Total Maximum Daily Loads

for the

Northern and Central Indian River Lagoon and Banana River Lagoon, Florida

Nutrients and Dissolved Oxygen

April 2007

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Region4 serving the southeast

In compliance with the provisions of the Federal Clean Water Act, 33 U.S.C §1251 et. seq., as amended by the Water Quality Act of 1987, P.L. 400-4, the U.S. Environmental Protection Agency is hereby establishing these Total Maximum Daily Loads (TMDLs) for nutrients and dissolved oxygen in the North and Central Indian River Lagoon and Banana River Lagoon (WBIDs 2963A, 2963B, 2963C, 2963D, 3057A, 3057B, 3082, 3085, 3085A, 3098, 3128, 3129A, 3135, 3136, 5003C, 5003D). Subsequent actions must be consistent with this TMDL.

____________________/s/_____________________ _____4/11/2007______

James D. Giattina, Director
Water Management Division

Date

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LIST OF ABBREVIATIONS

BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BCUD	Brevard County Utility Department
BMAP	Basin Mangagement Plan
BRL	Banana River Lagoon
CFR	Code of Federal Regulations
CSWY	Causeway
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EMC	Event Mean Concentration
EST	Estuary
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transporation
FLUCCS	Florida Land Use Cover Classification System
FPL	Florida Power and Light
FS	Florida Statutes
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program- Fortran
HUC	Hydrologic Unit Code
IRBR	Indian River/Banana River
IRCUD	Indian River County Utility Department
IRL	Indian River Lagoon
IWR	Impaired Waters Rule
LA	Load Allocation
LB/AC/YR	Pound per acre per year
LB/YR	Pounds per year
MGD	Million Gallons per Day
MG/L	Milligram per liter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agriculture Statistics Service
NHD	National Hydrography Data
NOAA	National Oceanic and Atmospheric Administration

NPDES	National Pollutant Discharge Elimination System
PLRG	Pollutant Load Reduction Goal
PLSM	Pollutant Load Screening Model
RO	Reverse Osmosis
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SSURGO	Soil Survey Geographic Database
SWIM	Surface Water Improvement and Management Plan
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WBID	Water Body Identification
WCS	Watershed Characterization System
WLA	Waste Load Allocation
WQS	Water Quality Standards
WMD	Water Management District
WMP	Water Management Plan
WTF	Water Treatment Facility
WWTP	Waste Water Treatment Plant

SUMMARY SHEET

Total Maximum Daily Load (TMDL)

1. **303(d) Listed Waterbody Information**

State: Florida

Major River Basins:

Northern and Central Indian River Lagoon and Banana River Lagoon (encompassed by Cape Canaveral HUC 03080202 and Vero Beach HUC 03080203).

1998 303(d) Listed Waterbodies for TMDLs addressed in this report:

WBID	Segment Name	County	Class and Waterbody Type	Constituent(s)
2963A	Indian River above Sebastian Inlet	Brevard	II estuary	Nutrients and D.O.
2963B	Indian River above Melbourne Cswy	Brevard	III estuary	Nutrients and D.O.
2963C	Indian R. above Melbourne Cswy	Brevard	II estuary	Nutrients
2963D	Indian R. above 520 Cswy	Brevard	III estuary	Nutrients and D.O.
3057A	Banana River below Mathers	Brevard	III estuary	Nutrients and D.O.
3057B	Banana River above 520 Cswy	Brevard	III estuary	Nutrients and D.O.
3082	Eau Gallie River	Brevard	III estuary	Nutrients
3085	Crane Creek	Brevard	III stream	Nutrients and D.O.
3085A	Crane Creek	Brevard	III estuary	Nutrients
3098	Turkey Creek	Brevard	III estuary	Nutrients and D.O.
3128	North Prong Sebastian River	Brevard	III stream	Nutrients and D.O.
3129A	Sebastian River above Indian River	Brevard	III estuary	Nutrients and D.O.
3135	C-54 Canal	Brevard	III estuary	Nutrients and D.O.
3136	Felsmere Canal	Brevard, Indian River	III stream	Nutrients and D.O.
5003C	South Indian River	Indian River	III estuary	Nutrients and D.O.
5003D	South Indian River	Indian River	II estuary	Nutrients and D.O.

Notes:

D.O. = dissolved oxygen

2. TMDL Endpoints (i.e., Targets)

The TMDLs are based upon an interpretation of narrative water quality standards which protect waters from anthropogenic nutrient enrichment and concentrations that cause an imbalance in natural populations of aquatic flora and fauna. The nutrient targets are the average annual loadings of total nitrogen (TN) and total phosphorus (TP) that are expected to promote seagrass depth distributions in the Indian River and Banana River estuaries within a -10% departure from full-restoration conditions.

Sub-lagoon	Seagrass Depth Target (median, m)	TN (lb/ac/yr)	TP (lb/ac/yr)
North Indian River Lagoon	1.5 – 1.8	2.88	0.368
Central Indian River Lagoon	1.2 – 1.7	2.89	0.570
Banana River Lagoon	1.4 – 1.8	2.18	0.374

Nutrient loads were estimated from PLSM and HSPF models for 1943, 1996, 1999, and 2001. Seagrass depth-limits were estimated from the union of mapped seagrass coverages for 1943, 1986, 1989, 1992, 1994, 1996 and 1999. Full restoration seagrass conditions are defined as the deepest seagrass coverage achieved among those mapping years.

3. TMDL Approach

The TMDLs were determined from linear regression models that relate seagrass depth limits to annual TN and TP loading in three sub-lagoons. These areal point and nonpoint load limits (lb/ac/yr) were then multiplied by the acreage of each sub-lagoon to determine the average annual loads of TN and TP in units of pounds/year (lb/yr). Sub-lagoon loads were distributed among segments in proportion to their current nonpoint source loads. The Waste Load Allocations (WLAs) for each point source facility were developed considering their current permit limits, the quality and frequency of the actual discharge, and the assimilative capacity of the receiving watershed. Load Allocations (LAs) were calculated as the difference between the total allowable load (TMDL) and the WLA.

4. TMDL Allocations for Sub-lagoons

Sublagoon	Parameter	TMDL (lb/day)[1]	TMDL (lb/year) [1]	WLA[2]		LA (lb/year)
				Facility (lb/year)	MS4 (%)	
North IRL	TN	1,068	389,906	17,311	35%	372,595
	TP	136	49,821	1,794	49%	48,027
Central IRL	TN	2,250	821,282	26,222	56%	795,060
	TP	444	161,983	2,071	48%	159,912
Banana River Lagoon	TN	307	112,029	6,173	63%	105,856
	TP	53	19,220	1,221	67%	17,999

Notes for TMDL Allocations table:

1. TMDL values in this table represent the total allocations for each sub-lagoon area. Tables of allocations for individual lagoon segments are provided in the main document. TMDLs address 303(d) listings for nutrients and D.O. For convenience, the TMDLs are provided in both units of lbs/day and lbs/year, but are intended to be implemented on an annual basis. Nothing in this TMDL should be understood to preclude appropriate water quality trading implemented within the context of DEP's NPDES program. The WLA component includes individual allocations for NPDES facilities (e.g., WWTPs) and MS4s as contained in Table 10 of this report. Due to the infeasibility of separating the contributions from diffuse MS4 and non-MS4 sources, MS4s are incorporated into the Load Allocation, and are allocated the same percent reductions. WLAs for facilities are the maximum annual loads.
2. Percent reduction in current nonpoint source loading to achieve the Load Allocation for that sub-lagoon. The percent reductions are applied to nonpoint sources and MS4s.

5. **Endangered Species (yes or blank):** Yes

6. **USEPA Lead on TMDL (USEPA or blank):** USEPA

7. **TMDL Considers Point Source, Nonpoint Source, or both:** Both

8. **Major NPDES Discharges to surface waters addressed in USEPA TMDL:**

NPDES Permit	Facility Name	Impacted Segment	Facility Type	TN Maximum Annual Allocation (lbs/year)	TP Maximum Annual Allocation (lbs/year)
FL0021521	Cocoa, J. Sellers	IR6-7	Domestic WWTP	5,556	1,423
FL0001473	FPL Cape Canaveral Power Plant	IR6-7	Power Plant w/RO	2,555	146
FL0021571	City of Rockledge	IR-8	Domestic WWTP	30	30
FL0043443	Melbourne Reverse Osmosis WTF	IR9-11	Reverse Osmosis	9,170	195
FL0040622	Brevard Co. South Beaches (BCUD)	IR12	Domestic WWTP	173	36
FL0041122	Melbourne, City of- Grant St.	IR12	Domestic WWTP	182	8
FL0042293	Barefoot Bay	IR14-15	Domestic WWTP	476	78
FL0021661	Vero Beach, City of	IR16-20	Domestic WWTP	12,173	916
FL0042544	Vero Beach Reverse Osmosis WTF	IR16-20	Reverse Osmosis	2,985	487
FL0166511	Indian River Co. Hobart RO WTF	IR16-20	Reverse Osmosis	2,759	96
FL0041637	West Regional IRCUD	IR16-20	Domestic WWTP	2,838	159
FL0037940	Indian River Co. South RO WTF	IR16-20	Reverse Osmosis	4,636	291
FL0020541	Cape Canaveral, City of	BR3-5	Domestic WWTP	2,151	158
FL0021105	Cocoa Beach, City of	BR3-5	Domestic WWTP	4,022	1,063

1. Introduction

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA, 1991).

The State of Florida Department of Environmental Protection (FDEP) developed a statewide, watershed-based approach to water resource management. Under the watershed management approach, water resources are managed on the basis of natural boundaries, such as river basins, rather than political boundaries. The watershed management approach is the framework FDEP uses for implementing TMDLs. The state’s 52 basins are divided into five groups. Water quality is assessed in each group on a rotating five-year cycle. Although Indian River Lagoon (IRL) is a Group 5 basin, it was designated as a special water for which TMDLs will be developed outside the normal basin rotation. FDEP established five water management districts (WMD) responsible for managing ground and surface water supplies in the counties encompassing the districts. The Indian River Lagoon system resides mostly in the St. Johns River Water Management District (SJRWMD) while the very southern portion of the Lagoon is within the South Florida Water Management District (SFWMD).

For the purpose of planning and management, the WMDs divided the district into planning units defined as either an individual primary tributary basin or a group of adjacent primary tributary basins with similar characteristics. These planning units contain smaller, hydrological based units called drainage basins, which are further divided by FDEP into “water segments”. A water segment usually contains only one unique waterbody type (stream, lake, canal, etc.) and is about 5 square miles. Unique numbers or waterbody identification (WBIDs) numbers are assigned to each water segment.

2. Problem Definition

Florida’s final 1998 Section 303(d) list identified numerous Water Body Identifications (WBIDs) in the Indian River Lagoon Basin as not supporting water quality standards (WQS). The TMDLs addressed in this document are being established pursuant to USEPA commitments in the 1998 Consent Decree in the Florida TMDL lawsuit (Florida Wildlife Federation, et al. v. Carol Browner, et al., Civil Action No. 4: 98CV356-WS, 1998). After assessing all readily available water quality data, USEPA is responsible for developing TMDLs in several WBIDs (Figure 1). The parameters addressed in these TMDLs are nutrients and dissolved oxygen (D.O.).

Most waterbodies in the Indian River Lagoon Basin are designated as Class III (freshwater & marine) waters having a designated use for recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Other waterbodies are Class II (marine) estuaries with a designated use of Shellfish Propagation or Harvesting. The level of impairment is denoted as threatened, partially or not supporting designated uses. A waterbody that is classified as threatened currently meets WQS, but trends indicate the designated use may not be met in the next listing cycle. A waterbody classified as partially supporting designated uses is defined as somewhat impacted by pollution and water quality criteria are exceeded on some frequency. For this category, water quality is considered moderately impacted. A waterbody that is categorized as not supporting is highly impacted by pollution and water quality criteria are exceeded on a regular or frequent basis. In such waterbodies, water quality is considered severely impacted.

To determine the status of surface water quality in the state, three categories of data – chemistry data, biological data, and fish consumption advisories – were evaluated to determine potential impairments. The level of impairment is defined in the Identification of Impaired Surface Waters Rule (IWR), Section 62-303 of the Florida Administrative Code (F.A.C.). The IWR defines the threshold for determining if waters should be included on the state's planning list and verified list. Potential impairments are determined by assessing whether a waterbody meets the criteria for inclusion on the planning list. Once a waterbody is on the planning list, additional data and information will be collected and examined to determine if the water should be included on the verified list.

USEPA proposed draft nutrient and D.O. TMDLs for the Indian River Lagoon and Banana River Lagoon in June 2003 (USEPA, 2003). A public meeting was held in July 2003. About 20 sets of comments were received during the public comment period which ended in August 2003. The present document represents a re-proposal of these TMDLs. Changes include: incorporation of several point sources that were omitted previously, refinements to the modeling performed by SJRWMD to develop the non-point source loads, addition of point sources into the modeling effort, selection of seagrass health as the target endpoint for the waterbody meeting its designated use and narrative nutrient criteria, and applying Florida's IWR approach to confirm that the subject WBIDs are impaired as indicated by the most up to date water quality data.

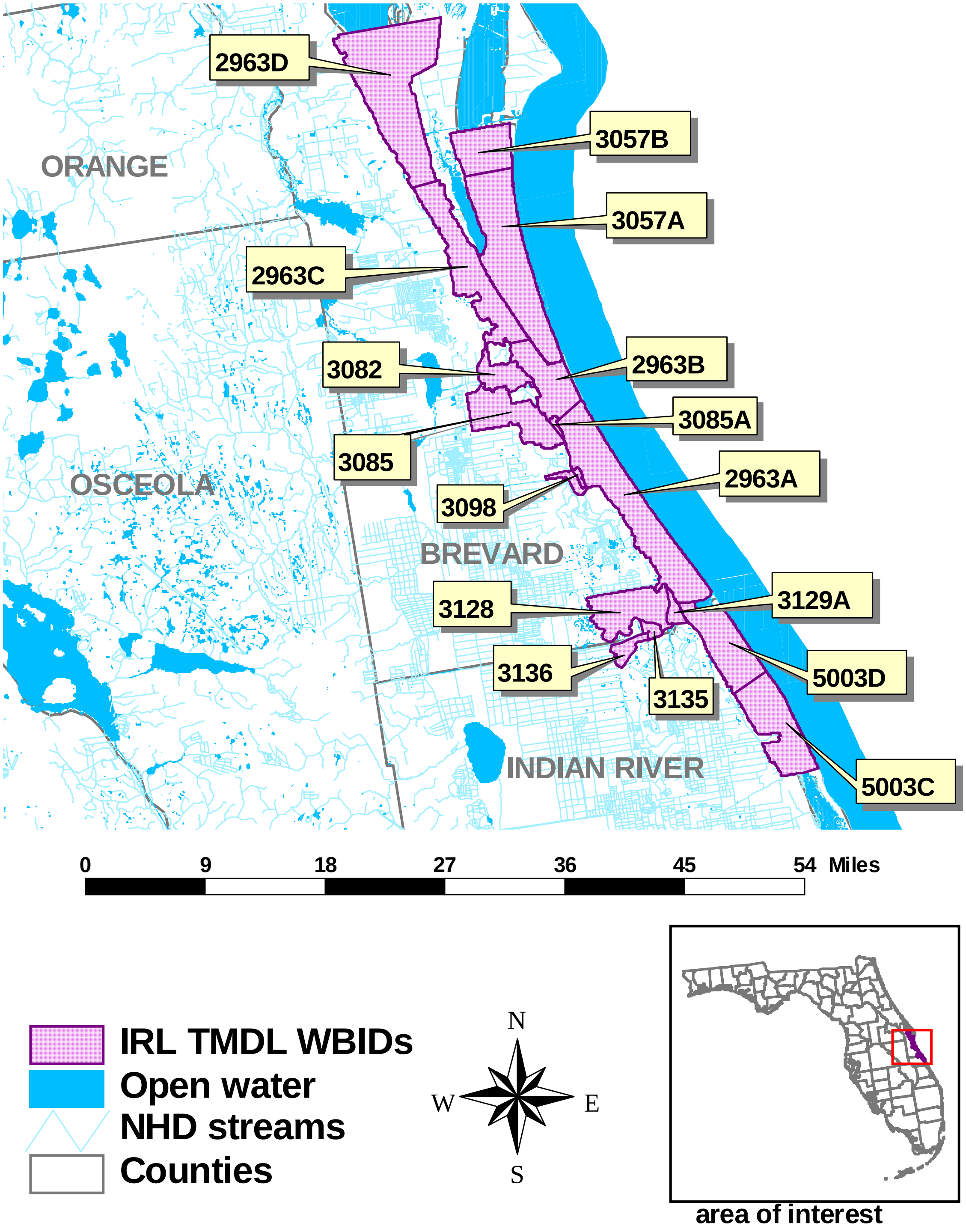


Figure 1. Impaired Waterbody Identifications (WBIDs) addressed in this TMDL.

3. Watershed Description

The Indian River Lagoon runs along the central portion of the Atlantic coastline of Florida for a distance of 155 miles from the Ponce De Leon Inlet southward to Jupiter Inlet and includes portions of Volusia, Brevard, Indian River, St. Lucie, Martin and Palm Beach Counties. The watershed consists of three major inter-connected lagoons commonly referred to as Mosquito Lagoon, Indian River Lagoon and Banana River Lagoon. The lagoon system and contributing watershed currently covers an area of approximately 2,284 square miles, almost twice the size of the original watershed of approximately 1,150 square miles. The Indian River and Banana River lagoons have an average depth of just under 6 feet. Average annual rainfall within the watershed is approximately 50.2 inches and average annual evapotranspiration is almost 49 inches. Tributary streams to the Indian River Lagoon are relatively short in length. Some of the western edge of the watershed is bounded by the St. Johns River Basin which runs south to north and discharges to the Atlantic Ocean east of Jacksonville.

Circulation within the lagoon is influenced by winds, freshwater inflows from tributaries, and tidal exchange via direct connections to the Atlantic Ocean. In general, the Mosquito Lagoon and Banana River Lagoon are characterized by low freshwater inflows and poor flushing with little or no direct connection to the Atlantic Ocean. The Indian River Lagoon portion has four connections to the Atlantic via Sebastian Inlet, Fort Pierce Inlet, St. Lucie Inlet and Jupiter Inlet. Freshwater inflows come from direct overland runoff, streams, drainage canals, groundwater seepage, discharges from reverse osmosis drinking water facilities, and discharges from wastewater treatment plants.

The Indian River Lagoon is a nationally renowned aquatic ecosystem that supports tremendous biodiversity and provides recreational and commercial fishing resources as well. The Indian River Lagoon has received the attention of the State of Florida Department of Environmental Protection, the SJRWMD and SFWMD, and the National Estuary Program. Tremendous efforts are underway by these agencies and programs to document the resources, identify historic and current environmental conditions and develop plans to restore and maintain these valuable natural resources.

