NUTRIENT LOADING ESTIMATES:
ATMOSPHERIC DEPOSITION & POINT SOURCES
TASK 1.B

INDIAN RIVER LAGOON
TOTAL MAXIMUM DAILY LOAD REVISION

BREVARD COUNTY, FLORIDA

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1.0 INTRODUCTION

In March 2009, Total Maximum Daily Loads (TMDLs) were finalized for nine water body segments (WBIDs) within the Indian River Lagoon (IRL), starting north of Fort Pierce Inlet up to the northern IRL, and including four WBID segments within the Banana River Lagoon.

The local Stakeholders conducted an extensive review of the methodologies, assumptions, and models utilized in the development of the TMDLs, along with analyses of recent seagrass mapping from the area. This evaluation identified several potential problems with the TMDLs and concluded that they need to be re-evaluated. The local Stakeholders identified the need to update and revise the TMDLs utilizing more recent data and alternate approaches.

To complete this effort, the Stakeholders have retained a team of consultants to assist with the process. Of this group, Janicki Environmental, Inc., and Applied Technology and Management, Inc. (ATM) were engaged to complete the Data Compilation, Assessment, and TMDL Approach Development (Task 1). Task 1 has four subtasks:

Task 1.A - Compilation of Available Data, Literature, and Models
Task 1.B - Development of Loading Estimates
Task 1.C - Development of Understanding of IRL Physical/Chemical/Biological Response Processes
Task 1.D - Development of Technical Approach Document

This *Nutrient Loading Report* provides the deliverable under Task 1.B. Nutrient loading to the IRL comes from four main sources: domestic and industrial point-source dischargers, atmospheric deposition, groundwater (baseflow), and stormwater runoff from the watershed.

The determination of the baseflow and the stormwater runoff loads have been completed under separate work scope. This report presents calculations for the atmospheric deposition and point source discharges. The atmospheric deposition calculations are based on the equivalent rainfall estimates used in the modeling for the stormwater runoff. Rainfall chemistry data were obtained from the National Atmospheric Deposition Program (NADP) site at Kennedy Space Center (Florida), with additional data from the St. Johns River Water

Management District (SJRWMD) site at Coconut Point in Sebastian Inlet. Figure 1-1 shows the locations of the two stations in relation to the IRL Lagoon Basins (Northern, Central, and Banana River). Following methods used previously for estimation of atmospheric deposition to Tampa Bay, Sarasota Bay, and Charlotte Harbor, monthly total atmospheric deposition (sum of wet and dry deposition) for both total nitrogen (TN) and total phosphorus (TP) were calculated. Point source loads were developed using Florida Department of Environmental Protection (FDEP) monthly Discharge Monitoring Report (DMR) data.

The objective of this report is to provide estimated total monthly loads (from point sources and atmospheric deposition) to each seagrass segment in the IRL from January 1995 to December 2010 for total nitrogen and total phosphorus. Within the report, estimated pollutant loadings are presented for the larger basins (Banana River, IRL North, and IRL Central), as well as by individual seagrass segments. Section 2 presents the methodology and results for the atmospheric deposition. Section 3 presents the methodology and results for the point source discharges. Additionally, the report provides comparisons between the four types of load (baseflow, stormwater, atmospheric, and point sources) both temporally and spatially throughout the study area (Section 4).

2.0 ATMOSPHERIC DEPOSITION

Total atmospheric deposition is defined as the sum of wet deposition (rainfall) and dry deposition (gaseous constituent interaction and dust fallout) directly to the surface of the lagoon system. Atmospheric deposition of nutrients to the larger watershed is incorporated into nonpoint source loading estimates provided by the Pollution Load Screening Model (PLSM).

Three data types are needed to estimate total atmospheric deposition:

- An estimate of the hydrologic load directly to the surface via precipitation,
- An estimate of the pollutant concentration in that precipitation, and
- An estimate of dry deposition from empirical data or model-based estimates.

The segment-specific hydrologic loads to the surface of the IRL via precipitation were based upon the hydrologic load or rainfall calculations performed for the watershed modeling. This work is being conducted under separate task. Monthly totals were provided by lagoon segment. Details on the calculation of the rainfall distribution are provided as part of the watershed modeling effort.

