TECHNICAL PUBLICATION 82-4

A SURVEY OF WATER QUALITY CHARACTERISTICS AND CHLOROPHYLL A CONCENTRATIONS IN THE CALOOSAHATCHEE RIVER SYSTEM, FLORIDA

Final Report

by
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SOUTH FLORIDA WATER MANAGEMENT DISTRICT
RESOURCE PLANNING DEPARTMENT
WEST PALM BEACH, FLORIDA

JULY 1982

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ABSTRACT

A coordinated effort was made to sample water quality and chlorophyll a levels in the Caloosahatchee River and associated tributaries in southwest Florida during 1978-80.

Routine water samples were collected monthly from 17 river and 17 tributary sites. The data was collected to characterize the quality of water discharges to the Caloosahatchee River by selected tributaries and Lake Okeechobee, to determine the impact of these inflows upon the river, and to identify the water quality conditions associated with the phytoplankton levels in the Caloosahatchee River.

Chlorophyll a was used as an indicator of phytoplankton biomass. Chlorophyll a samples were collected, concurrent with routine water quality samples and at the investigator's discretion, during potential algal bloom conditions.

Overall volumes of discharges at each major water control structure, S-77 S-78, and S-79, were greater than the historic period of record as a result of unusual winter regulatory discharges. Discharge from Lake Okeechobee was a principal factor influencing the quality of water in the Caloosahatchee River.

Phosphorus demonstrated a well defined seasonal pattern at S-77 which was sensitive to water releases. The lowest phosphorus levels occurred during the winter when S-77 was discharging, while the highest levels occurred during the summer when S-77 was not discharging. Phosphorus increased in the East Caloosahatchee River Basin between S-77 and S-78 then decreased in the West Caloosahatchee River Basin to S-79. The East Basin tributaries generally had higher phosphorus concentrations than the river. The West Basin tributaries had lower phosphorus concentrations than the river.

Total nitrogen concentrations decreased linearly from Lake Okeechobee to S-79. As a group, the average nitrogen concentrations in the tributaries were less than the river. Ammonia and nitrate trends were reversed in the tributaries, with ammonia levels decreasing from S-77 to S-79 and nitrate increasing from S-77 to S-79. Organic nitrogen was the principal component of the total nitrogen levels in the river. Ammonia was the principal inorganic constituent in the East Basin and nitrate was the principal inorganic component in the West Basin.

Chloride levels along the river were opposite to the trend noted for phosphorus. Chloride levels decreased from S-77 to the LaBelle area of the river, then increased again toward S-79. The tributary input appears responsible, in part, for the levels in the river.

The river was generally well mixed with depth for temperature, pH, and specific conductance. Dissolved oxygen showed a summer vertical gradient with low values near the bottom. The dissolved oxygen levels during the winter months were well mixed with depth and relatively high (6-8 mg/L).

Chlorophyll a levels were usually higher in the East Basin, between S-77 and S-78, than in the West Basin, from S-78 to S-79. On a seasonal basis, chlorophyll a levels throughout the river were typified by (a) autumn and winter minimum with a concentration $\leq$ 10 mg/m3; (b) spring increase in May and early June; and (c) summer maximum with chlorophyll a levels ranging from about 20-40 mg/m3.

Chlorophyll a concentrations exhibited an inverse relationship with inorganic nitrogen concentration, especially NO_3 and NO_2. Inorganic phosphorus was usually available for phytoplankton growth well above analytical detection limits. Chlorophyll a concentration and water temperature consistently exhibited the highest positive correlation based on linear regression analyses.

The relation between water flow (expressed as residence time) and chlorophyll a concentration was examined under a number of conditions. Usually, during low flow periods in spring and summer, phytoplankton populations can respond to ambient water quality characteristics. Conversely, large flows generated from basin surface water runoff or Lake Okeechobee regulatory releases can usually flush or dilute high chlorophyll a levels from the river.

Daily sampling for water quality at two locations in the West Basin (at the Alva Bridge and near the Lee County Water Treatment Plant) during the late spring of 1978, and in conjunction with biweekly sampling at the routine river stations, indicated the presence of a nutrient rich, low volume source of water that was partially responsible for nutrient enrichment in the western portion of the river.

Based on mass loading calculations, Lake Okeechobee contributed the most water (55%), nitrogen (62%), and chloride (42%) to the river. The tributaries in the East Basin contributed the least amount of water (21%) and the most phosphorus (43%). The tributaries in the West Basin contributed low percentages of nitrogen (15%) and phosphorus (18%) and almost equal amounts of water (24%) and chloride (26%).

Alkalinity, chloride, fluoride, nitrates, and turbidity were all within the State's criteria limits for predominantly fresh waters. Dissolved oxygen, total iron, certain pesticides, and zinc were occasionally outside the limits established by the State Criteria for Class IA and Class III water, while ammonia and pH were occasionally in excess for Class III waters only.

ACKNOWLEDGEMENT

We are indebted to numerous individuals and organizations whose help made this study possible. Special mention goes to:

Robert Martens, South Florida Water Management District, whose technical expertise and enthusiasm was an invaluable asset to all aspects of this study;

Dr. Benjamin F. McPherson and Henry LaRose, U.S. Geological Survey, for supplying necessary hydrologic data and for their suggestions on sampling design;

U. S. Army Corps of Engineers, Clewiston, for assistance with the automatic sampler installation and operation at S-77;

Ben Pratt and Fred Lescher, Lee County Division of Transportation, for their assistance in the installation of an automatic sampler in Alva;

Wayne Johnston and personnel of the Lee County Public Utilities Water Treatment Plant for assistance in sample collection, equipment needs, and design suggestions; and

The technical support from numerous field and laboratory technicians at the South Florida Water Management District.

PART I

INTRODUCTION

Recent population growth in southwest Florida has progressed more rapidly than the average for other areas of the state. Well over half of the total population in the Lower West Coast Planning Area is located in Lee County (65%), followed by Collier (27%), Hendry (6%), and Glades (2%) Counties, respectively (SFWMD, 1980).

As a consequence of this growth, the lower west coast is exhibiting a transition in land use. Agricultural areas in Lee County are being replaced by expanding urbanization (Brown, 1976). Native wetlands and forests in Lee and Hendry Counties are being developed for agriculture in an attempt to meet the needs of an ever-increasing population (Brown, 1976; De Bellevue, 1976).

As agriculture expands and the population increases, a system to provide for water supply and flood protection becomes necessary. The distribution of rainfall in south Florida is highly variable due to the erratic paths of thunderstorms and other precipitation events. As a result, rainfall can be substantial in some areas and deficient in others. The flat topography and predominately sandy soils overlying a relatively impervious aquitard make it necessary to remove excess water. Consequently, drainage canals have been constructed over much of the lower west coast and, in some cases, have disrupted the natural drainage features. De Bellevue (1976) reports that approximately 90% of Hendry County is drained by a system of primary canals receiving water from an estimated 886 kilometers (550 miles) of secondary canals, which in turn receive water from about 1931 kilometers (1,200 miles) of ditches.

The Caloosahatchee River is the major waterway in southwest Florida and provides a fresh water source for agricultural irrigation and municipal uses, as well as providing for drainage, flood control, navigation, and recreation.

Consequently, a thorough understanding of the Caloosahatchee River and its tributaries is important in order to effectively manage the resources.

This report contains eight parts. Part I provides general introductory material, including the purpose and scope, previous investigations, a description of the study area, the hydromechanics of the river and structures, the land use, and the rainfall conditions during the study period.

Part II describes the materials and methods used during the study and presents the location of the study area and stations sampled.

Part III contains three sections. Following an introductory section, the second section presents the general chemistry of the major inflows to the Caloosahatchee River Basin which includes discussion of S-77 and the major tributaries sampled in the East and West Caloosahatchee River Basins. This is followed by a review of the spatial and temporal water quality characteristics of the river as a complete system.

Part IV presents the results of the chlorophyll a sampling and discusses the relationships between chlorophyll a and various physical and chemical parameters. The chlorophyll a distribution is examined on a seasonal and spatial basis, and the events surrounding a major algal bloom in June 1980 are reviewed.

Part V discusses the results of an intensive water quality sampling progam in the West Caloosahatchee Basin during April-June 1978 and relates these results to the chlorophyll a characteristics.

Part VI describes the material loadings to the Caloosahatchee River system from Lake Okeechobee and the collective influence of other inputs in the East and West Caloosahatchee River Basins. Material loads from the Caloosahatchee River to the coastal estuaries are also reviewed.

Part VII reviews the river quality for all parameters for which the State of Florida has threshold criteria for State waters. This is followed by Part VIII, the summary and conclusions. A technical appendix at the end provides the reader with additional supporting materials used in the interpretation of the data collected during this three year study.

In this report, reference to winter periods was assumed to include the period between the first day of November and the last day in April. The summer period was assumed to include the time period between May 1 and October 31. These periods also coincide with the usual dry and wet seasons, respectively. The raw data is available upon request.

PREVIOUS INVESTIGATIONS

A list of the previous water quality and phytoplankton investigations in the Caloosahatchee River study area is presented in Table 1. The specific reports are listed in the bibliography. Previous investigations can be segregated into four categories according to the type of material discussed. In the first category, the Caloosahatchee River system is linked to studies which have been performed in association with Lake Okeechobee. These reports generally discuss nutrient loadings from Lake Okeechobee or the specific chemical or biological quality of waters at or near S-77.

The second category involves general surface and groundwater data associated with the Caloosahatchee River study which may influence its quality but does not necessarily discuss the actual quality of the river. This category does not include any biological studies. The third category documents general information which is limited in purpose and scope. This information generally includes mapping of chemical constituents on a statewide basis or randomly presenting select chemistry at select sites. The final category lists reports which specifically present or discuss the chemical and biological water quality of the Caloosahatchee River and its tributaries.

TABLE 1. PREVIOUS WATER QUALITY INVESTIGATIONS IN THE CALOOSAHATCHEE RIVER STUDY AREA

CATEGORY I Lake Okeechobee Outflows at S-77	II General Surface/ Ground Water Associated with the Caloosahatchee River	III Miscellaneous	IV Water Quality Specific to the Caloosahatchee River & Tributaries
Joyner, 1971	Kenner and Brown, 1956	Odum, 1953	Boggess, 1968
Joyner, 1974	Boggess, 1968	Parker, et al., 1955	Boggess, 1970
Davis and Marshall, 1975	Boggess, 1975	Kaufman, 1969	Boggess, 1972
U.S. Environmental Protection Agency, 1977	Klein, et al., 1975	Kaufman, 1969	General Development Corp., 1974
Dickson, et al., 1978	O'Donnell, 1976	Higer and Kolipinski, 1970	Boggess and Missimer, 1975
Federico, et al., 1981		Kaufman, 1970	Dye, et al., 1975
		Anderson, 1971	Environmental Sciences and Engineering, 1977
		Martin, et al., 1971	Florida Dept. of Environmental Regulation, 1979
		Freiberger, 1972	South Florida Water Mgmt. Dist., 1980
		Joyner, 1973	LaRose and McPherson, 1980
		Slack and Kaufman, 1973	South Florida Water Mgmt. Dist., 1980
		Miller, 1975	Miller, 1980
		Carriker, et al, 1976	
		Irwin and Healey, 1976	
		Slack and Goolsby, 1976	
		Goolsby, et al., 1976	
		Dysart and Goolsby, 1977	
		South Florida Water Management Dist., 1973-80	
		U.S. Dept. of the Interior, Geological Survey, 1965-77	

PURPOSE AND SCOPE

The Caloosahatchee River Study was initiated in January 1978 because of the importance of the system to the lower west coast, the general lack of water quality data specific to the Caloosahatchee River and its tributaries, and a recent recurrence of nuisance algal blooms near the Lee County Water Treatment Plant. The primary goals of this study were to develop a water quality data base for the Caloosahatchee River and its major tributaries, to generate comprehensive background and baseline data on chlorophyll a in the fresh water portion of the Caloosahatchee River, and to examine factors associated with nuisance algal blooms. These data would also be useful in the development of a water use plan for the lower west coast of Florida.

The specific objectives were:

(1) To determine the quantitative and qualitative relationships between Lake Okeechobee and the Caloosahatchee River.

(2) To determine the water quality characteristics in each of the two main river basins.

(3) To determine the relative impacts of selected tributaries within each of the two main reaches of the river,

(4) To document the seasonal and spatial trends in the distribution of chlorophyll a in the Caloosahatchee River, and

(5) To identify the chemical and biological water quality conditions associated with the recurrent algal blooms upstream of the W. P. Franklin Lock and Dam (S-79) during potential bloom periods (April - July).

This report culminates a series of interim reports by the South Florida Water Management District on the water quality and chlorophyll a concentrations in the Caloosahatchee River. Preliminary data has been presented earlier in a technical memorandum entitled, Water Quality Aspects of the Caloosahatchee River System Phase II 1978-1979.

DESCRIPTION AND HYDROLOGY OF THE CALOOSAHATCHEE RIVER STUDY AREA

The function of Lake Okeechobee in the water management of south Florida is as a balancing reservoir, receiving runoff from the north, northwest, and south, and within the limits of safe storage capacity, retaining a portion of the runoff to meet water supply demands. The stage of Lake Okeechobee is controlled to provide flood protection and water supplies for the surrounding drainage basins. The same canal network and water control system which regulates water releases from Lake Okeechobee to control lake stage also serves for both irrigation and drainage of adjacent lands. Outflow from Lake Okeechobee is controlled, in part, by the St. Lucie and Caloosahatchee Canals which discharge to the Atlantic and Gulf coasts, respectively.

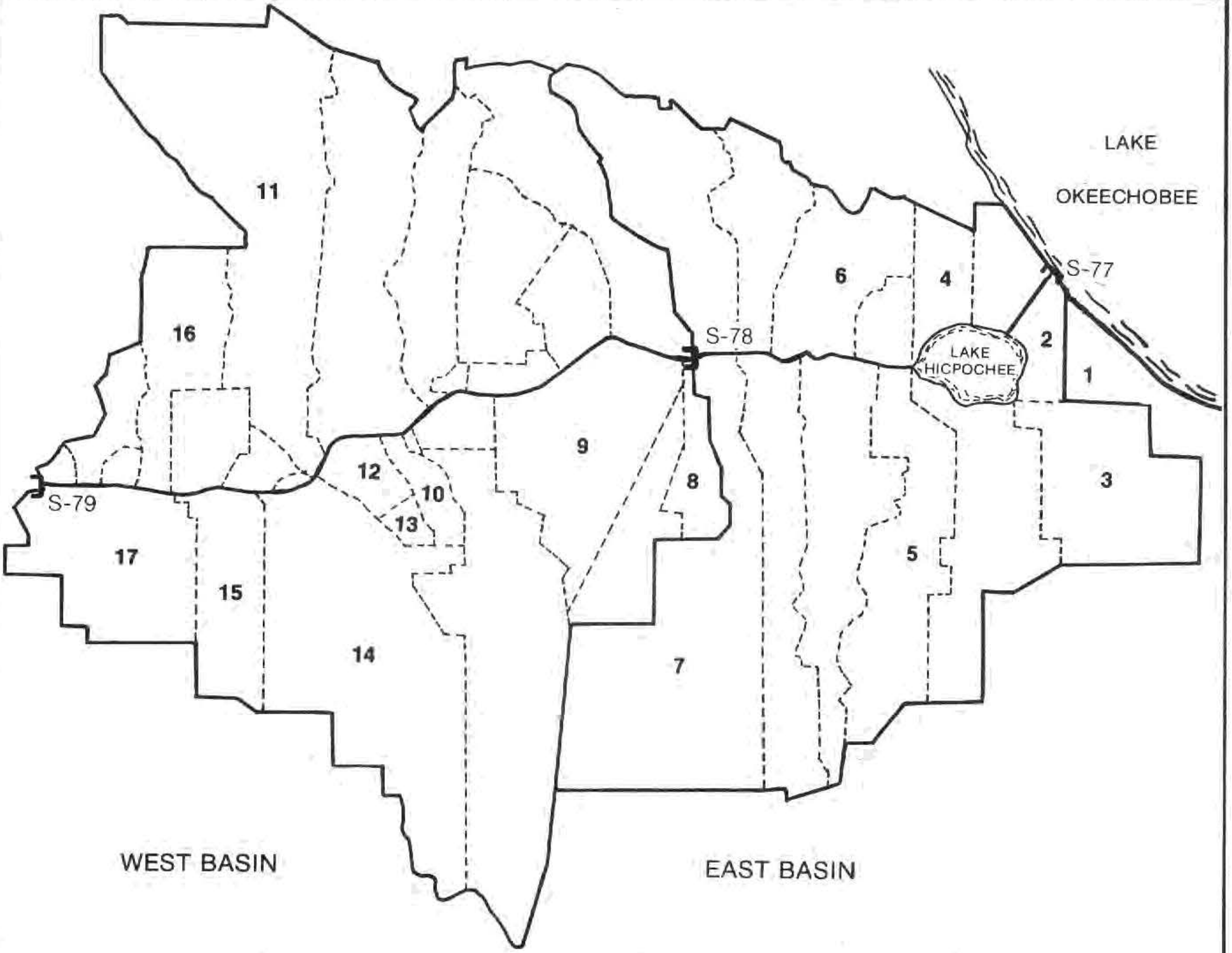
The Caloosahatchee River was originally a relatively shallow, meandering river with its headwaters in the vicinity of Lake Hicpochee. Improvement efforts by Hamilton Disston in the 1880's included "channelization" of the river from Fort Myers to Lake Okeechobee for navigation and water control. By 1918 three lock and spillway structures were constructed between Moore Haven and Fort Thompson. The Rivers and Harbors Act of 1930 authorized further improvements of the Caloosahatchee River, and by 1937 the river had a navigable channel about 2 meters deep and 24 meters wide. The plan of improvement authorized under the Central and Southern Florida Flood Control Project required channel enlargement and construction of the Franklin Locks at Olga. This construction was undertaken from 1962-1968.

Presently, the Caloosahatchee River (designated C-43), is an improved canal which has been straightened and channelized throughout most of its 104.6 km (65 mile length) and ranges from 50 to 130 meters wide and 6 to 9 meters deep. Many of the bends found in the natural setting remain as oxbows along both sides of the canal in the western basin.

The Caloosahatchee River originates at Moore Haven on the southwest shore of Lake Okeechobee. Water from Lake Okeechobee is released through a combination spillway (S-77) and navigation lock (HGS No. 1) and flows southwest about 10 kilometers (6 miles) through a nearly level overflow basin, Lake Hicpochee. The river continues westerly to Ortona, approximately 24 kilometers (15 miles) from Moore Haven, where a second lock and spillway (S-78) aids in the control of water levels on adjacent lands upstream. Water levels and salinities control in the remaining 42 kilometer (26 mile) reach of the Caloosahatchee River are controlled by the W. P. Franklin Lock and Dam (S-79). The size and capacity of C-43 and the water control structures were designed to provide for a number of functions including local drainage and flood control, salinity control, irrigation and municipal water supply, navigation, and maintenance of Lake Okeechobee's regulation schedule.

The drainage influence of the Caloosahatchee River extends, on an average, about 24 kilometers (15 miles) on either side of the river (U. S. Army Corps of Engineers, 1963). Ortona Lock (S-78) separates the Caloosahatchee River study area into two distinct hydrologic boundaries. The upper pool, or East Caloosahatchee Basin, has a drainage area of about 875 km^2 (216,133 acres) while the lower pool, or West Caloosahatchee Basin, drains approximately 1287 km^2 (318,253 acres) of land (Isern and Brown, 1980). The hydrologic boundaries and tributary drainage basins are shown in Figure 1, which also lists the sampled tributary drainage basins and their respective drainage areas. Water levels upstream and downstream of S-78 are maintained at approximately 3.5 meters msl and 1.0 meters msl, respectively.

Tributary drainage in the East Basin is more complex than the drainage in the West Basin, differing mainly with regard to adjacent land usage and water



Tributary Name/Code	Drainage Area (Acres)	% of Total by County
ECB:		
1. S-235 (Open;Closed)	(16,000.0)	(100% Glades:outside basin)
2. Diston Island Canal/CR-03.2T	3,328	100% Glades
3. Whidden Corner Canal/CR-04.3T	19,994	3% Glades, 97% Hendry
4. C-19 at S-47D/CR-06.8T	11,008	100% Glades
5. Grassey Marsh East Canal/CR-06.8T	19,206	5% Glades, 95% Hendry
6. Meanderline Ditch/Cr-08.9T	14,637	100% Glades
7. Long Hammock Canal/CR-14.0T	48,096	6% Glades, 94% Hendry
WCB:		
8. Goodno Canal No. 2/CR-14.9T	5,895	11% Glades, 89% Hendry
9. Okaloacoochee Branch/CR-22.0T	20,781	26% Glades, 74% Hendry
10. Crawford Canal/CR-26.2T	1,811	100% Hendry
11. Jack's Branch/CR-30.3T	44,428	50% Charlotte, 43% Glades, 7% Hendry
12. Banana Branch of Roberts Canal/CR-30.4T	29,338	10% Collier, 90% Hendry
13. Ft. Simmons Branch	Data not currently available	Data not currently available
14. Townsend Canal/CR-33.5T	43,930	100% Hendry
15. Bedman Creek/CR-36.2T	13,331	18% Hendry, 82% Lee
16. Cypress Creek/CR-38.2T	11,968	68% Lee, 32% Charlotte
17. Hickey Creek/CR-39.6T	Data not currently available	Data not currently available

Based on unpublished records - South Florida Water Management District, Resource Planning Department, Water Resources Division

Figure 1 TRIBUTARY DRAINAGE BASINS OF THE EAST AND WEST CALOOSAHATCHEE BASINS control. Most of the canals in and around the periphery of Lake Hicpochee drain agricultural lands. There are five major canals east and south of Lake Hicpochee: Diston Island Canal, Nine Mile Canal, Whidden Corner Canal, Lake Hicpochee Canal, and Grassey Marsh East Canal. Of the five, Grassey Marsh East Canal is the only one which drains to the Caloosahatchee River directly. The Diston Island Canal drains lands east of Lake Hicpochee to the Caloosahatchee River by pumping water either to the Lake Hicpochee perimeter canal or to the canal draining through S-235. The Nine Mile Canal gravity drains to a minor canal below the pump and spillway structure located on the Whidden Corner Canal, ultimately draining to Lake Hicpochee. The Whidden Corner Canal and the Lake Hicpochee Canal drain lands in Hendry County between the river and S.R. 80 by pumping the water south then west to the Caloosahatchee River by way of the Grassey Marsh East Canal. Alternately, the drainage of lands between Lake Hicpochee and S.R. 80 may occur as gravity drainage toward Lake Hicpochee through the Whidden Corner and Lake Hicpochee Canals. All of the West Basin canals drain directly into C-43.

Generally, most of the tributaries adjoining the Caloosahatchee River exhibit increased flow toward the river during the summer. During the winter, some canals withdraw water from the Caloosahatchee River for irrigation purposes.

Figure 2 displays the daily discharge at S-77 from 1973 to 1980, inclusive. Discharges through S-77 are usually made when the stage of Lake Okeechobee exceeds the regulation limits (regulatory releases) or supplemental fresh water is needed in the downstream pools (water supply or pool stage maintenance releases). Historically, water releases were relatively predictable and followed a seasonal pattern. Pool stage maintenance releases (less than 2,000 acre-feet/day) occurred during the winter to supply water for local irrigation needs within each basin. As long as Lake Okeechobee was below regulation

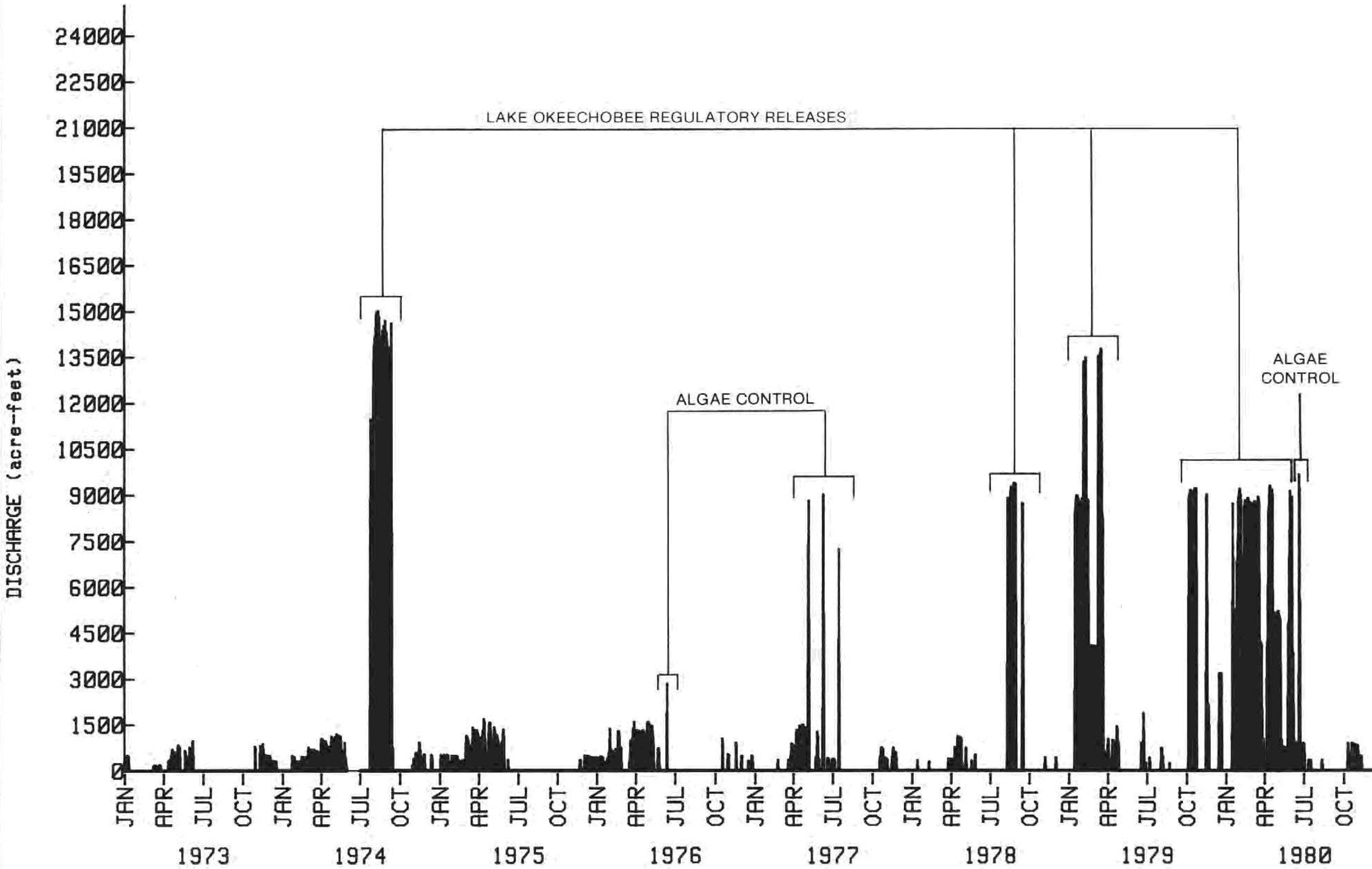


Figure 2 DAILY DISCHARGE AT S-77

schedule, releases usually did not occur during the summer as rainfall was sufficient to satisfy local demands. Occasionally, as in 1974, regulatory releases (greater than 2,000 acre-feet/day) were made during the summer (July and August) to lower the stage of Lake Okeechobee to within the regulation limits. Major water releases also occurred (June 1976 and May, June, and July 1977) to flush massive algal blooms from the river that had accumulated adjacent to the Lee County Water Treatment Plant.

The pattern of discharge activity at S-77 during this study period was atypical. Water releases at S-77 in 1978 were minimal. During the first water release period (March-April), approximately 18,000 acre-feet of water (averaging 534 acre-feet/day) were released to maintian downstream pool stages in the East and West Basins. The second water release period in August was regulatory and totaled approximately 180,000 acre-feet of water (averaging 5,800 acre-feet/day). During the remainder of the year, S-77 exhibited intermittent releases lasting only a few days at a time. Lake Okeechobee was effectively isolated from the Caloosahatchee River during 1978. Discharges through S-77 occurred on only 76 days during the year.

In 1979 and 1980, unusual winter regulatory releases were made from S-77 between January and May, a "trend" unprecedented since 1973. Water releases in 1979 and 1980 at S-77 were not only more frequent but were also of greater magnitude and longer duration than in 1978. The 1979 winter regulatory release between January 11 and March 19 averaged approximately 8,000 acre-feet/day. From March 21 to April 25 an average of 589 acre-feet/day of water was released to maintain downstream pool stages. Regulatory releases were also necessary during October, November, and December of 1979 and lasted about one week during each month.

During the winter of 1980, specifically the period between January 14 and March 24, regulatory releases at S-77 averaged approximately 7,000 acre-feet/day.

Although the average daily discharges during this period were less than the same period in 1979, regulatory discharges in 1980 continued intermittently for an additional three months. However the total regulatory discharge for the first six months of 1980 (454,931 acre-feet) was less than the total regulatory discharge for the first three months of 1979 (511,305 acre-feet). An algal bloom control release also occurred in mid-June 1980. This was the first time such a bloom had occurred since 1977.

Regulatory releases at S-77 are accompanied by similar magnitude discharges at S-78 and S-79 to transport the excess water to tidewater. Since another primary function of S-78 and S-79 is to regulate local drainage within the basins and maintain an optimum stage level in C-43, they can also operate independently of S-77. Figures 2, 3, and 4, and Table 2, contrast the duration and volume of discharge at the three structures for the 1978-1980 study period.

Generally, water releases through S-78 and S-79 were almost continuous during the study period while discharges at S-77 were comparatively less frequent. The annual discharge for the entire study period was greater than the historic average between 1966 and 1977. Historically, water releases at all the structures were greatest during the summer. During this study, however, discharges at each structure demonstrated a dramatic winter increase.

Discharge records at S-78 and S-79 also provide an estimate of the water residence times within each section of the canal. The volume of the eastern pool, from S-77 to S-78, was calculated to be about 9400 acre-feet (4.09×10^8 ft^3). The volume of the western pool, from S-78 to S-79, was calculated to be about 29,000 acre-feet (1.26×10^9 ft^3). Theoretically, a daily discharge at S-78 of 9,400 acre-feet, equal to the volume of the east pool, would indicate a complete exchange of water in 24 hours and have a residence time of about one day.

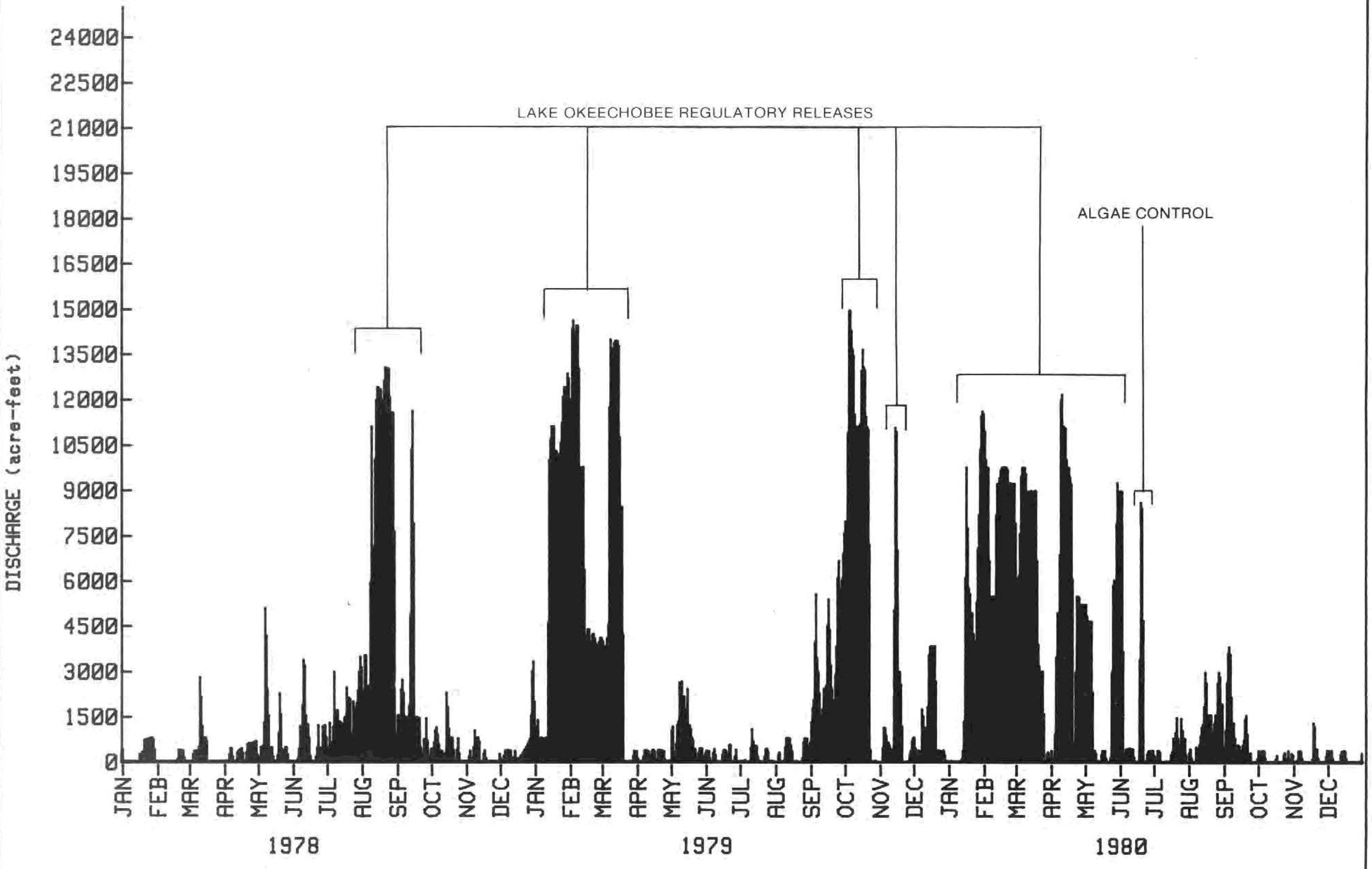


Figure 3 DAILY DISCHARGE AT S-78

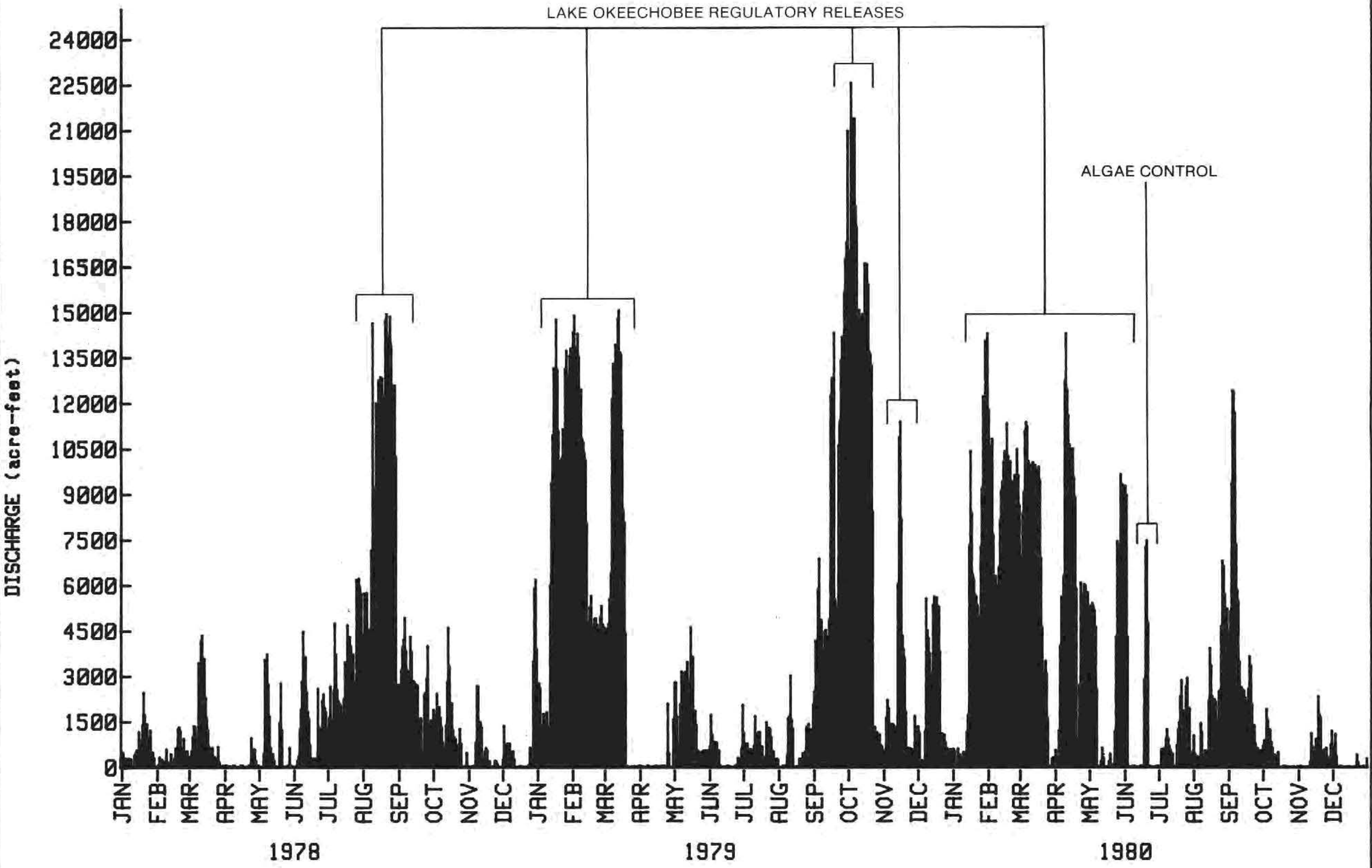


Figure 4 DAILY DISCHARGE AT S-79

TABLE 2. MONTHLY DISCHARGE COMPARISON ON THE CALOOSAHATCHEE RIVER BETWEEN THE HISTORIC AVERAGE AND STUDY PERIOD AVERAGE.

Discharge in Acre-Feet

	S77			S78			S79		
	Historic 1/	Study Period 2/	% of Historic	Historic	Study Period	% of Historic	Historic	Study Period	% of Historic
January	32,035	91,626	286	35,542	120,353	339	47,327	141,480	299
February	23,102	144,086	624	25,992	156,280	601	35,883	168,483	470
March	48,605	117,147	241	60,044	122,207	204	86,973	138,503	159
April	80,439	64,337	79	77,203	67,183	87	79,080	68,293	86
May	35,550	33,629	94	41,094	50,007	122	45,006	61,517	137
June	49,898	23,706	48	97,019	24,537	25	41,963	29,770	70
July	57,870	1,366	2	118,947	23,060	19	183,983	51,643	28
August	87,684	61,547	70	147,176	103,520	70	183,089	133,890	73
September	15,393	8,562	56	55,071	68,213	124	113,189	149,393	132
October	32,988	63,902	194	55,365	93,107	168	93,996	138,503	147
November	35,305	13,757	39	39,943	21,930	55	51,095	33,737	66
December	25,052	9,191	37	23,378	20,243	87	32,108	34,290	107
Annual Total	523,921	632,856	121	776,774	870,640	112	993,692	1,486,469	150
Dry Season Total	244,538	440,144	180	262,102	508,196	194	332,466	921,753	277
Wet Season Total	279,383	192,712	69	514,672	362,444	70	661,226	564,716	85

1/ Historic average data from USGS Water Resources Data 1966-1977 (Published)

2/ Study period average data from USGS Water Resources Data, 1978-1980 (Published)

RAINFALL

Rainfall in the Caloosahatchee River study area was computed from the U.S. Department of Commerce's Climatological Data (1960-1980) and the U.S. Army Corps of Engineers' data logs (1978-1980). The average monthly data and seasonal totals are presented in Table 3. This table shows that the total annual rainfall during the study period was slightly less than the historic average, except at S-78. The winter rainfall was greater than the historic average and the summer rainfall was less.

GENERAL SOIL CHARACTERISTICS AND LAND USE

Soils in the Caloosahatchee River drainage area of Glades, Hendry, and Lee Counties are predominantly level, poorly drained sandy soils (Florida Dept. of Administration, 1975). The area between Lake Okeechobee and Lake Hicpochee, however, consists of well decomposed organic soils 41-91 cm thick, over sand.

Table 4 describes the level I and selected level II land use/cover patterns in the Caloosahatchee River study area. Pasture is the dominant land use in both basins, representing 51% of the East Basin area and 48% of the West Basin area. Wetlands occupy a substantial portion of the East Basin (35%) whereas forested uplands (20%), wetlands (11%), orchards and groves (9%), and urban areas (6%), are important land uses in the West Basin.

TABLE 3. AVERAGE MONTHLY RAINFALL IN THE CALOOSAHATCHEE RIVER STUDY AREA

Rainfall in Inches

	Historic	S-77 Study Period	% of Historic	Historic	S-77 Study Period	% of Historic	Historic	S-77 Study Period	% of Historic
January	1.75	3.56	203	1.53	3.18	208	2.44	4.41	181
February	2.06	0.91	44	1.94	0.90	46	1.65	1.84	112
March	2.88	2.47	86	2.61	1.98	76	3.56	2.63	74
April	2.67	2.73	102	2.20	2.36	107	1.05	1.78	169
May	4.43	5.87	132	3.88	5.32	137	4.17	4.51	108
June	8.65	3.34	39	7.53	4.35	58	8.27	4.66	56
July	7.16	5.98	84	6.28	8.20	130	7.87	4.94	63
August	6.57	5.32	81	6.40	6.94	108	6.00	7.97	133
September	7.49	9.93	132	6.83	6.13	90	5.15	6.48	126
October	4.48	1.92	43	3.40	2.28	67	2.89	1.20	42
November	1.14	2.05	180	1.18	2.15	182	1.57	1.89	120
December	1.53	2.32	152	1.43	2.75	192	2.02	2.51	124
Total	50.22	46.40	92	45.14	46.54	103	46.64	44.82	96
Summer	38.18	32.36	85	34.32	33.22	97	34.35	29.76	87
Winter	12.04	14.04	117	10.82	13.32	123	12.29	15.06	122

TABLE 4. LAND USE/COVER PATTERNS IN THE CALOOSAHATCHEE RIVER STUDY AREA*

	East Caloosahatchee Basin Area		West Caloosahatchee Basin Area	
	Acres	Percent	Acres	Percent
I. Urban & Built-up Land				
Residential	692	(<1)	4,401	(1)
Open and Others	643	(<1)	14,482	(5)
Total Urban	1,530	(1)	18,993	(6)
II. Agriculture				
Cropland	4,299	(2)	2,315	(1)
Pasture	110,882	(51)	151,508	(48)
Orchards, Groves, etc.	848	(<1)	29,119	(9)
Total Agriculture	116,029	(54)	182,952	(57)
III. Rangeland				
Grassland	194	(<1)	3,288	(1)
Scrub & Bushland	6,020	(3)	9,614	(3)
Total Rangeland	6,214	(3)	12,902	(4)
IV. Forested Uplands	14,078	(6)	64,898	(20)
V. Wetlands	76,451	(35)	35,299	(11)
VI. Water	1,177	(<1)	1,572	(<1)
VII. Barren Land	654	(<1)	1,637	(<1)
Total Area	216,133		318,253	

* Abridgement of Isern and Brown, 1980

PART II

MATERIALS AND METHODS

SAMPLING LOCATIONS AND FREQUENCY

Water Chemistry: Thirty-three stations (17 tributary sites and 16 mainstream sites) were routinely sampled in the Caloosahatchee River study area. Their codes and corresponding site descriptions are presented in Table 5 and their locations are shown in Figure 5.

Station identification numbers include a two-letter prefix representing the study area (CR) and a three-digit number corresponding to the mileage from a point of orientation located at the center of the Lake Okeechobee Rim Canal (adjacent to S-77 spillway in Moore Haven). The suffix (T) in the identification code refers to a tributary station. The mileage indication for the tributary stations refers to that point where the Caloosahatchee River and the tributary intersect.

Routine water samples were collected monthly from the river and tributary stations and biweekly downstream of S-77 between January 1979 and December 1980. In addition to the bimonthly sampling at S-77, an automatic sampler was installed upstream of S-77 in January 1979 to collect weekly time composite samples during discharge events.

The sampling frequency for all stations (except at S-77) increased to bimonthly during the potential algal bloom period between April and July in 1978 and 1979. In addition to the bimonthly sampling during this intensive study period, daily samples were collected at two stations in 1978; daily time composite samples were collected at station CR-36.0 (Alva Bridge) with an automatic sampler; and daily grab samples were collected at station CR-40.3 by personnel of the Lee County Public Utilities Water Treatment Plant. All automatic sampling for the intensive period was discontinued after 1978 and all bimonthly sampling was discontinued after 1979.