4. Water Quality Standards

Most of the waterbodies in the Indian River Lagoon watershed are Class III Freshwater or Marine with a designated use of Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife. Other waterbodies are Class II (marine) estuaries with a designated use of Shellfish Propogation or Harvesting. Designated use classifications are described in the Florida Administrative Code (F.A.C.), Section 62-302.400(1), and water quality criteria for protection of all classes of waters are established in F.A.C. 62-302.530. Individual criteria should be considered in conjunction with other provisions in water quality standards, including Section 62-302.500 F.A.C. [Surface Waters: Minimum Criteria, General Criteria] that apply to all waters unless alternative criteria are specified in F.A.C. Section 62-302.530. Several WBIDs were listed due to elevated concentrations of chlorophyll *a*. While there is no water quality standard specifically for chlorophyll *a*, elevated levels of chlorophyll *a* are frequently associated with a violation of the narrative nutrient standard, which is described below.

4.1. Narrative Nutrients (Class II and III, Fresh and Marine):

The State of Florida has a narrative water quality criterion for nutrients that applies to Classes I, II, and III (including fresh and marine waters) and states that:

> "In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." [Section 62.302.530 (48)(b) F.A.C.]

The state also has an additional narrative water quality criterion for nutrients that applies to all classes of water and states that:

> "The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter. Man-induced nutrient enrichment (total nitrogen or total phosphorus) shall be considered degradation in relation to the provisions of Sections 62-302.300, 62-302.700, and 62-4.242, F.A.C." [see Section 62.302.530 (48)(a) F.A.C.]

4.2. Dissolved Oxygen (Class II Marine):

The water quality criterion states that D.O. in Class II Marine waters:

> "Shall not average less than 5.0 mg/L in a 24-hour period and shall never be less than 4.0 (mg/l). Normal daily and seasonal fluctuations above these levels shall be maintained." [FAC 62-302.530 (31)]

4.3. Dissolved Oxygen (Class III Fresh and Marine):

The water quality criteria for D.O. in Class III Fresh and Marine waters are as follows:

> <u>Freshwater</u>: "Shall not be less than 5.0 mg/L. Normal daily and seasonal fluctuations above these levels shall be maintained." [FAC 62-302.530 (31)]
>
> <u>Marine</u>: "Shall not average less than 5.0 mg/L in a 24-hour period and shall never be less than 4.0 mg/L. Normal daily and seasonal fluctuations above these levels shall be maintained." [FAC 62-302.530 (31)]

5. Linkage of Water Quality Standards to the Critical Resource

While the Consent Decree identifies specific WBIDs impaired for nutrients (chlorophyll *a*) and D.O., the 2002 Indian River Lagoon Surface Water Improvement and Management (SWIM) Plan update provides a more thorough analysis and representation of the significant water quality issues confronting the Indian River Lagoon (Steward et al, 2003). Two of the primary goals of the Indian River Lagoon SWIM Plan are as follows:

- "To attain and maintain water and sediment of sufficient quality … in order to support a healthy, macrophyte-based estuarine lagoon system."
- "To attain and maintain a functioning macrophyte-based ecosystem which supports endangered and threatened species, fisheries and wildlife."

Essentially, these Indian River Lagoon SWIM Plan goals are consistent with the concept established in the State of Florida water quality standards for narrative nutrients (62-302.530 (48(b)) F.A.C.) which states that "In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." Thus, a healthy macrophyte-based aquatic ecosystem within the Indian River Lagoon would be a direct indication of full support of aquatic flora and fauna.

In order to achieve this goal of a healthy macrophyte-based ecosystem, the Indian River Lagoon SWIM Plan sets forth a series of seagrass and water quality objectives designed to create in-lagoon water quality conditions conducive to such a healthy ecosystem. One of the water quality objectives is defined as "Decreas(ing) inputs of excessive loadings of nutrients from point and nonpoint sources." The cause and effect relationship between nutrient loads and seagrass health is established within the Indian River Lagoon SWIM Plan and is based upon the principle that increased nutrient loads lead to both direct and indirect causes of light attenuation that limit the ability of seagrass to thrive. One of the technically derived management tools established to achieve this water quality objective of decreasing nutrient inputs is the Pollutant Load Reduction Goal (PLRG). PLRGs can be described as the recommended reduction of existing pollutant loads to a waterbody in order to be protective of the resource. Alternatively, PLRGs can be considered as a planning objective that helps put existing and proposed discharges from point and nonpoint sources into perspective in a relative or watershed-wide sense. The establishment of PLRGs is a requirement of Florida's SWIM program, and the application of PLRGs to support the development of TMDLs is specifically addressed within the Florida Watershed Restoration Act (403.067 F.S.). By achieving the Indian River Lagoon total nitrogen (TN) and total phosphorus (TP) PLRGs, the system is expected to respond with increased coverage of seagrasses, increased diversity in macrophytes, and a natural D.O. regime that will support the designated uses of Recreation, Propagation and Maintenance of a Healthy, Well-Balanced Population of Fish and Wildlife.

6. Water Quality Assessment

A water quality assessment was conducted to review pertinent water quality data and information for listed segments within the Indian River Lagoon. The primary constituents that were evaluated were: D.O., chlorophyll *a*, nitrogen, phosphorus, and seagrass coverage. Readily available water quality data were assessed using the FDEP IWR database, version 24, and information provided by the SJRWMD. The IWR database contains data from readily available sources within the state of Florida, including data from the WMDs. Concerns have been raised about the inclusion or exclusion of some Indian River Lagoon data from the IWR database (Steward, 2006). FDEP is currently in the process of verifying and working through these issues. IWR data were reviewed for this assessment, but these data concerns do not affect the TMDL approach or load allocations. Consistent with the IRL SWIM Plan and associated PLRG, the water quality assessment ultimately targets maintenance of a healthy seagrass ecosystem in the estuary. Florida's narrative nutrient criterion requires prevention of an imbalance in natural populations of aquatic flora and fauna. Maintaining the seagrass, which is a conspicuous floral feature of Indian River Lagoon, is also consistent with the overall goal of meeting water quality standards and the designated use of the waterbody.

6.1. Linkage of Indian River Lagoon WBIDs to SWIM Segments:

WBIDs are the basic unit of surface water quality data aggregation and assessment for the State of Florida's Clean Water Act Section 305(b) Water Quality Assessment Report and Section 303(d) Impaired Waters Lists. Table 1 presents the specific WBIDs within the Indian River Lagoon that were originally identified as impaired for nutrients and D.O. on the 1998 Section 303(d) list and in the 1999 Consent Decree. While WBIDs are useful tools for data aggregation and assessment, they are not always the most appropriate representation of a watershed to facilitate the development of a TMDL. For the Indian River Lagoon SWIM Update, the SJRWMD developed a delineation of the Lagoon and its tributary drainage basins that serves as more useful representation and subdivision of the system for calculating loads from contributing watersheds. The Indian River/Banana River (IRBR) estuary was divided into distinct "sub-lagoon" regions. Impaired WBIDs addressed in this TMDL fall within these Banana River and North and Central Indian River sub-lagoons. Distinct lagoon segments were delineated based on natural or constructed breakpoints and tributary drainages within the lagoons to reflect distinct physiographic, hydrologic, biologic, and water quality characteristics. Contiguous segments were aggregated where kriging (spatial representation of the data in order to identify spatial patterns or differences) and cluster analysis (a data analysis technique that groups data into sub-sets with associations or similarities) revealed no significant differences in turbidity and salinity between them. Within the Banana River Lagoon and North and Central Indian River Lagoon there are 28 distinct segments that were aggregated to 15 final lagoon segments.

Table 1 and Figure 2 display the original impaired WBID units and their relationship to the SWIM lagoon segments. Since the waterbodies are 303(d)-listed by WBIDs, and the

IWR database stores and retrieves data by assigned WBID, the data assessment provided below is based on WBID delineations. In recognition that the SWIM segmentation scheme may better represent differences in water quality and hydrodynamics between watersheds, this TMDL will present current and allowable pollutant loads for the Indian River Lagoon based on the SWIM delineations. Load estimates for lagoon segments represent the total contribution of nutrient loads to that portion of the lagoon from that segment's entire contributing watershed.

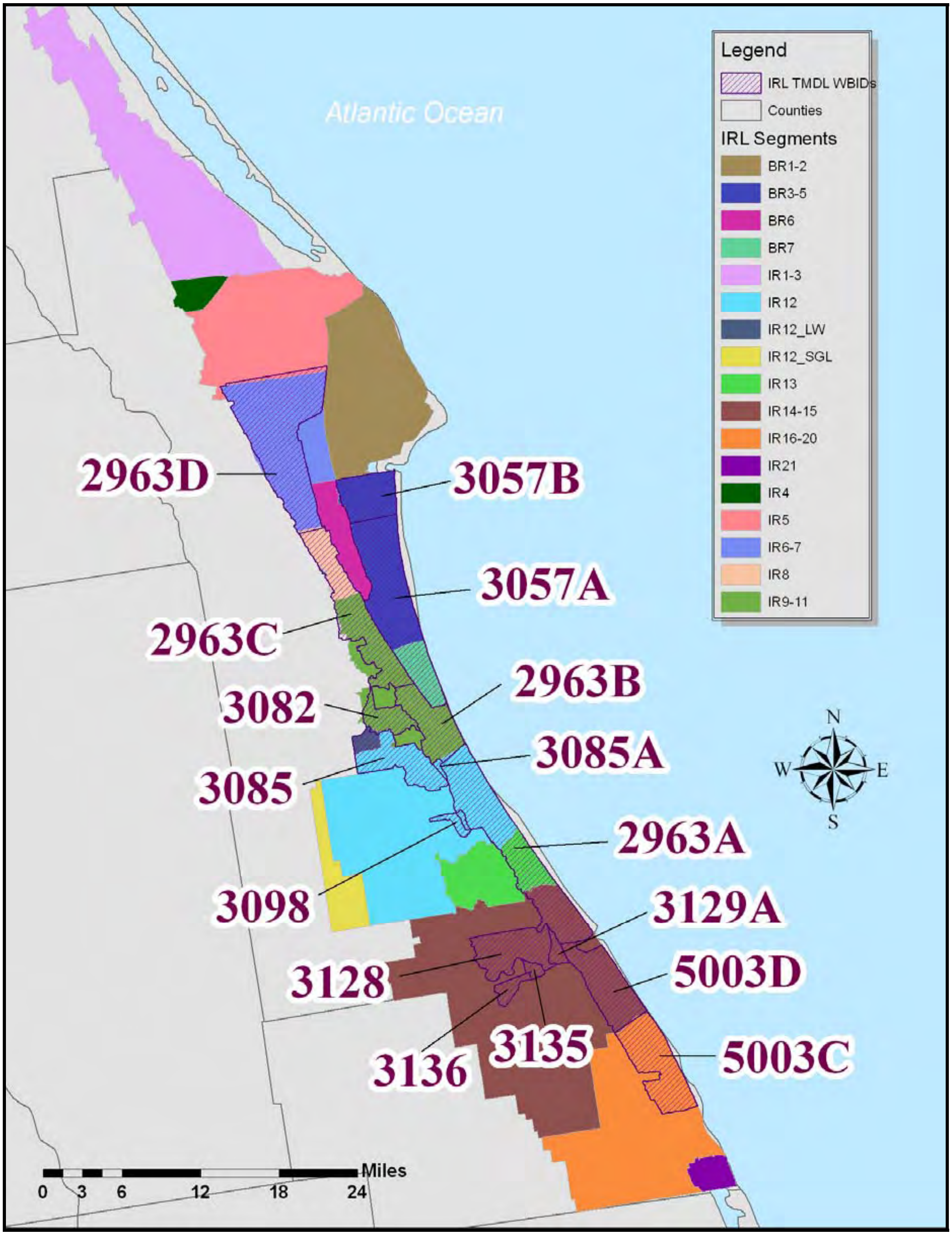


Figure 2. IRL WBIDs and land areas contributing to each lagoon segment.

Table 1. Indian River Lagoon Water Body Identifications (WBIDs), lagoon segments and data assessment.

WBID Name	WBID	IRL Segment(s)	Waterbody	1998 303(d) Listed Parameters	>10% of D.O. < Criterion?		Seagrass Target Met?[1]		TN (mg/L) > 1.0 (EST) or 1.6 (STR) IWR24?[2]		TP (mg/L) > 0.19 (EST) or 0.22 (STR) IWR24?[2]	
					Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
INDIAN R. AB SEBASTIAN INLET	2963A	IR12, 13, 14-15	ESTUARY	Nutrients, DO	X			X	X			X
INDIAN R. AB MELBOURNE CSWY	2963B	IR9-11	ESTUARY	Nutrients, DO	X			X	X			X
INDIAN R. AB MELBOURNE CSWY	2963C	IR 8, 9-11	ESTUARY	Nutrients		X		X	X			X
INDIAN R. AB 520 CSWY	2963D	IR6-7	ESTUARY	Nutrients, DO	X			X	X			X
BANANA R. BL MATHERS	3057A	BR3-5, BR7	ESTUARY	Nutrients, DO	X			X	X			X
BANANA R. AB 520 CSWY	3057B	BR3-5	ESTUARY	Nutrients, DO	X			X	X			X
EAU GALLIE RIVER	3082	IR9-11	ESTUARY	Nutrients	X			X	X			X
CRANE CREEK	3085	IR9-11, IR12	STREAM	Nutrients, DO	X			X		X		X
CRANE CREEK	3085A	IR12	ESTUARY	Nutrients	X			X		X		X
TURKEY CREEK	3098	IR12	ESTUARY	Nutrients, DO	X			X	X			X
N. PRONG SEBASTION R.	3128	IR14-15	STREAM	Nutrients, DO	X			X		X		X
SEBASTION R. AB IND R.	3129A	IR14-15	ESTUARY	Nutrients, DO		X		X		X		X
C-54 CANAL	3135	IR14-15	ESTUARY	Nutrients, DO	X			X	X			X
FELSMERE CANAL	3136	IR14-15	STREAM	Nutrients, DO		X		X		X		X
S. INDIAN RIVER	5003C	IR16-20	ESTUARY	Nutrients, DO		X		X		X		X
S. INDIAN RIVER	5003D	IR14-15	ESTUARY	Nutrients, DO		X		X		X		X

Note: 1. Comparison against full-restoration median seagrass depths. Some segments achieve median seagrass depths within a -10% departure from the full target in some years, but no segment consistently meets the full-restoration or even the -10% departure targets.

2. EST= estuary; STR=stream.

6.2. Water Quality Data:

The water quality parameters and WBIDs in this TMDL report are required to be included because they were on Florida's 1998 303(d) list (see summary sheet). In addition, an independent assessment was made using the most recent data for these WBIDs in order to determine present water quality conditions and confirm impairment. Data for individual WBIDs were compared to the State of Florida Water Quality Standards to determine potential for impairment for D.O. and nutrients. Nutrients were assessed based on a weight-of-evidence approach that takes into account nutrient concentrations, chlorophyll *a* levels, D.O. concentrations, and seagrass depth distributions. Other indicators of imbalance of flora and fauna, such as excessive algal growth or impacts on seagrasses may also be used to indicate impairment by nutrients within a waterbody. Seagrasses are an important, native member of the flora in estuaries such as Indian River Lagoon. Seagrasses stabilize sediments, improve water clarity, and provide food and shelter to various marine organisms.

The state of Florida typically uses chlorophyll *a* as the primary indicator of nutrient enrichment, because its concentrations are a good measure of the biomass of phytoplankton, i.e. microscopic algae that drift in the water column. However, research indicates that in shallow estuaries such as Indian River Lagoon, nutrient enrichment may lead to a shift away from seagrasses to other primary producers such as drift algae, ephiphytic macroalgae and benthic microalgae before phytoplankton (Harlin, 1995; Bricker et al., 1999; Nixon et al., 2001). Studies have also shown declines in seagrass communities associated with increases in drift and attached macroalgae (Hanisak, 2001). The Indian River Lagoon is known to have a high drift algal biomass that varies seasonally (Virnstein and Carbonara, 1985). Comparisons of drift algae and seagrass transect lengths show that where algal density and percent cover are high in Indian River Lagoon, seagrass transects are generally shorter (Figure 3; Steward, 2006). In this way, nutrient enrichment may lead to "an imbalance in natural populations of aquatic flora or fauna" that is not necessarily reflected in chlorophyll concentrations but rather in the health of seagrass ecosystems.

Light is an important factor affecting the distribution of seagrasses, so any pollutants that diminish water transparency, thereby reducing light penetration, will negatively impact seagrass coverage. The Indian River/Banana River Lagoon PLRG study set maximum loading targets for TN, TP, and total suspended solids (TSS) as a function of seagrass depth limits in the lagoon. The PLRG study found strong, negative correlations between watershed loadings of nutrients and TSS and the depth limit of seagrass. This conclusion is supported by research conducted in Lemon Bay Estuary of Florida that showed negative impacts on turtle grass biomass and productivity due to watershed nitrogen loads (Tomasko et al., 1996).

