Technical Publication SJ 84-8

WATER QUALITY OF THE SOUTHERN REACH OF THE MIDDLE ST. JOHNS RIVER: A FOCUS ON THE DROUGHT OF 1980 THROUGH 1981.

by
Joel Steward
Environmental Specialist

Department of Water Resources

St. Johns River Water Management District

P. O. Box 1429
Palatka, Florida

August, 1984

Project Number 20 090 03

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I fully appreciate the time spent and comments given by several members of the Environmental Sciences Division staff during review of this report. Special thanks goes to Mr. Ted Taylor and the Environmental Services Division of Seminole County for their efforts in providing invaluable data and information.

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Due to a drought in 1980 and 1981, the seasonal pattern of stage levels for the southern reach of the middle St. Johns River (SMSJ) differed from the 30-year norm. Stage levels, which normally declined during the spring and increased during summer and fall (1950-80), declined in late spring and continued to decline through the summer (1980-81). This shift was accompanied by a decrease in stage levels by approximately one-half of the 30-year average. As a result, annual mean concentrations of several chemical constituents in the river doubled and, in some cases, tripled.

Chloride and sulfate concentrations throughout the SMSJ increased during the drought by approximately two-fold over levels in the preceding period (1976-79). The linear regression equations representing the change in chloride levels as a function of water depth in the river at S.R. 46 and Lake Washington were nearly equivalent. Also, the scatter plot of this correlation, in addition to other major ion data, indicates that a progressive downstream increase in major ion concentrations in the St. Johns River extends to the outlet of Lake Harney.

The mean total phosphorus (TP) and total nitrogen (TN) concentration in the SMSJ (1979-81) was 0.18 mg/l and 2.5 mg/l, respectively. The highest mean concentrations among the three major lakes of the SMSJ were present in Lake Jessup - 0.55 mg/l TP and 4.1 mg/l TN. Lake Jessup's nutrient export to the main channel of the St. Johns River was nominal; whereas, the Econ River contributed significantly to nutrient levels in the St.

Johns downstream from its confluence, particularly during low flows.

Phosphorus concentrations from the inlet of Lake Harney to the outlet of Lake Monroe decreased from 1975 to 1979, then increased two to three-fold during the drought. Nitrate concentrations downstream from the Econ's discharge, however, progressively increased since 1974 and doubled during the drought over levels in 1974-75. The drought reached its greatest severity during the months of May through October in 1980 and in 1981. During those two six-month periods, mean concentrations of TP were greater than and mean concentrations of nitrate and dissolved oxygen were less than during November through April (1979-81). The inverse relationship between dissolved oxygen concentration and flow, which was typical prior to 1980, was reversed during the drought.

Most of the nutrient loading into the SMSJ is of nonpoint source origin, except in Lake Jessup where a majority of the total nitrogen and phosphorus was contributed by several sewage treatment plants. During low flow months the Econ has its greatest impact on Lake Harney as a result of lowered dilution of nutrient loads from treated sewage effluent. Despite efforts toward reducing these point source discharges, net increases in phosphorus and BOD_5 loadings are expected as urban development in the basin continues.

INTRODUCTION

The southern reach of the middle St. Johns River (SMSJ), lying within the political boundaries of Seminole and Volusia Counties (Figures 1 and 2), is predominantly a shallow (2 m. average depth) lacustrine system with a low hydraulic gradient. There are two main channel lakes, Lake Harney and Lake Monroe, and a tributary-lake, Lake Jessup. The lakes and their interconnecting waterway drain an area of approximately 1300 Km^2 comprising 10 subsurface and 12 surface drained sub-basins of mixed land use (Brezonik et al., 1976). In addition, the Econlockhatchee River (Econ), an important tributary (Figure 2), drains 600 Km^2 of the western slope of the St. Johns River basin (Gerry, 1983).

Land use intensification, particularly the urban expansion in Seminole County and in the Econ River basin (Orlando metroplex), is the most important factor deleteriously affecting water quality (Brezonik et al., 1976; Florida Department of Environmental Regulation (FDER), 1982; Florida Game and Freshwater Fish Commission (FGFWFC), 1982). Levels of phosphorus, dissolved oxygen, BOD_5 and bacterial densities often violate standards set by FDER for Class III waters; especially in lakes Jessup and Monroe (Seminole County, 1982). Major nutrient loading from land use intensification has contributed most to the rate of eutrophication in the three lakes. As a result, the lakes are plagued with intermittent algae blooms and fish kills. Brezonik et al. (1976) classified lakes Harney, Jessup and Monroe as mesoeutrophic, hypereutrophic and eutrophic, respectively.

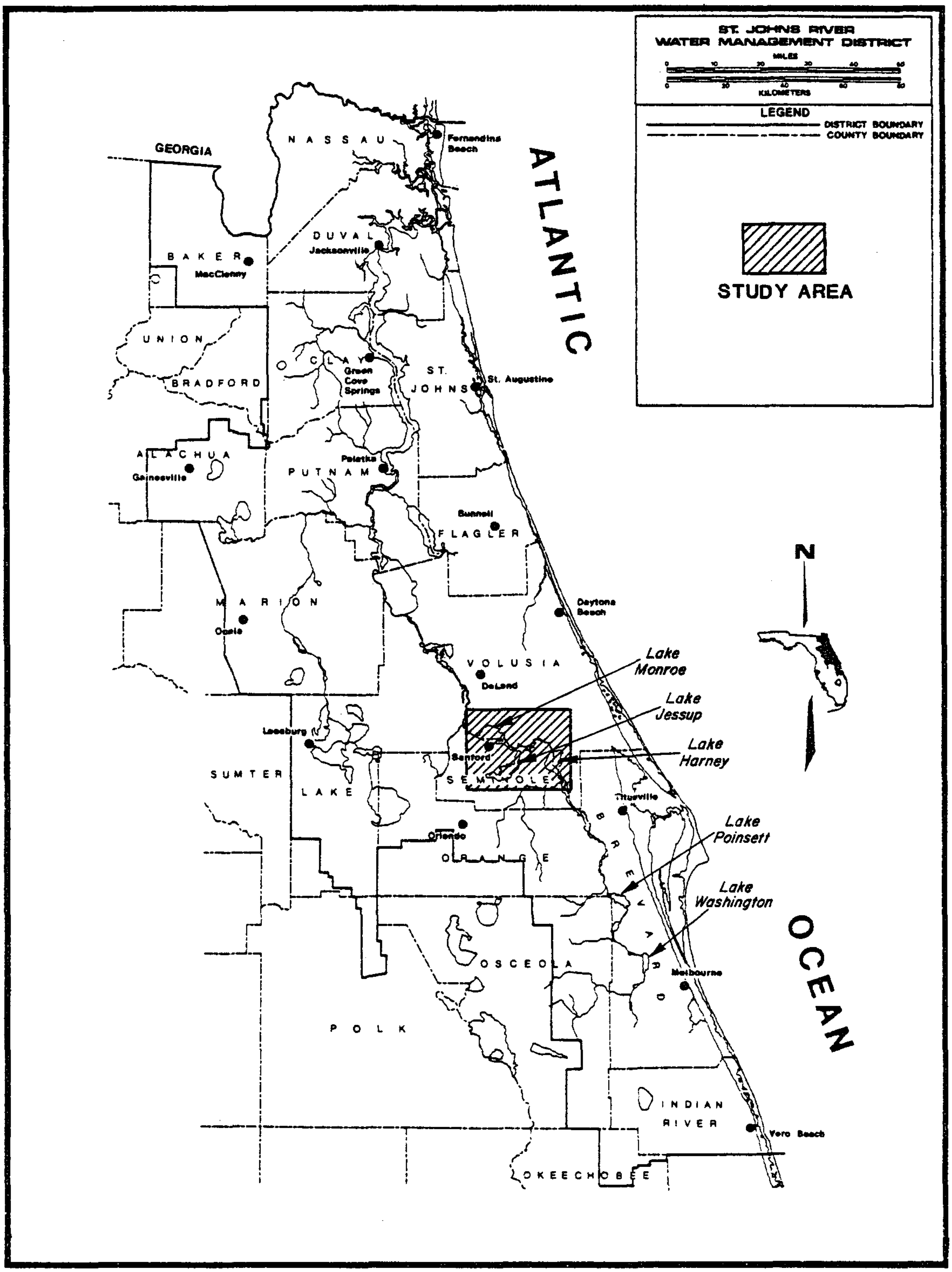


Figure 1. Map of the Study Area in the St. Johns River Water Management District

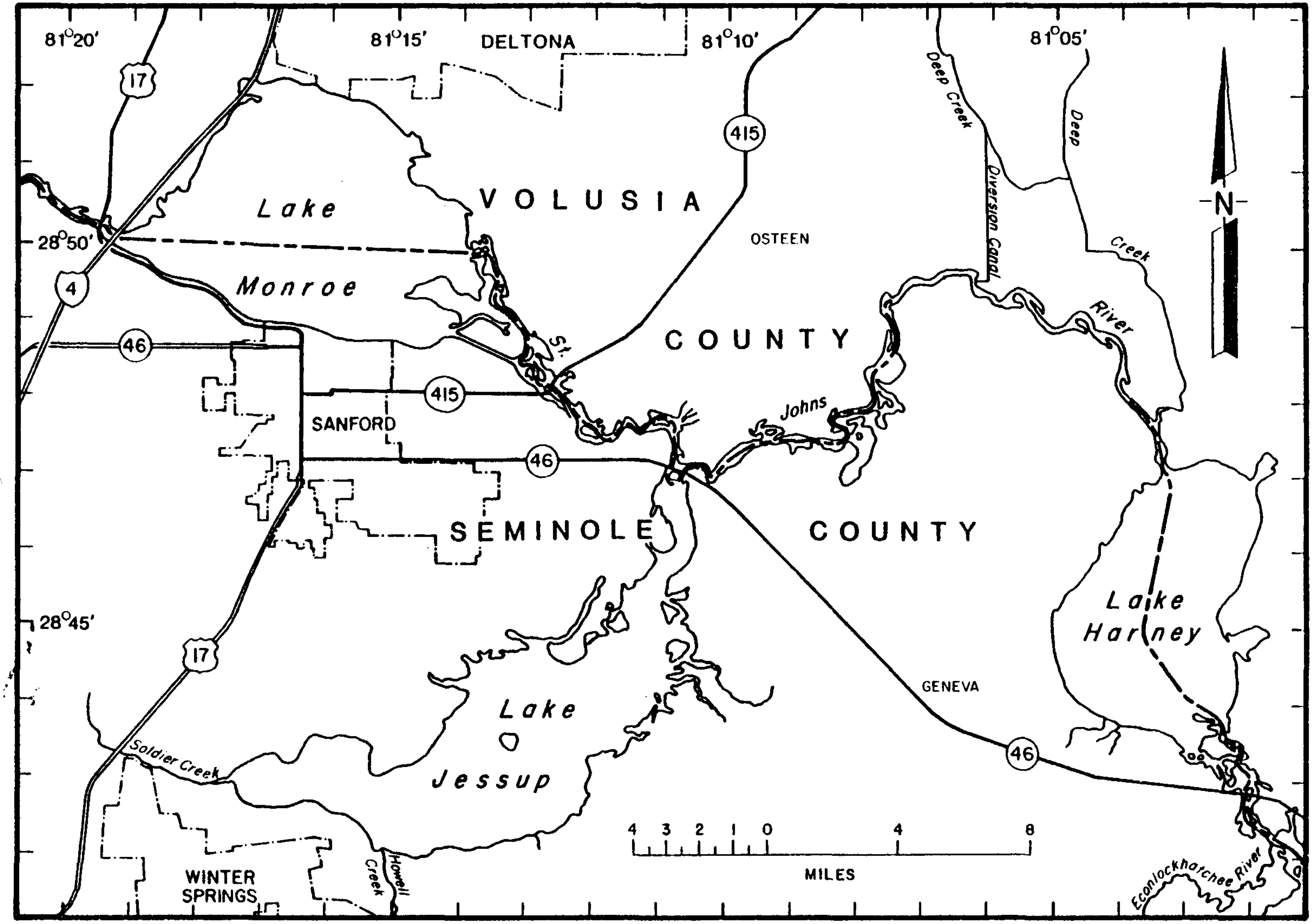


Figure 2. Map of the Study Area.

Efforts toward improving water quality in the basin are underway and are primarily focused on reducing point source nutrient and BOD_5 loading through advanced sewage treatment. Since 1982, several secondary sewage treatment facilities have been phased out with influent re-routed to a tertiary treatment facility (Iron Bridge) and effluent discharged into the Econ. However, it was concluded that point source abatement alone would not be sufficient in improving water quality (Brezonik et al., 1976) because nonpoint source (NPS) loads from urban, agricultural and silvicultural activities dominate the total nutrient input to the SMSJ (Connell Associates, Inc., 1974; Brezonik et al., 1976).

The quantity and quality of NPS runoff and the degree of impact from this and point source discharges in the SMSJ is largely a function of the hydrology, geomorphology and local climate as well as land use. A discussion of these factors as they relate to temporal and spatial water quality trends, and an evaluation of nutrient loading rates for lakes Harney, Jessup and Monroe is a necessary element in the development of basin management plans. Toward this end, prolonged low stage and flow are important factors to consider, thus, the recent drought (1980-81) provides an opportunity to quantify the effects of such an event on water quality.

METHODS

Analyses of water quality data collected by various governmental agencies form the basis for this report. Data were obtained from three agencies that regularly monitor the SMSJ system - United States Geological Survey (USGS), FDER, and Seminole County Division of Environmental Services (SCES) (Figure 3, Table 1). Data sets from USGS and FDER, which had been previously entered into the St. Johns River Water Management District's (SJRWMD) DATA-BASE, required updating and proofing for errors. Entry of the SCES data into DATA-BASE necessitated prior reorganization of the SCES data set and assignment of parameter STORET code numbers. All three data sets were collated and placed in a separate data base to make them readily accessible for statistical manipulation. This process will continue as new data are made available.

Interpretive efforts were concentrated on data collected from 1976 through February 1982. The bulk of these data were generated between 1979 and 1982 by SCES (Table 2), encompassing the drought period of 1980-81. Prior to data analysis, two stations in Lake Harney, EEN and FFN (Figure 3, Table 1) were combined for there was no significant difference between them for a host of parameters ($p>0.05$, $0.40<F<0.84$).

Three general stage and flow gradations, low, normal, and high, were utilized to examine relationships between water quantity and quality, and temporal and spatial nutrient loading rates. Differentiation of high stage from low was accomplished through use of stage frequency analysis tables presented in the

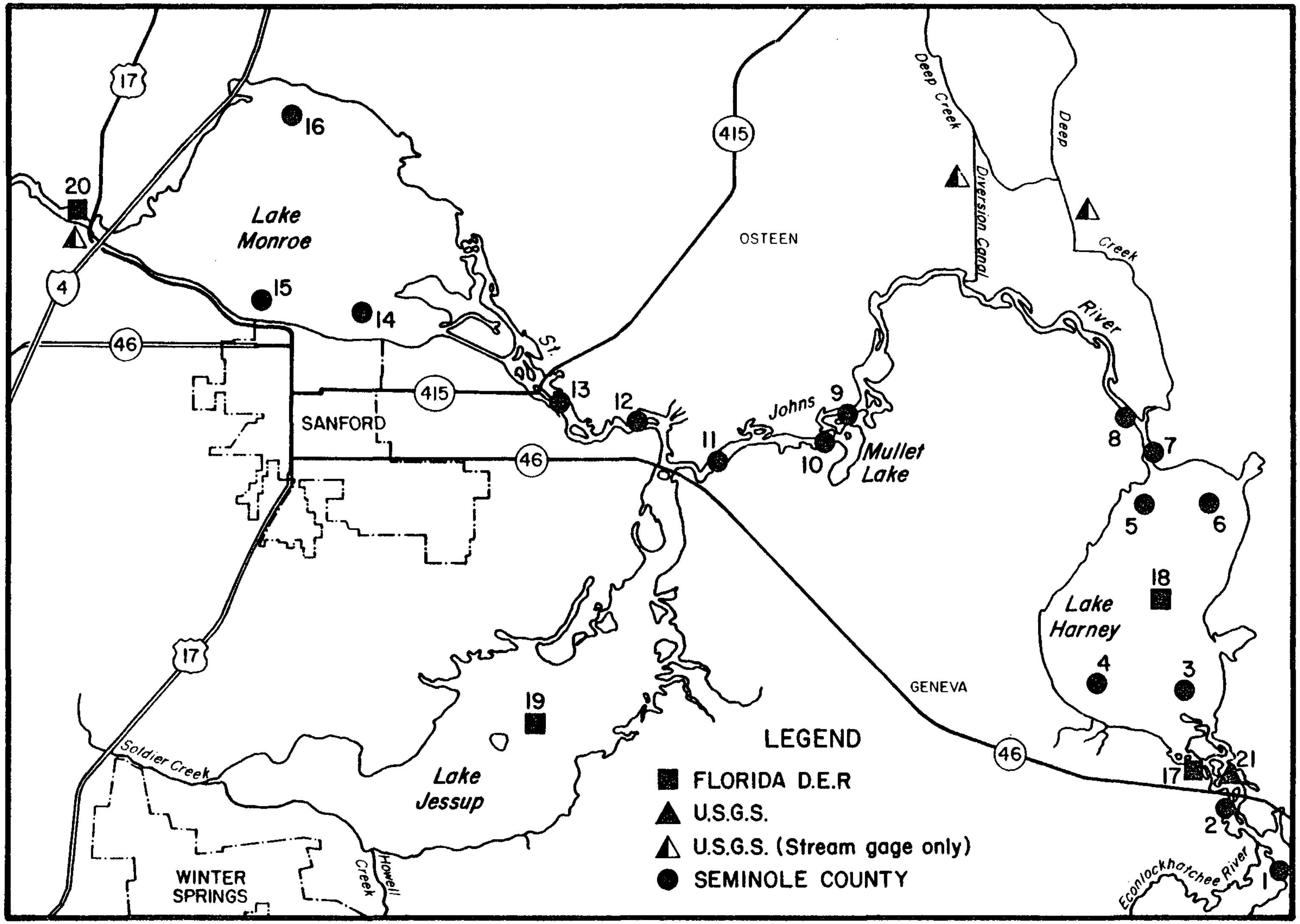


Figure 3. Tri-Agency Water Quality Monitoring Network in the Middle St. Johns River - Southern Reach.

