City of Naples
Semi-annual and Quarterly Stormwater Infrastructure Monitoring
Final Report

Prepared for:
City of Naples
Department of Streets and Stormwater

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List of acronyms and abbreviations

AMEC	AMEC Environment & Infrastructure, Inc.
BMPs	Best Management Practices
CFU	Colony Forming Units
City	City of Naples
DO	dissolved oxygen
FDEP	Florida Department of Environmental Protection
mg/L	milligrams per liter
mL	milliliter
MPN	Most Probably Number
ng/L	nanograms per liter
Q1	Quarter 1
SOPs	Standard Operating Procedures
TKN	Total Kjeldahl nitrogen
TMDL	Total Maximum Daily Load
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
µg/L	micrograms per liter
USDA	US Department of Agriculture
WBID	Water Body Identification

Glossary of Chemical Analysis Data Qualifiers Appearing in this Report

U and ND – These qualifiers have the same meaning, but different laboratories use different codes in conformance with their specific Quality Assurance procedures. Indicates that the compound was analyzed for but not detected. For example, if a chemical analysis result is shown as 0.10 U, 0.10 is the method detection limit. Therefore, “0.10 U” has an equivalent meaning as < 0.10. The chemical was not detected, and if the concentration were greater than 0.10, it could be detected.

I or J - These qualifiers have the same meaning, but different laboratories use different codes in conformance with their specific Quality Assurance procedures. Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit. Although the laboratory is confident the chemical is present in the sample, it is below the laboratory's practical quantitation limit, and therefore the concentration reported is less reliable.

B – used for bacterial counts. It is desirable that the number of colonies counted during the test is within 20 to 60 colonies per membrane. Counting the number of colonies is more reliable within the specified range – if too many it is hard to distinguish colonies; if too few, statistical uncertainty is higher. The laboratory may dilute samples to achieve the desired range, but it is not always possible to estimate the appropriate dilution prior to preparation of samples. The laboratory may rely on past results from the same facility/sample location to estimate the appropriate dilution.

V – The analyte was detected in a laboratory blank sample. This may indicate contamination within the laboratory. Where the V qualifier is reported, AMEC has reviewed the concentration of contamination reported in the laboratory blank and compared that with the concentration in the environmental samples. If the level in the blank is approximately equal to or greater than the concentration in the samples, AMEC overrides the laboratory's report by indicating the contaminant was not detected, annotating a higher detection limit in affected sample batches. If the level in the blank is much lower than the concentration in the environmental samples, the result is accepted and used as valid. For any data reported with a V qualifier under this contract, AMEC determined that the contamination level in the laboratory blanks was much lower than in the potentially affected environmental samples, and the reported data are usable.

Table of Common Names of Lakes compared with Lake Numbers

Lake #	Lake Name
1	Devils Lake
2	Swan Lake
3	Colonnade Lake
4	Hidden Lake
5	Lake Suzanne
6	Mandarin Lake
7	Naples Beach Club/Yucca Lake
8	North Lake
9	South Lake
10	Alligator Lake
11	Spring Lake
31	East Lake
12	Lake btw 14th & 15th Ave S
13	Lake btw 17th & 18th Ave S
14	Lantern Lake
15	Sun Lake Terrace
16	Thurner Lake
17	County Lake
18	
19	15th Ave N Lake (WTP Lake)
20	Forest Lake
21	Willow Lake
22	Lake Manor
23	Lowdermilk Lake
24	Half Moon Lake
25	Lake btw 16th & 17th Ave S
26	NCH Lake

1.0 Introduction

The City of Naples (City) has contracted AMEC Environment & Infrastructure, Inc. (AMEC) to conduct regular water quality monitoring of the City's stormwater lakes and conveyances. This report presents the results of stormwater and lakes monitoring conducted by AMEC during 2012, as well as an update to the prioritization strategy and remediation recommendations provided in the previous report submitted to the City (AMEC, 2012). Sampling conducted as part of this project and discussed in this report include the biannual lakes monitoring and source tracking efforts conducted in April and September of 2012, as well as the quarterly pump station monitoring conducted in April, July, September and December of 2012. The results of this continued monitoring have been used to fill data gaps identified by the previous report (AMEC, 2012) and to develop recommendations for structural and non-structural Best Management Practices (BMPs) that may be used by the City to improve the water quality of its stormwater lakes and the receiving waters of the state.

1.1 Work Efforts Performed by AMEC

1.1.1 Quarter 1 Monitoring

From April 4, 2012 through April 6, 2012, AMEC, under the City's direction, conducted stormwater sampling in major stormwater conveyances associated with selected City stormwater lakes and infrastructure. Sampling locations were determined based on past sampling efforts and findings (see AMEC, 2012 for additional discussion of historic water quality and sampling efforts). Grab samples were collected from storm sewers, selected stormwater lakes, and pump stations. Sampling was performed in accordance with Florida Department of Environmental Protection (FDEP) Standard Operating Procedures (SOPs) FQ 1000 (Quality Control), FS 2100 (Surface Water Sampling) and FT 1000 (Field Testing General), and was conducted using methods and locations consistent with prior sampling conducted by MACTEC Engineering & Consulting, Inc. (now AMEC) for the City in 2009, 2010 and 2011.

During the April 2012 sampling event, 0.04 inches of rainfall occurred on the evening of April 5, while 0.72 inches of rainfall occurred during the middle of the day on April 6. Prior to the April 2012 sampling event, the most recent significant (greater than 0.10 inches) rainfall event occurred on March 16, 2012, at 0.85 inches. For analysis purposes, it can be assumed that antecedent conditions for all sampling locations except 4th Ave. Alley occurred following a span of relatively dry conditions, which also coincided with the end of the local dry season. Sample location 4th Ave. Alley was sampled during the storm event on April 6, as it was a unique opportunity to obtain "1st flush" characteristics of the flow coming from the commercial area along 5th Ave. The results of this sample location are discussed further in Section 2.3.4.

1.1.2 Quarter 2 Monitoring

On July 5, 2012, AMEC collected water samples from the three pump stations located throughout the City. Sampling procedures were as described in Section 1.1.1.

Prior to the July 2012 sampling event, 0.50 inches of rainfall occurred on July 4, 2012. For analysis purposes, it can be assumed that antecedent moisture conditions were representative of the South Florida wet season, in which rainfall events generally occur more than once per week and do not allow significant "first flush" characteristics to build up within the watershed as compared to dry season events.

1.1.3 Quarter 3 Monitoring

From September 25, 2012 through September 27, 2012, AMEC, under the City's direction, conducted stormwater sampling in major stormwater conveyances associated with selected City stormwater lakes and infrastructure. Sampling locations were similar to Quarter 1 locations, with the exception of the source tracking locations. Grab samples were collected from storm sewers, selected stormwater lakes, and pump stations. Sampling procedures were as described in Section 1.1.1.

During the September 2012 sampling event, .07 inches of rainfall occurred on the evening of September 25, while the remaining sampling days received no rainfall. Prior to the September 2012 sampling event, rainfall events were fairly consistent, with few dry periods that lasted more than 72 hours. For analysis purposes, it can be assumed that antecedent conditions followed a span of wet conditions, representative of the end of the local wet season.

1.1.4 Quarter 4 Monitoring

On December 6, 2012, AMEC collected water samples from the three pump stations located throughout the City as well as at the discharge point of the water treatment plant's reclaimed water distribution system. Sampling procedures were as described in Section 1.1.1.

Prior to the December 2012 sampling event, 0.11 inches of rainfall occurred on November 6, 2012. For analysis purposes, it can be assumed that antecedent moisture conditions were representative of the South Florida dry season.

1.2 Current and Recent City Action

Over the past several years, the City has taken several approaches aimed at addressing some of the water quality issues affecting their stormwater. Included here is a brief synopsis of some of the meaningful action items the City has implemented.

Aerators

Aerators are designed to promote increased circulation and oxygenation to the entire water column, allowing the natural processes responsible for nutrient and pollutant sequestration to occur more efficiently and to reduce the chance of the bottom sediments becoming anoxic, which generally results in nutrient solubilization and release. They can be an effective first step in the overall remediation of a stormwater treatment pond, and should be used concurrently with steps to reduce overall external loading to the system. To date, the City has installed aerators in 9 of its stormwater lakes, of which 1 was installed in the 2012 fiscal year (FY).

Floating Islands

Floating Islands are a low cost way of providing additional treatment capacity within an existing stormwater treatment body or restoring the condition of a eutrophied lake or pond. With regular maintenance (harvesting) and coverage of just 5% of the targeted waterbody, FDEP is currently crediting floating islands with 20% removal of total nitrogen and total phosphorus. The City currently has a total of 13 floating islands installed in 6 of its stormwater lakes. The first of these was installed in July 2009, and the program has been growing, with seven installed in FY 2012.

Roadside Stormwater Swales

Roadside stormwater swales are an effective way of increasing filtration and infiltration of the stormwater runoff generated on roads and sidewalks, and typically do not require large amounts of space. From 2010 to present, the City has restored or installed approximately 2.5 miles of swales.

Several of these projects have been installed so recently that AMEC has not collected enough post-installation water quality data to evaluate their benefits.

2.0 Background Information

2.1 Impaired Waters

One of the primary reasons for performing a water quality evaluation for the City's stormwater is there are multiple downstream waterbodies that are currently impaired for various pollutants. The Gordon River Extension [Water Body Identification (WBID) 3278K] and Naples Bay Coastal (WBID 3278R) are impaired according to the Everglades West Coast Group 1 Basin/ South District verified list published by FDEP in May of 2009. Naples Bay is impaired for copper, fecal coliform, dissolved oxygen (DO), and iron. The Gordon River Extension is impaired for DO, and causative pollutants are identified as total nitrogen (TN) and total phosphorus (TP). The concentration causing impairment for copper is ≥ 3.7 micrograms per liter (µg/L) fecal coliform is > 43 colony forming units (CFU)/100 milliliters (mL), iron is > 0.3 milligrams per liter (mg/L), and DO is < 4.0 mg/L. Of these parameters, all but fecal coliform (Low Priority) were identified as Medium Priority for Total Maximum Daily Load (TMDL) Development (EWC, 2009).

Although the causative pollutants for impairment are not quantitatively described for either the Gordon River or Naples Bay, a point of reference may be helpful in using the reference concentration used for the Gordon River TMDL, which identifies TN as 0.74 mg/L and TP as 0.04 mg/L.

2.2 Unique Element of 2012 Monitoring – Caffeine Added as Indicator of Human Wastes

A unique aspect of the current monitoring effort includes the analysis of caffeine in selected samples, which has been chosen by AMEC and the City to be used as an indication of anthropogenically derived bacterial sources. Because caffeine is a relatively ubiquitous substance in human waste streams and is often found in concentrations that can be easily detected given current analytical methods, it can be used in source tracking efforts where anthropogenic bacterial contamination is suspected. Caffeine concentrations that have been observed in sanitary effluents, stormwater, and surface waters are summarized in Table 2. Although concentrations range widely, most observations of sanitary effluent exceed 1,000 nanograms per liter (ng/L), while effective treatment systems in the US (Oppenheimer, *et al.*, 2011) generally reduce average caffeine levels in treated sanitary effluents to 127 ng/L; surface water bodies with little or no anthropogenic input are likely to have concentrations less than 50 ng/L. Stormwater was characterized by Sankararamakrishnan and Guo (2005) who found very high concentrations in one stormwater sample from Asbury Park, NJ, a location with a very old sanitary sewer system, but more typical values observed were from 200 to 500 ng/L.

Table 2-1. Summary of Caffeine Concentrations Observed in Surface Waters and Effluents

Reference	Sample Type	Caffeine (ng/L)
Buerge, *et al.* (2003)	Untreated effluent	7,000-73,000
	Treated effluent	30-9,300
	Lakes and rivers	60-250
	Mountain lakes	< 2
Glassmeyer, *et al.* (2005)	rivers	40-2,600
	Treated effluent	53-7,990
Sankararamakrishnan and Guo (2005)	Stormwater	144-44,700
Oppenheimer, *et. al.* (2011)	Treated effluent	127
	Surface water affected by effluent	64
	Surface water no effluent	ND
Kolpin, *et* al. (2002)	Streams	81-6,000

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3.0 Monitoring Results

Included in this section is a discussion of sampling locations and results. Locations were determined based on previously identified data gaps, as well as areas that, based on past data, may represent potentially elevated pollutant sources. Although the majority of samples taken represent non-storm related base flow conditions, the results of these sampling efforts provide useful information that allow for the characterization of long-term water quality and stormwater lake condition. Ultimately, the results will be used to identify those areas that will benefit most from targeted structural and non-structural BMPs.

3.1 Pump Station Monitoring Results

As a quarterly effort, each of the City's 3 main pump stations have been sampled for TN, TP, total suspended solids (TSS), copper, fecal coliform, and enterococcus as a continued monitoring effort of three locations that represent significant dry and wet weather hydrologic and nutrient loading to downstream impaired waters. Caffeine has been used selectively at these locations where source identification is desired. Table 3-1 shows the results from the current year monitoring efforts at each of the three pump stations. Sample locations are given in Figures 3-1 through 3-4, which shows all sample locations by drainage basin. PW-Pump is also commonly referred to as the Public Works Pump, 11-Pump as Cove Pump, and 14-Pump as Lantern Lane Pump.