Table 5 CALOOSAHATCHEE RIVER SAMPLE LOCATIONS

A. RIVER STATION LOCATIONS:

*1. CR-00.1, at S-77-upstream (automatic sampler)

2. CR-03.0, C-43 3 miles west of Moore Haven Lock (S-77)

*3. CR-04.5, C-43 4.5 miles west of Moore Haven Lock (S-77)

4. CR-06.0, C-43 6 miles west of Moore Haven Lock (S-77)

*5. CR-09.0, C-43 9 miles west of Moore Haven Lock (S-77)

6. CR-11.0, C-43 11 miles west of Moore Haven Lock (S-77)

EAST BASIN *7. CR-13.5, C-43 2.3 miles east of Ortona Lock (S-78)

WEST BASIN 8. CR-16.0, C-43 1.2 miles west of Ortona Lock (S-78)

*9. CR-19.0, C-43 4.2 miles west of Ortona Lock (S-78)

10. CR-22.5, C-43 1.0 miles east of LaBelle Bridge (SR-29)

11. CR-26.0, C-43 2.5 miles west of LaBelle Bridge (SR-29)

12. CR-30.4, C-43 1.6 miles west of Ft. Denaud Bridge (C-78A)

13. CR-32.0, C-43 3.6 miles west of Ft. Denaud Bridge (C-78A)

14. CR-36.0, C-43 5.0 miles east of Franklin Lock (S-79) ADJACENT TO ALVA BRIDGE

15. CR-37.0, C-43 4.0 miles east of Franklin Lock (S-79)

16. CR-39.0, C-43 2.0 miles east of Franklin Lock (S-79)

17. CR-40.3, C-43 at Franklin Lock adjacent to Olga surface water intake at water plant.

B. TRIBUTARY STATION LOCATIONS:

**1. CR-00.2T, S-235

*2. CR-03.2T, Diston Island Canal at Diston Island, Hicpochee Pump

*3. CR-04.3T, Whidden Corner Canal (C-5) at S.R. 80

*4. CR-04.8T, C-19 at S-47D

**5. CR-06.8T, Grassey Marsh East Canal

*6. CR-08.9T, Meander line Ditch at S.R. 78

EAST BASIN *7. CR-14.0T, Long Hammock Canal at S.R. 89

WEST BASIN *8. CR-14.9T, Goodno Canal No. 2 at S.R. 89 near Ortona

9. CR-22.0T, Okaloacoochee Branch at S.R. 80 near Port LaBelle

10. CR-26.2T, Crawford Canal at S.R. 80

11. CR-30.3T, Jack Branch at Norris Road

12. CR-30.4T, Banana Branch of Robert's Canal at S-78A

13. CR-31.0T, Ft. Simmon's Branch at S-78A

14. CR-33.5T, Townsend Canal at S.R. 80

15. CR-36.2T, Bedman's Creek at S.R. 80

16. CR-38.2T, Cypress Creek at S.R. 80

17. CR-39.6T, Hickey's Creek at S.R. 78

*Stations added during 1979
**Stations added during 1980

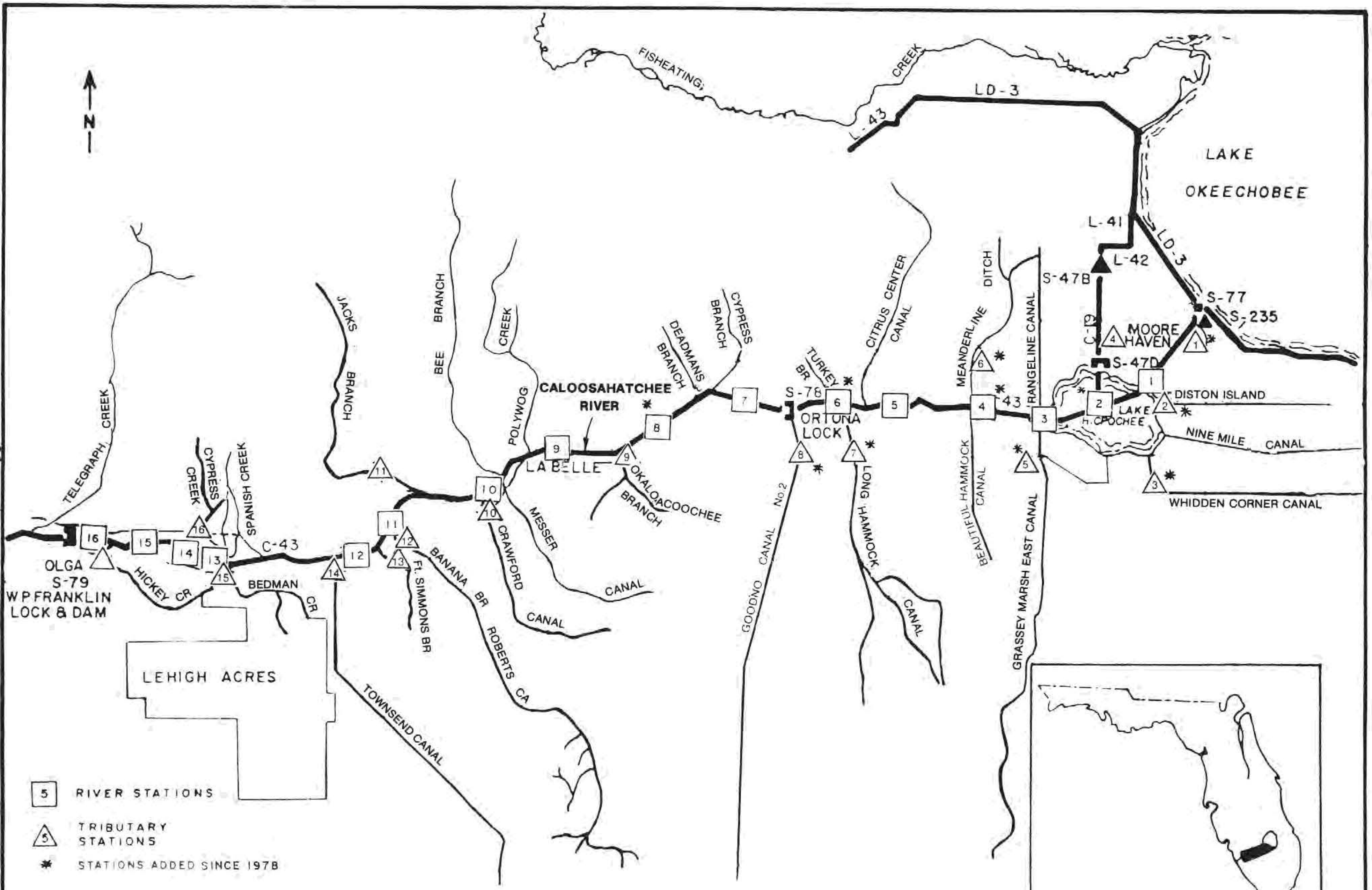


Figure 5 CALOOSAHATCHEE RIVER STUDY AREA

Chlorophyll a: Field sampling for chlorophyll *a* analyses was conducted concurrent with the water quality sampling program and at those river stations depicted in Figure 5. In 1979, one additional station was added just upstream of S-77. Routine sampling was conducted at monthly intervals from January 1978 to December 1980. The sampling frequency was increased to biweekly for the intensive study period, April - June 1978 and April - July 1979. These biweekly samples were also collected concurrent with water quality samples. Additional sampling trips for chlorophyll *a* collection were made at the investigator's discretion during the critical months of April - June.

SAMPLING PROCEDURES AND ANALYTICAL METHODS

Water Chemistry: Field depth profile measurements for dissolved oxygen, temperature, specific conductance, and pH were routinely measured at two meter intervals at each river station and one meter intervals at each tributary site with a Hydrolab (R) System 8000. River and tributary grab samples were both collected in a polyethylene bucket at approximately mid-channel, either by boat or from a bridge.

In anticipation of vertical differences in the water quality, separate water samples were collected in 1978 from the surface in a polyethylene bucket and from one meter above the bottom with a 5 liter PVC Niskin type sampler. A two-tailed, paired t test revealed that surface and bottom values for total nitrogen, total phosphorus, and chloride were not significantly different at the 0.005 level of significance for all stations in 1978. Ammonia, however, was significantly different at the 0.005 level of significance. Nevertheless, discrete sampling was replaced with composite sampling in 1979 and 1980.

In order to test the validity of compositing samples as a routine method for collection, quality checks were performed at three stations during 1979. These tests included the collection and analysis of a composite sample, a discrete surface and bottom sample, and then computing a relative percent difference. The results are presented in Appendix A. Generally, composite sampling resulted in representative quality information.

Unfiltered aliquots of water were collected for total nutrient analysis. Samples for the analysis of dissolved constituents were filtered at the time of collection through a 0.45 micron Nuclepore (R) membrane filter. All water samples were stored on ice in the dark in polyethylene bottles until returned to the laboratory, at which time they were transferred to a refrigerator and held at 4°C for subsequent analysis (usually within one to two weeks). The routine chemical determinations performed on each sample are listed in Table 6.

In conjunction with the intensive study, daily water samples were collected approximately one meter below the surface with an ISCO Automatic Sampler Model 1392 and composited in a refrigerated polyethylene bottle. The automatic sampler was adjusted to provide for maximum sample collection. The sample was retrieved weekly, filtered, and returned to the laboratory for subsequent analysis. The routine chemical determinations performed on each composite sample are listed in Table 7A. The laboratory methods used for all sample analyses were either recommended or approved by the Environmental Protection Agency or the American Public Health Association (Appendix B).

Chlorophyll *a*: During 1978, water samples for chlorophyll *a* analysis were collected at each station from the surface, mid-depth, and one meter above the bottom (vertical profile) on routine and biweekly intensive period trips. Triplicate samples were taken at two stations each month. During the special additional sampling trips, water samples were obtained from the surface only.

In 1979 and 1980 vertical profiles were obtained, in triplicate, from two stations each month. Otherwise, chlorophyll *a* samples were taken from the surface at each sample station.

TABLE 6. GENERAL FIELD AND LAB WATER QUALITY DETERMINATIONS* 1978-1980

I. River Sites and Tributary Sites

A. Routine Monthly and Bimonthly Determinations

1. Field Measurements (2 meter profile/River, 1 meter profile/ Tributary)

a. Physical Parameters - temperature, specific conductance, dissolved oxygen, pH, depth, (Secchi Disc - River only)

2. Lab Measurements (Composite/River, Surface/ Tributary)

a. Physical Parmeters

(1) Turbidity, Color (all Tributaries plus River stations CR-03.0, CR-22.5, CR-40.3)

(2) Total Suspended Solids (River Stations CR-03.0, CR-22.5, CR-40.3 only)

b. Nutrients - NO_X^-, NO_2^-, TKN, NH_4^+, TPO_4, OPO_4^{3-}

c. Major and Minor Constituents

(1) Alkalinity (River Stations CR-03.0, CR-22.5, CR-40.3)

(2) Cl^-

d. Metals

(1) Total Fe

(2) Ca^{2+}, Mg^{2+}, Na^+, K^+ (River Stations CR-03.0, CR-22.5, CR-40.3)

e. Other - F^-

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*This table does not reflect all the variables sampled during this course of the study. Many were dropped after the first year and still others were dropped only at certain stations. This inforamtion generally reflects the final program design for 1980.

TABLE 7a. COMPOSITE SAMPLE WATER QUALITY DETERMINATIONS, 1978-1980.

II. River Sites - Composite Sample (CR-00.1, CR-36.0) and Grab Sample (CR-40.3)

A. Daily and Weekly Determinations

1. Field Measurements (none)

2. Lab Measurements

a. Physical Parameters

(1) Lab Specific Conductance

b. Nutrients - NO_X^-, NO_2^-, TKN, NH_4^+, TPO_4, $TdPO_4$, OPO_4^{3-}

c. Major and Minor Constituents

(1) Cl^-

d. Metals - (none)

e. Other - (none)

TABLE 7 b. SEDIMENT SAMPLE QUALITY DETERMINATIONS, 1978-1980

III. Select River Sites (Appendix C)

A. Annual Determinations

1. Field Measurements - (none)

2. Lab Measurements

a. Physical parameters - pH, texture, organic matter, carbonates

b. Nutrients - TKN, total elemental P

c. Major and Minor Constituents - none

d. Metals - K^+, Ca^{2+}, Mg^{2+}, Total Fe

e. Other - none

Raw water samples for chlorophyll a analysis were taken from just beneath the water surface (about 15-20 cm) with a one liter polyethylene bottle. Water samples from deeper in the water column were collected with a Niskin sampler and transferred immediately into polyethylene bottles. Samples were tagged, stored on ice in the dark, and returned to the lab within two days for subsequent analyses.

Chlorophyll a concentrations were determined by the trichromatic method (Strickland and Parsons, 1968). About 800 - 1000 ml of water were filtered through a 0.45 micron pore size Gelman (R) glass fiber filter. A few drops of saturated magnesium carbonate solution were added to the filters which were then frozen for up to two weeks. The filters were then ground with a tissue grinder for 1 - 2 minutes in a 90% acetone: 10% magnesium carbonate solution. The resulting solution was refrigerated for 18-24 hours to further insure pigment extraction by the acetone, centrifuged at 3000 rpm for 20-30 minutes, and analyzed in a spectrophotometer against a 90% acetone: 10% magnesium carbonate blank.

Results are reported as mg chlorophyll a/m^3 of river water. In instances where duplicate or triplicate samples were collected, the mean value is reported in this text. Furthermore, East Basin or West Basin values represent the average of all surface samples collected within that basin on a given sample trip.

Basin to basin differences were considered significant at $\alpha = .95$, using a one-tailed t test. Simple linear regression analyses used mean basin values for the parameters tested during routine monthly sample periods.

Sediment and Pesticides: Sediment samples were collected annually at each river station with a Ponar dredge. In the field, the samples were placed in clean glass containers and stored on ice. In the laboratory the samples were refrigerated at 4oC. The routine chemical determinations performed on each sample are listed in Table 7B.

Water samples for pesticide scans were collected from the surface at river stations CR-0.00, CR-16.0, and CR-40.3 in October 1979. These samples were analyzed by the U. S. Geological Survey (Part VII). A second set of samples were taken at the same location in April 1981 for confirmation.

PART III

WATER QUALITY RESULTS AND DISCUSSION

INTRODUCTION

This part of the report is separated into three sections: (1) an introductory section, (2) a section on the major inflows to the Caloosahatchee River Basins, beginning with a review of the water quality at S-77 and concluding with a review of the water quality at the major tributaries in the East and West basins, and (3) a final section discussing the water quality characteristics of the Caloosahatchee River.

Review of the chemical characteristics at S-77, section two, is presented with specific attention given to the effects of discharge and season on phosphorus, nitrogen, and chloride. The data used in the evaluation of the quality discharge from Lake Okeechobee at S-77 was taken from unpublished information collected by the South Florida Water Management District's Water Chemistry Division. Discussion of the major tributaries and their effect upon the Caloosahatchee River will center on the phosphorus, nitrogen, and chloride data and will be preceded by a general overview of the quality of the waters for all the tributaries.

The third section will describe the surface water characteristics of the Caloosahatchee River. The focal point of this section will be a detailed review of nitrogen, phosphorus, and chloride. A brief discussion of other routine parameters, including pH, specific conductance, dissolved oxygen, and temperature will also be presented. This will be followed by the depth profile data collected *in situ* and a summary of findings.

CHEMISTRY OF MAJOR INFLOWS TO THE CALOOSAHATCHEE RIVER BASINS

CHEMICAL AND PHYSICAL CHARACTERISTICS AT S-77

A summary of the water quality data for S-77 is presented in Table 8 and represents the 8-year period April 1973 - December 1980. The temperature, dissolved oxygen, pH, specific conductance, color, total suspended solids, and turbidity data are presented in Figure 6 along with the corresponding discharge for each sample date.

Temperature and dissolved oxygen exhibited seasonal fluctuations. Temperature closely reflected the ambient air temperatures with high and low values measured in the summer and winter, respectively. Dissolved oxygen concentrations were generally lower from July to October and highest from January to April.

Color levels at S-77 appeared to be highest at the end of the summer and lowest at the end of the winter. The pH levels, from 1975 through 1977, appeared to be highest during the latter part of the winter and lowest during the latter part of the summer. Through the study period (1978-1980), however, this apparent trend for pH was obscured.

Table 9 compares the average concentration of select parameters at S-77 to discharge and season. Variations in pH appeared to be primarily a function of discharge rather than season. The average pH during discharge was slightly higher (7.7) than the pH during no discharge (7.5). There was no difference between seasons.

The average alkalinity at S-77 was 137 mg/L $CaCO_3$ ranging from a low of 10.5 mg/L $CaCO_3$ to a high of 433.5 mg/L $CaCO_3$ (Table 9). Alkalinity concentrations were lower during discharge than no discharge (Table 9). When discharge was occurring at S-77 there was little difference between the seasonal average

TABLE 8. SUMMARY OF SELECTED GENERAL CHEMICAL CHARACTERISTICS OF WATER AT S-77; APRIL 1973 TO DECEMBER 1980

Parameter [1/]	No. of Samples	Mean	Standard Deviation	Range Min. - Max.
pH (standard units)	187	7.6	0.5	6.2 - 8.8
Alkalinity (total as $CaCO_3$)	209	136.9	44.5	10.5 - 433.5
Specific Conductance (micromhos/cm at 25°C)	155	628	237	260 - 2700
Color (Pt units)	81	85	47	9 - 265
Temperature, water (°C)	167	25.2	4.4	14.2 - 31.5
Dissolved Oxygen	166	5.4	2.2	1.0 - 10.4
Total Suspended Solids	88	7	7	<1 - 51
Turbidity (NTU's)	105	1.7	1.5	0.5 - 15.0

[1/] Parameters in mg/L unless otherwise stated

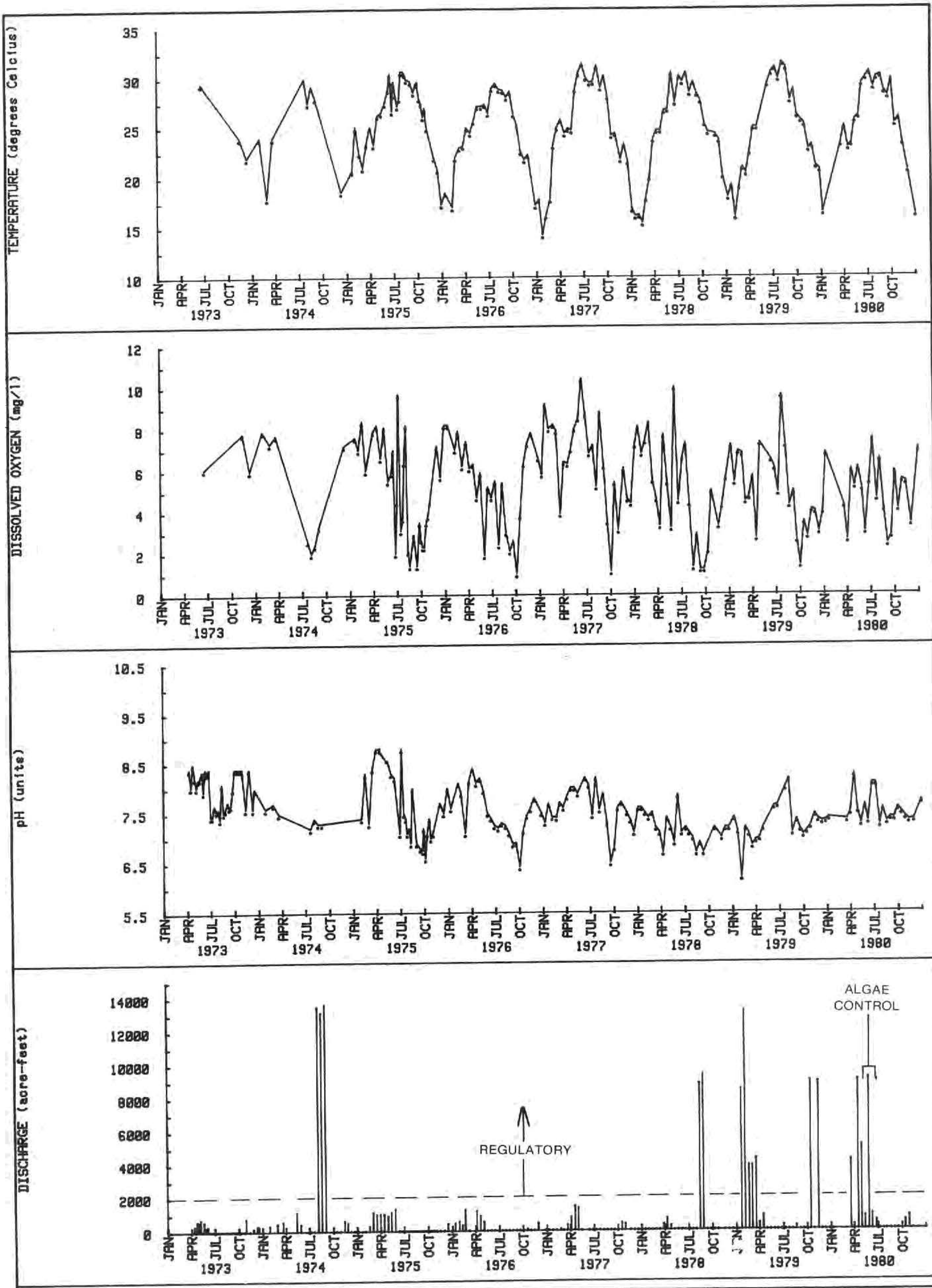


Figure 6 GENERAL CHEMISTRY OF WATER AT S-77

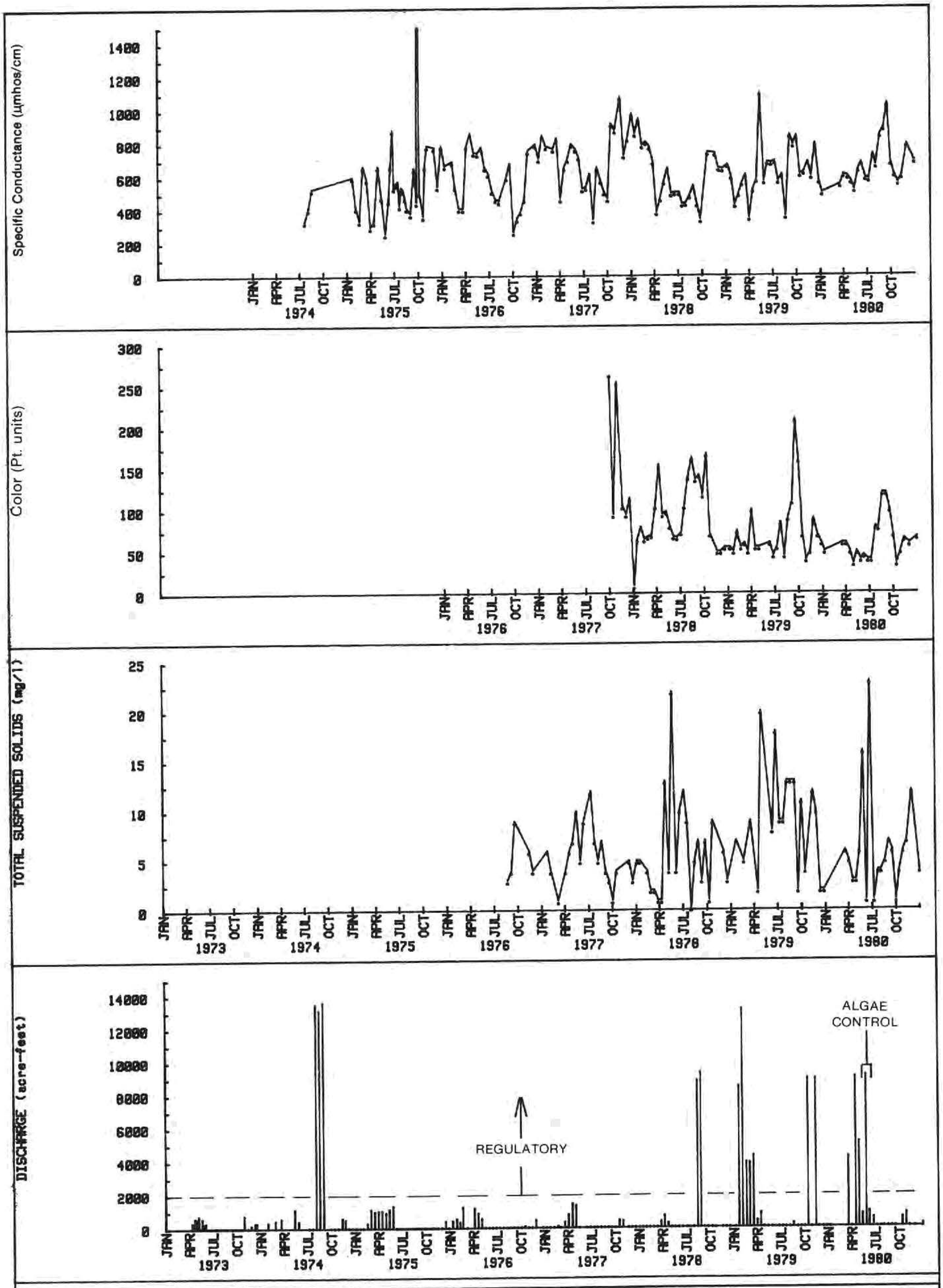
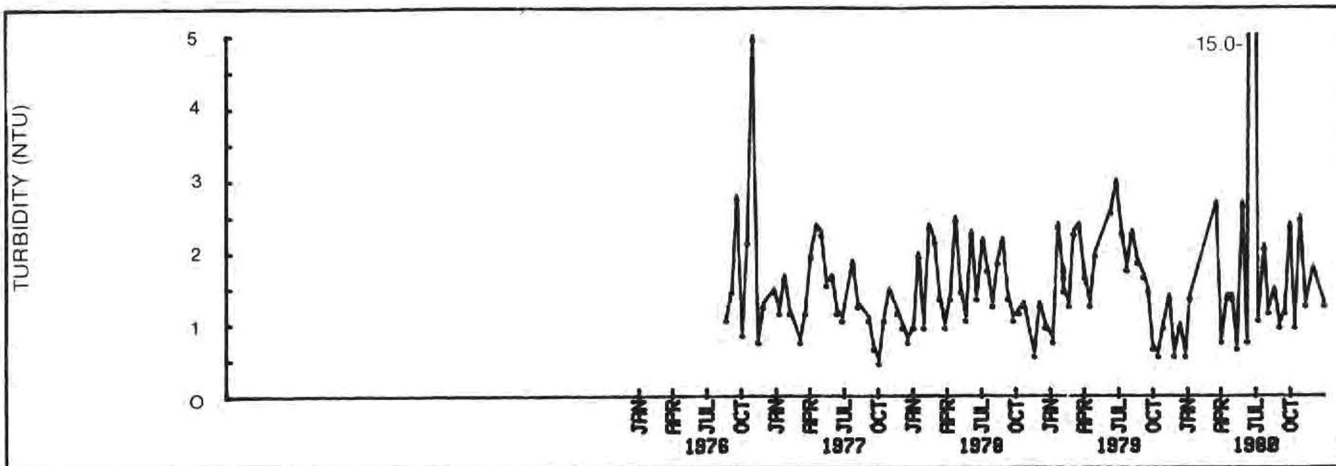


Figure 6 CONTINUED



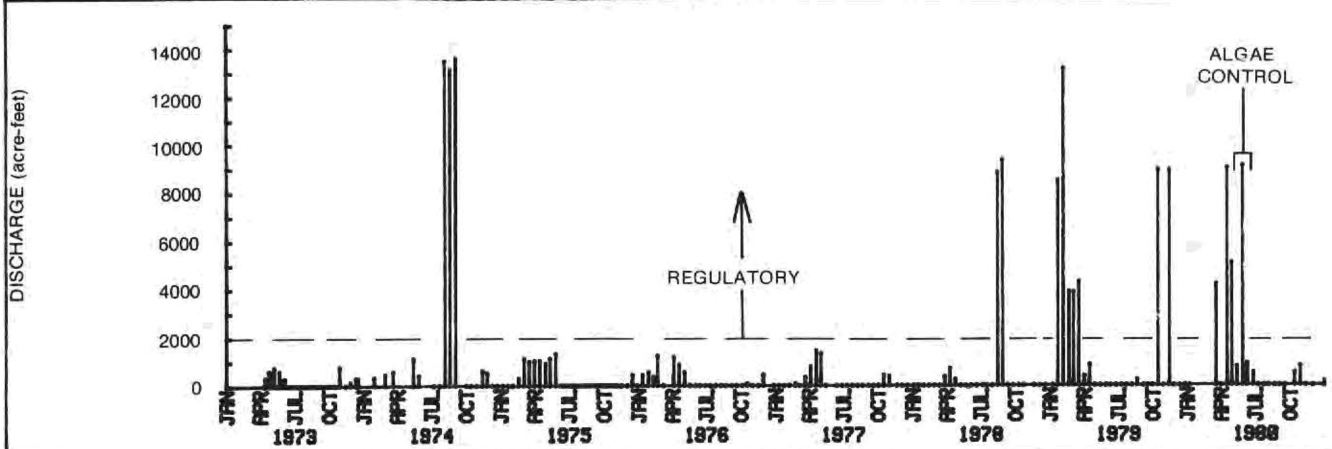


Figure 6 CONTINUED

TABLE 9. AVERAGE CONCENTRATION COMPARISON BETWEEN DISCHARGE AND SEASON OF OCCURRENCE FOR SELECT PARAMETERS AT S-77, 1973-1980

	pH units		Alkalinity mg/L $CaCO_3$		Specific Conductance micromhos/cm	
	Summer	Winter	Summer	Winter	Summer	Winter
Discharge	7.7	7.7	118	127	573	570
No discharge	7.5	7.5	130	181	633	709

	Color Pt. units		Dissolved Oxygen mg/L		Turbidity NTU	
	Summer	Winter	Summer	Winter	Summer	Winter
Discharge	89	71	4.3	6.2	2.6	1.8
No discharge	103	66	4.7	6.2	1.4	1.4

	Total Suspended Solids mg/L	
	Summer	Winter
Discharge	12	5
No Discharge	7	5

alkalinity concentrations and the average alkalinity of 125 mg/L $CaCO_3$ in Lake Okeechobee (Federico et al., 1981). When there was no discharge, the average alkalinity concentration was substantially higher in the winter (181 mg/L) than in the summer (130 mg/L).

Specific conductance at S-77 was lower during discharge than during no discharge (Table 9). During discharge events, very little difference was evident between the seasonal averages (summer: 573 micromhos/cm; winter: 570 micromhos/cm) or between the average specific conductance (589 micromhos/cm) of the limnetic waters of Lake Okeechobee (Federico et al., 1981). When S-77 was not discharging, the average specific conductance downstream of S-77 was greater in the winter than the summer and was greater than the Lake Okeechobee average.

Water color at S-77 ranged from 9 to 265 Pt units with an average of 85 Pt units (Table 8). Color levels were highest and lowest during the summer and winter, respectively, when S-77 was not discharging. This trend is typical in south Florida with maximum values coinciding with periods of active decomposition and leaching of organic materials accompanied by the flushing action of high rainfall and increased runoff (Kaufman, 1969). Discharge at S-77 tended to moderate the large seasonal differences which were measured when discharge was not occurring. However, the color of water at S-77 during discharge was still greater than the average color level of 43 Pt units noted by Federico et al. (1981) in the limnetic zone of Lake Okeechobee. The color levels measured during this study may be an indication of the levels found in the Rim Canal waters of the lake.

Dissolved oxygen was more affected by the season of occurrence than by discharge. During the summer the dissolved oxygen concentrations were relatively low with a discharge mean of 4.3 mg/L and a no discharge mean of 4.7

mg/L. During the winter the dissolved oxygen concentrations of the surface waters were more than 30% greater than the summer concentrations (Table 9). The average dissolved oxygen concentration was 6.2 mg/L during both discharge and no discharge conditions.

Turbidity and total suspended solids levels were generally very low. The highest average values of each were measured during summer discharge events. The lowest turbidity values were recorded during no discharge periods and appeared unaffected by season, while the lowest total suspended solids levels occurred during the winter and were unaffected by discharge.

Phosphorus: Figure 7 presents a summary of the phosphorus and discharge data at S-77 from 1973 to 1980. Phosphorus demonstrated a well defined seasonal pattern which was extremely sensitive to water releases. Increased phosphorus levels were routinely measured during the summer, probably as a result of local runoff downstream of S-77. During the summer, total and ortho phosphorus averaged 0.106 mg P/L and 0.062 mg P/L, respectively (Table 10). However, the duration and magnitude of the summer values were mitigated by water releases from Lake Okeechobee. With the onset of releases, reductions in the phorphorus levels occurred. The highest levels of phosphorus measured (0.44 and 0.53 mg P/L) (Figure 7) corresponded with the extreme rainfall periods in July 1974 (18.6 inches) and September 1979 (17.7 inches). Large water releases from Lake Okeechobee, which immediately followed these peak concentrations, reduced the levels of total phosphorus. The average summer concentration during discharge, downstream of S-77, was lower than the average summer concentration without discharges (0.049 and 0.056 mg/L), respectively. This pattern of lower phosphorus levels during discharge also occurred during the winter (discharge: 0.056 mg/L: no discharge: 0.118 mg/L). The levels of ortho phosphorus

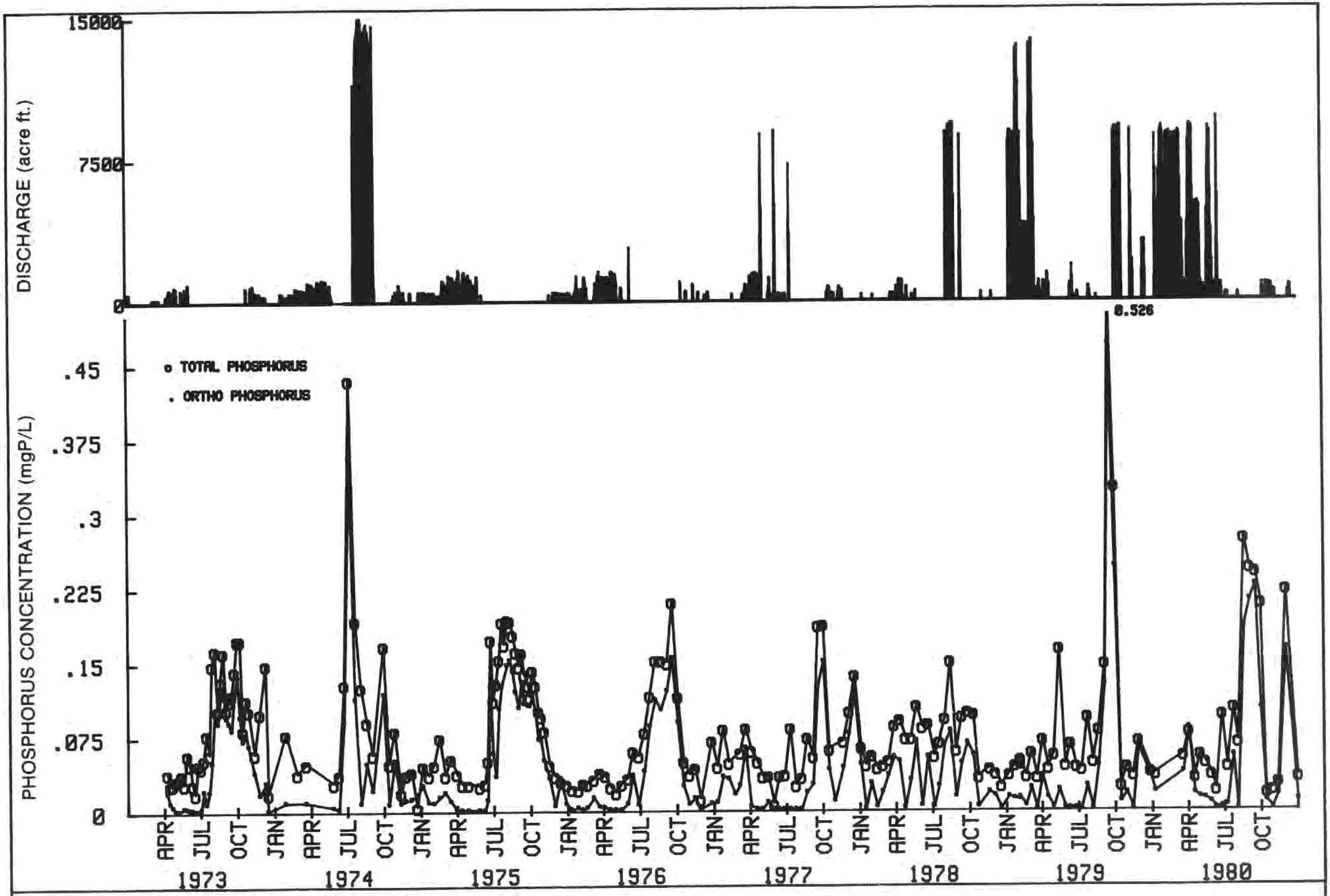


Figure 7 PHOSPHORUS CONCENTRATIONS AND DAILY DISCHARGE AT S-77

TABLE 10. PHOSPHORUS CONCENTRATIONS AT S-77; 1973-1980

	Total Phosphorus mg P/L			Ortho Phosphorus mg P/L		
	Min.	(Mean)	Max.	Min.	(Mean)	Max.
A. Annual						
1973	0.020	(0.085)	0.175	0.002	(0.046)	0.137
1974	0.006	(0.094)	0.437	0.003	(0.053)	0.358
1975	0.027	(0.099)	0.195	0.002	(0.053)	0.153
1976	0.013	(0.066)	0.212	0.002	(0.034)	0.155
1977	0.008	(0.071)	0.189	0.002	(0.033)	0.151
1978	0.026	(0.072)	0.152	0.002	(0.032)	0.080
1979	0.027	(0.088)	0.526	0.002	(0.045)	0.470
1980	0.019	(0.095)	0.275	0.002	(0.056)	0.227
B. Period of Record	0.006	(0.084)	0.526	0.002	(0.046)	0.470
Summer average		0.106			0.062	
Winter average		0.052			0.022	
Discharge average		0.052			0.015	
No discharge average		0.100			0.061	

C. Discharge and Season of Occurence:

	Total Phosphorus mg P/L		Ortho Phosphorus mg P/L	
	Summer	Winter	Summer	Winter
Discharge	0.056	0.049	0.017	0.014
No discharge	0.118	0.056	0.074	0.030

reflected the same trend. The lowest phosphorus levels, therefore, occurred during the winter when discharges were being made from Lake Okeechobee.

Nitrogen: A summary of the total and inorganic nitrogen data collected at S-77 since 1973 is presented in Table 11. Figure 8 presents a time series display of the inorganic nitrogen components. Since 1977, there was an increase in the variability of total nitrogen, as well as an increase in the average concentration, with the most pronounced changes occurring in 1979 and 1980. Prior to 1977, the average annual total nitrogen concentration was less than 1.8 mg N/L with discrete measurements ranging from 0.37 mg N/L in 1976 to 2.98 mg N/L in 1973 (Table 11). Since 1977, the average annual total nitrogen concentration has exceeded 2.0 mg N/L with discrete measurements ranging from 0.65 mg N/L to 4.86 mg N/L, (Table 11). This range of 4.2 mg N/L is almost double the range prior to 1977. The overall study period total nitrogen concentration was 1.97 mg N/L and was primarily composed of 88% organic nitrogen.

Nitrogen concentrations at S-77 appeared to be influenced both by discharge and season (Table 12). The lowest total nitrogen, total Kjeldahl nitrogen, and nitrite levels were concurrent with winter discharges while ammonia and nitrate were lowest during summer discharge conditions. The average total nitrogen, TKN, ammonia, and nitrite levels were highest during the summer when S-77 was not discharging. Nitrate was highest during the winter when discharge at S-77 was not occurring.

Chloride: Figure 9 summarizes the chloride data collected since 1973 at S-77. Chloride demonstrated a relatively pronounced seasonal pattern with lower values occurring during the summer and higher values occurring during the winter. When S-77 was not discharging, the summer chloride concentration was68.7 mg/L while the winter concentration was 95.9 mg/L (Table 13). Discharge from Lake

TABLE 11. NITROGEN CONCENTRATIONS AT S-77; 1973-1980

	Total Nitrogen mg N/L			TKN mg N/L			NH_4 mg N/L			NO_3 mg N/L			NO_2 mg N/L		
	Min.	(Mean)	Max.	Min.	(Mean)	Max.	Min.	(Mean)	Max.	Min.	(Mean)	Max.	Min.	(Mean)	Max.
A. Annual:															
1973	1.19	(1.79)	2.98	1.16	(1.67)	2.82	0.01	(0.08)	0.22	0.004	(0.092)	0.299	0.002	(0.021)	0.071
1974	0.41	(1.63)	2.54	0.18	(1.57)	2.52	0.01	(0.07)	0.33	0.004	(0.059)	0.194	0.004	(0.009)	0.032
1975	1.08	(1.75)	2.13	1.02	(1.60)	2.05	0.01	(0.10)	0.47	0.004	(0.126)	0.451	0.004	(0.020)	0.074
1976	0.37	(1.70)	2.15	0.32	(1.61)	2.07	0.01	(0.10)	0.34	0.018	(0.088)	0.302	0.004	(0.013)	0.040
1977	1.23	(2.17)	4.27	1.23	(1.97)	3.09	0.01	(0.08)	0.40	0.004	(0.183)	1.221	0.004	(0.021)	0.118
1978	1.45	(2.03)	2.78	1.33	(1.92)	2.58	0.01	(0.11)	0.26	0.004	(0.098)	0.661	0.004	(0.015)	0.055
1979	0.65	(2.26)	4.86	0.64	(2.15)	4.17	0.01	(0.19)	0.81	0.004	(0.080)	0.558	0.004	(0.028)	0.134
1980	1.07	(2.56)	3.98	0.99	(2.47)	3.88	0.01	(0.19)	0.87	0.012	(0.072)	0.210	0.004	(0.021)	0.103
B. Period of Record:															
Av. Concentration		1.97			1.85			0.12			0.102			0.019	
Min. Concentration		0.37			0.18			0.01			0.004			0.002	
Max. Concentration		4.86			4.17			0.87			1.221			0.134	
Summer average		2.03			1.91			0.14			0.077			0.022	
Winter average		1.91			1.75			0.12			0.150			0.014	
Discharge average		1.85			1.79			0.06			0.063			0.008	
No discharge average		2.03			1.88			0.14			0.123			0.046	

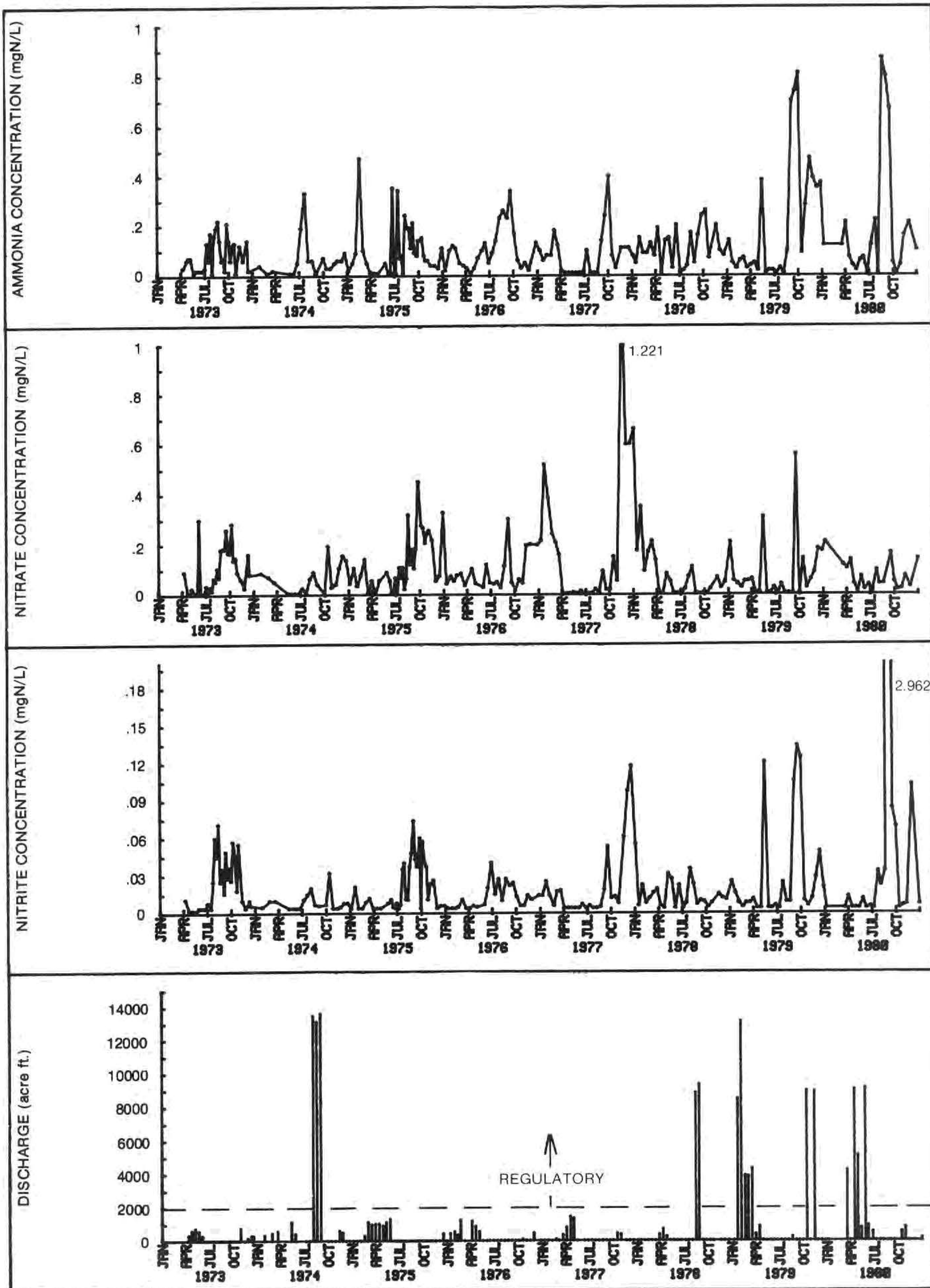


Figure 8 NITROGEN CONCENTRATIONS AT S-77

TABLE 12. NITROGEN CONCENTRATION COMPARISON BETWEEN DISCHARGE AND SEASON OF OCCURRENCE AT S-77, 1973-1980

	Total Nitrogen mg N/L		TKN mg N/L	
	Summer	Winter	Summer	Winter
Discharge	1.96	1.77	1.89	1.70
No discharge	2.03	2.03	1.92	1.80

	Ammonia mg N/L		Nitrate mg N/L	
	Summer	Winter	Summer	Winter
Discharge	.05	.07	.056	.068
No discharge	.15	.12	.083	.214

	Nitrite mg N/L	
	Summer	Winter
Discharge	.009	.007
No discharge	.026	.023

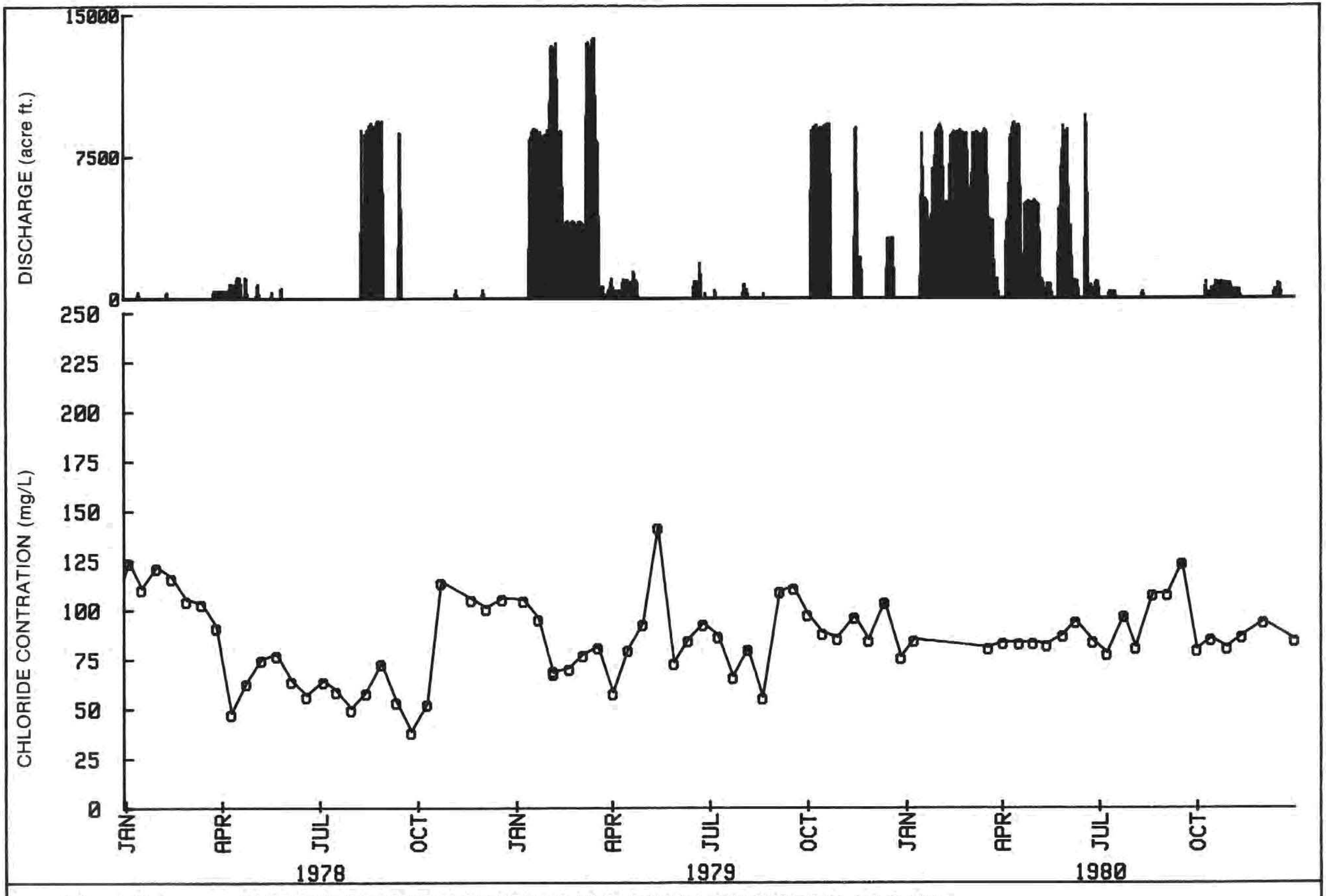


Figure 9 CHLORIDE CONCENTRATION AND DAILY DISCHARGE AT S-77

Okeechobee removed this seasonal variation causing the mean summer and winter concentrations to be almost equal (84 mg/L) (Table 13).

