Mosquito Lagoon Water Quality and Associated Data Summary

Volusia County and Mosquito Lagoon RAP Stakeholder Group

June 2017

MOSQUITO LAGOON REASONABLE ASSURANCE PLAN (RAP)

Mosquito Lagoon Water Quality and Associated Data Summary

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1 INTRODUCTION

Volusia County, along with local stakeholders, have partnered with the Florida Department of Environmental Protection (FDEP) on the development of a Reasonable Assurance Plan for the protection of Mosquito Lagoon and to ensure it meets its designated uses and complies with numeric nutrient criteria. In 2016, the stakeholders chose the team of Jones Edmunds and Associates, Inc. and Janicki Environmental, Inc. to provide technical support for this endeavor. Documents and materials prepared for this collaboration are collected on a Teamwork site hosted by Wildwood Consulting, Inc., facilitators for FDEP.

1.1 Background

A Reasonable Assurance Plan (RAP) outlines a path to reduce loads to impaired waters in order to bring them into compliance with state and federal criteria. Unlike a Basin Management Action Plan (BMAP), the RAP is a stakeholder led effort to reach compliance with measurable goals while a BMAP is led by the State when a Total Maximum Daily Load (TMDL) has been determined.

In the case of Mosquito Lagoon, the criteria to be met are the Numeric Nutrient Criteria (NNC) for total nitrogen (TN), total phosphorus (TP) and chlorophyll *a*. The method for determining the current criteria is laid out in the *2014 Report on Numeric Nutrient Criteria for Estuaries* (FDEP, 2014). This document described the processes used to develop NNC for estuaries throughout the state. Where they could, FDEP relied upon local knowledge to assist in the effort. In the case of Mosquito Lagoon, staff of the St. Johns River Water Management District (SJRWMD) had already completed an effort to develop nutrient thresholds (Steward et al., 2010). This SJRWMD effort was a expressed as a five-year rolling average. Since the Department wanted the criteria to be expressed as not to be exceeded more than once in three year period, FDEP chose to reevaluate that effort. Given that the approach taken by FDEP is a reference period approach a critical element of the approach is the definition of the reference period. The reference period should be representative of a “good” or “healthy” period for the waterbody and encompass a reasonably lengthy period of time during which a wide range of environmental (i.e., meteorologic) conditions. FDEP updated the previous analysis to meet their requirements yet utilized the same reference period, 2004 – 2008.

1.2 Objective

The objective of this technical memorandum is to describe the physical and hydrological setting of Mosquito Lagoon and the segmentation scheme used to describe the conditions. There will also be a discussion of the available data regarding seagrasses, the primary aquatic habitat of interest. Finally, a description of the available water quality data and a discussion of key parameters and trends will be presented.

2 GEOGRAPHY, HYDROLOGY and SEGMENTATION

2.1 Geographic Setting

Mosquito Lagoon is located on the east coast of Florida and is considered the northern extent of the North Indian River Lagoon Basin which stretches from Ponce de Leon Inlet in the north to Fort Pierce Inlet in the south (Figure 2-1). The lagoon is contained by two coastal counties, Volusia County and Brevard County with several municipalities within its watershed.

Figure 2-1. Location of the Mosquito Lagoon within the IRL Basin.

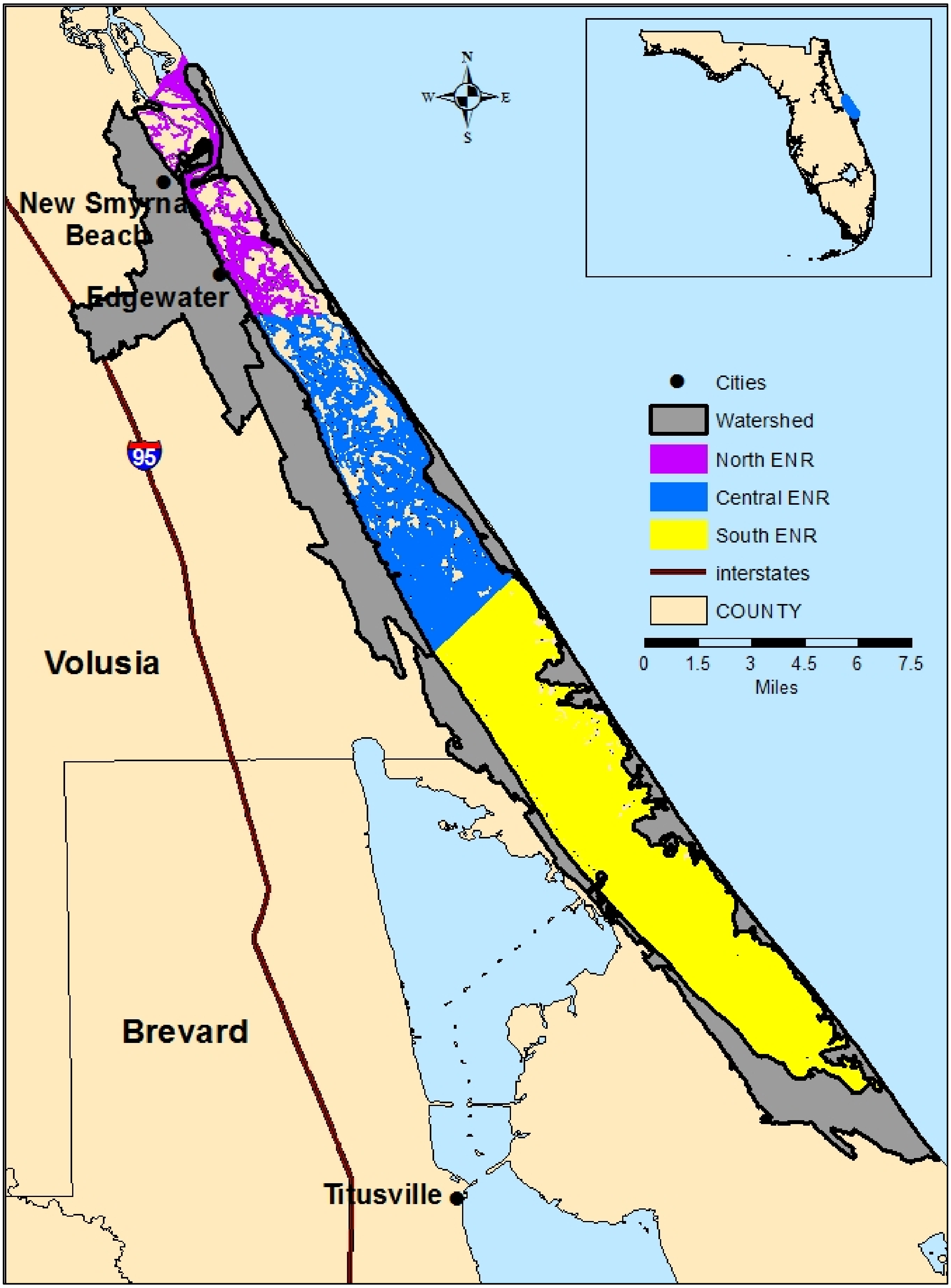
2.2 Segmentation Scheme

As part of the development of numeric nutrient criteria, Mosquito Lagoon was divided into three estuarine nutrient regions (ENR) with regionally specific nutrient criteria (Figure 2.2). These regions roughly approximate the regions used by the St Johns River Watershed Management District (SJRWMD) segments used to monitor and manage the primary aquatic resource within the Indian River Lagoon region, seagrasses, though it has been identified as the transition zone where seagrasses give way to oysters as it marks the seagrasses northern most extent on the east coast of Florida. The regions have rather lengthy segment names but will be simply referred to as North, Central and South ENRs (Table 2-1). The following discussions will use this scheme as the basis to present the various bioogical and water quality data analyses.

Table 2-1. Crosswalk between FDEP ENR Terminology and and shorthand.

Estuarine Nutrent Region Name	Estuarine Nutrent Region Code	Shorthand
Mosquito Lagoon (Ponce de Leon to Edgewater)	ERNAA13	North ENR
Mosquito Lagoon (Edgewater to Oak Hill)	ERNAA12	Central ENR
Mosquito Lagoon (Oak Hill to the Southern Terminus)	ERNAA11	South ENR

Figure 2-1. Location of the Mosquito Lagoon Estuarine Nutrient Regions along with the associated watersheds.



