NAPLES BEACH RESTORATION AND WATER QUALITY IMPROVEMENT PROJECT

Water Quality Improvements – Phase 1

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Naples Beach Restoration & Water Quality Improvement Project
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1. Introduction

The Naples City Council contracted Erickson Consulting Engineers, Inc. (ECE) to perform an assessment of water quality improvement technologies and to evaluate where best to integrate these contaminant removal technologies and methodologies into the planned Naples Beach Restoration and Water Quality Improvement Project - Phase 1. ECE evaluated the existing levels of pollutants in the system, the type of proven technology or methodology including best management practices (BMP) for existing City maintenance programs. Placement of these technologies given geospatial constraints of existing infrastructure were evaluated and sited to optimize removal success.

A nutrient removal model was applied to simulate the potential removal percentages based on the City's planned 2021-2023 Project changes to the stormwater system and resulting discharge to the (a) south pipe network and (b) 3 lake system of North Lake, South Lake and Alligator Lake and their confluence at the south pump station. The south pump station will discharge to the Gulf through diffusers to enhance mixing, approximately 1100 feet (ft) offshore.

The anticipated removal efficiencies applied to the model were evaluated based upon the State of Florida Department of Environmental Protection (FDEP) established efficiency rates and loading methodology with input values based on the City's WQ baseline data, recent testing of pollutants (total suspended sediments (TSS) and turbidity), and loading rates for catch basins, TSS organic fraction, and concentrations of TN and TP. Detailed descriptions of the existing baseline data, and removal efficiencies for specific technologies and changes to the City's existing water quality system (swales, street sweeping and lake dredging) are discussed in Sections 2 through 7.

1.1 <u>Project Overview</u>

The Phase 1 Project Area located in drainage Basin 2 encompasses 232 Acres within SWFWMD Basin II and includes five drainage sub-basins ("Basins", see **Figure 1**), excluding dune sub-catchments. The Phase 1 Project Area includes the "3-Lake System" within Basin 5/6 and various stormwater pipes and catch basins that discharge to the Gulf of Mexico through five gravity stormwater beach outfalls.

