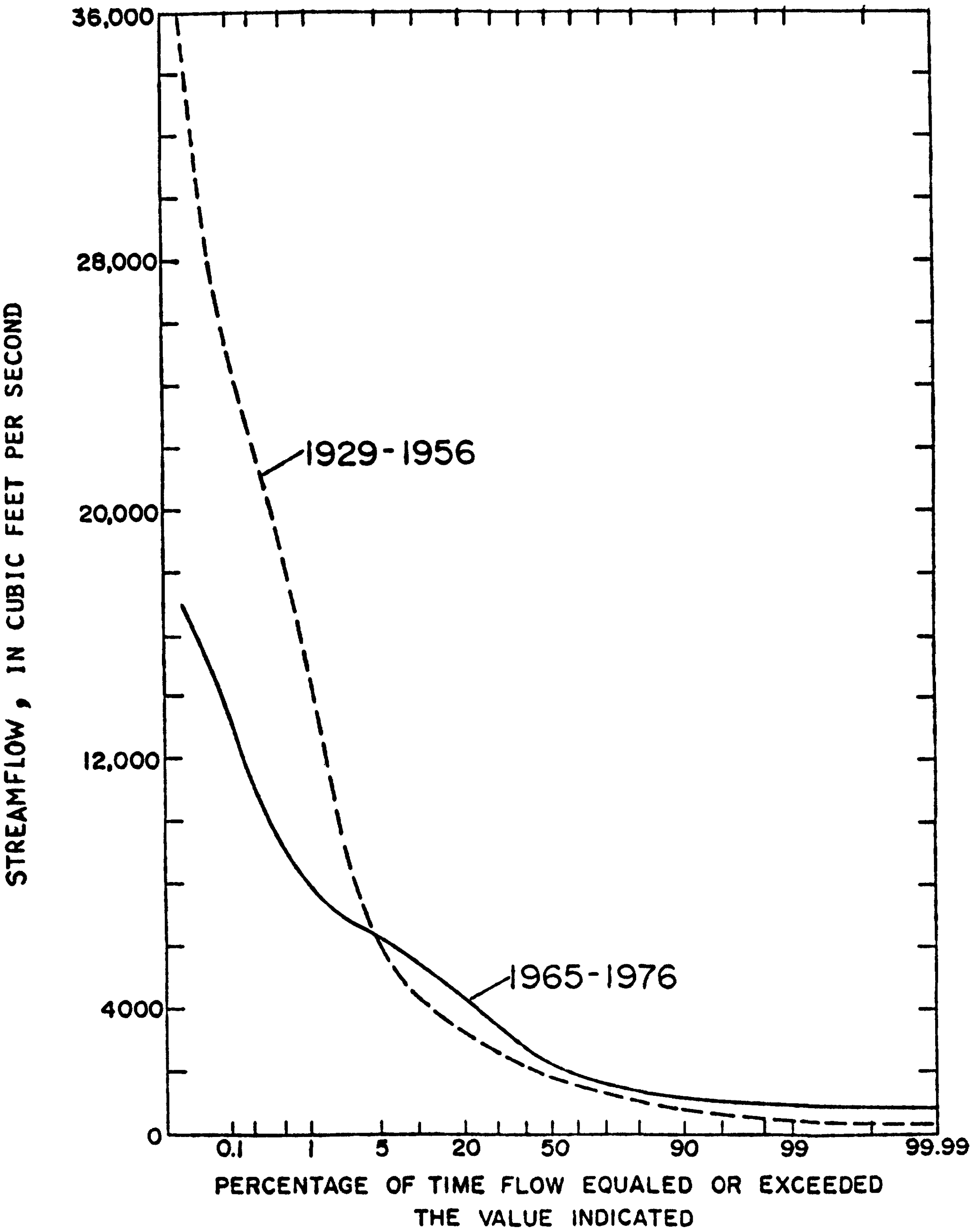

Figure 3.--Flow durations of the Chattahoochee River at the Atlanta station before and after construction of Buford Dam.

to the river from seven WTF's. Tributary inflow in this reach during low-flow periods is about 200 ft^3/s. Therefore, the estimated net flow at the Fairburn station during weekend low-flow periods is about 1,450 ft^3/s, of which about 13 percent is treated wastewater. In the reach, two fossil-fuel thermoelectric plants withdraw and subsequently discharge about 900 ft^3/s of heated water which raises the average temperature of the river 2.0°C (fig. 4). Figure 4 shows that the highest temperatures and the greatest differences in temperatures occur during the summer months.

The combined effects of 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 8 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 monitor. Average daily DO concentrations of less than 5.0 mg/L occurred 31 percent of the hours in the month of October. Figure 5 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 less than about 1,500 ft^3/s.

In the year 2000, municipal water-supply withdrawals from the river are estimated to be 670 ft^3/s (table 5). Future plans to modify the flow regime of the river to meet increasing demands on the surface-water supply include either (1) construction of a re-regulation structure upstream of the study area, (2) modification of Morgan Falls Dam and Bull Sluice Lake (impounded by Morgan Falls Dam), or (3) changes in the hydropower releases from Buford Dam (Metropolitan Atlanta Water Resources Study, 1977). Treated wastewater returns to the river in the year 2000 are estimated to be 433 ft^3/s, of which 380 ft^3/s will be discharged in the reach from Atlanta to just downstream from Fairburn (table 6). Regardless of the alternative selected, the estimated flow at the Fairburn station during low-flow periods will be about 1,500 ft /s, or not greatly different than the presently (1977) observed weekend low flow. Treated wastewater will account for about 25 percent of this flow. During an extended drought period like that which occurred in the years 1954-56, with peak water-supply withdrawals and average wastewater returns, estimated flow at Fairburn could be about 1,100 ft^3/s. The increased wastewater discharges during warm-weather low-flow periods could cause more severe DO concentration problems in the river downstream from Atlanta than occur today.

One of the stated prime benefits of West Point Lake is recreation (U.S. Army Corps of Engineers, 1975). When the lake was formed in late 1974, concerns were raised by several agencies over the future water-quality conditions in the lake because the lake is about 70 miles downstream from a major metropolitan area (Vick and others, 1976). Magnitudes of upstream point- and nonpoint-source loads were considered sufficiently large to cause nuisance problems (algae blooms) which could spoil the recreational potential of the lake. During periods of rainfall, direct runoff from streets, parking lots, and construction sites in the Atlanta Metropolitan Area can contribute large total and dissolved-constituent loads to the river and subsequently to West Point Lake. Two CSO's, Clear Creek and Tanyard Branch, are in the Peachtree Creek basin (fig. 6). These combined sewers were constructed many

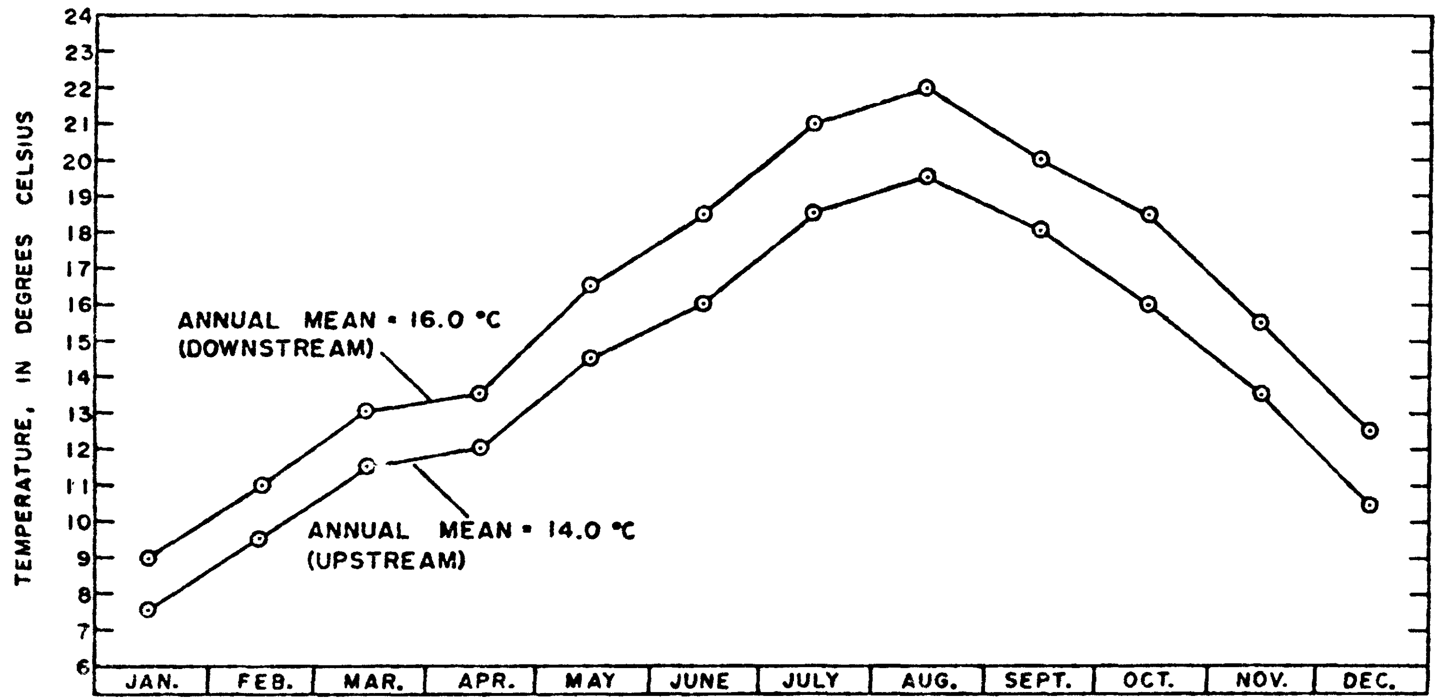

Figure 4.--Temperature of river water upstream and downstream of the Atkinson-McDonough thermoelectric generating plants.

Table 8.--Mean monthly air temperature and number of days and hours per month during 1977 in which the dissolved-oxygen concentration was less than 5.0 milligrams per liter at the Chattahoochee River near Fairburn monitor

Month	Number of days	Number of hours	Mean monthly air temperature[a] (°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

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

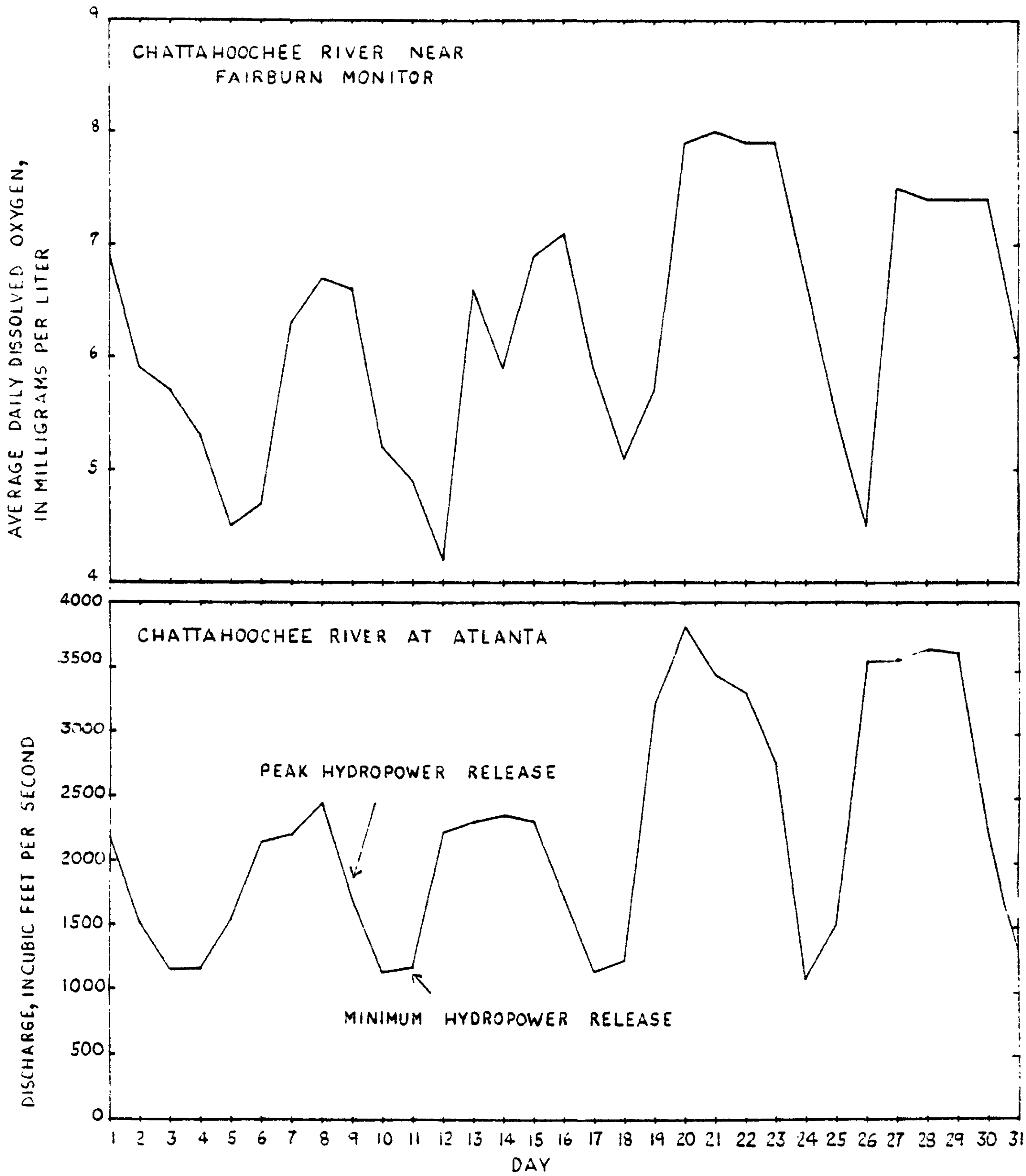

Figure 5.--Dissolved-oxygen concentrations at the Fairburn station monitor and mean daily discharge at the Atlanta station during July 1977.

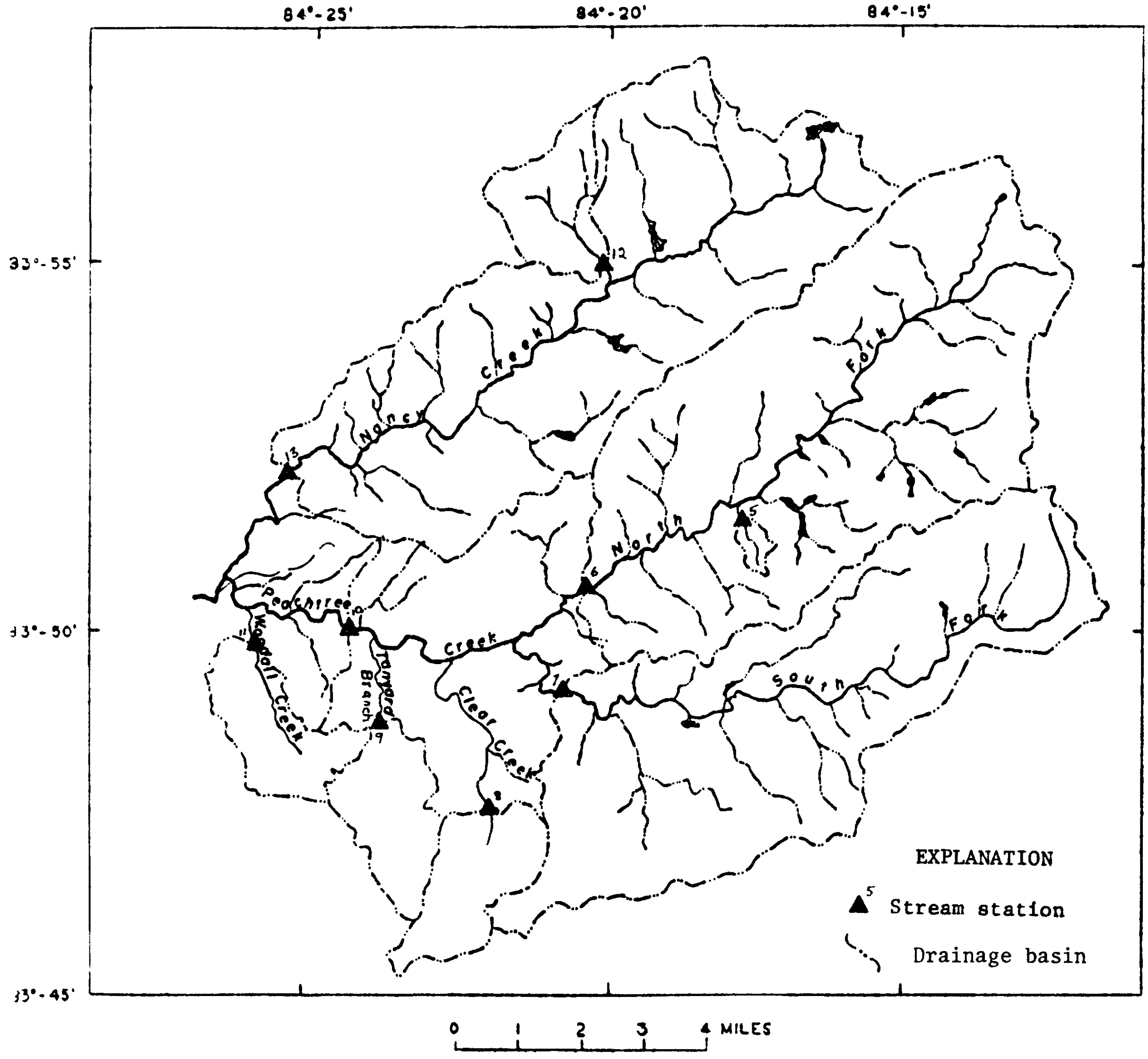

Figure 6.--Data-collection sites in Peachtree Creek basin.

years ago. Clear Creek CSO, for example, was built in 1922. A combined sewer carries sewage at all times and during periods of rainfall, serves as the collector and transporter of stormwater from streets and other sources. During dry weather periods, interceptors located in the combined sewers convey wastewater to a nearby WTF. During wet weather, the interceptors can become hydraulically loaded, and the sewage plus stormwater is then discharged over the overflow regulator into a nearby watercourse. Discharges from combined sewers can contribute large constituent loads to the receiving stream.