TABLE 1. Water Quality Monitoring Key for SMSJ Basin

AGENCY/KEY NO.		STATION NAME*	LAT.-LONG.	DESCRIPTION
Seminole County	1	AAS	284214-810140	St. Johns River (SJR) above the Econ
Seminole County	2	BBS	284254-810201	SJR below the Econ, SR 46
Seminole County	3	CCS	284415-810235	Lake Harney, southeast corner
Seminole County	4	DDS	284415-810410	Lake Harney, southwest corner
Seminole County	5	EEN	284643-810318	Lake Harney, northwest corner
Seminole County	6	FFN	284643-810212	Lake Harney, northeast corner
Seminole County	7	GGS	284718-810328	Lake Harney outlet
Seminole County	8	HHS	284741-810336	SJR below Deep Creek
Seminole County	9	MLN	284735-810748	Mullet Lake, north
Seminole County	10	MLR	284728-810814	Mullet Lake Ramp
Seminole County	11	ULJ	284659-811014	SJR upstream of Lake Jessup
Seminole County	12	DLJ	284748-811058	SJR downstream of Lake Jessup
Seminole County	13	OBS	284805-811230	SJR near Osteen Bridge SR 415
Seminole County	14	MOE	284847-811439	Lake Monroe, Southeast
Seminole County	15	MOS	284900-811638	Lake Monroe, south near Sanford STP
Seminole County	16	MON	285156-811619	Lake Monroe, north near Power Plant
FDER	17	20010012	284249-810251	SJR at SR 46
FDER	18	20010026	284530-810335	Lake Harney, center
FDER	19	20010183	284406-811143	Lake Jessup near Bird Island
FDER	20	20010003	285013-811922	SJR at Sanford, 17-92
USGS	21	02234000	284250-810208	SJR above Lake Harney

* Station code used for computer retrieval of parameters of interest.

TABLE 2. Summary of Water Quality Studies of the Middle St. Johns River System - Southern Reach

Agency	Study Date	Sampling Location	Sampling Frequency	Parameter
Brevard County	3/1969-1/1972	19 stations on St. Johns and Lakes Jessup, Harney and Monroe (includes 1 station on Big Econlockhatchess and 1 station on Howell Creek)	11 times at 3-4 month intervals	Color, turbidity, chlorides specific conductance, tannins, coliforms, calcium, copper, phytoplankton count, fecal streptococci, zinc and iron
Orange County	8/1969-7/1974	" " "	6 times at irregular intervals some bridge stations monthly	pH, specific conductance, temperature, dissolved oxygen, pigments, phosphates, packed cell, volume, plankton counts
Orange County	11/1970-1/1972	3 stations on Little Econlockhatchee	12 times at irregular intervals	Macroinvertebrates (qualitative and multiple plate samplers)
Orange County	11/1970-5/1972	" "	7 times at irregular intervals	Periphyton pigments and total count
Orange County	10/1968-6/1971	5 stations on Big Econlockhatchee	Irregular, 2-3 times per station during entire study	Benthic invertrates
Orange County	10/1969	" "	Once	Chlorophyll *a*
Orange County	5/1971	" "	Once	Plankton count, chlorophyll *a*
Florida DER	1/1973-2/1973	7 stations in Lake Jessup	Twice, at a 1 month interval	Dissolved oxygen, biochemical oxygen demand, total N, total P
Florida DER	4/1973	7 stations in Lake Jessup	Once	Macroinvertebrate diversity, number of species, and number /m 2

TABLE 2. Summary of Water Quality Studies of the Middle St. Johns River System - Southern Reach (Continued)

Agency	Study Date	Sampling Location	Sampling Frequency	Parameter
U.S.E.P.A.	1973	3 stations in Lake Monroe an 2 in Lake Jessup (1 station on each lake for phytoplankton)	All stations sampled 3/14, 9/5/ and 11/5	Phytoplankon count, chlorophyll a, temperature, dissolved oxygen, conductivity, pH, alkalinity, total P, ortho-P, ammonia, Kjeldhal N, inorganic N, total N
U.S.E.P.A.	1973	1 station in Lake Jessup.	Once, on 3/14	Algal assay procedure
U.S.E.P.A.	1973	1 station in Lake Monroe.	Once, on 11/5	Algal assay procedure
U.S.G.S.	1954-1974	5 stations in St. Johns River, 1 in Lake Monroe, 3 in Econlockhatchee River, 2 in Howell Creek, 1 in Gee Creek and 1 in Soldier Creek	Monthly for flow, irregular for other parameters.	pH, turbidity, suspended solids, dissolved solids flow, hardness, color, major cations, iron, sulfate, chlorides
Brezonik et al. (1976)	1974-1975	Interpretation of previously collected data.	--	Comprehensive water and sediment quality analyses
Game and Fresh Water Fish Comm. (Dingell-Johnson Project, F-33)	1976-1981	2 stations in Lake Monroe	Bimonthly	Comprehensive water quality analyses
Florida DER	Present	1 station in St. Johns River at SR 46, 1 in Lake Harney, 1 in Lake Jessup, and 1 at outlet at Lake Monroe.	Irregular at SR 46 and Lake Harney, nearly once a month for Lakes Jessup and Monroe.	Conductivity dissolved oxygen, pH, alkalinity, color, sulfate, chloride, suspended solids, TOC, metals, % volatile solids, total phosphorus, TKN, nitrate + nitrite.

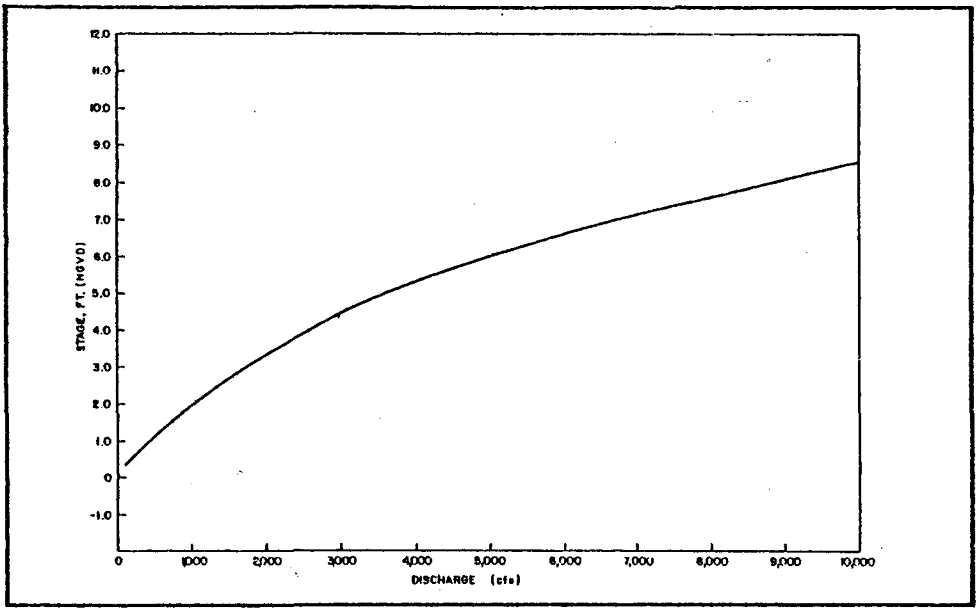
TABLE 2. Summary of Water Quality Studies of the Middle St. Johns River System - Southern Reach (Continued)

Agency	Study Date	Sampling Location	Sampling Frequency	Parameter
U.S.G.S.	Present	1 station in St. Johns River at SR 46.	irregular, approximately 3 times a year	conductivity dissolved oxygen, pH, stage, turbidity, suspended solids, complete nutrient and major cation analyses.
U.S.G.S.	Present	1 station at outlet of Lake Monroe.	Daily	Stage
U.S.G.S.	Present	1 station at Deep Creek near Osteen.	Daily	Discharge
U.S.G.S.	Present	1 station at Deep Creek Diversion Canal.	Irregular	Temperature and flow.
Seminole County	Present	See Figure 3 and Table 1.	Irregular, once a month or every other month.	Secchi, conductivity, suspended solids, dissolved oxygen, pH, turbidity, alkalinity, BOD_5, chlorides, total phosphorus, TKN, ammonia, COD, nitrite, nitrate, major cations, and trace metals pesticides, biological diversity, biotic index, chlorophylls on a semi-annual basis.

Upper St. Johns River Basin Surface Water Management Plan, Volume 2 (SJRWMD, 1980). Maximum and minimum mean elevations which occur every two years for 90 consecutive days were chosen to define high and low stage level gradations in the St. Johns River at State Road 50 and State Road 46, upstream and downstream from the Econ, respectively.

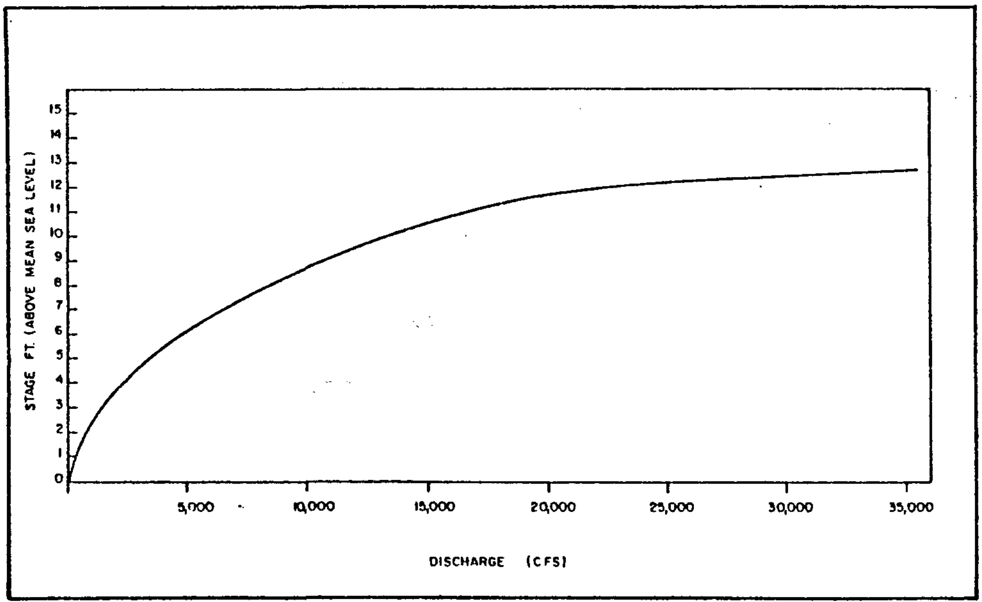
Flow values were derived from stage-discharge curves for the St. Johns River at State Road 46 and State Road 50 (Figures 4 and 5). At S.R. 46, high stages and flows were defined at or above 5.11 feet (NGVD) and 3750 cfs; and low stages and flows at or below 0.75 feet (NGVD) and 400 cfs. High stages and flows at S.R. 50 were considered to be 8.55 feet (NGVD) and 3,000 cfs or more; and low stages and flows were 4.27 feet (NGVD) and 100 cfs or less. Stage/flow levels which fell between the high and low delineations are considered normal levels.

For the Econ, low flows (35 cfs or less) were derived from a low-flow frequency graph (2 year recurrence - 90 day duration plot) in Phase 1 of the Water Resources Management Plan (SJRWMD, 1977). High flows (680 cfs or more) were calculated to occur 10% of the time in an average year (Harold Wilkening, personal communication, 1983) and were used to distinguish normal from high flow values.



STAGE-DISCHARGE RELATION, ST. JOHNS RIVER SR 46

Figure 4.



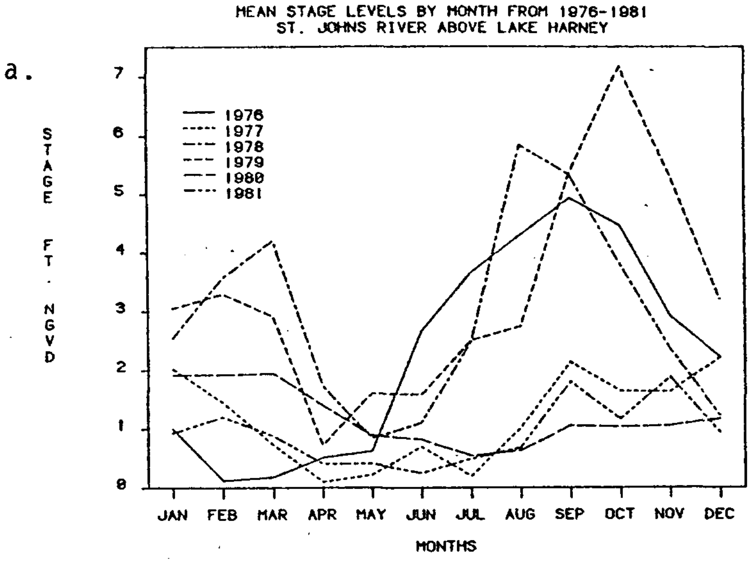
STAGE-DISCHARGE RELATION, ST. JOHNS RIVER SR 50

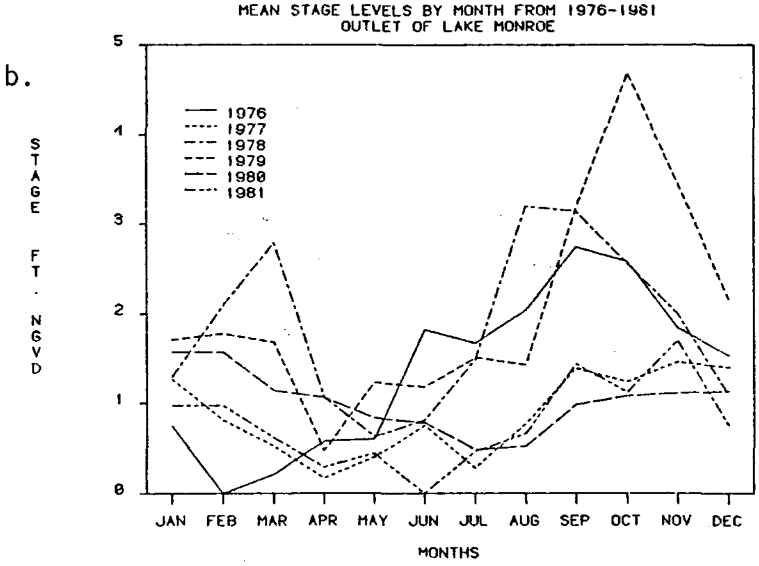
Figure 5.

RESULTS AND DISCUSSION

Among the natural factors affecting water quality in the SMSJ, water quantity is most significant. It directly influences water quality through dilution and indirectly through hydraulic residence times. For a 4 year period, 1976 through 1979, stage levels (recorded upstream of Lake Harney at S.R. 46 and at the outlet of Lake Monroe) declined during the spring and increased during summer and fall in a manner comparable to that exhibited over a 30 year period in the river at S.R. 46 (Figure 6). During the 1980-81 drought, seasonality in stage levels was suppressed as stage levels fell in late spring and throughout the summer. Mean stage levels (feet, NGVD) during 1980-81 fell approximately one-half below those for either of the preceding periods of record; from 2.42 (1976-79) or 2.67 (1950-80) to 1.09 (1980-81) at S.R. 46, and from 1.49 (1976-79) or 1.74 (1949-79) to 0.90 (1980-81) at the outlet of Lake Monroe.