In summary, most variables studied displayed some fluctuations due to season alone; however, discharge activity appeared to be the principal component regulating the water quality at S-77. During discharge, pH and turbidity levels were the only parameters to increase (pH regardless of season and turbidity slightly more in summer than in the winter). Alkalinity, specific conductance, total and ortho phosphorus, and all the nitrogen components had lower levels during discharge at S-77 than during no discharge. Chloride and color levels at S-77, during discharge events, were similar regardless of season. Discharge, however, moderated the seasonal extremes observed when discharge was not occurring. Total suspended solids were unaffected by discharge during the winter, but increased in the summer, especially during discharge. Dissolved oxygen was the only parameter which was unaffected by discharge, regardless of season.

CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE MAJOR TRIBUTARIES TO THE CALOOSAHATCHEE RIVER

The nature and chemical concentrations of waters in south Florida are influenced by many interrelated factors including the chemical composition of rainfall, the reaction of water to soils, bed materials, and the mineralization of rock and surficial sediments. Other related factors including streamflow, the activity of aquatic organisms, groundwater, and cultural effects, including the influence of municipal, agricultural, and industrial runoff.

The average color, turbidity, temperature, magnesium, sodium, potassium, chloride, total iron, total nitrogen and its constituents (except nitrate), and total and ortho phosphorus levels were all greater in the East Basin tributaries than in the West Basin tributaries. Only hardness, specific conductance,

TABLE 13. CHLORIDE CONCENTRATION AT S-77; 1973-1980

A. Annual:	Chloride mg/L Min	(Mean)	Max
1973	26.5	(65.8)	98.0
1974	27.1	(72.0)	108.7
1975	36.5	(63.3)	98.7
1976	31.8	(88.4)	139.7
1977	50.1	(94.6)	116.7
1978	38.8	(81.7)	124.7
1979	56.2	(86.2)	142.2
1980	78.3	(89.5)	124.2
B. Study Period:	26.5	(79.1)	142.2
Summer Average		71.9	
Winter Average		89.8	
Discharge Average		83.7	
No Discharge Average		76.6	

C. Discharge and Season of Occurrence:

	Summer	Winter
Discharge	83.8	84.3
No Discharge	68.7	95.9

dissolved oxygen, calcium, and nitrate levels were greater in the West Basin than the East Basin. Fluoride and pH were similar in the two basins (Table 14).

The water color of the East Basin tributaries was considerably higher than the West Basin tributaries. As was discussed earlier, the area between Lake Hicpochee and Lake Okeechobee, south of the Caloosahatchee River, has a large percentage of organic soils. The leaching of organic soils that accompanies the drainage of these agricultural lands may be contributing to the increased color levels in the East Basin. This was documented earlier by Kaufman (1969).

The tributaries contained low to moderate levels of dissolved oxygen and turbidity, and occasionally considerable levels of total iron.

Jack's Branch and Cypress Creek had cooler study period average temperatures than any of the other stations in either basin. Since these two tributaries are the only ones with extensive shading over much of the waterway, this probably accounts for the lower temperatures.

Phosphorus: The average phosphorus concentrations for all tributaries in the East and West Caloosahatchee River Basins is presented in Table 14. Figure 10 displays the average total phosphorus concentration and range of values, including the summer and winter season means, for the three year study. With the exception of the Diston Island Canal, phosphorus levels were slightly higher during the summer than the winter. The East Basin demonstrated more variability and had generally higher mean concentrations of total phosphorus than did the tributaries in the West Basin. In the East Basin, Grassey Marsh East Canal had the lowest mean total phosphorus value (0.088 mg P/L) which was only slightly less than the highest mean phosphorus concentration in the West Basin at the Townsend Canal (0.092 mg P/L). This elevated average for the Townsend

TABLE 14. SUMMARY OF WATER QUALITY AVERAGES FOR THE MAJOR TRIBUTARIES TO THE CALOOSAHATCHEE RIVER

Tributary Station	pH Units	Alkalinity mg/L $CaCO_3$	Hardness mg/L $CaCO_3$	Sp. Conductance micromhos/cm (25° C)	Color Pt Units	Turbidity NTU	Temperature °C	Dissolved Oxygen mg/L
S235	7.3	-	-	762	82	1.3	25.9	4.3
Diston Isl. Canal	7.1	-	407.9	1087	131	2.4	25.9	4.0
Whidden Corner C.	7.4	-	193.5	562	84	2.4	24.6	5.1
C-19 Canal at S47D	7.1	-	170.9	524	103	1.4	25.4	4.6
Grassey Marsh E.	7.2	-	-	583	97	1.3	24.5	3.8
Meanderline Ditch	7.2	-	162.2	496	111	4.2	24.9	6.2
Long Hammock Canal	7.3	-	175.7	514	105	2.7	24.5	5.1
East Basin (Avg.)	7.2	-	222.1	644	104	2.6	25.2	4.8
Goodno Canal	7.2	-	165.4	442	97	1.7	24.8	5.5
Okaloacoochee B.	7.4	221.3	245.7	528	46	2.3	25.1	7.8
Crawford Canal	7.2	181.2	236.2	624	76	1.4	24.9	6.1
Jacks Branch	6.9	167.9	208.6	524	64	0.8	22.6	5.3
Roberts Canal	7.4	169.4	223.1	617	88	2.0	24.3	6.6
Ft. Simmons B.	7.5	179.9	309.5	1005	66	2.1	24.1	6.9
Townsend Canal	7.4	170.9	213.3	601	77	1.7	25.2	6.2
Bedmen Creek	7.5	225.6	296.1	726	39	2.2	24.0	6.4
Cypress Creek	7.1	190.1	247.2	663	74	1.7	22.7	4.7
Hickeys Creek	7.5	232.4	337.3	753	37	1.8	25.3	6.3
West Basin (Avg.)	7.3	194.3	252.5	658	65	1.8	24.3	6.2

TABLE 14. (Continued)

All values in mg/L

Tributary Station	Calcium	Magnesium	Sodium	Potassium	Chloride	Fluoride	Total Iron	Sulfate
S235	-	-	-	-	101.3	0.3	0.22	-
Diston Isl. Canal	127.9	21.5	75.5	6.9	116.9	0.3	0.30	-
Whidden Corner C.	59.8	10.7	41.7	4.0	69.6	0.2	0.42	-
C-19 Canal @ S47D	51.2	10.5	38.1	4.6	68.1	0.2	0.42	-
Grassey Marsh E.	-	-	-	-	64.4	0.3	0.35	-
Meanderline Ditch	48.6	9.9	32.5	3.0	57.6	0.2	0.93	-
Long Hammock Canal	55.5	9.0	31.2	3.7	51.5	0.2	0.55	-
East Basin (Avg.)	68.8	12.6	44.1	4.5	74.6	0.2	0.50	-
Goodno Canal	54.7	7.0	23.8	2.9	40.6	0.2	0.70	-
Okaloacoochee B.	92.7	3.5	16.6	1.3	26.0	0.2	0.31	36.1
Crawford Canal	76.1	11.2	37.9	5.1	66.8	0.3	0.37	38.2
Jacks Branch	72.8	6.5	20.2	1.6	40.3	0.2	0.20	14.2
Roberts Canal	68.4	12.7	42.2	4.5	72.6	0.3	0.33	41.1
Ft. Simmons B.	88.2	21.7	97.4	6.2	170.5	0.4	0.28	81.5
Townsend Canal	66.4	11.6	38.6	4.1	68.7	0.3	0.26	34.4
Bedmen Creek	96.1	13.6	40.5	1.6	71.5	0.2	0.26	53.9
Cypress Creek	80.8	11.0	38.4	1.2	81.2	0.1	0.70	17.2
Hickeys Creek	107.2	16.9	27.8	1.2	51.0	0.2	0.18	66.3
West Basin (Avg.)	82.4	11.9	38.9	2.9	69.7	0.2	0.36	42.9

TABLE 14. (Continued)

All values in mg/L

Tributary Station	Total Nitrogen	Total Inorganic Nitrogen	TKN	Ammonia	Nitrate	Nitrite	Total Phosphorus	Ortho Phosphorus
S235	3.18	0.57	3.00	0.39	0.152	0.030	0.115	0.079
Diston Isl. Canal	5.68	2.14	5.50	1.96	0.143	0.040	0.206	0.141
Whidden Corner C.	2.41	0.22	2.30	0.11	0.097	0.011	0.106	0.066
C-19 Canal @ S47D	2.52	0.34	2.43	0.24	0.077	0.021	0.163	0.105
Grassey March E.	2.55	0.12	2.49	0.06	0.059	0.006	0.088	0.057
Meanderline Ditch	1.93	0.07	1.91	0.06	0.007	0.006	0.100	0.051
Long Hammock Canal	2.08	0.11	2.04	0.06	0.036	0.003	0.106	0.065
East Basin (Avg.)	2.92	0.53	2.83	0.44	0.077	0.017	0.131	0.083
Goodno Canal	1.87	0.09	1.82	0.04	0.042	0.006	0.074	0.049
Okaloacoochee B.	1.29	0.004	1.28	0.03	0.014	0.004	0.036	0.013
Crawford Canal	1.81	0.20	1.64	0.03	0.161	0.008	0.048	0.030
Jacks Branch	1.23	0.19	1.05	0.02	0.168	0.006	0.020	0.003
Roberts Canal	1.81	0.15	1.71	0.04	0.091	0.014	0.077	0.052
Ft. Simmons B.	1.92	0.30	1.66	0.04	0.238	0.017	0.065	0.040
Townsend Canal	1.90	0.30	1.65	0.05	0.234	0.014	0.092	0.069
Bedmen Creek	1.02	0.07	0.96	0.02	0.048	0.004	0.010	0.004
Cypress Creek	1.23	0.12	1.13	0.02	0.096	0.005	0.023	0.011
Hickeys Creek	1.06	0.05	1.02	0.01	0.038	0.005	0.033	0.015
West Basin (Avg.)	1.50	0.15	1.38	0.03	0.115	0.008	0.047	0.028

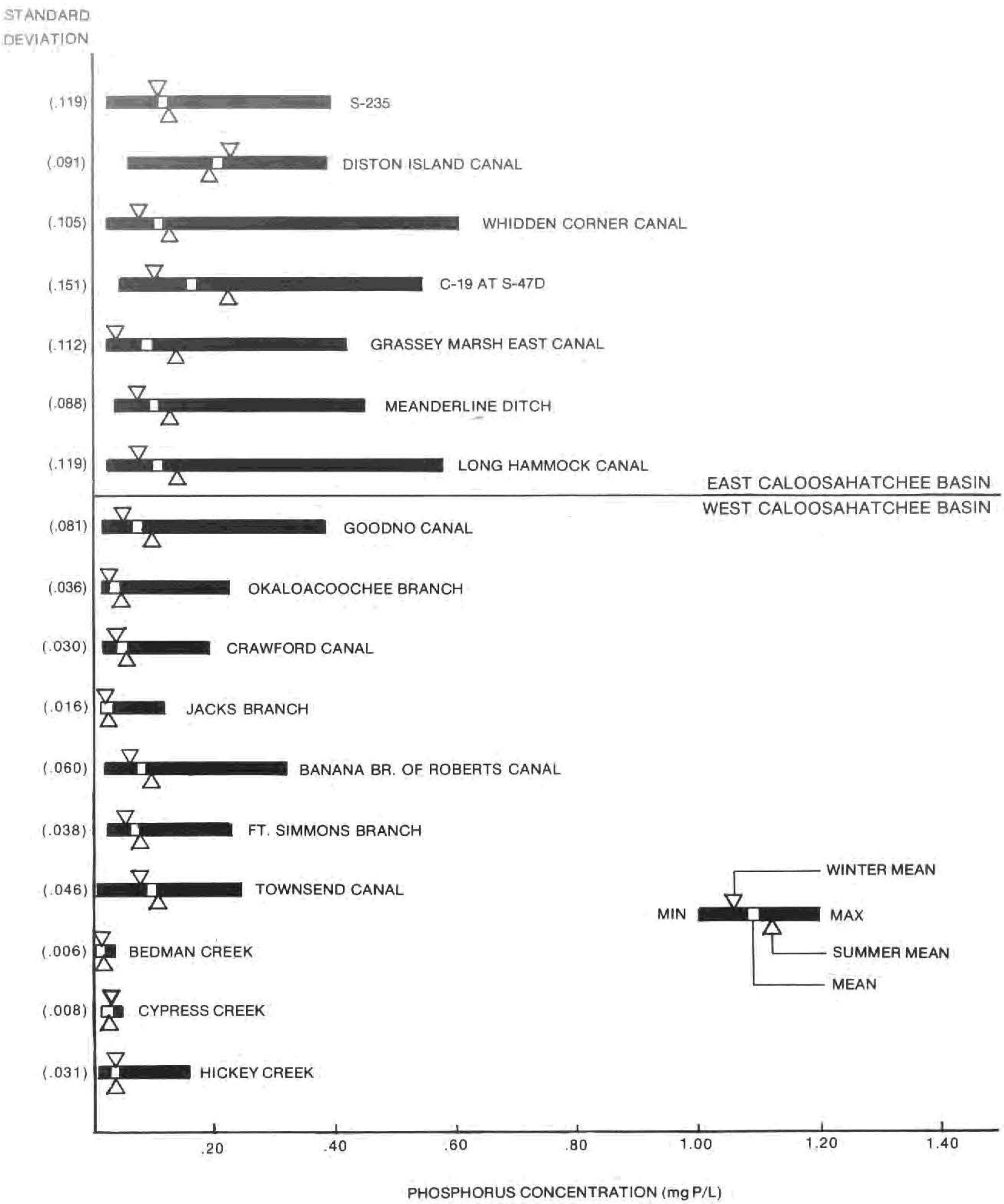


Figure 10 TRIBUTARY TOTAL PHOSPHORUS LEVELS

Canal may reflect the usually higher river average since the Townsend Canal was withdrawing water from the river during approximately 40% of the sampling trips. Although the land use in the East and West Basins is primarily agriculture, the drainage practices are considerably different. Nutrient polishing ponds and water reuse systems are utilized in the West Basin but not in the East Basin. The difference in land use intensity and drainage practices may also account for the lower phosphorus levels and narrower ranges in the West Basin as compared with the East Basin.

Ortho phosphorus was the principal component of the total phosphorus levels, accounting for about 60%. The average ortho phosphorus in the East Basin (0.083 mg P/L) was three times greater than the average in the West Basin (0.028 mg/L).

Nitrogen: The average concentration of total nitrogen and its constituents for all tributaries is presented in Table 14. The average total nitrogen concentration and range of values for the study is presented in Figure 11. As with phosphorus, average total nitrogen concentrations in the East Basin were generally higher than in the West Basin. The lowest average concentration in the East Basin (1.93 mg N/L at Meanderline Ditch) was similar to the highest average value in the West Basin (1.92 mg N/L at Ft. Simmons Branch). The highest average concentration of total nitrogen (5.68 mg N/L) was at the Diston Island Canal.

Organic nitrogen was the principal constituent of total nitrogen, comprising approximately 81% of the total for the East Basin and 90% of the total for the West Basin. The inorganic nitrogen was 83% ammonia in the East Basin and 77% nitrate in the West Basin.

Chloride: Generally, the chloride levels in the tributaries tended to decrease from Lake Okeechobee through the East Basin to a low point at the Okaloacoochee Branch Tributary. The concentrations for the remaining tributaries to the

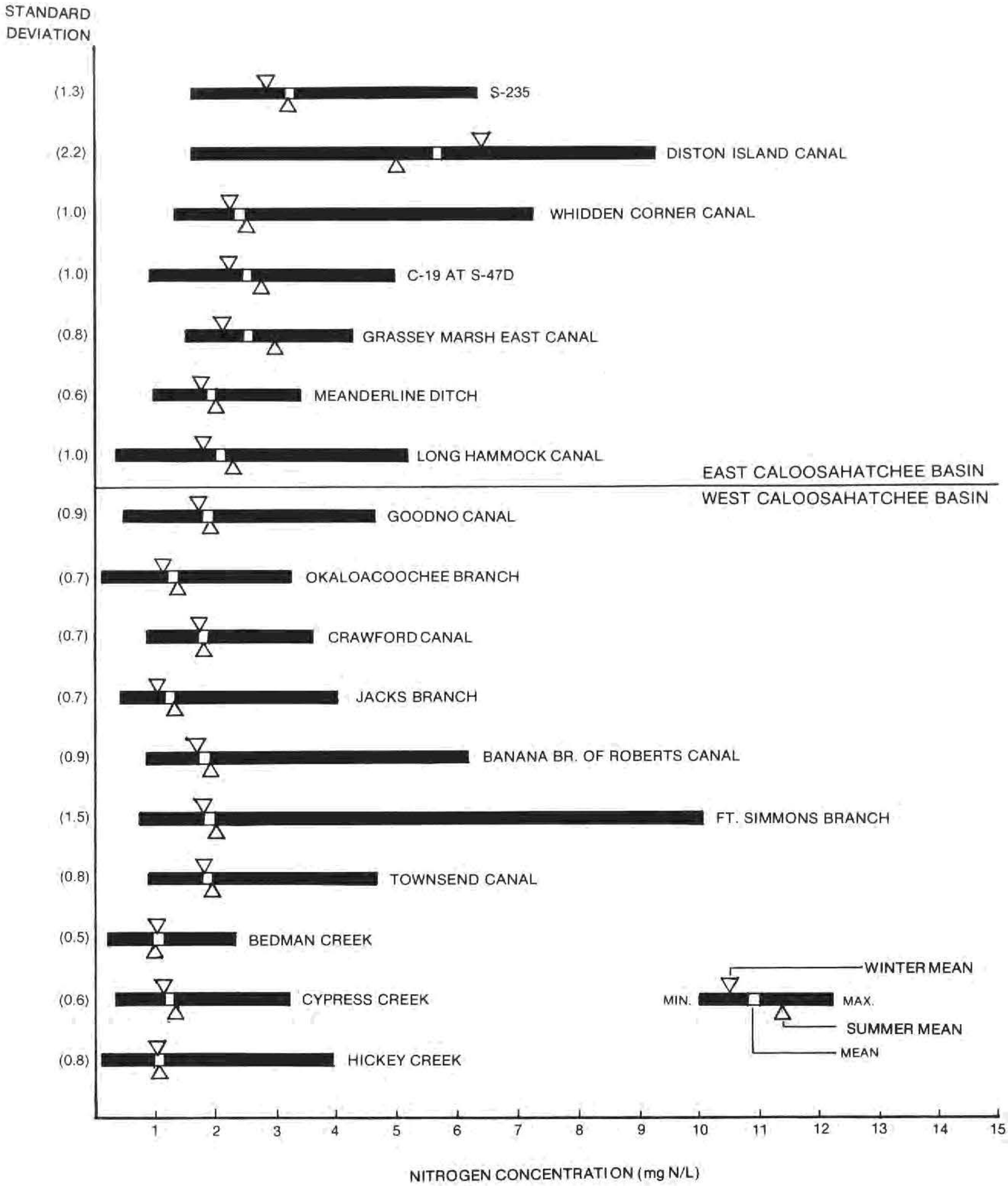


Figure 11 TRIBUTARY TOTAL NITROGEN LEVELS

west increased slightly except at the Ft. Simmons Branch. No consistent difference was noted between the wet and dry season means for the tributaries (Figure 12).

Ft. Simmons Branch had a mean chloride concentration (170.5 mg/L) which was approximately 46% higher than the next highest average value among the remaining stations (Diston Island Canal, 116.9 mg/L) and approximately 6.5 times greater than the lowest recorded average (Okaloacoochee Branch, 26.0 mg/L). The highest discrete chloride level measured was 614.0 mg/L, also at the Ft. Simmons Branch.

CHEMICAL AND PHYSICAL CHARACTERISTICS OF SURFACE WATERS IN THE CALOOSAHATCHEE RIVER

A summary of the surface data for the Caloosahatchee River is presented in Table 15. The average pH of the water in the Caloosahatchee River was 7.4 units (Table 15). The alkalinity levels along the river were sufficiently high so as to buffer any appreciable pH fluctuations which may have occurred as a result of seasonal fluctuations in tributary pH.

Average specific conductance levels increased slightly from S-77 to the Lake Hicpochee area, then decreased in the East Basin to the general area of LaBelle (Figure 13). From LaBelle to S-79, the specific conductance levels increased. The water discharged to the estuary through S-79 was, on the average, lower in specific conductance than that released into the river at S-77. Specific conductance levels in the river appeared to reflect the contribution of dissolved solids from the tributaries. Tributaries in the East Basin usually had lower specific conductance levels than West Basin tributaries.

The daytime dissolved oxygen concentrations for the river and the tributaries increased from S-77 to S-79 (Figure 14). Dissoved oxygen levels in the

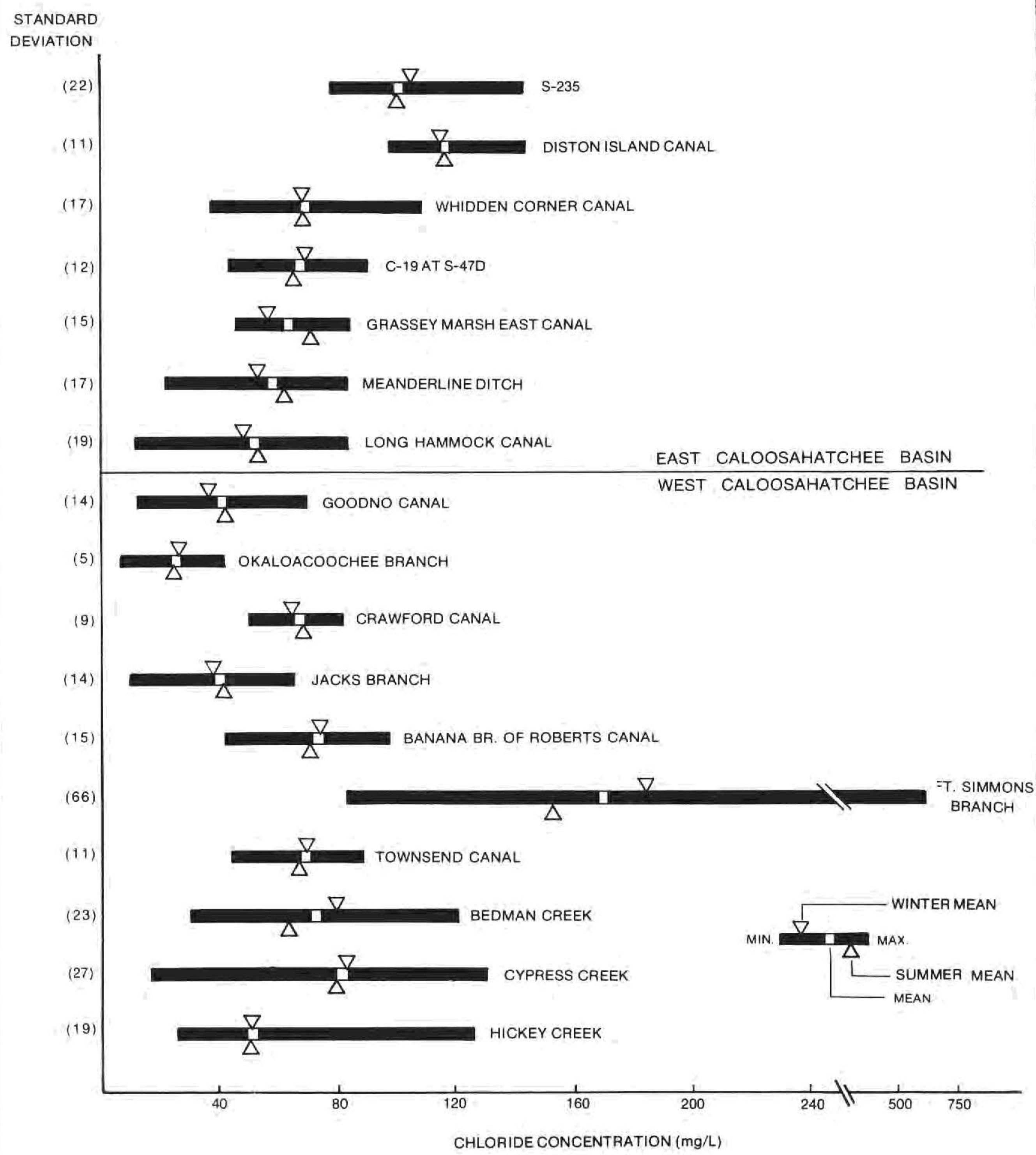


Figure 12 TRIBUTARY CHLORIDE LEVELS

TABLE 15. SUMMARY OF GENERAL CHEMICAL AND PHYSICAL CHARACTERISTICS OF SURFACE WATER IN THE CALOOSAHATCHEE RIVER; JANUARY 1978 TO DECEMBER 1980

(All values in mg/L except as noted)

Parameter	No. of Samples	Mean	Standard Deviation	Range min. - max.
pH (standard units)	588	7.4	0.3	6.3 - 8.6
Alkalinity, total as $CaCO_3$	256	149.2	31.5	53.5 - 247.0
Specific Conductance (micromhos/cm at 25°C)	622	578	98	266 - 990
Color (Pt units)	291	92	36	25 - 203
Temperature Water (°C)	659	25.4	4.5	15.2 - 33.0
Dissolved Oxygen	626	6.3	1.7	0.4 - 12.1
Total Suspended Solids	67	6	5	1 - 21
Turbidity (NTU's)	291	1.4	0.8	0.3 - 8.0
Calcium	473	54.5	11.9	24.4 - 101.6
Magnesium	473	12.3	2.8	5.6 - 23.9
Sodium	473	42.9	9.6	16.5 - 77.6
Potassium	473	4.2	0.9	1.6 - 8.6
Fluoride	458	0.2	<0.1	<0.1 - 0.4
Total Iron	627	0.23	0.14	0.02 - 0.84
Sulfate	167	30.0	10.3	13.3 - 73.2

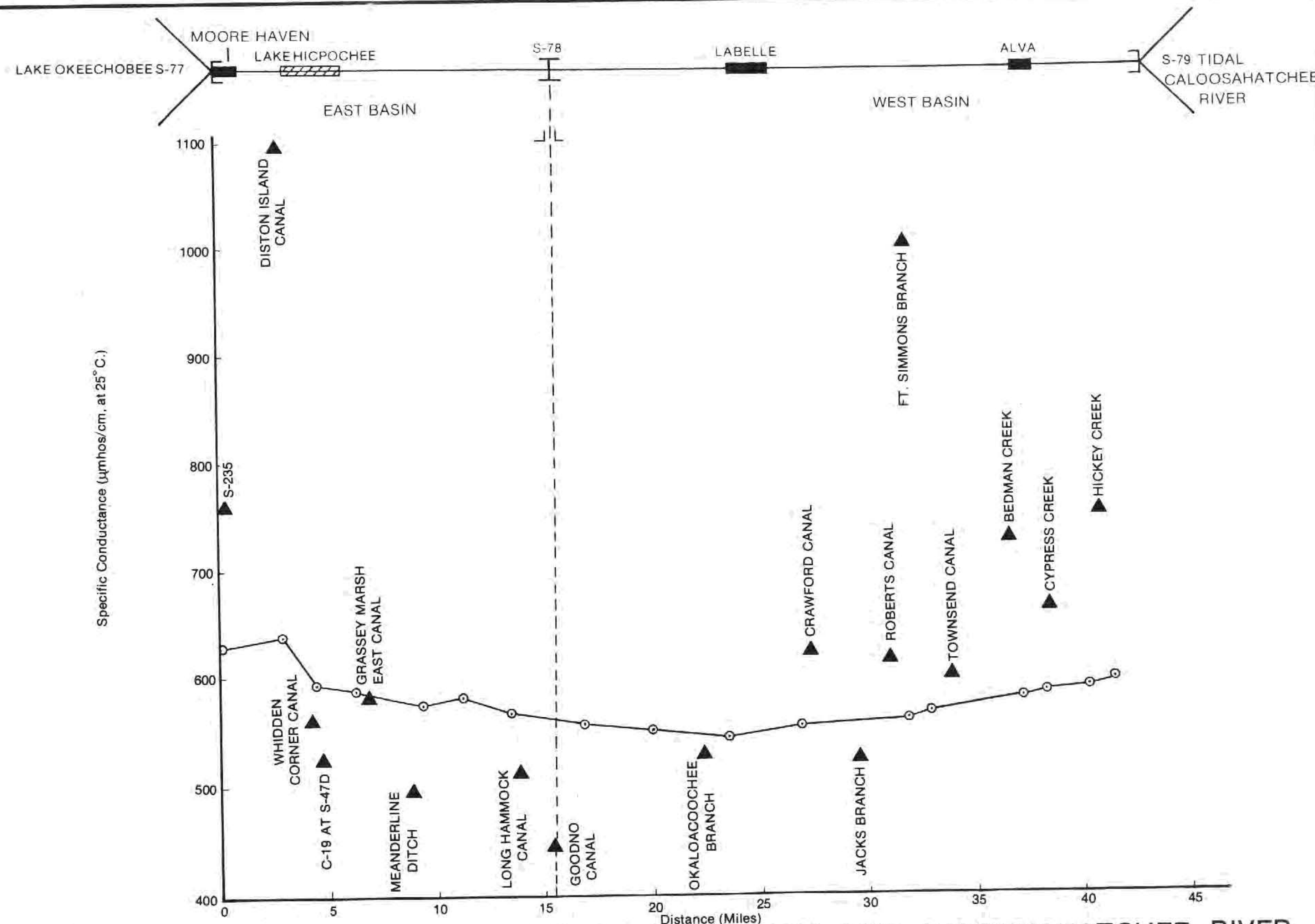


Figure 13 AVERAGE SPECIFIC CONDUCTANCE ALONG THE CALOOSAHATCHEE RIVER

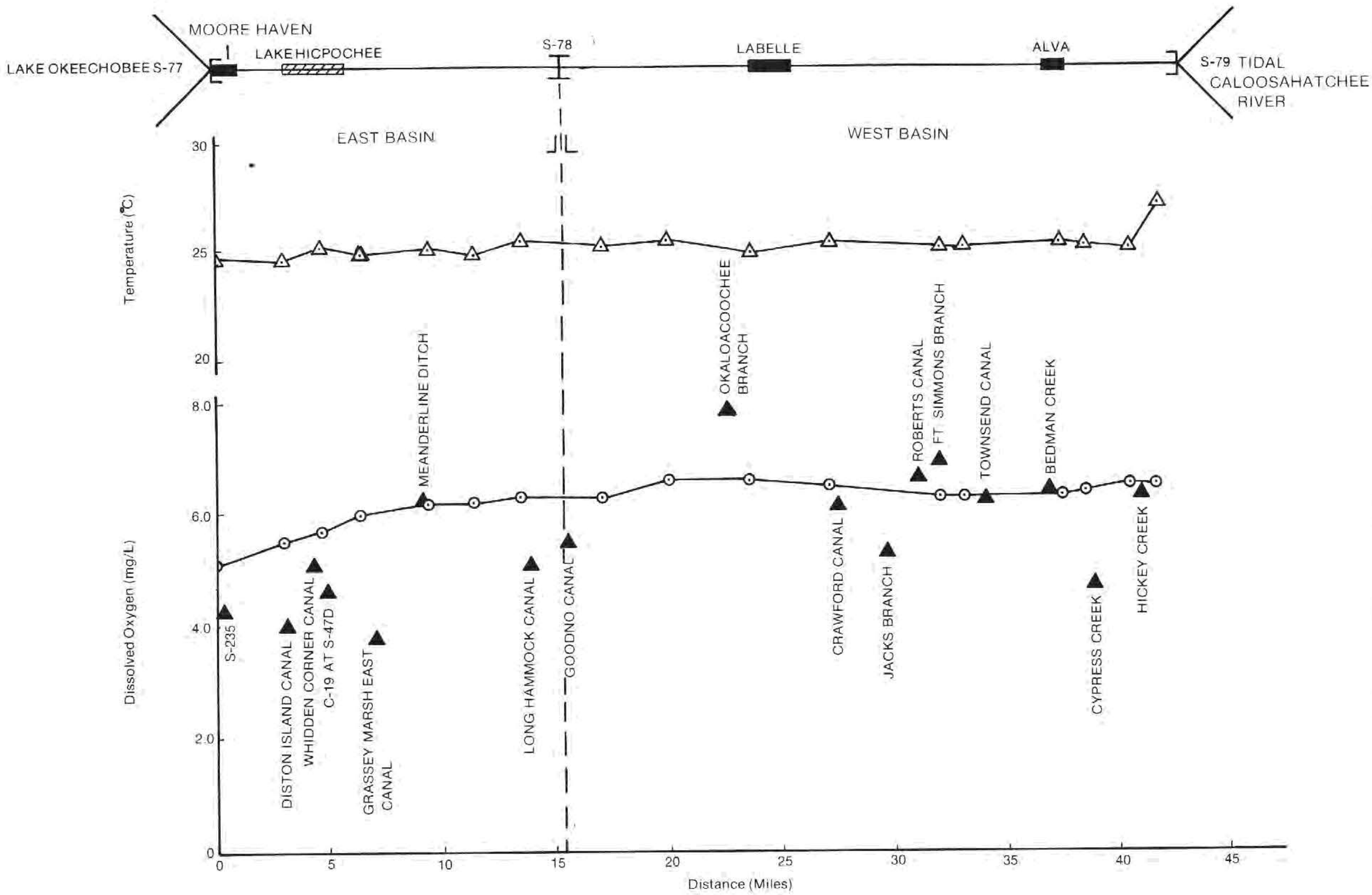


Figure 14 AVERAGE DISSOLVED OXYGEN AND TEMPERATURE ALONG THE CALOOSAHATCHEE RIVER

tributaries were less than in the river. The West Basin tributaries, collectively, had a higher dissolved oxygen concentration than the tributaries in the East Basin. Since the temperature of water remained relatively constant in both basins, the average percent saturation of oxygen, alo tended to increase along the river.

Phosphorus: Phosphorus displayed a distinct spatial trend along the Caloosahatcheee River (Figures 15 and 16). Average concentrations increased in the East Basin from S-77 to just west of S-78, then declined toward S-79. Cumulative tributary inputs downstream of S-77 appear to be the major factor elevating the river phosphorus levels since six of the seven tributaries sampled in the East Basin had greater concentrations of total phosphorus than the river. This trend was also noted for ortho phosphorus, where all the tributary values in the East Basin exceeded the river concentrations. Along the West Basin where total phosphorus levels decreased, all major tributaries sampled had lower phosphorus levels than the river. All the tributaries, except the Townsend Canal in the West Basin, had average ortho phosphorus concentrations less than the river. The Townsend Canal, however, was used frequently for irrigation during this study and, therefore, reflects the higher river ortho phosphorus values.

Total and ortho phosphorus concentrations increased in the four miles between the town of Alva and S-79. This response was most pronounced during the wet season and probably reflects the intensive agricultural land use (flower nursery and citrus) activities in close proximity to this reach of the river.

Distinct seasonal trends were also noted along the river (Figures 17, 18, and 19). As a group, the East and West Basin tributaries had higher phosphorus levels in the summer than during the winter. This seasonal trend in tributary