2.3 Landuse

Landuses within the watershed vary greatly from urban/suburban in the north to undeveloped/natural in the south. In fact, much of the central and southern lagoon is under state (Mosquito Lagoon Aquatic Preserve) and federal protection (Cape Canaveral National Seashore and Merritt Island National Wildlife Refuge). Table 2-2 tabulates the most recent landuse coverage which was used to estimate pollutant loadings within the Spatially Integrated Model for Pollutant Loading Estimates (SIMPLE) model (JEA, 2017).

Table 2-2. 2015 Land Uses Percentages

Landuse	North ENR	Central ENR	South ENR
AGRICULTURE	0	2	0.2
FOREST	14.1	25.6	15
GOLF COURSES	1.6	0	0
HEAVY INDUSTRIAL	1.1	0.2	0
HIGH DENSITY RESIDENTIAL	9.9	6.5	0
HIGH INTENSITY COMMERCIAL	5	1.1	0
LIGHT INDUSTRIAL	4.7	2.6	0.1
LOW DENSITY RESIDENTIAL	6	10.5	0
LOW INTENSITY COMMERCIAL	0.7	0.4	0
MEDIUM DENSITY RESIDENTIAL	33.6	10.2	0
OPEN	1.7	13.4	23.8
PASTURE	1.3	4.1	5.3
TRANSPORTATION	4.3	2.1	1.1
WATER	3.3	1.4	15
WETLANDS	12.3	20	39.7

2.4 Hydrologic Setting

Mosquito lagoon is bounded in the north by the Ponce de Leon Inlet where the Mosquito Lagoon and Halifax Rivers connect with the Atlantic Ocean (Figure 2.2). To the south, the lagoon connects with the north Indian River Lagoon through the Haulover Canal which was completed in the late 1800's. Residence times vary greatly depending on the proximity to either of these connections.

The area of the watershed compared to the surface area is interesting in that the area draining to the North ENR is four times greater where the South ENR is twice the size of its watershed (Table 2.3.1). Eleven individual basins were delineated to produce pollutant and hydrologic loadings to Mosquito Lagoon via the SIMPLE Model (JEA, 2017). The watershed received an average of 44.6" of rain over a 12 year period between 2004 and 2015 (JEA, 2017).

Table 2-4. Estuarine Nutrient Region physical characteristics.			
ENR	**Watershed area**	**Surface Water Area (m^2)**	**Surface water Volume (m^3)**
North ENR	46,467,865	9,874,688	28,772,127
Central ENR	33,087,900	37,342,963	65,619,574
South ENR	45,413,900	94,397,320	167,906,291

3 Available Data

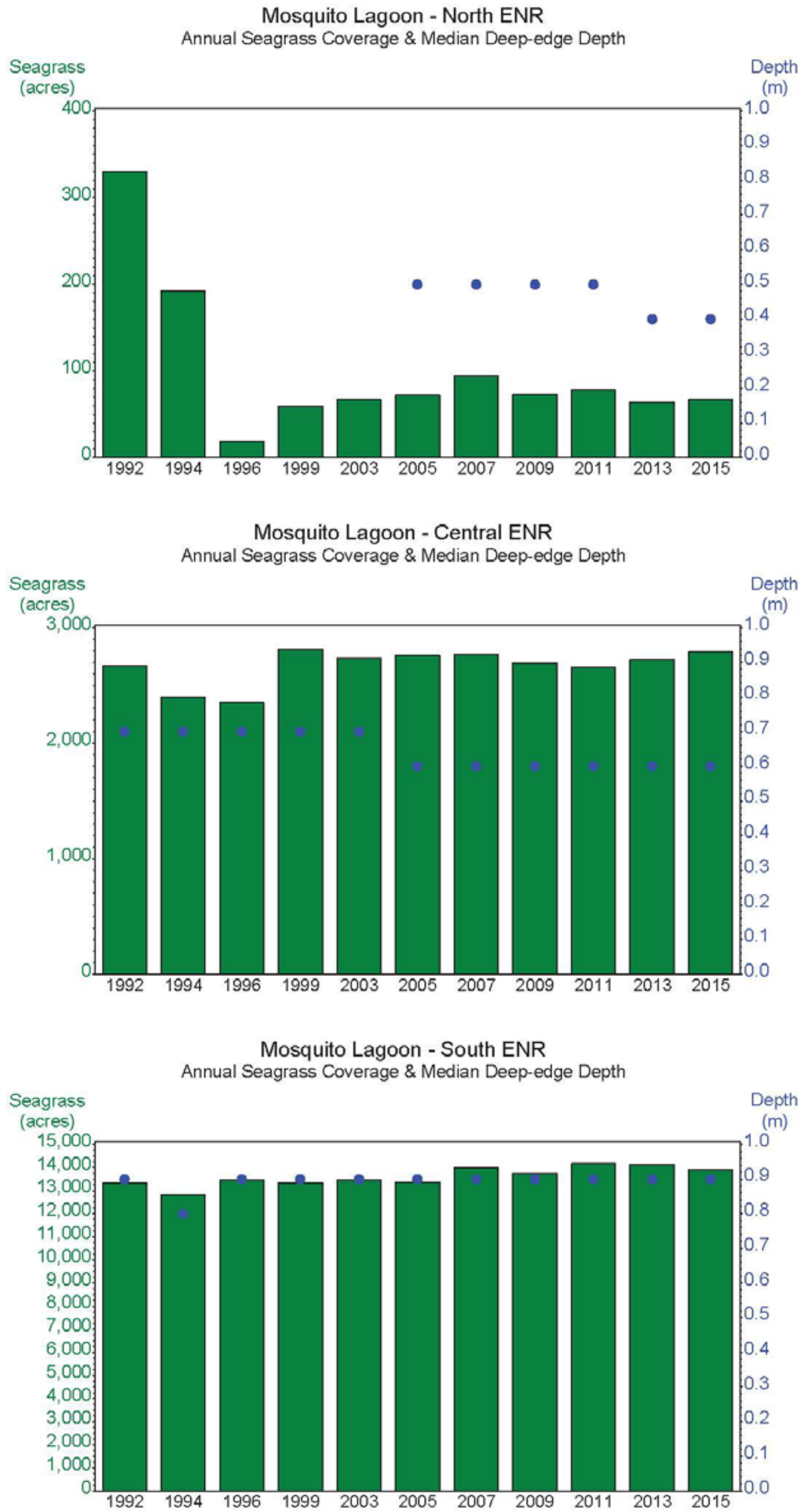
3.1 Seagrass Data

For this analysis, it was decided to focus on two seagrass parameters: seagrass extent and the median deep-edge. These two have both the appropriate spatial and temporal scales necessary to relate long-term water quality data.

- Seagrass extent is estimated utilizing aerial photographs geographic information system which allows managers to evaluate changes in seagrass acreage over time. This method allows for comparisons within different segmentation schemes and for inclusion in other analyses. The photographs, utilized for mapping prior to 1994 were acquired between January and April and since have been acquired generally between May and August. Efforts to produce maps occur every 2 to 3 years with data currently available for most of the Indian River Lagoon system for the following 12 years: 1943, 1992, 1994, 1999, 2003, 2005, 2006, 2007, 2009, 2011, 2013, and 2015.
- Median deep-edge depths are derived from the intersection of aerially mapped seagrass polygons overlaid upon the 1996 bathymetric transect data points and depths assigned to the deep edge boundary following the methods described in Steward et al., 2005. A 15.8 meter buffer is used to ensure assignment of a point along the line. Points from the shallow edges (generally less than 0.1 meters), known dredge-fill operations, bare areas within the seagrass polygons and those greater than 3.5m were excluded from further analysis. From the remaining points, the median deep-edge depth is calculated.

The collection of seagrass data is managed by the SJRWMD and was provided by Ms. Lori Morris (personal communication). Time-series plots of seagrass extent (green bars) and the median deep-edge depth (blue dots) are shown in Figure 3-1. There is an obvious difference between the North ENR and the other two. No studies were found that explored the cause of the apparent seagrass loss in the North ENR which is not seen in the other two which remained relatively stable throughout the period. The North ENR is where the transition from seagrasses to oysters is the most obvious and possible misidentification of oysters as seagrass early in the program.

Figure 3-1. Seagrass coverage, shown as green bars in the North (top), Central (middle) and South (bottom) ENRs of Mosquito Lagoon. Median deep-edge depths are represented by blue dots.