DATA COLLECTION AND METHODS OF DATA ANALYSIS

Water samples were collected and flow and temperature measurements were made at point and nonpoint sources of discharge during a wide range of flow conditions during the period from October 1975 to September 1977. Water samples were collected from streams using depth-integrating techniques. Water samples collected from West Point Lake were depth integrated through the photic zone. Water samples were chilled or filtered in the field when required.

Laboratory analysis of water samples included determinations of COD (chemical oxygen demand); BOD_u (ultimate biochemical oxygen demand); suspended sediment; dissolved solids; total and dissolved arsenic, chromium, copper, lead, and zinc; TOC (total organic carbon); DOC (dissolved organic carbon); NH_4-N (dissolved ammonium nitrogen); NO_3-N (dissolved nitrate plus dissolved nitrite as nitrogen); and total and dissolved PO_4-P (orthophosphate as phosphorus) and phosphorus concentrations using the methods described by Skougstad (1978). Laboratory analysis of water samples from the Whitesburg and West Point Lake stations also included determinations of phytoplankton concentrations and AGP (algal growth potential) using the methods described by Greeson and others (1977). Basic data used in this study will be published by the Georgia District, Water Resources Division of the U.S. Geological Survey.

Average annual stream-constituent loads were computed using the transport flow-duration curve method described by Miller (1951) and Colby (1956). Curves were developed for constituents by relating concentrations to discharges as shown by the example curve A in figure 7. For constituent concentrations that did not relate to discharge, curve B in figure 7, mean concentrations were determined by summing the constituent concentrations and dividing by the number of observations. The mean concentration was multiplied by the mean daily streamflow.

Stream-constituent loads for the storm period of March 12-15, 1976, were computed in a manner similar to that used to compute average annual loads. Each mean constituent concentration was determined from a concentration-flow curve for the mean water discharge at each station for the storm period. The resulting concentration was multiplied by the discharge volume.

Low-flow stream-constituent loads for the periods August 31 to September 9, 1976, and June 1-2, 1977, were computed by multiplying the mean constituent concentration by the mean water discharge.

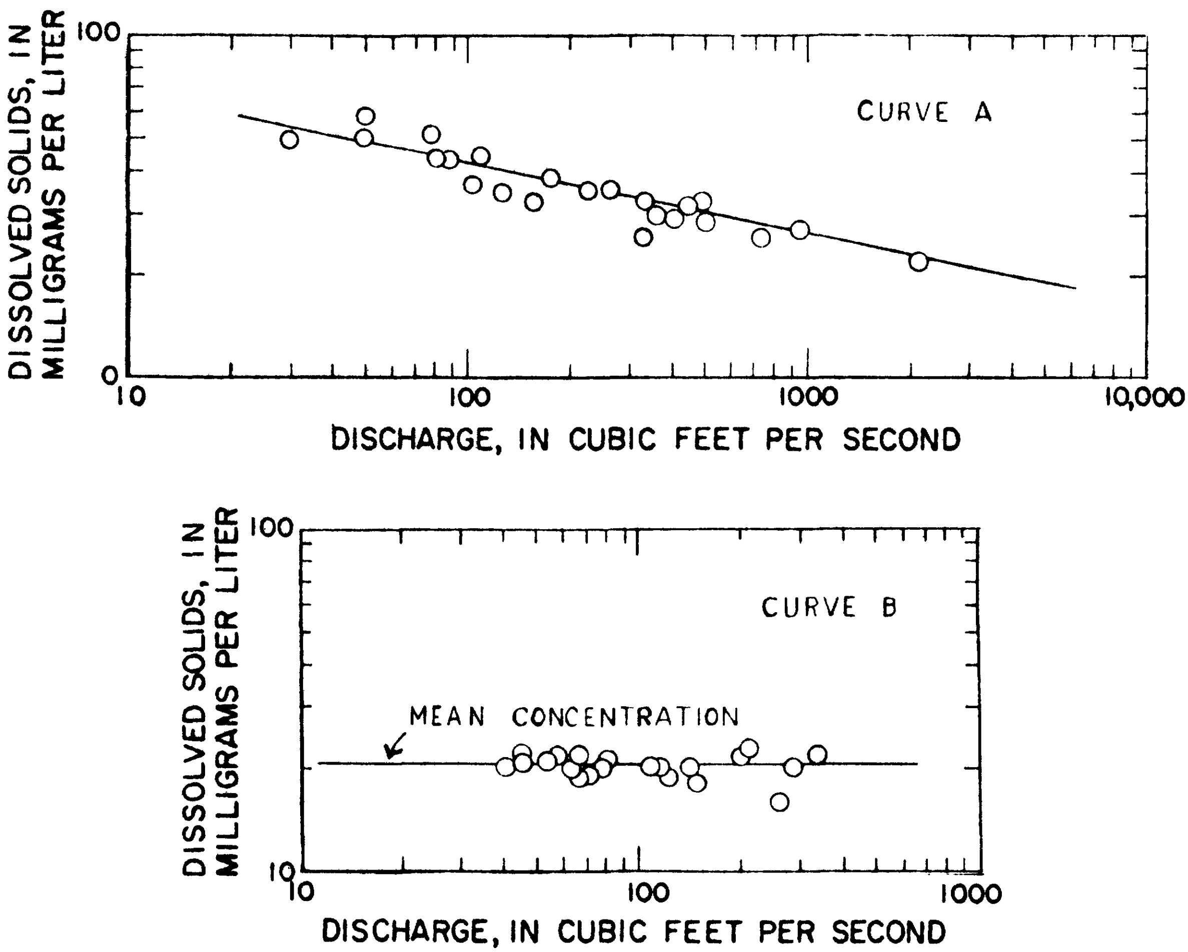

Figure 7.--Constituent concentration related to discharge, curve A, and constituent concentration not related to discharge, curve B.

Point-source constituent loads were computed by multiplying the mean constituent concentrations by the mean daily effluent discharge from each WTF. Mean constituent concentrations were determined from grab samples of effluent collected by the U.S. Geological Survey. Mean daily effluent discharges were computed from monthly plant-operator reports supplied by EPD. Point-source constituent loads to the river were computed by summing the constituent loads for each of the seven WTF's. Analyses of some point-discharge samples collected as part of the study effort were compared with analyses of samples collected and analyzed by treatment plant operators. In general, the analyses compared favorably.

Constituent loads at the Atlanta station are considered as nonpoint. Although four point sources discharge into the river in the Buford Dam-to-Atlanta reach, their total discharge in 1976 was about 10 ft^3/s, or less than 0.4 percent of the mean daily flow at Atlanta.

The input nonpoint-source constituent loads in the Atlanta-to-Fairburn and Fairburn-to-Whitesburg reaches of the river were computed for all flow conditions by subtracting the point-source constituent loads from the total stream-constituent loads originating in these two reaches. Nonpoint-source loads in the Atlanta-to-Fairburn and Fairburn-to-Whitesburg reaches of the river were also computed from urban, rural, and forested nonpoint-source yields (loads per unit area).

The effects of point and nonpoint discharges on the DO regime in the Atlanta-to-Franklin reach of the river were computed by the Velz (1970) rational accounting stream method from data collected during two low-flow periods. The effects of point and nonpoint discharges on phytoplankton concentrations in West Point Lake were computed from data collected by Cherry and others (1978) at Whitesburg (RM 259.85), Franklin (RM 235.46), LaGrange (RM 221.26), Abbottsford (RM 210.67), and at the West Point Dam pool (RM 202.36) stations.

POINT AND NONPOINT DISCHARGES

Point sources are the seven WTF's and the Atkinson-McDonough powerplants, all of which discharge into the Chattahoochee River or its tributaries in the Atlanta-to-Fairburn reach. Flow design and mean daily flow (1976) for each of the point sources are shown in table 9. The mean daily flow of the WTF's in 1976 was 179 ft^3/s, or about 4 percent of the mean daily flow of about 4,400 ft^3/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. The location of the streams is shown in figure 1. Land use and hydrologic data for the streams are shown in tables 3 and 7.

Table 9.--Flow design and mean daily flow of point sources for 1976

Map reference number	Facility	Flow design (ft^3/s)	Mean daily flow (ft^3/s)
4	Cobb Chattahoochee	16	15
14	R. M. Clayton	186	118
15	Atkinson-McDonough	1,197	909
17	Hollywood Road	2.3	2.3
20	U.S. Air Force Plant No. 6	11	2.6
22	South Cobb Chattahoochee	12	13
23	Utoy Creek	46	21
28	Camp Creek	23	6.8

In the next two sections some general observations about the water-quality characteristics of point and nonpoint discharges are listed, and the significance of relationships between some of the constituent concentrations are briefly discussed.

Point Discharges

Average annual loads and average daily concentrations of selected constituents for each of the seven WTF's are shown in table 10. Table 10 shows 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 constituent concentrations.

The low ratios of the concentrations of COD and the oxygen equivalent of TOC (96 mg/L) to BOD_u, 1.4:1 and 1.1:1, indicate that most of the organic carbonaceous material in the point discharges is readily decomposed by aerobic microbiological activity.

Nonpoint Discharges

Table 11 shows the average annual yields and average daily concentrations for selected constituents from the urban, rural, and forested areas. Average annual yields and average daily concentrations are highest for suspended sediment, dissolved solids, total and dissolved nitrogen, total and dissolved phosphorus, NH_4-N, COD, BOD_u, arsenic, copper, lead, and zinc in the urban area. The rural area has the highest average annual yields and average daily concentrations for NO_3-N, TOC, and DOC. Average annual yields and average daily concentrations are lowest in the forested area.

The concentration data in urban, rural, and forested nonpoint discharges (table 11) show that:

(1) About 65 percent of the nitrogen is dissolved and that NO_3-N comprises 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.

The ratios of the concentrations of COD to BOD_u are 1.9:1 in the urban discharges, 2.8:1 in the rural, and 2.5:1 in the forested. The ratios of the concentration of the oxygen equivalent of TOC to BOD_u are 2.3:1 in the urban discharges, 6.0:1 in the rural, and 2.7:1 in the forested. The high rural ratios suggest the presence of organic carbonaceous materials that are not readily decomposed by natural processes.

Table 10.--Magnitudes and nature of point discharges for selected constituents for the year 1976

Facility	Constituent (tons/yr)																	
	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	Total organic carbon	Dissolved organic carbon	Suspended solids	Dissolved solids	Total arsenic	Total chromium	Total copper	Total lead	Total zinc
Cobb Chattahoochee	330	160	4.4	130	66	27	1.1	1,200	1700	410	120	2,250	3,500	0.015	0.37	0.30	0.56	1.4
R. M. Clayton	2,300	1,500	32	1,030	440	190	17	13,000	18,000	5,000	1,300	9,880	28,800	.51	14	10	19	54
Hollywood Road	50	37	.39	30	10	6.8	.96	220	240	56	21	143	567	.0023	.046	.045	.076	.098
U. S. Air Force Plant No. 6	14	11	9.8	0.24	0.80	.68	.066	17	36	9.3	7.2	7.4	875	.00064	.10	.021	.044	.074
South Cobb Chattahoochee	200	170	8.2	120	75	52	4.5	620	1,200	240	110	636	3,120	.012	.24	.22	.59	1.0
Utoy Creek	270	240	7.0	160	68	42	1.6	960	1,400	520	190	564	5,120	.021	.54	.31	1.2	1.5
Camp Creek	76	71	60	2.4	33	29	1.0	100	250	69	38	111	1,350	.0067	.13	.061	.11	.28
Sum of annual loads (tons/yr)	3,200	2,200	120	1,500	690	350	26	16,000	23,000	6,300	1,800	13,600	43,300	0.57	15	11	22	58
Mean daily concentration (mg/L)[a]	18	12	0.70	8.5	3.9	2.0	0.15	90	130	36	10	77	245	0.003	0.09	0.06	0.12	0.33

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

Table 11.--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	Constituent															
	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	8.0	24	18	11	.003	.029	.028	.053
Average concentration	36.6	205	1.2	.94	.51	.07	.13	.01	5.0	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

The ratio of the concentrations of total nitrogen to total phosphorus is indicative of the degree and source of enrichment. The ratio in water from natural sources (soil) is about 8:1 (Malcolm, 1970). Ratios less than 8:1 may be indicative of sewage inputs into a stream. The urban ratio is 6.5:1, the rural is 9.2:1, and the forested is 7.1:1. There are no known sources of sewage in the forested area, whereas there are known sources, CSO's, in the urban area. If the sewage discharges are significant in the urban area, then the urban ratio should be appreciably different from the forested ratio, but it is not.

The ratio of the concentrations of NO_3-N:NH_4-N are 7.3:1 in the rural discharges, 4.2:1 in the forested, and 2.5:1 in the urban. The high rural ratio may be due to the application of fertilizer to croplands and the subsequent oxidation of reduced nitrogen forms to NO_3-N in the soil. The low urban ratio may reflect the lack of opportunity for nitrification to occur in the soil because of more impervious areas such as dwellings, parking lots, highways, and large commercial and industrial complexes.

Average annual constituent yields for the area draining the Clear Creek and Tanyard Branch CSO's are about the same as those in other urban streams (table 12). The two CSO's drain 7.24 mi of the Peachtree Creek basin (fig. 6). Constituent loads were computed for North and South Fork Peachtree Creeks and subtracted from constituent loads computed at the Peachtree Creek at Atlanta station to determine the constituent loads in the intervening area. Constituent yields in the intervening area are about the same as those for North and South Fork Peachtree Creeks.

Constituent concentrations for the Clear Creek CSO and North Fork Peachtree Creek for the storm period of March 12-15, 1976, are shown in table 13. Nitrogen, phosphorus, and BOD concentrations are high during the initial CSO discharges, and generally decrease to about one-half the initial concentration during the peak discharges (25 minutes later). Most constituent concentrations increase slightly during the recession. Constituent concentrations in CSO discharges are generally greater than those in North Fork Peachtree Creek during comparable periods of discharge. CSO's generally flow during periods of rainfall and cease to flow shortly after the rainfall stops, whereas North and South Fork Peachtree Creeks continue to flow for much longer periods. Thus, the storm-constituent yields for the intervening area draining the CSO's are about the same as those in other urban streams (table 14).

Relation of Nonpoint Constituent Yields to Urbanization

Average annual constituent yields from 15 basins in the Chattahoochee River basin were related to percentage of urbanization in each of these basins. Three of these basins are located upstream of Lake Sidney Lanier and are discussed by Faye and others (1978a). Each of the three basins is less than 0.6 percent urbanized. Seven of the basins are located in the Peachtree Creek basin (table 2). The other five basins are located downstream from Peachtree Creek.

Table 12.--Average annual yields of selected constituents for stations in Peachtree Creek basin

Map reference number	Station	Constituent (tons/mi^2/yr)								
		Dissolved solids	Total nitrogen	Dissolved nitrogen	Total phosphorus	Dissolved phosphorus	Ultimate biochemical oxygen demand	Chemical oxygen demand	Total lead	Total arsenic
10	Peachtree Creek at Atlanta	113	2.3	1.6	0.37	0.038	16	30	0.18	0.005
7	South Fork Peachtree Creek at Atlanta	107	2.4	1.7	.37	.041	15	20	.22	.003
6	North Fork Peachtree Creek near Atlanta	96.2	2.2	1.6	.32	.035	14	22	.14	.002
	Intervening area draining combined sewer overflows[a]	144	2.3	1.5	.43	.039	20	55	.20	.01

[a]Combined sewers are map reference numbers 8 and 9.

Table 13.--Constituent concentrations for Clear Creek combined-sewer overflow and North Fork Peachtree Creek during the storm period of March 12-15, 1976

Map reference number (fig. 6.)		Constituent (mg/L)									
		Dissolved solids	Total nitrogen	Dissolved nitrogen	Dissolved ammonium nitrogen	Dissolved nitrate nitrogen	Total phosphorus	Dissolved phosphorus	Chemical oxygen demand	Ultimate biochemical oxygen demand	Total lead
8	Clear Creek										
	Rise Initial discharge	99	9.0	4.0	2.2	0.84	1.8	0.80	80	100	0.920
	Peak 25 minutes after initial discharge	55	4.8	1.3	.44	.35	.99	.12	35	76	1.3
	Recession 50 minutes after initial discharge	62	3.8	1.8	.66	.43	.84	.22	55	36	.420
	Recession 65 minutes after initial discharge	79	4.2	1.5	.81	.61	.84	.43	60	56	.240
6	North Fork Peachtree Creek										
	Rise 6 hours after initial rise	44	3.0	1.6	.20	.55	.44	.04	10	18	.230
	Near peak 17 hours after initial rise	34	1.7	.92	.14	.34	.31	.03	25	12	.120
	Recession 24 hours after initial rise	38	1.3	.81	.14	.39	.26	.01	15	6.0	.046

Table 14.--Storm yields for selected constituents for stations in Peachtree Creek basin for period March 12-15, 1976
[units for yield are tons per square mile]

Map reference number (fig. 6)	Station	Constituent: Dissolved solids	Total nitrogen	Total phosphorus	Dissolved phosphorus	Ultimate biochemical oxygen demand	Total lead
10	Peachtree Creek at Atlanta						
	Yield	2.72	0.11	0.018	0.0020	0.70	0.0085
7	North Fork Peachtree Creek near Atlanta						
	Yield	3.25	.16	.024	.0031	.75	.0055
6	South Fork Peachtree Creek at Atlanta						
	Yield	2.80	.11	.020	.0020	.55	.012
	Intervening area containing combined sewer overflows[a]						
	Yield	1.88	.039	.0085	.00044	.85	.0080

[a]Combined sewers are key numbers 8 and 9.