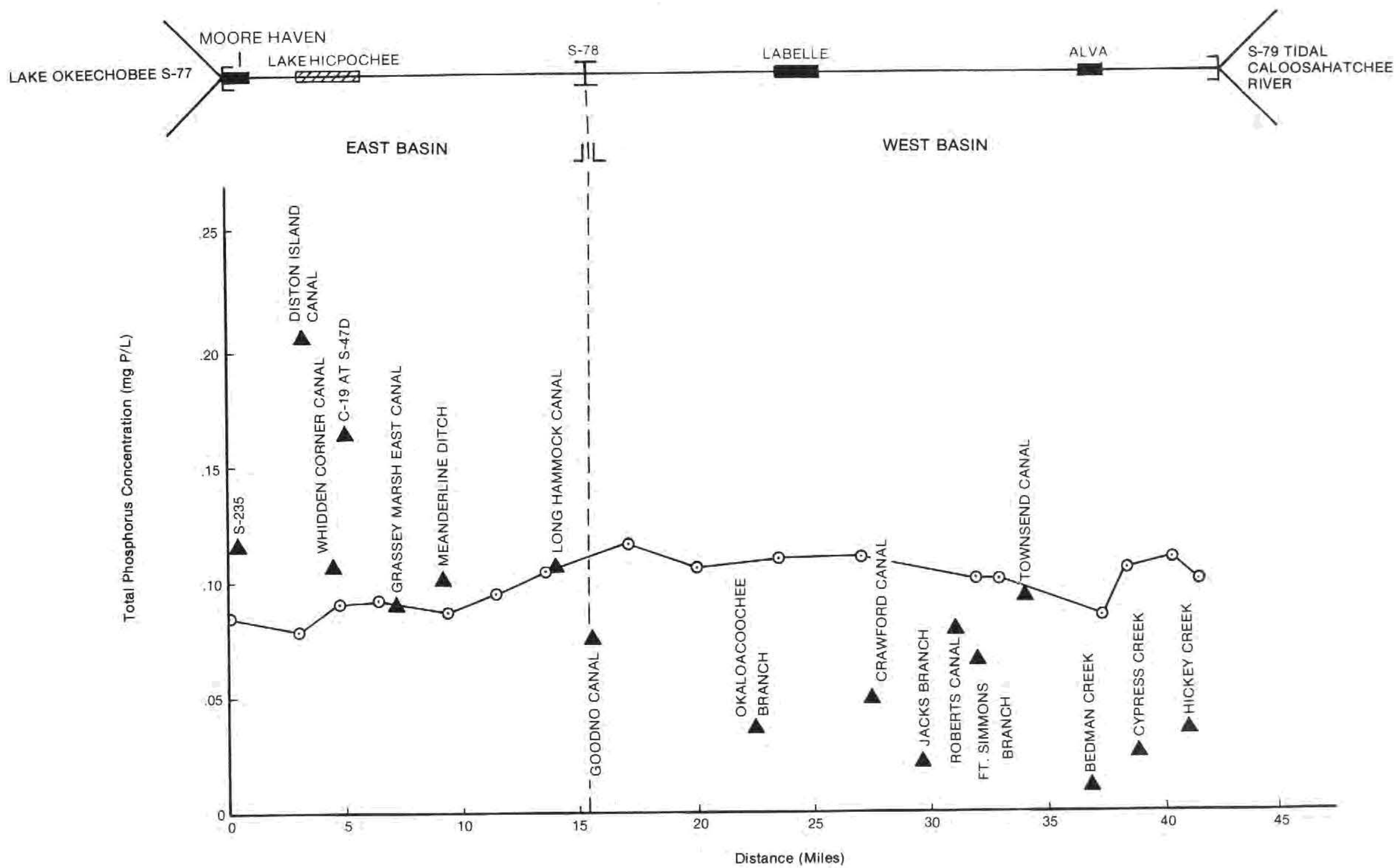


Figure 15 AVERAGE TOTAL PHOSPHORUS ALONG THE CALOOSAHATCHEE RIVER

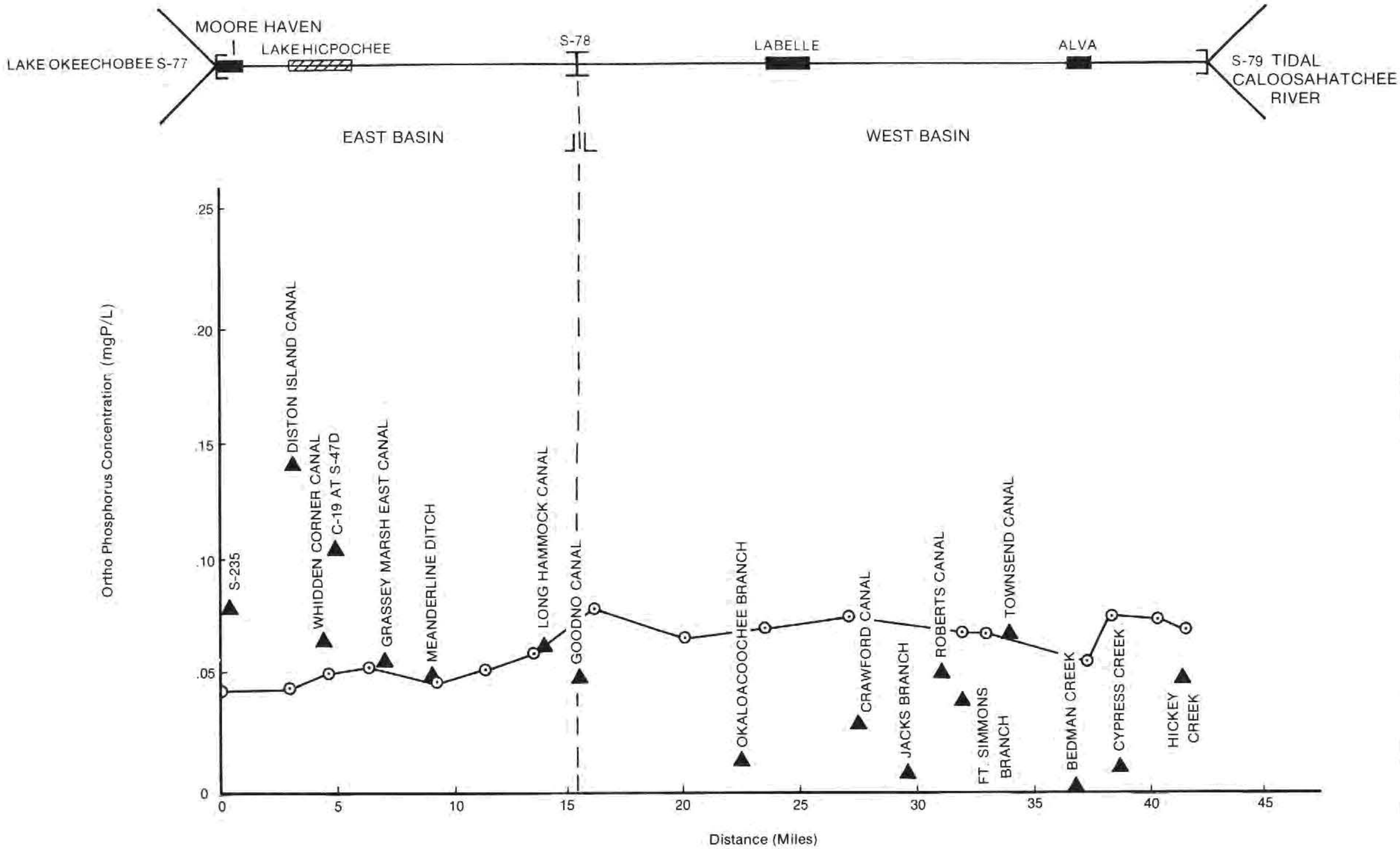


Figure 16 AVERAGE ORTHO PHOSPHORUS ALONG THE CALOOSAHATCHEE RIVER

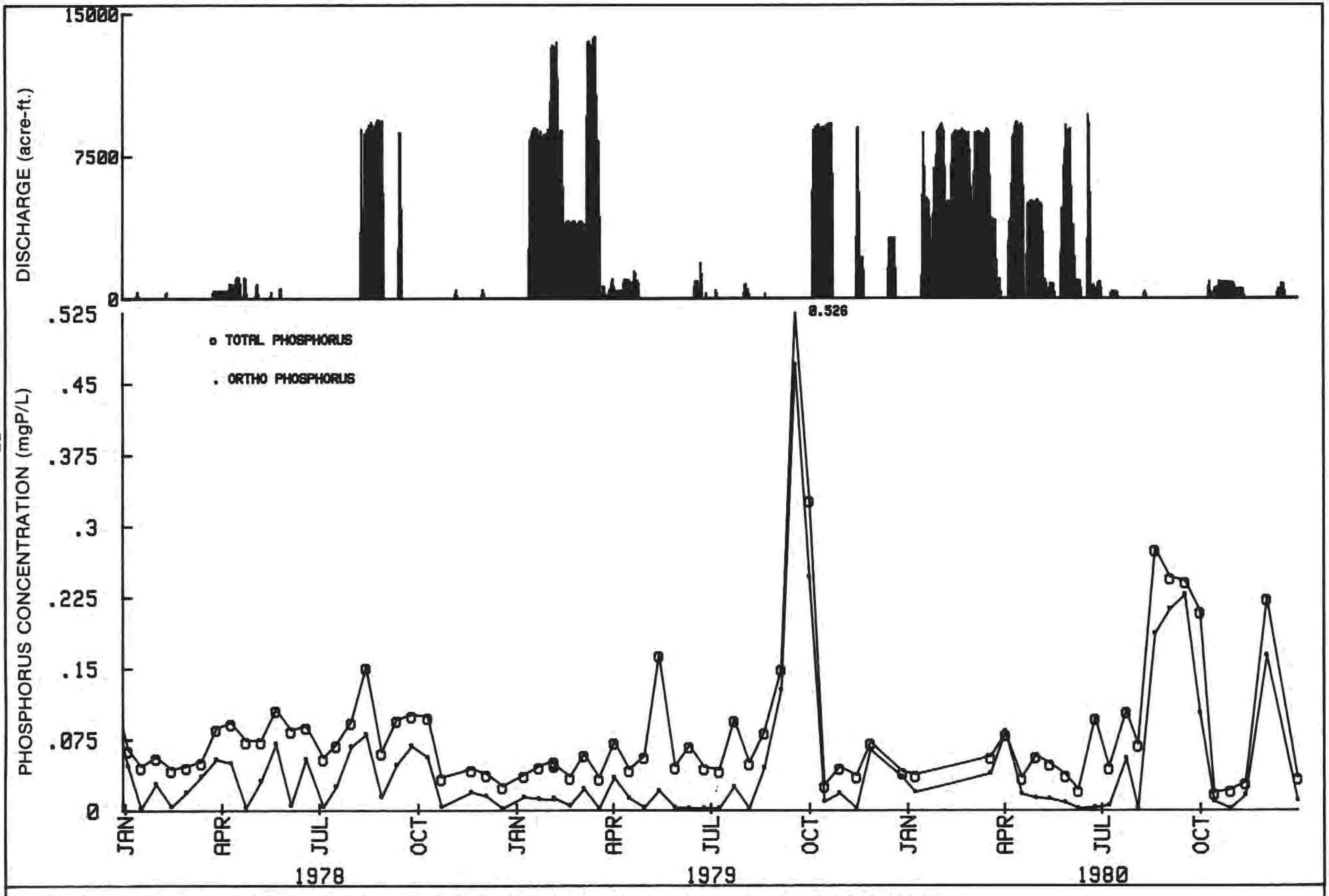


Figure 17 PHOSPHORUS CONCENTRATIONS AND DAILY DISCHARGE AT S-77

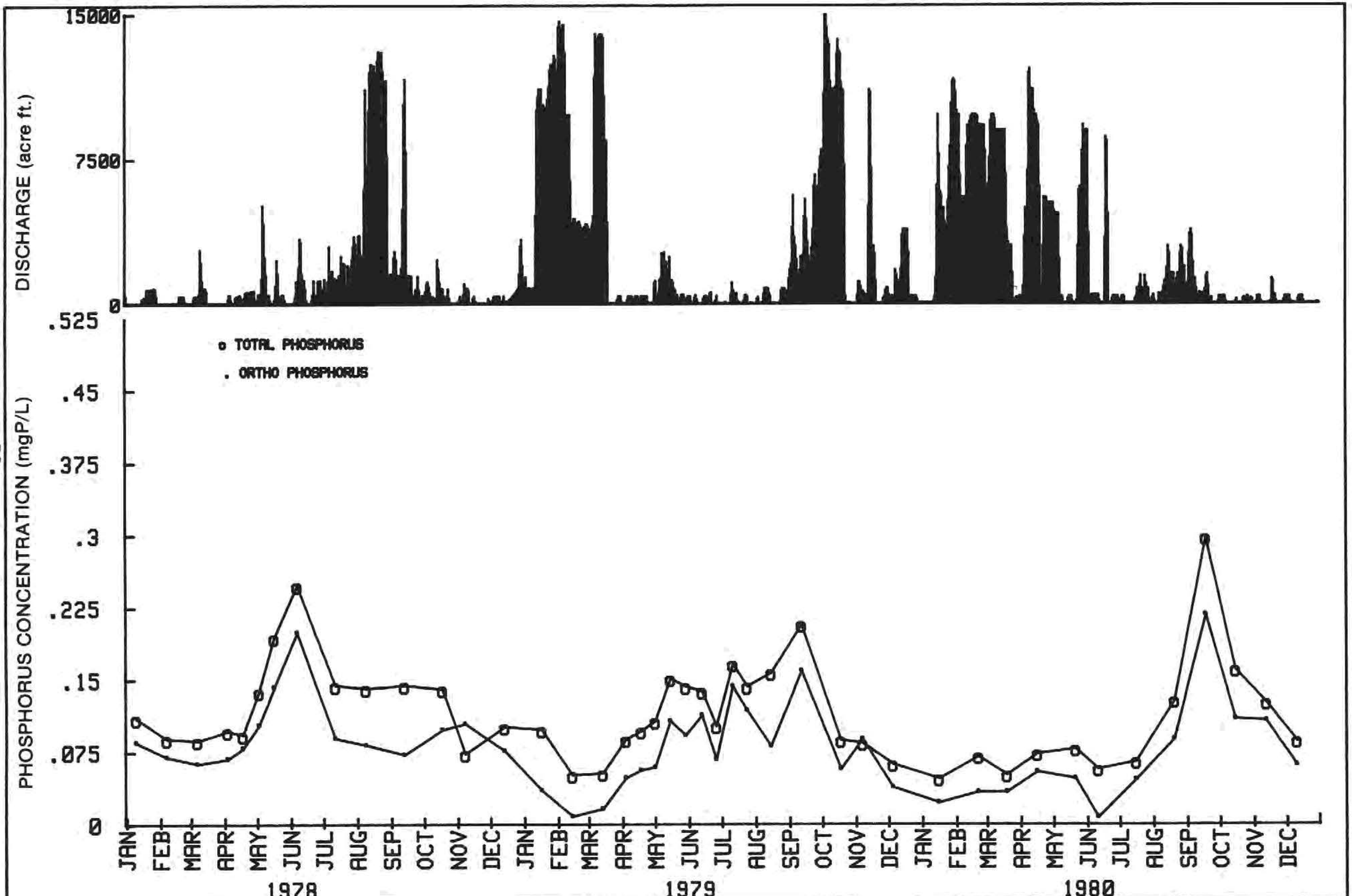


Figure 18 PHOSPHORUS CONCENTRATIONS AND DAILY DISCHARGE NEAR S-78 (CR-16.0)

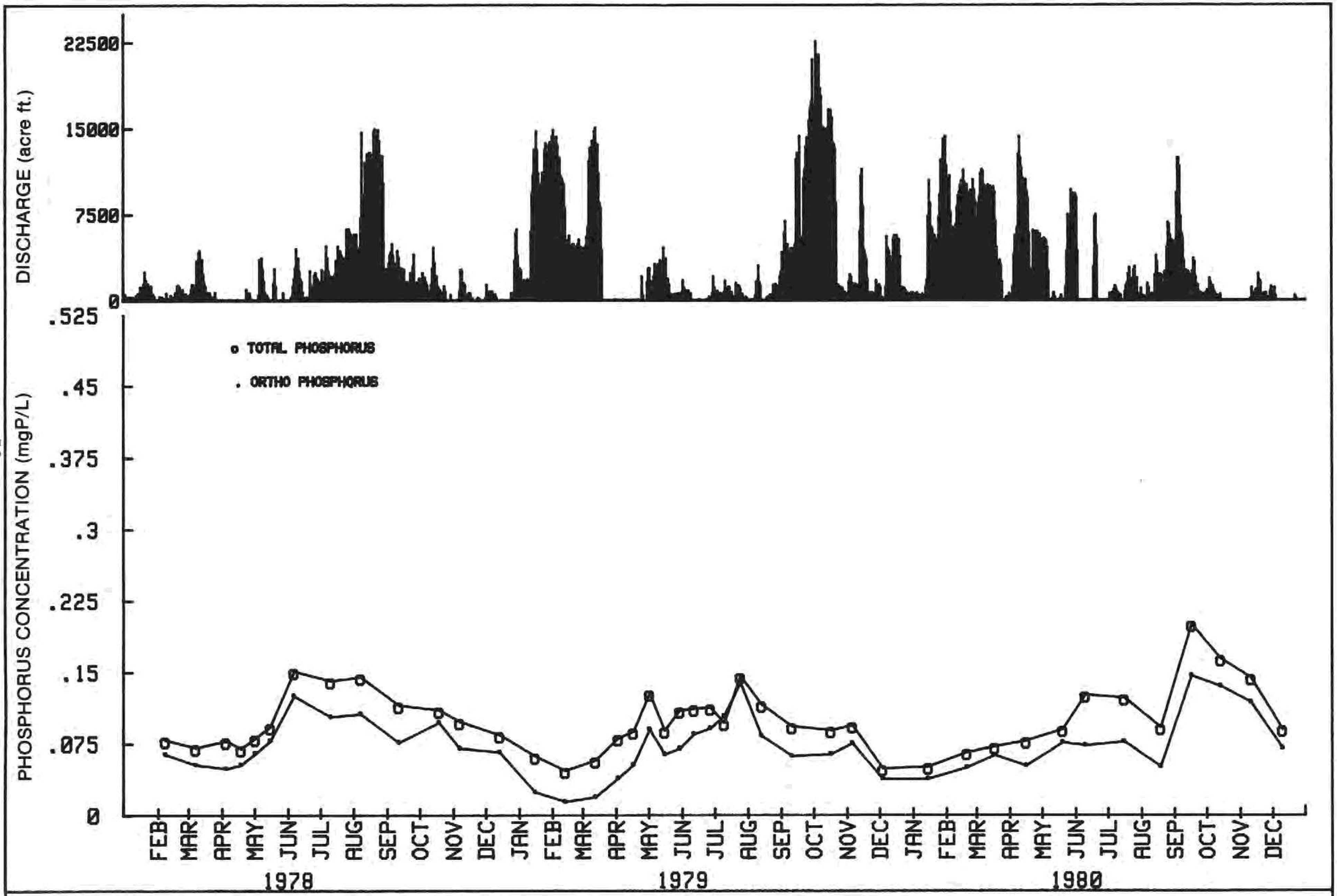


Figure 19 | PHOSPHORUS CONCENTRATIONS AND DAILY DISCHARGE AT S-79 (CR-40.3) phosphorus concentrations was also reflected in the levels measured along the river (Table 16).

Viewed as a complete system, the phosphorus levels in the water that was discharged from S-79 were slightly higher than the levels entering the system through S-77.

Nitrogen: Total nitrogen and total organic nitrogen levels decreased as the distance from Lake Okeechobee increased (Figures 20 and 21). Total organic nitrogen, both along the river and within each tributary, was the principal component of the total nitrogen. For that reason, the total nitrogen trends would closely follow the trends established by the organic nitrogen levels. The average total and organic nitrogen levels in the tributaries were either less than or equal to the river except for the five easternmost tributaries. These five easternmost tributaries, S-235 Canal, the Diston Island Canal, the Whidden Corner Canal, the C-19 Canal, and Grassey Marsh East Canal, all drain lands with soils that are primarily organic with normally high nitrogen content. The overall decreasing nitrogen levels along the river from Lake Okeechobee to S-79 are probably the result of tributary inflows, since the tributary total nitrogen concentrations were lower in the West Basin and higher in the East Basin. No apparent discharge or seasonal related trends were apparent along the river (Figures 22, 23, and 24).

The average inorganic nitrogen concentration of the water at S-77 was 0.26 mg/L (Figure 25). This average was generally maintained until Lake Hicpochee where the values dropped slightly. The average inorganic nitrogen levels remained similar along the river from Lake Hicpochee until Alva. West of Alva, there was an appreciable increase in the average inorganic nitrogen levels which exceeded all values along the previous 37 miles of the river.

TABLE 16. SEASONAL COMPARISONS OF PHOSPHORUS, NITROGEN AND CHLORIDE CONCENTRATIONS IN THE CALOOSAHATCHEE BASINS.

	TOTAL PHOSPHORUS mg P/L		TOTAL NITROGEN mg N/L		CHLORIDE mg/L	
	Summer	Winter	Summer	Winter	Summer	Winter
S-77	.109	.057	2.37	2.15	82.4	90.3
S-78	.145	.082	2.10	1.92	61.6	71.5
S-79	.119	.078	1.78	1.77	64.6	77.0
Tributaries:						
East Basin	.161	.109	2.90	3.10	77.9	77.4
West Basin	.055	.038	1.47	1.41	66.8	73.2
River:						
East Basin	.112	.064	2.29	2.07	74.2	78.9
West Basin	.130	.077	1.90	1.95	65.9	72.0

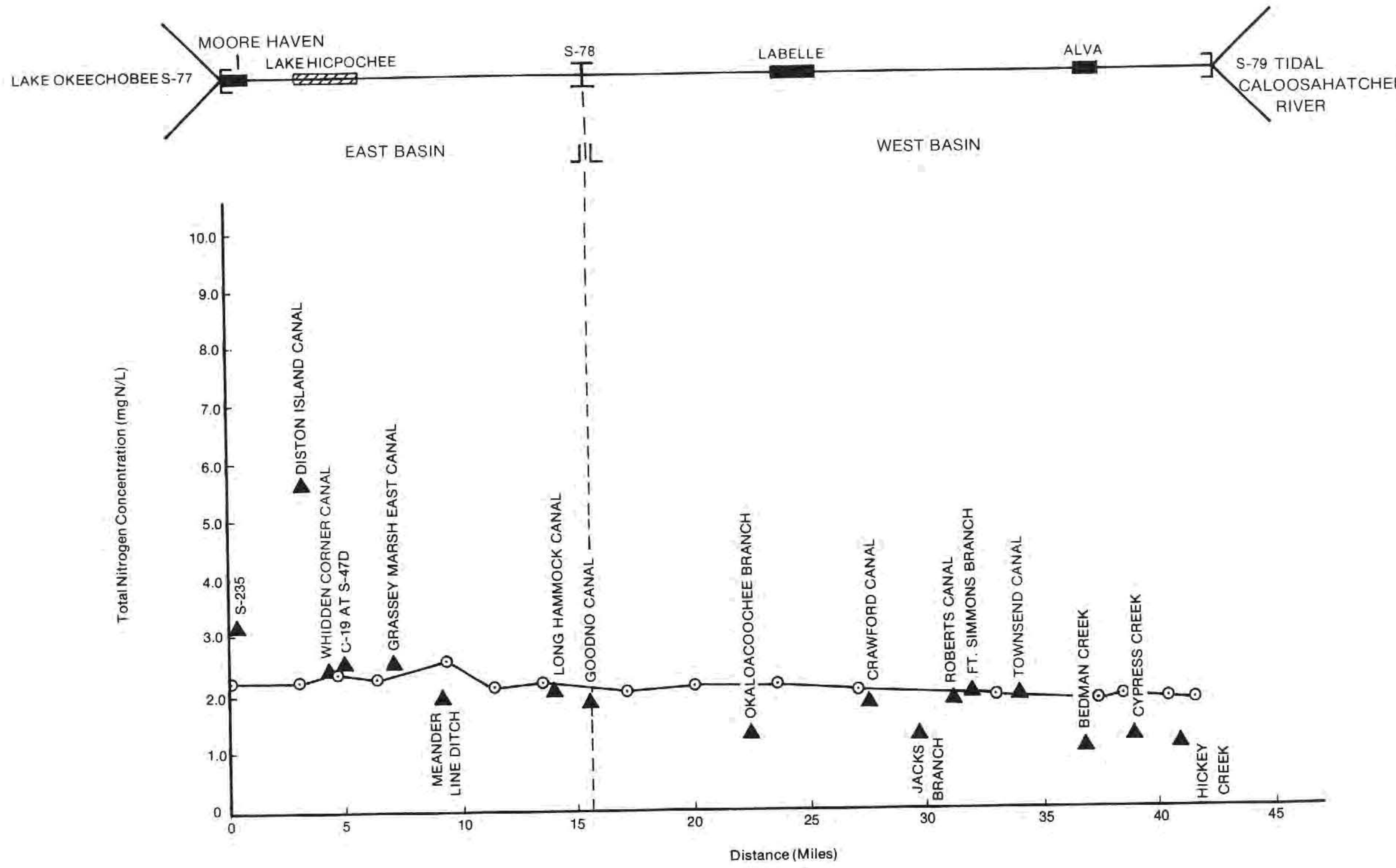


Figure 20 AVERAGE TOTAL NITROGEN ALONG THE CALOOSAHATCHEE RIVER

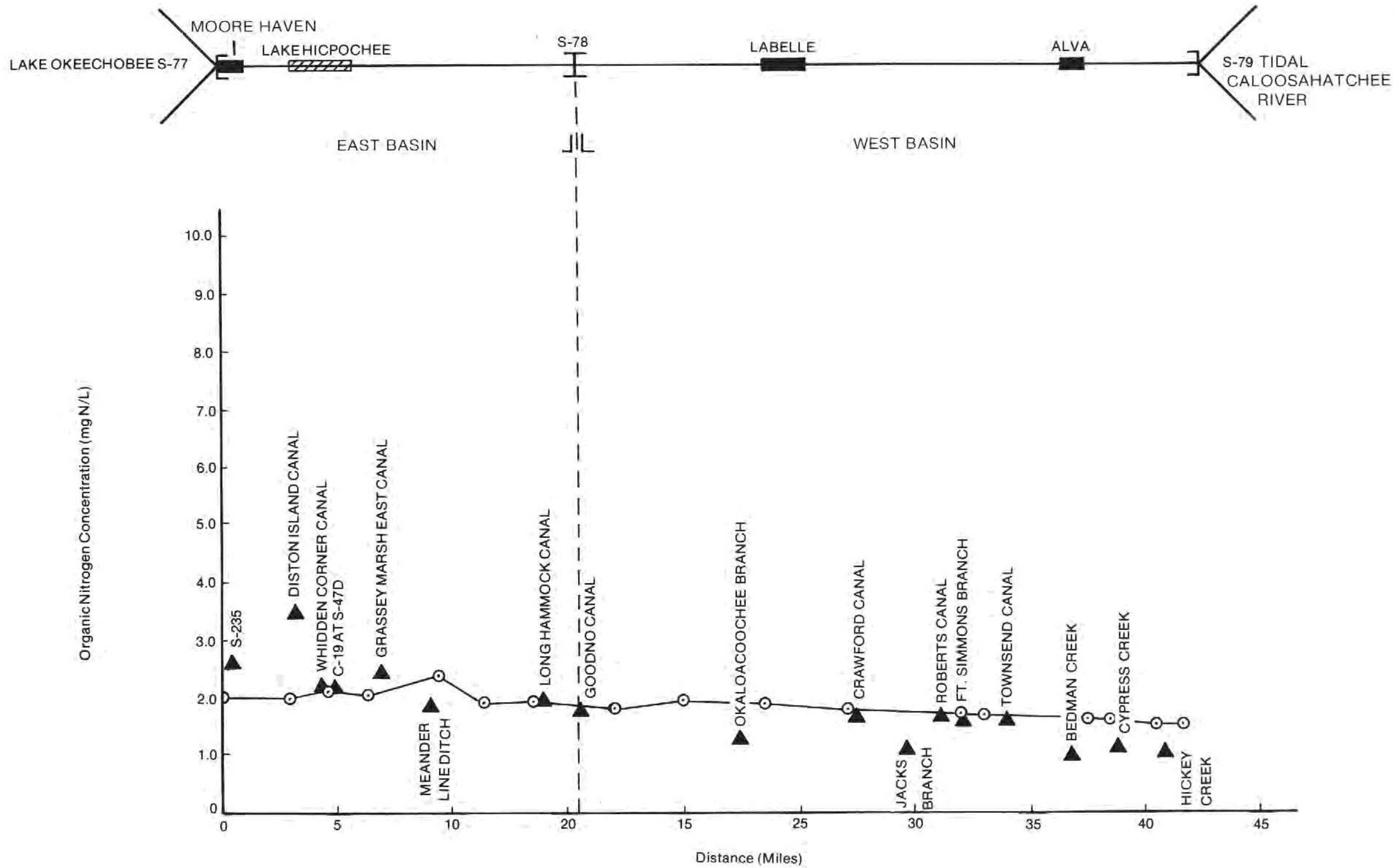


Figure 21 AVERAGE TOTAL ORGANIC NITROGEN ALONG THE CALOOSAHATCHEE RIVER

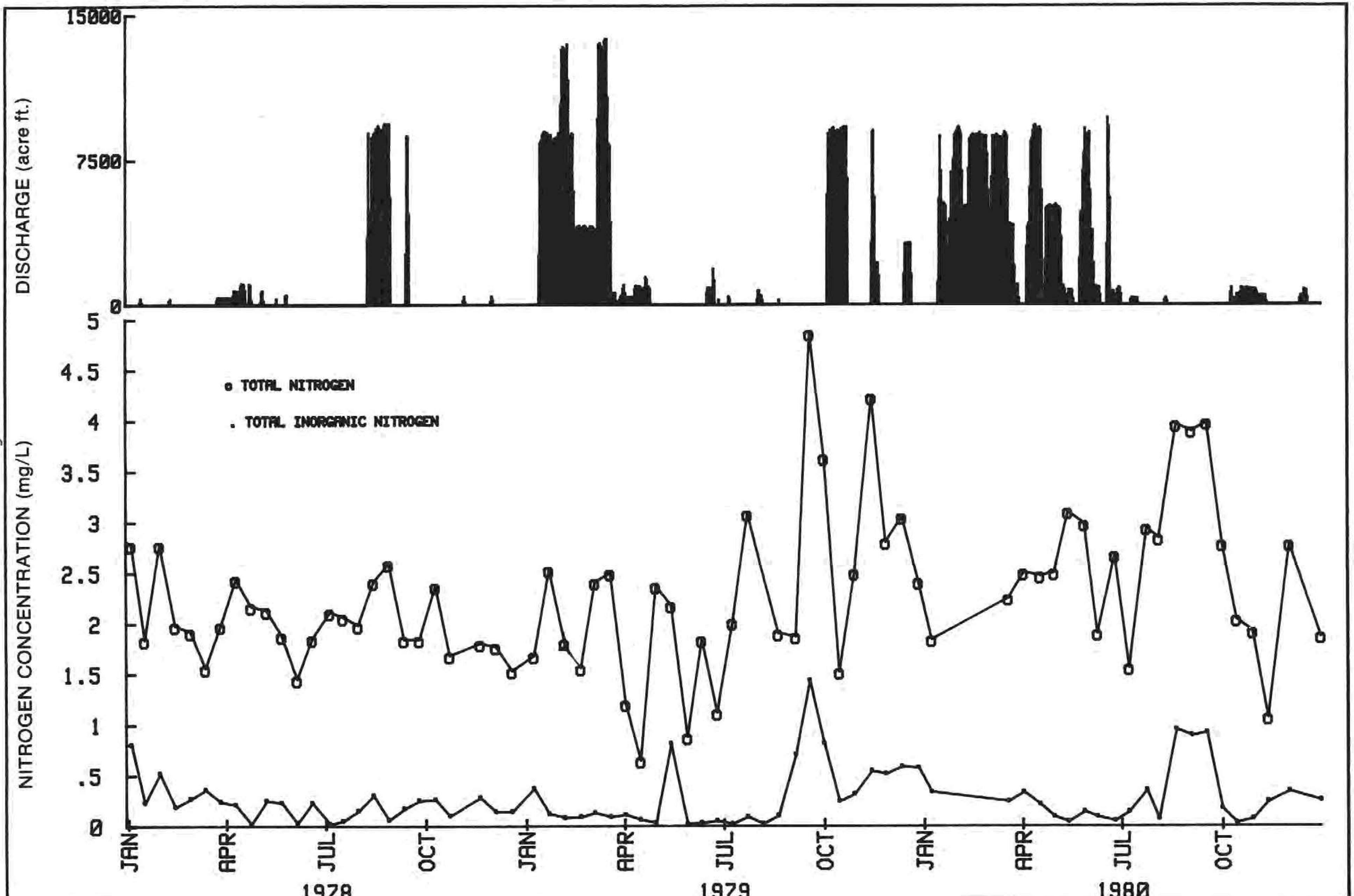


Figure 22 NITROGEN CONCENTRATIONS AND DAILY DISCHARGE AT S-77

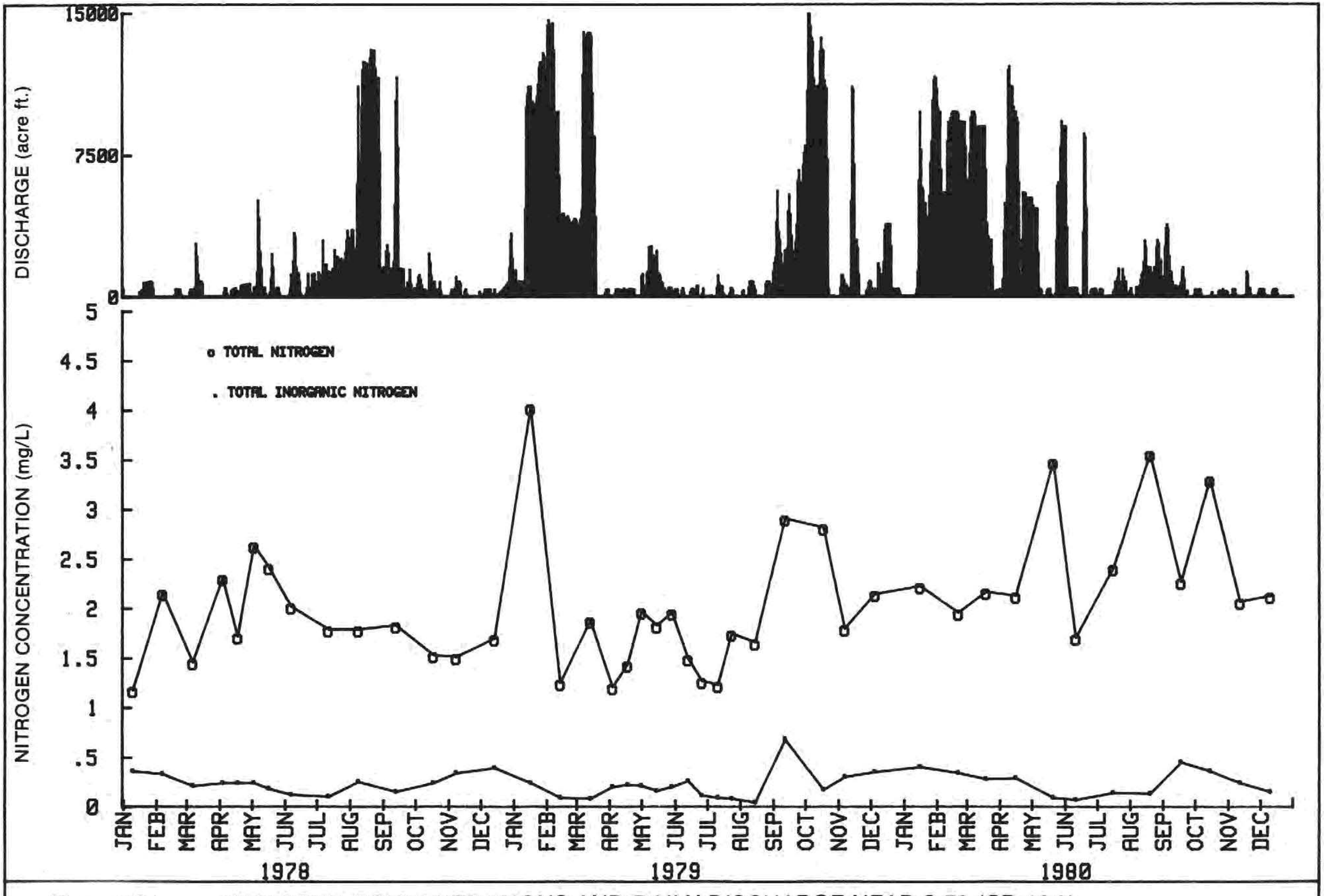


Figure 23 NITROGEN CONCENTRATIONS AND DAILY DISCHARGE NEAR S-78 (CR-16.0)

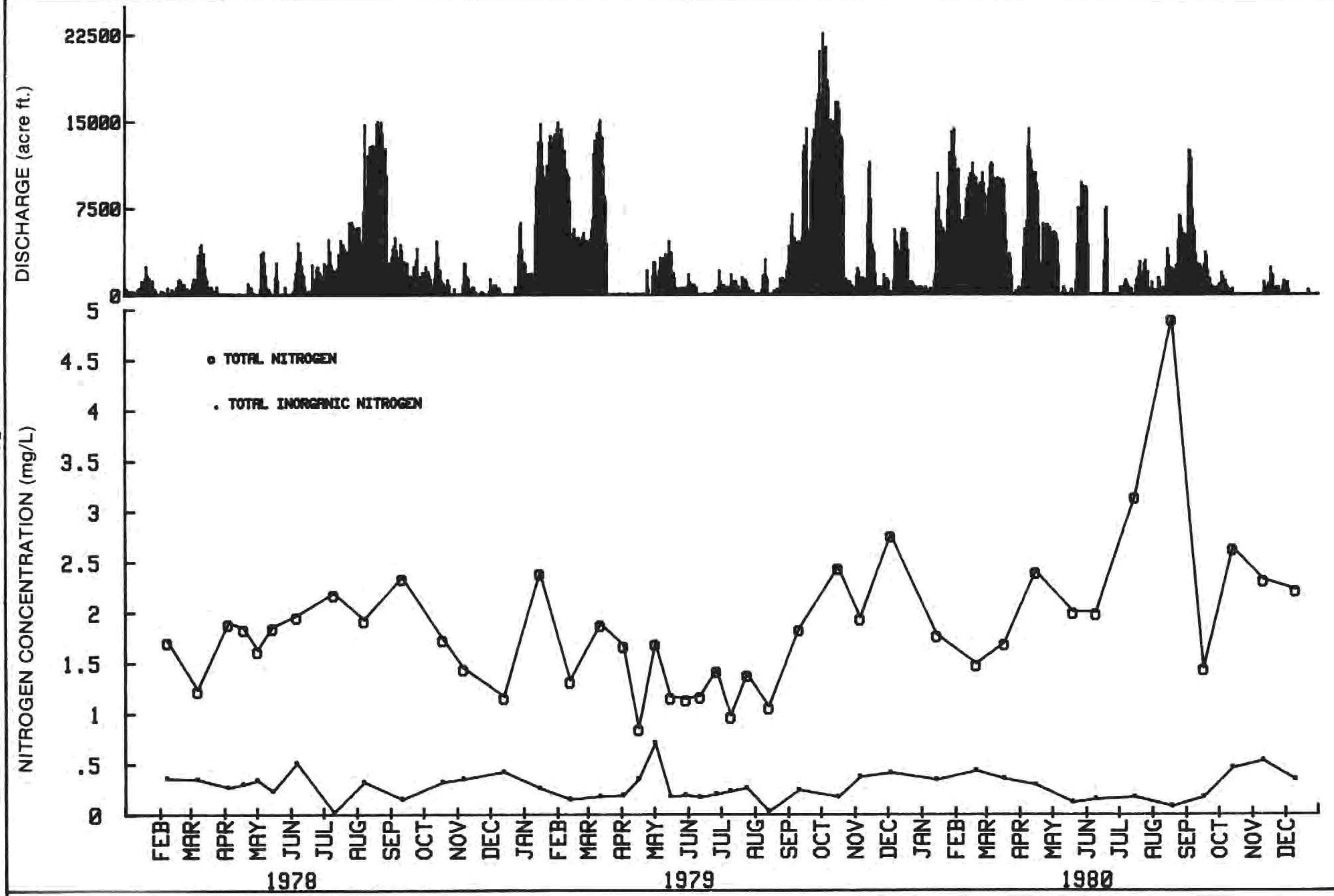


Figure 24 NITROGEN CONCENTRATIONS AND DAILY DISCHARGE AT S-79 (CR-40.3)

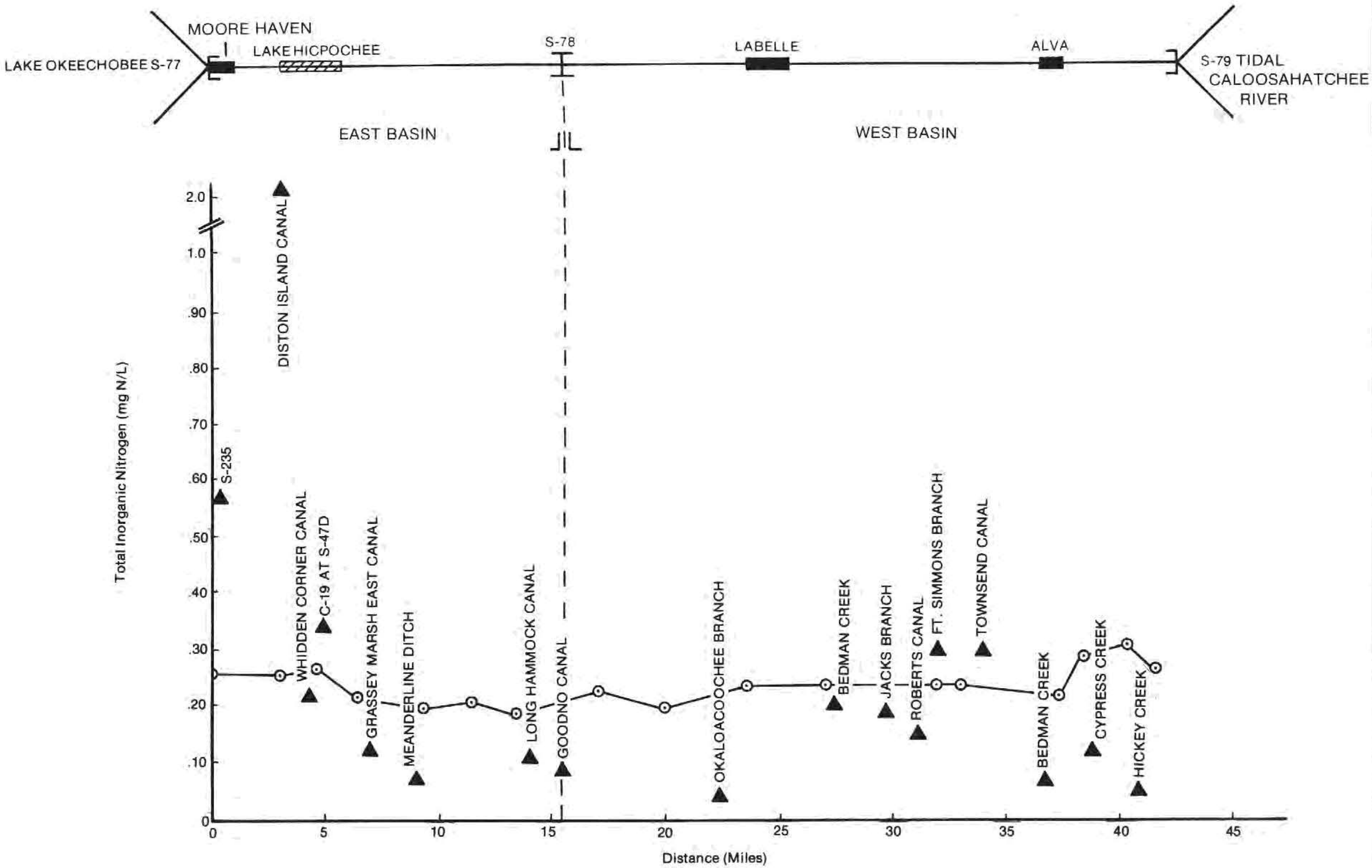


Figure 25 AVERAGE INORGANIC NITROGEN ALONG THE CALOOSAHATCHEE RIVER

The relatively consistent levels of inorganic nitrogen along the river do, however, mask an inverse relationship between ammonia and nitrate along the river (Figure 26). The highest average ammonia values were at S-77 and in the tributaries draining organic soils adjacent to Lake Okeechobee and Lake Hicpochee. Overall, ammonia levels declined rapidly from the Lake Okeechobee area through Lake Hicpochee and generally remained low throughout the remainder of the river. Station CR-04.5 was higher than either the upstream or downstream station, probably as a result of the influence of C-19 discharges on the Caloosahatchee River. A slight increase was noted in the four mile stretch of the river upstream of S-79. However, the ammonia levels in the water discharged to the tidal reach of the river were still about two-thirds less than the levels at S-77. The influence of the tributaries as well as the chemical oxidation and biological assimilation of ammonia probably accounted for the reduction in ammonia levels within the river.

The nitrate concentration increased as the distance from Lake Okeechobee increased. The lowest average nitrate concentration (0.084 mg/L) in the river was at S-77. The river nitrate levels were slightly higher than those for S-77, but generally remained unchanged through the East Basin. In the West Basin, the nitrate levels increased steadily until the general area of Alva where they increased dramatically. The nitrate concentration in the waters discharged to the tidal reach of the river were over 2.5 times greater than the nitrate concentration of waters entering the river at S-77.

<u>Chloride</u>: The spatial variations in the chloride levels of the river were opposite to those displayed by phosphorus. The average chloride concentrations decreased slightly from S-77 to S-78 and the increased slightly from S-78 to S-79 (Figure 27). Again, the tributary inputs appear to account for the majority of this variation. Tributaries in the East Basin usually had lower

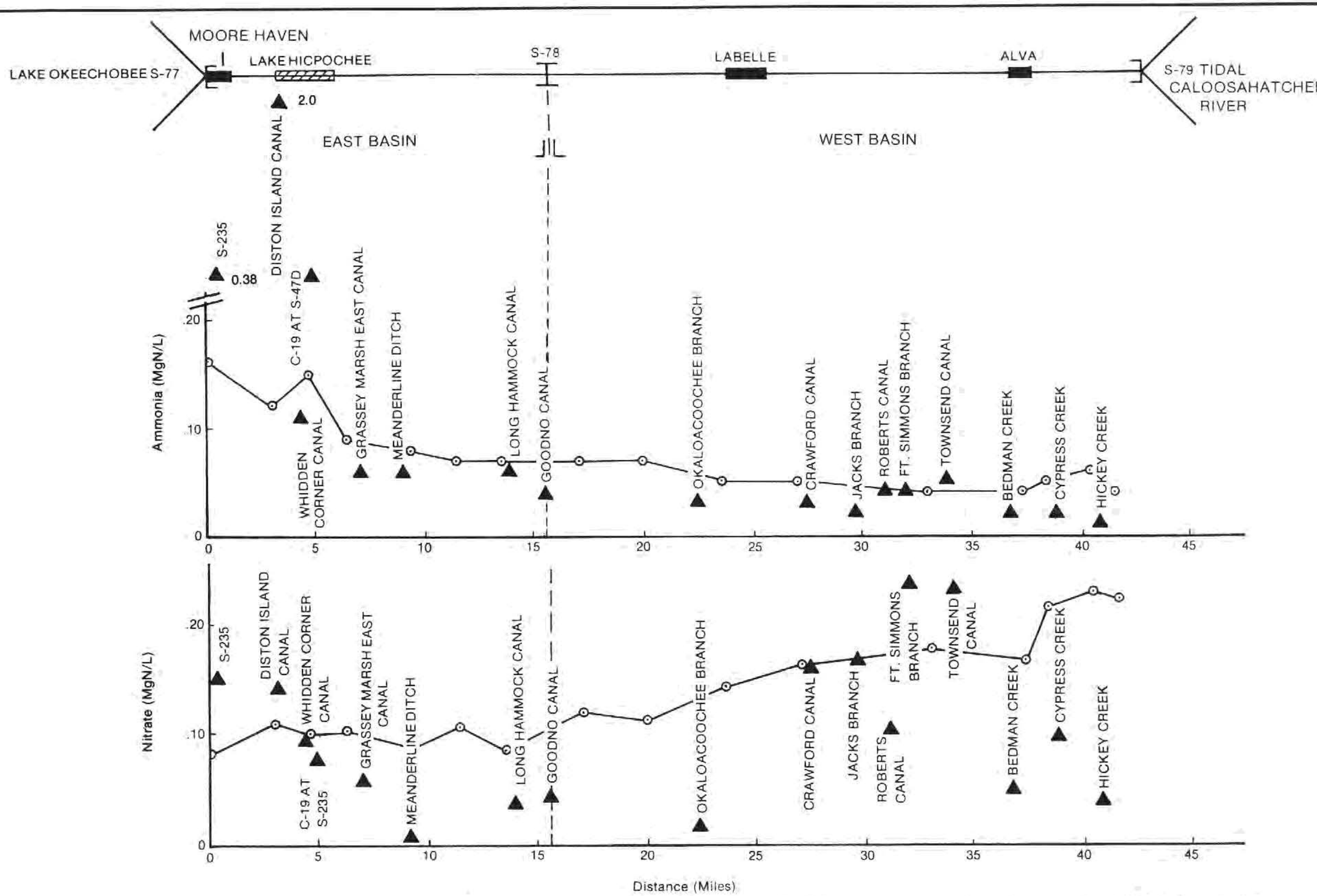


Figure 26 AVERAGE NITRATE AND AMMONIA LEVELS ALONG THE CALOOSAHATCHEE RIVER

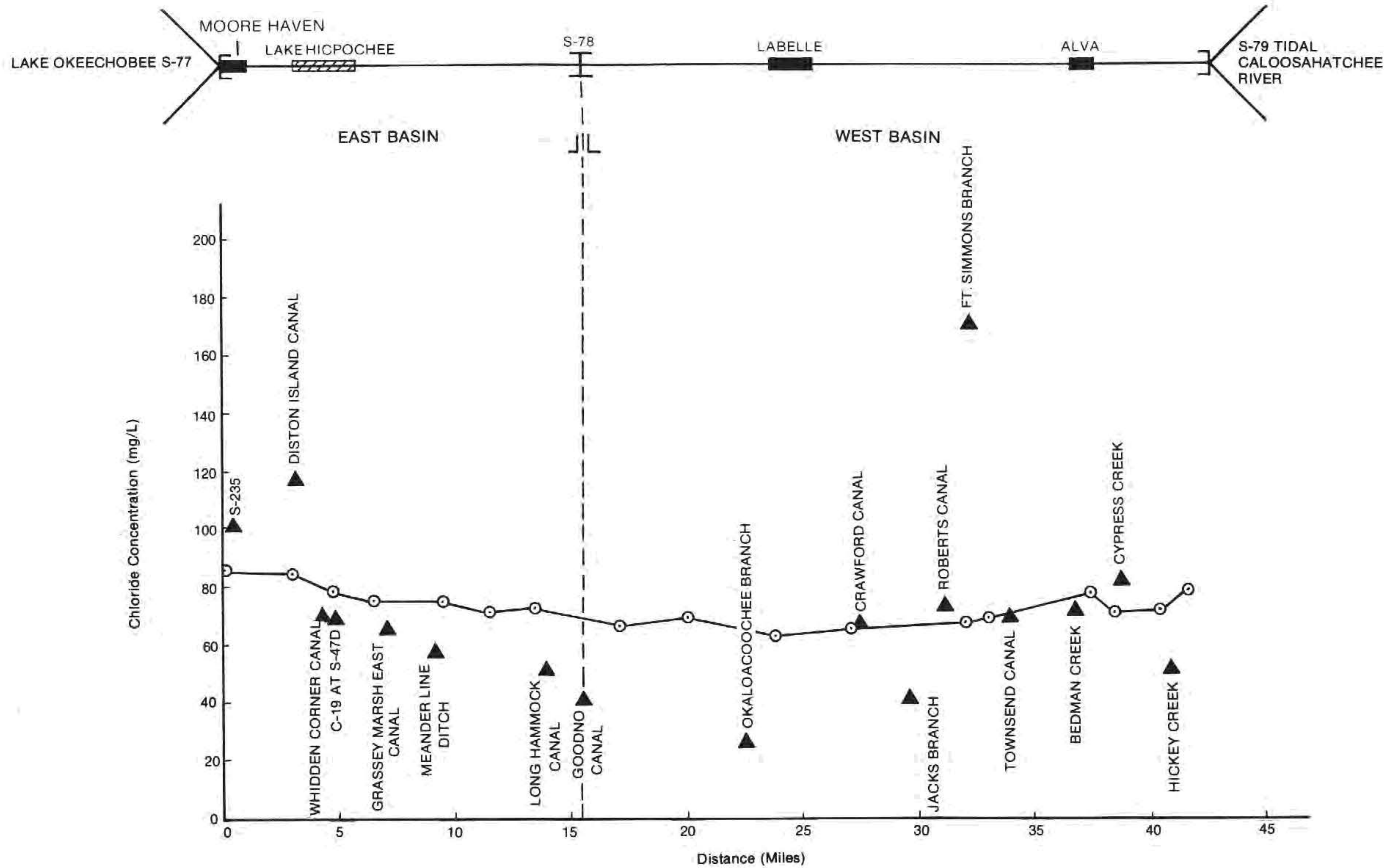


Figure 27 AVERAGE CHLORIDE ALONG THE CALOOSAHATCHEE RIVER

average chloride levels than the river except near Lake Okeechobee. Tributaries in the West Basin displayed generally higher average chloride levels than the tributries in the East Basin. Chloride levels in the water discharged by the river at S-79 were, on the average, lower than those in the river at S-77.