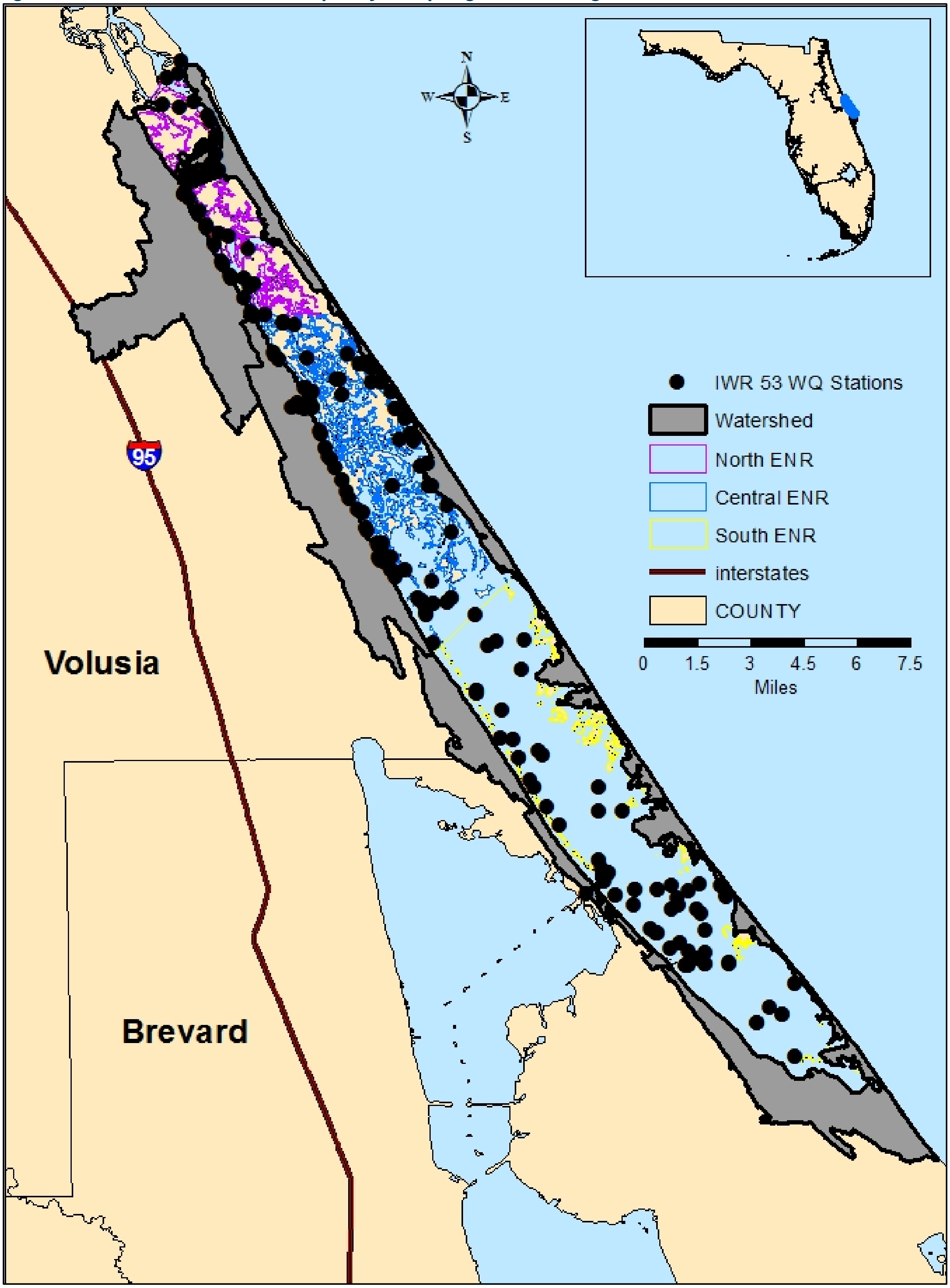


3.2 Water Quality Data

Mosquito Lagoon has had numerous agencies collecting water quality data since the 1970's. In order to compile data for this project, three data sources were combined to ensure the most complete dataset. When the this project began, FDEP's IWR Run 52 dataset was available and provided the brunt of the data. Unfortunately, the period of record covered by the that dataset didn't coincide with the pollutant loading estmates being developed so data was provided by the Volusia County Environmental Management Division and the SJRWMD. Once FDEP's IWR 53 dataset was made available, it was used which lessoned the need for the supplemental data. Data from these three sources were combined, screened for duplication and further checked for quality assurance issues and compiled as a SAS dataset for further analysis. The data were finally reviewed in cooperation with FDEP staff which recommended we remove certain Lakewatch data from the analysis due to upload errors. Data was also excluded from the Marine Resources Council of East Florida due to issues with the DO percent saturation results. Table 3-1 shows the annual sample count for the primary parameters of interest: TN, TP, and chlorophyll *a*. Figure 3-2 shows the distribution of samples throughout Mosquito Lagoon.

Table 3-1. Annual sample count the major parameters of interest.									
ENR	**South ENR**			**Central ENR**			**North ENR**		
Year	**TN**	**TP**	**Chl a**	**TN**	**TP**	**Chl a**	**TN**	**TP**	**Chl a**
1992	21	26	15	192	196	140	77	83	90
1993	10	11	10	82	94	121	34	41	76
1994	11	11	12	146	145	146	98	97	92
1995	11	10	12	136	122	146	98	90	95
1996	3	3	12	71	77	89	87	93	95
1997	13	19	17	84	93	84	103	104	95
1998	14	14	14	87	87	87	107	108	107
1999	12	12	12	80	80	80	102	103	105
2000	13	13	13	39	43	43	42	43	42
2001	23	37	43	46	52	57	67	66	44
2002	7	44	61	17	44	59	30	32	25
2003	12	26	27	38	44	33	97	93	12
2004	12	111	111	43	38	29	104	96	20
2005	14	41	41	35	29	24	71	63	11
2006	38	37	38	33	30	20	66	74	15
2007	32	32	31	30	28	33	64	64	27
2008	24	24	24	24	36	36	62	75	32
2009	13	23	22	12	22	20	48	54	19
2010	17	22	22	26	35	23	55	67	22
2011	24	21	24	33	31	34	38	39	35
2012	27	27	25	36	36	31	26	25	25
2013	33	32	33	35	32	38	33	32	37
2014	46	45	46	67	67	69	20	21	22
2015	14	26	29	22	33	38	19	33	39

Figure 3-2. Distribution of water quality sampling sites among the three ENRs.



3.2.1 Water Quality Trend Analysis

Temporal trends in water quality were assessed using time-series analyses to examine trends in water quality conditions in each ENR. ENR monthly mean water quality values were submitted for trend tests for the following parameters: TN, TP, chlorophyll *a*, and salinity. The period of time spanned 1989-2015 and was assessed to determine their suitability for trend and status analysis. If the data met the requirements for inclusion then the following assessment was made to determine the analysis path:

- A data point was defined for the purposes of assessing sampling sizes as the mean of all stations and sampling levels (surface, middle, bottom) within a basin;
- Trend testing was performed for the period of record corresponding to the beginning of monthly water quality sampling provided at least 60 samples and 5 years of monthly data were available for analysis.

All of the trend analyses were completed using a seasonal Kendall Tau approach. This approach removes seasonal trends that are common in water quality data as a result of seasonal fluctuations in temperature and rainfall and allows better resolution of increasing or decreasing trends in the data, independent of seasonal trends. The core statistical testing procedures were provided by the Environmental Protection Agency's (EPA's) seasonal Kendall Tau Fortran programs available from the EPA Laboratory in Corvallis, Oregon. The authors developed statistical software to drive these core programs, and produce the automated outputs.

The results are summarized in Table 3-2 and shown in Figures 3-3 through 3-5.

For all nutrient parameters, TN, TP, or chlorophyll *a,* the results either indicated no trends or decreasing trends. In the North ENR, both TN and TP were decreasing, and TN decreasing the in the Central ENR. Increasing trends in salinity were seen in both the North and South ENRs.

Table 3-2. Results of the seasonal Kendall Tau trends test. Units: TN (mg/L), TP (mg/L), Chl a (µg/L). N=number of samples, p=probability of a greater T, Slope=slope of trend line, Magnitude=relative magnitude of the change over time.

ENR	Parameter	Begin Year	End Year	Median	N	p	Slope	Trend	Magnitude
North	Chlorophyll a	1989	2015	4.61	315	0.895	-0.004	No Trend	
	TN	1989	2015	0.57	310	0.001	-0.016	Decreasing	Small
	TP	1989	2015	0.05	312	0.034	-0.001	Decreasing	Small
Central	Chlorophyll a	1989	2015	4.97	314	0.687	-0.008	No Trend	
	TN	1989	2015	0.77	304	0.000	-0.016	Decreasing	Small
	TP	1989	2015	0.06	312	0.818	0.000	No Trend	
South	Chlorophyll a	1989	2015	4.50	313	0.471	0.016	No Trend	
	TN	1989	2015	1.13	284	0.196	-0.007	No Trend	
	TP	1989	2015	0.04	296	0.857	0.000	No Trend	

Figure 3-3. Time series of mean monthly chlorophyll a concentrations in the North (upper), Central (middle) and South (bottom) ENRs of Mosquito Lagoon.

