FINAL TECHNICAL REPORT

STATUS AND TRENDS SUMMARY OF THE INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM MELBOURNE, FLORIDA

Prepared By:
Woodward-Clyde Consultants
Marshall McCully & Associates, Inc.
Natural Systems Analysts, Inc.

Prepared For:
Indian River Lagoon National Estuary Program
1900 South Harbor City Boulevard - Suite 109
Melbourne, Florida 32901-4749
October 1994

Woodward-Clyde

Woodward-Clyde Consultants
9950 Princess Palm Avenue, Suite 232
Tampa, Florida 33619

Project Number: 92F274C

TABLE OF CONTENTS

TABLE OF CONTENTS, Continued

LIST OF TABLES

LIST OF TABLES, Continued

LIST OF TABLES, Continued

LIST OF FIGURES

LIST OF FIGURES, Continued

LIST OF FIGURES, Continued

LIST OF FIGURES, Continued

INTERNATIONAL SYSTEM (SI METRIC)/ U.S. CUSTOMARY CONVERSION TABLES

TO CONVERT FROM	TO	MUTLIPLY BY
LENGTH		
centimeters	inches	0.3937
inches	centimeters	2.5400
feet	meters	0.3048
meters	feet	3.2808
kilometers	meters feet miles	1.0×10^3 $3.280\ 84 \times 10^3$ 0.621 37
miles	kilometers	1.609 34
AREA		
acres	hectares square feet square kilometers (km^2) square miles	0.404 69 4.356×10^4 .00404 .00156
hectares	square meters acres	1.0×10^4 2.471
square kilometers	hectares acres square miles (mi^2)	100.0 274.105 38 0.3861
square miles	hectares square kilometers (km^2) square feet acres	258.998 81 2.589 99 $2.787\ 84 \times 10^7$ 640.0
VOLUME		
liters	cubic feet gallons	0.035 31 0.264 17
gallons	liters cubic feet	3.785 41 0.133 68
cubic feet	cubic meters (m^3) gallons (gal) acre-feet (acre-ft)	$28.316\ 85 \times 10^{-3}$ 7.480 52 $22.956\ 84 \times 10^{-6}$
cubic yards	cubic meters cubic feet	0.764 55 27.0

INTERNATIONAL SYSTEM (SI METRIC)/ U.S. CUSTOMARY CONVERSION TABLES, Continued

TO CONVERT FROM	TO	MUTLIPLY BY
VOLUME		
cubic meters	gallons cubic feet cubic yards acre-feet	264.1721 35.314 67 1.307 95 8.107×10^{-4}
acre-feet	cubic feet gallons	43.560×10^{3} 325.8514×10^{3}
TEMPERATURE		
	degrees Celsius (C) (t_c)	$t_c = (t_f-32)/1.8 = t_k - 273.15$
	degrees Fahrenheit (F)	$t_f = t_c/1.8 + 32$
VELOCITY		
kilometers per hour	meters per second miles per hour	0.277 78 0.621 47
miles per hour	kilometers per hour meters per second	1.609 34 0.447 04
FORCE		
kilograms	pounds (lbs)	2.2046
MASS		
pounds (avdp)	kilograms	0.453 59
VOLUME PER UNIT TIME FLOW		
cubic feet per second	cubic meters per second (m^3/s) gallons per minute (gal/min) acre-feet per day (acre-ft/d) cubic feet per minute (ft^3/min)	0.028 32 448.831 17 1.983 47 60.0
gallons per minute	cubic meters per second cubic feet per second (ft^3/s) acre-feet per day	0.631×10^{-4} 2.228×10^{-3} 4.4192×10^{-3}
acre-feet per day	cubic meters per second cubic feet per second	0.014 28 0.504 17

1.0 INTRODUCTION

This Status and Trends Technical Summary Report is a summary of the findings of the Indian River Lagoon Characterization Report Study. In this report, the findings of the seven other technical reports of the characterization study have been synthesized to provide an overview of the status and trends of conditions within the Indian River Lagoon and its watershed. More detailed discussions of the information presented in this summary and the results are found in the following volumes which can be obtained from the IRLNEP:

- Physical Features
- Biological Resources
- Uses of the Indian River Lagoon
- Historical Imagery Inventory and Seagrass Assessment
- Non-Governmental and Governmental Programs
- Water and Sediment Quality Assessment
- Point and Non-point Source Loads Assessment

The information included in these volumes includes new data developed as a part of this characterization study as well as a synthesis of pertinent data developed by many other investigators who have studied the Lagoon over the last 40 years. The present status of the ecosystem of the Lagoon is a result of many factors including the physical features of the Lagoon waters and of the surrounding watershed, the effects of human development and change on these features, and the resulting responses of the biological systems and water chemistry of the Lagoon.

The features and functions that play a predominant role in setting the current condition of the Indian River Lagoon system and are important in determining the magnitude of impacts of alterations to the system are described in Chapter 3.0. Certain of these physical and chemical characteristics that have major roles in determining the carrying capability and assimilative capacity of the system are emphasized in this summary. Chapters 4.0 and 5.0 describe the pollutant loads of the wastewater and stormwater discharges and the resultant water quality in the Lagoon and its tributaries.

Trends in uses of the Lagoon and the surrounding watershed are summarized in Chapter 6.0 which describes changes in population, land use, and economic and recreational factors associated with the Lagoon. Biological resources of the Lagoon and the current status and trends of key elements such as seagrasses and endangered species are summarized in Chapter 7.0.

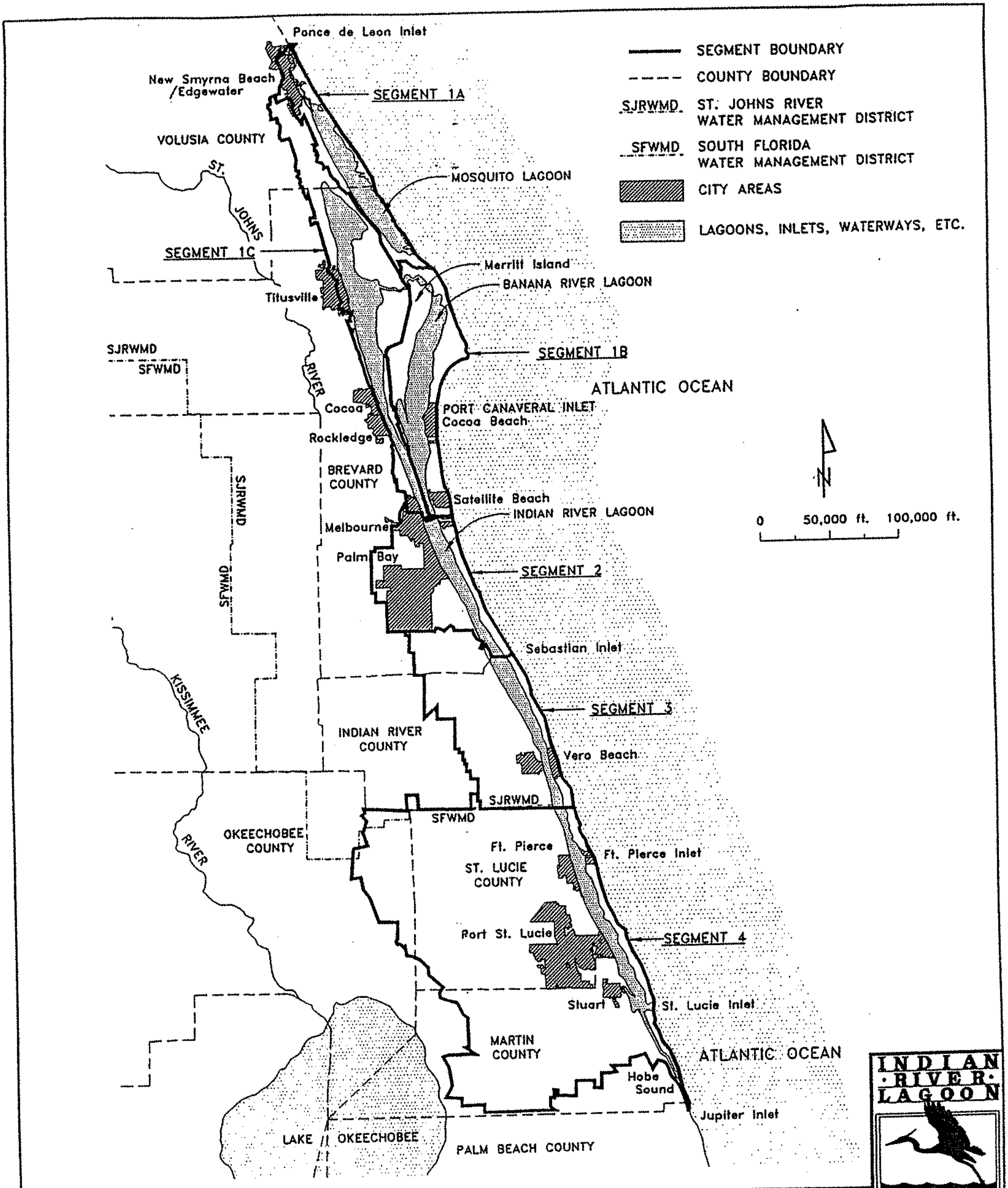
While the physical features of the Lagoon may form the structural framework for the assimilative capacity of the Lagoon, the ultimate waterbody conditions are also a factor of the amount of various substances entering the Lagoon and the distribution in time and space of these materials. The major sources of these materials are point source discharge from wastewater treatment plants, non-point source stormwater runoff, freshwater discharges from groundwater, contamination from boats and from development directly adjacent to the Lagoon, and possibly septic system leachate. Problems or issues that pose the greatest threats to the Lagoon are presented with an assessment of the state of the knowledge of the causes and effects of these problems.

Although it is important to understand the factors affecting the Lagoon and to describe the existing information, it is also important to understand what is not known about the system and what gaps exist in our understanding that may limit effectiveness in developing strategies and managing the Lagoon system. This status and trends summary attempts to point out data needs and other deficiencies for which more research is needed for proper management and understanding.

2.0
GENERAL INFORMATION

The Indian River Lagoon system is an estuary that lies on the east coast of Florida (Figure 2-1) approximately between latitudes 26°57'N and 29°03'N and between longitudes 80°05'W and 80°55'W. The northern boundary of the system is Ponce de Leon (or Ponce) Inlet in Volusia County. The southern boundary of the system is 155 miles (mi) to the south at Jupiter Inlet in Palm Beach County. This system includes the three water bodies known as Mosquito Lagoon, Banana River, and Indian River Lagoon, as well as the portion of Indian River Lagoon south of St. Lucie Inlet which is more widely known as Hobe Sound and Jupiter Sound. The watershed of the system is bounded on the east by the crown of the dune on the barrier island. The existing western limit is not so easily defined. In places it is the crest of the Atlantic Coastal Ridge, which is the watershed's natural inland limit. However, in many places in the watershed, drainage basins have been expanded by man to divert drainage to the Lagoon from areas formerly linked to other watersheds such as the St. Johns River.

An issue that surfaced early in this study was that of segmentation of the Lagoon, in terms of the best strategy for subdividing the Lagoon into workable subunits for characterizing or managing the system. The Lagoon system can be subdivided on the basis of hydrology and drainage units, hydrodynamic and geographic features, management authorities, or other means. No one method of dividing the Lagoon was found to be totally acceptable for all people or all purposes. The base segmentation scheme used for this study has been adapted from the segment scheme utilized by the St. Johns River Water Management District (SJRWMD) and the South Florida Water Management District (SFWMD). This scheme was first defined by Clapp (1987) and subsequently modified by Glatzel and Da Costa (1988b). The watershed surrounding the Lagoon also has been broken into basins or segments shown in Figure 2-1 corresponding to the segments of the Lagoon, based on drainage patterns, with all areas draining into a segment of the Lagoon included in that segment.

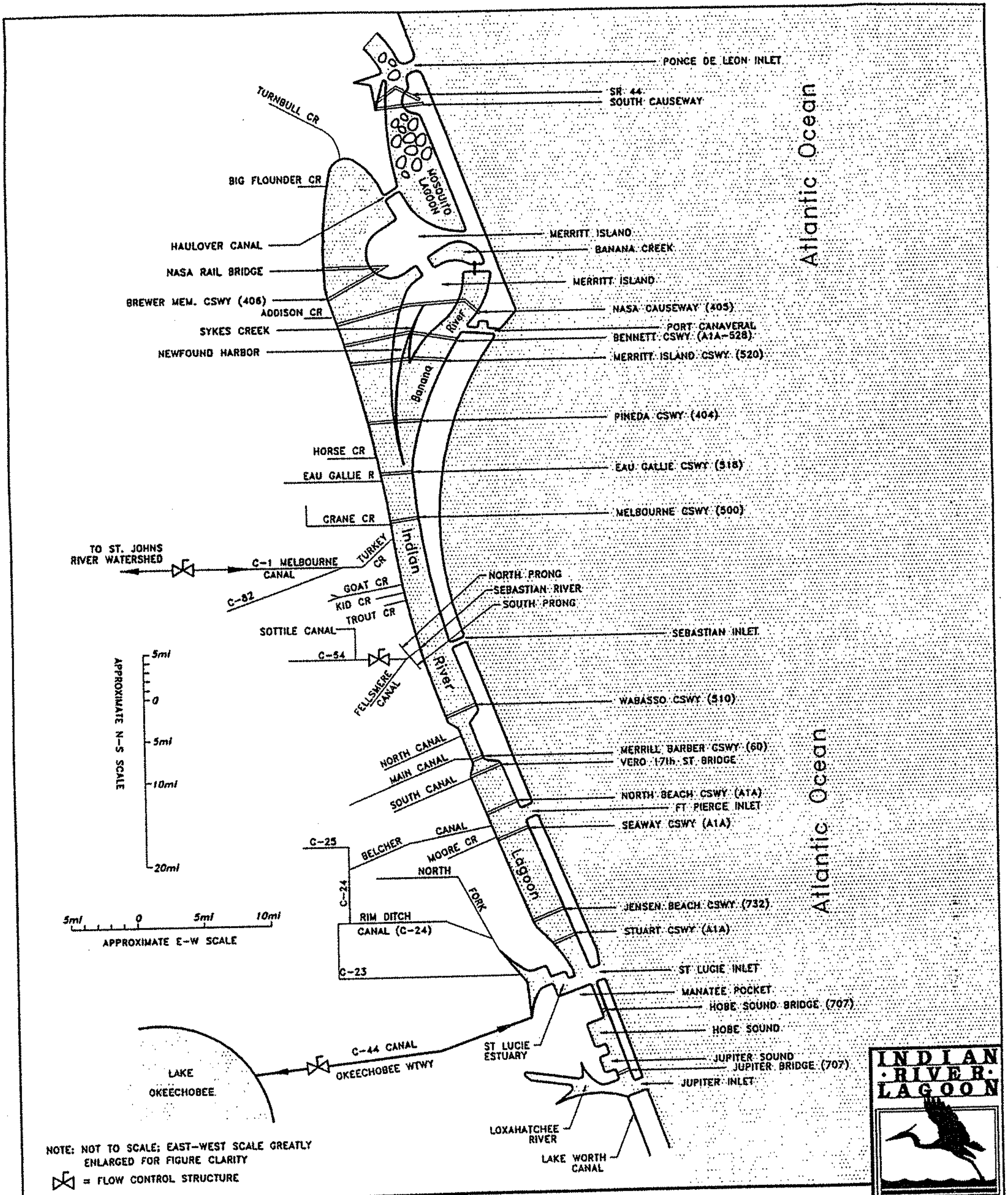


•Woodward–Clyde Consultants •Marshall McCully & Associates •Natural Systems Analysts	DRAWING NO.: INDIAN10.DWG DATE: 7-5-94	FIGURE 2-1 MAP OF INDIAN RIVER LAGOON SYSTEM AND WATERSHED SHOWING SEGMENTS

In the characterization study, the Indian River Lagoon system has been divided into six segments, based primarily on hydrodynamic and geographic features, as shown in Figure 2-1. The three northern segments (1A - Mosquito Lagoon, 1B - Banana River, and 1C - North Indian River Lagoon) are characterized by wide expanses of water, small watersheds, low tidal ranges, and low tidal flushing or exchange. Segment 2 (North Central Indian River Lagoon), which includes areas north of Sebastian Inlet that are within the influence of Sebastian Inlet, differs from the three northern segments because it has greater influxes of freshwater runoff and streamflow from a larger watershed. The resulting water chemistry and dynamics of Segment 2 differ fairly widely from other segments with respect to its lower average salinities and greater salinity variability.

The two southern segments (3 - South Central Indian River Lagoon and 4 - South Indian River Lagoon) represent stretches where the drainage basin has been artificially expanded and is very large in relation to Lagoon surface area and volume. Tidal exchange in Segments 3 and 4 also is high due to the presence of three inlets with tidal currents that are experienced throughout much of the segments. The increased influence of the inlets is a primary reason that the water quality and hydrodynamics of Segment 4 in particular differ from Segment 2.

Figure 2-2 is a diagrammatic representation of the Lagoon system in which the east to west scale has been expanded to allow better visualization of landmarks along the Lagoon. The major tributaries, inlets, and causeways serve as landmarks along the Lagoon as well as controllers of the functioning of the Lagoon.



•Woodward-Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.: INDIAN05.DWG
DATE: 7-5-94

FIGURE 2-2 MAJOR LANDMARKS OF THE INDIAN RIVER LAGOON SYSTEM

3.0 PHYSICAL FEATURES

3.1 INLETS AND HYDRODYNAMICS

The geographic setting and shape of the Indian River Lagoon system and its watershed control the functioning of the Lagoon and cause it to be different from most of the bays and estuaries in Florida. The long, narrow shape and shallow waters result in a sluggish circulation in many places. In addition, the only exchange with the ocean is through five widely separated inlets with restricted tidal flushing. This makes the Indian River Lagoon system especially sensitive to sudden influxes of pollutants or materials carried by stormwater runoff, as well as to the changes and increases in materials added to the Lagoon as a result of increasing urbanization, industrialization, and agriculture in the watershed.

Because of the Lagoon's small size (in relation to the oceans), generation of tides within the Lagoon is negligible. Tides in the Lagoon are the result of tidal forces that develop in the Atlantic Ocean and enter the Lagoon through the inlets. Smith (1990) describes each rise and fall of the astronomical tide (driven by gravitational forces of the sun, moon, and other celestial bodies) in terms of a long wave propagating through the inlets. As the water moves into the Lagoon, enhanced bottom friction in the shallow depths causes a steady reduction in the height of the tide and the resultant tidal currents.

The distance that a water molecule moves on either the flood or ebb portion of the tidal cycle is called the excursion distance (Smith, 1988). In the Indian River Lagoon, this distance is about 6 mi (10 km) at Ft. Pierce Inlet and 1 to 2 mi (2 to 3 km) near Sebastian Inlet, but is as little as a tenth of a mile (100 m) in places where tidal currents are least, such as in the North Indian River Lagoon (Segment 1C) and Banana River (Segment 1B). This means that ocean water entering the Lagoon is not carried far into the Lagoon by the direct effects of the twice-daily astronomical tide currents.

Other types of currents, including tidally averaged flows and weather related flows (meteorological currents) caused by wind pressures and barometric pressure differences, can move water molecules within the Lagoon. These forces have been estimated to be capable of moving water molecules at rates of nearly 0.5 to 1 mi (1 to 2 km) per day in parts of the Lagoon (Smith; 1988, 1990). However, such rates appear to vary throughout the Lagoon. Complete exchange or flushing of some parts of the Lagoon may take place in periods as short as 30 days near inlets such as Ft. Pierce and St. Lucie Inlets where astronomical tidal forces are significant, while the flushing action may take much longer in other areas.

The meteorological currents are thought to be the only significant currents capable of moving water in most of Mosquito Lagoon, Banana River, and the Indian River Lagoon north of Melbourne Causeway. Under certain conditions, there is virtually no mass flow of water in these sections and consequently no flushing. This means that these Segments (1A, 1B, 1C) are highly susceptible to inputs or loadings of pollutants and may not be able to withstand significant loadings without degradation of water quality. Several studies (Evink, 1980: Smith, 1990) have indicated that causeways and the Intracoastal Waterway (ICWW) may be major influences on the circulation patterns in the Lagoon and on exchange of water between different reaches of the Lagoon.

From Melbourne Causeway south to Sebastian Inlet, tidal flow and potential flushing action increase steadily, and they persist to the Indian River Narrows near Vero Beach. However, discharges from the surrounding watershed also increase, presenting a more complicated circulation pattern which is not clearly understood and which appears to change dramatically with different weather conditions. Flushing and transport of materials throughout this section may vary substantially, but there appears to be a potential susceptibility to increased loadings on this segment, based on existing hydrodynamic information.

Some tidal flow appears to be present everywhere between Ft. Pierce and St. Lucie Inlets, with tidal action and flushing most pronounced within 3 to 5 miles of either inlet. The Lagoon appears capable of assimilating larger amounts of freshwater and pollutants here because of greater flushing and exchange with the ocean. The hydrodynamics of the Lagoon between St. Lucie and Jupiter Inlets have not been well studied and are not well known.

Further detail on these subjects is included in Chapters 2.4 and 6.0 of the Physical Features Technical Report, that also recommends that additional hydrodynamic modeling be undertaken to better define the mixing patterns in the Lagoon and the effects of inlets and freshwater drainage since alterations to either inlet dispersion or drainage basin characteristics may affect mixing of water masses, water quality, and assimilative capacity in the Lagoon. Evaluation of effects on currents, mixing, flushing, and the resultant water quality is also recommended prior to any actions affecting inlet function or change in freshwater discharge.

3.2 HYDROLOGY AND WATER BALANCES

In an estuary such as the Indian River Lagoon, waters from different sources mix and combine. The effects of tides and other currents on mixing, flushing, exchange, and movement of this water have been mentioned in Section 3.1. However, the resultant mix of freshwater entering the Lagoon from rainfall and other sources and saltwater entering the Lagoon through the inlets is a major factor affecting the functioning of the Lagoon and the biological resources inhabiting the Lagoon. Water may be lost from the system through evaporation, and in certain parts of the Lagoon at certain times of the year evaporation may be the dominant factor affecting the water balance and may determine the salinity in the Lagoon.

The water balance or water budget accounts for the volume of fresh and salt water that enters, leaves, or is stored in the Lagoon. All water budgets are governed by the basic equation:

$$\textit{Inputs} - \textit{Outputs} + \textit{Accumulation} = 0$$

When inputs and outputs are equal, there is no accumulation or loss within a compartment of the budget such as the Lagoon. However, this is not the usual case in the Lagoon. During different parts of the year, there may be an excess of either inputs or outputs. If inputs and outputs do not balance, there must be either a change in the volume and water level of water within the Lagoon or water must move into or out of the Lagoon.

Major water inputs for the Lagoon are direct rainfall on the Lagoon surface, direct surface water runoff from stormwater in the surrounding watershed, streamflow, and discharges from wastewater treatment plants (WWTPs). Ground water inputs in the past have been assumed to be negligible, but recent information indicates that ground water input might be important in some locations during parts of the year. Data from several studies (Toth, 1987;

Pandit and El-Khazen, 1990) indicate that surficial aquifer seepage to the Lagoon may be on the order of 1.2 to 8 billion ft^3 per year, a value which is about 10 times smaller than the 82 billion ft^3 of estimated surface water input (Glatzel and Da Costa, 1988a). Outputs are evaporation and discharge through the inlets to the ocean. Glatzel and Da Costa (1988a, 1988b) developed a water budget for all segments except Mosquito Lagoon (1A). This budget indicates that there is an average annual net discharge of 70,866,600 million ft^3 (1,974,000 million m^3) of water that must be evaporated or released through the inlets to the ocean.

This net outflow is not evenly distributed over time and space in the Lagoon. Table 3-1 shows estimates of the inputs and outputs for each segment for 1988. There is great variation among inputs and outputs among the segments. In particular, there is great variation in the "net" column, which represents the water that must flow into or out of the Lagoon to balance the other inputs and outputs. The water balances in the northern sections (Segments 1B and 1C - Banana River and North Indian River Lagoon) differ substantially from those in the other parts of the Lagoon. Data for Mosquito Lagoon is not shown, but the Mosquito Lagoon pattern is thought to be similar to that of Banana River.

Figure 3-1 shows the net accumulation or loss of water (i.e., the "net" column in Table 3-1) over an average yearly period for three segments. These graphs show that between March and August, evaporation in the Banana River (Segment 1B) exceeds the freshwater input (resulting in the negative condition). This also occurs to a lesser extent in the North Indian River (Segment 1C) between March and May. In the three southern segments of the Indian River Lagoon, freshwater input always exceeds evaporation.

This water balance analysis also shows that the northern segments of the Indian River Lagoon system function very differently from the central and southern sections. When evaporation exceeds the supply of freshwater, an input of saline water from elsewhere must make up the difference. As a result, water from the southern reaches (Segment 2) must move into the northern segments (Segments 1B, 1C) to make up the difference.

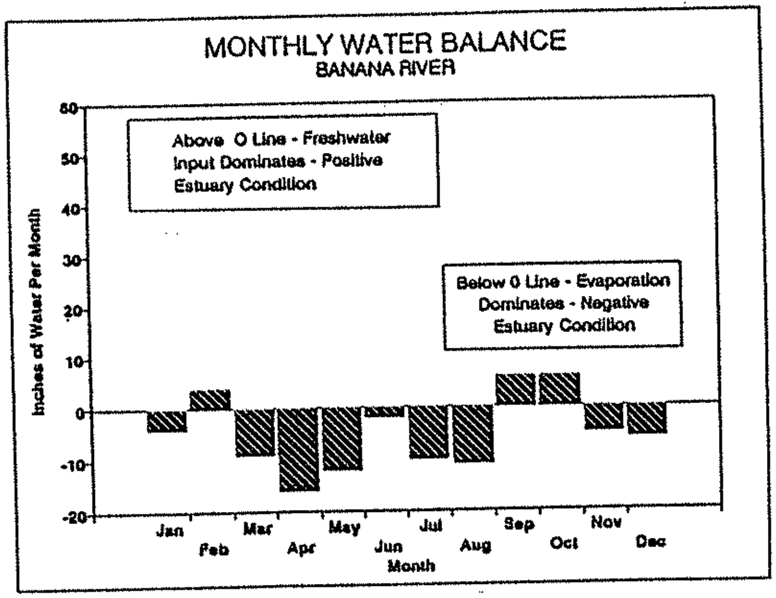
TABLE 3-1

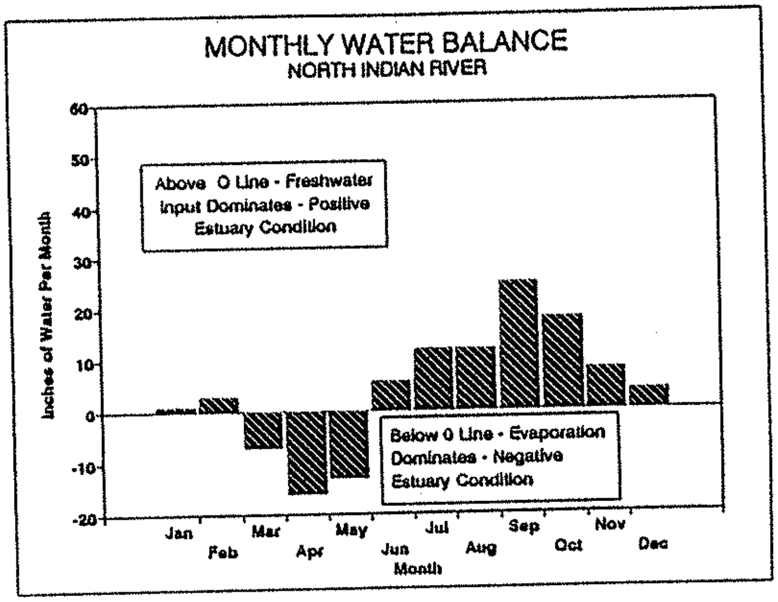
ESTIMATED NORMAL WATER BUDGET COMPONENTS FOR EACH OF THE SEGMENTS OF THE BANANA RIVER AND INDIAN RIVER LAGOON REGION (VALUES IN MILLION CUBIC METERS PER YEAR)

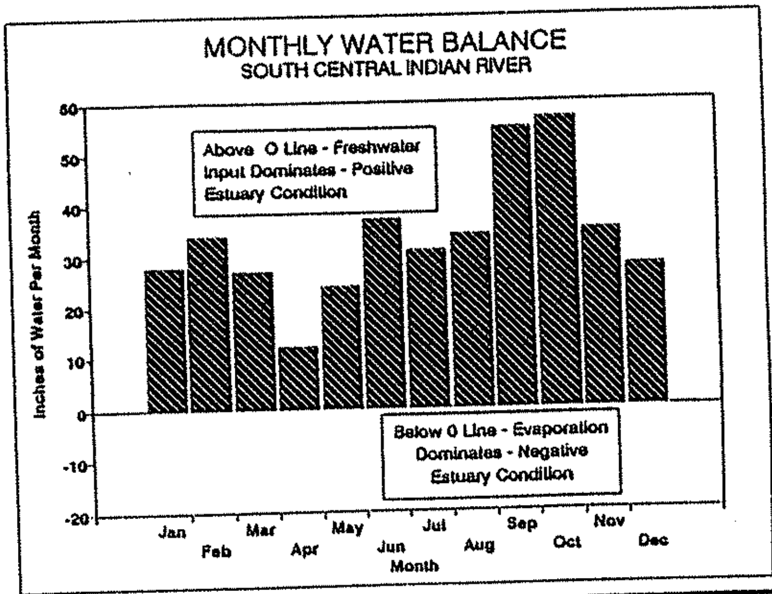
SEGMENT	INPUTS					OUTPUTS	NET
	(A) RAINFALL	(B) RUNOFF	(C) STREAMFLOW	(D) WWTPs	(E) TOTAL INPUTS (A-D)	(F) EVAPORATION	(G) dQ + dV (E-F)
1B - Banana River	186.14	16.94	0.00	19.90	222.98	(243.19)	(20.21)
1C - North Indian River Lagoon	391.05	104.87	0.00	13.63	509.55	(414.59)	94.96
2 - North Central Indian River Lagoon	93.50	173.94	318.24	14.01	599.69	(111.34)	488.35
3 - South Central Indian River Lagoon	98.48	121.93	321.03	7.69	549.13	(109.88)	439.25
4 - South Indian River Lagoon	155.93	214.83	750.79	18.00	1,139.55	(167.01)	972.54
TOTAL BANANA AND INDIAN RIVER LAGOONS	**925.10**	**632.51**	**1,390.06**	**73.23**	**3,020.90**	**(1,046.01)**	**1,974.89**

Source: Glatzel and Da Costa (1988b)

( ) = negative numbers







Source: Glatzel and Da Costa, 1988b.

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysis	DRAWING NO.: DATE:	FIGURE 3-1 THREE SEASONAL PATTERNS OF FRESHWATER INFLOW OR OUTFLOW PREDOMINANCE AS ILLUSTRATED BY SEGMENTS 1B, 1C, AND 3

This pattern is known as a "Negative Estuary" condition and is present in the Banana River during most of the year. This negative condition tends to prevent flow of water out of the Banana River and limits the potential flushing action. Pollutants discharged into the Banana River may not be flushed and may tend to remain and accumulate.

This condition may concentrate other substances, such as salts, nutrients, and contaminants in the water column and eventually in the sediments. Water quality monitoring data appears to support the premise that salts do accumulate in the northern Indian River Lagoon, Banana River, and Mosquito Lagoon, because salinities remain high in spite of very limited connections to the ocean.

The water balance analysis also supports the conclusion of the hydrodynamic analysis that the Banana River, Mosquito Lagoon, and North Indian River Lagoon segments may be especially vulnerable to inputs of nutrients and pollutants, and that they function differently from the southern and central sections in terms of freshwater and saltwater mixing and resulting salinity patterns.

Chapter 4.0 of the Physical Features Technical Report covers this subject in greater detail.

3.3 WATERSHEDS AND DRAINAGE PATTERNS

The watershed of the Indian River Lagoon has been broken into the six basins corresponding to the six segments of the Lagoon, as shown in Figure 2-1. These were further subdivided into 69 sub-basins for the characterization non-point source loading study. The total Indian River Lagoon watershed currently consists of 227,739 acres of Lagoon surface and 1,216,750 acres of surrounding basin as shown in Table 3-2.

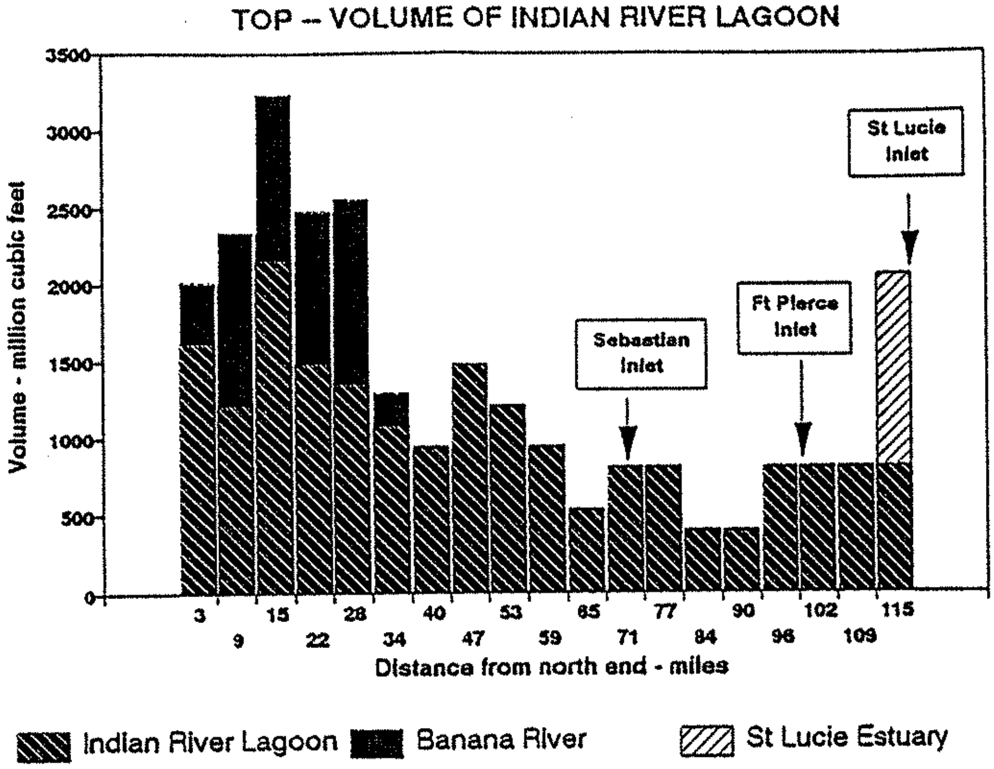
Table 3-2 and Figure 3-2 show that there is large difference between the ratio of the drainage basin (all lands exclusive of the Lagoon itself) surface area and the Lagoon surface area among the watersheds (total of Lagoon and surrounding drainage basins) of the 6 segments, with the northern segments having a much smaller amount of basin area in relation to the surface area of the Lagoon. This difference is an important factor for differences in Lagoon

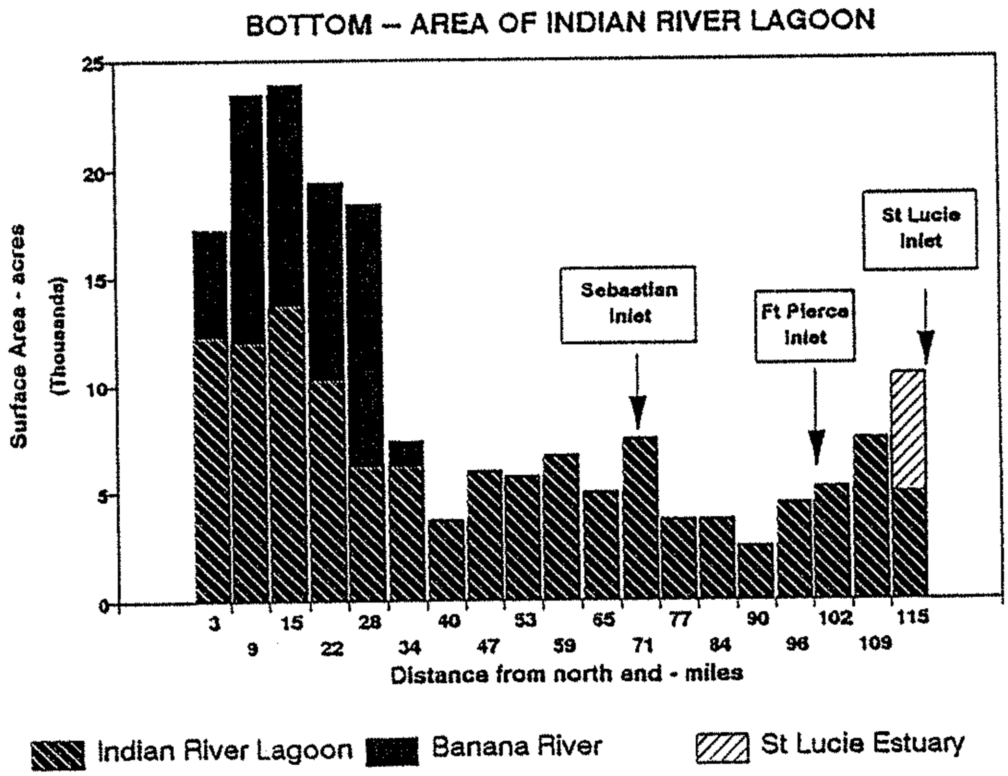
TABLE 3-2

LAGOON SURFACE AREA AND SURROUNDING WATERSHED AREAS OF THE INDIAN RIVER LAGOON SYSTEM

SEGMENT	LAGOON AREA		WATERSHED AREA		TOTAL AREA	
	km^2	acres	km^2	acres	km^2	acres
1A-Mosquito Lagoon	159	37,853	168	41,569	327	79,422
1B-Banana River	193	47,763	248	61,326	441	109,089
1C-North Indian River	286	70,728	454	112,197	740	182,925
2-North Central Indian River	93	23,089	429	105,866	522	128,955
3-South Central Indian River	71	17,486	724	178,947	795	196,433
4-South Indian River	125	30,820	2,903	716,845	3,028	747,665
TOTAL LAGOON	**927**	**227,739**	**4,926**	**1,216,750**	**5,853**	**1,444,489**

Source: MMA, 1993





Note: All Values at Mean Low Water

Sources: Glatzel and Da Costa, 1988a.

• Woodward-Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 3-2 VOLUME AND SURFACE AREA OF THE LAGOON IN 10-KM SECTIONS OF THE INDIAN RIVER LAGOON AND BANANA RIVER

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

functions and assimilative capacity of the various segments, as illustrated by the difference in the segment water budgets (Chapter 3.2).

The watershed differences are largely a result of the location of natural sandy ridges west of the Lagoon. Under historical conditions, the western limit of the natural watershed was determined by the position of these sandy coastal ridges which parallel the Lagoon. These ridges are remnants of old coastal dunes or barriers islands that were formed several thousand years ago when sea level was higher than it is today (Brooks, 1992). The primary watershed boundary ridge, the Atlantic Coastal Ridge, is no more than three miles from the Lagoon in Brevard and Volusia Counties. In Indian River County, a break in the Atlantic Coastal Ridge, through which the Sebastian River runs, naturally drains some of the area west of the Atlantic Coastal Ridge to the Lagoon. In the southern part of the Lagoon watershed, the Ten Mile Ridge (which is known as the Green Ridge in the most southern portions) becomes discontinuous and moves away from the coast to the west, allowing the St. Lucie River to drain waters from broad low-lying flats from ten to twenty miles away from the coast and the Lagoon.

The drainage pattern of Mosquito Lagoon (Segment 1A) is dominated by surface runoff with few natural streams. Similar conditions exist in the Banana River (Segment 1B) and in the Indian River Lagoon north of Melbourne (Segment 1C). Urban area surface runoff and ditch flow represent a substantial portion of the freshwater flow in the south end of Banana River (Segment 1B), the north end of Mosquito Lagoon (Segment 1A), and the portion of the North Indian River Lagoon (Segment 1C) south of Titusville. Seven wastewater treatment plants also contribute a substantial portion of the freshwater flow into Segments 1A, 1B, and 1C.

Drainage characteristics change to the south of Rockledge, due partly to the discontinuous nature of the ridge which allows for a greater drainage basin. In addition, extensive amounts of ditch and canal construction have occurred in the low-lying areas west of the Atlantic Coastal Ridge, extending the natural drainage basin even farther to the west in many places. Areas which used to be internally drained or which drained west to the St. Johns River and the Kissimmee River/Lake Okeechobee system have been hydraulically connected to the Lagoon by artificial canals. The drainage basin now extends up to 30 miles to the west in St. Lucie and Martin Counties. It has been estimated that up to 60% of the Indian River

Lagoon watershed is now comprised of artificially extended watershed, and that the former natural watershed of the Lagoon may have been only 2,319 km^2 (572,784 ac) as compared to the present 4,926 km^2 (1,216,750 ac) (Table 3-2).

Areas added to the watershed of the Lagoon by artificial diversion of natural drainage from other watersheds are known as "interbasin diversion areas". Much of the additional or extended drainage of these interbasin diversion areas is a result of drainage districts that were formed in the 1910s through 1930s under Chapter 298 of the Florida Statutes, which allowed the establishment of Chapter 298 Drainage Districts for purposes of controlling flooding and removing ground and surface water. Today, these "298 districts" remain exempt from discharge permitting requirements and regulations, other than for new construction.

The principal Chapter 298 drainage districts in the region are the:

- Melbourne-Tillman Drainage District (now known as the Water Control District of South Brevard) which discharges to Turkey Creek in Brevard County

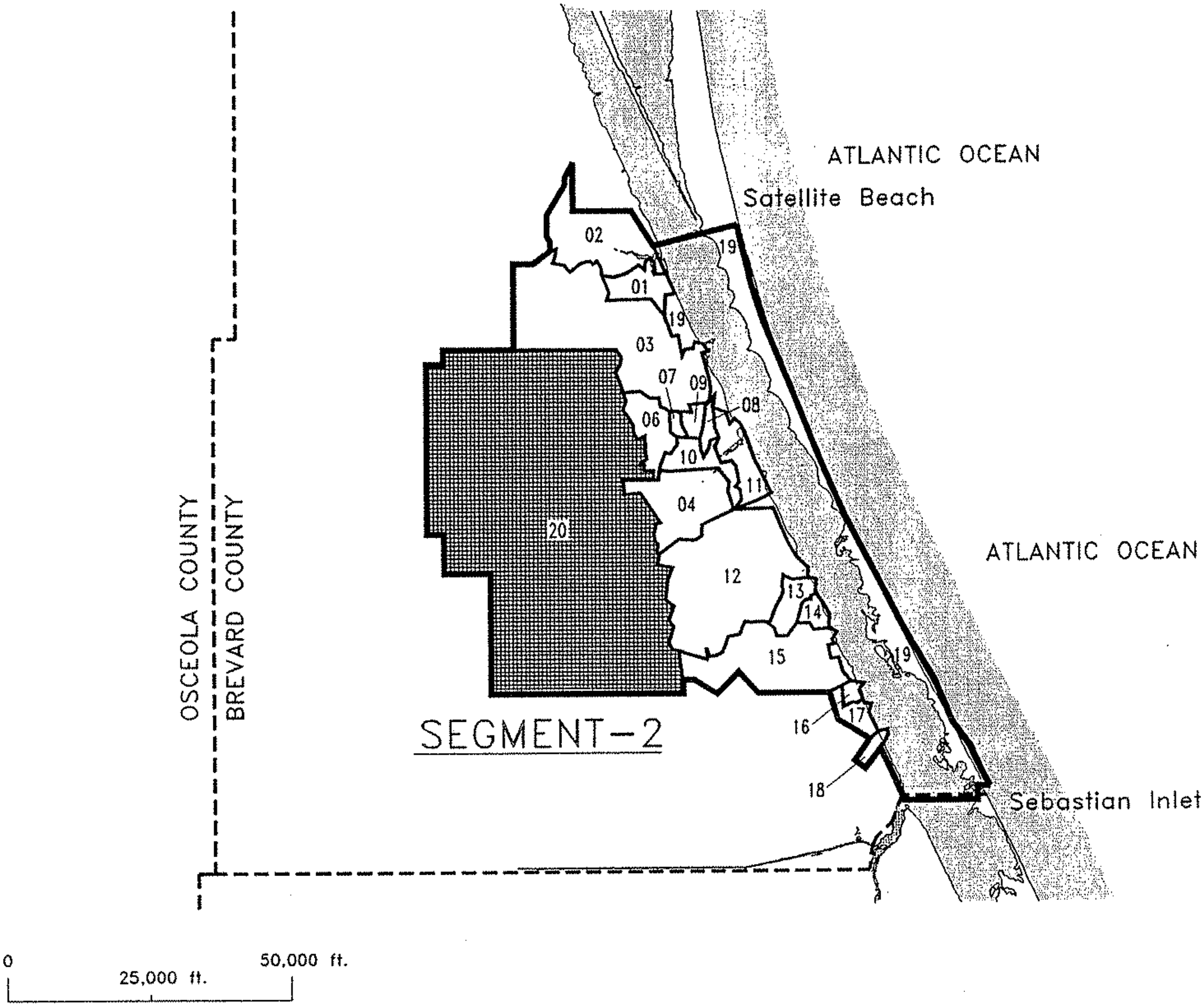
- Fellsmere Farms and Sebastian River Water Control Districts in Indian River County, which discharge to Sebastian River

- Indian River Farms Water Control District in Indian River County which discharges through the Vero North, Main, and South Canals to the Lagoon

- Ft. Pierce Farms and North St. Lucie Water Control Districts in St. Lucie County, which discharge to C-25 Canal or the Belcher Canal

Figures 3-3 to 3-5 show the sub-basins that include Chapter 298 drainage districts.