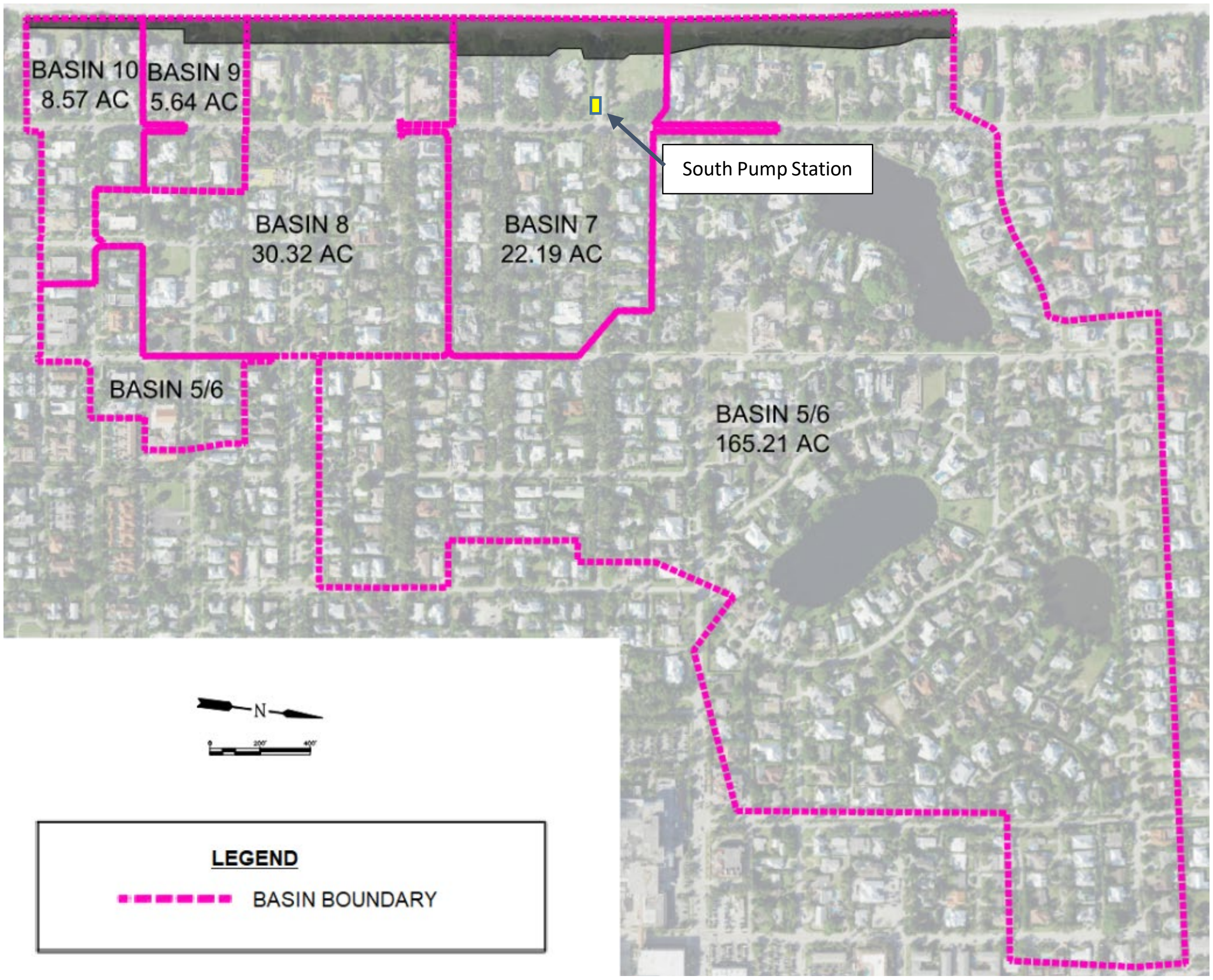


Figure 1 - Phase 1 Project Area

The project includes construction of a new stormwater management system to replace the existing gravity flow pipes to the beach outfalls with pump station (the "SPS") at 3rd Avenue North. A storm trunkline (between 2nd Avenue South to 3rd Avenue North) was also designed to replace existing gravity flow pipes to convey water from within the drainage area to the SPS. The City's aging stormwater infrastructure, comprised of some 60 inlet and manhole box structures, and extensive 12-18 inch concrete stormwater pipes pitted from age, provide an ideal growth environment for bacteria. The Project includes removal of existing stormwater infrastructure in the Gulf Shore Boulevard ("GSB") right-of-way (between 2nd Avenue South and South Gulf Drive) and installation of new curb inlets with pollutant filters, as well as new connecting stormwater pipes. Replacement of the aging, gravity based system will significantly improve conveyance to the new pump station, preventing water staging in drainage structures and swales. The runoff from roadways will be collected at curb inlets with catchment inserts to remove sediments that contribute to degraded water quality.

To further improve the water quality within the proposed stormwater system, the new system will include a water quality best management practice ("BMP") treatment train, consisting of strategically placed, individual stormwater BMPs to maximize pollutant removal efficiencies prior to discharge to the Gulf.

1.2 Water Quality Baseline Data

Water Quality Sampling events **(**Table 1**)** were conducted to establish the baseline conditions. Locations and sample data from these location by date are presented in **Figure 2,** with the baseline data listed in Section 2 below. The water quality baseline data establishes existing conditions specific to the Phase 1 Project area for the pollutants of concern which include Total Suspended Solids (TSS), Total Nitrogen (N), Total Phosphorous (P) and Bacteria (Enterococci).

Data included herein to establish the baseline levels of pollutant loading were collected and tested between 2016 and 2020. While there is a longer monitoring record available, these data are deemed representative of current conditions in consideration of: development density and impervious vs pervious acreages, rainfall intensities, street cleaning and management, and other factors affecting pollutants in the basins. Further details of these sampling events are presented in Section 2. Additional sampling is recommended in Section 0.