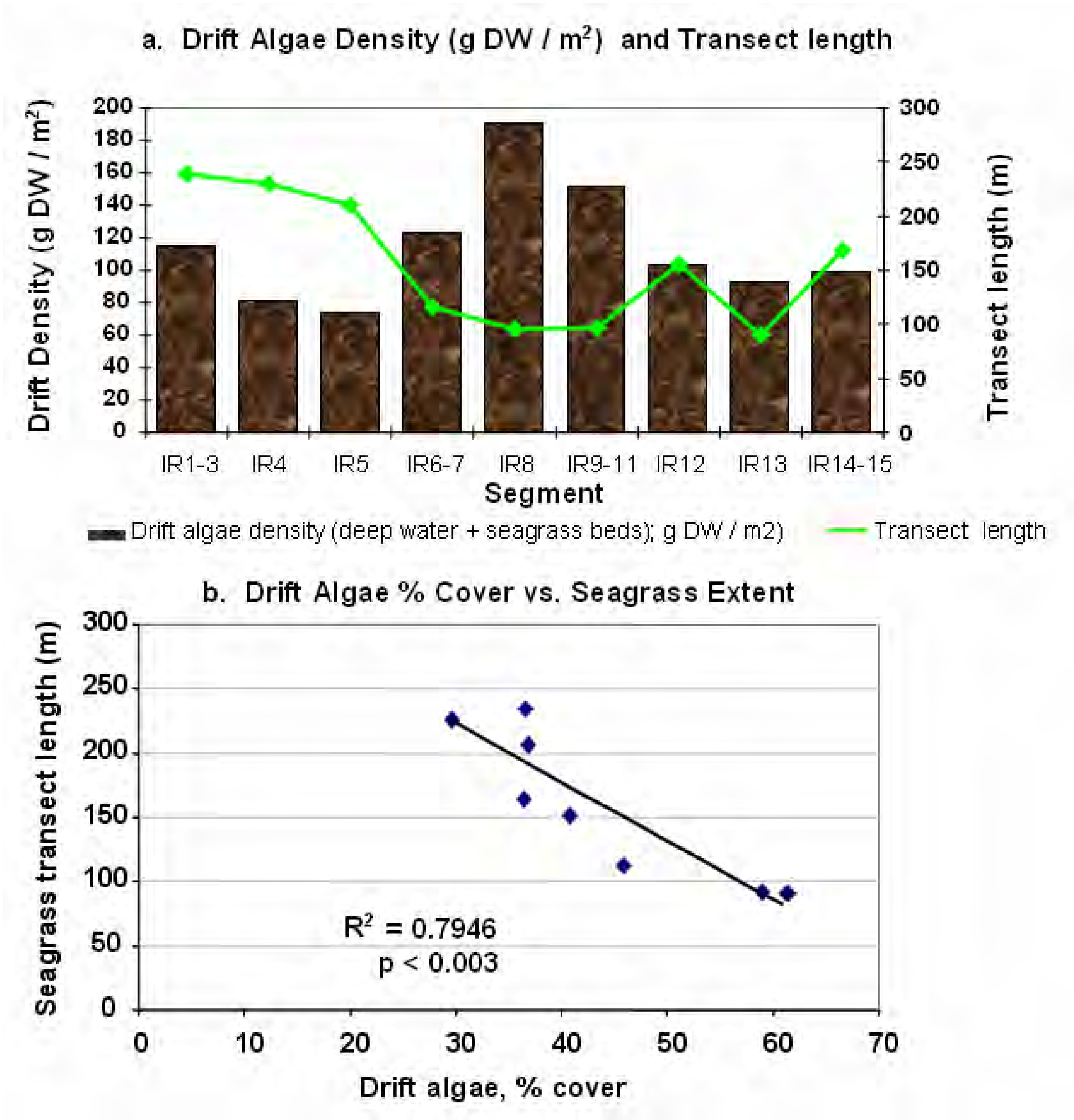


Figure 3. IRL Drift Algae (density and % cover) and Seagrass Extent (transect length) in 2005.

Note: g DW/m^2 = grams dry weight per square meter.

FDEP has developed screening level concentrations of nutrients that indicate levels of concern for TN and TP for consideration during assessments. The screening levels for TN are 1.0 mg/L in estuaries and 1.6 mg/L in streams. The values for TP are 0.19 mg/L in estuaries and 0.22 mg/L in streams. These screening values were compared to the median values of TN and TP in the data set for each WBID (FDEP IWR Run 24). As can be seen in Table 1, median nitrogen concentrations in most waterbodies exceed these screening thresholds. In addition, SJRWMD is currently working on defining water quality targets for estuarine segments of Indian River Lagoon. These targets include TN, TP, as well as other parameters and are being developed from the median concentrations observed where seagrass depth limits were within a -10% departure from their full-restoration levels. This project is still in progress, but it suggests TN concentrations of 0.98 mg/l based on 12-month medians, or 1.0 mg/l based on 18-month medians. For TP, the 12-month median is 0.05 mg/l, and the 18-month median is 0.06 mg/l (Steward, 2006). While the preliminary TN target concentration is close to FDEP's screening threshold, the TP target is much lower. Comparing the median TP concentration for each of the 13 estuarine WBIDs, seven waters exceed the TP target, and the medians for another five WBIDs are near the targets, with median TP concentrations between 0.05–0.06 mg/l. This indicates a problem with both excessive nitrogen and phosphorus.

D.O. was assessed using the number of exceedances and samples reported for the verified period in Florida's IWR Run 24. If the applicable D.O. criterion was exceeded in more than 10% of the data, the waterbody was considered potentially impaired (Table 1).

There are several factors that affect the concentration of D.O. in a waterbody. Oxygen can be introduced by wind, diffusion, photosynthesis, and additions of higher D.O. water (e.g. from tributaries). D.O. concentrations are lowered by processes that use up oxygen from the water, such as respiration and decomposition, and by additions of water with lower D.O. (e.g. swamp or groundwater). Natural D.O. levels are a function of water temperature, salinity, water depth and velocity, and relative contributions of groundwater. Warm water holds less oxygen than cool water, and slower-flowing, less turbulent water has less diffusion of atmospheric oxygen into it. Salinity decreases the ability of water to hold oxygen. D.O. levels fluctuate over the course of a day as the plants respire and photosynthesize. During daylight, submerged aquatic plants take up carbon dioxide and produce oxygen as by-products of photosynthesis. At night, photosynthesis does not occur and so the oxygen-consuming processes, such as respiration, dominate. Plots of D.O. and percent D.O. saturation data for individual WBIDs indicate that photosynthesis is a significant factor affecting D.O. concentrations in the lagoon. The data also show that D.O. can drop below the applicable criteria on some days in warmer months. Although recent data for biochemical oxygen demand (BOD), a measure of the amount of oxygen consumed by organisms in breaking down organic material, and total organic carbon (TOC), a measure of the organic content of the water, are limited, no significant correlations between TOC or BOD and D.O. (or D.O. percent saturation) were observed in the impaired WBIDs. Attaining and maintaining healthy populations of macrophytes through reductions of excess nutrients and TSS should allow the ecosystem to exhibit a natural D.O. regime.

Trends in the data suggest that recent management practices may have helped to improve general water quality in Indian River Lagoon. However, since most of the segments receive excess nutrient loadings and do not meet their depth limit target for seagrasses (Figure 4), nutrient impairment is indicated. The implementation of this TMDL and the PLRG developed by the SJRWMD will further improve water quality in Indian River Lagoon.

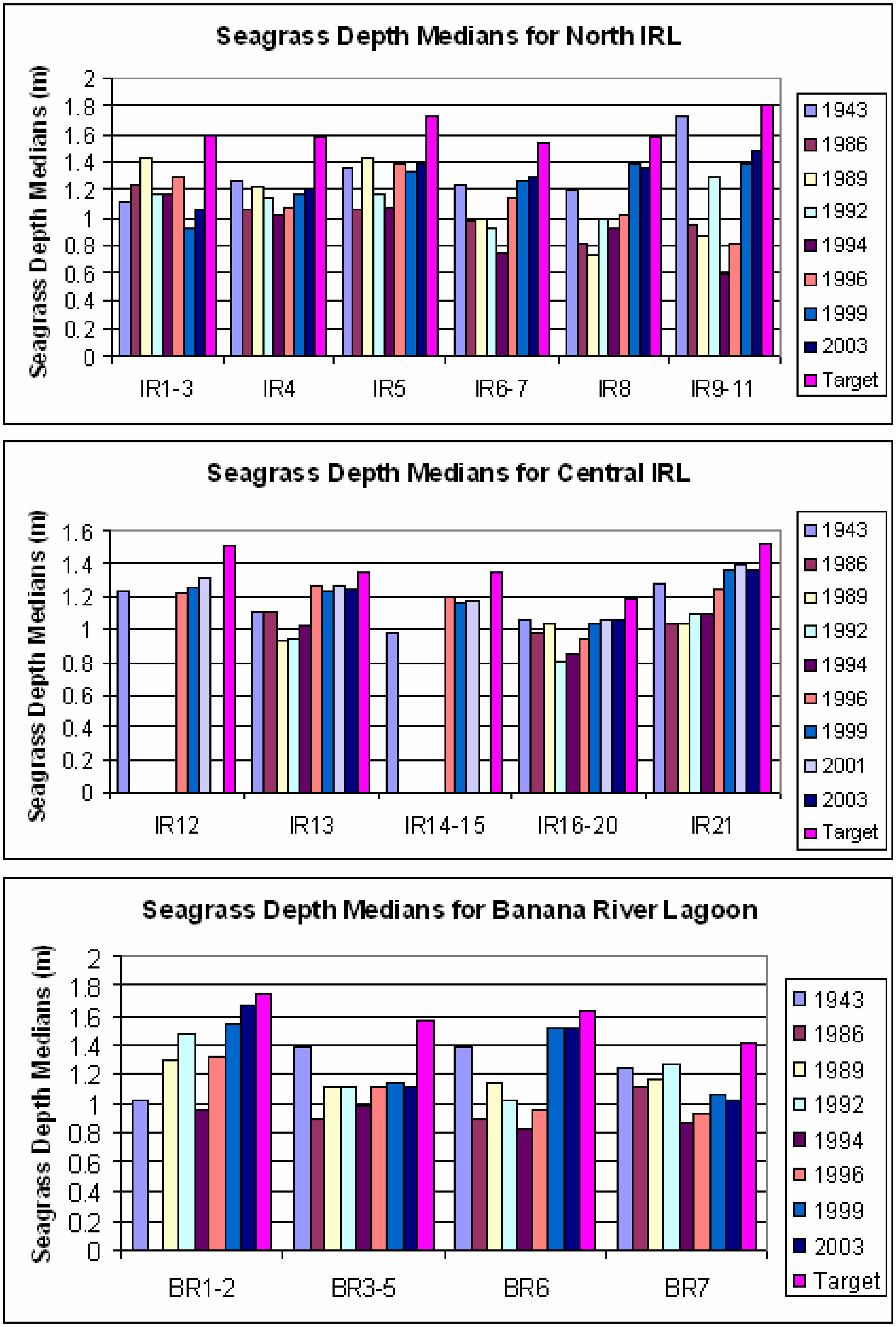


Figure 4. Seagrass depth medians for lagoon segments compared to full-restoration targets.

7. Source and Load Assessment

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of pollutants in the watershed and the amount of loading contributed by each of these sources. Sources are broadly classified as either point or nonpoint sources. Nutrients enter surface waters from both point and nonpoint sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater and treated sanitary wastewater must be authorized by National Pollutant Discharge Elimination System (NPDES) permits. NPDES permitted facilities, including certain urban stormwater discharges such as municipal separate stormwater systems (MS4 areas), certain industrial facilities, and construction sites over one acre, are stormwater driven sources considered “point sources” in this report.

Nonpoint sources of pollution are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. For nutrients, these sources include runoff of agricultural fields, golf courses, and lawns, septic tanks, and residential developments outside of MS4 areas. Nonpoint sources generally, but not always, involve accumulation of nutrients on land surfaces and wash-off as a result of storm events.

7.1. Point Sources:

7.1.1. Permitted Point Sources

Point source facilities are permitted through the Clean Water Act National Pollutant Discharge Elimination System (NPDES) Program. The FDEP NPDES program office in Orlando provided a listing of 33 NPDES facilities within the watershed that could potentially discharge into the waterbody. Discussions with FDEP concluded that there are 14 active NPDES-permitted facilities, including domestic wastewater treatment plants (WWTPs) and reverse osmosis water treatment facilities, that discharge nutrients within the North and Central Indian River Lagoon and Banana River Lagoon drainage area (Figure 5 and Table 2). In some cases, facilities do not discharge directly to a lagoon segment, but rather to an upstream tributary that flows to that lagoon segment. According to the Indian River Lagoon 2002 SWIM Update, point source discharges from WWTPs have decreased by an order of magnitude since 1986 (Steward et al., 2003).

In their recent PLRG analysis, the SJRWMD recognized that the actual discharge currently contributed by NPDES permitted facilities is, in most cases, a small fraction of the total annual external load of nutrients to the lagoon (on the order of 2%). However, most of these facilities still have permit limits that are much higher than their current discharges. In some cases, the difference is as high as 100-fold. If all of these facilities were to discharge at their permit limits, the contribution from them would become much more significant. Information on the permitted and actual discharges from these facilities is provided in Section 8.5.2.

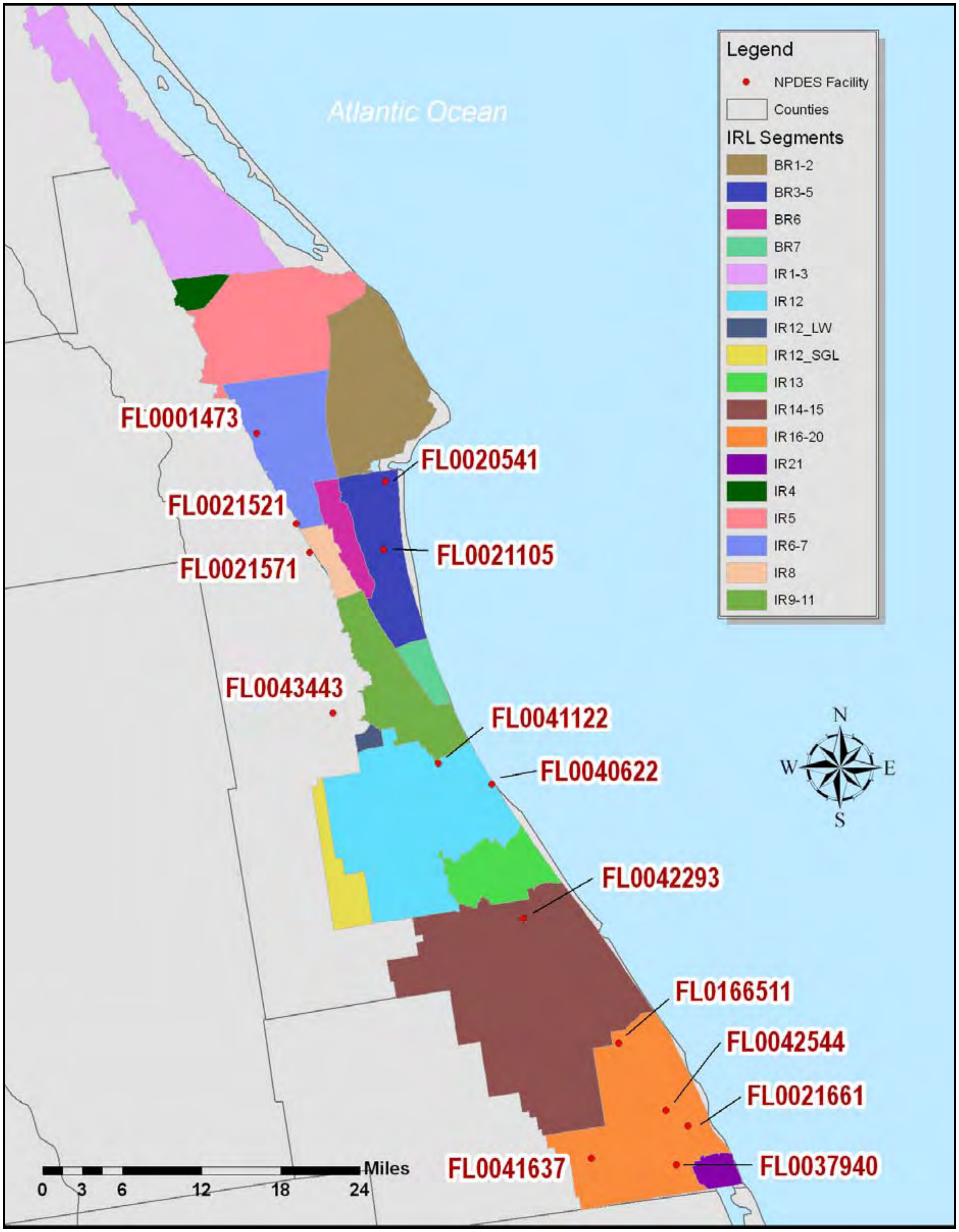


Figure 5. NPDES facilities that can discharge nutrients into the Indian River Lagoon.

Table 2. NPDES Permitted Facilities within Indian River Lagoon and Banana River Lagoon.

Facility Name	Facility ID	City, County	Latitude, Longitude	IRL Segment	Receiving Water
CAPE CANAVERAL WWTP	FL0020541	Cape Canaveral, Brevard	28.392972 80.617417	BR 3-5	Banana River
COCOA BEACH WWTP	FL0021105	Cocoa Beach, Brevard	28.31825 80.632944	BR 3-5	Banana River
FPL CAPE CANAVERAL POWER PLANT	FL0001473	Cocoa, Brevard	28.469444 80.764167	IR6-7	Indian River
COCOA (Jerry Sellers) WWTP	FL0021521	Cocoa, Brevard	28.362111 80.734833	IR 6-7	Indian River
ROCKLEDGE WWTP	FL0021571	Rockledge, Brevard	28.328222 80.723833	IR 8	Indian River
MELBOURNE, GRANT ST. WWTP	FL0041122	Melbourne, Brevard	28.090275 80.764167	IR12	Crane Creek/Indian River
BCUD SOUTH BEACHES WWTP	FL0040622	Melbourne Beach, Brevard	28.041389 80.544444	IR12	Indian River Lagoon
FL CITIES BAREFOOT BAY WWTP	FL0042293	Barefoot Bay, Brevard	27.888667 80.53625	IR 14-15	San Sebastian River
MELBOURNE REVERSE OSMOSIS WTF	FL0043443	Melbourne, Brevard	28.147389 80.728111	IR 9-11	Eau Gallie R. to Indian River
VERO BEACH REVERSE OSMOSIS WTF	FL0042544	Vero Beach, Indian River	27.652601 80.401332	IR 16-20	Main Canal
INDIAN RIVER COUNTY HOBART REVERSE OSMOSIS WTF	FL0166511	Vero Beach, Indian River	27.7345 80.446083	IR 16-20	Indian River Lagoon
VERO BEACH WWTP	FL0021661	Vero Beach, Indian River	27.630944 80.37825	IR 16-20	Indian River
IR COUNTY SOUTH REVERSE OSMOSIS WTF	FL0037940	Vero Beach, Indian River	27.590944 80.400167	IR 16-20	South Relief Canal/ Indian River Lagoon
IRCUD WEST REGIONAL WWTP	FL0041637	Vero Beach, Indian River	27.612944 80.502417	IR16-20	South Relief Canal/ Indian River

7.1.2. Municipal Separate Storm System Permits

Municipal Separate Stormwater Systems (MS4s) are point sources also regulated by the NPDES program. According to 40 CFR 122.26(b)(8), a MS4 is "a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):

> (i) Owned or operated by a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law)...including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges into waters of the United States.
>
> (ii) Designed or used for collecting or conveying storm water;
>
> (iii) Which is not a combined sewer; and
>
> (iv) Which is not part of a Publicly Owned Treatment Works."

MS4s may discharge nutrients and other pollutants to waterbodies in response to storm events. In 1990, USEPA developed rules establishing Phase I of the NPDES stormwater program, designed to prevent harmful pollutants from being washed by stormwater runoff into MS4s (or from being dumped directly into the MS4) and then discharged from the MS4 into local waterbodies. Phase I of the program required operators of "medium" and "large" MS4s (those generally serving populations of 100,000 or greater) to implement a stormwater management program as a means to control polluted discharges from MS4s. Approved stormwater management programs for medium and large MS4s are required to address a variety of water quality related issues including roadway runoff management, municipal owned operations, hazardous waste treatment, etc.