Another major ditch and canal system in the region is associated with the Central and South Florida Flood Control Project (CSFFCP), which includes large portions of St. Lucie and



LEGEND:

- = COUNTY BOUNDARIES
- = SEGMENT BOUNDARIES
- = WATER CONTROL DISTRICT OF SOUTH BREVARD
- 01 = SUB-BASINS

01–02	= ELBOW CREEK/EAU GALLIE RIVER		
03	= CRANE CREEK	16	= UNNAMED COASTAL
04–11	= TURKEY CREEK	17	= UNNAMED COASTAL
12	= GOAT CREEK	18	= UNNAMED COASTAL
13	= KID CREEK	19	= NORTH CENTRAL INDIAN RIVER LAGOON
14	= UNNAMED COASTAL	20	= WATER CONTROL DISTRICT OF SOUTH BREVARD
15	= TROUT CREEK		

N

SOURCE OF ALL DATA:
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

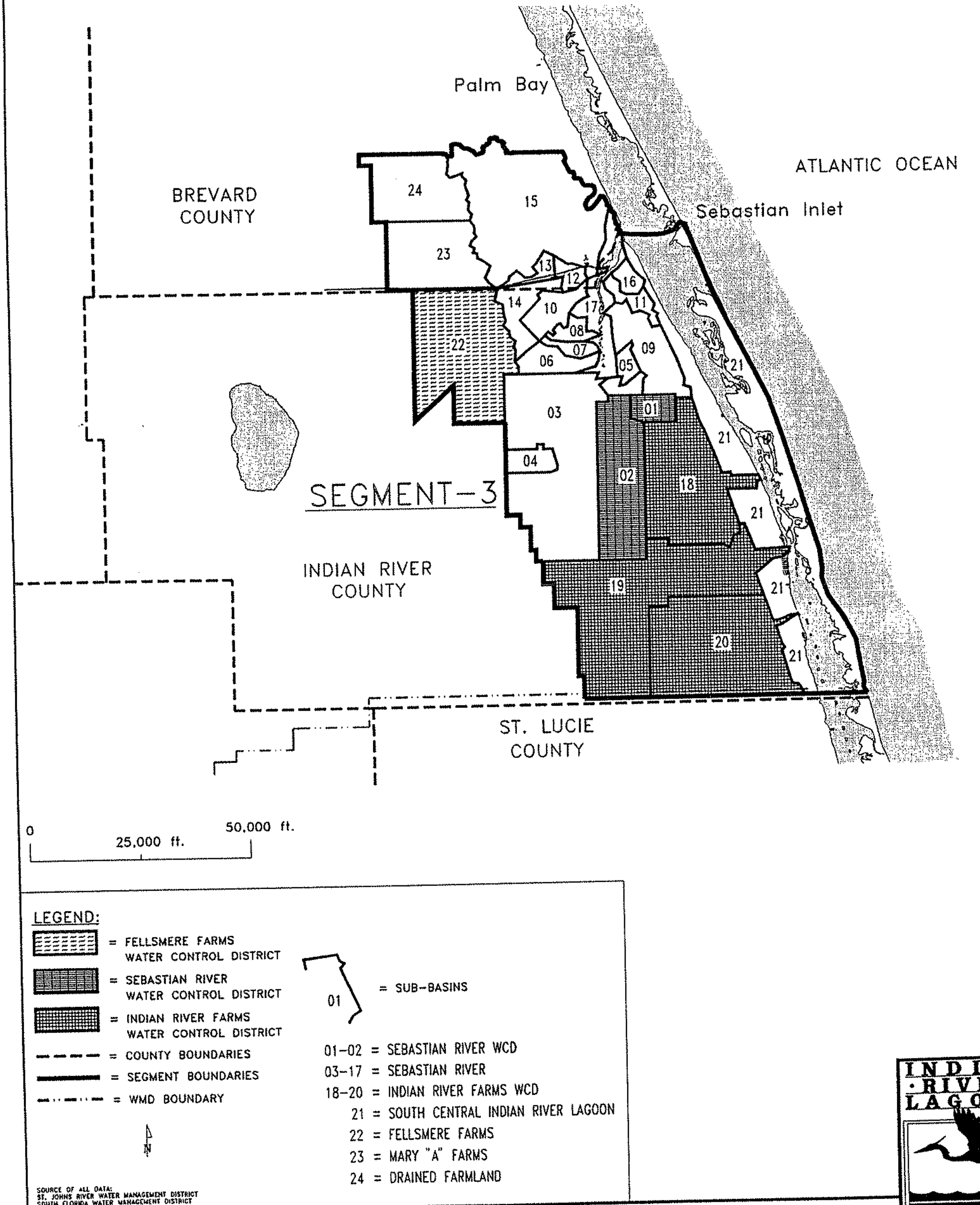
•Woodward–Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.: DRNSUB2.DWG

DATE: 8-16-94

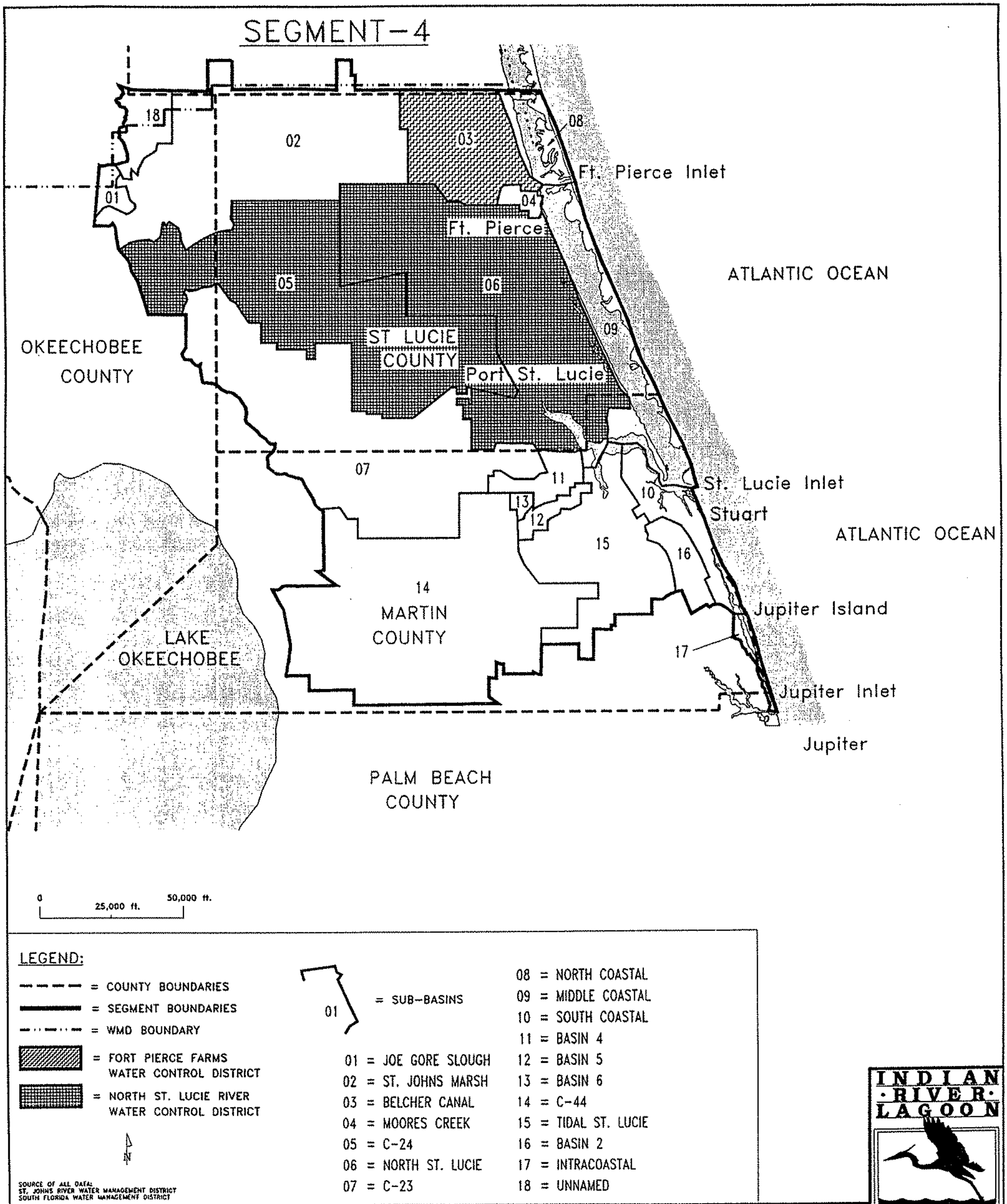
FIGURE 3–3 ACTIVE CHAPTER 298 DRAINAGE DISTRICTS IN THE NORTH CENTRAL INDIAN RIVER LAGOON WATERSHED (SEGMENT 2)

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



•Woodward-Clyde Consultants •Marshall McCully & Associates •Natural Systems Analysts	DRAWING NO.: DRNSUB3.DWG DATE: 8-16-94	FIGURE 3-4 ACTIVE CHAPTER 298 DRAINAGE DISTRICTS IN THE SOUTH CENTRAL INDIAN RIVER LAGOON WATERSHED (SEGMENT 3)

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



•Woodward-Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.: DRNSUB4.DWG

DATE: 8-16-94

FIGURE 3-5 ACTIVE CHAPTER 298 DRAINAGE DISTRICTS IN THE SOUTH INDIAN RIVER LAGOON WATERSHED (SEGMENT 4)

Martin Counties. This project was begun in the 1950s by the Corps of Engineers (COE) for control of flooding in south Florida (SJRWMD and SFWMD, 1993). The primary conveyance canals of this network are the C-25, C-24, and C-23 canals, which discharge to the Belcher Canal and North St. Lucie River in north and central St. Lucie County, and the C-44 or St. Lucie Canal.

The C-44, which is the largest drainage channel in the Lagoon watershed, was originally constructed between 1916 and 1924. It connects Lake Okeechobee to the South St. Lucie River through a control structure. During some storm events, this canal can discharge large volumes of water released from Lake Okeechobee to the St. Lucie River, causing great variability in the flow rates and salinity of the St. Lucie Estuary (SJRWMD and SFWMD, 1993). In 1991, a new schedule for releasing water from Lake Okeechobee was implemented to allow smaller releases over a longer period of time to reduce the variability of flow and salinity in the St. Lucie Estuary. It is too early to evaluate the effect caused by changes in the release schedule, but additional studies are being conducted by SFWMD (SJRWMD and SFWMD, 1993) to model and predict these effects as well as effects of other potential management options.

Additional information on the drainage and hydrology of the region can be found in Chapters 2.0 and 4.0 of the Physical Features Technical Report.

3.4 SOILS

Soils of the region fall into four general categories:

- Barrier island sands
- Soils typical of mainland coastal ridges, knolls, and higher elevation flatwoods
- Soils characteristic of swamps, marshes, sloughs, and low flatwoods and hammocks
- Soils of the tidal and waterfront areas

The barrier island sands may be moderately drained to excessively drained soils, or poorly drained tidal or waterfront soils. The coastal ridge soils are generally moderately drained to excessively drained. The higher elevation flatwoods have poor to moderate drainage characteristics due to a subsurface layer which impedes percolation. Soils of low flatwoods, swamps, marshes, and many hammocks are low lying and level, with poor to very poor drainage. The flatwoods soils are underlain by weakly cemented subsoils or hardpans, limiting infiltration and causing high water tables. The drainage of flatwoods soils can be relatively easily improved by ditching to remove standing water and lower the wet season groundwater table.

These soils can be divided into drainage groups, which have been defined by the Soil Conservation Service (SCS) as A, B, C, D, A/D, and B/D. Group A represents the best drained soils and includes the well-drained soils of the sand ridges. Groups B and C grade into less well-drained soils, and finally into Group D, which includes poorly-drained organic soils with high water tables. Groups A/D and B/D primarily include flatwoods soils with hardpans that naturally have poor infiltration rates when water tables are high (Group D), but can have good drainage with sufficient artificial drainage (Group A or B).

The types of soils in the watershed affect the function and water quality of the Lagoon. It is estimated that up to 70% of the soils of the watershed are flatwoods soils of the A/D or B/D groups. Most of these soils are in the extended watershed. This means that most of the watershed naturally had poor drainage and very little flow to the Lagoon, but that drainage was artificially improved by ditching to the Indian River Lagoon. This has resulted in significantly greater freshwater runoff from the watershed.

Soils in much of the barrier islands and directly adjacent to the west side of the Lagoon are well-drained to excessively drained sandy ridge soils, interspersed with poorly drained tidal or waterfront soils. While well-drained soils are usually considered well suited for septic systems because of their good drainage, they pose a special problem when adjacent to the Lagoon because the discharge from septic systems can easily and rapidly drain through the porous sands before bacteria and other pollutants have had a chance to be neutralized. Septic systems in poorly drained soils also tend to malfunction due to the high groundwater table that limits treatment in the soil and thus can discharge incompletely treated waste. Within the Indian River Lagoon watershed, there are numerous septic tanks located on up to

270,000 acres with soils poorly suited for this use. These septic systems may pose a threat to the Lagoon. Several studies have recently been completed to identify such areas (Indian River County Public Health Unit, 1992; Brevard County, 1993; Kearney and Kroesen, n.d.), but evaluation of the severity of the problem and potential management options have not yet been initiated (SJRWMD and SFWMD, 1993).

4.0 LOADINGS ASSESSMENT

4.1 POINT SOURCES

Point sources of potential pollutants are generally considered to be wastewater treatment plants or systems since the discharge is usually through a discrete and identifiable point. There are five basic classes of wastewater treatment systems in the region, categorized by discharge volume and treatment type. In the following list, the flow range of each class is shown, followed by the potential total possible design flows (as of 1993) of each class as allowed by permits in the Indian River Lagoon watershed:

- Regional wastewater treatment plants - Flow range is an average annual flow >5 million gallons per day (MGD) average daily flow (ADF); permitted design flow is 15.0 MGD

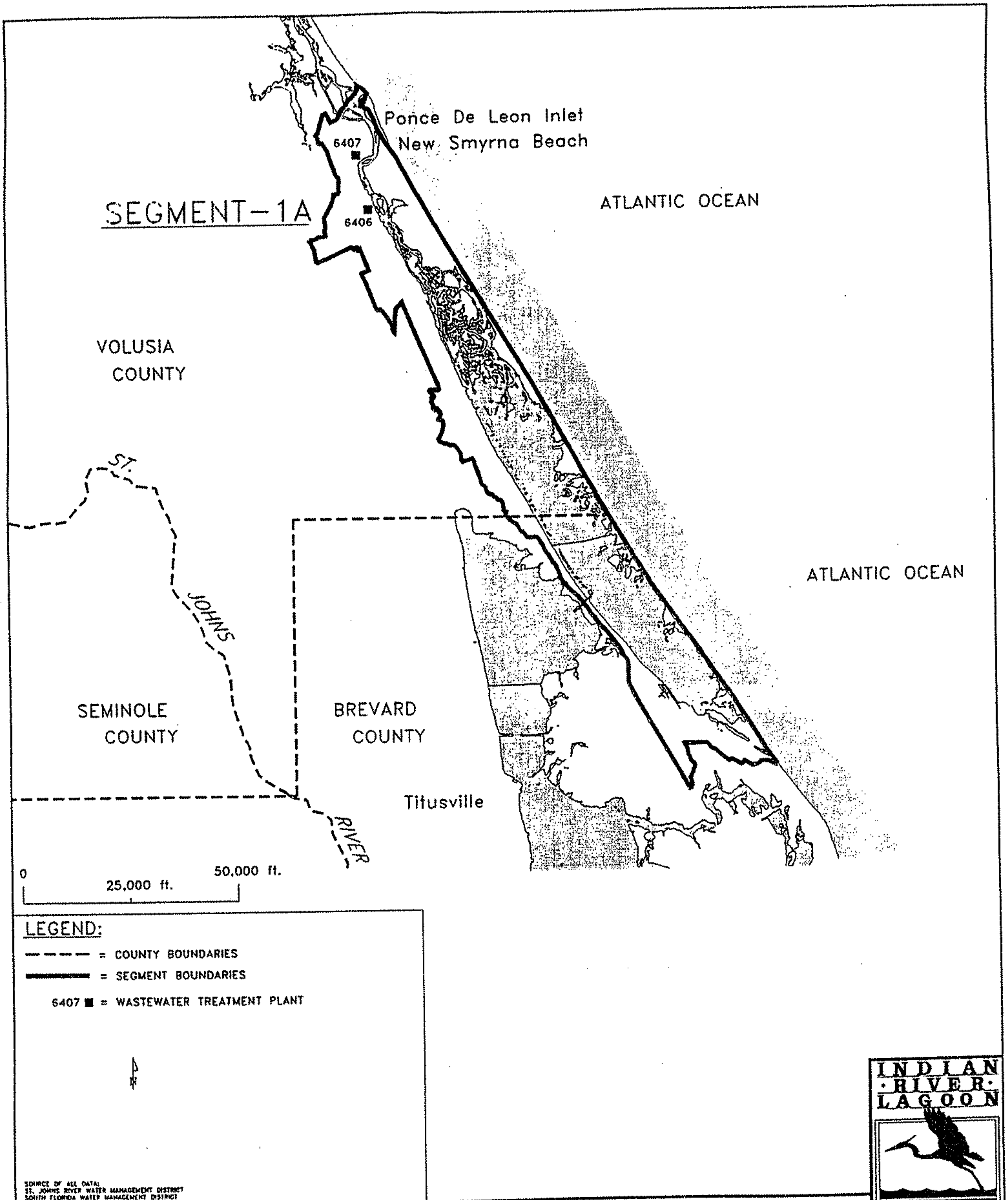
- Sub-regional wastewater treatment plants - Flow range is an average annual flow of 1.0 to 5.0 MGD ADF; permitted design flow is 28.6 MGD

- Package wastewater treatment plants - Flow range is an average annual flow of 0.001 to 1.0 MGD ADF; permitted design flow is 11.0 MGD

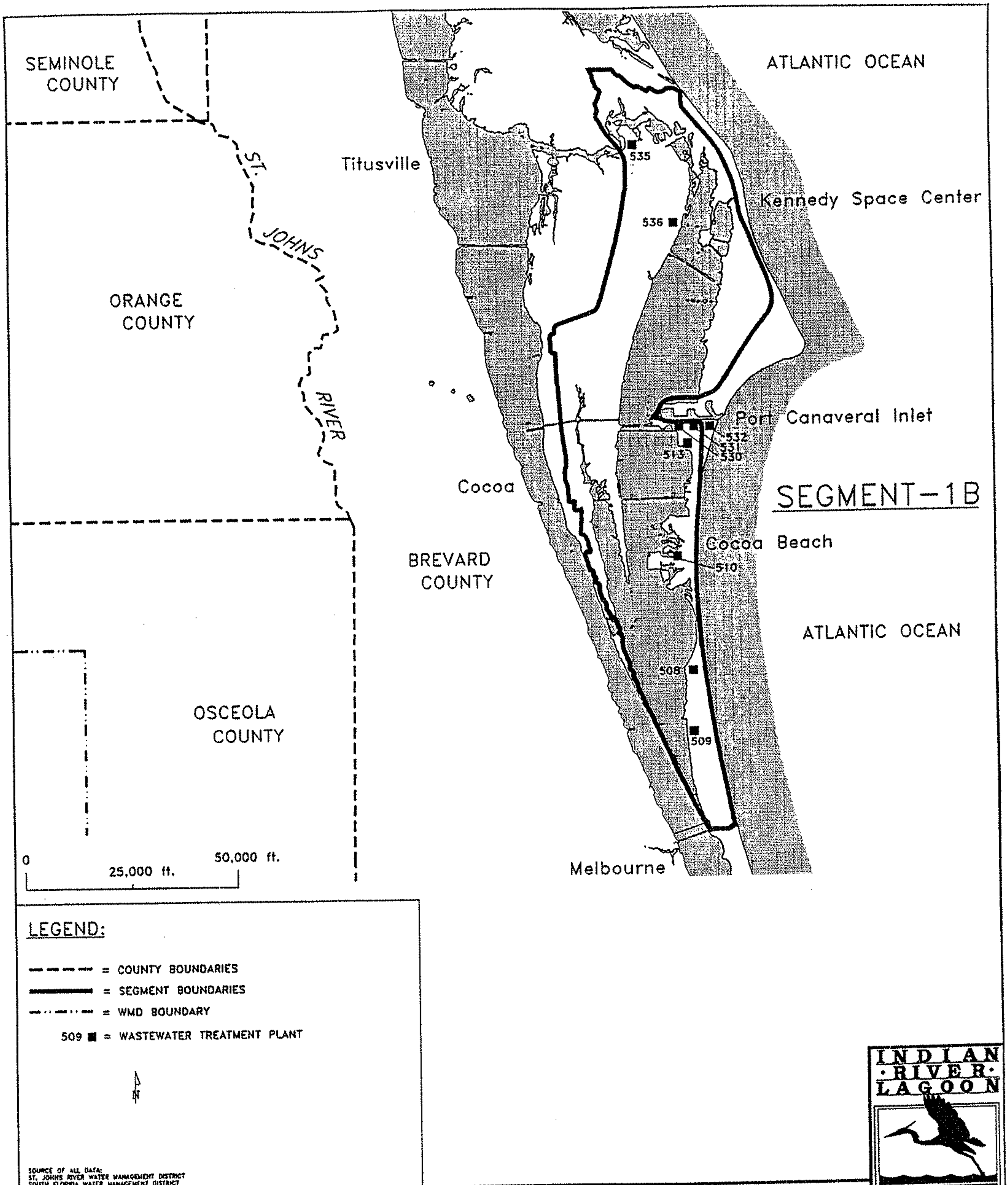
- Septic tank and drainfield systems - Estimated existing average annual flow per unit is 0-0.001 MGD ADF

- Industrial wastewater treatment plants - No limit to flow range; permitted average annual flow is over 1,800 MGD

The locations of wastewater treatment plants are shown in Figures 4-1 to 4-6. The names and characteristics of each plant are contained in the Point and Non-point Source Loads Assessment Technical Report, based on the identifying numbers shown in these figures. As of November 1993, there are only two regional wastewater treatment systems discharging directly into the Indian River Lagoon. These are the Ft. Pierce Utility Authority treatment



•Woodward–Clyde Consultants •Marshall McCully & Associates •Natural Systems Analysts	DRAWING NO.: SEG1AWTP.DWG DATE: 6-22-94	FIGURE 4-1 WASTEWATER TREATMENT PLANTS DISCHARGING DIRECTLY TO MOSQUITO LAGOON - SEGMENT 1A



·Woodward-Clyde Consultants
·Marshall McCully & Associates
·Natural Systems Analysts

DRAWING NO.: SEG1BWTP.DWG

DATE: 6-29-94

FIGURE 4-2 WASTEWATER TREATMENT PLANTS DISCHARGING DIRECTLY TO BANANA RIVER - SEGMENT 1B

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

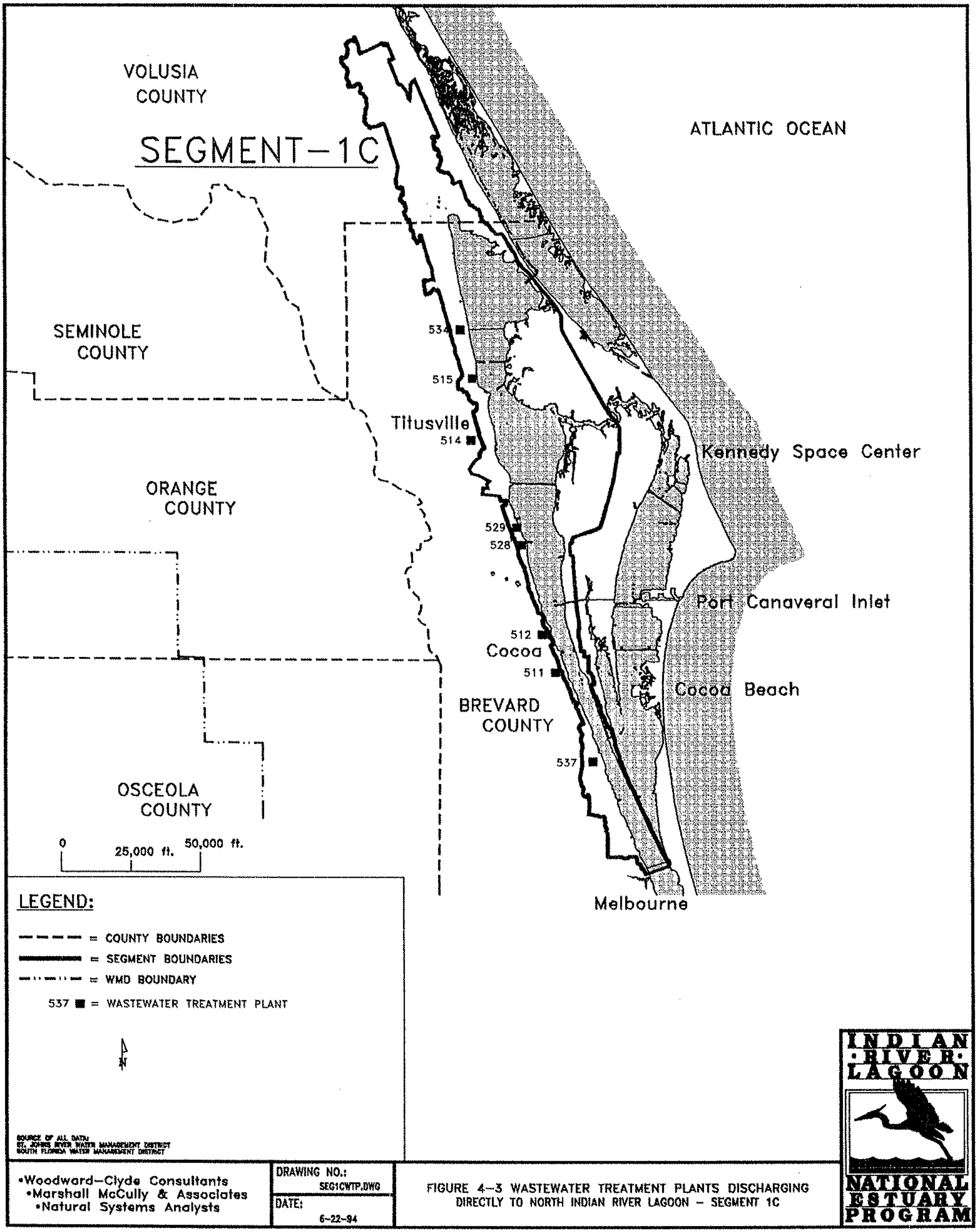
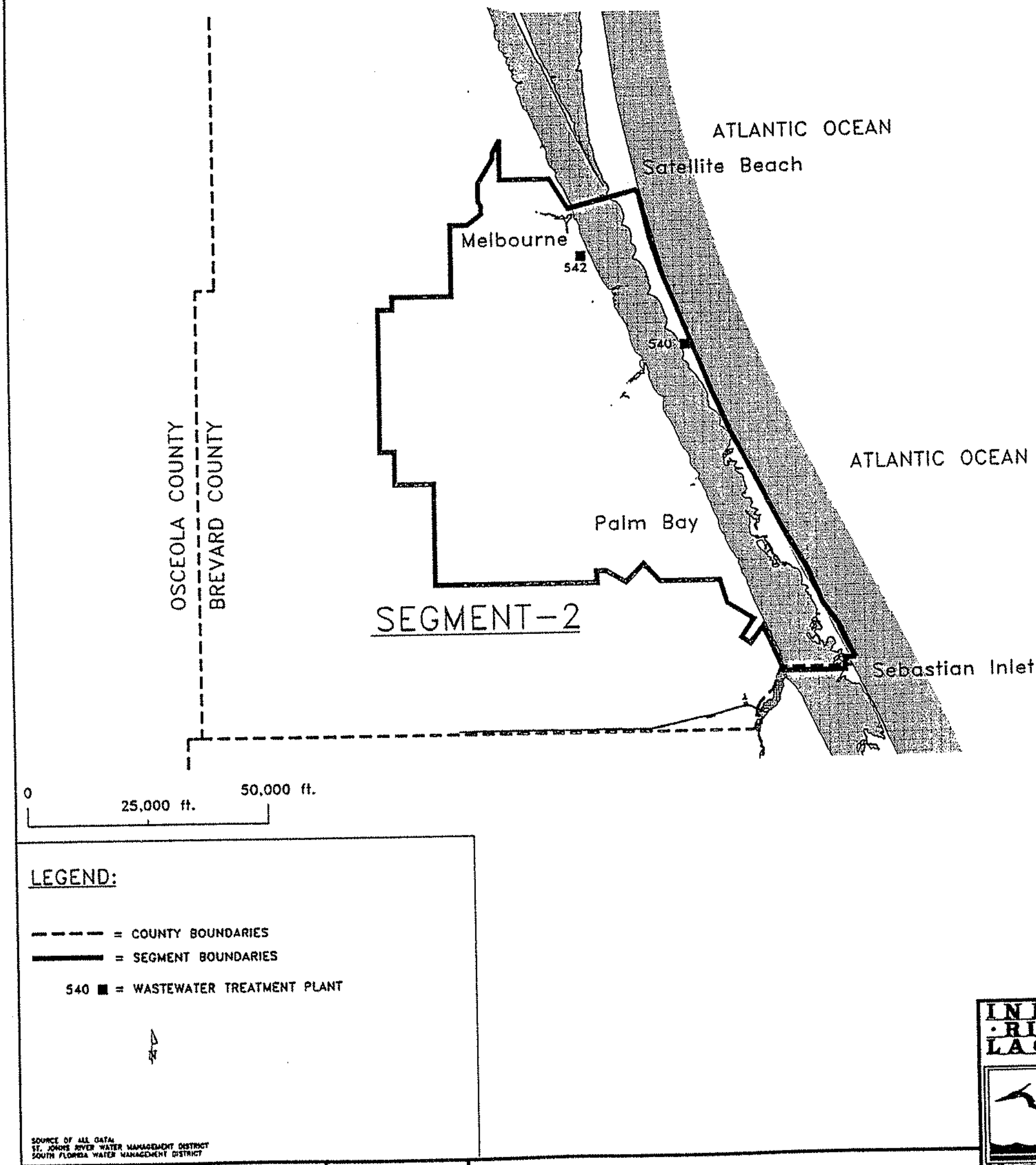
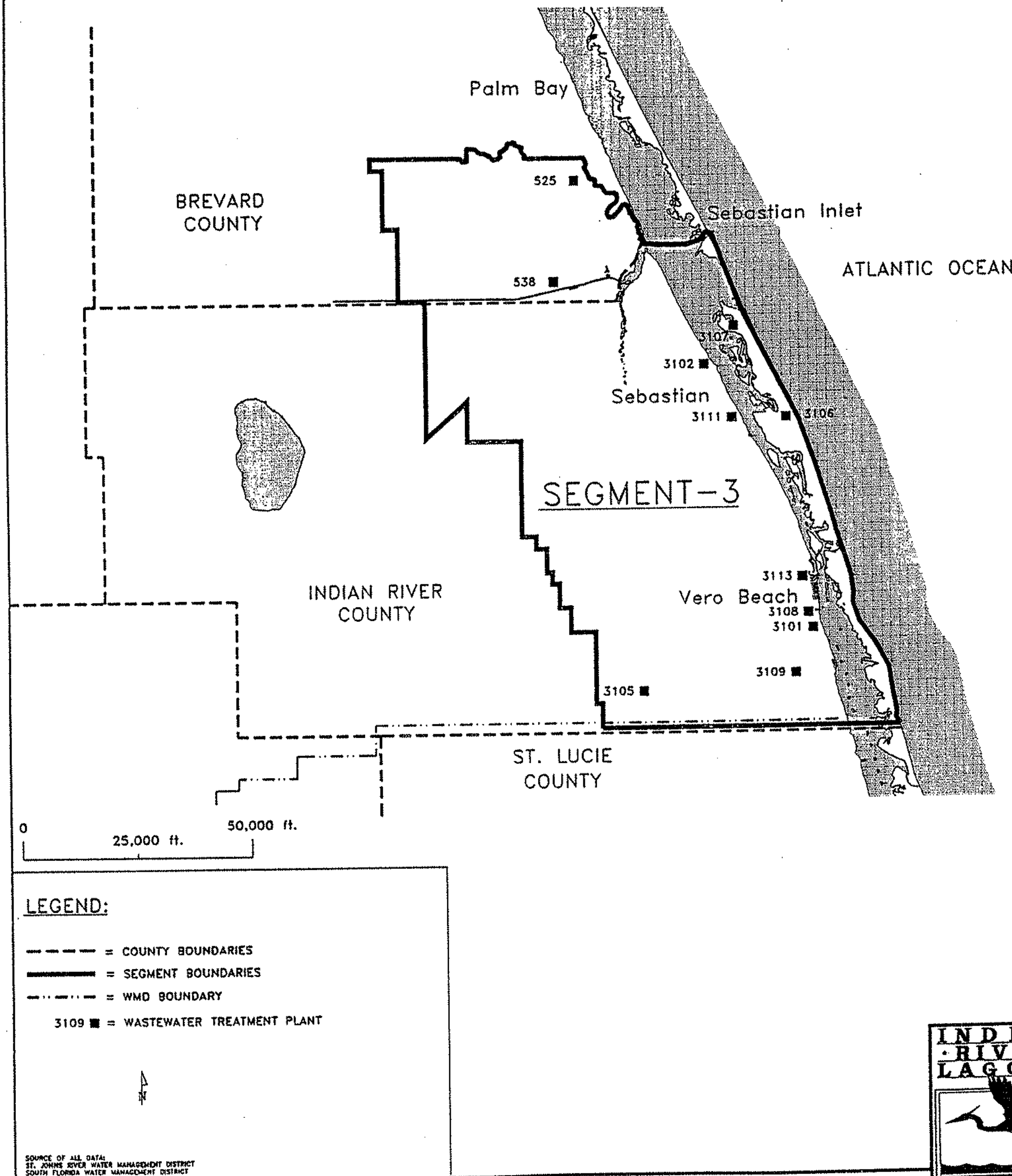


FIGURE 4–3 WASTEWATER TREATMENT PLANTS DISCHARGING DIRECTLY TO NORTH INDIAN RIVER LAGOON – SEGMENT 1C



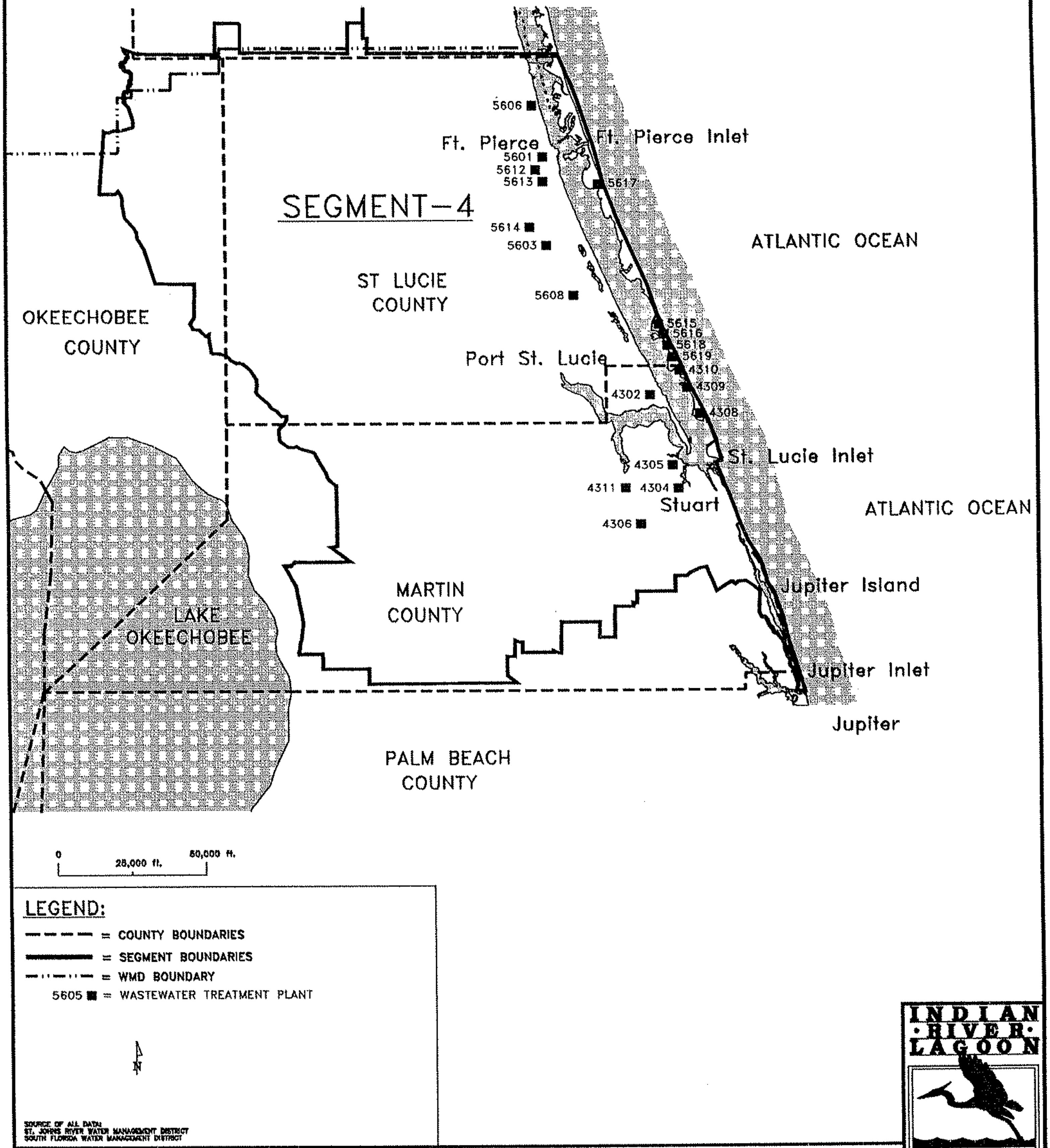
•Woodward–Clyde Consultants •Marshall McCully & Associates •Natural Systems Analysts	DRAWING NO.: SEG2WTP.DWG DATE: 6-29-94	FIGURE 4-4 WASTEWATER TREATMENT PLANTS DISCHARGING DIRECTLY TO NORTH CENTRAL INDIAN RIVER LAGOON - SEGMENT 2

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



•Woodward–Clyde Consultants •Marshall McCully & Associates •Natural Systems Analysts	DRAWING NO.: SEG3WTP.DWG DATE: 6-22-94	FIGURE 4-5 WASTEWATER TREATMENT PLANTS DISCHARGING DIRECTLY TO SOUTH CENTRAL INDIAN RIVER LAGOON - SEGMENT 3

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



•Woodward-Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.: SEG4WTP.DWG
DATE: 6-29-94

FIGURE 4-6 WASTEWATER TREATMENT PLANTS DISCHARGING DIRECTLY TO SOUTH INDIAN RIVER LAGOON – SEGMENT 4 plant in St. Lucie County (# 5617 on Figure 4-6) with a design flow of 9.0 MGD and the City of Cocoa Beach plant in Brevard County (# 510 on Figure 4-2) with a design flow of6.0 MGD. Average flow from all regional plants in the 1989-1990 period was about 33% to 50% of the design flow (FDEP, 1991).

In addition, there are currently 10 sub-regional facilities with a combined design flow of 28.6 MGD (FDEP, 1991). They are as follows:

- Utilities Commission/City of New Smyrna Beach, 4.0 MGD design flow - Segment 1A
- City of Edgewater, 2.50 MGD design flow - Segment 1A
- City of Cape Canaveral, 1.80 MGD design flow - Segment 1B
- Patrick Air Force Base/Capehart South, 1.0 MGD design flow - Segment 1B
- Patrick Air Force Base/Capehart North, 1.0 MGD design flow - Segment 1B
- City of Cocoa, 4.50 MGD design flow - Segment 1C
- City of Rockledge, 4.50 MGD design flow - Segment 1C
- City of Titusville (North), 2.75 MGD design flow - Segment 1C
- City of Titusville (South), 2.0 MGD design flow - Segment 1C
- City of Vero Beach, 4.5 MGD design flow - Segment 3

Of this sub-regional facility discharge, 6.5 MGD is discharged to Mosquito Lagoon (Figure 4-1); 3.8 MGD is discharged to Banana River (Figure 4-2); 13.8 is discharged to the North Indian River Lagoon (Figure 4-3); and 4.5 MGD is discharged to the South Central Indian River Lagoon (Figure 4-5). Actual sub-regional flows as of November 1992 were about 15.0 MGD.

There are no regional or sub-regional facilities that directly discharge to the North Central or South Indian River Lagoon (Segments 2 and 4) (Figures 4-4 and 4-6). There are many package wastewater treatment plants in these segments. Most of these are privately constructed and operated. Ten package treatment plants discharge directly to the Indian

River Lagoon, while over 100 discharge to groundwater aquifers in these two segments. There is evidence that some surficial aquifer discharge to the Indian River Lagoon may occur in Segments 2, 3, and 4 (Pandit and El-Khazen, 1990), while discharge from the intermediate and Floridan aquifers may occur near the northern end of the system in Segment 1C (Toth, 1987), so there is a possibility that some of this discharge may eventually reach the Lagoon.

As directed by Chapter 90-262 of the Florida Statutes, the Florida Department of Environmental Protection (FDEP) (1991) evaluated the package treatment plants and determined that 152 of these treatment plants constituted a potential water quality threat to the Lagoon because they discharge directly into the Lagoon, have percolation ponds or other sub-surface disposal systems within 100 feet of the Lagoon or its tributaries, or have had problems with operating reliability. The breakout of these facilities by Lagoon segment is shown in Table 4-1.

Chapter 90-262 also requires that all domestic wastewater treatment plants cease direct discharge to the surface waters of the Indian River Lagoon by 1996 for the expressed purpose of aiding in restoration and protection of the water quality of the Lagoon. If this is fully implemented as intended, approximately 24 MGD of domestic waste effluent flow will stop entering the Lagoon. This reduction will be apportioned among the segments as shown in Table 4-2.

The largest industrial wastewater sources are the four electric power generating plants which utilize Lagoon water for cooling and then re-discharge the heated effluent water to the Lagoon. These are the Orlando Utilities Commission (OUC) and Florida Power and Light (FPL) plants south of Titusville (# 529 and 528 on the Figure 4-4), the Vero Beach Municipal Power Plant (# 3108), and the Ft. Pierce Utilities Authority plant (# 5612). The total permitted discharge for the power plants is about 1,800 MGD. This water does not have the nutrient and pathogen components of domestic wastewater plants, but does have high temperature, as well as trace levels of chlorine and other contaminants picked up in use.

Another major industrial discharge comes from the reverse osmosis (RO) water treatment plants used to desalinate salt water for potable (drinking) water supplies. As of 1993, there

TABLE 4-1

PACKAGE WASTEWATER TREATMENT PLANTS CONSIDERED BY THE FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION TO BE POTENTIAL WATER QUALITY THREATS TO THE INDIAN RIVER LAGOON

SEGMENT	NUMBER OF POTENTIALLY THREATENING PACKAGE FACILITIES
1A - Mosquito Lagoon	1
1B - Banana River Lagoon	14
1C - North Indian River Lagoon	13
2 - North Central Indian River	5
3 - South Central Indian River	21
4 - South Indian River Lagoon	98

Source: FDEP, 1991

TABLE 4-2

REDUCTIONS IN DOMESTIC WASTE EFFLUENT FLOW ANTICIPATED BY 1996 UNDER THE NO DISCHARGE RULE OF CHAPTER 90-262 OF THE FLORIDA STATUTES

SEGMENT	REDUCTION IN ACTUAL FLOW (MGD) BY FACILITY TYPE			
	REGIONAL	SUBREGIONAL	PACKAGE	TOTAL
1A	0.0	2.7	0.0	2.7
1B	2.2	2.4	0.0	4.6
1C	0.0	7.8	0.0	7.8
2	0.0	0.0	0.4	0.4
3	0.0	2.7	0.0	2.7
4	5.2	0.0	0.2	5.4
TOTAL	**7.4**	**15.6**	**0.6**	**23.6**

Source: Based on data from FDEP, 1991

was a total RO wastewater flow of 4.1 MGD with another 9.8 MGD of new facilities proposed. Discharge from these facilities may contain elevated levels of brine (saline water), total dissolved solids, iron, or sulfur. Other industrial wastewater discharges, which total about 5 MGD include effluent from seafood packing plants, citrus processors, landfill and borrow pits, and general industrial facilities. The seafood packing plants are located only in Port Canaveral, and FDEP has issued orders to the seafood packing plants to cease discharges.

4.2 SEPTIC PLANT AND DRAINFIELD SYSTEMS

Septic systems may be unsuitable for much of the Lagoon watershed region because of the combination of a very high proportion of unsuitable soils with a high water table. These septic systems, or On-Site Disposal Systems (OSDS), are generally privately owned and maintained. OSDS is the waste disposal method of a large number of homes in the region, many of which are located close to the Lagoon. They may pose a potential threat to the Lagoon water quality because they can contribute phosphorus and nitrogen to the Lagoon, as well as fecal coliform bacteria (Longley, 1989).

Based on information from recent surveys of OSDS served areas (Indian River County Public Health Unit, 1992; Brevard County, 1993; Moses and Anderson, 1993; Kearney and Kroesen, n.d.), OSDS is estimated to treat over 17 MGD of wastewater discharge in the Indian River Lagoon watershed, an amount which comprises between 35% and 45% of the total domestic wastewater generated in the watershed.

The SJRWMD and SFWMD, in cooperation with the counties of the region, have recently compiled a survey required by Chapter 90-262 of the Florida Statutes identifying areas where OSDS are considered to be a threat to the water quality of the Indian River Lagoon system. Over 270,000 acres of potentially high or medium priority problem areas were identified and are broken down by segment in Table 4-3.

Of particular concern are those areas located near the major shellfish (clam and oyster harvesting only) harvesting waters of the Lagoon, where fecal coliform bacteria contamination may be a special problem. These include areas in Brevard, Volusia, and Indian River Counties. Essentially all areas served by OSDS in Brevard County on both

TABLE 4-3

EXTENT OF POTENTIAL HIGH AND MEDIUM PRIORITY PROBLEM AREAS WHERE OSDS UNITS ARE CONSIDERED TO BE POTENTIAL THREATS TO WATER QUALITY OF THE INDIAN RIVER LAGOON

SEGMENT	PROBLEM AREAS (ACRES)
1A - Mosquito Lagoon	20,450
1B - Banana River Lagoon	1,043
1C - North Indian River Lagoon	4,961
2 - North Central Indian River	7,262
3 - South Central Indian River	20,135
4 - South Indian River Lagoon	231,370

Source: Indian River County Public Health Unit, 1992
Brevard County, 1993
Moses and Anderson, 1993
Kearney and Kroesen, n.d.
Bielby, 1992

shores of the Indian River Lagoon between Mims (north of Titusville) and the Bennett Causeway (Highway 528) at Cocoa in Segment 1C are considered to be high priority areas for replacing OSDS with central sewer systems because of proximity to shellfish Bodies A, B, and C. Several areas totalling over 7,000 acres near the southern Brevard shellfish area (Body F) between Palm Bay and Sebastian Inlet (Segment 2) are also under consideration as high priority areas for alleviating potential water quality and bacterial contamination threats of OSDS (Brevard County, 1993).

Problem areas in the Mosquito Lagoon watershed (Segment 1A) include Bethune Beach and much of Florida Shores. Both of these areas are expected to be served by central wastewater systems by 1995 (Bielby, 1992). OSDS problem areas in the Banana River basin (Segment 1B) are located mainly on Merritt Island on the west shore of Banana River. In Indian River County, which includes all of Segment 3, most of the high and medium priority areas are centered around Vero Beach and the towns of Fellsmere and Sebastian. High priority areas in Segment 4 are generally considered to be parts of Port St. Lucie and Stuart and surrounding unincorporated areas on the barrier island and adjacent to the St. Lucie River (Moses and Anderson, 1993; Kearney and Kroesen, n.d.).

