82-34 WATER-QUALITY CHARACTERISTICS OF EVERGLADES NATIONAL PARK, 1959-77, WITH REFERENCE TO THE EFFECTS OF WATER MANAGEMENT 82-34

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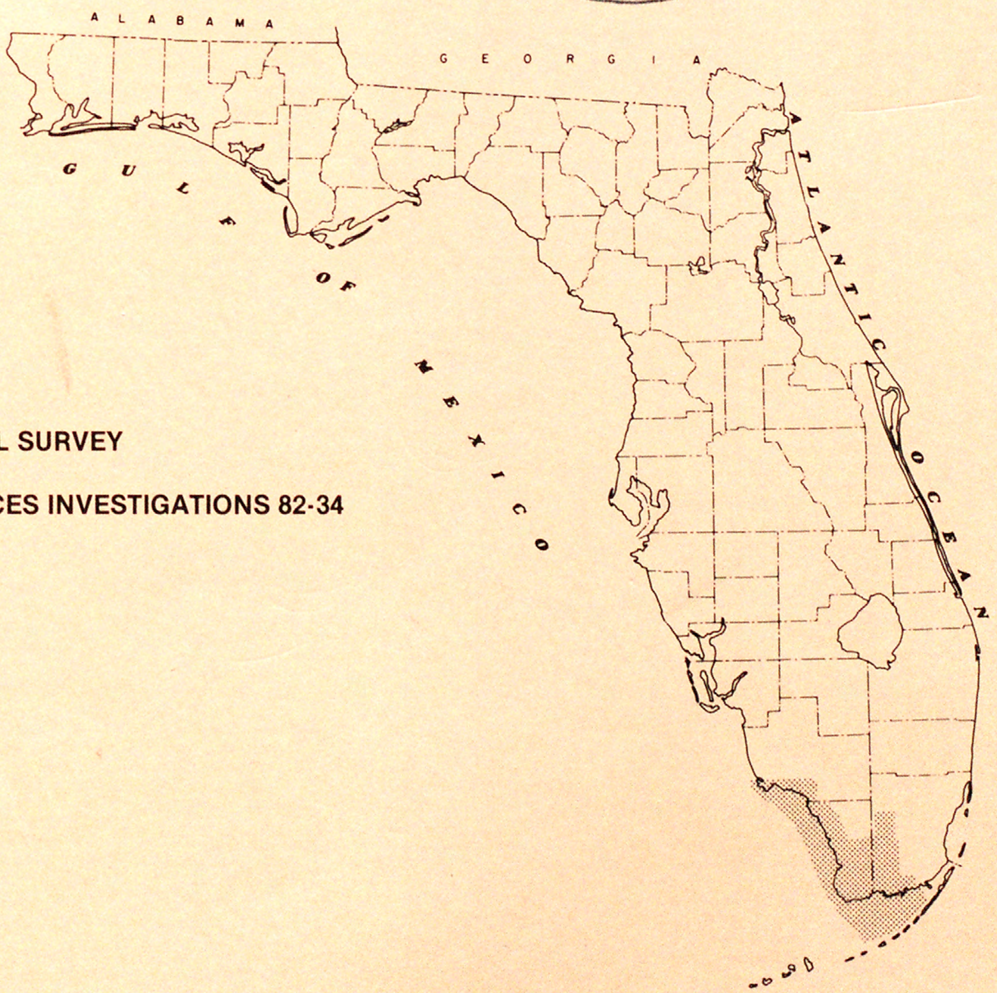

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Seasonal changes in major-ion, trace-element, and macronutrient concentrations are marked in the shallow marsh. Concentrations generally increase in the dry season due to evapotranspiration, changes in chemical equilibria, and precipitation.

Water-management practices in south Florida have changed the water quality in the Shark River Slough. Most major-ion, dissolved-solid, and iron concentrations and color levels have steadily increased since 1963. The water quality in the other two drainageways has not changed since sampling began.

Chlorinated-hydrocarbon insecticide residues in bottom material were found in low concentration at every sampling station in the park.

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By Bradley G. Waller

U.S. GEOLOGICAL SURVEY

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Prepared in cooperation with the

NATIONAL PARK SERVICE

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ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System (SI) of units and abbreviation of units

Multiply	By	To obtain
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
	0.02832	cubic meter per second (m^3/s)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

WATER-QUALITY CHARACTERISTICS OF EVERGLADES NATIONAL PARK, 1959-77, WITH REFERENCE TO THE EFFECTS OF WATER MANAGEMENT

By Bradley G. Waller

ABSTRACT

The U.S. Geological Survey has collected water-quality data in the Everglades National Park since 1959. Major ions, macronutrients, trace elements, and pesticides are the primary chemical groups analyzed. The period of record and frequency of sampling vary for each chemical group, with the longest record for the major ions and the shortest for the macronutrients.

Within the park there are three major drainageways: Big Cypress Swamp, Shark River Slough, and Taylor Slough. Each drainageway exhibits unique hydrologic conditions, yet there is a high degree of homogeneity in water-quality characteristics among these areas.

Seasonal changes in major-ion, trace-element, and macronutrient concentrations are marked in the shallow marsh. Concentrations generally increase in the dry season due to evapotranspiration, changes in chemical equilibria, and precipitation.

Water-management practices in south Florida have changed the water quality in the Shark River Slough. Most major-ion, dissolved-solid, and iron concentrations and color levels have steadily increased since 1963. The water quality in the other two drainageways has not changed since sampling began.

Chlorinated-hydrocarbon insecticide residues in bottom material were found in low concentration at every sampling station in the park.

INTRODUCTION

Near the turn of the century, the Everglades was a shallow, freshwater marsh of 4,000 mi^2 extending from Lake Okeechobee south to Florida Bay (fig. 1). Drainage and development of the northern part of the Everglades for agriculture began in the late 1890's and early 1900's. In the 1920's, when it became evident that the Everglades was important to man not only as agricultural land but also as a freshwater source and a unique subtropical wilderness, much of the central Everglades was set aside for water conservation. The Everglades National Park (fig. 2), established in 1947, covers over 2,350 mi^2 of the southern Everglades, mangrove forest, saline marshes, bays, and estuaries. The park encompasses most of the Shark River Slough and parts of Taylor Slough and the Big Cypress Swamp (fig. 3).

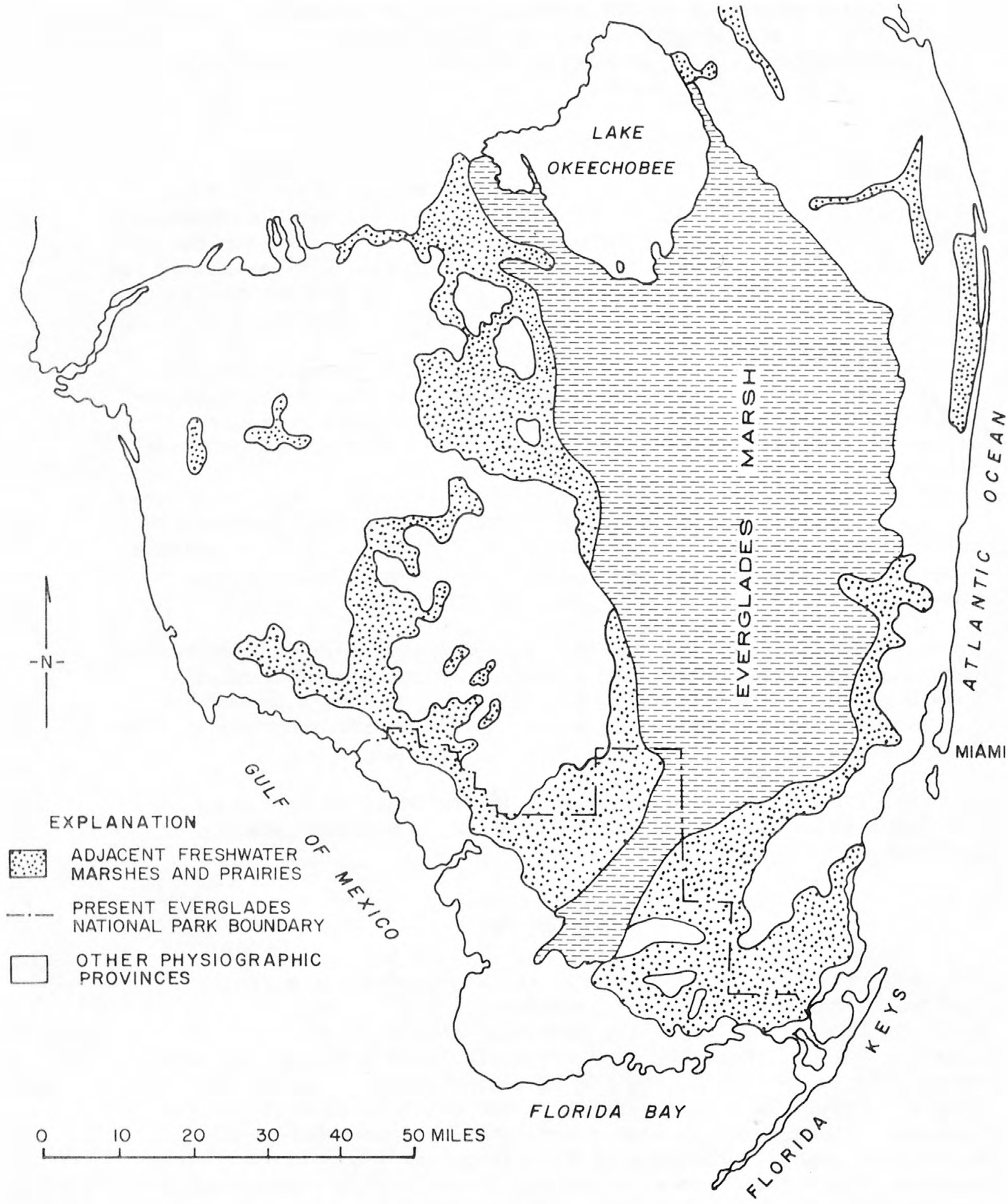


Figure 1.--The historic Everglades (after Davis, 1943).

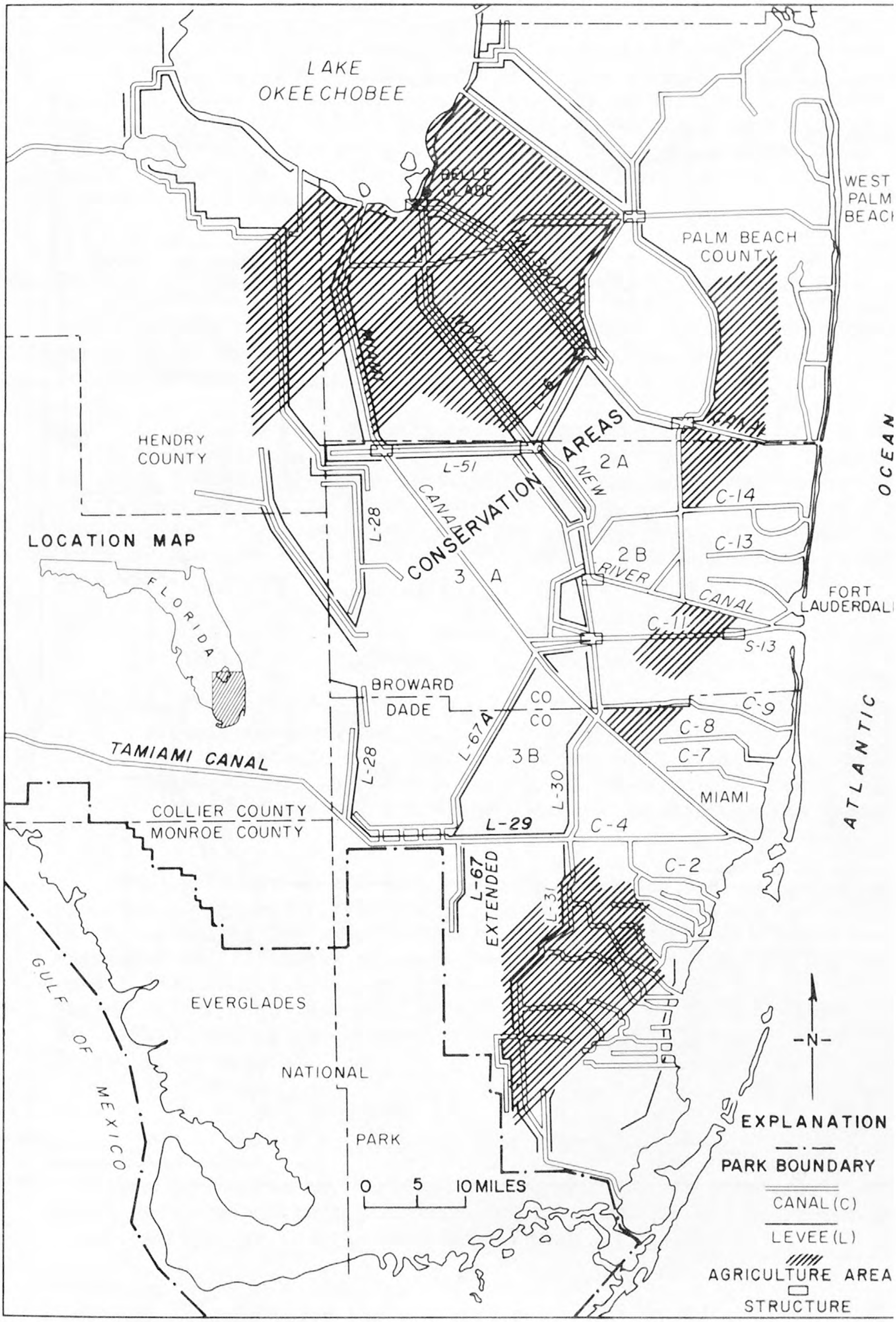


Figure 2.--Location of Everglades National Park, water conservation areas (1, 2, and 3), major levees and canals, and delineation of major agricultural areas in south Florida.