Long-term data for ammonium and nitrate concentrations in rainfall (wet deposition) were available from NADP Site FL99 at the Kennedy Space Center (Figure 1-1). Monthly precipitation-weighted nitrogen concentrations were obtained for 1995-2010 from this site. Appendix A (Table A-1) provides the concentration data utilized. The monthly wet TN deposition was developed by segment using these data, along with the available monthly rainfall from the watershed modeling effort. For each month, the rainfall and concentration were multiplied to develop the load for each parameter. The total TN was simply the sum of these two loads by month. The calculated monthly values are plotted within Appendix B.

At the FL99 site, no measurements of phosphorus concentrations in rainfall were available, and no measurements to allow estimation of dry deposition of either nitrogen or phosphorus were taken. Additional atmospheric deposition data are available from the SJRWMD Site IRL141, at Coconut Point in Sebastian Inlet and the Clean Air Status and Trends Network (CASTNET) at the same location (Figure 1-1). SJRWMD gathers wet deposition data,

whereas CASTNET maintains the dry measurements. A table of the monthly data, provided by SJRWMD, is presented in Appendix A (Table A-2). These data were available from August 2001 to December 2006. While the monitoring stations have continued to collect data since 2006, the data have not been subjected to a quality assurance and quality control (QA/QC) analysis, so that at this time, only data from 2001 through 2006 are utilized. In addition to the monthly data, CASTNET developed calculations of the annual wet and dry TN deposition from 2002 through 2009 at the same location. These data are summarized in Appendix A (Table A-3). Table 2-1 provides a summary of the available data.

Table 2-1. Summary of Available Atmospheric Deposition Stations for the Indian River North and Central Lagoons and Banana River Coastal Region

Station	Agency	Description	Data Period	Latitude	Longitude	Collects
IRL141	EPA/SJRWMD	Indian River Lagoon	8/01-12/06	27.849	-80.4554	Dry and Wet Deposition (TN, TP)
FL99	NOAA	Kennedy Space Center	08/83-Present	28.5428	-80.644	Wet Deposition (TN)

Source: EPA and NOAA.

The goal of this effort was to develop monthly atmospheric loads for each segment in the lagoon from 1995 through 2010. Based on the available data, only TN wet was measured for the entire period (FL99). To develop the TP wet load, the TN dry load, and the TP dry load for the entire period, relationships between TN wet and these other components were developed. The data from the IRL141 station and the CASTNET calculations were utilized to accomplish this.

Since no measurements of TP deposition in rainfall were made at the long-term site FL99, the data from IRL141 were evaluated for any relationship between wet deposition of nitrogen and that of phosphorus. Figure A-1 in Appendix A provides a plot showing the measured TN wet versus the measured TP wet for the data at IRL141. The data indicate a relationship of the form:

$$\text{Wet TP (kg/ha)} = 0.00159 + 0.01359 * \text{Wet TN (kg/ha)}$$

with an r^2 of 0.70 (indicating that 70 percent of the variation in wet TP deposition is explained by variation in wet TN deposition). Assuming that this relationship is the same at

FL99 as at IRL141 allows derivation of wet TP depositions as a function of wet TN deposition at FL99 for the full period 1995 to 2010.

Using the CASTNET data presented in Appendix A (Table A-3), the annual dry TN flux was calculated using the equation:

TN_{dry} (kg/ha) = (hNO_{3dry} (kg/ha) x 0.2223) + (NO_{3dry} (kg/ha) x 0.2259) + (NH_{4dry} (kg/ha) x 0.7765) (Based on molecular weight)

The wet TN flux was then calculated by summing wet annual NH_4 and NO_3 values. Annual ratios of dry to wet deposition were developed based upon these calculations. The values ranged from 0.21 to 0.41, with an average value of 0.28. Using the average value, the monthly TN dry deposition for the full 15-year period was calculated from the TN wet deposition at FL99 using the formula:

TN_{dry} (kg/mo) = TN_{wet} (kg/mo) x 0.28

Finally, to calculate the TP dry deposition, the IRL141 monthly data (Appendix A, Table A-2) were evaluated to develop the relationship between TP_{dry} and TP_{wet}. The TP dry fluxes were calculated from the data in Table A-2 from 2001 to 2006 using the following formula:

TP_{dry} (kg/ha) = $PO4_{dry}$ (kg/ha) x 0.3261 (based on molecular weight)

Similar to the TN_{dry} calculations, the ratio of the TP_{dry} to TP_{wet} was derived from the data in Table A-2. Ratios were developed using the monthly data from all the years. These ranged from 0.05 to 0.60, with an average of 0.21. Using the average value, the TP_{dry} was calculated from the TP_{wet} based on the formula:

TP_{dry} (kg/mo) = 0.21 x TP_{wet} (kg/mo)

These calculations provided the monthly wet and dry TN and TP depositions from 1995 to 2010. Figures 2-1 through 2-9 provide bar graphs showing the annual measured/calculated TN and TP depositions, along with the associated total rainfall or direct hydrologic load for

each of the primary basins. Appendix B provides plots of the monthly values by seagrass segment.

To provide a comparison of the atmospheric deposition utilized for this study versus that utilized in the original TMDL, data from the FDEP TMDL document (FDEP, 2009) are presented in Table 2-2. Loading numbers are based on the FDEP baseline year, which was based on average hydrologic conditions from 1975 through 2005. This represents yearly average rainfall of 53.2 inches for IRL North, 53.3 inches for IRL Central, and 50.6 inches for Banana River, respectively. The table shows the percent differences between FDEP calculations by segment for both TN and TP. The results show that overall, the TN loads are very similar, with an average system wide error of +3 percent. The TP loading shows generally that calculations presented have lower TP loads than those FDEP calculated.

Table 2-2. Comparison to FDEP Calculated Atmospheric Deposition

	1995-2010 Average (Rainfall = 49.1 inches)		FDEP Base Year		1995 Average (Rainfall = 54.1)		Percent Difference (1995 to FDEP Base)	
Segment	TN (lb/yr)	TP (lb/yr)	TN (lb/yr)	TP (lb/yr)	TN (lb/yr)	TP (lb/yr)	TN (lb/yr)	TP (lb/yr)
BR 1-2	78590	1432	73486	1649	83679	1498	14%	-9%
BR 3-5	77197	1429	83604	1876	84625	1524	1%	-19%
BR 6	12335	229	15172	340	13526	244	-11%	-28%
BR 7	7263	133	7465	168	7833	140	5%	-17%
Banana River	175386	3222	179727	4033	189663	3405	6%	-16%
IR 1-3	87766	1611	88,898	2013	89488	1631	1%	-19%
IR 4	10828	196	9,670	219	10638	194	10%	-11%
IR 5	80812	1466	67630	1532	79935	1451	18%	-5%
IR 6-7	61633	1122	65531	1484	62520	1133	-5%	-24%
IR 8	13788	255	15535	352	14915	269	-4%	-24%
IR 9-11	47147	855	49875	1129	50718	900	2%	-20%
IRL North	301974	5505	297139	6729	308213	5578	4%	-17%
IR 12	34956	630	35051	794	35077	632	0%	-20%
IR 13	14499	262	14915	338	13970	256	-6%	-24%
IR 14-15	58362	1054	56734	1285	54685	1007	-4%	-22%
IR 16-20	25323	460	24591	557	25238	460	3%	-17%
IR 21	10110	183	10415	236	10287	186	-1%	-21%
IRL Central	143250	2590	141706	3210	139256	2540	-2%	-21%
IRL Totals	620611	11317	618572	13972	637132	11523	3%	-18%

CASTNET provided annual TN deposition calculations at the Sebastian station. These data were compared to the calculated TN deposition at the IR 14-15 segment, the closest segment to Sebastian Inlet. Table 2-3 provides the comparisons. The largest annual error is 25 percent.