4.3 NON-POINT SOURCES

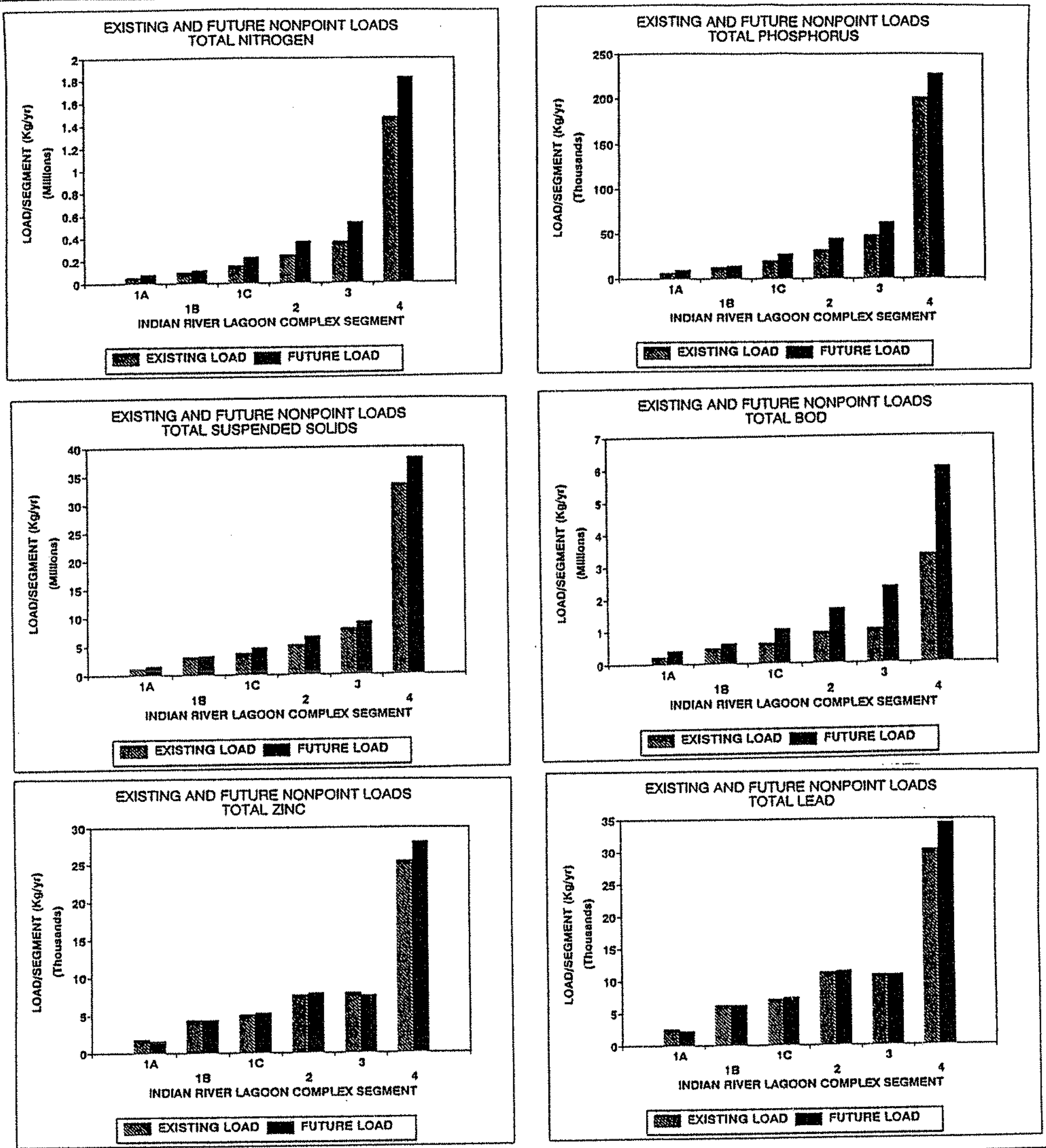
Non-point sources generally are a result of stormwater runoff that flows either directly to the Lagoon by overland surface flow or enters the Lagoon as stream or tributary flow. Livingston (1990) reports that up to 99% of the suspended solids, 90% of the metals and oxygen consuming materials, and 50% of the nutrients contributed to Florida waters are from this non-point source. Other major contaminants include oil and gas residues, fecal coliform bacteria, and pesticides (Wanielista and Yousef, 1993: Pait, et al., 1992).

It is not practical to measure directly all non-point source loadings throughout the Lagoon system. The common practice in estimating watershed wide loadings is to determine the amount of pollutant that comes from smaller, more easily measured areas and to use this data to develop loading rates for similar types of areas. A model is then developed to predict the loads for a watershed based on these loading rates and the amounts of each type of area in the watershed.

As part of this study, a model was used to estimate the total non-point source stormwater runoff loads for the existing state of the Lagoon based on data from the 1990-1992 period and the future condition based on land use projections through the year 2010. The model utilized was the Pollution Load Screening Model (PLSM) developed by the SJRWMD. This model, described in the Point and Non-Point Source Loads Assessment Technical Report, takes into account soil conditions, rainfall variability, and land use. It uses pollutant loading rates from studies of similar areas to predict total loads. Parameters which were modeled were total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), biological oxygen demand (BOD), lead (Pb), and zinc (Zn). These parameters were selected as being representative of important nutrient, turbidity/sediment, and toxic substance conditions.

This model utilized maps of existing land use and projections of future land use which were made on the basis of each county's and municipality's future land use elements of their Growth Management Plans. Loading rates were used for 36 combinations of land use and soil drainage/hydrologic group, which have been developed and confirmed as typical of Florida conditions by several researchers (Chow, 1964; Adamus and Bergman, 1993; Marshall, 1993; Wanielista and Yousef, 1993). For future conditions, it was assumed that all new development would be utilizing best management practices and meeting current regulations for control of stormwater. Allowances of 15% to 80% efficiency of pollutant removal were made, depending on parameter, to account for stormwater treatment that will be required for new development.

Figure 4-7 shows the resultant non-point source load projections for each segment of the Indian River Lagoon system. For all parameters, the highest annual loads are contributed by the watershed of Segment 4 (South Indian River Lagoon). Additionally, with the exception of lead and zinc, loads will increase for the future land use condition, even though stormwater treatment will be applied to new development. BOD is projected to increase at a greater rate than the other components. This is due to the fact that the efficiency of removal of existing management and treatment practices is less for BOD (15%) than for the other components (30%-80%).



INDIAN RIVER LAGOON

NATIONAL ESTUARY PROGRAM

Source: MMA, 1993.

• Woodward-Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 4-7 EXISTING AND FUTURE NON-POINT SOURCE POLLUTANT LOADS FOR EACH SEGMENT

Table 4-4 compares the total nutrient loads computed by the model for the existing and future condition for each segment of the Lagoon, with the point source nutrient loads based on maximum permitted discharge rates.

The numbers shown in this table are in pounds per year and are the sum of the nitrogen and phosphorus loadings. Since nitrogen and phosphorus water quality effects differ and the values are not directly additive, the numbers in this table are for comparative purposes only.

This data illustrates several characteristics of the loadings from the Indian River Lagoon system watershed. The point sources contribute the majority of the total loads in the Mosquito Lagoon, Banana River, and Indian River Lagoon north of the south end of Merritt Island (Segments 1A, 1B, 1C). In portions of the Indian River Lagoon (Segments 2,3,4) which are south of this area, non-point source loads are 3 to 10 times greater than point source loadings.

When direct wastewater treatment plant discharges to the Lagoon are terminated as required by Chapter 90-262, substantial decreases in total nutrient loads may occur in Mosquito Lagoon, Banana River, and North Indian River Lagoon (as illustrated in the Future Non-point Sources column in Table 4-4). However, total loads in the North Central, South Central, and South Indian River Lagoon segments (Segments 2,3,4) are estimated to increase as a result of increases in non-point source loads, despite reduction of point source loads.

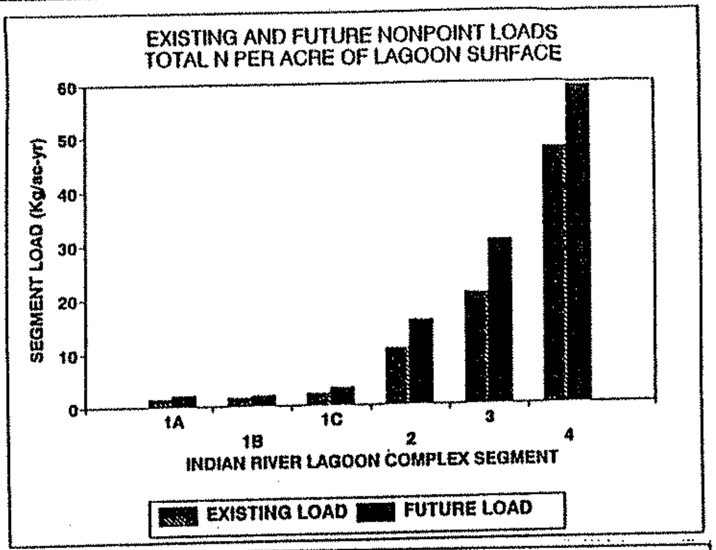
Figure 4-8 shows the existing and projected future non-point source loads per segment expressed in terms of the surface area of the Lagoon. Expression of loading rates on a per acre of Lagoon basis provides a measure of the degree of loading or saturation of the assimilative capacity of the Lagoon. Figure 4-8 indicates that the central and particularly the southern portions of the system (Segments 2, 3, and 4) will receive the heaviest loads, and that the input of oxygen consuming materials (BOD) in the future is expected to increase at a greater rate than other pollutants.

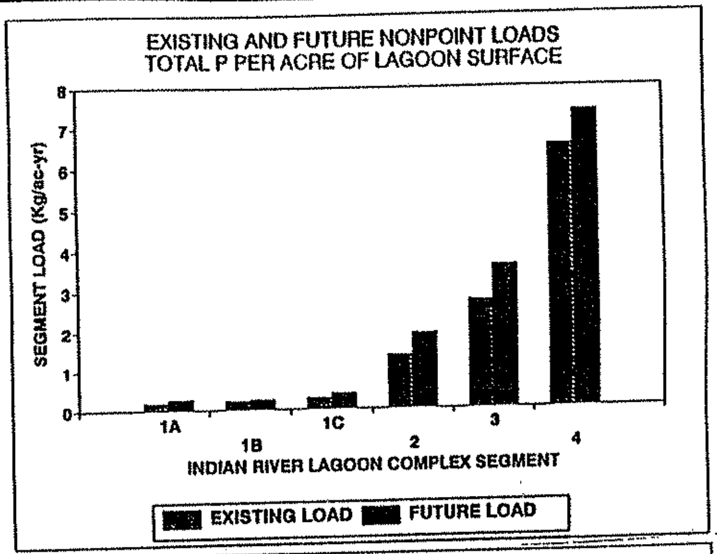
Table 4-5 shows the rankings of calculated future condition loads discharging to the Lagoon from each sub-basin in the Lagoon watershed. Sub-basins have been ranked in Table 4-5

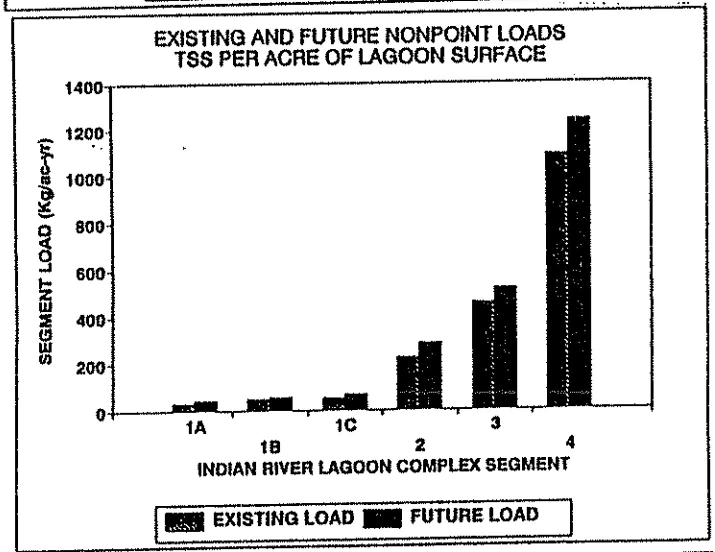
TABLE 4-4

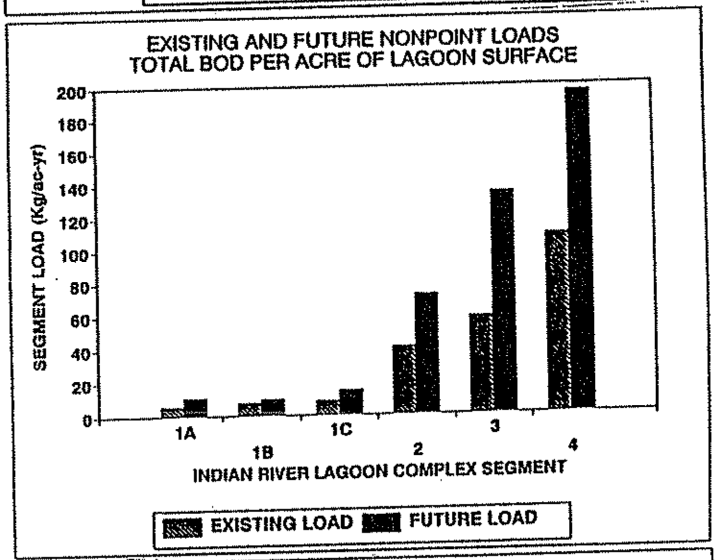
ESTIMATED TOTAL NUTRIENT LOADINGS FOR THE INDIAN RIVER LAGOON FOR THE EXISTING AND FUTURE CONDITIONS

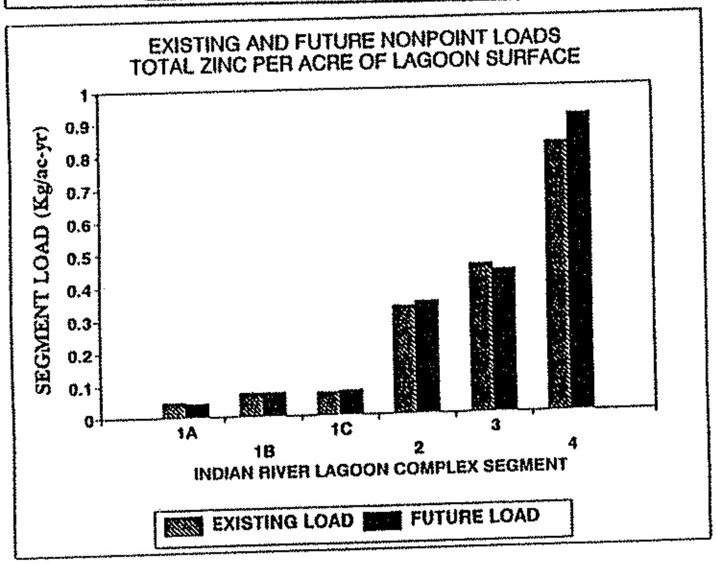
SEGMENT	ESTIMATED TOTAL NUTRIENT (TN+TP) LOADINGS (LBS/YR)			
	EXISTING POINT SOURCES	EXISTING NON-POINT SOURCES	EXISTING TOTAL SOURCES	FUTURE NON-POINT SOURCES
1A	289,095	112,647	401,742	168,372
1B	566,608	206,403	773,011	255,209
1C	679,351	340,472	1,019,823	502,874
2	52,035	524,681	576,716	809,106
3	261,910	799,897	1,061,807	1,185,316
4	543,481	3,236,294	3,779,775	4,019,202
TOTAL	**2,392,480**	**5,220,394**	**7,612,874**	**6,940,079**

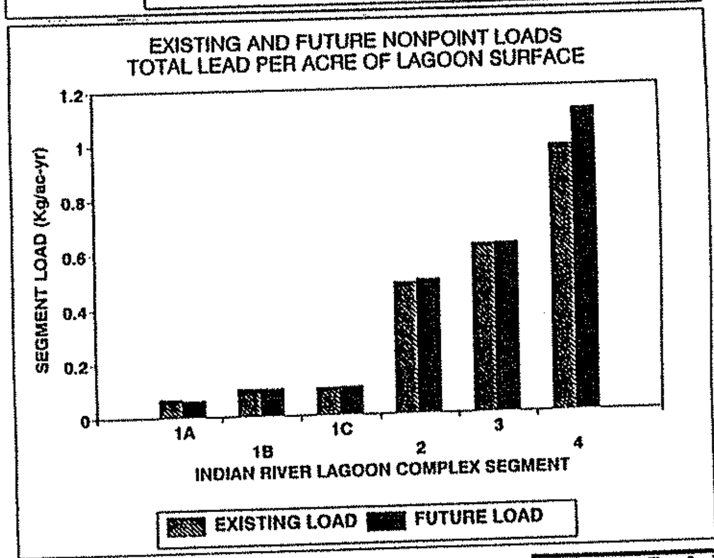












Source: MMA, 1993.

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 4-8 EXISTING AND FUTURE NON-POINT SOURCE POLLUTANT LOADING RATES PER ACRE OF LAGOON SURFACE

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

TABLE 4-5

RANKING OF SUB-BASINS BASED ON FUTURE NITROGEN LOADS TO THE INDIAN RIVER LAGOON COMPLEX

SEGMENT	SUB-BASIN	NAME	TN (kg/yr)	TP (kg/yr)	TSS (kg/yr)	BOD (kg/yr)	Zn (kg/yr)	Pb (kg/yr)
4	06	North St. Lucie	407,734	47,653	8,132,315	1,720,426	7,774	10,515
4	14	C-44	298,479	39,841	6,919,817	733,920	3,808	4,194
4	07	C-23	276,462	37,080	5,985,679	562,699	3,049	3,004
4	05	C-24	248,665	32,222	5,149,932	617,427	2,823	3,025
1C	06	North Indian River Lagoon*	173,830	21,065	3,775,955	816,682	4,323	5,967
3	18-20	Indian River farms WCD*	171,709	21,374	3,172,363	882,969	2,384	3,543
3	03-17	Sebastian River	165,761	17,623	2,354,467	616,527	2,210	3,176
4	02	St. Johns Marsh	164,907	22,047	3,483,793	331,379	1,916	1,916
2	20	...*	158,194	18,644	2,303,930	608,038	2,877	4,187
4	03	Belcher Canal	135,638	14,777	2,687,199	806,541	2,704	3,624
4	15	Tidal St. Lucie	117,142	13,751	2,241,819	407,212	1,854	2,362
3	21	South Central Indian River Lagoon*	96,777	12,768	2,054,091	552,727	2,044	2,818
1B	01	Banana River*	71,988	9,239	2,468,091	387,416	3,403	4,829
1A	02	Mosquito Lagoon*	63,221	7,906	1,271,315	318,550	1,377	1,963
2	03	Crane Creek*	52,233	6,734	1,327,208	289,235	1,535	2,222
4	04+09	Moore's Creek	50,612	5,914	1,008,671	258,416	1,317	1,830
1B	02	Sykes Creek*	43,774	5,135	805,773	209,671	1,014	1,403
2	04-11	Turkey Creek*	42,315	5,503	917,397	220,514	1,124	1,610
4	10	South Coastal	41,038	5,045	979,735	219,000	1,240	1,729
2	19	North Central Indian River Lagoon*	32,804	4,133	692,955	177,505	910	1,240
3	23	Mary "A" Farms	32,169	4,232	676,798	60,689	324	310
2	12	Goat Creek*	31,627	3,285	424,526	143,202	461	664
3	22	Fellsmere Farms	30,756	2,601	305,018	106,186	295	481
4	16	Basin 2	29,926	3,317	502,517	150,837	568	768
1C	02	Turnbull Hammock*	28,324	2,958	395,120	100,417	393	545
2	01-02	Elbow Creek/Eau Gallie River*	25,258	3,260	582,462	129,487	735	1,049

TABLE 4-5

RANKING OF SUB-BASINS BASED ON FUTURE NITROGEN LOADS TO THE INDIAN RIVER LAGOON COMPLEX, Continued

SEGMENT	SUB-BASIN	NAME	TN (kg/yr)	TP (kg/yr)	TSS (kg/yr)	BOD (kg/yr)	Zn (kg/yr)	Pb (kg/yr)
4	11	Basin 4	21,479	2,349	391,785	81,786	372	540
3	24	Sottile Farms	21,097	2,514	348,400	63,068	240	287
3	01-02	Sebastian River WCD	19,387	1,459	148,811	60,224	120	209
2	15	Trout Creek	15,453	1,572	168,025	57,277	156	219
4	08	North Coastal	14,575	1,499	264,562	77,780	278	382
4	13	Basin 6	13,543	1,638	270,157	46,485	281	379
1A	01	Florida Shores	13,152	1,896	274,306	72,825	194	283
1C	04	Pineda Golf Course*	9,039	1,037	138,821	42,607	160	230
1C	03	Addison Creek*	6,607	834	165,206	35,361	209	292
1C	05	Horse Creek*	6,014	748	122,080	29,380	145	211
1C	01	Little Cow Creek*	4,288	457	76,155	13,766	81	107
2	13	Kid Creek	3,272	333	42,395	14,091	50	72
4	12	Basin 5	2,898	338	53,887	10,791	38	49
2	17	...*	2,017	219	21,134	7,819	31	48
2	16	...*	1,390	147	23,256	8,046	22	30
2	14	...*	1,294	146	26,305	5,482	22	31
2	18	...	1,151	137	20,889	6,246	28	38
		LAGOON TOTAL	**3,147,999**	**385,430**	**63,175,120**	**12,060,706**	**54,889**	**72,381**

... = No formal name exists for sub-basin

* = Sub-basins discharging to Lagoon areas with low flushing capacity

by total nitrogen loads. The relative loads for the other parameters generally follow the total nitrogen pattern. Sub-basins in Segment 4 (the South Indian River Lagoon) dominate the total loadings, reflecting the size and land use of this segment of the Lagoon watershed system. Complete lists for each sub-basin for the existing and future loads can be found in Chapter 6.0 of the Point and Non-Point Source Loads Assessment Technical Report volume of the Indian River Lagoon characterization study.

The loading rate can also be used to describe the rate at which materials are removed from a land area or sub-basin, with higher loading rates reflecting greater potential for pollution of the receiving body. Tables 4-6 and 4-7 show loadings rates for four parameters that have been calculated for both the Indian River Lagoon region and the Sarasota Bay region (Heyl, 1992) for representative sub-basins of predominantly urban and relatively undeveloped/rural land use. The relative range of values is similar, with the somewhat higher values for Sarasota Bay possibly reflecting a greater density of development in some areas. The very low rates from the Mosquito Lagoon and Turnbull Hammock sub-basins of the Indian River Lagoon reflect the lack of extensive agricultural development in these areas.

Loadings rates for developed urban areas of the Indian River Lagoon region such as the Eau Gallie River watershed are generally about five times higher than essentially undeveloped "natural" watersheds such as Mosquito Lagoon. Rates for sub-basins with predominantly agricultural land use such as Mary "A" Farms are about 1.5 to 3 times higher than for largely undeveloped areas and about 0.3 to 0.5 times that of highly developed urban areas. This trend is also shown in Figure 4-9.

Figure 4-10 (A-F) shows the 22 sub-basins that are projected to have the highest nitrogen loading rates in the future, as well the 22 basins with the lowest rates. Several of the highest nitrogen loading sub-basins are among the largest currently existing generators of non-point source loads, but others such as the unnamed coastal sub-basins 14 and 18 in Segment 2 and sub-basin 3 in Segment 3 are predicted to have significant increases in rates and will move upward in the relative loadings ranking from existing conditions.

TABLE 4-6

COMPARISON OF EXISTING LOADING RATES FROM SIMILARLY DEVELOPED SUB-BASINS IN INDIAN RIVER LAGOON AND SARASOTA BAY WATERSHEDS

SUB-BASIN NAME	SUB-BASIN NUMBER	ESTUARY	PARAMETER AND EXISTING LOADING RATE			
			TN (kg/ha-yr)	TP (kg/ha-yr)	Zn (kg/ha-yr)	Pb (kg/ha-yr)
URBAN SUB-BASINS						
Florida Shores	1A-01	Indian River Lagoon	8.180	1.076	0.234	0.353
Eau Gallie River	2-01/02	Indian River Lagoon	9.077	1.250	0.368	0.509
Crane Creek	2-03	Indian River Lagoon	8.632	1.199	0.369	0.519
South Central Indian River Lagoon	3-21	Indian River Lagoon	7.226	1.014	0.245	0.345
Philippi Creek	...	Sarasota Bay	8.900	1.639	0.232	0.182
Bowlees Creek	...	Sarasota Bay	8.851	1.527	0.588	0.959
Whitaker Bayou	...	Sarasota Bay	16.002	3.609	0.646	0.646
Anna Maria	...	Sarasota Bay	8.415	1.691	0.350	0.437
SUBURBAN/RURAL SUB-BASINS						
Mosquito Lagoon	1A-02	Indian River Lagoon	1.299	0.167	0.046	0.066
Turnbull Hammock	1C-02	Indian River Lagoon	1.546	0.194	0.035	0.046
Kid Creek	2-13	Indian River Lagoon	1.979	0.253	0.186	0.127
Mary "A" Farms	3-23	Indian River Lagoon	3.679	0.515	0.048	0.049
South Creek	...	Sarasota Bay	3.655	0.759	0.096	0.017
Perico Island	...	Sarasota Bay	4.943	1.080	0.052	0.104

Sources: Heyl, 1992 and MMA, 1993
... = No designated number

S:\WP51\92F274C\STATREND\TABLES\TABLE4-6

10-19-94

TABLE 4-7

COMPARISON OF FUTURE (BUILT-OUT) LOADING RATES FROM SIMILARLY DEVELOPED SUB-BASINS IN INDIAN RIVER LAGOON AND SARASOTA BAY WATERSHEDS

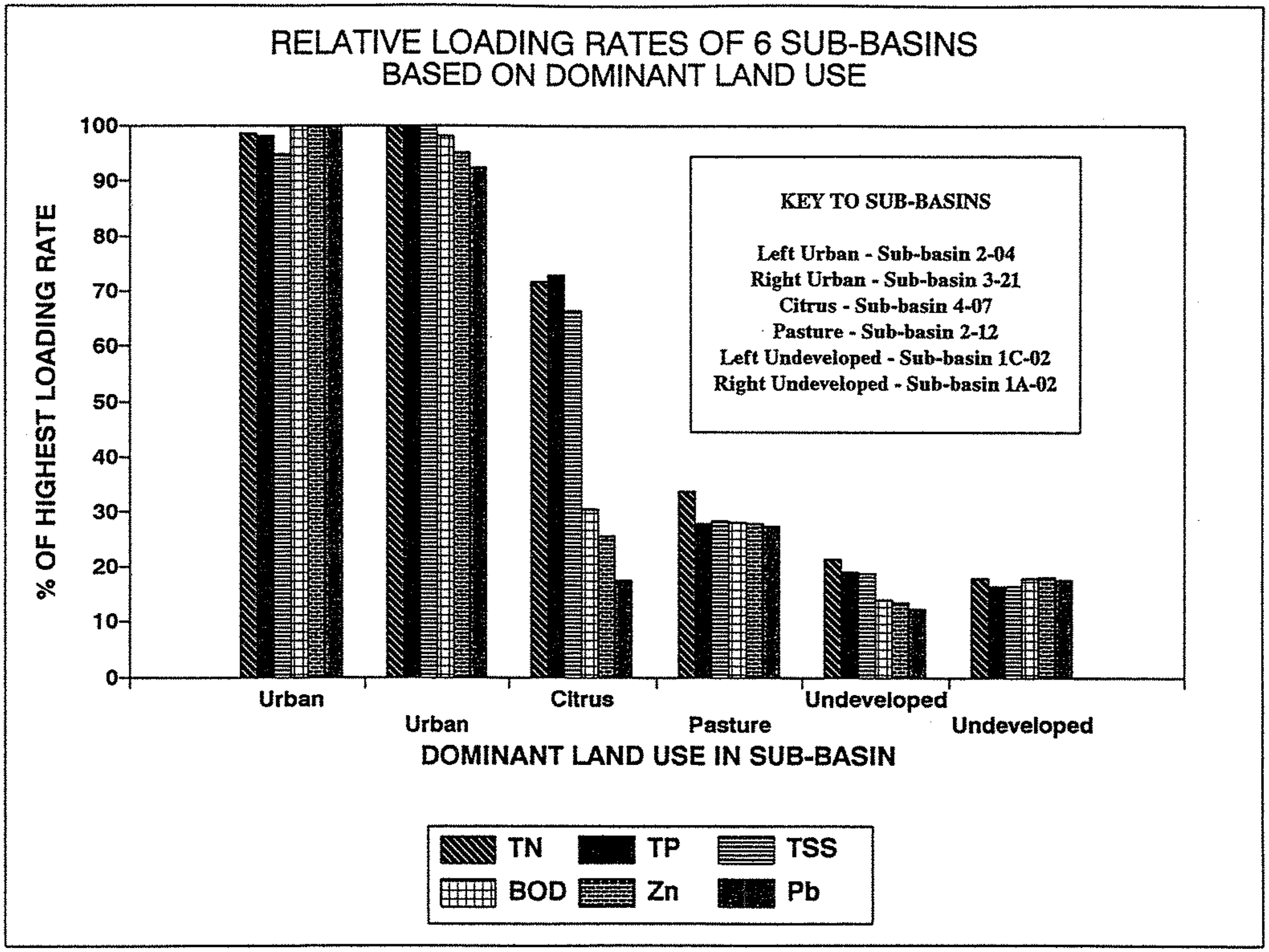
SUB-BASIN NAME	SUB-BASIN NUMBER	ESTUARY	PARAMETER AND FUTURE LOADING RATE			
			TN (kg/ha-yr)	TP (kg/ha-yr)	Zn (kg/ha-yr)	Pb (kg/ha-yr)
URBAN SUB-BASINS						
Florida Shores	1A-01	Indian River Lagoon	9.593	1.383	0.141	0.207
Eau Gallie River	2-01/02	Indian River Lagoon	10.062	1.299	0.293	0.418
Crane Creek	2-03	Indian River Lagoon	11.042	1.424	0.324	0.470
South Central Indian River Lagoon	3-21	Indian River Lagoon	13.424	1.771	0.283	0.391
Philippi Creek	...	Sarasota Bay	12.261	2.251	0.381	0.366
Bowlees Creek	...	Sarasota Bay	10.901	1.848	0.747	1.244
Whitaker Bayou	...	Sarasota Bay	15.681	3.300	0.680	0.760
Anna Maria	...	Sarasota Bay	10.229	2.057	0.544	0.424
SUBURBAN/RURAL SUB-BASINS						
Mosquito Lagoon	1A-02	Indian River Lagoon	2.054	0.257	0.045	0.064
Turnbull Hammock	1C-02	Indian River Lagoon	2.913	0.304	0.040	0.056
Kid Creek	2-13	Indian River Lagoon	6.958	0.708	0.107	0.153
Mary "A" Farms	3-23	Indian River Lagoon	5.683	0.748	0.057	0.055
South Creek	...	Sarasota Bay	6.055	1.271	0.182	0.092
Perico Island	...	Sarasota Bay	8.244	1.698	0.244	0.186

Sources: Heyl, 1992 and MMA, 1993

... = No designated number

S:\WP51\92F274C\STATREND\TABLES\TABLE4-7

10-19-94



Source: MMA, 1993.

• Woodward–Clyde Consultants
• Marshall McCully & Associates
• Natural Systems Analysis

DRAWING NO.:

DATE:

FIGURE 4-9 NON-POINT SOURCE POLLUTANT LOADING RATES OF TYPICAL SUB-BASINS DOMINATED BY DIFFERING LAND USES

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

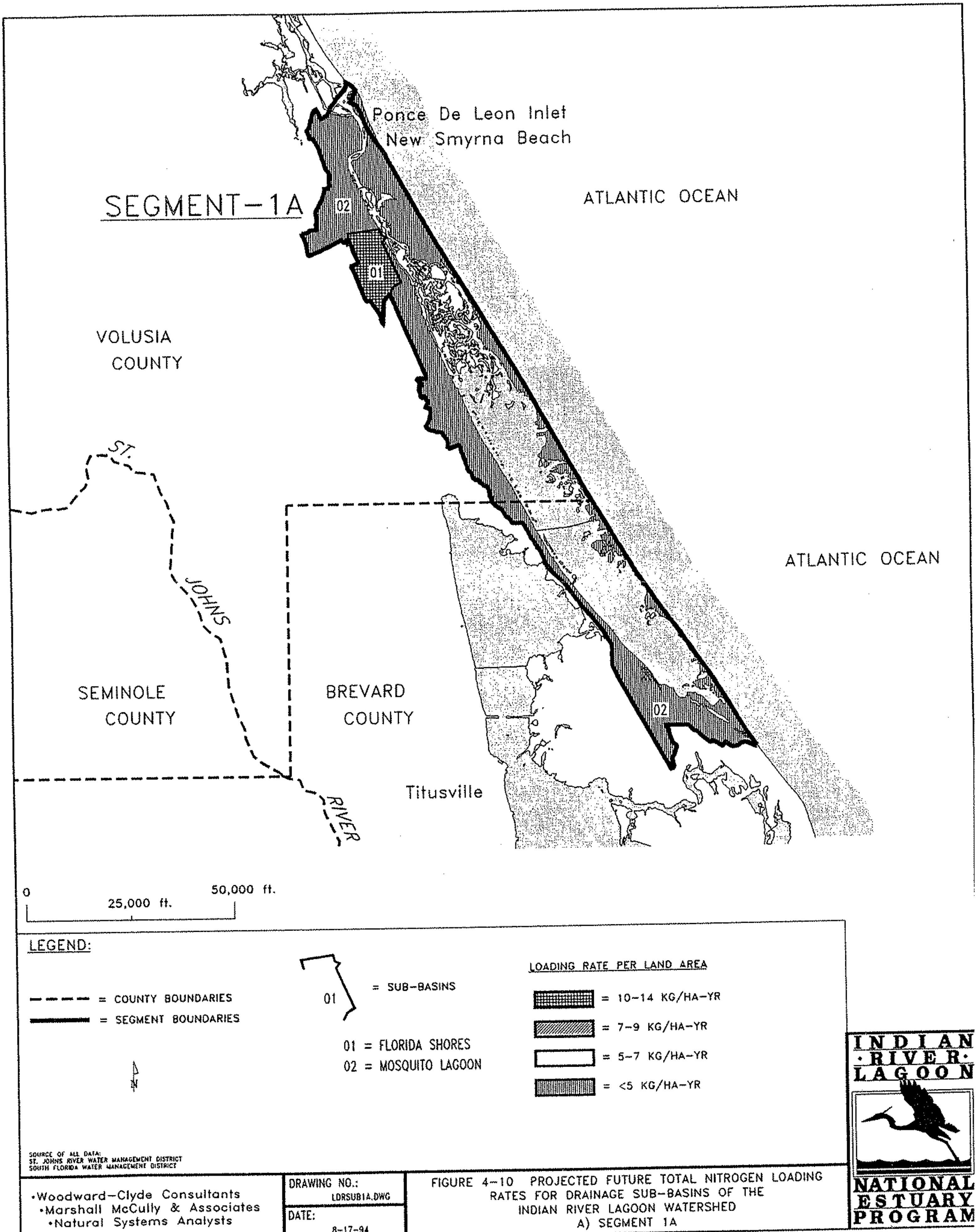
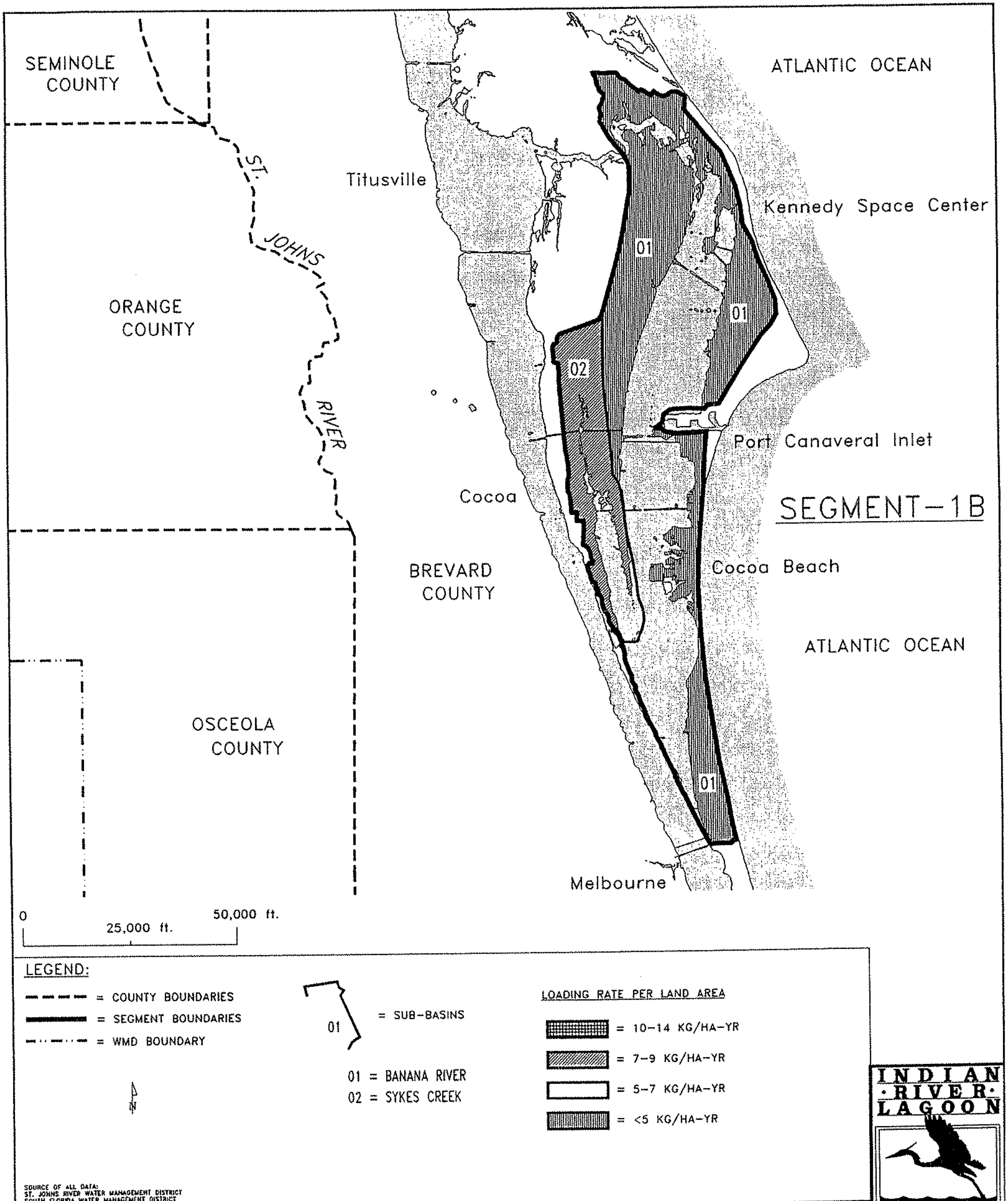


FIGURE 4-10 PROJECTED FUTURE TOTAL NITROGEN LOADING RATES FOR DRAINAGE SUB-BASINS OF THE INDIAN RIVER LAGOON WATERSHED A) SEGMENT 1A



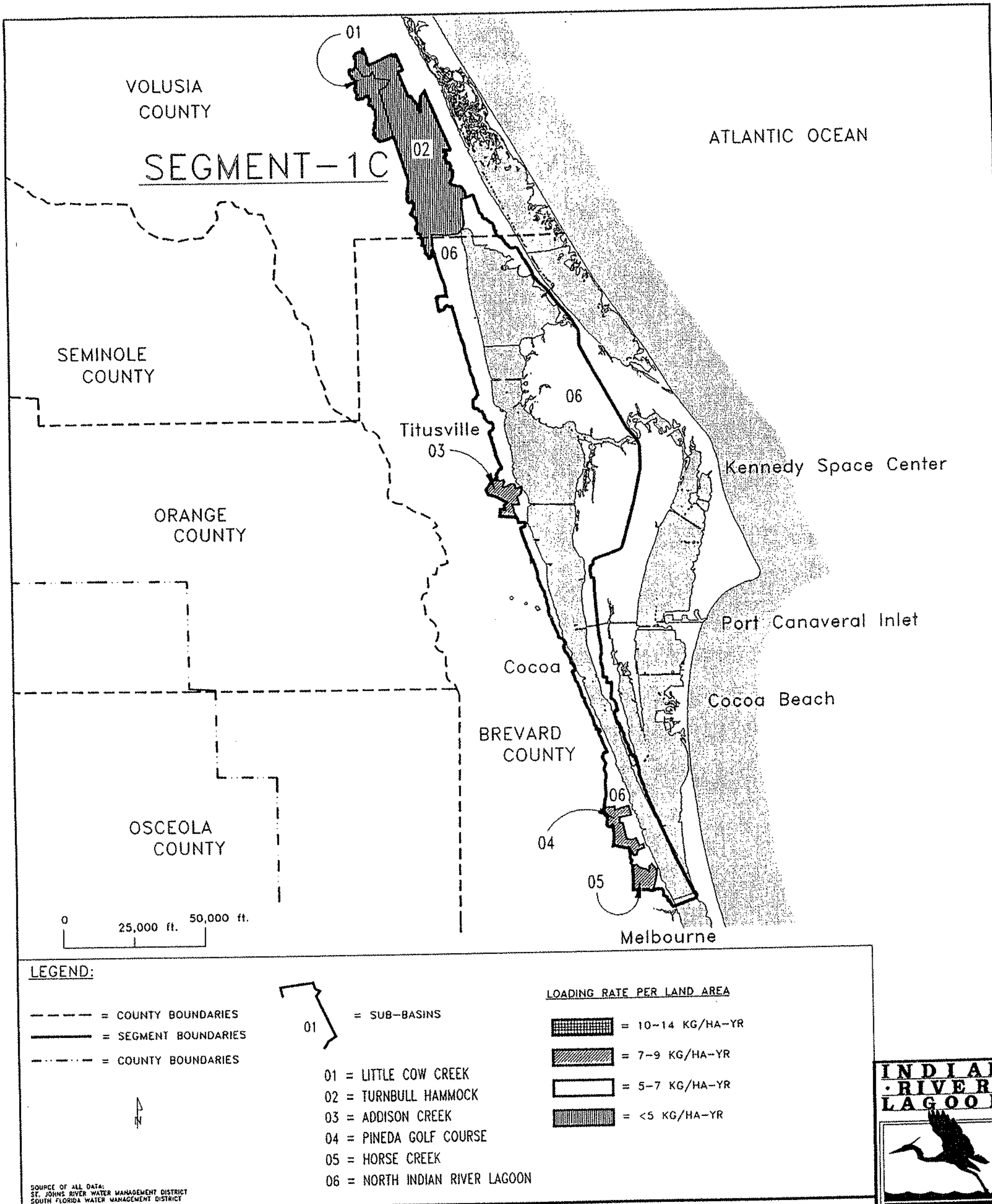
•Woodward-Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.: LORSUB1B.DWG

DATE: 8-17-94

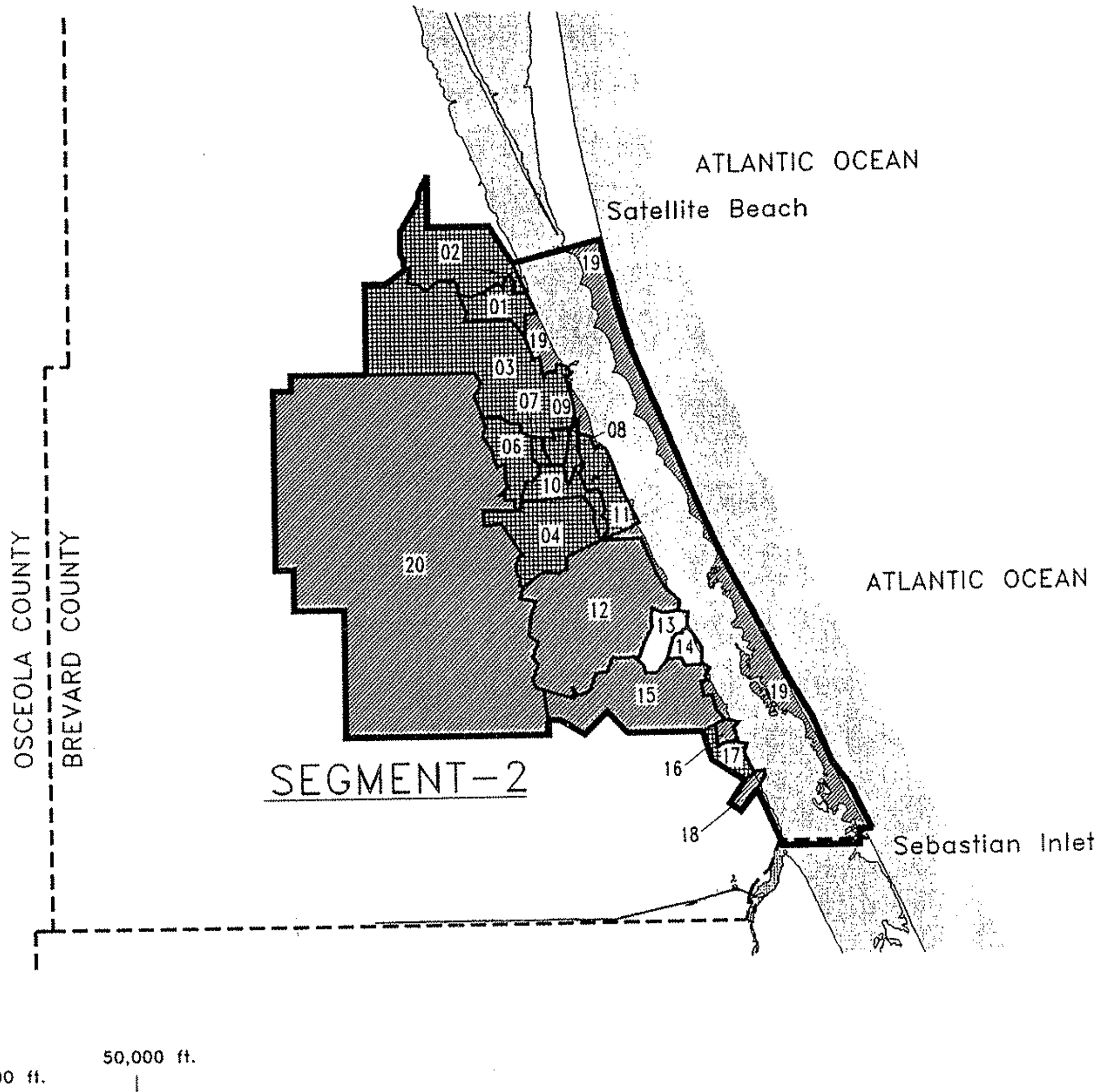
FIGURE 4-10 PROJECTED FUTURE TOTAL NITROGEN LOADING RATES FOR DRAINAGE SUB-BASINS OF THE INDIAN RIVER LAGOON WATERSHED B) SEGMENT 1B

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



•Woodward-Clyde Consultants •Marshall McCully & Associates •Natural Systems Analyst	DRAWING NO.: LORSUB1C.DWG DATE: 8-17-94	FIGURE 4-10 PROJECTED FUTURE TOTAL NITROGEN LOADING RATES FOR DRAINAGE SUB-BASINS OF THE INDIAN RIVER LAGOON WATERSHED C) SEGMENT 1C

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



LEGEND:

01 = SUB-BASINS

— — — = COUNTY BOUNDARIES

▬▬▬ = SEGMENT BOUNDARIES

01-02 = ELBOW CREEK/EAU GALLIE RIVER
03 = CRANE CREEK
04-11 = TURKEY CREEK
12 = GOAT CREEK
13 = KID CREEK
14 = UNNAMED COASTAL
15 = TROUT CREEK
16 = UNNAMED COASTAL
17 = UNNAMED COASTAL
18 = UNNAMED COASTAL
19 = NORTH CENTRAL INDIAN RIVER LAGOON
20 = WATER CONTROL DISTRICT OF SOUTH BREVARD