Table 3-1. 2012 Quarterly Pump Station Monitoring

Sample ID		**TKN**	**NOx**	**TN**	**TP**	**TSS**	**Cu**	**FC**	**Ent.**	**Caff.***
Units		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(cfu/100 mL)	(MPN)	(ng/L)
PW-Pump	Q1	1.1	0.22 I	1.3	0.069	2.8	2.0	3400	870	14 I
	Q2	0.92	0.27	1.2	0.080	7.6	8.2 V	1980 B	500	
	Q3	0.83	0.26 I	1.1	0.088	4.8	38	4200	516	
	Q4	1.1	0.30	1.4	0.099	1.2	1.3 I	5200	437	
11-Pump	Q1	1.2	0.41 I	1.6	0.12	3.6	1.7 I V	9910 B	1730	150
	Q2	1.3	0.22	1.5	0.14	4.0	2.9	112000 B	200	630
	Q3	1.3	0.46 I	1.8	0.60	5.2	3.2	4700	127	260 ND
	Q4	1.4	0.41	1.8	0.13	2.8	1.1 I	450 B	501	50 U
14-Pump	Q1	0.88	0.18 I	1.1	0.83	4.8	2.9 V	4000	300	32 I
	Q2	0.86	.047 I	0.91	0.15	54	45 V	1350 B	1200	
	Q3	1.1 J3	0.10 U	1.1	0.16	74	3.6	220	333	
	Q4	1.6	0.32	1.9	0.40	4.0	2.2	360 B	550	

U - Indicates that the compound was analyzed for but not detected
B - Results based upon colony counts outside the acceptable range
I - Indicates the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit
* Caffeine not analyzed in all samples

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3.2 Semi-annual Sampling Locations

A significant portion of the 2012 monitoring efforts include continued monitoring of 18 stormwater lakes. Locations were identified by AMEC and the City based on the findings of AMEC (2012) addressing areas with relatively high pollutant loading, poorly functioning stormwater lakes, and/or data gaps. Results from these locations will be used to substantiate future structural and non-structural BMPs targeted at treatment of stormwater lake quality. Table 3-2 shows the results from the current year efforts of each monitored lake, while Figures 3-1 through 3-4 show sample locations by major drainage basin. A photo log of 2012 sample locations is also given in Appendix C.

Table 3-2. 2012 Biannual Lakes Condition Assessment

Sample ID		**TKN**	**NOx**	**TN**	**TP**	**TSS**	**Cu**	**FC**	**Ent.**	**Caf.***
Units		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(cfu/10 0 mL)	(MPN)	(ng/L)
1NW	Q1	0.96	0.10 U	0.96	0.028	1.0 U	9.8	100 U	3	
1SE	Q3	0.75	0.10 U	0.75	0.076	24	17	231 B	100	
2B	Q1	1.2	0.10 U	1.2	0.10	8.8	12	180 B	461	
	Q3	0.85	0.10 U	0.85	0.045	6.4	6.2	1840 B	961	
3B	Q1	1.1	0.10 U	1.1	0.11	4.8	5.6	1440 B	140	
	Q3	1.0	0.10 U	1.0	0.13	5.2	2.8	259 B	47	
5B	Q1	5.3	0.10 U	5.3	0.42	17	10	270 B	84	
	Q3	0.89	0.10 U	0.89	0.12	4.8	3.0	310	7	
6B	Q1	0.83	0.10 U	0.83	0.048	2.4	0.63 I	100 U	9	
	Q3	1.2	0.10 U	1.2	0.13	11	0.46 I	5200	101	
7B	Q1	3.7	0.10 U	3.7	0.17	18	6.0	100 U	118	
	Q3	1.6	0.10 U	1.6	0.084 J3	24	20	15 B	27	
8B	Q1	1.3	0.10 U	1.3	0.060	6.8	4.9	100 U	270	
	Q3	1.4	0.10 U	1.4	0.077	9.2	1.7 I	162 B	51	
9B	Q1	1.3	0.10 U	1.3	0.17	6	11	100 U	34	
	Q3	1.1	0.10 U	1.1	0.047	16.0	3.1	66	49	
10B	Q1	1.6	0.10 U	1.6	0.095	9.6	1.9 I	721 B	182	
	Q3	1.1 J3	0.10 U	1.1	0.031	8.0	1.8 I	374 B	186	
11B	Q1	1.2	0.10 U	1.2	0.056	3.6	4.9 V	100 U	93	
	Q3	0.99	0.10 U	0.99	0.11	3.6	3.0	489 B	194	
14B	Q1	0.76	0.10 U	0.76	0.89	7.2	3.4 V	100 U	372	ND 13
	Q3	1.9	0.10 U	1.9	0.22	14	2.3	2 U	142	
15B	Q1	1.2	0.10 U	1.2	0.023	4.4	41	100 U	46	
	Q3	0.89	0.10 U	0.89	0.030	4.80	8.2	230	17	
16B	Q1	0.85	0.10 U	0.85	0.015	1.0 U	1.1 I	90 B	24	
	Q3	0.91	0.10 U	0.91	0.022	3.60	0.28 I	490	39	
19B	Q1	2.2	0.19 I	2.4	0.055	4.4	1.2 I	180 B	313	
	Q3	1.20	0.10 U	1.2	0.047	8.4	0.39 I	410	27	
20B	Q1	1.6	0.10 U	1.6	0.062	8.4	0.60 I	100 U	29	
	Q3	1.80	0.10 U	1.8	0.068	13	0.91 I	4000	2420	
21B	Q1	1.1	0.10 U	1.1	0.0044 U	2.0	2.5	360 B	8	
	Q3	0.67	0.10 U	0.67 I	0.022	6.4	1.9 I	492	24	
22B	Q1	0.85	0.10 U	0.85	0.0091 I	1.2	1.1 I	100 U	8	
	Q3	0.85	0.10 U	0.85	0.10	8.8	0.64 I	2340 B	378	
26B	Q1	0.59	0.10 U	0.59 I	0.037	1.6	57	180 B	68	
	Q3	0.76	0.10 U	0.76	0.065	6.0	61 V	890 B	2	

U - Indicates that the compound was analyzed for but not detected
B - Results based upon colony counts outside the acceptable range
I - Indicates the reported value is between the laboratory method of detection limit and the laboratory practical quantitation limit
* Caffeine not analyzed in all samples.

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3.3 Roaming Sampling Locations

Roaming samples, also referred to as source identification samples, are intended to identify possible sources in areas where past sampling have indicated relatively high concentrations of one or more stormwater contaminants of interest. During this year's stormwater characterization program, caffeine has been added as an indicator of the significance of human waste, such as leaking sewers or septic systems. Sucralose, an artificial sweetener, was also analyzed in source identification samples collected in April 2012, but sucralose was not detected in any samples apparently due to interferences affecting the analytical method. Therefore sucralose will not be tested in future sample events, and the results are not discussed further. Table 3-3 shows the results from current year monitoring efforts at each of the selected roaming locations, while Figures 3-1 through 3-4 show sample locations by major drainage basin. A photo log of 2012 sample locations is also given in Appendix C.

Table 3-3. 2012 Roaming Location Samples

Sample ID		**TKN**	**NOx**	**TN**	**TP**	**TSS**	**Cu**	**FC**	**Ent.**	**Caf.**
Units		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(cfu/ 100mL)	(MPN)	(ng/L)
1A	Q1	1.1	0.10 U	1.1	0.10	4.4	9.6	180 B	96	
11A	Q1	1.9	0.10 U	1.9	0.11	7.6	3.9 V	1080 B	185	440
22A	Q1	0.70	0.10 U	0.70	0.056	4.4	1.0 I	270 B	69	90
4th Ave. Alley	Q1	1.0	0.14 I	1.1	0.18	36	6.2	2160 B	100 U	550
4th Ave. Garage	Q1	0.31	0.10 U	0.31 I	0.057	1.2	2.9 V	100 U	6	
BC-Pond	Q1	2.5	0.10 U	2.5	0.27	11	6.5 V	100 U	961	
Gordon Dr.	Q1	2.0	1.2	3.2	0.56 J3	12	11 V	43000	500	120
1A3	Q3	0.71	0.10 U	0.71	0.13 J3	2.0	3.3	673 B	152	
22A3	Q3	0.76	0.10 U	0.76	0.12	3.6	0.99 I	2450 B	162	260 ND
4th Ave 3	Q3	1.2	0.10 U	1.2	0.16	2.0	3.2	508	107	260 ND
CP	Q3	1.4	0.27 I	1.7	0.14		1.7 I	2300	2420	260 ND
Gordon Dr. 3	Q3	0.46	0.10 U	0.46 I	0.020	8.8	3.5	84	28	16 I
Reuse 1	Q3	0.63	0.94	1.6	0.34	1.6	1.2 I	2 U	1 U	260 ND
Reuse 2	Q3	0.96	1.2	2.2	0.39	1.6	4.1	2 U	1 U	13 U
Reuse 3	Q4	0.82	0.33	1.2	0.74	1.6	.96 I	100 U	1 U	50 U

U or ND - Indicates that the compound was analyzed for but not detected
B - Results based upon colony counts outside the acceptable range
I or J - Indicates the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit
V - Chemical detected in laboratory blank indicating potential contamination in the laboratory. The levels observed in the blank were much lower than found in environmental samples.

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3.4 Reclaimed Water

As part of the 2012 sampling program, three samples were allocated to the City reclaimed water distribution system. Due to the increasing use of reclaimed water for residential and commercial irrigation, the City has become interested in managing the resource effectively and responsibly. AMEC collected three samples from the reclaimed water distribution system, including two samples during the Q3 sampling event and one sample during the Q4 sampling event. The two samples collected during the Q3 sampling event, Reuse 1 and Reuse 2, were collected at the water treatment plant (post treatment) and at a discharge point near the farthest southern extent of the distribution system, respectively. Due to an unanticipated laboratory interference with the caffeine result from Reuse 1, it was decided to take a second sample at the same location during the Q4 sampling event in order to obtain a more meaningful result for caffeine, as well as to obtain one more data point for all other parameters. Table 3-4 shows the results from the reclaimed water sample locations, while Figures 3-1 through 3-4 show sample locations by major drainage basin. A photo log of 2012 sample locations is also given in Appendix C.

Table 3-4. 2012 Reclaimed Water Sample Results

Sample ID		TKN	NOx	TN	TP	TSS	Cu	FC	Ent.	Caff.
Units		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(cfu/ 100mL)	(MPN)	(ng/L)
Reuse 1	Q3	0.63	0.94	1.6	0.34	1.6	1.2 I	2 U	1 U	260 ND
Reuse 2	Q3	0.96	1.2	2.2	0.39	1.6	4.1	2 U	1 U	13 U
Reuse 3	Q4	0.82	0.33	1.2	0.74	1.6	.96 I	100 U	1 U	50 U

U - Indicates that the compound was analyzed for but not detected
ND - Not detected at the reporting limit (or MDL if shown)
I - Indicates the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit

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3.5 Summary of Available Data

One goal of the current year's contract was to fill in any data gaps identified in past reports for the purpose of developing a comprehensive database of City water quality data. AMEC compiled all available data, which include sampling efforts conducted by the City in 2008 and 2009, sampling efforts conducted by MACTEC in 2009, and sampling efforts conducted by MACTEC/AMEC in 2010 and 2011. Table 3-5 is a summary of said data, organized by major drainage basin. Each value represents the mean of all available (or geometric mean for fecal coliform and *Enterococcus*), with the number of sample points (n) each mean is based on and a description of the type of sample location. Sample locations are provided in Figures 3-1 through 3-4, which correspond to the major drainage basin groupings given in the table. Sample locations provided in Figures 3-1 through 3-4 are also inclusive of sample locations discussed in Sections 3.1 through 3.4.

Table 3-5. Summary of All Available Data (page 1 of 3)

Sample ID				TN[1]	TP	Cu	FC	Ent.	Caff.[2]
Basin	Sample ID	Type	(n)	mg/L	mg/L	µg/L	cfu/100mL	MPN	ng/L
Gordon River	22A3	Conveyance	1	0.76	0.12	1.0	2450	162	260
	US41	Conveyance	4	1.7	0.33	3.8	727	858	
	15A	Lake - Influent	4	1.3	0.071	8.7	327	665	
	20A	Lake - Influent	4	1.5	0.13	4.2	366	298	
	22A	Lake - Influent	5	0.98	0.078	4.2	1801	300	
	6B	Lake - Effluent	3	1.1	0.069	5.0	1308	15	
	15B	Lake - Effluent	7	1.0	0.023	15	224	46	
	16B	Lake - Effluent	3	1.0	0.024	0.89	561	20	
	17B	Lake - Effluent	1	1.3	0.090	0.30	520	50	
	19B	Lake - Effluent	6	1.2	0.042	1.1	419	183	
	20B	Lake - Effluent	7	1.6	0.083	0.70	481	196	
	21B	Lake - Effluent	3	1.1	0.019	3.4	481	14	
	22B	Lake - Effluent	10	0.68	0.065	1.7	428	117	

Table 3-5. Summary of All Available Data (page 2 of 3)