Phase II of the rule extends coverage of the NPDES stormwater program to certain "small" MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES stormwater program. Only a select subset of small MS4s, referred to as "regulated small MS4s", requires an NPDES stormwater permit. Regulated small MS4s are defined as all small MS4s located in "urbanized areas" as defined by the Bureau of the Census, and those small MS4s located outside of "urbanized areas" that are designated by NPDES permitting authorities.

There are several permitted MS4s in the northern and central Indian River Lagoon and Banana River Lagoon watersheds (Table 3).

Table 3. MS4 permits potentially affected by the Northern and Central Indian River Lagoon and Banana River Lagoon TMDLs.

Phase	Permit Name	Permit Number	County
II	FDOT District 4	FLR04E083	None
II	FDOT District 5	FLR04E024	None
II	Brevard County	FLR04E052	Brevard
II	City of Titusville	FLR04E079	Brevard
II	City of Cape Canaveral	FLR04E003	Brevard
II	City of Cocoa	FLR04E032	Brevard
II	City of Cocoa Beach	FLR04E062	Brevard
II	Town of Rockledge	FLR04E047	Brevard
II	City of Satellite Beach	FLR04E072	Brevard
II	Patrick Air Force Base	FLR04E074	Brevard
II	City of Indian Harbour Beach	FLR04E026	Brevard
II	Town of Indialantic	FLR04E030	Brevard
II	City of Melbourne	FLR04E027	Brevard
II	Town of Melbourne Beach	FLR04E041	Brevard
II	City of West Melbourne	FLR04E028	Brevard
II	City of Palm Bay	FLR04E077	Brevard
II	Town of Malabar	FLR04E050	Brevard
II	Indian River County	FLR04E068	Indian River
II	City of Sebastian	FLR04E124	Indian River
II	Town of Indian River Shores	FLR04E009	Indian River
II	City of Vero Beach	FLR04E010	Indian River
II	St. Lucie County	FLR04E029	St. Lucie
II	City of Fort Pierce	FLR04E065	St. Lucie

7.2. Nonpoint Sources:

Nonpoint source pollution generally involves a buildup of pollutants on the land surface that wash off during rain events and as such, represent contributions from diffuse sources, rather than from a defined outlet. Potential nonpoint sources are commonly identified, and their loads estimated, based on land cover data. Most methods calculate nonpoint source loadings as the product of the water quality concentration and runoff water volume associated with certain land use practices. The mean concentration of pollutants in the runoff from a storm event is known as the Event Mean Concentration (EMC).

Nonpoint sources contribute a greater annual load of nutrients into the Indian River Lagoon than do point sources (Steward and Green, 2006). The land use distribution of the Indian River Lagoon watershed provides insight into potential nonpoint sources of nutrients. As can be seen in Figure 6, there are several urban areas located throughout the watersheds contributing to Indian River Lagoon. This region has seen an expansion of urban areas in recent decades. Agriculture and rangeland are also important uses, especially in the Central Indian River sub-lagoon.

7.2.1. Urban Areas

Urban areas include land uses such as residential, industrial, extractive and commercial. Land uses in this category typically have somewhat high TN EMCs and average TP EMCs. Urban and other built-up land uses occur throughout the watershed, but are clustered along the shores of the lagoon and throughout segment IR 12.

Nutrient loading from non-MS4 urban areas is attributable to multiple sources including stormwater runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals.

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as outlined in Chapter 403 Florida Statutes (F.S.), was established as a technology-based program that relies upon the implementation of Best Management Practices (BMPs) that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C.

Florida’s stormwater program is unique in having a performance standard for older stormwater systems that were built before the implementation of the Stormwater Rule in 1982. This rule states: “the pollutant loading from older stormwater management systems shall be reduced as needed to restore or maintain the beneficial uses of water” (Section 62-4-.432 (5)(c), F.A.C.).

Nonstructural and structural BMPs are an integral part of the State’s stormwater programs. Nonstructural BMPs, often referred to as “source controls”, are those that can be used to prevent the generation of nonpoint source pollutants or to limit their transport off-site. Typical nonstructural BMPs include public education, land use management, preservation of wetlands and floodplains, and minimization of impervious surfaces. Technology-based structural BMPs are used to mitigate the increased stormwater peak discharge rate, volume, and pollutant loadings that accompany urbanization.

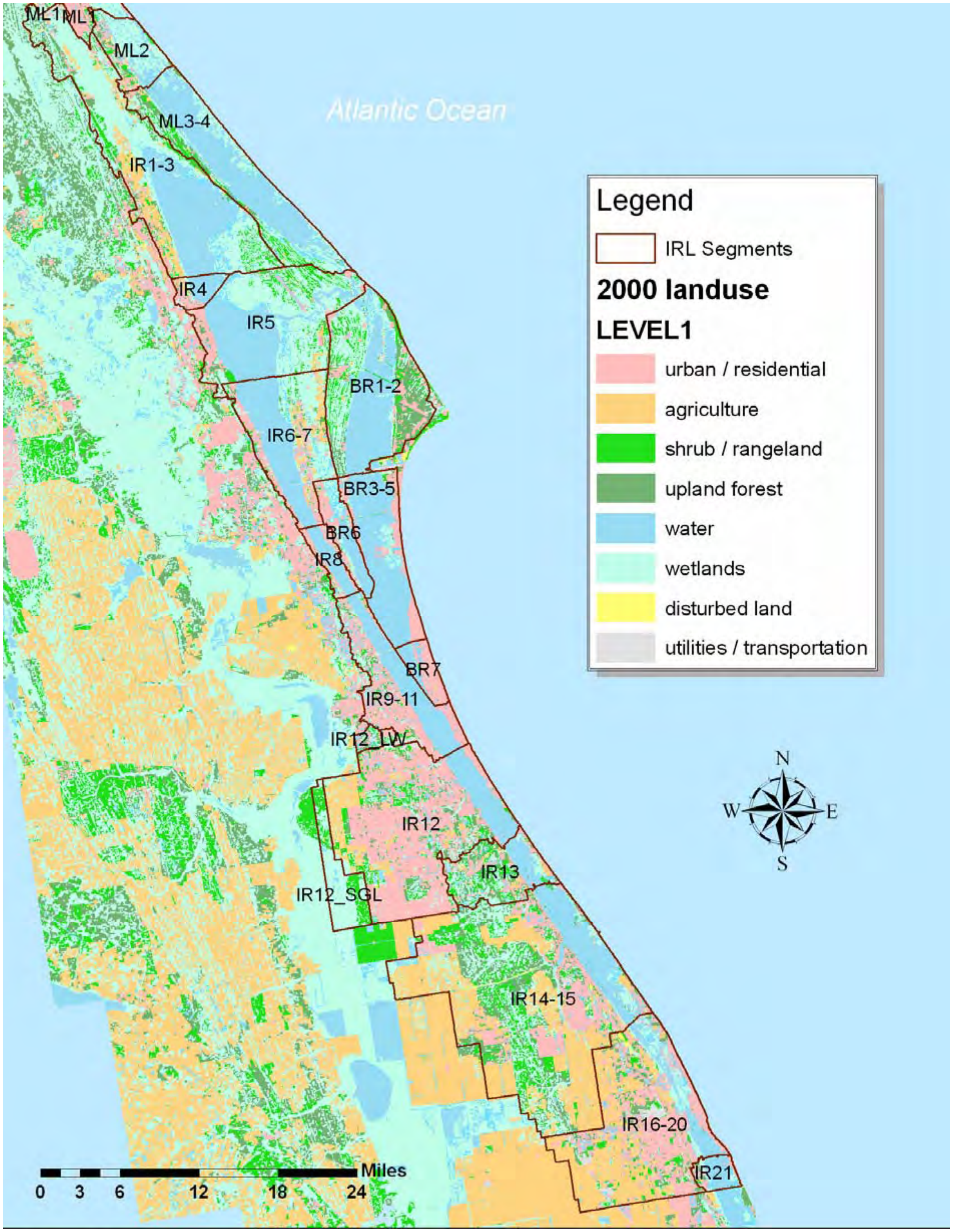


Figure 6. Land Uses within the Indian River Lagoon watershed.

7.2.2. Agriculture

Agricultural lands include improved and unimproved pasture, row and field crops, citrus, and specialty farms. The highest TN and TP EMCs are associated with agricultural land uses. Within the Indian River Lagoon watershed agricultural land uses are found primarily in inland areas within the contributing areas for lagoon segments IR12, IR14 and IR 16-20.

7.2.3. Rangeland

Rangeland includes herbaceous, scrub, disturbed scrub and coastal scrub areas. Rangeland occurs primarily in inland areas of IR14 and southward. EMCs for rangeland are about average for TN and low for TP.

7.2.4. Upland Forests

Upland forests include flatwoods, oak, various types of hardwoods, conifers and tree plantations. Within the Indian River Lagoon watershed upland forests occur from IR12 southward in inland areas in large and small patches. EMCs for upland forests are low for both TN and TP.

7.2.5. Water and Wetlands

These occur throughout the watershed and have very low EMCs down to zero. Open water occurs primarily in the lagoon along the eastern portion of the watershed, and in scattered undeveloped wetlands in the southwestern watershed.

7.2.6. Barren Land

Barren land includes beaches, borrow pits, disturbed lands and fill areas. Barren lands comprise only a small portion of the watershed.

7.2.7. Transportation, Communications and Utilities

Transportation uses include airports, roads and railroads. EMCs for these types of uses are in the mid-range for TN and TP.

7.2.8. Groundwater and Atmospheric Sources

Groundwater and atmospheric sources were considered in the PLRG analysis. Stepwise regression analyses show that atmospheric sources of nutrients do not significantly affect the relationship between nutrient loads and seagrass depth distributions at $\alpha = 0.15$ (Steward and Green, 2006). Since groundwater estimates were only available for the whole lagoon system, they could not be incorporated into the step-wise regressions. However, SJRWMD concluded that the contribution of groundwater sources was unlikely to be significant.

8. Analytical Approach

The TMDLs are based upon on-going efforts by the SJRWMD to develop PLRGs for the Indian River Lagoon watershed (Green and Steward, 2003; Steward and Green, 2006). The goal of a PLRG is to numerically estimate the reductions in pollutant loadings needed to restore a given waterbody (see Florida Administrative Code [Chapter 62-40.210(18)]). As part of this analysis, both the current loads and the loads at which a waterbody is expected to be restored must be determined. In addition, the SJRWMD modeled future, "build-out" conditions to estimate the impact of predicted growth in the area.

The Indian River/Banana River Lagoon PLRGs set maximum loading targets for TN, TP, and TSS as a function of seagrass depth limits in the lagoon. The logic behind this approach is that an excess of those pollutants will diminish water transparency and attenuate light penetration, in turn reducing seagrass coverage. Seagrasses have an important role in the ecology of estuaries such as Indian River Lagoon. Seagrasses stabilize sediments, improve water clarity, and provide food and shelter to various marine organisms. In addition, seagrass is a conspicuous floral feature of this waterbody, and Florida's nutrient criterion requires preventing an imbalance in natural populations of aquatic flora. Thus, maintaining healthy seagrass is consistent with the overall goal of meeting water quality standards and maintaining the designated use of the waterbody.

As part of the PLRG analysis, maximum seagrass depths were determined from the union of mapped seagrass coverages, which were available for 1943, 1986, 1989, 1992, 1994, 1996, and 1999 (Steward et al, 2005). Full restoration seagrass conditions are the median depth of the furthest extent of seagrass coverage achieved during this period. The TMDL value for Indian River Lagoon is equivalent to the mean annual loads of TN and TP that achieve the target seagrass depth of -10% from full restoration conditions (Table 4). The seagrass depth targets for the sub-lagoons are represented by a range of values, since seagrass depth targets were developed for each segment within them (Steward et al., 2005). The -10% departure was selected because Florida's water quality standard for transparency states that the depth at which photosynthetic activity can occur should not be reduced by more than 10% from natural background conditions (see Florida Administrative Code [Chapter 62-302.530(68)] for the water transparency standard, and [Chapter 62-302.200(14)] for the definition of Natural Background).

Table 4. Seagrass depth targets and corresponding annual nutrient loads in three sub-lagoons.

Sub-lagoon	Seagrass Depth Target (median, m)	TN (lb/ac/yr)	TP (lb/ac/yr)
North Indian River Lagoon	1.5 – 1.8	2.88	0.368
Central Indian River Lagoon	1.2 – 1.7	2.89	0.570
Banana River Lagoon	1.4 – 1.8	2.18	0.374

The nonpoint fraction of the nutrient loading estimates to which the seagrass depths are correlated were generated using the Pollutant Load Screening Model (PLSM) and the

Hydrologic Simulation Program- Fortran (HSPF). PLSM is a GIS-based watershed model that can estimate annual runoff and pollutant loads from spatial data (Adamus and Bergman, 1993, 1995). HSPF is a system of models commonly used to simulate the effects of changes in land use and point or nonpoint source treatments on watershed hydrology and associated water quality (Bicknell et al., 2001). Load predictions were made for four time periods where both seagrass depths and pollutant loading could be estimated: 1942-43, 1995-96, 1998-99, and 2000-01. The results for 2000 were used to represent current loads.

The actual annual nutrient loads contributed by NPDES point sources were determined from discharge data entered in the NPDES database. Point source loads for 1942-43 were not included due to a lack of data. However, it is assumed that any point source loading which occurred at that time would not be significant, especially as compared to nonpoint sources and also compared to the current and presumably much larger point source loading, which is a consequence of population growth. According to U. S. Census data, the population of Brevard, Indian River and St. Lucie Counties in 1940 was 36,970. By 1990, the population of these counties was 630,357, growing to 781,872 in 2000 (U.S. Census Bureau, 2006). This represents a growth of approximately 150,000 in only 10 years. These point source loads were added to the nonpoint source loads from PLSM and HSPF to determine the total loading to the lagoon in the four time periods.

For the purpose of these analyses, the IRBR estuary was divided into three distinct sub-lagoon regions: North Indian River Lagoon, Central Indian River Lagoon, and Banana River Lagoon. These sub-lagoons were further divided into segments that reflect distinct physiographic, hydrologic, biologic, and water quality characteristics based on spatial analysis of water quality data (Steward and Green, 2006). Regression models were used to relate the TN and TP loading to seagrass depths in the whole lagoon, and in sub-lagoon areas. Areal nutrient loads for the whole lagoon and sub-lagoons (in units of lbs/acre/year) were converted to annual loads (lbs/year) using their watershed acreages.

The Waste Load Allocations (WLAs) for each facility were developed considering their current permit limits, the quality and frequency of the actual discharge, and the assimilation capacity of the receiving watershed. Since TMDLs are the sum of the Load Allocation (LA) for nonpoint sources, the Waste Load Allocation for point sources, and the Margin of Safety (MOS), the LA was calculated as the difference:

$$\sum \mathrm{LA} = \sum \mathrm{TMDL} - \sum \mathrm{WLA} - \mathrm{MOS}$$

The modeling approach that was applied to simulate nutrient fate and transport in the Indian River Lagoon watershed, and relate these loads to seagrass health is described further in Sections 8.1, 8.2 and 8.3 and in Appendix A. The determination of the WLA is explained in Section 8.4.

Since D.O. is not a pollutant, the TMDLs need to allocate limitations for pollutants that cause low D.O. The causative pollutants targeted for these TMDLs are the nutrients TN and TP. The PLRG effort also targeted TSS, although the present TMDL does not. However, any control measures that are implemented to reduce nonpoint nutrient loading typically will simultaneously reduce TSS loading. Reductions in TSS loading, along with the removal of organically-enriched muck sediment, would likely result in improvements in D.O. within tributary creeks.

8.1. PLSM Model:

PLSM is a GIS-based stormwater runoff model that was originally developed as a tool to assist watershed planning in the SJRWMD. Since that time the model has been refined and improved for the Indian River Lagoon Watershed in support of the 2002 SWIM Update and more recent efforts. Although PLSM is considered a screening level model, useful for identifying potential stormwater runoff problems resulting from current and future land use patterns, the SJRWMD assessed its reliability in estimating annual nutrient loads to determine PLRGs for Indian River Lagoon (Steward and Green, 2006). Because it has only modest input requirements, PLSM has the advantage of being relatively easy to set up and run for different watersheds. PLSM is suitable for large watersheds with numerous pollutant sources, varied soils, and diverse land uses that have changed over time, such as the Indian River Lagoon watershed. Pollutant loads are expressed as the average annual load per acre and can be aggregated together or broken out to the level of individual drainage basins and/or lagoon segments, as necessary. PLSM generates pollutant loads from multiple spatially distributed inputs such as land use, soil types, hydrologic boundaries, rainfall, runoff coefficients, EMCs, and BMPs. By altering these variables, estimates of historic, current, and future loads of TN, TP, and TSS can be calculated.

PLSM was calibrated to four different catchments of the Indian River Lagoon and the results for runoff volume, TN, TP, and TSS compared against the predictions of other watershed models. The SJRWMD study concluded that PLSM loads were comparable to more complex models that had been developed and calibrated for their respective watersheds (Green and Steward, 2003; Steward and Green, 2006).

8.1.1. PLSM Set Up

The input requirements for PLSM include spatial data for the watershed, such as land uses, soil types, drainage boundaries and annual rainfall, as well as data to characterize the quantity and quality of runoff. Runoff coefficients are used to predict the volumetric ratio of runoff generated from a given amount of rainfall. EMCs are used to represent the average concentration of a pollutant in runoff derived from a particular land use in the watershed.

The land use data used in the Indian River Lagoon PLSM model were taken from Florida Land Use Cover Classificiation System (FLUCCS) land use coverages derived from photo-interpretation of aerial photographs (1943, 1989, 1994, and 1999). The data were reviewed and refined by ground-truthing and anecdotal reports from land appraisers and managers (Green and Steward, 2003). In some cases the land uses were re-classified to improve the accuracy of the dataset. Soils data came from the Soil Survey Geographic Database (SSURGO) developed by the Natural Resource Conservation Service. SSURGO provides spatial distributions for different soil types, and some of the characteristics for each soil, such as its hydrologic properties. Drainage boundaries were determined from USGS 7.5 minute quadrangle maps at 5-foot contours intervals, aerial photogrammetric mapping, and on-file drainage maps or plans obtained from local governments and water control districts. Prior to March 2000, annual rainfall volumes were taken from established National Weather Service Stations and were supplemented with data from the WMD's hydrological/meteorological network. Following March 2000, rainfall data were derived from Doppler Radar. Runoff coefficients and EMCs were compiled from literature values for studies conducted within Florida. Where possible, values were taken from studies conducted within the region, and were supplemented with field data collected within the Indian River Lagoon basin. Tables of the runoff coefficients and EMCs are provided in Appendix A.