N

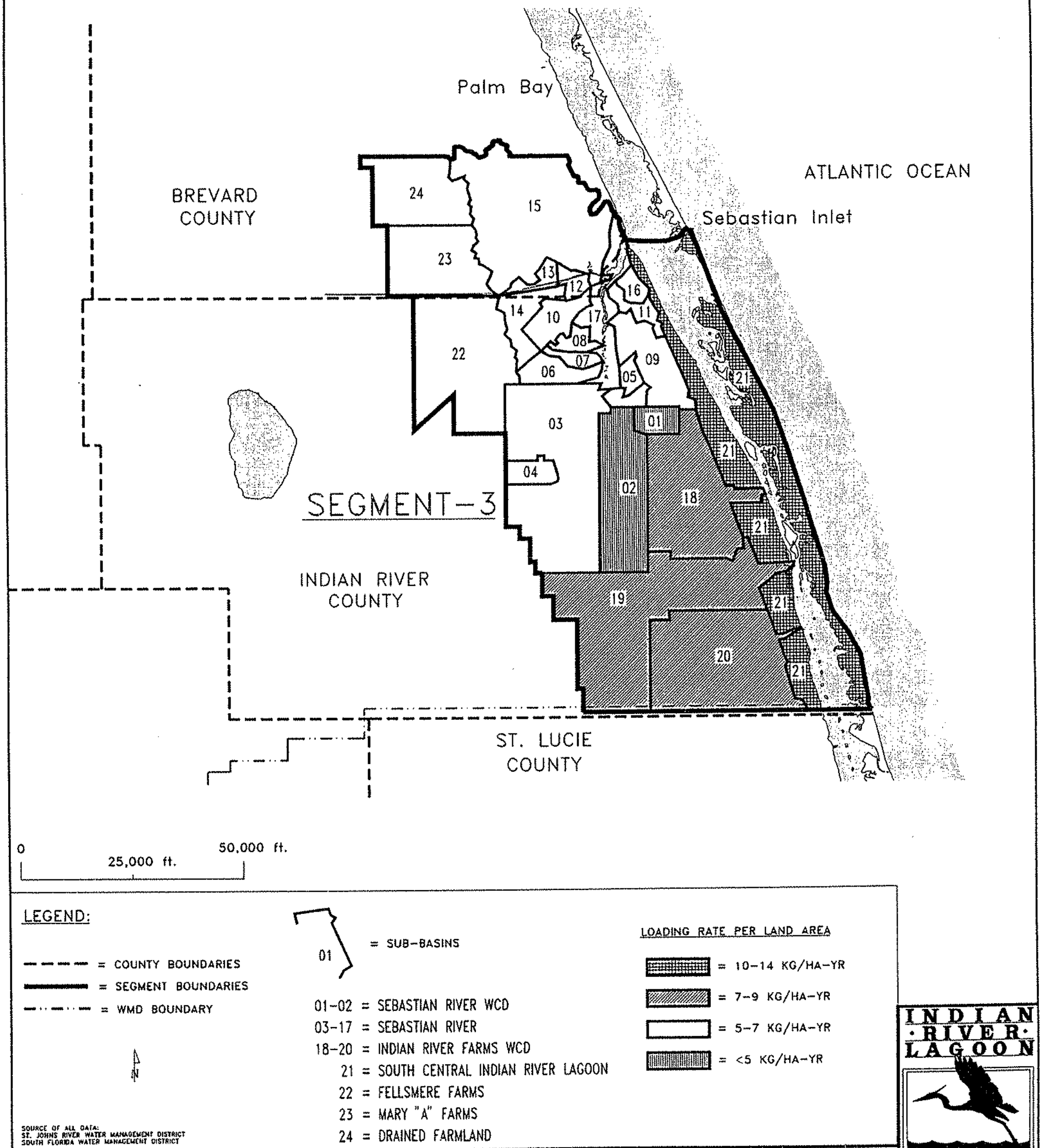
LOADING RATE PER LAND AREA

= 10-14 KG/HA-YR
= 7-9 KG/HA-YR
= 5-7 KG/HA-YR
= <5 KG/HA-YR

SOURCE OF ALL DATA:
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

•Woodward-Clyde Consultants •Marshall McCully & Associates •Natural Systems Analysts	DRAWING NO.: LDRSUB2.DWG DATE: 8-17-94	FIGURE 4-10 PROJECTED FUTURE TOTAL NITROGEN LOADING RATES FOR DRAINAGE SUB-BASINS OF THE INDIAN RIVER LAGOON WATERSHED D) SEGMENT 2

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



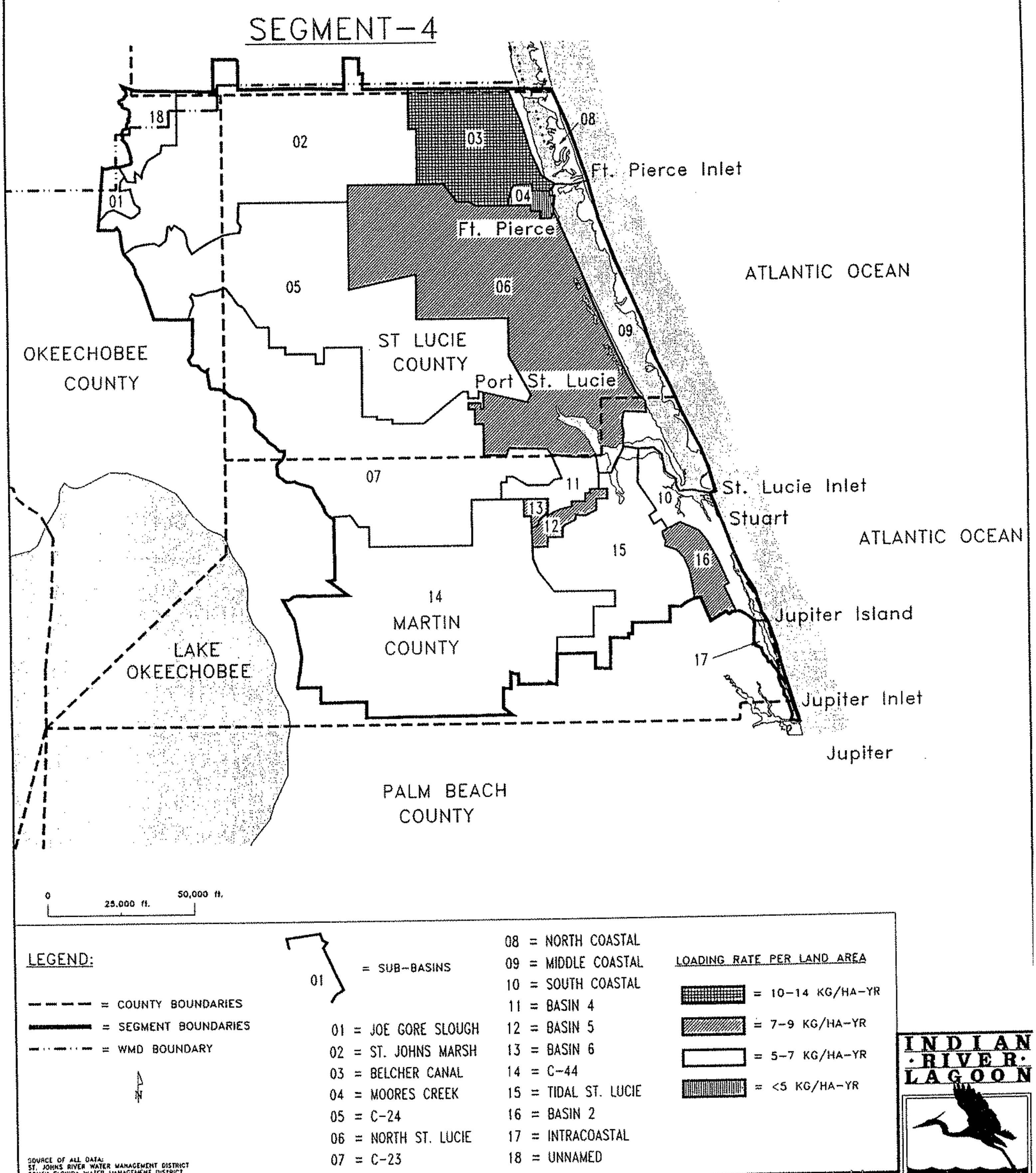
•Woodward-Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.: LDRSUB3.DWG

DATE: 8-17-94

FIGURE 4-10 PROJECTED FUTURE TOTAL NITROGEN LOADING RATES FOR DRAINAGE SUB-BASINS OF THE INDIAN RIVER LAGOON WATERSHED
E) SEGMENT 3

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



•Woodward-Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.: LDRSUB4.DWG

DATE: 8-17-94

FIGURE 4-10 PROJECTED FUTURE TOTAL NITROGEN LOADING RATES FOR DRAINAGE SUB-BASINS OF THE INDIAN RIVER LAGOON WATERSHED
F) SEGMENT 4

4.4 TRENDS IN POINT AND NON-POINT SOURCE LOADINGS

In many cases, evaluations of pollutant loadings tend to review loadings from point sources (primarily wastewater treatment plants) and non-point sources (stormwater) separately, when in fact the effects of these loadings are additive in making up the total load to a water body. In the case of the Indian River Lagoon complex, there is considerable variation in the total loadings and relative amounts of point and non-point source loads throughout the Lagoon, so management options should be evaluated based on both the overall status of the Lagoon and on local patterns.

Based on the entire Lagoon complex, WWTPs appear to contribute only about 30% of the total nutrients that enter the Lagoon at the present time. In the South Indian River Lagoon segment, WWTPs are estimated to contribute less than 15% of the total nutrient load. However, in certain segments (Mosquito Lagoon, Banana River, North Indian River Lagoon), they may contribute 65% to 75% of the total nutrient load. As a result, it may be logical to assign different priorities for management of point sources as a means of managing nutrient loading in different areas of the Lagoon. After the expected cessation of direct discharge from WWTPs to the Lagoon over the next few years, WWTPs are expected to contribute a very minor portion of the total nutrient loading to the Lagoon in the future. Existing programs for reuse, irrigation, or deepwell injection may provide a sufficient level of point source management on a Lagoon-wide basis.

Point sources may have pronounced localized influences, particularly as a result of nutrients in the effluent discharges. The Water and Sediment Quality Assessment Technical Report identifies certain water quality monitoring station locations in the Lagoon which appear to have higher levels of total nitrogen and chlorophyll *a* than nearby stations and which appear to be in the vicinity of localized point source discharges. For example, these locations include monitoring stations I05 to I07 and I12 to I15 (whose locations are shown in the Water and Sediment Quality Assessment Technical Report) near the outfalls of the Cocoa and Rockledge municipal WWTPs in Segment 1C and Stations B6 to B8 near the Cocoa Beach municipal plant. In certain areas, particularly in Segments 1A, 1B, and 1C, where currents and flushing are minimal (Chapter 2), the effects of existing and past discharges may be slow to disappear. Another factor to consider may be the fact that WWTP discharge may constitute a measurable proportion of the total freshwater input to the Lagoon in certain areas, particularly Banana River (described in Chapter 2).

The effects of septic systems, or OSDS, on the water quality of the Lagoon have not yet been adequately evaluated. These systems may be sources of nutrients (particularly nitrogen) and bacteria that may enter the Lagoon from systems that are improperly located, on unsuitable soils, or poorly maintained. Recent inventories by the counties have shown that there are significant numbers of potentially threatening OSDS units, which may currently be providing over 33% of the treatment capacity in the region. Such systems are clearly a cause for concern, particularly older units which may be nearing the end of their useful designed operating span. Programs are currently in place to provide central wastewater treatment to some of these areas, but at present there are no management plans for the great majority of these systems, and the potential threat and need for management is largely unknown. Additional research will be required to identify which areas, if any, pose significant threats to the water quality of the Lagoon, before management resources can be effectively committed for OSDS control.

As seen from Table 4-4, reductions of point source discharge in Segments 1A, 1B, and 1C may result in lower total nutrient loadings in these segments, but total nutrient loadings are anticipated to increase substantially over the next 15 to 40 years in Segments 2, 3, and 4 solely as a result of increased non-point source stormwater loading. In addition, increased future stormwater runoff will result in increases of about 16% for total suspended solids, 5% to 6% for lead and zinc, and 84% for BOD. Therefore, successful management of water quality for the Lagoon will be largely dependent on management strategies for control of loadings from non-point sources. In particular, parameters such as nutrients, BOD, turbidity, and total suspended solids are expected to require control.

The Growth Management Plans of the counties and municipalities provide insight into areas where the largest changes in land use and non-point source loadings are likely to occur. In many sub-basins, there may be little change due to relatively minor changes in land use. However, large increases for various parameters are projected to occur in several sub-basins and these areas of greatest change may be areas in which greatest change occurs in the Lagoon in response to increased loadings. Whether these increases will result in significant impacts on the Lagoon may also depend on the physical relationship of the sub-basin to the

Lagoon and the assimilative capacity of the Lagoon in the vicinity of the discharge point for the sub-basin.

Non-point source management strategies may include: 1) non-structural controls which limit the volume of runoff generated by reducing the extent of impervious area or reduce the amount of particulate matter or other pollutants exposed to runoff, and 2) structural controls which are designed to remove pollutants after they have already entered the runoff. Retention and wet- and dry-detention systems are structural controls that are best suited for moderate to small areas, due to land requirements. The model used to derive future loadings has assumed that such controls as required by existing regulations will be present on all new development, and loadings will increase substantially even with the use of such management options. In order to reduce the Lagoon-wide degree of increase of non-point source loadings, it will be necessary to employ additional management options in much of the watershed. Additional methods that may be considered include more restrictive regulations for additional retention/detention; land use zoning (such as minimum lot size or cluster developments), or density restrictions that reduce the amount of impervious surface area in new developments within sub-basins.

Other options that should be evaluated are measures that will result in reduced non-point source loadings from areas that will not undergo a change in land use. Options which may be suitable for parts of the Indian River Lagoon basin include retrofitting with structural controls in already developed areas and development of Best Management Practices (BMPs) for reducing the volume of pollutants exposed to stormwater. Options that have been employed in other watersheds include regular street sweeping and techniques to reduce the levels of nutrients and chemicals used in yards and agricultural areas. Regardless of what options are ultimately selected, additional management will be required if increases in total loadings to the Lagoon are to be reduced.

5.0 WATER AND SEDIMENT QUALITY

5.1 WATER QUALITY MONITORING NETWORK

One of the key initial activities of the IRLNEP and SWIM programs was to develop a Lagoon-wide water quality monitoring network (SJRWMD and SFWMD, 1993) to provide for a quality-controlled data base. Prior to this time water quality and flow data in the Lagoon and tributaries was collected by many separate agencies and organizations with no central coordination or quality control. There have been numerous problems associated with producing an integrated water quality analysis and picture of the entire Lagoon system. Some agencies have sampled monthly, while others sample on a quarterly or irregular basis. Parameters sampled have varied among agencies. Examples of inconsistent parameters that make it difficult to directly compare various water quality data sets include:

- Variability in sampling of different species of nitrogen with different programs sampling: total nitrogen (TN), total Kjeldahl nitrogen (TKN), and ammonia (NH_4). Few measurements have been made of dissolved inorganic nitrogen (DIN) which may be a key indicator of conditions in estuaries.

- Variability in sampling of chlorophyll with some agencies supplying corrected chlorophyll *a* data and others supplying uncorrected data. In some cases, it is not stated whether data has been corrected.

- Variability of sample depth and location which affects some parameters. Depth of sample may influence salinity and color, and bottom depth may affect Secchi disk readings.

- Not all agencies have measured color concentration.

- Most of the earlier data sets have poor documentation of sampling location and condition.

- Secchi disk values for water clarity in many data sets are questionable as to whether the disk was resting on the bottom, because this information was not recorded, or is no longer available.

- Variability in units of measurement (e.g., turbidity is expressed in JTUs in older data and in NTUs in newer data), or analysis procedures.

- Changes in limits of resolution and accuracy of analytical methods over time.

- Several values were outside of specified ranges.

- Numerous values for some parameters for some counties failed to show any variability over time and among stations, a result which would be very unlikely when dealing with these natural systems.

- Some data sets were incomplete, with missing dates or with missing data for some stations.

- Average values for some parameters differed substantially in certain portions of the Lagoon from values in other portions. The differences may represent actual differences in water quality, but since the differences also fell along jurisdictional sampling boundaries, sampling or analytical differences can not be ruled out, as different laboratories have been used and there is no performance audit program to compare the various laboratories.

The concept of a coordinated Lagoon-wide network began prior to the IRLNEP/SWIM program. However, the first data set that has been validated and verified on a Lagoon-wide basis is data from the 1988 to 1992 period. This data has been assembled and placed into a database at the SJRWMD, although the data set had not been fully checked for quality assurance or parsed and placed into a form suitable for statistical analysis in time for this characterization process. This however, is the first data set that has been represented as having gone through quality control.

The characterization study data analysis is the first attempt to assimilate the data Lagoon-wide. The purpose of a water quality monitoring network is to develop standardized operating procedures and parameters to be used, as a minimum, by all agencies sampling the Lagoon and to provide a central clearing house for storing and analyzing data. The network still has not been fully implemented, and coordination has not proceeded as rapidly as initially hoped. As of late 1993, significant quality control issues had not yet been resolved, and several parts of the SWIM data set appeared to contain errors which made some data unusable for trend analyses.

For future Lagoon water quality evaluation and development of a regional water quality monitoring program, it will be important to continue with development of this coordinated network and independent quality assurance process. Parameters and sampling procedures should be further standardized; sampling locations should be better described; and provisions should be made for performance audits for various laboratories cross checking of results and occasional split sample analysis.

5.2 LAGOON-WIDE WATER QUALITY ASSESSMENT

The scope of the water quality assessment for this study was limited to evaluation of averaged data due to the gaps in data and the questionable nature of parts of the data set. Averaging values over time has the advantages of smoothing out peaks and potentially erroneous data points, but at the same time loses much valuable information that may identify site specific variability and specific events.

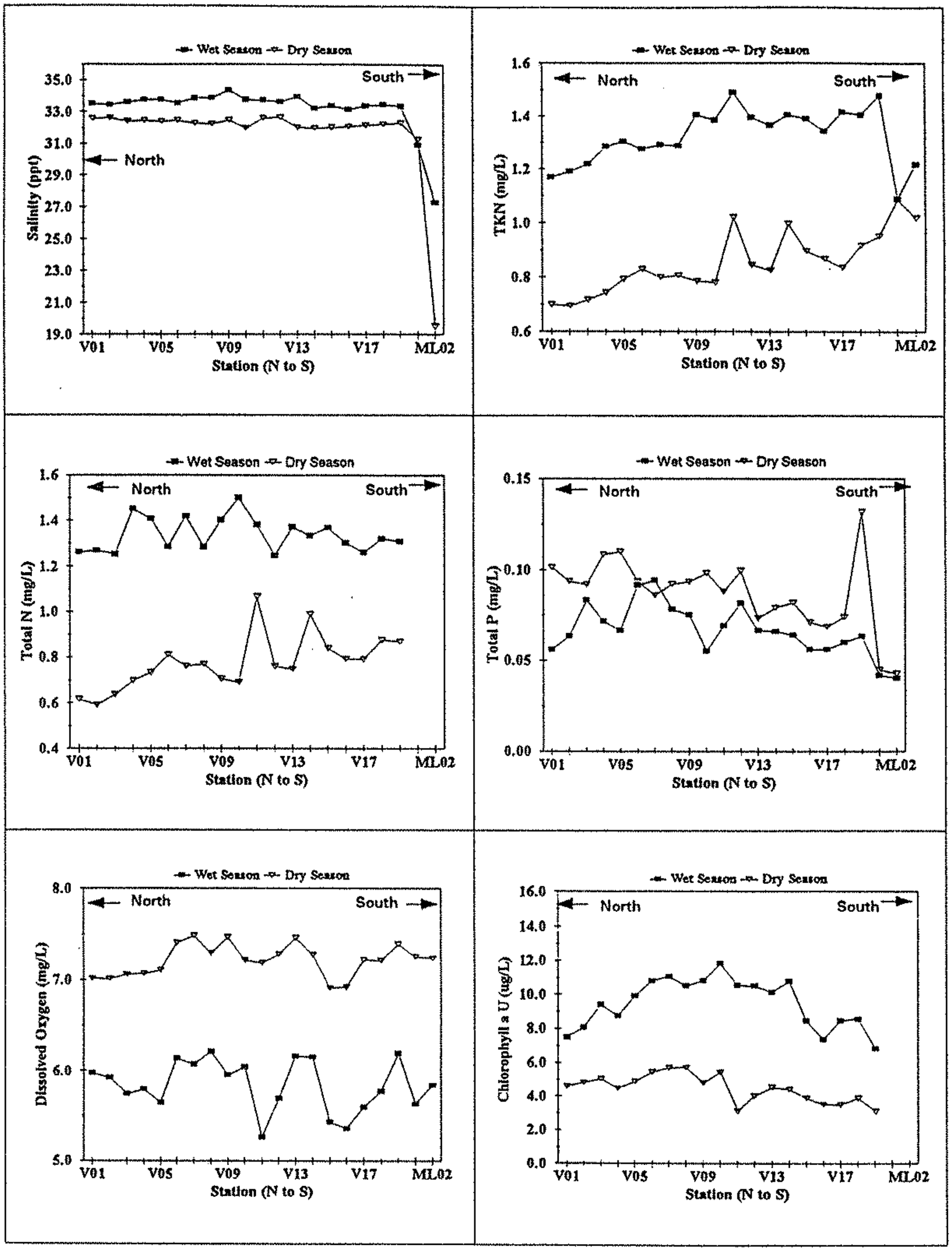
In order to provide the greatest amount of information to identify regional water quality status and spatial trends while reducing variability, available usable data from the 1988-1992 SWIM Network water quality data set was split into wet season (May - October) and dry season (November - April) periods and averaged at each station. Parameters for which at least some data was available for most stations are salinity, total nitrogen (TN), total Kjeldahl nitrogen (TKN), total phosphorous (TP), dissolved oxygen (DO), chlorophyll *a*, total suspended solids (TSS), color, Secchi disk depth, and turbidity.

The average values of the water quality data from the SWIM data set for Mosquito Lagoon, Banana River, and the Indian River Lagoon are shown in Figures 5-1 through 5-6 by station for the 1988-1992 period, showing spatial trends for the parameters that were examined. Monthly averages for tributaries of four segments for which data were available are shown in Figures 5-7 through 5-11.

An analysis of water quality data for the three year period consistent among most stations in the data base confirms that differences exist between the various geographical areas of the Indian River Lagoon system. For example, definite salinity differences occur throughout the Lagoon, reflecting the relative volumes of freshwater discharges and the influence of the inlets. Salinity is high and relatively constant spatially and temporally in Segment 4 (Figure 5-6) except for a high degree of variability around the mouth of the St. Lucie River where the low wet season average reflects the high flow periods of the river. To the north in Segment 3 (Figure 5-5), salinity drops rapidly as the influence of the three southern inlets decreases and as increased freshwater discharge from the Vero South, Main, and North Canals impacts salinity. Salinity in the Indian River Lagoon is lowest between Sebastian Inlet and Melbourne (Figures 5-3 and 5-4) due to the influence of large freshwater flows from Crane Creek, Turkey Creek and the Sebastian River. Salinity increases in Segment 1C north of Melbourne as evaporation becomes seasonally greater than freshwater inflow.

5.2.1 Water Quality Trends and Patterns in Mosquito Lagoon (Segment 1A)

In Mosquito Lagoon, the watershed is relatively undeveloped compared to the other five basins. During the period examined, salinity was relatively constant throughout the Lagoon and showed only a slight variation between wet and dry season. The salinity is nearly equal to that of ocean water and reflects the small amount of freshwater discharge to this segment. In Mosquito Lagoon, a strong but apparently natural wet season/dry season response is seen for many parameters. Nitrogen, chlorophyll *a*, TSS, and turbidity are about twice as high in the wet season. Total Kjeldahl nitrogen levels are almost identical to TN levels, indicating that organic nitrogen dominates the nitrogen load in this segment. Spatial patterns are generally uniform throughout Mosquito Lagoon with some apparent peaks in turbidity, chlorophyll *a* ,and TP in the area between Edgewater and Oak Hill (Stations V3 to V13). With the exception of TKN, values of measured water quality parameters throughout



Data Source: SJRWMD, 1993

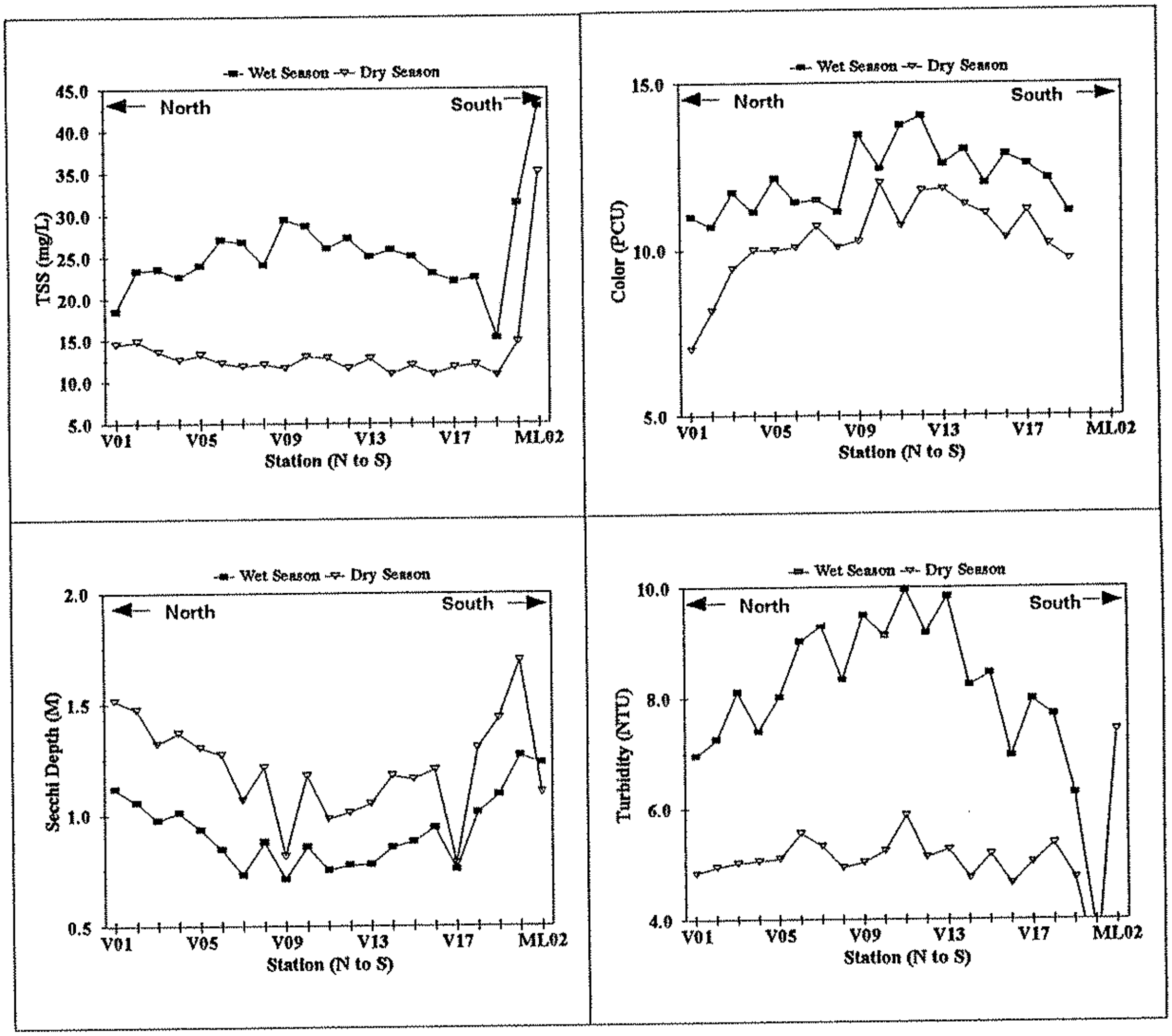
• Woodward–Clyde Consultants
• Marshall McCully & Associates
• Natural Systems Analysis

DRAWING NO.:

DATE:

FIGURE 5-1 SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 1A - MOSQUITO LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

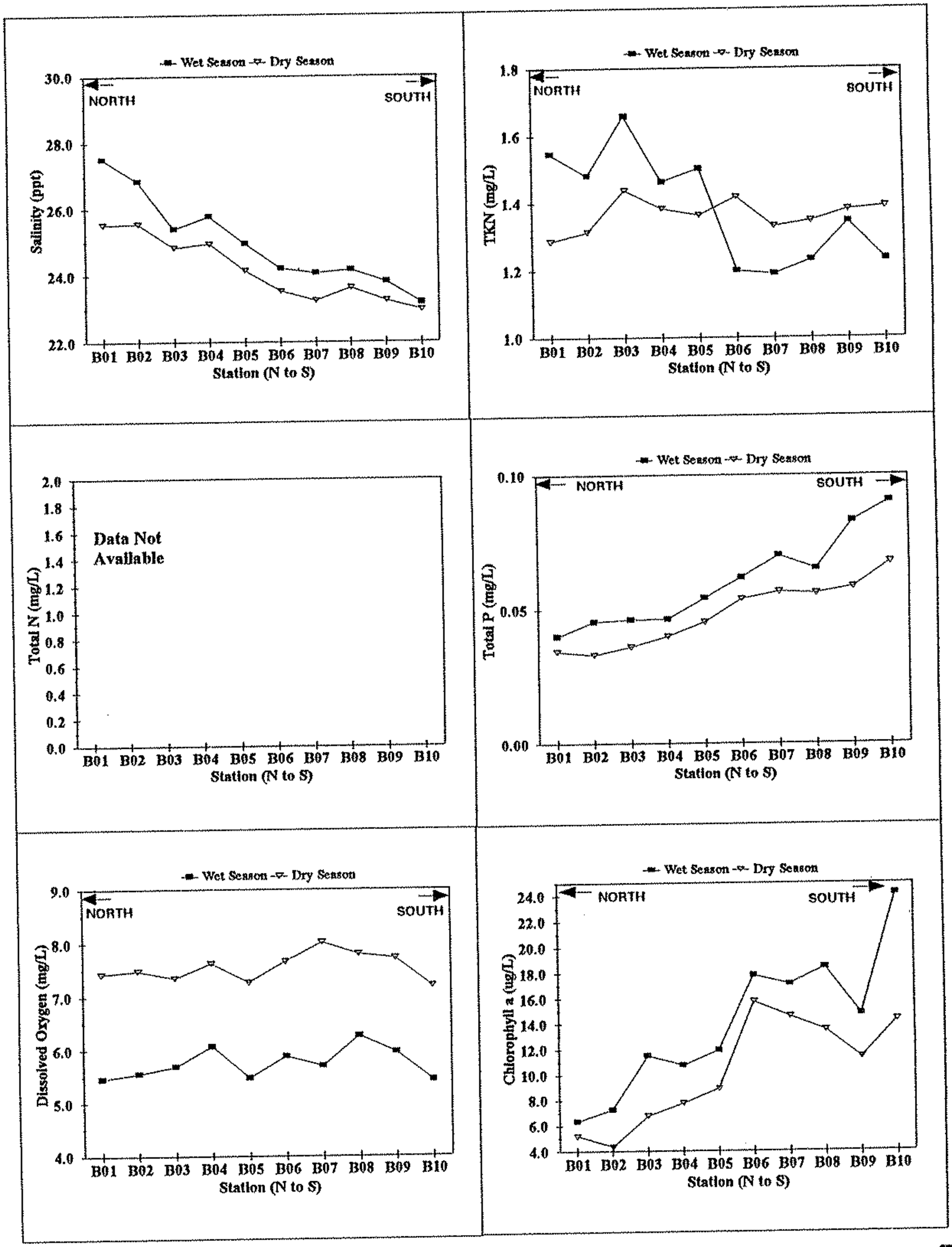
- Woodward-Clyde Consultants
- Marshall McCully & Associates
- Natural Systems Analysts

DRAWING NO.:

DATE:

FIGURE 5-1, (CON'T) SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 1A - MOSQUITO LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

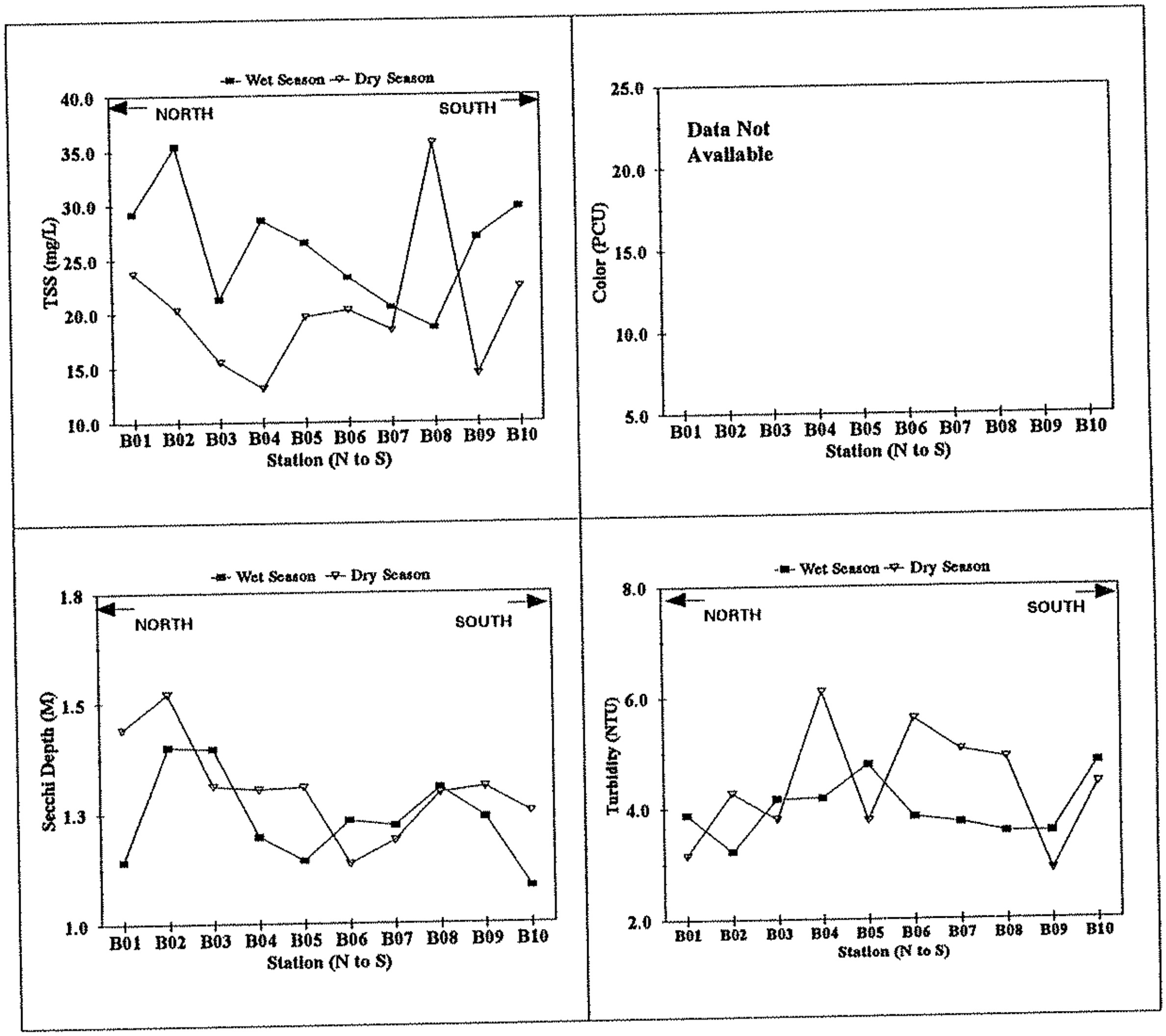
- Woodward–Clyde Consultants
- Marshall McCully & Associates
- Natural Systems Analysts

DRAWING NO.:

DATE:

FIGURE 5-2 SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 1B - BANANA RIVER

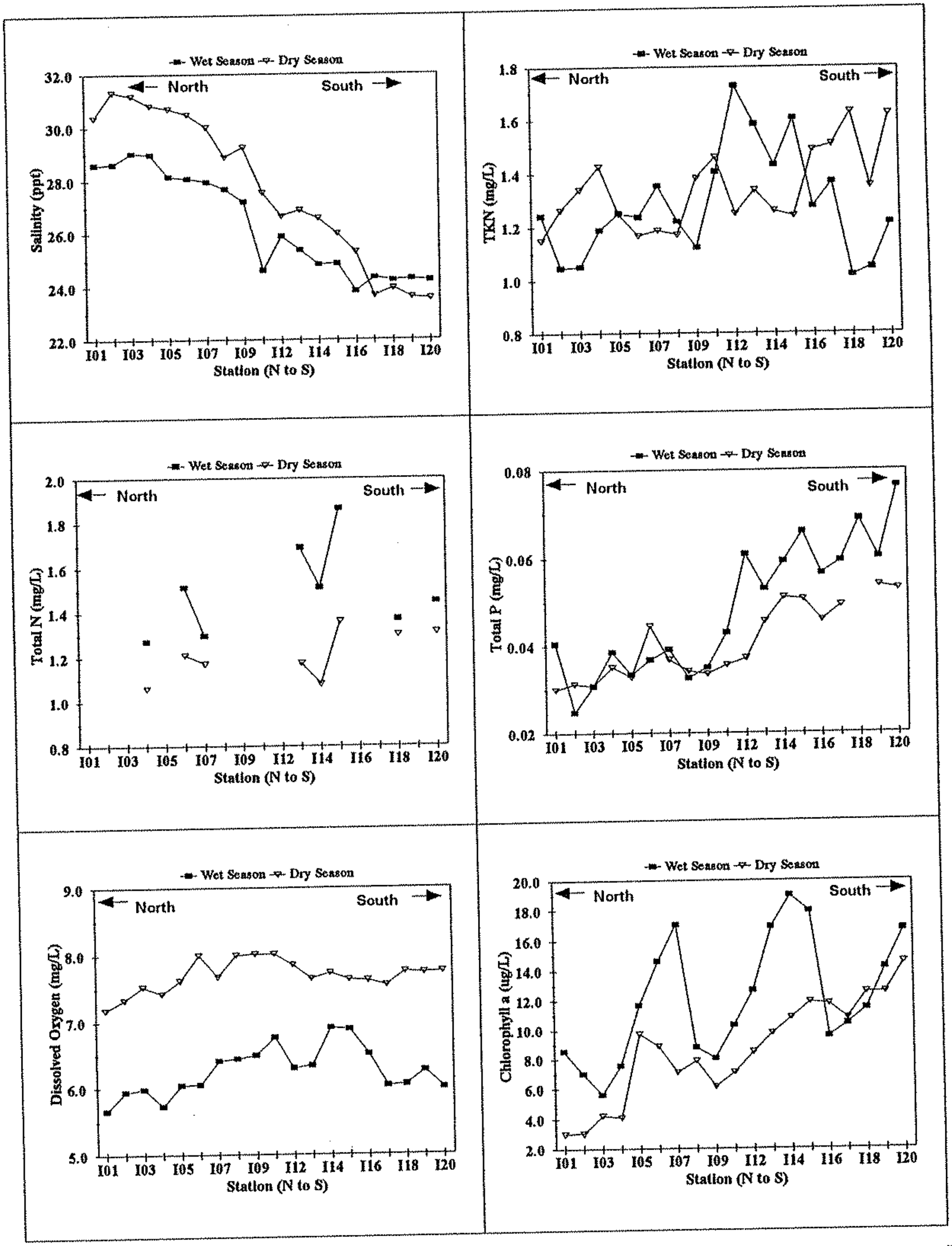
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-2, (CON'T) SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 1B - BANANA RIVER

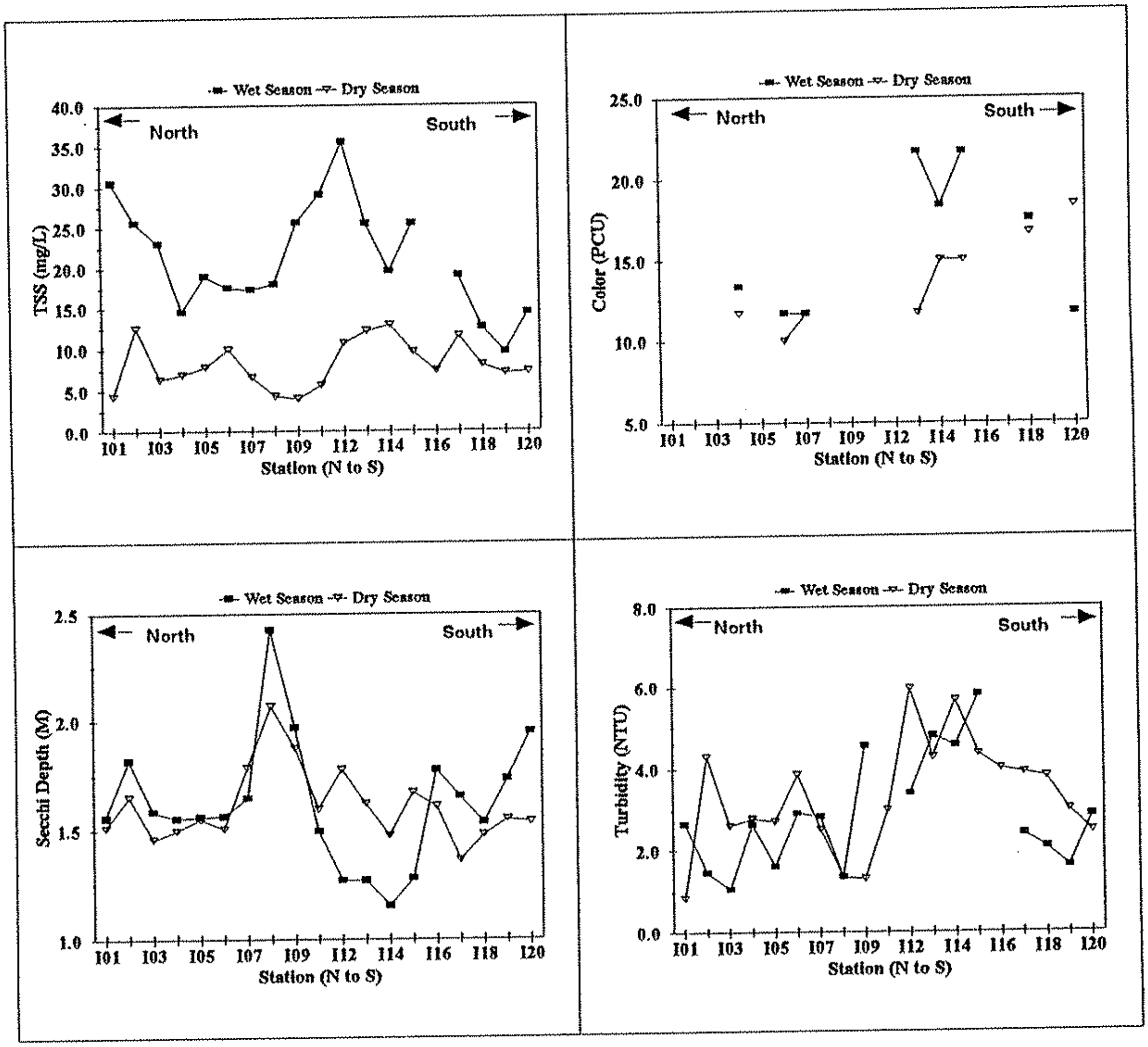
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-3 SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 1C - NORTH INDIAN RIVER LAGOON

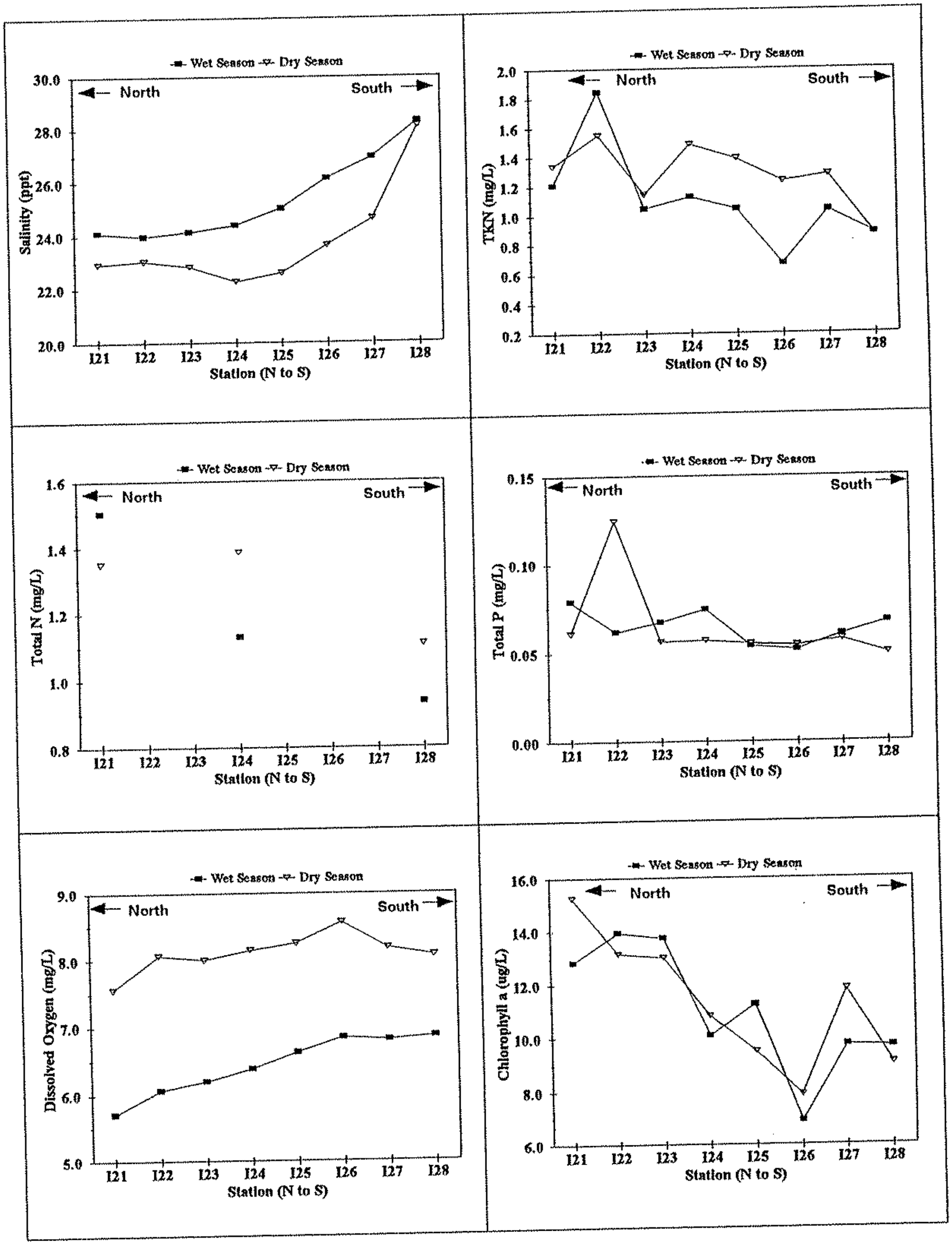
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

• Woodward-Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-3, (CON'T) SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 1C - NORTH INDIAN RIVER LAGOON