Seasonal variations in stage (up to 1.5m annually from 1950 to 1980) contribute to seasonality in water quality of the SMSJ (FGFWFC, 1982; FDER, 1980) primarily because of inverse correlations between stage and the concentrations of several chemical constituents (Figure 7 and 8). The strengths of these correlations and the effects of the 1980-81 drought on water quality are discussed in some detail in the following sections. The tri-agency water quality data for the study period are summarized in Tables 3 through 8.


a.
MEAN STAGE LEVELS BY MONTH FROM 1976-1981
ST. JOHNS RIVER ABOVE LAKE HARNEY
STAGE FT. NGVD
0
1
2
3
4
5
6
7
1976
1977
1978
1979
1980
1981
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTHS


b.
MEAN STAGE LEVELS BY MONTH FROM 1976-1981
OUTLET OF LAKE MONROE
STAGE FT. NGVD
0
1
2
3
4
5
1976
1977
1978
1979
1980
1981
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTHS

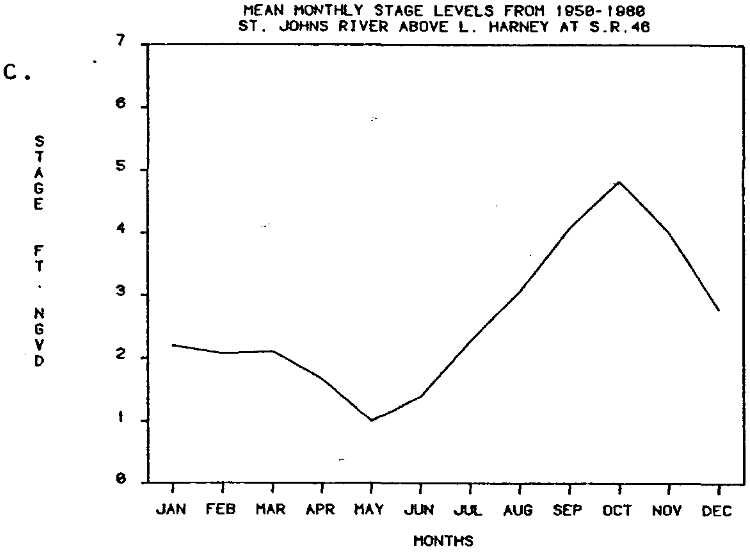

c.
MEAN MONTHLY STAGE LEVELS FROM 1950-1980
ST. JOHNS RIVER ABOVE L. HARNEY AT S.R.46
STAGE FT. NGVD
0
1
2
3
4
5
6
7
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTHS

Figure 6.

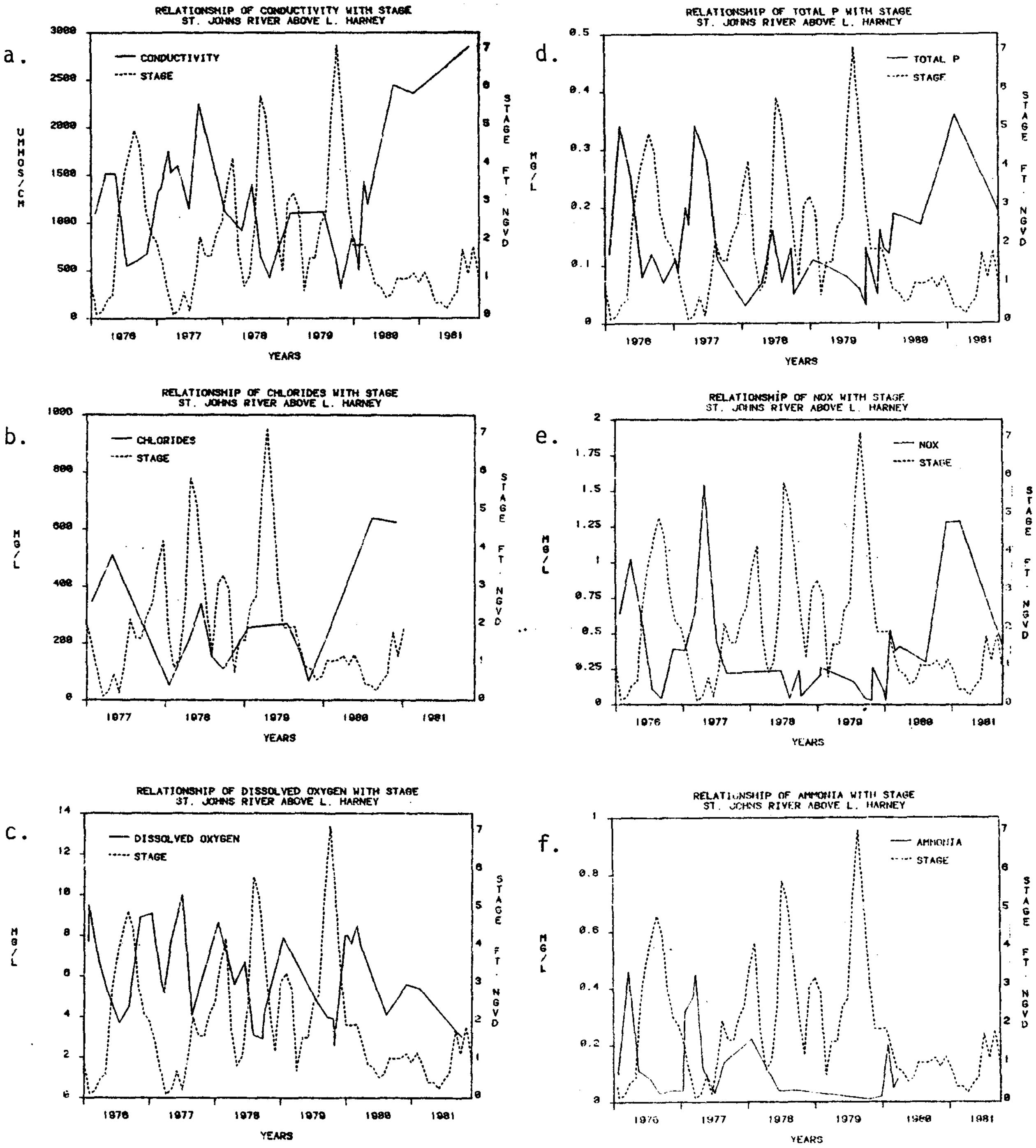

a.
RELATIONSHIP OF CONDUCTIVITY WITH STAGE
ST. JOHNS RIVER ABOVE L. HARNEY
CONDUCTIVITY
STAGE
UMHOS/CM
STAGE FT. NGVD
YEARS
3000
2500
2000
1500
1000
500
0
1976
1977
1978
1979
1980
1981
d.
RELATIONSHIP OF TOTAL P WITH STAGE
ST. JOHNS RIVER ABOVE L. HARNEY
TOTAL P
STAGE
MG/L
STAGE FT. NGVD
YEARS
b.
RELATIONSHIP OF CHLORIDES WITH STAGE
ST. JOHNS RIVER ABOVE L. HARNEY
CHLORIDES
STAGE
MG/L
STAGE FT. NGVD
YEARS
e.
RELATIONSHIP OF NOX WITH STAGE
ST. JOHNS RIVER ABOVE L. HARNEY
NOX
STAGE
MG/L
STAGE FT. NGVD
YEARS
c.
RELATIONSHIP OF DISSOLVED OXYGEN WITH STAGE
ST. JOHNS RIVER ABOVE L. HARNEY
DISSOLVED OXYGEN
STAGE
MG/L
STAGE FT. NGVD
YEARS
f.
RELATIONSHIP OF AMMONIA WITH STAGE
ST. JOHNS RIVER ABOVE L. HARNEY
AMMONIA
STAGE
MG/L
STAGE FT. NGVD
YEARS

Figure 7.

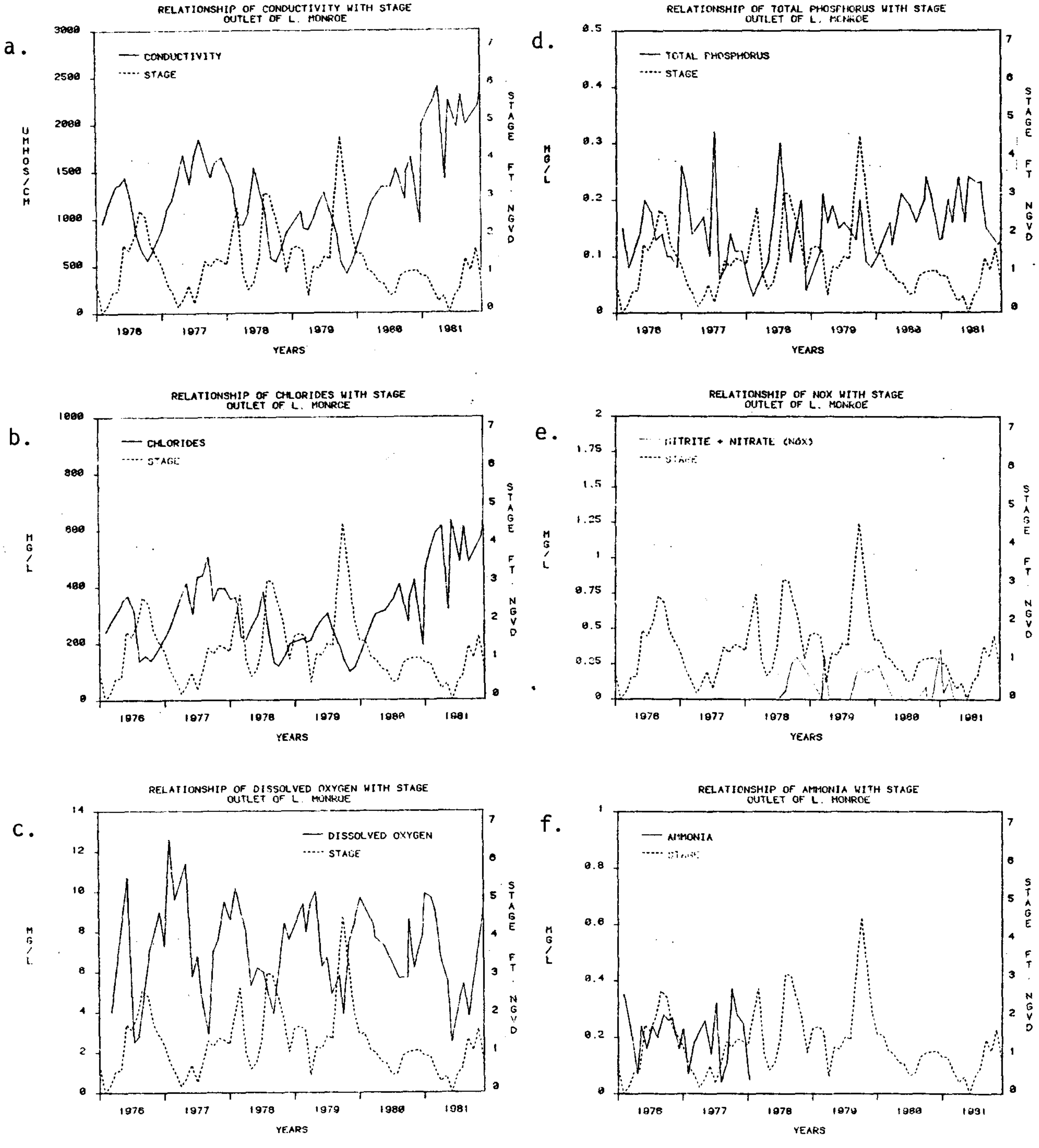
a.
RELATIONSHIP OF CONDUCTIVITY WITH STAGE
OUTLET OF L. MONROE
CONDUCTIVITY
STAGE
UMHOS/CM
0
500
1000
1500
2000
2500
3000
STAGE FT. NGVD
0
1
2
3
4
5
6
7
1976
1977
1978
1979
1980
1981
YEARS
b.
RELATIONSHIP OF CHLORIDES WITH STAGE
OUTLET OF L. MONROE
CHLORIDES
STAGE
MG/L
0
200
400
600
800
1000
STAGE FT. NGVD
0
1
2
3
4
5
6
7
1976
1977
1978
1979
1980
1981
YEARS
c.
RELATIONSHIP OF DISSOLVED OXYGEN WITH STAGE
OUTLET OF L. MONROE
DISSOLVED OXYGEN
STAGE
MG/L
0
2
4
6
8
10
12
14
STAGE FT. NGVD
0
1
2
3
4
5
6
7
1976
1977
1978
1979
1980
1981
YEARS
d.
RELATIONSHIP OF TOTAL PHOSPHORUS WITH STAGE
OUTLET OF L. MONROE
TOTAL PHOSPHORUS
STAGE
MG/L
0
0.1
0.2
0.3
0.4
0.5
STAGE FT NGVD
0
1
2
3
4
5
6
7
1976
1977
1978
1979
1980
1981
YEARS
e.
RELATIONSHIP OF NOX WITH STAGE
OUTLET OF L. MONROE
NITRITE + NITRATE (NOX)
STAGE
MG/L
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
STAGE FT. NGVD
0
1
2
3
4
5
6
7
1976
1977
1978
1979
1980
1981
YEARS
f.
RELATIONSHIP OF AMMONIA WITH STAGE
OUTLET OF L. MONROE
AMMONIA
STAGE
MG/L
0
0.2
0.4
0.6
0.8
1
STAGE FT. NGVD
0
1
2
3
4
5
6
7
1976
1977
1978
1979
1980
1981
YEARS

Figure 8.

TABLE 3.

RIVERINE STATIONS
$\bar{x}$ values (1980-1981, S.C. E. S.)[1]

Station I.D.	AAS	GGS	HHS	MLN	MLR	ULJ	DLJ	OBS
Temperature (·C)	22	22	22	24	25	24	24	24
Dissolved Oxygen (mg/l)	5.6	7.4	7.2	7.5	7.0	6.3	6.3	5.4
Conductance (μmhos/cm)	2981	2484	1791	2246	1929	1941	1885	1840
B.O.D. (mg/l)	1.5	4.2	3.8	3.3	4.2	3.3	4.1	4.0
Alkalinity (mg/l)	67	54	54	49	47	47	48	49
Hardness (mg/l)	--	--	--	--	--	--	--	--
Chlorides (mg/l)[2]	--	--	--	--	--	--	--	--
Sulfates (mg/l)	--	--	--	--	--	--	--	--
Total Phosphorus (mg/l)	0.17	0.16	0.11	0.08	0.11	0.13	0.15	0.17
Ortho-Phosphate (mg/l)	--	--	--	--	--	--	--	--
T.K.N. (mg/l)	1.90	--	--	--	--	--	--	--
Nitrate (mg/l)	0.42	0.15	0.14	0.18	0.17	0.19	0.26	0.16
Nitrite+Nitrate (mg/l)	--	--	--	--	--	--	--	--
Ammonia (mg/l)	0.20	0.15	0.12	0.06	0.07	0.09	0.08	0.07
T.O.C. (mg/l)	--	--	--	--	--	--	--	--

[1] Station BBS not included since its data has been treated in a combined fashion in Table 4.

[2] Only one value for Chlorides at each station, therefore, not included as a $\bar{x}$ value.

TABLE 4.

ST. JOHNS RIVER ABOVE LAKE HARNEY NEAR SR 46
Annual $\bar{x}$ Values[1]

	1976	1977	1978	1979	1980	1981	1982[2]
Temperature (·C)	21	22.5	25.1	22.6	21	23	16.5
Dissolved Oxygen (mg/l)	7.1	7.0	5.2	5.2	6.1	5.4	7.6
Conductance (µmhos/cm)	995	1568	841	787	1500	2435	2175
B.O.D. (mg/l)	1.3	2.1	1.5	--	--	1.1	1.1
Alkalinity (mg/l)	42	51	45	29	53	72	--
Hardness (mg/l)	--	300	179	--	--	--	--
Chlorides (mg/l)	--	433	164	201	492	613	--
Sulfates (mg/l)	--	112	56	66	174	206	--
Total Phosphorus (mg/l)	0.16	0.19	0.08	0.08	0.20	0.83	0.24
Ortho-Phosphate (mg/l)	0.14	0.18	0.12	0.07	0.13	0.57	--
T.K.N. (mg/l)	1.40	1.40	1.36	1.40	1.50	1.50	1.71
Nitrate (mg/l)	0.43	0.61	0.22	0.16	0.44	1.14	1.18
Nitrite+Nitrate (mg/l)	0.48	0.65	0.15	0.15	0.49	1.19	--
Ammonia (mg/l)	0.14	0.21	0.10	0.02	0.20	0.18	0.22
T.O.C. (mg/l)	24	18	29	22	16	--	--

[1] $\bar{x}$ values were calculated using combined data from USGS and FDER (1976-1981). Data from Seminole County Environmental Services were included for years 1980 and 1981.

2No 1982 data available from FDER or USGS; only Winter quarter data from Seminole County.

TABLE 5.

LAKE HARNEY
$\bar{x}$ values (S.C.E.S., FDER)

	CCS	DDS	DER_2		EEN + FFN
Station I.D.	(1980-82)	(1980-82)	(1976-81)	(1979-81)	(1980-82)
Temperature (·C)	23	23	24	22	23
Dissolved Oxygen (mg/l)	7.7	8.4	--	--	8.2
Conductance (µmhos/cm)	2279	2340	1241	1561	2387
B.O.D. (mg/l)	3.1	4.1	1.6	--	4.0
Alkalinity (mg/l)	53	52	46	46	51
Hardness (mg/l)	--	--	--	--	--
Chlorides (mg/l)	--	--	293	412	--
Sulfates (mg/l)	--	--	71	102	--
Total Phosphorus (mg/l)	0.20	0.20	0.09	0.11	0.16
Ortho-Phosphate (mg/l)	--	--	--	--	--
T.K.N. (mg/l)	3.4	3.1	1.3	1.19	3.4
Nitrate (mg/l)	0.40	0.20	--	--	0.18
Nitrite+Nitrate (mg/l)	--	--	0.08	0.04	--
Ammonia (mg/l)	0.10	0.10	0.33	--	0.06
T.O.C. (mg/l)	--	--	22	22	--

TABLE 6.