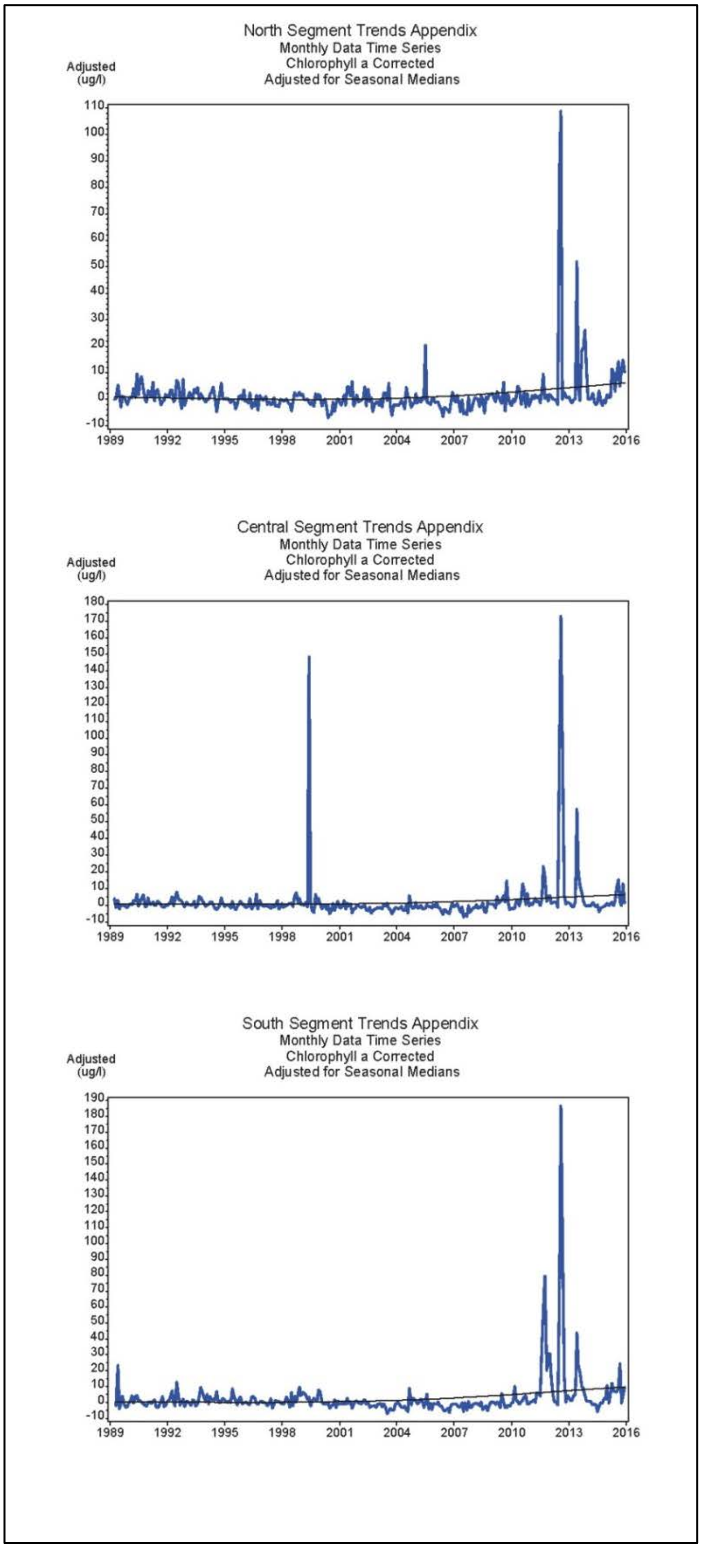


Figure 3-4. Time series of mean monthly TN concentrations in the North (upper), Central (middle) and South (bottom) ENRs of Mosquito Lagoon.

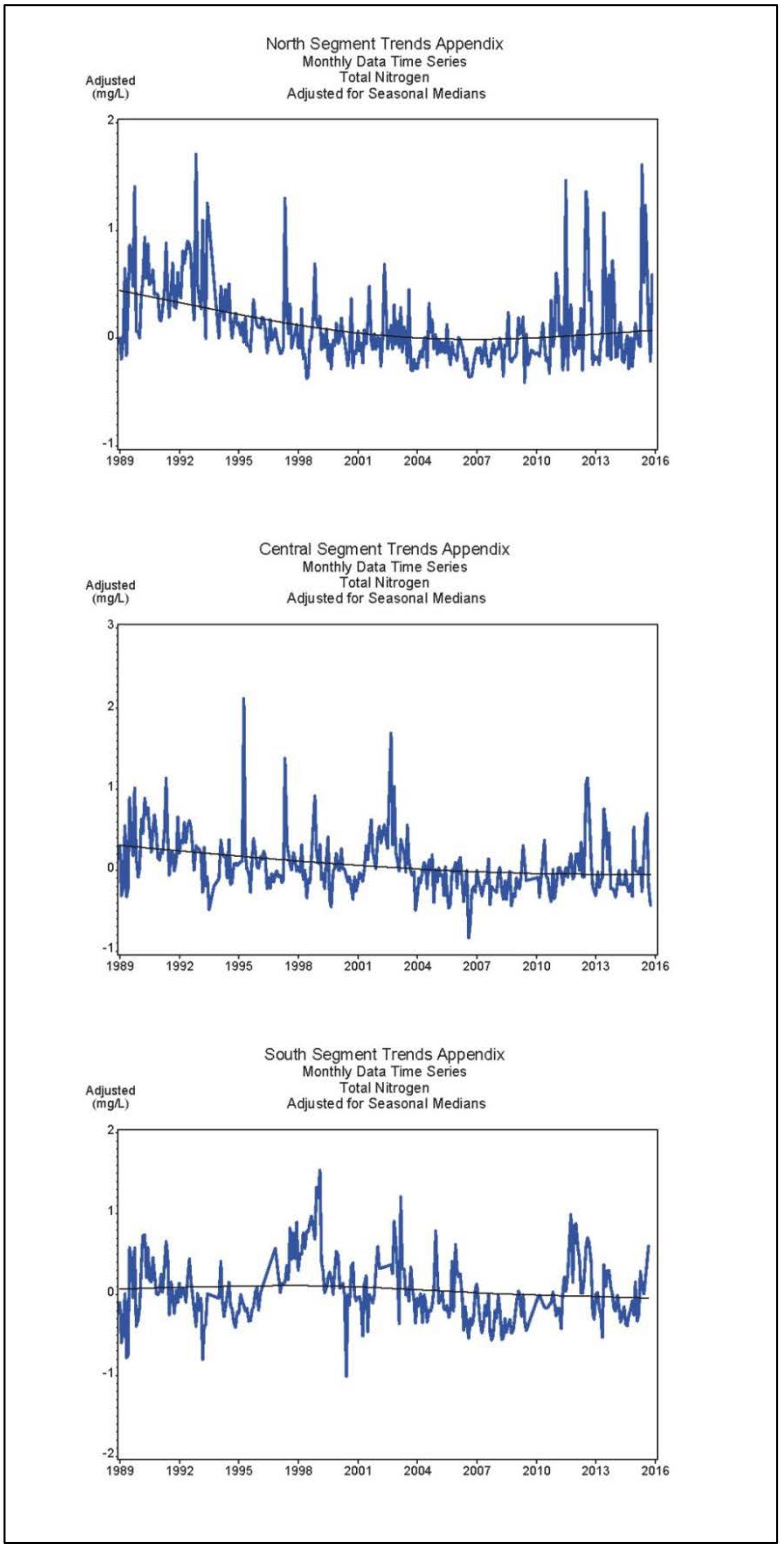
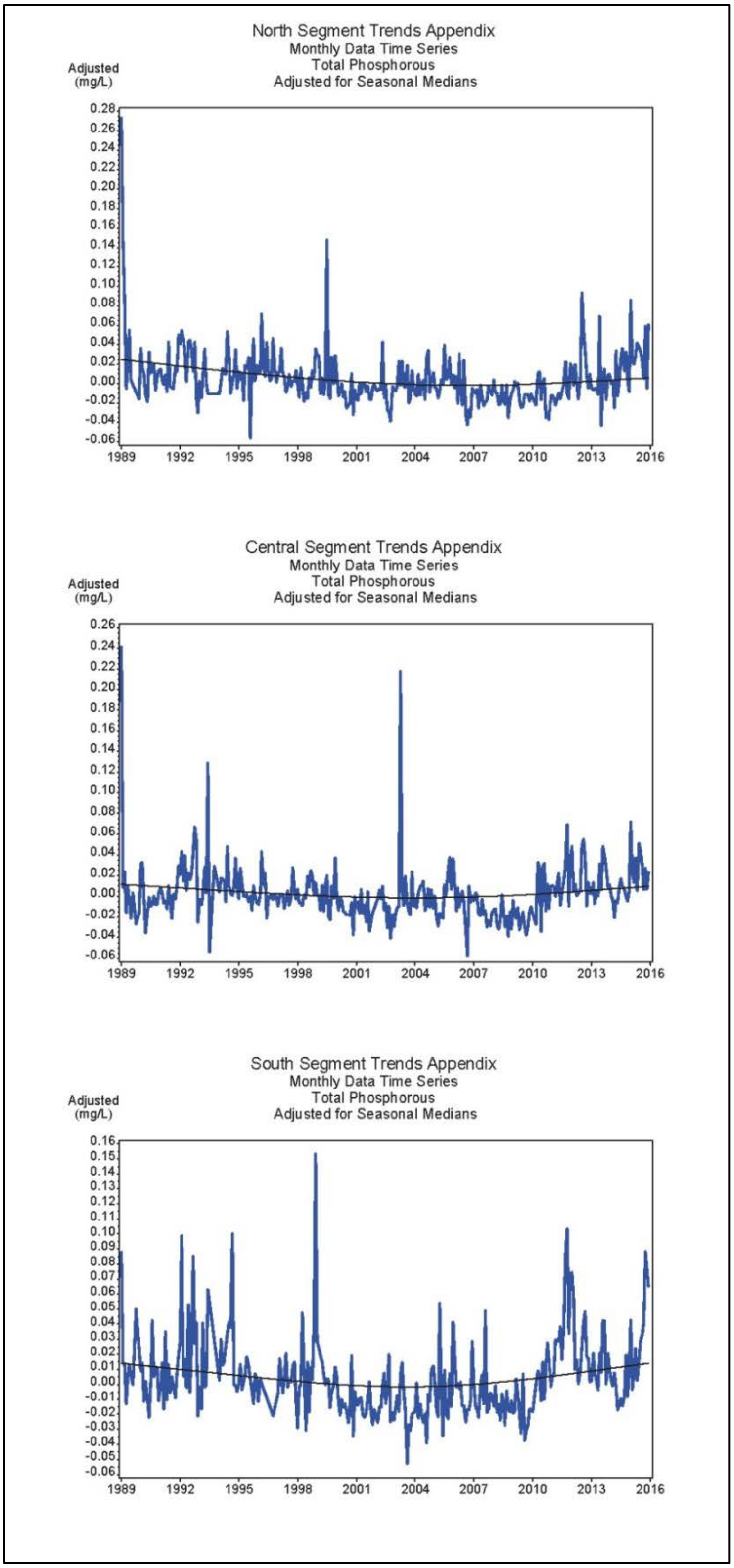