Table 1 - Water Quality Sampling Events

Entity	**Date(s)**	**Locations**	**Key Parameters Measured**
City of Naples	2012-2020	Alligator Lake, South Lake, North Lake	Turbidity, TSS, Total N, Total P, Bacteria
ECE	2016-2017	Beach Outfalls 6-10, and Alligator Lake	Turbidity, TSS, Total N, Total P, Bacteria
City of Naples	June & July 2020	Catch basins & swales, sub-catchments 8 & 9	Bacteria
City of Naples	September 2020	Upstream catch basin inlets (sediment)	Volatile & Fixed Solid fraction, particle size distribution, Nitrate- Nitrite for volatile fraction
ECE	November 2020	Upstream catch basins, sub-catchments 6-8)	Turbidity, TSS, Total N, Total P, Bacteria

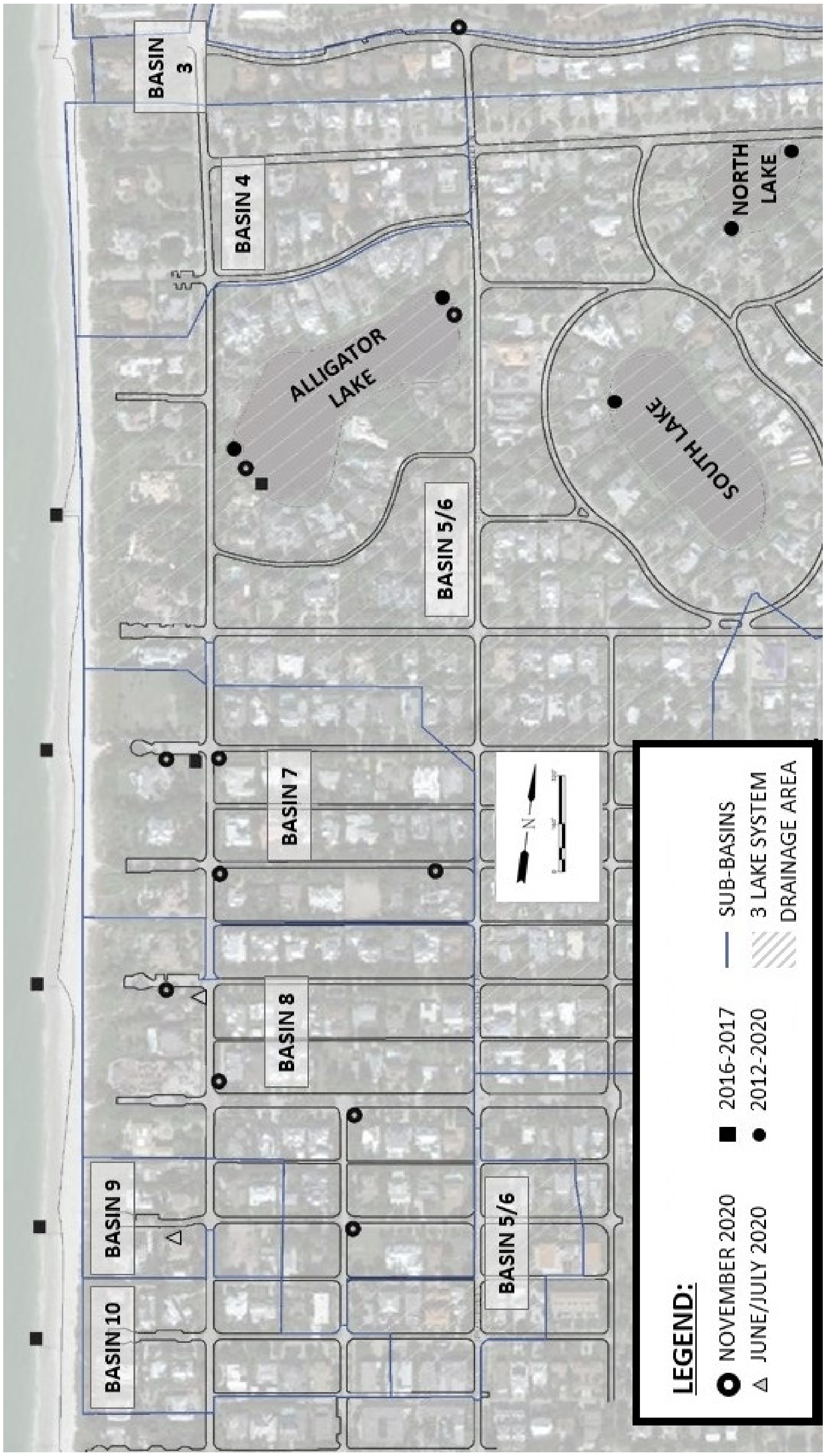
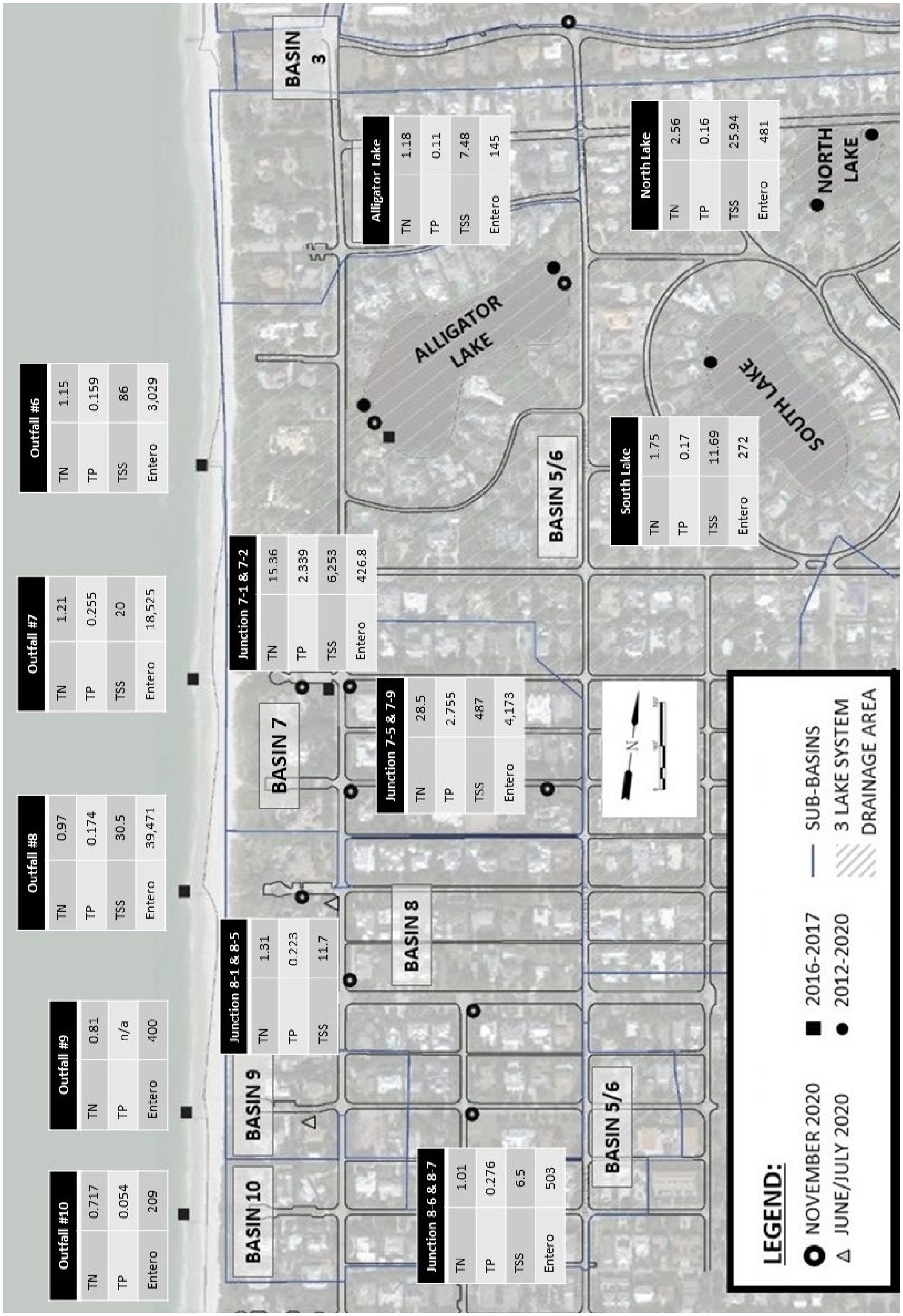


Figure 2 – Water Quality Sampling Locations



NOTES:
1. "TN" is Total Nitrogen (mg/L). "TP" is Total Phosphorus (mg/L). "TSS" is total suspended solids (mg/L). "Entrero" is enterococci bacteria (CFU/100mL).
2. All values provided are geometric means for lake data are geometric means of annual geometric mean values. Lake data are described further in Table 4 and Figures 7 and 8.
3. All outfall and upstream values are geometric means of available data.