LAKE JESSUP
Annual $\bar{X}$ values (FDER)

	1976	1977	1978	1979	1980	1981
Temperature (·C)	22	23	22	23	21	21
Dissolved Oxygen (mg/l)	6.8	9.4	10	9.1	9.0	9.4
Conductance (µmhos/cm)	942	1252	939	823	1080	2107
B.O.D. (mg/l)	10	9.7	--	--	--	--
Alkalinity (mg/l)	80	69	74	80	75	68
Hardness (mg/l)	--	--	--	--	--	--
Chlorides (mg/l)	236	300	189	190	274	530
Sulfates (mg/l)	47	60	51	52	59	144
Total Phosphorus (mg/l)	0.30	0.31	0.33	0.46	0.55	0.65
Ortho-Phosphate (mg/l)	--	--	--	--	--	--
T.K.N. (mg/l)	2.60	--	3.4	2.8	4.3	5.2
Nitrate (mg/l)	--	--	--	--	--	--
Nitrite-Nitrate (mg/l)	--	--	0.03	0.04	<0.01	0.01
Ammonia (mg/l)	0.25	0.21	0.20	--	--	--
T.O.C. (mg/l)	26	22	27	37	38	55

TABLE 7.

LAKE MONROE
$\bar{x}$ values (1979-1981, S.C.E.S.)

Station I.D.	MOE	MOS	MON
Temperature (·C)	23	23	25
Dissolved Oxygen (mg/l)	7.7	8.2	7.6
Conductance (µmhos/cm)	1404	1277	1196
B.O.D. (mg/l)	3.7	3.3	3.3
Alkalinity (mg/l)	43	49	47
Hardness (mg/l)	--	--	--
Chlorides (mg/l)[1]	--	--	--
Sulfates (mg/l)	--	--	--
Total Phosphorus (mg/l)	0.16	0.31	0.14
Ortho-Phosphate (mg/l)	--	--	--
T.K.N. (mg/l)	--	--	--
Nitrate (mg/l)	0.18	0.20	0.14
Nitrite+Nitrate (mg/l)	--	--	--
Ammonia (mg/l)	0.05	0.31	0.10
T.O.C. (mg/l)	--	--	--

[1] Only one value for Chlorides at each station, therefore, not included as a $\bar{x}$ value.

TABLE 8.

LAKE MONROE OUTLET
Near 17-92 Bridge

Annual $\bar{x}$ Values (FDER)

	1976	1977	1978	1979	1980	1981
Temperature (·C)	23.8	22.6	20.9	22.7	24.4	23.6
Dissolved Oxygen (mg/l)	7.4	7.7	6.6	--	--	--
Conductance (µmhos/cm)	994	1444	1032	886	1258	2124
B.O.D. (mg/l)	4.6	6.2	--	--	4.9	--
Alkalinity (mg/l)	57	64	51	48	48	67
Hardness (mg/l)	--	--	--	--	--	--
Chlorides (mg/l)	242	367	248	207	310	545
Sulfates (mg/l)	52	72	56	62	82	163
Total Phosphorus (mg/l)	0.13	0.16	0.12	0.15	0.17	0.18
Ortho-Phosphate (mg/l)	--	--	--	--	--	--
T.K.N. (mg/l)	--	--	1.45	1.59	1.69	1.72
Nitrate (mg/l)	--	--	--	--	--	--
Nitrite+Nitrate (mg/l)	--	--	0.18	0.12	0.10	0.02
Ammonia (mg/l)	0.22	0.21	0.05	--	--	--
T.O.C. (mg/l)	26	21	24	25	17	17

Major Ions

Progressive downstream increase in major ion concentrations in the upper St. Johns River has been observed by several investigators (Fall, 1982; Cox et al., 1976; Goolsby and McPherson, 1970). Recent data on the SMSJ (1979-81) show that this downstream gradient extends to the outlet of Lake Harney. From the northern reach of the upper basin to Lake Harney, mean concentrations of calcium rose from 57 to 100 mg/l and magnesium increased from 26 to 65 mg/l. Concomitantly, there was a slight increase in mean chloride and sulfate concentrations (410 to 435 mg/l and 93 to 102 mg/l, respectively). Downstream from the outlet of Lake Harney, concentrations of these major ions decreased by approximately one-half and remained at that level to the outlet of Lake Monroe. Potassium concentrations varied little temporally and spatially within the SMSJ; mean levels fluctuating from 8.0 mg/l upstream of Lake Harney to 6.6 mg/l in Lake Monroe. Available data for sodium are sparse but also show an increase in concentration in a downstream direction. Overall, the downstream gradient in major ion concentration in the SMSJ is exemplified by mean specific conductance (Figure 9).

Unlike most freshwater systems, sodium, not calcium, is the dominant cation in both the upper and SMSJ basins. From Lake Poinsett downstream to Lake Monroe (Figure 1), the sodium to calcium concentration ratio was approximately 4 ± 1 in contrast to a ratio of approximately 2 ± 1 upstream of Lake Poinsett. The shifts in the Na/Ca values and in the spatial concentration gradients for these major ions are, to a large degree, a function

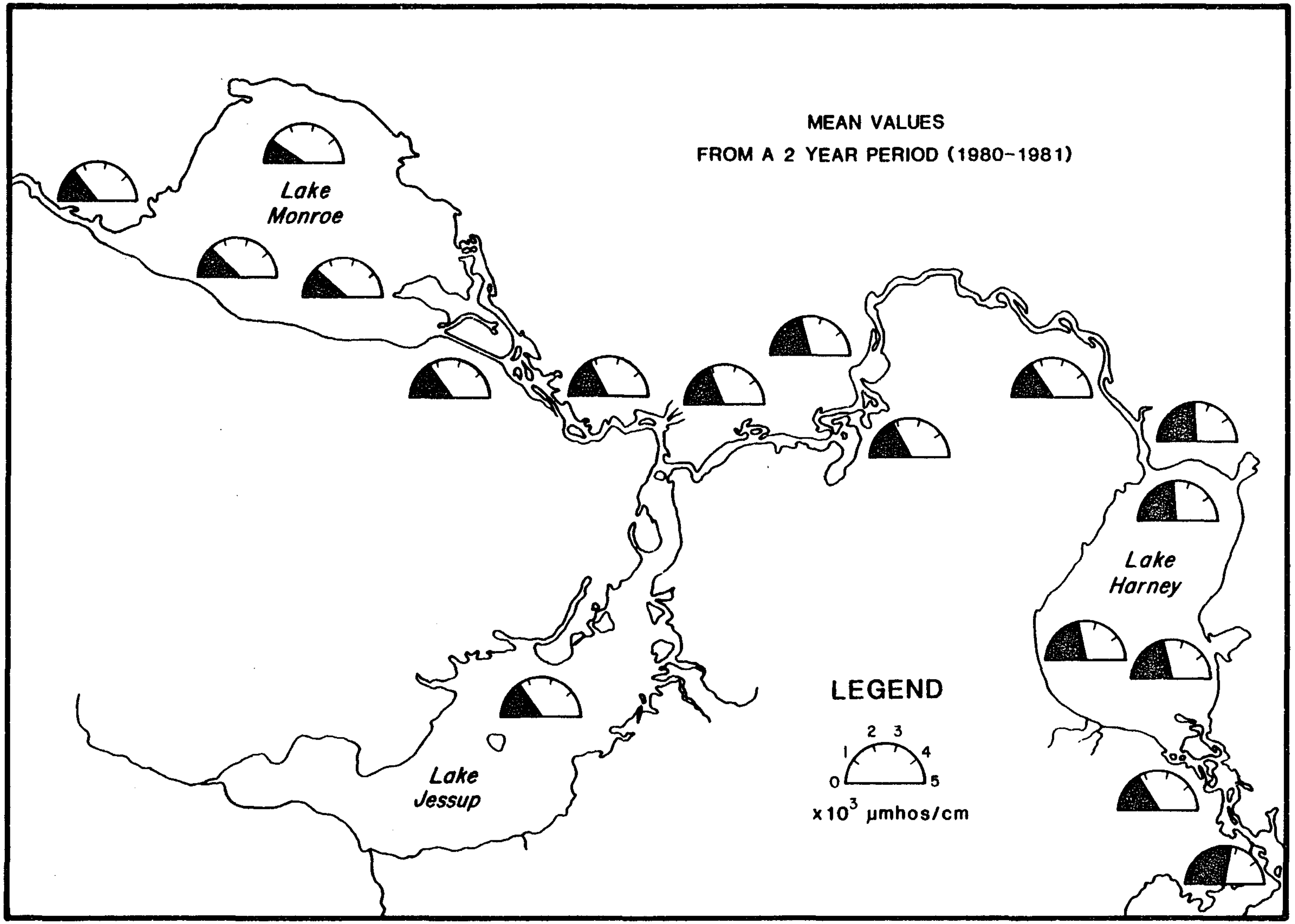
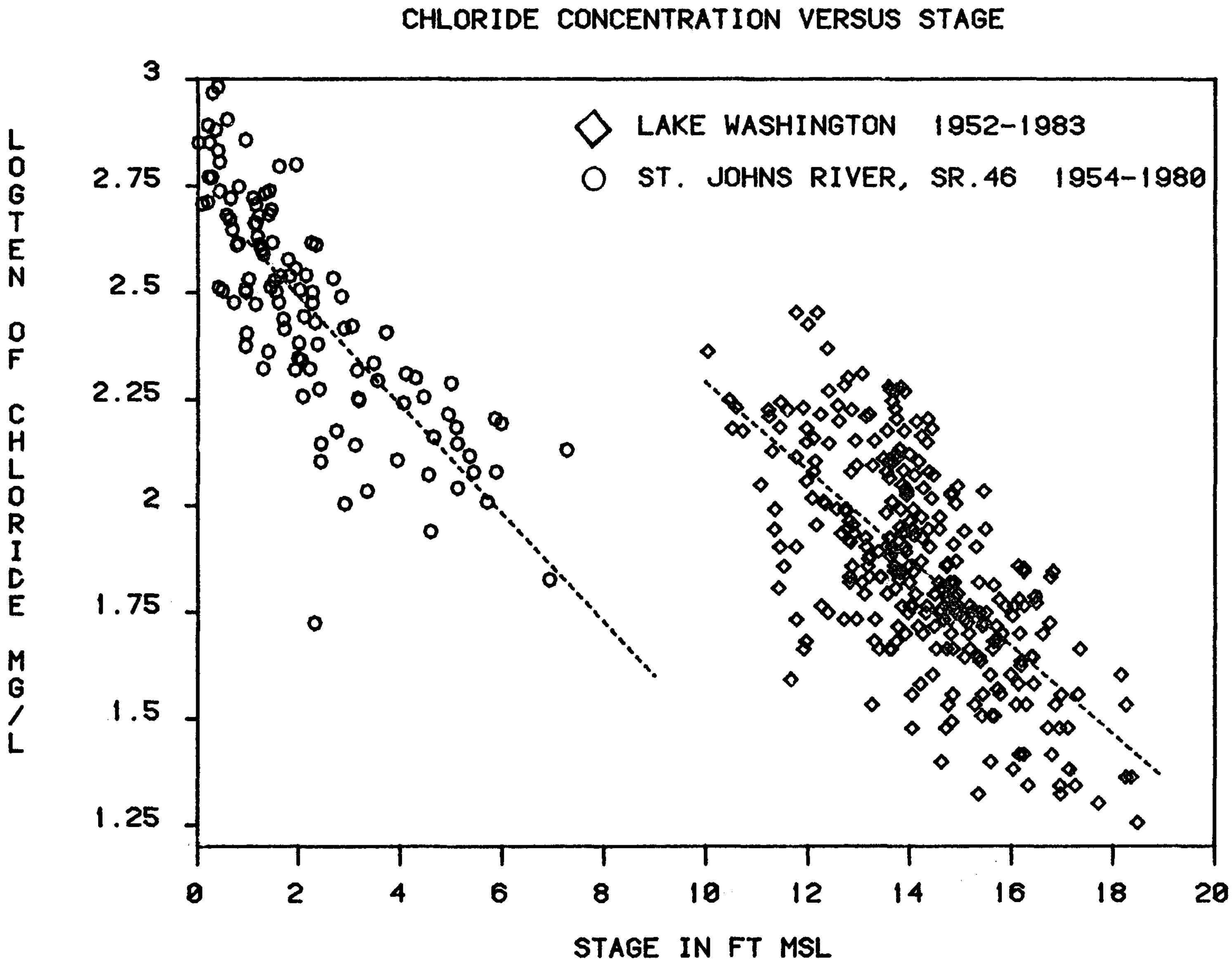


Figure 9. Conductivity in the Middle St. Johns River - Southern Reach.

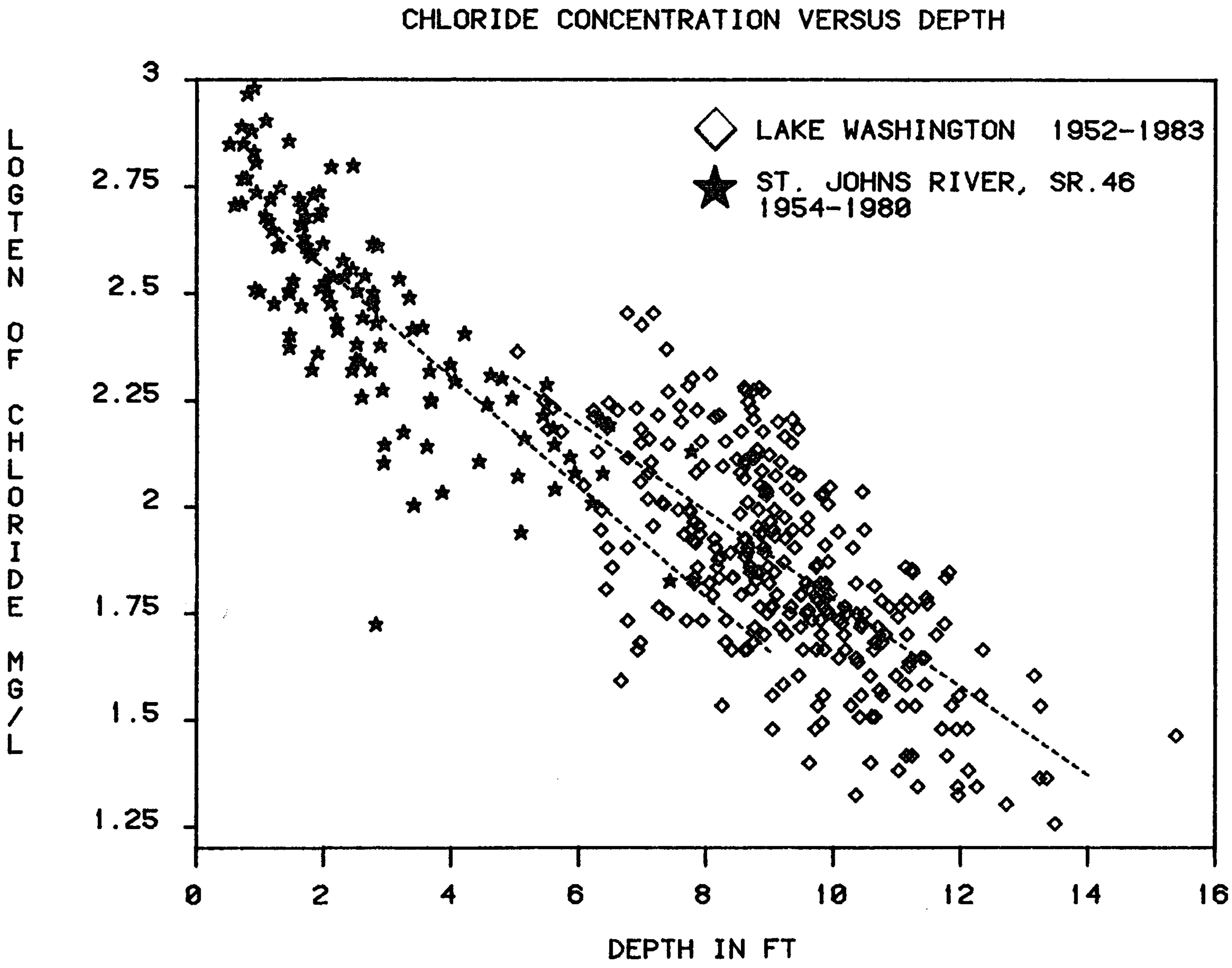
of various groundwater upwellings. These upwellings, basically, come from two different sources - relict seawater (RSW) and transitional water (TW), (Frazee, 1981). One possible RSW source is the St. Johns Fault located in the area around Lake Poinsett and continuing northward to an area southeast of Lake Harney. The high mineral concentrations and Na/Ca values in this area may result from this local RSW upwelling. Another RSW zone is located in the northeast section of Lake Jessup, but it apparently has a relatively negligible impact on surface waters. Transitional water is characterized as a mix of RSW with young, fresh recharge water of low mineral concentration and upwells in the river reach between Lake Harney and Mullet Lake (Frazee, 1981). Its potential effect is the dilution of mineral concentrations in the St. Johns River downstream from Lake Harney.

Major ion concentrations within the surface waters of the SMSJ are affected by stage levels. During the 1980-81 drought, the decline in stage levels was concomitant with an increase in conductivity, and a two-fold increase in chloride and sulfate concentrations over those levels in the preceding 4 years (1976-79), (Tables 4, 6 and 8). The increase in ion concentrations most likely reflected a progressive diminution of dilution of groundwater seepage by surface waters as stage levels dropped. This relationship is represented by the change in chloride concentration with stage (Figure 10). It is interesting to note that the slopes of the regression lines for Lake Washington data and S.R. 46 data are similar (Figures 10 and 11), even though RSW upwelling occurs downstream of Lake Washington. Thus, one might



Lake Washington: Y = 3.3 - 0.10x, R^2 =.46, D.F. = 295
S. R. 46: Y = 2.8 - 0.13x, R^2 =.62, D.F. = 116

Figure 10.