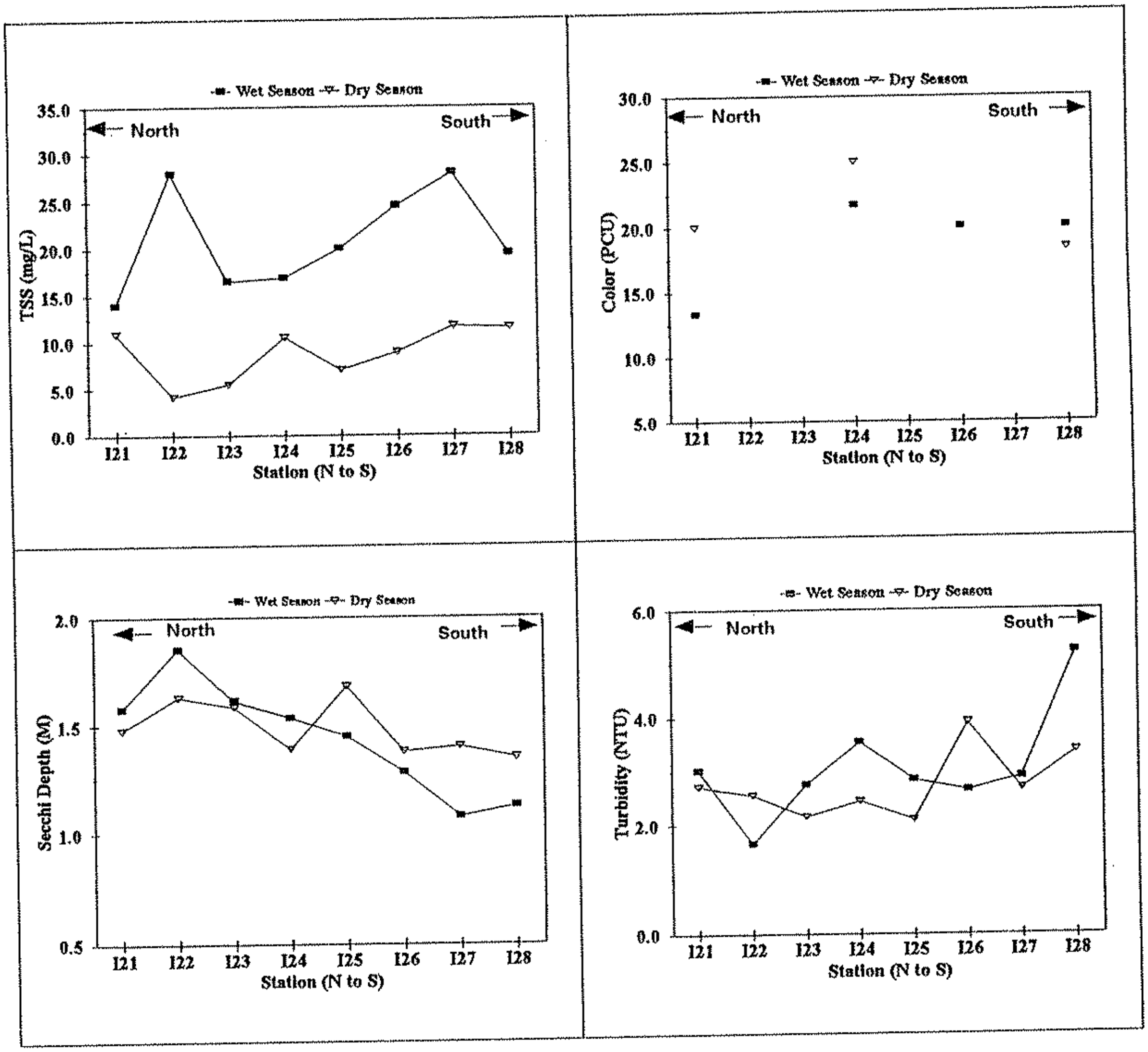
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

• Woodward-Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-4 SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 2 - NORTH CENTRAL INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

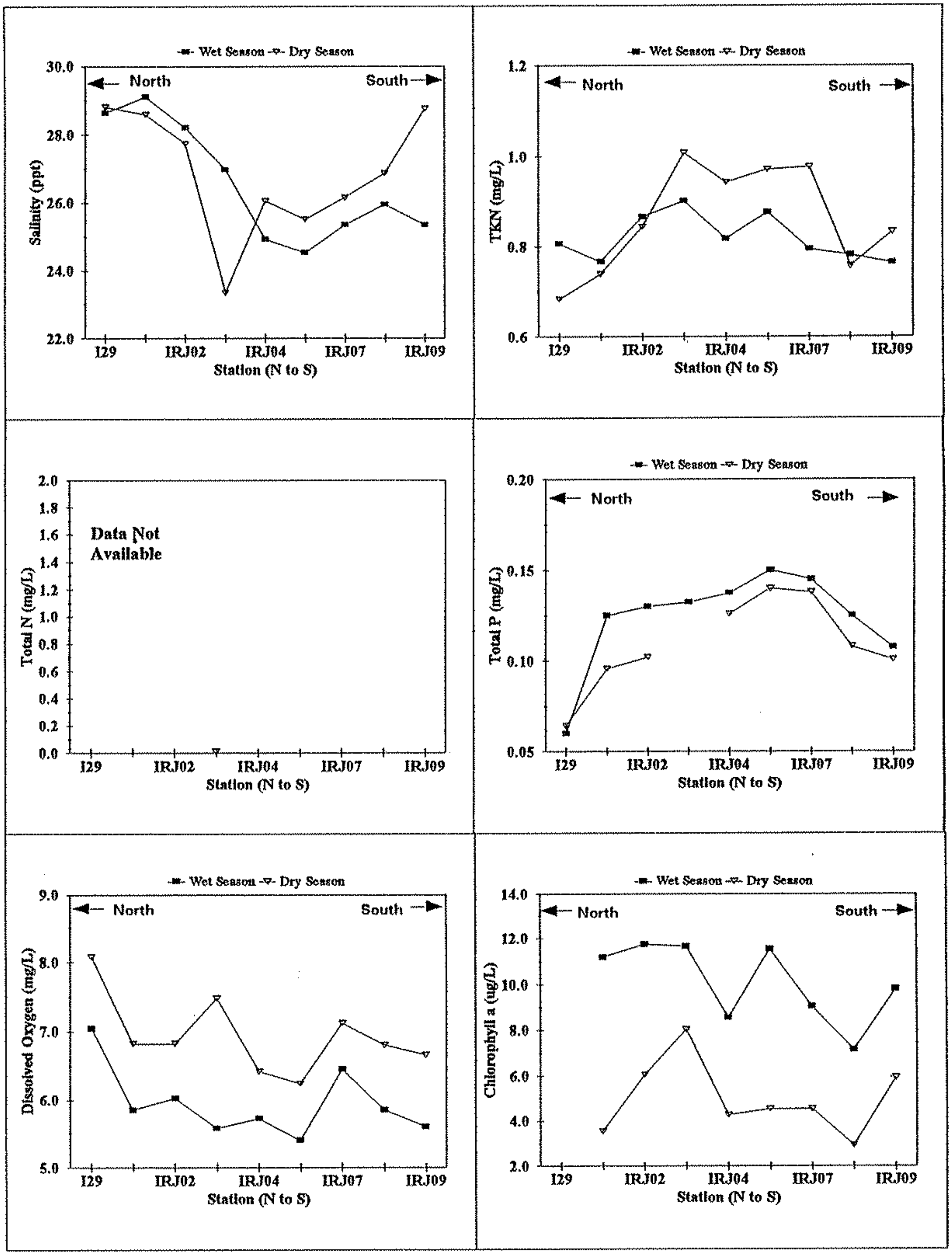
•Woodward-Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.:

DATE: 6-15-94

FIGURE 5-4, (CON'T) SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 2 - NORTH CENTRAL INDIAN RIVER LAGOON

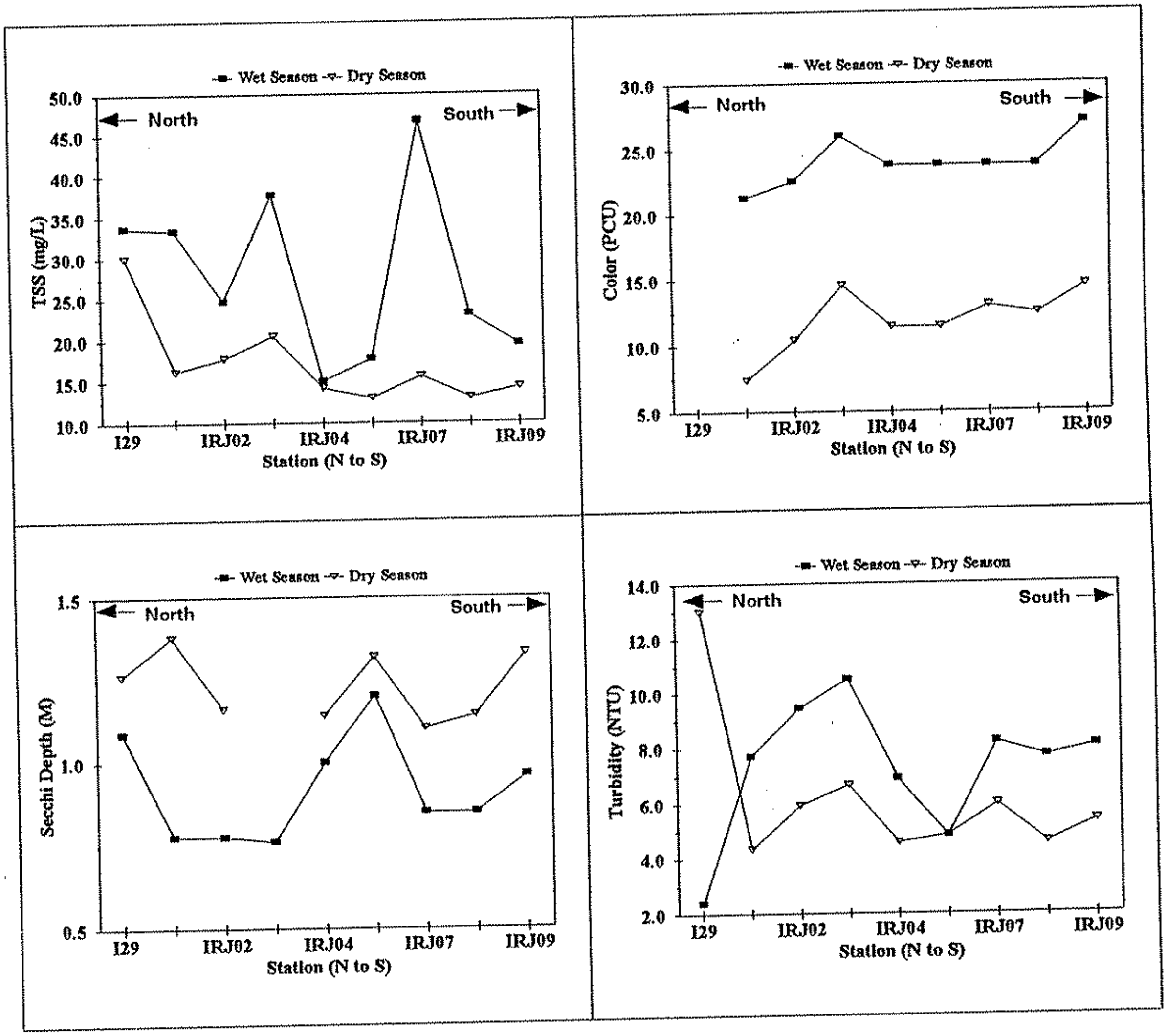
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-5 SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 3 - SOUTH CENTRAL INDIAN RIVER LAGOON

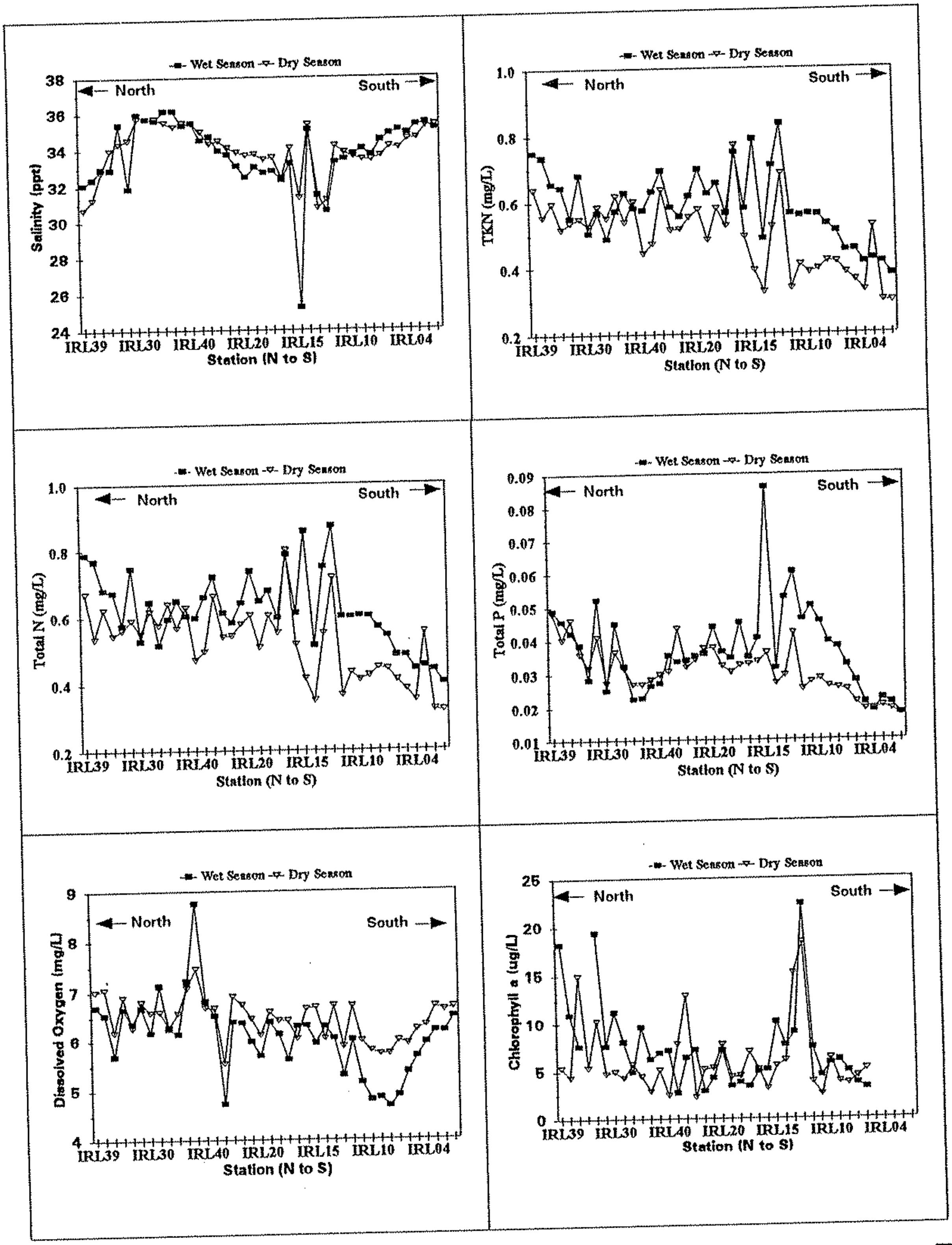
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SJRWMD, 1993

•Woodward–Clyde Consultants •Marshall McCully & Associates •Natural Systems Analysts	DRAWING NO.: DATE: 6-9-94	FIGURE 5-5, (CON'T) SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 3 - SOUTH CENTRAL INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Data Source: SFWMD, 1993

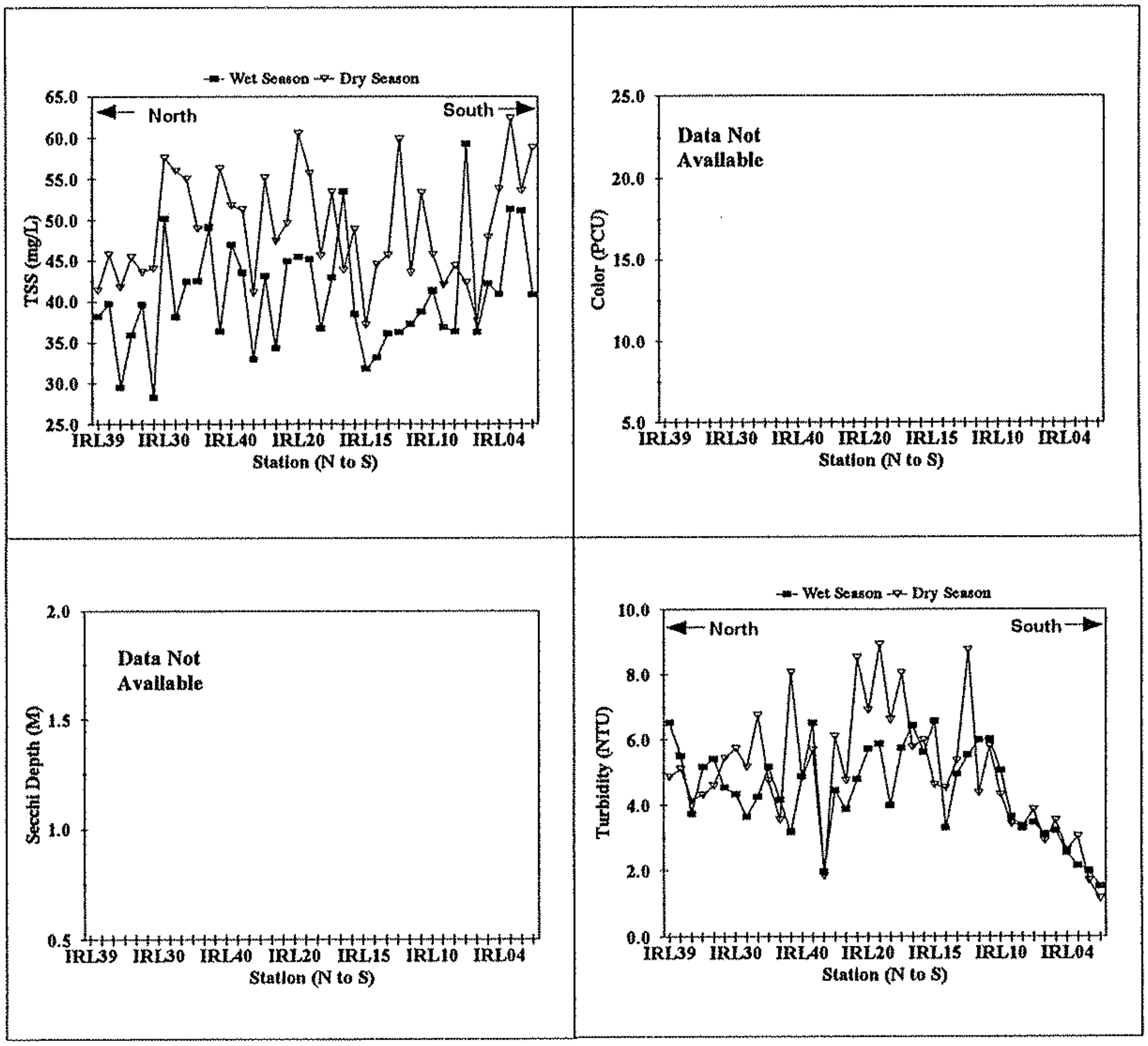
- Woodward-Clyde Consultants
- Marshall McCully & Associates
- Natural Systems Analysts

DRAWING NO.:

DATE:

FIGURE 5-6 SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 4 - SOUTH INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



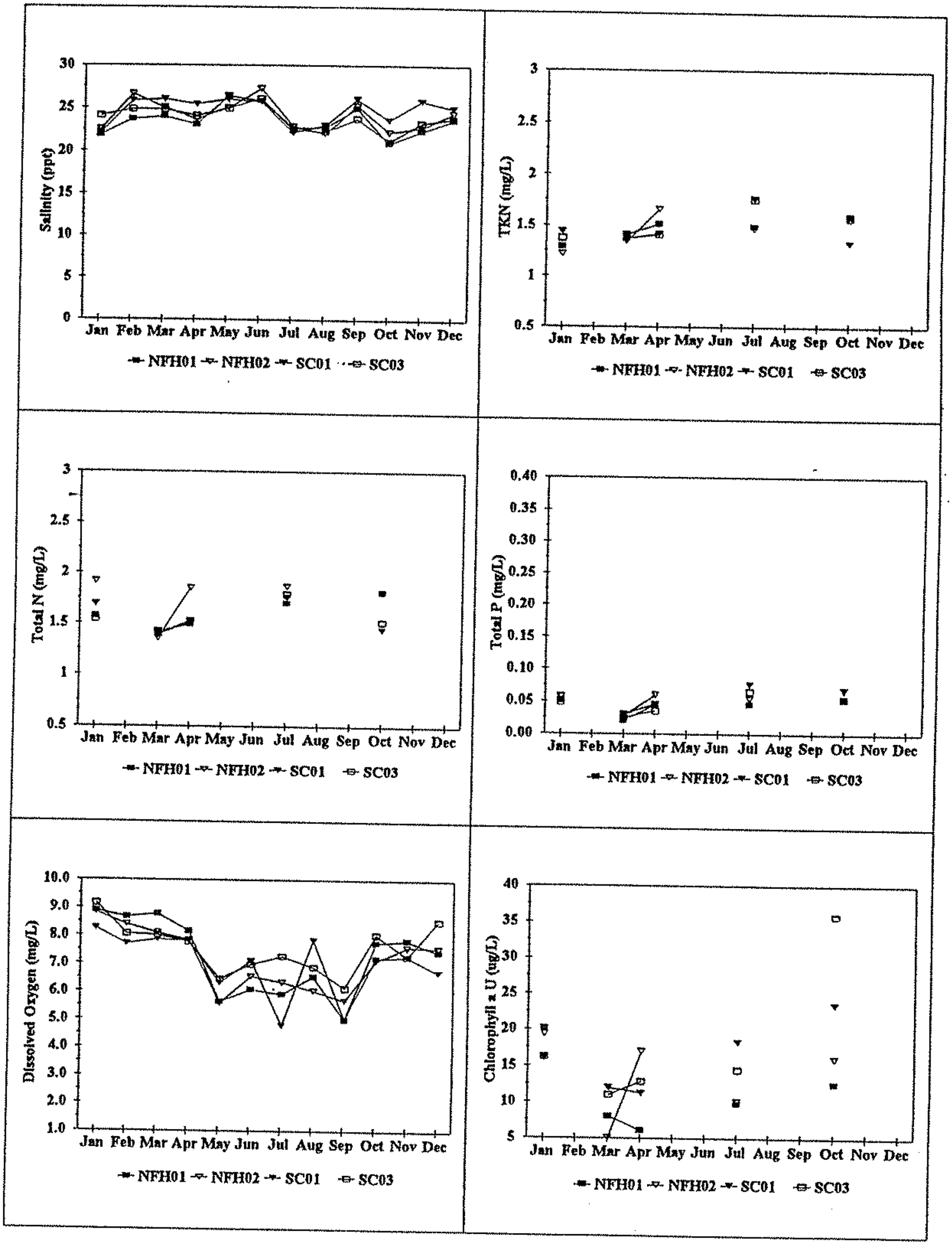
Data Source: SFWMD, 1993

•Woodward–Clyde Consultants
•Marshall McCully & Associates
•Natural Systems Analysts

DRAWING NO.:

DATE: 6-19-94

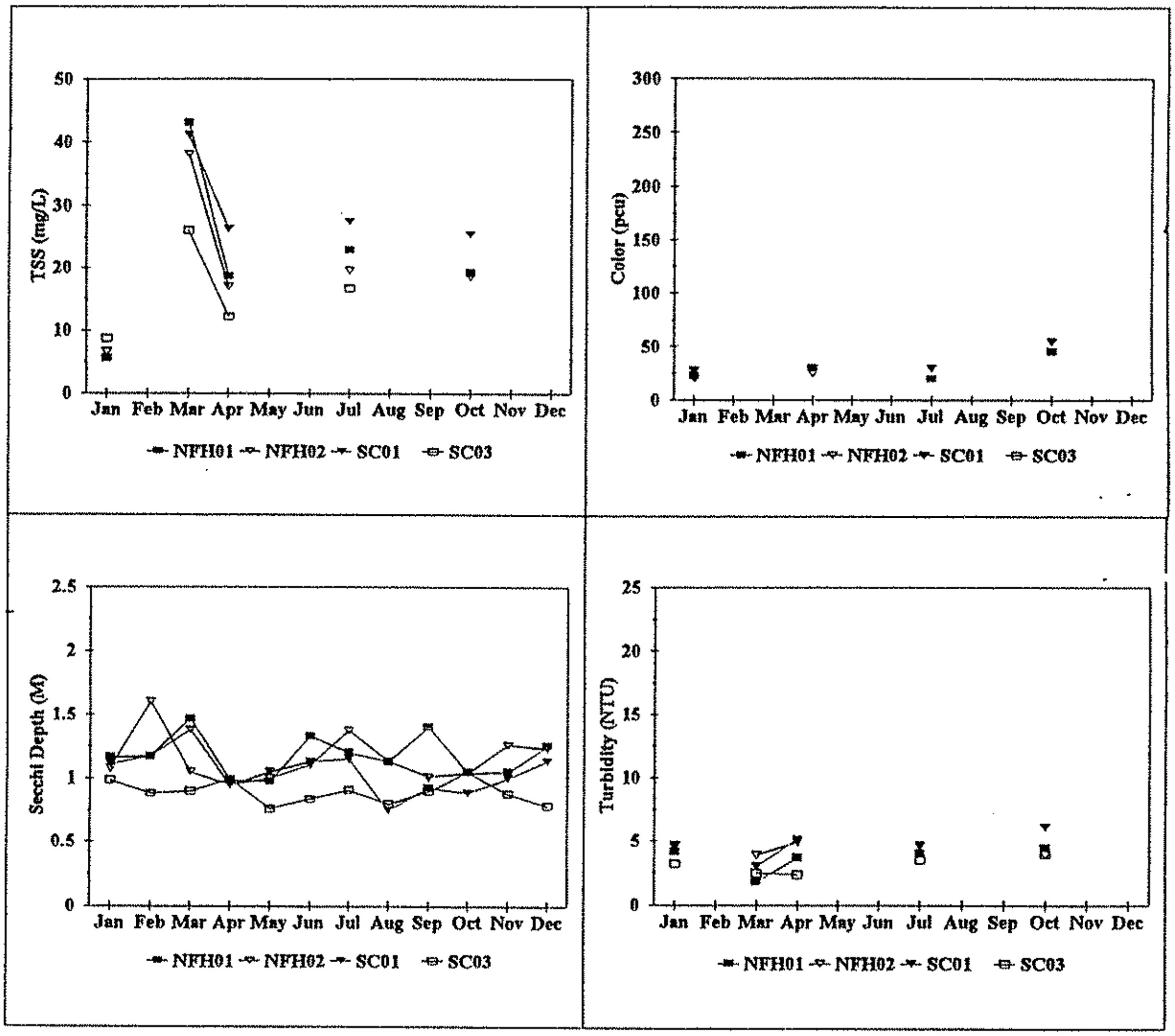
FIGURE 5-6, (CON'T) SPATIAL DISTRIBUTION OF WATER QUALITY PARAMETERS IN SEGMENT 4 - SOUTH INDIAN RIVER LAGOON



Explanation: NFH01 = Newfound Harbor Station 1, NFH02 = Newfound Harbor Station 2
SC01 = Sykes Creek Station 1, SC02 = Sykes Creek Station 2

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysis	DRAWING NO.: DATE:	FIGURE 5-7, MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE TRIBUTARIES IN SEGMENT 1B - BANANA RIVER

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: NFH01 = Newfound Harbor Station 1, NFH02 = Newfound Harbor Station 2
SC01 = Sykes Creek Station 1, SC02 = Sykes Creek Station 2

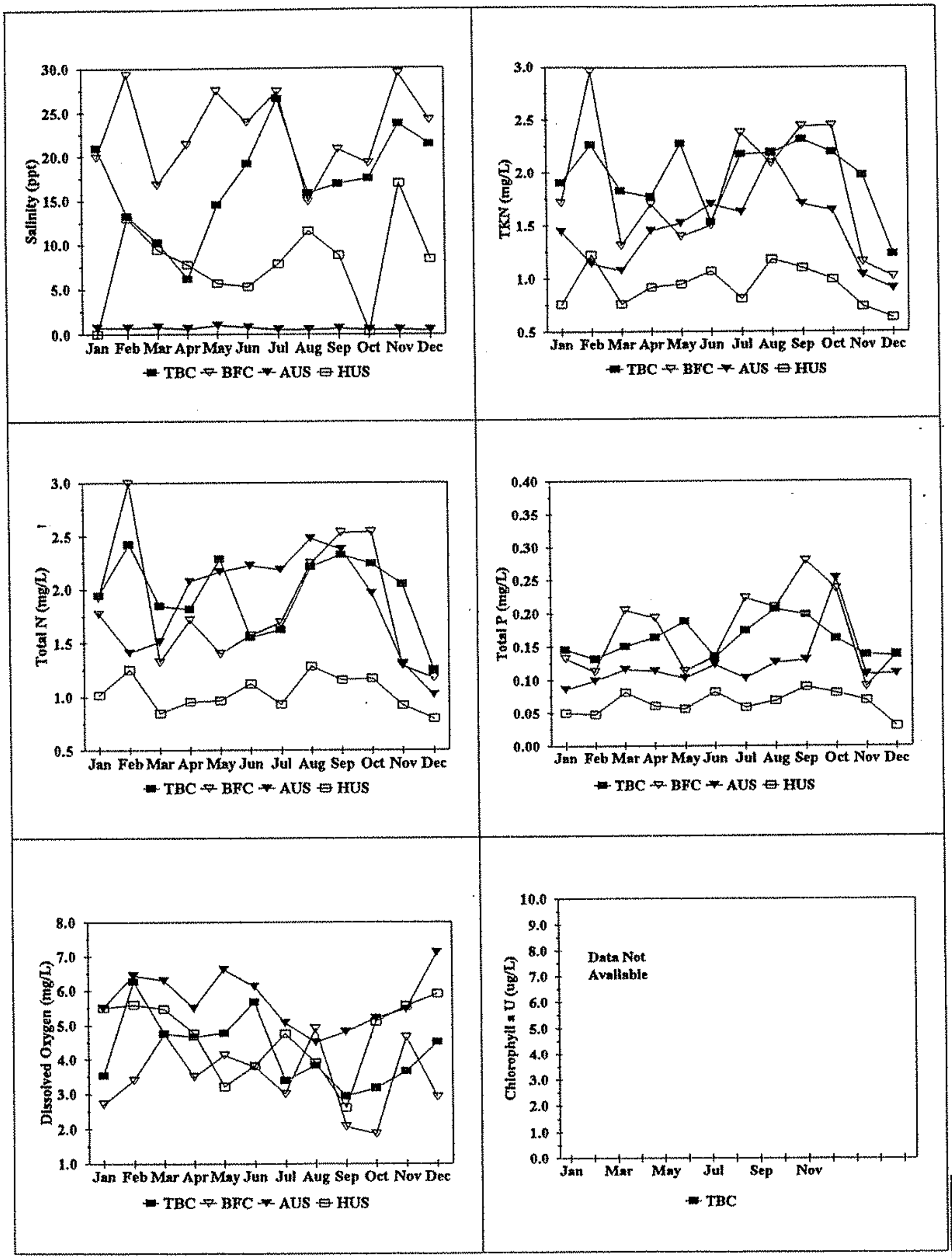
• Woodward-Clyde Consultants
• Marshall McCully & Associates
• Natural Systems Analysts

DRAWING NO.:

DATE:

FIGURE 5-7, (CON'T) MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE TRIBUTARIES IN SEGMENT 1B - BANANA RIVER

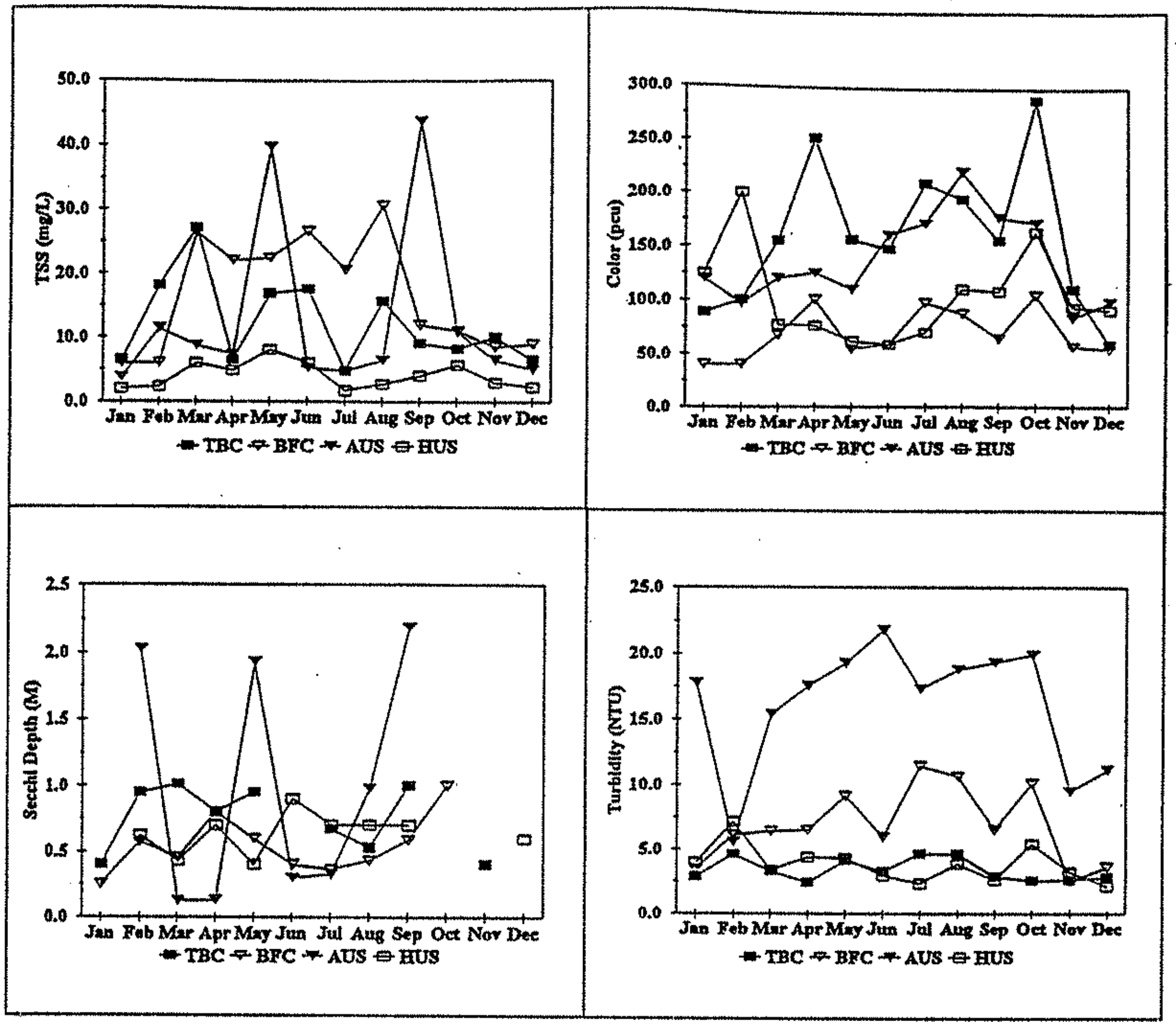
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: TBC=Turnbull Creek, BFC=Big Flounder Creek, AUS=Addison Creek at U.S. 1, HUS=Horse Creek at U.S. 1

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-8 MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE TRIBUTARIES IN SEGMENT 1C - NORTH INDIAN RIVER LAGOON

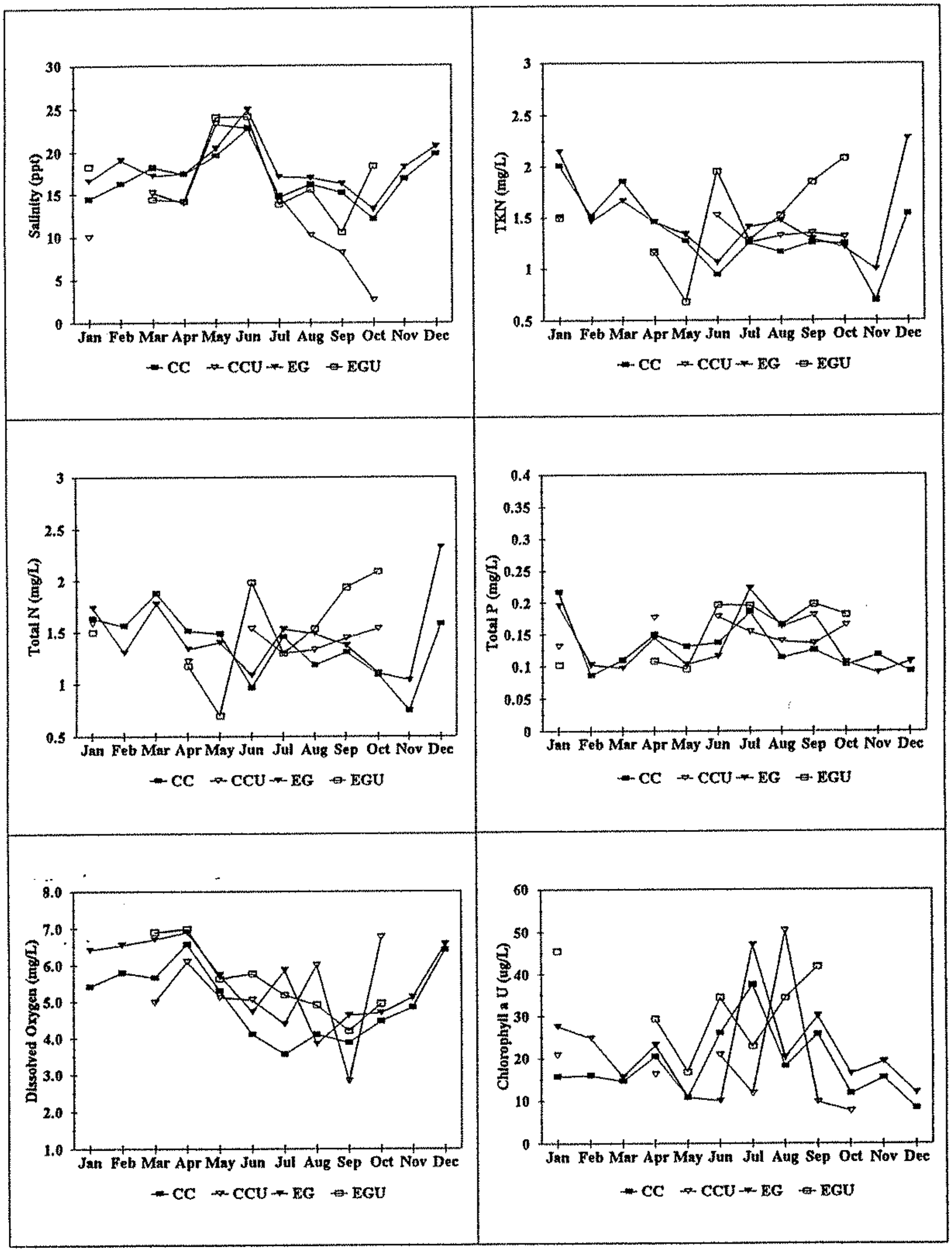
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: TBC=Turnbull Creek, BFC=Big Flounder Creek, AUS=Addison Creek at U.S. 1, HUS=Horse Creek at U.S. 1

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-8, (CON'T) MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE TRIBUTARIES IN SEGMENT 1C - NORTH INDIAN RIVER LAGOON

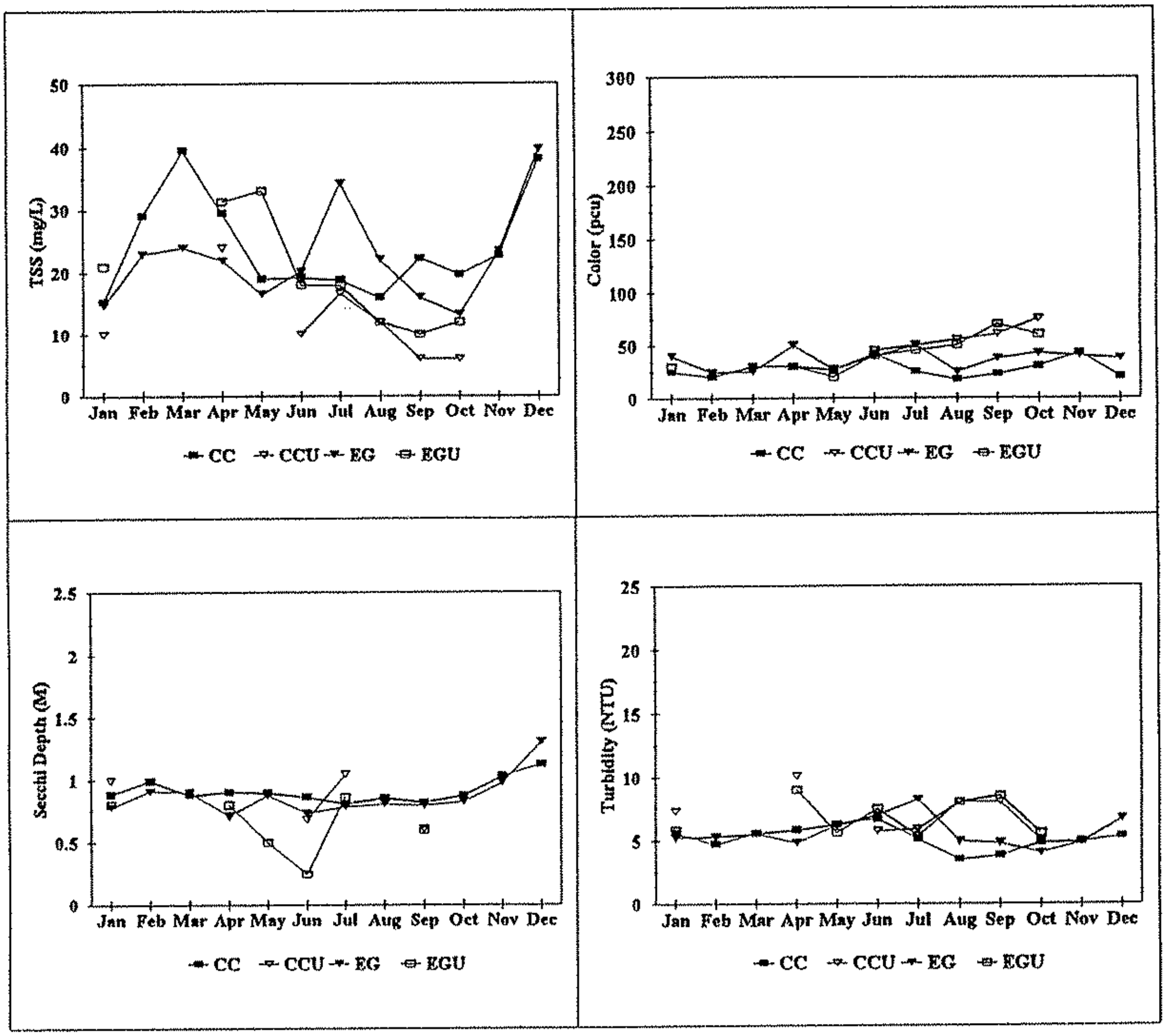
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: CC = Crane Creek, CCU = Crane Creek At U.S. 1, EG = Eau Gallie River, EGU = Eau Gallie River At U.S. 1

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-9 MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE NORTHERN TRIBUTARIES IN SEGMENT 2 - NORTH CENTRAL INDIAN RIVER LAGOON

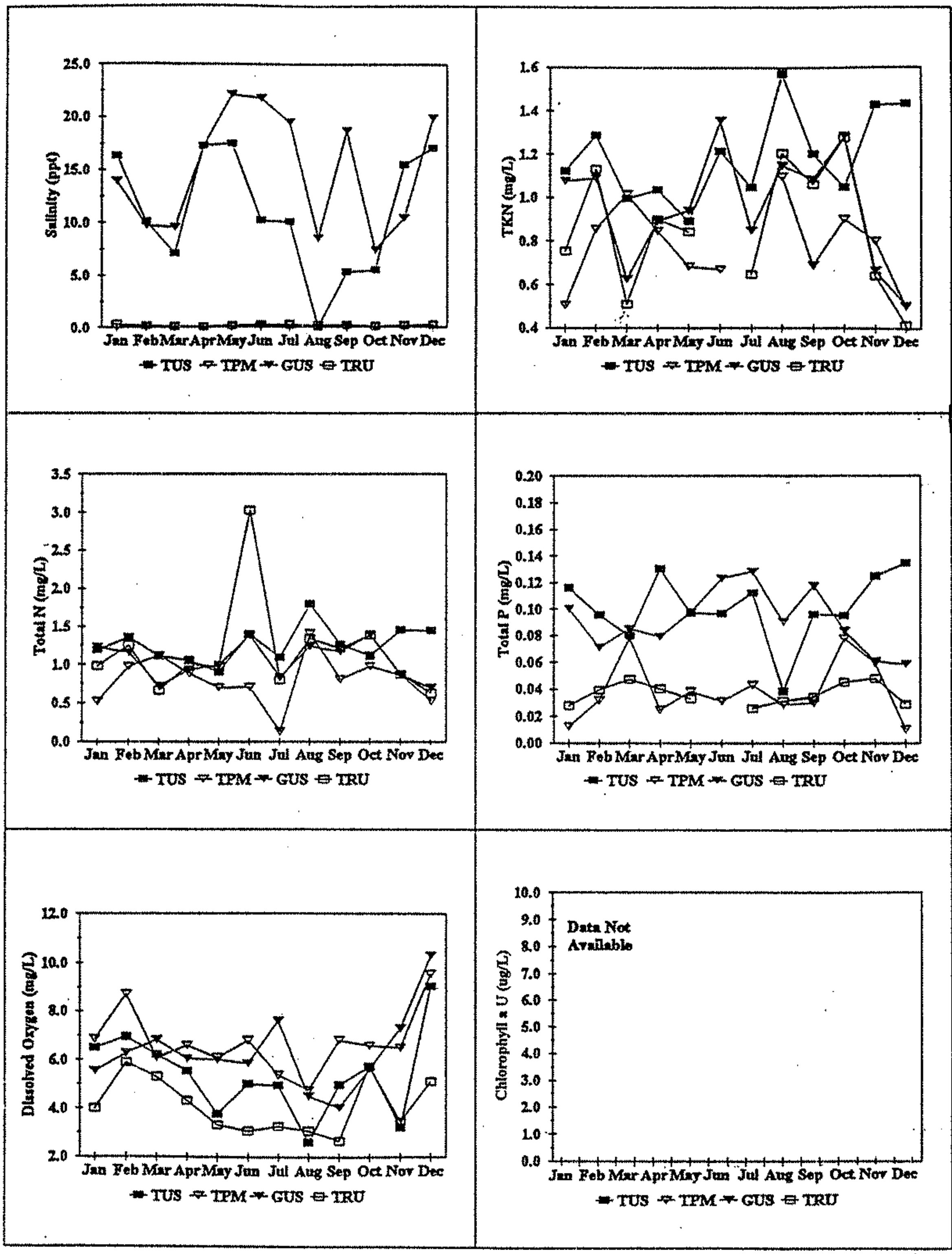
INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: CC = Crane Creek, CCU = Crane Creek At U.S. 1, EG = Eau Gallie River, EGU = Eau Gallie River At U.S. 1