The chloride concentrations recorded at S-77, S-78, and S-79 during the study are plotted in Figures 28, 29, and 30, respectively. These data, also summarized in Table 16, indicate that the chloride concentrations at all three structures were only slightly lower in the summer than in the winter.

PROFILE CHARACTERISTICS OF THE CALOOSAHATCHEE RIVER

Routine depth profile measurements were made at two meter intervals in the mainstream of the Caloosahatchee River for pH, specific conductance, temperature, and dissolved oxygen. Table 17 summarizes the river depth profile data collected between 1978 and 1980. The average and range of values for temperature, specific conductance, and pH remained fairly constant with depth. This was confirmed by the relatively consistent standard deviation value calculated for each depth. The dissolved oxygen concentrations decreased as the depth increased and were also more variable at the greater depths.

River stations CR-06.0 and CR-30.4 were selected for a detailed profile review since each appeared to represent the quality of water in the East and West Basin, respectively.

Since the rate of flow and the time of year may considerably influence the levels of pH, temperature, specific conductance, and dissolved oxygen it was necessary to consider these influences. Depth profiles measured during extreme cases of minimum and maximum flows in the winter and summer periods were selected for discussion. August 1978 (5,000 acre-feet/day) and February

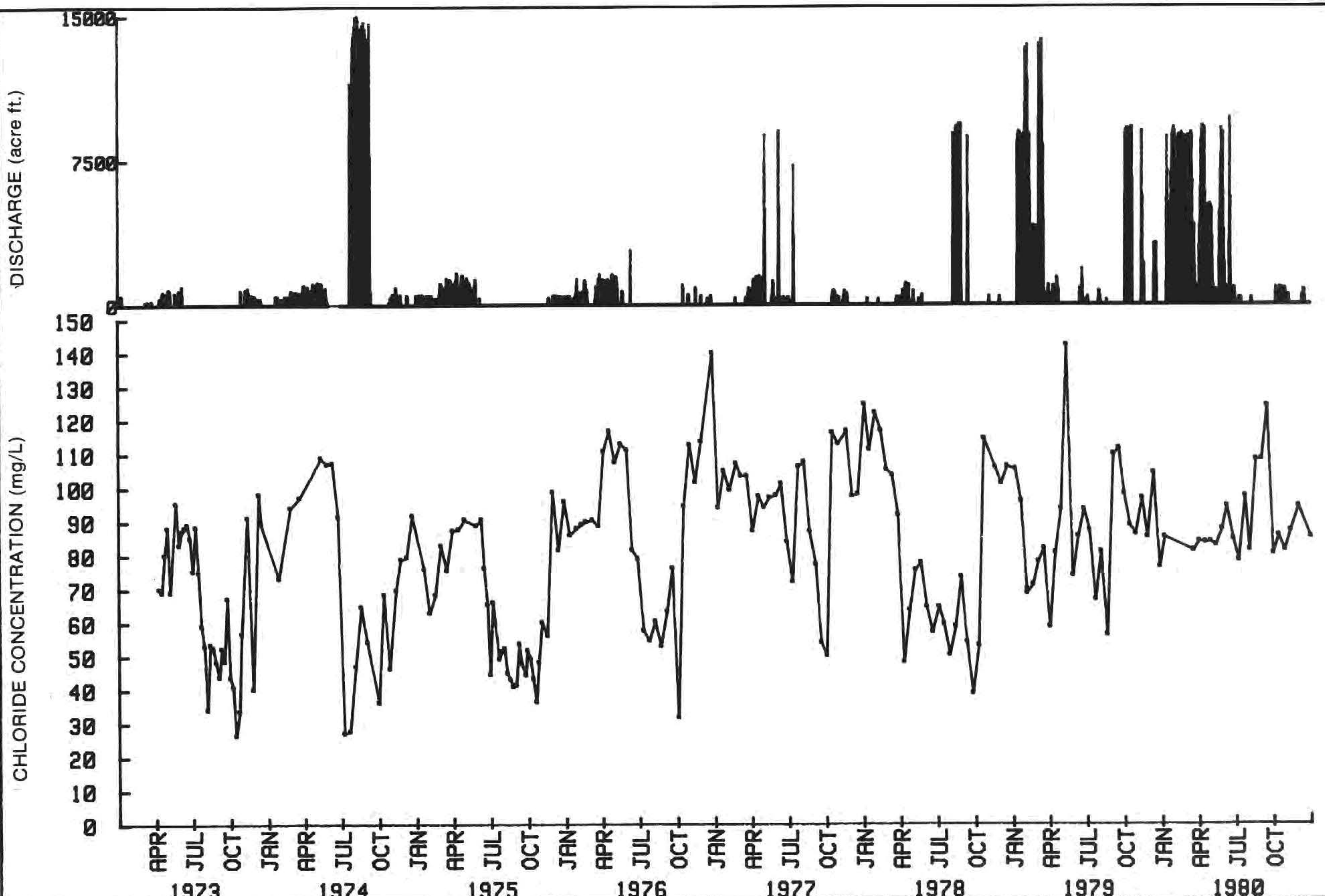


Figure 28 CHLORIDE CONCENTRATION AND DAILY DISCHARGE AT S-77

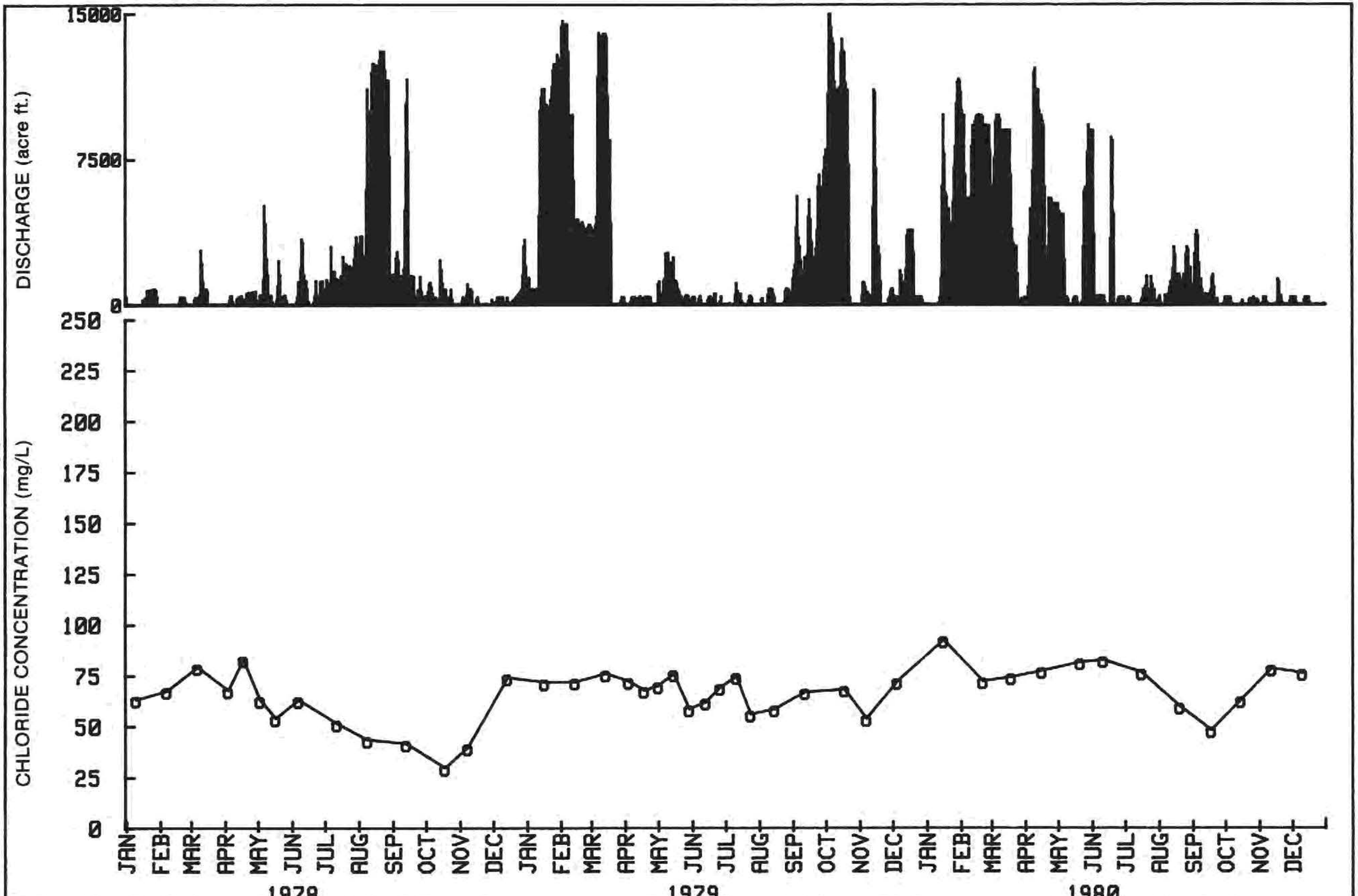


Figure 29 CHLORIDE CONCENTRATION AND DAILY DISCHARGE NEAR S-78 (CR-16.0)

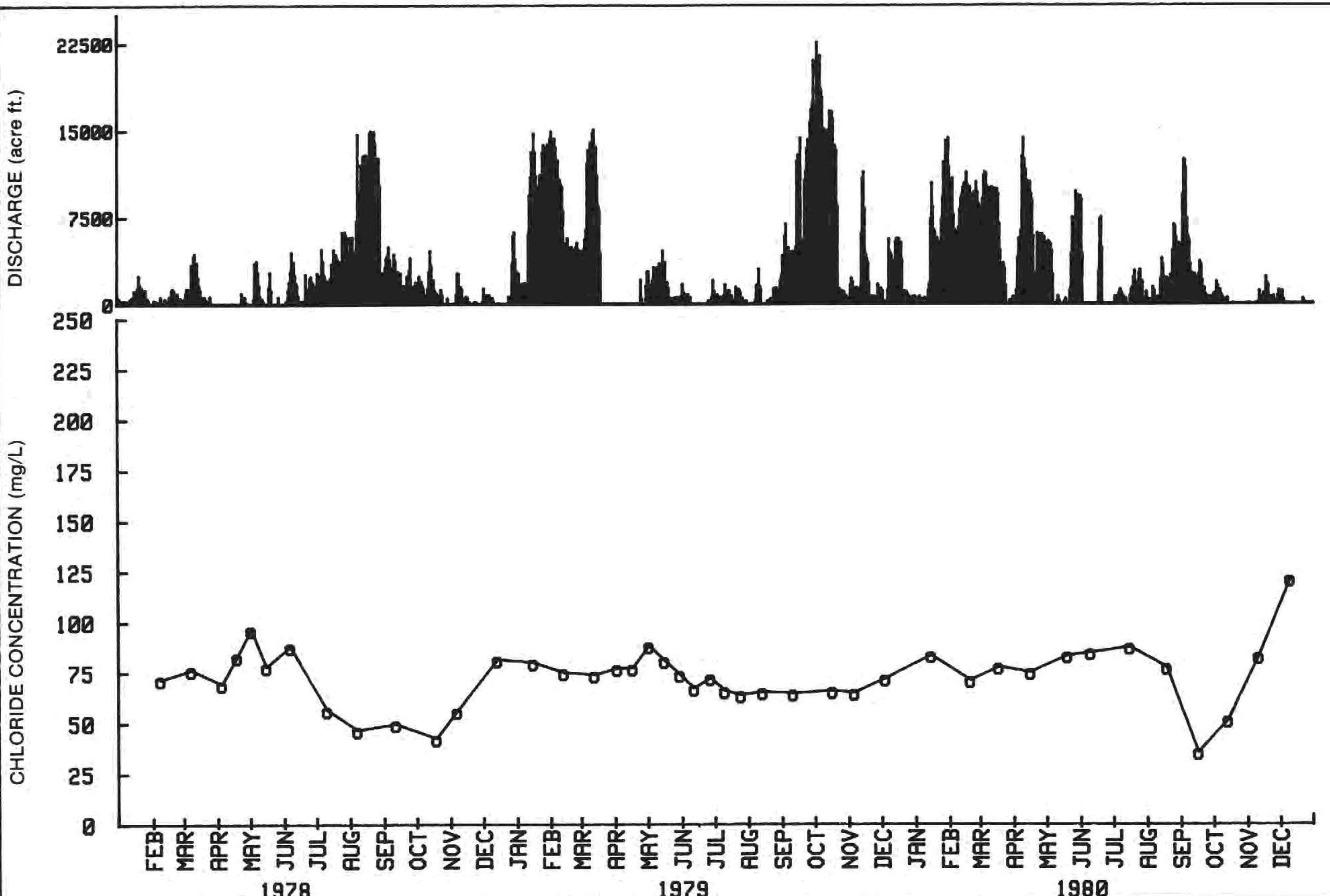


Figure 30 CHLORIDE CONCENTRATION AND DAILY DISCHARGE AT S-79 (CR-40.3)

TABLE 17. SUMMARY OF RIVER DEPTH PROFILE DATA INCLUDING THE RANGE OF VALUES AND THE AVERAGE CONCENTRATION

Temperature, °C

Depth Meters	No. of Values	Average Concentration	Standard Deviation	Range Min. - Max
0	659	25.4	4.5	15.2 - 33.0
2	604	24.6	4.3	15.1 - 30.9
4	604	24.4	4.3	15.1 - 30.6
6	426	24.4	4.2	15.5 - 30.5
All depths	2949	24.6	4.3	15.1 - 33.0

Specific Conductance, micromhos/cm at 25°C

Depth Meters	No. of Values	Average Concentration	Standard Deviation	Range Min. - Max
0	622	578	98	266 - 990
2	616	579	98	266 - 1000
4	615	579	98	270 - 1000
6	424	583	92	298 - 864
All depths	2947	585	114	266 - 1000

Dissolved Oxygen, mg/L

Depth Meters	No. of Values	Average Concentration	Standard Deviation	Range Min. - Max
0	626	6.3	1.7	0.4 - 12.1
2	620	5.8	1.6	0.2 - 9.8
4	619	5.4	1.7	0.2 - 9.6
6	426	4.7	2.0	0.1 - 9.3
All depths	2965	5.3	2.0	0.1 - 12.1

pH, Standard Units

Depth Meters	No. of Values	Average Concentration	Standard Deviation	Range Min. - Max
0	588	7.4	0.3	6.3 - 8.6
2	581	7.4	0.3	6.0 - 8.6
4	580	7.3	0.3	6.0 - 8.7
6	401	7.2	0.3	6.3 - 8.9
All depths	2783	7.3	0.3	6.0 - 8.9

1980 (8,000 acre-feet/day) were selected for the maximum flow periods; while February 1978 and June 1979 (flows less than 212 acre-feet/day) represent the minimum flow periods. The profile data and corresponding flows for these dates are presented in Figures 31 and 32.

The pH of the water was only slightly greater during the winter than during the summer. The effects of flow appear negligible and the river pH levels were well mixed, as indicated by the depth profiles at these two stations.

Specific conductance at both stations showed some effects of season and flow, but remained uniform in all instances. The specific conductance at both stations exhibited higher levels during the winter and during low flow conditions (Figures 31 and 32).

The water temperature in the river was seasonal with higher values occurring during the summer months. The temperature profiles did not appear to be altered by the flow characteristics in the summer. During the winter, though, the water temperature appeared higher when the flow was high (Figures 31 and 32). This may, however, be an artifact of the comparative differences between the 1978 and 1980 ambient air temperatures rather than flow.

Of the four variables considered, the dissolved oxygen depth profiles were most responsive to the flow and time of year. In both the East and West Basins the dissolved oxygen concentrations at each depth were greater during the winter case than during the summer case (Figures 31 and 32). During the winter, the dissolved oxygen concentrations were relatively constant with depth during both the high and low flow cases. However, during the summer high flow the dissolved oxygen gradients which were evident during summer low flow conditions were eliminated.

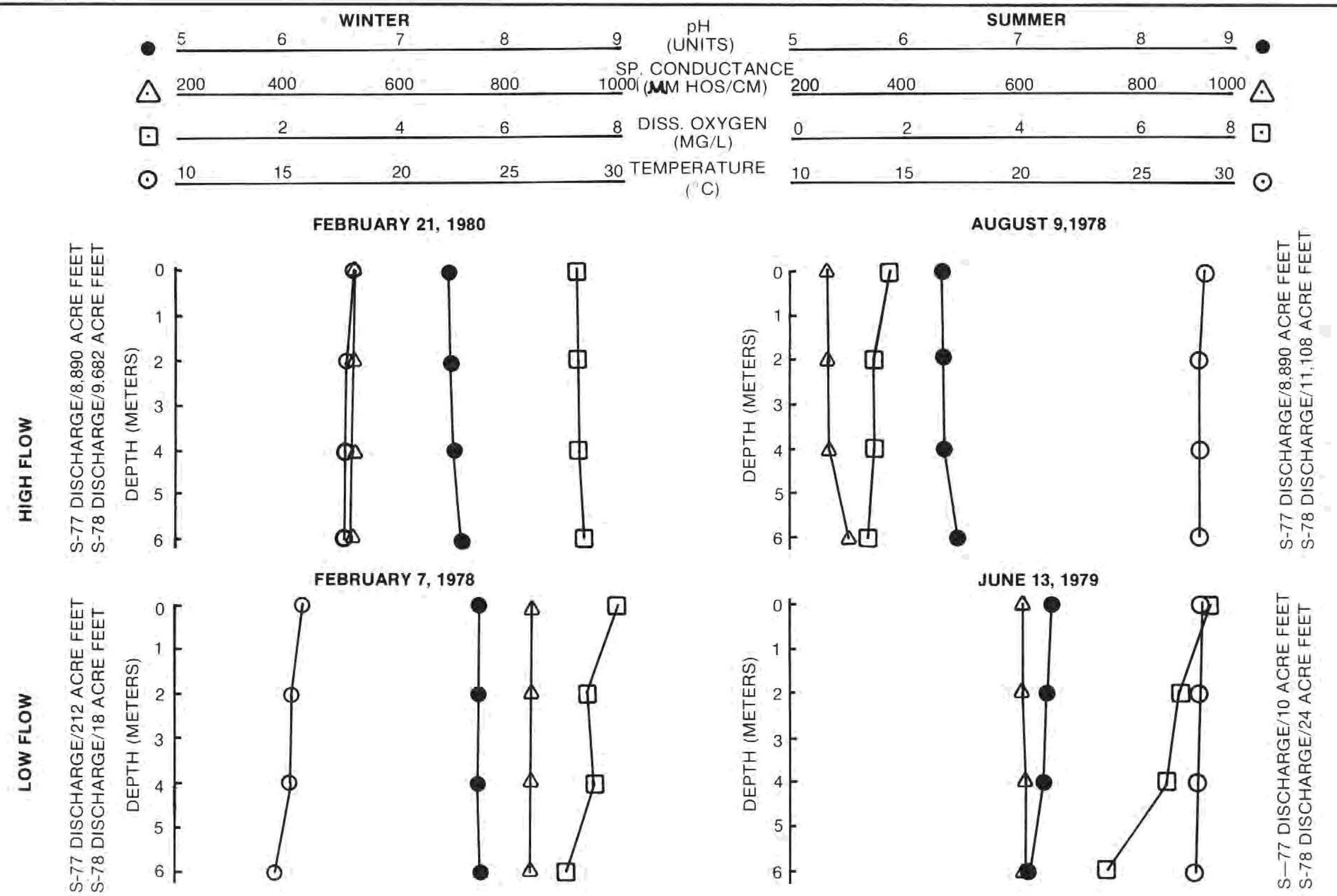


Figure 31 SEASONAL DEPTH PROFILES AT STATION CR-06.0 DURING A HIGH AND LOW FLOW PERIOD

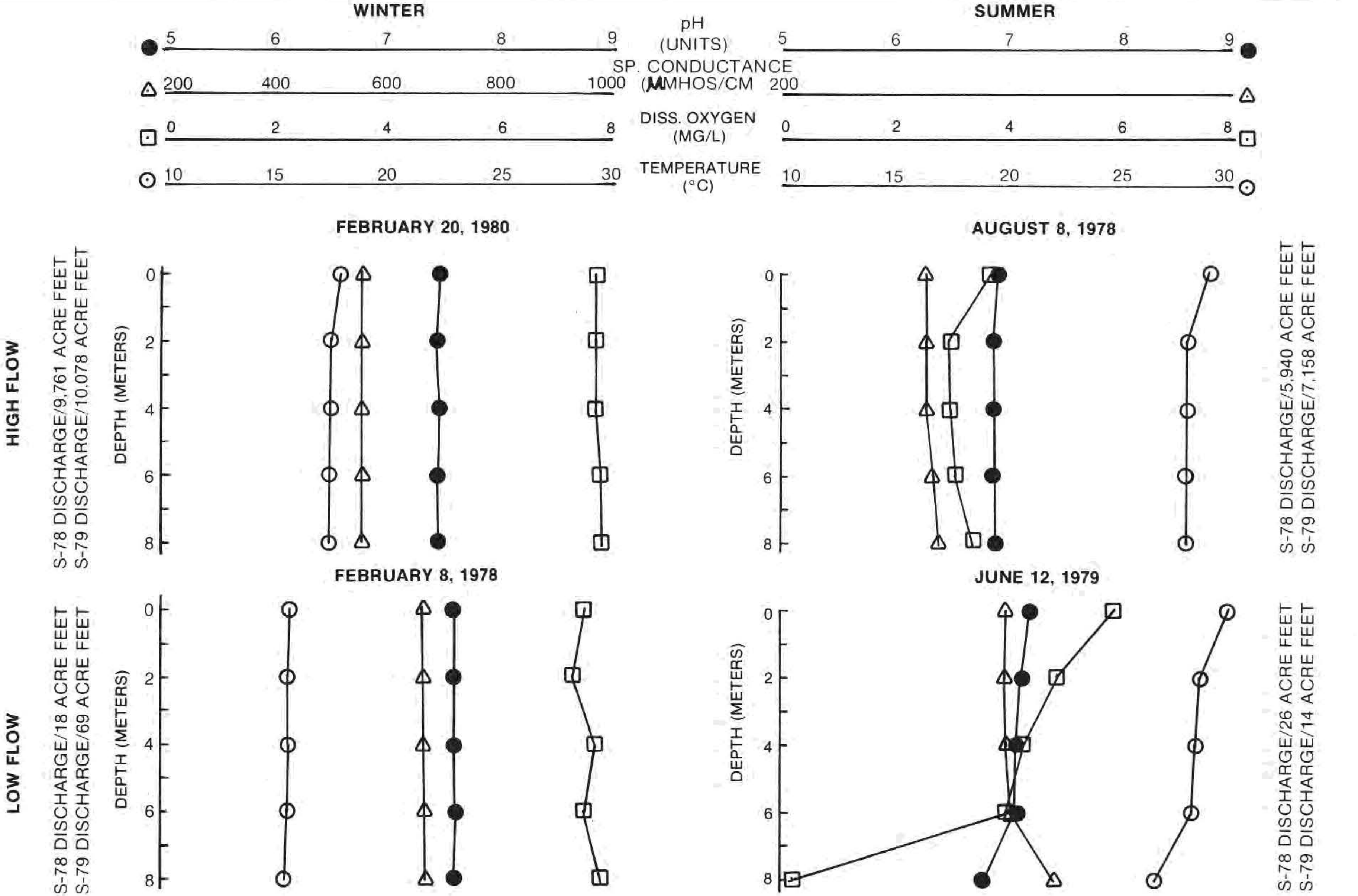


Figure 32 SEASONAL DEPTH PROFILES AT STATION CR-30.4 DURING A HIGH AND LOW FLOW PERIOD

Figures 33 and 34 represent a depth/time diagram of the dissolved oxygen isopleths which better illustrate the seasonal changes in the depth profiles. The dissolved oxygen concentrations were generally high (6-8 mg/L) throughout the water column from October to early Spring. The dissolved oxygen levels began declining in the summer wet season months with very low oxygen levels noted between 6 and 8 meters. This cycle was repeated for each of the three years and was most pronounced in 1978 and 1980.

At station CR-06.0, the dissolved oxygen concentrations were lowest on the surface and bottom with relatively higher concentrations at mid-depths. The low surface dissolved oxygen value at station CR-06.0 is suggestive of warmer, less oxygenated water entering from Lake Hicpochee.

SUMMARY

Phosphorus increased between S-77 and S-78, then decreased toward S-79. Tributary inputs appear to be the major factor influencing river phosphorus levels. Generally, water entering the river at S-77 had less phosphorus than water exiting at S-79. Total nitrogen and its components (except nitrate) decreased from S-77 to S-79. Nitrate increased between S-77 and S-79. Spatial variations in chloride levels were opposite to those displayed by phosphorus with levels decreasing between S-77 and the area of LaBelle, then increasing toward S-79. This is the same trend exhibited by specific conductance.

The pH and temperature of water in the East and West Basins did not change along the river, or with depth, and the effects of discharge appeared to be negligible. Specific conductance levels generally declined from Lake Okeechobee to the area of LaBelle, then increased toward S-79. Depth profiles indicated that during this study specific conductance remained vertically well

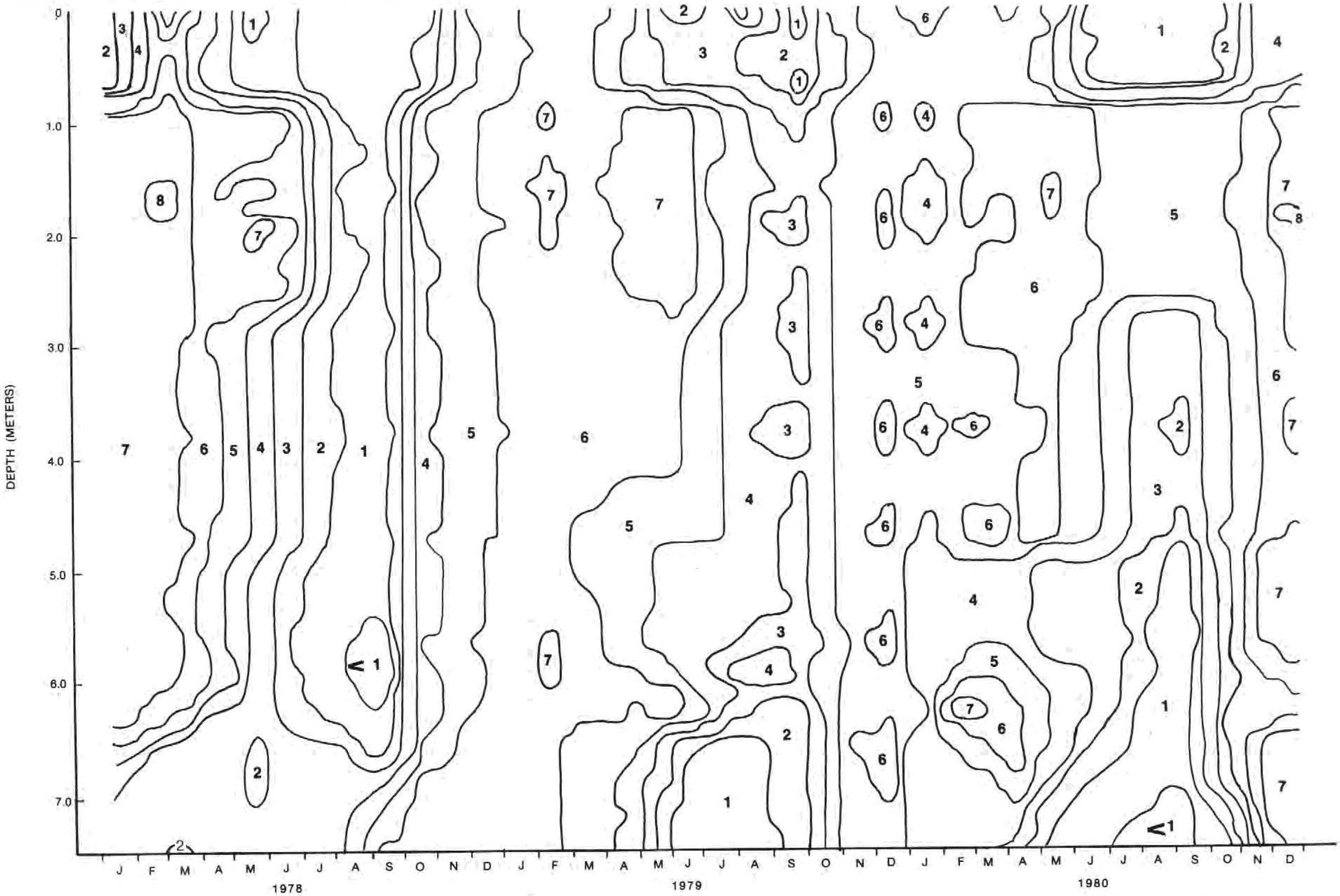


Figure 33 DEPTH-TIME DIAGRAM OF ISOPLETHS OF DISSOLVED OXYGEN CONCENTRATION IN MILLIGRAMS•LITER^{-1} AT STATION CR-06.0 EAST BASIN 1978-1980

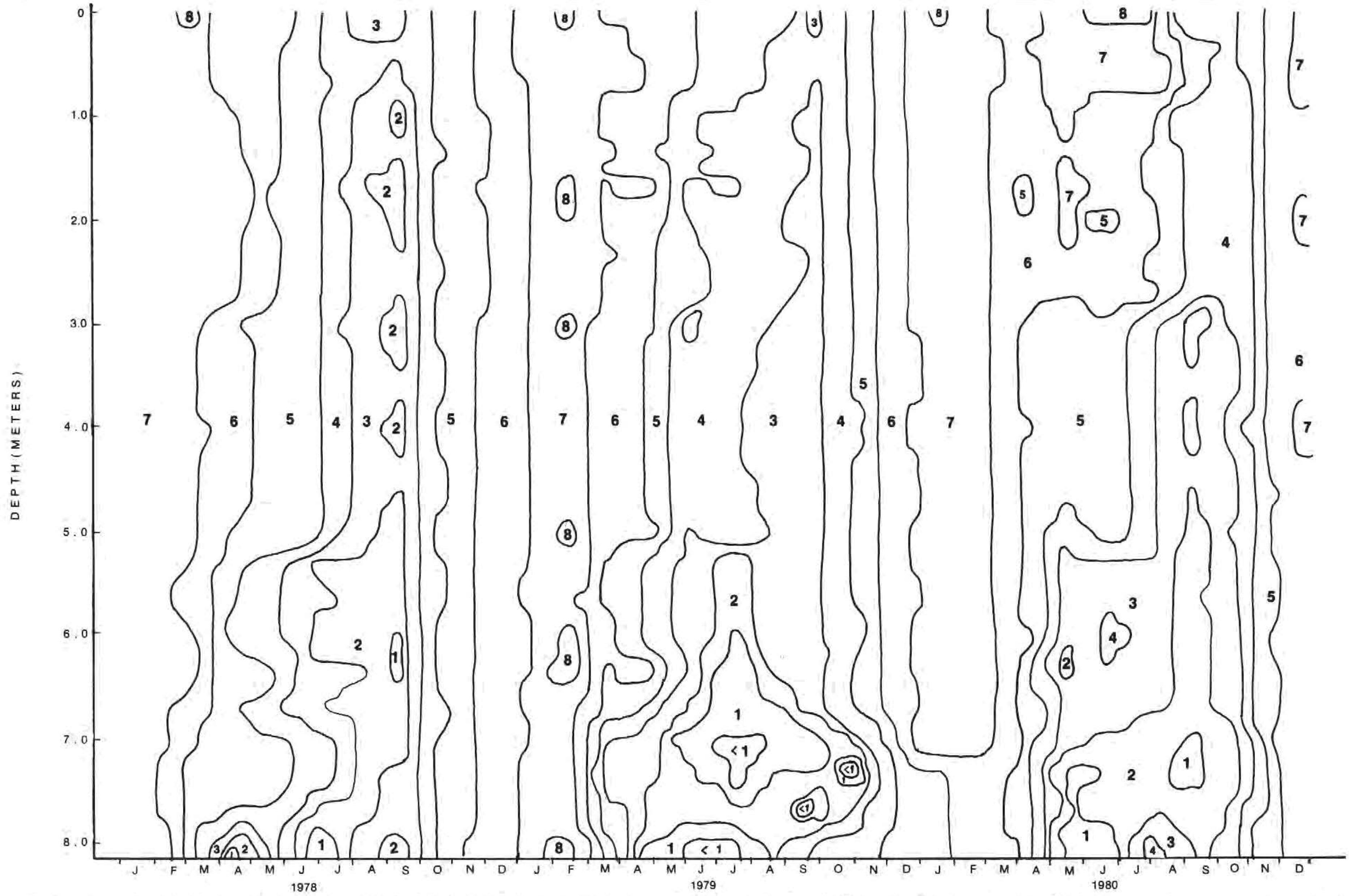


Figure 34 DEPTH-TIME DIAGRAM OF ISOPLETHS OF DISSOLVED OXYGEN CONCENTRATION IN MILLIGRAMS • LITER $^{-1}$ AT STATION CR-30.4 WEST BASIN 1978-1980

mixed regardless of season or flow. The accumulation of saline waters from the tidal reach of the West Basin (Boggess, 1968, 1972) was not evident during this study, probably as a result of high discharge. The dissolved oxygen concentrations at each depth were greater during the winter than during the summer in both basins. Flow appeared to eliminate any concentration gradients such as occurred during summer low flow periods. During the summer, the dissolved oxygen levels were usually low with very low levels between 6 and 8 meters deep.

PART IV

CHLOROPHYLL A

INTRODUCTION

Plankton are microscopic organisms which are suspended in a body of water and are not capable of sustained mobility. Phytoplankton is the assemblage of photosynthetic unicellular and colonial freshwater algae, which includes the common groups of green algae, blue-green algae, diatoms and dinoflagellates, among others. When phytoplankton populations increase to the point that they are visually noticeable by the greenish coloration or obvious accumulation of cells at the water surface, this is generally referred to as an algal bloom or plankton bloom.

District personnel investigated a massive algal bloom in the western portion of C-43, adjacent to the Lee County Water Treatment Plant, in early June 1976 and reported that the bloom consisted of blue-green algae dominated by *Anabaena flos-aquae* and *Microcystis aeruginosa* with chlorophyll *a* concentrations of 753 mg/m^3. During this bloom, taste and odor problems developed in the water supply system and a health hazard was feared when several cases of nausea and intestinal discomfort were reported (Marshall, 1976). Nearly 5000 acre-feet of water were released from Lake Okeechobee during June 10-11, 1976 to flush this bloom to tidal water. Other plankton blooms occurred near the Lee County Treatment Water Plant in May, June, and July 1977 for which larger fresh water releases were made. Consequently, a coordinated effort was made by the District to examine phytoplankton levels in the Caloosahatchee River in association with water quality characteristics.

Chlorophyll *a* concentration was used as an indicator of phytoplankton levels in C-43 because (a) it is the most important photosynthetic pigment in most groups of freshwater phytoplankton, (b) it is a readily measurable parameter using standard laboratory techniques, (c) a large number of samples can be collected in the field and analyzed in the laboratory in a relatively short period of time, (d) chlorophyll a concentrations are widely reported in the literature and can be used for comparative purposes, and (e) chlorophyll a concentrations are utilized in several schemes which indicate the trophic state of water bodies in Florida (Brezonik et al., 1969; Shannon and Brezonik, 1972).

The Caloosahatchee River experienced a variety of water flow regimes during the course of this study, ranging from riverine to reservoir-like. Since C-43 is designed to provide for a variety of functions (providing an outlet for Lake Okeechobee regulatory releases; accepting and transporting basin stormwater runoff; and providing water supply for irrigation and domestic purposes), the hydrologic flow conditions do not necessarily follow seasonal rainfall patterns. For example, regulatory releases from Lake Okeechobee can cause substantial flows in C-43 for extended periods of time. This condition has occurred in the wet season (August-September 1974) and more recently during the dry season (January-March 1979; January-May 1980). During such periods, chlorophyll a levels measured in C-43 can be greatly influenced by conditions in Lake Okeechobee. However, during some rainfall deficient periods, the residence time of water within each basin (estimated as the number of days required for an amount of water equal to the volume of the pool to pass through the downstream control structure) may be several months and the system functions as a reservoir. Consequently, an understanding of the hydrologic conditions prior to and during sampling periods is prerequisite to data interpretation.

The results and discussion of chlorophyll a sampling are presented in three sections in this part. Section 1 is limited to the chlorophyll a and selected water quality parameters from routine, monthly sampling during the three year study period. This limitation provides equal sampling periodicity for the assessment of trends. This section discusses the vertical, spatial, and seasonal distribution of chlorophyll a in C-43, and relates the seasonal distribution to selected physical and chemical characteristics of the water.

Section 2 presents the results of more frequent sampling for chlorophyll a and water quality parameters during the spring and summer months of each year in anticipation of a major algal bloom. Its purpose is to show a detailed picture of the interrelated factors occurring during the critical phytoplankton growth period.

The third section contrasts the events surrounding known major algal blooms in the western portion of C-43 since 1976, and summarizes pertinent information in order to put this phenomena into a management perspective.

CHLOROPHYLL A DISTRIBUTION

Vertical Distribution

Detectable concentrations of chlorophyll a (>0.1 mg/m^3) were found throughout the water column during all sampling periods. In 1978, the distribution of chlorophyll a was examined in a vertical profile at each of the sampling stations. The results showed a gradually declining concentration of chlorophyll a from the water surface to the bottom. This gradient was most pronounced when the surface concentrations were highest (July and September). Vertical profiles were continued at only two stations in 1978 and 1980. Appendix D summarizes the vertical gradients in chlorophyll a concentrations at two stations during each year of the study.

Whereas a declining vertical gradient in chlorophyll a was usually evident, there were a number of occasions when the concentration of chlorophyll a increased with depth in the water column. This phenomena usually occurred when major releases were made through C-43, but was otherwise unexplainable.

Surface water concentrations of chlorophyll a best depict algal bloom conditions and are of the most concern to this investigation; therefore, further discussion will be limited to chlorophyll a levels measured at the water's surface.

Spatial Distribution

Examination of chlorophyll a levels along the 41 mile length of C-43 during the three year study period indicated a distinct spatial trend. Figure 35 shows the annual mean and overall mean chlorophyll a concentration at each station in C-43. In general, chlorophyll a concentrations were highest in the eastern pool (between S-77 and S-78) and decreased in a westerly direction. Two factors which may contribute to this general trend are water flow and water quality.

A decreasing gradient in chlorophyll a concentration from east to west in C-43 would be most expected during periods when there was considerable water flow, especially from Lake Okeechobee regulatory releases. Ruttner (1952) cites several investigations which demonstrate that plankton entering a river from a lake decrease quantitatively downstream, more rapidly as the current becomes stronger. When the residence time of water within C-43 is short, phytoplankton may not have sufficient time for reproduction as they are swept from east to west, and some cells settle out along the river's course. The data for January-March 1979 and February-April 1980 depict an east to west gradient (Appendix E). Additionally, basin runoff water entering C-43 has an initial diluting effect which can reduce chlorophyll a concentrations.

Water quality trends along C-43 were discussed in Part III for the three year study period. Since there was greater nitrogen and phosphorus enrichment in the East Basin tributaries than in the West Basin tributaries, the higher nutrient supply in the East Basin may have also contributed to higher chlorophyll a levels in the East Basin. Detailed discussion of the chlorophyll a and water quality relationships will be presented after the seasonal distribution section.

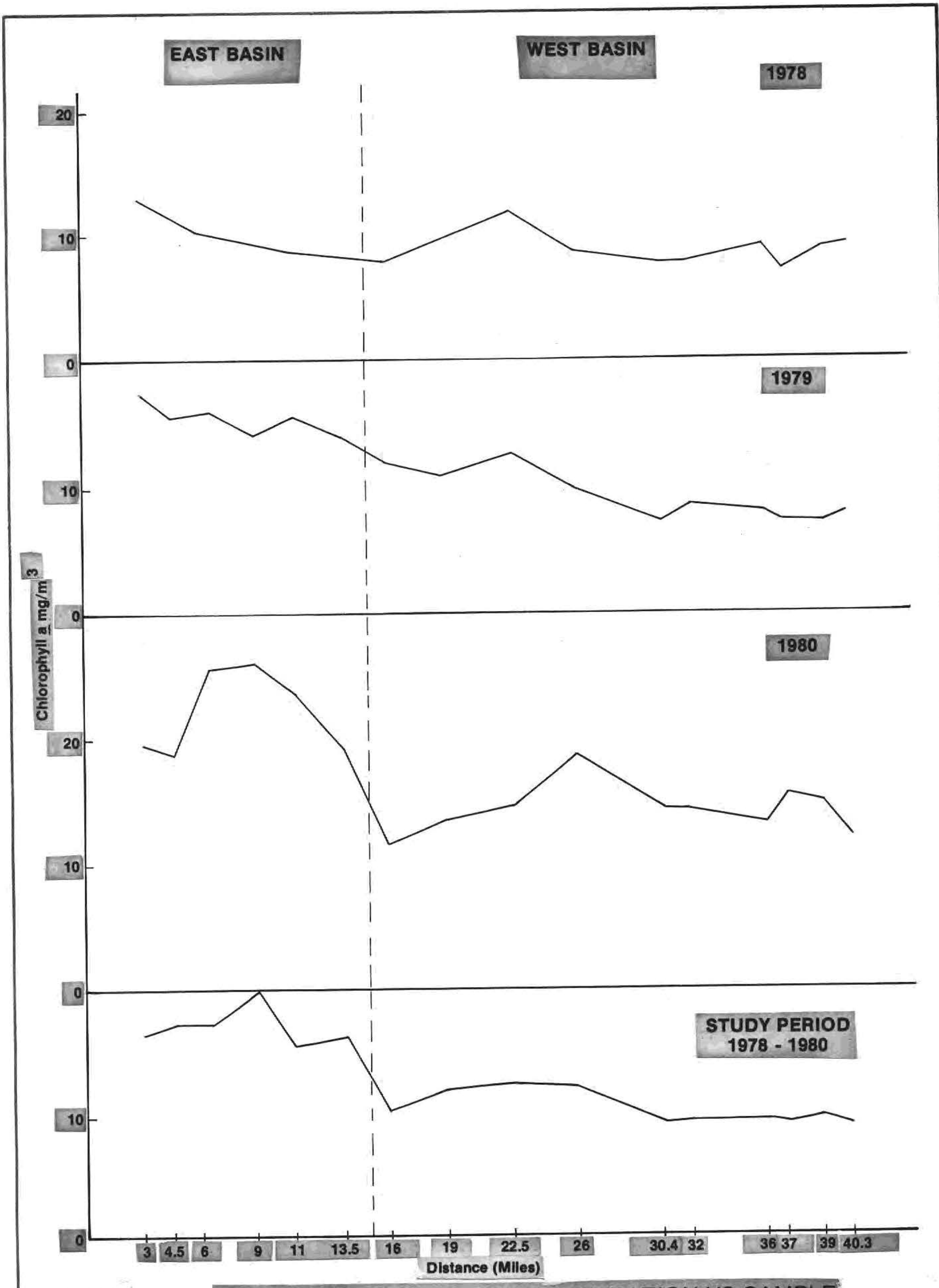


Figure 35 MEAN CHLOROPHYLL A CONCENTRATION VS SAMPLE STATION, 1978-1980

The Caloosahatchee River is divided into two distinct basins, with different water quality characteristics in the tributaries and somewhat different land use characteristics. Similarly, chlorophyll a concentrations were usually different between the East Basin and West Basin. Further examination of the data shows that there was generally a distinct difference between chlorophyll a levels in the East Basin and the West Basin. Mean chlorophyll a concentration in the East Basin was significantly higher than in the West Basin ($t_{.05}$) for 21 of 36 routine sampling trips, whereas the West Basin mean exceeded the East Basin mean only once (Appendix E).

Seasonal Distribution

Figure 36 shows the mean monthly chlorophyll a concentration for both East and West Basins for the three year study period. The overall trend exhibited by chlorophyll a in the Caloosahatchee River can be characterized as follows: relatively low concentrations (<10 mg/m^3) throughout the river during the autumn and winter (January-March and October-December); increasing concentrations during the spring; and summer maximum levels >20 mg/m^3. Regulatory discharges from Lake Okeechobee occurred mostly in the autumn and winter months of 1979 and 1980. During these releases, chlorophyll a concentrations were relatively low and differences between the East and West Basins were minimal.

Figure 36 also shows that during the spring and early summer months of 1978 (April-June) and 1979 (May-July), the seasonal increase in chlorophyll a was delayed in the West Basin as compared with the East Basin. During 1980, however, West Basin chlorophyll a levels increased dramatically from May to June. Some of the sharp reductions noted in chlorophyll a concentration corresponded with large discharges from Lake Okeechobee (August 1978) or basin runoff (September 1979 and September 1980) which effectively flushed the river phytoplankton and reduced residence time (See S-77, S-78, and S-79 hydrographs, Part II).