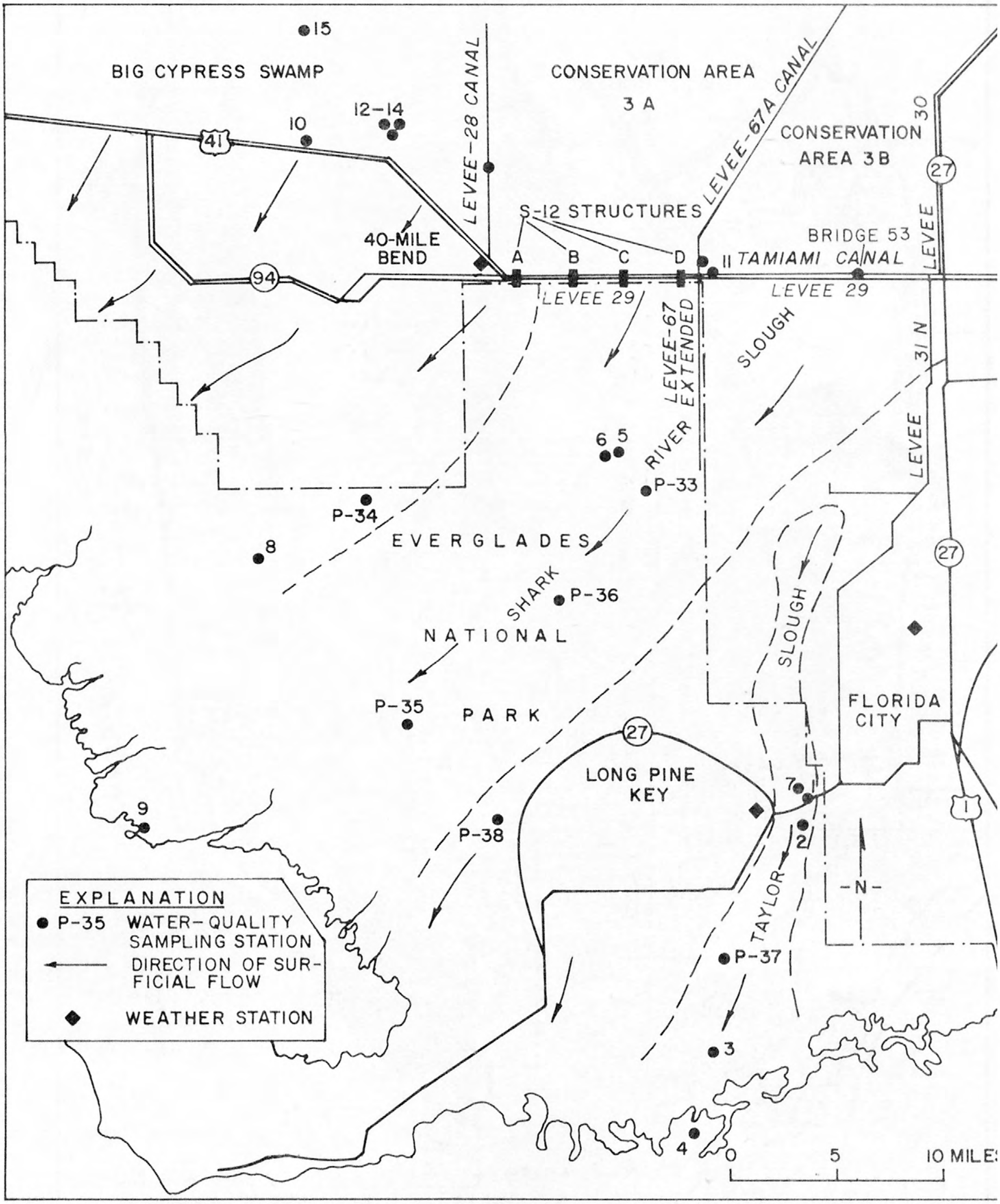


Figure 3.--Location of major drainageways and water-quality sampling stations in Everglades National Park.

The Everglades National Park has been a center for research in hydrology, aquatic chemistry, biology, vegetative studies, and resource management. Investigations have been undertaken by the park staff, by other government agencies, and by universities. In 1959, the U.S. Geological Survey began intensive hydrologic and biologic investigations within Everglades National Park. This report summarizes water-quality data collected from 1959-77 by the U.S. Geological survey during those investigations.

Purpose and Scope

The purpose of this report is to summarize the water-quality characteristics of Everglades National Park from 1959-77 and to indicate changes that might have occurred during that period.

The scope of this summary report consisted of assimilation and statistical analysis of water-quality data at the stations listed in table 1 during the 18-year period. Water samples were collected at frequencies ranging from biweekly to annually; the frequency of sampling and the constituents analyzed varied. Data from areas north of the park were utilized to determine if changes were occurring within the park.

Previous Investigations

Soon after the Everglades National Park project began in 1959, J. H. Hartwell (written commun., 1963) made a preliminary evaluation of the hydrologic situation within the park. Kolipinski and Higer (1969a; 1969b), McPherson (1971), and Kushlan and others (1975) summarized most of the hydrobiological studies carried out in the 1960's.

The hydrology of the park and adjacent areas was summarized by Leach and others (1972) and Klein and others (1975). Hartwell (1969) evaluated the water releases to the park from the north and suggested modifications to the release schedule. Earle and Hartwell (1973) analyzed the hydrologic and water-quality aspects of Taylor Slough from 1960-68. Waller (1975) and Waller and Earle (1975) analyzed the quality of the water entering the park from Conservation Area 3A.

Acknowledgments

The author thanks the staff of the National Park Service for their previous and continued support of hydrologic and water-quality investigations in Everglades National Park.

CLIMATE AND DRAINAGE

Everglades National Park has a subtropical climate characterized by hot, humid summers and warm, dry winters. The wet season extends from about May to November, with the remainder of the year being the dry season. Figure 4 gives average monthly and yearly rainfall for 1959-77. Average yearly rainfall for that period ranged from 37.61 inches in 1971 to 77.77 inches in 1968. Because most of the water in the park is shallow, the water temperature fluctuates rapidly with the air temperature.

The Everglades National Park is flat; altitudes range from 10 feet near 40-Mile Bend to sea level at the mangrove fringe. The land surface slopes to the estuaries at about 0.2 ft/mi. Two low ridges are located on either side of the Shark River Slough (fig. 3); the western ridge borders the Big Cypress Swamp, and the eastern ridge borders the upper part of Taylor Slough.

The main drainageways are Big Cypress Swamp, Shark River Slough, and Taylor Slough (fig. 3). Each is distinctive in its surficial flow patterns, soil types, vegetative communities, water chemistry, and periods of inundation. Flow patterns are indicated in figure 3.

During the wet season, inundation is common except on the highest elevations. When water levels begin to decline, the surface waters conform to the shape of the drainageways. Analyses of the water-quality data indicate little surface flow between the drainageways.

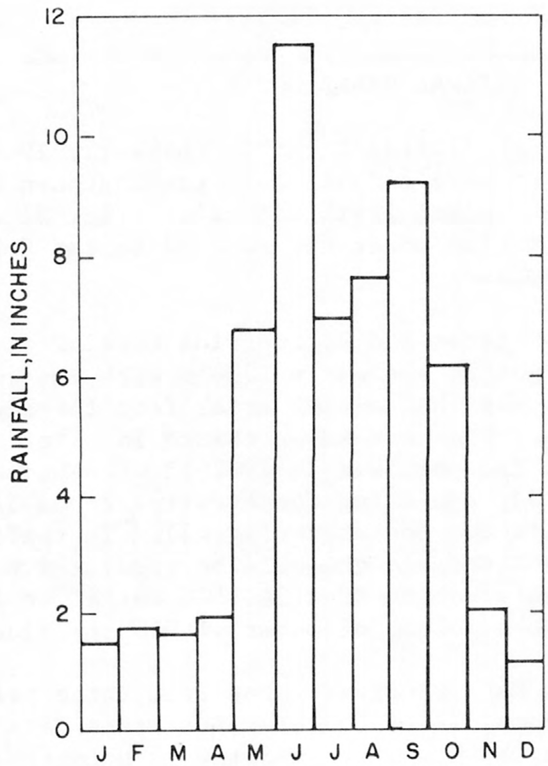
The determination of surficial drainage patterns is important in that:

1. Chemical constituents and suspended material are transported downstream along these flow patterns.

2. Characteristic vegetative communities' development follows along the flow patterns.

3. Alterations in flow patterns may cause long-term changes in biological communities, water quality, and inundation.

Water levels decline rapidly after flow through the drainageways stops. Thereafter, the freshwater losses from the park are by ground-water outflow and evapotranspiration.



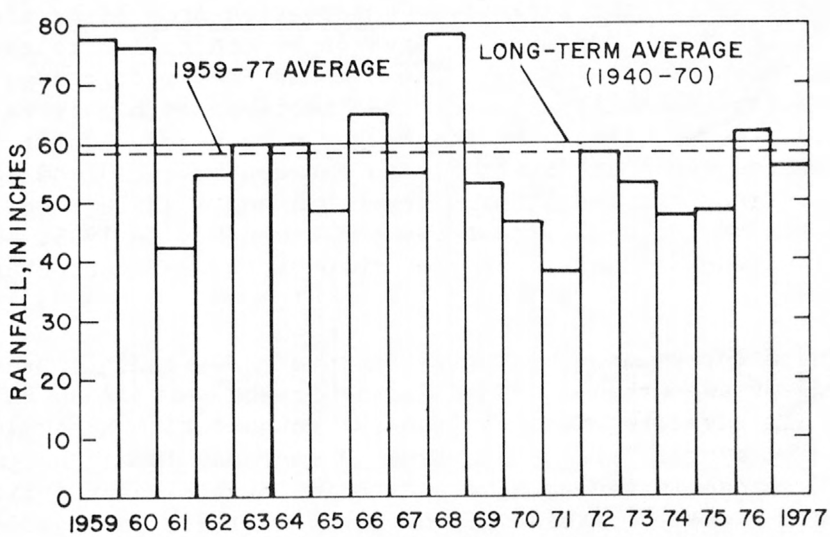


Figure 4.--Average monthly and average yearly rainfall for 40-Mile Bend, Homestead Agricultural Experiment, and Royal Palm Ranger stations, 1959-77.

GENERAL HYDROLOGY

Water control in south Florida began in the early 1900's, but few water control projects were completed in the southern Everglades before 1950. The Tamiami Trail and canal (fig. 2) were completed in the 1920's, but flow under the roadbed to the Everglades National Park was not impeded.

The major effects on flows and hydroperiod (period of inundation) within the park began in the early 1950's with the completion of Levees 30 and 31 dividing the coastal areas from the Everglades (Klein and others, 1975). The next major change in water-management practices affecting the park was in 1962-63 when Levees 28, 29, and 67A were completed, enclosing Conservation Areas 3A and 3B, and the S-12 structures became operable (fig. 3). Thereafter, the hydroperiod in the Shark River Slough could be regulated by controlled releases from Conservation Area 3A, and variation in rainfall had less effect on the volume of water within the slough.

Everglades National Park receives water from three principal sources: Big Cypress Swamp, Water Conservation Areas 3A and 3B, and rainfall. Flow from the Big Cypress Swamp is uncontrolled and accounts for about 56 percent of the total flow into the park (Klein and others, 1970). Contribution from the Big Cypress Swamp has changed little since measurements began in 1939.

Water enters the park from Conservation Area 3B by flow under Levee 29 and from Conservation Area 3A by controlled releases through the S-12 structures. The average yearly discharge from the conservation areas through these two sections is highly variable (fig. 5). Before 1963, the discharges were nearly equal; 60 percent entered the Shark River Slough between Levee 30 and Levee 67A, and 40 percent entered between Levee 67A and 40-Mile Bend. After completion of the S-12 structures and Levee 67A in 1963, 80 to 90 percent of the discharge occurred through the S-12 structures (Waller, 1975).

These water-management practices were designed to prevent flooding of the urban areas, decrease freshwater losses to the ocean, and regulate the flow from the conservation areas into the park. The overall effect has been an increase in discharge and a drastic change in the areal distribution of the water delivered to the park. Levee 67 extended, completed in 1963, increased the efficiency of flow through the S-12 structures but also divided the upper 10 miles of the Shark River Slough in half.

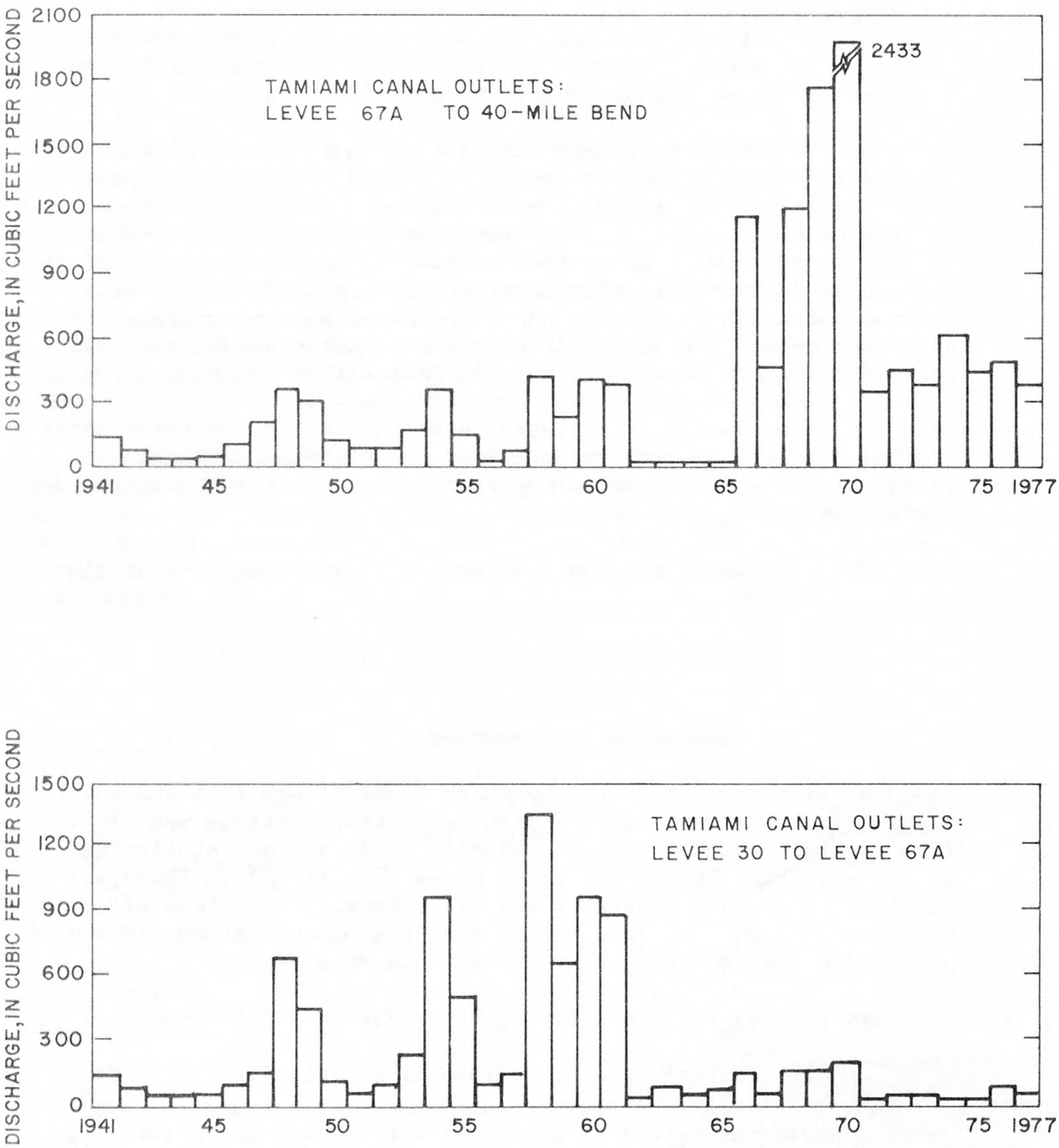


Figure 5.--Variation in average yearly discharge between Tamiami Canal Outlets, Levee 30 to Levee 67A and Levee 67A to 40-Mile Bend, for period of record.