Table 2-3. Comparison of CASTNET Annual Total TN Deposition with Total TN Deposition Calculated for Segment IR 14-15

Year	CASTNET TN (kg/ha)	Calculated TN (kg/ha)	Percent Difference
2002	3.90	4.45	14%
2003	3.97	3.85	-3%
2004	3.89	4.87	25%
2005	4.60	4.47	-3%
2006	3.03	2.90	-4%
2007	3.64	3.61	-1%
2008	3.42	3.84	12%
2009	3.04	3.70	22%

3.0 INDUSTRIAL AND DOMESTIC POINT SOURCE DISCHARGES

The FDEP (Gao, 2009) identified 41 facilities permitted under the National Pollutant Discharge Elimination System (NPDES) in the IRL basin. Of these, 19 have generic permits and have no requirements for routine monitoring. These facilities are all concrete batch plants and, while discharges may be "high in turbidity and may also change the pH of receiving waters, they are generally not considered major sources of nutrients (Gao, 2009)." Of the remaining 22 facilities, three are domestic wastewater facilities [the New Smyrna Beach Water Reclamation Facility (WRF) (FL0172090), Edgewater Wastewater Treatment Facility (WWTF) (FL0021431), and Brevard County Utilities Department (BCUD)/South Central Regional WWTF (FL0102679)] that do not discharge to the basin. The Vero Beach Municipal Power Plant (FL0002984) is not a source or discharger of additional nutrients to the system, and two others, the Cape Canaveral Air Force Station (CCAFS) Regional WWTF (FL0102920) and the Titusville Osprey WRF (FL0103268) are reuse facilities with no discharge to the IRL. The remaining 16 permit holders contribute nutrients to the system. These facilities, together with their NPDES permit numbers, facility type, location, and discharge segment, are provided in Table 3-1.

The data for the monthly flow, TN, and TP were based upon Monthly Operating Reports (MORs) and DMRs obtained from the FDEP for 1995 to 2010.

A database of domestic point source discharge information was developed, including monthly discharge rates and TN and TP concentration data. Both surface water dischargers and facilities with land application of effluent were included. Based upon the analyses of the data, specific discharges were identified as having insignificant total loads and, therefore, their monthly values were not included. These include the following:

- FL0021571 – City of Rockledge WWTP
- FL0001473 – Florida Power & Light Cape Canaveral Plant
- FL0000680 – Reliant Energy Indian River Power Plant

Table 3-1. Point Source Facilities that Discharge into the IRL and Banana River Lagoon

NPDES Permit Number	Facility Name	Facility Type	City, County	Impacted Seagrass Segment
FL0021521	Cocoa/J. Sellers WWTP	Domestic WWTP	Cocoa, Brevard	IR6-7
FL0001473	Florida Power & Light (FPL) Cape Canaveral Power Plant	Power Plant with RO	Cocoa, Brevard	IR6-7
FL0042005	Morton Salt	Industrial Wastewater	Cape Canaveral, Brevard	BR1-2
FL0020541	City of Cape Canaveral	Domestic WWTP	Cape Canaveral, Brevard	BR3-5
FL0021105	City of Cocoa Beach	Domestic WWTP	Cocoa Beach, Brevard	BR3-5
FL0000680	Reliant Energy Indian River	Power Plant	Titusville, Brevard	IR6-7
FL0021571	City of Rockledge WWTP	Domestic WWTP	Rockledge, Brevard	IR8
FL0043443	Melbourne RO WTF	RO	Melbourne, Brevard	IR9-11
FL0040622	Brevard County Utilities Department (BCUD)/ South Beaches	Domestic WWTP	Melbourne, Brevard	IR12
FL0041122	Melbourne/Grant St. WWTP	Domestic WWTP	Melbourne, Brevard	IR12
FL0042293	Barefoot Bay WWTP	Domestic WWTP	Barefoot Bay, Brevard	IR14-15
FL0021661	City of Vero Beach WWTP	Domestic WWTP	Vero Beach, Indian River	IR16-20
FL0042544	Vero Beach RO WTF	RO	Vero Beach, Indian River	IR16-20
FL0166511	Indian River County Utilities Department (IRCUD)/ Hobart RO WTF	RO	Vero Beach, Indian River	IR16-20
FL0041637	IRCUD/West Regional	Domestic WWTP	Vero Beach, Indian River	IR16-20
FL0037940	IRCUD/South RO WTF	RO	Vero Beach, Indian River	IR16-20

Source: FDEP, 2011.