Generally, constituent yields increase with increasing urbanization, and the slope of the constituent yield relationships is greater for dissolved constituents that for total constituents. Non-linear least square fit relationships of constituent yields to percentage of urbanization were developed for dissolved solids, BOD_u, total and dissolved phosphorus, total and dissolved nitrogen, and total lead. COD, TOC, DOC, and suspended nitrogen and phosphorus do not appear to be exponentially related to percentage of urbanization. However, the yields of these constituents are generally higher in urban than in the forested areas.

The relationship of average annual yields of dissolved solids (correlation coefficient is 0.87) and BOD_u (correlation coefficient is 0.93) is shown in figure 8. The dissolved-solids yield of 146 (tons/mi^2)/yr is from the 91 percent urbanized intervening area, which drains the CSO's in Peachtree Creek basin. The BOD_u yield from North Fork Peachtree Creek Tributary (at Meadowcliff Road near Chamblee) is shown in the plot, but was not included in the regression. Although the basin is 84 percent urbanized, it is mostly residential. The BOD_u yield of 6.2 (tons/mi^2)/yr from the residential area is about the same as the yield from forested areas. Average annual yields of total phosphorus and lead from the residential basin are also 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 Chattahoochee River

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

$$L = UU_y + RR_y + FF_y, \qquad (1)$$

where, L = nonpoint load in tons,
U = urban area in mi^2 (table 2),
U_y = urban constituent yield in (tons/mi^2)/yr (table 11),
R = rural area in mi^2 (table 2),
R_y = rural constituent yield in (tons/mi^2)/yr (table 11),
F = forested area in mi^2 (table 2),
and
F_y = forested constituent yield in (tons/mi^2)/yr (table 11).

Constituent loads computed from equation (1) 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 15. In general, nonpoint constituent loads can be estimated from urban, rural, and forested nonpoint discharge constituent yields.

Urban nonpoint loads in the Atlanta-to-Franklin reach (39.8 percent urban, 11.7 percent rural, and 48.5 percent forested) are equal to or greater

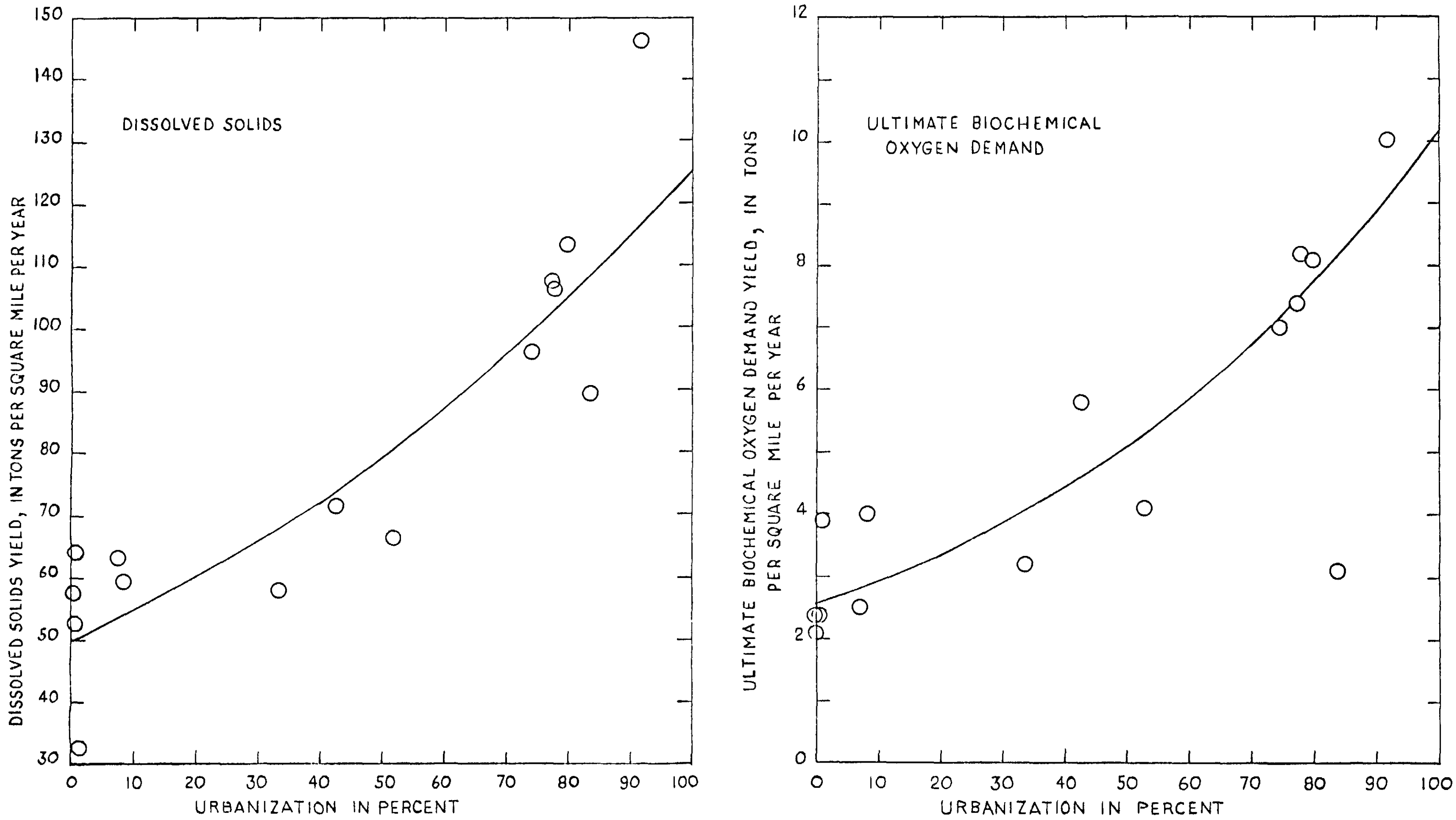

Figure 8.--Relationship of average annual yields of dissolved solids and biochemical oxygen demand (ultimate) to percentage of urbanization.

Table 15.--Comparison of average annual nonpoint constituent loads computed from urban, rural, and forested yields to nonpoint constituent loads computed from river measurements

	Constituent (tons/yr)							
	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	2.0
Forest	9,550	330	170	95	47	2.4	2,300	12
From equation (1)	41,200	1,000	670	420	150	13	7,000	58
From 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
From equation (1)	15,600	480	300	--	66	4.1	3,600	18
From 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
From equation (1)	56,700	1,500	970	--	220	17	11,000	76
From river measurements	69,900	1,900	800	--	440	99	15,000	110

than the sum of the rural and forested load. Forested nonpoint loads in the Fairburn-to-Whitesburg reach (6.5 percent urban, 16.8 percent rural, and 76.7 percent forested) are greater than the sum of the urban and rural loads. Urban loads in the Atlanta-to-Whitesburg reach (27.7 percent urban, 13.6 percent rural, and 59.2 percent forested) are generally the highest and rural loads the lowest.

Urban, Rural, and Forested Nonpoint Discharges to the Chattahoochee River During the Storm Period of March 12-15, 1976

Magnitudes of urban, rural, and forested nonpoint discharges were computed for the storm period of March 12-15, 1976. An analysis of the rainfall distribution by the Thiessen method (Linsley, Kohler, and Paulhus, 1975) indicates that the rainfall during the storm averaged about 2.4 inches and was uniformly distributed in the study area. Nonpoint yields and average concentrations for selected constituents for the storm period are shown in table 16.

The urban, rural, and forested nonpoint constituent loads for the storm period were computed for the Atlanta-to-Fairburn and Fairburn-to-Whitesburg reaches as in the preceding discussion of average annual loads. A comparison of these nonpoint loads is shown in table 17.

In the Atlanta-to-Fairburn reach, urban nonpoint constituent loads are, in general, about an order of magnitude greater than either the rural or forested loads. In the Fairburn-to-Whitesburg reach, rural nonpoint constituent loads are generally greater than either urban or forested loads. In the Atlanta-to-Whitesburg reach, urban nonpoint constituent loads are, in general, about twice the sum of rural and forested loads, and rural nonpoint loads are greater than forested nonpoint loads.

COMPARISON OF MAGNITUDES OF POINT AND NONPOINT DISCHARGES TO THE CHATTAHOOCHEE RIVER

Most of the average annual (fig. 9) and March 12-15, 1976, storm-constituent loads (fig. 10) 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 of 197,000 tons/yr, 48 percent of the total phosphorus load of 1,300 tons/yr, 51 percent of the total nitrogen load of 6,800 tons/yr, 82 percent of the TOC load of 36,000 tons/yr, and 74 to 80 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 of 2,480 tons, 84 percent of the total phosphorus load of 29 tons, 79 percent of the total nitrogen load of 97 tons, and more than 90 percent of the arsenic and lead loads at Whitesburg (fig. 10). Most of the low-flow (June 1-2, 1977) constituent loads at the Franklin station (RM 235.46) were from point discharges (table 18). Point discharges contributed 44 percent of the dissolved-solids load of 334 tons/day, 90 percent of the total phosphorus load of 2.7 tons/day, 92 percent of the PO_4-P load of 1.8 tons/day, 78 percent of the total nitrogen load of 12 tons/day,

Table 16.--Nonpoint yields and average concentrations for selected constituents for urban, rural, and forested nonpoint discharges during the storm period of March 12-15, 1976
[units for yield are tons per square mile; units for concentration are milligrams per liter]

Land use	Constituent											
	Dissolved solids	Total nitrogen	Dissolved nitrogen	Dissolved ammonium nitrogen	Dissolved nitrate nitrogen	Total phosphorus	Dissolved phosphorus	Chemical oxygen demand	Ultimate biochemical oxygen demand	Total organic carbon	Dissolved organic carbon	Total lead
Urban												
Yield	2.72	0.11	0.060	0.021	0.024	0.018	0.0020	0.90	0.70	0.55	0.24	0.0085
Average concentration	54.4	2.2	1.1	.42	.47	.37	.04	18	14	11	4.8	0.17
Rural												
Yield	1.94	.10	.070	.0080	.031	.011	.00070	2.2	.33	.65	.60	.0012
Average concentration	27.7	1.5	.98	.11	.45	.16	.01	32	4.8	9.7	8.3	.02
Forest												
Yield	.338	.015	.0085	.00070	.0027	.0013	.000010	.19	.065	.075	.048	.00050
Average concentration	21.0	.91	.51	.04	.16	.08	.01	12	4.0	4.5	2.9	.03

Table 17.--Comparison of March 12-15, 1976, storm nonpoint constituent loads computed from urban, rural, and forested constituent yields and nonpoint constituent loads computed from river measurements

	Constituent (tons)							
	Dissolved solids	Total nitrogen	Dissolved nitrogen	Dissolved inorganic nitrogen as nitrogen	Total phosphorus	Dissolved phosphorus	Total organic carbon	Total lead
Atlanta to Fairburn								
Urban	661	27	15	11	4.5	0.49	133	2.1
Rural	138	7.4	5.0	2.8	.78	.050	46	.089
Forest	100	4.4	2.5	1.0	.39	.003	22	.15
From equation (1)	899	39	22	15	5.7	.54	200	2.3
From river measurements	1,110	39	18	12	15	1.1	350	2.4
Fairburn to Whitesburg								
Urban	65.6	2.7	1.4	1.1	.45	.048	13	.20
Rural	121	6.5	4.3	2.4	.68	.043	40	.078
Forest	96.0	4.3	2.4	.97	.37	.003	21	.14
From equation (1)	283	13	8.1	4.5	1.5	.09	74	.42
From river measurements	290	7	8	4	5	.0	170	.2
Atlanta to Whitesburg								
Urban	727	30	16	12	5.0	.54	146	2.3
Rural	259	14	9.3	5.2	1.5	.093	86	.17
Forest	196	8.7	4.9	2.0	.76	.006	43	.29
From equation (1)	1,180	53	30	19	7.3	.64	280	2.8
From river measurements	1,400	46	26	16	20	1.1	520	2.6

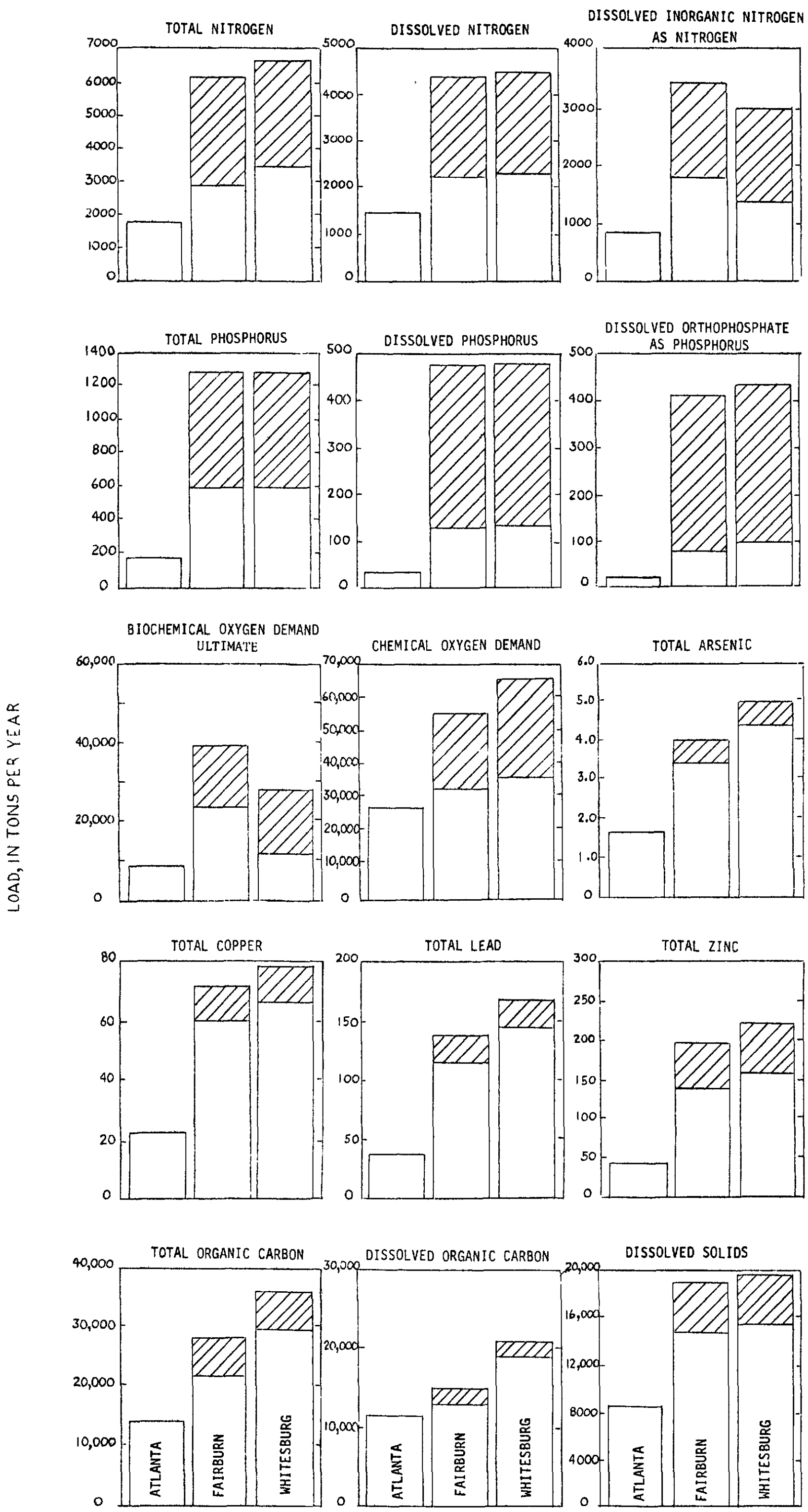

Figure 9.--Magnitudes and nature of average annual point (cross hatched) and nonpoint (clear) loads for selected constituents at stations on the Chattahoochee River at Atlanta, Fairburn, and Whitesburg.