WATER-QUALITY CHARACTERISTICS

Water-quality parameters are presented in two ways. First, an overall statistical analysis of all freshwater stations within the park is made for selected groups of parameters; second, selected stations within and adjacent to the park are analyzed for the same parameters to determine seasonal and spatial changes.

Some of the main factors that affect quality are: (1) quality and quantity of water entering the park from the north; (2) contact with surficial materials such as limestone, peat, marl, and muck; (3) addition of dry fallout from wind drift; and (4) anthropogenic changes in adjacent areas. Most parameters measured were sensitive to changes in rainfall, evapotranspiration, ground-water inflow, and the variation in flowing and stagnant water environments. The death and decay of plants and animals and biotic uptake are also important factors in the cycling of chemicals in the park.

The water quality at selected stations within the three major drainageways in the park was analyzed to determine chemical variation and similarities among them. The selected stations and drainageways (fig. 3) were:

1. Everglades station P-34 in the Big Cypress Swamp drainageway.

2. Everglades stations P-33 and P-36 in the Shark River Slough.

3. Taylor Slough near Homestead.

The water flowing into the Shark River Slough from the north was analyzed at four selected stations; three stations were in the flow section from Levee 67A to 40-Mile Bend, and one station was in the flow section from Levee 30 to Levee 67A (fig. 3). These were canal stations, and generally the water chemistry is less affected by hydrologic and biologic change than the marsh stations in the park. The stations and the flow sections were:

Tamiami Canal Outlets Levee 30 to Levee 67A (flow section)

1. Tamiami Canal at Bridge 53 (station);

Tamiami Canal Outlets Levee 67A to 40-Mile Bend (flow section)

2. Levee 67A Canal, 0.5 mile north of Tamiami Canal (station);

3. Tamiami Canal above S-12C (station);

4. Tamiami Canal above S-12A (station).

Major Ions

The principal dissolved minerals in water are derived from the dissolution of rocks and soil minerals and from atmospheric transport. The major-dissolved ions are biologically conservative but geochemically reactive in the Everglades aquatic system. In the Everglades marsh, calcium carbonate precipitates during daylight hours when the pH increases, and hydrogen sulfide is produced when water becomes ponded and stagnant and oxygen is depleted. In freshwater environments, the major ions are nontoxic to aquatic organisms. Water with a chloride concentration of less than 500 mg/L (milligrams per liter) is considered fresh (Reid and Wood, 1976).

Since 1959, more than 250 water samples have been collected in the park during wet and dry seasons for determination of specific conductance and concentrations of dissolved ions. Rainfall, evapotranspiration, and inflow of ground water and surface water have notable effects on the concentration of ions in the shallow marsh.

The following table lists the basic statistics for the major ions and specific conductance for all freshwater stations in the park (table 1). Calcium, sodium, bicarbonate, and chloride are the dominant ions. Stations affected by saltwater, such as P-35, show anomalous concentrations when compared with the freshwater stations and are not included.

Freshwater Stations1/ (Marsh)

[Constituents in milligrams per liter, except specific conductance]

Parameter	Number of samples	Minimum	Maximum	Average	Standard deviation
Specific conductance (umhos/cm at 25°C)	264	183.0	1,550	457.0	201.0
Calcium	249	25	173	62	24
Magnesium	249	.5	20	4.7	3.3
Potassium	250	0.0	15	1.3	1.7
Sodium	250	4.4	166	26	24
Chloride	254	7.0	400	48	48
Sulfate	248	0.0	130	4.9	14.5
Bicarbonate	255	48	534	188	62

The concentrations change seasonally due primarily to evapotranspiration and geochemical reactions in the ponded water. The following table lists selected constituents and specific conductance for the wet and dry seasons for freshwater stations2/ (marsh).

1/ Everglades stations P-33, P-34, P-36, P-37, P-38, Taylor Slough near Homestead, and Taylor Slough at Royal Palm.

2/ Everglades stations P-33, P-34, P-36, P-37, P-38, Taylor Slough near Homestead, Taylor Slough at Royal Palm, and Open Slough near Cottonmouth Camp.

Table 1.--Station names, identification numbers, and period of record for water-quality data

Station name and number shown in figure 3	Identification number	Period of record
Everglades freshwater station P-33	02290815	1959 - continuing
Everglades freshwater station P-34	02290870	1959-76
Everglades station P-35 (estuarine)	02290830	1960 - continuing
Everglades freshwater station P-36	02290828	1968-76
Everglades freshwater station P-37	02290810	1960-76
Everglades freshwater station P-38	02290820	1960-74
1 Taylor Slough near Homestead (freshwater station)	02290800	1960 - continuing
2 Taylor Slough at Royal Palm (freshwater station)	02290803	1970-76
3 Taylor River (estuarine)	02290798	1969-76
4 Madeira Bay (estuarine)	02290786	1969-74
5 Cottonmouth Camp (freshwater station)	02290812	1965-74
6 Open Slough near Cottonmouth Camp (freshwater station)	02290813	1965-74
7 Alligator Hole at Taylor Slough (freshwater station)	252405080362500	1968-73

Table 1.--Station names, identification numbers, and period of record for water-quality data--Continued

Station name and number shown in figure 3	Identification number	Period of record
8 Roger's River Headwaters (estuarine)	253400080570000	1970-74
9 Ponce de Leon Bay1/ (estuarine)	02290858	1965-73
10 Tamiami Canal outlets 40-Mile Bend to Monroe (Bridge 105)1/ (freshwater station)	02288900	1959 - continuing
11 L-67 Canal1/ (freshwater station)	254550080403000	1965-74
12 Jetport Borrow Pit No. 41/ (freshwater station)	255230080522200	1970-74
13 Jetport Borrow Pit No. 51/ (freshwater station)	255230080550000	1970-74
14 Cypress Pond near Jetport Borrow Pit No. 31/ (freshwater station)	255120080540000	1970-74
15 Cypress Pond at northwest corner of Jetport1/ (freshwater station)	255820080562200	1970-74

1/ Pesticide data only.

[Constituents in milligrams per liter, except specific conductance]

Parameter and season	Number of samples	Mini- mum	Maxi- mum	Average	Standard deviation
Specific conductance (umhos/cm at 25°C)					
Wet	101	222.0	780	347.0	123
Dry	173	183	1,550	517	209
Calcium					
Wet	101	25	98	50	15.6
Dry	158	26	173	70	24.5
Magnesium					
Wet	101	.5	12	3.5	2.5
Dry	158	.7	20	5.4	3.5
Sodium					
Wet	102	4.4	58	17	13
Dry	158	4.8	166	31	27.2
Chloride					
Wet	103	7.0	140	30	24
Dry	161	9.0	400	57	56
Sulfate					
Wet	100	.0	130	3.9	14.2
Dry	158	.0	130	6.3	17.2
Bicarbonate					
Wet	101	48	442	142	40
Dry	158	96	534	220	73

For every parameter, the average dry season value was greater than the wet season value. The minimum concentrations of major ions and specific conductance, however, were nearly identical for wet and dry seasons due to unseasonable high water levels and flow during the dry season in wet years (1960, 1966, and 1969). Maximum concentrations of major ions, except for sulfate, were much higher in the dry season than the wet season, due to evapotranspiration and ground-water inflow.

The seasonal variation of major ion concentrations for the three major drainageways is shown by Stiff diagrams (Stiff, 1951) in figures 6 and 7.

The Shark River Slough drainage represented by Stiff diagrams of station P-33 for 1959-60, 1967-68, and 1973-75 are shown in figure 6. The 1959-60 period was above average in rainfall, and the ionic balance remained much the same throughout the year. During 1967-68 when rainfall was above average, the ionic balance fluctuation increased changing both the concentration and proportion of dominant dissolved ions. This fluctuation was because of the influence of the inflow of water of a different ionic composition from the Levee 67A Canal. Below-average rainfall occurred during 1973-75, and the concentrations of major ions increased from the wetter years probably due to the more noticeable effect of evapotranspiration on the smaller volume of water in temporary storage in the Everglades, but the relative ionic composition remained the same as most of the 1967-68 period.

The seasonal variation of major ions in the Big Cypress Swamp drainage is represented by station P-34. During 1959-60, the ionic composition and concentration remained fairly stable (fig. 7). Calcium and bicarbonate were dominant. The higher concentrations of sodium chloride in some samples, such as that collected on June 17, 1971, and December 19, 1972, indicate the effects of evapotranspiration.

Seasonal variation of ion concentrations in Taylor Slough for both 1961 and 1970-71 are nearly the same as those for station P-34 (fig. 7). Calcium and bicarbonate are the dominant ions. Evapotranspiration during the dry season does not appear to change the ion concentrations as greatly as in the other two drainage areas.

At the northern inflow points to the park, average concentrations of major ions and dissolved solids are similar to those in the park. The following table lists the basic statistics for these ions and related parameters from 1959-77. Five stations are used to compute these statistics: S-12A, S-12B, S-12C, L-67A, and Bridge 53 (fig. 3).

Inflow Stations (Canals)

[Constituents in milligrams per liter, except specific conductance]

Parameter	Number of samples	Minimum	Maximum	Average
Specific conductance (umhos/cm at 25°C)	221	130.0	1,060.0	465.0
Calcium	126	16	133	61
Magnesium	122	.5	19	5.1
Sodium	126	3.2	94	21
Potassium	126	.1	5.6	1.2
Chloride	134	6.0	140	35
Sulfate	134	.0	66	8.6
Dissolved solids	111	96	525	253

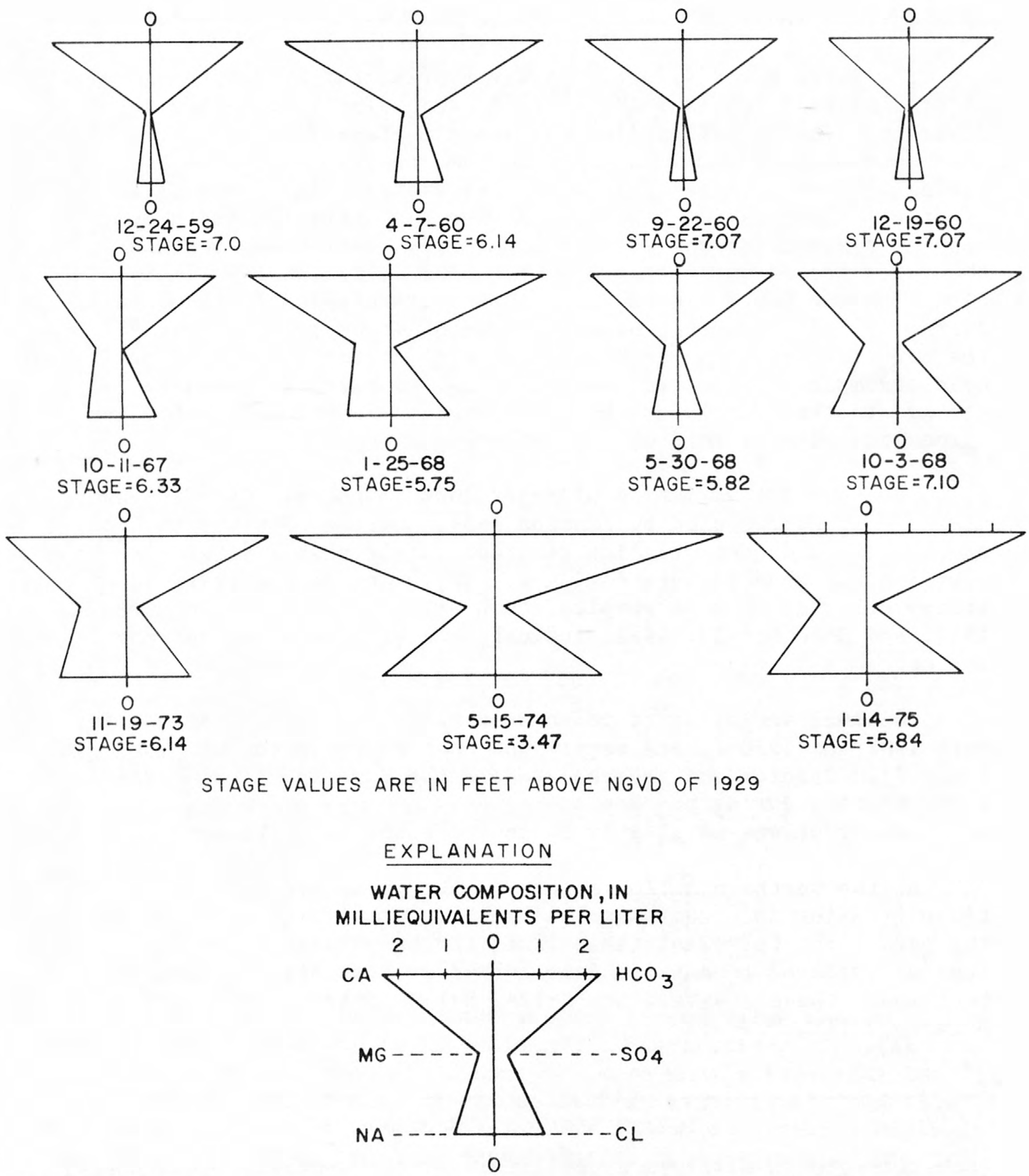


Figure 6.--Seasonal variation in major-ion composition at station P-33 (Shark River Slough).