The DMR data for each of the remaining discharges were entered into the database. Of the 13 remaining discharges, four had highly sparse data, or highly limited periods of discharge, which precluded the development of reasonable monthly loads. These facilities are:

- FL0040622 - BCUD/South Beaches
- FL0041122 - Melbourne/Grant St. WWTP
- FL0042293 - Barefoot Bay WWTP
- FL0042005 Morton Salt

The data for the remaining nine discharges were used to calculate the loads (in pounds per month) from 1995 to 2010. Where data indicated no discharge, the values were set to 0 for that month. Figures 3-1 through 3-9 present the annual total loads from 1995 to 2010 for each of the nine discharges. The individual segments to which the discharges flow are listed in Table 3-1.

The database was subjected to quality control measures to ensure that the most accurate flows and concentrations obtainable were used in the loading estimates. The entries were scanned for incongruous data points. Obvious outliers (such as flows of two or three orders of magnitude higher than the design capacity of the facility) were removed from the record. Complete records existed for most domestic WWTFs, with facilities reporting flow rate and concentrations for TN and TP on a monthly basis.

For those data gaps that could not be filled with actual recorded data, two methods were used to complete the record, depending upon the amount of data missing, as follows:

- If 1 to 3 consecutive months of data were missing, discharge and/or pollutant concentrations were set to those of the last month for which values existed.
- If data from more than 3 consecutive months were missing, discharge and/or pollutant concentrations were set to the monthly averages for the remaining data for that year.

4.0 COMBINED LOADS

Utilizing the baseflow and stormwater runoff from the watershed modeling work, monthly total loads were developed by segment. These represent the total loads to be utilized in development of correlations between receiving water quality and loads. Annual total loads were developed by summing the monthly loads and combining the seagrass segment loadings into the three primary basins within the Indian River Lagoon (Banana River, IRL North, and IRL Central).

Figures 4-1 through 4-3 present the annual hydrologic loads to the three primary basins. The results are presented for the baseflow, stormwater runoff and atmospheric load. The point source flow values are insignificant in comparison to the other contributions; therefore, these were not included. The plots show the difference in the relative contribution of each of the sources between the basins.

Figures 4-4 through 4-6 present the annual TN loads to the three primary basins. The results are presented for the baseflow, stormwater runoff, atmospheric load, and point source loads. The plots show the difference in the relative contribution of each of the sources between the basins. Table 4-1 presents the average percent contribution for each over the full period from 1995 to 2010.

Table 4-1. Relative Contribution of Nutrient Loads to Indian River Lagoon North, Indian River Lagoon Central, and Banana River Lagoon

	Baseflow		Runoff		Atmospheric		Point Sources	
Location	TN	TP	TN	TP	TN	TP	TN	TP
Banana River	44%	51%	18%	32%	34%	8%	4%	9%
IRL North	52%	54%	23%	40%	24%	5%	1%	1%
IRL Central	60%	53%	31%	44%	6%	1%	2%	3%

Figures 4-7 through 4-9 present the annual TP loads to the three primary basins. The results are presented for the baseflow, stormwater runoff, atmospheric load, and point source loads. The plots show the difference in the relative contribution of each of the sources between the basins. Table 4-1 presents the average percent contribution for each over the full period from 1995 to 2010.

Examination of the results shows that the relative contributions of the watershed (baseflow and runoff) load versus the atmospheric load varies considerably by basin. The atmospheric load plays the greatest role in the TN loads, with up to a 34 percent contribution, on average, in the Banana River versus less than 10 percent in the IRL Central. Atmospheric deposition of TP, in contrast, plays less than a 10 percent role in any basin, with near a 1 percent contribution in the IRL Central.

5.0 BIBLIOGRAPHY

Gao, Xueqing. 2009. TMDL Report - Nutrient and Dissolved Oxygen TMDLs for the Indian River Lagoon and Banana River Lagoon, March 2009. Division of Environmental Assessment and Restoration, Bureau of Watershed Management. Tallahassee, Florida. Florida Department of Environmental Protection, 2009. p. 71.

Appendix A

Monthly Wet Deposition Concentration Data at National Atmospheric Deposition Program (NADP) Site (FL99) at the Kennedy Space Center and Monthly Wet and Dry Deposition Concentration Data the CASTNET and SJRWMD Site (IRL141) at Sebastian Inlet

Appendix B

Monthly Atmospheric Deposition Plots