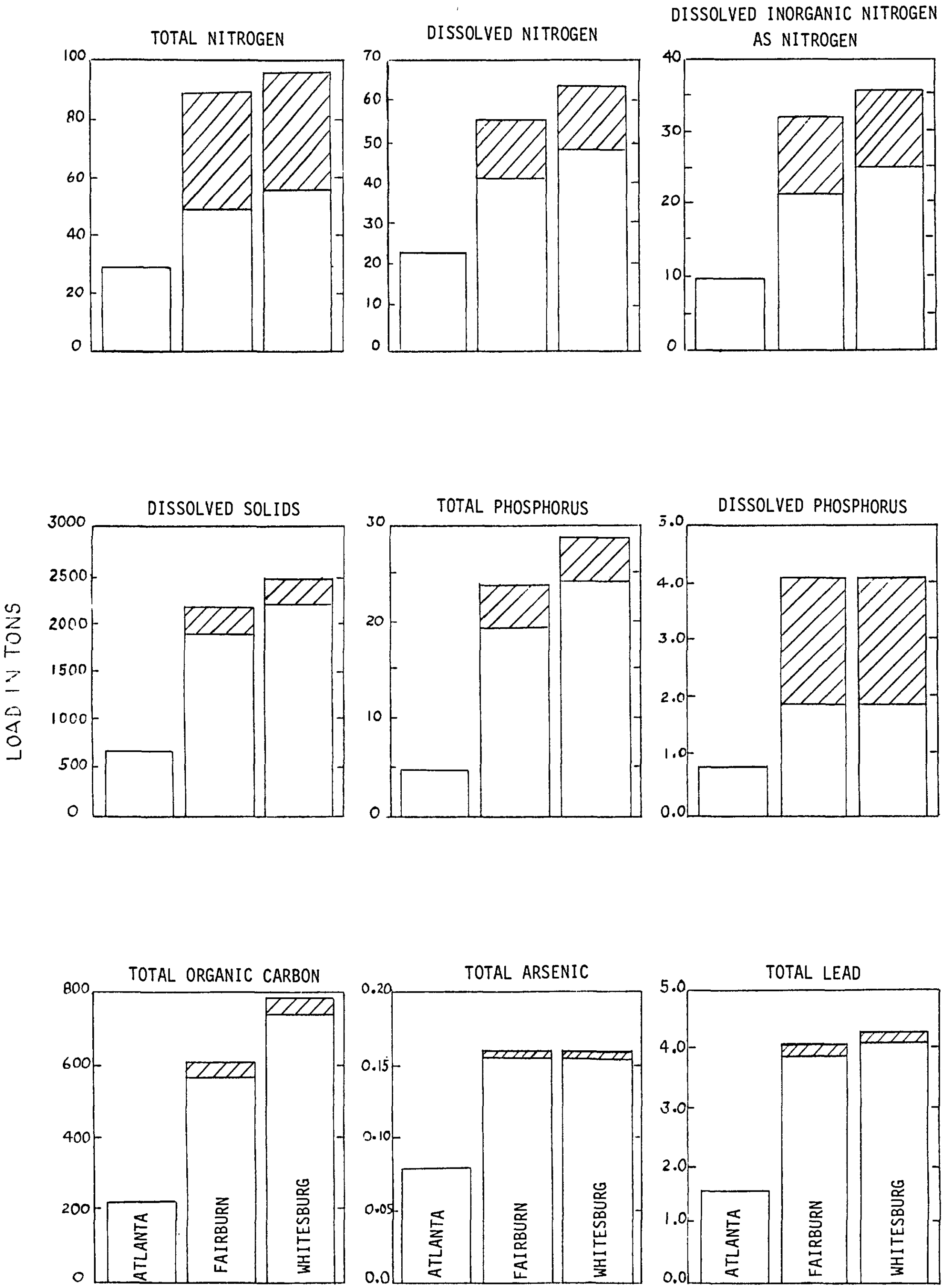

Figure 10.--Magnitudes and nature of point (cross hatched) and nonpoint (clear) loads for selected constituents at stations on the Chattahoochee River at Atlanta, Fairburn, and Whitesburg during the storm period of March 12-15, 1976.

Table 18.--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

Stream station	Constituent (tons/day)					Flow
	Dissolved solids	Total phosphorus	Total orthophosphate as phosphorus	Total nitrogen	Total inorganic nitrogen as nitrogen	(ft^3/s)
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 (tons/day)	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	

and 80 percent of the inorganic nitrogen as nitrogen load of 8.4 tons/day. Magnitudes and sources of selected constituent loads are shown in figures 11, 12, and 13.

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. 14). 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 as compared to constituent concentrations in the river resulting from nonpoint discharges (table 18). Point-source loads are relatively constant in comparison to nonpoint-source loads. The minimum DO concentration at the Fairburn 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.

The present and future effects of point and nonpoint discharges on the DO concentrations of the river nnd the phytoplankton concentrations in West Point Lake during warm-weather low-flow periods are discussed in the following sections.

PRESENT AND FUTURE EFFECTS OF POINT AND NONPOINT DISCHARGES ON THE DISSOLVED-OXYGEN REGIME OF THE 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 for two low-flow periods, August 31 to September 9, 1976, and June 1-2, 1977. Data used in the determination of the effects are shown in table 19. The method used in the determination was the Velz (1970) rational method of stream analysis.

The DO concentration 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 magnitudes 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 magnitudes of streamflow and increments of tributary inflow along the water-course, and reaeration from the atmosphere. (Photosynthesis was not significant in the study reach.) 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,

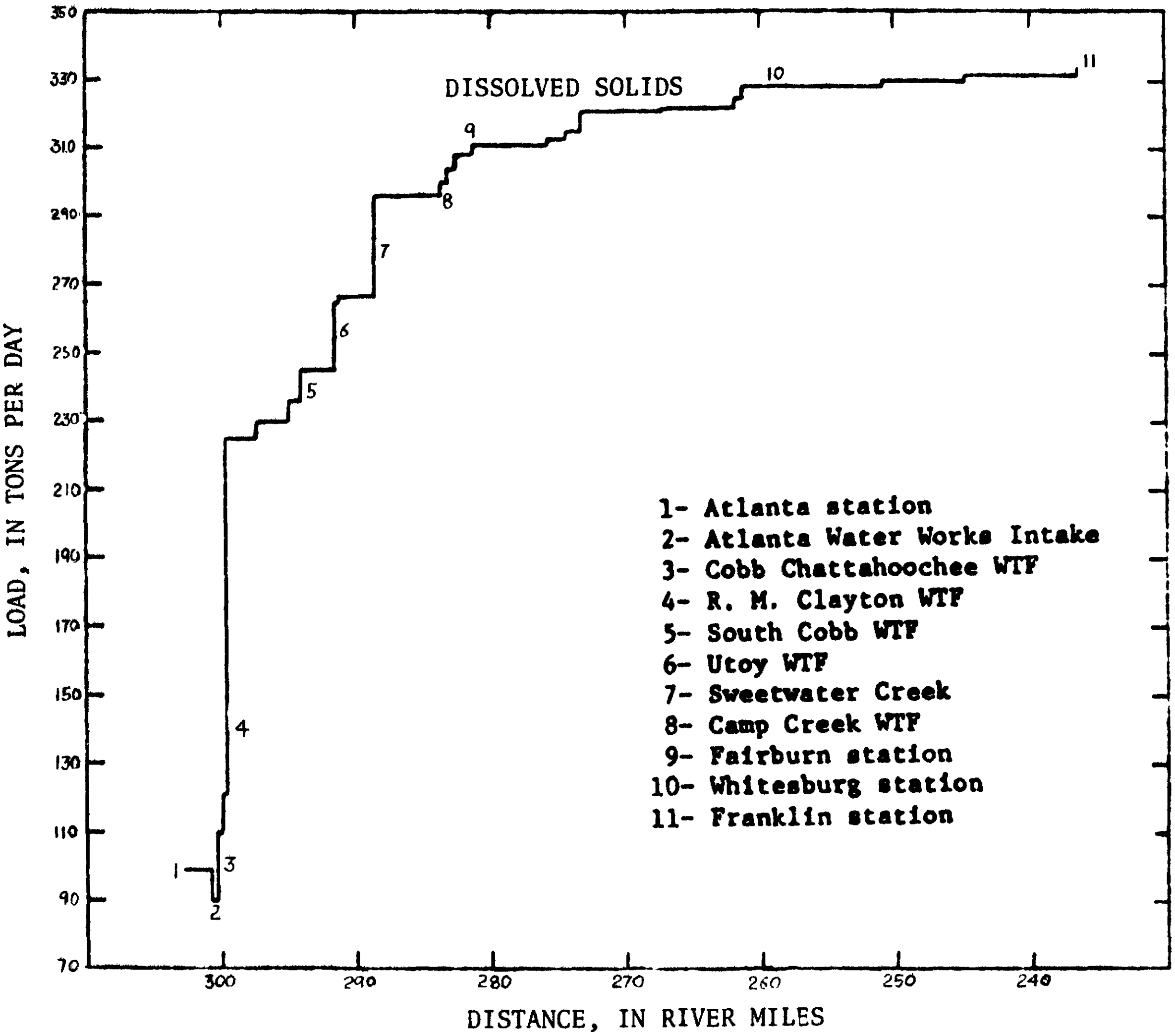

Figure 11.--Magnitudes of point and nonpoint dissolved-solids loads in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

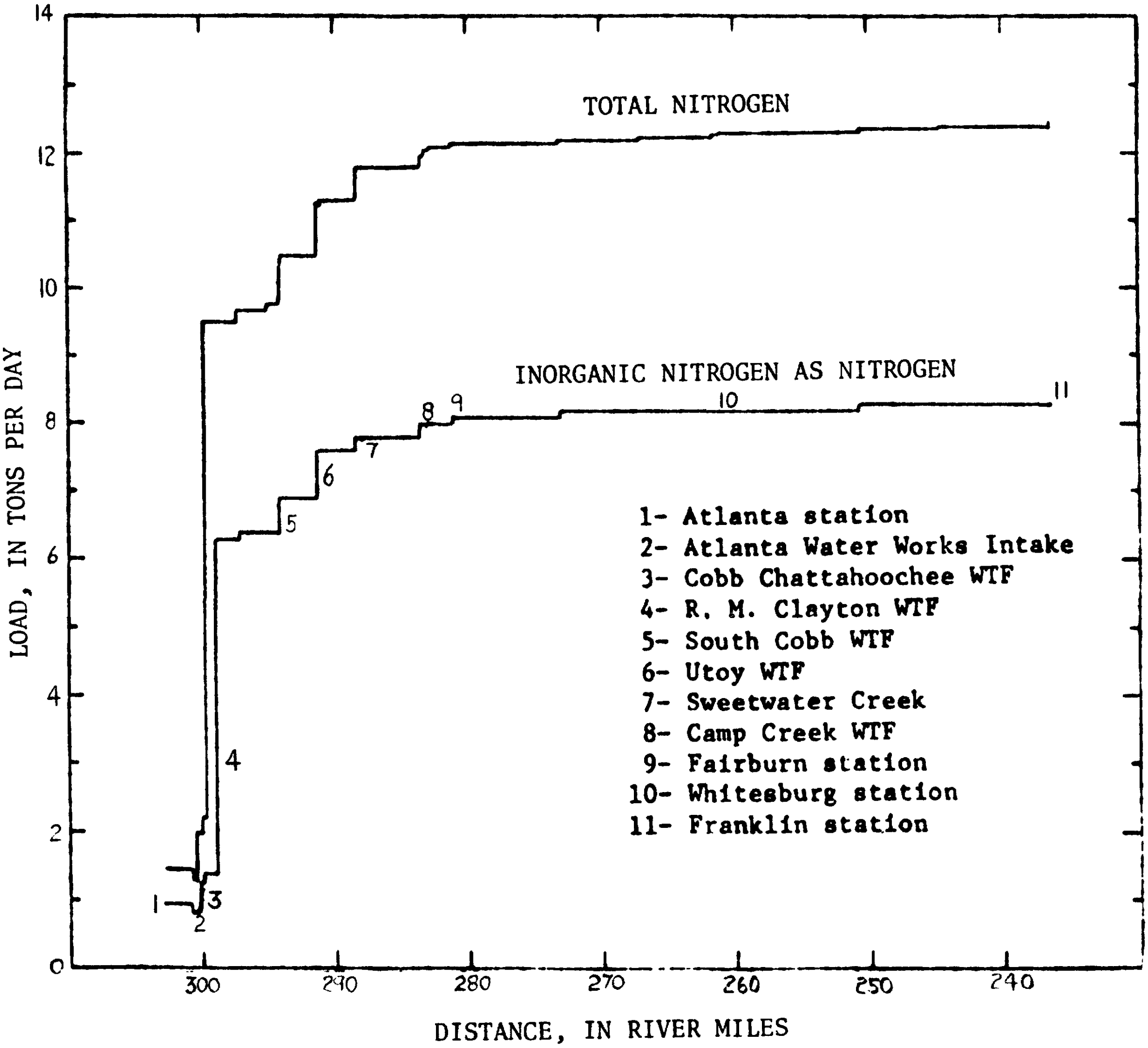

Figure 12.--Magnitudes of point and nonpoint nitrogen loads in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

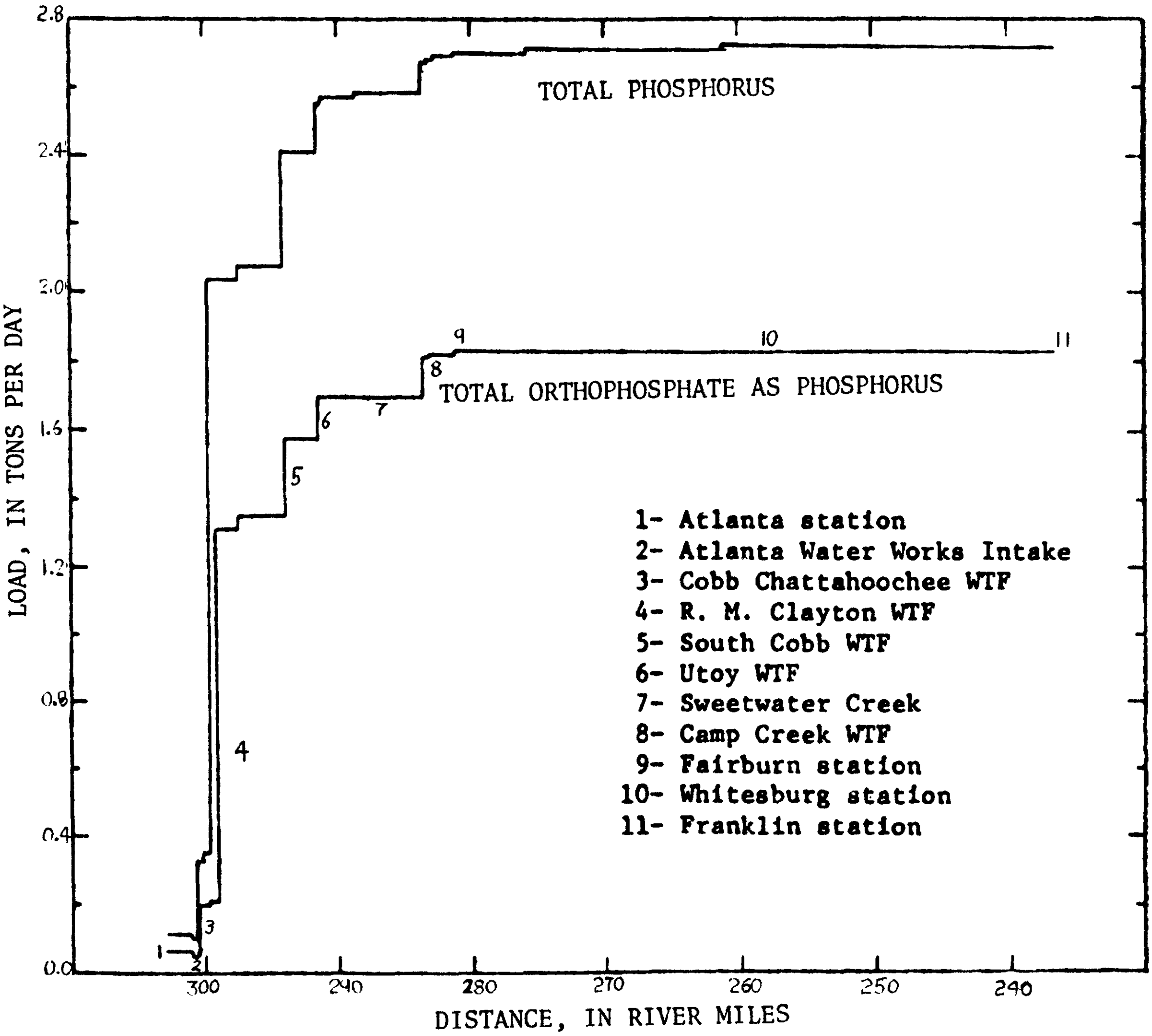

Figure 13.--Magnitudes of point and nonpoint phosphorus loads in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

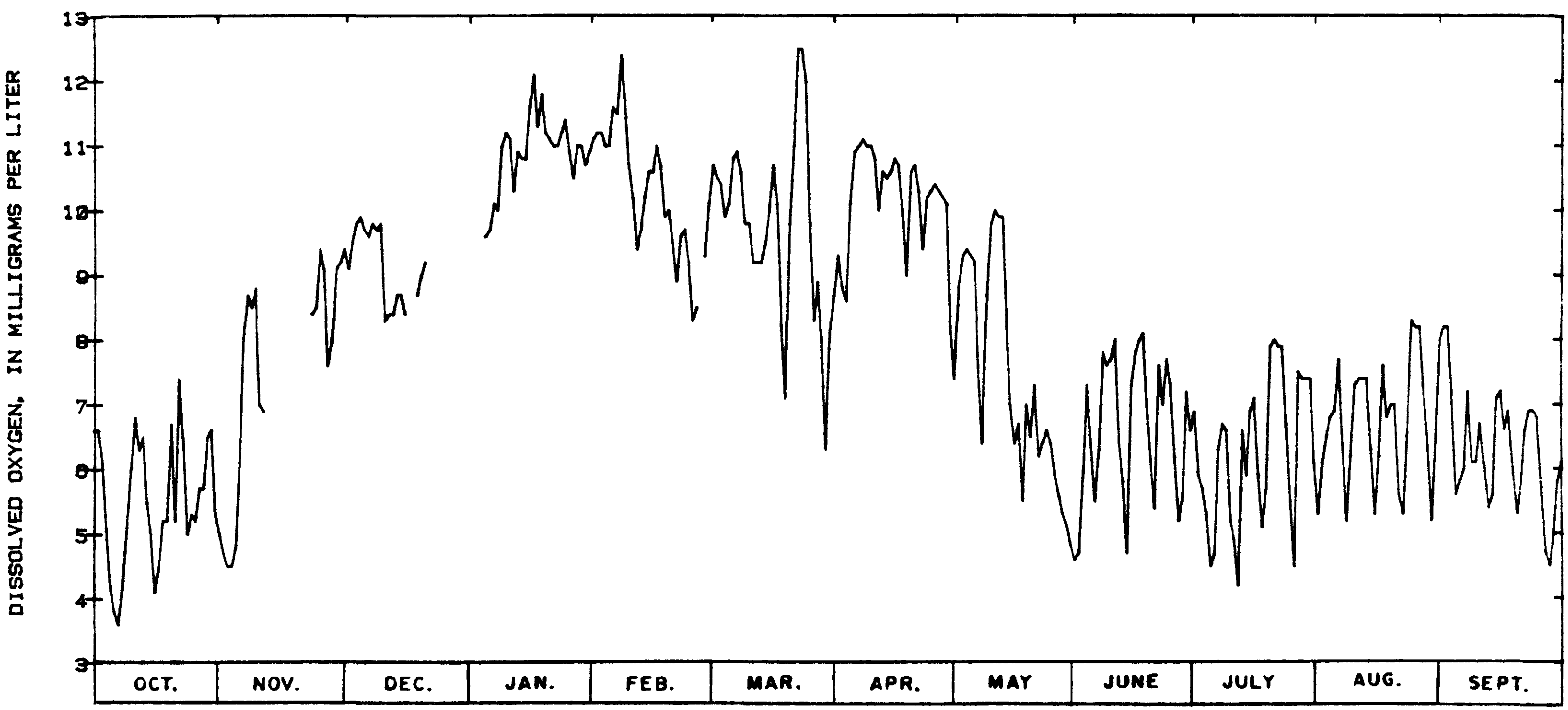

Figure 14.--Mean daily dissolved-oxygen concentrations at the Chattahoochee River near Fairburn station monitor, October 1976 to September 1977.