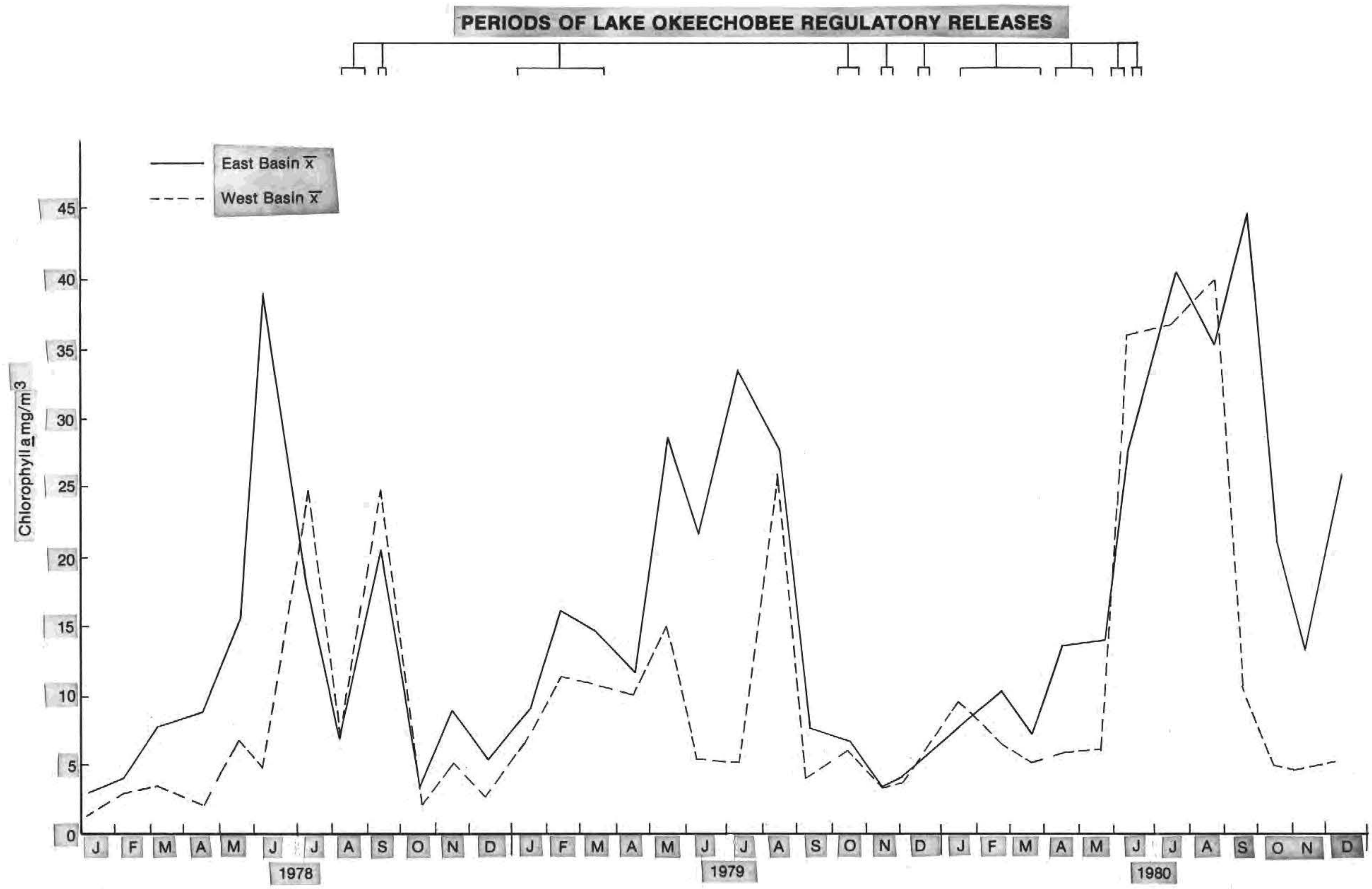


Figure 36 AVERAGE CHLOROPHYLL A CONCENTRATION DURING ROUTINE SAMPLING TRIPS IN THE EAST AND WEST RIVER BASINS

Chlorophyll a and Water Chemistry Trends

Figure 37 graphically compares the three year trends for phosphorus, nitrogen, and water temperature with chlorophyll a. Temperature and phosphorus concentrations (ortho and total phosphorus) exhibit similar trends to chlorophyll a concentrations, with peak values occurring during the summer months and minimum values in the winter months. However, ortho phosphorus concentrations were occasionally reduced during summer months, (for example, September 1978, August 1979, and June-July 1980) which may indicate biological assimilation. Water flow in C-43 can also be related to some water quality changes. The peak ortho phosphorus concentrations in September 1979 and September 1980 corresponded with increased basin flows and were derived from stormwater runoff.

Inorganic nitrogen concentrations (nitrite + nitrate + ammonia) generally exhibited an inverse relationship with chlorophyll a; i.e., the inorganic nitrogen concentration was lowest during the summer plankton growth period, and increased during the winter months. The September 1979 and September 1980 nitrogen peaks corresponded with periods of considerable stormwater runoff. Mean basin values for ammonia and nitrite + nitrate also plotted on Figure 37 show that ammonia was generally low in concentration and contributed only a small portion to the total inorganic nitrogen levels in the West Basin. In the East Basin the ammonia concentration was substantially higher, especially in January 1980.

Simple linear regression analysis was used to test for some of the trends suggested from a graphic examination of the data. The parameter of residence time was also tested as an independent variable. The results of these analyses (Table 18) show that only water temperature was consistently, positively correlated with chlorophyll a, whereas total inorganic nitrogen and nitrite + nitrate were negatively, or inversely, correlated with chlorophyll a. For both of these variables the relationships were significant but generally weak, indicating

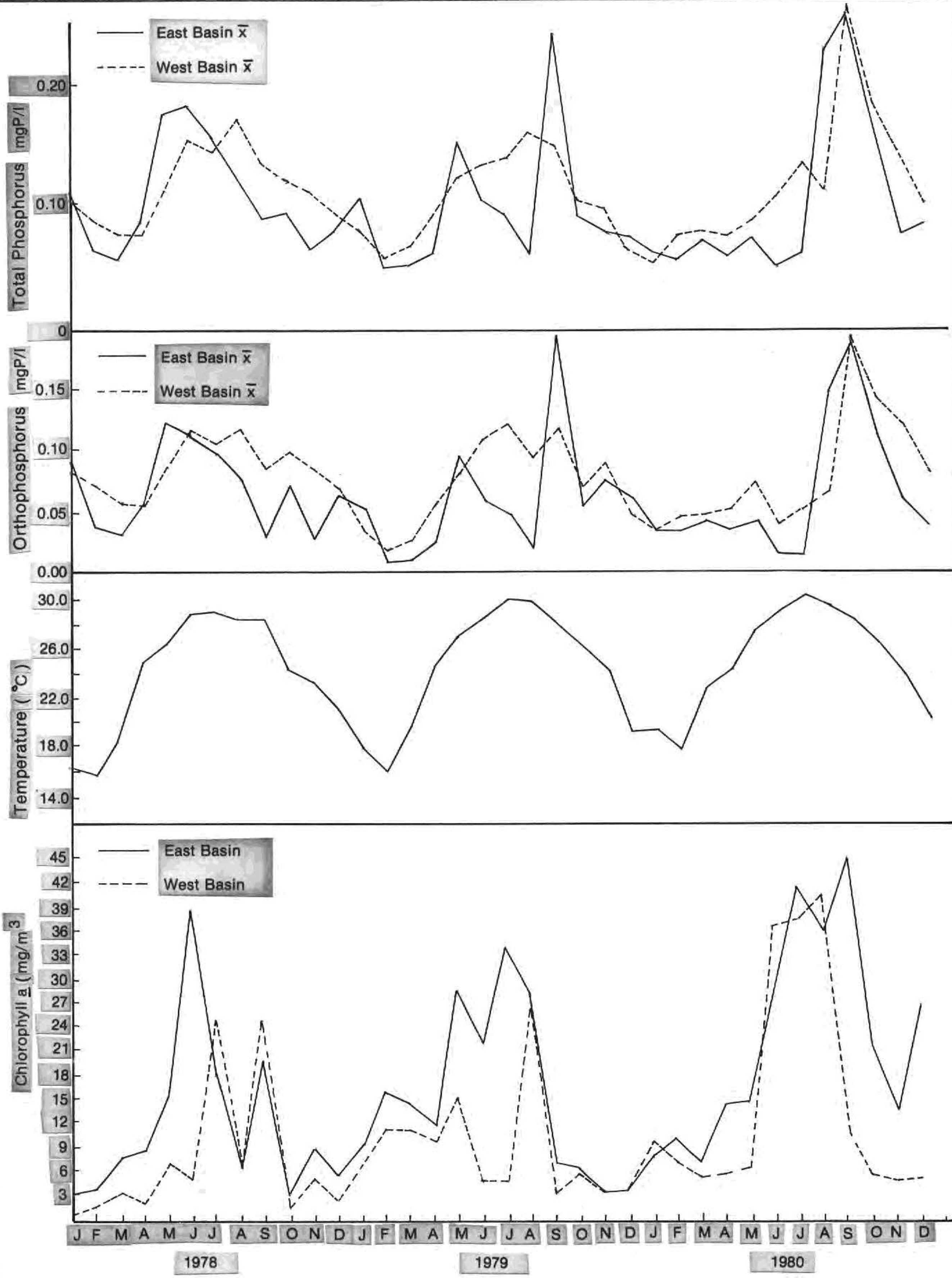


Figure 37A MEAN PHOSPHORUS, WATER TEMPERATURE AND CHLOROPHYLL A CONCENTRATIONS IN THE CALOOSAHATCHEE RIVER DURING ROUTINE SAMPLING TRIPS, 1978 - 1980

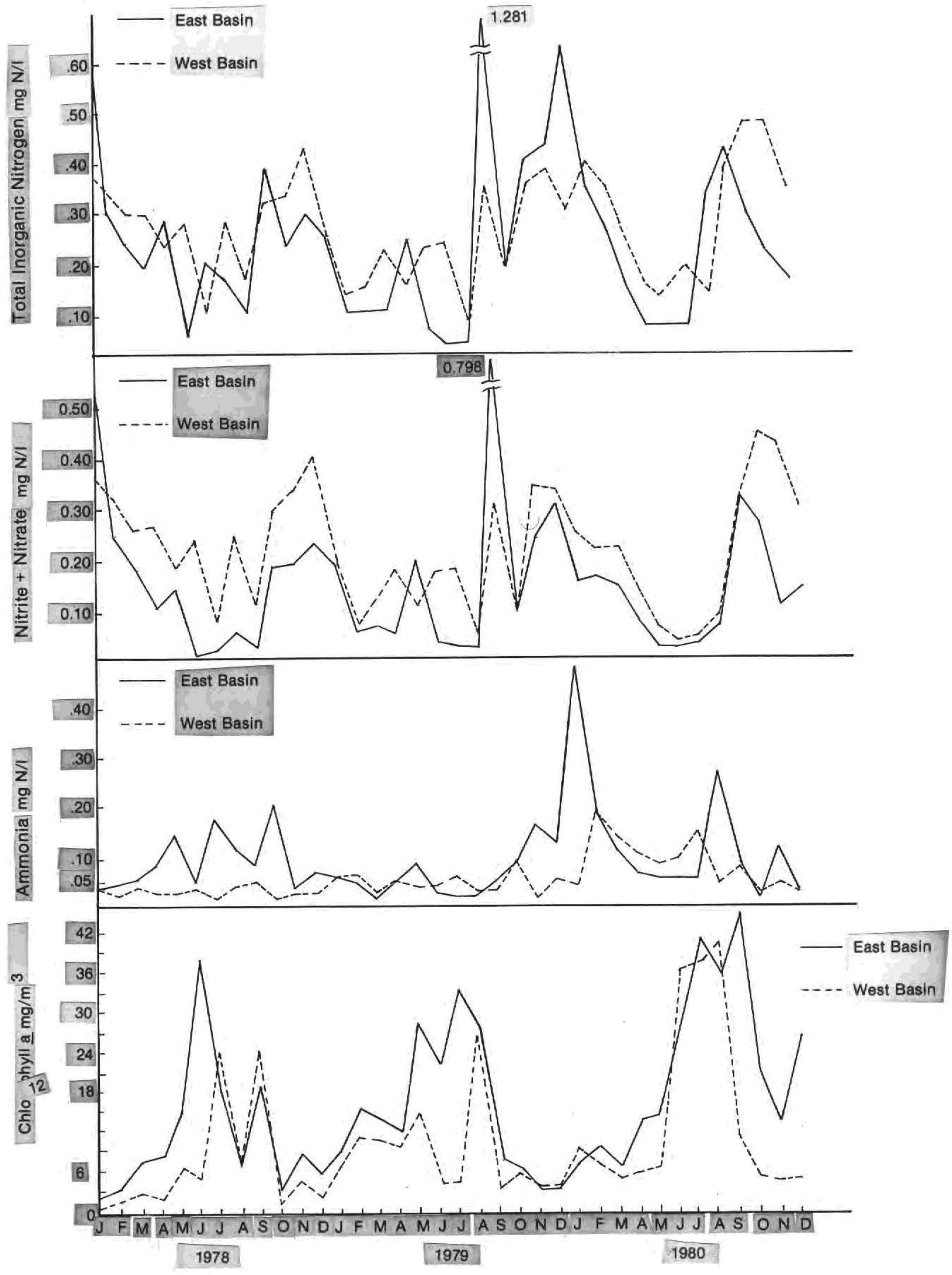


Figure 37B MEAN INORGANIC NITROGEN AND CHLOROPHYLL A CONCENTRATIONS IN THE CALOOSAHATCHEE RIVER DURING ROUTINE SAMPLING TRIPS, 1978 - 1980

TABLE 18. SIGNIFICANT CORRELATION COEFFICIENTS[1] FROM SIMPLE LINEAR REGRESSION ANALYSIS OF CHLOROPHYLL A VS. SELECTED PHYSICAL AND CHEMICAL VARIABLES

Conditions	n	Temp.	Residence Time	Total N	Total Inorganic N	NO_x	NH_4	TPO_4	OPO_4
Monthly $\overline{x}$, both basins	72	.529	-	.343	-.428	-.525	-	-	-
Monthly $\overline{x}$, East Basin	36	.621	-	-	-.365[2]	-.367[2]	-	-	-
Monthly $\overline{x}$, West Basin	36	.491	-	-	-.669	-.690	-	-	-
Both basins (no Reg. Rel.)[3]	52	.602	-	.405	-.453	-.587	-	-	-
East Basin (no Reg. Rel.)	26	.704	-	-	.399[2]	-.439	-	-	-
West Basin (no Reg. Rel.)	26	.572	-	.507	.716	-.765	-.514	-	-

(1) Significant at α = .99

(2) Significant at α = .95

(3) No Reg. Rel. = sample dates during which Lake Okeechobee regulatory releases were made were eliminated from the data set

- = no significant linear correlations

Note: all t values were significant at α = .95

that the combined influence of a variety of factors affect chlorophyll a concentrations.

Water temperature increases during the spring and early summer months are also indicative of light intensity and photoperiod increases which accompany the increased solar radiation. Brylinski and Mann (1973) demonstrated that, based on data from 55 water bodies distributed throughout the world, variables related to solar energy input had a greater influence on phytoplankton productivity than variables relating to nutrient input. Wetzel (1975) suggested that even in cool, northern areas the increasing light in the spring may be the dominant factor contributing to the spring "outburst." The negative correlations exhibited between chlorophyll a and inorganic nitrogen and nitrite + nitrate suggests that available levels of inorganic nitrogen were reduced as chlorophyll a concentrations increased.

Regression analysis performed separately on East Basin and West Basin data sets showed improved correlations between chlorophyll a and temperature in the East Basin, and a stronger relationship between chlorophyll a and inorganic nitrogen in the West Basin. Furthermore, when data from sample dates on which Lake Okeechobee regulatory releases were made (low residence time) were eliminated, correlation coefficients were generally improved.

There were no significant, linear relationships determined between chlorophyll a and the variables total phosphorus, ortho phosphorus, or water residence time.

Phytoplankton utilize nitrogen and phosphorus at an atomic ratio of approximately 15:1 (7.2:1 mass ratio). Water bodies with mass ratios greater than 7.2:1 are considered nitrogen enriched, and phytoplankton growth could be potentially limited by the availability of phosphorus. Conversely, if the ratio of inorganic nitrogen to inorganic phosphorus is less than 7.2:1, phytoplankton growth could be limited by the supply of nitrogen. Some blue-green algal species,however, are able to fix atmospheric nitrogen and continue to grow despite nitrogen depletion in the water. Ratios of inorganic nitrogen to inorganic phosphorus in C-43 averaged 2.6:1 in the East Basin and 3.6:1 in the West Basin. These ratios are low because there was an abundance of ortho phosphorus in C-43, not because inorganic nitrogen was lacking. Comparisons of total and inorganic nutrient concentrations in water bodies in south and central Florida (Table 19) indicate that C-43 is both phosphorus and nitrogen enriched compared with most lakes, but has water quality better than many canals.

During the late spring months of 1978 and the summer months of 1979, chlorophyll a levels in the West Basin were considerably lower than in the East Basin, although the levels of inorganic nutrients and residence times were similar in both basins during these periods. It is suggested that there may have been some trace element limitation, or inhibiting agent in the West Basin waters, which interfered with plankton growth during these periods. Isolation and verification of algal inhibitors is difficult under controlled laboratory conditions (Roll, 1980) and is certainly beyond the limitation of these field investigations.

CHLOROPHYLL A - SPRING/SUMMER PERIOD

Data in this section represent an increased frequency of sampling for chlorophyll a and water quality parameters during the late spring and summer months in anticipation of a major algal bloom. Its purpose is to present a detailed picture of the interrelated factors occurring during the critical phytoplankton growth period.

Figures 38, 39, and 40 display the average chlorophyll a and inorganic nutrient concentrations for the East and West Basins during the spring and

TABLE 19. SUMMARY OF MEAN TOTAL AND INORGANIC NUTRIENT CONCENTRATIONS FROM SELECTED WATER BODIES IN CENTRAL AND SOUTH FLORIDA (mg/L)

	Date	NO_x	NH_4	Total Inorg. Nitrogen	Total N	oPO_4	Total PO_4	Inorganic N / Inorganic P
LAKES:								
Lake Placid[2]	9/74 - 9/76	.039	.030	.069	0.40	.002	.012	34.5 : 1
Lake Istokpoga[2]	9/73 - 8/76	.028	.030	.058	1.03	.008	.048	7.3 : 1
Lake Kissimmee[1]	7/73 - 6/74	.020	.017	.037	1.28	.002	.028	18.5 : 1
Lake Okeechobee[3]	4/74 - 12/79	-	-	.160	1.73	.018	.063	8.9 : 1
Lake Tohopekaliga[1]	7/73 - 6/74	.035	.024	.059	1.63	.184	.300	0.3 : 1
C-43:								
C-43 East Basin	1/78 - 12/80	.141	.110	0.247	2.83	.058	.095	2.6 : 1
C-43 West Basin	1/78 - 12/80	.207	.050	0.260	2.04	.073	.106	3.6 : 1
CANALS:								
Kissimmee R. @ S-65E[3]	4/73 - 3/80	-	-	.197	1.39	.058	.092	3.4 : 1
North New River @ S-2[3]	4/73 - 3/80	-	-	2.24	5.82	.077	.132	29.1 : 1
Fisheating Creek[3]	4/73 - 3/80	-	-	.139	2.08	.161	.235	0.9 : 1
Nubbin Slough @ S-191[3]	4/73 - 3/80	-	-	.601	2.29	.749	.906	0.8 : 1

Adapted from:

1 Milleson, 1975

2 Milleson, 1978

3 Federico, et al., 1981

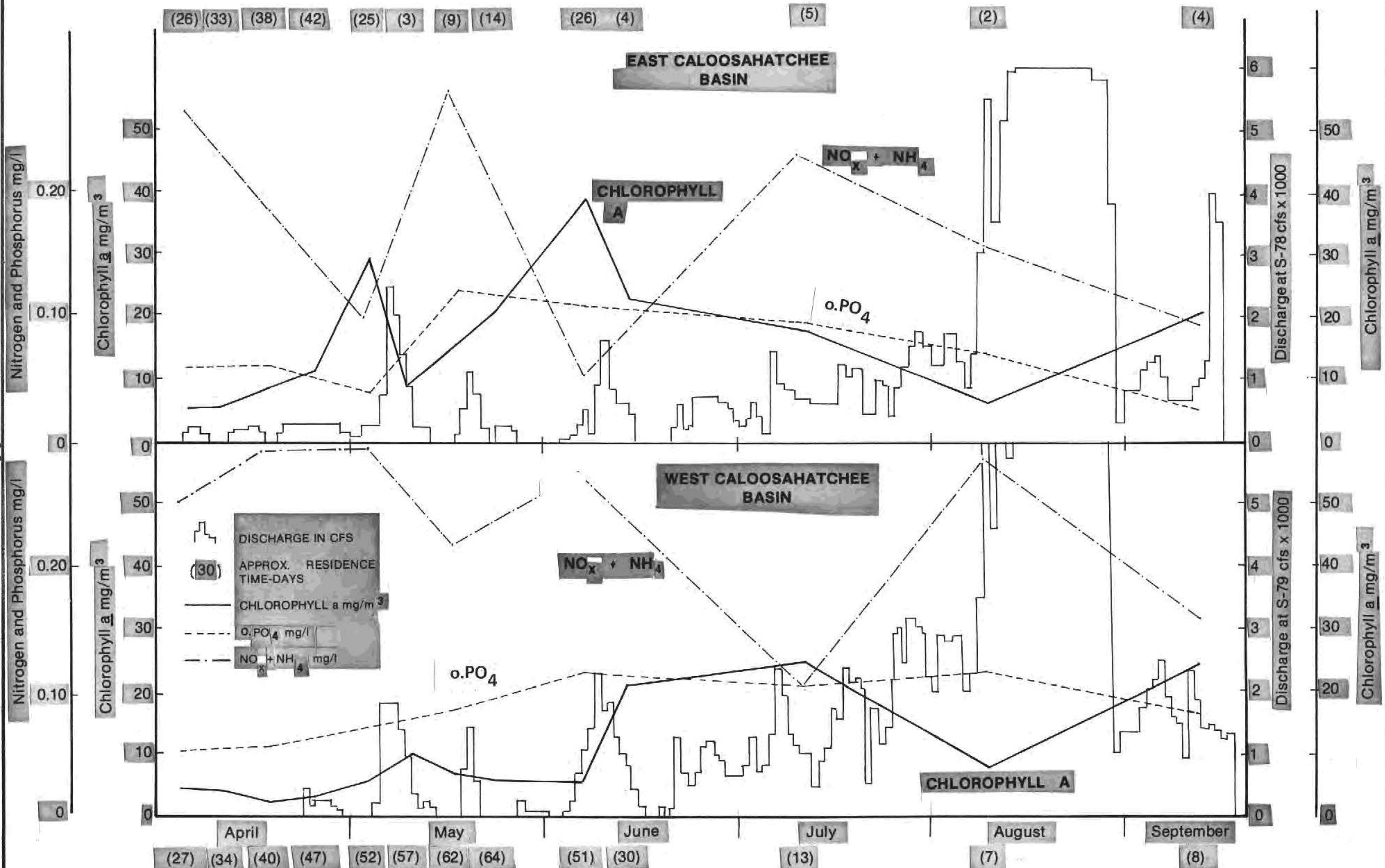


Figure 38 AVERAGE CHLOROPHYLL A AND INORGANIC NUTRIENT CONCENTRATIONS IN THE CALOOSAHATCHEE RIVER BASINS, APRIL-SEPTEMBER 1978

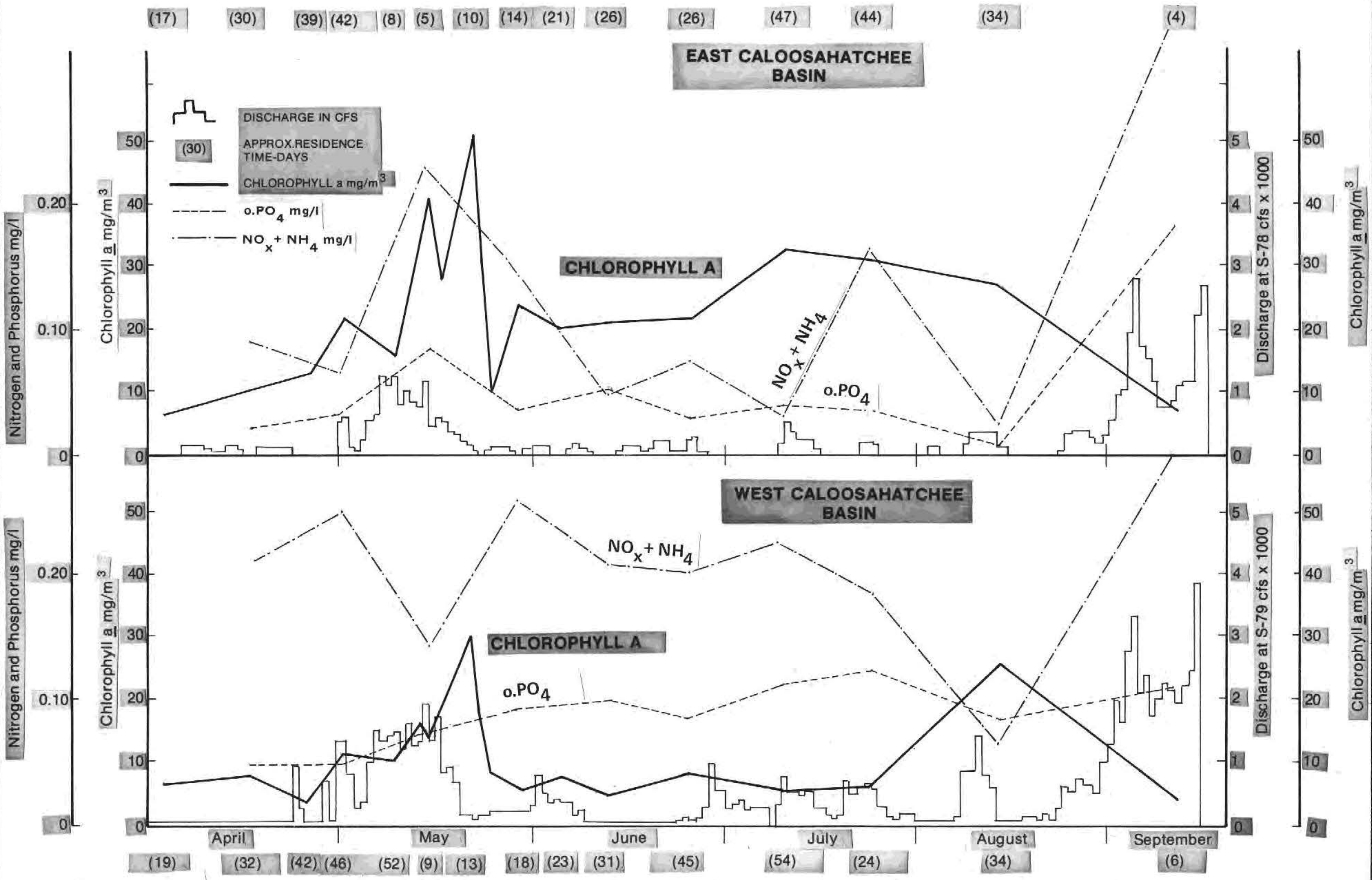


Figure 39 AVERAGE CHLOROPHYLL A AND INORGANIC NUTRIENT CONCENTRATIONS IN THE CALOOSAHATCHEE RIVER BASINS, APRIL-SEPTEMBER 1979

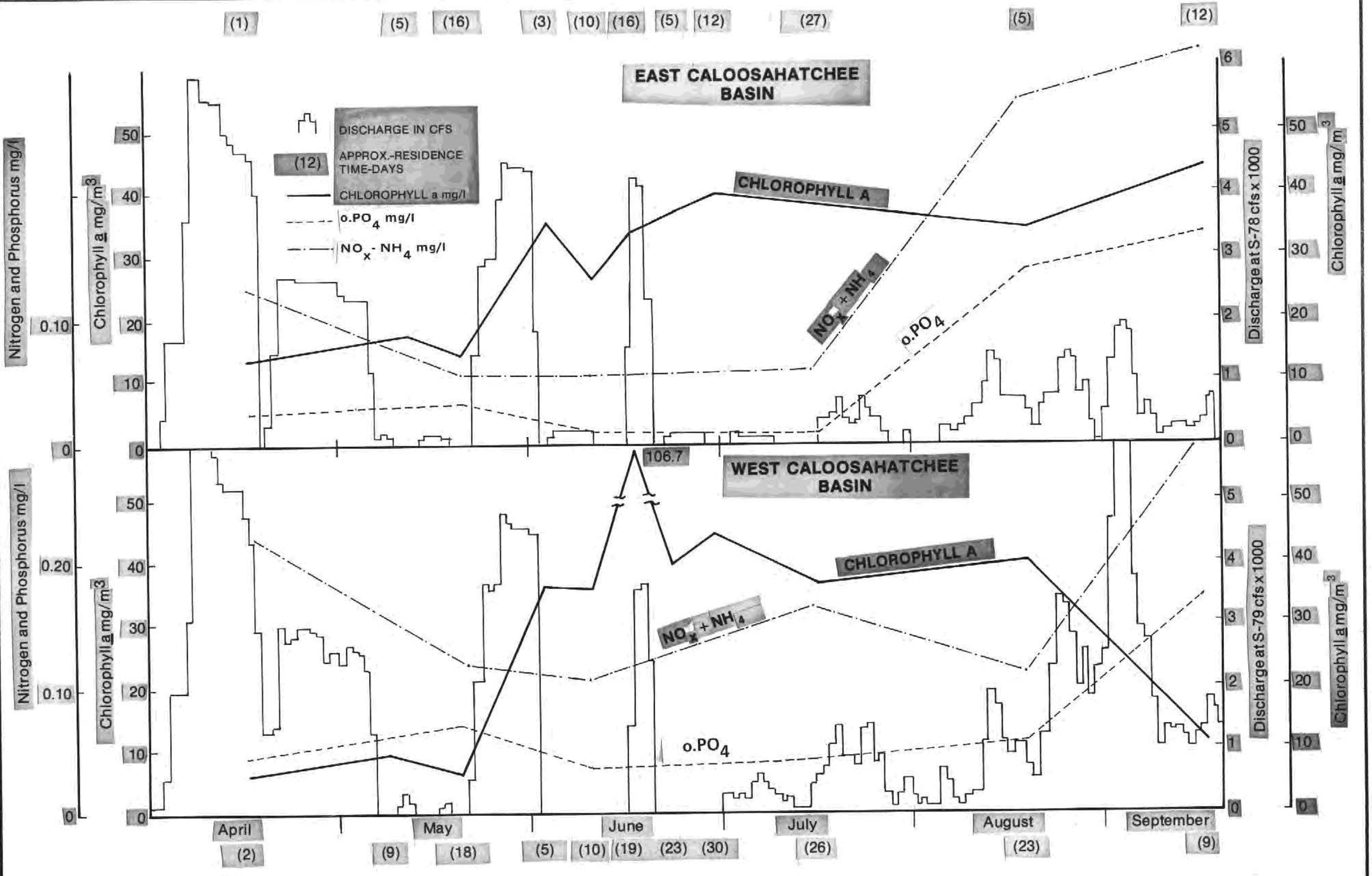


Figure 40 AVERAGE CHLOROPHYLL A AND INORGANIC NUTRIENT CONCENTRATIONS IN THE CALOOSAHATCHEE RIVER BASINS, APRIL-SEPTEMBER 1980

summer months of 1978, 1979, and 1980, respectively. Superimposed on these graphs are the daily discharge rates at S-78 and S-79 to indicate water flow characteristics during the sample period. Estimated water residence times are also shown for all sample trips. Important trends and observations are reviewed in the text.

In Figure 38 (1978) the late spring (April-May) chlorophyll a increases in the East Basin are contrasted with the delayed increase (until mid-June) in the West Basin. Additionally, inorganic nitrogen concentrations exhibited an inverse relationship to chlorophyll a concentration in both basins, suggesting biological uptake. The ability of water inflow, from basin runoff, to reduce chlorophyll a concentrations through dilution and flushing action is evident during May 3-9 and June 6-13 in the East Basin. In both instances, a volume of water sufficient to nearly exchange the volume of the East Basin flowed into and through the basin in a short time period. The Lake Okeechobee regulatory release in August reduced chlorophyll a levels in both basins.

In addition to some of the trends noted during 1978, Figure 39 shows the extreme variability in chlorophyll a concentrations which were detected with frequent sampling during May 1979. Because of such short term variations, any discussion of chlorophyll a concentration changes between weekly or monthly sampling intervals should be tempered. Substantial increases in nitrogen and phosphorus concentration corresponded with increased flows from basin runoff during mid-May in the East Basin and also in September in both basins. The remainder of the summer of 1979 was a low flow period; residence times were nearly a month or more. However, chlorophyll a levels in the West Basin remained low through June and July and only reached normal summer values in excess of 20 mg/m^3 in mid-August.

Events surrounding the first "nuisance" algal bloom of the three year study period are shown in Figure 40. Lake Okeechobee regulatory releases had occurred continuously from January through April, and intermittently during May 1980. Immediately after regulatory releases ceased, samples on June 3 indicated that chlorophyll a levels were uniformly high throughout the entire river (avg. = 37 mg/m^3) and were similar to a value recorded upstream of S-77 (Appendix E). By June 10, inorganic nutrient levels were low at most stations, and on June 17, severe bloom conditions were encountered in the west end of the the West Basin. A maximum chlorophyll a concentration of 159.2 mg/m^3 was measured at CR-37.0, while the West Basin average value for chlorophyll a was 106.7 mg/m^3. Water releases from Lake Okeechobee June 17-20 effectively flushed the bloom to tidewater, and chlorophyll a concentrations stabilized at about 40 mg/m^3 through C-43 for the remainder of the summer.

MANAGEMENT PERSPECTIVE

The problems now faced by investigators after a three year monitoring period are: (1) why do algal blooms occur in the vicinity of the water treatment plant, (2) can these blooms be predicted, and (3) can these blooms be prevented.

The following summarizes pertinent information:

1. Temperature: Phytoplankton growth responds to increased water temperature as well as the accompanying, but not measured, increases in solar radiation, light intensity, and photoperiod. A consistent trend has developed such that major chlorophyll a increases and nuisance algal blooms usually occur (when they occur) during May and June.
2. Nutrient Concentrations: Inorganic nitrogen and phosphorus levels in C-43 are high in comparison with many other water bodies in south Florida. Inorganic nitrogen, on occasion, appeared to be the potentially limiting

nutrient for phytoplankton growth. This was evidenced by low inorganic nitrogen to inorganic phosphorus ratios of about 3:1 and significant inorganic nitrogen reduction during chlorophyll a peaks. Chlorophyll a exhibited significant negative correlations with total inorganic nitrogen concentrations.

3. Residence Time: A linear relationship was not evident between chlorophyll a and residence time based on three years of routinely collected data. However, the rapid reduction of residence time caused by high volume discharges can have considerable influence on chlorophyll a levels. It was observed that stormwater runoff reduced chlorophyll a levels in May and June 1978 in the East Basin and in September 1979 in both basins. Likewise, Lake Okeechobee discharges reduced chlorophyll a concentrations in August 1978 and effectively flushed an algal bloom to tidewater in June 1980. Conversely, many of the high chlorophyll a concentrations occur during low flow periods when residence times are considerable.

Severe algal blooms have occurred in the western portion of C-43 during three of the past five years. Figure 41 examines the hydrologic conditions preceding these blooms. During 1976 and 1977, water flow through the Caloosahatchee River during the late winter and early spring months was minimal, and nuisance algal blooms in the West Basin occurred after periods of relatively long residence times. Water quality in 1976 was probably influenced by basin runoff resulting from May and early June rainfall. The spring of 1977 was much drier, so it is doubtful that basin runoff contributed much to nutrient enrichment of C-43 prior to the May 1977 algal bloom.

Nuisance algal blooms did not occur in 1978 and 1979. Figure 41 shows that these two years had substantially more water flow in the spring months (March-May) than occurred in 1976 and 1977.

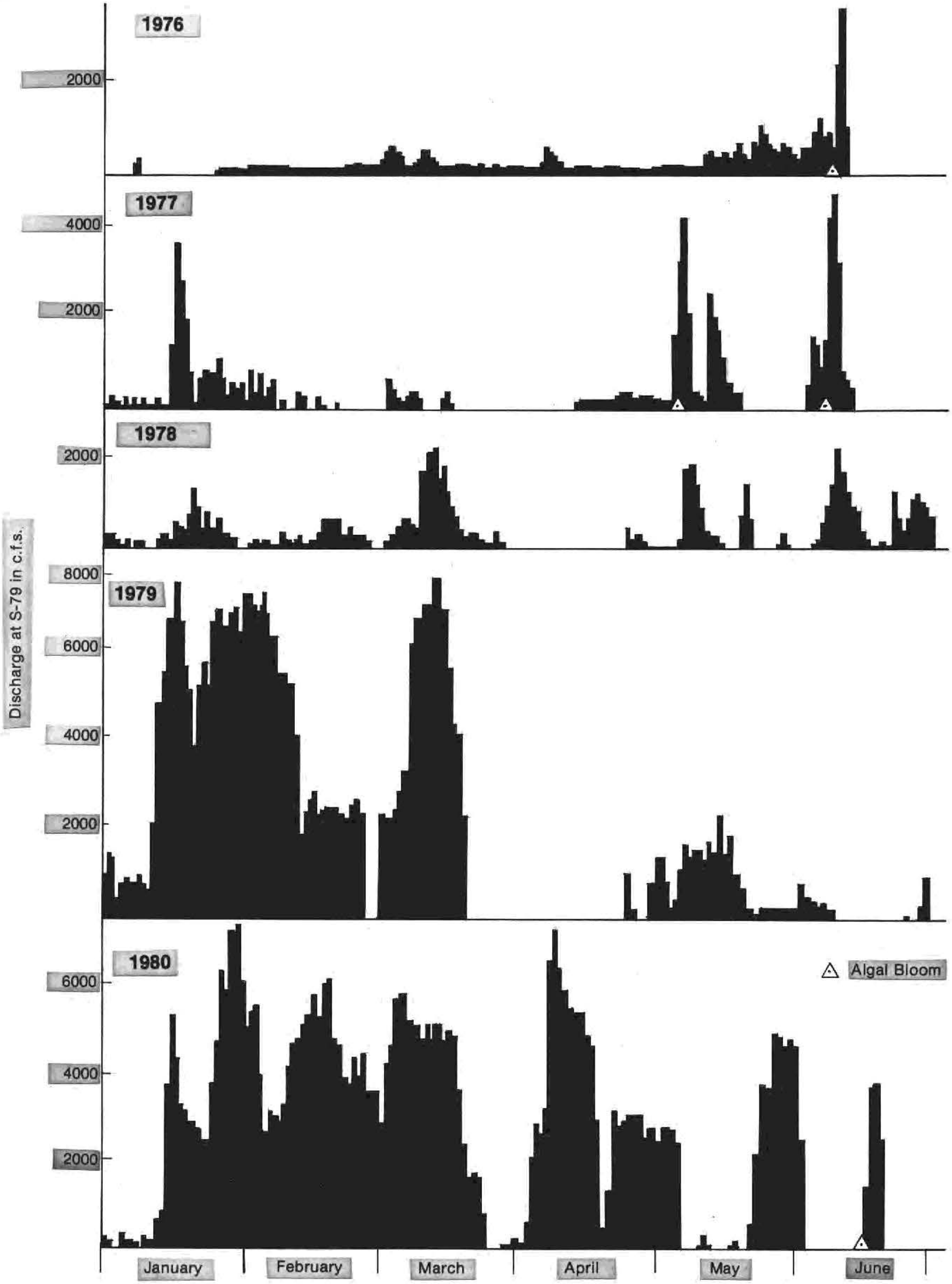


Figure 41 ANTECEDENT WATER FLOW CONDITIONS (AS MEASURED AT S-79) DURING ALGAL BLOOM AND NON-BLOOM YEARS 1976-1980

Based on the preceding four years observation of hydrologic conditions, a major plankton bloom was not anticipated in 1980; however, in June 1980 a major algal bloom occurred within two weeks of the termination of regulatory releases from Lake Okeechobee. This shows that extremely long residence times are not a necessary prerequisite for an algal bloom.

The water quality characteristics of C-43 on selected dates in May and June 1980 provide some insight into the 1980 algal bloom. Figure 42 shows that chlorophyll a concentrations were low and inorganic nutrient concentrations were moderate through much of C-43 on May 20. By June 10, chlorophyll a had increased throughout most of C-43, while inorganic phosphorus was low from Station CR-22.5 eastward. Toward the west, concentrations of inorganic phosphorus and inorganic nitrogen were higher, especially in the vicinity of CR-36.0. There was no water discharged at S-79 during June 10-17 in the West Basin; consequently, phytoplankton were able to respond to the ambient water quality and a major algal bloom was encountered from CR-26.0 westward on June 17.

While temperature, nutrient availability, and residence times are important factors which can influence phytoplankton growth, the data available from this study does not indicate an identifiable, critical combination of these factors as a basis for predicting an algal bloom in advance.

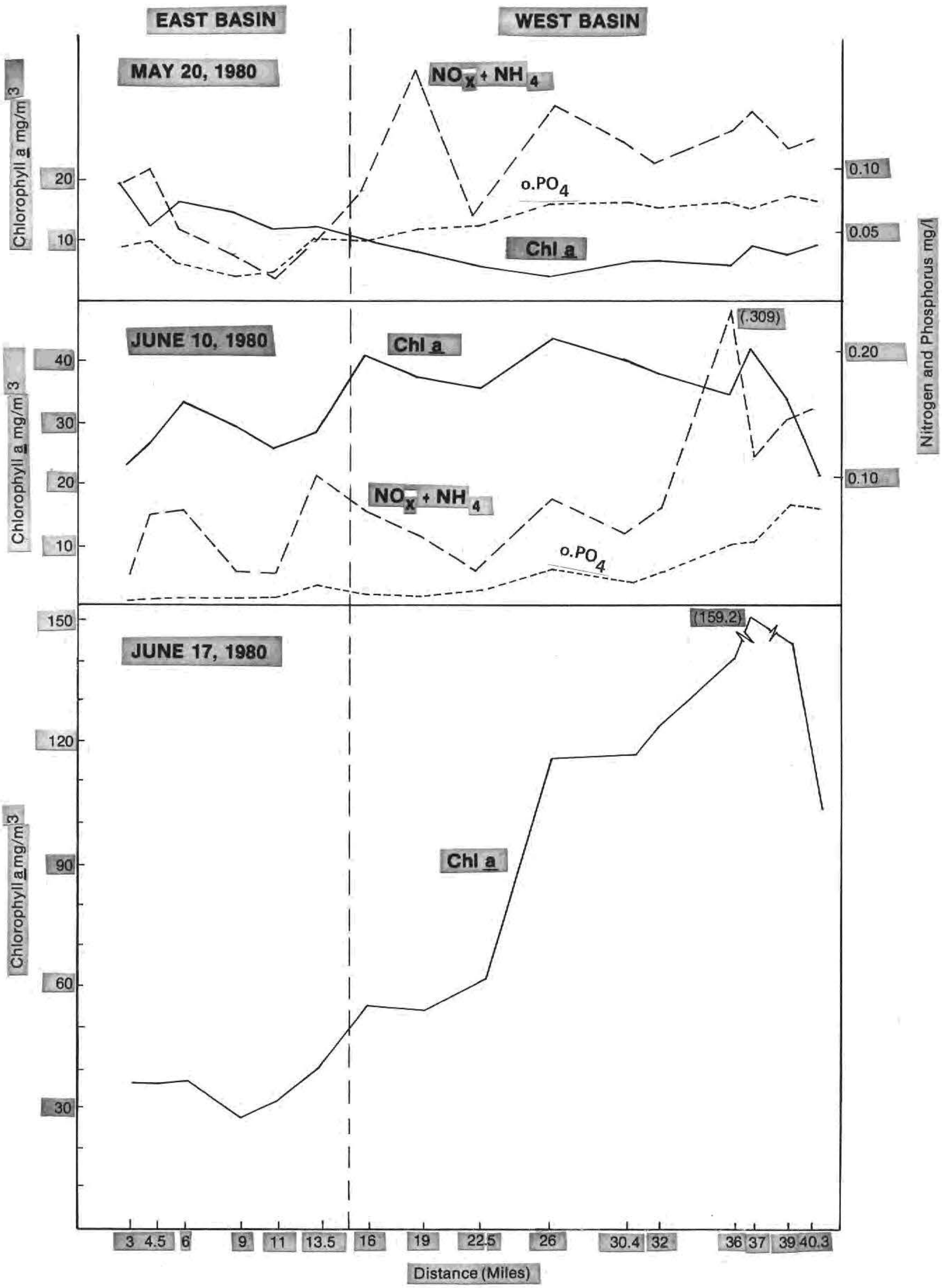


Figure 42 CHLOROPHYLL A AND INORGANIC NUTRIENT LEVEL ALONG C-43 PRIOR TO AND DURING A NUISANCE ALGAL BLOOM, 1980

PART V

INTENSIVE STUDY

INTRODUCTION

Prior to this study, numerous algae blooms were reported in the Caloosahatchee River at the Lee County Water Treatment Plant near Olga, Florida. These blooms usually occurred between April and July, and affected treatment plant operations. On such occasions, large water releases of limited duration were made from Lake Okeechobee to flush the algae from the river. Although only a temporary remedy to an immediate problem, the apparent regular occurrence of these blooms prompted the development of a program to identify the water quality conditions associated with these recurrent algal blooms.

During the April - June 1978 intensive sampling period, the frequency of routine water quality sampling was increased from monthly to bimonthly, and daily water quality samples were collected with an automatic sampler at the Alva Bridge (CR-36.0) and by personnel at the Lee County Water Treatment Plant (CR-40.3).