8.1.2. PLSM Calibration

As a result of a 2002-2003 study of runoff loading in the Crane Creek catchment, the Indian River Lagoon PLSM model was recently re-calibrated, and new estimates for average annual flow and loads for TN, TP, and TSS were made (Steward and Green, 2006). The model was simultaneously calibrated to achieve the best overall fit against measured pollutant loads in four catchments: Crane Creek, C-1 Canal of Turkey Creek, South Prong of Sebastian River, and Briar Creek. These catchments were selected because they represent the variety of land uses within the Indian River Lagoon watershed and because three of them also had another water quality model developed and calibrated for that basin.

During calibration of PLSM, the sensitivity of the model to each land use (i.e. the pollutant load from that land use, as a percentage of the total load) was determined. To account for changes in soil storage in unusually wet or dry years, correction factors were applied to the calculation of total discharge if the average annual rainfall varied from the 30-year mean by ten percent or more. Stormwater treatment was accounted for by applying loading reduction factors to developments constructed after Florida's stormwater treatment rules went into effect in 1984. Aerial photo-interpreted land use maps, circa 1989, were used as a baseline for determining treated from non-treated development.

When SJRWMD evaluated the PLSM model output against measured annual loads for the four sub-basins, they concluded that the results were comparable. PLSM slightly under-predicted flow and TSS, and slightly over-predicted TN and TP (Figure 7). However, as SJRWMD noted, the available loading data are total watershed loadings that include stream baseflow (Green and Steward, 2003).

PLSM results from the Indian River Lagoon model were also compared to the three calibrated watershed models used in three of the four catchments (Green and Steward, 2003; Steward and Green 2006). These models were HSPF (Bicknell et al., 2001), CALSIM (Pandit and Gopalakrishnan, 1996, 1997), and LOADSIM (Pandit and Swain, 1992). CALSIM is a generalized water resources simulation model developed by the Department of Water Resources, Office of State Water Project Planning, in California. LOADSIM is a spreadsheet model that can be used to predict stormwater runoff of nutrient and TSS under present and future land use scenarios. PLSM flows and loads corresponded favorably to the values derived from those models as well. Flows and TN loads had very close correspondence, while PLSM estimated TP loads were approximately 16% higher, and TSS loads were 9.5% lower, than the other models.

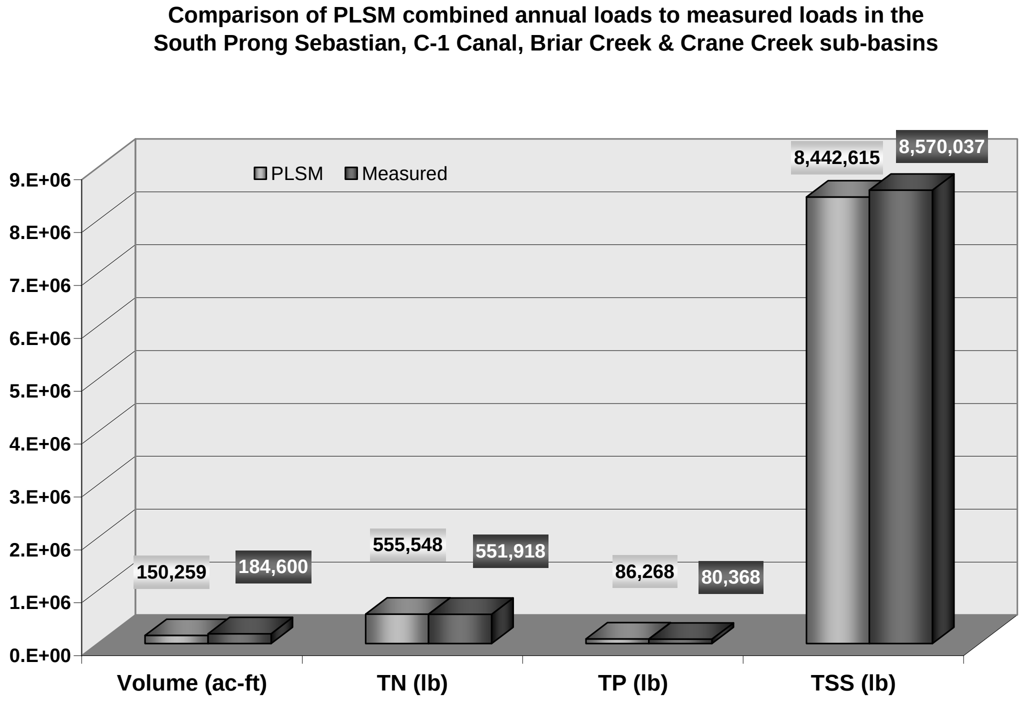


Figure 7. PLSM Estimated versus Measured Loads for Four Basins in the IRL Watershed.

8.2. HSPF Model:

As a check on the PLSM pollutant load estimates, HSPF was set up for the Indian River Lagoon and used to generate independent loading estimates for 1943, 1996, 1999, and 2001.

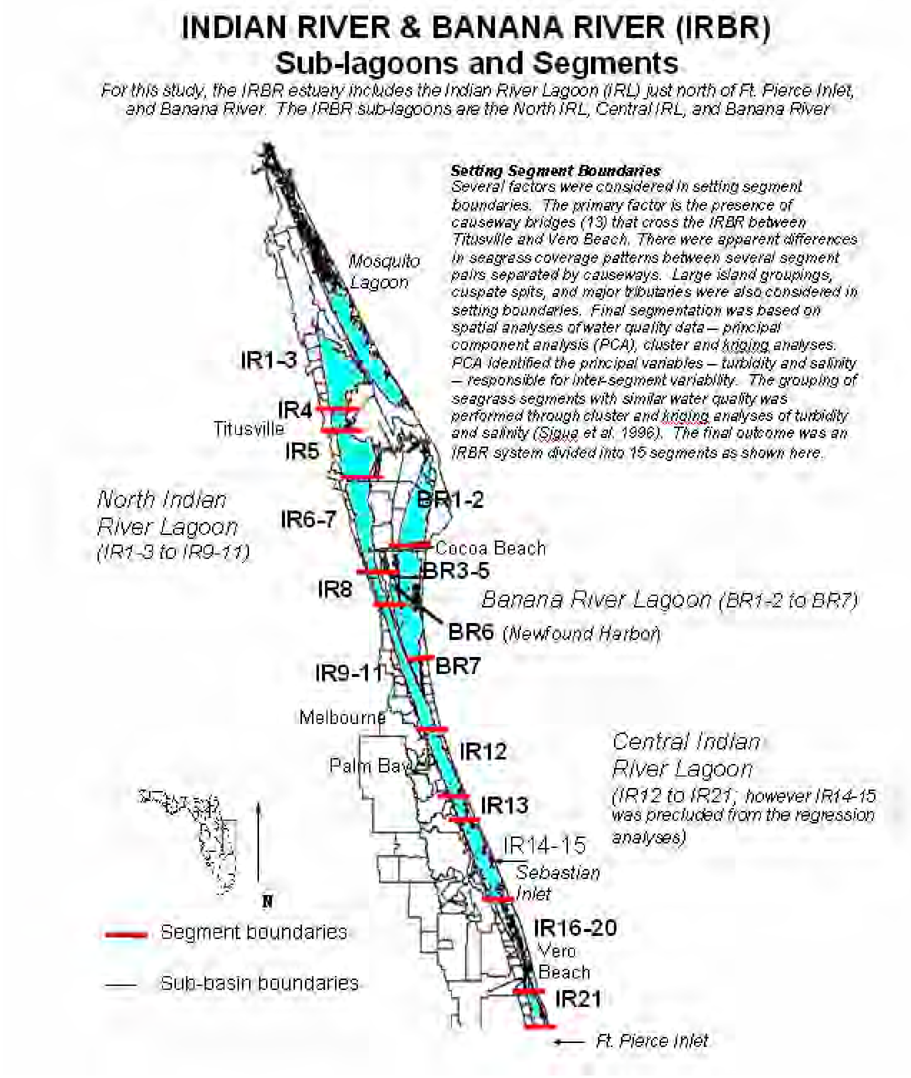
HSPF is a comprehensive system of models that can be used to simulate the effects of changes in land use and point or nonpoint source treatments on watershed hydrology and associated water quality (Bicknell et al., 2001). Various constituents are simulated, such as nitrogen (inorganic nitrogen, nitrite, nitrate, ammonia), phosphorus (orthophosphate, inorganic phosphorus, phosphate), biochemical oxygen demand, D.O., organic and inorganic carbon, zooplankton, phytoplankton, and benthic algae, fecal coliform bacteria and other pathogens, sediment loading and suspended sediment, carbon dioxide, pH, alkalinity, and streamflow. The model has a long history and has been extensively reviewed and used in many complex applications. HSPF simulates the fate and transport of conventional and toxic pollutants that are discharged from a point source or generated as runoff from pervious and/or impervious surfaces to a one-dimensional river reach or other well-mixed waterbody, and then integrates this with in-stream hydraulics and sediment-chemical interactions. In fact, it is one of the few watershed models that can simulate both processes on the land and in the receiving water. The model can simulate high and low flows and produce stream hydrographs and pollutographs for any point in the watershed, as well as a time history of the runoff flow rate, loads for three sediment types (sand, silt, and clay), and nutrient and pesticide concentrations.

HSPF can run with any user-defined time step from 1 minute to 1 day, as long as the time step chosen divides evenly into one day. The time periods simulated can be as short as a few minutes, or as long as hundreds of years. The model output lends itself to frequency-duration analysis. Disadvantages of the HSPF model are that it can require extensive data inputs and be challenging to set up and use correctly. Data inputs include, but are not limited to, continuous rainfall and other meterological data such as evapotranspiration, temperature, and solar intensity. Other inputs include geographic data such as land use, soils, agricultural practices, locations of dams, data on point source discharges, and environmental monitoring data for flow and water quality. Default values are available for a number of the model parameters, and parts of the program may be by-passed if suitable data are not available. The model is appropriate for well-mixed waters with one-directional flow. Simulation processes are lumped for each land use type in each sub-watershed. The use of smaller sub-watersheds can minimize this limitation, but will increase the complexity and runtime of the model.

8.3. Regression Models:

In 2003, linear regression models were introduced into the PLRG analysis in order to quantify variability in the relationship between total pollutant loads and seagrass depth limits. The total loads of nitrogen, phosphorus and TSS against which the seagrass depths were regressed were calculated as the sum of point and nonpoint sources in 1943, 1996 1999, and 2001. As described above, the point source loads were determined from discharge data in the NPDES database. The nonpoint source loads were determined from either the PLSM or HSPF model. While the mechanistic relationship between nutrient loads and seagrass depth targets dictates that nutrient loads should be the independent/causal variable (i.e. on the x-axis of the graph), the variables were switched in order to determine the target nutrient loads that correspond to the -10% departure target. These regressions were performed for the entire lagoon area (i.e. whole lagoon) and, in recognition of the biologic and hydrologic differences that exist between different areas of the lagoon, the regressions were also performed for the three main sub-lagoon areas (Steward and Green, 2006). These sub-lagoons areas are the North Indian River Lagoon, Central Indian River Lagoon, and Banana River Lagoon. One of the factors leading to these hydrologic differences is the presence and relative location of tidal inlets. For example, the Sebastian and Fort Pierce Inlets allow the Central Indian River sub-lagoon to have much higher flushing rates.

The North, Central and Banana River Lagoons were further sub-divided into 15 smaller segments. Figure 8 shows these segments, as presented in Steward and Green (2006). The locations of causeway bridges, which can cause changes in hydrodynamic circulation patterns, were a major factor used to set the location of segment boundaries. Also considered were known differences in seagrass coverage. Kriging (spatial representation of the data in order to identify spatial patterns or differences) and cluster analysis (a data analysis technique that groups data into sub-sets by associations or similarities) were used to assess the spatial variability of turbidity and salinity, and support re-combining segments where no differences were found. Segments IR1-3 through IR9-11 are part of the North Indian River Lagoon (North IRL), while segments IR12 through IR21 are part of the Central Indian River Lagoon, and BR1-2 through BR7 constitute the Banana River Lagoon.



INDIAN RIVER & BANANA RIVER (IRBR)
Sub-lagoons and Segments

For this study, the IRBR estuary includes the Indian River Lagoon (IRL) just north of Ft. Pierce Inlet, and Banana River. The IRBR sub-lagoons are the North IRL, Central IRL, and Banana River

Setting Segment Boundaries
Several factors were considered in setting segment boundaries. The primary factor is the presence of causeway bridges (13) that cross the IRBR between Titusville and Vero Beach. There were apparent differences in seagrass coverage patterns between several segment pairs separated by causeways. Large island groupings, cuspate spits, and major tributaries were also considered in setting boundaries. Final segmentation was based on spatial analyses of water quality data – principal component analysis (PCA), cluster and kriging analyses. PCA identified the principal variables – turbidity and salinity – responsible for inter-segment variability. The grouping of seagrass segments with similar water quality was performed through cluster and kriging analyses of turbidity and salinity (Sigua et al. 1996). The final outcome was an IRBR system divided into 15 segments as shown here.

Figure 8. Indian and Banana River Sub-lagoons and Segments (Steward and Green, 2006).

Since two different models (PLSM and HSPF) were used to generate annual loading estimates of TP, TN, and TSS for the whole lagoon and for the sub-lagoons, it was decided that the annual loading targets should be taken from whichever model demonstrated a stronger correlation with seagrass distribution. While the loads from the two models were comparable, PLSM results had higher correlation coefficients (R^2) and significance (p values), with the exception of TP loads in the North Indian River Lagoon (Steward and Green, 2006). Therefore, the HSPF regression model was used to set the annual load target for TP in North Indian River Lagoon, and the PLSM regression models were used to set all other targets.

Given that the relationship between light penetration and water quality is best described exponentially, the load data were log-transformed before being used in the linear regression models. This data transformation resulted in a normally-distributed dataset. The data were back-transformed to represent the load targets in units of lbs/acre/yr (Steward and Green, 2006). These load targets were then converted to annual loads (lbs/yr) for the whole lagoon and three sub-lagoons based on acreages.

8.4. Point Source Loads:

For the regression models, the actual annual nutrient loads contributed by point sources were determined from discharge and nutrient data entered in FDEP's NPDES database. Point source loads for 1942-43, which are assumed to be relatively insignificant, were not included due to a lack of data. Point source loads were added to the nonpoint source loads from PLSM and HSPF to calculate the total loading to the lagoon in the four time periods (1942-43, 1995-96, 1998-99 and 2000-01) when both seagrass depths and nonpoint source pollutant loading had been estimated. Thus, the regression models include point and nonpoint sources.

After the total annual pollutant loading targets were determined from the regression models, the Waste Load Allocations (WLAs) for each facility were developed considering their current permit limits, the quality and frequency of their actual discharge, and the assimilative capacity of the receiving waters. For each NPDES facility, monthly discharge volume and TN and TP concentration data were obtained from FDEP. Annual TN and TP loads were calculated for the years 2001-2005. The arithmetic mean and the 95th percentile of these annual loads were also calculated. TN and TP values are provided in Table 7 and Table 8, respectively. These average annual loads and the 95th percentile of the annual loads were compared against permitted loads and discharge concentrations for each facility.

Those facilities that already achieve low nutrient concentrations and/or discharge infrequently were allocated annual TN and TP loads equivalent to the 95th percentile of their discharged nutrient load for 2001 to 2005. WLAs that were calculated differently are discussed below.

The Cocoa J. Sellers WWTP (FL0021521) is allocated its average annual TN load as a maximum annual limit since it has a high load (5,556 lbs/year) and a high TN concentration (5.83 mg/L) in its discharge. Since the concentration of TP in its discharge averages only 0.57 mg/L, the facility is allocated the 95th percentile for TP.

The Vero Beach WWTP (FL0021661) is allocated its annual average TN and TP loads as maximum annual limits because of its high loads and high concentrations (12.35 mg/L and 12,173 pounds TN, and 1.06 mg/L and 916 pounds TP).

The Rockledge WWTP (FL0021571) is known to discharge a very small load of TN and TP (about 10 lbs/year TN and TP) only when it performs Mechanical Integrity Testing. The last time Rockledge conducted this testing was in 1996-1997. The facility is allocated limits of 30 lbs/year for both TN and TP, an amount sufficient for this purpose.

The Cape Canaveral Power Plant (FL0001473) is allocated its currently permitted loads for TN and TP (146 lbs/year TP and 2555 lbs/year TN) since its contribution is a very small percentage of the TMDL for its lagoon segment (3% for TN and 1% for TP).

The Cape Canaveral WWTP (FL0020541), located in BR3-5, is allocated the 95th percentile of its annual load as a maximum limit because it has low effluent concentrations and loads (0.11 mg/L and 112 pounds per year for TP, and 1.1 mg/L and 1342 pounds per year for TN). However, the Cocoa Beach WWTP (FL00211005), which discharges to the same lagoon segment as the Cape Canaveral WWTP, has much higher effluent concentrations (6.7 mg/L TN and 1.3 mg/L TP) and much higher loads (12,476 pounds TN per year and 2291 pounds TP per year). After reserving the allocation for Cape Canaveral, Coach Beach was allocated annual load limts for TN and TP that result in 15% of the TMDL for segment BR3-5 being allocated for point sources, with the other 85% allocated for nonpoint sources.

Although the loads currently contributed by NPDES permitted facilities is generally a small fraction of the total annual external load of nutrients to the lagoon, most facilities have permit limits that are much higher than their current discharges. In some cases, the difference is 10-fold, 20-fold or even 100-fold. If all of these facilities were to discharge at their present permit limits, the contribution from them would become much more significant and it could offset gains made by reducing nonpoint sources. This is especially true of the BR3-5 segment. In fact, the present permits for the two facilities in BR3-5 exceed the entire TMDL including the nonpoint source allocation for this lagoon segment (71,124 pounds TN permitted for two facilities versus 39,830 pounds for the entire point and nonpoint TMDL, and 20,967 pounds TP permitted versus 7879 for the TMDL; Table 7 and Table 8).

Annual rainfall data from five National Oceanic and Atmospheric Administration National Weather Service rain gages in the watershed (Daytona Beach International Airport, Titusville, Melbourne International Airport, Vero Beach Airport, and Fort Pierce) indicate that from 2000-2005 annual rainfall ranged from 34.8 to 69.9 inches, as compared to the overall 30-year annual average of 53.1 inches (Table 5). Thus, the time period used to develop the nonpoint load and derive the WLA for the NPDES facilities includes a reasonable range of dry and wet years. Average annual loads provide a useful indication of the overall nutrient load which is delivered to the IRL watershed, ultimately provoking the combination of factors that lead to light attenuation and diminished seagrass health and distribution.

Table 5. Annual rainfall from NOAA gages in the Indian River Lagoon Watershed (2000-2005).