Table 19.--Chemical, physical, and flow data used to compute dissolved oxygen 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 Chattahoochee 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	283.27	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				

1977, were conducted during steady-state low-flow river conditions. Arrangements were made with Georgia Power Company and the U.S. Army Corps of Engineers to maintain a uniform release from Morgan Falls Dam, and likewise were made with plant operators to insure that normal operating procedures were maintained at the WTF's. The June 1-2, 1977, survey was used to verify the cause-effect relationships developed in June 1977.

Refined time of passage along the course of the river was determined from channel cross-section soundings taken at intervals of about 1,200 feet from Atlanta (RM 302.97 to Franklin (RM 235.46). In the upper reach, RM 302.97 to RM 281.88, the channel is relatively uniform, but in the lower reach, RM 281.88 to RM 235.46, the channel is characterized by pools and riffles. Observed channel soundings were adjusted to the prevailing streamflow during each of the surveys by stage-rating curves. Prevailing streamflow was determined from discharge measurements of the river and tributaries. In reaeration computations, effective depth was computed from the occupied channel volume divided by the stream surface area from reach to reach. Special reaeration studies were conducted in the lower reach where extensive shoals occur.

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 BODu. 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 at 20°C was determined from all 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, 36 and 21 tons/day, in the Atlanta-to-Franklin reach of the river at the prevailing time of passage as shown curve A in figure 15. 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 16. The overall close agreement between the independently observed and computed river concentrations supports the adoption of the BOD_u decay rate of 0.07 (at 20°C). The lowest BOD concentrations, 3.6 to 5.2 mg/L, were observed at the Atlanta station, and the highest, 9.0 to 18 mg/L, at SR (State route) 280. The high BOD_u concentrations at SR 280 were due to the addition of 32 tons/day of BOD_u from point discharges. The range of BOD concentrations at SR 280 was mostly due to variations in the BOD_u discharges from the R. M. Clayton WTF (fig. 17). 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. 16). 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 was determined from observed NH_4-N concentration changes in the river with consideration of effects due to dilution during the June 1977 survey. Ehlke (1978) indicated that the oxidation of NH_4-N to NO_3-N in the study reach of the river appears to be related to nitrifying bacteria on the sediment. The k_3 selected was applied to a mass balance integration of point- and nonpoint-source NH_4-N loads,

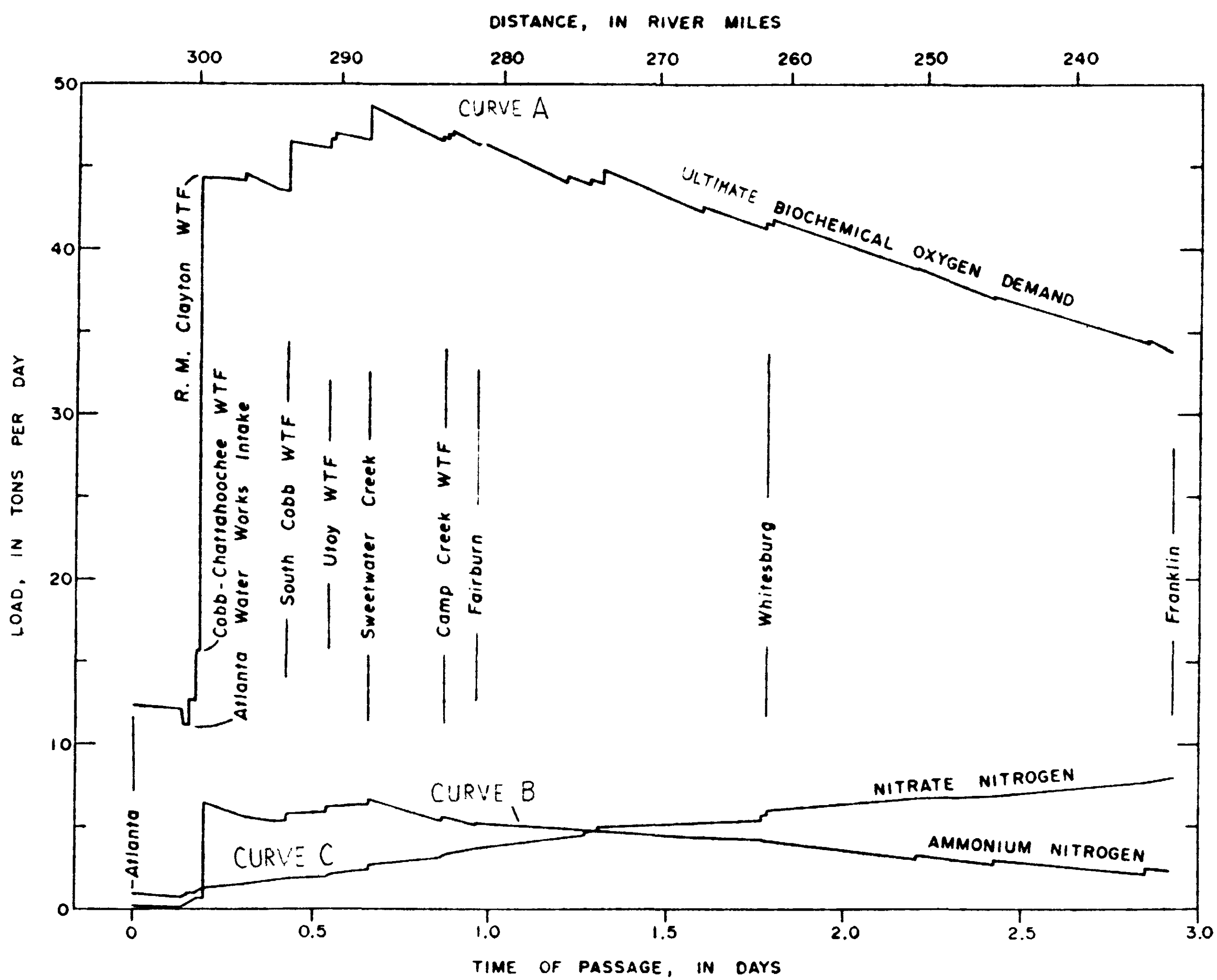

Figure 15.--Magnitudes of point-and nonpoint-source biochemical oxygen demand, ammonium nitrogen, and nitrate nitrogen loads in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

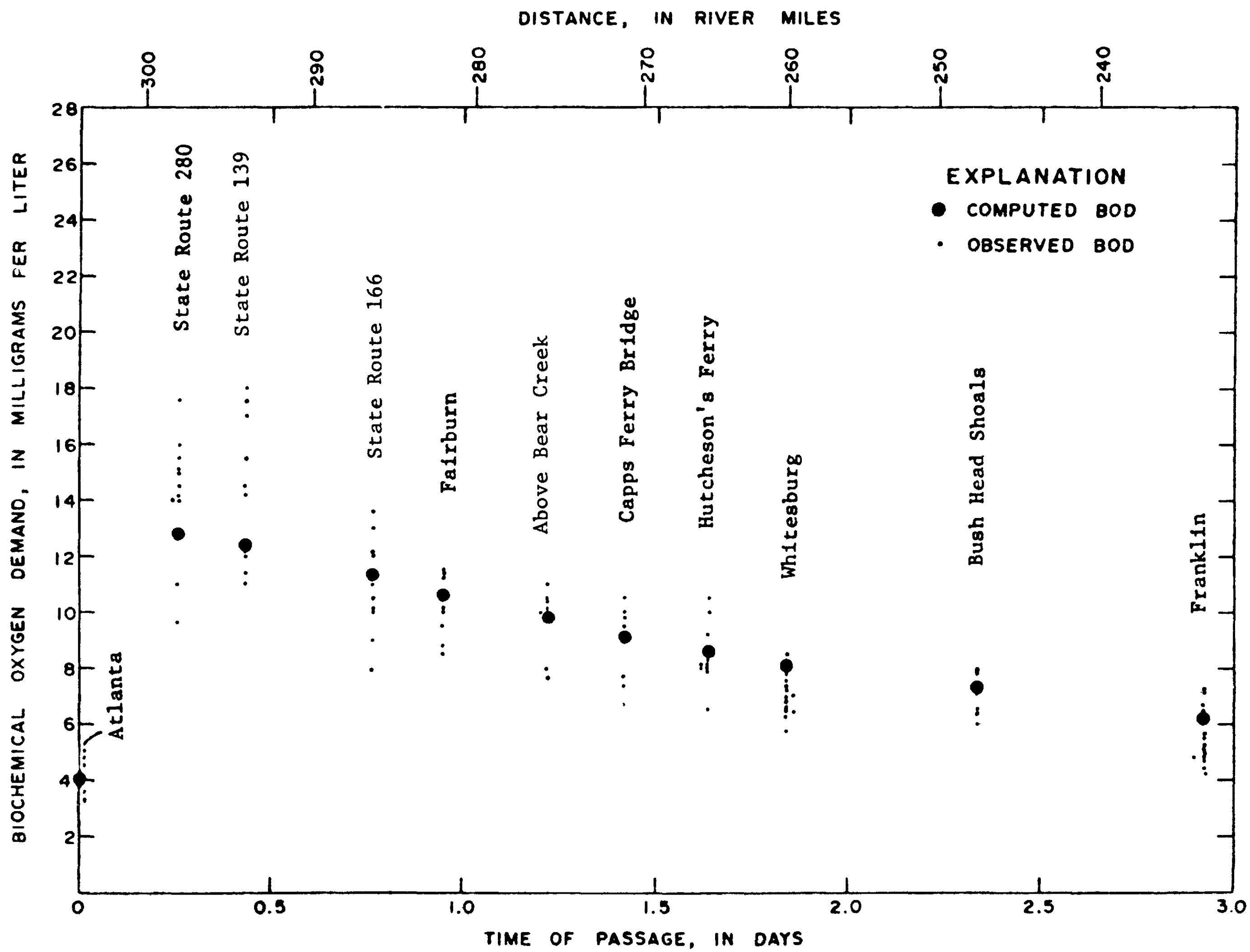

Figure 16.--Comparison of observed and computed ultimate biochemical oxygen demand concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

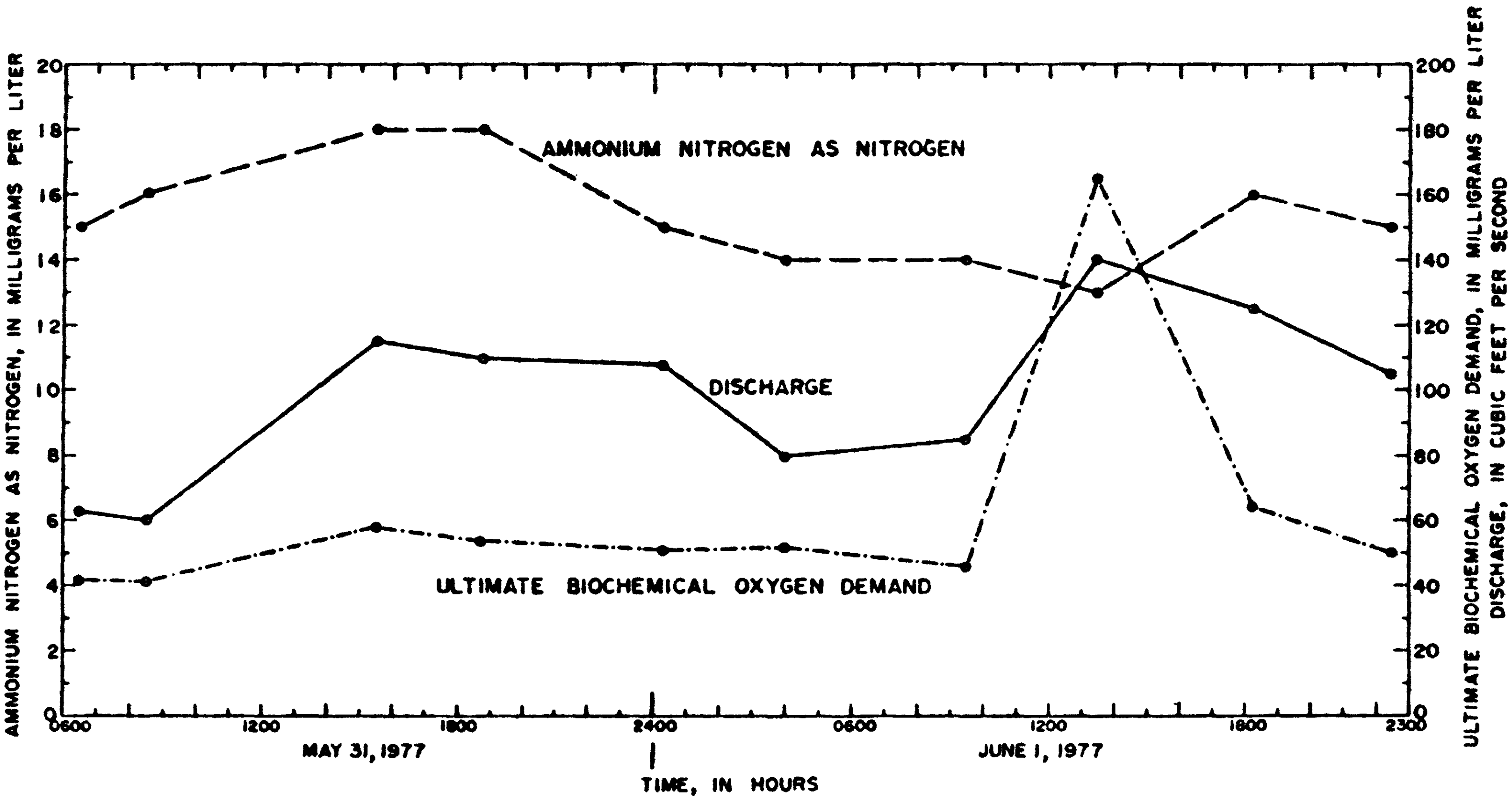

Figure 17.--Ammonium nitrogen and ultimate biochemical oxygen demand concentrations and effluent discharge variations during low-flow period, May 31 to June 1, 1977, R. M. Clayton WTF.

6.8 and 0.21 tons/day in the Atlanta-to-Franklin reach of the river at the prevailing time of passage as shown by curve B in figure 15. From curve B, 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, from curve C in figure 15, increases 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 18. 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, 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 high NH_4-N concentrations at SR 280 were due to the addition of 6.9 tons of NH_4-N to the river from point discharges (fig. 15). The range of NH_4-N concentrations at SR 280 was mostly due to variation in R. M. Clayton WTF NH_4-N discharges (fig. 17). The observed 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 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 19. The overall close agreement indicates that the formation of NO_3-N was mostly due to the oxidation of NH_4-N at a rate 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.

Because the computed BOD_u and NH_4-N rates of deoxygenation are independent of the observed river DO concentration, an overall confirmation of the self-purification factors adopted is shown by the comparison of the observed and computed river DO concentrations in figure 20 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 increase from 4.4 mg/L at 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 nitrogenous (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 21, and the effect of nitrogenous demands only (k_3 = 0.19) is shown in figure 22. In the upper reach of the river, RM 302.97 to RM 271.19, 48 percent of the carbonaceous oxygen demands are exerted 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 21 and 22.