This chapter presents a detailed examination of the changes in phosphorus, nitrogen, chloride, and chlorophyll a concentrations with time during this period and relates these to concurrent hydrologic and meteorologic events.

Hydrologic and Meteorologic Conditions

Daily rainfall and discharges recorded at S-79 are depicted on the figures that follow. Water movement in the West Basin from April 1 to June 13, 1978 was minimal. Low volume water supply releases were made from Lake Okeechobee into the Caloosahatchee River during most of April and occasionally during May. Beginning May 27, however, rainfall was reported on nine of the next 18 days. Rainfall events during May 4 - 6 and June 6 - 10 caused substantial runoff and releases of water from S-79. Total flow out of the West Basin was 3,635 acre-feet in April, or about 13% of the total basin volume. May outflow was 23,781 acre-feet (82%) while 22,465 acre-feet (77%) flowed through S-79 during the first 13 days of June.

WATER QUALITY CHARACTERISTICS

Each of the figures that follow depict the daily concentration of a phosphorus or nitrogen constituent at the two intensive sampling locations, CR-36.0 (Alva Bridge) and CR-40.3 (Water Plant), daily rainfall totals and discharges at S-79, and the corresponding water quality data from biweekly sampling at nearby river and tributary stations.

Phosphorus: Figure 43 depicts the water quality trends for total phosphorus in the western portion of the West Basin of C-43 during the intensive sampling period, while Figure 44 shows the inorganic phosphorus components.

For the period April 3 to June 12 there was an approximate doubling of total phosphorus concentration: CR-36.0 increased from 0.056 to 0.130 mg P/L: CR 40.3 from 0.064 to 0.136 mg P/L. Some of the isolated peaks (April 24 at CR-36.0; May 6 - 7 at CR-40.3; and June 8 at both stations) coincided with substantial rainfall events. The general trend for ortho phosphorus was similar to total phosphorus, with overall increases reported for CR-36.0 (0.032 to 0.081 mg P/L) and CR-40.3 (0.046 to 0.100 mg P/L). Ortho phosphorus daily fluctuations were more erratic than total phosphorus, especially at station CR-36.0, where substantial reductions were noted on April 18 - 19 and May 23 -26.

The intensive study phosphorus data shows that a substantial increase in concentration occurred on every date sampled in the one mile portion of river between CR-36.0 and CR-37.0. Total phosphorus increases between these stations ranged from .021 mg P/L to .043 mg P/L and represented increases of 30 - 83%. Further increases were occasionally reported downstream of CR-37.0. The source of this phosphorus enrichment does not appear to be any of the

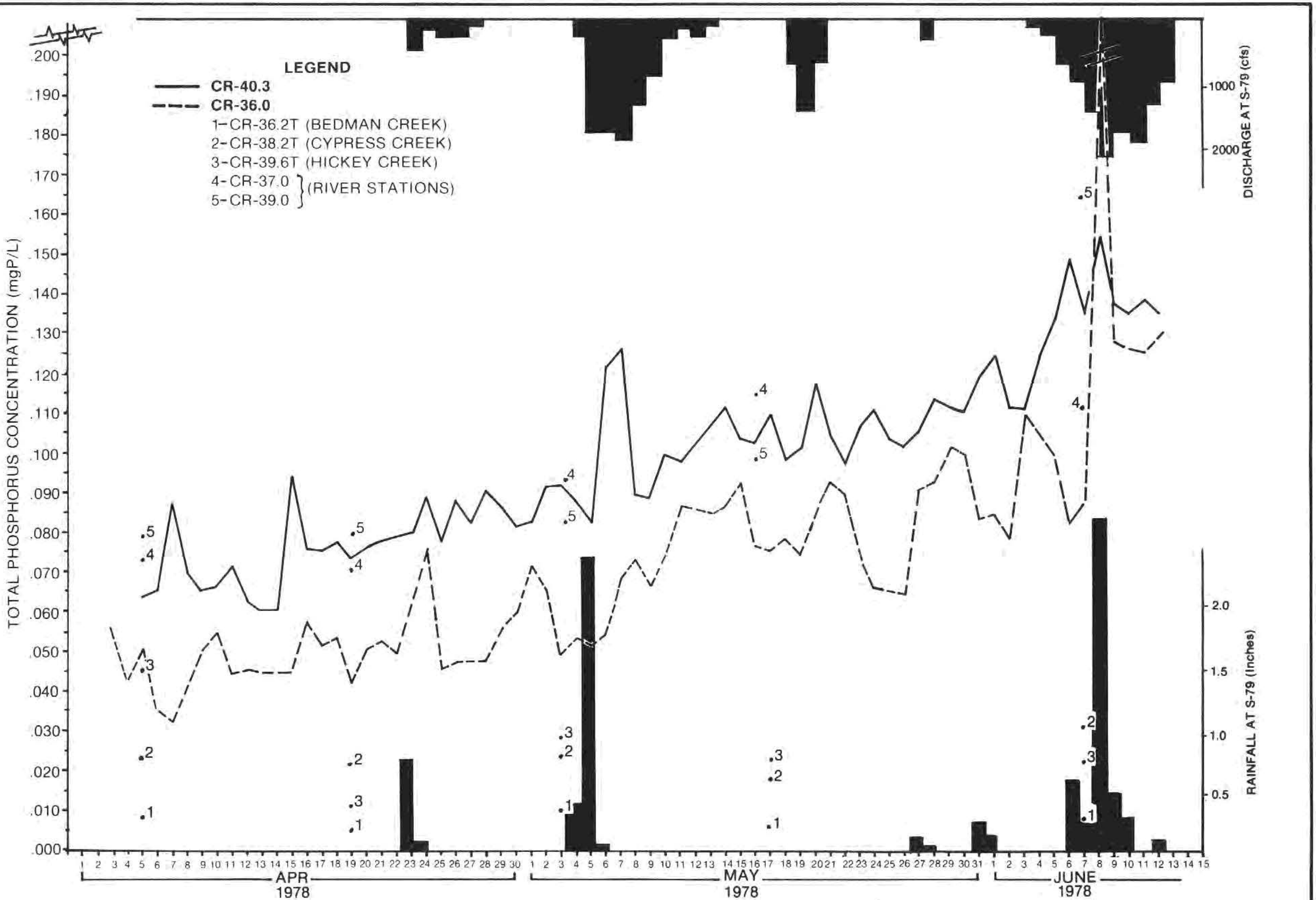


Figure 43 INTENSIVE STUDY TOTAL PHOSPHORUS DATA, 1978

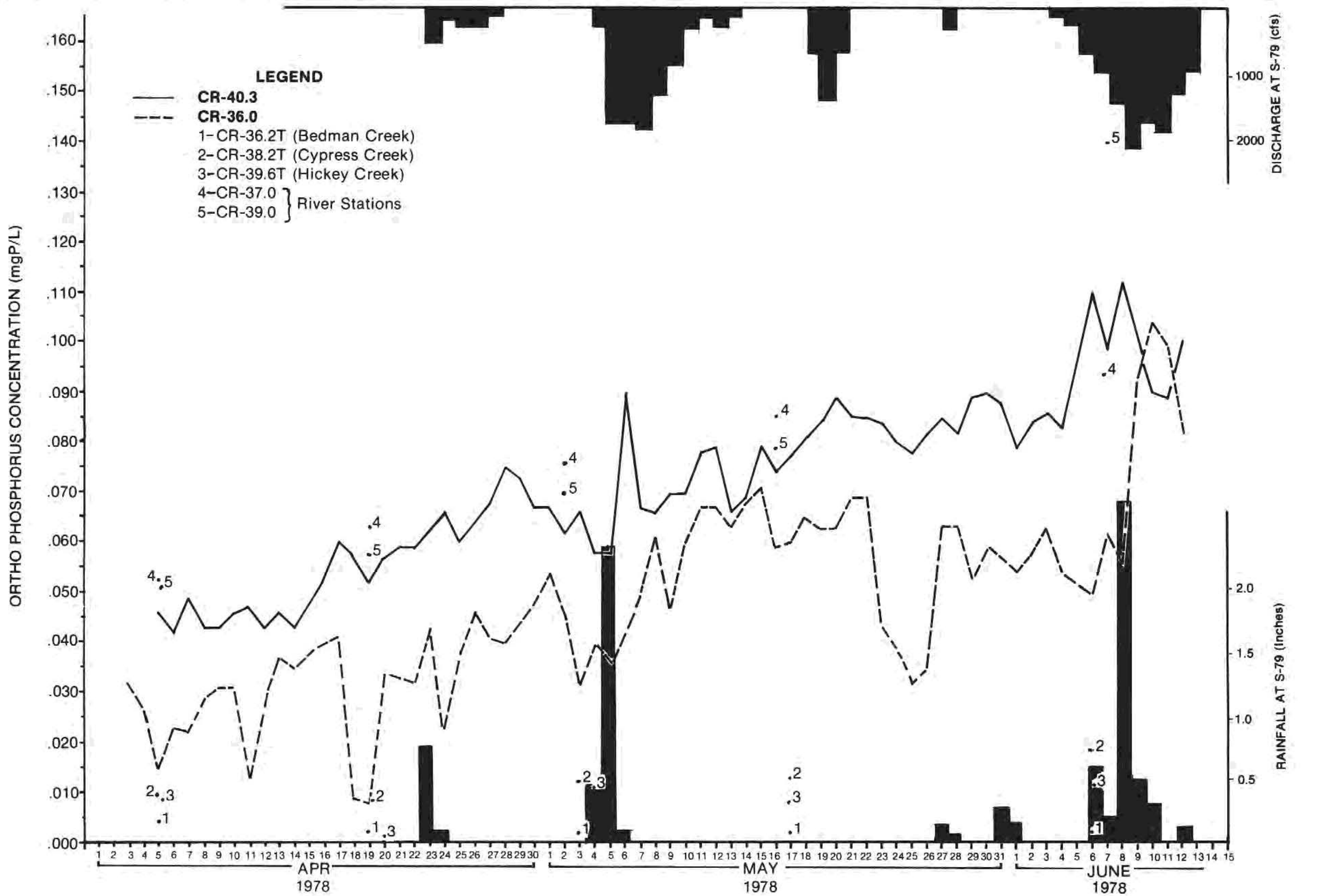


Figure 44 INTENSIVE STUDY ORTHO PHOSPHORUS DATA, 1978

sampled tributaries in the area (Bedman, Cypress or Hickey Creeks) since water quality in those tributaries was of better quality than the river.

Nitrogen: Figure 45 displays the trends in nitrate concentrations during the intensive sampling period. Like phosphorus, some of the major peaks in nitrate concentration, especially at CR-40.3, correspond with major rainfall events.

While phosphorus displayed a gradual but steady increase during the intensive period, nitrate concentration increased for the first month, then declined over the latter six weeks. The decline in nitrate concentration may have been the result of dilution from increased runoff and biological activity in the western portion of the river during May, and especially mid-June.

A considerable increase in nitrate concentration between stations CR-36.0 and CR-37.0 is also depicted on this Figure. This also suggests an unsampled source of poor quality water entering the western portion of C-43, since all of the sampled tributaries were relatively low in nitrate.

Unlike nitrate, ammonia concentrations in the western portion of C-43 were low throughout most of the intensive study period and displayed no distinct spatial trend. Figure 46 shows that the only substantial increases in ammonia concentration at both of the daily monitored stations occurred during the latter part of May and again around June 8. The June increase corresponds with rainfall, but the late May increase is apparently unrelated to runoff.

The tributaries in the vicinity of this study area were consistently low in ammonia concentration and, therefore, exhibited no influence on the concentrations in the river.

Chlorophyll *a*: No distinguishable trends in chlorophyll *a* concentration were apparent in the western portion of C-43 during this time period. The mean

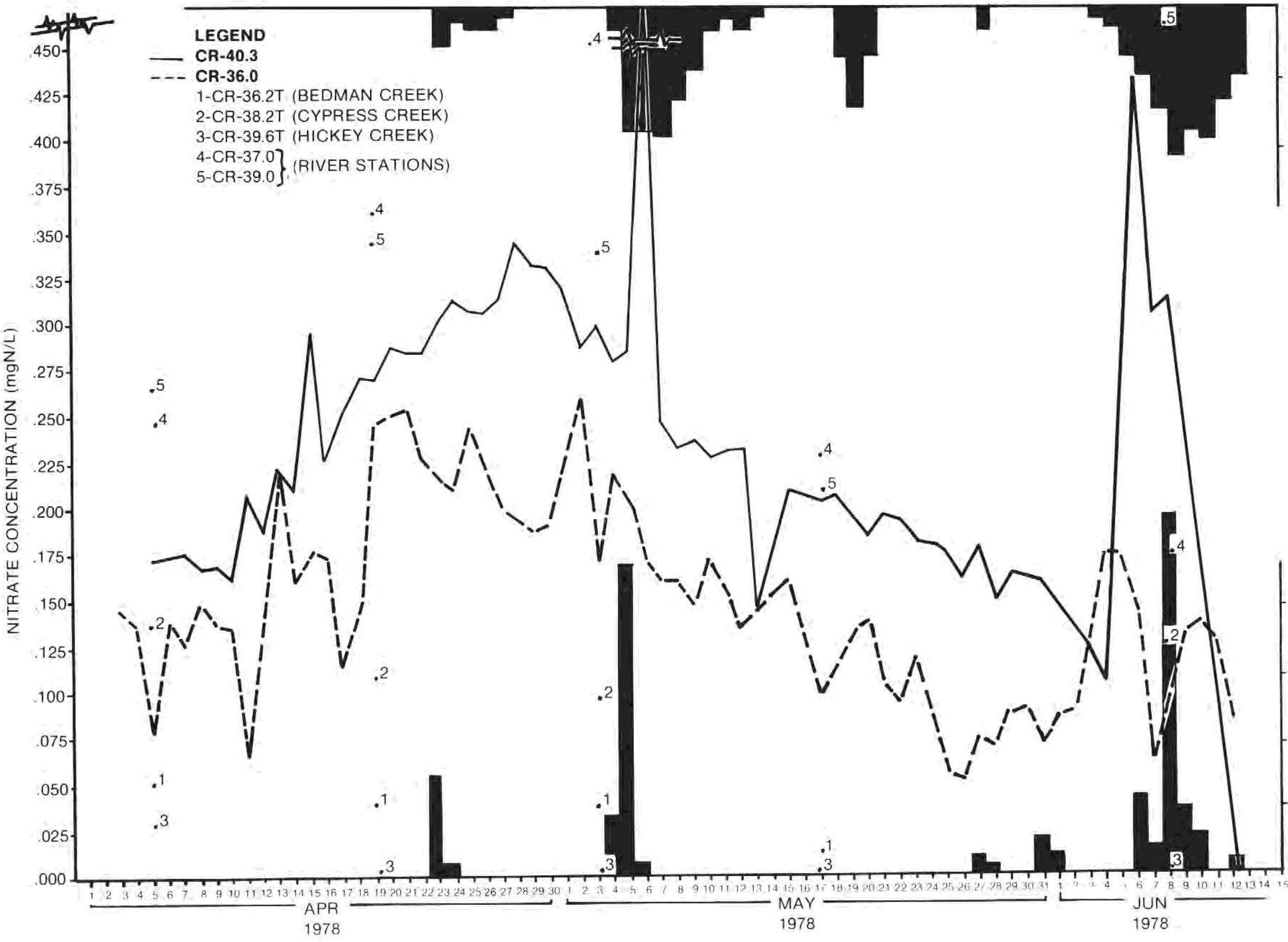


Figure 45 INTENSIVE STUDY NITRATE DATA, 1978

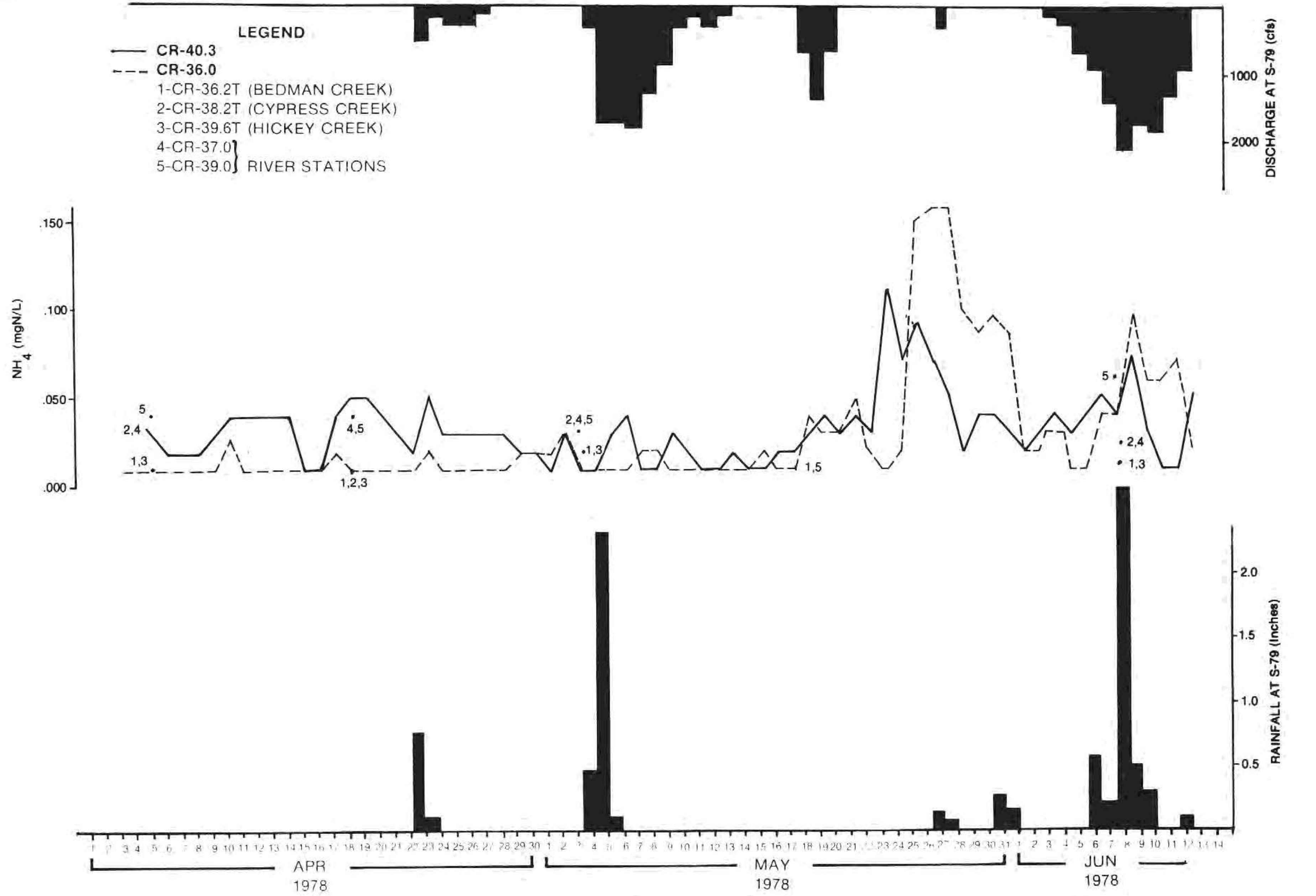


Figure 46 INTENSIVE STUDY AMMONIA DATA, 1978

chlorophyll a concentration at stations CR-36.0, CR-37.0, CR-39.0, and CR-40.3ranged from 1.6 to 5.6 mg/m^3 on nine sample dates between April 4 and June 7. On June 13 the mean value increased an order of magnitude to 18.6 mg/m^3. Examination of the data in Appendix E shows that this increase is probably the result of a more productive mass of water flowing from the East Basin to the West Basin. A concurrent reduction in nitrate concentration (Figure 45) may be related to the increase in chlorophy ll a levels.

Chloride: Chloride concentrations between stations CR-36.0 and CR-40.3 changed very little either spatially or temporarlly. Figure 47 shows that the differences among these intensive stations and the intervening river stations, CR-37.0 and CR-39.0, were small. Unlike nitrogen and phosphorus, however, the sampled tributaries did exhibit chloride concentrations which were generally quite different than the chloride concentrations along the river. Chloride levels for Bedman Creek and Cypress Creek were usually greater than the river, while Cypress Creek chloride levels were lower.

Elevated chloride levels in late April and early May, and again in June, corresponded to peak rainfall events in the West Basin. During dry periods the primary water supply for irrigation purposes is groundwater, which usually exhibits higher chloride levels. Consequently, the elevated chloride levels in the West Basin may reflect the flushing of mineralized sediments concentrated by groundwater irrigation and evaporation during the dry season.

SUMMARY

During the 1978 intensive water quality study, no significant algae bloom developed. Nitrogen and phosphorus concentrations increased substantially in the western portion of C-43, especially between stations CR-36.0 and CR-37.0. Three major tributaries in the vicinity, Bedman's, Cypress, and Hickey's Creeks, exhibited a better quality of water than the Caloosahatchee River.

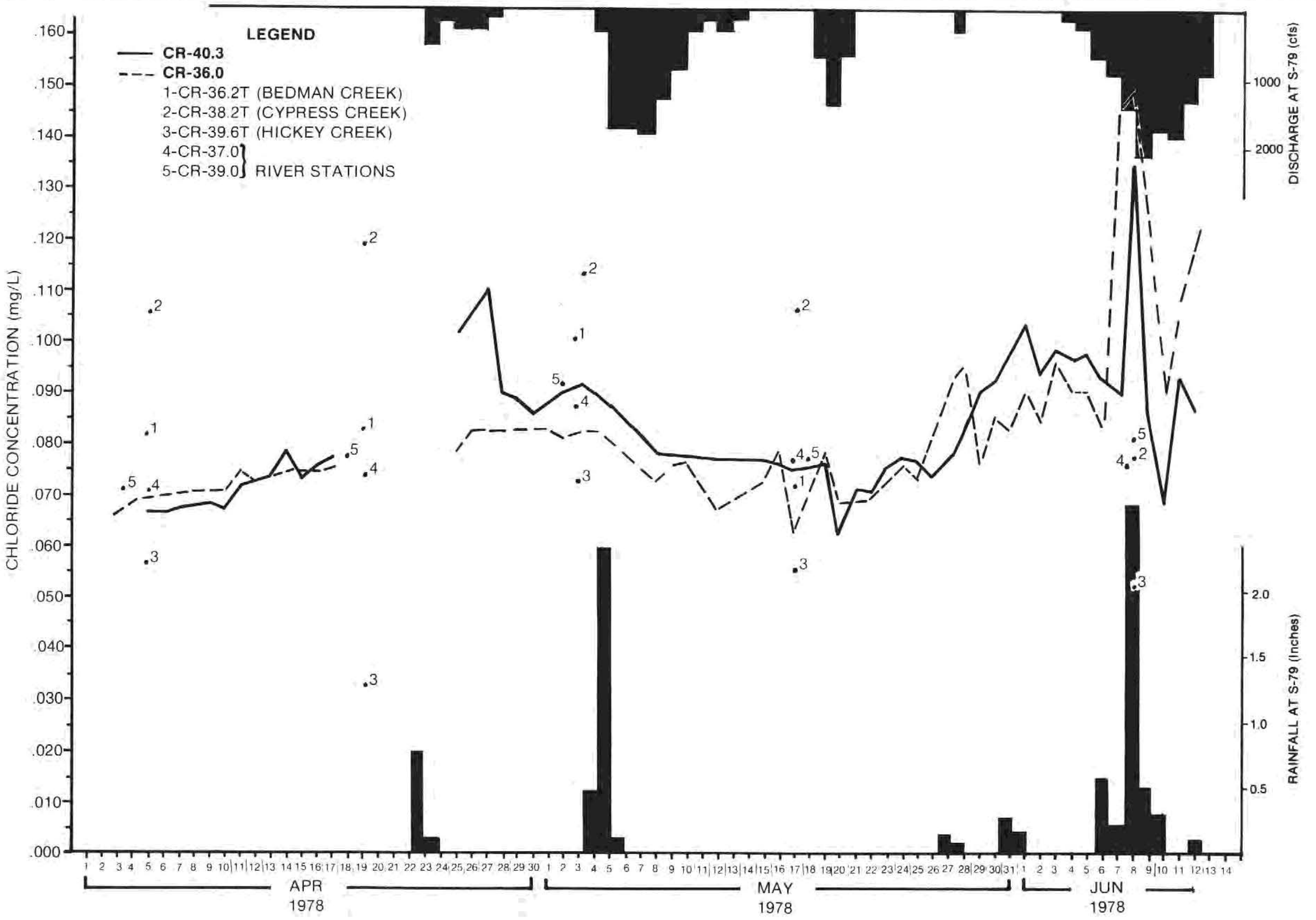


Figure 47 INTENSIVE STUDY CHLORIDE DATA, 1978

Consequently, the enrichment in C-43 appears to be from an unsampled source, and may be from intensive agricultural activities (citrus and ornamental plants) adjacent to the river. Water quality data preceding the June 17, 1980 algal bloom (PART IV) also suggests nutrient enrichment in this portion of the river.

PART VI

MATERIAL LOADINGS ANALYSIS

INTRODUCTION

Two of the objectives of this study were to determine the quantitative relationships between Lake Okeechobee and the Caloosahatchee River and to determine the qualitative and quantitative contribution of the tributaries to the two main reaches of the river. This part will describe the methodology used to calculate the nitrogen, phosphorus, and chloride loads. The annual loads at S-77 from 1973 to 1980 will be discussed, followed by the East and West Basin loads for the period 1978-80. Basin loads are presented in this part of the report based upon flow at the major water control structures, since major tributary flow, seepage, and evapotranspiration data were unavailable and a water budget was not calculated.

Hydrologic data was available for the three major water control structures, S-77, S-78, and S-79. Corresponding water chemistry data was taken from the nearest downstream station, except for S-79 where water chemistry data was taken just upstream at river station CR-40.3.

During 1979 and 1980 an automatic sampler was installed at S-77 to collect water samples during discharge. Table 20 compares the results of the annual nutrient and chloride total mass loading rates for the upstream automatic sampler data and the downstream grab sample data. This data indicates that the loading rates for S-77, based upon the downstream grab sample, may be slightly greater than the upstream automatic sampler data for total nitrogen and chloride and lower for total phosphorus. Since the upstream data covers only a portion of the study period and is incomplete for December 1980, the downstream data will be used for the loading analysis.

TABLE 20. ANNUAL MASS LOAD COMPARISON BETWEEN THE UPSTREAM AUTOMATIC SAMPLER DATA (COMPOSITE ON TIME) AND THE DOWNSTREAM GRAB SAMPLE DATA DURING 1979 AND 1980

		Total Nitrogen Tonnes	Total Phosphorus Tonnes	Chloride Tonnes
1979	Automatic Sampler	1715.8	76.2	60,904
	Grab Sample	2212.6	63.8	83,488
* 1980	Automatic Sampler	2064.4	51.8	72,248
	Grab Sample	2357.9	51.6	88,673

*These annual values are based on 11 months, since December 1980 data is not available.

Based on the annual rainfall for the study period (PART I), the materials budget reflects a slightly drier than normal period with atypical discharges from S-77.

LOADING CALCULATION METHODOLOGIES

Loading rates at S-77 were computed from daily hydrology data (U. S. Geological Survey, 1973-1980) and biweekly chemistry data collected since 1973. Loading rates at S-78 and S-79 were computed from daily hydrology data (U. S. Geological Survey, 1978-1980) and monthly chemistry data collected between 1978 and 1980. In calculating the material loads, two chronologically successive chemistry data points were averaged to give an estimated chemistry value for the time period between the two sampling dates. This average was then applied to the discrete daily flow data for the same time period, producing daily loadings within the time period represented by the chemistry data. This process was then repeated until the total time period was covered (Scheider et al., 1979). The East and West Basin loads were calculated by subtracting the loads at S-77, S-78, and S-79, respectively.

LAKE OKEECHOBEE LOADINGS TO THE CALOOSAHATCHEE RIVER

Table 21 shows the annual mass loadings to the Caloosahatchee River from Lake Okeechobee (S-77) for the period 1973-1980. By comparison, the three year period of this study, 1978-1980, was atypical due to very high flows. The flows in 1979 (811,136 acre-feet) and 1980 (855,658 acre-feet) were about 3.5 times greater than the preceding six year average and were up to 18 times greater than 1973. Major regulatory water releases in 1974 and again in 1979 and 1980 were responsible for the large flows in those three years. The annual flow in 1974 (751,364 acre-feet), although similar in magnitude to the 1979 and 1980 discharges, included significant summer regulatory discharges. The water releases during 1979 and 1980 were mainly winter regulatory discharges.

TABLE 21. AVERAGE AND ANNUAL MASS LOADINGS TO THE CALOOSAHATCHEE RIVER FROM LAKE OKEECHOBEE AT S-77 FOR THE PERIOD OF RECORD (1973-1980)

Year	Flow Acre-feet	Mass Load Tonnes T-P	Mass Load Tonnes T-N	Mass Load Tonnes Cl
1973	46,771	3.2	88.9	4,431
1974	751,364	93.3	1687.9	52,526
1975	118,742	5.7	214.0	12,302
1976	109,346	4.5	212.7	13,624
1977	139,849	8.0	333.3	16,612
1978	231,570	29.5	661.1	17,834
1979	811,136	63.8	2212.6	83,488
1980	855,658	51.7	2358.0	88,674
Average	383,054	32.5	971.1	36,186

During the eight year period, phosphorus loads at S-77 were highly variable and ranged from a low of 3.2 tonnes in 1973 to a high of 93.3 tonnes in 1974. S-77 discharged an annual average nitrogen load of 971 tonnes between 1973 and 1980 with a low in 1973 of 89 tonnes and a high in 1980 of 2,358 tonnes. The chloride mass load was also lowest in 1973 (4,431 tonnes) and highest in 1980 (88,674 tonnes), averaging 36,186 tonnes.

BASIN LOADING COMPARISON

Table 22 presents the annual mass load and percent contribution of total phosphorus, total nitrogen, and chloride in the Caloosahatchee River system each year of the study. On the average, Lake Okeechobee contributed 55% of the water to the river between 1978 and 1980, 62% of the nitrogen, 39% of the phosphorus, and 64% of the chloride. Except for phosphorus, the greatest contribution of flow, total nitrogen, and chloride occurred in 1980.

Except for the 1978 flows, the tributaries in the East Basin consistently contributed the least amount of water and chloride, averaging 21% and 10%, respectively. The nitrogen and phosphorus percent contributions averaged 23% and 43%, respectively. The tributaries in the East Basin consistently demonstrated a disproportionately higher phosphorus contribution when compared with flow. From 1978 to 1979, the percent contribution of water decreased from 38% to 22%, whereas the phosphorus percent contribution decreased from 55% to only 49%. In 1980, the percent of flow from the East Basin tributaries was further reduced to 9%; however, the reduction to the percentage of phosphorus was not proportional, being reduced to 27%.

Tributaries in the West Basin consistently contributed the least percentage of nitrogen and phosphorus, averaging 15% and 18%, respectively, and only a slightly greater percentage of water (24%) than the East Basin (21%).

TABLE 22. AVERAGE ANNUAL MASS LOAD AND PERCENT CONTRIBUTION TO THE CALOOSAHATCHEE RIVER

		Flow		Total N		Total P		Chloride	
	Source	A-F	% of Total Contribution	Tonnes	% of Total Contribution	Tonnes	% of Total Contribution	Tonnes	% of Total Contribution
	Lake Okeechobee	231,570	33%	661	38%	30	28%	17,833	36%
1978	East Basin	269,498	38%	487	28%	58	55%	11,277	23%
	West Basin	204,023	29%	572	33%	17	16%	19,895	41%
	Total (S-79)	705,091		1720		105		48,955	
	Lake Okeechobee	811,136	52%	2213	60%	64	44%	83,488	61%
1979	East Basin	336,044	22%	1127	30%	72	49%	15,542	11%
	West Basin	410,153	26%	344	9%	10	7%	38,262	28%
	Total (S-79)	1,557,333		3684		146		137,292	
	Lake Okeechobee	855,658	72%	2358	78%	52	41%	88,674	81%
1980	East Basin	107,966	9%	351	12%	34	27%	2,411	2%
	West Basin	222,919	19%	330	11%	41	32%	17,988	16%
	Total (S-79)	1,186,543		3039		127		109,073	
	Lake Okeechobee	1,898,364	55%	5232	62%	146	39%	189,995	64%
1978-80	East Basin	713,505	21%	1965	23%	164	43%	29,180	10%
	West Basin	837,098	24%	1246	15%	68	18%	76,145	26%
	Total (S-79)	3,448,967		8443		378		295,320	

PART VII

WATER QUALITY STANDARDS

Florida Administrative Code (FAC) Chapter 17-3 water quality criteria was adopted in 1972, and revised in 1979, with the intent of maintaining and improving the quality of waters in the State. General surface water criteria have been established for all waters in Florida with additional specific criteria adopted according to a classification system based on designated use (Table 23).

There are two major groups of water quality parameters covered in FAC Chapter 17-3, those with specific numeric criteria defining pollution, and those constituents for which no numerical threshold values have been established. These latter interpretive criteria cover any substance considered by the Florida Department of Environmental Regulation (FDER) to be deleterious and/or toxic according to the designated usage.

FAC Chapter 17-3 receiving water criteria are applied only after a reasonable opportunity for mixing with the receiving surface waters has been afforded. The reasonableness of the opportunity for mixing is stated to be dependent upon the condition of the receiving body of water; the nature, volume, and frequency of the proposed waste including any possible synergistic effects with other pollutants or substances present; and the cumulative effect of the proposed mixing zone and other mixing zones in the vicinity.

Due to the nature and design of this study, strict application of FAC Chapter 17-3 quality criteria is not possible. No provisions were made in the study design to delineate mixing zones or assess "natural background" levels. A comparison, however, between the water quality data collected during the study (1978-1980) and FAC Chapter 17-3 quality criteria does lend some perspective to the overall quality of waters in the Caloosahatchee River study area.

TABLE 23. CLASSIFICATION OF WATERS

Classification	Designated Users
Class I-A	Potable Water Supplies - Surface Waters
Class I-B	Potable and Agricultural Water Supplies and Storage - Groundwaters
Class II	Shellfish Propagation or Harvesting - Surface Waters
Class III	Recreation, Propagation and Management of Fish and Wildlife - Surface Waters
Class IV	Agricultural Water Supplies - Surface Waters
Class V-A	Navigation, Utility, and Industrial Uses - Surface Waters
Class V-B	Freshwater Storage, Utility and Industrial Uses - Groundwaters

The Caloosahatchee River flows from Lake Okeechobee through a three county area to the Caloosahatchee estuary west of the W. P. Franklin Lock and Dam (S-79). The Caloosahatchee River's designated usage is divided at the Hendry-Lee County line. Glades and Hendry County segments are designated Class III waters and Lee County as Class IA waters since the river supplies potable water to Lee County and the city of Fort Myers. All tributaries discharging to the Caloosahatchee River are designated as Class III waters.

Presented in Table 24 are the numeric threshold criteria for 12 select FAC Chapter 17-3 quality parameters and corresponding results from this study. Although other parameters have general or specific criteria, there was either insufficient data for proper evaluation or some judgment was required regarding "background" information. Consequently, these parameters have been omitted.

Alkalinity, chloride, fluoride, nitrates, and turbidity levels were never beyond the threshold limits established by the State criteria for fresh water according to designated usage, and as such, will not be discussed further. Of the remaining parameters, dissolved oxygen, total iron, some pesticides, and zinc were occasionally beyond the limits established by State Criteria for Class IA and Class III waters, while ammonia and pH were in excess for Class III waters only.

Ammonia. Ammonia is a biologically active compound present in most waters as a normal biological degradation product of nitrogenous organic matter. FAC Chapter 17-3 states that ammonia (un-ionized), for Class IA and Class III waters, shall not exceed 0.02 mg/L for predominantly fresh waters. Temperaature and pH are the most important factors controlling the levels of un-ionized ammmonia in natural waters. The concentration of un-ionized ammonia is directly proportional to temperature and inversely proportional to pH.

TABLE 24. SELECT FAC CHAPTER 17-3 SURFACE WATER QUALITY PARAMETERS FOR ALL STATIONS FOR STUDY PERIOD 1978-1980

Parameter	Class I-A Numeric Standard	River Reach Min.	River Reach Max.	River Reach Mean
Alkalinity (mg/L $CaCO_3$)	not <20 mg/l as $CaCO_3$	106.0	189.5	152.6
Ammonia (mg/L ionized)	not >0.02 mg/L (mg/L un-ionized)**	0.01	0.52	0.04
Chloride (mg/L)	not >250.0 mg/L	35.5	148.8	76.1
Dissolved Oxygen (mg/L)	not <5.0 mg/L	2.5*	12.1	6.4
Fluoride (mg/L)	not >1.5 mg/L	0.1	0.4	0.2
Nitrates (mg/L)	not >10.0 mg/L	0.004	0.626	0.204
Pesticides and herbicides	see text	see text		
pH	$6.0 \leq X \leq 8.5$	6.7	8.5	7.5
Specific Conductance (micromhos/cm)	see text	390	802	588
Total Iron (mg/L)	not >0.30 mg/L	0.04	0.80*	0.23
Turbidity (JTU)	not >50.0 JTU above background	0.03	8.0	1.3
Zinc (mg/L)	not >0.03 mg/L	0.01	0.07*	0.03

* Represents some values beyond the limits of State Standards

** Based upon an average pH for the study area of 7.4 and 25°C, the concentration of total ammonia ($NH_3 + NH_4^+$) which contains an un-ionized ammonia concentration of 0.020 mg/L NH_3 (mg/L) is equal to 1.58 mg/L

TABLE 24. (Continued)

Class III

Parameter	Standard	River Reach Min.	River Reach Max.	River Reach Mean	Tributary Inflows Min.	Tributary Inflows Max.	Tributary Inflows Mean
Alkalinity (mg/L $CaCO_3$)	Not <20 mg/L ($CaCO_3$)	53.5	247.0	147.5	25.5	368.6	193.7
Ammonia (mg/L ionized)	Not >0.02 mg/L (mg/l un-ionized)	0.01	1.22	0.07	0.01	5.26*	0.15
Chloride (mg/L)	No numerical threshold criteria	29.6	123.6	71.2	6.9	614.0	71.1
Dissolved Oxygen (mg/L)	Not <5.0 mg/L	0.4*	11.4	6.2	0.6*	14.0	5.8
Fluoride (mg/L)	Not >10 mg/L as ion	0.1	0.4	0.2	0.1	0.5	0.2
Nitrates (mg/l)	No numerical threshold criteria	-	-	-	-	-	-
Pesticides and herbicides	See text	-	-	-	-	-	-
pH	$6.0 \leq X \leq 8.5$	6.3	8.6*	7.4	6.4	8.6*	7.3
Specific Conductance (micromhos/cm)	See text	266	990	575	98	2680	652
Total Iron (mg/L)	not >1.0 mg/L	0.02	0.84	0.23	0.02	3.57*	0.39
Turbidity (JTU)	not >50 JTU above background	0.3	4.8	1.5	0.2	18.0	2.0
Zinc (mg/l)	not >0.03 mg/L)	0.01	0.08*	0.03	0.01	0.11*	0.03

The U. S. Environmental Protection Agency published a report in July 1976 entitled, Quality Criteria for Water which presented a table of concentrations for total ammonia ($NH_3 + NH_4^+$) and un-ionized ammonia.

In the Caloosahatchee River study area, the average pH is approximately 7.4 units and the average annual temperature is approximately 25°C. Under these conditions, the concentration of total ammonia ($NH_3 + NH_4^+$) necessary to contain an un-ionized ammonia concentration of 0.020 mg NH_3/L is approximately 1.58 mg/L. At no time did either the river average approach a total aqueous ammonia concentration of 1.58 mg/L or did the specific sample dates approach an un-ionized ammonia concentration of 0.02 mg NH_3/L. Of the tributaries sampled, only the Diston Island Canal (CR-03.2T) occasionally exceeded an un-ionized ammonia concentration of 0.02 mg NH_3/L.

Dissolved Oxygen. The FAC Chapter 17-3 criteria for dissolved oxygen for Class IA and Class III waters states that the dissolved oxygen shall not be less than 5 mg/L. Normal daily and seasonal fluctuations above this level shall be maintained for predominantly fresh waters.

All dissolved oxygen measurements were taken during daylight hours between 0700 and 1700 when the dissolved oxygen levels are generally highest. Dissolved oxygen in the river (Table 25) ranged between 0.4 mg/L and 12.1 mg/L, with an overall mean of 6.2 mg/L. Dissolved oxygen in the tributaries (Table 26) ranged between 0.6 mg/L and 14.0 mg/L, with an average of 5.6 mg/L for the tributaries.

Each table includes the total number of dissolved oxygen measurements taken at each station (surface only) and the number of values less than 5.0 mg/L. The dissolved oxygen in the river and tributaries was less than 5.0 mg/L, 22 and 31 percent of the time, respectively.

Pesticides. Pesticide samples were collected from the water column in October

TABLE 25. DISSOLVED OXYGEN* REVIEW ON THE CALOOSAHATCHEE RIVER, 1978-1980

River Station	Surface Min.	Surface Max.	Surface Mean	Bottom Mean	Total No. Observations	Total No. Suface Observ. <5.0 mg/L
Class III						
S-77						
CR-03.0	0.4	9.5	5.5	3.6	41	18
CR-04.5	2.4	9.8	5.7	3.8	29	10
CR-06.0	0.6	10.4	6.0	3.9	43	11
CR-09.0	3.1	9.4	6.2	4.4	29	6
CR-11.0	1.0	10.5	6.2	4.6	43	10
CR-13.5	3.3	10.4	6.3	4.2	29	5
CR-16.0	3.6	9.2	6.3	4.7	43	10
CR-19.0	3.3	9.9	6.6	4.7	28	3
CR-22.5	2.3	9.4	6.6	5.0	42	4
CR-26.0	1.8	11.4	6.5	4.2	43	8
CR-30.4	3.2	10.6	6.3	4.1	44	7
CR-32.0	2.5	10.6	6.3	3.9	43	7
Grand Mean			6.2	4.2		
TOTAL					457	99 or 22%
Class IA						
CR-36.0	2.5	11.2	6.3	4.3	43	10
CR-37.0	2.6	10.8	6.4	4.3	42	9
CR-39.0	2.6	12.1	6.5	4.3	42	10
CR-40.3	2.6	11.9	6.5	4.5	42	10
Grand Mean			6.4	4.4		
TOTAL					169	38 or 22%

*All Concentrations from surface in mg/l

TABLE 26. DISSOLVED OXYGEN* REVIEW OF TRIBUTRIES IN THE CALOOSAHATCHEE RIVER STUDY AREA DURING 1978 AND 1979

Tributary Station	Minimum	Maximum	Mean	Total No. Observations	Total No. Surface Observ. <5.0 mg/L
Class III					
C-20 at S235	1.6	6.7	4.3	12	6
Diston Isl. Canal	0.8	8.6	4.0	29	22
Whidden Corner C.	1.1	8.9	5.1	29	14
C-19 at S47D	1.4	7.2	4.6	28	13
Grassey Marsh East Canal	1.4	6.9	3.8	12	8
Meander Line Ditch	0.6	14.0	6.2	29	12
Long Hammock Canal	2.0	9.7	5.1	29	14
Goodno Canal	1.3	11.8	5.5	29	15
Okaloacoochee Canal	2.7	13.9	7.8	43	8
Crawford Canal	3.1	8.7	6.1	39	9
Jack's Branch	2.7	8.6	5.3	42	19
Roberts Canal	1.6	9.0	6.6	43	5
Ft. Simmons Branch	4.6	9.3	6.9	43	1
Townsend Canal	2.7	9.9	6.2	43	6
Bedman's Creek	4.8	9.1	6.4	43	2
Cypress Creek	1.9	7.8	4.7	43	25
Hickey Creek	4.3	8.0	6.3	42	3
Grand Mean			5.6		
TOTAL				578	182 or 31%

* All concentrations from surface in mg/L

1979 at river stations CR-00.0 (the Lake Okeechobee Rim Canal at S-77) and CR-16.0 (downstream of S-78) and analyzed by the U. S. Geological Survey. A pesticide sample was also collected from the water column adjacent to the Lee County Water Treatment Plant at station CR-40.3, a portion of the river classified at Class IA. The results, by class, are presented in Tables 27 and 28. Interpretation of the data is difficult in many cases because the FAC Chapter 17-3 criteria is below the limit of detection used in the analyses. Generally, most substances tested for were not present in detectable amounts. Aldrin plus Dieldrin and DDT were in excess of the FAC Chapter 17-3 criteria for both classifications of water, while chlordane exceeded the State Criteria for Class III waters only. Additional sampling in April 1981 confirmed only chlordane to be excess of State Standards.

pH. FAC Chapter 17-3 General Criteria for Surface Waters states that the pH of receiving waters shall not be caused to vary more than one unit above or below the natural background pH of the water; the lower value shall not be less than six and the upper value shall not be more than eight and one-half. No pH values were recorded beyond these limits for the Class IA reach of the river during the study. In the Class III reach of the river, station CR-22.5 and the Meander Line Ditch tributary both exhibited one instance with a maximum pH in excess of 8.5 units (Table 24). This occurred in June and July 1980 at the Meander Line Ditch and river station CR-22.5, respectively.