Lake Washington: Y = 2.8 - 0.10x, R^2 = .46, D. F. = 295
S. R. 46: Y = 2.8 - 0.13x, R^2 = .62, D. F. = 116

Figure 11.

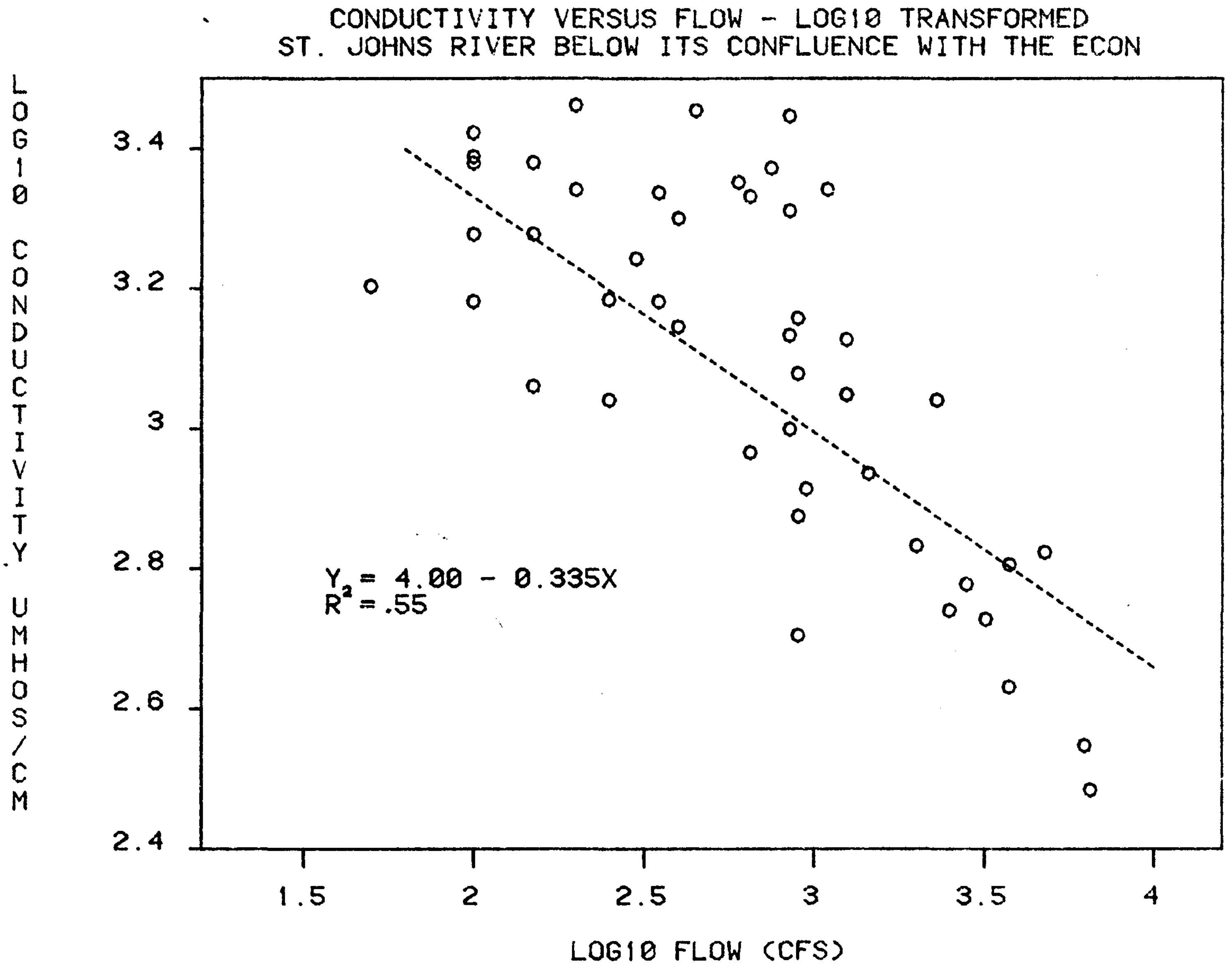

CONDUCTIVITY VERSUS FLOW - LOG10 TRANSFORMED
ST. JOHNS RIVER BELOW ITS CONFLUENCE WITH THE ECON
LOG10 CONDUCTIVITY UMHOS/CM
3.4
3.2
3
2.8
2.6
2.4
1.5
2
2.5
3
3.5
4
LOG10 FLOW (CFS)
$Y_2 = 4.00 - 0.335X$
$R^2 = .55$

Figure 12.

Table 9.

Statistical Correlations Between Various Parameters and Flow (and Stage) for the St. Johns River Above and Below the Econ (1976-1981).

Parameters (Log 10 transformation included)	St. Johns River Above the Econ (Station AAS)		St. Johns River Below the Econ (SR 46)	
	Correlation Coefficient	r^2(%)	Correlation Coefficient	r^2(%)
Dissolved Oxygen-Flow	0.02	0.10	-0.54	29
Log D.O.-Log Flow	0.16	2.70	-0.60	36
Conductivity-Stage	-0.91	82	-0.71	50
Log Cond.-Log Stage	-0.88	78	-0.69	47
Conductivity-Flow	-0.85	72	-0.67	45
Log Cond.-Log Flow	-0.89	79	-0.74	55*
Chloride-Stage	N.A.+	N.A.	-0.73	53
Log Chlor.-Log Stage			-0.69	47
Chloride-Flow	N.A.	N.A.	-0.68	46
Log Chlor.-Log Flow			-0.73	54
BOD5-Flow	-0.42	18	-0.31	9.7
Log BOD5-Log Flow	-0.48	23	-0.31	9.7
Ammonia-Flow	0.14	2.0	-0.44	19
Ammonia-Log Flow	0.12	1.5	-0.55	30
Nitrate-Flow	0.28	8.1	-0.49	24*
Log Nit.-Log Flow	0.47	22	-0.69	49*
Total Phosphorous	0.09	0.8	-0.53	28*
Log TP-Log Flow	0.24	5.7	-0.70	49*

* Graphically Displayed
+ Not available or analyzed

expect a greater slope or increase in chloride concentration with decreasing stage or depth at S.R. 46; but such an occurrence was absent. This may be due to the impact of the Econ whose discharge above S.R. 46 dampened the concentration effect of any RSW intrusion. Furthermore, the inverse conductivity-stage/flow relationship in the St. Johns River (Figure 12) appeared to be weakened by the Econ's discharge as indicated by correlation statistics (Table 9). This will need to be further evaluated since the data set for the station above the Econ is small (N=16).

Major Nutrients

The mean total phosphorus (TP) concentration for the entire stretch of the SMSJ (excluding Lake Jessup) from 1979 through 1981 was 0.18 mg/l. Lake Jessup, for the same period of record, had the highest mean TP concentration of the three lakes, 0.55 mg/l (Figure 13), and the highest single measurement of 1.05 mg/l within the SMSJ. Despite this large concentration, there was no significant difference between sites upstream (Station ULJ) and downstream (Station DLJ) of the lake's outlet for TP ($t=1.6$, $d.f=17$, $0.10<p<0.20$). Apparently, weak outflows and, at times, reverse flows at the outlet of Jessup (USGS, Orlando) limit its effects on water quality in the St. Johns River. The long residence time in Lake Jessup (an average of 100 days, one order of magnitude greater than either lakes Harney or Monroe (Brezonik et al., 1976)) and its comparatively low color contribute to its

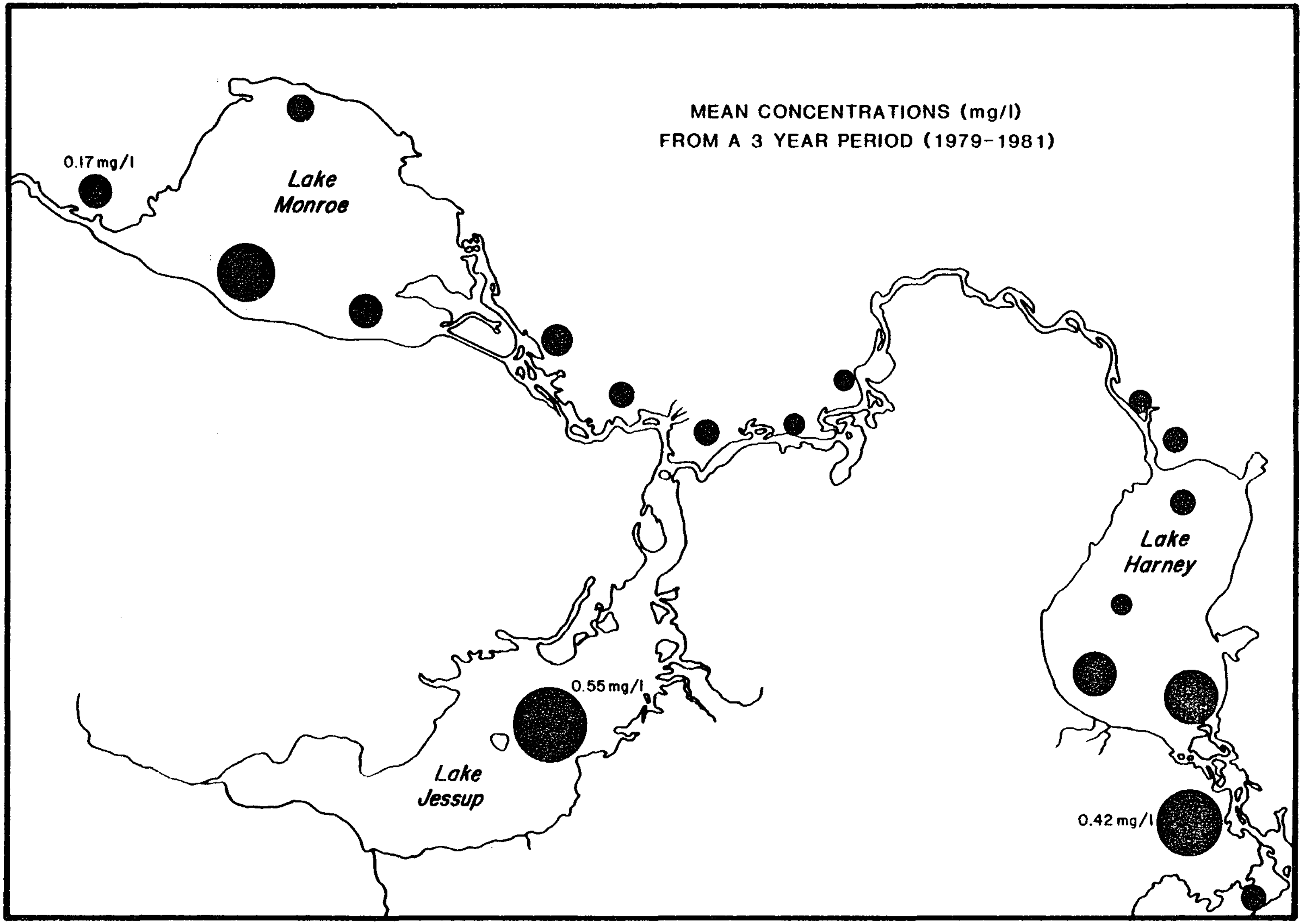


Figure 13. Total Phosphorus Concentrations in the Middle St. Johns River - Southern Reach.

high algal productivity and trophic degradation (Seminole County, 1982).

Augmented concentrations of phosphorus also appeared in two other areas of the SMSJ - along the southern perimeter of Lake Monroe (at the point of discharge from Sanford's wastewater treatment facility) and immediately downstream from the confluence of the Econ and St. Johns Rivers (Figure 13, Tables 4 and 7). The influence of the Econ on phosphorus concentrations in the St. Johns River (1979-81) is statistically evident by the significantly lower levels of TP in a site upstream (Station AAS) than in one downstream from the Econ's outlet (S.R. 46), ($t=2.1$, $d.f=26$, $0.02<p<0.05$). The mean TP concentration at the outlet of Lake Harney was 50% lower than at S.R. 46 (0.42 mg/l) demonstrating a downstream reduction in concentration through dilution and assimilation (Figure 13).

The basin-wide spatial trend for orthophosphates generally followed that of TP (based on analysis of data collected in 1973-75 by FDER). In lakes Monroe and Jessup, 57% to 58% of the TP was in the form of orthophosphate. The orthophosphate data set for Lake Harney is too small for any analysis.

The mean total nitrogen (TN) concentration for the SMSJ was 2.5 mg/l (1979-81). The greatest concentrations were present in Lake Jessup with a mean of just over 4.1 mg/l, followed by the stretch of river downstream from the Econ into Lake Harney with a mean of 3.0 mg/l (Tables 5 and 6). Levels of TN in Lake Monroe were comparatively low at nearly 2.0 mg/l. As was the case for

TP, TN concentrations in Lake Jessup did not significantly influence concentrations in the river (t-test for stations ULJ and DLJ, t=0.8, d.f=12, p>0.20).

Inorganic forms of nitrogen comprised 46% of the TN downstream from the Econ at S.R. 46, but only 11% in Lake Harney, 16% in Lake Monroe, and 6% or less in Lake Jessup. The large organic nitrogen input in the SMSJ is probably due to NPS runoff from agricultural and silvicultural practices (Florida Department of Agriculture; Livingston and Cox, 1983). During dry periods of the year, the floodplains of Lake Harney and Deep Creek have been used as cattle pastureland. This activity, in addition to the silviculture in the sub-basin, may have promoted high TKN levels in Lake Harney (x=2.8 mg/l, 1979-81, Table 5). Likewise, a high degree of agricultural encroachment in Lake Jessup's floodplain has possibly contributed to its high concentrations of TKN (x=4.1 mg/l, 1979-81, Table 6).

Inorganic nitrogen in lakes Jessup and Monroe was predominantly ammonia (50% in Monroe and 87% in Jessup). Elsewhere, nitrate was the major component, ranging from 83% of the inorganic fraction at S.R. 46 to 63% for all other riverine stations combined. The large concentrations of nitrate and its large percentage of the TN in the river at S.R. 46 (Table 4, Figure 14) were, again, due to the heavy nutrient outflow from the Econ. The impact of the Econ on downstream nitrate concentrations in the St. Johns was significant by the statistical comparison between a site upstream of the confluence (Station AAS, SCES) and one downstream (S.R. 46), (t=3.5, d.f=27, 0.001<p<0.002). A mean

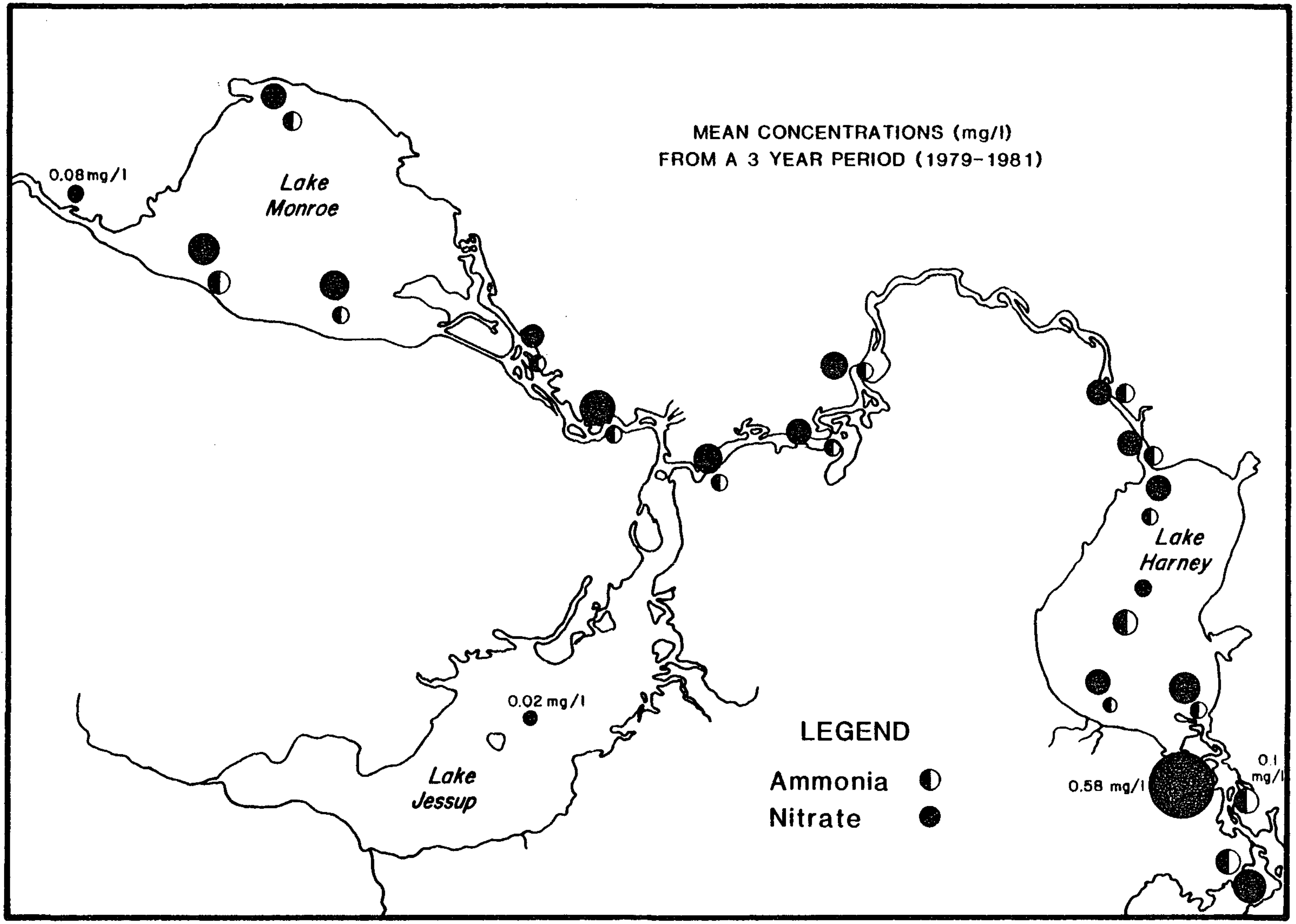


Figure 14. Inorganic Nitrogen Concentrations in the Middle St. Johns River-Southern Reach.

nitrate concentration of 0.58 mg/l at S.R. 46 (1979-81) had, nevertheless, diminished by 80% to the outlet of Lake Harney (Figure 14).