Figure 3 - Baseline Water **Quality (2016-2020)**

1.3 Water Quality Improvement Goals and State Standards

Permits for the construction of the stormwater system have not specified pollutant limits or water quality improvement goals. ECE has worked collaboratively with SFWMD, FDEP and the City of Naples to identify water quality goals to ensure reduced pollutant discharge loads to the Gulf or adverse impact to the Gulf ecosystem. Because of the ambitious nature of these water quality goals, monitoring and adaptive management will be required with possible inclusion of additional water quality improvement measures to achieve the goals.

The existing system's aging and undersized pipes, tidally dependent drainage affected by sea level rise and maintenance requirements to remove sand deposits in the discharge pipes causes stormwater staging resulting in high TSS levels and associated nutrient growth, and bacteria loads. Removal of the existing, porous concrete, gravity flow system and replacement with a positive flow to a pump station is expected to improve the water quality in the system.

Project success will be measured against no negative impact on the Gulf adjacent to the mixing zone immediately post-construction and achievement of the water quality goals within 3-years post-construction. Post-construction monitoring at two locations including (a) beyond the mixing zone in the Gulf and (b) at the pump station within the system prior to and immediately prior to discharge is recommended.

Water quality criteria for surface waters in Florida are dependent on the designated class of the water body, classified by designated public use. There are six classes of water bodies in Florida; Class I waters require the highest degree of protection; Class V require the lowest. Surface Waters of the State are Class III unless described in rule 62.302.400, F.A.C.[1] The Phase 1 Project area lies within Class II watersheds, and discharges to a Class III water body (Gulf of Mexico).

2. WQ Baseline Data

Historic water quality sampling within the SFWMD Basin II includes sampling conducted by the City in the 3-Lake System (North, South and Alligator Lakes), data collected by ECE at the beach outfalls (discharges into the Gulf of Mexico), and upstream data collected by ECE and the City. The City of Naples routinely collects water quality samples from City Lakes.

A Comprehensive Monitoring and Adaptive Management approach and is outlined in Section 6 below, and proposes to include future quarterly monitoring (pre- and post-construction of the

[1] www.floridadep.gov/dear/water-quality-standards/content/surface-water-standards-classes-uses-criteria

Project) and will commence with sampling events in 2021 (June-July 2021 and Aug-Sept 2021), as described in Appendix E.

2.1. **Lake Water Quality Sampling**

The City of Naples historically conducted water quality sampling in the lakes twice per year (once in the wet season and once in the dry season), with the frequency of sampling increasing to either quarterly or monthly following December 2014. The exception is North Lake which did not commence water quality sampling until October 2017. The following historic data is available for the 3-Lake system located within Drainage Basin II which is comprised of North Lake (8B), South Lake (9B) and Alligator Lake (10B) (Figure **4**).

- North Lake (8B): Monthly since Oct 2017
- South Lake (9B): Twice per Year until December 2014, increasing to monthly thereafter.
- Alligator Lake (10B): Twice per Year until December 2014, increasing to quarterly thereafter.

Figure 4 - City Stormwater Lake Sampling Locations

The City completed the *Naples Bay Water Quality and Biological Analysis Report* (Cardno, 2020 – Draft) which concluded the following regarding the 3-Lake system:

- Combined discharge to the Gulf of Mexico or Naples Bay saw a decrease in salinity, and an increase in suspended solids, TN and enterococci.
- The few copper measurements taken at South Lake (9B) were higher during the pre-2015 than they have been over the last 5 years.
- Suspended solids, TN, and TP were generally higher with a greater range of concentrations at North Lake (8B).
- Bacteria (enterococci) had a lower median colony measurements but the 75th percentile ranges were still as high as 500 cfu/100mL.

