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Biological and Microbiological Assessment of the Upper Chattahoochee River Basin, Georgia

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CONVERSION FACTORS

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

English	*Multiply by*	*Metric*
ft (foot)	3.048×10^{-1}	m (meter)
ft^3/s (cubic foot per second)	2.832×10^{-2}	m^3/s (cubic meter per second)
in. (inch)	2.540	cm (centimeter)
	2.540×10^{-1}	mm (millimeter)
mi (mile)	1.609	km (kilometer)
mi^2 (square mile)	2.590	km^2 (square kilometer)

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ABSTRACT

Biological and microbiological studies were conducted by the U.S. Geological Survey as a part of the Intensive River-Quality Assessment studies of the upper Chattahoochee River basin. Phytoplankton concentrations in cells per milliliter (mL) were generally higher downstream from Atlanta than upstream. The highest concentrations, mostly blue-green algae, occurred in West Point Lake with an average of 90,000 cells per milliliter (cells/mL) for the sampling period. The lowest concentrations occurred upstream of Lake Sidney Lanier (1,000 cells/mL). Dissolved orthophosphate and nitrite plus nitrate concentrations were highest in the river reaches and upper reaches of the two lakes and were lowest at the dam pools of both lakes. The high nitrite plus nitrate concentrations downstream from Atlanta were primarily a result of nitrification by *Nitrosomonas* and *Nitrobacter* bacteria.

Algal growth potential was highest downstream from Atlanta (25 milligrams per liter (mg/L) at Whitesburg) and was the lowest in the headwaters and at the dam pools of Lake Sidney Lanier and West Point Lake. Analysis of data collected at sites in West Point Lake indicated that, from the upper to the lower reaches, algal growth potential decreased in response to increases in phytoplankton concentration. Algal growth potential and phytoplankton concentration changes were greater at higher temperatures than at lower ones. Little or no change occurred in the algal growth potential or in phytoplankton concentrations at temperatures lower than about 13°C. Phytoplankton concentrations appeared to be related to water temperature and location in the lake at sites where algal growth potential was greater than about 0.5 mg/L. Phytoplankton concentrations decreased downstream from sites where algal growth potential was less than 0.5 mg/L.

Concentrations of *Nitrosomonas* and *Nitrobacter* were higher in the river-bed sediment than in the water column on a number-per-milliliter and per-gram basis. The rate of nitrification in the Atlanta to Franklin reach of the river was comparatively low, that is, 0.02 mg/L per hour. Nitrification was an important cause of dissolved-oxygen consumption in a 45-mi reach of the river downstream from the Atlanta wastewater treatment facilities. Dissolved-oxygen consumption as a result of nitrification may be greatest during low flow conditions when dilution of ammonium is least and time of travel is greatest.

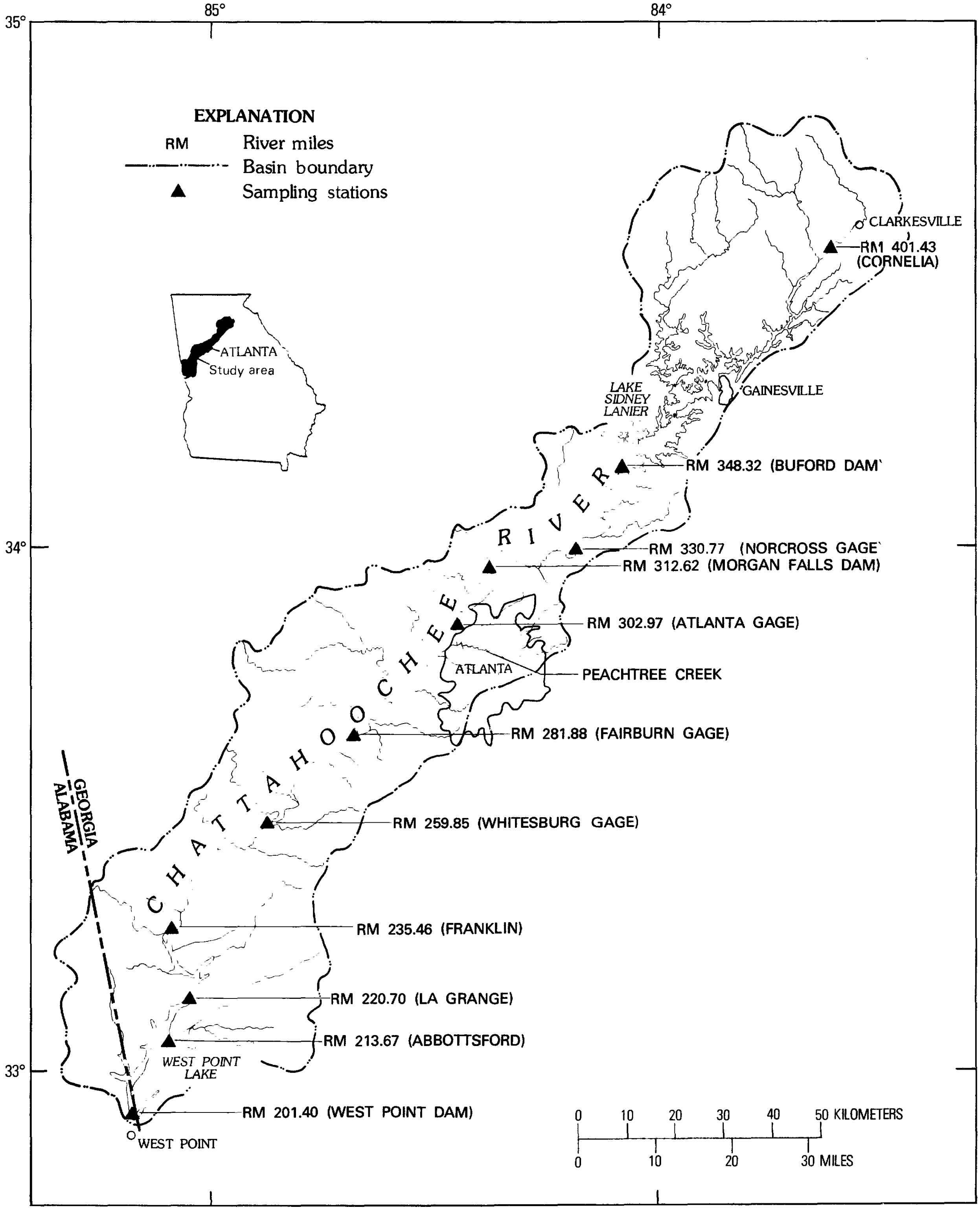
INTRODUCTION

For more than 10 years, the Department of Interior, Advisory Committee on Water Data for Public Use has been concerned about water-quality information needed for planning river basin development. Specifically, the Committee has been concerned about the following: (1) Definition of existing water quality of the Nation's rivers, (2) analysis of water-quality trends, (3) desirability of advanced waste-water treatment on a national, State, or river basin level, and (4) definition of the relationship of land use to water quality.

In 1972, the Committee recommended that the U.S. Geological Survey conduct multidisciplinary river-quality studies. The first study was conducted in the Willamette River basin, Oregon, and began in January 1973. The objectives were to define the types and quantities of data required to assess river-quality problems and to develop methods for assessing the planning alternatives in terms of potential impacts on river quality.

The Chattahoochee River basin was selected as the study area for a second river-quality assessment. The river-quality assessment of the upper Chattahoochee River basin (fig. 1) upstream of the West Point Dam began April 1, 1975. Its purpose is to provide meaningful information to resource managers and to suggest alternatives for basin development and for future uses of the Chattahoochee River, in which maintenance and improvement of water quality are requisites.

Objectives of the biological and microbiological study are the following: (1) to use biologi-



Base from U.S. Geological Survey
quadrangle maps 1:24 000

FIGURE 1.—Study area and sampling stations in the upper Chattahoochee River basin.

cal and microbiological data to aid in estimating water-quality conditions in selected river reaches and two lakes (West Point and Sidney Lanier), (2) to assess the potential for algal growth in both lakes and selected reaches of the river, and (3) to determine what factors affect biological and microbiological communities and populations. The scope of this report includes a discussion of hydrology, land use and water use, and general biological and microbiological conditions in the study area.

Acknowledgments—We express our sincere appreciation for the interest shown by the Advisory Committee on Water Data for Public Use and the Advisory Committee's Working Group for River-Quality Assessments.

DESCRIPTION OF BASIN

The upper Chattahoochee River (fig. 1) rises on the southern slopes of the Blue Ridge Mountains in northeast Georgia and flows generally southwestward through the metropolitan Atlanta area to the Georgia–Alabama State line. The drainage area of the upper Chattahoochee River is 3,440 mi^2. Land surface altitudes range from about 4,000 ft in the headwaters to about 635 ft above West Point, Ga.

Rainfall in the basin averages about 54 in. a year with higher rainfalls occurring in the upland areas and in the southernmost part of the basin. Annual air temperatures in the basin average about 16°C with the coldest temperatures occurring in the mountainous areas.

HYDROLOGY

The flow of the Chattahoochee River is dependent on rainfall and regulation by hydroelectric-generating facilities. The highest flows generally occur during the spring of the year, and the lowest, in late autumn. The average flow at Buford Dam, based on 35 years of record, is 2,168 ft^3/s. At Atlanta, which is about midway in the study area, the average daily discharge based on 43 years of record, is 2,603 ft^3/s. A maximum discharge of 59,000 ft^3/s occurred at the Atlanta gage in 1946, and a minimum daily discharge of 296 ft^3/s occurred in 1957.

Flow in the reaches has been regulated for many years because of hydroelectric-generating facilities at Buford Dam and Morgan Falls. The most pronounced changes in regulated flow have occurred subsequent to the construction of Buford Dam. Figure 2 shows the flow durations of the Chattahoochee River at Atlanta before and after regulation by Buford Dam. The frequency of both the higher and lower flows has decreased.

In 1960, the city of Atlanta and the Georgia Power Co. modified the Morgan Falls Dam and reservoir to provide a minimum flow of 750 ft^3/s from Morgan Falls. In 1974, the Georgia Environmental Protection Division recognized the increasing demand for water supply and the need for high-quality water downstream from Atlanta for water-quality maintenance and required a minimum flow of 750 ft^3/s just upstream of Peachtree Creek. This requirement, considering water-supply withdrawals, results in a minimum release from Morgan Falls of approximately 1,100 ft^3/s.

LAND USE

Land in the upper Chattahoochee River basin from its headwaters to the West Point Dam is predominantly forest (table 1). Upstream of Buford Dam, about 80 percent of the land is forested and 16 percent used for agriculture. Agricultural activities are concentrated in the stream valleys and on the lower slopes. Crops and pastures occupy a significant part of the agricultural land. Poultry operations, primarily broiler chicken production, are an economically dominant agricultural activity. Gainesville is the largest urban area in this part of the basin.

TABLE 1.—*Land use in the upper Chattahoochee River basin*

Basin above:	River mile	Land use (in square miles) Urban	Agriculture	Forest	Drainage area
Buford Dam	248.32	36.8	164.6	838.6	1,040
Atlanta	302.97	128.9	239.3	1,081.7	1,450
Fairburn	281.88	371.5	310.2	1,378.2	2,060
Whitesburg	259.85	395.6	372.2	1,662.1	2,430
West Point Dam	201.40	433.1	545.9	2,461.1	3,440

In the river reach from Buford Dam to Atlanta, about 60 percent of the land is forested, 22 percent is urbanized, and 18 percent is agricultural. About 40 percent of the agricultural land consists of cropland and pasture with corn and soybeans as the dominant crops.