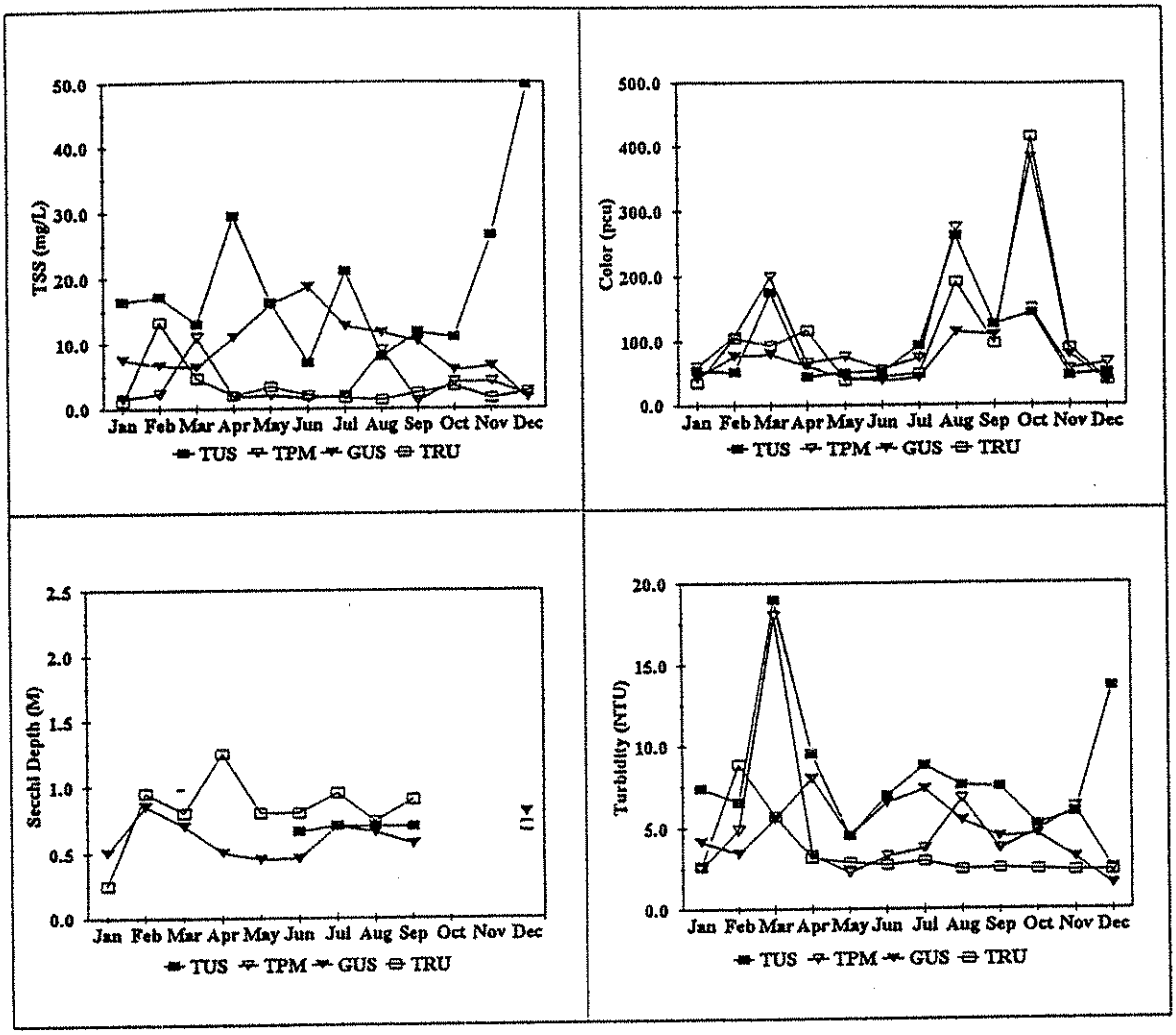
• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-9, (CON'T) MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE NORTHERN TRIBUTARIES IN SEGMENT 2 - NORTH CENTRAL INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



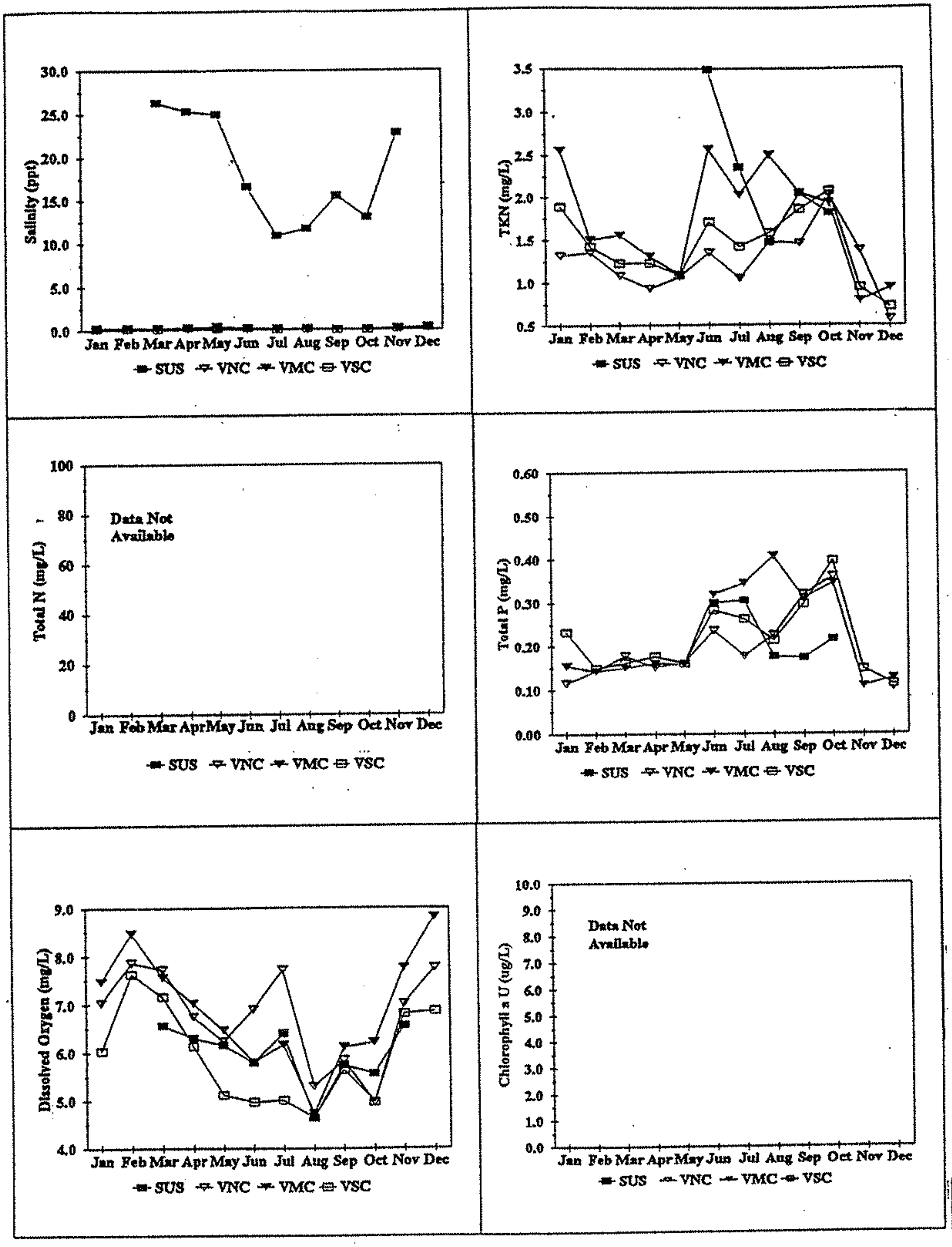
Explanation: TUS=Turkey Creek at U.S. 1, TPM=Turkey Creek at Port Malabar Blvd., GUS=Goat Creek at U.S. 1, TRU=Trout Creek at U.S. 1

• Woodward-Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-10 MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE SOUTHERN TRIBUTARIES IN SEGMENT 2 - NORTH CENTRAL INDIAN RIVER LAGOON	INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: TUS=Turkey Creek at U.S. 1, TPM=Turkey Creek at Port Malabar Blvd., GUS=Goat Creek at U.S. 1, TRU=Trout Creek at U.S. 1

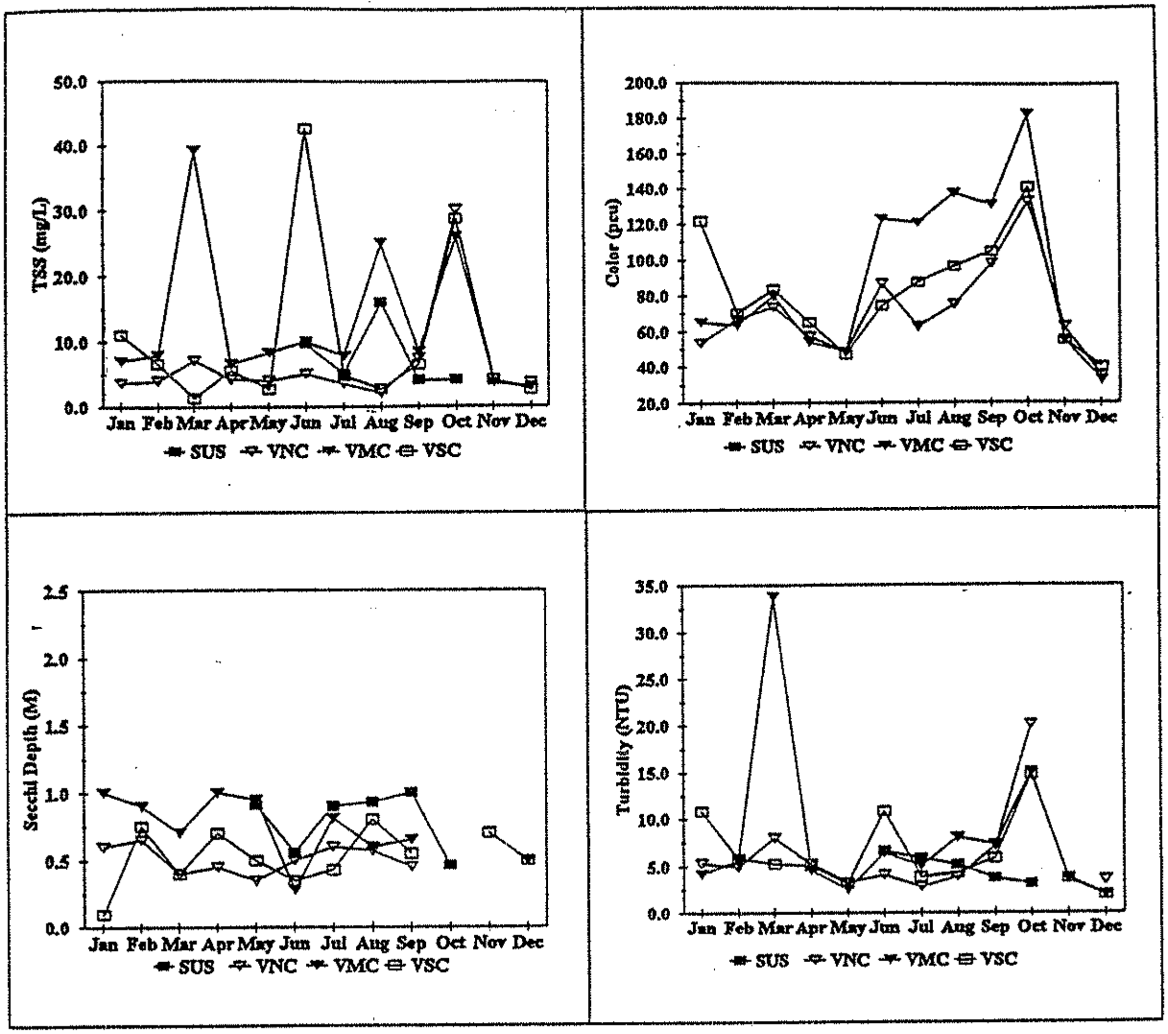
• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-10,(CON'T). MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE SOUTHERN TRIBUTARIES IN SEGMENT 2 - NORTH CENTRAL INDIAN RIVER LAGOON	INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: SUS=Sebastian River at U.S. 1, VNC=Vero North Canal, VMC=Vero Main Canal, VSC=Vero South Canal

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-11 MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE TRIBUTARIES IN SEGMENT 3 - SOUTH CENTRAL INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



Explanation: SUS=Sebastian River at U.S. 1, VNC=Vero North Canal, VMC=Vero Main Canal, VSC=Vero South Canal

- Woodward—Clyde Consultants
- Marshall McCully & Associates
- Natural Systems Analysts

DRAWING NO.:

DATE:

FIGURE 5-11, (CON'T). MONTHLY AVERAGES FOR WATER QUALITY PARAMETERS OF THE TRIBUTARIES IN SEGMENT 3 - SOUTH CENTRAL INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

Mosquito Lagoon are generally near the more favorable range of values reported for the Indian River Lagoon complex.

5.2.2 Water Quality Trends and Patterns in Banana River (Segment 1B)

In Segment 1B (Banana River), salinity decreases from north to south, probably reflecting the lack of freshwater inflows and dominance of evaporative forces in the north Banana River. Total Kjeldahl nitrogen levels consistently are among the higher levels observed in the region and appear to have little geographic variation during the dry season. However, TKN is higher in the wet season in the north end of Banana River. An explanation of this pattern is not readily apparent since wet season runoff sources appear to be more limited in the north. One possible explanation may be that wind driven circulation may be pushing nitrogen-containing discharge from WWTPs in the central part of the segment to the north where it may become concentrated. In the northern end of Banana River, TP and chlorophyll *a* levels are both fairly low and similar to the average conditions in the Indian River Lagoon. However, both of these parameters rise steadily to the south, reaching levels nearing the regional maximum at the south end of Banana River near Satellite Beach and Patrick Air Force Base. Secchi disk depth appears to decline from an annual average depth of about 1.4 m in the north to about 1.25 m in the south, possibly as an effect of increased phytoplankton populations and chlorophyll *a* in the south. On the basis of the available data, other parameters examined show no readily discernable patterns. Based upon the relatively high levels of both TKN and TP observed in the Banana River, high chlorophyll *a* levels might be expected throughout the segment. This appears to be the case in the southern half of the Banana River from Cocoa Beach south, but chlorophyll *a* levels in the northern half of Banana River are relatively low.

The water column of the southern Banana River also appears to have elevated levels of several metals, in particular cadmium. However, the concentrations are well below the maximum levels allowed under state water quality standards and are well within the range of values that have been found in many other estuaries (Trocine and Trefry, 1993).

The elevated nutrient, chlorophyll *a*, and metals concentrations in the Banana River south of Cocoa Beach appear to represent an area of generally poor water quality. Although some of the elevated levels of these parameters may come from urban non-point sources, runoff volume is fairly low in this segment (Chapter 4). Therefore probable sources are the WWTP facilities at Cape Canaveral, Cocoa Beach, Satellite Beach, and Patrick Air Force Base. Other possible sources may include non-point sources from Patrick Air Force Base and OSDS-served areas on Merritt Island. Termination of discharge from the WWTPs under Chapter 90-262 may result in lower concentrations of nutrients, chlorophyll *a*, and metals in the water column, but monitoring data at this point in time are not sufficient to identify such trends. Because of limited tidal flushing and currents in the Banana River, concentrations may remain high for some period of time after WWTP discharge is discontinued.

Tributary data from Sykes Creek and Newfound Harbor indicate that water quality is similar to that in the southern Banana River. The TP and chlorophyll *a* concentrations in Sykes Creek and Newfound Harbor appear to have decreased from values of about 0.09-0.13 mg/L for TP and 12-30 μg/L for chlorophyll *a* (Windsor and Steward, 1987) since the period from 1980-85. Total nitrogen concentration in Sykes Creek appears to have remained similar or has increased since 1980-85.

5.2.3 Water Quality Trends and Patterns in North Indian River Lagoon (Segment 1C)

Water quality conditions in the part of this segment north of Titusville are similar to those in Mosquito Lagoon. However, the impact of urban land use can be seen from near Titusville to the south end of the segment at Melbourne. To the north of Titusville (Stations I1 to I7), salinity remains fairly high (over 28 ppt) while TKN, TP, chlorophyll *a*, and turbidity remain among the lower values seen within the Indian River Lagoon. Salinity decreases south of Titusville during both wet and dry seasons, and lower wet season salinity is a response to increased precipitation and freshwater discharges in the southern part of the segment.

Chlorophyll *a* values increase dramatically at locations adjacent to Titusville, especially near the wastewater treatment plant outfalls. In the relatively short stretch Between Titusville and Sharpes, near the OUC and FPL electric power plant outfalls, chlorophyll *a* concentrations decrease and dry season TKN values become greater than wet season concentrations. The area between Sharpes and Rockledge is associated with an increase in wet season TKN, TP, and chlorophyll *a* concentrations. In this portion of the Lagoon, TKN and chlorophyll *a* values tend to be higher and to have greater variability among stations than in other segments of the Indian River Lagoon. The peaks appear to be related to the wastewater treatment plant discharges in this area. Cessation of discharge from these plants may result in lower observed chlorophyll *a* and TKN values in this reach in the future.

Existing literature and water quality data (Hand, et al., 1986; Hand and Paulic, 1992; Trocine and Trefry, 1993) indicate few problems with metals in the water column in Segment 1C. Some elevated lead levels have been reported from the Titusville area (Trocine and Trefry, 1993) but all reported levels are well within state water quality standards. Although copper has not been reported as a problem in the water of this segment, elevated copper and lead levels have been reported in the tissues of hard clams from the Cocoa and Titusville areas of Segment 1C (Trocine and Trefry, 1993).

The four major tributaries of this segment are, from north to south, Turnbull Creek, Big Flounder Creek, Addison Creek, and Horse Creek. With the exception of salinity which is lower and color which is higher, the water quality parameters in Horse Creek are similar to those of the Lagoon. In the other three tributaries, TN and TKN appear to be near the upper range of values in Lagoon water from this segment. Tributary TP concentrations are from 1 to 3 times higher than those in the Lagoon. Turbidity, color, and TSS are consistently higher in the tributaries, and the Secchi disk depth is lower. Color values in Turnbull Creek and Addison Creek are consistently above 100 PCU, as opposed to typical values of <30 PCU in the Lagoon. These color values are among the highest reported in the region.

5.2.4 Water Quality Trends and Patterns in North Central Indian River Lagoon (Segment 2)

The effects of the freshwater discharges from the extended watershed and the freshwater discharges from the Eau Gallie River, Crane Creek, and Turkey Creek can be clearly seen in Segment 2 (North Central Indian River Lagoon). Salinity is highest at the south end at Sebastian Inlet where it remains near 28 ppt, but it decreases steadily northward to average between 22 ppt and 25 ppt between Turkey Creek and the Eau Gallie River at Melbourne. Most water quality parameters in this segment appear to be typical of the mid range of values reported for the region with the exception of salinity, which is below average and TKN which is near the upper range of reported values.

Total Kjeldahl nitrogen and TP remain fairly constant throughout this segment, with the exception of substantially higher wet season peaks seen at Station I22 between the Eau Gallie River and Crane Creek. Both of these tributaries, as well as Turkey Creek, have been established as among watersheds with the largest stormwater sources of nitrogen in the region (Point and Non-Point Source Loads Assessment Technical Report). Chlorophyll *a* concentration is highest in the northern part of Segment 2 near Melbourne, a fact which is not totally consistent with the relatively constant TKN and TP concentrations. There appears to be a slight trend of increasing TN and TKN toward the north, implying that nitrogen may be the limiting factor for phytoplankton in this segment. Higher chlorophyll *a* levels in the north also may be a response to the increased nutrient concentrations between Crane Creek and the Eau Gallie River. Nutrient levels remain high as far south as Sebastian Inlet, possibly reflecting both wastewater treatment plant discharges and urban stormwater runoff from the Melbourne - Palm Bay area. South of Sebastian Inlet, TKN and chlorophyll *a* concentrations decrease, even though stormwater freshwater runoff inputs increase significantly, suggesting that chlorophyll *a* concentrations may be more strongly linked to the wastewater treatment discharges.

Areas in the North Central Indian River Lagoon have generally had some of the highest reported copper concentrations in the water column of the Lagoon. In particular, metals levels have been reported as high in Melbourne and Eau Gallie Harbors and Turkey Creek (Trocine and Trefry, 1993). Concentrations of copper from 3 to 10 times background levels have been reported in Eau Gallie Harbor (Holbrook, 1984). Areas of elevated copper are generally associated with centers of boating activity and appear to be related to the use of copper-based anti-fouling paints for boats. Several studies have also reported elevated levels of copper, zinc, and mercury in hard clams or barnacles in the Eau Gallie Harbor area (Barber and Trefry, 1981; Trefry, et al., 1983).

Water quality data was evaluated for five tributaries of this segment - the Eau Gallie River, Crane Creek, Turkey Creek, Goat Creek, and Trout Creek. Mean monthly salinity values range from 0 ppt to 27 ppt. In general, the reported TN,TKN, and TP concentrations in Turkey Creek, Goat Creek, and Trout Creek are similar to those within the Lagoon in this segment. The average TKN concentrations (0.7 to 1.8 mg/L) in this segment of the Lagoon are also among the highest of any segment, possibly reflecting the inputs from these tributaries. Although TKN and TN in the Eau Gallie River and Crane Creek are similar to those of the other three tributaries, the TP levels in these two waterways are about twice the levels in the Lagoon and the other tributaries. Turbidity is slightly higher than in the Lagoon and Secchi disk depth is about half that of the Lagoon. Color in all tributaries is much higher than in the Lagoon.

Earlier data from 1980 through 1985 (Windsor and Steward, 1987) for two other major tributaries of this segment indicate that annual average TN levels have been much higher in the Eau Gallie River (1.5 to 2.4 mg/L) and Crane Creek (2.4 to 4.2 mg/L) than in Turkey Creek (0.9 to 1.3 mg/L). A comparison of the data from the 1988-92 period to the 1980-85 period indicates a possible reduction of TP levels in Turkey Creek from a annual mean range of 0.15 to 0.19 mg/L between 1980 and 1985 to a peak monthly average of 0.14 between 1988 and 1992. In the 1980-85 period, TP values were much higher in the Eau Gallie River (0.3 to 0.4 mg/L) and Crane Creek (0.6 to 1.0 mg/L) than in the Lagoon or the other tributaries of this segment. A substantial reduction of TP to between 0.1 and 0.2 mg/L apparently has occurred in the Eau Gallie River and Crane Creek since 1985. Chlorophyll *a* data from the 1988-92 period and from the 1980-85 period (Windsor and Steward, 1987) also indicates that levels in the Eau Gallie River and Crane Creek were greater than in the other tributaries or the Lagoon by a factor of two or more. This data indicates that the Eau Gallie River and Crane Creek may be the primary sources of nutrients in this segment. The peaks in TKN and TP that occur at the water quality monitoring station (I22) between these tributaries also support this interpretation.

5.2.5 Water Quality Trends and Patterns in South Central Indian River Lagoon (Segment 3)

In Segment 3 (South Central Indian River Lagoon), the effects of the Sebastian River and the Indian River Farms Water Control District discharges are obvious, as salinity values drop to about 26.0 ppt near the Vero North, Main, and South Canal outfalls. This part of the Lagoon has a small surface area so evaporation is reduced as well. Another example of the effect of the freshwater discharge into this segment is color. Wet season color values are higher than dry season values by a factor of 3, indicating discharge of colored, tannin-laden waters during wet season stormwater and groundwater flow. Total phosphorous values around the three Vero canal discharge points are substantially higher than elsewhere in the Lagoon. Total Kjeldahl nitrogen is also elevated in this portion of the Lagoon between

Wabasso and Vero Beach, indicating that this entire segment of the Lagoon may be affected by the discharges from the Sebastian River and Indian River Farms Water Control District.

Water quality appears to be similar in the four major tributaries of this segment. The Sebastian river and the Vero South, Main, and North Canals all have TP concentrations near the upper end of the range of Lagoon water values in the dry season and two to three times higher than the Lagoon in the wet season. Total Kjeldahl nitrogen concentration is also higher in all of these tributaries than in the Lagoon. Turbidity and TSS appear to be lower in the tributaries in many instances than in the Lagoon.

5.2.6 Water Quality Trends and Patterns in South Indian River Lagoon (Segment 4)

In Segment 4 (South Indian River Lagoon Basin), salinity values remain high throughout most of the segment, dropping only at the discharge of the Belcher Canal (C-25), and the St. Lucie River which is the discharge point for a very extensive system of drainage canals. The volume of discharge from both of these systems is very high, higher than the Sebastian River discharge, and a large volume of water would seem likely to be introduced into the Lagoon. However, unlike the North Central and South Central segment discharges, there are physical features at both of these discharge locations that seem to limit the dispersion of these discharges into the Lagoon. Ft. Pierce Inlet is directly across the Lagoon from the Belcher Canal and the causeways on the north and south sides of the inlet may tend to channel Belcher Canal discharges to the inlet. There also are causeways north and south of St. Lucie Inlet on each side of the path between the St. Lucie River and the St. Lucie Estuary mouth. Some dispersion may occur into the Lagoon north of the estuary mouth, but is limited by the shoaling between the inlet and the Stuart Causeway.

Other than in the immediate vicinity of the Belcher Canal and the St. Lucie River, TKN, TN, TP, and chlorophyll *a* values are generally similar and within the lower ranges of average values found throughout the lagoon system. Nutrient and turbidity levels appear to be somewhat lower in the Jupiter Inlet to Hobe Sound portion than elsewhere in Segment 4.

Recent data was not available for tributaries of the South Indian River Lagoon segment. However, data from the 1980-85 period (Windsor and Steward, 1987) indicates that TN annual average concentrations in the C-24, C-44, and C-23 canal tributaries of the St. Lucie

River were between 1.0 and 2.2 mg/L, within the range of Lagoon concentrations in the 1988-92 period. Total phosphorus concentrations were much higher (0.09 to 0.27 mg/L) in the canals than in the Lagoon (0.03 to 0.08 mg/L). The 1980-85 Segment 4 tributary nutrient levels are similar to those found in the Segment 3 tributaries in the 1988-92 period. The fact that nitrogen and phosphorous levels in Segment 4 of the Lagoon have remained relatively low implies that this section of the Lagoon may have a high assimilative capacity and/or good flushing characteristics, or that the waters from the St. Lucie River do not mix thoroughly with those of the Lagoon.

Relatively high values of some metals have been reported from portions of Segment 4. Elevated copper concentrations have been reported throughout this segment from the north end to Manatee Pocket in the St. Lucie Estuary. High levels of lead also have been reported in Manatee Pocket (Trocine and Trefry, 1993). Elevated levels of copper, cadmium, and lead have also been reported for Ft. Pierce Harbor and Taylor Creek (Trocine and Trefry, 1993).

5.3 SEDIMENT QUALITY

Approximately 90% of the bottom area of the Indian River Lagoon complex is believed to consist primarily of sandy sediments and shell fragments (Trefry, et al., 1990). However, fine-grained, organic-rich sediments, referred to as muck, occurs in about 10% of the Lagoon in deposits ranging up to more than 6 ft thick. These muck deposits tend to have high oxygen demand and may also be readily suspended in the water column, reducing light penetration and covering benthic communities as they settle (Trocine and Trefry, 1993).

The sediment quality of most of the open parts of the Indian River Lagoon is good. Substrate contamination of particle-reactive metals and synthetic organic compounds appears to be associated only with the muck deposits that occur in about 10% of the Lagoon area. These deposits tend to be found in the mouths of the tributary creeks, in sheltered areas near harbors and causeways, and in the deeper parts of the Intracoastal Waterway. The largest of these areas is Manatee Pocket in the St. Lucie Estuary. About 40% of the ICWW bottom is comprised of muck sediments.

Studies utilizing Cesium-137 (Cs-137) and Lead-210 (Pb-210) radionuclides indicate that the muck may have started to accumulate between 50 and 100 years ago (Trefry, et al., 1990) and that rates of accumulation may be between 0.1 and 0.4 in/yr. The radionuclide studies have also indicated that metals contamination is generally restricted to the upper 1.3 ft of muck and that this upper portion of the muck represents accumulations that have occurred since about 1950 (Trefry, et al., 1990). Elevated levels of copper, lead, and zinc, and other metals have been noted at several locations where muck deposits are found. Trocine and Trefry (1993) sampled sediment metals concentrations at 45 locations throughout the Lagoon and found 15 stations at which concentrations of one or more metals were above the statewide background levels as estimated by FDEP. Table 5-1 and Figures 5-10 and 5-11 show locations where elevated levels of aluminum (Al), silver (Ag), cadmium (Cd), copper (Cu), chromium (Cr), iron (Fe), mercury (Hg), manganese (Mn), lead (Pb), and zinc (Zn) were found. Areas in which the greatest accumulations of metals in sediments are found include Manatee Pocket in Segment 4, the Melbourne and Eau Gallie Rivers in Segment 2, and the south Banana River near Patrick Air Force Base (Segment 1B). Elevated levels of Cu, Pb, Zn, and/or Hg have also been reported near Melbourne (Segment 2), near Titusville and Cocoa (Segment 1C), near Taylor Creek at Ft. Pierce (Segment 4), and near canal outfalls in Mosquito Lagoon (Segment 1A).

Generally these elevated levels of metal concentrations are associated with leaching and reabsorption from boat bottom paints, chips and flakes of this paint adjacent to boat yards, and, in the case of lead, direct aerosol deposition of fossil fuel combustion products. Sediment build-up inside of the Lagoon adjacent to the inlets also has been identified as a problem. These deposits interfere with navigation and change the tidal regime within large parts of the Lagoon. Management of the effects of inlet maintenance operations on the circulation and water quality of the Lagoon should be part of the Indian River Lagoon management plan.

5.4 TOXIC SUBSTANCES

Concentrations of Cd, Cr, Cu, Fe, Hg, Pb, and Zn found in Indian River Lagoon hard clams reflect both natural and anthropogenic inputs to the system. In most cases concentrations of Cd, Cu, Hg, and Zn in clam samples are greater than those from sediment samples taken in the same area. Bioaccumulation for these metals appears to be occurring from particulate

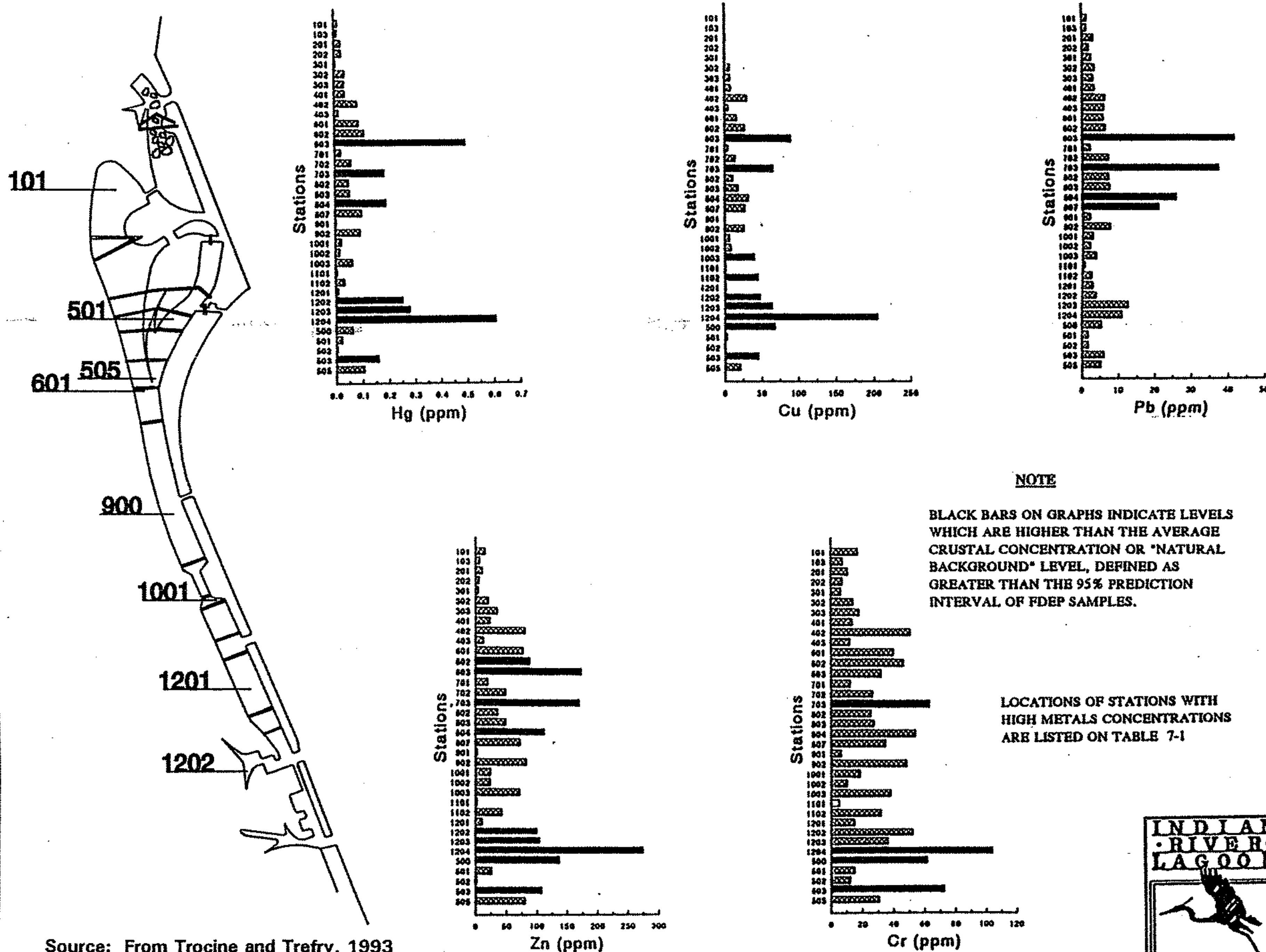
TABLE 5-1

MATRIX OF LOCATIONS WITH SEDIMENT METAL CONCENTRATIONS GREATER THAN THE FDEP ESTIMATED BACKGROUND LEVEL[1,2]

STATION	LOCATION	Al	Ag	Cd	Cu	Cr	Fe	Hg	Mn	Pb	Zn	NUMBER OF METALS ABOVE AVERAGE
202	Indian River Lagoon-Titusville		●									1
402	Indian River Lagoon-Cocoa								●			1
500	Port Canaveral				●	●					●	3
503	South Banana River		●		●	●		●			●	5
505	Banana River-South End			●								1
602	Indian River Lagoon near Eau Gallie										●	1
603	Eau Gallie Harbor	●	●		●			●	●	●	●	7
703	Melbourne Harbor		●		●	●		●		●	●	6
804	Turkey Creek Mouth							●		●	●	3
807	Indian River Lagoon near Turkey Creek						●			●		2
1003	Indian River Lagoon South of Vero Beach				●							1
1102	Indian River Lagoon near Taylor Creek			●	●							2
1202	Manatee Pocket				●			●			●	3
1203	Manatee Pocket				●			●			●	3
1204	Manatee Pocket				●	●		●			●	4

Source: Trocine and Trefry, 1993

1 = See Figure 5-2 for definition of background level
2 = Dot represents presence of above-average concentrations of that metal



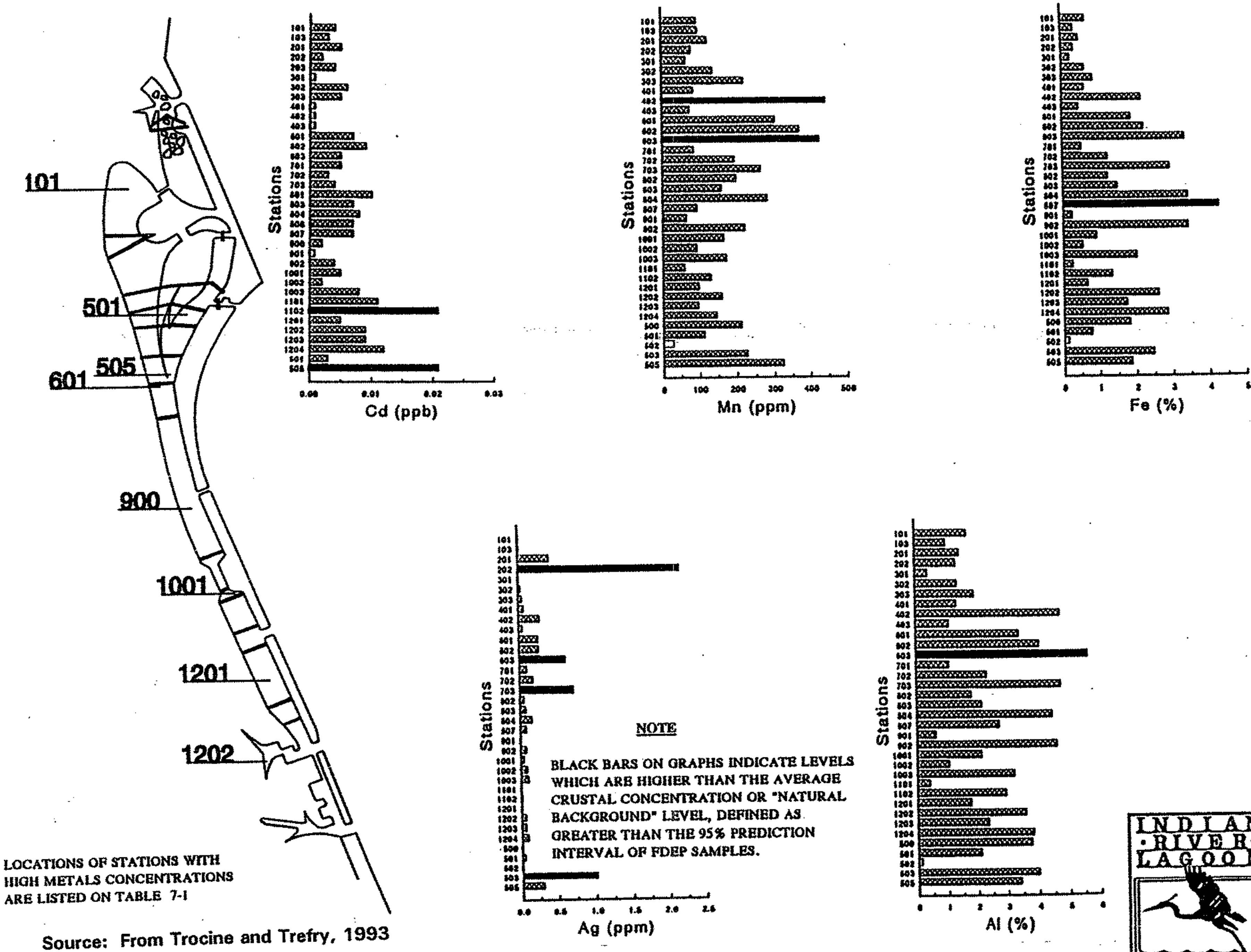
Source: From Trocine and Trefry, 1993

NOTE

BLACK BARS ON GRAPHS INDICATE LEVELS WHICH ARE HIGHER THAN THE AVERAGE CRUSTAL CONCENTRATION OR "NATURAL BACKGROUND" LEVEL, DEFINED AS GREATER THAN THE 95% PREDICTION INTERVAL OF FDEP SAMPLES.

LOCATIONS OF STATIONS WITH HIGH METALS CONCENTRATIONS ARE LISTED ON TABLE 7-1

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysis	DRAWING NO.: DATE:	FIGURE 5-12 SEDIMENT CONCENTRATIONS FOR Hg, Cu, Pb, Zn and Cr



NOTE

BLACK BARS ON GRAPHS INDICATE LEVELS WHICH ARE HIGHER THAN THE AVERAGE CRUSTAL CONCENTRATION OR "NATURAL BACKGROUND" LEVEL, DEFINED AS GREATER THAN THE 95% PREDICTION INTERVAL OF FDEP SAMPLES.

Source: From Trocine and Trefry, 1993

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 5-13 SEDIMENT CONCENTRATIONS FOR Cd, Mn, Fe, Ag AND Al

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

and dissolved sources throughout the Lagoon (Trocine and Trefry, 1993). Clams found in the Cocoa area appear to be the most impacted. Areas near the Eau Gallie and Melbourne Harbors, and south Banana River also appear to have some accumulation of metals in tissues of marine organisms. Preliminary indications are that Cu, Pb, and Zn levels in some locations may be at a level potentially affecting hard clams and oysters. However, there are too few data to make conclusions at this time. Lagoon-wide results from clam studies indicate that the maximum concentrations for Cd, Hg, and Pb are up to 10 times greater than minimum levels. For Zn, there is a difference of greater than 50 times. These differences indicate that some areas of the Lagoon system have been more impacted than others. A focus on areas identified in the Toxic Substances Survey as having elevated levels, coupled with investigation of water and sediment quality may, identify causes for differences. Currently, the U.S. Food and Drug Administration (FDA) maintains standards for commercial sale only for the concentration of Hg within shellfish. The levels reported in the hard clams of the Indian River Lagoon are well below the maximum Hg levels allowed by FDA.

5.5 SUMMARY OF WATER QUALITY TRENDS AND PATTERNS

The use of a Lagoon-wide data set and monitoring network allows for identification of trends and patterns in water quality throughout the region. For the first time, this coordinated data network can: 1) allow detailed investigation into the relationship of Lagoon water quality to tributary water quality; 2) assist in evaluating the relative contribution of point and non-point sources; 3) identify potential sources of water quality problems; and 4) allow comparisons between different portions of the Lagoon. The use of the Lagoon-wide network should help to optimize management resource allocation and allow management options tailored to specific areas and situations.

The SWIM data network represents a major advance in managing water quality actions. However, it is still in a developmental phase and many problems remain to be solved. The data base at the time of this evaluation lacked adequate data for several key areas of the region, including all tributaries in the South Indian River Lagoon (Segment 4), the Eau Gallie River and Crane Creek (Segment 2), and Sykes Creek and Newfound Harbor (Segment 1B). The periods of record were not complete for stations in Indian River County (South Central Indian River Lagoon - Segment 3) and data for several parameters are missing from numerous stations. At the present time, it is difficult to make direct comparisons of data because of different periods of record, numbers of observations, and frequencies of observation among different stations. As a result of these gaps in the data base, the characterization study evaluation of water quality had to be conducted at an elementary level. The data are generally still too limited to allow meaningful time-series analysis for determining changes in water quality over time.

It is therefore very important that consolidation, improvement, and update of the SWIM network data base be continued and that coordinated management and sufficient resources be available to assign this element a high priority. More detailed recommendations on changes or additions to the SWIM data network are included in the Water and Sediment Quality Assessment Technical Report.

On the basis of information available at the time of this study, several observations on the status of the water quality can be made at this time.

- In the Indian River Lagoon proper, salinity is highest in the South Central portion (Segment 4) with values consistently between 30 and 36 ppt. Proceeding northward, salinity declines rapidly from the St. Lucie/Indian River County line to a point just north of the Vero North Canal where it reaches an average value of about 26 ppt. Salinity rises in the vicinity of Sebastian Inlet, but then declines to the north to average values of 22 to 24 ppt near Turkey Creek, depending on season. Average salinity remains at this level through Cocoa, at which point it rises to values near 30 ppt north of Titusville. Salinity shows both wet and dry season gradients increasing to the north in Banana River, but salinity is almost constant between 32 and 34 ppt throughout Mosquito Lagoon.

- The salinity gradients in the Lagoon system appear to represent balances of the effect of mixing with ocean waters through the inlets, the extent of evaporation from the Lagoon surface, and the magnitude of freshwater inflows from tributaries, runoff, and WWTPS. It appears that the higher salinities in Mosquito Lagoon (Segment 1A), north Banana River (Segment 1B), and the

North Indian River Lagoon (Segment 1C) are primarily the result of evaporation from the large surface areas of the Lagoon coupled with low freshwater inflow from small drainage basins. Although the drainage basin and freshwater inflows are large in Segment 4, the tidal exchange from Ft. Pierce, St. Lucie, and Jupiter Inlets appears to dominate the salinity balance. Freshwater inflow appears to dominate the balance in Segments 2 and 3, resulting in lowered salinities. Any factors which affect this balance should also affect salinity distribution in the Lagoon. Inlet alterations which change tidal currents, changes in the size of drainage basins or percentages of impermeable surface, and changes in rainfall patterns all may result in changes to the salinity regime of the Lagoon. It is probable that the extension of the natural drainage basins in Segments 2,3, and 4 have increased flows and reduced salinity from pre-development levels. Opening, closing, and stabilizing inlets during the past 100 years have also affected this balance.

- The data set for TN has many gaps and is of limited use in evaluating Lagoon-wide patterns. Total Kjeldahl nitrogen values are similar to TN values and have good coverage of the Lagoon. The TKN data indicate that concentrations in the northern portion of the Indian River Lagoon (Segments 1C and 2) and Mosquito Lagoon (Segment 1A) are generally higher (0.7 to 1.4 mg/L) than in the southern (Segments 3 and 4) Indian River Lagoon (0.3 to 0.8 mg/L). Concentrations are highest (1.2 to 1.7 mg/L) in Banana River. Concentrations are often somewhat higher in tributaries than in the Lagoon, particularly in Segment 3, but nitrogen levels in the Lagoon do not appear to follow the patterns of tributaries as closely as TP values.

- Total phosphorus levels are generally consistent over most of the Lagoon with average concentrations between 0.03 and 0.09 mg/L. Higher levels may be present in Segment 3 between Sebastian River and Vero Beach and possibly in an area near the Eau Gallie River and Crane Creek in Segment 2. These areas of higher TP appear to be near the outfalls of the Eau Gallie River, Crane Creek, Sebastian River, Vero North Canal, Vero Main Canal, and Vero South canal. All of these tributaries appear to have TP levels which are substantially higher than in the Lagoon itself or in most other tributaries.

- Chlorophyll *a* data may not be fully comparable throughout the Lagoon because of differences in analysis methods and differences or ambiguities in reporting data (e.g corrected vs uncorrected values). However, with this caveat, it appears that chlorophyll *a* concentration generally averages below 14 μg/L in most areas. This level has been identified as being within what is considered to be a "healthy" range in other estuaries (Ries, 1993). Chlorophyll *a* averages at least 16 μg/L in the south Banana River (Segment 1B); at locations near Titusville, Cocoa, and Melbourne in Segment 1C; and near WWTP discharge points near Ft. Pierce Inlet.

- The pattern of chlorophyll *a* concentration throughout the Lagoon needs to be examined in greater detail. On the level of the present evaluation, no consistent pattern between chlorophyll *a* concentration and nitrogen or phosphorous concentration appears to occur on a Lagoon-wide basis. Thus the available water quality information does not confirm that either of these nutrients is the limiting nutrient on a consistent basis and does not provide an estimation of the levels of these nutrients that correspond to increased phytoplankton growth. Measurement of dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorous (DIP) may be required to fully define the nutrient dynamics of phytoplankton in the Lagoon. Such measurements may not be necessary as long as chlorophyll *a* levels remain at moderately low levels.

- The highest values for Secchi disk depth are recorded in the North Indian River Lagoon segment (Segment 1C) with average values between 1.4 and 2.4 m. Values in the North Central and South Central Indian River (Segments 2 and 3) range from about 0.5 to 1.5 m. Values in Mosquito Lagoon and Banana River are between these levels. No Secchi desk depths were available for the south segment. Values in tributaries usually range from 0.3 to 1.0 m.

- Color data is sparse for the Lagoon-wide data set. No firm conclusions can be drawn. There is some indication that color follows a pattern inverse to that of Secchi disk depth, with lower values at the north end of Indian River Lagoon and higher values in Segments 2 and 3. However, the data to support this observation are very limited. Average color values (7 to 15 PCU) in Mosquito Lagoon are at the lower end of the range for the Lagoon complex. No data are available for Banana River and the South Indian River Lagoon. Color values in most tributaries are generally much higher (30 to 150 PCU) than in the Lagoon.

- The highest average values for total suspended solids (30 to 60 mg/L) were measured in the South Indian River Lagoon (Segment 4), with values in the rest of Indian River Lagoon, Banana River, and Mosquito Lagoon in the range from 5 to 30 mg/L. Turbidity is generally lowest in the North Central Indian River Lagoon segment (Segment 2). In Mosquito Lagoon (Segment 1A), the South Central Indian River Lagoon (Segment 3), and the South Indian River Lagoon (Segment 4) north of St. Lucie Inlet, values are relatively high.

- In general, dissolved oxygen decreases for all segments during the wet season. Otherwise, there do not appear to be any major trends among segments.

- From the information presented, it can be seen that the most samples analyzed for the indicator parameters were from the South Indian River Lagoon segment which also has the highest number of stations. The lowest number of samples analyzed was from the South Central Indian River Lagoon segment which also has the least number of stations.

- Because of the variability of water quality from each Lagoon tributary, it is difficult to make any general conclusions. However, the following observations are indicated: color values are an order of magnitude higher in the tributaries than in the open water of the Lagoon; TP and TKN are present in the tributaries in higher concentrations than the open waters; dissolved oxygen is lower for tributaries of Segments 1C and 2 than in the open waters of the Lagoon; and salinity appears to be lower in tributaries of Segments 1C and 3 than in the open Lagoon.

- Trace metal (Cd, Cu, and Pb) concentrations for water from the Indian River Lagoon reflect both natural and anthropogenic inputs.