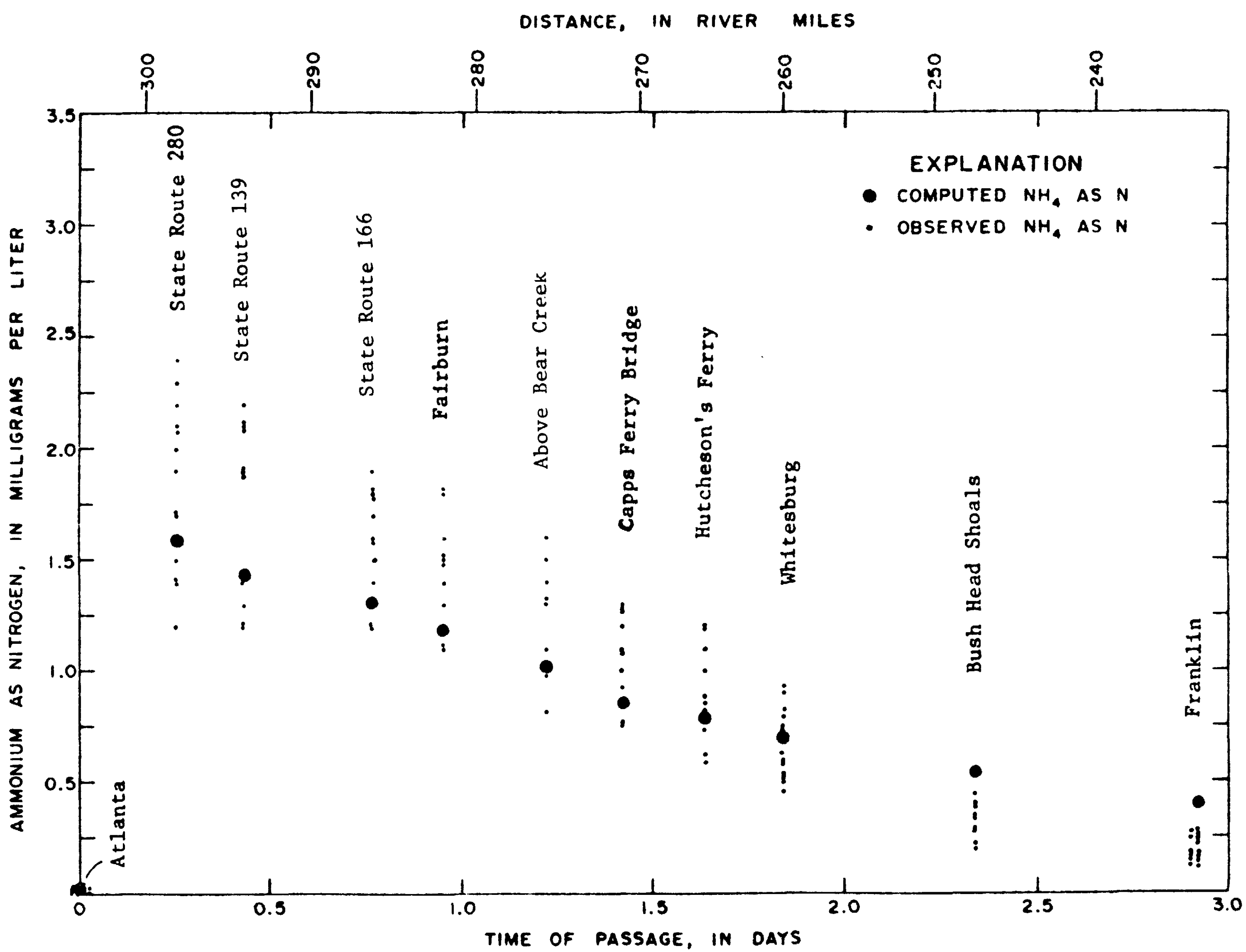

Figure 18.--Comparison of observed and computed ammonium nitrogen concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

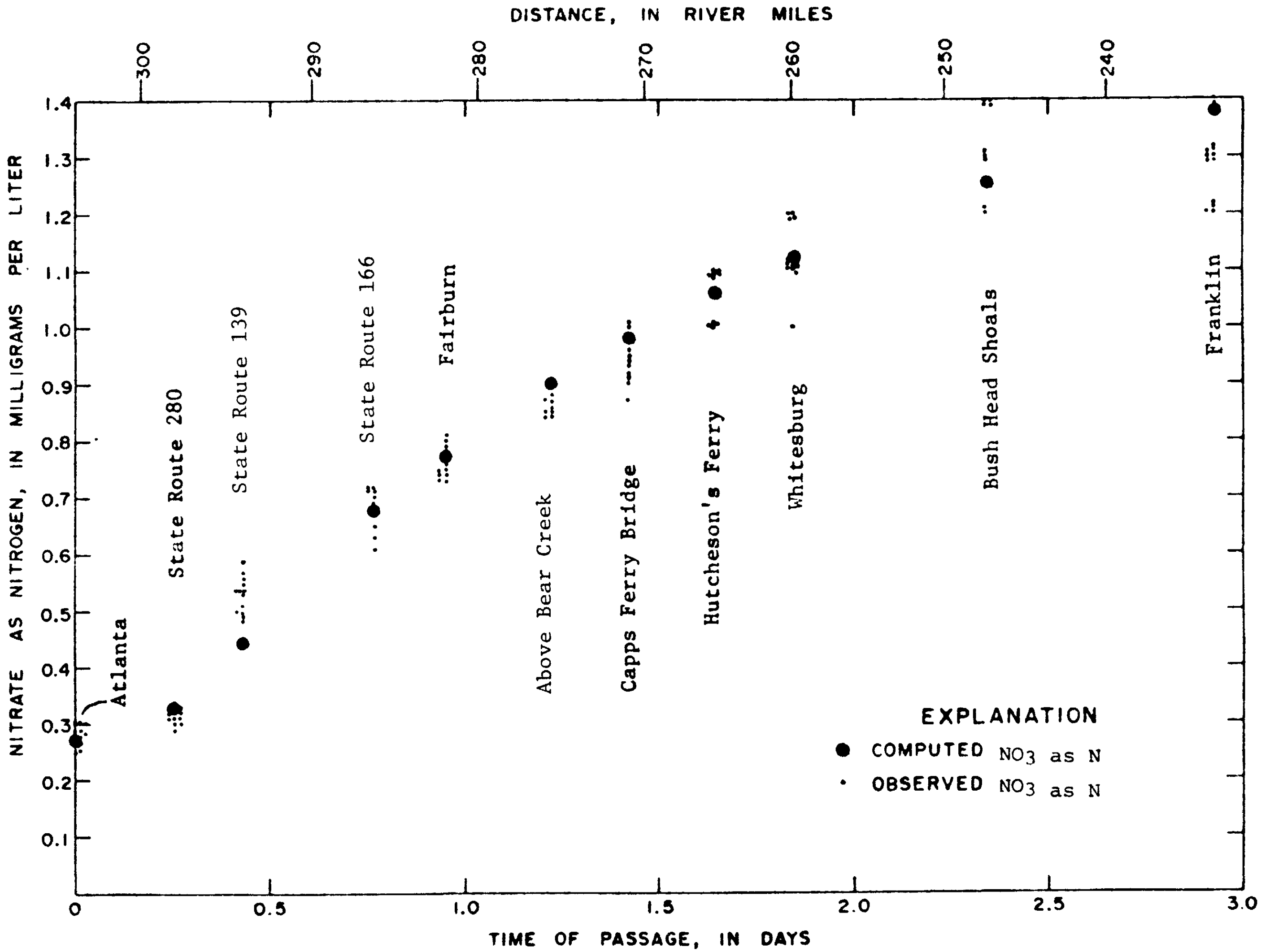

Figure 19.--Comparison of observed and computed nitrate nitrogen concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

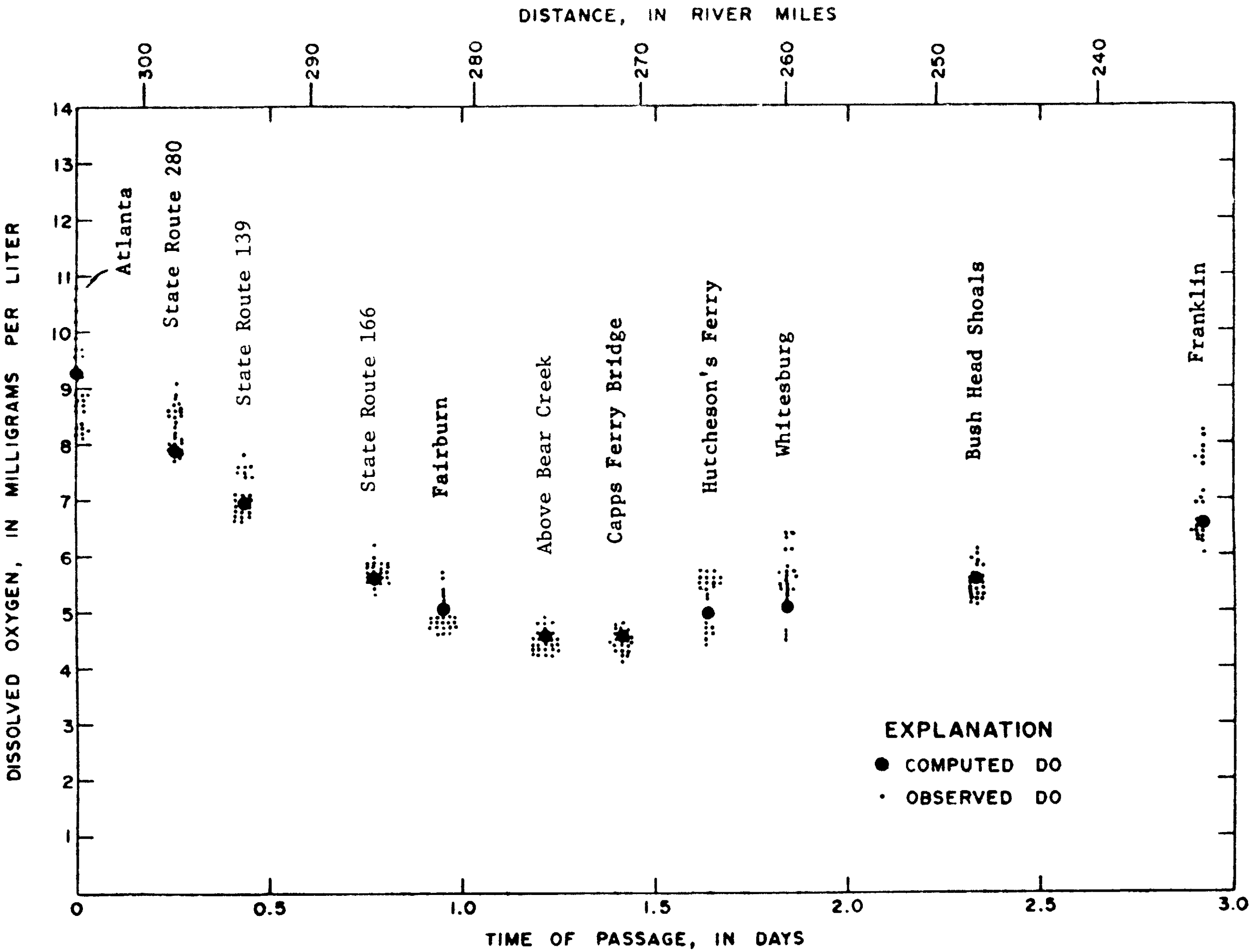

Figure 20.--Comparison of observed and computed dissolved-oxygen concentrations in the Atlanta-to-Franklin reach of the river during

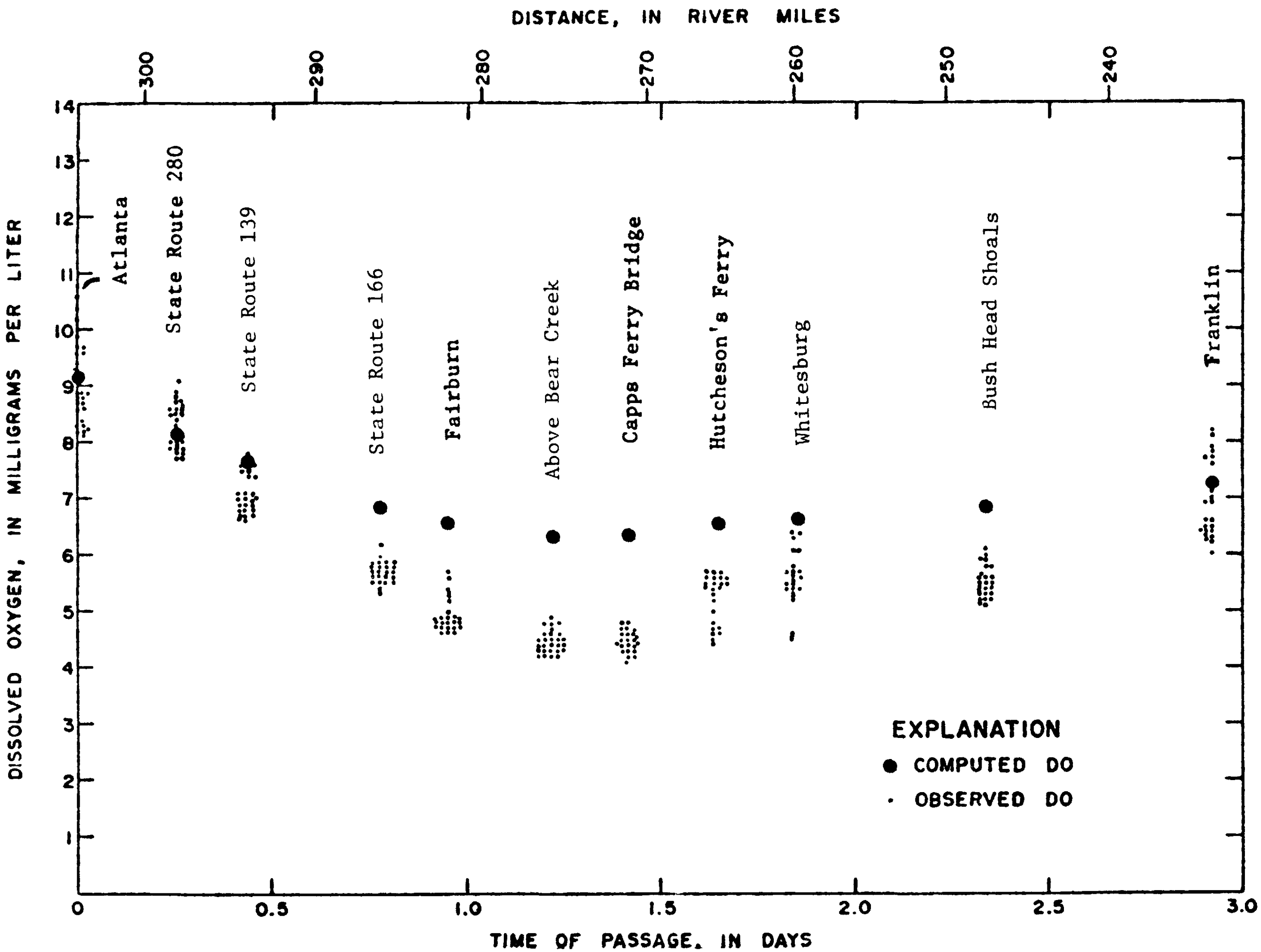

Figure 21.--Dissolved-oxygen concentrations observed and dissolved-oxygen concentration profile due only to carbonaceous oxygen demands in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

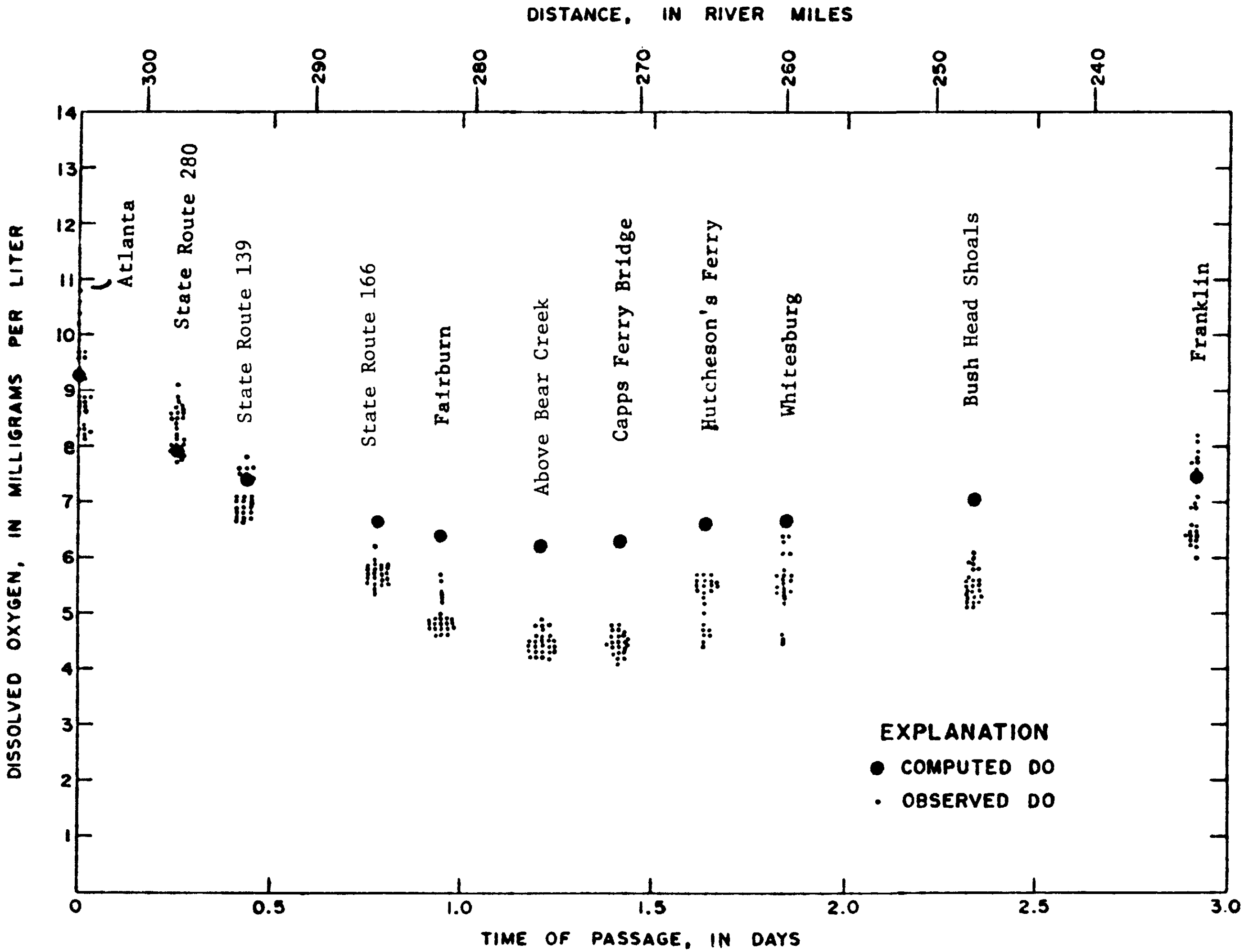

Figure 22,--Dissolved-oxygen concentrations observed and dissolved-oxygen concentration profile due only to nitrogenous oxygen demands in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

Average observed water temperatures in the Atlanta-to-Franklin reach are shown in figure 23. 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 (Faye and others, 1978b). 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 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 DO computed profile from data collected during the low-flow period of August 31 to September 9, 1976, (table 19) is shown in figure 24. A 0.07 k_1 and 0.19 k_3 rate (same as those in June 1977) were used in the DO computations. The flows at the Atlanta station and tributaries and the 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 (figs. 20 and 24) permit use of the method of analysis to project expected results from wastewater management alternatives. The minimum DO concentration in the Atlanta-to-Franklin reach of the river was related to changes in streamflow and wastewater treatment. DO profiles were computed based on observed June 1977 point-source discharges of 185 ft^3/s and estimated year 2000 discharges of 373 ft^3/s in the Atlanta-to-Franklin reach. The DO profiles are based on (1) point-source discharges containing concentrations of 15, 30, and 45 mg/L BOD_u with 5, 10, and 15 mg/L NH_4-N, (2) 7Q10 (lowest consecutive 7-day mean flow that occurs once in 10 years) tributary inflow (93 ft^3/s) in the Atlanta-to-Franklin reach, and (3) streamflow at the Atlanta station ranging from 860 to 1,800 ft^3/s. Table 20 summarizes the computed effects and also shows the river reach in RM where DO concentrations are less than 5.0 and 4.0 mg/L.