The basin from Atlanta to West Point Dam includes most of metropolitan Atlanta, the largest city in the basin. Land in the Atlanta

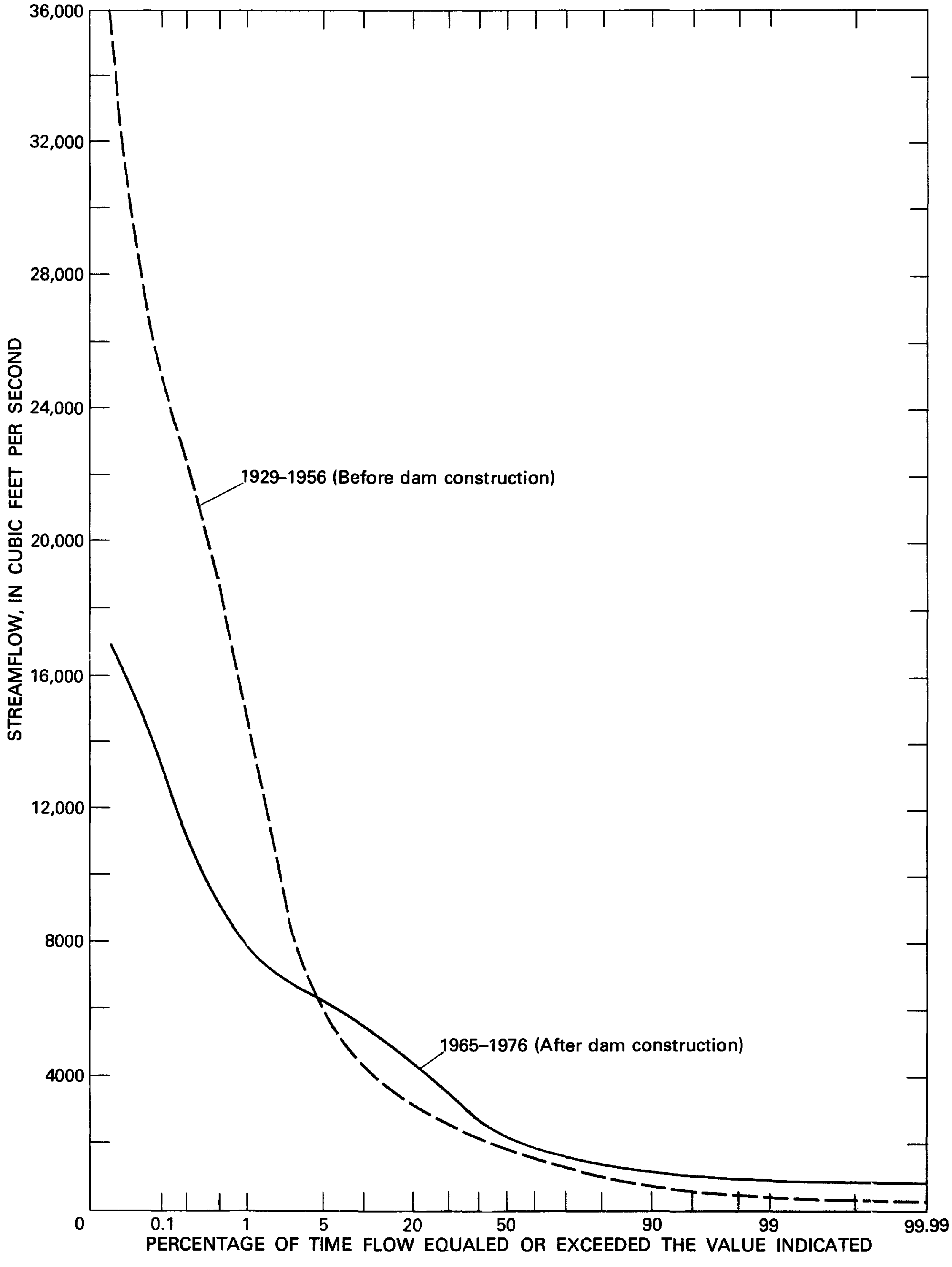


FIGURE 2.—Flow durations of the Chattahoochee River at Atlanta gage before and after construction of Buford Dam.

area is predominantly residential, but commercial and industrial activities are significant. Some of the more important industrial activities include automobile assembling, food processing, and light manufacturing. Downstream from Atlanta, forest land is predominant.

Agricultural use of the land is about the same as in the Buford Dam–Atlanta reach, and the types of agricultural operations are similar.

WATER USE

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

Six electric, power-generating facilities are located adjacent to the Chattahoochee River and have a combined generating capacity of about 3.8 million kilowatts. Buford Dam and Morgan Falls Dam are peak-power, hydroelectric-generating facilities and plants. Atkinson, McDonough, Yates, and Wansley are fossil-fuel thermoelectric powerplants. Morgan Falls is a run-of-the-river facility which utilizes hydropower-released waters from Buford Dam. The estimated average water use and generating capacity for the plants are shown in table 2.

TABLE 2.—*Estimated average water use and generating capacity for electric-generating facilities in the upper Chattahoochee River basin*

[Data provided by Georgia Power Co.]

River mile	Name of facility	Hydroelectric facilities: Capacity (kilowatts)	Average water use (ft^3/s)
	Hydroelectric facilities		
348.32	Buford Dam	86,000	2,200
312.62	Morgan Falls Dam	16,800	2,500
	Thermoelectric facilities		
299.11	Atkinson-McDonough	730,000	909
259.70	Yates	1,250,000	1,030
249.20	Wansley	1,760,000	[a] 73

[a] One small unit online in 1976.

In 1976, water-supply withdrawals in the upper Chattahoochee River basin were about 290 ft^3/s, of which about 276 ft^3/s was withdrawn directly from the Chattahoochee River in the reach from Buford Dam to Fairburn. Other water supplies were withdrawn from Lake Sidney Lanier and West Point Lake. Table 3 lists the major water users in the basin and shows present (1976) and estimated withdrawals for the year 2000. Large amounts of wastewater are discharged to the Chattahoochee River, particularly in the Atlanta area (table 4).

Several reaches of the river are used extensively for recreation. The mountainous headwater areas are popular for trout fishing, camping, and hunting. Lake Sidney Lanier, a popular water resort area, has numerous public access areas, boat-launching facilities, campgrounds, marinas, yacht clubs, and cottages. Lake Sidney Lanier has a higher number of annual visitor-days than any other U.S. Army Corps of Engineers facility in the Nation (Metropolitan Atlanta Water Resources Study Group, 1976). The reach from Buford Dam to Atlanta is periodically stocked with game fish and provides recreation for fishermen, canoeists, and rafters. This reach is being considered for an urban national park. The reach between Morgan Falls Dam and Peachtree Creek is one of the most scenic on the river and is the site for an annual raft race that involves thousands of participants and onlookers. The shoals in the reach from Whitesburg to Franklin are popular for fishing and boating.

TABLE 3.—*Estimated water-supply withdrawals in the upper Chattahoochee River basin for the years 1976 and 2000*

[Data provided by Metropolitan Atlanta Water Resources Study Group]

Facility	River mile	Withdrawals (ft^3/s) 1976	2000
Hall County [a]	------	3	9
Forsyth County [a]	------	----	2
Gwinnett County [a]	------	----	68
City of Buford [a]	------	1	1
Gwinnett County	338.92	12	12
DeKalb County	325.44	91	187
Atlanta-Fulton County	------	----	243
Cobb County	310.85	39	117
City of Atlanta	300.62	134 [b]	110
City of LeGrange	214.37	11	12
Total	------	291	761

[a] Withdrawals upstream of Buford Dam.
[b] from plant records

TABLE 4.—*Estimated wastewater discharges to the Chattahoochee River and tributaries for the years 1976 and 2000*

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

Location	River mile	Discharges (ft^3/s) 1976	2000
Gainsville Linwood [a]	------	2.2	4.2
Gainsville Flat Creek [a]	------	5.6	9.3
Buford	338.12	1.7	2.0
John Creek	329.30	2.9	4.8
Crooked Creek	325.15	1.8	12
Big Creek	317.37	4.1	17
Cobb-Chattahoochee	300.56	15	31
R. M. Clayton	300.24	118	161
Hollywood	297.50	2.3	-----
South Cobb	294.28	13	48
Utoy	291.60	21	44
Sweetwater	288.58	-----	2.6
Camp Creek	283.78	6.8	27
Regional Interceptor	------	-----	42
Annewakee Creek	281.46	-----	6.0
Bear Creek	275.95	-----	7.7
LaGrange Yellow Jacket	214.12	1.5	3.0
Total	------	196	422

[a] Upstream of Buford Dam.

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

FUTURE EFFECTS OF WATER USE ON RIVERFLOW

Future consideration for modifying the flow regime from Buford Dam to meet increasing demands for water supply include construction of a new regulation structure downstream from Buford Dam, modification of Morgan Falls Dam and reservoir, or changes in the hydropower releases from Buford Dam (Metropolitan Atlanta Water Resources Study, 1977).

In the year 2000, during an extended drought period such as occurred in 1954–56, a minimum flow of 1,717 ft^3/s could be maintained from Buford Dam. Considering water-supply withdrawals, wastewater returns, and no streamflow accretions between Buford Dam and Atlanta, the estimated net flow at Atlanta in the year 2000 would be 1,310 ft^3/s. The flow would provide 560 ft^3/s for water supply downstream from the Atlanta gage and 750 ft^3/s for water-quality maintenance. Average water-supply withdrawals in the reach from Buford Dam to Fairburn (RM 281.88) are estimated to be 669 ft^3/s (table 3) in the year 2000. During a drought period, net flow at Fairburn, assuming no accretion of tributary inflow and an average wastewater return of 350 ft^3/s, would be 1,398 ft^3/s or about the same that occurred during low flow periods in 1976.

NATURE OF THE PROBLEM

The problems associated with water quality in the upper Chattahoochee River basin are generally related to urbanization. Urbanization has created large demands on the Chattahoochee River as the major water supply for Atlanta and as the major transporter of municipal wastes from Atlanta. In 1976, about 280 ft^3/s was withdrawn from the river upstream of Peachtree Creek (river-mile (RM) 300.54) for water-supply and about 180 ft^3/s of secondary treated wastewater was discharged into the river between Peachtree Creek and Fairburn (RM 281.88). In this reach two thermoelectric powerplants withdraw and subsequently discharge heated effluent directly into the river. The net effect of discharges from these powerplants and from other point sources is to reduce the waste-assimilative capacity of the river.

During periods of rainfall, combined sewer overflows and direct runoff from streets and parking lots can contribute large dissolved and suspended constituent loads to the river. During these periods, sediment loads carried by the Chattahoochee River and its tributaries can be high. During periods of low flow, low dissolved oxygen (DO) and high biochemical oxygen demand (BOD) concentrations and high fecal coliform bacteria counts occur in the river downstream from Atlanta.

Several alternatives have been proposed to modify the flow regime of the river to meet the increasing water-supply demand. Regardless of which alternative is selected, streamflow downstream from Atlanta will not be greatly different from that at present, and wastewater discharges will increase.

METHODS OF DATA COLLECTION

Biological, microbiological, chemical, and physical data were collected from October 1975 to September 1976 at stream and lake stations shown on figure 1. Monthly water samples were collected at each station for determination of algal growth potential (AGP), phytoplankton, dissolved nitrate as nitrogen (NO_3-N), and dissolved orthophosphate as phosphorus (PO_4-P) concentrations. Additional water samples were collected for chemical and microbiological determinations during low and high streamflows.

Water samples for determination of AGP were filtered in the field in a pressure vessel through a 0.22-micrometer Millipore[1] filter at pressures of less than five pounds per square inch and then chilled to 4°C. The algal assay is a widely used procedure, but two basic methods of sample preparation exist. One method (Greene and others, 1975; Miller and others, 1975) autoclaves the sample before filtration, provides a total AGP. The total AGP is usually higher than the dissolved AGP because autoclaving releases nutrients from the plankton. The other method, described by Greeson and others (1977) measures the dissolved AGP and was used throughout the study.

[1] The use of the brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Unfiltered samples for phytoplankton determinations were preserved with a solution containing copper sulfate, formaldehyde, and a detergent. Water samples for nitrogen and phosphorus determinations were filtered in the field through a 0.45-micrometer Millipore filter.

Nitrifying bacteria and related chemical constituents were measured during sustained low flow in the Chattahoochee River. The flow was maintained at 1,150 ft^3/s for 3 days before sampling on June 1–2, 1977. Nitrifying bacteria were determined from water and riverbed samples collected at sites shown on figure 1. Water samples were collected in 1-L autoclaved bottles made of polypropylene using depth-integrated techniques. Riverbed samples were collected using a USGS, BM 60 sampler. After retrieving the sample, the top 1 cm of sediment was subsampled with a sterilized test tube and placed in a sterile Whirlpak[1] plastic bag. Both water and sediment samples were placed in an ice chest while enroute to the laboratory. In-stream DO and temperature measurements were made using a DO meter (Yellow Springs model 57).[1] Separate water samples were collected for laboratory determinations of BOD, NH_4-N (ammonium as nitrogen), NO_2-N (nitrite as nitrogen) and NO_3-N. The laboratory chemical methods used are described by Brown and others (1970) with the exception of BOD, which was determined by the method described by Hines and others (1977).

Nitrifying bacteria in water column and riverbed sediments were determined by a modification of the three tube most probable number (MPN) procedure described by Greeson and others (1977). A 1-mL aliquot of culture material was tested for the presence or absence of nitrite at intervals of 30, 45, and 60 days and the highest value (usually the last one) was recorded as the MPN estimate.

PHYTOPLANKTON

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

Figure 3 shows phytoplankton concentrations from the headwaters of the Chattahoochee River to the West Point Dam during August 1976. The highest concentrations (mostly blue-green algae) occurred in West Point Lake. The lowest concentration occurred at Norcross. Figures 4, 5, and 6 show the monthly variation in average concentrations of the various phytoplankton genera in Lake Sidney Lanier and West Point Lake. Average concentrations of blue-green and green algae were highest in West Point Lake. In the spring, monthly concentrations of diatoms (fig. 4) were highest in Lake Sidney Lanier. The spring diatom increase, as shown in figure 4, did not occur in West Point Lake. Blue-green algae were dominant in both lakes, and concentrations were highest during the summer months. Diatom concentrations generally exceeded the green-algae concentrations in both lakes.