Water Quality Sampling and testing data averaged using annual geometric means (AGM) from 2017 and 2020 for North Lake, South Lake, and Alligator Lake are summarized in Table 2. Total suspended solids data varied between 4-30mg/L in 2016/17, 3-20mg/L in 2017/18, 0-40mg/L in 2018/2019 and 3-75mg/L in 2019/2020. The detailed sampling results are provided in Appendix A.

Table 2 – 2017-2020 AGM Lake Water Quality Monitoring

Pollutant		North Lake	South Lake	Alligator Lake
TN (mg/l)	FY 2016-2017		1.74	1.34
	FY 2017-2018	1.80	1.54	1.09
	FY 2018-2019	3.48	1.75	1.33
	FY 2019-2020	2.69	1.98	0.99
	Geometric Mean	2.56	1.75	1.18
TP (mg/l)	FY 2016-2017		0.40	0.15
	FY 2017-2018	0.12	0.19	0.13
	FY 2018-2019	0.18	0.09	0.12
	FY 2019-2020	0.19	0.13	0.06
	Geometric Mean	0.16	0.17	0.11
TSS	FY 2016-2017		15.00	10.00
	FY 2017-2018	20.00	10.00	5.00
	FY 2018-2019	50.00	10.00	10.00
	FY 2019-2020	17.45	12.45	6.25
	Geometric Mean	25.94	11.69	7.48

As shown in Figure **5**, total suspended solids are increasing at 2mg/L per year in South Lake and 4.6mg/L in North Lake while decreasing at -0.75mg/L in Alligator Lake between 2017 and 2020.

In Figure **6**, turbidity measurements are consistent with the TSS trends whereby North and South Lakes are increasing and Alligator Lake is decreasing between 2017 and 2020. While Nitrogen levels in Alligator Lake have been reasonably consistent between 2012 and 2020, total nitrogen in North Lake and South Lake are increasing at 0.5 to 0.6 mg/L per year between 2017 and 2020. Phosphorus sampling in the lakes indicates in Figure **6** that total phosphorus levels for South Lake and Alligator Lake were stable (less than 0.01mg/L change on average per year), but phosphorus levels in North Lake increased at 0.06mg/L per year.