Figure 3-5. Time series of mean monthly TP concentrations in the North (upper), Central (middle) and South (bottom) ENRs of Mosquito Lagoon.



3.3 Pollutant Loading

Pollutant loading estimates were developed using the SIMPLE model for the watersheds draining directly to the lagoon. SIMPLE is a GIS-based pollutant loading model that provides in this case, monthly loading estimates through six modules: runoff, baseflow, point source, septic, irrigation and wet/dry fall (atmospheric deposition). For this effort, irrigation was excluded and an external method was used to estimate atmospheric loadings to the lagoon (JEA, 2017).

Time series plot of monthly total loads for nitrogen are shown in Figure 3-6.

3.3.1 Freshwater Replacement Time

The SIMPLE model can also estimate the hydrologic load as the amount of freshwater entering the lagoon. From that, we can determine the freshwater replacement time (FRT), or flushing rate, for the lagoon systems. Similar to the age of water (next section), it provides an estimate of how long water remains in the system the higher the value, the more times the ENRs volume can be replaced by water imputed from the watershed. Time series plots of monthly total loads FRT are shown in Figure 3-7.

Figure 3-6. Time series of monthly nitrogen load to the North (upper), Central (middle) and South (bottom) ENRs of Mosquito Lagoon.

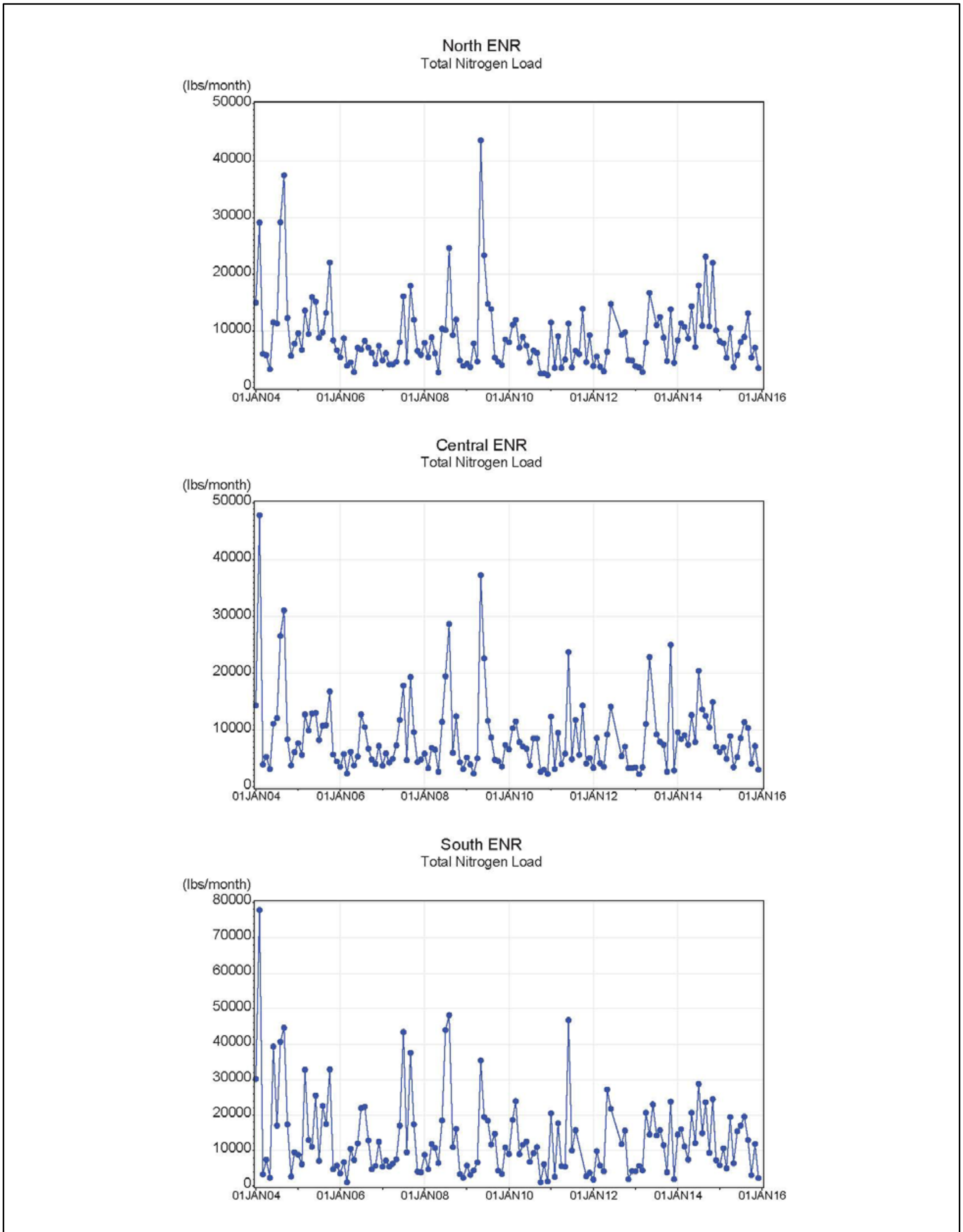
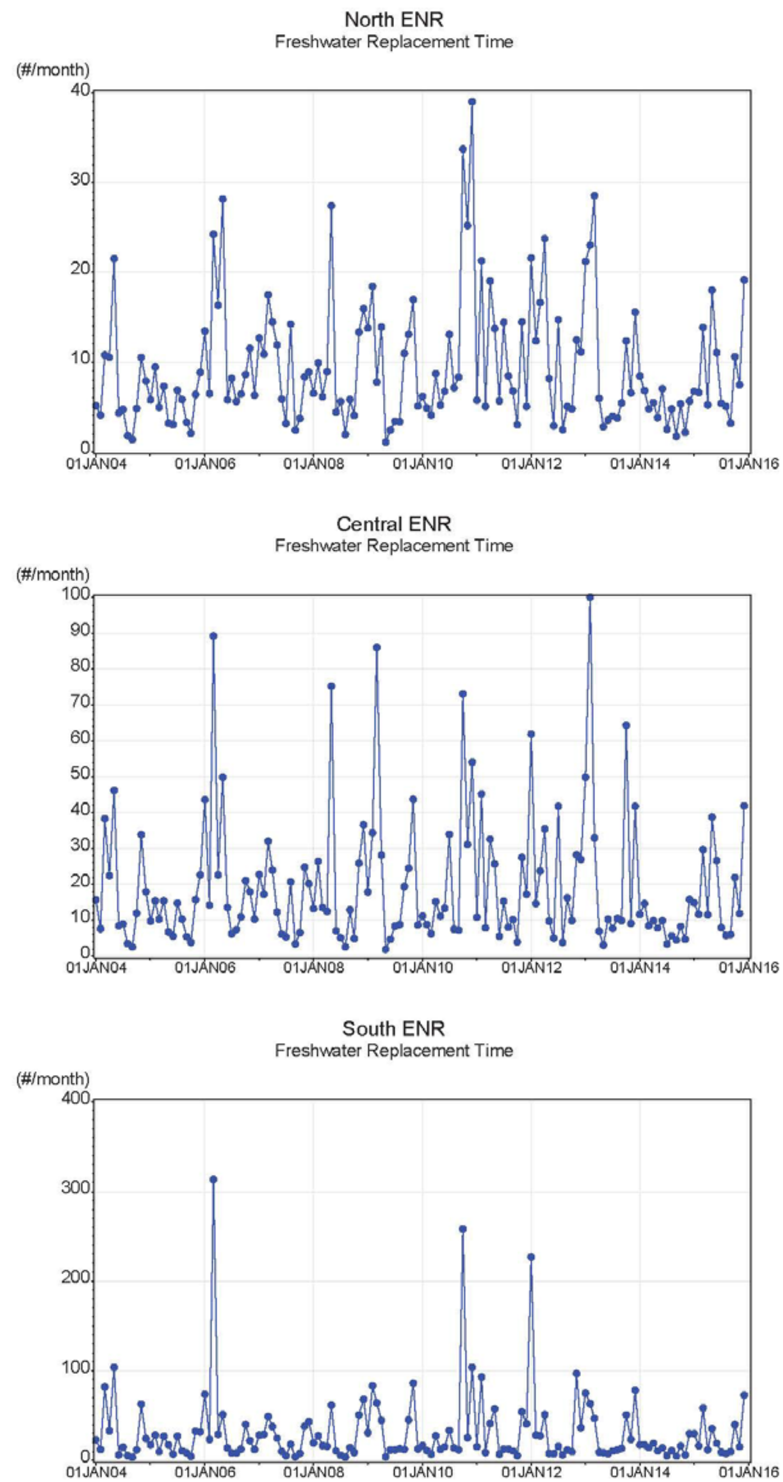