Figure 7 shows mean annual concentrations of total phytoplankton, dissolved PO_4-P, and NO_2+NO_3-N from the upper reaches of the Chattahoochee River to the West Point Dam. Phytoplankton concentrations upstream of Lake Sidney Lanier were less than 1,000 cells/mL, and in the lake they were about 10,000 cells/mL. Concentrations downstream from Lake Sidney Lanier to the upstream end of West Point Lake at Franklin were less than 4,000 cells/mL. Maximum concentrations in West Point Lake were about 90,000 cells/mL.

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

ALGAL GROWTH POTENTIAL

Figure 8 shows the mean annual concentrations of AGP, dissolved PO_4-P and NO_2+NO_3-N from the upper to lower reaches of the study area. The AGP and nutrient concentrations were less than 10 and 0.4 mg/L respectively upstream of Atlanta.

AGP decreased from about 25 mg/L at Franklin to about 1 mg/L at the West Point Lake dam pool. Dissolved PO_4-P decreased

[1] The use of the brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

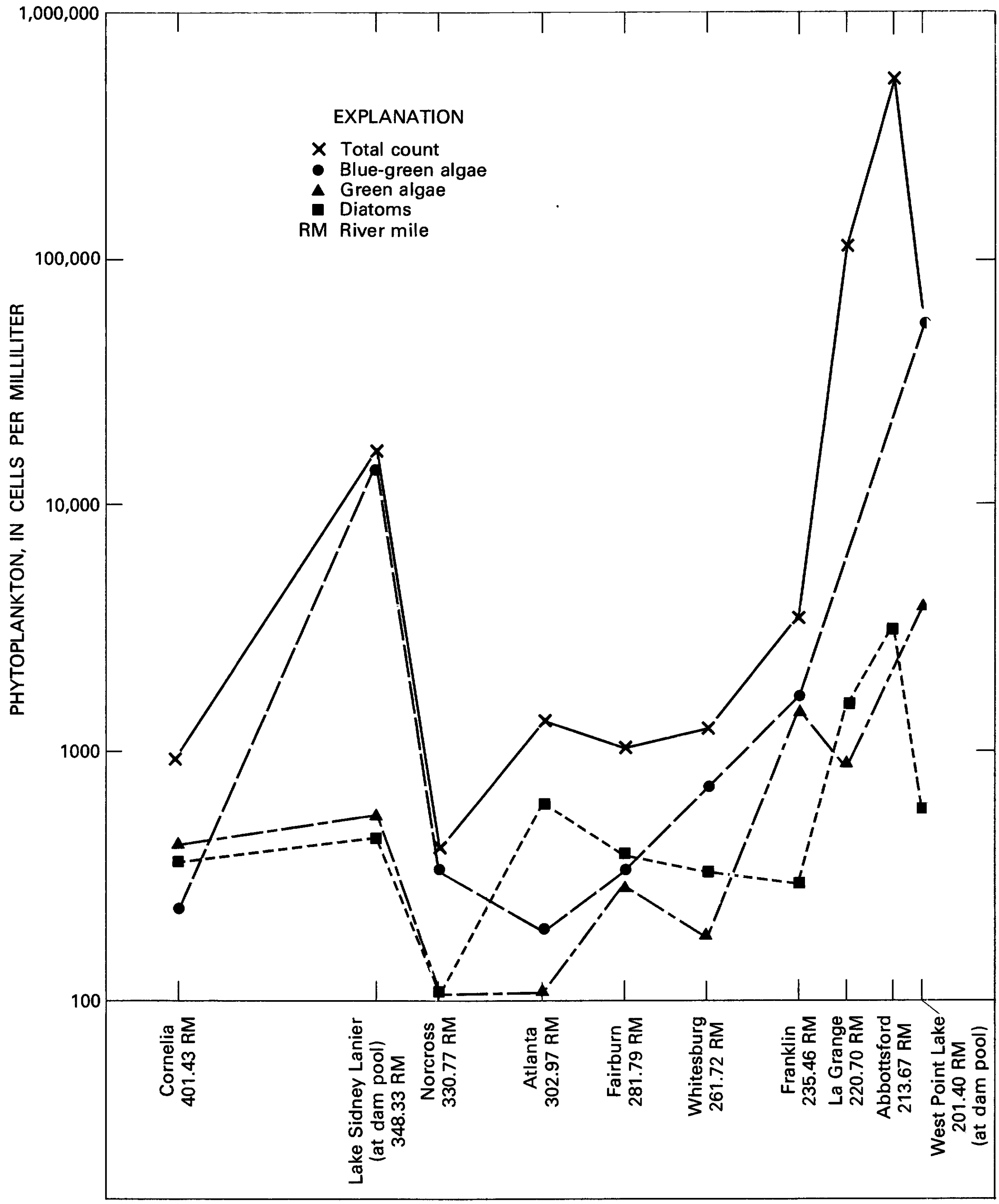


Figure 3.—Phytoplankton concentrations by river mile for August 1976.

from 0.1 mg/L at Franklin to less than 0.01 mg/L at the West Point dam pool, and dissolved NO_2+NO_3-N decreased from 0.6 mg/L at Franklin to about 0.1 mg/L at the dam pool.

RELATION OF ALGAL GROWTH POTENTIAL TO NUTRIENTS IN WEST POINT LAKE

A multiple-variable regression equation of the general form

$$Y=b_0+b_1X_1+b_2X_2+\ldots\ldots b_nX_n \qquad (1)$$

was used to determine the relation of various nutrients to AGP. The regression equation includes a dependent variable designated as Y; several independent variables designated as X_1, $X_2 \ldots\ldots X_n$; and partial regression coefficients designated as b_0, b_1, $b_2 \ldots\ldots b_n$. The subscript n indicates the number of independent variables.

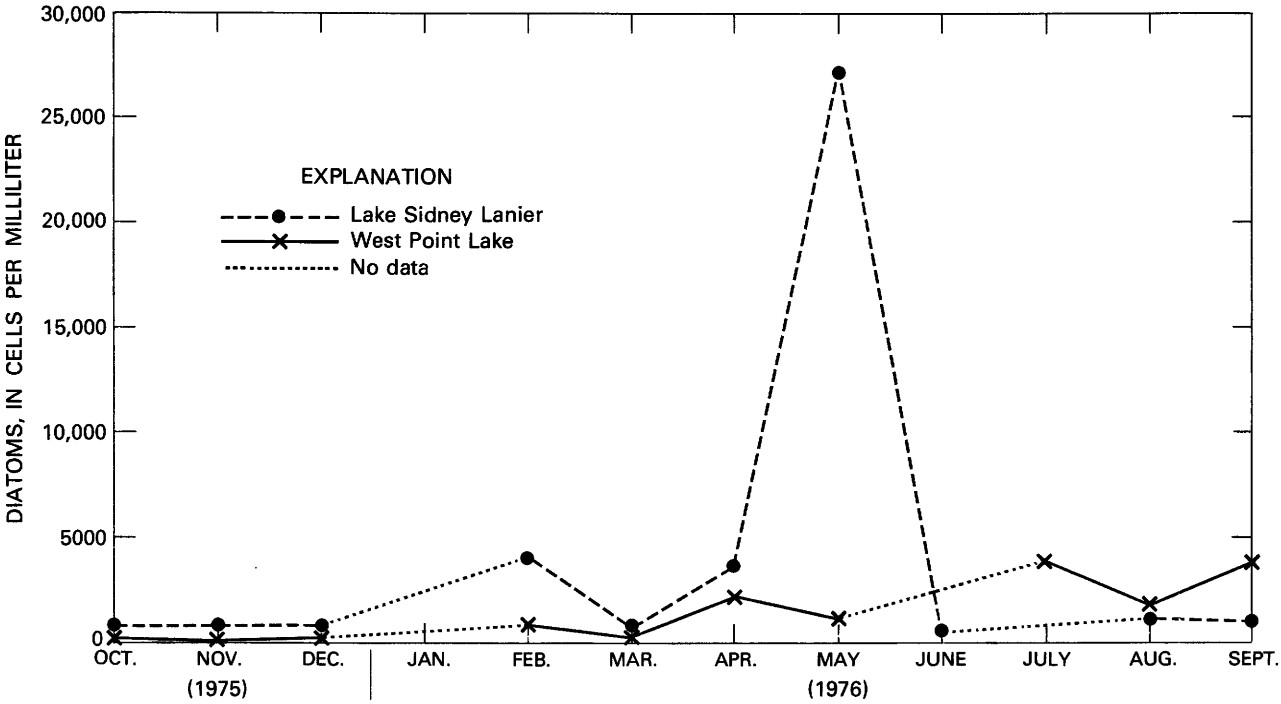


FIGURE 4.—Average diatom concentrations by month in Lake Sidney Lanier and West Point Lake.

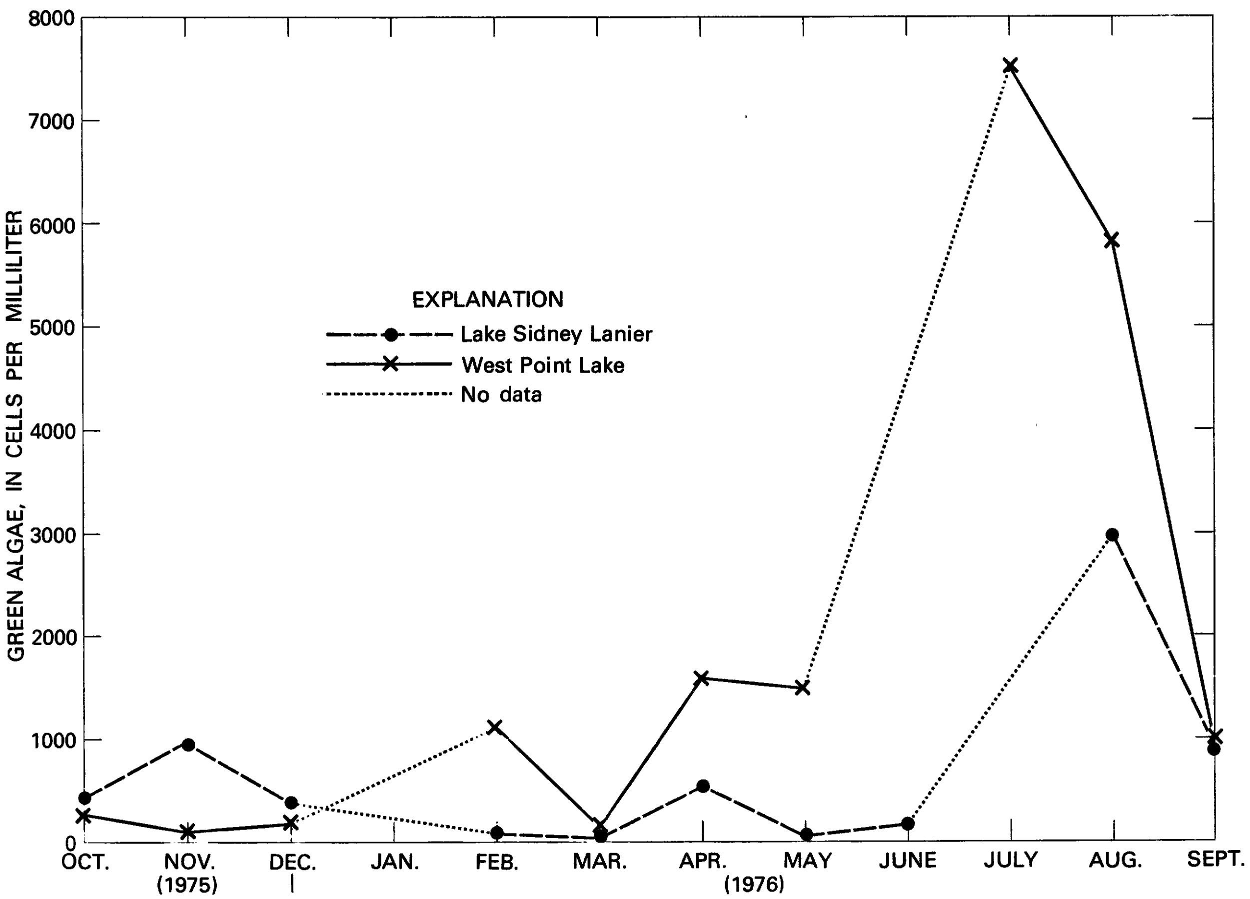


FIGURE 5.—Average green algae concentrations by month in Lake Sidney Lanier and West Point Lake.