Sample ID				**TN[1]**	**TP**	**Cu**	**FC**	**Ent.**	**Caff.[2]**
Basin	Sample ID	Type	(n)	mg/L	mg/L	µg/L	cfu/100mL	MPN	ng/L
Naples Bay	11A1	Conveyance	1	1.2	0.23	2.3	2000	1990	
	11A2	Conveyance	1	0.90	0.084	2.2	33	461	
	11A3	Conveyance	1	4.5	0.50	25	3600	7330	
	11A4	Conveyance	1	1.0	0.046	2.6	5200	378	
	11B1	Conveyance	1	1.1	0.15	2.3	1190	534	
	11B2	Conveyance	1	8.0	0.94	16	4700	11800	
	11B3	Conveyance	1	4.3	0.47	22	4200	6110	
	11B4	Conveyance	1	0.65	0.13	6.9	60	10	
	11D	Conveyance	4	1.5	0.17	1.4	944	1517	
	14A1	Conveyance	1	3.1	0.71	1.2	2900	2420	
	14A2	Conveyance	1	3.1	0.62	2.0	134	100	
	14A3	Conveyance	1	1.1	0.39	14	1530	4710	
	14A4	Conveyance	1	1.6	0.79	0.38	15200	158	
	14B2	Conveyance	1	2.6	0.98	2.7	1320	2990	
	14B3	Conveyance	1	1.4	0.16	8.7	2000	4820	
	14B4	Conveyance	1	1.8	0.28	0.38	2500	980	
	4th Ave 3	Conveyance	1	1.2	0.16	3.2	508	107	260
	4th Ave. Alley	Conveyance	1	1.1	0.18	6.2	2160	100	550
	4th Ave. Garage	Conveyance	1	0.31	0.057	2.9	100	6	
	CP	Conveyance	1	1.7	0.14	1.7	2300	2420	260
	GD	Conveyance	1	3.2	0.56	11.0	43000	500	120
	PW2	Conveyance	1	2.0	0.058	3.9	5800	3830	
	PW3	Conveyance	1	0.80	0.068	12	2300	1480	
	PW4	Conveyance	1	0.79	0.10	5.6	1200	78	
	11A	Lake - Influent	1	1.9	0.11	3.9	1080	185	440
	11B	Lake - Effluent	13	1.2	0.076	5.8	534	297	
	12B	Lake - Effluent	1	1.7	0.025	0.3	490	50	
	13B	Lake - Effluent	1	1.7	0.056	8.4	3600	130	
	14B	Lake - Effluent	3	1.6	0.51	2.0	40	117	13
	24B	Lake - Effluent	2	3.1	0.97	2.9	3919	46	
	25B	Lake - Effluent	1	1.8	0.069	5.6	2300	13	
	26B	Lake - Effluent	3	0.78	0.38	46	398	22	
	28B	Lake - Effluent	1	1.8	0.13	5.4	5300	110	
	GD3	Private Lake	1	0.46	0.020	3.5	84	28	16
	11-Pump	Pump Station	8	1.6	0.20	2.0	3346	507	273
	14-Pump	Pump Station	8	1.5	0.43	8.8	1002	1061	32
	PW-Pump	Pump Station	5	1.3	0.11	12	2629	662	14

Table 3-5 . Summary of All Available Data (page 3 of 3)

Sample ID				**TN**[1]	**TP**	**Cu**	**FC**	**Ent.**	**Caff.**[2]
Basin	Sample ID	Type	(n)	mg/L	mg/L	µg/L	cfu/100mL	MPN	ng/L
Moorings Bay	1A3	Conveyance	1	0.71	0.13	3.3	673	152	
	1A	Lake - Influent	1	1.1	0.10	9.6	180	96	
	2A	Lake - Influent	4	1.2	0.11	25	414	455	
	5A	Lake - Influent	4	1.1	0.18	6.7	97	52	
	1NW-B	Lake - Effluent	2	0.98	0.026	6.7	120	8	
	1SE-B	Lake - Effluent	2	0.98	0.062	14	152	14	
	2B	Lake - Effluent	7	0.92	0.067	15	298	290	
	3B	Lake - Effluent	3	1.1	0.12	3.7	497	24	
	4B	Lake - Effluent	1	0.95	0.068	2.1	21	8	
	5B	Lake - Effluent	7	1.7	0.16	7.3	193	31	
	23B	Lake - Effluent	1	0.70	0.021	3.7	280	23	
Sample ID				**TN**[1]	**TP**	**Cu**	**FC**	**Ent.**	**Caff.**[2]
Basin	Sample ID	Type	(n)	mg/L	mg/L	µg/L	cfu/100mL	MPN	ng/L
Gulf of Mexico	**BC**	Conveyance	4	3.1	0.26	5.2	791	105	
	BC-Pond	Private Lake	1	2.5	0.27	6.5	100	961	
	8A	Lake - Influent	4	1.3	0.16	1.5	784	144	
	7B	Lake - Effluent	2	2.7	0.13	13	39	56	
	8B	Lake - Effluent	6	1.3	0.10	2.4	112	128	
	9B	Lake - Effluent	3	1.5	0.14	6.4	105	37	
	10B	Lake - Effluent	7	1.0	0.054	2.3	83	202	

Bold = Direct Discharge
[1]Calculated as the sum of NOx and TKN
[2](n) = 3 for 11-Pump Caffeine, (n) = 1 for all other caffeine results
Caffeine was not analyzed in all samples.

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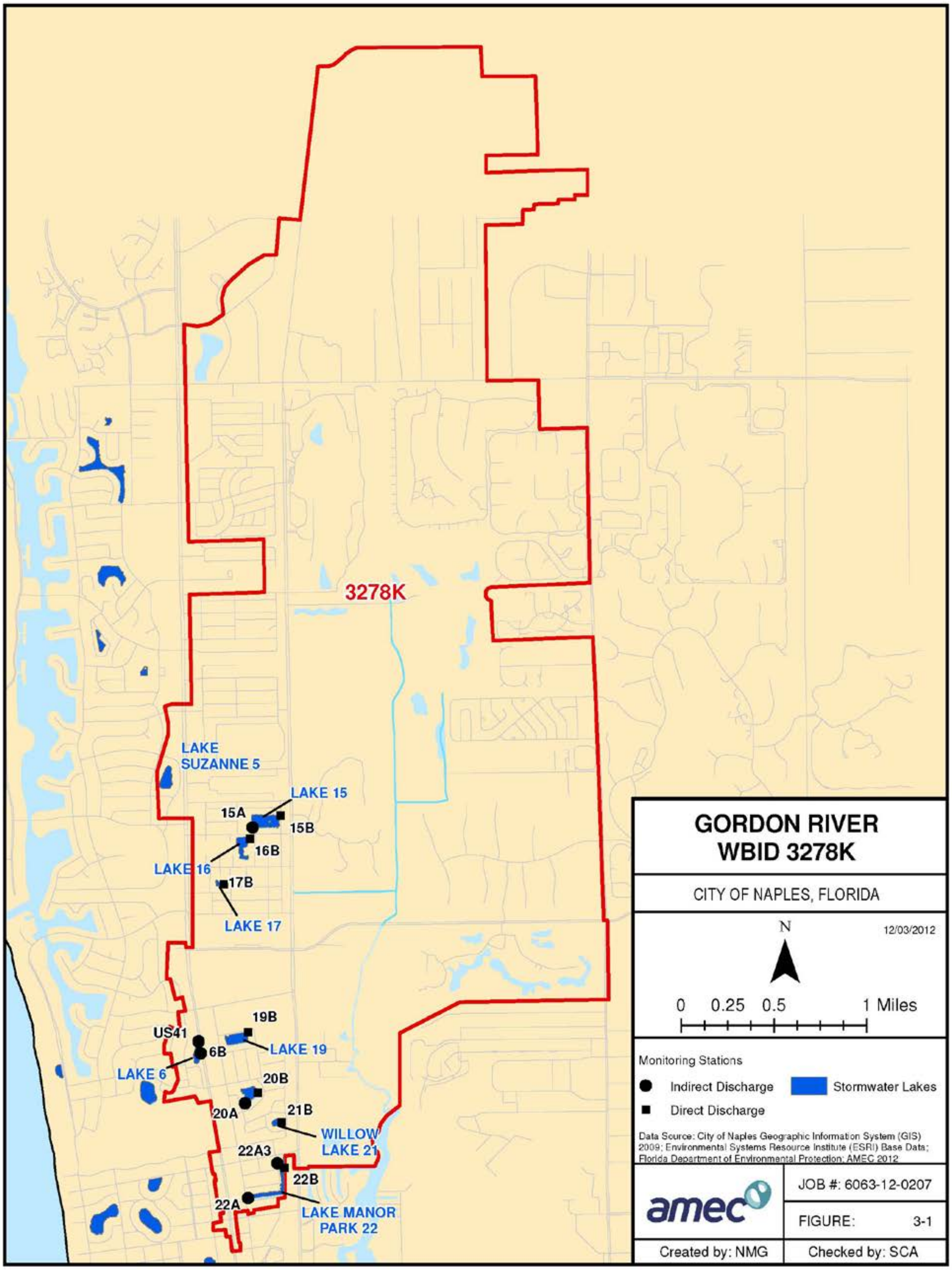
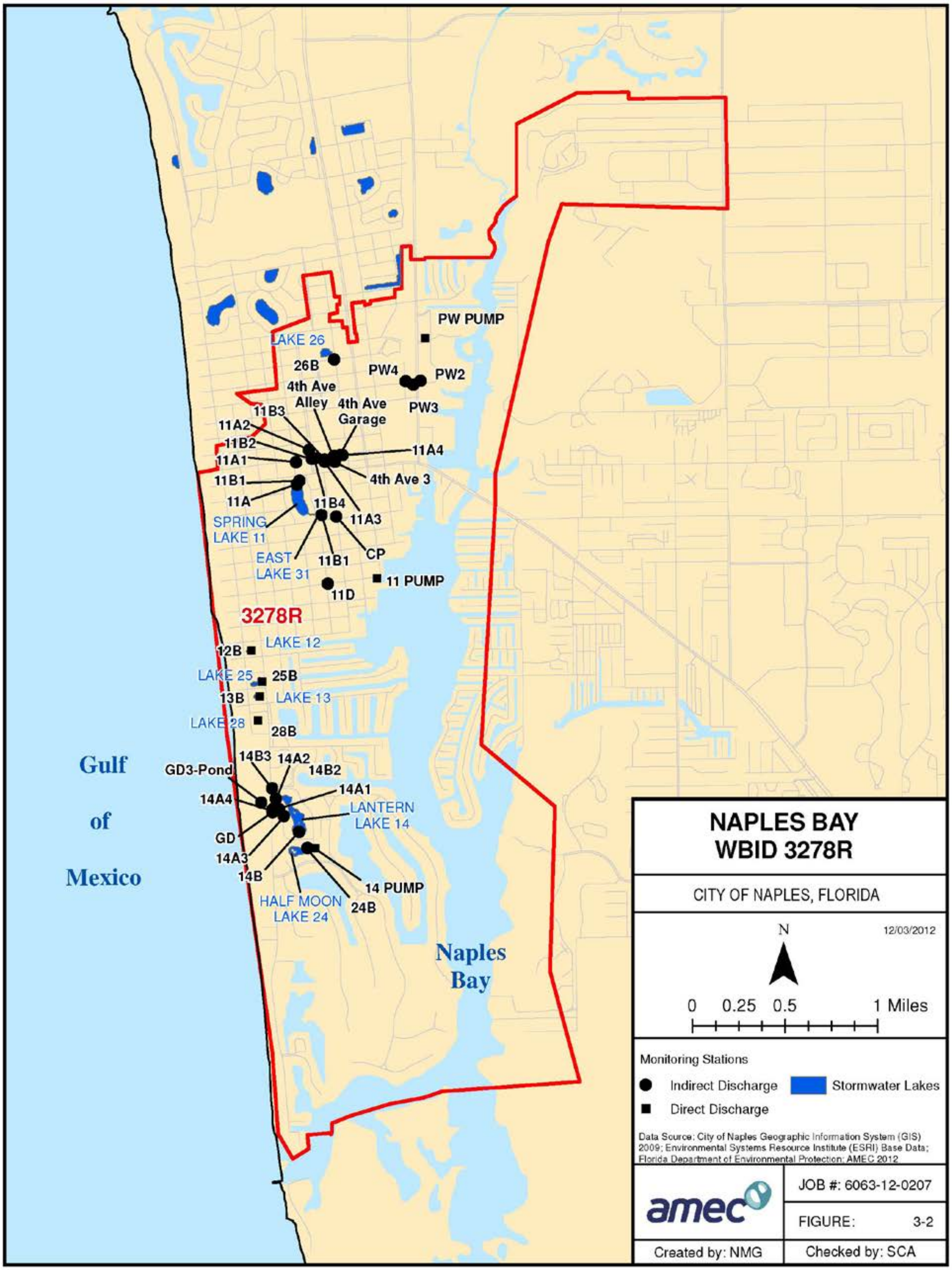
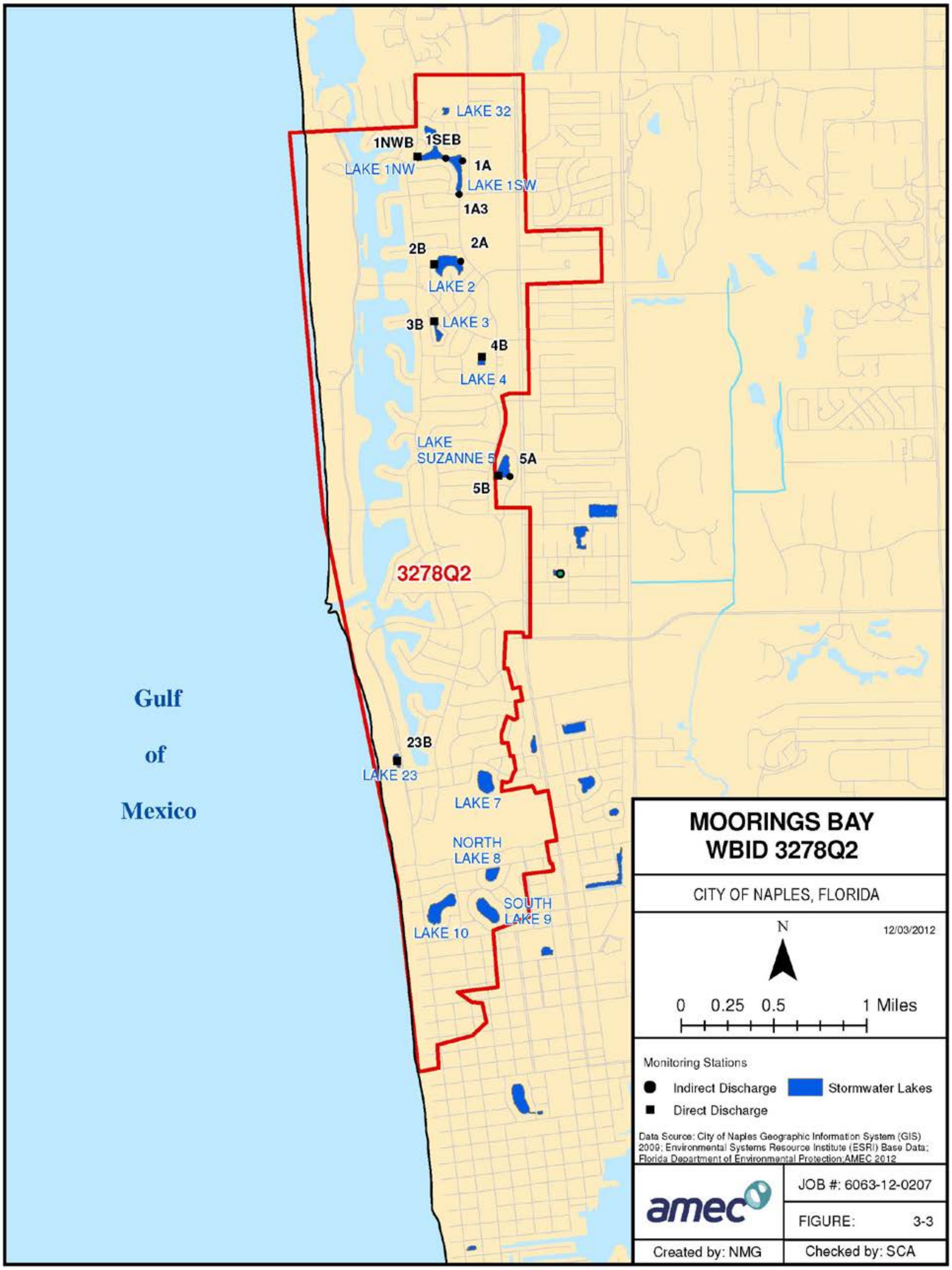
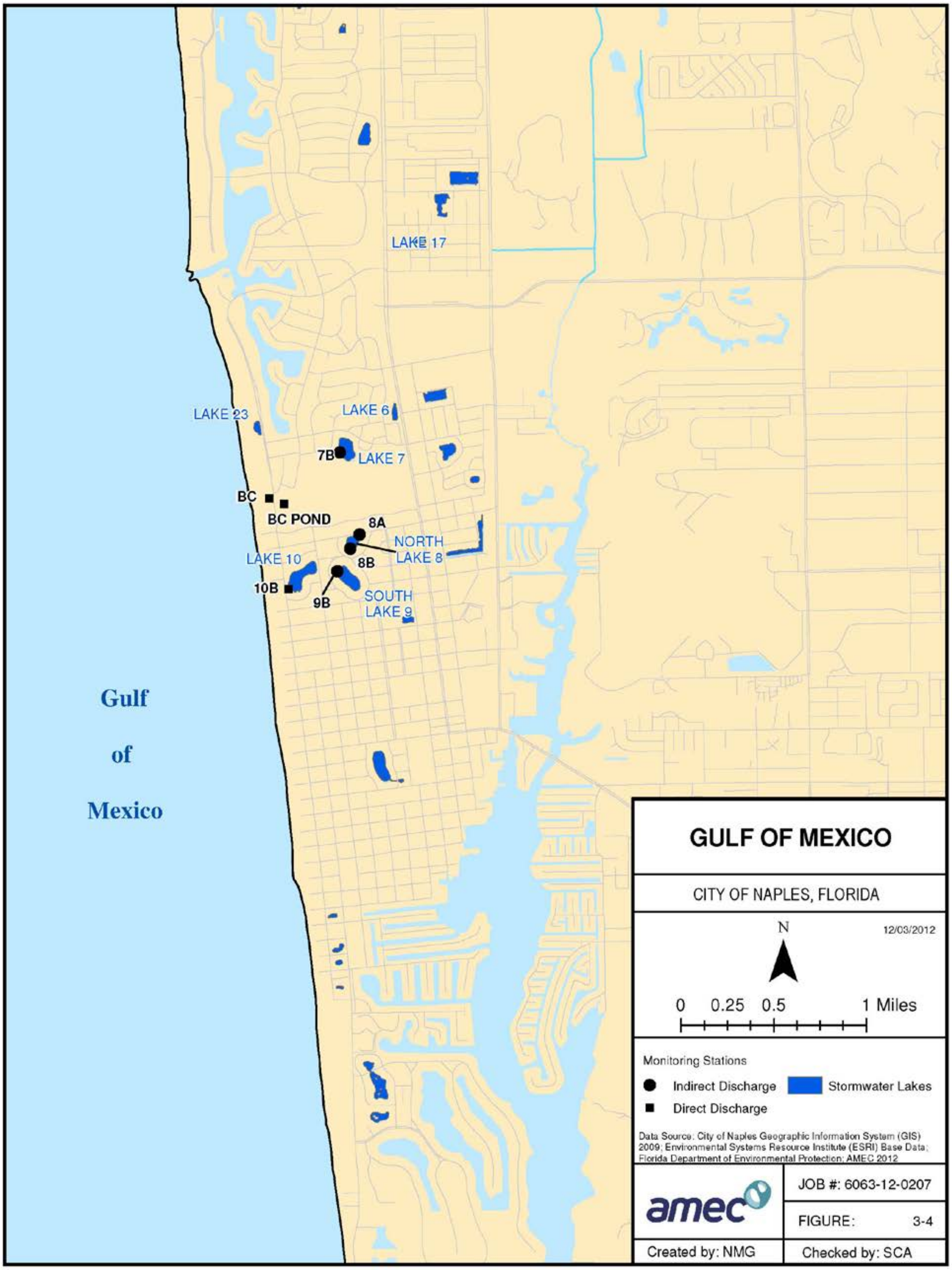