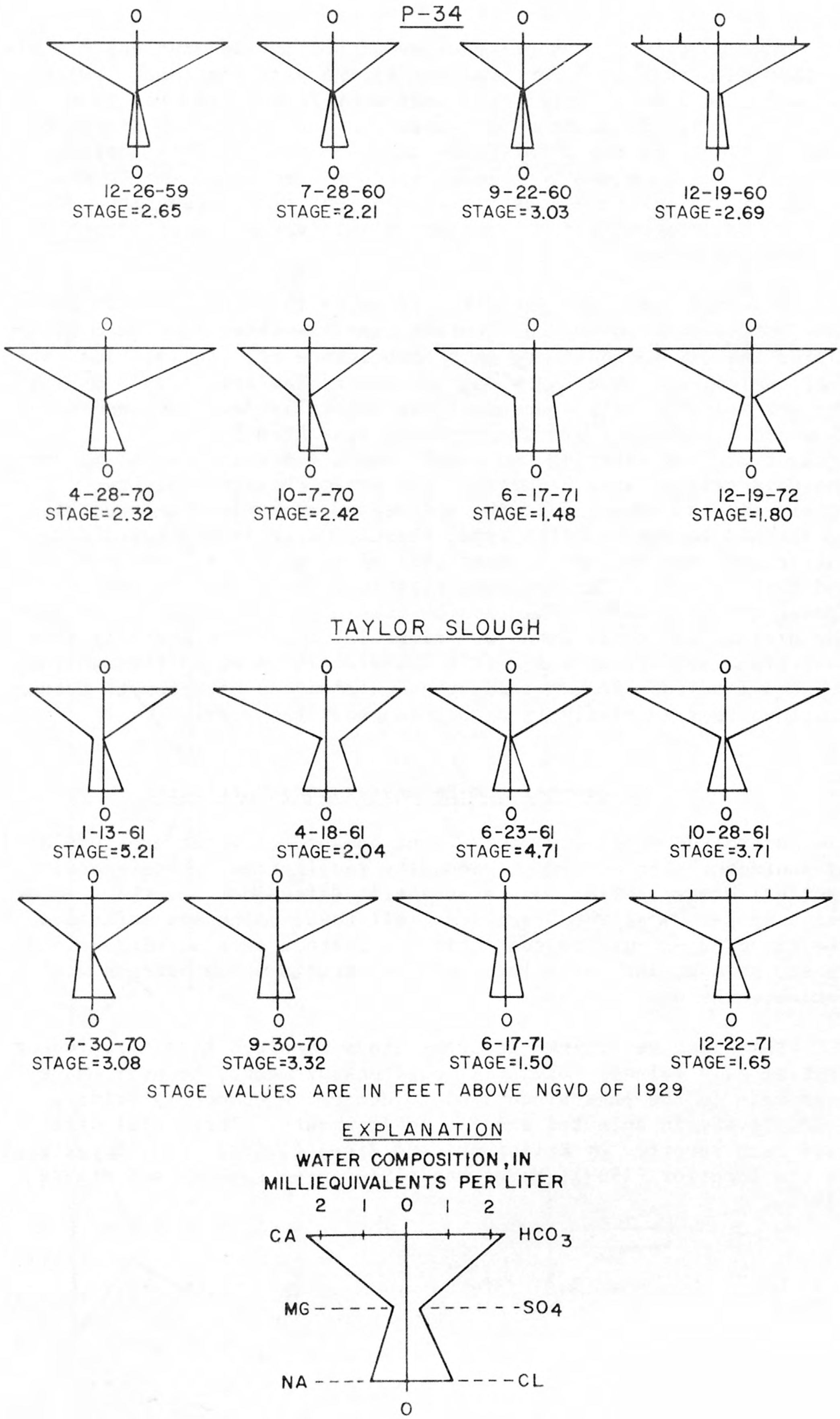


Figure 7.--Seasonal variation in major-ion composition at station P-34 (Big Cypress Swamp) and Taylor Slough.

The range in ion concentrations at the inflow stations (canals) is less than the range for stations in the park (marshes). Water in canals is less affected by evapotranspiration than water in marshes; thus, the maximum concentrations and ranges of dissolved ions are lower in the canals than in the marshes. This lessened effect is due to a small ratio of surface area to volume in the canals and a lack of a substantial emergent plant community. The minimum ion concentrations are approximately the same for both the marshes and canals.

Seasonal and areal variation in major ion concentration at four inflow stations on the Tamiami Canal is shown in figure 8. During the dry season there is a codominance of calcium, bicarbonate, sodium, and chloride along the entire Tamiami Canal. During the wet season, ionic concentrations generally decrease, and calcium and bicarbonate are the dominant ions from S-12A to S-12C because of flow entering the canal from the Big Cypress Swamp and the Conservation Area 3A marsh. The ionic character of Levee 67A Canal remains unchanged in the wet season as a mixed calcium bicarbonate and sodium chloride type, because water is channeled down this canal from the north where this mixed water is common (Waller and Earle, 1975). The ion concentrations in Levee 67A Canal decrease slightly due to dilution by rainfall and overland flow from the marsh. The canal water at Bridge 53 is derived entirely from subsurface seepage of water from Conservation Area 3B through the crushed limestone in Levee 29, thus calcium and bicarbonate concentrations remain relatively high throughout the year.

Oxygen-Related Parameters and Nutrients

Dissolved-oxygen concentrations in surface water are regulated by photosynthetic activity, community respiration, temperature, chemical decomposition, and atmospheric diffusion. In the shallow marsh ecosystem of the Everglades, all these processes influence the dissolved-oxygen concentrations. Factors such as wind, cloud cover, season, and water level will determine which process will dominate the oxygen cycle.

The dissolved-oxygen concentrations reported herein represent daytime only values. Diel (24 hour) measurements, however, have been made in the park since 1966 to determine community primary productivity in selected aquatic environments. These diel data have been reported by Kolipinski and Higer (1969a), U.S. Department of the Interior (1969), McPherson (1970), and Kushlan and others (1975).

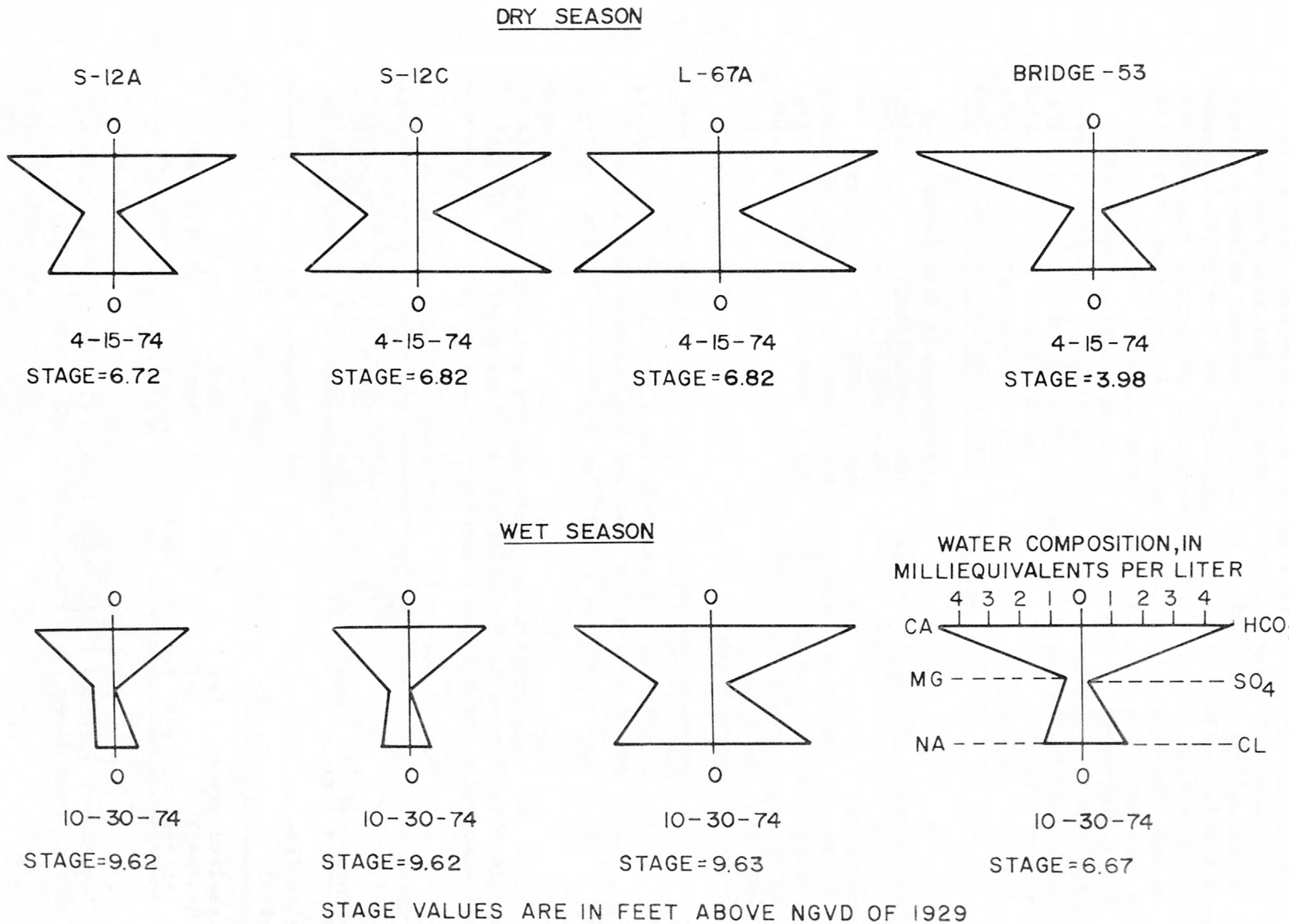


Figure 8.--Seasonal and areal variation of major-ion composition at four stations on the Tamiami Canal.

Oxygen-related parameters measured for the period of record are color and turbidity which affect light penetration for photosynthetic activity, BOD (biochemical oxygen demand) and temperature, which regulates dissolved-oxygen concentrations in that the oxygen-carrying capacity is inversely proportional to the temperature. Color and temperature have been measured routinely since 1959; dissolved oxygen and turbidity have been measured since the late 1960's. Biochemical oxygen demand determinations are few (20). The following is a summary of these oxygen-related parameters for all stations, freshwater and estuarine, that are sampled within the park boundaries:

Parameter	Number of samples	Minimum	Maximum	Average	Standard deviation
Temperature (°C)	373	9.8	38.8	25.0	5.9
Color (Pt-Co units)	374	1.0	200	31	26
Turbidity (Jackson Turbidity Units [JTU])	121	.0	180	11	22
Dissolved oxygen	123	.7	14.2	6.0	2.4
Biochemical oxygen demand	20	.0	8.9	2.3	2.2

One sample taken at station P-36 (an alligator hole) on May 14, 1974, at the end of a very dry year had the maximum values for turbidity (180 JTU), color 200 (Pt-Co), and dissolved oxygen (14.2 mg/L).

The following comparison of wet and dry season data for color and dissolved oxygen is for selected long-term stations1/ in the park that had a sufficient data base.

Parameter	Season	Number of samples	Minimum	Maximum	Average	Standard deviation
Color (Pt-Co units)	Dry	159	2.0	200.0	26.0	24.0
	Wet	102	5.0	100	22	20
Dissolved oxygen	Dry	45	.7	14.2	6.5	2.7
	Wet	11	3.9	10.2	6.3	2.1

1/ Everglades stations P-33, P-34, P-35, P-36, P-37, P-38, Taylor Slough near Homestead, and Taylor Slough at Royal Palm.

During the dry season, color and turbidity generally increase due to evaporation and concentration of metabolic byproducts and organic acids in the marshes. Dissolved oxygen shows a greater range and higher variability during the dry season due to periodic phytoplankton blooms and increases in oxidizable organic material (Kolipinski and Higer, 1969b).

The water in the Everglades basin (fig. 1) typically has high content of organic material as compared to other natural drainage basins, as indicated by total phosphorus, organic nitrogen, and TOC (total organic carbon). This organic material consists of phytoplankton, zooplankton, detritus (tripton), and dissolved organics such as lignins, tanins, and humic acids.

Chemical analysis of organic material in the park began in 1966, and most sampling was after 1969. The average concentration of organic material in the park is typical of the surface waters in the Everglades basin (Waller and Earle, 1975). Organic nitrogen generally exceeded 1.5 mg/L, TOC generally exceeded 20 mg/L, and total phosphorus was usually less than 0.5 mg/L. The following table summarizes the data for organic material in the park.

[Chemical constituents in milligrams per liter]

Constituent	Number of samples	Minimum	Maximum	Average	Standard deviation
Organic nitrogen	125	0.0	32.0	2.2	3.5
Total organic carbon	81	.0	231	24	31
Total phosphorus	79	.0	2.7	.08	.32

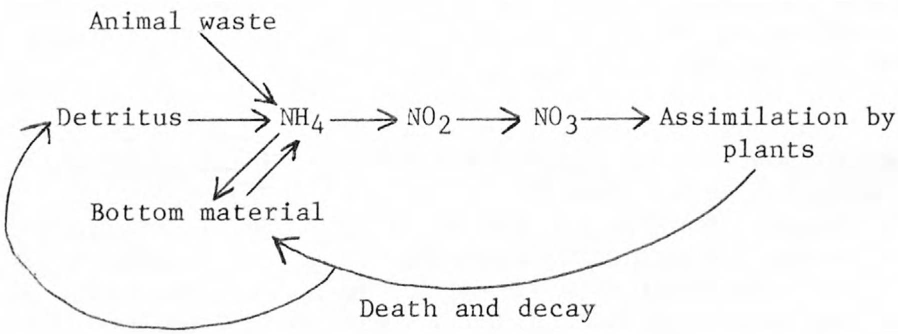
The large range in concentration is caused by ponding and subsequent drying. The combination of animal activities, plant secretions, death and decay of biota, and ponding greatly increases the concentration of organic material. A comparison of wet and dry season concentrations for selected long-term stations follows:

[Chemical constituents in milligrams per liter]

Constituent and season	Number of samples	Minimum	Maximum	Average	Standard deviation
Organic nitrogen					
Wet	19	0.16	6.5	1.7	1.8
Dry	48	.18	32	2.6	4.8
Total organic carbon					
Wet	3	3.0	21	19	9.6
Dry	29	.0	231	24	43
Total phosphorus					
Wet	4	.01	.02	.015	.007
Dry	33	.00	.80	.060	.140

The maximum concentrations of TOC (231 mg/L) and organic nitrogen (32 mg/L) were detected on May 14, 1974, at station P-36 during a plankton bloom at the end of the dry season.

The major inorganic nutrients in the park are the nitrogen species, ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), and orthophosphate (PO_4). The nitrogen species change from one form to another depending upon dissolved-oxygen concentration and biological action. A simplified, schematic diagram of the reactions is:



The orthophosphate ion is readily assimilated by plants; it forms chemical complexes with calcium (forming the mineral apatite) and coprecipitates with iron and manganese hydroxides. Because the south Florida environment has an abundance of aquatic plants, calcium and iron concentrations of orthophosphate are generally very low (0.0 to 0.03 mg/L).