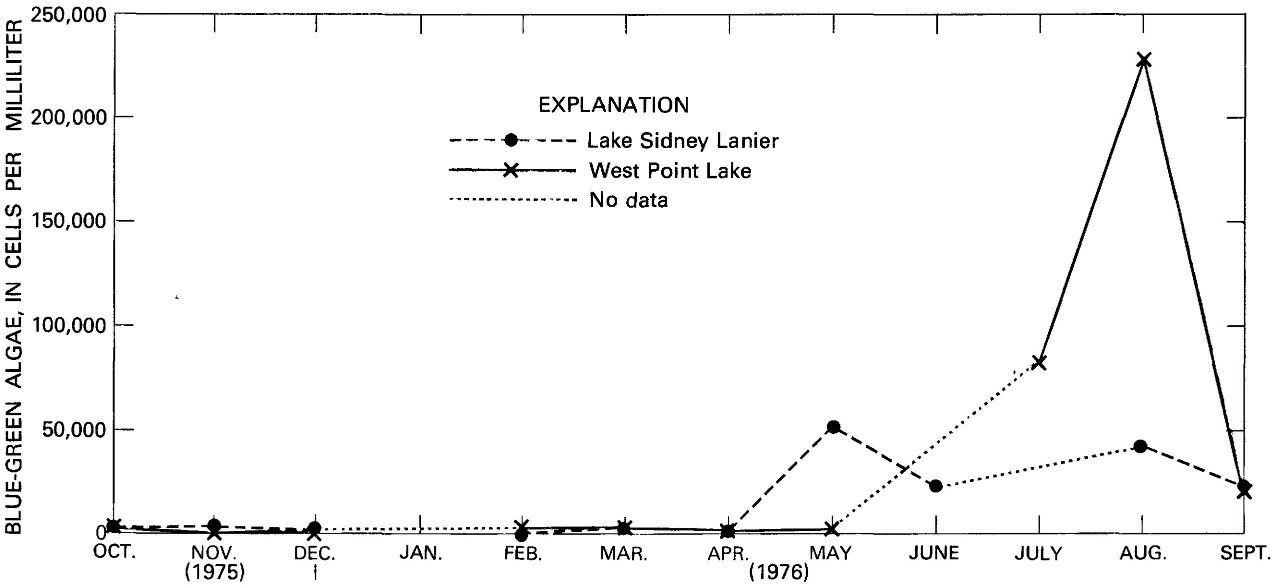


FIGURE 6.—Average blue-green algae concentrations by month in Lake Sidney Lanier and West Point Lake.

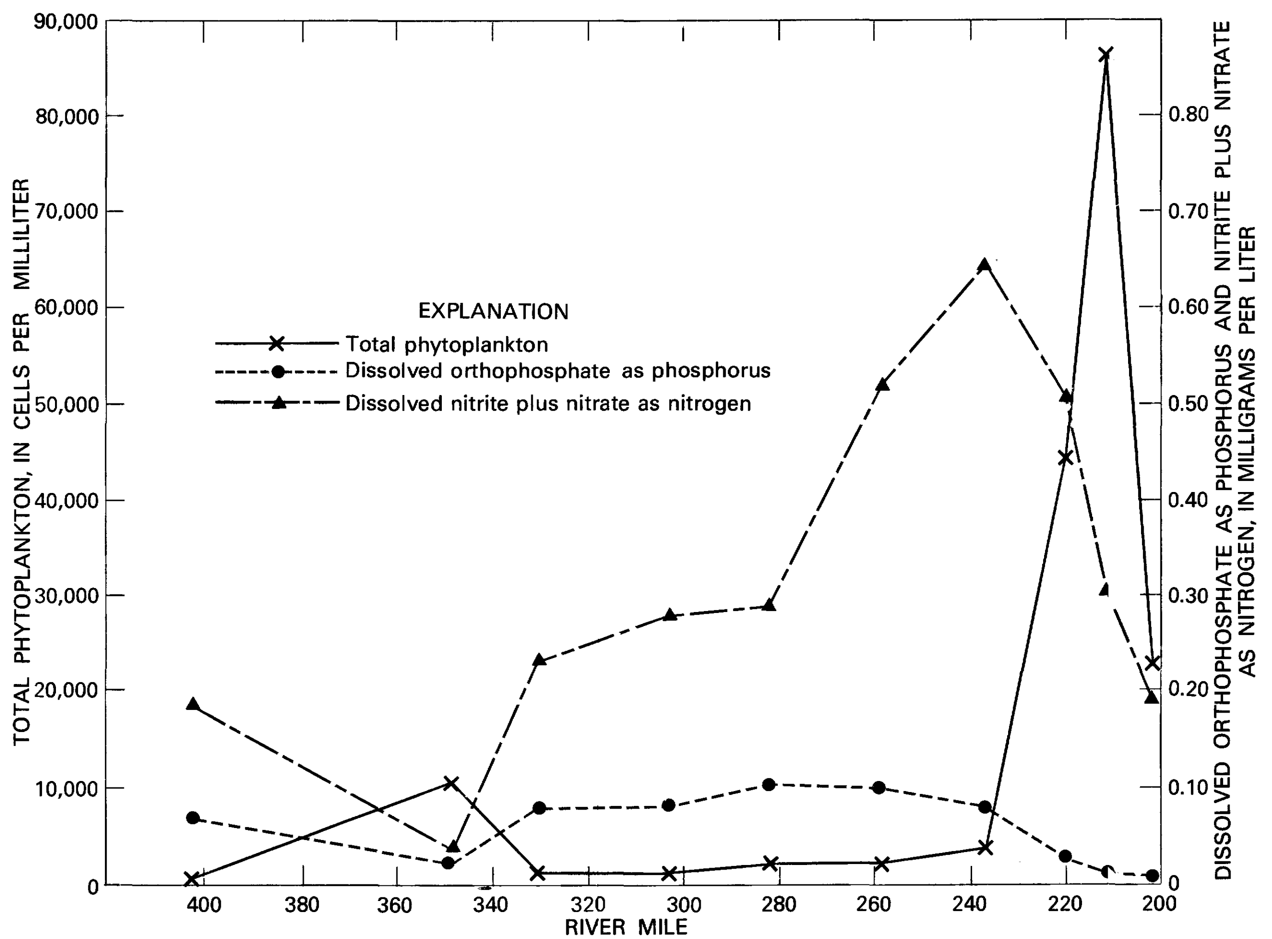


FIGURE 7.—Mean annual concentrations of total phytoplankton, dissolved orthophosphate, and nitrite plus nitrate by river mile.

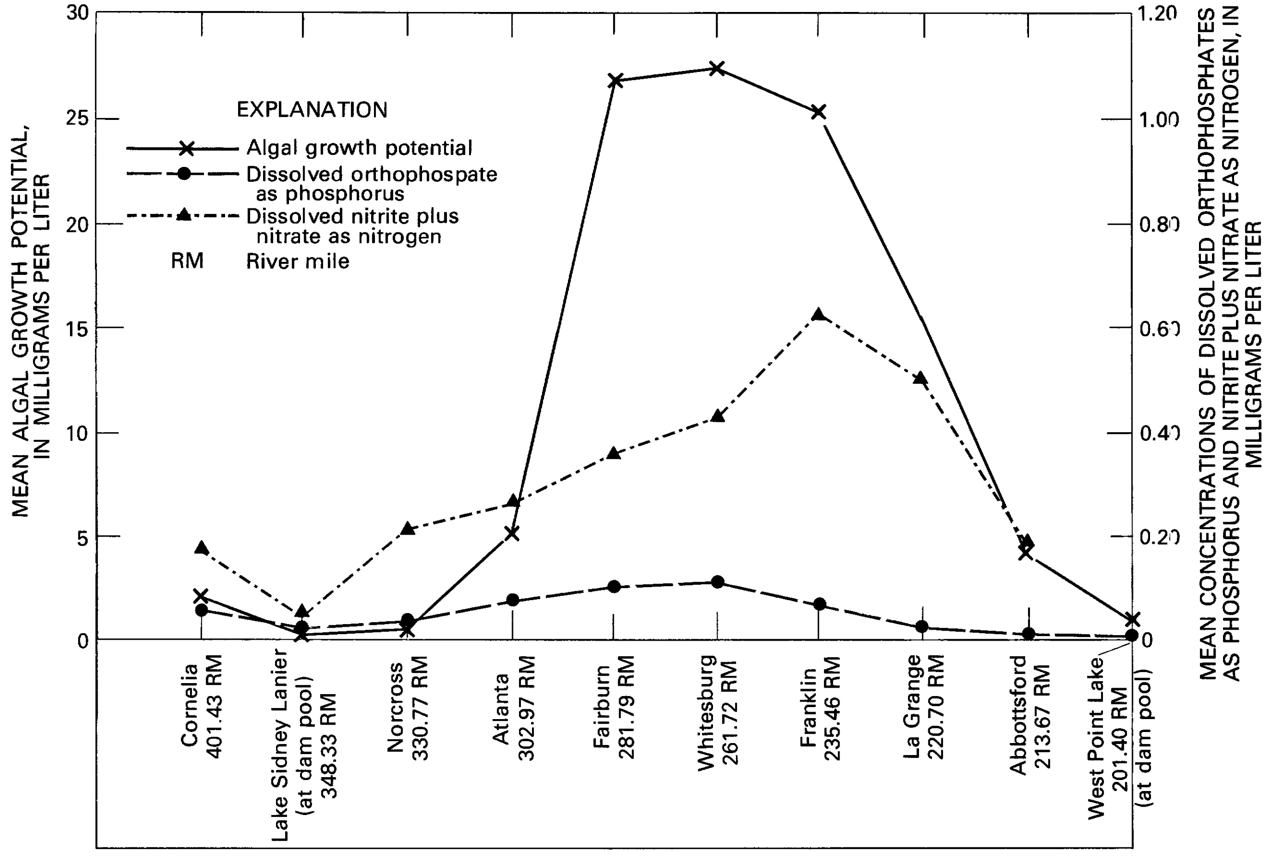


FIGURE 8.—Mean annual concentrations of algal growth potential, dissolved orthophosphate, and nitrite plus nitrate by river mile.

Regression parameters used in this study include the multiple correlation coefficient and the standard error of estimate, which indicate, respectively, the degree of association between the dependent and independent variables and the predictive quality of the regression model. Significance tests used were the *F*-test and *t*-test. Values of *F* indicate the "worth" of the entire regression, and values of *t* are measure of the significance of the regression parameters.

Several regression equations based on the general form described were developed and used to evaluate the relation of dissolved concentrations of NH_4-N, NO_2-N, NO_3-N, PO_4-P, and SiO_2 (silica) to AGP. The best equation determined from the regression of available data (table 5) from West Point Lake is defined by equation 2, which shows that orthophosphate and nitrate are the principle nutrients affecting AGP (Cherry and others, 1978).

$$\text{AGP (mg/L)} = 211\ (PO_4-P,\ \text{mg/L}) + 13.4\ (NO_3-N,\ \text{mg/L}) - 0.8 \quad (2)$$

The multiple correlation coefficients and standard error of estimate of equation 2 are 0.96 and 3.7 mg/L. The computed *F* of the regression is 172.5, which is significant at a level of confidence greater than 99 percent. The significance of orthophosphate and nitrate concentrations relative to APG is indicated by the results of the *t*-test as follows:

coefficient	*computed t*	*Levels of significance of t*
b_1 (PO_4-P)	8.02	0.1 percent
b_2 (NO_3-N)	3.10	0.1 percent

Thus, concentrations of dissolved orthophosphate are shown to be more significantly related to AGP than corresponding concentrations of dissolved nitrate. Statistically, both parameters are highly significant.

A comparison of calculated (equation 2) and observed AGP, as presented in figure 9, shows that AGP in West Point Lake can be estimated when only concentrations of dissolved orthophosphate and nitrate are known.