Further substantiation of the relative impact of the Econ on the St. Johns River can be shown by comparing the correlations between nutrient concentrations and flow at station AAS and at the tri-agency station at S.R. 46 (Table 9). A weak positive correlation exists upstream of the Econ discharge (Station AAS), downstream from which the trend shifts to a negative curvalinear relationship, and a stronger linear correlation upon logarithmic transformation of the data, for TP and nitrate concentrations with flow (Figure 15 and 16).

Much of the nutrient laden discharge from the Econ originated from secondarily treated sewage effluent and urban generated NPS runoff (Goolsby and McPherson, 1970). Consequently, fluctuations in TP concentrations in the Econ and its confluence with the St. Johns River have probably followed trends in urban released phosphorus. Total phosphorus concentrations decreased from 1975 to 1980 (Figure 17) which, most likely, was a result of reduction in inorganic phosphorus loads from urban areas. One reason for this reduction was the virtual elimination of polyphosphates from household detergents. These polyphosphates, hydrolyzed to orthophosphates, may have accounted for 50% to 70% of the phosphates in treated wastewater discharge (Stoker and Seager, 1972). Interestingly enough, concentrations of orthophosphates, which made up approximately 82% of the TP in the St. Johns at S.R. 46 (1969-80), dropped 60% at the same

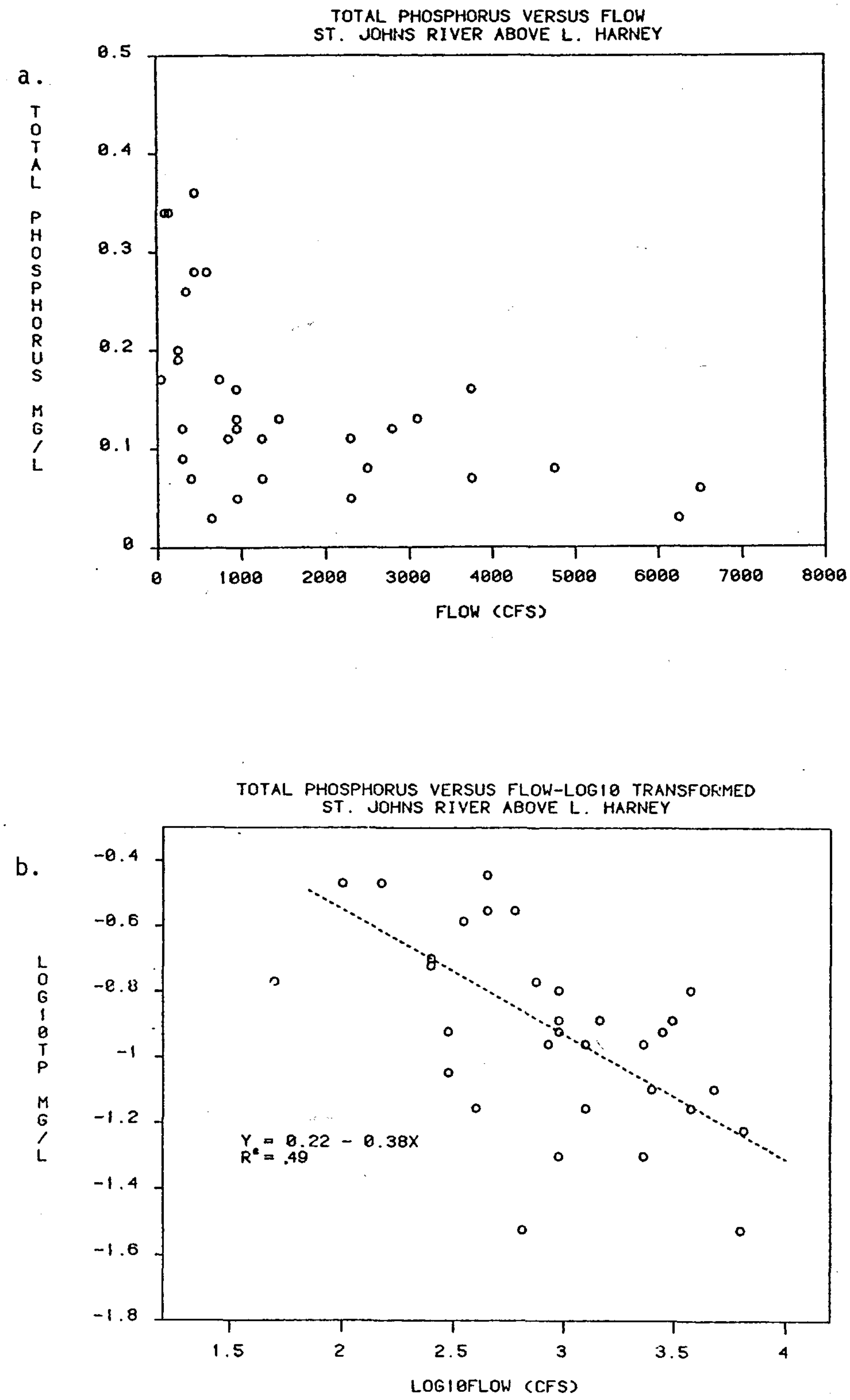
a.
TOTAL PHOSPHORUS VERSUS FLOW
ST. JOHNS RIVER ABOVE L. HARNEY
TOTAL PHOSPHORUS MG/L
0.5
0.4
0.3
0.2
0.1
0
0
1000
2000
3000
4000
5000
6000
7000
8000
FLOW (CFS)
b.
TOTAL PHOSPHORUS VERSUS FLOW-LOG10 TRANSFORMED
ST. JOHNS RIVER ABOVE L. HARNEY
LOG10TP MG/L
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
1.5
2
2.5
3
3.5
4
LOG10FLOW (CFS)
Y = 0.22 - 0.38X
R² = .49

Figure 15.

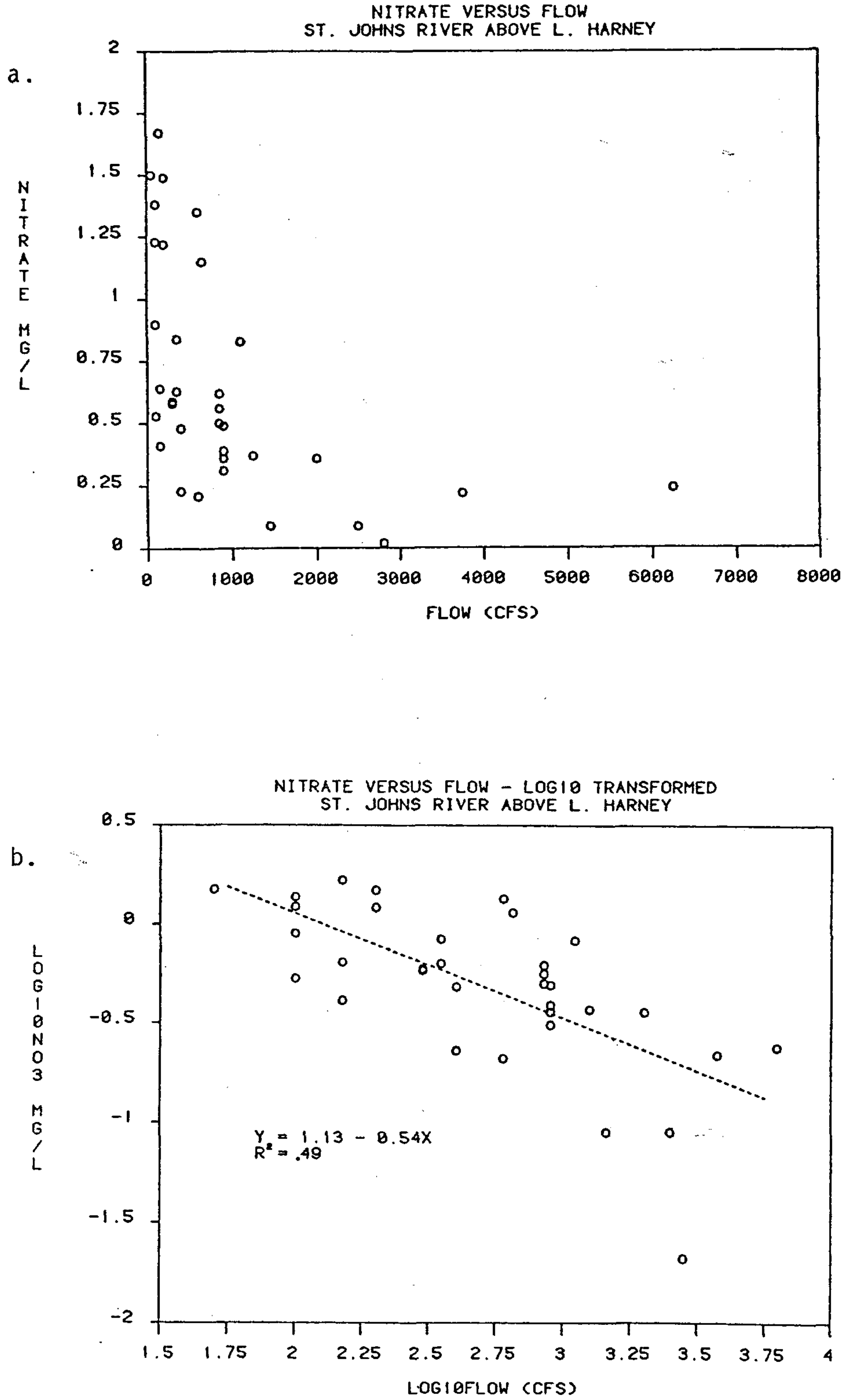

a.
NITRATE VERSUS FLOW
ST. JOHNS RIVER ABOVE L. HARNEY
NITRATE MG/L
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
0
1000
2000
3000
4000
5000
6000
7000
8000
FLOW (CFS)
b.
NITRATE VERSUS FLOW - LOG10 TRANSFORMED
ST. JOHNS RIVER ABOVE L. HARNEY
LOG10NO3 MG/L
0.5
0
-0.5
-1
-1.5
-2
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
LOG10FLOW (CFS)
Y = 1.13 - 0.54X
R² = .49

Figure 16.

location after 1975 (Figure 17, Table 4). Concentrations continued to decline until 1980, at which time an increase in concentration occurred due to low stage and flow induced by the drought. Nitrate levels, however, progressively increased over time with consistently high levels during the 1980-81 drought (Figure 17, Table 4). During the recent drought, nitrogen concentrations nearly doubled in much of the basin relative to the preceding period (1976-79). One exception to this trend were nitrate levels at S.R. 46 which, like basin-wide levels of phosphorus, increased nearly three-fold.

Within the SMSJ, annual fluctuations in nutrient levels are partially determined by stage/flow. During higher stage months of November through April (1979-81), in the main channel of the SMSJ, TP concentrations greatly fluctuated (S.D.=0.11 mg/l) around a mean of 0.14 mg/l and increased to 0.21 mg/l (S.D.=0.14 mg.l) during the lower stage months of May through October (1979-81). In contrast, the mean nitrate concentration was lower during May through October (0.28 ± 0.7 mg/l) than during November through April (0.42 ± 0.9 mg/l). As with the basin as a whole, Lake Jessup responded to the lower stage period with an increase in the mean TP concentration (from 0.34 ± 0.20 mg/l (November-April) to 0.42 ± 0.15 mg/l (May-October)) and a decrease in the mean nitrate concentration (from 0.04 ± 0.05 to 0.02 ± 0.03 mg/l for the respective monthly periods). Following suit, nitrate + nitrite levels at the outlet of Lake Monroe dropped from a November-April mean of 0.10 ± 0.12 to 0.04 ± 0.08 mg/l during the lower-stage months.

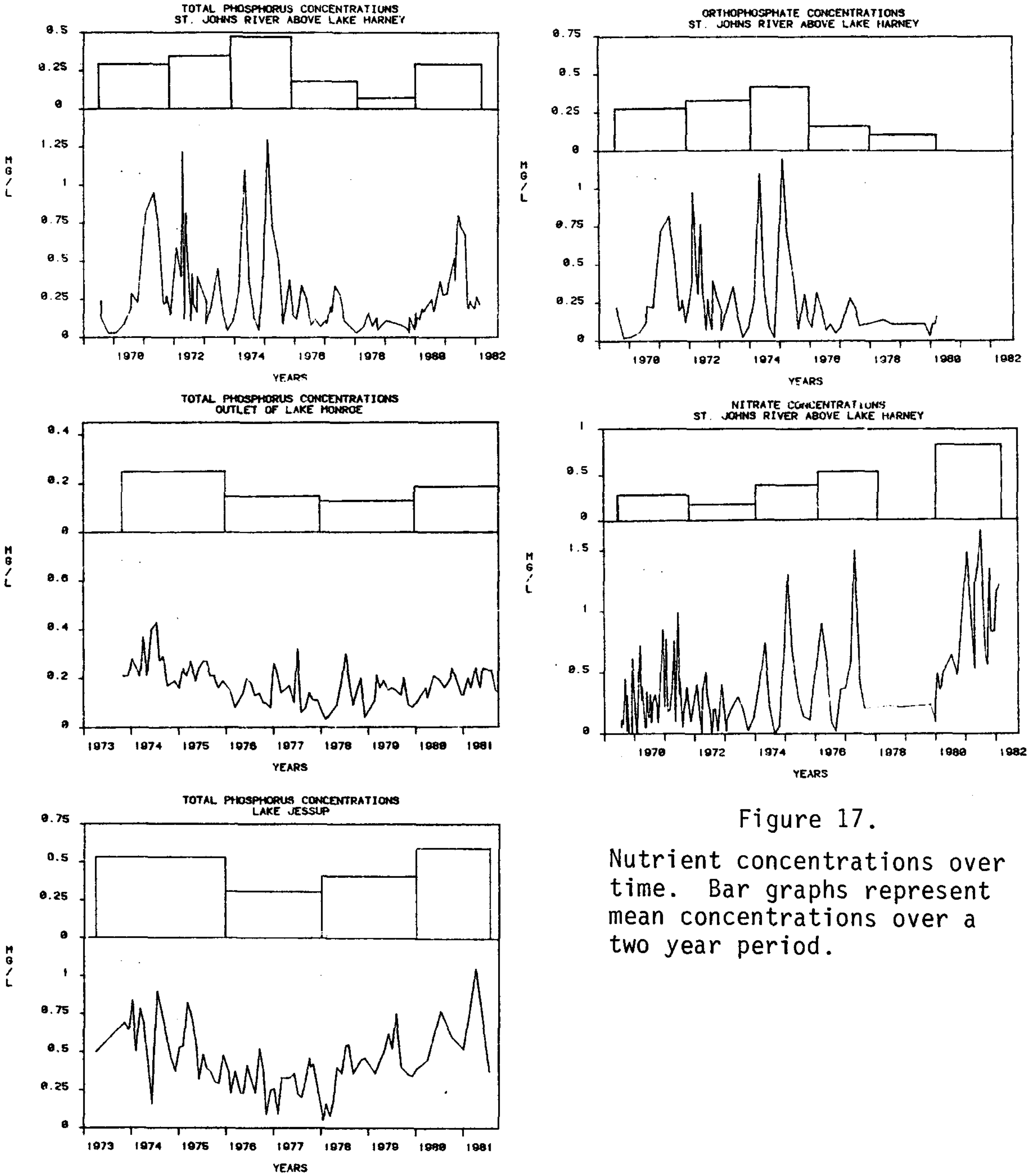


Figure 17.

Nutrient concentrations over time. Bar graphs represent mean concentrations over a two year period.

It appears that nitrate levels are not directly dependent upon stage/flow levels, but rather on the length of residence times which do vary as a function of flow. Sources for nitrate are more diffuse and possibly less contingent upon urban related outflows than those for phosphates. The warmer weather and longer residence times, during spring through fall of 1979 through 1981, maximized phytoplankton productivity; thus, removing the readily accessible nitrates to satisfy nutrient requirements ([chlorophyll a] = 177 ± 54 ug/l for May-October, and 38 ± 37 ug/l for November-April). This increased productivity and uptake of nitrates yielded greater organic nitrogen concentrations, often comprising 90% to nearly 100% of the total nitrogen during the summer months.