Inorganic nutrients have been sampled in the park since 1970. The following table is a summary of inorganic nutrient data for all stations within the park:

[Chemical constituents in milligrams per liter]

Constituent	Number of samples	Minimum	Maximum	Average	Standard deviation
Nitrate	104	0.00	1.50	0.07	0.20
Nitrite	104	.00	.09	.01	.018
Ammonium	105	.00	7.4	.43	1.1
Orthophosphate	88	.00	1.2	.03	.14

Ammonium is the dominant inorganic nutrient and shows the highest variability and greatest range. The other three nutrients (NO_3 NO_2, and PO_4) are at relatively low average concentrations, typical of a productive marsh (Waller and Earle, 1975). Inorganic nutrients generally increase during the dry season due to evapotranspiration, increased respiratory metabolism in a smaller volume of water, and increased anaerobic conditions, particularly at the water-sediment interface. Aquatic respiratory metabolism increases during the dry season because organisms are concentrated in a small volume of water and because decay and respiratory demands often become dominant over photosynthetic activity. Greater metabolic activity tends to increase anaerobic conditions, which in turn facilitates the release of ammonium and orthophosphate from the bottom material.

Concentrations or levels of oxygen-related parameters, organic materials, and inorganic nutrients at the major inflow points to the park generally are lower and have smaller ranges than stations within the park. Some nitrogen and phosphorus compounds vary seasonally at these inflow points (Waller and Earle, 1975), due primarily to the influx of water from Conservation Areas 1 and 2 to Conservation Area 3. The following table lists the concentrations or levels of oxygen-related parameters, organic material, and inorganic nutrients for five inflow stations: S-12A, S-12B, S-12C, Levee 67A, and Bridge 53 (fig. 3).

[Constituents in milligrams per liter, except color and turbidity]

Parameter	Number of samples	Minimum	Maximum	Average
Color (Pt-Co units)	137	10.0	150.0	47.0
Turbidity (Jackson Turbidity Units [JTU])	138	1.0	34	6.1
Dissolved oxygen	149	.6	12.5	5.2
Biochemical oxygen demand	51	.1	4.5	1.6
Organic nitrogen	154	.0	7.9	1.5
Total organic carbon	138	.0	70	24
Total phosphorus	136	.0	1.0	.03
Nitrate	149	.0	1.8	.10
Nitrite	149	.0	.16	.01
Ammonium	153	.0	1.1	.23
Orthophosphate	146	.0	.11	.01

The average values for the above parameters are lower than those reported for stations within the park except for color and nitrate. Color on the average is 50 percent higher at the inflow stations (47 versus 31 Pt-Co units). These higher color values are caused by thick peat and muck soils in the central Everglades and Shark River Slough where the inflow stations are located. The park station averages include samples from Taylor Slough and Big Cypress Swamp, where the color is typically lower due to the thinner, less organic, marl soil cover. Average nitrate is slightly higher (0.10 versus 0.07 mg/L) in the canals than in the park.

Trace Elements

Trace elements have been analyzed in the surface waters of Everglades National Park since 1959. Before 1965, the analyses were mainly for iron, but after 1965 analyses included aluminum, arsenic, chromium, copper, lead, manganese, mercury, nickel, and zinc.

Most trace elements are toxic to organisms if the elements are in high concentrations. Because of possible toxicity to organisms, criteria have been estabished by the U.S. Environmental Protection Agency (1977) for maximum allowable concentrations in surface waters (table 2). The specific toxicity levels for many aquatic organisms have not yet been determined for many of the trace elements.

The physical and chemical reactions of trace elements in aqueous media are complex. Their solubility is controlled by temperature, pH, hardness, chemical reactions, absorption and adsorption by organic material, and assimilation by plants and animals. In some cases, trace elements accumulate to high concentrations in organisms, a process termed "biomagnification." Waller and Earle (1975) determined that concentrations of cobalt, copper, iron, lead, and manganese were one to two orders of magnitude higher in bottom material and plants than in surface water in the Everglades basin.

Trace elements are derived from the dissolution of lithologic material and by man's activities. Lead, cadmium, and chromium are common traffic-generated elements. Agricultural activities contribute such trace elements as zinc, copper, mercury, manganese, and arsenic by spraying, dusting, and fertilizing.

Average concentrations of most trace elements (table 3) are below estabished criteria levels (U.S. Environmental Protection Agency, 1977). Average concentrations of iron, manganese, and zinc approach or exceed established criteria, and aluminum concentrations exceed 1,000 ug/L (micrograms per liter) in some samples. The concentrations of these four metals are low during high water, but increase greatly during the dry season. The major ions and specific conductance may increase two to three times during the dry season, whereas the concentrations of these four metals commonly increase tenfold. The chemical-biological phenomenon, which causes this increase, involves oxidation-reduction potentials, ionic complexes, and microbial metabolic processes.

Average concentrations of most trace elements at the inflow points (canal stations) to the park (table 4) are generally lower than those within the park (table 3), because chemical and biological processes in the canals are more stable throughout the year than those in the marsh. Smaller fluctuations in dissolved oxygen and pH within the canals provide an environment where the metals can be maintained at lower concentrations, fluctuate less in concentration, and exhibit less seasonal variation. Average concentrations of arsenic, chromium, copper, and zinc were higher at the canal inflow points.

Table 2.--U.S. Environmental Protection Agency (1977) criteria for total recoverable trace elements in water

[Chemical constituents in micrograms per liter]

Trace element	Criteria	Purpose
Arsenic	50.0	Domestic supply 1/
Cadmium	12	Aquatic life
Chromium	100	Aquatic life
Copper	1,000	Domestic supply 1/
Iron	1,000	Aquatic life
Lead	50	Domestic supply 1/
Manganese	100	Aquatic life
Mercury	.05	Aquatic life
Nickel	Not established	(1)
Zinc	5,000	Domestic supply 1/

1/ Aquatic life tolerance dependent on 96-hour LC_{50} bioassay of sensitive local species.

Table 3.--Average and maximum concentrations of trace elements in surface water at stations 1/ in Everglades National Park, 1959-77

[Chemical constituents in micrograms per liter]

Trace element	Number of samples	Maximum 2/	Average	Standard deviation
Aluminum (total)	126	4,700	215	504
Arsenic (total)	70	20	4.2	4.3
Arsenic (dissolved)	126	130	7.3	16
Cadmium (total)	71	35	1.5	4.8
Chromium (total)	96	20	2.0	5.2
Copper (total)	28	14	2.7	4.0
Copper (dissolved)	160	50	4.3	8.0
Cobalt (total)	51	10	.9	2.0
Iron (total)	108	9,500	723	1,313
Iron (dissolved)	286	1,300	88	178
Manganese (total)	110	260	28	45
Manganese (dissolved)	128	250	17	28
Mercury (total)	80	6.7	.4	.9
Nickel (total)	49	41	5.8	10
Lead (total)	63	190	16	32
Lead (dissolved)	166	60	5.7	8.6
Zinc (total)	38	100	27	22
Zinc (dissolved)	163	650	31	65

1/ Stations listed in table 1.

2/ Analyses were not always made for both dissolved and total concentrations in water but were made for dissolved, thus, the maximum dissolved concentration can exceed the maximum total concentration of a constituent as an analysis for total concentration was not made.

Table 4.--Average and maximum concentrations of trace elements in surface water at points of inflow 1/ to Everglades National Park

[Chemical constituents in micrograms per liter]

Trace element	Number of samples	Maximum 2/	Average
Aluminum (total)	8	100	36.0
Arsenic (total)	41	40	8.7
Cadmium (total)	42	10	1.1
Chromium (total)	34	40	3.0
Copper (total)	36	130	6.1
Copper (dissolved)	35	20	4.1
Cobalt (total)	40	5	.6
Iron (total)	49	950	251
Iron (dissolved)	121	340	53
Lead (total)	44	30	5.4
Manganese (total)	46	30	12
Mercury (total)	36	1	.08
Zinc (total)	34	250	28
Zinc (dissolved)	40	230	24

1/ S-12A, S-12B, S-12C, S-12D, Levee 67A, and Bridge 53.

2/ Analyses were not always made for both dissolved and total concentrations in water but were made for dissolved, thus, the maximum dissolved concentration can exceed the maximum total concentration of a constituent as an analysis for total concentration was not made.

Pesticides

In south Florida, insecticides and fungicides are used extensively for agriculture and horticulture, and herbicides are used for vegetation control along roads and in canals. Agricultural development adjacent to the Everglades National Park boundary is confined mainly to the southeast boundary near the Taylor Slough drainageway (fig. 2).

Pesticide concentrations in surface water and bottom material in Everglades National Park have been monitored since 1966. Chlorinated-hydrocarbon insecticides were analyzed initially. Kolipinski and Higer (1969b) investigated the biomagnification of the DDT family in the park ecosystem. Phosphorthionate insecticides and herbicides were sampled as the pesticide monitoring program expanded. Polychlorinated biphenyls (PCB), which are industrial compounds were also analyzed at selected stations since 1968.

The chlorinated hydrocarbon insecticides pose the greatest threat to the integrity of the park ecosystem, because they accumulate in the environment (Kolipinski and Higer, 1969b). These insecticides include aldrin, dieldrin, endrin, toxaphene, chlordane, heptachlor, heptachlor epoxide, lindane, and the DDT family. Aquatic organisms concentrate these insecticides by ingesting contaminated material or by absorption from the water.

Organophosphate insecticides and the herbicides (silvex, 2,4-D, and 2,4,5-T) are soluble in water, do not readily accumulate in the environment, and do not appear to be a threat to the ecosystem except during direct application.

Pesticide analyses in water collected at stations (table 5) in and adjacent to Everglades National Park are listed in table 6. Analyses were made for PCB and 21 pesticides. Only half of the pesticides analyzed were detected. Of the samples collected, pesticides were detected in only 2 percent. Dieldrin, diazinon, the DDT family, 2-4D, and silvex, were most frequently detected. The average concentrations of the pesticides detected were extremely low (trace to 0.017 ug/L) (table 6), and the median concentrations of all pesticides were 0.00 ug/L.

DDD, DDE, DDT, dieldrin, diazinon, and 2,4-D were the only pesticides detected in surface water within the park. The following is a summary of those samples.

Pesticide	Number of samples	Number of detections	Maximum concentration (ug/L)
DDD	53	2	0.01
DDE	54	6	.01
DDT	55	9	.02
Dieldrin	51	1	.01
Diazinon	34	1	.01
2,4-D	51	5	.05

Table 5.--Stations within and adjacent to Everglades National Park where surface water was analyzed for pesticides, 1965-77

Station name and number shown in figure 3	Identification number
Everglades Station, P-33	02290815
Everglades Station, P-34	02290870
Everglades Station, P-35	02290830
Everglades Station, P-36	02290828
Everglades Station, P-37	02290810
Everglades Station, P-38	02290820
Cottonmouth Camp, 5	02290812
Open Slough near Cottonmouth Camp, 6	02290813
Taylor Slough near Homestead, 1	02290800
Taylor River, 3	02290798
Tamiami Canal Outlets, 40-Mile Bend to Monroe (Bridge 105), 10	02288900
Ponce de Leon Bay, 9	02290858
Madiera Bay, 4	02290786
L-67 Canal above S-12E, 11	254550080403000
Alligator Hole at Taylor Slough, 7	252405080362500
Jetport Borrow Pit No. 4, 12	255230080522200
Jetport Borrow Pit No. 5, 13	255230080550000
Cypress Pond near Jetport Borrow Pit No. 3, 14	255120080540000
Cypress Pond at northwest corner of Jetport, 15	255820080562200
Roger's River Headwaters, 8	253400080570000

Table 6.--Concentrations of pesticides in surface water at stations[1/] within and adjacent to Everglades National Park

[Chemical constituents in micrograms per liter]

Pesticide	Number of samples	Minimum	Maximum	Average
	Chlorinated-hydrocarbon insecticides			
Aldrin	96	0.00	(2)	(2)
Chlordane	64	.00	0.00	0.000
DDD	96	.00	.50	.006
DDE	97	.00	2.3	.017
DDT	98	.00	.07	.003
Dieldrin	96	.00	.05	.001
Endrin	97	.00	(2)	(2)
Heptachlor	96	.00	(2)	(2)
Heptachlor epoxide	65	.00	.00	.000
Lindane	96	.00	(2)	(2)
Toxaphene	50	.00	.00	.000
	Polychlorinated biphenyls			
PCB	58	.00	.00	.000
	Organophosphate insecticides			
Diazinon	66	.00	.01	.000
Ethion	60	.00	.00	.000
Malathion	67	.00	.00	.000
Methyl parathion	67	.00	.00	.000
Methyl trithion	58	.00	.00	.000
Parathion	67	.00	.00	.000
Trithion	58	.00	.00	.000
	Herbicides			
2,4-D	89	.00	.13	.004
2,4,5-T	89	.00	.00	.000
Silvex	89	.00	.26	.003
Total	= 1,719			

1/ Stations listed in table 5.

2/ Trace concentrations are less than 0.005 ug/L for individual samples, and less than 0.001 ug/L for average values.

Of more than 1,700 analyses, only 24 detections were noted or less than 2 percent of the total. Most insecticides were from the DDT family, which are no longer legal to use. The maximum values are low when compared with values in agricultural and urban areas in south Florida (Waller and others, 1975).

Analyses of pesticide residues in bottom material within and adjacent to Everglades National Park have been made since 1969. The initial analyses were for chlorinated-hydrocarbon insecticide residues, but by 1971 organophosphate insecticide and herbicide residue determinations were included in most analyses.

The chlorinated hydrocarbons are persistent and are bound to the organic fraction of the sediments by ionic attraction, covalent bonding, adsorption, and entrapment. The possibility of these compounds reentering the water column is relatively small because they are physically and chemically bound to the bottom material. They also can be assimilated into living plant cells, and thus, be incorporated within the cells. Physical and chemical binding into the sediments and residual accumulation in detrital plant cells in the sediment makes the bottom material a "sink" for chlorinated hydrocarbon insecticide residues.

Organophosphate insecticides were not detected in any sample, and the herbicide silvex was detected in only one sample from the bottom material in the Levee 67A Canal, probably the result of direct application of silvex to control the aquatic weeds. In sharp contrast to the single occurrence of organophosphate residues, is the relatively high number of detections (nearly 80 percent) of the chlorinated-hydrocarbon residues.

DDD, DDE, DDT (DDT family), chlordane, and dieldrin were the only insecticides detected in the bottom material of the park (table 7). The DDT family was detected in 78 percent of all samples, dieldrin in 27 percent, and chlordane in 16 percent. This pattern of detection in bottom material is similar to that noted by Waller and Earle (1975) for the Everglades basin where the DDT family was detected in 96 percent of all samples, dieldrin in 60 percent, and chlordane in 21 percent.