- Metal contamination in sediments, tissues of hard clams, and the water column has been identified mostly in tributaries and sheltered harbors along the Lagoon. These include selected sites in the Titusville area, Eau Gallie Harbor, Melbourne Harbor, Turkey Creek, Taylor Creek, and Manatee Pocket. The southern portion of Banana River also has elevated metals contents.

- Dissolved Cu concentrations in harbors at concentration up to 13 times background levels (0.4 ppb) appear to be related to leaching from antifouling paints applied to marine craft.

- Metals levels in tissues of hard clams in general do not appear to be at levels known to cause damage to clams. The only human health standard for metals in shellfish is for mercury, and the highest levels recorded from the Lagoon are well within acceptable ranges set by FDA. Concentrations of metals in the water column are within FDEP standards for Class II and Class III waters with few exceptions. Therefore, metals contamination does not appear to be a severe problem in the Lagoon, with the possible exception of a few isolated areas. There is insufficient data to state whether levels are increasing or decreasing in the Lagoon.

6.0 USES OF THE LAGOON

6.1 POPULATION AND LAND USE

6.1.1 Population Changes

Table 6-1 shows actual and projected changes in population for the Lagoon region between 1970 and 2010. The past and present numbers are based on data for actual census population from the U.S. Bureau of Census official census data for 1970 and 1990. The total population within the basins of each of the 6 segments of the Lagoon system is an estimate based upon actual census population data by county. The proportion of the actual population within each segment was obtained by allocating proportions of populations of census tract units among segments, based on the proportion of the unit within each segment. Future population is estimated through extrapolation of population trends from the most recent census periods produced by the University of Florida Bureau of Economic and Business Research (BEBR, 1982-1990)).

The Lagoon region as a whole has generally followed the State of Florida's historic growth trends, with this trend expected to continue. The period from 1970 to 1990 saw a Lagoon-wide population growth rate of 124%, with total population increasing from 301,978 to 678,763. Growth rates of individual segments between 1970 and 1990 ranged from 35% in the already heavily developed Segment 1B (Banana River) to 220% in Segment 4 (South Indian River Lagoon) which is the largest and fastest growing segment.

An overall average 60% growth rate for the period from 1990 to 2010 is projected, with an anticipated 2010 population of 1,082,853. Population increases by 2010 within individual segments are projected to range from 18% in Segment 1B to 94% in Segment 4.

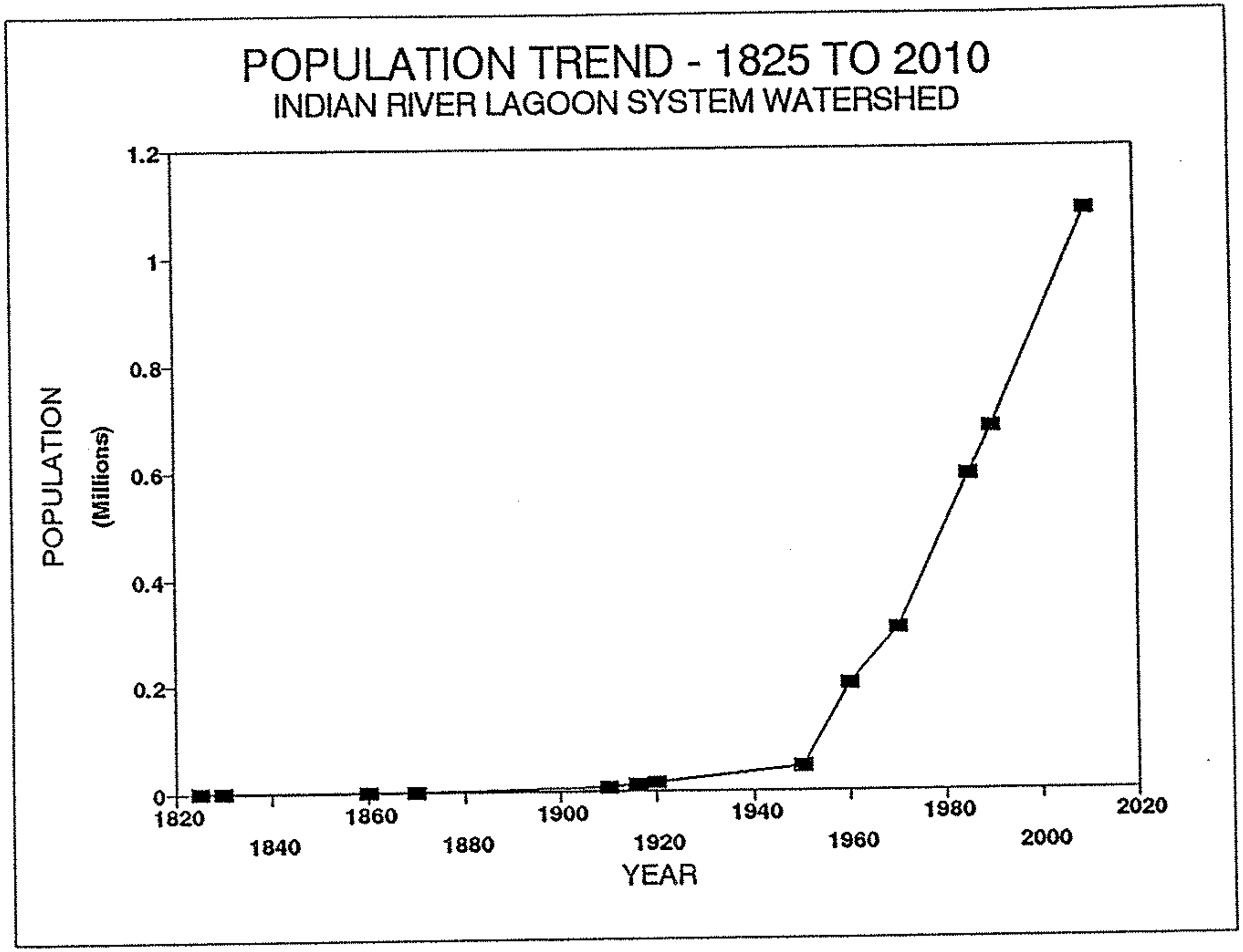
When one considers that the population of the region was about 1,200 people in 1870, 15,000 in 1920, and 45,000 in 1950 (Barile, 1988), the magnitude of the population growth in the region since 1950 becomes apparent. Figure 6-1, which shows the estimated

TABLE 6-1

POPULATION DATA AND PROJECTIONS FOR INDIAN RIVER LAGOON SEGMENTS

PARAMETER	SEGMENT 1A	SEGMENT 1B	SEGMENT 1C	SEGMENT 2	SEGMENT 3	SEGMENT 4	REGIONAL TOTAL
1970 Population	11,905	60,709	54,689	60,143	36,542	77,990	301,978
Percentage of Growth in this Interval	188%	35%	45%	133%	155%	220%	124%
1990 Population	34,320	81,993	79,494	139,974	93,218	249,764	678,763
Percentage of Projected Growth in this Interval	58%	18%	22%	44%	57%	94%	60%
2010 Projected Population	54,520	96,470	97,106	249,764	146,782	486,210	1,082,853

Source: Bureau of Economic and Business Research, 1982-1992
United States Bureau of the Census, 1992



• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 6-1 POPULATION TRENDS FOR THE INDIAN RIVER LAGOON SYSTEM WATERSHED FROM 1825 TO 2010

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

population of the Indian River Lagoon region since the earliest known records, illustrates the dramatic increases that will have occurred in the second half of the twentieth century. Since population growth is the primary stimulus of land use change, this process has driven the major changes in the drainage basins around the Lagoon. Many important environmental impacts also change in proportion to population, so these trends indicate increased needs for wastewater treatment and disposal, increased stormwater discharge to the Lagoon, and increased use of the Lagoon as evidenced by increasing numbers of boats and marinas on the Lagoon.

As seen in the preceding sections, pollutants from stormwater runoff are expected to increase in the future if additional management actions are not taken. These projections are based directly on land use changes which are in turn a function of population changes.

6.1.2 Land Use Changes

Land use in the current period (1988-1990) in the region was computed using existing GIS-based land use maps provided by SJRWMD (1993) and SFWMD (1993). Future land use was estimated on the basis of the Future Land Use Elements of each county's and municipality's Growth Management Plan. The future land use projections are estimates only, and substantial variation exists in the probable accuracy among counties. This is due to variability in the ways that individual counties estimate future land use needs. In some counties (i.e., St. Lucie), this projection is more representative of the built-out or maximum possible density condition, while in others (i.e., Brevard) it is more representative of predicted actual conditions based on population estimates. Methods and data sources used for analysis are presented in the Uses of the Lagoon Technical Report.

Urban land use has been estimated to have increased by 895% between 1940 and 1987, with agricultural land use increased by 352% in the same period (Hoffman and Haddad, 1988). The characterization study, based on county growth projections, predicts that the urban land use category will continue to increase by over 240% by the year 2010 in the Indian River Lagoon watershed. Agricultural land is predicted to decrease by 6%, while natural or open space lands are estimated to decrease by over 30%.

6.2 ECONOMIC USES

6.2.1 Recreational Uses

Although direct natural resources-based employment is estimated to account for over 10% of the total employment in only one county (St. Lucie County) in the region, the status of the local economies is linked to the health and use of the Lagoon, since the Lagoon is one of the primary tourist and recreational attractions of the region. About 16% of the hotel and restaurant outlets in the state occur within the Indian River Lagoon watershed, and many are dependent on Lagoon-based attractions such as fishing and fresh seafood (Florida Department of Commerce, 1993).

Recreational fishing pressure on the Lagoon has grown substantially. One estimate of the number of recreational fishing trips originating in the Lagoon, based on data from Yingling (1987) and the United States Bureau of the Census (1992), indicates that the total number of boat and non-boat trips (expressed as person-days of fishing) have increased from 806,000 in 1970 to 1,910,000 in 1990, with 2,890,000 trips possible in 2010. Another study (Milon and Thunberg, 1993) has estimated even greater use of the Lagoon, with 3.1 million trips in 1992 and 5.0 million trips in 2010. Surveys have indicated that spotted seatrout, snook, and redfish are the preferred targets of almost 50% of recreational fishermen in the region (Milon and Thunberg, 1993).

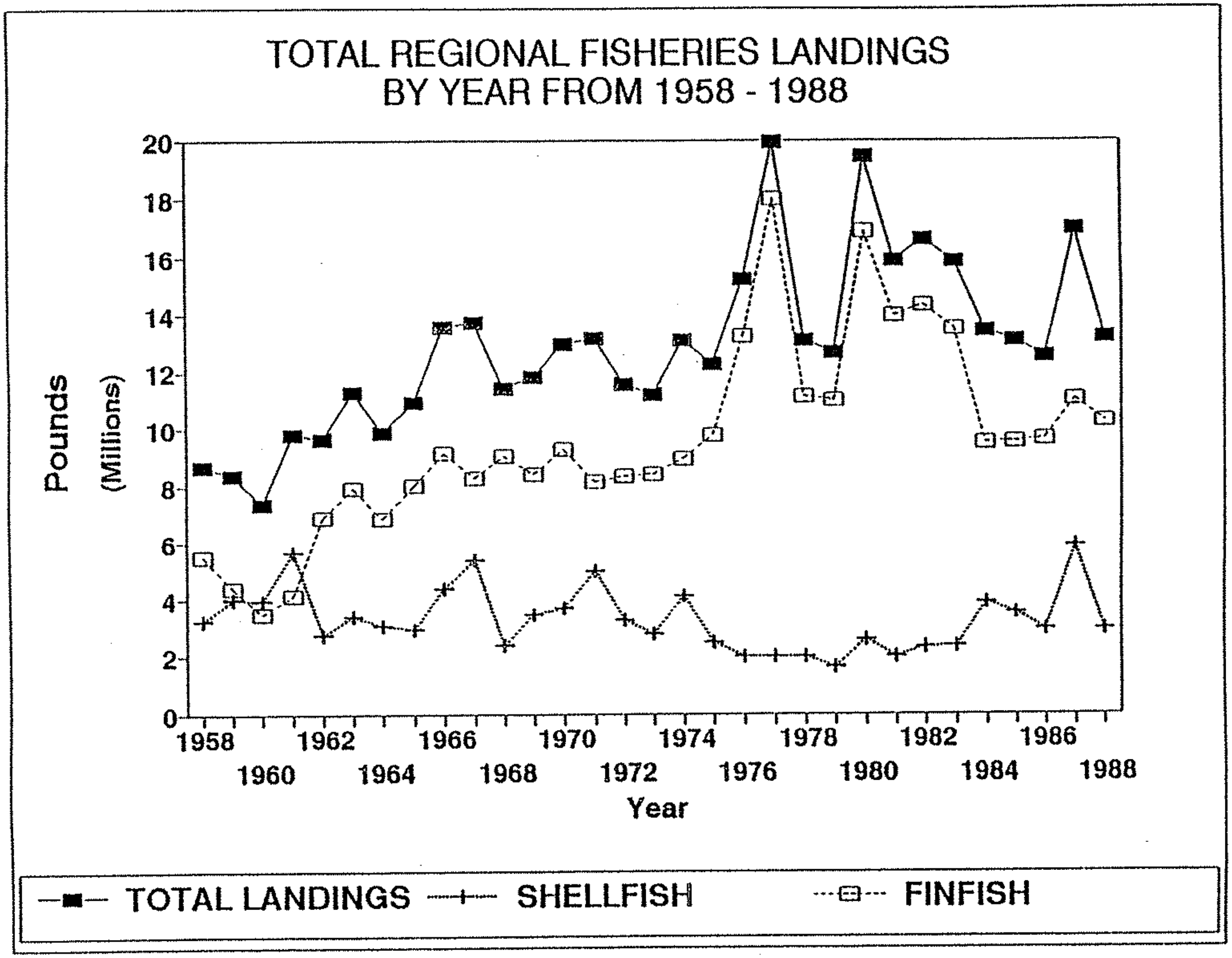
The number of facilities serving boaters and fishers has also increased substantially between 1984 and 1992 in the Lagoon. Registered recreational boats in a four-county (Brevard, Indian River, St. Lucie, Martin) area increased from about 28,800 to over 38,000 between 1979 and 1985 (Adams, 1985). Between 1984 and 1992, the number of boatyards and marinas between New Smyrna Beach and Stuart increased from 56 to 84 (Yingling, 1987; Argus Business, 1993). This recreational use of the Lagoon has been estimated to have a current economic value of between $244 million and $346 million (based on information from Bell, et al., 1982; Milon and Thunberg, 1993).

6.2.2 Commercial Fisheries and Agriculture

A cannery for sea turtles, fish, and oysters in 1866 appears to have been the first documented commercial fishery activity in the Indian River Lagoon (Earll, 1887). However, commercial fishery did not become a significant industry in the region until the late 1890s when improved rail transportation, improved boat access through opening of new inlets and dredging of channels, and increasing local population opened new markets for seafood (Rathjen and Bolhassen, 1988). Over 2.5 million pounds of fisheries products were shipped from Ft. Pierce in 1895, with over half of the total consisting of mullet (Wilcox, 1896). Between 1898 and the late 1950's, commercial fishing intensity within the Lagoon appears to have been relatively evenly distributed throughout the Lagoon, with trolling for spotted seatrout accounting for about half of the Florida seatrout catch (Tabb, 1960).

The Lagoon region produces about 14% of the state's fresh landings of seafood (Adams, 1985). Total commercial landings of fish and shellfish increased to about 8 million pounds in 1958 and peaked in 1977 at a level of 19.9 million pounds, following a dramatic rise in landings during the 1970s (Figure 6-2). Prior to 1975, total landings were similar for all of the counties along the Lagoon. However, several changes in landings patterns occurred between the late 1960s and 1975 which have resulted in substantially different distributions of landings since 1975. Finfish landings have shown only a slight geographic change in total landings patterns, but a dramatic shift has occurred for shellfish landings (Figure 6-3). By 1988, Brevard County accounted for 82% of the shellfish landings of the Lagoon region, while landings for Indian River, St. Lucie, and Martin Counties had decreased from 22% to 3% of the regional total.

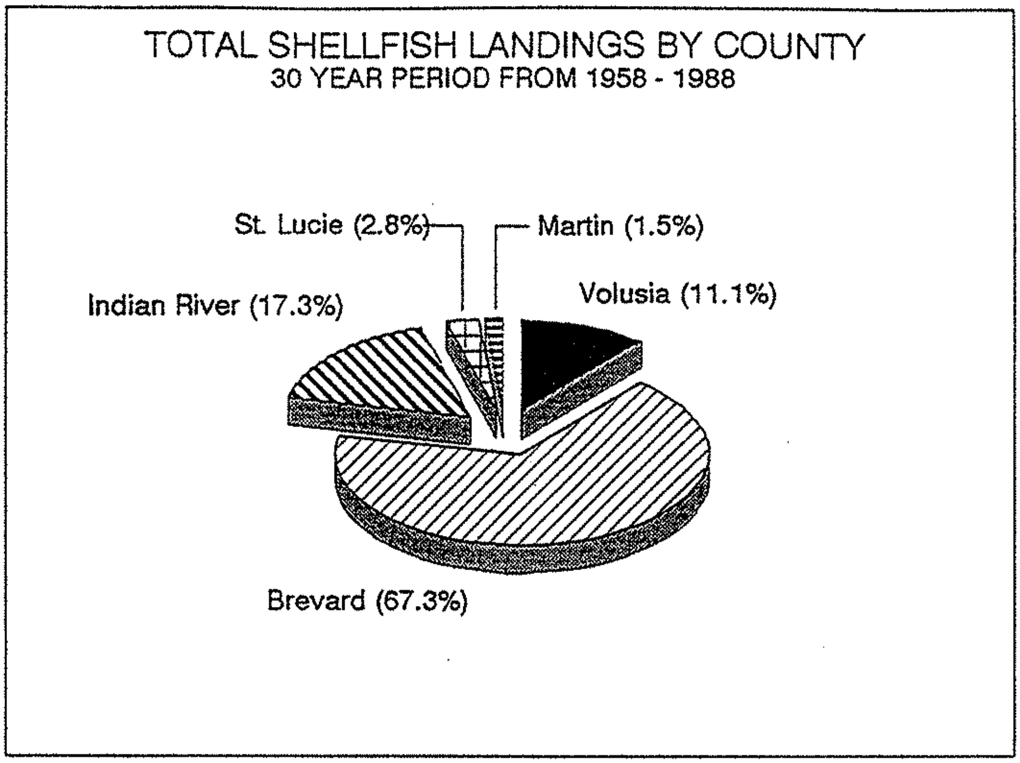
The changes in shellfish landings have been the result of several factors. Total shellfish landings decreased from about 4 million pounds in 1960 to under 2 million pounds in 1980. Blue crabs historically comprised almost all of the shellfish harvest until the mid 1980s when hard clam landings increased to over 1 million pounds in 1985 in Brevard County alone. The increase in the hard clam fishery in Brevard County in particular was responsible for the increase in shellfish landings. From a peak of over 1.5 million pounds in 1985, hard clam landings generally declined by about 67% by 1991. A rebound to over 945,000 pounds



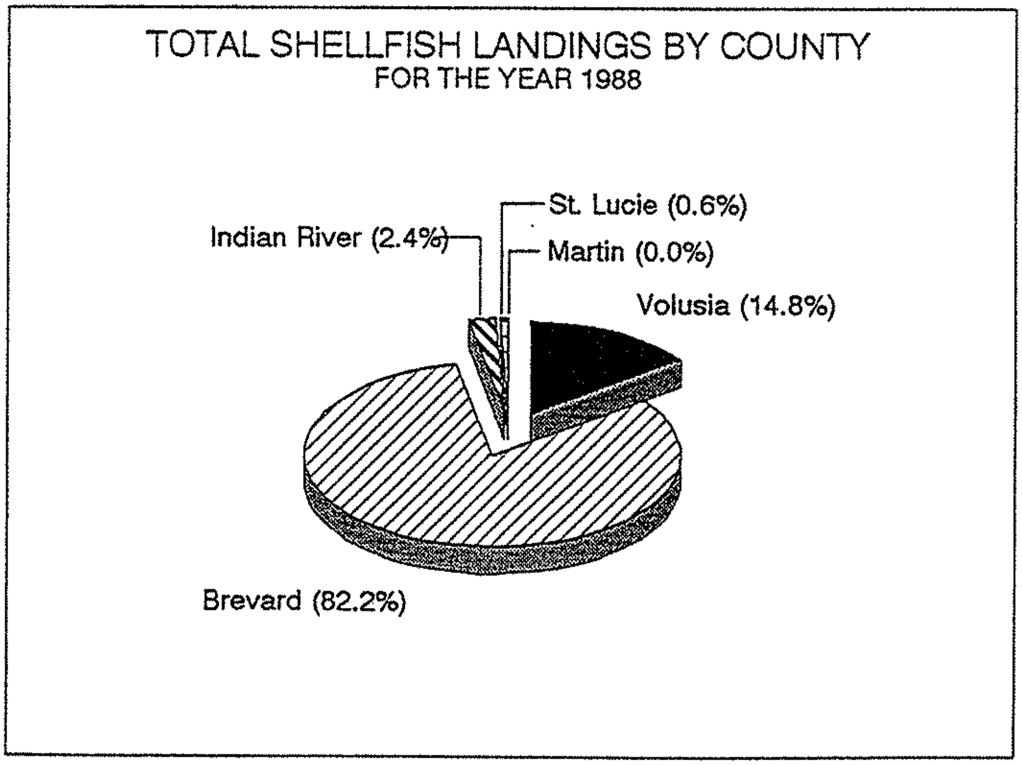
Sources: Florida Department of Natural Resources, various years
National Marine Fisheries Service, various years
Rathjen and Bolhassen, 1988.

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysis	DRAWING NO.: DATE:	FIGURE 6-2 TOTAL FISHERIES LANDINGS FOR THE INDIAN RIVER LAGOON REGION BY YEAR FOR THE PERIOD 1958 TO 1988

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM



a) ANNUAL AVERAGE TOTAL FROM THE 1958 THROUGH 1988 PERIOD



Sources:

Florida Department of Natural Resources, various years
National Marine Fisheries Service, various years
Rathjen and Bolhassen, 1988.

b) ANNUAL TOTAL FOR THE YEAR 1988

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.:	FIGURE 6-3 COUNTY HISTORIC (1958-1988 CUMULATIVE) AND RECENT (1988) ANNUAL SHELLFISH LANDINGS AS A PERCENTAGE OF THE REGIONAL TOTAL
	DATE:	

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

in 1993 has since occurred (FDNR, 1994). Blue crabs still comprise virtually all of the shellfish harvest in St. Lucie and Martin Counties.

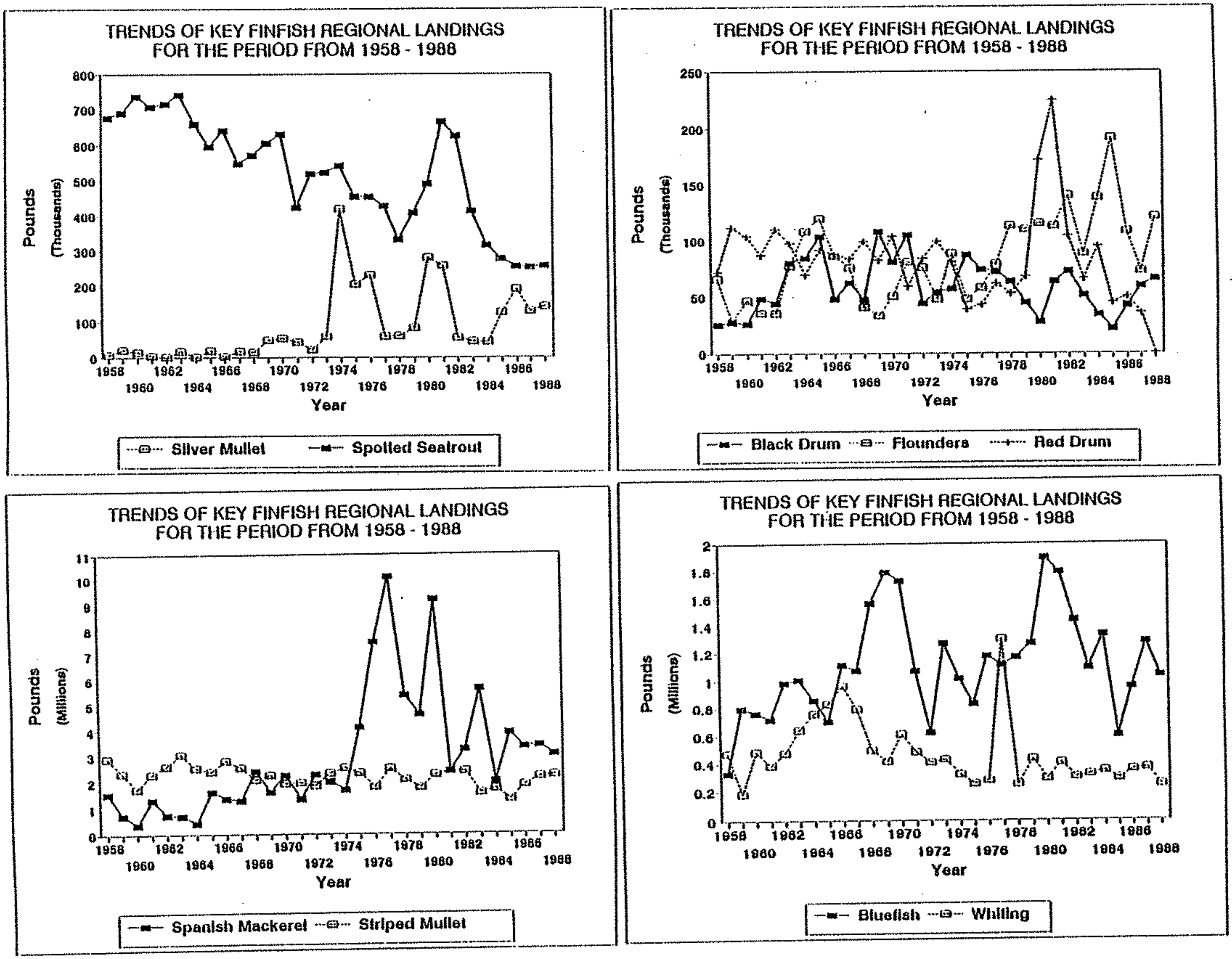
Although total fish and shellfish landings have increased, there have been significant changes in the types of species and the proportions among fish and shellfish species landed throughout this period. There is also a trend from landing of high value fish to lower value fish over time. Some species, such as the spotted seatrout, appear to have had a decrease of over 50% in landings since 1958, while others such as the Atlantic sheepshead, croaker, silver mullet, and mangrove snapper have increased (Figure 6-4) (FDNR, 1994).

The Uses of the Lagoon volume of this series of Technical Reports contains more detailed information on uses of the Lagoon, including landings information for individual fish and shellfish species for the period from 1958, when such data was first compiled by the National Marine Fisheries Service and the Florida Department of Natural Resources Marine Fisheries Information System, to 1991.

The Indian River Lagoon Citrus Region produced about 78,000,000 boxes of fresh citrus in 1990-91 from over 700,000 acres of producing citrus trees, representing over 38% of the total Florida citrus harvest (Florida Department of Agriculture and Consumer Services, 1992). Growth in citrus acreage in the region between 1988 and 1991 comprised 55% of the total citrus acreage increase in Florida over that period.

6.3 TRENDS IN USES OF THE LAGOON

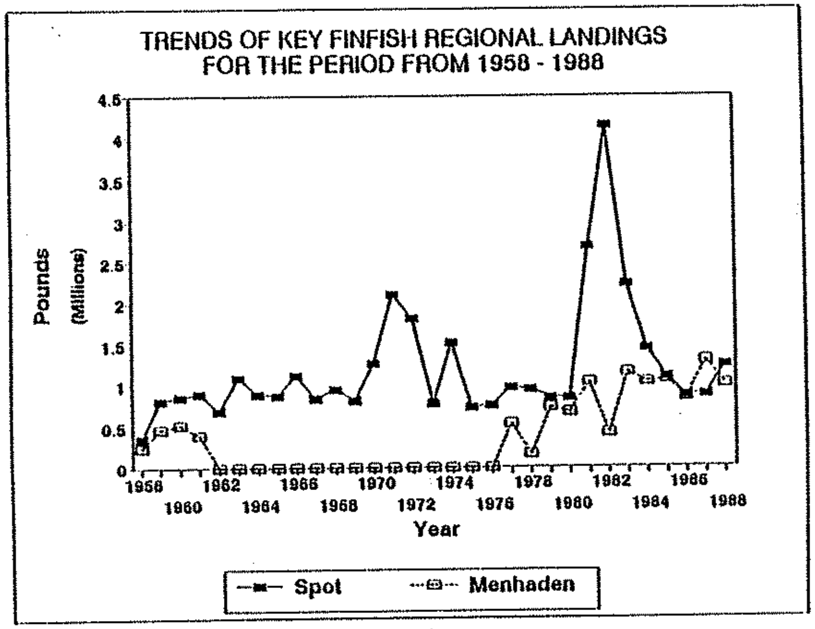
Although conditions in the watershed of the Lagoon have been changing to a more highly developed or urbanized state since the early 1800s, this process has greatly escalated in the second half of the twentieth century. The 1990 population of the region is estimated to have been almost 15 times larger than that in 1950, and an additional increase of 60% is predicted by the year 2010. The amount of urban land use has also been estimated to have increased by almost 10 times between 1940 and 1987 (Hoffman and Haddad, 1988) and is predicted to increase by a factor of almost 2.5 by 2010. Based on these estimates, the population and amount of urbanized area may have increased by almost 25 times over a period of less than 75 years.

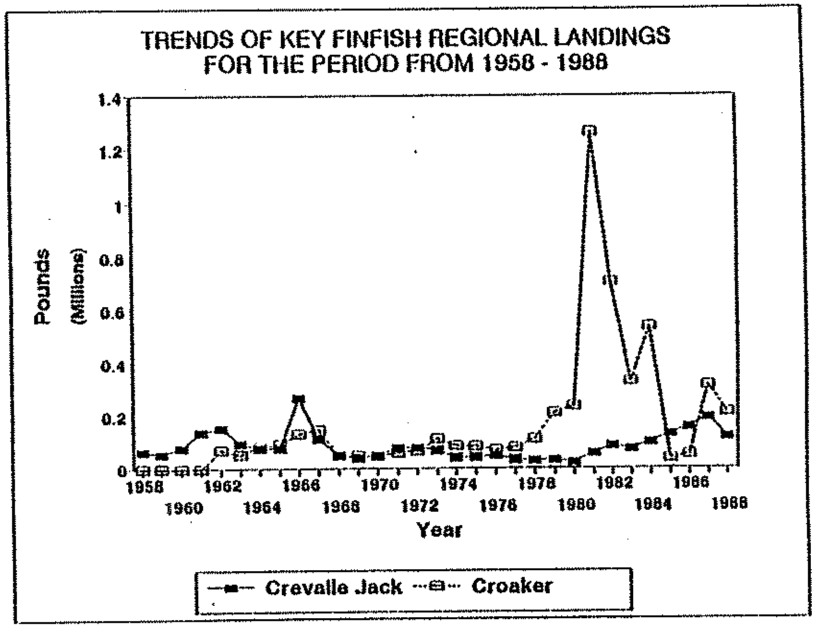


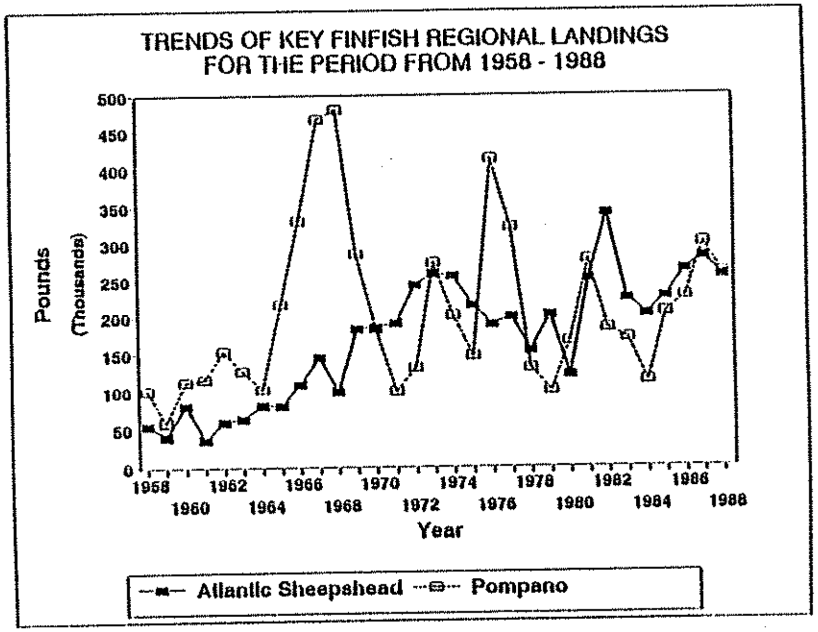
Sources: Florida Department of Natural Resources, various years
National Marine Fisheries Service, various years
Rathjen and Bolhassen, 1988.

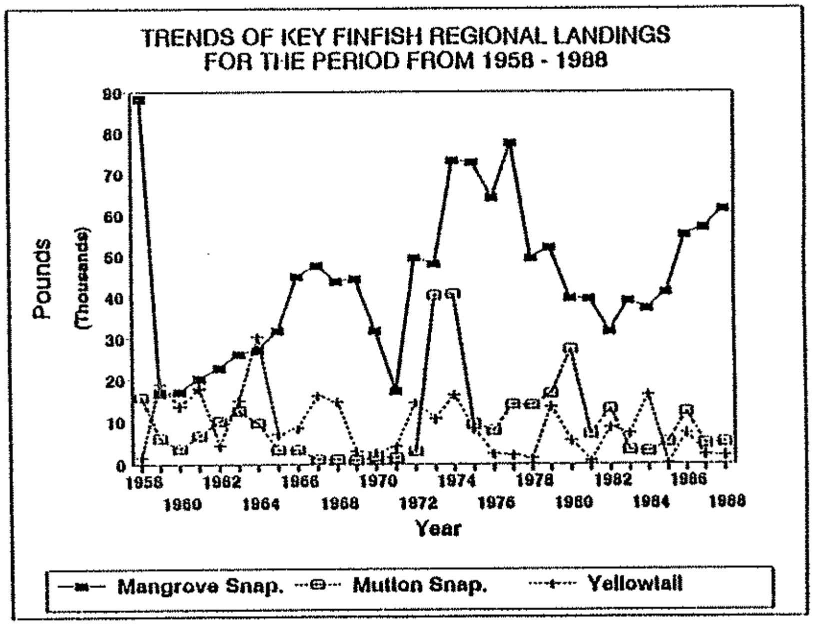
• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysis	DRAWING NO.: DATE:	FIGURE 6-4 LANDINGS TRENDS FOR KEY ESTUARINE-BASE FINFISH SPECIES FOR THE PERIOD FROM 1958 TO 1988

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM









Sources: Florida Department of Natural Resources, various years
National Marine Fisheries Service, various years
Rathjen and Bolhassen, 1988.

• Woodward–Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 6-4, (CON'T) LANDINGS TRENDS FOR KEY ESTUARINE-BASE FINFISH SPECIES FOR THE PERIOD FROM 1958 TO 1988

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

This increase in the human population and use of the watershed is also evidenced by large increases in agricultural acreage, fisheries landings, recreational fishing trips, and boating support facilities. Major impacts of this growth have affected and will continue to affect the resources of the Lagoon.

The increase in non-point source loadings, described in Chapter 4.2, is a direct result of changes in land use resulting from population growth. Construction of new stormwater-control or treatment facilities is one potential management option for reducing the magnitude and impacts of these loadings. However, such devices may require significant land areas in the face of declining availability of land. Therefore, alternative management strategies such as retrofitting or alteration of existing stormwater systems and control or minimization of stormwater runoff at the source through capture and reuse or through naturalized landscaping under programs such as the Florida Yard Program or xeriscaping concept may be useful management options. Differences in land use patterns among watersheds must also be taken into account when considering management options. Different problems and approaches may be required for areas such as the southern half of Segment 1B (Banana River) which already are highly developed, and for areas like Segment 4 (South Indian River Lagoon) in which much of the watershed is agricultural or undeveloped land.

Increased population will also result in increased needs for water supplies and wastewater treatment. Although cessation of direct wastewater discharges to the Lagoon is anticipated due to the Indian River Act (Chapter 90-262), increases in population will require innovative management methods to dispose of the increased wastewater disposal needs of an expanding population.

Increased population will also result in increased boating and fishing pressure on the Lagoon. The question of whether improvements in habitat or water quality will be sufficient to counter the estimated threefold or greater increase in recreational fishing pressure needs to be answered. Several additional impacts may also result from increased boating and fishing pressure as pointed out in Chapter 4. Elevated copper levels in the sediments and water column of the Lagoon have been associated most regularly with marinas and harbors where copper-based anti-fouling boat paints are concentrated. Boats also are thought to affect seagrass beds through physical damage and through decreasing light penetration by re-suspending mucks and fine sediments. Impacts to manatees from boat collisions (Chapter

7) have also been shown to be proportional to the amount of boat traffic (Kinnaird, 1983). Addressing these increasing pressures of an expanding population will remain one of the most difficult of management problems.

Differences also exist in the ways that individual counties and municipalities predict and allocate growth and plan for changing land use. As a result of the differing criteria and methods used by counties in developing the future land use elements of their Growth Management Plans, the land use projections in this report are approximate and may not match population projections. Since land use changes will affect freshwater drainage and the pollutant loadings to the Lagoon, more consistency in land use projection by local governments should be encouraged to allow consistent predictions of land use change effects throughout the Lagoon and the most efficient utilization of available management resources.

7.0
BIOLOGICAL RESOURCES

7.1 HISTORICAL ANALYSIS OF SEAGRASS STATUS AND TRENDS

As part of the characterization process, the extent of submerged aquatic vegetation (SAV) beds over the past 20 years was analyzed through the use of aerial photographs because SAV represents one of the most diverse and productive habitat types in the Lagoon (Zieman, 1982). Aerial photographs as far back as 1940 were utilized to evaluate change in extent and depth distribution. The term "submerged aquatic vegetation" refers to rooted vascular plants known as seagrasses and to attached algae species. Analysis of SAV for the Indian River Lagoon system is intended to focus on seagrass beds, but by necessity some algal beds may be included in the analysis since differentiation of seagrass and algae is not always possible on aerial photographs.

The historical imagery and mapping studies compared SAV abundance and acreage for the 1970-76, 1984-86, and 1992 periods. For these periods, total abundance and the approximate percentage of the potentially available seagrass habitat which was occupied by these beds were compared. Potentially available habitat is defined here as that which is within the depth limits of sufficient light penetration for long-term survival of the three dominant species of seagrasses (*Halodule wrightii, Syringodium filiforme, Thalassia testudinum*). An average mean low water depth of 6 ft (1.8 m) was used as an approximation of the maximum penetration of this photosynthetically available radiation (PAR). This depth has been proposed as an approximation for seagrass average maximum depth limits for non-degraded waters of other estuaries such as Chesapeake Bay (Orth, 1993) and Tampa Bay (Ries, 1993) and has been suggested as a possible target level or management objective for the Indian River Lagoon by the SAV Initiative (Morris and Tomasko, 1993). The SAV Initiative is an approach to managing seagrasses that has been developed in a series of workshops by various Lagoon managers and scientists. This approach recognizes the importance of seagrass beds and also the fact that the water quality of the Lagoon will be reflected by the health of the seagrasses. This may eventually allow water quality target levels to be established for parameters affecting water clarity (i.e., TSS, turbidity, color, and chlorophyll *a*) based on the requirements of seagrasses.

The 6-ft depth is regarded as a possible general average for the entire Lagoon. The actual depth will vary based upon actual requirements of different seagrass species and on local physical factors controlling water quality. For example, areas near inlets where oceanic water mixes with estuarine water generally have the greatest water clarity and this may allow seagrass growth and survival at greater depths. Some areas of the Lagoon are subject to naturally low light penetration because of high water color levels caused by tannic acids from creeks and swamps.

The limited amount of color data in the SWIM water quality data set indicates that Turnbull Creek in the North Indian River Lagoon (Segment 1C) has highly colored water. Because this source of reduced water clarity is apparently natural, management options to improve light penetration may be of little effect in this area of the Lagoon. Other areas of the Lagoon may have reduced light penetration due to high TSS, turbidity, or chlorophyll *a* levels. These areas are generally in areas where freshwater discharges occur and/or where tidal currents are minimal. Such areas include the Banana River (Segment 1B) and much of the Indian River Lagoon from Titusville to Vero Beach (Segments 1C, 2, and 3). Since the quality of the water entering the Lagoon from discharges can affect Lagoon TSS, turbidity, and chlorophyll *a* levels, water clarity in these areas of the Lagoon may be improved by management options that improve water quality. Several research projects are currently in progress to define the light penetration characteristics of the Lagoon and to determine seagrass responses to light levels in the Lagoon. The information from these studies will be important for the development of water quality goals and methods for the Lagoon.

As a first step in evaluating changes in seagrass occurrence and response over time, the maximum depth of seagrass beds and maximum depth of seagrass occurrence, as apparent from aerial photographs and existing mapping studies, were compared for several periods (1940-44, 1957-58, 1965-67, 1970-76, 1984-86, 1992) that cover approximately the last 50 years in Mosquito Lagoon, Banana River, and the Indian River Lagoon. The segments were subdivided into 56 smaller subsegments for a more detailed assessment of area-specific conditions throughout the system.

An assessment and inventory of aerial photographs and historical imagery sources applicable to SAV within the region found fairly consistent local sources of photographic coverage available on a local basis. This photography included coverage of most areas as far back as

1943. It is not possible to obtain local coverage of all areas within a single year, except for 1992. However, full coverage is provided within the following periods: 1943-44, 1952-54, 1957-58, and 1984-86.

SAV apparently has decreased 11% system-wide since the 1970s as indicated in Table 7-1. However, total acreage was higher (83,170 ac) in 1986 than in either the 1970s (78,519 ac) or 1992 (70,139 ac). The greater abundance in 1986 may have been due to an increased abundance of deeply occurring beds of the seagrasses *Halophila* spp. and the alga *Caulerpa prolifera*. Table 7-1 also shows the subtidal bottom area of the Lagoon.

Trends in SAV abundance appear to be present in some smaller portions of the system. In particular, decreases of 38% and 42% respectively have occurred in the North Central Indian River Lagoon (Segment 2) between Melbourne Causeway and Sebastian Inlet and in the North Indian River Lagoon (Segment 1C). Some of the decrease in the North Indian River Lagoon segment appears to be due to a decrease in deep beds south of Turnbull Creek, possibly a response to a major storm in 1991. However, the portion of the Indian River Lagoon from NASA Causeway to Grant Farm Island has had decreases in coverage of 31% to 83%, representing a continuous cover loss trend since 1970.

Trends in maximum depth of the outer edge of the seagrass beds support the concept of a trend of long-term decreasing vigor in Segments 1C and 2. The average maximum depth of the beds only varied between 3% and 19% during the same time period in Segments 1B (Banana River), 1A (Mosquito Lagoon), and 4 (South Indian River Lagoon) over the 1943 to 1992 period. However, a steady decrease of 50% in maximum depth in Segment 1C (North Indian River Lagoon) occurred from 1943 to 1992. Similar steady decreases up to a 37% reduction in depth of seagrass growth occurred in Segment 2 (North Central Indian River Lagoon) and 44% in Segment 3 (South Central Indian River Lagoon).

The long-term continuing decrease in SAV acreage and depth of seagrass beds in the central part of Indian River Lagoon indicates a long-term trend of seagrass decline in this area related to an inability to survive in deeper water. The SAV Initiative (Morris and Tomasko, 1993) has demonstrated that depth of seagrass occurrence often is a function of light penetration into water, and that light penetration is a function of water quality. Thus there appears to be a cause and effect relationship between declining water quality and declining

TABLE 7-1

EXTENT OF SUBMERGED AQUATIC VEGETATION THROUGHOUT THE INDIAN RIVER LAGOON SYSTEM FROM 1970 TO 1992

SAV COVER (ACRES) 1973 to 1992				
SEGMENT	1970s TOTAL SAV	1986 TOTAL SAV	1992 TOTAL SAV	TOTAL BOTTOM AREA
1A-Mosquito Lagoon	13,583	12,414	16,699	33,131
1B-Banana River	22,368	16,628	21,476	46,959
1C-North Indian River	30,239	34,110	17,689	69,753
2-North Central Indian River	3,390	3,719	2,091	23,302
3-South Central Indian River	2,460	2,977	2,934	15,794
4-South Indian River	6,480	13,322	9,249	31,068
Indian River Lagoon Subtotal	42,568	54,128	31,963	139,917
TOTAL SYSTEM	**78,519**	**83,170**	**70,139**	**220,007**

seagrass cover in Segments 1A, 2, and possibly 3. Portions of Segments 1A, 2, and 3 have had the greatest long-term percentage declines in seagrass cover. Since these portions account for approximately 27% of the potentially available habitat in the Indian River Lagoon system, the declining seagrass trend in these areas is a cause for concern.

Seagrass status in the remaining segments appears to be generally stable, although some variation on a more local scale does occur. These variations appear to be related to sampling or interpretive differences among years, variation in deep-water seagrass and algal species beds between years, or seagrass reaction to site- and time-specific random events such as individual storms. Some changing patterns of species composition and of seagrass/algae composition appear to be occurring in parts of the system, particularly in the Banana River, but existing data is insufficient to adequately describe any trends.

Lastly, seagrasses appear to cover a relatively small amount of the potentially available habitat less than 6 ft in depth. Less than 40% of this potentially available habitat in the Lagoon is covered by SAV. The areas where seagrasses cover the greatest proportion of this potential area are in Mosquito Lagoon (Segment 1A), Banana River (Segment 1B), and North Indian River Lagoon (Segment 1C), where total cover in waters less than 6 ft deep has ranged between 25% and 51%. Lowest coverage is in the North Central Indian River Lagoon (Segment 2) and South Central Indian River Lagoon (Segment 3), where it has never been above 20% in the time periods covered by this study. These numbers indicate that additional environmental factors such as substrate type, water temperature, water level variability, or salinity may also be influencing seagrass abundance and distribution.

7.2 SEAGRASS REQUIREMENTS AND DISTRIBUTION

Indian River Lagoon is home to seven species of seagrasses. In approximate order of abundance in the Lagoon, these are shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), turtle grass (*Thalassia testudinum*), star grass (*Halophila engelmanni*), paddle grass (*Halophila decipiens*), Johnson's seagrass (*Halophila johnsonii*), and widgeon grass (*Ruppia maritima*). Figure 7-1 shows the generalized appearance of these species as well as the most common algae of the SAV beds.