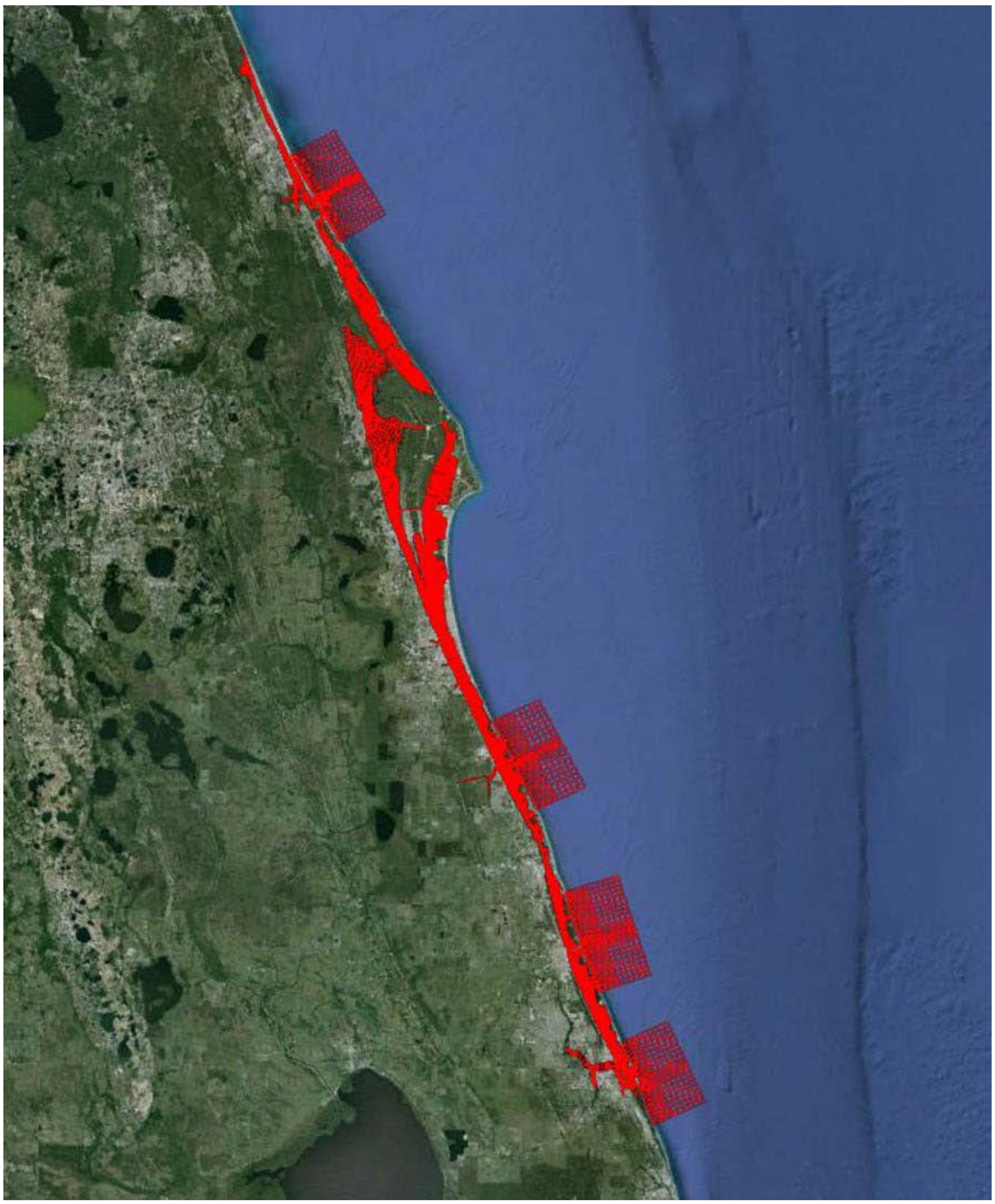
Figure 3-7. Time series of monthly freshwater replacement time for the North (upper), Central (middle) and South (bottom) ENRs of Mosquito Lagoon. .



3.4 EFDC Model

The SJRWMD Environmental Fluid Dynamics Code (EFDC) hydrodynamic model of the IRL was utilized to determine the Age of Water, freshwater replacement times and intersegment fluxes between the different ENRs. The EFDC model is a general purpose modeling package for simulating two- and three dimensional flow, transport and salinity in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands and near shore to shelf scale coastal regions. The SJRWMD EFDC model covers all of the Mosquito Lagoon, Indian River Lagoon, Banana River Lagoon, and the areas offshore of the inlets connecting the lagoon system with the offshore (Figure 3-8). The model simulation period goes from January 1, 1995 through January 1, 2011, with 1995 utilized as a spin-up period for the salinity conditions in the lagoon. As such, useable results from the model start on January 1, 1996. (ATM, 2015).