3278K
LAKE
SUZANNE 5
LAKE 15
15A
15B
16B
LAKE 16
17B
LAKE 17
19B
US41
6B
LAKE 19
LAKE 6
20B
20A
21B
WILLOW
LAKE 21
22A3
22B
22A
LAKE MANOR
PARK 22
GORDON RIVER
WBID 3278K
CITY OF NAPLES, FLORIDA
N
12/03/2012
0 0.25 0.5 1 Miles
Monitoring Stations
Indirect Discharge
Stormwater Lakes
Direct Discharge
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data; Florida Department of Environmental Protection; AMEC 2012
amec
JOB #: 6063-12-0207
FIGURE: 3-1
Created by: NMG
Checked by: SCA

ATTACHMENT C - Jan 2013 Final Storwaterwater Water Quality Report



ATTACHMENT C - Jan 2013 Final Storwaterwater Water Quality Report




LAKE 17
LAKE 23
LAKE 6
7B
LAKE 7
BC
BC POND
8A
NORTH
LAKE 8
LAKE 10
8B
10B
9B
SOUTH
LAKE 9
Gulf
of
Mexico
GULF OF MEXICO
CITY OF NAPLES, FLORIDA
N
12/03/2012
0 0.25 0.5 1 Miles
Monitoring Stations
Indirect Discharge
Stormwater Lakes
Direct Discharge
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data; Florida Department of Environmental Protection; AMEC 2012
JOB #: 6063-12-0207
FIGURE: 3-4
Created by: NMG
Checked by: SCA

4.0 Reclaimed Water Analysis

AMEC was tasked to support the City's public outreach program during this contract year, and suggested limited research to support development of guidance to City residents who use reclaimed water for landscape irrigation. Several lines of investigation were undertaken, including sampling and analysis of reclaimed water, mapping of areas receiving reclaimed water, calculation of nutrients likely to be supplied to landscapes receiving reclaimed water, and interpretation of existing stormwater and lakes water quality parameters in the context of this information. The City has an expanding reclaimed water distribution system which represents both an important water conservation and landscape nutrient resource but may have an adverse effect on stormwater quality. This analysis will help provide guidance for proper management of this resource in a way that is beneficial to the City, City residents and receiving waters of the state.

4.1 Reclaimed Water as a Supplemental Fertilizer

For the evaluation of the viability of City reclaimed water as a supplemental fertilizer source for City residents, historical nutrient concentration data were provided by the City and is included in the format it was received in Appendix A. These data were summarized for total nitrogen (TN) and total phosphorus (TP) concentrations. Typical rates of irrigation water use were combined with the nutrient concentrations to estimate TN and TP applied with reclaimed water to residential landscapes. The estimated TN and TP application rates were compared with recommended TN and TP application rates for typical Florida turf grass.

The average annual TN concentration in City reclaimed water was 2.26 milligrams per liter (mg/L), while that for TP was 0.36 mg/L.

In a study of Florida residential lawns, Augustin (2000) found that a properly irrigated lawn in Ft. Myers Florida required approximately 32 inches of irrigation per year. This rate was used as a baseline for the following analysis. It should be noted however that this is an ideal rate, and not necessarily representative of actual practices by homeowners. In a recent study in central Florida, it was found that homeowners applied 2-3 times more irrigation water than what the vegetation needs (Haley *et al*. 2007). Not only does this increase the nutrient mass delivered to the landscape when reclaimed water is used, it also decreases turfgrass nutrient uptake efficiency (NUE), which is generally reduced as a result of excessive irrigation (Martinez *et al*. 2011). If nutrients are not taken up efficiently in an "over-watering" scenario, then a greater fraction of the applied nutrients run off and infiltrate to groundwater, ultimately transported to waters of the State.

4.1.1 Nitrogen

The "basic" (lowest) UF/IFAS recommended fertilization for St. Augustine grass in South Florida is 4 pounds N per 1,000 square feet (ft^2) (Sartain, 2007). Using the measured annual average concentration of 2.26 mg/L TN, combined with a recommended 32 inches per year of irrigation application (less than 1 inch per week), a mass of 0.36 lbs N per 1,000ft^2 is delivered to the landscape, which is approximately 9% of the minimum recommended rate.

4.1.2 Phosphorus

In peninsular Florida phosphorus is available in the soil in quantities that are sufficient for lawngrasses (Trenholm *et al.* 2002). Therefore, although the quantities of phosphorus in reclaimed water are small, it should be assumed that when irrigating with reclaimed water, frequent application of low concentration TP in reclaimed water will be sufficient to sustain turfgrass TP requirements, with no need for additional fertilization. This assumption is also tentatively supported by the Florida Department of Environmental Protection and St. Johns River Water Management District, who are in the process of developing a statewide Reuse Best Management Practice guideline. Using an average annual irrigation rate of 32 inches per year, and an average TP concentration of 0.36 mg/L, a mass of 0.063 lbs P per 1,000ft^2 is delivered to the landscape.

4.2 Implications for City Irrigation Practices

Although the concentration of TN in City reclaimed water is not sufficient to meet UF/IFAS recommended annual fertilization rates, there are two factors that should be taken into account that have the potential to significantly influence turfgrass nutrient requirement. The first is the difference in delivery method; NUE is greater when fertilization occurs more frequently. Traditional fertilization practices typically entail one to several major applications throughout the year, however only a portion of the nutrients applied are actually taken up by the vegetation. The surplus fertilizer is then either washed off to downstream surface waters or infiltrates to shallow groundwater. If that same amount of fertilizer were instead applied in smaller doses using a more frequent application rate (e.g. via irrigation 1 to 3 times per week), the turfgrass NUE would be greater, resulting in less fertilizer export from the lawn.

On the other hand, overwatering decreases NUE. Differences in cost and watering restrictions between potable and reclaimed water tend to encourage excessive watering when reclaimed water is available. Based on data gathered from naplesgov.com regarding utility rates (dated September 9, 2011) and irrigation restrictions, irrigating with reclaimed water is both cheaper and less restricted. The cost of irrigating with potable water starts at $1.31 per 1,000 gallons, compared to a flat rate of $0.39 per 1,000 gallons for reclaimed. Also, if watering with non-reclaimed water, approved windows are three days per week, in early morning hours only between 12:01 a.m. and 8 a.m. for all types of irrigation and 5:00 p.m. to 7:00 p.m. for low-volume hand watering with the use of automatic self-canceling or closing nozzle. In contrast, irrigation with reclaimed water is far less restrictive, as it is allowed from before 10:00 a.m. or after 4:00 p.m., any day of the week. The economic and use restriction differences between the two sources increases the likelihood that overwatering using reclaimed water will occur. If substantial overwatering occurs (2 to 3 times the recommended rate of 32 inches per year), there is not only a greater mass of nutrients being applied, but transpiration rates and NUEs decrease due to over-saturation of the soil, resulting in greater runoff and nutrient export rates.

Finally, winter watering with reclaimed water applies nutrients when turfgrasses are dormant and fertilizers are not required, nor generally applied. Winter irrigation with reclaimed water is also expected to result in reduced NUE, with greater runoff and nutrient export.

Application of chemical fertilizers is likely to be required to achieve the high quality of turfgrass that many City residents desire. Reclaimed water will supply customers' lawns with enough phosphorus, so phosphorus-free fertilizer is recommended. If irrigation rates are consistent with UF/IFAS recommendations, fertilizers supplying nitrogen will be desirable, although some reduction of application rates may be warranted. Resources available to assist residents in determining an appropriate fertilizer application rate include:

- UF/IFAS guidance (Martinez *et al,* 2011, http://edis.ifas.ufl.edu/ae479, also attached);
- A state of Florida certified commercial urban landscape fertilizer applicator; or
- Collier County UF/IFAS Extension (239-353-4244).