TABLE 5.—*Water temperature, algal growth potential, and concentrations of nutrients and phytoplankton in West Point Lake*

Location (river mile)	Collection period	Average lake temperature (°C)	Nitrate NO_3—N (mg/L)	Orthophosphate PO_4—P (mg/L)	Algal growth potential (mg/L)	Phytoplankton (cells/mL)
Franklin (0.0)	Nov. 15–18, 1975	16.8	----	----	13.0	2,400
	Dec. 16–17, 1975	13.1	0.76	0.10	33.0	1,000
	Feb. 24, 1976	14.2	0.55	0.10	25.0	1,100
	Mar. 22, 1976	14.1	0.43	0.02	12.0	410
	Apr. 17, 1976	20.9	0.58	0.06	24.0	500
	May 19–20, 1976	21.0	----	----	13.0	3,600
	July 2, 1976	26.6	0.71	0.12	28.0	6,300
	Aug. 10, 1976	28.2	0.84	0.13	36.0	19,000
	Aug. 24, 1976	29.0	0.84	0.10	30.0	3,800
	Sept. 10, 1976	25.8	0.96	0.14	43.0	1,200
LaGrange (14.2)	Nov. 15–18, 1975	16.8	----	----	14.0	310
	Dec. 16–17, 1975	13.1	0.43	0.02	5.7	2,100
	Feb. 24, 1976	14.2	0.52	0.05	16.1	1,900
	Mar. 22, 1976	14.1	0.32	0.01	5.8	250
	Apr. 17, 1976	20.9	0.24	0.01	5.0	4,100
	May 19–20, 1976	21.0	0.41	0.03	13.0	3,200
	July 2, 1976	26.6	0.56	0.04	20.0	94,000
	Aug. 10, 1976	28.2	0.70	0.05	22.0	240,000
	Aug. 24, 1976	29.0	0.50	0.03	19.0	120,000
	Sept. 10, 1976	25.8	0.73	0.02	18.0	23,000
Abbottsford (24.8)	Nov. 15–18, 1975	16.8	----	----	13.1	930
	Dec. 16–17, 1975	13.1	0.54	0.01	2.4	5,000
	Feb. 24, 1976	14.2	0.51	0.03	8.9	3,700
	Mar. 22, 1976	14.1	0.24	0.01	3.6	670
	Apr. 17, 1976	20.9	0.13	0.00	2.1	27,000
	May 19–20, 1976	21.0	0.40	0.01	3.8	14,000
	July 2, 1976	26.6	0.0	0.0	1.5	140,000
	Aug. 10, 1976	28.2	0.25	0.00	0.3	130,000
	Aug. 24, 1976	29.0	0.26	0.00	0.6	560,000
	Sept. 10, 1976	25.8	0.25	0.00	0.3	66,000
Dam pool (33.1)	Nov. 15–18, 1975	16.8	----	----	0.7	6,100
	Dec. 16–17, 1975	13.1	0.46	0.00	1.4	7,500
	Feb. 24, 1976	14.2	0.40	0.01	2.8	10,000
	Mar. 22, 1976	14.1	0.35	0.00	0.9	6,200
	Apr. 17, 1976	20.9	0.22	0.00	0.9	21,000
	May 19–20, 1976	21.0	0.10	0.00	0.5	40,000
	July 2, 1976	26.6	0.00	0.00	0.7	30,000
	Aug. 10, 1976	28.2	0.01	0.01	0.4	27,000
	Aug. 24, 1976	29.0	0.06	0.00	0.5	62,000
	Sept. 10, 1976	25.8	0.09	0.00	0.4	43,000

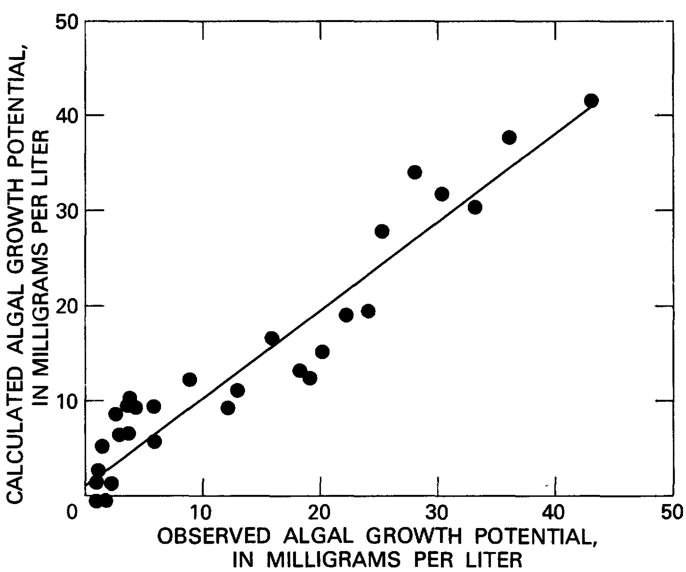


FIGURE 9.—Comparison of calculated and observed algal growth potential in the West Point Lake from Franklin to West Point Dam.

RELATION OF PHYTOPLANKTON GROWTH TO THE ALGAL GROWTH POTENTIAL

Plots relating phytoplankton concentrations to water temperature at sites in West Point Lake are shown in figure 10 (Cherry and others, 1978). Phytoplankton concentrations increase with increasing temperature at all sites. The concentrations are generally higher at downstream sites than at upstream ones at the same temperature, except at the dam pool, where the concentrations are lower at the higher temperatures than at the Abbottsford site.

The observed AGP and phytoplankton concentrations are plotted against river miles downstream from the Franklin station in Figures 11 and 12. A linear relation between miles downstream of Franklin and AGP and phytoplankton concentrations occurred during all sampling periods when AGP was greater than about 0.5 mg/L.

Figures 11 and 12 and data in table 5 (July–September 1976) indicate that, where algal

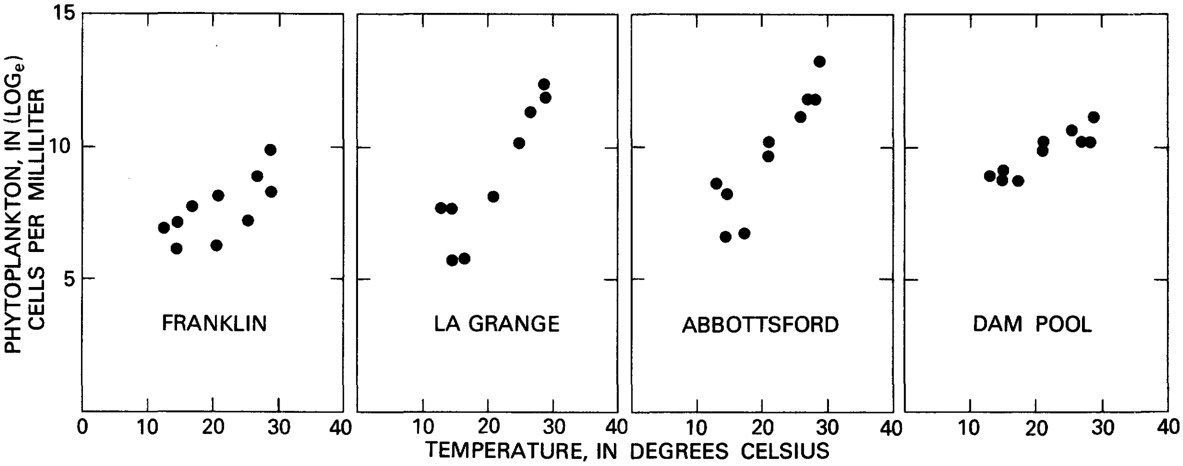


FIGURE 10.—Relation of phytoplankton concentrations to water temperature at sites in West Point Lake.

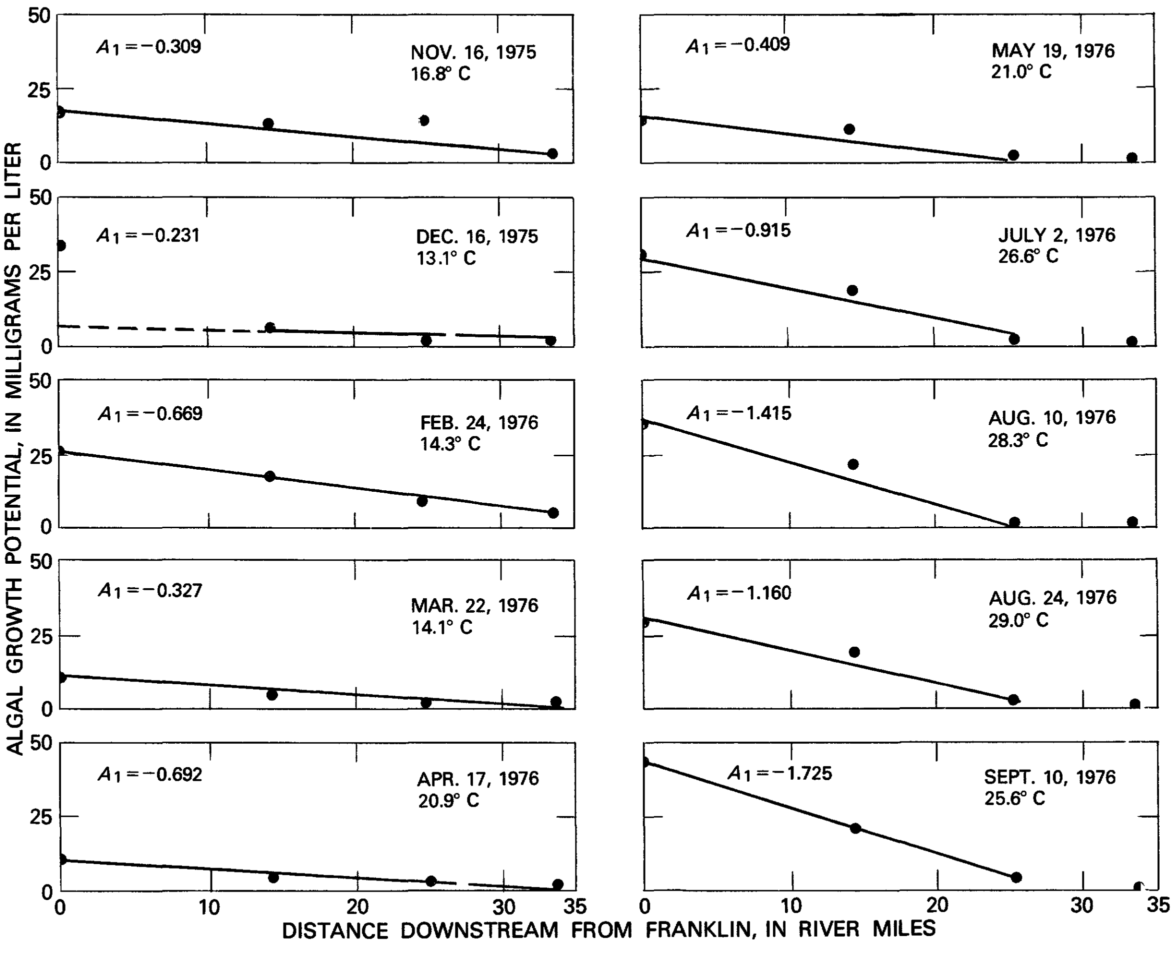


FIGURE 11.—Plots of observed algal growth potential by river mile downstream from Franklin station.

growth potential was less than about 0.5 mg/L, a decrease in the phytoplankton concentration occurred downstream. Therefore, the availability of nutrients, as indicated by AGP, appears to be limiting phytoplankton growth in the lower reaches of the lake.

The rates of change of AGP and phytoplankton concentrations increased with distance for

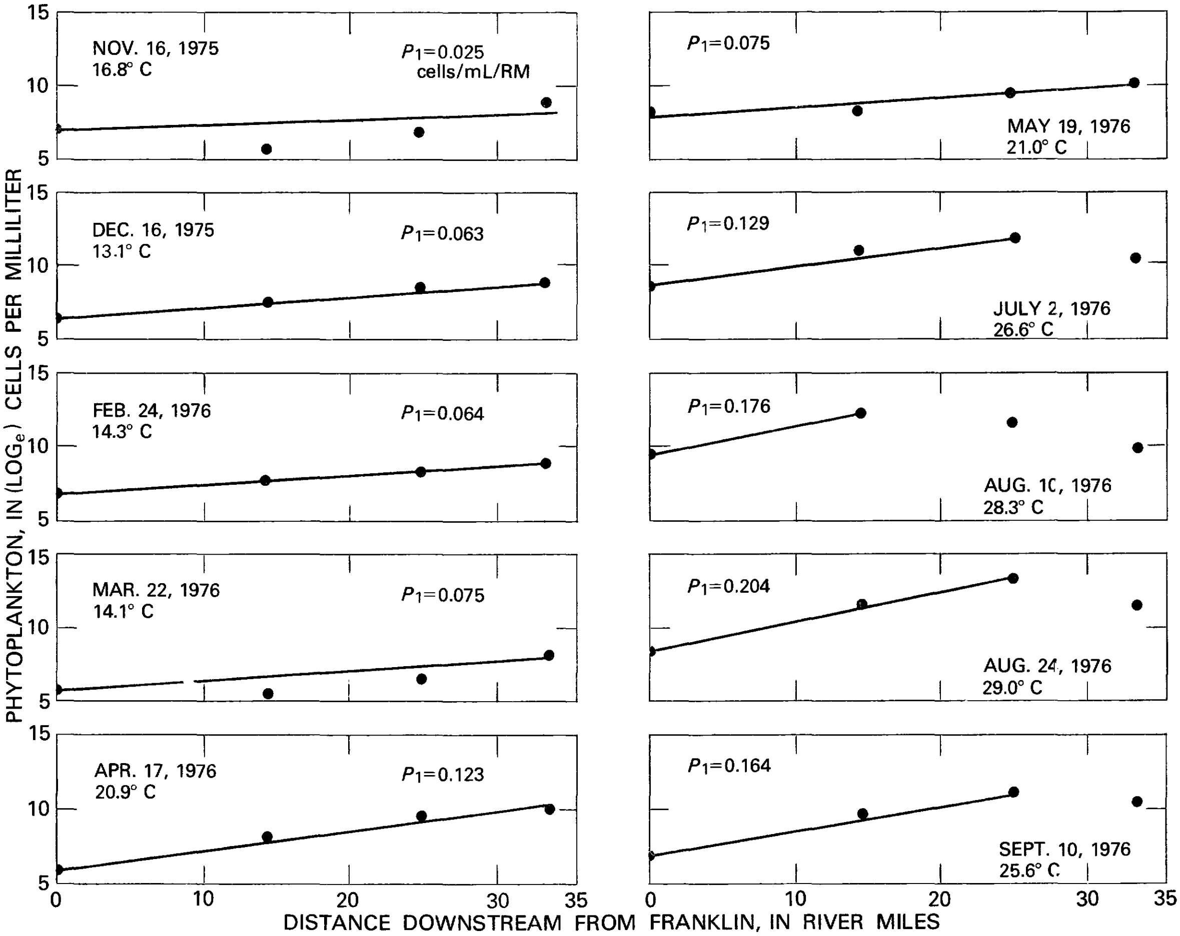


FIGURE 12.—Plots of observed phytoplankton concentrations by river mile downstream from Franklin station.

each of the sampling periods and are plotted against water temperature in figures 13 and 14 (Cherry and others, 1978). Both rates increased with increasing temperature greater than 13°C.