Dissolved Oxygen

Dissolved oxygen (D.O.) concentrations were, on the average, greater in the lakes. The lowest D.O. concentrations in the SMSJ were in riverine areas at or immediately downstream from confluences of tributaries with the river (Figure 18). From May through October of 1980 and 1981, the areas above the Econ and adjacent to the outlet of Lake Jessup had mean D.O. concentrations of 4.2 and 4.3 mg/l, respectively, which were below the state minimum of 5.0 mg/l (FDER). During the same time period, the site downstream from the Econ (S.R. 46) had the lowest mean concentration, 3.6 ± 1.0 mg/l (nearly all D.O. measurements at S.R. 46 during this period in 1980 and 1981 were below the state minimum). This was much lower than the preceding 12 year mean of 5.9 ± 2.0 mg/l (S.R. 46) for the months of May through October. The lowest D.O. measurements have, characteristically, been in the summer and fall months of the year (1969-81, Figure 19). The drop in mean D.O. concentrations during 1980 and 1981 downstream from the Econ's outlet was partially attributable to the drought and reached its greatest severity during May through October of both years. This may have been the result of low flows of the Econ and the St. Johns River which had the potential to carry greater concentrations of oxidizable material into Lake Harney. For both drought years combined, the mean level of BOD_5 in Lake Harney doubled to 4.9 ± 2.1 mg/l in May through October from a mean of 2.4 ± 1.0 mg/l in November through April.

Low D.O. was implicated as the major factor leading to a large fish kill in mid-June, 1980. This event occurred in the

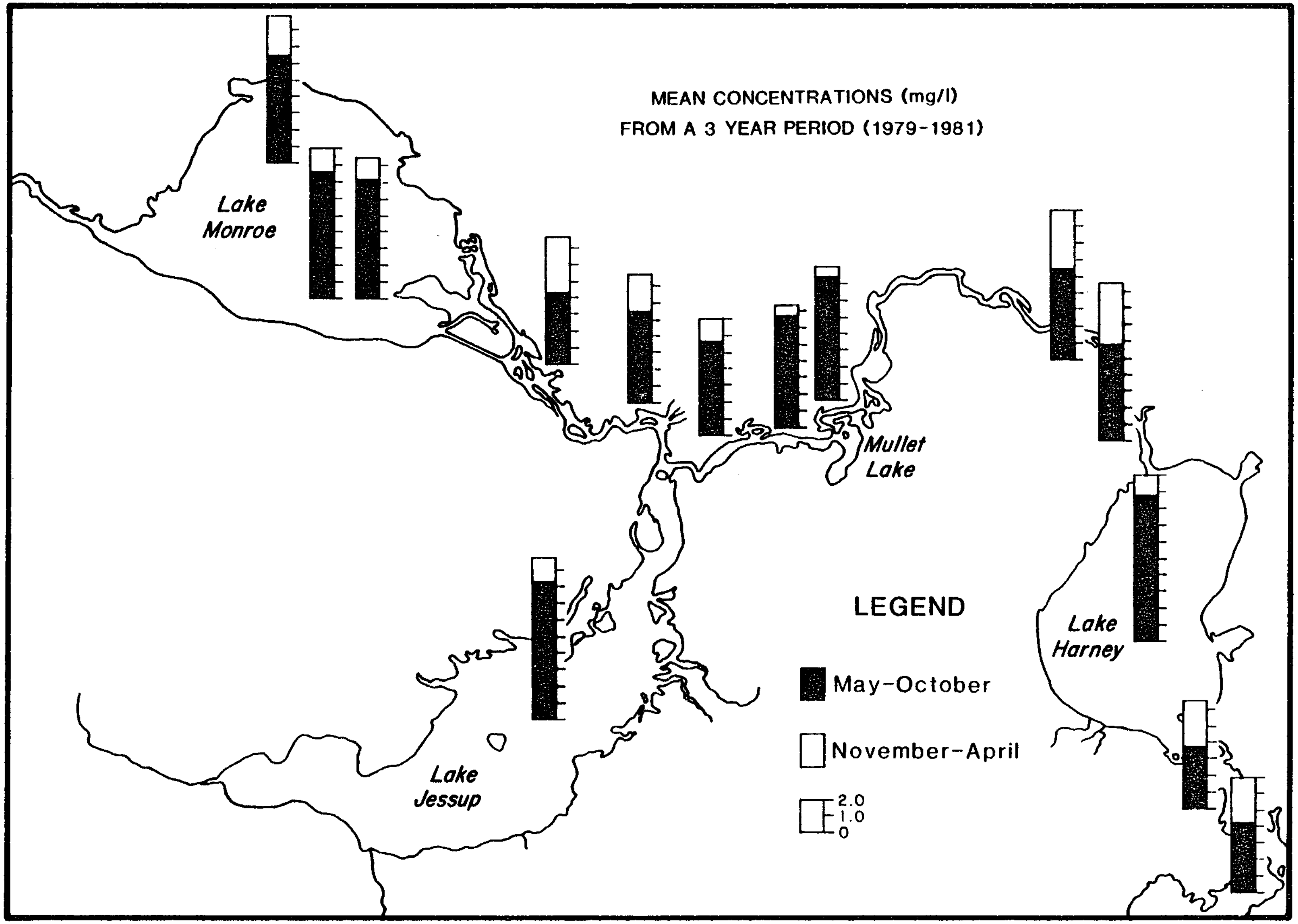
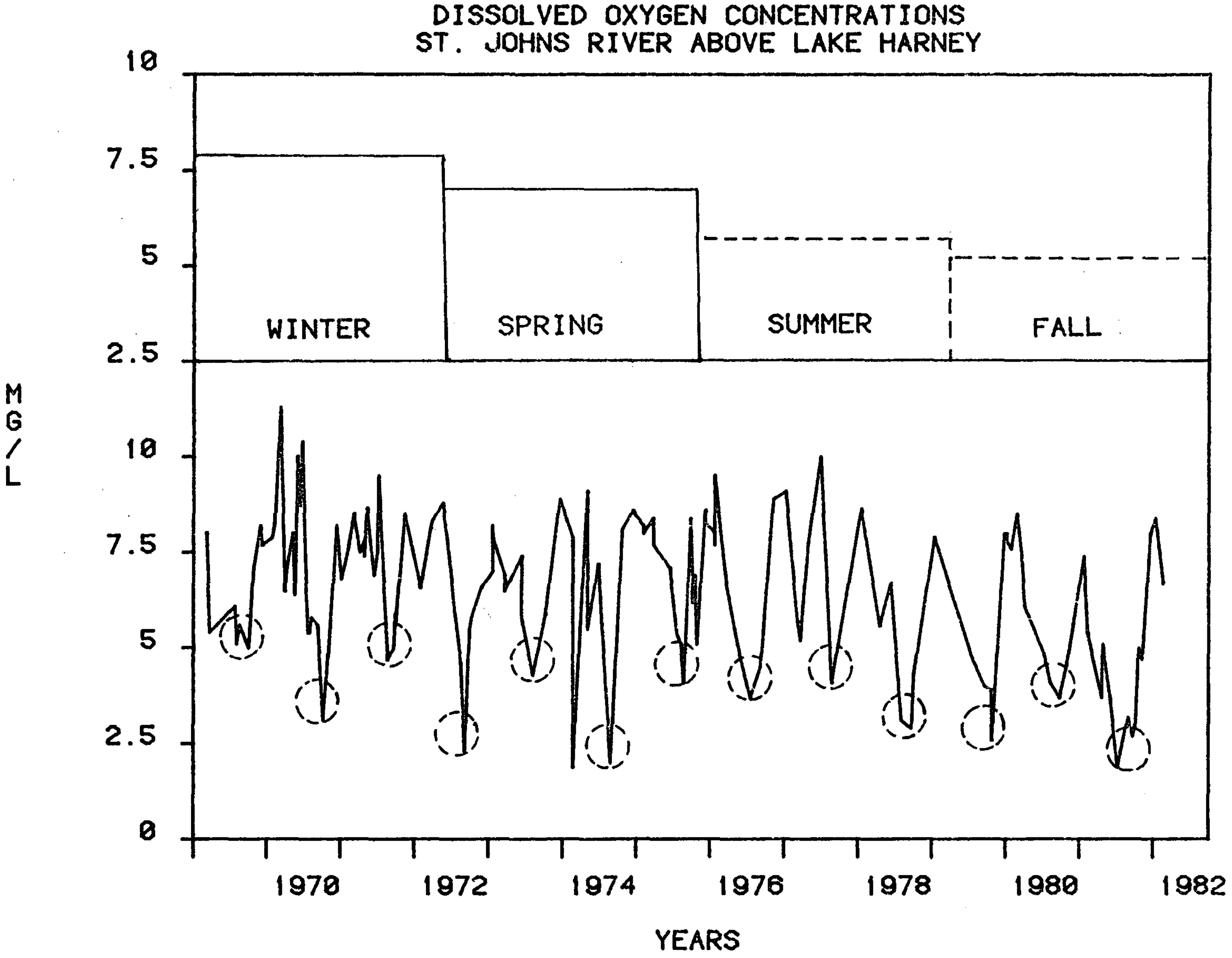


Figure 18. Dissolved Oxygen Concentrations in the Middle St. Johns River - Southern Reach.

Figure 19.



Bar graph represents mean concentration for each season during 1969 through January 1982. Dash lines indicate summer and fall months.

section of the river between Lake Harney and Mullet Lake where heavy concentrations of algae were observed (maximum chlorophyll a concentration was 1800 μg/l, FDER). Oxygen consumption through algal decomposition contributed to the near anoxic conditions (2 to 0.3 mg/l surface D.O. and 0.2 to 0.05 mg/l near-bottom D.O., FDER and SJRWMD).

In the SMSJ overall, D.O. concentrations from November through April (1980-81) rebounded 0.3 to 3.5 mg/l over levels measured during May through October and with less fluctuation (Figure 18). The highest D.O. levels were measured in lakes Harney and Jessup followed by Lake Monroe. Depth profiles taken in the river at S.R. 46 (1973-76, USGS) and at four sites in Lake Harney (1980-81, SCES) revealed very minimal D.O. stratification during November through April with a surface to near bottom mean difference of 0.4 mg/l for the former and 1.3 mg/l for the latter. In contrast, stratification became more delineated at those sites during May through October with a mean difference (surface to bottom) of 1.2 mg/l at S.R. 46 and 2.9 mg/l in Lake Harney.

Normally, there is an inverse relationship between flow and dissolved oxygen in both the upper and middle basins (Goolsby and McPherson, 1970, Brezonik et al., 1976). However, during 1980 and 1981 a reversal of this trend occurred in the SMSJ (Figure 7c and 8c) at S.R. 46 and the outlet of Lake Monroe. In fact, removal of the 1980-81 D.O. data from the data set strengthens the negative correlation normally observed at S.R. 46 (Table 9) by 38%.

Nutrient Loading

Trend analysis in nutrient loading and the system's subsequent environmental response must include demographics and land use trends even though these criteria are culturally dynamic and, therefore, difficult to measure with respect to nutrient export rates. Nevertheless, these criteria are considered upon brief evaluation of actual loading rates (based on recent data) and upon assessment of permissible loading rates and future loading trends (based on a literature review).

Relative to lakes Jessup and Monroe, a more in-depth evaluation and assessment for Lake Harney is provided for two reasons: 1) In contrast to the areas downstream from its outlet, there is a considerable amount of hydrologic and water quality data available for Lake Harney and the St. Johns River upstream of its inlet. 2) To evaluate the conditions under which the Econ may or may not prevail over other sources of impact on the St. Johns River at S.R. 46 and Lake Harney.

The mean low-flow in the St. Johns River at S.R. 46 for the entire period from 1976 through February, 1982, and for the drought period (1980-81) exclusively were nearly equivalent, 240 ± 120 cfs and 235 ± 120 cfs, respectively (Appendix 1). The difference occurred in the mean normal-flows, 1200 ± 790 cfs for the entire period (1976-82) and 850 ± 29 cfs for the drought period. Nevertheless, the normal-flow loading rate increase of 2 to 4 times over low-flow rates for BOD_5, TN and TP was relatively consistent for both periods. This compares similarly to the area upstream of the Econ's confluence with the St. Johns River in that the normal-flow loading rates for BOD_5 and TN at Station AAS (1980-81) were 3 to 4 times over low-flow rates, but 26 times over low-flow rates for TP (Appendix 2).

A loading rate table for the Econ is not provided in the appendices of this report but is provided in a technical report by Gerry (1983), in which there is a substantial amount of data (1979-81) on normal flow values but very little for low flows of 35 cfs or less. It is interesting to note that in the Econ during normal flows (1979-81), the mean BOD_5 loading rate (2300 ± 1700 lbs/day) was greater than that of TN (1900 ± 800 lbs/day). This is opposite of the normal flow situation that existed in the St. Johns downstream of the Econ (9500 ± 3600 lbs/day TN and 3400 ± 1100 lbs/day BOD_5, 1979-81) and upstream of the Econ (2100 lbs/day TN and 1000 ± 420 lbs/day BOD_5, 1979-81). The fact that there is a weak correlation between flow and BOD_5 concentrations despite its increased levels with increased flow does suggest NPS as a major contributor to BOD_5 loads to the Econ (Gerry, 1983). This is of particular concern during high flows because unabated nonpoint loading will greatly affect the total pollutant load, particularly after the "first flush" period of a major storm. Since 1970 there has been little or no increase in TN or TP loading; however, BOD_5 loading in the Econ has increased 18% (Gerry, 1983). Nevertheless, Brezonik et al. (1976) believed that this has little to do with oxygen depletion problems in the St. Johns near S.R. 46 and within Lake Harney since most BOD_5 was satisfied before entering the St. Johns. Similarly, Lake Monroe may continue to experience oxygen deficits despite reductions in point-source loadings of BOD_5 (Connell Associates, Inc., 1974).

From 1979 through 1981, TN loads from the Econ and the St. Johns River upstream from the Econ were nearly equivalent, approximately 2100 lbs/day from each source. However, under low flow conditions the Econ released nearly twice the TN load (900 lbs/day) of the St. Johns near the confluence (500 lbs/day). Likewise, TP loading from both sources approached parity under normal flow conditions (300 lbs/day from each source) but became diverged under low flows with the Econ discharging over half of the TP load measured downstream from its outlet. These loading rates are gross estimates because variation in assimilative capacities with distance and discharge rate are not accounted for. In addition, flow values given for the Econ were measured at the S.R. 13 bridge, approximately five land miles from its confluence with the St. Johns. This may account for some of the discrepancy between the actual recorded flow measurement at S.R. 46 and the combined flow values from the Econ and S.R. 50.

On the average, a major portion of the pollutant loading into Lake Harney is of NPS origin via tributary and the St. Johns River particularly during normal and high flows. Evidently, the Econ has its greatest impact on the St. Johns during low flow months as a result of limited dilution of sewage discharges. This conclusion is in agreement with the findings of Brezonik et al. (1976). In the same report, Brezonik and his staff developed a more comprehensive, yet indirect, nutrient budget for the three middle basin lakes based on literature values for nutrient export rates from various land uses. They determined that the Econ accounts for 17% of the TN and 30% of the TP loading to Lake Harney which receives in total 44.2 x 10^5 lbs/year TN and 10.5 x 10^5 lbs/year TP, yielding respective areal loading rates of 89.2 and 21.2 g/m^2-yr. These estimates were calculated from data collected from 1967 through 1974, during which the mean normal flow rate was higher than during 1979-81.

An update on the comprehensive loading estimates for Lake Harney was done by recalculating the total St. Johns River input and the area of the lake based on the mean normal stage for 1979-1981 period (Table 10). Lake Harney received approximately 40 x 10^5 lbs/year TN and 3.0 x 10^5 lbs/year TP giving an areal loading rate of 90 g/m^2-yr TN and 6.8 g/m^2-yr TP (1979-81). The diffuse source and precipitation input can be considered relatively negligible; only 1% to 2% of the total input. This includes the sediments, from which an insignificant amount of nitrogen and phosphorus was released with respect to the amount derived from allochthonous sources (Nisson, 1975).

Loading values for lakes Jessup and Monroe (Table 10) were calculated with the aid of the precipitation and diffuse source values of Brezonik et al. (1976) and of recently published sewage treatment plant discharges (Williams, 1981). Compared to Lake Jessup, lakes Harney and Monroe receive a tremendous annual input of nutrients, 98% of which is from the St. Johns River. Lake Jessup, however, behaves as a tributary, contributing to, rather than receiving from, the river. Lake Jessup's potential outflow of nutrients is often superseded by the St. Johns River at high

TABLE 10. Nitrogen and Phosphorus loading to Lakes Harney, Jessup and Monroe during 1979-1981. Included are loading rate criteria for lakes proposed by Shannon and Brezonik (1972).

	Harney		Jessup*		Monroe*	
Parameter	TN	TP	TN	TP	TN	TP
Total input (x 10^5 lbs/yr)	40	3.0	4.3	1.1	88	9.2
Areal rate (g/m^2-yr)	90	6.8	6.4	1.7	114	12

	N	P
Permissible Loading (g/m^2-yr)	2.0	0.28
Critical loading (g/m^2-yr)	3.4	0.49

*Loading values are modified from Brezonik et al., 1976, and FGFWFC, 1980-1981.

flow, thus it has nominal impact on the St. Johns and Lake Monroe regardless of flow conditions. Lake Jessup is also unique in that a majority of the total deposition of nitrogen and phosphorus, 63% and 88%, respectively, can be traced to effluent of several sewage treatment plants. As previously mentioned, efforts toward reducing these loads to Jessup are underway with a re-routing of sewage lines to the Iron Bridge facility. The reductions would place subsequent loading to Lake Jessup within tolerance of the general permissible loading criteria (Table 10). Some improvement of Lake Jessup may be realized with removal of all or most point-source input and the compliance of remaining load inputs with site-specific permissible loading criteria. This is particularly important in light of expanding urban development within the Lake Jessup basin.