Year	Daytona Beach Intl AP	Titusville	Melbourne Intl AP	Vero Beach AP	Fort Pierce
2000	49.60	56.85	61.66	58.73	63.11
2001	40.47	34.76	43.25	46.14	39.42
2002	53.31	59.32	65.92	50.60	60.62
2003	69.91	58.57	56.94	54.88	44.19
2004	47.87	47.72	40.54	46.07	53.26
2005	65.51	61.65	61.60	61.22	58.06
30-year mean (1975-2005)	**51.18**	**53.84**	**50.73**	**55.79**	**54.04**

Note: Rainfall totals were calculated from April to the following March to correspond with the modeling and seagrass mapping year used by SJRWMD.

8.5. RESULTS

8.5.1. Pollutant Loading Targets

The linear regressions described in Section 8.3 related the seagrass depth targets in Table 4 to estimates of total annual loads from point and nonpoint sources to determine pollutant loading targets for Indian River Lagoon. Regressions were performed to determine annual loading rate targets for the whole lagoon, as well as for the North IRL, Central IRL, and Banana River sub-lagoons. These annual loading rate targets were also provided in Table 4. The sub-lagoon regressions generally yielded stronger correlation statistics than the whole-lagoon regressions, which is not surprising given that there is considerable spatial and hydrodynamic variability between them. An example of the regressions is provided in Figure 9. Other regression charts may be found in the PLRG report (Steward and Green, 2006), which is also provided in Appendix C.

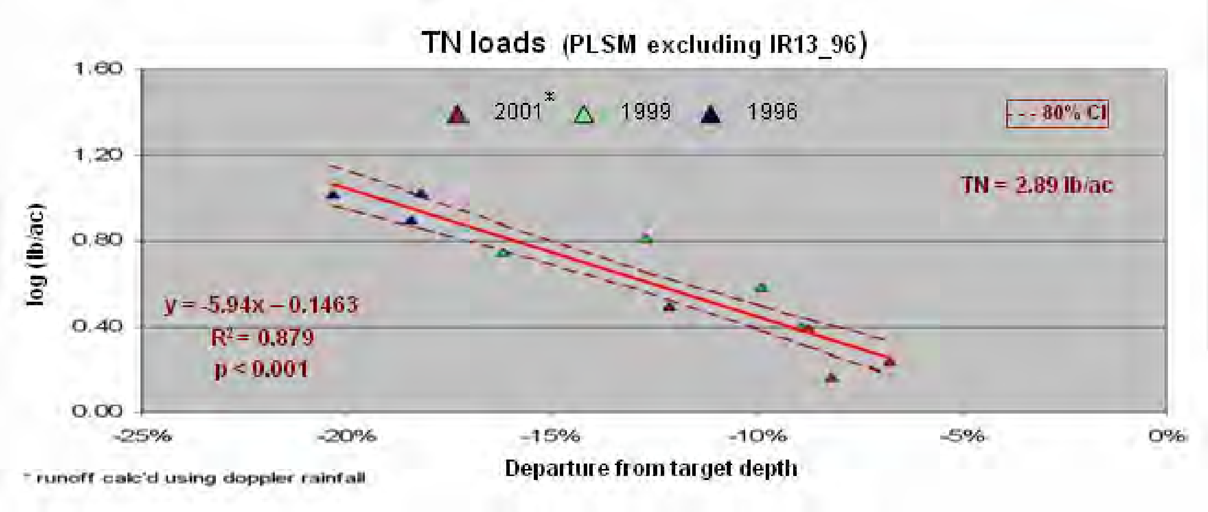


Figure 9. Regression for target annual TN loads in the Central Indian River Sub-Lagoon.

The areal sub-lagoon loading rates, in units of lbs/acre/year, were multiplied by the sub-lagoon drainage areas to convert them to total annual loads in units of lbs/year. These numbers represent the maximum annual loads of TN or TP that are expected to achieve the seagrass depth targets, and as such represent the TMDL value for each sub-lagoon. Current point source loads (actual annual discharges for 2000-2005) were then subtracted from the TMDL values, and the difference assigned to nonpoint sources. The percent contribution of each segment (or group of segments) toward the sublagoon’s total current load was then used to distribute the nonpoint loads among them. Any point source load for a given segment was then added back to the distributed nonpoint load to determine the TMDL for that individual segment. The final TMDLs and load reductions needed to achieve those TMDLs in each segment are presented in Table 6. Nothing in this TMDL should be understood to preclude appropriate water quality trading implemented within the context of FDEP's NPDES program.

Table 6. TMDL values for TN and TP in sub-lagoons and segments.

North Indian River Lagoon						
	TN Current Load (lb/yr)	TN TMDL[1] (lb/yr)	TN Reduction[2] (lb/yr; %)	TP Current Load (lb/yr)	TP TMDL[1] (lb/yr)	TP Reduction[2] (lb/yr; %)
North IRL total	**589,119**	**389,906**	**199,213 (34%)**	**94,178**	**49,821**	**44,357 (47%)**
IR1-3	134,968	88,322	46,646	13,901	7,307	6,594
IR4	20,743	13,574	7,169	4,435	2,331	2,104
IR5	125,855	82,358	43,497	20,377	10,711	9,666
IR6-7	122,049	81,993	40,056	19,193	10,361	8,832
IR8	24,288	15,894	8,394	4,418	2,322	2,096
IR9-11	161,216	107,765	53,451	31,854	16,789	15,065
Central Indian River Lagoon						
	TN Current Load (lb/yr)	TN TMDL[1] (lb/yr)	TN Reduction[2] (lb/yr)	TP Current Load (lb/yr)	TP TMDL[1] (lb/yr)	TP Reduction[2] (lb/yr)
Central IRL[3] total	**1,819,397**	**821,282**	**998,115 (55%)**	**310,938**	**161,983**	**148,955 (48%)**
IR12	508,932	226,361	282,571	81,740	42,376	39,364
IR13	62,789	27,896	34,893	7,743	4,010	3,733
IR14-15	728,576	323,757	404,819	121,211	62,791	58,420
IR16-20	506,777	237,793	268,984	97,885	51,584	46,301
IR21	12,323	5,475	6,848	2,359	1,222	1,137
Banana River Lagoon						
	TN Current Load (lb/yr)	TN TMDL[1] (lb/yr)	TN Reduction[2] (lb/yr)	TP Current Load (lb/yr)	TP TMDL[1] (lb/yr)	TP Reduction[2] (lb/yr)
Banana R. Lagoon total	**304,244**	**112,029**	**192,215 (63%)**	**57,764**	**19,220**	**38,544 (67%)**
BR1-2	127,782	42,828	84,954	20,660	6,176	14,484
BR3-5	88,831	39,830	49,001	19,827	7,879	11,948
BR6	46,213	15,489	30,724	9,724	2,907	6,817
BR7	41,418	13,882	27,536	7,553	2,258	5,295

Notes:

1. The TMDL approach yields values on an annual basis. To convert the units to lbs/day, divide the annual load by 365 days. Nothing in this TMDL should be understood to preclude appropriate water quality trading implemented within the context of DEP's NPDES program. 2. Reduction in total current loading (point + nonpoint sources) to achieve TMDL for that sublagoon. 3. The regressions for the Central IRL sub-lagoon exclude IR14-15, which encompasses the Sebastian Inlet.

A review of estimated nonpoint loads from PLSM and HSPF indicates that the current runoff of TN and TP varies throughout the Indian River Lagoon watershed (Table 6). Figure 10 shows estimates of current annual TN and TP nonpoint source loads for each lagoon segment. These estimates were generated using 2000 land cover data in the PLSM model (except for the TP loads in North IRL, which were generated with HSPF). Figure 11 shows the same estimates of annual TN and TP loads on a per-acre basis.

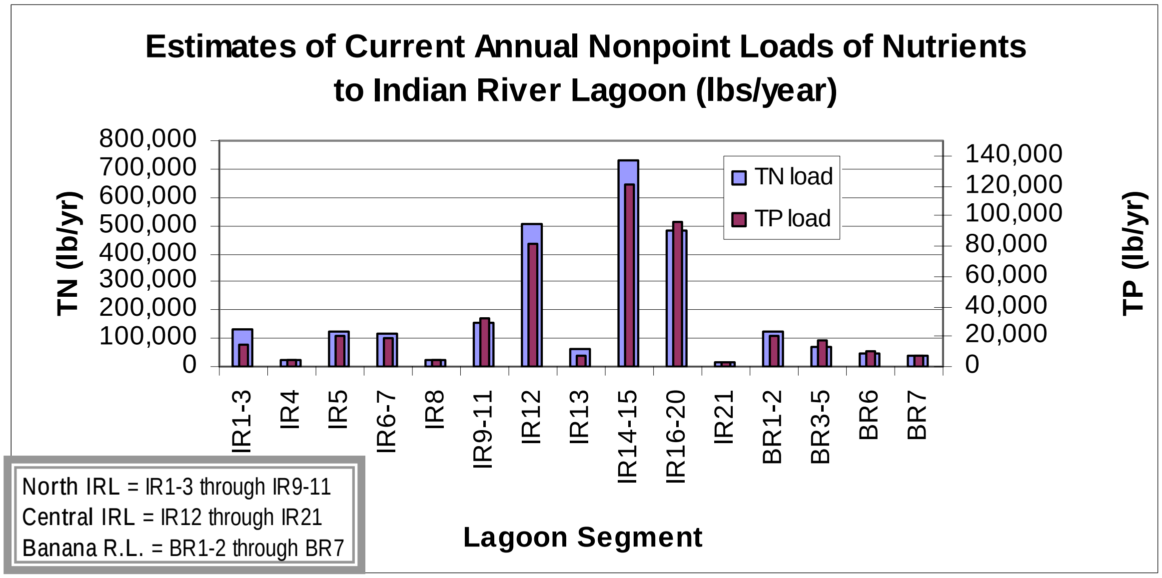


Figure 10. Current Annual Nonpoint Loads of TN and TP for Each Lagoon Segment.

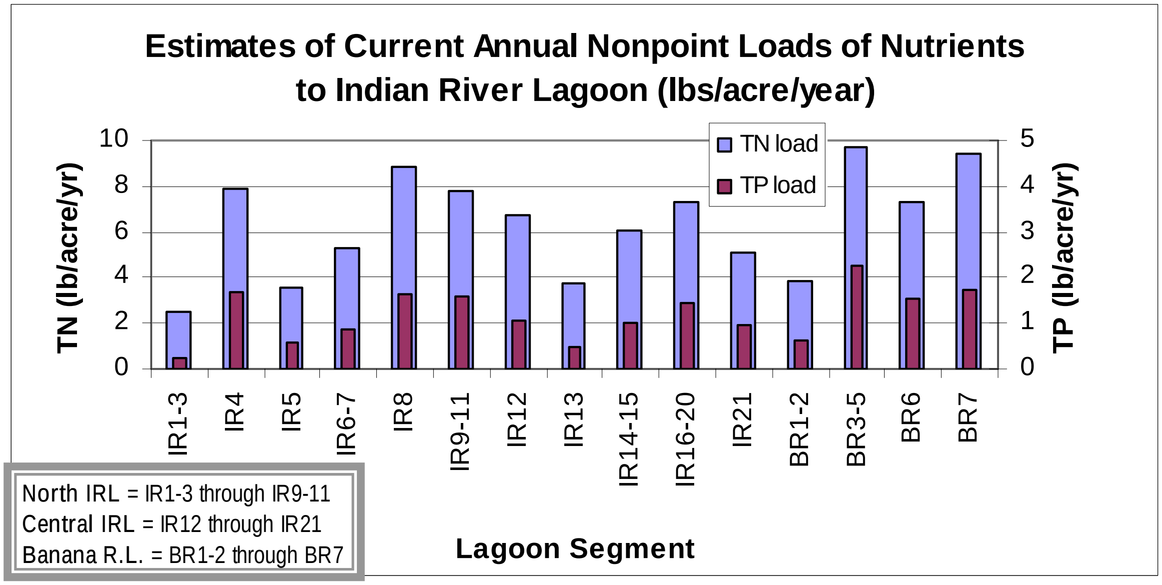


Figure 11. Current Average Annual Nonpoint Loads per acre for each Lagoon Segment.

North IRL segment 1-3 has the lowest per acre loading rates of TN and TP of any segment (Figure 11). This is probably related to the higher proportion of open water and undeveloped lands in the contributing area for that segment. Many of the Central IRL segments experience high loading. The Banana River Lagoon (BRL) segments appear to contribute much lower nutrient loads each year, but given their smaller drainage areas, those segments have some of the highest per acre loading rates. The BRL sub-lagoon, which includes highly developed residential and commercial areas, will require the largest percent reduction for both TN (63%) and TP (67%; Table 6).

To determine the effect of seasonal variability on the correlation between nutrient loading and seagrass depth distribution, point and nonpoint loads were determined and regressions were calculated for the modeled wet and dry seasons in 1942-1943, 1995-1996, 1998-1999; 2000-2001. The modeled wet season is the three month period from August through October, and the modeled dry season was defined as the three month period from February through April. The seasonal regression results yielded reasonable correlation and significance, and may prove to be a useful addition to annual load targets. These results are summarized and discussed in Steward and Green (2006).

8.5.2. Point Sources

Available discharge data and permit limit information were used to calculate the permitted annual loads of TN and TP, actual average annual loads, and the 95th percentile of annual loads for the NPDES dischargers within the Indian River Lagoon watershed. Waste Load Allocations were determined for each facility according to the approaches described in section 8.4. WLAs for TN and TP are provided in Table 7 and Table 8, respectively, and represent the maximum annual loads allocated to each facility. In both tables, the blue rows contain the total values for a sub-lagoon, and grey rows are the total for a segment containing more than one discharger. Cells highlighted in yellow contain the values that were selected for each Waste Load Allocation, as described in more detail in section 8.4.

Table 7. Permitted annual TN limits, discharges, and WLAs for facilities in the IRL watershed.

Segment	NPDES FACILITY	2000-2005 Flow-weighted Concentration TN (mg/L)[1]	Annual Average Load 2001-2005 TN (lb/yr)[2]	95th Percentile Annual Load TN (lb/yr)[3]	Permit Concentration TN (mg/L)[4]	Permit Flow Equiv. (mgd)[5]	Permit Annual Load TN (lb/yr)[6]	TMDL TN (lb/yr)[7]	WLA TN (lb/yr)[8]	WLA % of TMDL TN (%)[9]
North IRL								**389,906**	**17,311**	**4%**
IR1-3	NO						0	88,322	0	0%
IR4	NO						0	13,574	0	0%
IR5	NO						0	82,358	0	0%
IR6-7	FL0021521 Cocoa J. Sellers	5.83	5,556	8,932	12	1.125	41,007		5,556	
IR6-7	FL0001473 Cape Canaveral PP						2,555		2,555	
TOTAL IR6-7								81,993	8,111	10%
IR8	FL0021571 Rockledge		0	0	12	0.062	2,253	15,894	30	0.2%
IR9-11	FL0043443 Melbourne RO	2.38	6,585	9,170	3	1.250	11,422	107,765	9,170	9%
Central IRL								**821,282**	**26,222**	**3%**
IR12	FL0040622 BCUD South Beaches	6.91	62	173	12	0.123	4,506		173	
IR12	FL0041122 Melb. Grant St.	11.70	53	182	20	0.068	2,503		182	
TOTAL IR12								226,361	355	0.08%
IR13	NO						0	27,896	0	0%
IR14-15	FL0042293 Barefoot Bay	1.92	148	476	3	0.188	1,709	323,757	476	0.1%
IR16-20	FL0021661 Vero Beach	12.35	12,173	24,794	20	0.740	45,063		12,173	
IR16-20	FL0042544 Vero Beach RO	2.35	2,438	2,985	4	0.5	6,092		2,985	
IR16-20	FL0166511 IR Co Hobert RO	1.96	2,221	2,759	3	0.750	6,853		2,759	
IR16-20	FL0041637 W. Regional IRCUD	0.78	1,397	2,838	1	4.0	12,184		2,838	

Segment	NPDES FACILITY	2000-2005 Flow-weighted Concentration TN (mg/L)[1]	Annual Average Load 2001-2005 TN (lb/yr)[2]	95th Percentile Annual Load TN (lb/yr)[3]	Permit Concentration TN (mg/L)[4]	Permit Flow Equiv. (mgd)[5]	Permit Annual Load TN (lb/yr)[6]	TMDL TN (lb/yr)[7]	WLA TN (lb/yr)[8]	WLA % of TMDL TN (%)[9]
IR16-20	FL0037940 IR Co S RO	1.59	3,752	4,636	3	1.5	13,707		4,636	
TOTAL IR16-20			21,981	38,012			83,899	237,793	25,391	11%
IR21	NO						0	5,475	0	0%
Banana R.								**112,029**	**6,173**	**6%**
BR1-2	NO						0	42,828	0	0%
BR3-5	FL0020541 Cape Canaveral	1.10	1,342	2,151	3	1.8	16,448		2,151	
BR3-5	FL0021105 Cocoa Beach	6.70	12,476	18,446	12	1.5	54,676		4,022	
TOTAL BR3-5			13,818	20,597			71,124	39,830	6,173	15%
BR6	NO						0	15,489	0	0%
BR7	NO						0	13,882	0	0%

Notes:

1. Average flow-weighted nutrient concentration in the discharge summarized from monthly data reported to FDEP by the facility. The 2000-2005 time period corresponds to the modeling time period used by SJRWMD for the TMDL development.
2. Average annual nutrient load discharged by the facility from 2001-2005. Loads are calculated from monthly discharge and monthly effluent nutrient concentration as reported by the facility to FDEP, with unit conversion factors. Annual loads are calculated from April to the following March to correspond with the modeling year used by SJRWMD. The average annual load is the average of the five annual loads. The five year time period corresponds to the five year cycle of an NPDES permit.
3. The calculated 95th percentile of the discharge's five annual nutrient loads. See footnote 2.
4. The effluent nutrient concentration in the facility's NPDES permit issued by FDEP. Provided for reference only, not used in WLA calculations.
5. The permitted annual flow equivalent in the NPDES permit issued by FDEP. Some facilities are permitted to discharge only 60 or 91 days during the rainy season. The flow and number of discharge days allowed in the permit are multiplied along with conversion factors to calculate an annual flow equivalent. Provided so intermittent discharge facility flow can be compared to continuous discharge facilities. Provided for reference only, not used in WLA calculations.
6. The annual load allowed by the facility's NPDES permit issued by FDEP calculated by multiplying the permit discharge flow, the permit effluent nutrient concentration and conversion factors. Provided for reference only, not used in WLA calculations.
7. The proposed TMDL (all point and nonpoint sources) for that lagoon segment calculated by the SJRWMD modeling approach (Steward and Green, 2006).
8. Proposed Wasteload Allocation for all point sources in that lagoon segment. The basis for specific allocations is highlighted yellow, as described in more detail in section 8.4.
9. The percent of the TMDL for the lagoon segment that was allocated to the point sources, with the remainder allocated to nonpoint sources.