Specific Conductance. Specific conductance ranged from 98 to 2680 micromhos/cm throughout the study area with a river and tributary average of 578 and 652 micromhos/cm, respectively. Chapter 17-3 states that the specific conductance shall not be increased more than 100% above background levels, or to a maximum level of 500 micromhos/cm in those surface waters in which the specific conductance of the water at the surface is less than 500

TABLE 27. SELECT FAC CHAPTER 17-3 PESTICIDE CRITERIA AND OBSERVED LEVELS* FOR CLASS III WATERS - OCTOBER 1979

		Observed Levels	
Determination	State Criteria	CR-00.0	CR-16.0
**Aldrin plus Dieldrin	not >0.003	0.03	0.04
**Chlordane	not >0.01	< 0.1	0.1
**DDT	not >0.001	0.01	0.02
Endosulfan	not >0.003	< 0.01	< 0.01
Endrin	not >0.004	< 0.01	< 0.01
Heptachlor	not >0.001	< 0.01	< 0.01
Lindane	not >0.01	< 0.01	< 0.01
Malathion	not >0.1	< 0.01	< 0.01
Methoxychlor	not >0.03	< 0.01	< 0.01
Mirex	not >0.001	< 0.01	< 0.01
Toxaphene	not >0.005	< 0.1	< 0.1
Polychlorinated Biphenyls	not >0.001	< 0.1	< 0.1

* All levels in micrograms (μg)/liter

**Values which exceed State criteria according to FAC Chapter 17-3

TABLE 28. SELECT FAC CHAPTER 17-3 PESTICIDE CRITERIA AND OBSERVED LEVELS* FOR CLASS I-A WATERS - OCTOBER 1979

Station	Determination	State Criteria	Observed Levels
CR-40.3	**Aldrin plus Dieldrin	not >0.003	0.03
	Chlordane	not >0.01	0.0
	2,4-D	not >100	0.04
	2,4,5-TP (silvex)	not >10	0.01
	**DDT	not >0.001	0.01
	Endosulfan	not >0.003	< 0.01
	Endrin	not >0.004	< 0.01
	Heptachlor	not >0.001	< 0.01
	Lindane	not >0.01	< 0.01
	Malathion	not >0.1	< 0.01
	Methoxychlor	not >0.03	< 0.01
	Mirex	not >0.001	< 0.01
	Toxaphene	not >0.005	< 0.1
	Polychlorinated Biphenyls	not >0.001	< 0.1

* All levels in micrograms (μg)/liter

** Values which exceed state criteria according to FAC Chapter 17-3 micromhos/cm; and shall not be increased more than 50% above background level, or to a maximum of 5,000 micromhos/cm for predominantly fresh waters in which the specific conductance of the water at the surface is equal to or greater than 500 micromhos/cm. Specific conductance in the study area was usually greater than 500 micromhos/cm. Generally, however, even though the specific conductance of certain tributaries was occasionally 50% greater than the river average, the maximum specific conductance recorded in any tributary (2680 micromhos/cm) was still considerably less than the maximum allowable level for predominantly fresh water (5,000 micromhos/cm). The average specific conductance of all the tributaries except Diston Island Canal (CR-03.2T) and Ft. Simmons Branch (CR-31.0T) was less than 50% greater than the river average. No tributary specific conductance value ever approached the maximum level of 5,000 micromhos/cm.

Total Iron. The total iron concentrations for the river and tributaries, collectively, ranged between 0.02 mg/L and 3.57 mg.L. The Class IA criteria for iron in fresh waters is 0.03 mg/L while in Class III waters the iron value shall not exceed 1.0 mg/L. The Class IA waters usually exceeded the 0.30 mg/L criteria. With the exception of the Diston Island Canal (CR-03.2T), C-19 (CR-04.8T), and the Grassey Marsh East Canal (CR-06.8T), all remaining tributaries in the East Basin demonstrated total iron values in excess of the State Criteria of 1.0 mg/L for Class III waters. All tributaries in the West Basin exhibited total iron values less than the maximum criteria level, except Crawford Canal (CR-26.2T), Jack's Branch (CR-30.3T), Ft. Simmons Branch (CR-31.0T), and the Townsend Canal (CR-33.5T), which occasionally had levels greater than 1.0 mg/L.

Zinc. Zinc was sampled during the 1978 study year only. The overall average for zinc in the river (0.03 mg/L) was slightly higher than the tributaries

(0.02 mg/L) with a collective range between 0.01 and 0.09 mg/L. FAC Chapter 17-3 indicates that zinc in Class IA and Class III waters shall not exceed 0.03 mg/L. All stations, with the exception of the Okaloacoochee Branch (CR-22.0T), Crawford Canal (CR-26.2T), and the Banana Branch of Robert's Canal (CR-30.4T) in the study area exceed this criteria at some time.

PART VIII

FINDINGS AND CONCLUSIONS

GENERAL

1. Discharge from Lake Okeechobee at S-77 during the study period was atypical. Prior to this study, Lake Okeechobee discharges followed predictable, cyclic patterns of regulatory releases in the summer and nominal water supply releases in the winter. During 1978, Lake Okeechobee was effectively isolated from the Caloosahatchee River system with discharge at S-77 occurring only 76 days of the year. During 1979 and 1980, unprecedented dry season regulatory releases were necessary to lower Lake Okeechobee stages.
2. During this study, the total annual discharges at S-77, S-78, and S-79 were greater than the 11 year historic averages for each of these structures.
3. Depth composite sampling along the Caloosahatchee River has been shown to be a viable alternative to discrete depth sampling and results in representative quality values for all parameters tested except ammonia.

CALOOSAHATCHEE INFLOWS

4. Discharge activity was the principal factor influencing the concentration of most measured variables at S-77. During discharge, chloride, pH, turbidity, and suspended solids increased while nitrogen, phosphorus, alkalinity, and specific conductance decreased. Dissolved oxygen was unaffected by discharge and was higher in the winter than in the summer.
5. Tributaries in the East Caloosahatchee River Basin had higher concentrations for all variables measured except hardness, specific conductance, dissolved oxygen, calcium, nitrate, and fluoride than the tributaries in the West Caloosahatchee Basin.

6. Ortho phosphorus accounted for approximately 60% of the total phosphorus levels in the tributaries. Organic nitrogen was the principal component of the total nitrogen. The inorganic nitrogen was 83% ammonia in the East Basin but only 23% ammonia in the West Basin. Nitrate nitrogen was the principal inorganic nitrogen species in the West Basin.

CALOOSAHATCHEE RIVER

7. Phosphorus levels increased in the East Basin along the river from S-77 to S-78, then decreased in the West Basin toward the W.P. Franklin Lock and Dam (S-79). These increases and decreases were, in part, the result of tributary influences.

8. Total nitrogen concentrations decreased almost linearly from Lake Okeechobee to the W.P. Franklin Lock and Dam. Tributary influences were linked to this decrease since, as a group, the mean concentrations were less than the river. Ammonia and nitrate demonstrated reverse trends along the river, with ammonia levels decreasing from S-77 to S-79 and nitrate levels increasing slightly in the East Basin and drastically in the West Basin.

9. Chloride levels in the river decreased slightly in the East Basin but increased slightly in the West Basin.

10. Based on the temperature, pH, and specific conductance data for two stations, the river appeared well mixed with depth. There was some stratification of dissolved oxygen during the summer months. The dissolved oxygen levels during the winter months were constant with depth and were high, relative to the summertime values.

CHLOROPHYLL A

11. Chlorophyll a, a principal photosynthetic pigment in most groups of algae,

was used as an indicator of phytoplankton levels in the Caloosahatchee River. Chlorophyll a was detected at all locations and depths sampled during the three year study period. Based on surface values, chlorophyll a exhibited a general seasonal trend of (a) low concentrations (<10 mg/m3) in the late fall and winter months, November-March, (b) increasing concentrations during the spring months, April to early June and, (c) maximum summertime levels in excess of 20 mg/m3.

12. A distinct spatial trend was evident with East Caloosahatchee Basin chlorophyll a concentrations usually greater than West Caloosahatchee Basin values. However, in recent years, extensive nuisance phytoplankton blooms have occurred in the West Caloosahatchee Basin.

13. Chlorophyll a concentrations were positively correlated with water temperature and negatively correlated with inorganic nitrogen. There was no statistically significant relationship established between chlorophyll a concentration and water residence time. However, a number of cases were examined during which water flow through the Caloosahatchee River, from Lake Okeechobee regulatory releases or basin stormwater runoff, influenced chlorophyll a concentration by dilution or flushing phytoplankton populations downstream.

14. A major algal bloom was encountered in the West Basin only during the final year of the study. This algal bloom, coincidentally, occurred shortly after the termination of Lake Okeechobee regulatory releases. Previous nuisance blooms in 1976 and 1977 followed periods of low flow in the system.

INTENSIVE STUDY

15. No algae bloom occurred during the 1978 water quality study period. Daily total and ortho phosphorus data collected by the automatic sampler

during the intensive study period increased approximately two-fold between April and June 1978. This increase was not due to any sampled tributaries since all had phosphorus concentrations less than the river. Nitrate increased substantially during late April and early May, then decreased. The decrease was probably due to dilution as rainfall runoff from the tributaries and increased summertime biological productivity along the river.

16. Increases in the nitrogen and phosphorus concentrations from river station CR-36.0 to CR-40.3 appear to be the result of a high nutrient source being introduced between river stations CR-37.0 and CR-39.0. This source contributes an insignificant flow based on the chloride data, and is probably from local agricultural activity adjacent to the river.

MATERIAL LOADINGS

17. Comparative analysis of mass loading data indicates that, on the average, Lake Okeechobee contributed 55% of the water, 39% of the phosphorus, 62% of the nitrogen, and 64% of the chloride that the Caloosahatchee River ultimately discharges to the Gulf of Mexico. The tributaries in the East Basin contributed the most phosphorus (43%) and the least amount of water (21%) and chloride (10%). The tributaries in the West Basin consistently contributed the least percentage of nitrogen and phosphorus averaging 15% and 18%, respectively.

18. The tributaries in the West Basin displayed phosphorus and chloride levels comparable to the concentrations entering the river from Lake Okeechobee. The nitrogen levels, however, were only one half as great as those which entered at S-77.

STATE STANDARDS REVIEW.

19. Alkalinity, chloride, fluoride, nitrates, and turbidity levels were at no time during the study period outside the threshold limits established by

the State criteria for fresh water. Only the Diston Island Canal exceeded the recommended un-ionized ammonia criteria for Class III waters. Dissolved oxygen, dissolved zinc, and total iron were beyond the limits established by the State criteria for Class IA and Class III waters. The Meanderline Ditch and one river station approximately 15 miles downstream had slightly greater pH values than the maximum limit (8.5 units) for Class III waters on one occasion. The pesticides Aldrin plus Dieldrin and DDT were present in excess of the FAC Chapter 17-3 criteria for both classifications of water while chlordane was in excess of the State criteria for Class III waters only.

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APPENDIX A

RELATIVE ACCURACY RESULTS OF THE COMPOSITE SAMPLING METHODS

APPENDIX A. QUARTERLY COMPOSITE DATA ACCURACY FOR SELECT PARAMETERS AT STATION CR-03.0 DURING 1979

	Alkalinity (meq/l)	Ammonia (mg/l)	Ortho-P (mg/l)	Total-P (mg/l)	NO_x (mg/l)	TKN (mg/l)	Sodium (mg/l)	Chloride (mg/l)	TSS (mg/l)	T-Fe (mg/l)
March '79										
Composite	2.54	.017	.009	.048	.051	1.89	48.93	77.1	8.3	.16
Surface	2.51	.02	.008	.042	.050	2.60	49.56	77.1	7.0	.15
Bottom	2.49	.01	.008	.047	.054	1.69	49.56	77.1	7.0	.17
Rel. % Diff.	-1%	-13%	12%	-9%	+2%	+12%	+1%	0%	-18%	0%
June '79										
Composite	2.58	.03	.048	.103	<.008	1.22	44.85	73.7	3.0	.18
Surface	2.58	.04	.047	.093	.025	1.83	45.35	73.7	4.0	.29
Bottom	2.55	.03	.036	.087	<.008	1.94	45.18	73.7	3.0	.18
Rel. % Diff.	-1%	+14%	-14%	-14%	+50%	+35%	+1%	0%	+14%	+25%
Sept. '79										
Composite	3.70	.79	.258	.267	.818	3.70	61.94	106.1	3.0	.18
Surface	3.75	.81	.233	.272	.887	3.58	62.73	107.2	0.0	.20
Bottom	3.81	.84	.263	.270	.887	4.07	62.73	108.3	2.0	.18
Rel. % Diff.	+2%	+4%	-4%	+1%	+8%	+3%	+1%	+2%	-200%	+5%
Dec. '79										
Composite	2.89	.20	.056	.068	.289	2.64	70.37	84.8	2.0	.07
Surface	2.89	.20	.056	.072	.307	2.64	56.38	84.8	5.0	.08
Bottom	2.89	.18	.056	.069	.302	2.17	56.38	84.8	4.7	.11
Rel. % Diff.	0%	+5%	0%	-3%	-5%	+10%	-25%	0%	+59%	+26%
Mean Rel. % Diff.	0%	+2%	-2%	-6%	+14%	+15%	-6%	0%	-36%	+14%

QUARTERLY COMPOSITE DATA ACCURACY FOR SELECT PARAMETERS AT STATION CR-22.5 DURING 1979

	Alkalinity (meq/l)	Ammonia (mg/l)	Ortho-P (mg/l)	Total-P (mg/l)	No_x (mg/l)	TKN (mg/l)	Sodium (mg/l)	Chloride (mg/l)	TSS (mg/l)	T-Fe (mg/l)
March '79										
Composite	2.62	.05	.030	.070	.086	2.11	49.25	77.5	16.0	.30
Surface	2.59	.03	.015	.053	.081	1.81	49.41	77.3	7.0	.16
Bottom	2.62	.03	.015	.099	.080	1.93	48.46	77.7	31.0	.47
Rel. % Diff.	-0%	-67%	-100%	+8%	-7%	-13%	-1%	0%	+16%	+6%
June '79										
Composite	3.18	.06	.118	.135	.186	.62	33.02	57.7	2.0	2.92
Surface	3.21	.04	.115	.121	.169	.62	33.18	57.1	0.0	.44
Bottom	3.19	.06	.129	.138	.179	1.39	34.33	57.7	3.0	.38
Rel. % Diff.	+1%	-20%	+3%	-4%	-8%	+38%	+2%	0%	-33%	-62%
Sept. '79										
Composite	2.33	.03	.181	.204	.345	1.80	32.58	57.1	3.0	.34
Surface	2.36	.02	.181	.207	.368	1.92	33.37	57.1	1.0	.39
Bottom	2.36	.02	.187	.207	.288	2.72	33.37	57.1	5.0	.44
Rel. % Diff.	+1%	-50%	+2%	+1%	-5%	+22%	+2%	0%	0%	+19%
Dec. '79										
Composite	2.46	.02	.044	.061	.312	2.34	42.45	62.6	6.0	.21
Surface	2.37	.03	.048	.060	.290	2.26	51.19	60.3	0.0	.22
Bottom	2.43	.03	.045	.062	.355	2.00	52.71	61.5	3.0	.12
Rel. % Diff.	-2%	-33%	-4%	0%	-3%	10%	+18%	3%	-200%	-24%
Mean Rel. % Diff.	0%	-42%	-25%	+1%	-6%	+14%	+5%	+1%	+54%	-15.3%

QUARTERLY COMPOSITE DATA ACCURACY FOR SELECT PARAMETERS AT STATION CR-40.3 DURING 1979

	Alkalinity (meq/l)	Ammonia (mg/l)	Ortho-P (mg/l)	Total-P (mg/l)	No_x (mg/l)	TKN (mg/l)	Sodium (mg/l)	Chloride (mg/l)	TSS (mg/l)	T-Fe (mg/l)
March '79										
Composite	2.58	.04	.019	.058	.136	1.75	47.51	74.0	5.0	.18
Surface	2.58	.07	.028	.054	.141	1.81	47.51	75.0	5.0	.16
Bottom	2.56	.04	.027	.065	.147	1.33	47.67	74.6	6.0	.20
Rel. % Diff.	-0%	+27%	+31%	+3%	+6%	+11%	0%	+1%	+9%	0%
June '79										
Composite	3.46	.05	.085	.112	.122	1.06	38.11	67.3	4.0	.18
Surface	3.26	.02	.080	.119	.108	1.39	38.44	69.2	2.0	.22
Bottom	3.48	.08	.086	.111	.140	0.56	35.48	64.1	1.0	.22
Rel. % Diff.	-3%	0%	-2%	+3%	+2%	-8%	-3%	-1%	-167%	+18%
Sept. '79										
Composite	2.22	.02	.062	.093	.218	1.62	38.93	64.8	1.0	.23
Surface	2.24	.02	.061	.088	.212	1.74	38.93	64.8	1.0	.17
Bottom	2.24	.03	.061	.086	.212	1.74	39.24	64.8	3.0	.19
Rel. % Diff.	+1%	+20%	-2%	-7%	-3%	+7%	+1%	0%	+50%	-28%
Dec. '79										
Composite	3.01	.04	.038	.049	.368	2.40	53.47	72.0	5.0	.07
Surface	3.01	.04	.038	.052	.334	2.15	52.71	72.0	6.0	.07
Bottom	2.95	.04	.038	.050	.334	2.17	49.67	83.7	4.0	.79
Rel. % Diff.	-1%	0%	0%	-4%	+10%	+11%	-4%	-7%	+20%	+84%
Mean Rel. % Diff.	-1%	+12%	+7%	-1%	+4%	+5%	-2%	-2%	-22%	+18%

$$\text{Relative Percent Difference} = \left[\frac{\frac{1}{2}(S+B) - C}{\frac{1}{2}(S+B)}\right] 100$$

Where S = Surface Value
B = Bottom Value
C = Composite Value

APPENDIX B

ANALYTICAL METHODS FOR WATER CHEMISTRY DATA

12/2/81

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
Water Chemistry Laboratory

Analytical Methods

AutoAnalyzer II Method

Determination	Method	Range	Sensitivity	Detection Limit
Alkalinity	Colorimetric Automated Methyl Orange, Technicon AA II Method #111-71W, modified EPA Method #310.2	0-5.0 meq/L	0.1 meq/L	0.1 meq/L
Ammonia	Colorimetric Automated Phenate, Technicon AA II Method #154-71W, modified EPA Method #350.1	0-0.50 mg/L	0.01 mg/L	0.01 mg/L
Chloride	Colorimetric Automated Ferricyanide, Technicon AA II Method #99-70W, modified EPA Method #325.2	0-200.0 mg/L	2.0 mg/L	4.0 mg/L
Nitrite	Colorimetric Automated Diazotization with Sulfanilamide and coupling with N-(1 naphthyl) ethylenediamine dihydrochloride, Technicon colorimetric, automated AA II Method #120-70W, modified EPA Method #353.2	0-0.200 mg/L	0.002 mg/L	0.004 mg/L
Nitrate	Same as nitrite with Cadmium Reduction Column. Technicon AA II Method #100-70W, modified EPA Method #353.2	0-0.200 mg/L	0.002 mg/L	0.004 mg/L
Total Kjeldahl Nitrogen	Colorimetric, Semi-automated Block Digestor, Technicon AA II Method #376-75W, 334-74A, modified EPA Method #351.2	0-10.0 mg/L	0.1 mg/L	0.20 mg/L
Ortho Phosphate	Colorimetric, Automated, Phosphomolybdic Acid Blue Complex with Ascorbic Acid Reduction, Technicon AA II Method #155-71W, modified EPA Method #365.1	0-0.10 mg/L	0.001 mg/L	0.002 mg/L
Total Phosphate	Colorimetric, Semi-automated Persulfate Digestion followed by same method as Ortho Phosphate Technicon AA II Method #155-71W, modified EPA Method #365.1	0-0.10 mg/L	0.001 mg/L	0.002 mg/L

AutoAnalyzer II Method (Continued)

Determination	Method	Range	Sensitivity	Detection Limit
Silicates	Colorimetric, Automated Ascorbic Acid Reduction of Silicomolybdate Complex, Technicon AA II Method #105-71W	0-20.0 mg/L	0.20 mg/L	0.40 mg/L
Sulfate	Colorimetric, Automated Methylthymol Blue, Technicon AA II Method #118-71W, modified EPA Method #375.2	0-250.0 mg/L	5.0 mg/L	5.0 mg/L
Total Dissolved Iron	Colorimetric, Automated TPTZ Complex with thioglycolic acid pretreatment, Technicon AA II Method #109-71W	0-1.0 mg/L	0.02 mg/L	0.02 mg/L
Total Iron	Colorimetric, Semi-automated, Hydrochloric Acid Digestion modified Standard Methods 13th Ed., pp 192, 1971, followed by Total Dissolved Iron Determination	0-1.0 mg/L	0.02 mg/L	0.02 mg/L

Physical Parameters

Determination	Method	Range	Detection Range
Suspended Solids	Gravimetric Standard Methods Procedure #208D, 14th Ed., pp 94, 1975, EPA Methods #160.1 to 160.4	20-20,000 mg/L	1.0 mg/L or 5% whichever is greater
pH	Electrometric, EPA Method #150.1	0-14 pH	(sensitivity 0.01 pH)
Turbidity	Nephelometric, Standard Methods #214A, 14th Ed., pp 132, 1975, EPA Method #180.1	0-1,000 N.T.U.	2% of scale used
Color	Colorimetric, modified Standard Method #204A, 14th Ed., pp 64, 1975 (modified as per N.C.A.S.I. Technical Bulletin #253) modified EPA Method #110.2	0-500 mg/L as platinum in platinum-cobalt solution	1.0 mg/L

AutoAnalyzer II Method (Continued)

Determination	Method	Range	Detection Range
Conductivity	Electrometric, Specific Conductance at 25° C, modified Standard Methods #205, 14th Ed., pp 71, 1975, modified EPA Method #120.1		

Miscellaneous

Determination	Method	Range	Detection Range
Fluoride	Potentiometric, Ion Selective Electrode, Standard Methods #414B, 14th Ed., pp 391, 1975, EPA Method #340.2	0-2.0 mg/L	.04 mg/L

Metals - Major Cation

Atomic Absorption

Determination	Method	Range	Detection Range
Sodium	Atomic Abosrption Direct Aspiration with Dual Capillary System, EPA Method #273.1	0-150 mg/L	As calculated from absorbance
Potassium	Atomic Absorption Direct Aspiration with Dual Capillary System, EPA Method #258.1	0-10 mg/L	As calculated from absorbance
Calcium	Atomic Absorption Direct Aspiration with Dual Capillary System, Samples are treated with La_2O_3/HCl, EPA Method #215.1	0-150 mg/L	As calculated from absorbance
Magnesium	Atomic Absorption Direct Aspiration with Dual Capillary System, Same Treatment as calcium, EPA Method #242.1	0-40 mg/L	As calculated from absorbance

Trace Metals

Determination	Method	Range
Zinc	Atomic Absorption, Direct Aspiration, EPA Method #289.1	0-1.0 mg/L

Trace Metals

Determination	Method	Range
Strontium	Atomic Absorption, Direct Aspiration, Standard Methods #321A, 14th Ed., 1975	0-10.0 mg/L
Lead	Atomic Absorption, Furnace Technique, EPA Method #239.2	0-0.020 mg/L
Cadmium	Atomic Absorption, Furnace Technique, EPA Method #213.2	0-0.002 mg/L
Manganese	Atomic Absorption, Furnace Technique, EPA Method #243.2	0-0.010 mg/L
Cobalt	Atomic Absorption, Furnace Technique, EPA Method #219.2	0.0.020 mg/L
Chromium	Atomic Absorption, Furance Technique, EPA Method #218.2	0-0.010 mg/L
Nickel	Atomic Absorption, Furance Technique, EPA Method #249.2	0-0.020 mg/L
Copper	Atomic Absorption, Furnace Technique, EPA Method #220.2	0-0.020 mg/L
Arsenic	Atomic Absorption, Furnace Technique, EPA Method #206.2	0-0.010 mg/L
Mercury	Atomic Absorption, Manual Cold Vapor Technique, Modified EPA Method #245.1	0.0.004 mg/L

Sediment

Determination	Method		Range	Sensitivity	Detection Limit
Total Kjeldahl N	Digestion:	Technicon Publication #TA 4-0323-10	-	-	-
	Analysis:	Technicon Publication #371-74A	0.0-3.0%		0.06%
Total P	Digestion:	Technicon Publication #TA 4-0323-10	-	-	-
	Analysis:	M. L. Jackson 1958. Soil Chemical Analysis	0.0-0.5%	-	0.01%
Ca	Fusion:	J.H. Medlin, et al, 1969. A.A. Newsletter 8:546	-	-	-
	Analysis:	Perkin Elmer Manual	0.0-6.0%		0.12%

Sediment (Continued)

Determination	Method	Range	Sensitivity	Detection Limit
Mg	Fusion: J. H. Medlin et al, 1969. A.A. Newsletter 8:546 Analysis: Perkin Elmer Manual	- 0.0-1.6%	- -	- 0.03%
K	Fusion: J. H. Medlin et al, 1969. A.A. Newsletter 8:546 Analysis: Perkin Elmer Manual	- 0.0-1.6%	- -	- 0.03%
Organic Matter	C. A. Black, Ed. 1965. Methods of Soil Analysis Gravemetric	0.0-100%		
Inorganic Carbon	C. A. Black, Ed. 1965. Methods of Soil Analysis Gravemetric	0.0-100%	-	-
Fe	Fusion: J. H. Medlin et al, 1969. A.A. Newsletter Analysis: Perkin Elmer Manual	-	-	-
pH	M. L. Jackson, 1958. Soil Chemical Analysis	0-14 pH unit		
Sample Preparation	M. L. Jackson, 1958, Soil Chemical Analysis	-	-	-
Particle Size	Foth and Jacobs, 1964; Laboratory Manual for Soil Science	-	-	-

APPENDIX C

BENTHIC SEDIMENT DATA IN C-43

TABLE C-1

AVERAGE SEDIMENT DATA FOR THE CALOOSAHATCHEE RIVER (1978-1980)

% Concentration

River Station	lab pH	TKN	TEP*	K	Ca	Mg	TFe	Organic Matter	Carbonates	Texture
ECB:										
CR-00.5	7.37	.17	.047	.09	1.42	.05	.31	3.5	-	
CR-03.0	7.30	-	.041	-	-	-	-	5.7	16.2	sandy clay loam
CR-04.5	7.29	1.20	.084	-	3.47	.19	-	14.8	21.3	loamy sand
CR-06.0	7.32	.10	.085	-	1.91	.30	-	9.4	48.9	clay loam
CR-09.0	7.57	.06	.079	-	4.77	.03	-	1.7	29.6	sandy clay loam
CR-11.0	7.60	.06	.182	-	2.19	.03	-	2.6	29.1	light clay
CR-13.5	7.30	.14	.188	-	3.44	.26	-	5.7	15.6	loamy sand
WCB:										
CR-16.0	7.49	.38	.071	.24	4.93	.17	1.42	8.7	64.9	sandy clay loam
CR-19.0	7.21	.47	.172	-	3.46	.39	-	13.1	37.0	sandy clay loam
CR-22.5	7.34	.26	.221	-	2.80	1.08	-	7.8	34.3	medium clay
CR-26.0	7.54	.10	.156	.40	3.55	1.73	.68	5.5	62.9	medium clay
CR-30.4	7.34	.44	.180	-	4.03	1.29	-	11.7	45.8	medium clay
CR-32.0	7.27	.36	.156	-	4.05	1.46	-	12.2	46.9	medium clay
CR-36.0	7.51	.13	.415	.34	4.85	.84	1.25	5.0	42.5	sandy clay loam
CR-37.0	7.40	.36	.307	-	4.07	1.13	-	8.3	48.5	medium clay
CR-39.0	7.53	.12	.235	-	6.39	3.31	-	4.8	61.5	light clay
CR-40.3	7.65	.28	.214	.30	4.99	1.18	-	10.9	54.5	silty clay loam

*TEP - total elemental phosphorus

APPENDIX D

SUMMARY OF CHLOROPHYLL A VERTICAL PROFILE

DATA AT TWO SELECTED STATIONS

TABLE D-1. SURFACE AND BOTTOM CONCENTRATIONS OF CHLOROPHYLL A IN MG/M^3 AT TWO SELECTED STATIONS IN C-43 DURING 1978-1980.

	1978		1979		1980	
Month / Station	26.0	40.3	22.5	40.3	22.5	40.3
January	1.5 / 1.3	1.4 / 0.8	11.1* / 12.1	3.4* / 3.6	10.4 / 10.2	8.0 / 3.8
February	6.3 / 2.3	1.0* / 1.4	14.1* / 19.6	9.6 / 9.6	8.6* / 9.6	5.6* / 6.5
March	4.9 / 1.3	4.7 / 2.3	12.1* / 18.8	6.8* / 8.7	6.3* / 10.0	3.9 / 2.4
April	4.2 / 2.4	4.3 / 2.6	19.7 / 10.8	14.7 / 4.8	6.7* / 13.9	3.8* / 9.0
May	9.6 / 2.2	4.1 / 2.3	15.4 / 4.7	3.2 / 2.8	4.6* / 5.1	7.6* / 10.4
June	6.8 / 2.8	1.9 / 1.1	3.3 / 2.5	8.3 / 3.4	35.3 / 29.8	20.2 / 13.8
July	23.2 / 5.4	21.2 / 10.8	8.5 / 3.8	7.6 / 4.4	45.5 / 40.8	32.2 / 28.6
August	4.7 / 1.9	8.3 / 1.9	45.7 / 7.0	21.1 / 11.0	27.8 / 18.1	44.5 / 28.6
September	18.2 / 4.4	29.5 / 6.0	3.3 / 2.1	4.0 / 3.7	12.6 / 3.2	6.1 / 4.2
October	1.6* / 2.2	2.1 / 1.3	6.8* / 8.2	4.8 / 4.7	6.1 / 4.3	5.7 / 2.9
November	7.2 / 1.5	5.2 / 1.5	2.0 / 1.0	7.3 / 1.3	5.0 / 4.1	4.6 / 2.6
December	2.6 / 2.3	2.7 / 2.7	1.4* / 3.5	4.0 / 3.6	6.8 / 3.5	6.9 / 2.4

Results are mean of three replicate samples

6.3 = surface value mg chlorophyll a/m^3
4.0 = bottom value mg chlorophyll a/m^3

* sample date on which bottom value exceeded the surface value

APPENDIX E

CHLOROPHYLL A DATA COLLECTED FROM THE CALOOSAHATCHEE RIVER BETWEEN S-77 AND S-79; 1978-1980

TABLE E-1. SURFACE WATER CONCENTRATION OF CHLOROPHYLL A IN MG/M^3 IN THE CALOOSAHATCHEE RIVER DURING 1978.

	Station \ Date	1-10*	2-7*	3-7*	4-4	4-11	4-18*	4-25	5-3	5-9	5-18*	5-23	6-7	6-13*	7-11*	8-8*	9-12*	10-17*	11-16*	12-14*
Upstream	3.0	4.7	4.8	12.1	3.7	2.8	15.3	11.7	37.7	8.1	21.1	13.2		23.5	21.0	6.3	18.9	3.6	13.7	5.1
	6.0	2.1	4.4	3.4	4.7	5.2	7.8	15.2	42.6	8.5	17.3	28.1	42.6	20.8	18.2	6.3	22.5	3.7	7.9	6.1
	11.0	2.3	2.8		4.7	7.7	3.7	4.0	8.7	9.9	7.6	19.4	34.6	24.8	14.9	7.8	20.0	1.6	5.3	4.0
	$\bar{x}$	3.03	4.00	7.75	4.37	5.23	8.93	10.30	29.67	8.83	15.33	20.23	38.60	23.03	18.03	6.8	20.47	2.97	8.97	5.07
	s.d.	1.45	1.06	6.15	0.58	2.45	5.88	5.73	18.32	0.95	6.96	7.48	5.66	2.04	3.05	0.87	1.84	1.18	4.30	1.05
	% cv	48	27	79	13	47	66	56	62	11	45	37	15	9	17	13	9	40	48	21
Downstream	16.0		3.1	1.9	2.1		2.8	3.1	5.9	7.1	11.4	4.8	11.5	30.8		8.0	13.1	1.3	3.4	2.6
	22.5	1.5	5.4	2.8	5.2		2.2	1.4	3.8	5.6	18.4	5.1	15.3	22.8		8.6	52.1	1.3	5.4	3.6
	26.0	1.8	7.3	5.1	4.7	3.7	3.3	1.4	9.2	22.3	3.2	10.8	4.8	15.5	26.8	5.5	16.8	1.5	8.8	2.6
	30.0	1.5	2.4	5.9	2.2	3.7	1.5	2.2	4.1		2.1	6.3	2.6	19.7	22.0	7.0	18.7	1.7	1.0	2.6
	32.0	0.6	1.2	2.0	2.1		2.2	1.6	8.2	13.3	3.6	10.5	2.4	20.0	18.2	8.3	25.6	1.7	1.4	2.7
	36.0	0.9	1.1	2.0	3.0	3.1	1.4	2.1	3.5		6.6	4.3	1.7	24.2	37.1	7.1	18.4	1.8	6.4	0.1
	37.0	1.2	1.6	2.5	3.1		1.9	1.3	4.7	5.9	7.1	3.6	1.8	15.4	13.4	9.4	22.5	1.3	4.2	2.6
	39.0	0.9	1.3	3.7	3.1		1.5	2.6	2.7		4.6	3.6	2.3	16.6	33.4	5.8	19.4	2.0	9.4	2.6
	41.0	1.5	1.1	5.1	3.9	3.1	1.7	3.3	4.2	4.9	4.1	3.4	1.5	18.2	23.0	8.2	32.8	2.1	5.3	2.8
	$\bar{x}$	1.24	2.72	3.44	3.27	3.40	2.06	2.11	5.14	9.85	6.79	5.82	4.88	20.36	24.84	7.54	24.38	1.63	5.03	2.47
	s.d.	0.41	2.21	1.56	1.13	0.35	0.65	0.76	2.21	6.82	5.16	2.88	5.02	4.97	8.30	1.30	11.84	0.30	2.92	0.94
	% cv	33	81	45	35	10	32	36	43	69	76	49	1.03	24	33	18	49	19	58	38
Entire River	$\bar{x}$	1.73	3.04	4.23	3.54	4.19	3.78	4.16	11.28	9.51	8.93	9.43	11.01	21.03	22.80	7.36	23.40	1.97	6.02	3.12
	s.d.	1.11	2.03	2.96	1.11	1.74	4.03	4.48	13.70	5.44	6.57	7.66	14.47	4.49	7.67	1.21	10.28	0.83	3.57	1.49
t value (upstream $\bar{x}$ vs downstream $\bar{x}$)		3.55	0.96	2.19	1.61	1.52	3.78	4.63	4.38	-0.24	2.27	5.11	8.46	0.86	-1.34	-0.85	-0.55	3.50	1.85	4.05
East > West $t_{(.05)}$		x		x			x	x	x		x	x	x					x	x	x

* Routine monthly sampling trips. Other dates added during critical growth period, or in anticipation of impending algal bloom

TABLE E-2 . SURFACE WATER CONCENTRATION OF CHLOROPHYLL A IN MG/M^3 IN THE CALOOSAHATCHEE RIVER DURING 1979.

	Station \ Date	1-15*	2-12*	3-12*	4-3	4-17*	4-26	5-1	5-9	5-14	5-15*	5-22	5-23	5-25	5-29	6-5	6-12*	6-26	7-10*	7-24	8-14*	9-11*	10-17*	11-6*	12-4*
East Basin	0.1**	6.8	17.6	18.1	8.7	15.0	24.6	22.1	16.6	-	25.1	28.6	43.7	-	-	31.6	23.3	33.3	14.3	23.1	17.3	8.2	5.2	9.7	7.0
	3.0	9.1	19.0	14.9	5.4	14.9	33.9	32.0	26.9	99.6	32.7	56.2	52.2	15.6	24.9	36.0	35.7	21.9	27.8	19.1	31.0	9.3	5.4	4.3	3.5
	4.5	10.1	15.9	12.7	6.9	14.6	19.3	18.0	11.5	23.9	21.0	47.1	17.0	10.3	32.6	30.4	28.2	28.8	29.3	31.3	32.3	6.1	7.4	4.0	4.2
	6.0	7.6	14.5	15.1	7.2	16.7	9.3	25.2	13.1	17.6	32.3	57.9	36.4	6.7	32.5	27.8	26.7	30.3	32.6	38.9	26.2	7.5	6.2	3.1	3.5
	9.0	8.7	16.5	12.6	7.3	10.0	5.3	20.8	9.7	55.1	25.2	37.9	27.6	12.0	42.5	15.5	18.6	18.7	32.8	35.3	25.0	6.2	6.8	2.9	3.1
	11.0	9.7	16.4	17.4	7.6	7.7	7.3	26.2	14.1	38.7	32.3	47.1	33.5	10.2	11.1	10.7	12.9	17.5	39.6	29.4	25.6	8.0	8.1	3.2	5.0
	13.5	9.4	14.2	14.2	10.2	5.4	5.6	11.4	21.2	16.4	27.8	65.1	23.8	5.8	9.5	5.2	6.7	15.8	39.1	36.9	27.2	8.1	6.2	2.9	5.8
	$\bar{x}$	9.1	16.1	14.5	7.4	11.5	13.4	22.3	16.1	41.9	28.6	51.9	31.7	10.1	25.5	20.9	21.5	22.2	33.5	31.8	27.9	7.5	6.7	3.4	4.2
	s.d.	0.9	1.7	1.8	1.6	4.5	11.3	7.2	6.6	31.9	4.8	9.7	12.2	3.6	13.0	12.2	10.7	6.1	4.9	7.6	3.0	1.2	1.0	0.6	1.0
	% cv	10	11	12	22	39	84	32	41	76	17	19	38	36	51	58	50	27	15	24	11	16	15	18	24
West Basin	16.0	11.2	12.1	19.7	4.5	6.7	4.3	8.9	15.0	19.7	23.8	35.0	6.3	3.7	4.6	5.8	3.5	12.0	14.3	8.7	31.2	4.8	8.0	1.6	3.7
	19.0	8.7	14.9	13.7	8.7	13.8	4.9	42.4	10.2	9.2	24.8	31.7	23.4	4.6	5.1	5.6	4.8	11.8	4.9	25.5	21.1	-	5.8	1.6	5.2
	22.5	11.1	14.1	12.1	7.1	19.7	6.3	12.9	6.5	21.4	15.4	14.0	8.7	12.7	6.3	10.0	3.3	8.5	-	4.9	45.7	3.3	6.8	2.0	1.4
	26.0	10.0	13.5	10.3	17.6	12.6	5.7	13.8	17.7	24.3	13.4	22.7	9.9	10.4	7.7	8.2	3.4	6.0	4.9	5.9	28.1	4.0	7.2	3.9	4.4
	30.4	5.8	11.5	9.2	7.6	5.1	3.0	7.2	13.8	34.7	17.1	35.6	23.1	5.7	10.0	23.0	4.4	9.2	5.4	3.1	-	6.6	5.5	2.6	3.5
	32.0	5.1	11.1	10.2	7.4	6.7	3.2	8.2	12.6	14.6	17.6	30.3	15.3	9.5	7.5	7.6	4.4	7.4	4.3	2.0	22.5	4.3	5.8	4.0	3.8
	36.0	4.9	9.4	12.5	5.8	8.4	3.2	7.6	4.8	9.9	17.3	45.3	24.9	16.6	5.0	6.5	5.5	8.5	4.3	3.7	17.0	3.1	5.1	3.2	3.2
	37.0	3.4	9.0	8.3	5.5	4.6	3.9	7.3	4.6	10.5	10.4	62.4	23.8	8.8	5.3	7.5	6.3	8.6	1.9	3.7	23.6	3.2	5.8	4.5	3.8
	39.0	5.6	8.3	6.1	6.0	5.5	3.2	6.7	10.1	10.2	6.6	27.1	26.7	7.1	4.9	6.3	7.9	6.1	3.3	3.2	23.6	3.7	5.1	4.8	4.0
	40.3	3.4	9.6	6.8	5.1	14.7	3.5	7.7	14.0	13.3	3.2	13.1	34.7	15.2	3.6	5.7	8.3	7.6	4.1	4.4	21.1	4.0	4.8	7.3	4.0
	$\bar{x}$	6.9	11.4	10.9	7.5	9.8	4.1	12.3	10.9	16.8	15.0	31.7	19.7	9.4	6.0	8.6	5.2	8.6	5.3	6.5	26.0	4.1	6.0	3.5	3.7
	s.d	3.1	2.3	3.9	3.8	5.1	1.2	10.9	4.5	8.2	6.7	14.6	9.2	4.3	1.9	5.2	1.8	2.0	3.5	6.9	8.4	1.1	1.0	1.8	1.0
	% cv	45	20	36	51	52	29	89	41	49	45	46	47	46	32	60	35	23	66	100	32	27	17	51	27
Entire River	$\bar{x}$	7.7	13.1	12.2	7.5	10.4	7.6	16.0	12.9	26.2	20.0	39.3	24.2	9.7	13.3	13.2	11.3	13.7	16.6	16.0	26.7	6.0	6.2	3.5	3.9
	s.d.	2.6	3.1	3.7	3.0	4.8	8.1	10.6	5.8	23.2	9.0	16.1	11.7	4.0	12.4	10.2	10.3	7.8	14.9	14.3	6.7	1.5	1.0	1.8	1.0
East > West t(.05)			x				x			x	x	x	x		x	x	x	x	x	x		x			

* Routine monthly sampling trips. Other dates added during critical growth period, or in anticipation of impending algal bloom

** 0.1 is located upstream of S-77 in Lake Okeechobee and is shown for comparative purposes only

TABLE E-3 . SURFACE WATER CONCENTRATION OF CHLOROPHYLL A IN MG/M^3 IN THE CALOOSAHATCHEE RIVER DURING 1980.

	Station \ Date	1-15*	2-20*	3-18*	4-16*	5-8	5-20*	6-3	6-10*	6-17	6-23	6-30	7-8***	7-16*	8-19*	9-17*	10-14*	11-11*	12-10*
	0.1**	8.4	18.8	14.2	11.2	-	20.8	37.0	18.9	-	28.1	34.0	37.9	-	26.2	33.5	13.5	4.6	11.4
East Basin	3.0	-	10.8	7.9	14.7	20.3	19.2	37.3	23.1	36.0	27.5	40.4	-	25.0	19.8	35.6	28.5	11.7	17.4
	4.5	7.2	10.5	7.8	10.5	17.2	12.0	36.6	26.4	35.6	37.4	29.2	-	25.6	28.4	41.4	26.0	11.1	19.0
	6.0	4.8	9.6	9.1	14.6	19.8	16.0	35.8	33.3	36.7	47.5	40.2	-	50.8	41.2	74.9	21.7	11.8	19.1
	9.0	8.6	9.9	4.0	18.8	18.2	14.0	36.2	28.4	27.7	35.1	45.4		54.9	60.4	46.0	20.3	13.3	31.7
	11.0	7.3	10.6	6.2	10.9	14.8	11.8	40.9	25.3	31.7	36.0	45.0	-	50.2	32.7	53.0	16.2	17.1	37.3
	13.5	11.0	10.5	6.9	12.6	16.1	11.7	31.6	28.0	39.9	35.1	41.8	-	38.4	30.0	18.0	14.8	15.5	32.4
	$\bar{x}$	7.8	10.3	7.0	13.7	17.7	14.1	36.4	27.4	34.6	36.4	40.3	-	40.8	35.4	44.8	21.2	13.4	26.1
	s.d.	2.3	0.5	1.8	3.1	2.1	3.0	3.0	3.5	4.3	6.4	5.9	-	13.2	14.0	18.9	5.3	2.4	5.1
	% CV	29	5	26	23	12	21	8	13	12	18	15		32	40	42	25	18	20
West Basin	16.0	12.0	11.1	5.7	8.6	-	9.2	31.6	40.5	55.1	37.0	38.8	-	13.0	20.5	5.1	3.8	4.6	6.6
	19.0	8.0	9.3	5.2	8.1	9.5	7.8	43.7	36.9	53.8	30.5	46.0	-	35.6	25.2	11.2	3.0	3.2	8.3
	22.5	10.4	8.6	6.3	6.7	8.2	4.6	42.7	35.3	61.5	33.1	43.0	-	45.5	27.8	12.6	6.1	5.0	6.8
	26.0	10.5	5.3	6.5	5.6	9.9	3.2	44.1	43.4	114.2	30.8	38.6	-	39.6	77.1	13.4	6.2	7.7	5.6
	30.4	10.2	5.5	5.6	5.8	12.8	5.0	33.7	39.2	115.3	31.6	34.1	48.3	41.2	40.7	8.2	3.7	5.7	3.3
	32.0	15.4	4.1	5.8	5.6	13.6	5.3	45.3	37.6	123.0	29.7	33.7	-	29.2	43.2	9.8	5.9	4.8	3.5
	36.0	6.0	6.2	4.3	5.2	9.9	4.8	32.1	33.7	139.8	55.5	49.8	58.4	43.8	32.6	11.3	5.6	4.1	2.9
	37.0	7.7	6.4	3.8	5.5	8.5	7.6	29.9	40.6	159.2	56.2	53.7	-	47.4	44.9	12.8	6.2	3.2	3.2
	39.0	8.8	6.4	3.5	4.0	10.9	6.0	33.3	32.6	141.0	52.4	60.0	-	42.2	44.5	19.5	3.6	5.0	5.0
	40.3	8.0	5.6	3.9	3.8	6.7	7.6	35.2	20.2	103.9	54.9	57.4	71.7	32.2	44.5	6.1	5.7	4.6	6.9
	$\bar{x}$	9.7	6.8	5.1	5.9	10.0	6.1	37.2	36.0	106.7	41.1	45.5	58.3	37.0	40.1	11.0	5.0	4.8	5.2
	s.d.	2.6	2.1	1.1	1.5	2.2	1.9	6.0	6.5	38.0	11.7	9.5	11.1	10.2	15.8	4.1	1.3	1.3	1.9
	% CV	27	31	22	25	22	31	16	18	36	28	21	19	28	39	37	26	27	37
Entire River	$\bar{x}$	9.1	8.1	5.8	8.8	13.1	9.1	36.9	32.9	79.6	39.3	43.6	-	38.4	38.3	23.7	11.1	8.0	13.1
	s.d.	2.6	2.4	1.6	4.4	4.4	4.6	5.0	6.9	46.5	10.1	8.5	-	11.2	14.9	20.4	8.8	4.6	11.7
	East > West t(.05)		X	X	X	X	X		-X	-X						X	X	X	X

* Routine monthly sampling trips, other dates added during critical growth period, or in anticipation of impending algal bloom
** 0.1 is located upstream of S-77 in Lake Okeechobee, and is shown for comparative purposes only
*** $\bar{x}$ of two samples