The analysis does not consider the impact of streamflow augmentation at the Atlanta station during the summer months on: (1) Hydroelectric power generation at Buford Dam, (2) recreation at Lake Sidney Lanier, and (3) surface-water supply withdrawals in the Buford Dam—to-Atlanta reach of the river. The analysis also does not consider the economic benefits or costs accrued by communities from streamflow augmentation or changes in wastewater treatment levels.

The curves in figure 25 relate the minimum DO concentration in the river to streamflow at Atlanta with point-source discharges containing BOD_u concentrations of 15, 30, and 45 mg/L and NH_4-N concentrations of 5, 10, and 15 mg/L

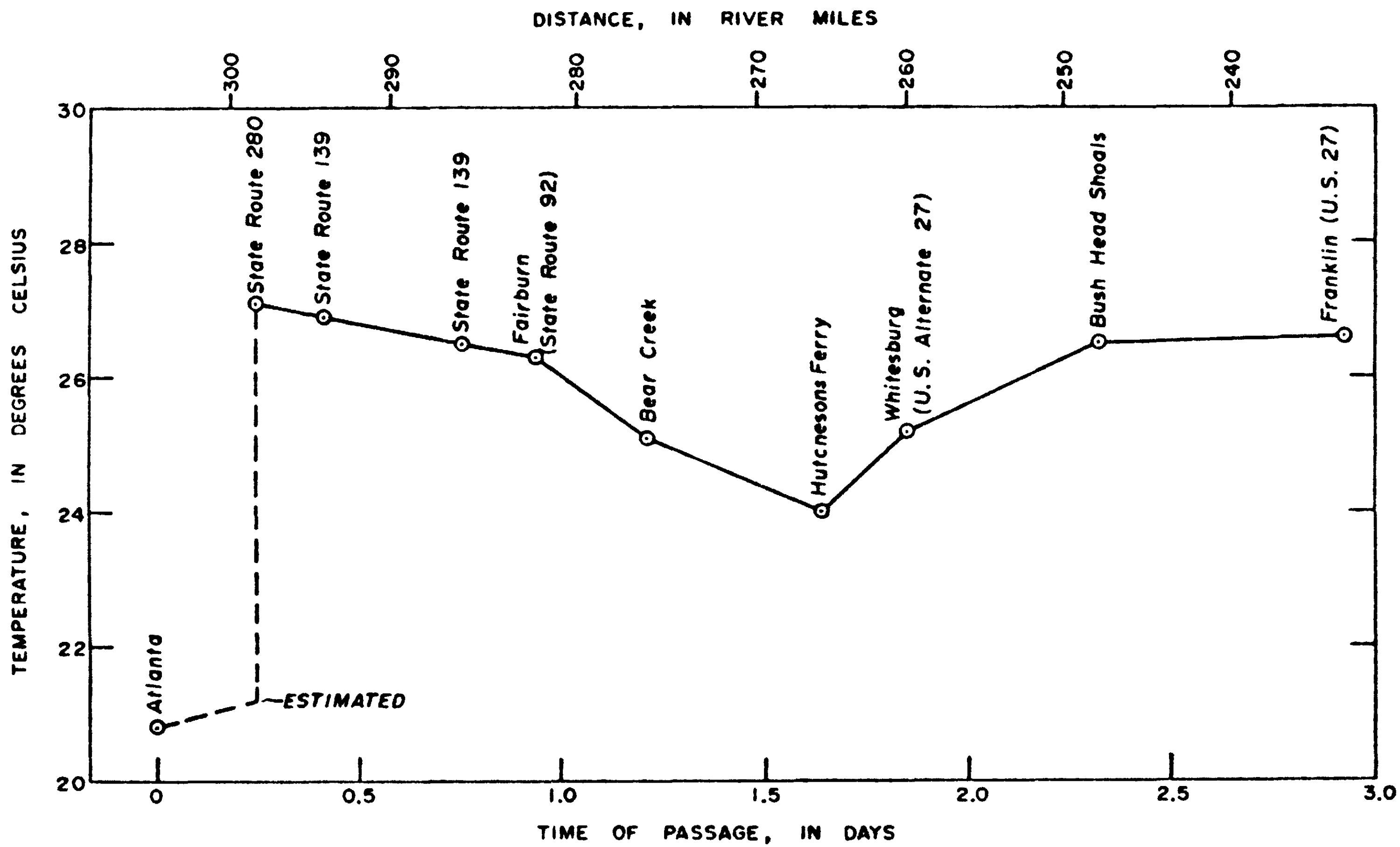

Figure 23.--Temperature of river water in the Atlanta-to-Franklin reach of the river during low-flow period, June 1-2, 1977.

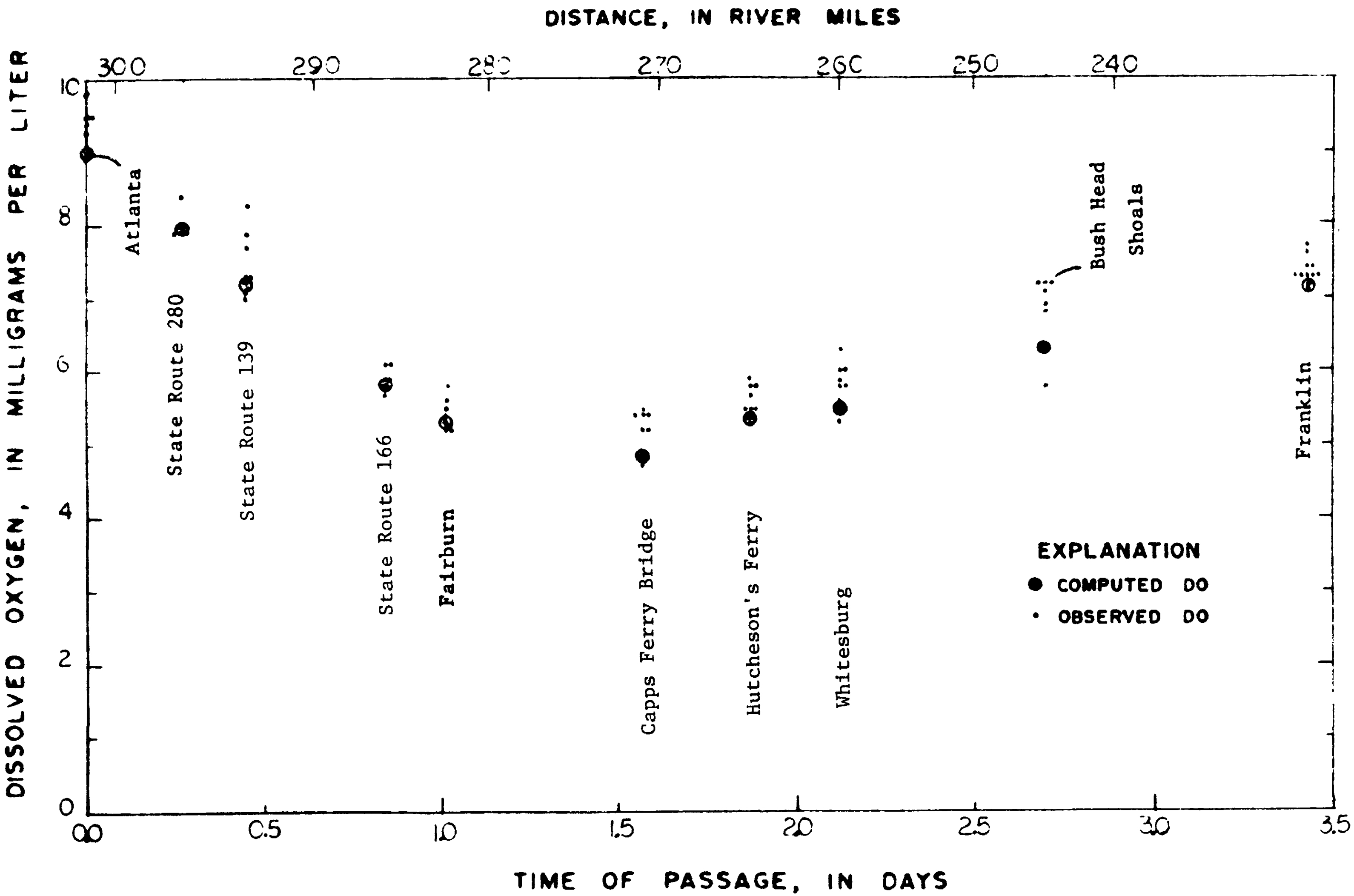

Figure 24.--Comparison of observed and computed dissolved-oxygen concentrations in the Atlanta-to-Franklin reach of the river during low-flow period, August 31 to September 9, 1976.

Table 20.--Summary of present (1977) and future (year 2000) effects of changes in streamflow and wastewater treatment of the minimum dissolved oxygen concentration in the Atlanta-to-Franklin reach of the river during critical low-flow periods.

Point source discharge concentrations of: Ultimate biochemical oxygen demand (mg/L)	Point source discharge concentrations of: Ammonium nitrogen (mg/L)	Streamflow at Atlanta station (ft /s)	Minimum concentration of dissolved oxygen in Atlanta to Franklin reach of the river (mg/L)	Distance in river miles where dissolved oxygen concentration is less than: 5.0 mg/L (mi)	Distance in river miles where dissolved oxygen concentration is less than: 4.0 mg/L (mi)
		1977			
15	5	860	6.2	0	0
15	5	1,200	6.4	0	0
15	5	1,400	6.5	0	0
15	5	1,800	6.7	0	0
15	10	860	5.3	0	0
15	10	1,200	5.6	0	0
15	10	1,400	5.8	0	0
15	10	1,800	6.1	0	0
15	15	860	4.4	17	0
15	15	1,200	4.8	7	0
15	15	1,400	5.1	0	0
15	15	1,800	5.6	0	0
30	5	860	5.9	0	0
30	5	1,200	6.0	0	0
30	5	1,400	6.1	0	0
30	5	1,800	6.2	0	0
30	10	860	5.0	0	0
30	10	1,200	5.2	0	0
30	10	1,400	5.4	0	0
30	10	1,800	5.6	0	0
30	15	860	4.0	19	0
30	15	1,200	4.4	12	0
30	15	1,400	4.6	7	0
30	15	1,800	5.1	0	0
45	5	860	5.5	0	0
45	5	1,200	5.6	0	0
45	5	1,400	5.7	0	0
45	5	1,800	5.8	0	0
45	10	860	4.6	16	0
45	10	1,200	4.8	10	0
45	10	1,400	5.0	0	0
45	10	1,800	5.3	0	0
45	15	860	3.6	20	14
45	15	1,200	4.0	14	0
45	15	1,400	4.2	10	0
45	15	1,800	4.7	5	0
		2000			
15	5	860	4.7	11	0
15	5	1,400	5.5	0	0
15	5	1,800	6.2	0	0
15	10	860	3.2	20	13
15	10	1,400	4.2	24	0
15	10	1,800	4.9	15	0
15	15	860	1.6	28	19
15	15	1,400	2.8	34	19
15	15	1,800	3.7	39	4
30	5	860	4.1	15	0
30	5	1,400	5.0	0	0
30	5	1,800	5.6	0	0
30	10	860	2.5	22	16
30	10	1,400	3.6	26	4
30	10	1,800	4.4	20	0
30	15	860	.9	32	21
30	15	1,400	2.2	46	25
30	15	1,800	3.1	42	14
45	5	860	3.6	17	10
45	5	1,400	4.5	10	0
45	5	1,800	5.1	0	0
45	10	860	2.0	27	18
45	10	1,400	3.1	27	12
45	10	1,800	3.9	37	0
45	15	860	.4	53	26
45	15	1,400	1.7	47	27
45	15	1,800	2.6	43	33

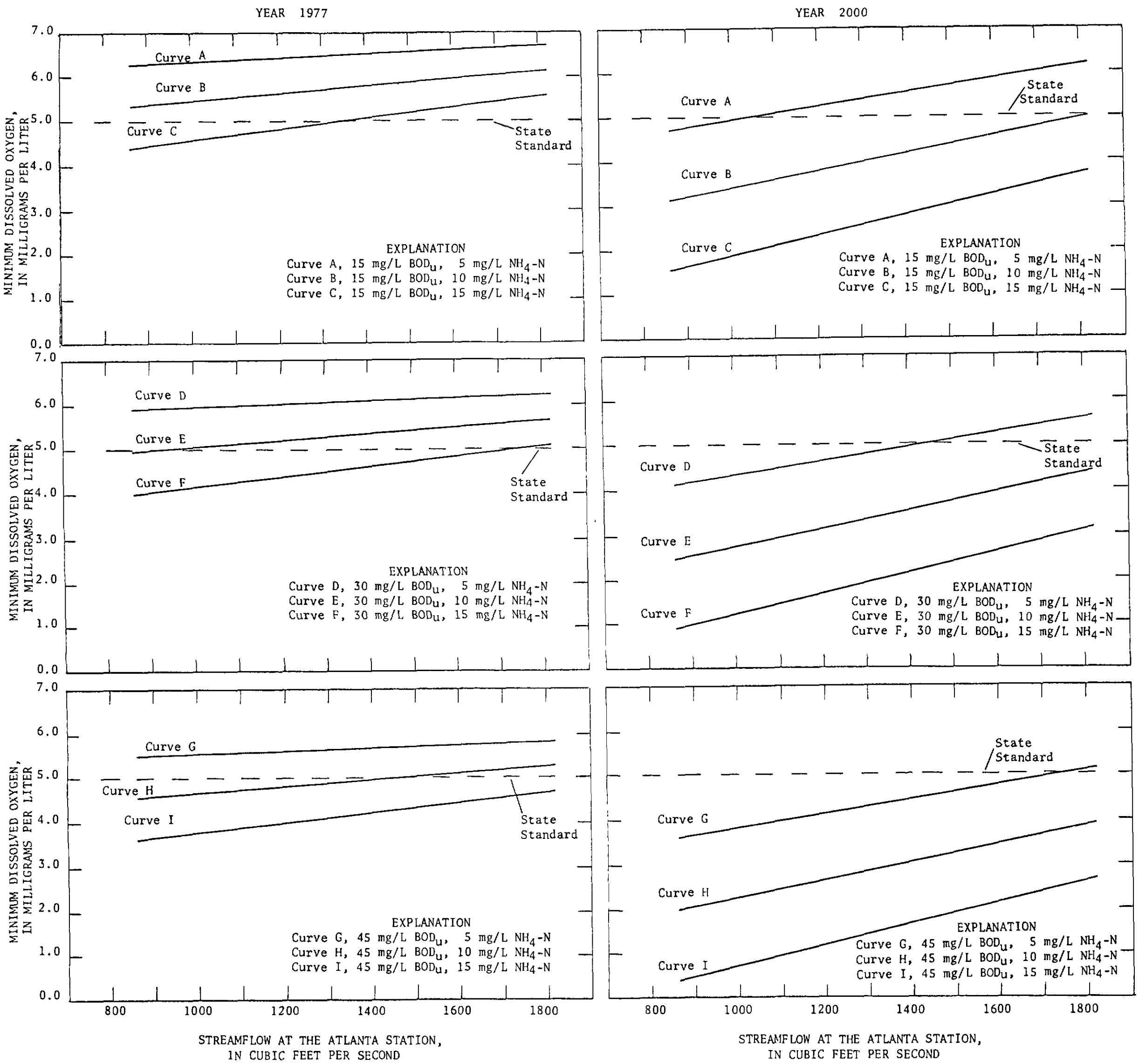

Figure 25.--Relationship of minimum dissolved-oxygen concentration in the Atlanta-to-Franklin reach of the river to streamflow at Atlanta computed on the basis of (1) point-source discharges containing ultimate biochemical oxygen demand concentrations of 15, 30, and 45 milligrams per liter and ammonium nitrogen concentrations of 5, 10, and 15 milligrams per liter, and (2) seven-day ten-year mean tributary inflow.

for the years 1977 and 2000. For the year 1977, all curves either intersect or lie above the specified State DO concentration standard with the exception of curve I (45 mg/L of BOD_u and 15 mg/L of NH_4-N). Curve I shows that a decrease in minimum DO concentration from 4.7 to 3.7 mg/L. From table 20, point-source discharge concentrations of 45 mg/L of BOD and 15 mg/L of NH_4-N result in DO concentrations of less than 5.0 mg/L in a 1 mile reach of the river with a streamflow of 1,800 ft^3/s; decreasing the streamflow from 1,800 to 860 ft^3/s results in DO concentrations of less than 5.0 mg/L in a 20 mile reach of the river. For the year 2000, curves A, B, D, and G intersect the 5.0 mg/L DO standard, and no 15 mg/L of NH_4-N curve intersects the 5.0 mg/L line.