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

$$A_1 = -(0.0673T - 0.625), \quad (3)$$

where

A_1 = rate of change of AGP per river mile in (mg/L)/RM, and
T = average water temperature, in °C.

The relationship between the rate of change of phytoplankton concentration and water temperature with river mile is defined from about 10°C to 30°C by the following equation:

$$P_1 = 0.0084T - 0.066, \quad (4)$$

where

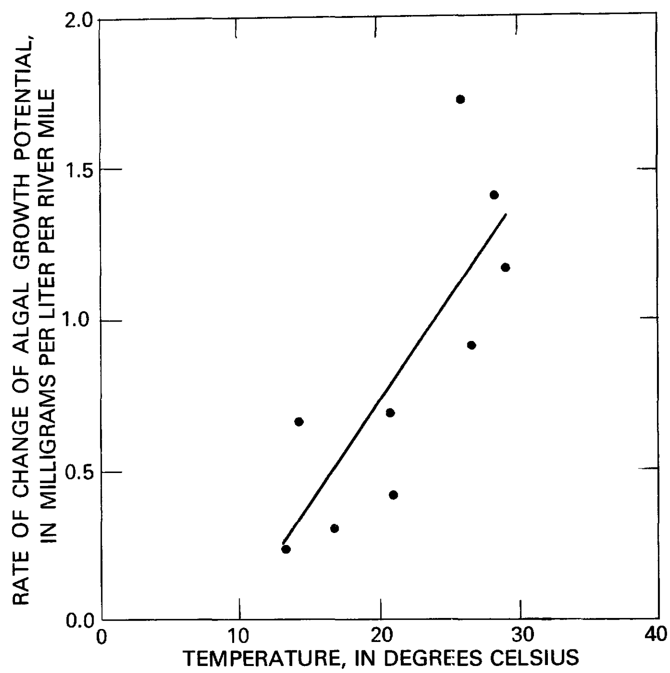


FIGURE 13.—Relationship of temperature to the rate of change of algal growth potential per river mile.

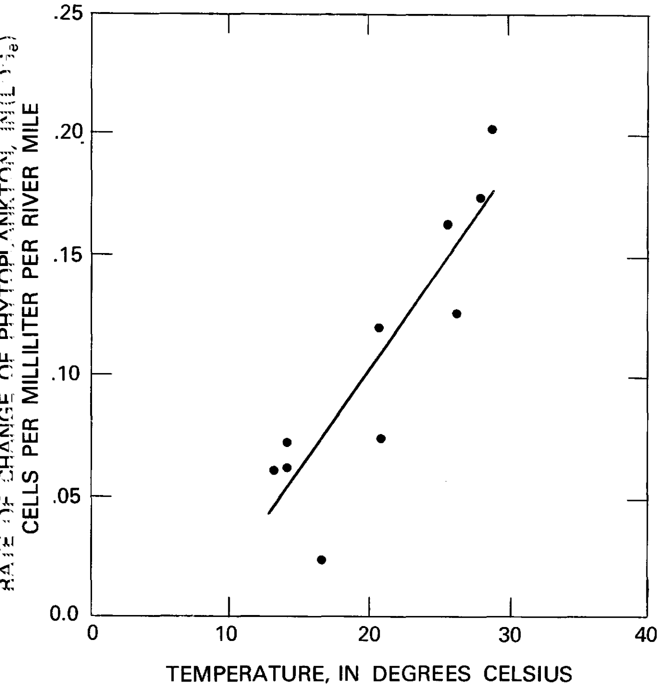


FIGURE 14.—Relationship of temperature to the rate of change of phytoplankton concentration per river mile.

P_1 = rate of change of phytoplankton concentration per river mile, in ($\log_e$ cells/mL)/RM,

T = average water temperature, in °C.

Therefore, knowing the AGP and phytoplankton concentrations and the water temperature of the lake, the AGP and phytoplankton concentration can be estimated at downstream sites in the lake using the following equations (Cherry and others, 1978):

$$C_{ar} = (A_1 R) + C_{ai}, \qquad (5)$$

where

C_{ar} = AGP in mg/L at river mile R, downstream from Franklin,

A_1 = rate of change of AGP, in (mg/L)/RM,

R = river mile downstream of Franklin, and

C_{ai} = AGP, in mg/L, from Franklin.

$$C_{pr} = (P_1 R) + C_{pi}, \qquad (6)$$

where

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

P_1 = rate of increase of phytoplankton concentration, in ($\log_e$ cells/mL)/RM,

R = river mile downstream from Franklin, and

C_{pi} = phytoplankton concentrations, in ($\log_e$) cells/mL, at Franklin.

Figure 15 shows a comparison of calculated (equation 2) and observed AGP, and figure 16 shows a comparison of calculated (equation 6) and observed phytoplankton concentrations for each of the sampling periods. The calculated concentrations approximate the observed ones.

Estimated maximum phytoplankton concentrations at sites in the West Point Lake at various temperatures are shown in figure 17. At 30°C, a maximum phytoplankton concentration in the lake would occur at the dam pool with a estimated minimum of 47 mg/L AGP concentration at Franklin. At 30°C, a maximum phytoplankton concentration would occur at Abbottsford with an estimated minimum of 35 mg/L AGP at Franklin. Maximum phytoplankton concentrations, at 30°C, at other upstream sites would occur with lower AGP at Franklin. Estimated phytoplankton concentrations, at 30°C, and with a 47 mg/L AGP at Franklin, would not exceed 7,500, 100,000, 750,000, and 3.5 million cells/mL at Franklin, LaGrange, Abbotsford, and the dam pool, respectively.

The analysis of the relation of phytoplankton to AGP indicates that at sites where the AGP has decreased to less than about 0.5 mg/L, the phytoplankton concentrations decrease downstream. Where AGP is greater than about 0.5 mg/L, phytoplankton concentrations are dependent on water temperature and distance downstream from Franklin. Whether factors other than AGP would limit phytoplankton growth approaching 3.5 million cells/mL could not be determined from the data.

NITRIFICATION

Nitrification can be an important factor affecting the dissolved-oxygen balance in streams. The DO balance in the Chattahoochee River was determined by Stamer and others (1978) during the low-flow period of June 1–2, 1977, in the reach from Atlanta (RM 302.97) to Franklin (RM 235.46). Hourly field measurements at 11 sites were compared with values computed (fig. 18) using the method described by Velz (1970). DO concentration decreases in

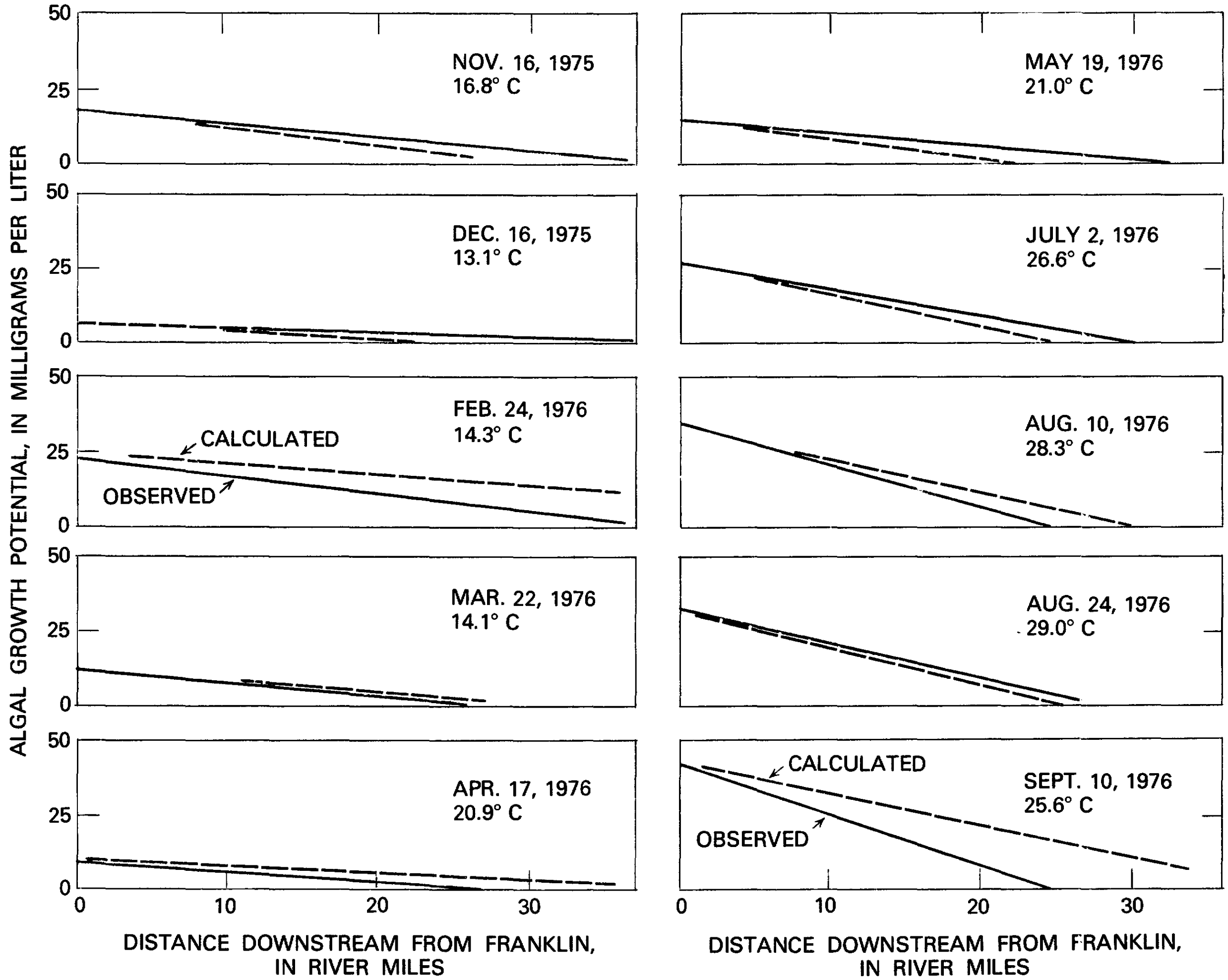


FIGURE 15.—Comparison of calculated and observed algal growth potential for each sampling period.

the river were attributed to a combination of nitrogenous and carbonaceous oxygen demands. Nitrogenous demands (nitrification) caused approximately 50 percent of the DO decrease in the reach (Stamer and others, 1978). Figure 19 shows the DO decrease resulting from nitrification to the total decrease in DO during the period of June 1–2, 1977.

Nitrification or oxidation of NH_4-N to nitrate proceeds in two steps catalyzed by the chemoautotrophic bacteria, *Nitrosomonas* and *Nitrobacter* (Alexander, 1964):

$$NH_4^+ + 1\text{-}1/2\ O_2 \xrightarrow{\textit{Nitrosomonas}} NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + 1/2\ O_2 \xrightarrow{\textit{Nitrobacter}} NO_3^-$$

The treatment of wastewater reduces the carbonaceous oxygen demand because utilizable carbon substrates are quickly attacked by many heterotrophic bacteria (Strom and others, 1976). The nitrogenous oxygen demands often are not greatly affected during wastewater treatment because initially the reaction kinetics of nitrification proceed slowly. As a result, nitrification may occur downstream from treated wastewater outfalls.

The mean concentrations of *Nitrosomonas* and *Nitrobacter* bacteria in the water column and benthic sediments during the period June 1–2, 1977, as determined by Ehlke (1978) are shown in figures 20 and 21.