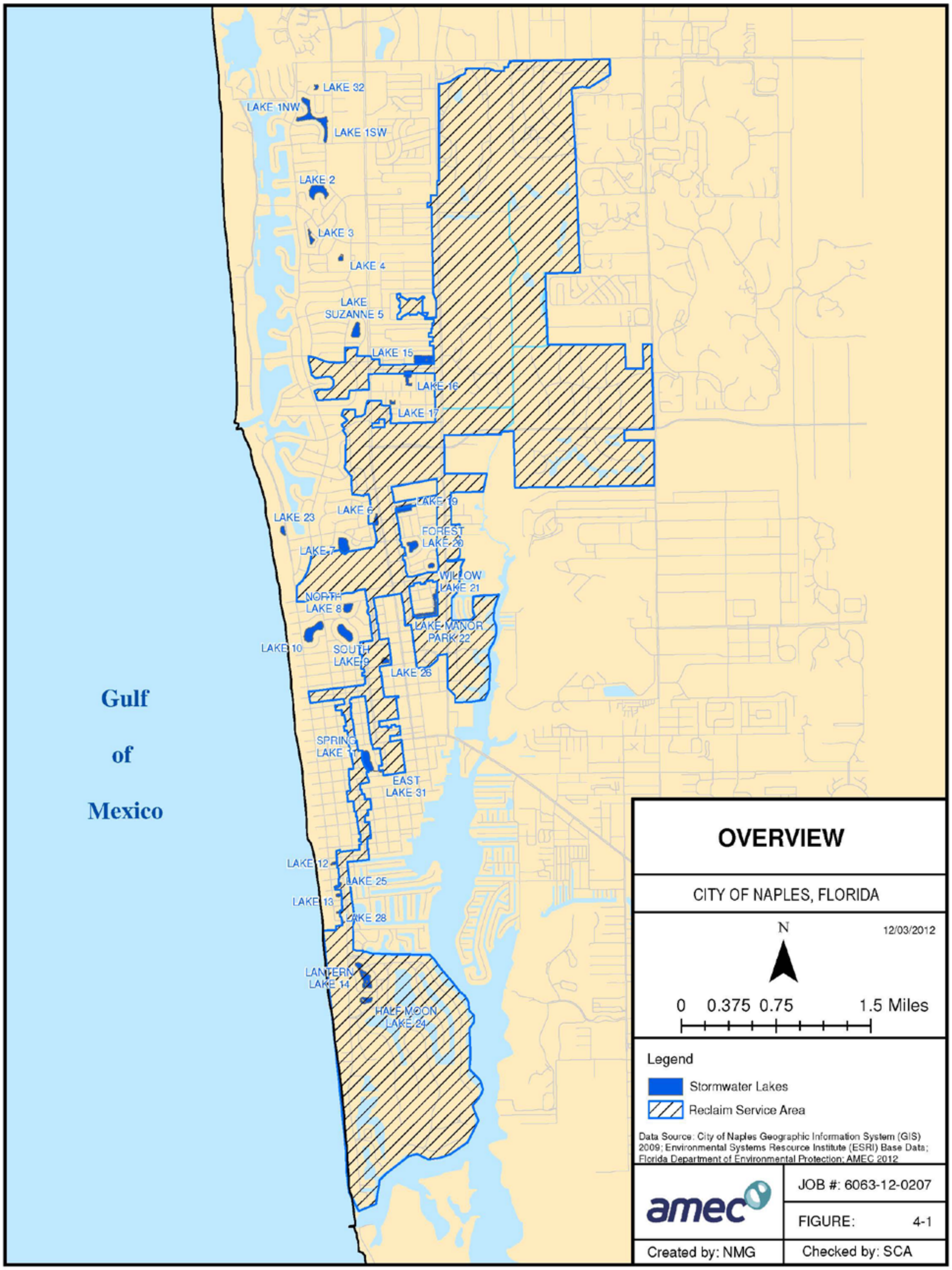
All information reviewed as part of this analysis indicate that excessive watering, which is more likely if reclaimed water is supplied, can be similarly detrimental to water quality in the City's lakes and estuaries as overfertilization. In addition to excessive irrigation of lawns and ornamentals, spraying on paved surfaces or directly on the City's lakes (known as overspray) should be avoided particularly when using reclaimed water. A study conducted in central Florida in residential areas irrigated with reclaimed water found that irrigation overspray, even if only 5% of the total irrigation volume, could represent over half of the nutrient export to our water bodies (Erich Marzolf, personal communication).

If implemented properly, turfgrass irrigation using reclaimed water can provide benefits to the water provider, end user, and environment. It has the potential to reduce the cost of treatment to a potable quality, reduce the cost of irrigation water to the end user, and reduce the amount of fertilizer purchased by the end user. If managed improperly however, it can represent a substantial increase in nutrient mass loading to downstream waterbodies. A public outreach program that focuses on the following details would provide an effective first step in educating the public about the inherent benefits associated with reclaimed water irrigation, and how it can be implemented to reduce costs to both the public and the environment:

- Proper irrigation rates – less is more;
- Proper fertilization rates – no TP, savings in TN; and
- Reduce overspray – more harmful than it appears.

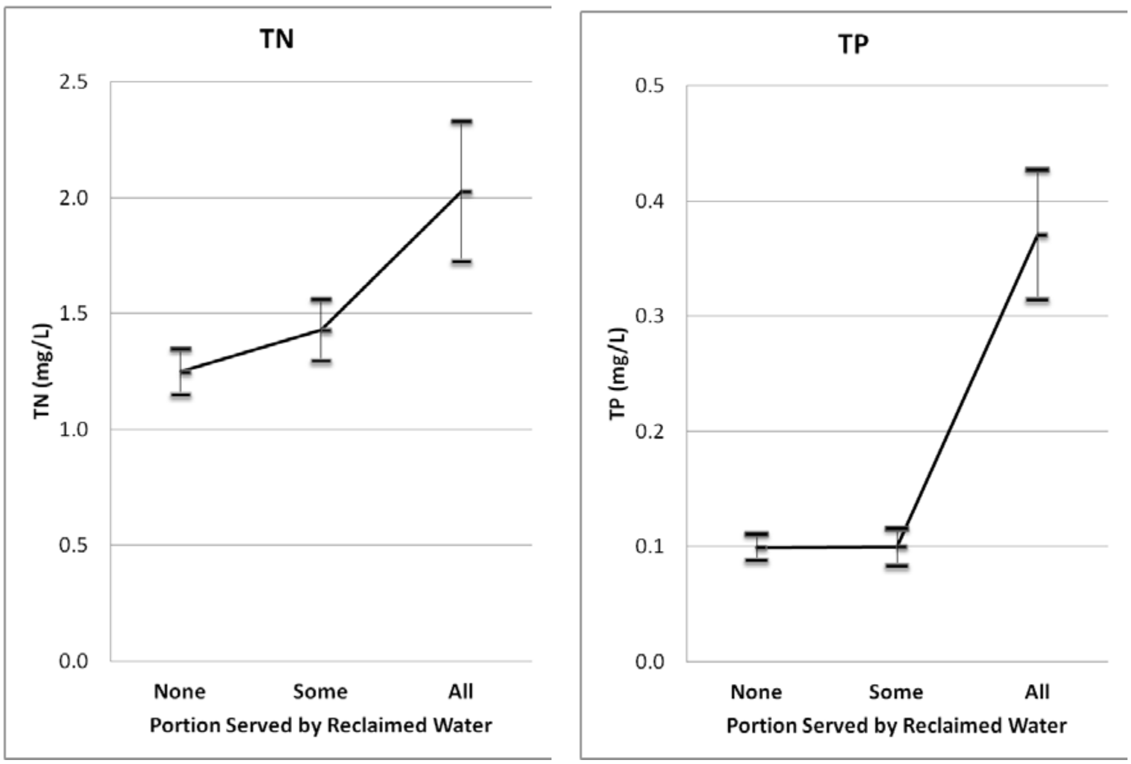
4.3 Effects of Reclaimed Water on Observed Water Quality

For the second part of the reclaimed water analysis, the current reclaimed water service area was obtained from the City of Naples Geographic Information System database and crossed with the monitoring locations and results discussed in Section 3. Figure 4-1 shows the coverage of the reclaimed water service area throughout the City. Several statistical analyses were then performed to determine if sample locations receiving runoff from a reclaimed water service area showed any indication of being influenced by the nutrient content within the reclaimed water.


LAKE 32
LAKE 1NW
LAKE 1SW
LAKE 2
LAKE 3
LAKE 4
LAKE SUZANNE 5
LAKE 15
LAKE 16
LAKE 17
LAKE 19
LAKE 6
LAKE 23
FOREST LAKE 20
LAKE 7
WILLOW LAKE 21
NORTH LAKE 8
LAKE MANOR PARK 22
LAKE 10
SOUTH LAKE 9
LAKE 26
Gulf of Mexico
SPRING LAKE 11
EAST LAKE 31
LAKE 12
LAKE 25
LAKE 13
LAKE 28
LANTERN LAKE 14
HALF MOON LAKE 24
OVERVIEW
CITY OF NAPLES, FLORIDA
N
12/03/2012
0 0.375 0.75 1.5 Miles
Legend
Stormwater Lakes
Reclaim Service Area
Data Source: City of Naples Geographic Information System (GIS) 2009; Environmental Systems Resource Institute (ESRI) Base Data; Florida Department of Environmental Protection; AMEC 2012
amec
JOB #: 6063-12-0207
FIGURE: 4-1
Created by: NMG
Checked by: SCA

As a first step, AMEC staff reviewed all sample locations presented in Table 3-5 against the reclaimed service area coverage. Sample locations were given one of three designations depending on how much of the runoff sampled was directly influenced by the current reclaimed water distribution system – all, some, or none. TN and TP in stormwater appear to be closely related to the portion of the sub-basin that is served by reclaimed water, as illustrated by Figure 4-2, showing the average concentrations of TN and TP, with error bars indicating the standard error of the average.

Figure 4-2. Relationship between TN and TP Concentration and Reclaimed Water Service Area



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A two sample t-Test was performed to compare the difference between the observed means of the "none" group and the "all" group for TN and TP. Analyses were performed on all sample locations provided in Table 3-5 and illustrated in Figure 4-2, as well as just lake effluent locations provided in Table 3-5. The results of the analysis are provided in Table 4-1, with averages presented for each statistical group and standard errors indicating uncertainty in the averages. Values given in ***bold italics*** represent statistically significant differences between "all" and "none" groups at the 0.05 level of significance.

Table 4-1. TN and TP in Stormwater/Lakes Affected by Reclaimed Water

Sample Set	Parameter	units	Reclaimed Service Area Coverage	
			None	All
All Sample Locations	TN	mg/L	***1.2 ± 0.10***	***2.0 ± 0.30***
	TP	mg/L	***0.10 ± 0.011***	***0.37 ± 0.056***
Lake Effluent Sample Locations	TN	mg/L	1.4 ± 0.15	1.6 ± 0.50
	TP	mg/L	***0.075 ± 0.013***	***0.48 ± 0.19***

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For the analysis performed on all sample locations, the mean concentrations of TN and TP from sample locations within reclaimed water service areas were significantly greater than the mean concentrations of sample locations outside of reclaimed water service areas. For analysis performed on only lake effluent sample locations, the mean concentration of TP from sample locations within reclaimed water service areas was significantly greater than the mean concentration of sample locations outside of the reclaimed water service area. The results of this analysis indicate that the use of reclaimed water is associated with an increase in the nutrient concentrations of the runoff generated within these areas. Results also indicate that the phosphorus enrichment caused by use of reclaimed water is not being effectively remediated within the affected stormwater lakes, and better controls through public education and resource management should be considered.

5.0 Revised Prioritization Analysis

As part of the work performed under the previous contract with the City, AMEC developed a condition assessment framework that allowed for prioritization of future remediation efforts (See Section 7 of AMEC, 2012). The condition assessment generated several indices based on modeled nutrient loadings, predicted nutrient removal efficiency, observed nutrient removal efficiency and observed general conditions which were then used to rank each of the 28 lakes on a scale from 1 to 100. Lakes with a higher score were deemed more impaired, meaning that they were functioning at a reduced capacity and contributing most to the trophic impairment of receiving waterbodies. Future remediation efforts directed at these higher scoring lakes would provide the lowest cost/benefit to the City.

One of the final recommendations of the AMEC (2012) Report was to "Revise [the] Prioritization Analysis" with future water quality data. Although the initial prioritization analysis provided a comprehensive assessment of the trophic condition of City lakes based on all available nutrient data, several of the input indices were based on observed lake data that were admittedly limited at the time. As a result, AMEC recommended that those data gaps, particularly for the more impaired lakes, be amended as part of future monitoring efforts. AMEC also intentionally constructed the calculation framework so that these future data amendments could be made with relatively little effort so long as monitoring of the 28 lakes was continued in a consistent manner so as to provide compatible input data. The revised nutrient prioritization analysis discussed herein is a reflection of the updated data inputs.

Also included in this section is a discussion of fecal coliform and copper loadings generated from each stormwater pond and its sub-basin. The purpose of these loading analyses is to show which lakes contribute the greatest annual load of each pollutant to downstream waterbodies, and therefore where future targeted remediation strategies may be best implemented. This analysis is built upon the volumetric loading analyses performed in the previous contracted work, with the concentration data used to calculate mass and colony loadings inclusive of all available data to date. Although the copper and fecal coliform rankings that will be presented in this section are only based on total annual mass or colony loadings of each pollutant (as opposed to a suite of indices), they provide a simple approach to identification of those ponds that are contributing most to downstream waterbody impairments.

5.1 Revised Nutrient Prioritization Analysis

The prioritization analysis provided by AMEC (2012) is the basis for the Revised Nutrient Prioritization Analysis. The analysis provided a ranking of each stormwater lake in terms of unique indices that took into account factors such as volumetric loadings, nutrient loadings, observed nutrient concentrations, predicted nutrient concentrations, and general condition and function indicators. As part of the revision provided here, several updates were made that reflect updates made to loading calculations, updates made to index inputs, and the results of the continued water quality monitoring.