The average concentrations of chlorinated hydrocarbons in bottom material (table 7) are nearly identical to those determined by Waller and Earle (1975) at four stations on the Tamiami Canal. For stations within the park, average concentrations of dieldrin and chlordane were 0.2 and 1.8 ug/kg (micrograms per kilogram), and average concentrations of DDD, DDE, and DDT were 3.5, 4.2, and 0.9 ug/kg, respectively (table 7).

Table 7.--Concentrations of pesticides and polychlorinated biphenyl residues in bottom material in Everglades National Park

[Chemical constituents in micrograms per kilogram]

Pesticide	Number of samples	Average	Maximum	Percent detection
	Chlorinated-hydrocarbon insecticides			
DDT Family				78
DDD	120	3.5	90.0	
DDE	119	4.2	41	
DDT	117	.9	35	
Dieldrin	113	.2	9.3	27
Chlordane	105	1.8	40	16
	Herbicide			
Silvex	78	--	160	1
	Polychlorinated biphenyls			
PCB	95	108	8,500	13
	Overall percent of all detections			= 80

At every station in the park, chlorinated-hydrocarbon insecticide residues were detected in bottom material, with the exception of Madeira Bay (station number 4 in figure 3). The distribution of these insecticide residues is widespread, and no trends are apparent (fig. 9). Residues of the DDT family and dieldrin were detected at every freshwater station, while chlordane was detected at only half the stations.

Polychlorinated biphenyls were detected in 13 percent of all bottom material sampling stations within and adjacent to the park (table 7). The most probable source of PCB is from industrial products and volatilized plastics from agricultural burning. The major transport mechanism of chlorinated-hydrocarbon insecticides and PCB is probably through the atmosphere.

The average concentration of PCB (108 ug/kg) in bottom material is skewed by three high concentrations of 8,500, 580, and 300 ug/kg while the median concentration is 0.0 ug/kg. These high concentrations are probably localized.

One of the most serious threats to the Everglades National Park ecosystem is the biomagnification of the chlorinated-hydrocarbon insecticides and PCB. The chlorinated hydrocarbons found in bottom material have the potential of entering the food chain through organisms in the detrital trophic level, which in turn, are ingested by consumers. Biomagnification of these compounds through the food chain is known to cause metabolic dysfunction in some organisms, and thus, could potentially threaten the park ecosystem (Brown, 1978).

CHEMICAL CHARACTERISTICS OF THREE MAJOR DRAINAGEWAYS

The water-quality characteristics of the three major drainageways in Everglades National Park--Big Cypress Swamp, Shark River Slough, and Taylor Slough--are compared to determine physical or chemical variations. Each drainageway is represented by a long-term station as follows:

Station	Period of record
Everglades Station P-34 (Big Cypress Swamp)	1959-76
Everglades Station P-33 (Shark River Slough)	1959-77
Taylor Slough near Homestead (Taylor Slough), (number 1 in figure 3)	1960-77

A statistical analysis of data on nutrients, oxygen-related parameters, major ions, and trace elements indicates the effects of: (1) water quality upstream of each drainageway; (2) soil type and vegetative communities; (3) water management; and (4) variation in chemical reactions within the three areas.

The average concentrations for the oxygen-related parameters varied little between drainageways as shown in the following summary:

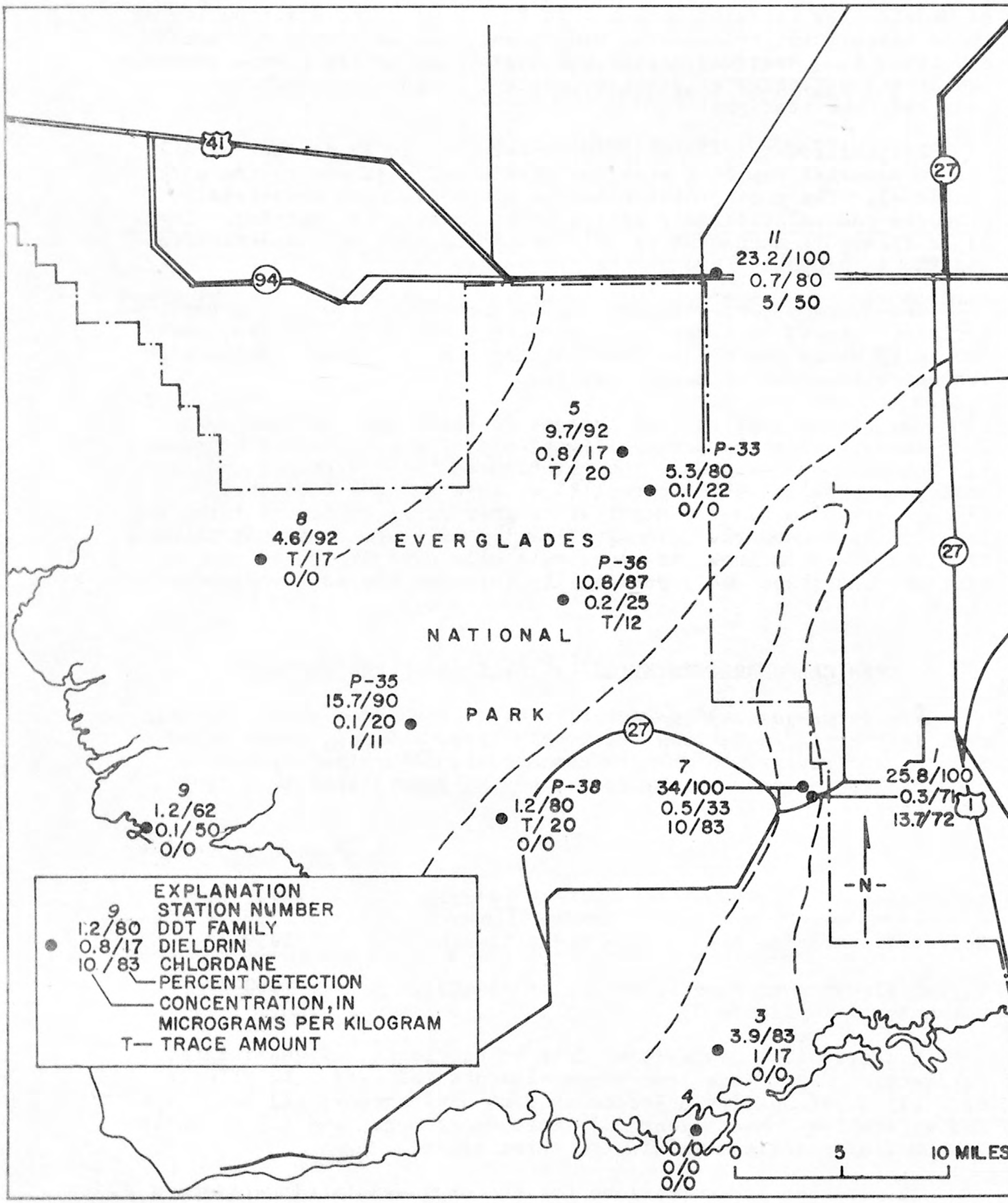


Figure 9.--Average concentrations of the DDT family of pesticides, dieldrin, and chlordane in bottom material at stations within Everglades National Park.

[Oxygen-related parameters in milligrams per liter, except turbidity and color]						
Parameter	Station	Number of samples	Mini- mum	Maxi- mum	Average	Standard deviation
Dissolved oxygen	P-34	10	5.2	9.9	7.4	1.7
	P-33	16	.7	8.6	6.0	2.4
	Taylor Slough	13	2.7	10.2	5.2	2.3
Turbidity (Jackson Turbidity Units [JTU])	P-34	11	1.0	44	10	12
	P-33	16	2.0	40	12	10
	Taylor Slough	10	1.0	40	10	14
Color (Pt-Co units)	P-34	46	5.0	45	20	11
	P-33	52	10	120	44	25
	Taylor Slough	56	1.0	55	18	14

The average value for color in the Shark River Slough (P-33) is more than twice that in the other two drainageways and is caused by leaching of peat and the influence of highly colored water from the Levee 67A canal.

Macronutrient concentrations in the three drainageways are summarized in the following table:

[Chemical constituents in milligrams per liter]						
Constituent	Station	Number of samples	Mini- mum	Maxi- mum	Average	Standard deviation
Ammonium	P-34	8	0.06	0.46	0.21	0.17
	P-33	15	.02	1.9	.38	.59
	Taylor Slough	11	.00	.68	.15	.19
Nitrite	P-34	8	.00	.07	.01	.02
	P-33	15	.00	.04	.01	.01
	Taylor Slough	11	.00	.09	.02	.03
Nitrate	P-34	8	.00	.76	.13	.26
	P-33	15	.00	.03	.01	.01
	Taylor Slough	11	.00	.60	.13	.19
Organic nitrogen	P-34	10	.30	2.1	1.0	.64
	P-33	18	.74	11	2.7	2.8
	Taylor Slough	11	.17	3.0	.90	.96
Ortho-phosphate	P-34	7	.00	.08	.02	.03
	P-33	13	.00	.10	.02	.03
	Taylor Slough	9	.00	.05	.01	.02
Total phosphorus	P-34	5	.02	.11	.03	.05
	P-33	12	.00	.22	.03	.06
	Taylor Slough	7	.00	.08	.02	.03
Total organic carbon	P-34	6	1.0	20	11	7.6
	P-33	12	3.0	73	28	23
	Taylor Slough	8	.0	15	7.6	4.9
Total inorganic carbon	P-34	6	34	79	53	17
	P-33	11	10	63	45	15
	Taylor Slough	8	26	52	37	9.7

Ammonium is the dominant inorganic nitrogen specie followed by nitrate, especially at station P-34 and Taylor Slough. Nitrite is absent or in very low (less than 0.09 mg/L) concentrations. The following table is a summary of average nitrogen species composition:

[Nitrogen species in milligrams per liter]

Constituent	P-34	P-33	Taylor Slough
Ammonium	0.21	0.38	0.15
Nitrite	.01	.01	.02
Nitrate	.13	.01	.13
Inorganic nitrogen	.35	.40	.30
Organic nitrogen	1.0	2.7	.90
Total nitrogen	1.35	3.10	1.20

Organic nitrogen is nearly three times higher in average concentration at station P-33 than at station P-34 or Taylor Slough. Organic nitrogen comprises 87 percent of the total nitrogen at station P-33, 75 percent at Taylor Slough, and 74 percent at station P-34.

Average inorganic nitrogen concentrations were nearly equal in all three drainageways. Concentrations ranged from 0.30 mg/L at Taylor Slough to 0.40 mg/L at P-33.

Average total phosphorus and orthophosphate concentrations are low (0.01 to 0.03 mg/L) because the extensive vegetative communities and the organic detritus readily assimilate the orthophosphate, and the exposed limestone chemically binds the phosphorus.

Average total organic carbon concentrations are much higher in the Shark River Slough (28 mg/L) than in the Big Cypress Swamp (11 mg/L) or Taylor Slough (7.6 mg/L). Average concentrations of inorganic carbon (primarily carbonate) are fairly uniform ranging from 37 mg/L at Taylor Slough to 53 mg/L at station P-34. Water near exposed limestone (such as station P-34) tends to have higher concentrations of inorganic carbon than where soil covers the limestone.

The dominant major ions are calcium and bicarbonate (table 8). The water at station P-34 had the highest average concentrations of calcium and bicarbonate, and hardness. In addition to the dominance of calcium and bicarbonate, the water at station P-33 has a codominance of sodium and chloride and higher average concentrations of magnesium; thus, specific conductance measurements and dissolved solids concentrations are higher at station P-33. Average concentrations of potassium and sulfate do not appear to vary.

Table 8.--Concentrations of major ions, dissolved solids, and hardness in surface water and levels of pH and specific conductance at stations P-33, P-34, and Taylor Slough, 1959-77

[Chemical constituents in milligrams per liter, except pH and specific conductance]

Constituent and station	Number of samples	Minimum	Maximum	Average	Standard deviation
Calcium					
P-34	45	35.0	173	68.0	27.0
P-33	52	36	140	58	20
Taylor Slough	56	25	110	59	17
Magnesium					
P-34	45	.6	20	3.1	3.2
P-33	52	.5	16	6.7	4.0
Taylor Slough	55	.5	15	3.0	2.1
Sodium					
P-34	45	4.6	70	13	11
P-33	52	5.1	98	27	20
Taylor Slough	56	4.4	26	10	4.5
Potassium					
P-34	45	.0	4.2	.72	.74
P-33	52	.0	6.4	1.6	1.5
Taylor Slough	56	.2	15	1.6	3.0
Chloride					
P-34	46	7.5	135	23	20
P-33	52	8.0	140	43	30
Taylor Slough	58	4.5	54	16	8.7
Sulfate					
P-34	46	.0	37	3.4	6.8
P-33	50	.0	77	3.9	11
Taylor Slough	56	.0	62	4.4	10
Bicarbonate					
P-34	49	112	534	215	87
P-33	54	96	394	191	54
Taylor Slough	58	106	310	185	44
Dissolved solids					
P-34	38	130	514	234	89
P-33	45	134	587	298	116
Taylor Slough	51	114	420	209	67

Table 8.--Concentrations of major ions, dissolved solids, and hardness in surface water and levels of pH and specific conductance at stations P-33, P-34, and Taylor Slough, 1959-77--Continued

[Chemical constituents in milligrams per liter, except pH and specific conductance]

Constituent and station	Number of samples	Minimum	Maximum	Average	Standard deviation
Hardness					
P-34	45	94.0	444	183	68.0
P-33	52	98	390	173	54
Taylor Slough	56	23	296	159	46
Noncarbonate hardness					
P-34	45	0	75	13	16
P-33	52	0	146	18	31
Taylor Slough	56	0	76	9.6	17
pH					
P-34	50	7.0	8.5	1/7.7	.3
P-33	54	7.0	8.5	1/7.7	.4
Taylor Slough	58	7.0	8.5	1/7.7	.3
Specific conductance (umhos/cm at 25°C)					
P-34	50	215	891	407	152
P-33	55	218	1,160	458	184
Taylor Slough	59	160	660	352	99

1/ Median.

Concentrations of aluminum, iron, and manganese are higher in the Shark River Slough (table 9). Iron concentrations average three times higher at station P-33 than at station P-34 or Taylor Slough. Average lead concentrations are slightly higher at Taylor Slough, probably due to the proximity of a highway. Highest average mercury concentrations are at station P-34.

In general summary, the Shark River Slough (P-33) has the highest levels or concentrations of color, organic material, sodium, chloride, magnesium, dissolved solids, specific conductance, aluminum, iron, and manganese. The Big Cypress (P-34) had the highest average concentrations of calcium, bicarbonate, hardness, and inorganic carbon. Only the average concentration of lead was higher at Taylor Slough (1). Average turbidity, dissolved oxygen, inorganic nitrogen, total phosphorus, orthophosphate, pH, potassium, and sulfate are approximately the same in the three drainageways.