Presently, Lake Monroe receives less TP and TN loading from treatment plants (5% of the TP and 1% of the TN input) than lakes Harney and Jessup. The removal of all sewage treatment discharges into lakes Monroe and Harney would still place loading rates an order of magnitude above the critical or dangerous loading rate (Table 10). But, lakes Harney and Monroe are more characteristic of riverine rather than lacustrine systems (due to their relatively short residence times) and their sediments have better nutrient assimilative properties than sediments found in Jessup (Nisson 1975). Therefore, a more specific loading rate criteria should be designed for lakes Harney and Monroe individually.

The Iron Bridge tertiary treatment facility is expected to decrease TN and TP loads into the St. Johns River and Lake Harney by 70% and BOD_5 loads by 50%; thereby satisfying the FDER wasteload allocation limits (FDER, 1977 and 1980). Nevertheless, urban-related annual loadings for TN, TP, and BOD_5 are expected to nearly double by the year 2000 (208 reports by Volusia Council of Governments, 1977, and East Central Regional Planning Council, 1977). These estimates parallel the projected doubling of the population in the SMSJ basin to over 700,000 by the year 2010 (Marella and Ford, 1980) (not including the constant influx of tourists). Loadings related to agricultural and silvicultural activities will probably decrease due to urban encroachment which will result in a net decrease in basin-wide annual TN loading (Volusia 208 Program, 1977). However, a net increase in basin-wide annual TP and BOD_5 loading is projected primarily through NPS urban runoff (Volusia 208 Program, 1977).

CONCLUSIONS

The potential for a severe water quality-induced destabilizing event (e.g. fish kill) in the SMSJ increases as river stage levels or flows drop below a certain miniumum threshold, especially during May through October. Based on the drought period data, this threshold minimum is approximately 2.4 feet (NGVD) or 1300 cfs at S.R. 46 and/or 1.6 feet (NGVD) at the outlet of Lake Monroe (S.R. 17-92). Further analysis of post-drought water quality data, as it is made available, should include reevaluation of this threshold minimum particularly in light of current reductions in point-source nutrient loadings.

Permissible and critical nutrient loading rate criteria should be reassessed for lakes Harney and Monroe, taking into account hydraulic retention time - an important variable affecting the trophic status for both lakes. As urban development continues, the reduction or, at least, the control of NPS nutrient loading within site-specific permissible loading rate criteria is essential to maintain present water quality.

LITERATURE CITED

BREZONIK, P.L., J.L. FOX, N.E. CARRIKER, J.G. HAND, J.D. NISSON, AND T.V. BELANGER. 1976. Analysis of eutrophication and water quality factors in the middle St. Johns River Basin. Report to the Florida Department of Environmental Regulation, Tallahassee.

CONNELL ASSOCIATES, INC. 1974. Water quality modeling study, St. Johns River basin, Vol. 1, Report to Florida Department of Environmental Regulation, Tallahassee.

___________. 1974. Final report for water quality modeling study of St. Johns River basin, Kissimmee River basin, lower Florida basin, and Florida east coast basin for Florida Department of Environmental Regulation.

COX, D.T. AND H.L. MOODY. 1976. Upper St. Johns River Study, Dingell-Johnson Project F-25. Federal aid in fish restoration. Florida Game and Freshwater Fish Commission.

___________, E.D. VOSATKA, H.L. MOODY, AND L. HARTZOG. 1976. Stream investigations completion report: Upper St. Johns River Study. Florida Game and Freshwater Fish Commission, Tallahassee.

EAST CENTRAL FLORIDA PLANNING COUNCIL. 1977. Orlando metropolitan 208 study, stormwater management practices evaluations.

FALL, C. 1982. Water quality monitoring annual report, 1979-1981. Technical Report No. 17, Water Resources Department, St. Johns River Water Management District, Palatka.

FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES. Division of Forestry. Silviculture best management practices manual.

FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION. 1982. St. Johns River water quality status, 1982. St. Johns River District, Orlando.

___________. 1980. St. Johns River water quality, 1980. Orlando.

___________. 1977. Wasteload allocation for the Little Econlockhatchee River system - nutrient modeling results.

FLORIDA GAME AND FRESHWATER FISH COMMISSION. 1982. Study 1: ecological aspects of the fishery, Dingell-Johnson Project F-33, federal aid in fish restoration, St. Johns River fishery resources, 1976-1981.

FRAZEE, J.M., Jr. 1981. Geochemical pattern analysis: method of describing the Southeastern Regional Aquifer System. Studies of the Hydrogeology of the Southeastern U.S., B.F. Beck (ed.). Special Publ. No. 1, Georgia Southwestern College. Pp. 46-58.

GERRY, L. R. 1982. Econlockhatchee River System: status report. Technical Report No. 22, Water Resources Department, St. Johns River Management District, Palatka.

GOOLSBY, D.A., AND B.F. MCPHERSON. 1970. Preliminary evaluation of chemical and biological characteristics of the upper St. Johns River basin, Florida. U.S. Geological Survey open file report no. 71001.

LIVINGSTON, E., AND J. COX. 1983. The Florida development manual: a guide to sound land and water management. Florida Department of Environmental Regulation, Tallahassee.

MARELLA, R. AND B. FORD. 1982. Current and projected population of the St. Johns River Water Management District, 1980. Information Circular No. 8, Water Resources Department, St. Johns River Water Management District, Palatka.

NISSON, J.D. 1975. Sediment-water nutrient dynamics. M.S. Thesis. University of Florida, Gainesville.

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT. 1980. Upper St. Johns River basin surface water management plan, Vol. 2. Paltaka.

____________. 1977. Water resource management plan, Phase 1. Palatka.

SEMINOLE COUNTY DEPARTMENT OF PUBLIC WORKS. 1982. Surface water quality report. Division of Environmental Services.

SHANNON, E.E., AND P.L. BREZONIK. 1972. Relationships between trophic state and N and P loading rates. Environ. Sci. Technol. 6:719-725.

STOKER, H.S., AND S. L. SEAGER. 1972. Environmental chemistry: air and water pollution. Scott, Foresman and Company. Glenview, Illinois.

VOLUSIA COUNCIL OF GOVERNMENTS. 1977. Investigation and control of water quality factors in the middle St. Johns River basin, 208 water quality management plan, Vol. 3.

____________. 1977. 208 water quality management program, final plan, Vol. 1.

WILKENING, H. 1983. Personal communication, St. Johns River Water Management District, Palatka.

WILLIAMS, V. 1981. A summary of point source sewer plant discharges to the St. Johns River south of Lake George, 1980-1981. Florida Game and Freshwater Fish Commission, Kissimmee.

Appendix 1. Loading rates (lbs/day) calculated from data obtained from Seminole County, DER and USGS at SR 46 located above Lake Harney.

	DATE	BOD$_5$	TN	TP	Flow (cfs)
1976	1/26	3300	5000	300	450
	3/23	250	1500	170	100
	5/16	6200	4300	640	500
	7/17	--	21000	1000	2500
	9/17	13000	16000	1600	2700
	11/9	9000	14000	660	1900
1977	1/11	3850	9100	700	1300
	3/7	4150	4600	400	400
	4/28	340	730	80	50
	6/30	7200	1900	300	200
	8/24	920	2700	200	375
1978	6/13	2780	2700	300	375
	8/2	--	27000	1300	3900
	9/21	--	28000	2500	3900
	10/4	--	21000	740	3000
1979	1/16	--	17000	1300	2400
	7/16	--	8600	500	1300
	9/18[1]	--	26000	1400	4700
	10/23	--	40000	1000	7000
	10/25	--	59000	3700	5800
	12/26	--	14000	350	1400
1980	1/8	--	6700	710	900
	1/9	--	7600	310	900
	1/30	--	11000	600	900
	2/27	--	9500	530	900
	3/21	--	7500	840	900
	4/7	--	10500	710	850
	6/13	--	2200	250	200
	7/14	--	1350	44	150
	8/12	--	1500	170	200
	9/26	--	3200	--	400
	10/30	1560	--	640	350
	12/2	--	8800	900	650

Appendix 1. Continued. . . .

1981	1/26	395	1230	54	200
	2/12	--	6000	700	375
	4/21	--	2050	260	100
	4/28	--	2770	180	100
	6/3	1185	4100	400	100
	7/9	1110	4200	540	150
	8/31	5040	4900	2800	850
	9/23	2940	3930	820	850
	10/6	--	3700	350	375
	10/23[2]	2960	9000	700	600
	11/9	3800	14100	1160	1100
	12/19	2070	4480	320	350
1982	1/15	2250	8950	860	650
	2/19	1480	2960	213	200

---

[1] Hurricane David occurred September 3-4.

[2] USGS provided stage data from 10/23/81 to 2/19/82 of provisional status at the time of this compilation.

Appendix 2. Loading rates (lbs/day) calculated from data obtained from Seminole County at Station AAS located above the confluence of the Econlockhatchee and St. Johns Rivers and from USGS at SR 50.

	DATE	BOD_5	TN	TP	Flow (cfs)
1980	4/7	-	-	132	534
	9/26	-	-	-	125
	10/30	146	-	7.3	37
1981	1/26	245	-	6.7	62
	4/21	-	-	14	37
	4/28	-	-	6.5	26
	6/3	398	-	14	13
	7/9	30	126	1.7	5.0
	8/31	1500	2140	700	152
	9/23	830	1700	270	338
	10/23*	600	900	23	88
	11/9	1500	2700	200	250
	12/19	900	1200	85	120
1982	1/15	900	3700	430	267
	2/19	420	1400	30	142

* USGS provided discharge data from 10/23/81 to 2/19/82 of provisional status at the time of this compilation.

Appendix 3. Interbasin Comparison: SMSJ and Upper Basins (1979-81). Sources for this Comparative Survey are this Study and Fall, 1982.

Similarities:

1. Water quantity is an important factor affecting water quality in both basins.

2. The downstream increase in conductivity in the upper basin is extended to the outlet of Lake Harney, then drops to a level comparable to the northern reach of the upper St. Johns River (Figure I).

3. The inverse relationship between chloride concentrations and stage is statistically similar for two sites in the river, S.R. 46 and Lake Washington.

4. The mean TN level in the SMSJ (2.5 mg/l, 1979-81) is not much higher than that found in the upper basin (2.0 mg/l, 1979-81). The greatest concentrations were found in Lake Jessup and the northern reach of the upper St. Johns River (Figure II).

5. Ammonia is the predominant inorganic nitrogen fraction in the upper basin and only in lakes Monroe and Jessup in the SMSJ basin. Nitrates are the major inorganic fraction downstream from the Econ into Lake Harney where the highest levels are found for both basins together.

6. Determination of the limiting nutrient in both basins has been generally inconclusive. Data do indicate nitrogen limitation in both basins, although Lake Harney tends to be phosphorus limited at times.

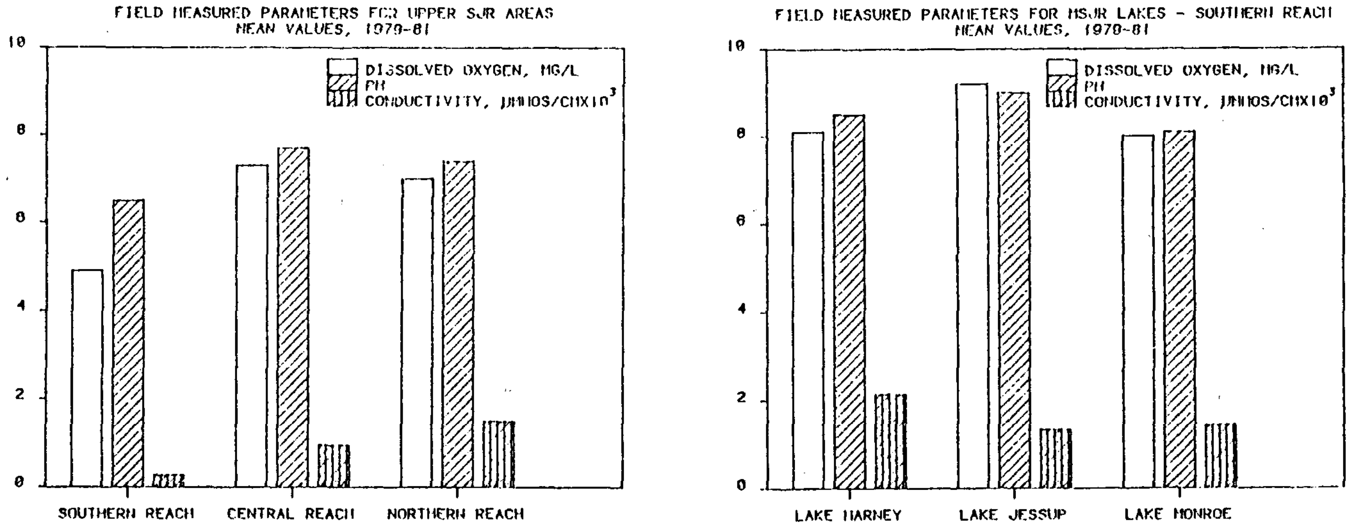
7. In both basins, D.O. concentrations are higher in the lakes than in the riverine sections.

Contrasts:

1. No significant man-made alteration of the hydrologic regime in the SMSJ has occurred; whereas the upper basin has had extensive physiographic alteration within its floodplain, thus altering is hydrologic regime (SJRWMD, 1979).

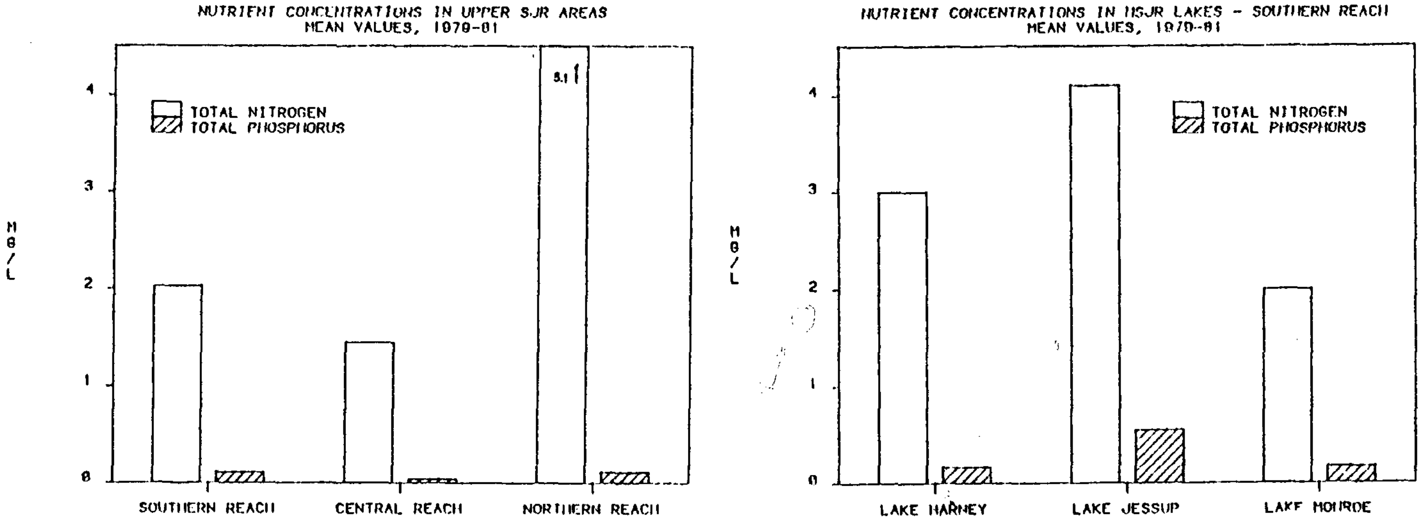
2. Impacts on water quality in the SMSJ have been the result of urban and agricultural encroachment onto its floodplain and significant indirect urban influences via the Econ. Primarily, impacts on water quality in the upper basin have been related to agricultural activities.

Figure I.


FIELD MEASURED PARAMETERS FOR UPPER SJR AREAS
MEAN VALUES, 1979-81

FIELD MEASURED PARAMETERS FOR MSJR LAKES - SOUTHERN REACH
MEAN VALUES, 1979-81

Figure II.


NUTRIENT CONCENTRATIONS IN UPPER SJR AREAS
MEAN VALUES, 1979-81

NUTRIENT CONCENTRATIONS IN MSJR LAKES - SOUTHERN REACH
MEAN VALUES, 1979-81

Figure I and II. Areas in the upper St. Johns River designated as southern, central and northern reaches refer to Blue Cypress Lake area, Fellsmere grade to Lake Washington weir and Lake Washington to S.R. 520, respectively.

3. Morphometrically, the SMSJ is more lacustrine than the upper basin.

4. The three lakes of the SMSJ exhibit higher D.O., pH, and TP levels than the upper basin (Figures I and II).

5. The mean total phosphorus concentration in the main channel of the SMSJ (0.18 mg/l, 1979-81, excluding Lake Jessup) was over twice that found in the upper basin.

6. Nitrate and nitrite (NO_x) levels in the SMSJ (excluding Lake Jessup) were two to three times greater than in the upper basin except downstream from the Econ into Lake Harney where NO_x levels were over a magnitude greater.

7. The inverse relationship between flow and D.O., normally observed in both basins (Goolsby and McPherson, 1970; Brezonik et al., 1976), was reversed during the drought in the SMSJ.