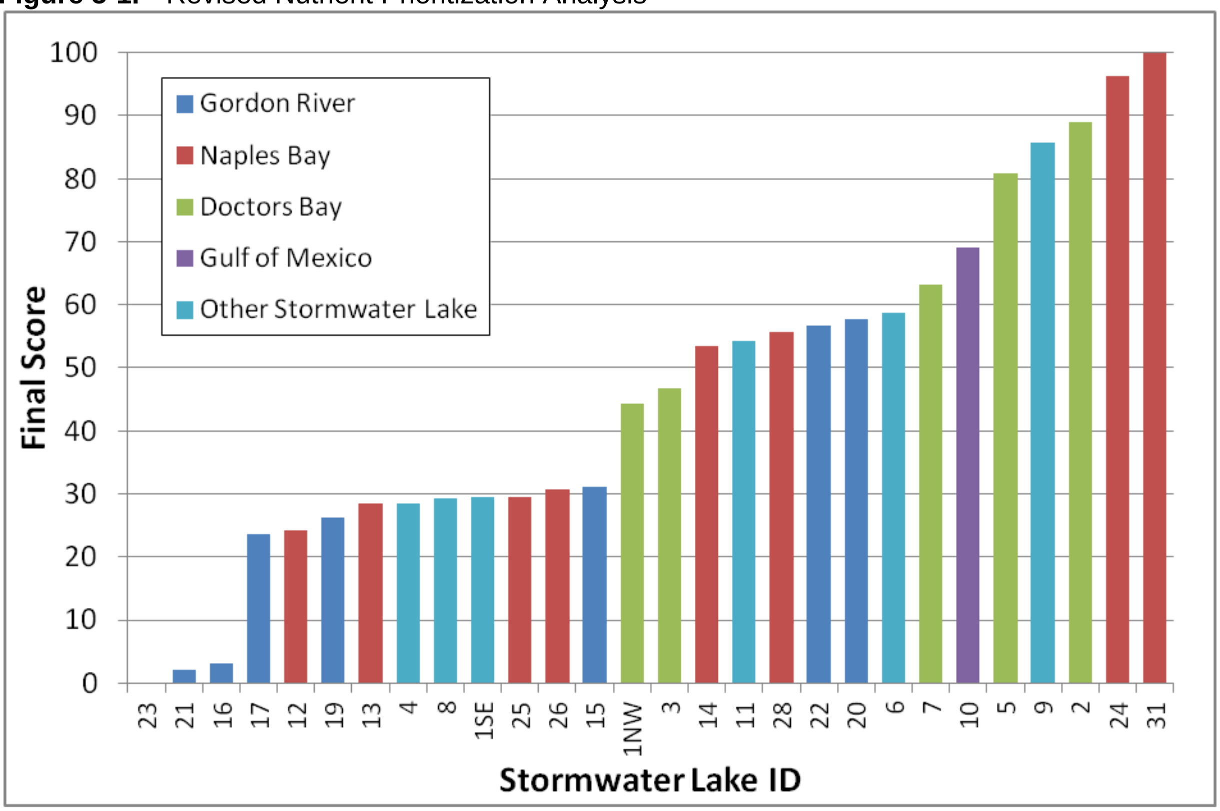
The first revision that was made to the AMEC (2012) Prioritization Analysis reflected updates to the assumed routing of the Lake 7, 8, 9, and 10 system. Initially, based on drainage maps provided by the City, volumetric loadings (and therefore mass loadings) generated from Lake 7 were assumed to flow, in series, to Lakes 8, 9 and 10 prior to discharge into the Gulf of Mexico. However, during current year monitoring efforts, it was determined that discharge from Lake 7 was instead routed to Doctors Bay. The loading calculations were revised accordingly, which had the effect of reducing the total load directed to and discharged from Lakes 8, 9 and 10. Because Lakes 9 and 10 were located near the top of the previous final ranking, this "improved" their scores somewhat, and provided a more accurate condition assessment as given below.

The second revision that was made to the AMEC (2012) Prioritization Analysis was the removal of TSS from index inputs. TSS is a broad water quality parameter and as such has some overlap with more pertinent parameters such as TN and TP. Because TN and TP were already direct inputs into four of the seven indices and were directly related to previously identified causes of downstream waterbody impairments, it was decided to remove TSS to avoid any redundancy in the calculations and provide a more direct assessment of lake condition. This also had the effect of "improving" the score of Lake 10, which had previously scored high due to an overestimation of volumetric loading and several anomalously high TSS values (even though corresponding TN and TP concentrations were fairly typical).

The final revision made to the AMEC (2012) Prioritization Analysis was to incorporate water quality data from current year monitoring efforts. The additional data points helped to fill in previously identified data gaps and to reinforce previously identified water quality trends.

Figure 5-1 shows the results of the Nutrient Prioritization Analysis. The ranking is based on seven unique indices, details of which can be found in AMEC (2012). A score of 0 represents a properly functioning Lake, whereas a score of 100 represents a Lake in poor condition that has lost its nutrient removal capacity and is likely functioning as a source of nutrient loading to downstream waterbodies. Lakes are categorized by receiving waterbody.

Figure 5-1. Revised Nutrient Prioritization Analysis



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Based on the revised ranking, Lakes 31 (East Lake), 24 (Half Moon Lake), 2 (Swan Lake), 9 (South Lake) and 5 (Lake Suzanne) are in the poorest health with respect to nutrients and would likely benefit most from remediation efforts. Due to the nature of the input calculations and for the purpose of this analysis, it can be assumed that the results for Lake 31 (East Lake) are also a reflection of the condition of Lake 11 (Spring Lake), and remediation efforts directed at both Lakes would provide an overall condition improvement.

5.2 Copper Loading Analysis

Copper is one of the designated causes of impairment (see Section 2) to downstream waterbodies, and is a focus of current monitoring efforts. In order to provide guidance to City staff on where sources are being generated, source tracking and continued monitoring has been conducted as discussed in previous sections and reports. Results of current year monitoring efforts have been added to all previously available water quality data and combined with the hydrologic analyses performed as part of AMEC (2012) to calculate total annual mass loadings of copper generated from each stormwater lake using the following equation:

$$M_d = 0.00123 V_d \, C_{Ave}$$

where:

M_d = annual mass discharged from lake (kg/yr)
V_d = annual volume discharged from lake (acre-ft/yr)
C_{Ave} = average concentration measured at lake outfall (µg/L)

A summary of inputs is provided in Table 5.1 and illustrated in Figure 5-2, with lakes categorized by receiving waterbody.

Table 5-1. Summary of Copper Loading Analysis

Basin	Lake ID	Annual Volume Discharged[1] (acre-ft/yr)	Average Concentration (µg/L)	Annual Mass Discharged (kg/yr)
Gordon River	15	68	15	1.2
	16	20	0.89	0.022
	17	25	0.30	0.009
	19	32	1.1	0.043
	20	43	0.70	0.037
	21	7.6	3.4	0.032
	22	118	1.7	0.25
Naples Bay	12	3.0	0.30	0.0011
	13	10	8.4	0.11
	14	34	2.0	0.083
	24	9.4	2.9	0.034
	25	4.3	5.6	0.030
	26	17	46	0.97
	28	4.0	5.4	0.027
	31	116	4.5	0.64
Doctors Bay	1NW	125	6.7	1.0
	2	191	15	3.6
	3	60	3.7	0.28
	5	97	7.3	0.88
	7	46	13	0.74
	23	9.8	3.7	0.045
Gulf of Mexico	10	140	2.3	0.41
Other Stormwater Lake	4	30	2.1	0.078
	8	62	2.4	0.18
	9	100	6.4	0.80
	6	25	5.0	0.16
	11	111	7.3	1.0
	1SE	51	14	0.85

[1]Source: AMEC (2012)
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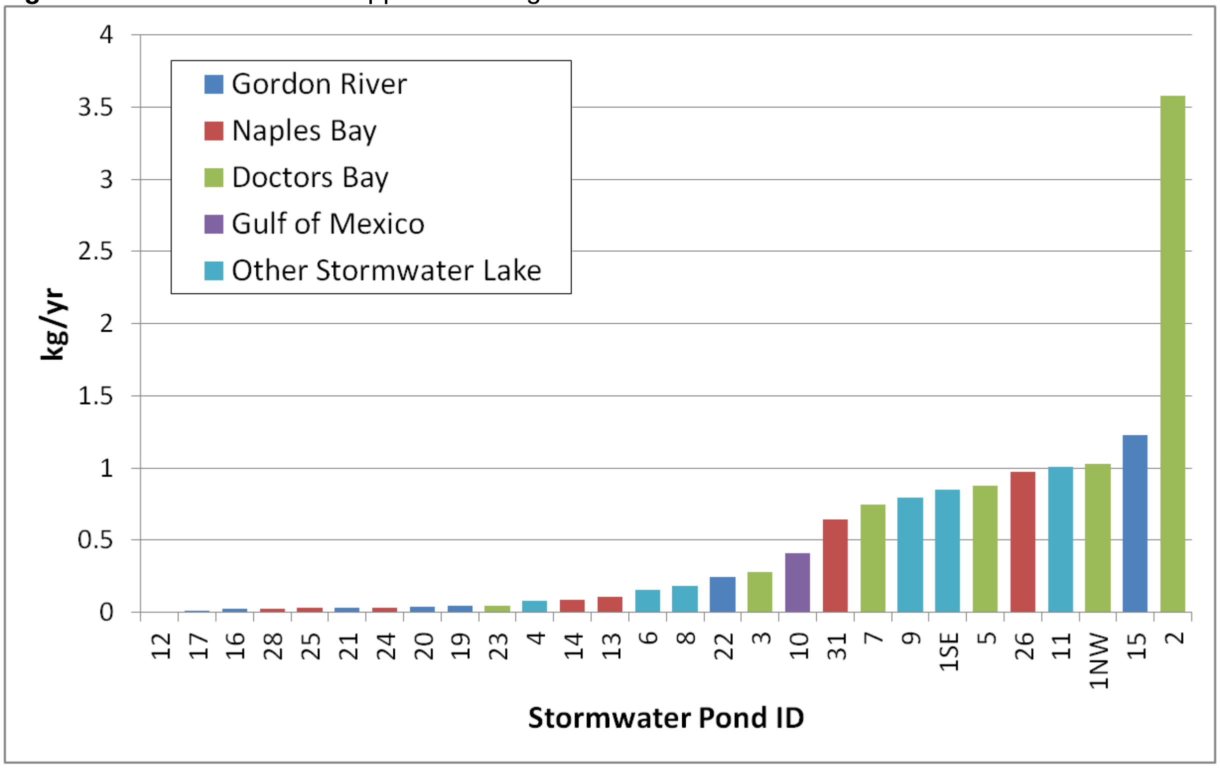
Figure 5-2. Total Annual Copper Discharge



Created By: SCA   Checked By: WAT

Of all the monitored stormwater lakes, Lake 2 (Swan Lake) has the greatest annual copper discharge at 3.6 kg/yr. This is due to the elevated copper concentrations that are consistently observed at the discharge (mean=15.1µg/L, max=63µg/L, n=7) as well as the fact that the calculated annual discharge volume (191acre-ft/yr) is the greatest of all evaluated stormwater lakes. After Lake 2, there are nine stormwater lakes that discharge between 0.5 and 1.5 kg/yr, with the remaining stormwater lakes discharging less than 0.5 kg/yr.

5.3 Fecal Coliform Loading Analysis

Fecal coliform is also one of the designated causes of impairment (see Section 2) to downstream waterbodies, and is a focus of current monitoring efforts. In order to provide guidance to City staff on where sources are being generated, source tracking and continued monitoring has been conducted as discussed in previous sections and reports. Results of current year monitoring efforts have been added to all previously available water quality data and combined with the hydrologic analyses performed as part of AMEC (2012) to calculate total annual loadings of fecal coliform (quantified as CFU/yr) generated from each stormwater lake using the following equation:

$$CFU_d = 1.23\times10^7 \times V_d \times C_{Ave}$$

where:

- CFU_d = annual Colony Forming Units discharged from lake (CFU/yr)
- V_d = annual volume discharged from lake (acre-ft/yr)
- C_{Ave} = average concentration measured at lake outfall (CFU/100mL)

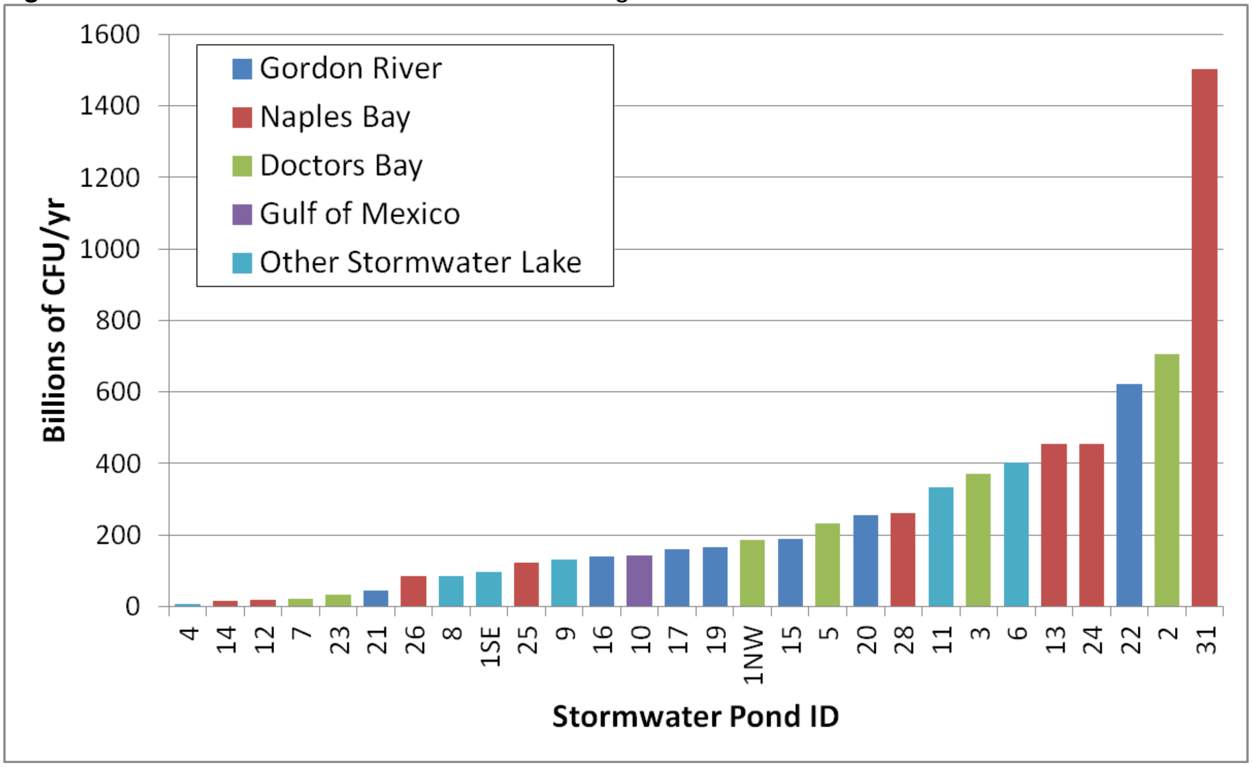
A summary of inputs is provided in Table 5.1 and illustrated in Figure 5-2, with lakes categorized by receiving waterbody.