LONG-TERM TRENDS IN WATER QUALITY

Since water-quality monitoring began in 1959, several water-management structures and practices have been operational that directly affect the water levels, flow patterns, and discharge within the park. These major water-management structures, all completed in 1963, are Levee 29, Levee 67 and Levee 67A complex, and the S-12 structures. These structures facilitated a more rapid and controlled discharge of water into the park. The chief hydrologic effects were the lowering of the water levels and shortening of the inundation in the Shark River Slough between Levee 30 and Levee 67A, and the raising of the water levels and lengthened inundation in the part of Shark River Slough west of Levee 67 extended (Leach and others, 1972). In contrast, a more subtle change in the chemistry of the surface water in the park began in 1963-64. Changes in concentrations of major ions, dissolved solids, and color are attributed to the changing quality of inflow water at the S-12 structures and redistribution of the flow patterns since 1963. These constituents constitute the longest term, most intensively sampled parameters in the park. Because these parameters are biologically conservative in their reactions, their concentrations are affected primarily by dilution from rainfall, evapotranspiration, and geochemical reactions.

The water in the Shark River Slough, represented by Everglades station P-33, has been changing in quality since the mid-1960's, notably an increase in the concentrations of magnesium, potassium, and chloride (fig. 10). Increases in color and specific conductance have also occurred since the mid-1960's at station P-33 (fig. 11). The Big Cypress and Taylor Slough stations have not shown long-term changes in water quality (1959-77).

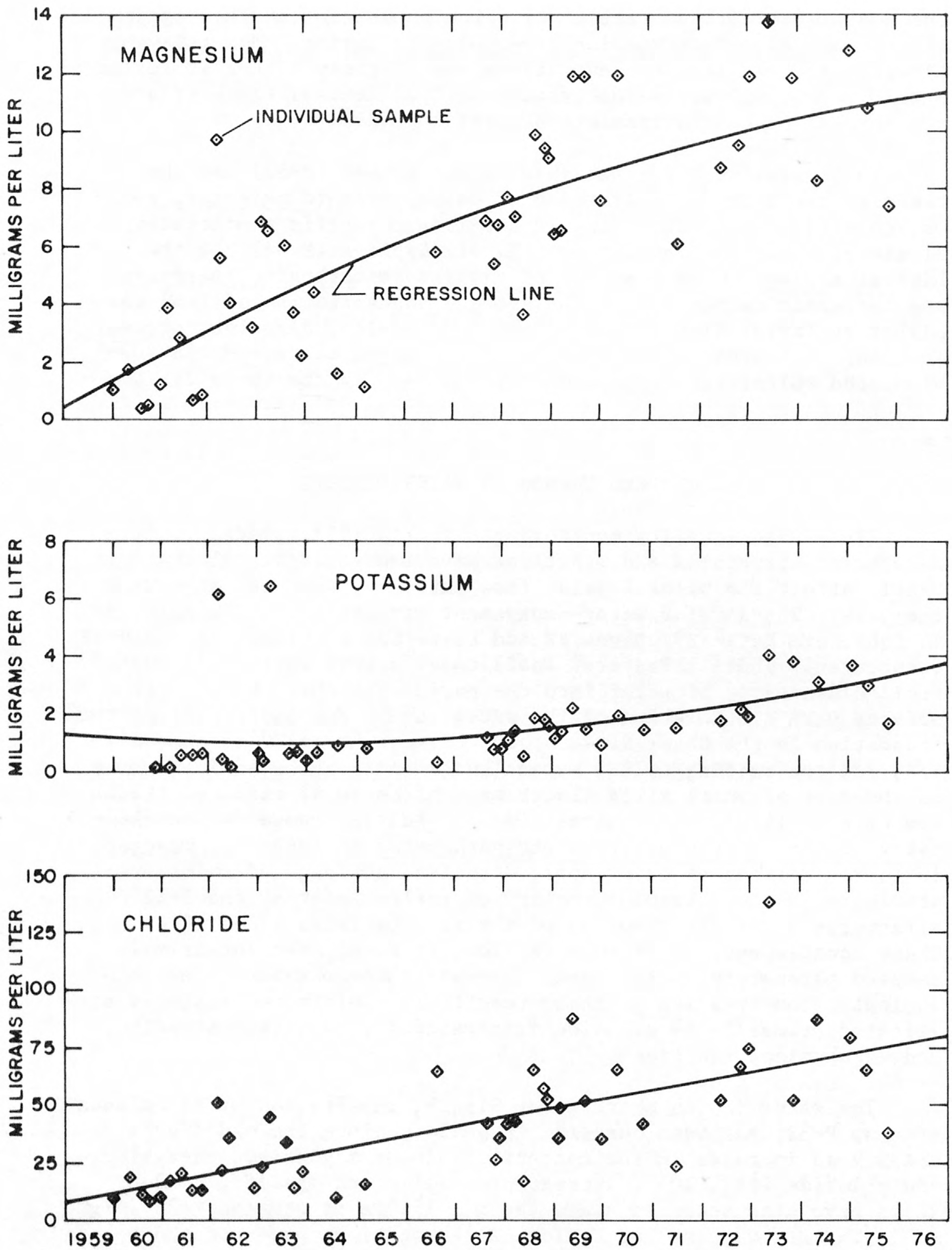


Figure 10.--Concentrations of dissolved magnesium, potassium, and chloride at Everglades station P-33, 1959-77.

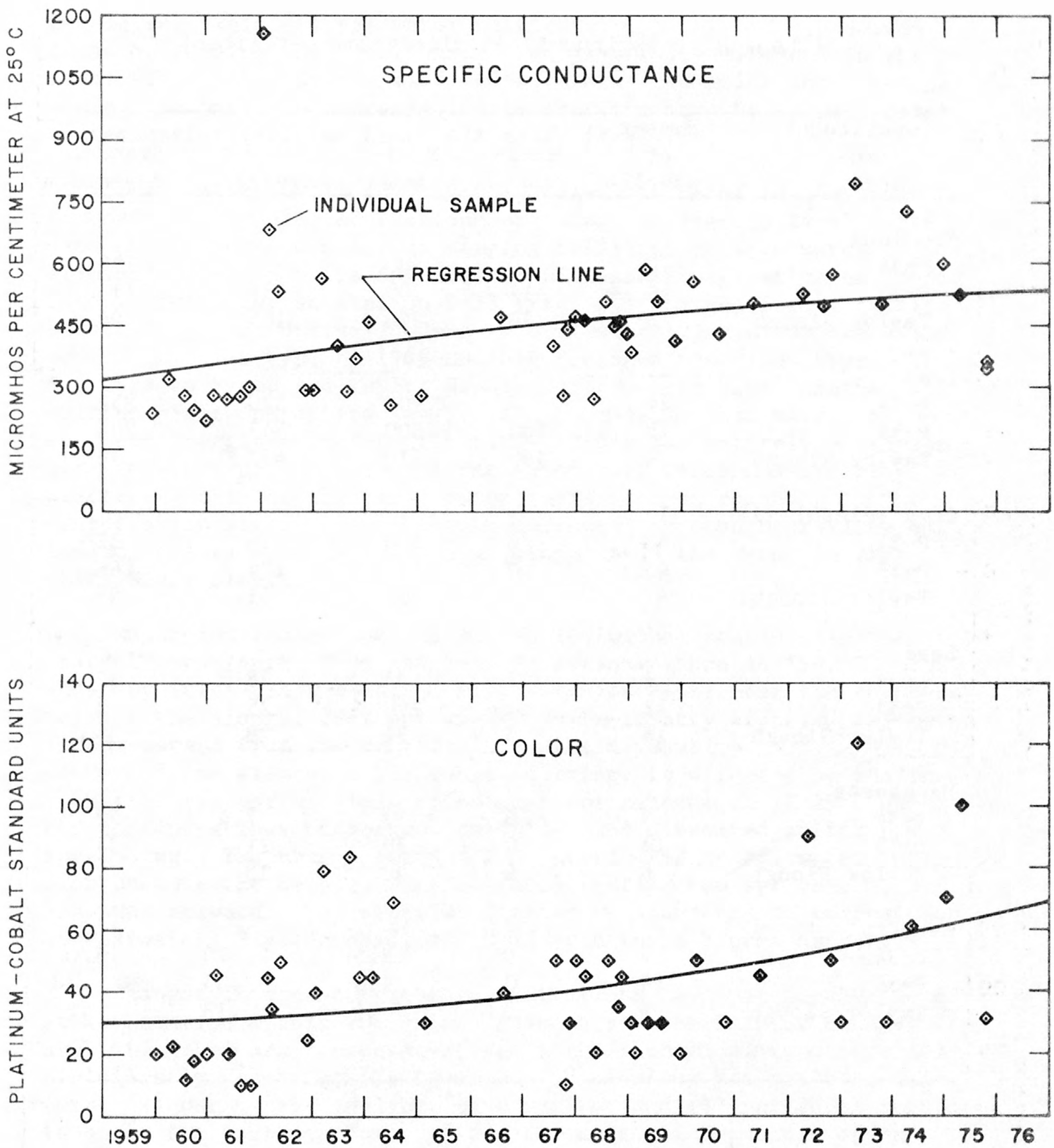


Figure 11.--Color and specific conductance levels at Everglades station P-33, 1959-77.

Table 9.--Concentrations of trace metals in surface water at stations P-33, P-34, and Taylor Slough, 1959-77

[Chemical constituents in micrograms per liter]

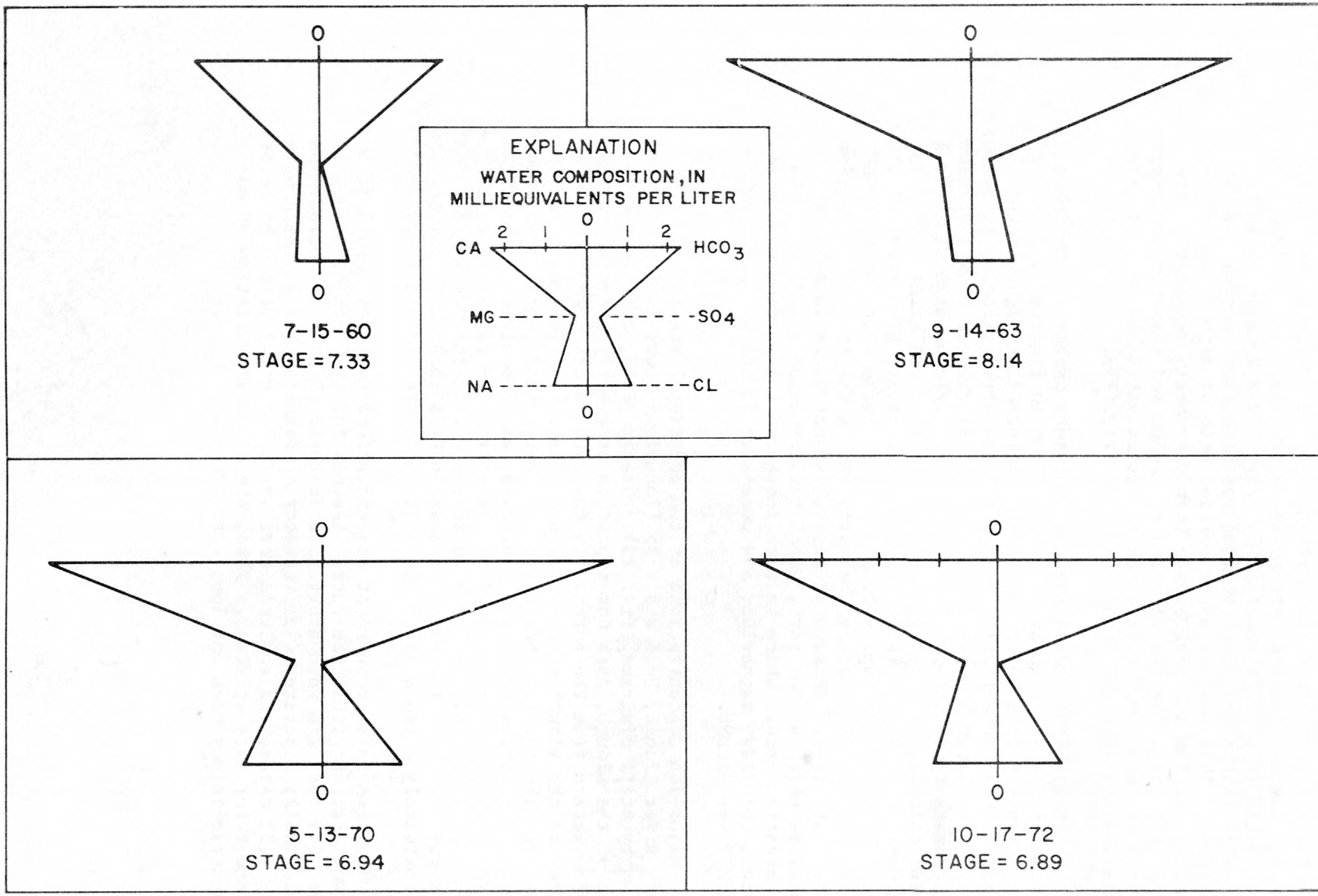
Constituent and station	Number of samples	Mini- mum	Maxi- mum	Average	Standard deviation
Aluminum					
P-34	12	0	500	119	159
P-33	19	11	300	131	111
Taylor Slough	6	10	280	105	94
Iron					
P-34	10	0	2,900	520	852
P-33	18	100	9,500	1,543	2,204
Taylor Slough	6	190	710	432	198
Iron (dissolved)					
P-34	40	0	150	24	32
P-33	45	0	700	124	168
Taylor Slough	47	0	500	41	85
Lead					
P-34	4	11	35	18	12
P-33	12	0	190	25	53
Taylor Slough	6	3	94	28	35
Manganese					
P-34	9	0	30	7.4	12
P-33	19	0	70	21	21
Taylor Slough	6	0	20	13	7.8
Mercury					
P-34	5	0	2.5	.70	1.0
P-33	13	0	1.3	.33	.38
Taylor Slough	6	0	.6	.18	.23

The water entering the northeast part of Shark River Slough from the Tamiami Canal betwee Levee 30 and Levee 67A (Bridge 53) has changed in quality since 1959. When Levee 29 was completed, the water in the canal was derived entirely from seepage through the levee. This seepage water carried with it higher concentrations of calcium and bicarbonate than previously detected in the canal (fig. 12). By the mid-1960's, sodium and chloride concentrations also began to increase due to contamination by seepage water contamination from the Levee 67A canal (fig. 13).