The *Nitrosomonas* concentration was 10–100 times greater in the benthic sediment than in the water column. This is consistant with studies elsewhere (Tuffey and others, 1974; Curtis and others, 1975). The *Nitrosomonas* concentration in the water column was the least at RM 302.97 but was almost constant further

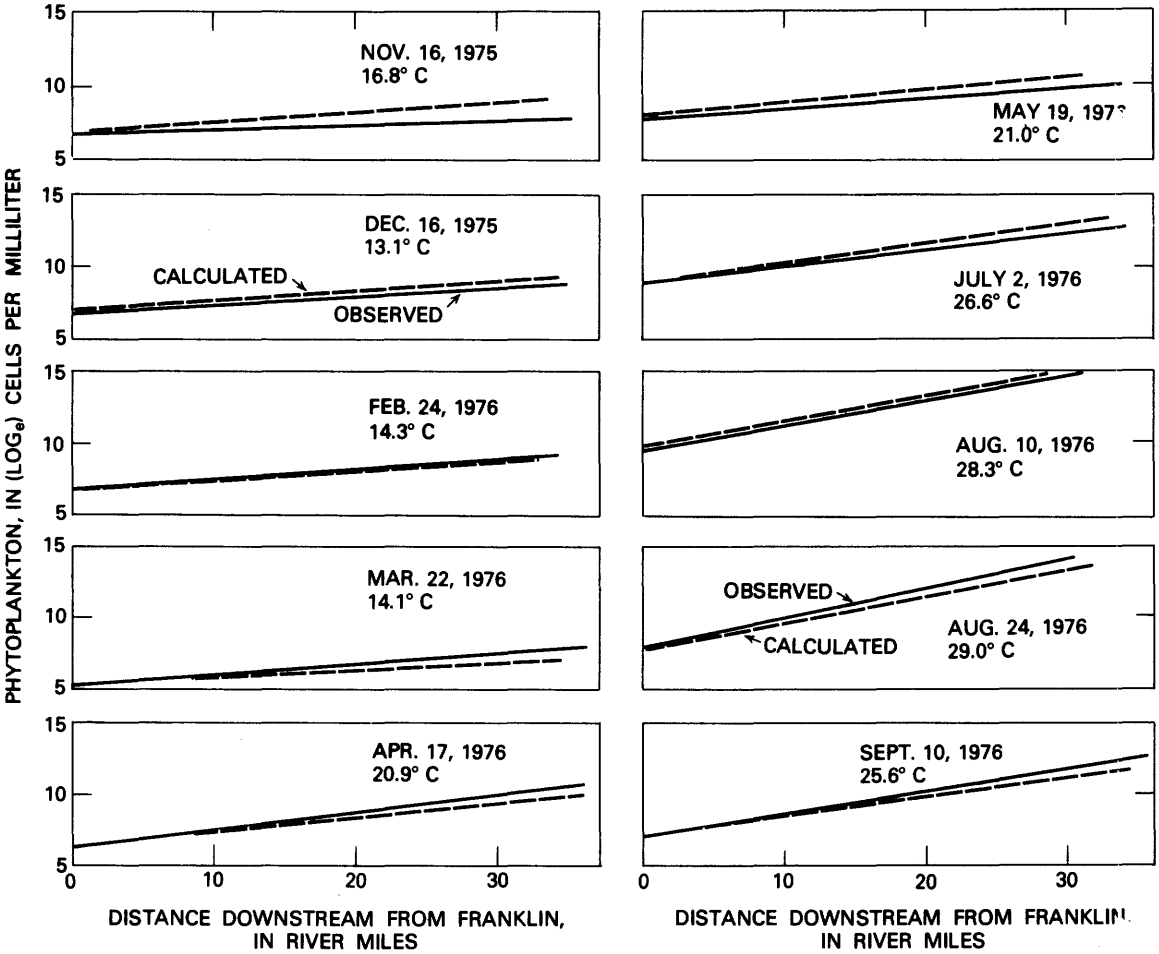


FIGURE 16.—Comparison of calculated and observed phytoplankton concentrations for each sampling period.

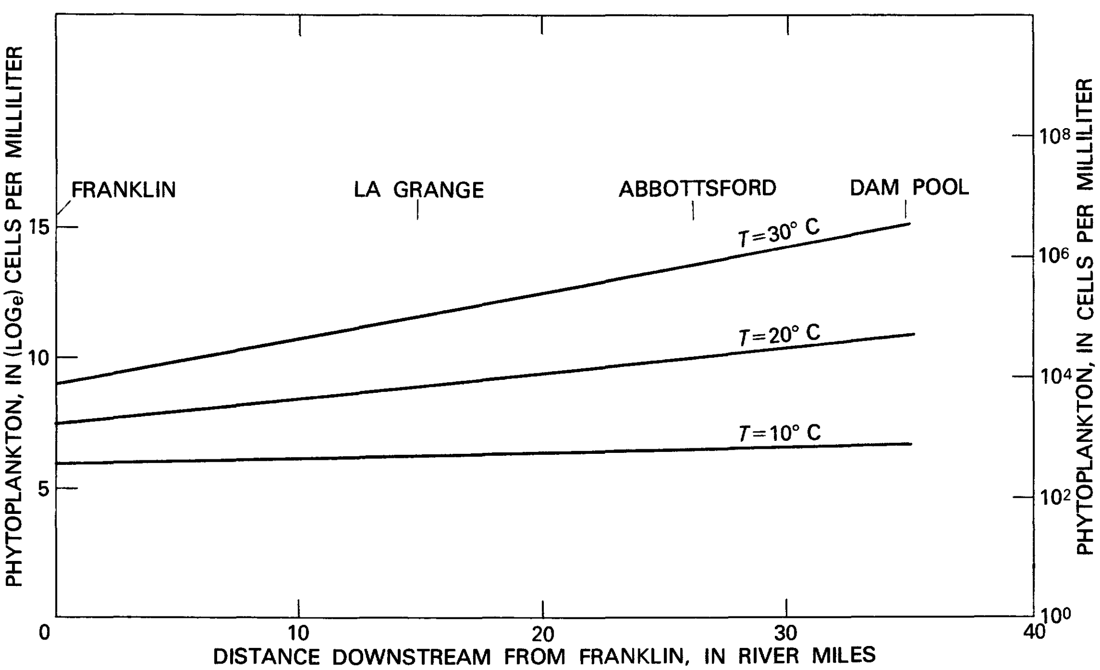


FIGURE 17.—Estimated maximum phytoplankton concentrations at sites in West Point Lake at various temperatures.

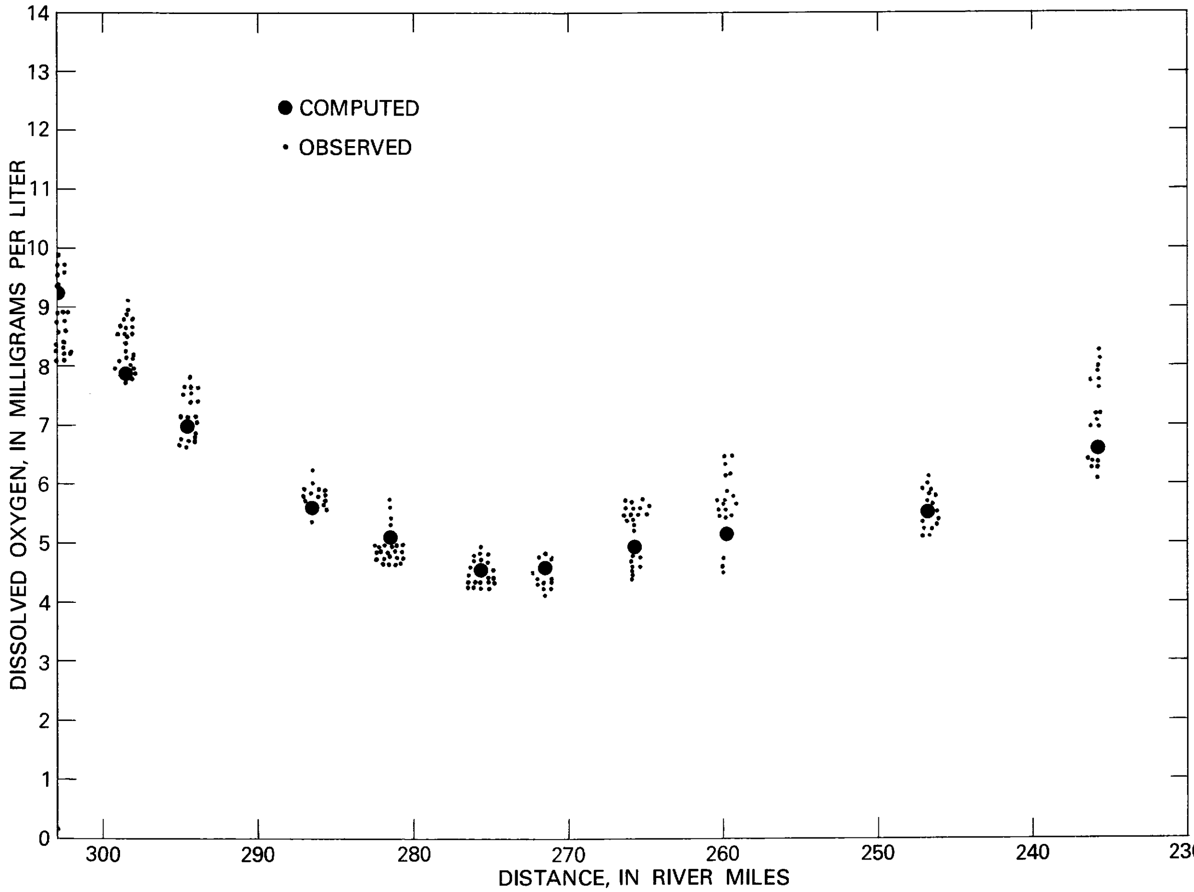


FIGURE 18.—Comparison of computed and observed dissolved-oxygen concentrations in the Atlanta to Franklin reach during low flow period, June 1–2, 1977.

downstream. This collection site was upstream of all facilities in metropolitan Atlanta. *Nitrosomonas* concentrations generally were greatest near RM 298.77. This site is downstream from the two major Atlanta wastewater treatment facilities (RM 300.24 and RM 300.52). *Nitrosomonas* concentrations at Capps Ferry Bridge (RM 271.19) and Franklin (RM 235.46) were also greater than at most other collection sites.

The concentration of *Nitrobacter* in benthic sediment was greatest near RM 271.19 and RM 235.46, approximately 10^3 per gram. In the reach containing municipal point-source discharges (RM 300.52–RM 283.78), concentrations of *Nitrobacter* generally were less in benthic sediments than elsewhere in the study area. The *Nitrobacter* concentration in the water column was nearly constant from RM 302.97 to RM 235.46. As with other studies (Tuffey and others, 1974; Curtis and others, 1975), the *Nitrobacter* concentration in benthic sediments was 10–100 times greater than in the water column. The *Nitrobacter* concentration was generally lower than the *Nitrosomonas* concentration.

The observed mean NH_4-N, NO_2-N, and NO_3-N concentrations for June 1–2, 1977, are shown in figure 22. During the June 1–2, 1977, sampling period, the concentrations of NH_4-N and NO_2-N were lowest near RM 302.97. The concentration of NO_3-N, which is the end product of nitrification, was about 0.1 mg/L at RM 302.97 and increased to about 1.2 mg/L at RM 235.46. The concentrations of NH_4-N and NO_2-N increased rapidly downstream from the municipal wastewater outfalls. The NH_4-N concentration was maximum at RM 298.77.

The concentrations of NH_4-N decreased at almost a constant rate of 0.02 mg/L/h during June 1–2, 1977, from RM 298.77 to RM 235.46, based on a travel time of 65.07 h and a change in concentration of NH_4-N from 1.8 mg/L to 0.2 mg/L (fig. 22).

Concentrations of NO_3-N increased at almost a constant rate of 0.02 mg/L/h during the

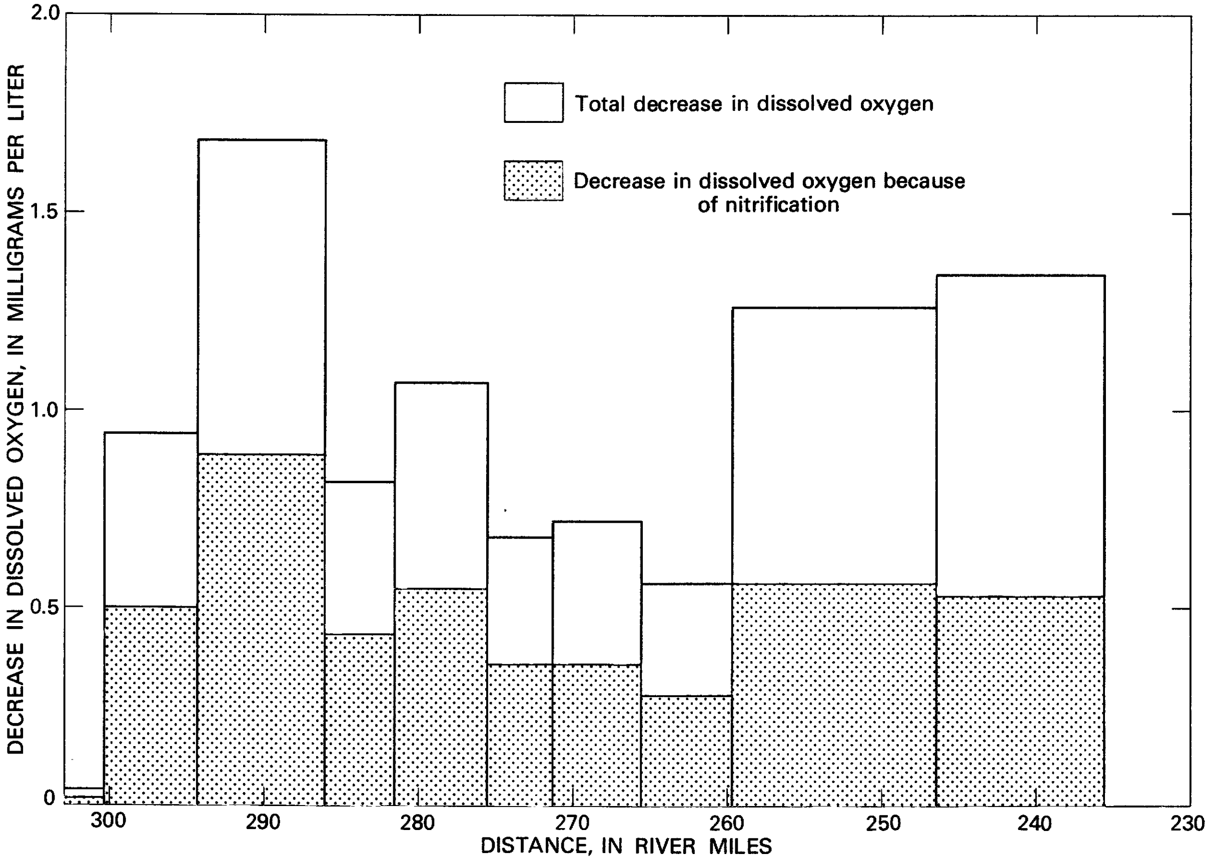


FIGURE 19.—Comparison of decreases in dissolved oxygen resulting from nitrification to total decrease in dissolved oxygen in the Atlanta to Franklin reach during low flow period, June 1–2, 1977.