Table 5-2. Total Annual Fecal Coliform Discharge

Basin	Lake ID	Annual Volume Discharged[1] (acre-ft/yr)	Average Concentration (CFU/100mL)	Annual Mass Discharged (billions of CFU/yr)
Gordon River	15	68	224	188
	16	20	561	140
	17	25	520	161
	19	32	419	166
	20	43	481	257
	21	7.6	481	45
	22	118	428	622
Naples Bay	12	3.0	490	18
	13	10	3600	454
	14	34	40	16
	24	9.4	3919	454
	25	4.3	2300	121
	26	17	398	85
	28	4.0	5300	260
	31	116	1049	1503
Doctors Bay	1NW	125	120	187
	2	191	298	705
	3	60	497	370
	5	97	193	231
	7	46	39	22
	23	9.8	280	34
Gulf of Mexico	10	140	83	143
Other Stormwater Lake	4	30	21	8
	8	62	112	85
	9	100	105	130
	6	25	1308	404
	11	111	243	334
	1SE	51	152	95

[1]Source: AMEC (2012)
Created By: SCA
Checked By: WAT

Figure 5-3. Total Annual Fecal Coliform Discharge



Created By: SCA Checked By: WAT

Lake 31 (East Lake) discharges the greatest number of bacteria to downstream waterbodies, as indicated in Figure 5-3. As stated in past reports, East Lake is connected to Spring Lake (Lake 11), and the two can typically be assumed to represent one contiguous waterbody. Following East Lake, Lake 2 (Swan Lake) and Lake 22 (Lake Manor) contribute the highest bacteria loadings to downstream waterbodies.

5.4 Summary Prioritization Analysis

Based on the results presented above, a prioritization ranking can be derived based on targeted pollutants. By comparing stormwater lakes with respect to individual pollutants, future remediation strategies can be implemented effectively. Table 5-3 summarizes the results of Section 5 by listing the top five lakes in each pollutant category that would benefit most from BMP implementation. Commonly implemented structural and nonstructural BMPs are then provided based on the targeted pollutant, and should be considered based on the ranking provided in Table 5-3.

Table 5-3. Summary of Pollutant Specific Rankings

Order	Nutrients (TN/TP)		Copper		Fecal Coliform	
	Lake ID	Score	Lake ID	Loading (kg/yr)	Lake ID	Loading (billions of CFU/yr)
1	**31**	100	**2**	3.6	**31**	1503
2	**24**	96	**15**	1.2	**2**	705
3	**2**	89	**1NW**	1.0	**22**	622
4	**9**	86	**11**	1.0	**24**	454
5	**5**	81	**26**	1.0	**13**	454

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The rankings given above should be viewed as a preliminary assessment of where to target future remediation efforts. Each stormwater lake should also be evaluated in terms of which receiving waterbody its discharge is directed to. For example, Lake 31 (East Lake) and Lake 22 (Lake Manor) discharge into Gordon River and upper Naples Bay, respectively, and are ranked high in at least one category given in Table 5-3. Gordon River and Naples Bay have been identified as impaired (see Section 2.1), and therefore FDEP requirements to implement improvements in water quality are more imminent. Further, Gordon River and upper Naples Bay are less tidally influenced than lower Naples Bay and Moorings Bay, for example, and as such are more sensitive to increased pollutant loadings than the more tidally influenced and regularly flushed systems. These types of qualitative evaluations should be used in combination with the more quantitative measures provided in Table 5-3 when deciding where to direct future BMPs. Also, as with any capital investment, other factors will need to be considered including implementation feasibility and cost, however the above provides a starting point for targeted solutions.

5.5 Possible Structural and Non-Structural BMPs

As indicated in Section 2, causes of impairments for the state waters in and around the City include nutrients, copper and fecal coliform. As such, data collected as part of the current year monitoring efforts as well as past years' monitoring efforts have been organized to highlight those areas most in need of improvement, with focus placed on general stormwater lake health as well as specific pollutants. Included in this section is a list of possible structural and non-structural BMPs that are recommended by various regulatory agencies including FDEP and EPA, and that are commonly implemented in similarly urbanized watersheds. Although there are a number of structural and nonstructural BMPs that can potentially reduce all targeted pollutants, there are some that are more effective than others, and some that are designed more for individual pollutants. The BMPs discussed below have been evaluated based on their overall effectiveness as well as their applicability to the targeted pollutant categories discussed above.

5.5.1 LID BMPs

In urbanized areas, available land is often the primary impediment to installation of structural stormwater Best Management Practices (BMPs). Low Impact Development (LID) is a practice that is becoming widely accepted as an effective stormwater treatment option in such areas however, and a growing body of research and guidance is available to local governments and resource managers. LID techniques attempt to mimic the predevelopment hydrologic regime of a site, using features that minimize runoff and pollutant export through increased retention, detention and infiltration. The approach of LID strategies generally address increased runoff at a local, site-by-site scale, as opposed to larger basin-scale features such as detention ponds. Accordingly, they can be implemented as new development, redevelopment, or general site improvement installations. This makes it appealing not only from a cost standpoint, but from an implementation feasibility standpoint as well, as land requirements are generally minimal and regulations can be incorporated into local ordinances and regulatory policy.

Below is a list of commonly utilized LID BMPs. LID BMPs function by either reducing the total volume of stormwater discharged from a site, filtering the stormwater prior to discharge from the site, or both. Although most LID BMPs operate using some combination of the two, each one typically has a dominant mechanism and can be implemented based on that primary function. In general, any BMP that reduces the total volume of runoff from a site will reduce the pollutant load as well, making it applicable to nutrient (TN/TP), metals, and bacteria reduction. BMPs that function in more of a filtration capacity may not be as effective for bacteria reduction, but can still be effective in nutrent and metals reduction. The below BMPs have been categorized based on their primary treatment mechanism – volume reduction or filtration.

Volume Reduction LID BMPs:

- Bioinfiltration
- Pocket Wetlands
- Porous Pavement
- Rain Barrels/Cisterns
- Rain Gardens

Filtration LID BMPs:

- Filter Strips
- Soil Amendments
- Tree Box Filters
- Vegetated Buffers
- Vegetated Swales

A number of sources for information on LID BMPs also exist, including Lowimpactdevelopment.org and the USEPA National Menu of Stormwater Best Management Practices. Information available includes construction and implementation guidance, treatment performance, and guidance on incorporating rules into local ordinances and regulatory policy.

LID BMPs represent a method of stormwater treatment that is widely applicable to the City and should be considered wherever possible. Practices should be implemented City wide, with particular attention focused towards those areas shown to have high levels of nutrients, metals or bacteria. These include, but are not limited to, the commercial district of 5^{th} Ave. S that drains into Spring Lake, the drainage basins for any lakes identified in Table 5-3, and each of the pump station watersheds. Based on the long term water quality for the pump stations, LID BMPs more suited to bacterial removal (i.e. volume reduction LID BMPSs) should be considered for the Cove Pump Station (11-Pump) drainage basin, whereas all types of LID BMPs should be considered for Public Works Pump Station (PW-Pump) drainage basin and Lantern Lane Pump Station (14-Pump) drainage basin.

5.5.2 Sediment Treatment and Removal

As documented in this report as well as AMEC (2012), many of the 28 City stormwater lakes have the potential for significant improvements in pollutant removal efficiencies, however most have large deposits of legacy sediments that contribute to internal nutrient recycling, re-suspension and export. Ultimately, the accumulated sediment in many of these systems may require removal or chemical inactivation before additional corrective actions such as LID BMPs or homeowner education are implemented. Short of complete sediment removal, there are certain in-situ treatment options that may be appropriate in isolated cases and at a reduced cost compared to full chemical inactivation.

Several methods of in-situ treatment options exist, however one promising amendment recently introduced to Florida is a bentonite (clay) matrix embedded with lanthanum (a rare earth metal). The current trade name for the substance is Phoslock®, however several manufacturers are developing similar materials. Phoslock® works by forming a highly stable bond with orthophosphate, the bioavailable form of phosphorus. When bound, the phosphorus contained in the stable compound is no longer available to stimulate growth in microorganisms or plants, and the compound settles to the bottom where it continues to bind to orthophosphate released from the sediment until its sorption capacity is met. These settled compounds then remain non-bioavailable.

Although Phoslock® is specifically targeted to phosphorus removal from both the water column and sediment, it may have indirect effects on the reduction of nitrogen in both City stormwater lakes and downstream waters of the state. High phosphorus levels, particularly when accompanied by relatively lower nitrogen levels, can promote cyanobactera (or “blue-green algae”) blooms that fix large amounts of nitrogen from the atmosphere, which then adds to the overall eutrophication of the system and can be exported to downstream waterbodies. By controlling phosphorus levels in freshwater and brackish systems, this possible source of nitrogen can be eliminated, and a waterbody can be restored to a healthier state.

Several of the stormwater lakes have been observed to have elevated phosphorus levels concurrent with large algal blooms. These conditions are not only indicative of appropriate conditions for cyanobacteria blooms in the stormwater lakes themselves, but export of large quantities of phosphorus to downstream waters of the state has the potential to promote cyanobacteria blooms in those waters as well. Lakes that have been previously identified as having trophic conditions conducive to cyanobacteria proliferation and/or elevated phosphorus concentrations include Lakes 5 (Lake Suzanne), 14 (Lantern Lake) and 24 (Half Moon Lake). Further consideration should be given to in-situ phosphorus remediation in these lakes as a proof of concept for overall nitrogen and phosphorus reduction.

In addition to in-situ treatment, spot dredging or whole lake dredging should be considered for some of the more overloaded City stormwater lakes. When lakes sediment becomes super saturated with nutrients or metals, it can take years or even decades for external pollutant load reductions to have any effect on the water quality of the lake, as the sediment can serve as a constant internal source of nutrients. In such cases of extreme sediment nutrient concentration, removal of sediment is often the best course of action. Additional investigation is warranted in these situations to determine the overall chemistry of the sediment, to evaluate the potential water quality improvements that may occur due to sediment removal, and to determine a total cost/benefit analysis compared to other less costly remediation strategies. Lakes identified in AMEC (2012) or as having a high score in Sections 5.1 or 5.2 should be considered for spot or whole lake dredging.

5.5.3 End of Pipe Treatment Methods

End of Pipe Treatment Methods, although not ideal in that they often treat the symptom and not the source, can be effective when source treatment options are not easily defined or cost effective. Based on continued bacteria source tracking efforts performed in this and past years' contracts, AMEC and the City have been able to locate areas of likely sources, but have been less successful in "pinpointing" actual sources. As a result, while efforts to locate and remediate actual sources continue, end of pipe treatment methods may help reduce current and future bacteria export to downstream waterbodies.

One such end of pipe treatment method utilizes antimicrobial filter media, with variations produced by various manufacturers such as Fabco Industries, Inc and AbTech Industries, Inc. The material, when combined implemented using configurations such as Fabco's StormSafe Helix design, is designed to be an in-line installation into existing stormwater pipes. When placed in series with a large debris separator/sediment sump at the front end, the technology has been shown to provide significant bacterial count reductions while not causing large losses in hydraulic capacity. The filters can be installed with a high flow bypass mechanism as well, further reducing upstream flooding concerns.

The Fabco Industries, Inc. StormSafe Helix or similar antimicrobial end of pipe treatment could be implemented in the 5th Ave. S commercial district or along Gordon Dr. in the Lantern Lane Pump Station drainage basin, where source tracking efforts have confirmed consistently high bacteria counts. As previously stated however, this should not be considered as a final solution to bacteria treatment in the area, as source elimination should always be the preferred course of action.

5.5.4 Floating Islands

Floating Islands are a low cost and increasingly popular method of increasing the treatment capacity of existing ponds, lakes and wetlands. The City has already installed several floating islands in the following lakes:

- North Lake (8)
- Lake 12
- Lantern Lake (14)
- Forest Lake (20)
- Willow Lake (21)
- Lake Manor (22)
- Lake 25
- East Lake (31)

and should continue adding to their floating island inventory so long as staff resources are available for regular maintenance. After installation, regular (at least once per year) maintenance is imperative to maintain proper functioning of the systems, as the primary treatment mechanism utilized by floating islands is vegetative nutrient uptake. Vegetation, ideally, should be harvested following the growing season, so that nutrients that were assimilated during the growing season are not released back into the system upon senescence. Lakes that would benefit most from floating islands include those identified in Section 5.1 as having high scores.

5.5.5 Homeowner Education

Homeowner Education is a non-structural BMP that can be effective in the reduction of nutrients, metals and bacteria. In Section 4, it was demonstrated that the City reclaimed water can be used as a partial nitrogen supplement and a full phosphorus supplement for landscape fertilization, and that areas within the current reclaimed water service area have significantly greater concentrations of TN and TP within the surface water. Homeowners (and business owners) should be aware of this resource, and should be educated about its benefits and potential for abuse. Homeowner education strategies can be implemented for copper and bacteria controls as well. More specifically, homeowners should be aware of the detrimental effects of copper-based algaecides in causing downstream waterbody impairments, as well as the importance of proper disposal of pet waste. A low cost action that the City can take in areas of elevated bacteria concentrations, including the Broad Street and Lantern Lane Pump Station drainage basins, is installation of signage and pet waste stations that promote responsible pet waste management and educate the public on the effects of pet waste on the impairment of downstream waterbodies. The City may wish to review reclaimed water pricing strategies and modifying watering restrictions so that excessive irrigation is not encouraged.