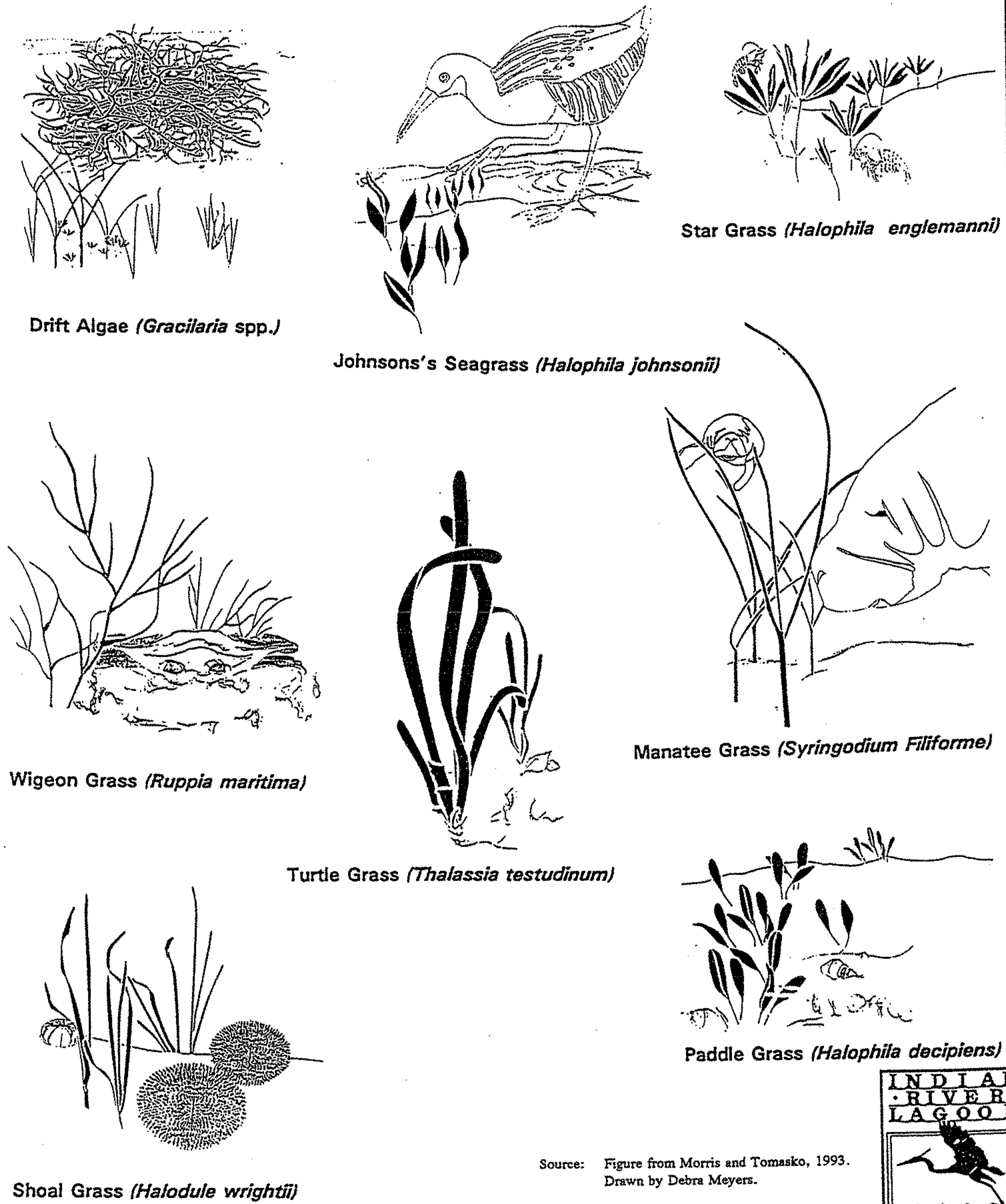
Most of these species have definite distribution patterns within the Lagoon, which may be important in influencing diversity and productivity of other species. The ecology of Johnson's seagrass is poorly known but it is restricted to a small region of southeast Florida, primarily in Segment 4 of the Indian River Lagoon. Because of its restricted range, it has been proposed for listing as a threatened or endangered species by the U.S. Fish & Wildlife Service (FWS).

The *Halophila* species appear to be capable of surviving in lower light conditions (as low as 5-10% of surface sunlight) than the other species (which probably require 15-25% of surface light intensity). Thus *Halophila* species (particularly *H. engelmanni*) may occur at deeper depths than the other species. The distribution of the other species appears to be explained primarily by differences in temperature, salinity, and possibly substrate throughout the Lagoon. Transect-based studies of seagrasses have shown that turtle grass is restricted to the Lagoon south of Sebastian Inlet, possibly in response to temperature and salinity conditions or reproductive success (Thompson, 1978; Virnstein and Cairns, 1986; Natural Systems Analysts, 1994). Shoal grass and manatee grass are co-dominants of the grass beds to depths of about 4.5 ft (1.5 m) throughout most of the Lagoon. The portion of Indian River Lagoon in Segments 1C, 2, and 3 from about Melbourne to Wabasso (between Sebastian Inlet and Vero Beach) is an exception (Thompson, 1978). In this reach, manatee grass almost disappears and shoal grass is the only dominant species. This is also the area of greatest seagrass decline in cover and depth of occurrence, so the changes in SAV abundance in this area may be related to declines of manatee grass. Low or fluctuating salinity is suspected to have had an effect on species distribution in this area.

Additional information on seagrass communities and extent is found in the Historical Imagery and Seagrass Assessment Technical Report and in Chapter 4.0 of the Biological Resources Technical Report.

7.3 OTHER HABITATS AND COMMUNITIES

The areas not occupied by seagrass beds that have sandy, muddy, or hard substrate bottoms generally have much less diverse and productive plant and animal communities (Virnstein, et al., 1983). Plant life is composed of floating algae (phytoplankton) and attached algae



• Woodward—Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysts	DRAWING NO.: DATE:	FIGURE 7-1 PRINCIPAL SEAGRASS AND MACROALGAE SPECIES OF THE INDIAN RIVER LAGOON	INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

species. The attached algae of the Lagoon have not been well studied, but they appear to be highly diverse and productive. The ecological function and degree to which these interact with seagrasses is poorly known, but they appear to be increasing in abundance in the Lagoon.

The phytoplankton community is a very important factor in the ecological health of the estuary, since phytoplankton forms a key base of the food web for many species and a sufficiently high phytoplankton density is a factor in estuarine productivity. However, overabundance of phytoplankton can also lead to water chemistry imbalances and fish kills, and can decrease light penetration. The reduction of light in the water column can reduce seagrass production and disrupt other parts of the food web. Seagrass productivity is important because phytoplankton have been estimated to contribute only 2 to 7% of the total primary productivity of the Indian River Lagoon as opposed to 50 to 85% for seagrasses or up to 90% for attached algae in some cases (Heffernan and Gibson, 1983). Throughout much of the year, most of the dominant species of phytoplankton are diatoms, but flagellate species may be abundant in late summer and autumn (Heffernan and Gibson, 1983).

In some other Florida estuaries such as Tampa Bay, a strong link between total nitrogen loading and phytoplankton abundance has been found (Tomasko, 1993). In these cases, chlorophyll *a* concentrations have been generally above 20 mg/L. In most of the Indian River Lagoon, levels have been found to below 20 mg/L (Chapter 5). Evidence from studies in other estuaries (Fisher, et al., 1992) has indicated that nitrogen is most often the limiting nutrient factor for phytoplankton growth in estuaries. The available nutrient and chlorophyll *a* data (Chapter 5) indicates that this probably will be the case in much of the Indian River Lagoon, but insufficient data is available to document this hypothesis. Additional research to establish the limiting nutrient factors for phytoplankton in the Indian River Lagoon would be useful in determining needs and strategies for managing nutrients in stormwater and wastewater discharges.

There is some evidence that chlorophyll levels in the early 1980s may have represented the maximum levels observed in the Lagoon. In general, recent levels seem to be lower than in the 1980s and similar to those recorded in the 1970s, with an average just over 10 mg/L. This overall level appears to be somewhat above the average values for Mosquito Lagoon, which may represent a "natural" benchmark, but the levels appear to be below the levels found to have contributed to water quality problems in Tampa Bay (Tomasko, 1993).

Much of the animal life consists of almost 700 benthic invertebrate species such as polychaete worms which live beneath the surface of the bottom. Amphipods, crustaceans, and gastropods are the most abundant invertebrates that live above the sediments.

These communities and habitats are described more fully in Chapter 4.0 of the Biological Resources Technical Report.

7.4 TIDAL WETLANDS AND MOSQUITO IMPOUNDMENTS

Salt marshes and mangrove forests are intertidal communities that are adapted to the areas fringing the Indian River Lagoon that are irregularly inundated by saltwater. Although Myers and Ewel (1990) have estimated that up to 10% of Florida's salt marshes occur along the Lagoon, the true salt marshes are almost entirely restricted to the northern portions of the complex north of Cocoa. The greatest extents are along Mosquito Lagoon (Segment 1A) and the North Indian River Lagoon (Segment 1C) in the Merritt Island National Wildlife Refuge (MINWR) and Kennedy Space Center (KSC).

Mangrove forests are dominated by red mangrove trees at or below the mean high water line and black mangroves or white mangroves above this elevation. Mangrove forests do occur throughout the Indian River Lagoon system, but periodic frosts tend to kill back the cold-sensitive tropical mangroves so that the mangroves rarely grow beyond the shrub stage north of Sebastian Inlet.

The salt marshes and mangrove forests along most of the Indian River Lagoon system differ from those in much of Florida because they are only irregularly inundated by tides, usually during the seasonal periods of highest water level that occur in late summer and fall (Figure 7-2). This lack of regular inundation results from the low tidal fluctuation that is characteristic of much of the Lagoon (described in Chapter 3.0). Because of the narrow tidal range, a low natural berm often occurs at the waterward edge of many wetlands. Only during the autumn high water period do the tides reach into the upper extremes of the marshes on a regular basis. Hydrologic conditions caused by this situation are conducive to breeding of salt marsh mosquitos (Provost, 1967), which have been documented as being extremely abundant in this region as far back as the days of early Spanish exploration.

Between about 1920 and 1950, numerous attempts were made to control mosquitos by ditching to drain these wetlands or by spraying breeding areas with insecticides. In the 1950s and 1960s, the spraying of insecticides, usually DDT, was the commonly used method of mosquito control in the region, as in the rest of the United States. Use of DDT throughout the United States resulted in severe impacts on many birds such as bald eagles and pelicans which ate fish contaminated with the pesticides. In the Indian River Lagoon region, an alternative mosquito control method known as "impounding" wetlands was tried as early as the 1930s. This method was regularly put into use by the 1950s, but most impoundments were created in the late 1960s and early 1970s (Rey and Kain, 1989). The use of these impoundments allowed lower DDT usage than in many other coastal areas of the United States during the 1960s, so that impacts on species such as the brown pelican were less in the Indian River Lagoon than in many other areas.

Impoundments resulted in several other environmental problems along the Lagoon. These impoundments were created by constructing dikes (berms) around wetlands and, through the use of pumps or artesian wells, flooding the wetlands. Water is pumped into the impoundments, resulting in more or less permanent flooding of the soil. Because salt marsh mosquitos require alternating wet and dry soils for egg laying and hatching, flooding the marsh breaks this breeding cycle and reduces mosquito levels. However, the flooding and changes in the naturally fluctuating water levels also kill native salt marsh plants such as cordgrasses and change the species composition of the marshes and mangrove communities. Impoundment construction has encouraged invasion of the region by nuisance and/or exotic plants such as Brazilian pepper.

Death of mangrove trees in impoundments has resulted in a loss of roosting (resting) and rookery (nesting) habitat for many species of wading birds, and has also reduced feeding habitats for these species along the Lagoon. The dikes have also isolated the wetlands from the Lagoon, preventing the export of materials which normally form an important part of the food base for the Lagoon and its marine species (Gilmore, et al., 1982, 1987). Fish are no longer able to move into the wetlands to feed or to use them as protection from larger fish.

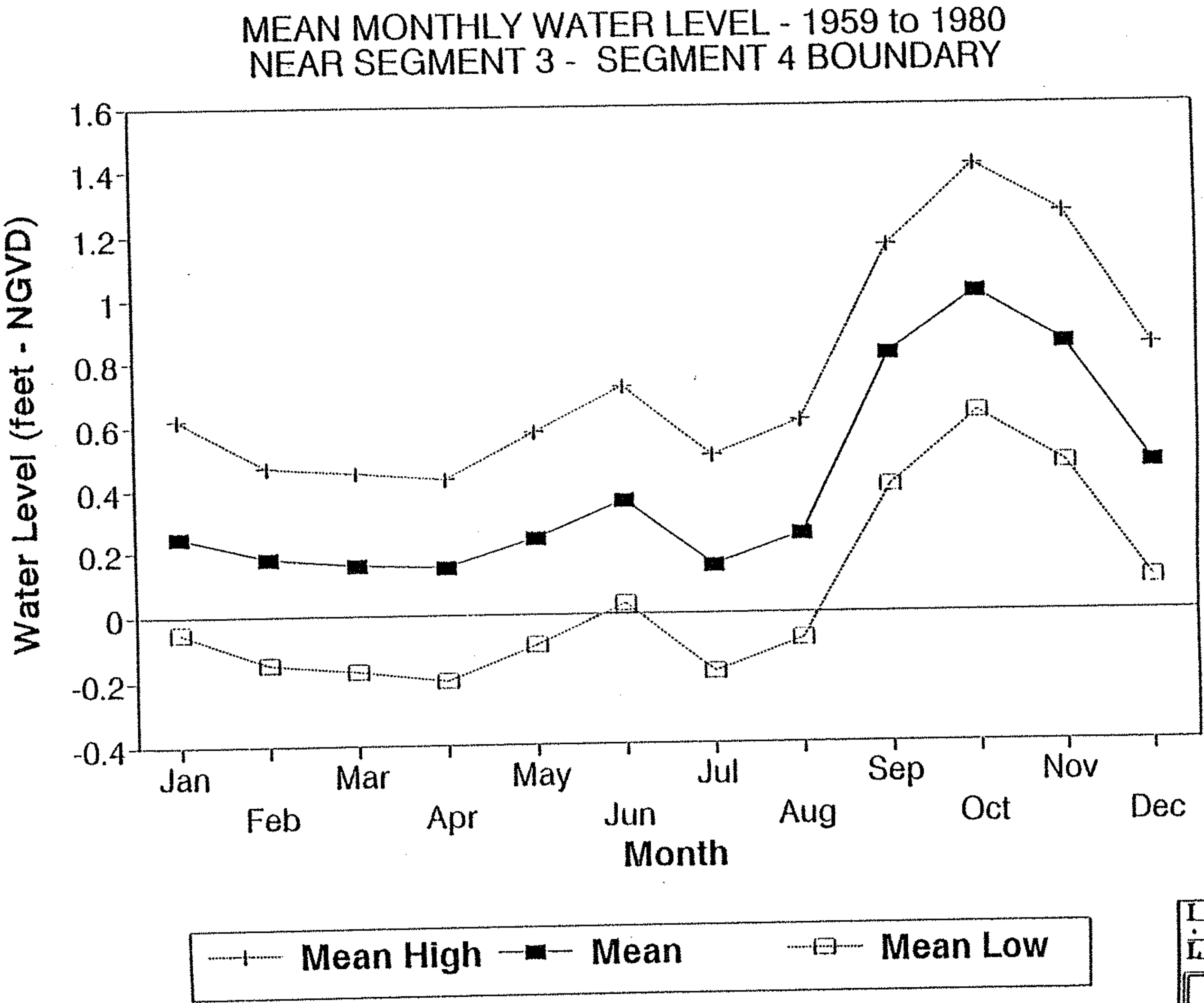
Releases of water with low dissolved oxygen, high sulfates, high nutrients, and other water quality problems have also resulted from impoundment operation (Rey and Gilmore, 1989).

Since unimpounded marshes of the Indian River Lagoon system have been found to have productivities much higher than reported in other Florida marshes (Montague and Wiegert, 1990), this blockage of food export to the Lagoon may have a major effect on the ability of the Lagoon to support fishes and other organisms. As of 1991, nearly 40,000 acres of marshes and mangrove forests had been impounded along the Lagoon so the potential loss of productivity was substantial.

The Subcommittee on Managed Marshes (SOMM) was formed as an interagency task force to address management problems of impoundments. This group includes representatives of FDEP, the water management districts, and the agencies that operate the impoundments. About 70% of the total 39,000 acres of impoundments are managed by MINWR, with Brevard, Indian River, and St. Lucie Counties all operating between 7% and 12% each. Improvements in management techniques have been implemented since the mid-1980s. These management techniques generally involve some form of rotational schedule for alternating flooding and drying cycles known as Rotational Impoundment Management (RIM) and/or installing culverts or other options for allowing more natural tidal cycles and avenues for fish movement into wetlands.

As of mid-1993 about 25,000 acres of impoundments (65%) of impoundments had one of these management options installed to some degree. Activities have been underway by all management authorities to implement these improvements. Funding and other support from the SWIM program has been a major incentive. Currently the SJRWMD SWIM program is developing a management plan for many of the remaining unmanaged impoundments in Brevard and Volusia County in conjunction with the Counties and MINWR. This regional management plan will help to restore much of the remaining acreage. St. Lucie County has also implemented management for over 70% of its impoundments and plans to add another 15% soon.

The major impediments to further implementation appear to be continuing problems in management objective and coordination regarding issuance of state permits for management actions and problems with implementation on privately owned lands. The greatest amount



Sources: Smith, 1986
Smith, 1988.

• Woodward-Clyde Consultants • Marshall McCully & Associates • Natural Systems Analysis	DRAWING NO.: DATE:	FIGURE 7-2 SEASONAL WATER LEVEL VARIATION IN THE INDIAN RIVER LAGOON

INDIAN RIVER LAGOON NATIONAL ESTUARY PROGRAM

of privately owned impoundment lands is in St. Lucie County where this will continue to restrict further implementation of management, unless alternatives are developed. Regional or state coordination and support for acquiring private lands is recommended to resolve this issue.

Although research has shown that transient fish use of impoundments is increased when the impoundments are opened through culverts or breaching, there are indications that other functions may not be restored to the same extent. Gilmore, et al. (1987) have indicated that full use of seasonally impounded marshes by fiddler crabs and other crustaceans may not occur, and that the fiddler crabs may serve an important function in energy and organic matter cycling, as well as in soil water chemistry. Further research into the energy cycling and export functions of impounded marshes is recommended to determine if these functions are adequately restored by the present RIM management techniques. Additional evaluation of drawdowns and other aspects of block management for enhancement of avian and other wildlife populations of the region is also recommended, as is incorporation of regional management strategies to incorporate enhancements for various wildlife groups.

Chapter 3.0 of the Biological Resources Technical Report contains more information and recommendations on mosquito impoundments.

7.5 FISHERIES RESOURCES

Over 680 fish species have been recorded from the Lagoon and the immediately adjacent waters, a diversity that is one of the richest in the continental United States. However, no standardized sampling has been performed that would allow for detailed comparisons of fish populations throughout the estuary. The Department of Environmental Protection has recently initiated a program of sampling juvenile fish species that will allow some comparisons throughout parts of the Lagoon, and tracking of fish populations over time.

More than twice as many fish species have been reported in the southern part of the Lagoon as in the northern part, primarily because of climate difference, a scarcity of reefs and hard substrates in the northern portion, and the greater number of inlets in the south (Gilmore, 1977; Snelson, 1983). A decline in the number of tropical species occurs with greater distance northward. Habitats for fishes in the Lagoon can be broken into eight groups, including freshwater tributaries and canals, river mouths with widely fluctuating salinities, mosquito impoundments, mangroves and salt marshes, open sand bottoms, seagrass beds, Lagoon ledges and hard bottoms, and Atlantic inlets. Inlets, hard bottom "reefs" and seagrass beds generally have the richest assemblages of fish.

No firm data on trends in fish population specifically in the Lagoon is yet available. Commercial landings for the region have increased since 1958 (Chapter 6), but the landings figures include adjacent Atlantic waters. Observations on individual species closely associated with the Lagoon are generally inconclusive. One exception is the spotted seatrout, a species that is closely associated with the Lagoon throughout its life cycle. The data show that this species has declined by about 60% since 1958, a rate of decrease that is similar to that in other Florida estuaries. Restrictions on commercial and recreational catches of the common snook and the red drum since the late 1980s have apparently greatly increased populations in the Lagoon.

Several groups of fishes are important in the overall ecology of the Lagoon. Species such as the bay anchovy, stripped mullet, and silver mullet eat submerged plants, detritus, or phytoplankton, forming a key link in the food chain and converting plant material to animal protein. Such species comprise the greatest biomass and numbers of fish in the estuary. Reconnection of thousands of acres of mosquito impoundments may have a beneficial effect on the food chain for many fishes and lead to increased populations.

Shellfish also comprise a significant portion of the fisheries resources. The major sources of consumable shellfish are the blue crab, southern hard clam, and American oyster. Blue crabs accounted for almost 80% of total shellfish landings in terms of poundage between 1958 and 1988, but total landings peaked in 1966. Since about 1975, landings have remained relatively constant at between 1.5 and 3 million pounds.

The oyster was second in landings until 1977 when it was surpassed by the hard clam. Total commercial landings of oysters have generally been less than 150,000 pounds, with Brevard County accounting for over 70% of total harvest. The hard clam had limited harvesting until the mid-1970s in the Lagoon. By the early 1980s, hard clam harvests had increased ten times over levels of the 1960s. A peak in harvest was reached in 1985 with a subsequent decline. Hard clam harvests have increased again in recent years (Chapter 6), but are still below peak levels

Hard clams are generally restricted to sandy bottoms with some shell material, while oysters can survive in a wider range of bottom types. This bottom preference tends to limit hard clam harvests to a few areas of the Lagoon. The most important are the shellfish harvesting areas known as Areas A, B, C and F in north and south-central Brevard County.

Both hard clams and oysters are somewhat sensitive to temperature and salinity levels. Hard clams are generally limited to areas where salinities exceed 20 ppt (parts per thousand), with eggs and young life stages much more sensitive to low salinities than mature individuals. Salinities of 15 ppt have been documented as causing mortality of juvenile clams. Salinity tolerance of oysters is more complex, but they generally are capable of tolerating lower salinities than hard clams.

Landings of shellfish have generally declined since the mid 1980s. Existing data seem to be unclear as to the cause of these fluctuations. It is not known if the variation is due to harvesting effort, changes in culture techniques, closing of waters for failure to meet water quality standards, or changes in clam populations. Clarification of these aspects is recommended to allow a better definition of the carrying capacity of the Lagoon for hard clam harvest.

Closures of approved shellfish harvesting areas for failure to meet water quality and bacteria standards, impacts on clam and oyster survival caused by large fluctuations in salinity due to heavy stormwater discharge, and overharvesting have all been implicated in the decline, although firm data is lacking. The future of shellfishing in the water of the Lagoon is unpredictable, largely due to the fact that the industry is dependent on the water quality of the Lagoon. Potential bacterial contamination from septic systems, stormwater runoff, and discharges from boats remains as a potential threat. Targeting of areas near the designated shellfish harvesting areas that are served by septic systems for installation of central sewer systems and cessation of wastewater discharges to the Lagoon may be major steps for protecting this resource. Such actions should be considered, but the link between OSDS seepage and conditions in the Lagoon has not been definitively established. It is recommended that recent advances in the use of tracer materials for tracing septic system seepage be utilized to provide better definition of potential links and areas of greatest impact. Management of stormwater discharge to limit salinity fluctuation in the St. Lucie Estuary and in Segment 2 and north Segment 3 near the south Brevard harvesting areas may also be necessary, and further study of this issue is recommended. Many areas where OSDS contamination is suspected are also areas with large amounts of impervious urban surface directly adjacent to the Lagoon. Existing information is not sufficient to discriminate between these two potential sources, and the relative impact of each should be addressed.

7.6 OTHER SPECIES

The Indian River Lagoon is home to many other animal species including at least 16 amphibian, 52 reptile, 367 bird, and 30 mammal species. Amphibians and reptiles are present in all of the habitat associations, but they are most common in the freshwater wetlands and uplands surrounding the Lagoon.

The Indian River Lagoon system has one of the highest bird diversities of estuaries in the United States with 125 species that breed and 172 species that overwinter in the region. It is a major stop-over location on the Eastern Flyway for migrating birds, and over 200,000 waterfowl have been reported to use the habitats of MINWR at a single time.

The Lagoon is also an important nesting and feeding area for many shore birds and wading birds. Although the number fluctuates as use of rookeries fluctuates, approximately 60 rookeries (colonial nesting sites) are present in the Lagoon watershed, with the greatest numbers in the South Central Indian River Lagoon (Segment 3) (20 rookeries) and the South Indian River Lagoon (Segment 4) (15 rookeries). The North Central Indian River Lagoon segment (2) has the fewest rookeries with only one.

Impacts to bird species probably began in the late 1800s and early 1900s, when killing of wading birds for the feather or plume trade decimated many of the populations of species such as the reddish egret and roseate spoonbill. More recent impacts have included effects of DDT and impoundment of tidal wetlands. However, loss of freshwater wetland and upland habitat to drainage and development has probably caused the greatest impacts.

The Indian River Lagoon has long served as a major refuge for bird species. Pelican Island National Wildlife Refuge was the first national wildlife refuge, and it was virtually the only nesting site of brown pelicans on the east coast of Florida for several years in the mid-1900s. Pelican populations have recovered strongly, but some researchers feel they are still in jeopardy because of reduced genetic variability in the population. Populations of many wading birds are appear to be slowly recovering, with roseate spoonbills in particular establishing populations at MINWR. Other species which depend on marshes, such as the tricolored heron, are still declining. Recent studies comparing managed impoundments with summer drawdowns to those without drawdowns (Swain, et. al., 1992) have indicated that some species of birds appear to respond well to new management strategies such as drawdowns and that regional impoundment management may be utilized in the future to enhance bird populations.

Mammals probably are the least studied group of wildlife in the region, although use of the Lagoon is limited by most species. There are two marine mammal species that utilize the Lagoon extensively. These are the Florida manatee, discussed later, and the Atlantic bottlenose dolphin. Dolphin populations have only been studied in detail since the 1970s. It is currently believed that there is a population that resides permanently within the Lagoon, and a population that resides mainly in the Atlantic Ocean but enters the Lagoon in the summer. The Treasure Coast Dolphin Project has identified a resident population of about 25 dolphins in the southern Lagoon, and the Lagoon-wide population is estimated to be about 300, although the data is very limited. The dolphin population is believed to be stable in the Lagoon at this time, although there are several potential threats. About 20 dead dolphins are reported each year, with about 8% to 12% believed to be related to boat accidents or entanglement with fishing nets. A fungal skin disease (Lobo mycosis) also affects about 12% of the population. The disease is debilitating to the dolphins. Its cause is unknown, but some researchers believe it may be linked to water quality.

7.7 THREATENED AND ENDANGERED SPECIES

The Indian River Lagoon has an exceptionally large number of threatened and endangered species, as exemplified by MINWR which has the largest number of any of the national wildlife refuges. There are 11 species present listed by FWS as endangered and 9 species as threatened. In addition, 26 other species are listed by FWS or the State of Florida at some level. One half of the nesting least tern population of the state is thought to nest in KSC, which also has one of the three largest concentrations of scrub jays in the state. The barrier island along the Lagoon is the primary habitat of the southeastern beach mouse.

Several other species are endemic to very specific salt marsh habitats of the region. The demise of the dusky seaside sparrow, which had very specific habitat requirements for the marshes of the Indian River Lagoon region, is a prime example of the threats to these species. It was restricted to the coastal marshes, but became extinct in 1987 because of alteration of this habitat by mosquito impoundments and other factors. The Smyrna seaside sparrow has similar restricted requirements and is believed to have been eliminated from the Mosquito Lagoon area because of these changes.

Other listed species which are restricted to specific habitats of the region are the mangrove rivulus, a small fish that occurs only in the intertidal mangrove forests, and the Atlantic salt marsh snake. This snake is restricted to the marshes along Mosquito Lagoon in southern Volusia County. Its future is dependent on preservation of its habitat, and some groups have recommended that marshes in this region be classified as significant habitat.

The beaches of this island complex are the primary nesting grounds of the green turtle and the loggerhead turtle, both of which are endangered and spend part of their lives as juveniles in the Lagoon. Freezes stun or kill significant numbers of these sea turtle in the Lagoon periodically. Impacts with boats and entanglement with nets and fishing lines are believed to be the principal causes of death in the Lagoon, however, based on data from the Sea Turtle Stranding and Salvage Network (STSSN). Sea turtles in the Lagoon are also infected with a disease (papillomatosis) which causes tumorous growths in about 25% of the population. This disease first appeared in the Lagoon about 1982 and has become more prevalent. The cause is unclear, but it may be affected by water quality conditions.

The Indian River Lagoon is home to about 20% of the Florida population of the Florida manatee, or sea cow. Warm season population levels in the Lagoon up to 300 have been counted in Banana River alone, where an abundance of seagrass and warm waters may attract the species. A portion of the Banana River has been established as a manatee sanctuary with restriction of motorboats, which have been identified as the leading human related cause of mortality. Collisions with boats accounts for about 27% of manatee mortality, and over 33% of deaths are attributed to human related causes. Studies in Brevard County (Kinnaird, 1983) have indicated that mortality pattern is strongly correlated to boat density, and that high boat traffic, presence of larger boats, and patterns where boats operate outside of defined linear channels all are characteristic of high mortality zones.

The studies have indicated that impacts of boats are the largest threat to manatees in the Lagoon. Since boat traffic has been increasing and is projected to continue increasing, boat related mortality is expected to increase and to remain as a major threat to the manatee population.

8.0
STATUS AND TRENDS SUMMARY

The functioning of the Lagoon is highly dependent on the physical processes and its physical structure, especially in light of its long narrow configuration. The interaction of freshwater drainage, inlet exchange with the ocean, and evaporative processes influences the salinity, currents, and flushing of the Lagoon. Insufficient knowledge exists of these processes and Lagoon-wide modeling of these processes is recommended to better understand the system.

Extensive drainage extensions and canals constructed since the late 1800s have greatly expanded the drainage basin of the Lagoon, especially in Indian River, St. Lucie, and Martin Counties. This has resulted in a greatly enlarged volume of freshwater entering the Lagoon in these areas, thereby affecting salinity and pollutant loadings. The effects of this are most greatly felt in Segments 2 and 3 where there appears to be insufficient interaction with the ocean to buffer these effects. Although specific actions are underway to reduce some of this drainage in many of the "interbasin diversion" areas, additional modeling and research is recommended to evaluate the effects of these inputs in the Lagoon in light of the effects of inlets and circulation.

Water quality currently appears to fall within generally accepted standards for most parameters throughout the Lagoon, although there are certain instances and locations where problems are experienced. In particular, salinities appear to drop below acceptable levels for many estuarine species in parts of Segments 2 and 3 where freshwater inflows exceed the assimilative capacity.

Wasteload levels are currently split between point and non-point sources, with nutrient loadings dominated by point sources in the northern end of the system and by non-point sources in the southern half. With the cessation of wastewater treatment plant discharge by 1996, nutrient levels discharged to the northern Lagoon should drop considerably. However, projected increases in non-point source nutrient loadings in Segments 2, 3, and 4 by 2010 should counterbalance any reductions in these segments and control of stormwater loadings should be considered as a high priority for maintaining the water and sediment quality of the Lagoon.

Biological changes have occurred in the Lagoon as well as physical changes. Seagrass distribution has changed since at least the 1970s with indications of change extending as far back as 1943. While the overall level may not have changed significantly, there have been extensive reductions in cover between Vero Beach and the north end of Indian River Lagoon proper. These changes appear to have coincided with reductions of the depth of seagrass occurrence in many areas, indicating that reduced light penetration may be a factor in loss of seagrass habitat. Water quality management to prevent decreases in light penetration should also be considered as a primary management priority.

Impounding of salt marshes and mangrove forests has affected almost 40,000 acres of coastal wetlands and removed their production from the Lagoon ecosystem. Approximately 70% of these impoundments have since been reconnected in some form, with additional activities underway to reconnect additional areas. This program appears to be very successful and of benefit to the Lagoon. However, problems resulting from private ownership tend to restrict further activity. Efforts should be made to resolve these ownership/access conflicts.

The Lagoon is also home to many threatened and endangered species. Water quality may potentially be a threat to aquatic mammals and marine turtles, but interactions with boats and entanglement in nets and fishing lines are the major threats to these species. Habitat loss of salt marshes has eliminated at least one species and has the potential to eliminate other species without habitat protection and reduction of adverse effects of impoundments. Efforts to maintain, enhance, and purchase coastal habitats and upland buffer zones along the Lagoon should also be a regional management priority.

9.0
REFERENCES

Adams, C.M. 1985. "The Indian River Lagoon System-An Economic Perspective" *in* Proceedings of the Indian River Symposium, 1985. D. Barile (ed). The Marine Resources Council of East Central Florida. Melbourne, Florida.

Adamus, C. and M. Bergman. 1993. Development of a Nonpoint Source Pollution Load Screening Model. Draft report. St. Johns River Water Management District, Palatka, Florida.

Argus Business. 1993. Waterway Guide. Argus Business Publications. Atlanta, Georgia.

Barber, S. and J.H. Trefry. 1981. "*Balanus eburneus*: A Sensitive Indicator of Copper and Zinc Pollution in the Coastal Zone." Bulletin of Environmental Contamination and Toxicology. Vol. 27. pp. 654-659.

Barile, D.D. 1988. "Historic Overview of the Indian River Lagoon Region" *in* The Indian River Lagoon Estuarine Monograph. Vol. I (unpublished). D. Barile (ed). The Marine Resources Council of East Central Florida. Melbourne, Florida.

Bell, F.W., P.E. Sorenson, and V.R. Leeworthy. 1982. The Economic Impact and Valuation of Saltwater Recreational Fisheries in Florida. Florida Sea Grant College Technical Report SGR-47, University of Florida, Gainesville, Florida.

Bielby, N.W. 1992. Surface Water Improvement and Management Program Final Report for Volusia County. Florida Department of Health and Rehabilitative Services, Volusia County Public Health Unit. New Smyrna Beach, Florida.

Brevard County. 1993. A Survey of the On-Site Sewage Disposal Systems in the Brevard County Indian River Lagoon Drainage Basin. Draft. Brevard County Natural Resources Management Division. Brevard County, Florida.

Brooks, H.K. 1992. Geologic Map of Florida. Institute of Food and Agricultural Sciences. University of Florida. Gainesville, Florida.

Bureau of Economic and Business Research. 1982-1990. Florida Estimate of Population. University of Florida. Gainesville, Florida.

Chow, V.T. 1964. Handbook of Applied Hydrology. McGraw-Hill, New York.

Clapp, D. 1987. "Overview of Physiographic and Surface Drainage Features" *in* Indian River Lagoon Reconnaissance Report. J. Steward and J. Van Arman (eds). St. John River Water Management District, Palatka, Florida and South Florida Water Management District, West Palm Beach, Florida. pp. 1-27.

Earll, R.E. 1887. "Eastern Florida and its Fisheries" *in* The Fisheries and Fishing Industries of the United States. G.B. Goode (ed). Section 11, A geographical Review of the Fisheries Industries and Fishing Communities for the Year 1880. Washington GPO (in Rathjen and Bolhassen, 1987).

Evink, G.L. 1980. Studies of Causeways in the Indian River, Florida. Report # FL-ER-7-80. Florida Department of Transportation, Tallahassee, Florida.

Fisher, T.R., E.R. Peele, J.W. Ammerman, and L.W. Harding, Jr. 1992. "Nutrient Limitation of Phytoplankton in Chesapeake Bay. Marine Ecology Progress Series. Vol. 82. pp. 51-63.

Florida Department of Agriculture and Consumer Services. 1992. Florida Agricultural Statistics: Citrus Summary, 1991. Florida Crop and Livestock Reporting Service. Orlando, Florida.

Florida Department of Commerce. 1993. Florida County Comparisons. Division of Economic Development. Tallahassee, Florida.

Florida Department of Environmental Protection. 1991. Indian River Lagoon System Water Quality Threats from Package Wastewater Treatment Plants. Florida Department of Environmental Regulation, Tallahassee, Florida.

Florida Department of Natural Resources. 1987. 1985 Annual Landings Summary. Marine Fisheries Information System. Tallahassee, Florida.

Florida Department of Natural Resources. 1988. 1986 Annual Landings Summary. Marine Fisheries Information System. Tallahassee, Florida.

Florida Department of Natural Resources. 1990a. 1988 Annual Landings Summary. Marine Fisheries Information System. Tallahassee, Florida.

Florida Department of Natural Resources. 1990b. 1987 Annual Landings Summary. Marine Fisheries Information System. Tallahassee, Florida.

Florida Department of Natural Resources. 1994. 1989-1993 Annual Landings Summary. (unedited data). Marine Fisheries Information System. Tallahassee, Florida.

Gilmore, R.G. 1977. "Fishes of the Indian River Lagoon and Adjacent Waters, Florida." Bulletin of the Florida State Museum. Vol. 22. pp. 101-147.

Gilmore, R.G., D.W. Cooke, and C.J. Donohoe. 1982. "A Comparison of the Fish Populations and Habitat in Open and Closed Salt Marsh Impoundments in East-Central Florida." Northeast Gulf Science. Vol. 5. pp. 25-37.

Gilmore, R.G., P.B. Hood, R.E. Brockmeyer, and D.M. Scheidt. 1987. Final Report: Effects of Increased Culvert Density on Utilization of Marsh Impoundments by Fishes and Macrocrustaceans. Unpublished report to St. Lucie County Mosquito Control District. Vero Beach, Florida.

Glatzel, K.A. and S.L. Da Costa. 1988a. "Hydrology of the Indian River Lagoon" *in* Indian River Lagoon Estuarine Monograph. Vol. II (unpublished). D. Barile (ed.). The Marine Resources Council of East Central Florida. Melbourne, Florida.

Glatzel, K.A. and S.L. Da Costa. 1988b. Variability of a Coastal Lagoon Water Balance. Presented at American Water Resources Association Symposium on Coastal Water Resources. May 22-25, 1988. Wilmington, North Carolina.

Hand, J. and M. Paulic. 1992. 1992 Water Quality Assessment 305(b) Main Report. Florida Department of Environmental Protection. Tallahassee, Florida.

Hand, J., V. Trauxe, and J. Watts. 1986. 1986 Florida Water Quality Assessment: 305(b) Technical Report. Florida Department of Environmental Regulation, Bureau of Water Quality Management. Tallahasee, Florida.

Heffernan, J.J. and R.A. Gibson. 1983. "A Comparison of Primary Production Rates in Indian River, Florida Seagrass Systems." Florida Scientist Vol. 46. pp. 295-305.

Heyl, M.G. 1992. "Point-and Nonpoint-Source Loading Assessment of Sarasota Bay." *in* Sarasota Bay: Framework for Action. Sarasota Bay National Estuary Program. Sarasota, Florida.

Hoffman, B.A. and K.D. Haddad. 1988. "General Land Use and Vegetation Changes in the Indian River Lagoon System" *in* Indian River Lagoon Monograph. Vol. II (unpublished). D. Barile (ed.). The Marine Resources Council of East Central Florida. Melbourne, Florida.

Holbrook, S.H. 1984. "Partitioning and Fate of Antifouling Paint Copper Released into an Estuarine Environment." M.S. thesis. Florida Institute of Technology. Melbourne, Florida.

Indian River County Public Health Unit. 1992. On-Site Sewage Disposal System Inventory Indian River County, Florida. Florida Department of Health and Rehabilitative Services, Indian River County Public Health Unit. Vero Beach, Florida.

Kearney, G. and B. Kroesen. n.d. Martin County On-Site Septic Systems and the Indian River Lagoon: A Data Base Inventory and Analysis of Problem Areas. Florida Department of Health and Rehabilitative Services, Martin County Public Health Unit.

Kinnaird, M.F. 1983. Site-Specific Analysis of factors Potentially Influencing Manatee Boat/Barge Mortality: Site-Specific Reduction of Manatee Boat/Barge Mortality. Report #4, U.S. Fish and Wildlife Service. Cooperative Agreement # 14-16-0004-81-923.

Livingston, E.H. 1990. "Overview of Stormwater Management" *in* Proceedings of the Stormwater Quality Short Course. October 11-12, 1990. Florida Engineering Society and Florida Department of Environmental Regulation. Tallahassee, Florida.

Longley, L.M. 1989. "A Preliminary Investigation of OSDS Water Quality Effects at a Selected Site in Palm Bay, Florida." M.S. thesis. Florida Institute of Technology, Melbourne, Florida.

Marshall, F.E. III, 1993. "Nonpoint Source Loadings to the Indian River Lagoon." Presented at: Stormwater Research Conference, Tampa, Florida, October 7 & 8, 1993.

Milon, J.W. and E. Thunberg. 1993. A Regional Analysis of Current and Future Florida Resident Participation in Marine Recreational Fishing. Florida Sea Grant College Program. Sea Grant Report #112. University of Florida. Gainesville, Florida.

Montague, C.L. and R.G. Wiegert. 1990. "Salt marshes" *in* Ecosystems of Florida. R. Myers and J. Ewel (eds). University of Central Florida Press. Orlando, Florida.

Morris, L. and D.Tomasko. 1993. Proceedings and Conclusions for the Submerged Aquatic Vegetation Initiative and the Photosynthetic Active Radiation Workshop. Indian River Lagoon National Estuary Program and St. Johns River Water Management District, Palatka, Florida.

Moses, J.H. and J.E. Anderson. 1993. S.W.I.M. Program Septic Tank Study for St. Lucie County, Florida. Florida Department of Health and Rehabilitative Services, St. Lucie County Public Health Unit. Ft. Pierce, Florida.

Myers, R.L. and J.J. Ewel (eds). 1990. Ecosystems of Florida. University of Central Florida Press. Orlando, Florida.

Natural Systems Analysts, Inc. 1994. 1992 Seagrass Mapping Final Report. Indian River Lagoon. Final Report to St. Johns River Water Management District. Palatka, Florida.

Orth, R. 1993. "The Chesapeake Bay Experience" *in* Proceedings and Conclusions for the Submerged Aquatic Vegetation Initiative and the Photosynthetic Active Radiation Workshop. L. Morris and D. Yomasko (eds). Indian River Lagoon National Estuary Program and St. Johns River Water Management District, Palatka, Florida.

Pait, A.S., A.E. DeSouza, and D.R.G. Sarrow. 1992. Agricultural Pesticide Use in Coastal Areas: A National Summary. National Oceanic and Atmospheric Administration (NOAA), Strategic Environmental Assessments Division. Rockville, Maryland.

Pandit, A. and C.C. El-Khazen. 1990. "Groundwater Seepage Into the Indian River Lagoon at Port St. Lucie." Florida Scientist. Vol. 53(3). pp. 169-179.

Provost, M.W. 1967. Managing Impounded Salt Marsh for Mosquito Control and Estuarine Resource Conservation. LSU Marsh and Estuary Symposium. Baton Rouge, Louisiana. pp 163-171.

Rathjen, W.F. and J. Bolhassen. 1988. "The Fisheries of the Indian River Lagoon" *in* Indian River Lagoon Monograph. Vol. III (unpublished). D. Barile (ed). The Marine Resources Council of East Central Florida. Melborne, Florida.

Rey, J.R. and R.G. Gilmore. 1989. Effects of Mosquito Control and Water Manipulation on Water Quality, Hydrology, and Fishes Indigenous to Perimeter Ditches of RIM-Managed Impoundments, Breached Impoundments, and Natural Tidal Creeks: Final Report. CM-194A. Indian River County Mosquito Control District. Ft. Pierce, Fl.

Rey, J.R. and T. Kain. 1989. A Guide to the Salt Marsh Impoundments of Florida. Florida Medical Entomology Laboratory, Vero Beach, Florida.

Ries, T.F. 1993. "The Tampa Bay Experience" *in* Proceedings and Conclusions for the Submerged Aquatic Vegetation Initiative and the Photosynthetic Active Radiation Workshop. L. Morris and D. Yomasko (eds). St. Johns River Water management District, Palatka, Florida.

St. Johns River Water Management District. 1993. GIS Land Use Files. Palatka, Florida.

St. Johns River Water Management District and South Florida River Water Management District. 1993. Surface Water Improvement and Management (SWIM) Plan for the Indian River Lagoon. Draft. St. Johns River Water Management District, Palatka, Florida and South Florida Water Management District, West Palm Beach, Florida.

Smith, N.P. 1988. "Indian River Lagoon Water Level Variations" *in* Indian River Lagoon Estuarine Monograph. Vol. II (unpublished). D. Barile (ed.). The Marine Resources Council of East Central Florida. Melbourne, Florida.

Smith, N.P. 1990. "An Introduction to the Tides of Florida's Indian River Lagoon" *in* Water Levels. Florida Scientist. Vol. 53. No. 3. pp. 216-225.

Snelson, F.F., Jr. 1983. "Ichthyofauna of the Northern Part of the Indian River Lagoon System, Florida." Florida Scientist. Vol. 46. pp. 197-206.

South Florida Water Management District. 1993. GIS Land Use Files. West Palm Beach, Florida.

Swain, H., J. Shenker, and J. Rosier. 1992. Waterbird Use of Rotationally Managed Saltmarsh Impoundments. Final Report, December 1992, for St. Lucie County Mosquito Control District. Florida Institute of Technology. Melbourne, Florida.

Tabb, D.C. 1960. The Spotted Seatrout Fishery of the Indian River Area, Florida. State of Florida, Florida Board of Conservation Technical Series #33.

Thompson, M.J. 1978. "Species Composition and Distribution of Seagrass Beds in the Indian River Lagoon, Florida." Florida Scientist. Vol. 41. No. 2. pp. 90-96.

Tomasko, D. 1993. "The Sarasota Bay Experience" *in* Proceedings and Conclusions for the Submerged Aquatic Vegetation Initiative and the Photosynthetic Active Radiation Workshops. L. Morris and D. Tomasko (eds). Indian River Lagoon National Estuary Program and St. Johns River Water Management District. Melbourne, Florida and Palatka, Florida.

Toth, D. 1987. "Hydrogeology" *in* Indian River Lagoon Joint Reconnaissance Report. J.S. Steward and J. Van Arman (eds). St. Johns River Water Management District and South Florida Water Management District. Palatka, Florida.

Trefry, J.H., M. Sadoughi, M.D. Sullivan, J.S. Steward, and S. Barber. 1983. "Trace Metals in the Indian River Lagoon, Florida: The Copper Story." Florida Scientist. Vol. 46. pp. 415-427.

Trefry, J.H., N.C. Chen, R.P. Trocine, and S. Metz. 1990. Manatee Pocket Sediment Analysis. Florida Institute of Technology. Melbourne. Florida.

Trocine, R.P. and J.H. Trefry. 1993. Toxic Substances Survey for the Indian River Lagoon System. Florida Institute of Technology. Melbourne, Florida.

United States Bureau of the Census. 1971. "1970 Census of Population." Number of Inhabitants, Florida. U.S. Department of Commerce, U.S. Government Printing Office. Washington, D.C.

United States Bureau of the Census. 1992. "1990 Census of Population." Number of Inhabitants, Florida. U.S. Department of Commerce, U.S. Government Printing Office. Washington, D.C.

University of Florida Bureau of Economic and Business Research. 1992. "Population Studies." Bulletin No. 99, Volume 25, No. 1.

Virnstein, R.W. and K.D. Cairns. 1986. Seagrass Maps of the Indian River Lagoon. Final Report to Florida Department of Environmental Regulation. Seagrass Ecosystems Analysts, Inc. Vero Beach, Florida.

Virnstein, R.W., P.S. Mikkelsen, K.D. Kairns, and M.A. Capone. 1983. "Seagrass Beds Versus Sand Bottoms: the Trophic Importance of Their Associated Benthic Invertebrates." Florida Scientist Vol. 46. No. 3/4. pp. 363-381.

Wanielista, M.P. and Y.A. Yousef. 1993. Stormwater Management. John Wiley and Sons, Inc., New York.

Wilcox, W.A. 1896. Commercial Fisheries of Indian River, Florida. Report of the U.S. Commercial Fisheries Commission. Vol. 22: pp. 249-262.

Windsor, J.G. and J.S. Steward. 1987. "Water and Sediment Quality" *in* Indian River Lagoon Joint Reconnaissance Report. J.S. Steward and J. Van Arman (eds). St. Johns River Water Management District and South Florida Water Management District. Palatka, Florida.

Yingling, J. 1987. "Economic Values" *in* Indian River Lagoon Joint Reconnaissance Report. J.S. Steward and J.A. Van Arman (eds). St. Johns River Water Management District and South Florida Water Management District. Palatka, Florida.

Zieman, J.C. 1982. The Ecology of Seagrasses of South Florida: a Community Profile. FWS/OBS-82/25. U.S. Fish & Wildlife Service. Washington, D.C.