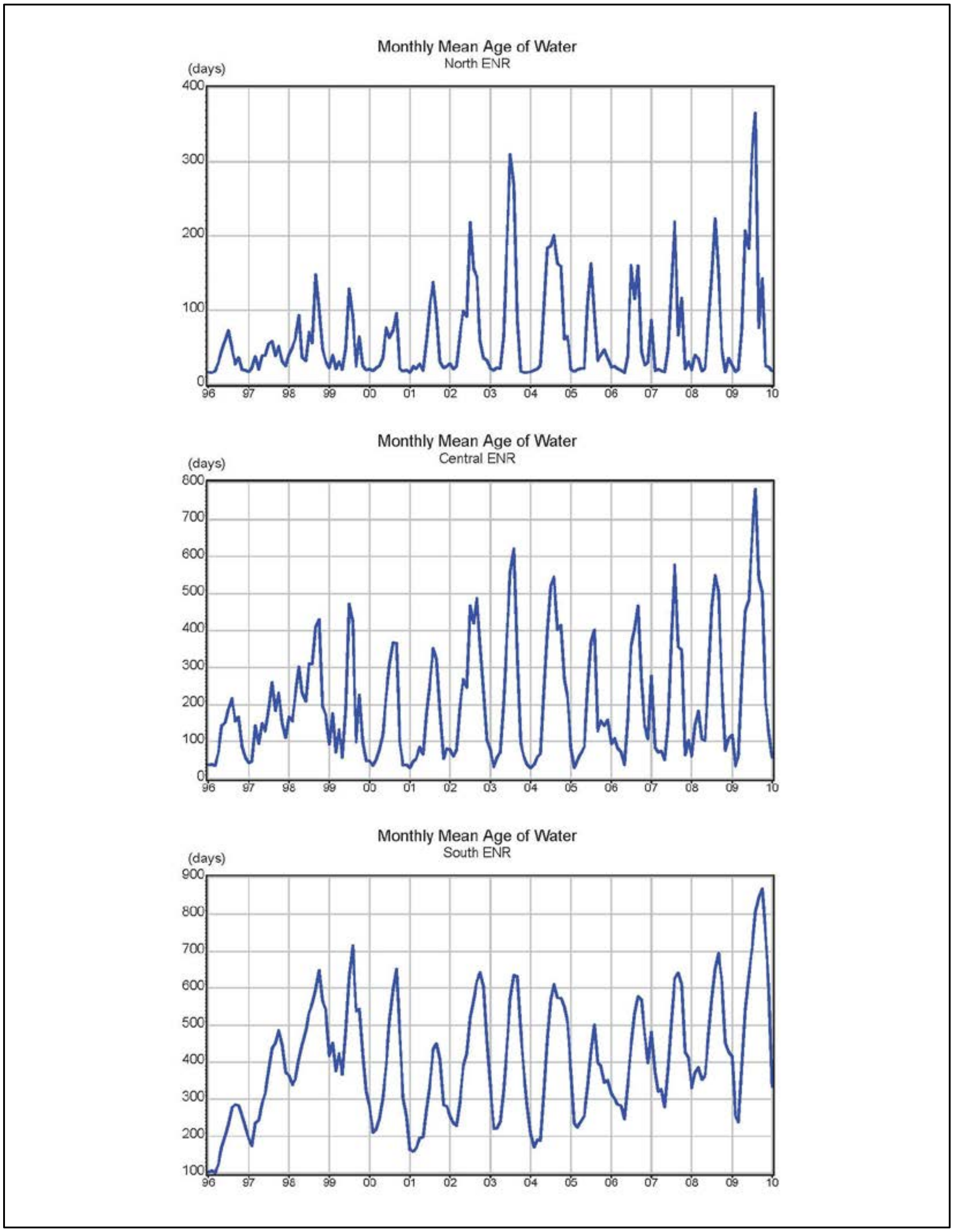
Figure 3-8. Extent of the SJRWMD's EFDC model grid of the IRL. .



3.4.1 Age of Water

The Age of Water tracks the number of days a "parcel" of water remains within the modeled system. Plots of the monthly mean age of water is shown in Figure 3-9. As is expected, waters in the North ENR remain for shorter periods than those in the Central and South ENRs due to the proximity to Ponce de Leon Inlet.

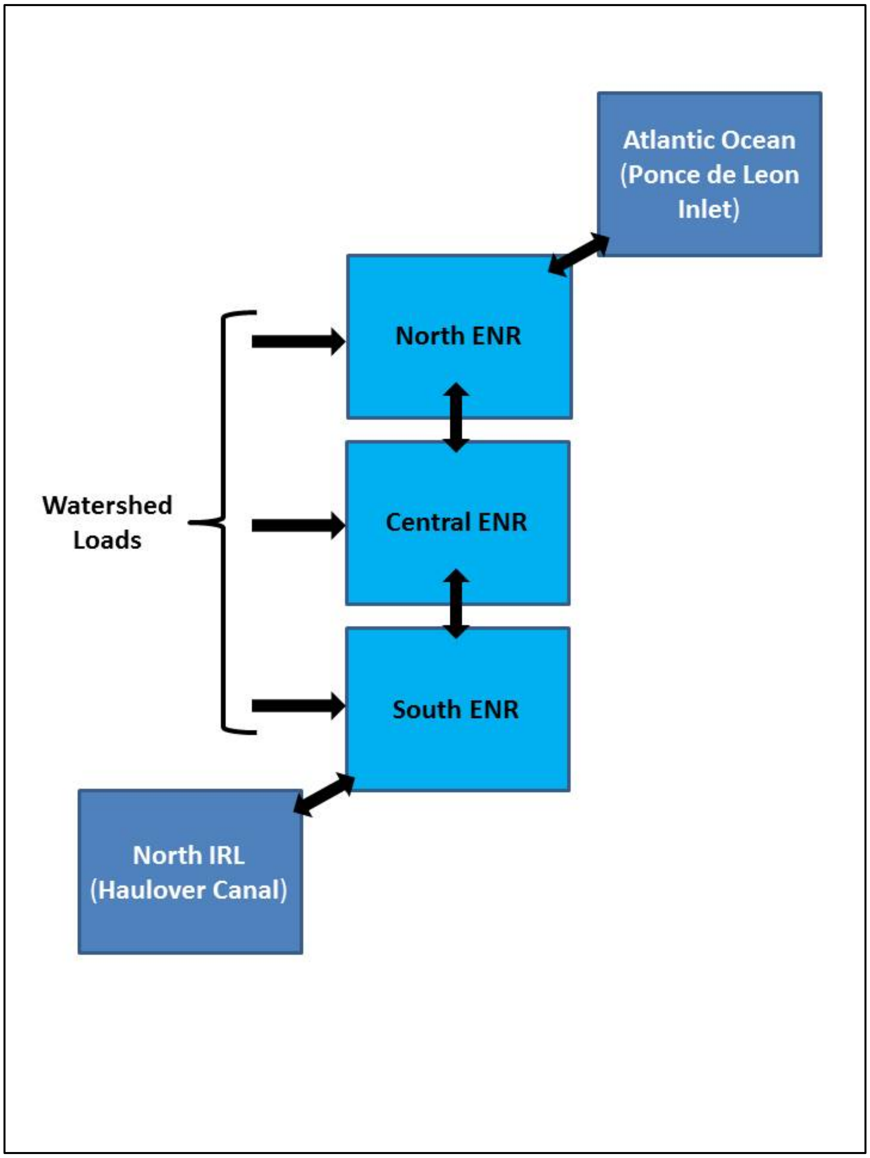
Figure 3-9. Time series of the monthly mean age of water for the North (upper), Central (middle) and South (bottom) ENRs of Mosquito Lagoon.



3.4.2 Intersegment Flux

Net monthly fluxes were calculated from the time series of flows output from the EFDC model to develop the intersegment hydrologic exchange and the exchanges between across the external boundary. The flows were output at the connection points between the segments. The model in Figure 3-10 illustrates the influence on each ENR from watershed loadings, exchange between each ENR, and exchange with boundary areas.

Figure 3-10. Mosquito Lagoon connectivity and flow diagram.



To develop the mass exchange of nutrients between segments, the monthly hydrologic fluxes were multiplied by concentrations of TN within the segments. The segment concentrations were based upon an averaging of all available data collected in the particular segment for that month. To calculate the net TN flux, for a given segment:

$$Net\ TN\ flux(L) = watershed\ load(l) + north\ boudary\ flux + south\ bouundary\ flux$$

These values are summarized seasonally in Figure 3-11 and 3-12.

Figure 3-11. Seasonal TN fluxes showing the exchange between the North ENR and the Atlantic Ocean (Top) and the Central ENR (Bottom). Negative fluxes represent the mass exiting the segment.