The analysis above indicates that several wastewater management alternatives can be selected to meet the specified State DO standard with present (1977) point-source flows (185 ft^3/s) in the study reach during critical low-flow periods. Because of the estimated increase in point-source flows from 185 ft^3/s presently to about 370 ft^3/s in the year 2000, some changes in present wastewater treatment levels will be necessary during critical low-flow periods to meet the specified DO standard even with a streamflow of about 1,800 ft^3/s at Atlanta.

PRESENT AND FUTURE EFFECTS OF POINT AND NONPOINT DISCHARGES ON THE WATER QUALITY OF WEST POINT LAKE

Oswald and Goleuke (1966) first used the term "algal growth potential" 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; Greene 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.

Cherry and others (1978b) analyzed data collected for a period of about 1 year at sites in West Point Lake. The data are shown in table 21. Their analysis showed that AGP decreases in response to increases in phytoplankton concentration from the upper to lower reaches of the lake. Changes in AGP and phytoplankton concentration are greater at higher temperatures than at lower temperatures. Little or no decrease in the AGP or increase in the phytoplankton concentration with distance downstream from Franklin occur at temperatures less than about 13°C. Phytoplankton concentrations in the lake are related to water temperature and site, provided the AGP at the site is greater than about 0.5 mg/L. Phytoplankton concentrations decrease downstream from sites where the AGP is less than 0.5 mg/L.

Phosphorus appears to be the nutrient that limits phytoplankton growth in the lake. The observed data indicate that in the lake at sites where the

Table 21.--Water temperature and concentrations of nutrients, algal growth potential, and phytoplankton in the West Point Lake
[concentrations are in milligrams per liter except for temperature, in degrees Celcius, and phytoplankton, in cells per milliliter]

Location (river mile)		Franklin (0.00)				LaGrange (14.2)				Abbottsford (24.8)				Dam Pool (33.1)			
Collection period	Average lake temperature	Dissolved nitrate nitrogen	Dissolved orthophosphate as phosphorus	Algal growth potential	Phyto-plankton	Dissolved nitrate nitrogen	Dissolved orthophosphate as phosphorus	Algal growth potential	Phyto-plankton	Dissolved nitrate nitrogen	Dissolved orthophosphate as phosphorus	Algal growth potential	Phyto-plankton	Dissolved nitrate nitrogen	Dissolved orthophosphate as phosphorus	Algal growth potential	Phyto-plankton
Nov. 15-18, 1975	16.8	-	-	13	2,400	-	-	14	310	-	-	13	930	-	-	0.7	6,100
Dec. 16-17, 1975	13.1	0.76	0.10	33	1,000	0.43	0.02	5.7	2,100	0.54	0.01	2.4	5,000	0.46	0.00	1.4	7,500
Feb. 24, 1976	14.2	.55	.10	25	1,100	.52	.05	16.1	1,900	.51	.03	8.9	3,700	.40	.01	2.8	10,000
Mar. 22, 1976	14.1	.43	.02	12	410	.32	.01	5.8	250	.24	.01	3.6	670	.35	.00	.9	6,200
Apr. 17, 1976	20.9	.58	.06	24	500	.24	.01	5.0	4,100	.13	.00	2.1	27,000	.22	.00	.9	21,000
May 19-20, 1976	21.0	-	-	13	3,600	.41	.03	13	3,200	.40	.01	3.8	14,000	.10	.00	.5	40,000
July 2, 1976	26.6	.71	.12	28	6,300	.56	.04	20	94,000	.0	.0	1.5	140,000	.00	.00	.7	30,000
Aug. 10, 1976	28.2	.84	.13	36	19,000	.70	.05	22	240,000	.25	.00	.3	130,000	.01	.01	.4	27,000
Aug. 24, 1976	29.0	.84	.10	30	3,800	.50	.03	19	120,000	.26	.00	.6	560,000	.06	.00	.5	62,000
Sept. 10, 1976	25.8	.96	.14	43	1,200	.73	.02	18	23,000	.25	.00	.3	66,000	.09	.00	.4	43,000

AGP concentration is about 0.5 mg/L, the dissolved PO_4-P concentration is about 0.0 mg/L, and the NO_3-N concentration is about 0.1 mg/L.

The analysis also indicated that AGP at sites in the lake can be estimated using the equation:

$$C_{ar} = (-0.0673T + 0.625)\ R + C_{ai}, \qquad (2)$$

where, C_{ar} = AGP in mg/L, at river mile, R,
R = river mile downstream from Franklin,
C_{ai} = AGP in mg/L, at Franklin,
and
T = lake water temperature, in °C.

AGP at Franklin (C_{ai}) can be estimated from the relationship between AGP and nutrient concentrations at the Whitesburg station (equation 3), because AGP at Whitesburg and Franklin are about the same (fig. 26). The Chattahoochee River at Whitesburg is free-flowing and gaged, which allows for development of nutrient-concentration and flow relationships as shown in figure 27. The relationship between AGP and nutrient concentrations at the Whitesburg station (not included in the analysis by Cherry and others, 1978b) was determined from a multiple linear regression analysis (correlation coefficient is 0.97) and is defined by:

$$C_{aw} = 8.10 + 137.5\ (PO_4\text{-}P) + 4.61\ (NO_3\text{-}N), \qquad (3)$$

where, C_{aw} = AGP in mg/L, at Whitesburg,
PO_4-P = dissolved orthophosphate (as phosphorus) concentration, in mg/L, at Whitesburg,
and
NO_3-N = nitrate (as nitrogen) concentration, in mg/L, at Whitesburg.

The analysis by Cherry and others (1978b) also showed that phytoplankton concentrations in the lake at sites where AGP is greater than about 0.5 mg/L can be estimated using the equation:

$$C_{pr} = (0.0084T - 0.066)\ R + C_{pi},$$

where, C_{pr} = phytoplankton concentration, in (loge) cells/mL, at river mile, R,
T = lake water temperature, in °C,
R = river mile downstream from Franklin,
C_{pi} = phytoplankton concentration, in (loge) cells/mL, at Franklin,

and that the phytoplankton concentration at Franklin (C_{pi}) is related to lake water temperature and can be estimated because the AGP at Franklin is greater than 0.5 mg/L:

$$C_{pi} = 0.147T + 4.51,$$

where, C_{pi} = phytoplankton concentration, in (loge) cells/mL, at Franklin,
and
T = lake water temperature in °C.

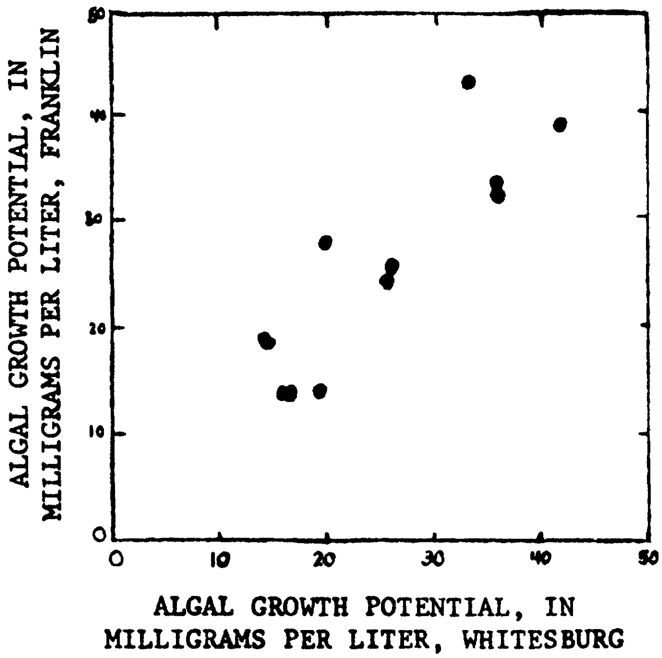

Figure 26.--Plots of algal growth potential at Franklin versus algal growth potential at Whitesburg.

Based on the analysis by Cherry and others (1978b), the 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, average daily nonpoint-source PO_4-P and NO_3-N loads, and July mean monthly discharge (3,490 ft^3/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-source PO_4-P and NO_3-N loads, and July mean monthly discharge 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 discharge (1,990 ft^3/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 -N load, observed June 1977 nonpoint-source PO_4-P and NO_3-N loads, and observed June 1977 discharge at Whitesburg.

A summary of the conditions and effects is shown in table 22. PO_4-P and NO_3-N concentrations at Whitesburg for condition (1) were determined from the concentration-flow relationships in figure 27. 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 discharge at Whitesburg. These analyses assume 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-N and NO_3-N concentrations are as NO_3-N.

The data indicate that with present PO_4-P and NO_3-N loads from point and nonpoint sources and mean monthly July discharges at Whitesburg the maximum phytoplankton concentration is 260,000 cells/mL at RM 216.40 in West Point Lake. Phytoplankton concentrations could reach 3.6 million 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 120,000 cells/mL at RM 220.71 with a concentration of 1.0 mg/L of phosphorus in point discharges.

Point-source flows are estimated to increase from 179 ft^3/s in 1976 to about 380 ft^3/s in the Atlanta-to-Whitesburg reach in 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 discharge (3,490 ft^3/s) at Whitesburg,

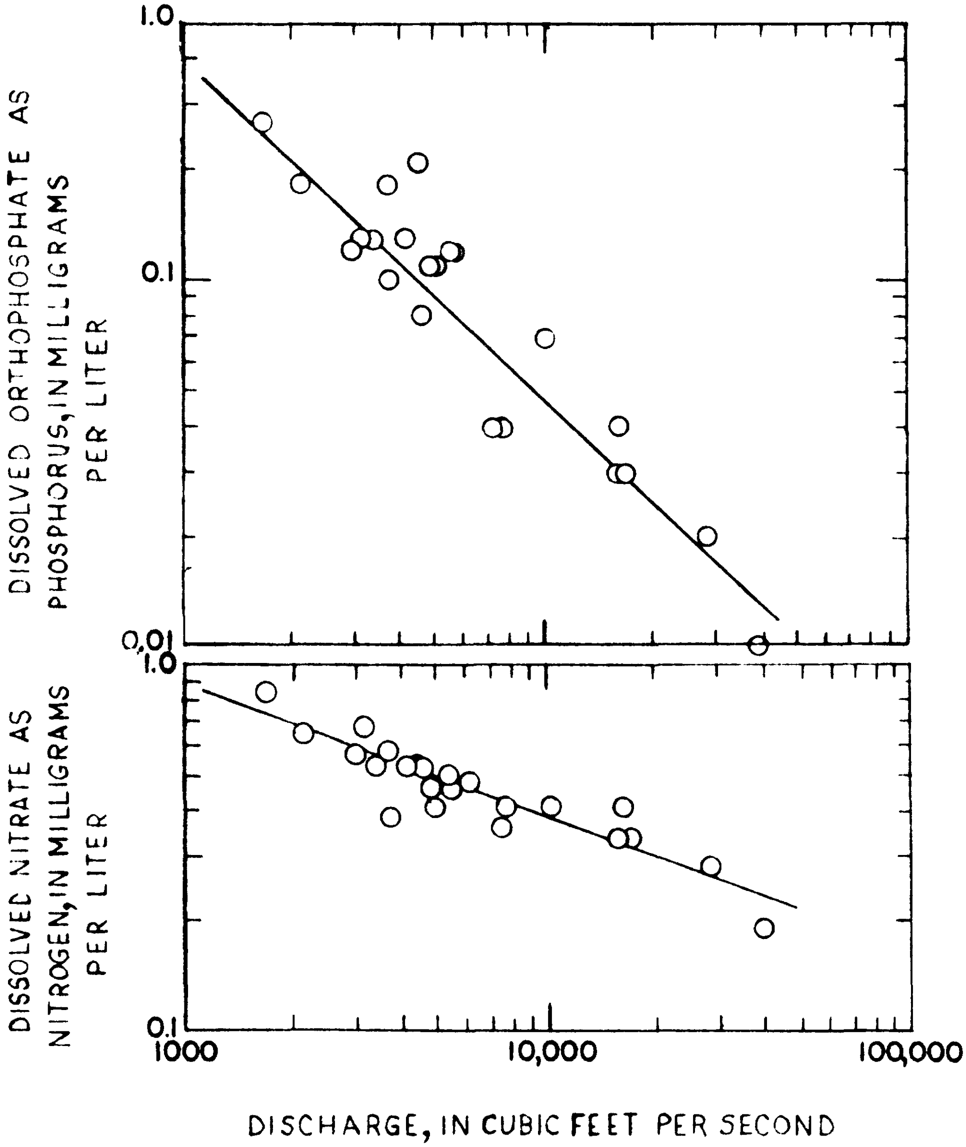

Figure 27.--Relationship of dissolved orthophosphate and dissolved nitrate concentrations to water discharge in the Chattahoochee River near Whitesburg.

(2) Average daily point-source PO_4-P load based on 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 discharge 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 discharge 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 discharge (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 discharge at Whitesburg.

The data given in table 22 show that with present wastewater treatment levels in the year 2000 with discharges 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 mi upstream at the dam pool. Point-source discharges containing 1.0 mg/L phosphorus and streamflows of 1,990 ft^3/s and 3,490 ft^3/s would result in the maximum phytoplankton concentrations of 630,000 cells/mL at about the Abbottsford station and 110,000 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 million 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 exceed 2 million cells/mL with July mean monthly flows (3,490 ft^3/s at Whitesburg) with future average daily point-source PO_4-P loads and present levels of treatment.

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 in Georgia. One objective of the study was to assess the magnitudes, nature, and effects of point and nonpoint discharges in the Chattahoochee River basin from Atlanta to the West Point Dam.

Average annual yields and average daily concentrations for most constituents are analyzed largest in the urban areas and smallest in the forested areas. Yields and concentrations in the rural areas are intermediate.

Table 22.--Summary of present (1977) 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: Flow	Whitesburg: Dissolved orthophosphate as phosphorus	Whitesburg: Dissolved nitrate nitrogen	Whitesburg: Algal growth potential	West Point Lake: River mile[c]	West Point Lake: Phytoplankton concentration[e]
				1976			
1	Present	3,490	0.12	0.56	27	19.06	260,000
2	Modified present[a]	3,490	.03	.56	15	10.43	53,000
3	[b]Observed June 1977	1,990	.34	1.0	.59	[d]33.10	3,600,000
4	[a]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	[f]3.10	3,600,000
5	Modified present	1,990	.09	2.7	33	23.74	630,000

[a] Point PO_4-P load based on 1.0 milligrams per liter phosphorus concentration in discharge.

[b] Concentrations of nitrogen and phosphorus were not determined on filtered water samples. During low-flow conditions, dissolved and total values are nearly the same.

[c] River mile downstream of Franklin where AGP is 0.5 milligrams per liter.

[d] AGP at RM 33.10 is 13 milligrams per liter.

[e] Phytoplankton concentration at river mile where AGP is 0.5 milligrams per liter.

[f] AGP at RM 33.10 is 28 milligrams per liter.

Average annual constituent yields in the area draining the Clear Creek and Tanyard Branch combined-sewer overflows in the Peachtree Creek basin are generally about the same as those in other urban areas. Combined-sewer overflow discharges, which generally occur during periods of rainfall, contain large constituent concentrations during the initial discharges, but the concentrations decrease during peak flows to values similar to those in other urban areas.

On an average annual basis and during the storm period of March 12-15, 1976, nonpoint-source loads for most constituents analyzed were larger than point-source loads at the Whitesburg station. Most of the nonpoint-source constituent loads in the Atlanta-to-Whitesburg reach were from urban areas. 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 Whitesburg.

Average daily concentrations of DO (dissolved oxygen) of less than 5.0 mg/L (milligrams per liter) 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. The low DO concentrations occurred mostly on weekends when power generation at the Buford Dam hydroelectric facility was minimal.

During a low-flow period, June 1-2, 1977, five municipal point-sources contributed 63 percent of the BOD_u, 97 percent of the NH_4-N, 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 NH_4-N 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 BOD_u and NH_4-N concentrations caused DO concentrations to decrease from about 8.0 mg/L at RM 299 to about 4.5 mg/L at RM 271. Nitrogenous oxygen demands ($k_3 = 0.19$) 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 at 20°C.

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.

During a critical low-flow period, a streamflow at Atlanta of about 1,800 ft^3/s and point-source flows of 185 ft^3/s containing concentrations of 45 mg/L of BOD_u and 15 mg/L NH_4-N 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 NH_4-N, 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 NH_4-N, and a streamflow of about 900 ft^3/s, the minimum DO concentration is 5.5 mg/L.

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 NH_4-N, 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 NH_4-N concentrations of 45 and 5 mg/L, respectively, require a streamflow of about 1,800 ft^3/s to meet the specified DO concentration standard by the State of Georgia.

Dissolved PO_4-P is the nutrient presently limiting phytoplankton growth in West Point Lake when water temperatures are greater than about 26°C. The highest phytoplankton concentration observed was 560,000 cells per milliliter Estimated phytoplankton concentrations for 1977 could exceed 3 million cells per milliliter, at 30°C, in West Point Lake if the algal growth potential at Whitesburg (Franklin) is about 50 mg/L during extended low-flow periods such as the observed 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 per milliliter 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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