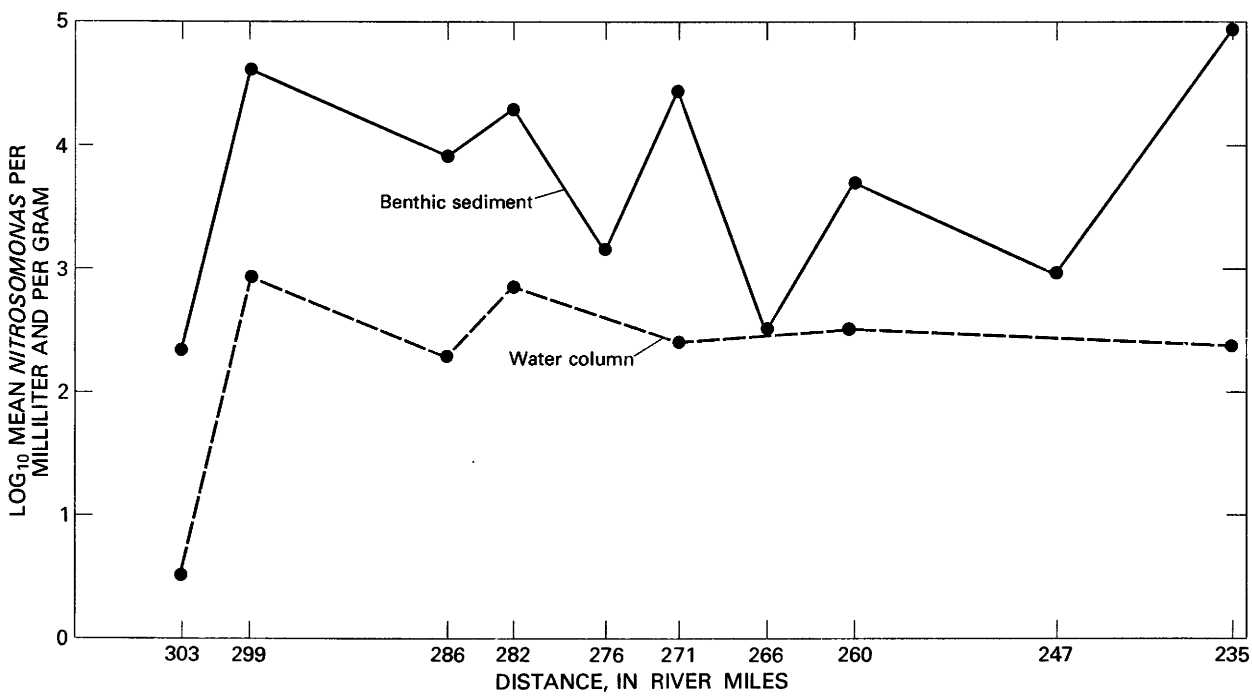


FIGURE 20.—*Nitrosomonas* population in Chattahoochee River water and benthic sediment during June 1–2, 1977.

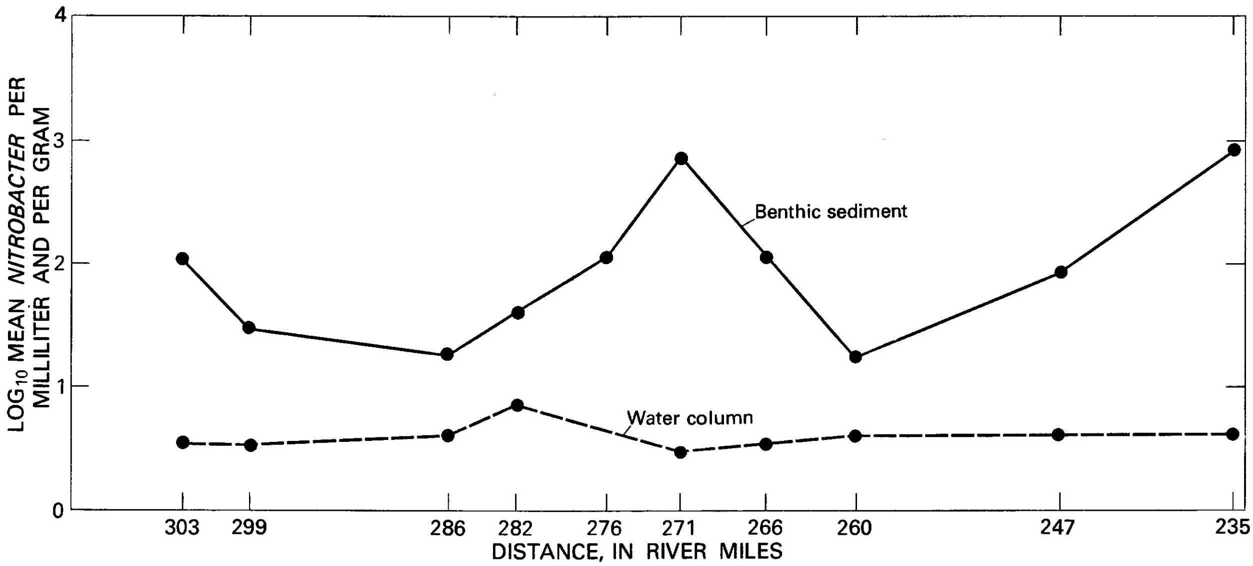


FIGURE 21.—*Nitrobacter* population in Chattahoochee River water and benthic sediment during June 1–2, 1977.

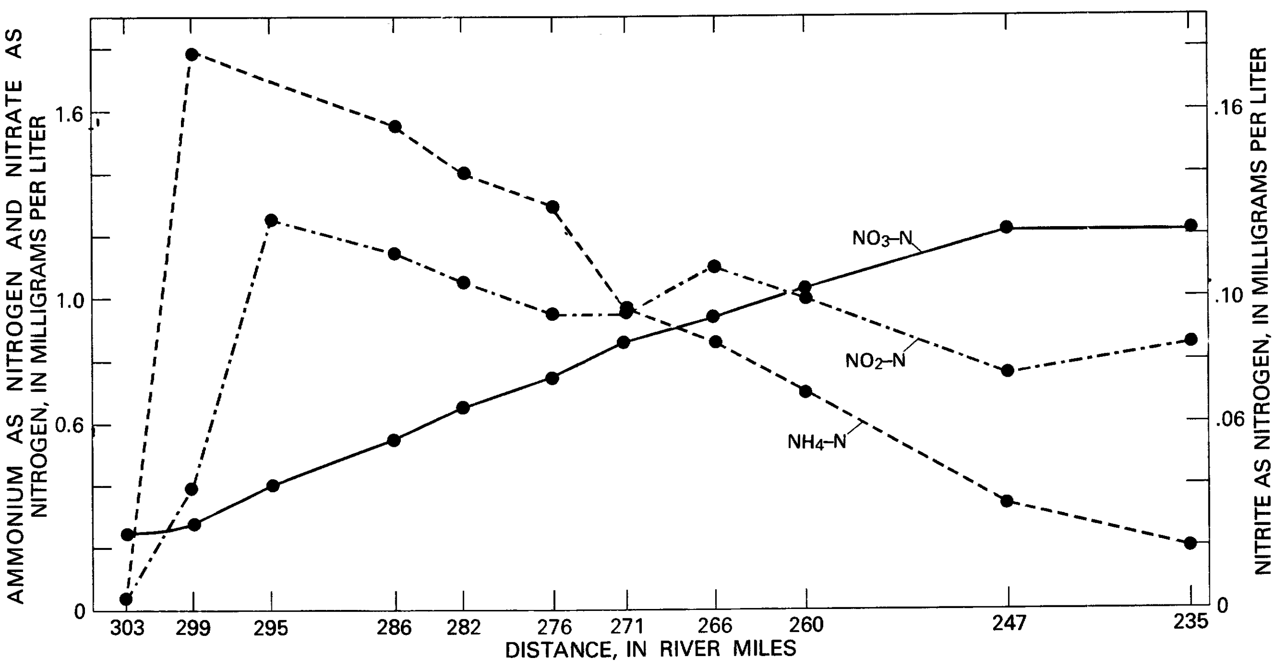


FIGURE 22.—Mean concentrations of ammonium, nitrite, and nitrate in the Chattahoochee River during June 1–2, 1977.

period of June 1–2, 1977, from RM 302.97 to RM 246.93. The disappearance of NH_4-N was approximately equal to the formation of NO_3-N during the period of June 1–2, 1977, from RM 298.99 to RM 246.97.

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

All sampling for nitrifying bacteria was done when the flow of the Chattahoochee River was near 1,150 ft^3/s and the mean depth from RM 302.97 to RM 258.63 was about 1.42 m. Using the data of figures 20 and 21, the relative concentrations of *Nitrosomonas* and *Nitrobacter* in a 142-cm water column and 1-cm benthic sediment column can be calculated. Averaging the data, 53 percent of the *Nitrosomonas* is calculated to be in the water column and 47 percent, in the top 1 cm of benthic sediment. Similarly, 72 percent of the *Nitrobacter* was present in the water column and 28 percent, in the benthic sediment. This indicates that, during the study period, most nitrifying-bacterial activity occurred in the water column, not in the benthic sediment.

SUMMARY AND CONCLUSIONS

For more than ten years, the Advisory Committee on Water Data for Public Use has been interested in obtaining information needed for planning river basin development. The upper Chattahoochee River basin study began April 1, 1975, and was the second intensive river-quality assessment conducted by the U.S. Geological Survey, with the purpose of providing demonstration products for management decisions, alternatives for basin development, and maintenance and improvement of water quality in the upper Chattahoochee River basin.

The biological and associated chemical data were collected from October 1975 through September 1976 at selected stations in Lake Sidney Lanier, West Point Lake, and the Chattahoochee River.

Phytoplankton concentrations (cells/mL) were generally higher downstream from Atlanta than upstream. The highest concentrations (mostly blue-green algae) occurred in West Point Lake with an average of 90,000 cells/mL for the sampling period. The lowest concentrations occurred upstream of Lake Sidney Lanier (1,000 cells/mL). Concentrations downstream from Lake Sidney Lanier were less than 1,800 cells/mL. The dissolved PO_4-P concentrations were highest in the river reaches and upper reaches of the two lakes, and lowest at the dam pools of both lakes. This was also true for the dissolved NO_2+NO_3-N concentrations. AGP was highest downstream from Atlanta and lowest in the headwaters and at the dam pools in both lakes. Analysis of data collected in the West Point Lake during sampling periods indicates that AGP decreases in response to increases in phytoplankton concentration from the upper to lower reaches of the lake. AGP and phytoplankton concentration changes are greater at higher temperatures than at lower ones. Little or no decrease in the AGP or increase in phytoplankton concentration occurs with distance at temperatures less than about 13°C. Analysis of the data indicates that phytoplankton concentration is related to water temperature and location in the lake at sites where AGP is greater than about 0.5 mg/L. Phytoplankton concentration decreases downstream in the lake at sites where AGP is less than 0.5 mg/L.

Concentrations of *Nitrosomonas* in the water column and in the benthic sediment increased in the reach RM 302.97 to RM 298.99, and decreased from RM 298.99 to RM 235.46 during the low flow period, June 1–2, 1977. Nitrifying bacteria were present in greater concentrations in the benthic sediment than in the water column on a number-per-milliliter or per-gram basis. If the entire water column (1.4 m) were considered, the total number of nitrifying bacteria was greater in the water column than in the top 1 cm of benthic sediment. It is probable that most nitrifying-bacteria activity would occur in the water column rather than in the benthic sediment of the Chattahoochee River. The rate of NH_4-N disappearance (0.02 mg/L/h) was approximately equal to the formation of NO_3-N during the period of June 1–2, 1977.

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