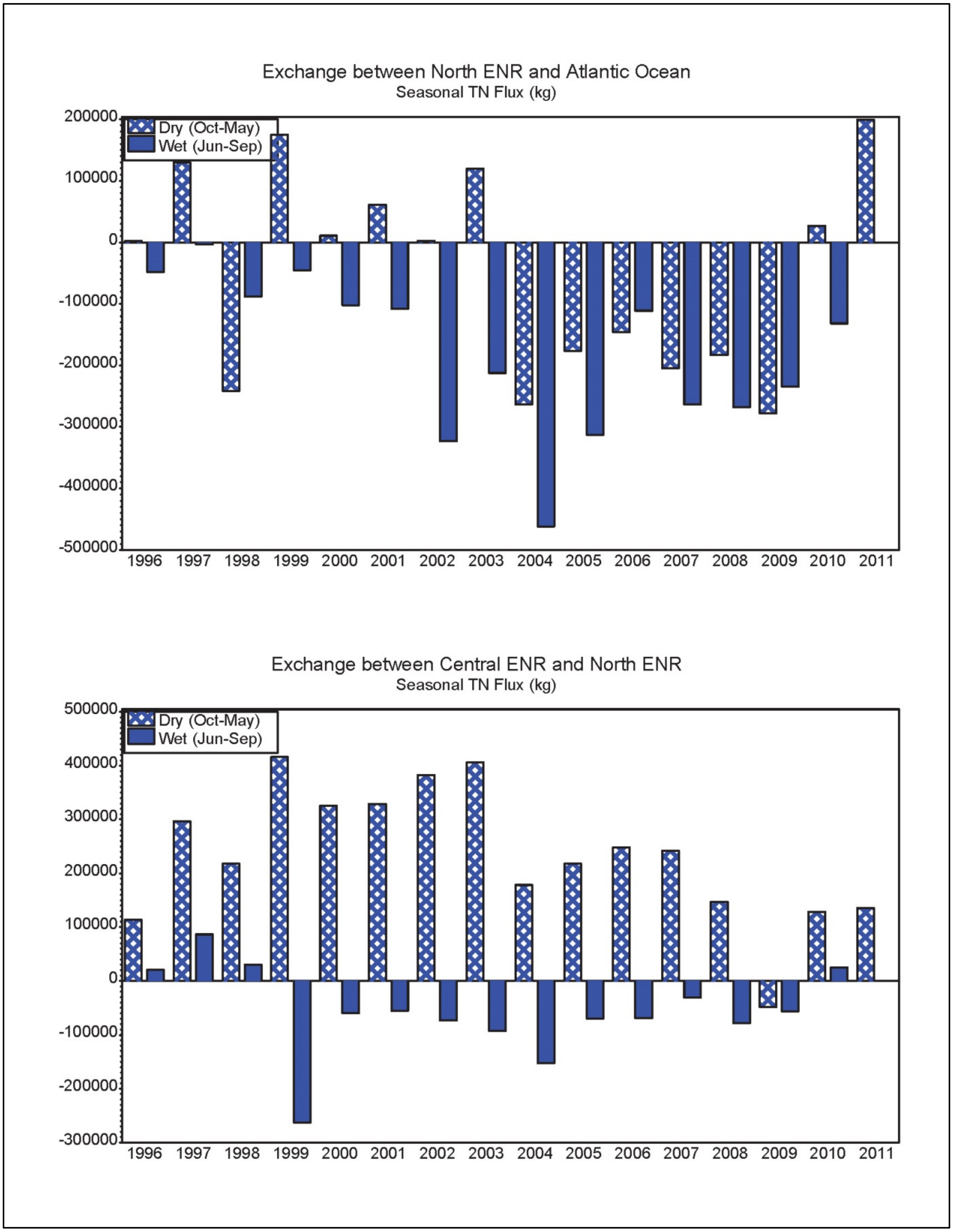
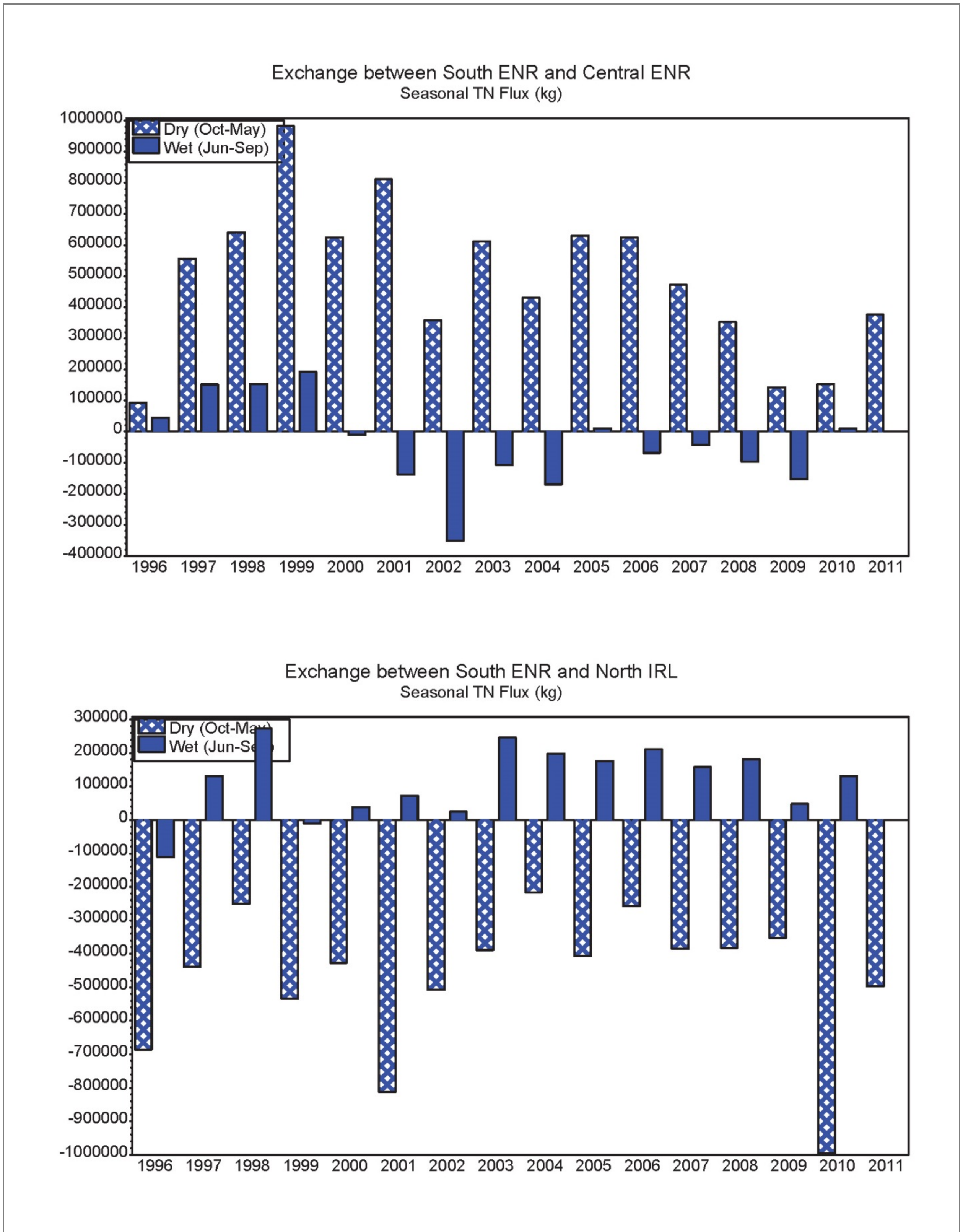


Figure 3-12. Seasonal TN fluxes showing the exchange between the South ENR and the Central ENR (Top) and the North IRL (Bottom). Negative fluxes represent the mass exiting the segment.



4 Conclusion

As demonstrated above, a vast array of data is available describing the conditions in Mosquito Lagoon. The next step will be to investigate the relationships between each these elements to determine the best conditions to restore and maintain the water quality to support the target aquatic habitat, seagrasses.

5 References

Applied Technology & Management (ATM). 2015. Task 2 Technical Memorandum: Total Loads, Intersegment Transfer, and Mass Balance. Prepared for Brevard County, Florida.

Jones, Edmunds and Associates (JEA), 2017. Mosquito Lagoon Reasonable Assurance Plan (RAP) Watershed Model Development Report. Prepared for Volusia County and Mosquito Lagoon RAP Stakeholder Group.