Table 8. Permitted annual TP limits, discharges, and WLAs for facilities in the IRL watershed.

Segment	NPDES FACILITY	2000-2005 Flow-weighted Concentration TP (mg/L)[1]	Annual Average Load 2001-2005 TP (lb/yr)[2]	95th Percentile Annual Load TP (lb/yr)[3]	Permit Concentration TP (mg/L)[4]	Permit Flow Equiv. (mgd)[5]	Permit Annual Load TP (lb/yr)[6]	TMDL TP (lb/yr)[7]	WLA TP (lb/yr)[8]	WLA % of TMDL TP (%)[9]
North IRL								**49,821**	**1,794**	**4%**
IR1-3	NO						0	7,307	0	0%
IR4	NO						0	2,331	0	0%
IR5	NO						0	10,711	0	0%
IR6-7	FL0021521 Cocoa J. Sellers	0.57	578	1,423	4.0	1.125	13,669	10,361	1,423	
IR6-7	FL0001473 Cape Canaveral PP						146		146	
TOTAL IR6-7								10,361	1,569	15%
IR8	FL0021571 Rockledge		0	0	4.0	0.062	751	2,332	30	1%
IR9-11	FL0043443 Melbourne RO	0.05	101	195	1.0	1.250	3,807	16,789	195	1%
Central IRL								**161,983**	**2,071**	**1%**
IR12	FL0040622 BCUD South	1.39	13	36	4.0	0.123	1,502		36	
IR12	FL0041122 Melb. Grant St.	0.49	2	8	1.0	0.068	125		8	
TOTAL IR12								42,376	44	0.09%
IR13	NO						0	4,010	0	0%
IR14-15	FL0042293 Barefoot Bay	0.33	22	78	1.0	0.188	570	62,791	78	0.1%
IR16-20	FL0021661 Vero Beach	1.06	916	1,411	6.0	0.740	13,518		916	
IR16-20	FL0042544 Vero Beach RO	0.53	340	487	4.0	0.5	6,092		487	
IR16-20	FL0166511 IR Co Hobert RO	0.04	45	96	1.0	0.750	2,284		96	
IR16-20	FL0041637 W. Regional	0.06	81	159	0.1	4.0	1,218		159	

Segment	NPDES FACILITY	2000-2005 Flow-weighted Concentration TP (mg/L)[1]	Annual Average Load 2001-2005 TP (lb/yr)[2]	95th Percentile Annual Load TP (lb/yr)[3]	Permit Concentration TP (mg/L)[4]	Permit Flow Equiv. (mgd)[5]	Permit Annual Load TP (lb/yr)[6]	TMDL TP (lb/yr)[7]	WLA TP (lb/yr)[8]	WLA % of TMDL TP (%)[9]
IR16-20	FL0037940 IR Co S RO	0.04	112	291	1.0	1.5	4,569		291	
TOTAL IR16-20			1,494	2,444			27,681	51,584	1,949	4%
IR21	NO						0	1,222	0	0%
Banana R.								**19,220**	**1,221**	**6%**
BR1-2	NO						0	6,176	0	0%
BR3-5	FL0020541 Cape Canaveral	0.11	112	158	0.5	1.8	2,741		158	
BR3-5	FL0021105 Cocoa Beach	1.30	2,291	3,599	4.0	1.5	18,226		1,063	
TOTAL BR3-5			2,403	3,757			20,967	7,879	1,221	15%
BR6	NO						0	2,907	0	0%
BR7	NO						0	2,258	0	0%

Notes:

1. Average flow-weighted nutrient concentration in the discharge summarized from monthly data reported to FDEP by the facility. The 2000-2005 time period corresponds to the modeling time period used by SJRWMD for the TMDL development.
2. Average annual nutrient load discharged by the facility from 2001-2005. Loads are calculated from monthly discharge and monthly effluent nutrient concentration as reported by the facility to FDEP, with unit conversion factors. Annual loads are calculated from April to the following March to correspond with the modeling year used by SJRWMD. The average annual load is the average of the five annual loads. The five year time period corresponds to the five year cycle of an NPDES permit.
3. The calculated 95th percentile of the discharge's five annual nutrient loads. See footnote 2.
4. The effluent nutrient concentration in the facility's NPDES permit issued by FDEP. Provided for reference only, not used in WLA calculations.
5. The permitted annual flow equivalent in the NPDES permit issued by FDEP. Some facilities are permitted to discharge only 60 or 91 days during the rainy season. The flow and number of discharge days allowed in the permit are multiplied along with conversion factors to calculate an annual flow equivalent. Provided so intermittent discharge facility flow can be compared to continuous discharge facilities. Provided for reference only, not used in WLA calculations.
6. The annual load allowed by the facility's NPDES permit issued by FDEP calculated by multiplying the permit discharge flow, the permit effluent nutrient concentration and conversion factors. Provided for reference only, not used in WLA calculations.
7. The proposed TMDL (all point and nonpoint sources) for that lagoon segment calculated by the SJRWMD modeling approach (Steward and Green, 2006).
8. The proposed Wasteload Allocation for all point sources for that lagoon segment. The basis for specific allocations is highlighted yellow, as described in more detail in section 8.4.
9. The percent of the TMDL for the lagoon segment that was allocated to the point sources, with the remainder allocated to nonpoint sources.

9. TMDLs

A TMDL for a given pollutant and waterbody is comprised of the sum of individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is represented by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards and the waterbody's designated use. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be set and thereby provide the basis to establish water quality-based controls. These TMDLs are expressed as annual mass loads, since the approach used to determine the TMDL targets relied on annual loadings. The TMDLs targets were determined to be the conditions needed to restore and maintain healthy seagrass ecosystems. Trophic shifts and declines in seagrass communities are processes that tend to occur over longer periods. Furthermore, it is important to consider nutrient loading over time, since nutrients can accumulate in waterbodies.

The TMDLs for Indian River Lagoon are based upon the results of a PLRG conducted by the SJRWMD. The PLRGs for Indian River Lagoon were determined as average annual loads for each sub-lagoon. These loads were then distributed among individual segments as described in Section 8.5.1, and shown in Table 6. The TMDLs and their components are presented for each of the three sub-lagoons in Table 9. The TMDLs are expressed as daily and annual loads of TN and TP and are calculated to achieve the narrative nutrient criteria. The TMDLs are intended to be implemented on an annual basis. Achieving the narrative nutrient criteria is expected to also result in achieving appropriate D.O. and chlorophyll regimes as these impairments are a direct result of symptoms associated with cultural eutrophication caused by nutrient enrichment. LAs for the nonpoint sources in each segment, and WLAs for individual NPDES facilities, are provided in their respective sections below.

Table 9. TMDL Allocations for Indian River Lagoon.

				WLA[2]		
Sublagoon	**Parameter**	**TMDL (lb/day)[1]**	**TMDL (lb/year)**	**Facility (lb/year)**	**MS4 (%)[3]**	**LA (lb/year)**
North IRL	**TN**	1,068	389,906	17,311	35%	372,595
	TP	136	49,821	1,794	49%	48,027
Central IRL	**TN**	2,250	821,282	26,222	56%	795,060
	TP	444	161,983	2,071	48%	159,912
Banana River Lagoon	**TN**	307	112,029	6,173	63%	105,856
	TP	53	19,220	1,221	67%	17,999

Notes:

1. TMDL values in this table represent the total allocations for each sub-lagoon area. Tables of allocations for individual lagoon segments are provided in Table 6. TMDLs address 303(d) listings for nutrients and D.O. For convenience, the TMDLs are provided in both units of lbs/day and lbs/year, but are intended to be implemented on an annual basis. Nothing in this TMDL should be understood to preclude appropriate water quality trading implemented within the context of DEP's NPDES program.
2. The WLA component includes individual allocations for NPDES facilities (e.g., WWTPs) and MS4s as contained in Table 10 of this report. Due to the infeasibility of separating the contributions from diffuse MS4 and non-MS4 sources, MS4s are incorporated into the Load Allocation, and are allocated the same percent reductions. WLAs for facilities are the maximum annual loads.
3. Percent reduction in current nonpoint source loading to achieve the Load Allocation for that sub-lagoon. The percent reductions are applied to nonpoint sources and MS4s.

9.1. Critical Conditions and Seasonal Variation

USEPA regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The critical condition is the combination of environmental factors creating the "worst case" scenario of water quality conditions in the waterbody. By achieving the water quality standards at critical conditions, it is expected that water quality standards should be achieved during all other times. Seasonal variation must also be considered to ensure that water quality standards will be met during all seasons of the year, and that the TMDLs account for any seasonal change in flow or pollutant discharges, and any applicable water quality criteria or designated uses (such as swimming) that are expressed on a seasonal basis.

The critical condition for nonpoint source loadings is typically an extended dry period followed by a rainfall runoff event. During the dry weather period, nutrients build up on the land surface, and are washed off by rainfall. The critical condition for continuous point source loading typically occurs during periods of low stream flow when dilution is minimized. Although loading of nonpoint source pollutants contributing to a nutrient impairment may occur during a runoff event, the expression of that nutrient impairment is more likely to occur during warmer months, and at times when the waterbody is poorly flushed.

Since nutrients can accumulate in waterbodies, it is important to consider their loading over longer time periods. For Indian River Lagoon, critical conditions were incorporated into TMDL development by setting the targets using annual nutrient loads that correlated to the seagrass depth limit targets. The PLSM and HSPF models that were used to determine nonpoint source contributions account for loading during both wet and dry conditions throughout the years that were simulated. Point source contributions were also incorporated as the total annual loads discharged in those years. The years between 2001-2005, on which the WLA calculations are based, also represent conditions above and below 30-year average annual precipitation (Table 5). Seasonal variation was incorporated in the TMDL analysis by simulating loads during all seasons over multiple years. This incorporates the influence of seasonal (and inter-annual) changes in flow and meteorological conditions such as temperature, rainfall, and rainfall intensity on the loadings to Indian River Lagoon. Nutrient loadings determined for Indian River Lagoon take into account each season of the year, including the growing season.

To further distinguish the effect of seasonal variability on the correlation between nutrient loading and seagrass depth distribution, point and nonpoint loads were determined and regressions performed for the modeled wet and dry seasons in 1942-43, 1995-96, 1998-99, and 2000-01. The modeled wet season is August through October, which are the three wettest months on average, and the modeled dry season is defined as the three month period from February through April, which is the middle of the dry season. The seasonal regression results yielded reasonable correlation and significance, and may prove to be a useful addition to annual load targets for implementation purposes. However, these nutrient TMDLs are based upon the annual loading targets, since it is desirable to account for the total annual loading from all months of the year (including non-peak wet and dry seasons) when allocating to point and nonpoint sources.

9.2. Margin of Safety

The MOS accounts for uncertainty in the relationship between a pollutant load and the resultant condition of the waterbody. There are two methods for incorporating a MOS into TMDLs (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations

- Explicitly specify a portion of the total TMDL as the MOS and use the remainder for Allocations

The Indian River Lagoon TMDLs were developed using an implicit margin of safety. The sublagoon targets for TN and TP are set to achieve within -10% of the the maximum seagrass depths documented in each segment of Indian River Lagoon between 1943 and 1999. With the exception of TN in Central Indian River Lagoon, these TMDLs are similar to the loading estimates for 1943, when human alteration of the watershed was fairly minimal. The estimated TP load for Central Indian River Lagoon in 1943 is higher than its target. However, an implicit MOS is provided by the presence of the Sebastian Inlet, which did not exist in 1943 but today provides flushing to the Central Indian River sub-lagoon that lessens the impact of pollutant loads.

9.3. Waste Load Allocations

Only MS4s and NPDES facilities discharging directly into lagoon segments (or upstream tributaries of those segments) are assigned a WLA. The WLAs, if applicable, are expressed separately for continuous discharge facilities (e.g., WWTPs) and MS4 areas, as the former discharges during all weather conditions whereas the later discharges in response to storm events.

9.3.1. NPDES Dischargers

Table 10 presents a summary of the NPDES permitted facilities and their allocated TN and TP loads.

Table 10. WLAs for NPDES facilities in IRL watershed.

NPDES Permit	Facility Name	Impacted Segment	TN Maximum Annual Allocation (lbs/year)[1]	TP Maximum Annual Allocation (lbs/year)[1]
FL0021521	Cocoa, J. Sellers WWTP	IR6-7	5,556	1,423
FL0001473	FPL Cape Canaveral Power Plant	IR6-7	2,555	146
FL0021571	Rockledge, City of WWTP	IR-8	30	30
FL0043443	Melbourne Reverse Osmosis WTF	IR9-11	9,170	195
FL0040622	Brevard Co. South Beaches (BCUD)	IR12	173	36
FL0041122	Melbourne, City of- Grant St. WWTP	IR12	182	8
FL0042293	Barefoot Bay WWTP	IR14-15	476	78
FL0021661	City of Vero Beach WWTP	IR16-20	12,173	916
FL0042544	Vero Beach Reverse Osmosis WTF	IR16-20	2,985	487
FL0166511	Indian River Co. Hobart RO WTF	IR16-20	2,759	96
FL0041637	West Regional IRCUD WWTP	IR16-20	2,838	159
FL0037940	Indian River Co. South RO WTF	IR16-20	4,636	291
FL0020541	City of Cape Canaveral WWTP	BR3-5	2,151	158
FL0021105	City of Cocoa Beach WWTP	BR3-5	4,022	1,063

Note: 1. To convert the units of the Waste Load Allocations to lbs/day, divide by 365 days.

9.3.2. Municipal Separate Storm System Permits

The WLA for MS4s are expressed in terms of percent reductions equivalent to the reductions required for nonpoint sources. Given the available data, it is not possible to estimate loadings coming exclusively from the MS4 areas. Although the aggregate WLAs for stormwater discharges are expressed in numeric form, i.e. percent reduction, based on the information available today, it is infeasible to calculate numeric WLAs for individual stormwater outfalls because discharges from these sources can be highly intermittent, are usually characterized by very high flows occurring over relatively short time intervals, and carry a variety of pollutants whose nature and extent varies according to geography and local land use. For example, municipal sources such as those covered by these TMDLs often include numerous individual outfalls spread over large areas. Water quality impacts, in turn, also depend on a wide range of factors, including the magnitude and duration of rainfall events, the time period between events, soil conditions, fraction of land that is impervious to rainfall, other land use activities, and the ratio of stormwater discharge to receiving water flow.

These TMDLs assume for the reasons stated above that it is infeasible to calculate numeric water quality-based effluent limitations for stormwater discharges. Therefore, in the absence of information presented to the permitting authority showing otherwise, these TMDLs assume that water quality-based effluent limitations for stormwater sources of nutrients derived from this TMDL can be expressed in narrative form (e.g., as best management practices), provided that: (1) the permitting authority explains in the permit fact sheet the reasons it expects the chosen BMPs to achieve the aggregate WLA for these stormwater discharges; and (2) the state will perform ambient water quality monitoring for nutrients for the purpose of determining whether the BMPs in fact are achieving such aggregate WLA.

The percent reduction calculated for nonpoint sources is assigned to the MS4 as loads from both sources typically occur in response to storm events. Permitted MS4s will be responsible for reducing only the loads associated with stormwater outfalls which it owns, manages, or otherwise has responsible control. MS4s are not responsible for reducing other nonpoint source loads within its jurisdiction. All future MS4s permitted in the area are automatically prescribed a WLA equivalent to the percent reduction assigned to the LA. BMPs for the MS4 service area should be developed to meet the percent reduction for both nitrogen and phosphorus as prescribed in Table 9.

9.4. Load Allocations

The LA was calculated as the difference between the TMDL and WLA for each segment (Table 11):

$$\sum \text{LAs} = \text{TMDL} - \sum \text{WLAs}$$

Allocating by lagoon segment allows local and regional governments to work cooperatively to devise the most cost effective sub-basin specific load reduction plans that achieve maximum load reductions for the least amount of money. Also, because lagoon segments and their drainage basins represent the actual contributing drainage area for that portion of the lagoon, achieving the allowable load targets in those segments should lead to direct improvement in the water quality of that segment.

Table 11. LAs for Lagoon Segments.

North Indian River Lagoon		
	TN Load Allocation (lbs/yr)[1]	TP Load Allocation (lbs/yr)[1]
North IRL total	**372,595**	**48,027**
IR1-3	88,322	7,307
IR4	13,574	2,331
IR5	82,358	10,711
IR6-7	73,882	8,792
IR8	15,864	2,292
IR9-11	98,595	16,594
Central Indian River Lagoon		
	TN Load Allocation (lbs/yr)[1]	TP Load Allocation (lbs/yr)[1]
Central IRL total	**795,060**	**159,912**
IR12	226,006	42,332
IR13	27,896	4,010
IR14-15	323,281	62,713
IR16-20	212,402	49,635
IR21	5,475	1,222
Banana River Lagoon		
	TN Load Allocation (lbs/yr)[1]	TP Load Allocation (lbs/yr)[1]
Banana R. Lagoon total	**105,856**	**17,999**
BR1-2	42,828	6,176
BR3-5	33,657	6,658
BR6	15,489	2,907
BR7	13,882	2,258

Note: 1. To convert the units of the LAs to lbs/day, divide by 365 days.

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10. Appendix A- PLSM Model Structure and Runoff Inputs.

The majority of nutrient loading estimates to which the seagrass depths are correlated were generated using the Pollutant Load Screening Model (PLSM). The input requirements for PLSM include spatial data for the watershed, such as land uses, soil types, drainage boundaries annual rainfall, and implementation of stormwater BMPs, as well as data to characterize the quantity and quality of runoff (Figure 12). Runoff coefficients are used to predict the volumetric ratio of runoff generated from a given amount of rainfall. EMCs are used to represent the average concentration of a pollutant in runoff derived from a particular land use in the watershed.

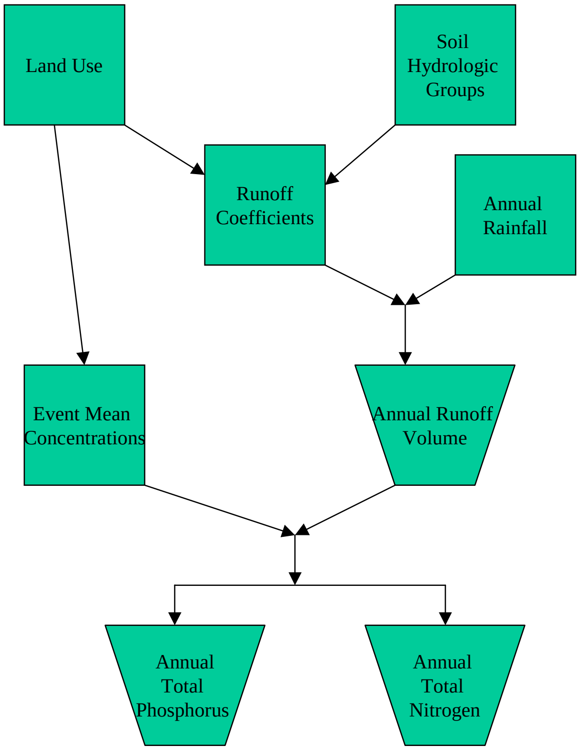

Figure 12. PLSM Computational Framework.