Stiff diagrams indicating the long-term change in the ionic composition at selected stations are shown in figures 14-15. The data shown are from selected samples collected at high water to eliminate the concentrating effects of evapotranspiration on ponded water. The water at station P-33 (fig. 14) changed from a calcium bicarbonate type during 1960-63 to a mixed calcium bicarbonate and sodium chloride type by 1966 and has remained the mixed type. The Big Cypress Swamp and Taylor Slough drainageways have remained a calcium bicarbonate type water. It is probable that water in the southern Everglades before the early 1960's was entirely a calcium bicarbonate type. Because of the subsequent water-management practices north of the park, water quality began changing in the conservation areas, which in turn increased the concentrations of sodium, chloride, magnesium, and potassium in the water in the Shark River Slough.

Major-ion concentrations at two additional stations in the Shark River Slough, P-38 and P-35 (locations shown in fig. 3), are shown by Stiff diagrams (fig. 15). Station P-38, near the southern edge of the slough, does not appear to be greatly affected by the inflow waters from the north. In contrast, station P-35 in the center of the slough on the mangrove fringe is affected by the inflow from the north. This effect was not evident until 1966 when the concentrations of sodium, chloride, and dissolved solids began increasing. The change could not be attributed to saltwater intrusion because the samples were collected during the wet season, and flow was seaward. The water at station P-35 changed in composition approximately 2 years after the S-12 structures became operable.

Changes in macronutrient concentrations have not been detected at any station within the park. Reasons for the lack of change are: (1) they are nonconservative in their chemical reactions and biologically reactive; (2) frequency of sampling has not been uniform; (3) parameters analyzed have varied; and (4) period of record is short for most stations. Also, the seasonal variation of macronutrients may mask any long-term trends.



STAGE VALUES ARE IN FEET ABOVE NGVD OF 1929

Figure 12.--Long-term change in ionic composition at Tamiami Canal Outlets, Levee 30 to Levee 67A (Bridge 53).

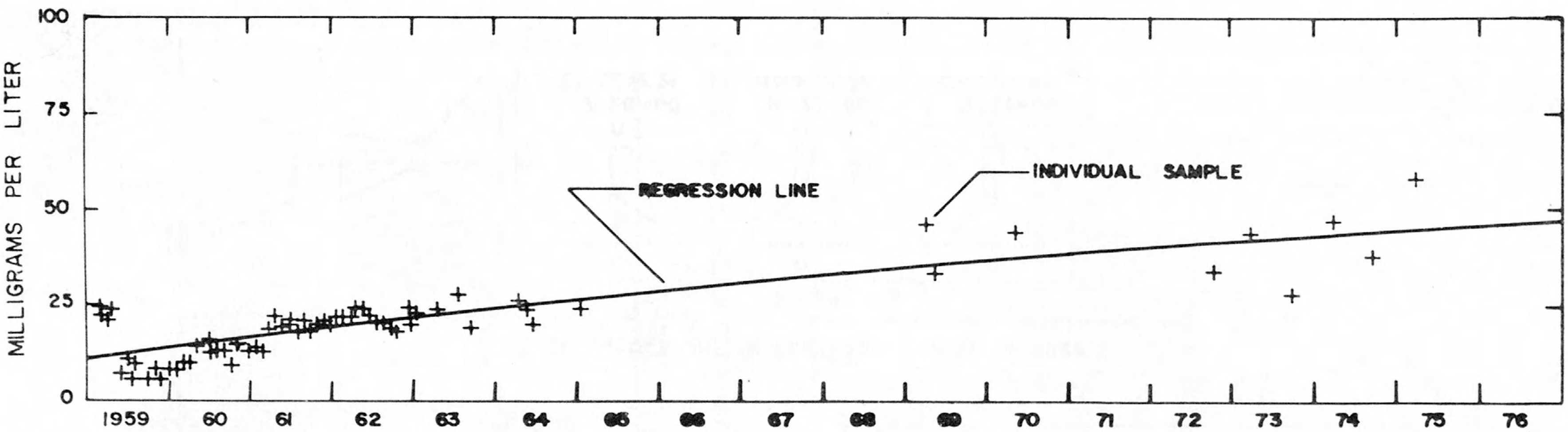


Figure 13.--Concentrations of dissolved chloride at Tamiami Canal Outlets, Levee 30 to Levee 67A (Bridge 53), 1959-77.

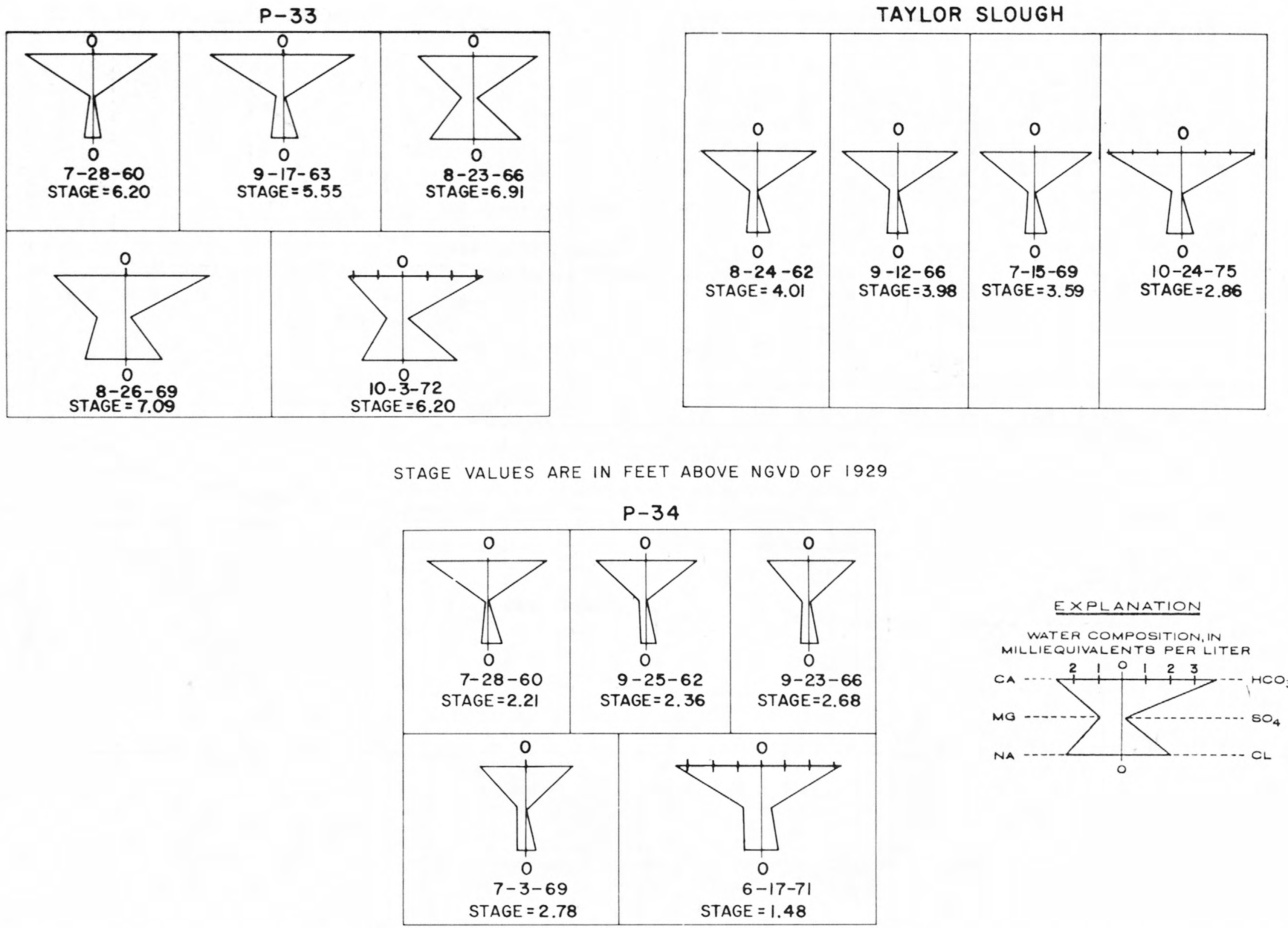


Figure 14.--Long-term change in ionic composition at Everglades stations P-33, P-34, and Taylor Slough.

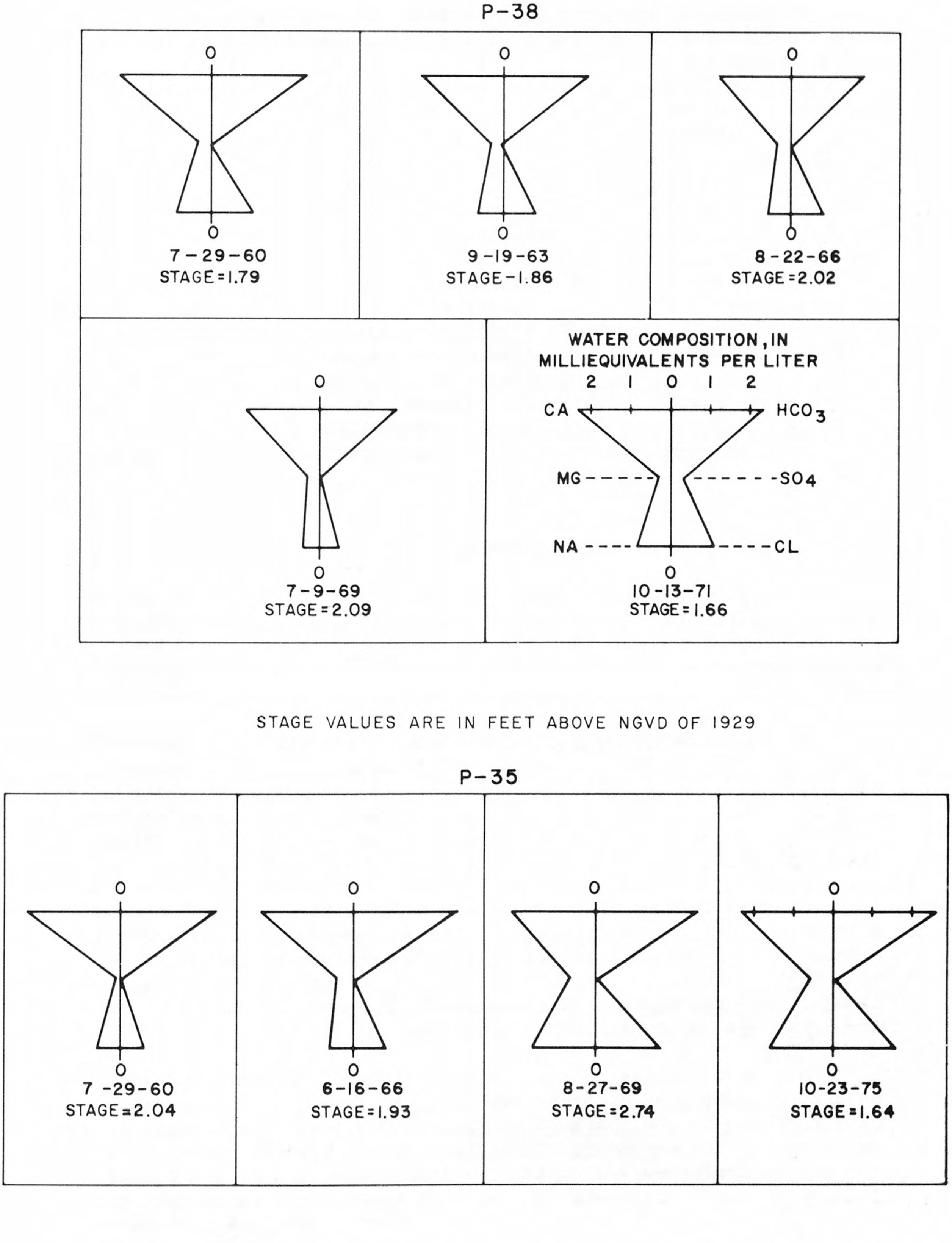


Figure 15.--Long-term change in ionic composition at Everglades stations P-38 and P-35.

Trace-element concentrations within the park do not appear to vary over time, although few data are available at all the stations, except for iron. Lack of a data base coupled with the short-term collection, lack of a consistent periodicity of sampling for the same elements, and the nonconservative chemical reactions that trace elements undergo make analysis of long-term trends difficult. Most elements are stabilized at low concentrations (not exceeding U.S. Environmental Protection Agency criteria) but do vary seasonally due to evaporation and changes in temperature, pH, and oxidation-reduction potentials.

The overall long-term changes in the quality of water in the Everglades National Park have occurred as a result of changing the water-delivery system at the northern boundary. These changes were noted in the gradually increasing concentrations of certain major ions, dissolved solids, and color. Only the Shark River Slough drainageway is affected by these increased concentrations. The extent and degree of this effect vary due to rainfall, antecedent dry conditions, and the volume and distribution of flow through the S-12 structures.

SUMMARY

The U.S. Geological Survey has collected surface water and bottom material samples in Everglades National Park since 1959 and analyzed them for major ions since 1959 and for physical parameters, macronutrients, trace elements, and pesticides since the mid-1960's.

There are three major drainageways in the park: Big Cypress Swamp, Shark River Slough, and Taylor Slough. The park receives its water from three principal sources: (1) uncontrolled sheet flow from the Big Cypress Swamp; (2) regulated flow from Water Conservation Area 3A and underflow from 3B; and (3) rainfall. Before 1963, all surface-water flow into the park was uncontrolled.

Seasonal changes in water levels cause marked changes in surface-water quality. Evapotranspiration of ponded water, increased metabolic activity, and changes in the oxidation-reduction potential at the water and sediment interface are the major physical-chemical reactions that cause increasing concentrations and levels of parameters during the dry season.

Long-term changes in the concentrations of sodium, magnesium, potassium, chloride, dissolved solids, and iron and color levels have occurred in the Shark River Slough. No long-term changes in water quality have occurred in either the Big Cypress Swamp or Taylor Slough drainageways. Water-quality changes can be attributed primarily to the channelization of more mineralized water down the Levee 67A Canal directly to Shark River Slough, and the implementation of water-management practices since 1963.

Macronutrient concentrations increase greatly during low water. Nitrogen species are dominated by organic nitrogen. Phosphorus and carbon concentrations are dominated by either organic or inorganic forms depending on water levels and soil type at the particular sampling station.

Trace-element concentrations, except for iron, do not exceed U.S. Environmental Protection Agency criteria during periods of high water. As water levels recede during the dry season, trace-element concentrations fluctuate in the ponds. The greatest increases in concentrations were noted for iron, manganese, aluminum, and zinc.

Pesticides were detected in less than 2 percent of all surface-water samples collected within and adjacent to Everglades National Park. In contrast, nearly 80 percent of all bottom material samples analyzed contained detectable pesticide residues. Most of the residues were chlorinated-hydrocarbon insecticides. Their distribution in the park is widespread and is primarily caused by atmospheric transport.

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