6.0 Conclusions and Recommendations

The results of the current year monitoring efforts were able to fill in critical data gaps and support more targeted remediation recommendations. Analysis of results generally followed and reinforced trends observed in previous reports, including identification of conveyances with elevated pollutant concentrations and lakes with consistently high discharge pollutant concentrations.

With respect to nutrients, including TN and TP, the revised prioritization analysis provided in Section 5.1 was able to provide an improved ranking of those stormwater lakes that would most benefit from general nutrient remediation strategies. These lakes include, in order of descending rank, 31 (and 11), 24, 2, 9 and 5. One of the main metrics used to gage condition in this ranking was annual nutrient export, so that any efforts focused at improving the trophic condition of each of these lakes will have the biggest “bang for the buck” in reducing total nutrient loadings to downstream waters of the state. Specific remediation efforts that could be applicable to these areas were outlined in Section 5.5, and include various LID BMPs, sediment removal or in-situ treatment, floating islands and homeowner education.

The prioritization established with respect to total copper export, provided in Section 5.2, identified the 5 lakes with the highest annual export of copper to downstream waterbodies. As discussed in this report and previous reports, these large exports can be due to a multitude of factors, including excessive runoff from roads, current or past copper algaecide application, or legacy copper stored in lake sediment as the result of all past inputs. In addition to these five lakes, the Public Works Pump Station has resulted in consistently elevated measured copper concentrations. Future BMPs directed towards copper treatment should be focused within this drainage basin, as well as the drainage basins of each of the highest exporting stormwater lakes. BMPs effective at copper treatment generally include most LID practices, including any installation designed for overall volume reduction or any installation that promotes increased contact time with organic material, such as vegetated buffers, swales, and natural soil infiltration.

During this contract, caffeine was analyzed in 18 samples that were also analyzed for fecal coliforms. The analysis of caffeine was impaired in some of those samples due to unexpected analytical interferences, resulting in unusually high detection limits. Five of the 18 caffeine analyses were not meaningful due to unusually high detection limits. These are the results reported as 260 ND in Tables 3-1 and 3-3. For the remaining 13 caffeine analyses, AMEC determined that fecal coliform levels are significantly correlated with caffeine. This indicates that a portion of the fecal coliforms observed in stormwater in the City can be attributed to sewage contamination within stormwater conveyances. Specifically, 39% of the variation in fecal coliform levels is associated with caffeine, a distinct indicator of human effluents. This finding also clarifies that other sources, such as pet waste or wildlife, probably also contribute to observed levels of fecal coliform levels.

The fecal coliform prioritization provided in Section 5.3 identified the 5 lakes with the highest annual export of fecal coliform bacteria to downstream waterbodies. This analysis, together with the source tracking efforts that identified the 5th Ave. S commercial district and the portion of the Lantern Lane Pump Station drainage basin along Gordon Dr. as areas with elevated fecal coliform concentrations, should be used to guide future targeted remediation efforts. Treatment options that should be considered in these areas include any LID BMP designed for volume reduction, homeowner education, and the filter media discussed in Section 5.5. Source tracking efforts should continue, with additional focus placed on identifying aging infrastructure, including sanitary sewer and storm sewer conveyances. Besides intentional illicit dumping, pet waste and wildlife influences, failing infrastructure represents a likely source of bacterial contamination to surface waters in any highly urbanized environment. A review of infrastructure age and condition should be undertaken by the City, with condition assessments performed on the oldest or most heavily-used areas.

The reclaimed water analysis in Section 4 provided results that indicated additional attention paid to homeowner education and proper resource management was warranted. The analysis showed that the City and its residents have a valuable resource with the potential for substantial cost savings to all parties, however proper and efficient management of the resource must first be implemented. The analysis showed that the reclaimed water generated from the City water treatment plant contained sufficient phosphorus to warrant the complete elimination of phosphorus from fertilizer used on turfgrass in reclaim water service areas, and contained nitrogen in quantities that warrant a significant reduction in nitrogen fertilizer applied to turfgrass in reclaim water service areas. Furthermore, the statistical analysis performed on the data presented in Table 3-5 show that surface waters within reclaimed water service areas show significantly higher concentrations of nitrogen and phosphorus than surface waters outside of these areas. This is indication that the landscapes within the reclaimed service areas are likely becoming saturated with respect to their ability to retain nutrients, and are thus exporting nitrogen and phosphorus due to the excesses being applied.

7.0 References

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Appendix A

Ambient Water Quality

Quarter 1

ATTACHMENT C - Jan 2013 Final Storwaterwater Water Quality Report

Quarter 1 Ambient Water Quality Parameters

Parameter		**Type**	**In/Out**	**Flow**	**Date**	**Time**	**Sample Type**	**Temp**	**pH**	**DO**	**Conductivity**
Units				(Y/N)				(°C)	(s.u.)	(mg/l)	(µS/cm)
Location											
Pump Stations	PW-Pump	Pump Station		N	4/4/12	11:30 AM	bailer	26.85	7.2	6.14	1430
	14-Pump	Pump Station	In	N	4/5/12	9:30 AM	bailer	26.97	7.51	4.99	7091
	11-Pump	Pump Station		Y	4/5/12	11:45 AM	bailer	25.05	7.09	4.52	2428
Semi-Annual Sampling Locations	1NW-B	Lake	Out	N	4/4/12	9:15 AM	bailer	27.27	7.88	5.38	508
	2B	Lake	Out	Y	4/4/12	9:00 AM	bailer	27.33	8.17	9.17	462
	3B	Lake	In	N	4/6/12	8:15 AM	bailer	26.15	7.64	5.81	707
	5B	Lake	Out	Y	4/4/12	9:55 AM	bailer	27.82	8.52	9.25	442
	6B	Lake	Out	Y	4/4/12	2:10 PM	bailer	29.37	7.65	6	617
	7B	Lake		N	4/6/12	8:30 AM	bailer	26.67	8.09	4.2	1321
	8B	Lake		N	4/6/12	9:00 AM	bailer	27.48	7.98	4.99	860
	9B	Lake		N	4/6/12	9:15 AM	bailer	26.81	8.24	5.94	802
	10B	Lake		N	4/6/12	9:45 AM	bailer	26.3	7.73	3.3	9660
	11B	Lake	Out	Y	4/5/12	10:45 AM	bailer	27.29	7.83	4.72	622
	14B	Lake	Out	Y	4/5/12	9:05 AM	bailer	27.7	7.9	4.87	8072
	15B	Lake	Out	Y	4/4/12	10:15 AM	bailer	27.59	8.66	7.55	507
	16B	Laek		Y	4/4/12	10:45 AM	bailer	27.79	7.95	7.23	409
	19B	Lake	Out	Y	4/4/12	12:20 AM	bailer	27.08	7.33	5.25	1031
	20B	Lake	Out	Y	4/4/12	12:40 AM	bailer	28.27	8.16	7.36	540
	21B	Lake	In	N	4/4/12	1:20 PM	bailer	29.38	7.86	8.02	472
	22B	Lake	Out	Y	4/4/12	1:45 PM	bailer	28.93	8.77	19.6	466
	26B	Lake	Out	Y	4/4/12	2:30 PM	bailer	27.7	7.13	2.54	496
Roaming Locations	1A	Lake	In	N	4/6/12	7:45 AM	bailer	26.57	7.49	4.35	507
	BC-Pond	Lake	Out	N	4/5/12	12:45 PM	bailer	27.95	8.04	6.91	1634
	22A	Lake	In	N	4/4/12	1:20 PM	bailer	N/A	7.16	2.4	701
	4th Ave. Alley	Conveyance		N	4/6/12	10:00 AM	bailer	22.83	8.28	7.12	47
	4th Ave. Garag	Outfall	Out	N	4/5/12	10:00 AM	bailer	24.7	7.24	0.31	530
	11A	Lake	In	N	4/5/12	10:25 PM	bailer	27.3	7.84	3.73	635
	GD	Conveyance	Out	Y	4/5/12	9:45:00 AM	bailer	23.56	7.65	3.96	1472

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Quarter 2

ATTACHMENT C - Jan 2013 Final Storwaterwater Water Quality Report

Quarter 2 Ambient Water Quality Parameters

Parameter		**Type**	**In/Out**	**Flow**	**Date**	**Time**	**Sample Type**	**Temp**	**pH**	**DO**	**Conductivity**
Units				(Y/N)				(°C)	(s.u.)	(mg/l)	(µS/cm)
Location											
Pump Stations	PW-Pump	Pump Station			7/5/2012	1:20 PM	bailer	28.55	7.14	3.96	7072
	14-Pump	Pump Station		Y	7/5/2012	11:30 AM	bailer	29.98	7.51	4.63	8755
	11-Pump	Pump Station		N	7/5/2012	12:30 PM	bailer	27.57	7.27	3.11	1490

Created By: SCA

Checked By: TSK

Quarter 3

ATTACHMENT C - Jan 2013 Final Storwaterwater Water Quality Report

Quarter 3 Ambient Water Quality Parameters

Parameter		Type	In/Out	Flow	Date	Time	Sample Type	Temp	pH	DO	Conductivity
Units				(Y/N)				(°C)	(s.u.)	(mg/l)	(µS/cm)
Location											
Pump Stations	PW-Pump	Pump Station		Y	9/25/12	2:45 PM	bailer	28.09	7.19	4.56	1486
	14-Pump	Pump Station		Y	9/26/12	11:15 AM	bailer	27.75	7.15	4.15	30706
	11-Pump	Pump Station			9/26/12	9:45 AM	bailer	27.72	6.51	6.01	1331
Semi-Annual Sampling Locations	1SE-B	Lake	Out	N	9/25/12	9:45 AM	bailer	27.33	7.31	4.81	453
	2B	Lake	Out	Y	9/25/12	10:30 AM	bailer	27.54	7.29	4.52	1718
	3B	Lake	Out	Y	9/25/12	11:00 AM	grab	27.35	7.16	4.74	877
	5B	Lake	Out	Y	9/25/12	11:15 AM	grab	28.48	7.17	3.35	411
	6B	Lake	Out	Y	9/25/12	12:45 PM	grab	28.19	7.15	4.47	641
	7B	Lake	Out	N	9/26/12	7:30 AM	bailer	27.73	8.44	8.79	1240
	8B	Lake	Out	Y	9/26/12	8:00 AM	grab	27.51	7.22	4.22	660
	9B	Lake	Out	N	9/26/12	8:30 AM	bailer	27.1	7.32	4.51	651
	10B	Lake	Out	Y	9/26/12	9:00 AM	bailer	27.42	6.81	6.34	9139
	11B	Lake	Out	Y	9/26/12	9:30 AM	grab	27.43	5.88	2.41	533
	14B	Lake	Out	Y	9/26/12	11:00 AM	grab	27.58	5.91	2.73	7529
	15B	Lake	Out	Y	9/25/12	11:30 AM	grab	28.66	7.83	6.56	477
	16B	Lake	Out	N	9/25/12	11:45 AM	grab	28.01	7.29	1.43	468
	19B	Lake	Out	Y	9/25/12	12:00 PM	grab	28.33	7.61	8.04	554
	20B	Lake	Out	Y	9/25/12	1:00 PM	grab	28.39	7.5	4.23	437
	21B	Lake	Out	N	9/25/12	1:30 PM	bailer	28.54	7.22	4.14	430
	22B	Lake	Out	Y	9/25/12	2:30 PM	grab	27.67	6.93	2.02	589
	26B	Lake	Out	Y	9/27/12	7:30 AM	grab	26.31	NA	1.19	536
Roaming Locations	CP	Conveyance	Conveyance	Y	9/26/12	10:45 AM	bailer	28.38	6.13	4.12	766
	22A3	Lake	In	N	9/25/12	2:00 PM	pump	28.05	6.96	0.88	506
	4th Ave 3	Conveyance	Conveyance	Y	9/26/12	1:00 PM	pump	27.08	6.92	0.41	653
	1A3	Lake	Out	N	9/25/12	9:30 AM	pump	28.46	6.84	0.85	441
	GD3-Pond	Lake (private)	Out	N	9/26/12	11:45 AM	bailer	27.72	7.14	4.37	8730
	24B	Lake	Out	Y	9/26/12	12:45 PM	grab	27.91	8.07	4.76	1293
	Reuse 1	Treatment Plant	Water Supply		9/25/12	3:00 PM	grab	30.37	6.9	6.49	1045
	Reuse 2	Port Royal Pipe	Water Supply		9/26/12	12:30 PM	grab	28.87	6.74	6.9	1054

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Quarter 4

ATTACHMENT C - Jan 2013 Final Storwaterwater Water Quality Report

Quarter 4 Ambient Water Quality Parameters

Parameter		**Type**	**In/Out**	**Flow**	**Date**	**Time**	**Sample Type**	**Temp**	**pH**	**DO**	**Conductivity**
Units				(Y/N)				(°C)	(s.u.)	(mg/l)	(µS/cm)
Location											
Pump Stations	PW-Pump	Pump Station			12/6/2012	12:35 PM	bailer	26.36	7.07	3.76	3314
	14-Pump	Pump Station		Y	12/6/2012	10:13 AM	bailer	22.79	7.06	4.53	1148
	11-Pump	Pump Station		N	12/6/2012	11:03 AM	bailer	25.49	7.08	4.25	2084
Roaming	Reuse 3	Roaming		Y	12/6/2012	2:20 PM	grab	25.59	6.97	7.96	

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Checked By: TSK