10.1. Event Mean Concentrations

EMCs are multiplied by the annual average runoff volume to calculate an average annual TN or TP load for that parcel. The EMC reflects the average concentration of TP or TP expected in surface water running off from a parcel of land with a consistent land use. The sum of all loads within a drainage basin is calculated to develop a total annual load of TN and TP and an average annual load per acre for a watershed. Table 12 displays the EMCs.

Table 12. EMCs for Calculating Nutrient Loads in PLSM.

Land Use Code	Land Use	Nutrient Concentrations mg/l			Source
		TP	TP	TSS	
1100	Residnt_Low	1.85	0.220	13.0	(Adamus/Bergman) mod[1]
1101	Rural Residential	1.05	0.220	3.5	Malabar calibration
1190	RL construction	1.38	0.080	65.5	calibration
1200	Residnt_Med	2.23	0.316	29.0	(Adamus/Bergman) mod[1]
1290	RM construction	1.38	0.080	125.0	calibration
1300	Residnt_High	2.10	0.516	102.5	(Adamus/Bergman) mod[1]
1320	MH Parks	2.42	0.520	44.5	Calibration[1]
1390	RH construction	1.38	0.080	145.0	Calibration[1]
1410, 1420, 1460, 1470	Commercial_high	1.93	0.497	105.0	(Adamus/Bergman) mod[1]
1430 & 1480	Commercial_low	1.58	0.180	81.0	(Adamus/Bergman) mod[1]
1490	Commer construct	1.38	0.080	145.0	Calibration[1]
1500 - 1540, 1560	Industial	1.79	0.310	106.9	(Adamus/Bergman) mod[1]
1550	Light Industrial	1.55	0.150	73.5	(Adamus/Bergman) mod[1]
1600 - 1640	Mining	1.18	0.150	93.9	(Adamus/Bergman)
1650	M-Reclaimed Lands	1.25	0.080	11.1	(RO)
1700 - 1790	Institution	1.80	0.478	98.0	(Adamus/Bergman) mod[1]
1800 & 1810	Rec_Open	1.25	0.080	11.1	(Adamus/Bergman) mod[1]
1820	Golf Course	1.78	0.380	11.1	Guana Basin Study
1830	Race Track	2.08	0.340	50.3	(Adamus/Bergman Trans)
1840	Marinas	1.58	0.150	81.0	LC
1850	Parks	1.25	0.095	11.0	RO
1860	Recreation Facilities	1.58	0.100	11.1	Calibration[1]
1870	Stadiums	2.04	0.242	52.7	LC + weighted RM
1900-1930	Open Land	1.20	0.076	24.1	Calibration[1]
2110	Improved Pasture	2.70	0.576	30.1	(Harper, 1994, Trefry, LSJR) mod
2120, 2130	Lowuse_Ag (Pasture)	2.52	0.090	19.7	(Dierberg, Trefry Adamus/Bergman) mod
2150	Field Crops	2.52	0.265	15.7	Malabar calibration
2140 & 2160	Row Crops	4.56	1.000	55.3	(Adamus/Bergman, Zhang)
2200 – 2230	Citrus	1.92	0.506	30.5	(Adamus/Bergman, Zhang) mod[1]
2240	Abandoned Grove	1.49	0.250	15.7	(RO)
2310 & 2320	Feed Lots	3.74	1.130	59.4	ECFRPC Boggy Creek, 1987
2410 – 2430 & 2460	Nurseries	2.30	0.565	22.0	(Adamus/Bergman +20%NP)

		Nutrient Concentrations mg/l			
2510	Stables	2.32	0.500	34.7	(Pasture60%/LDR40%)
2520	Dairies	2.82	0.715	76.1	(Pasture/Ind)
2540	Aquaculture	1.87	0.265	11.1	Consensus
2600 & 2610	Fallow Crop	2.91	0.547	37.2	(open/Crop)
3100	Rangeland Herb	1.20	0.064	6.0	(Adamus/Bergman, LSJR)
3200 &3300	Range Shrub/Mixed	1.20	0.064	6.0	(Adamus/Bergman, LSJR)
4000 – 4370	Forests	0.70	0.090	3.0	(LSJR, Riekerk-82)
4400 – 4900	Silviculture	0.70	0.090	3.0	(LSJR, Riekerk-82)
5100 – 5190	Watercourses	0.60	0.050	3.0	(Harper/LSJR)
5200 – 5340	Lakes_Reservoirs	0.60	0.135	0.0	(Harper/LSJR)
5400	Estuary	0.00	0.000	0.0	Consensus
5690	Sloughs	0.00	0.000	0.0	Consensus
6000 – 6300	Forest Wetlands	0.00	0.000	0.0	Consensus
6400 – 6490	Herb/shrub Wetlands	0.00	0.000	0.0	Consensus
6500, 6510 & 6520	Unveg'd Wetland	0.00	0.000	11.0	(Barren-TSS)
7000 – 7340	Beaches-Barren	1.25	0.053	11.1	(Adamus/Bergman)
7400	Disturbed	1.38	0.109	34.0	(avg. subcategories)
7410	Rural Transition	1.51	0.115	12.0	(LDR/Rec)
7420 – 7430	Borrow-Spoil	1.25	0.202	62.5	Barren/Mining
7440	Causeway fill	1.25	0.102	11.1	(RO)
8100	Transportation	1.18	0.470	26.2	(Adamus/Bergman) mod[1]
8140	4-Lane divided Hwy	1.20	0.480	45.0	(Adamus/Bergman) mod[1]
8110	Airports	1.15	0.150	40.0	Calibration[1]
8120	Railroads	1.25	0.053	11.1	(RO)
8150	Port Facilities	1.95	0.430	93.9	(HC)
8160	Canals Navigable	0.60	0.077	3.1	(Water-Harper, 1994)
8130, 8180	Highload Transp	2.00	0.430	93.9	(HC)
8210 & 8220	Communications	1.25	0.080	11.1	(RO)
8310	Power Plants	1.79	0.310	93.9	(Ind)
8320	Powerlines	1.25	0.080	11.1	(RO)
8330 & 8340	Water/Sewer Plants	1.77	0.177	19.1	ND
8350	Landfill	1.39	0.177	74.6	(10%Trans/20%LDR/70%Min)
8390	Utility Construction	1.38	0.109	93.9	(Ind-TSS, Disturbed-TP&TP)

Notes:

1. Concentrations calibrated to measured loads from South Prong, Briar Creek, Crane Creek and C-1 watersheds.

10.2. Runoff Coefficients

SJRWMD has defined runoff coefficients based on the combination of soil type and land uses within a minimum polygon size of .45 acres. Runoff coefficients are multiplied by annual rainfall to estimate the annual volume of excess rainfall washing off a particular parcel.

Table 13 displays the runoff coefficients that were used to generate the pollutant loads based on land use. These runoff coefficients are derived from numerous standard references and additional local studies and reflect a serious effort by SJRWMD to improve the PLSM model.

Table 13. Runoff Coefficients for Calculating Nutrient Loads in PLSM.

Land Use Code	Land Use	RO Coefficients, by soil hydrologic group							Source
		A	B	C	D	B/D	C/D	U	
1100	Resident_Low	0.174	0.230	0.286	0.342	0.342	0.342	0.286	Adamus/Bergman* [3]
1101	Rural Residential	0.174	0.230	0.286	0.402	0.402	0.402	0.316	Malabar study
1190	RL under construct	0.160	0.181	0.202	0.223	0.223	0.223	0.191	Disturbed
1200	Resident_Med	0.220	0.304	0.389	0.473	0.304	0.389	0.347	Adamus/Bergman
1290	RM under construct	0.160	0.181	0.202	0.223	0.223	0.223	0.191	Disturbed
1300	Resident_High	0.631	0.662	0.692	0.733	0.662	0.692	0.677	Adamus/Bergman
1320	MH Parks	0.631	0.662	0.692	0.723	0.662	0.692	0.677	Adamus/Bergman
1390	RH under construct	0.160	0.181	0.202	0.223	0.223	0.223	0.191	Disturbed
1410, 1420, 1460, 1470	Commercial_high	0.886	0.887	0.888	0.900	0.887	0.888	0.890	Adamus/Bergman
1430 & 1480	Commercial_low	0.583	0.629	0.674	0.720	0.629	0.674	0.652	Adamus/Bergman modified Crane Cr
1490	Com under construct	0.160	0.181	0.202	0.223	0.223	0.223	0.191	Disturbed
1500 - 1540, 1560	Industial	0.760	0.793	0.825	0.858	0.793	0.825	0.809	Adamus/Bergman modified Crane Cr
1550	Light Industrial	0.544	0.577	0.609	0.642	0.577	0.609	0.593	Calculated Imperv[1] Crane Cr study
1600 - 1650	Mining	0.220	0.304	0.389	0.473	0.304	0.389	0.347	Adamus/Bergman
1660	M-Reclaimed Lands	0.127	0.155	0.182	0.210	0.183	0.196	0.169	RO
1700 - 1790	Institution	0.696	0.741	0.786	0.856	0.741	0.786	0.770	Crane Creek Calibration
1800, 1810, 1860	Rec_Open	0.127	0.155	0.182	0.210	0.183	0.196	0.169	Adamus/Bergman*
1820	Golf Course	0.182	0.222	0.258	0.298	0.222	0.258	0.240	Calculated Imperv[1]
1830	Race Track	0.630	0.703	0.777	0.850	0.703	0.777	0.740	Transportation
1840	Marinas	0.232	0.319	0.407	0.494	0.319	0.407	0.363	Calculated Imperv[1]
1850	Parks	0.126	0.212	0.300	0.387	0.212	0.300	0.256	Calculated Imperv[1]
1870	Stadiums	0.499	0.543	0.589	0.637	0.543	0.589	0.576	Calculated Imperv[1]
1900-1930	Open Land w/streets	0.151	0.193	0.234	0.276	0.193	0.234	0.213	Low Res & Open
2110	Improved Pasture	0.251	0.305	0.359	0.405	0.405	0.405	0.330	Adamus/Bergman
2120, 2130, 2150	Lowus_Ag	0.189	0.256	0.334	0.411	0.411	0.411	0.283	Adamus/Bergman
2140, 2160	Crops	0.204	0.281	0.358	0.435	0.281	0.358	0.320	Harper 1994

		RO Coefficients, by soil hydrologic group							
2200 – 2220	Citrus	0.251	0.268	0.285	0.302	0.268	0.285	0.277	Harper 1994
2240	Abandoned Grove	0.251	0.268	0.285	0.302	0.268	0.285	0.277	Citrus
2310 & 2320	Feed Lots	0.157	0.190	0.224	0.251	0.190	0.224	0.207	ECFRPC - Calculated Imperv[1]
2410 – 2430 & 2460	Nurseries	0.251	0.268	0.285	0.302	0.268	0.285	0.277	Citrus
2510	Stables	0.205	0.260	0.315	0.370	0.260	0.315	0.288	(Calculated % impervious)
2520	Dairies	0.506	0.549	0.592	0.636	0.549	0.592	0.571	Pasture/Ind
2610	Fallow Crop	0.204	0.281	0.358	0.435	0.281	0.358	0.320	Crops-Harper
3100	Rangeland Herb	0.100	0.195	0.300	0.411	0.411	0.411	0.252	From CNs - see Range C
3200 &3300	Range Shrub/Mixed	0.060	0.176	0.287	0.400	0.400	0.400	0.231	From CNs - see Range C
4000 – 4370	Forests	0.102	0.206	0.309	0.413	0.413	0.413	0.258	Hedrickson 2000, Riekerk-82
4400 – 4900	Silviculture	0.102	0.206	0.309	0.413	0.413	0.413	0.258	Hedrickson 2000, Riekerk-82
5000 – 5190	Watercourses	1.000	1.000	1.000	1.000	1.000	1.000	1.000	Harper 1994
5200 – 5340	Lakes_Reservoirs	0.500	0.500	0.500	0.500	0.500	0.500	0.500	Harper 1994
5400	Estuary	1.000	1.000	1.000	1.000	1.000	1.000	1.000	Consensus
5690	Sloughs	0.191	0.228	0.266	0.303	0.303	0.303	0.247	Same as Wetland
6000 – 6300	Forest Wetlands	0.191	0.228	0.266	0.303	0.303	0.303	0.247	Harper Wetland
6400 – 6490	Herb/shrub Wetlands	0.191	0.228	0.266	0.303	0.303	0.303	0.247	Harper Wetland
6510 & 6520	Unveg’d Wetland	0.191	0.228	0.266	0.303	0.303	0.303	0.247	Harper Wetland
7000 – 7340	Beaches-Barren	0.102	0.206	0.309	0.413	0.413	0.413	0.258	Hedrickson 2000
7400	Disturbed	0.160	0.181	0.202	0.223	0.223	0.223	0.191	Avg. of subcategories
7410	Rural Transition	0.151	0.193	0.234	0.276	0.234	0.234	0.255	Avg. LDR/RO*
7420 – 7430	Borrow-Spoil	0.169	0.169	0.169	0.169	0.169	0.169	0.169	Constant 0.169[2]
8140 & 8150	Transportation	0.630	0.703	0.777	0.850	0.703	0.777	0.740	Harper 1994
8110	Airports	0.326	0.399	0.473	0.546	0.399	0.473	0.436	Calculated Imperv[1] Crane Cr study
8120	Railroads	0.200	0.250	0.300	0.350	0.250	0.300	0.275	Wanielista,Yousef 1981
8160	Canals Navigable	1.000	1.000	1.000	1.000	1.000	1.000	1.000	Harper 1994
8130, 8180	Highload Transp	0.886	0.887	0.888	0.900	0.887	0.887	0.890	HC
8210 & 8220	Communications	0.127	0.155	0.182	0.210	0.155	0.182	0.169	RO

		RO Coefficients, by soil hydrologic group							
8310	Power Plants	0.760	0.793	0.825	0.858	0.793	0.825	0.809	Industrial
8320	Powerlines	0.127	0.155	0.182	0.210	0.210	0.210	0.169	RO
8330 & 8340	Water/Sewer Plants	0.174	0.230	0.286	0.342	0.230	0.286	0.258	LDR
8350	Landfill	0.252	0.329	0.407	0.485	0.329	0.407	0.368	(10%Trans/20%LDR/70%Min)
8390	Utility Construction	0.160	0.181	0.202	0.223	0.181	0.202	0.191	Disturbed

Notes:

1 Calculated per method described by Harper (1994) % Impervious(0.9) + % Pervious(0.2)

2. Borrow-Spoil – the in-situ soil group no longer applies since it has either been excavated or buried with off-site material. SCS uses a separate designation in such instances. Used a constant runoff coefficient equivalent to the mean value of recreational-open space.

3. Assignment of B/D coefficient depended on site-specific evaluation. If >1 unit/acre assume B conditions. If density ≤ 1 unit/acre, assign value for D soils (findings from Malabar study).

4. Other notes:
    a. Land use: Lands without a designated use are assigned an average concentration base don area-weighted concentrations within the specific sub-basin.
    b. Highload Transportation - Separated from transportation category to include bus and truck terminals & auto parking facilities. Assume high percent impervious (80-100%) with heavy vehicle use/parking.
    c. Communications – mostly comprised by lone transmission towers not part of commercial building.
    d. Stables & Dairies - Does <u>not</u> include large areas pasture that might be associated with such enterprises.
    e. Stadiums - Only those <u>not</u> assoiciated with schools/universities. Some overlap with commercial racetracks.
    f. <u>Runoff Coefficients</u>: Coefficients orignally derived from Chow (1969) and later modified with data from Harper (1994), Hendrickson, et. al. (2000), and as noted below.
    g. U Hydrologic Group – assign mean of the four hydrologic groups for particular land use.
    h. W Hydrologic Group – Assign coefficient for U soils & particular land use category if different from water.
    i. Soil surveys do not precisely overlay with land use maps and contradiction occurs at the edges. Otherwise, assign 1.000
    j. C/D & B/D Hydrologic Groups — Use D where undeveloped; B or C where developed.
    k. ***** Exceptions: used mean value, e.g.- (B+D)/2, for each indicated land use. Assumed that some minor drainage improvements occurred, but were not sufficient to lower the water table over entire site such that the higher hydrologic group should be used. Therefore, only a portion behaves as higher hydrologic group and remainder behaves as lower group.

11. Appendix B- HSPF Model Framework.

In HSPF, a watershed is represented by land segments that sub-divide it into areas of similar hydrologic characteristics. Land and soil processes are represented by a series of storages, and flow out of these storages is routed laterally to downslope segments or river reaches. Depending on whether infiltration is sufficient to affect the water budget, land segments are classified as pervious or impervious Delineation of a watershed requires data for stream reaches (from the National Hydrography Dataset), digital elevation (DEM), and hydrologic units. Other geographic data, such as land use, soils, and the location of dams is also input into the model.

The three application modules in the HSPF model are used to simulate hydrology, hydraulics, and water quality. The PERLND module covers these processes for pervious areas, while the IMPLND module covers the processes for impervious areas. The RCHRES module simulates processes that occur in-stream.

PRLND models the movement and interaction of overland flow (i.e. runoff), interflow, and groundwater flow (i.e. baseflow) with dissolved constituents. The required inputs include data on air, soil and water temperatures, soil moisture and water budgets (including snow and ice, if applicable), water quality and sediment characteristics, and nitrogen and phosphorus, etc. Overland flow is assumed to be one-dimensional kinematic-wave flow.

The IMPLND module is used to represent urban or other impervious areas. It also requires information on air and water temperatures, water budget (including snow and ice, if applicable), and the quality of runoff. Though there is no infiltration in impervious segments, precipitation, evaporation, and overland flow are simulated. Water and various pollutants are allowed to build up and wash off from the land surface.

RCHRES routes the runoff generated within the PERLND and IMPLND sub-modules through one-dimensional streams and reservoirs and simulates hydraulics and various instream processes. These processes include (but are not limited to) sediment scour, transport, and deposition, nutrient balances for nitrogen and phosphorus, chemical interactions, biodegradation, DO and BOD, and changes in plankton populations. The model requires input data for river geometry and boundary conditions, plus any inflows or withdrawals. The meterology of the sub-basins must be known. It assumes that the receiving water is well-mixed with width and depth.

HSPF also has modules that are designed to analyze the time series data that is output from the model.

12. Appendix C- PLRG Report.

This report is included as a separate file.