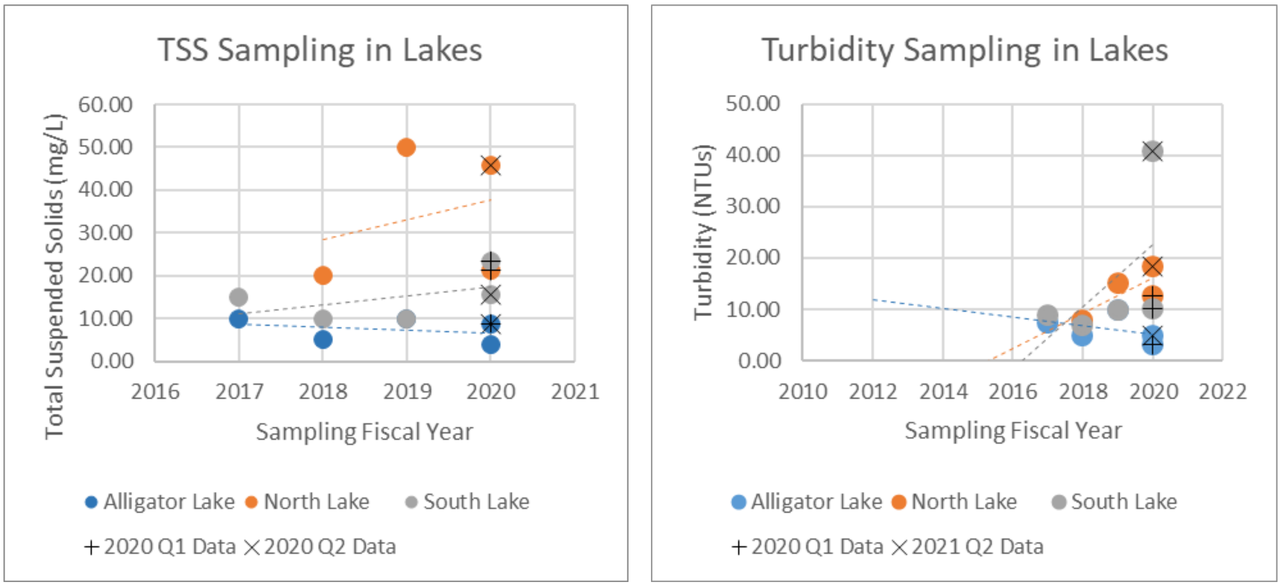


Figure 5 - TSS (left) and Turbidity (right) Sampling in Lakes

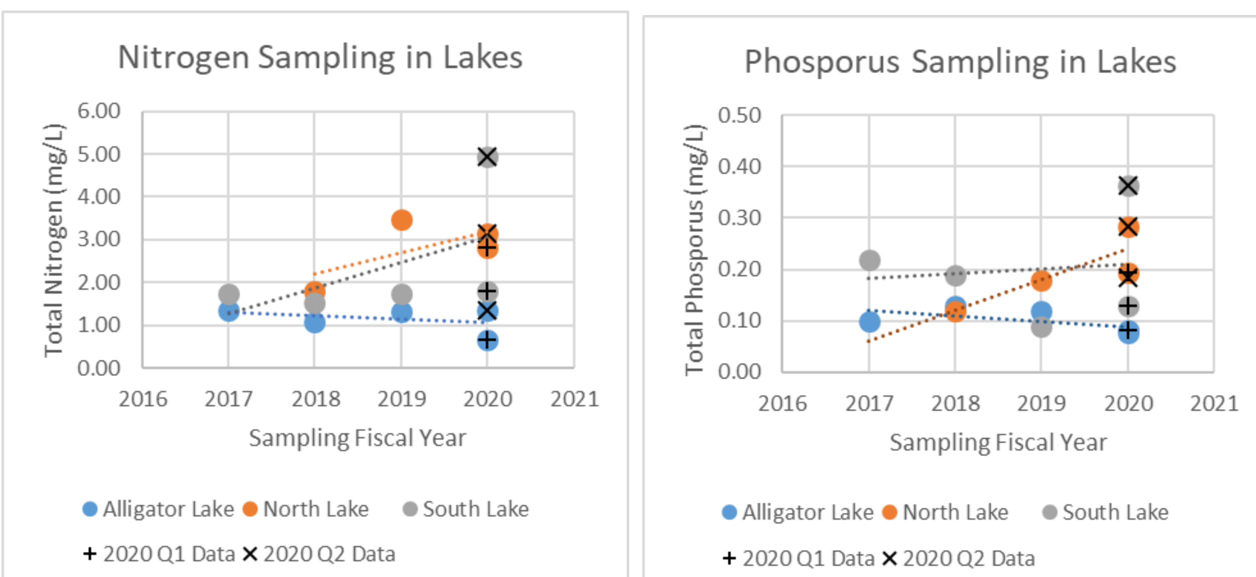


Figure 6 - Nitrogen (left) and Phosphorus (right) Sampling in Lakes

2.2. **Beach Outfall Water Quality Sampling**

The goal of the 2016-2017 sampling effort was to identify and quantify the types and concentrations of pollutants that presently discharge through the City's beach outfall pipes (#2-10) to identify and evaluate alternative treatment methods for the Project. Specifically, the objectives were:

1. Strategically siting the sampling locations for overall geographic location to estimate and quantify the sub-basin contribution and concentrations for outfalls characterized by high discharge rates;
2. Timing the sampling to capture the "worst case conditions" for an approximate 0.5" or greater rainfall event;
3. Following established standard methods for sampling and testing to measure pollutants of concern and gather related key baseline and physical information; and
4. Utilizing adaptive management to assess the sampling and testing results to incorporate feedback loops that may result in siting and protocol changes; and
5. Gaining an understanding of variability and levels of water quality impacts to the Gulf associated with stormwater at these outfalls and opportunities to reduce levels of pollutants.

Sampling was conducted at the locations shown in Table **3** and Figure **7**.

Table 3 - Water Quality Sampling Locations

Outfall #	Location	Characteristics
Outfall 2	R-63, north of 8th Avenue North at the Naples Beach Hotel & Golf Club	High discharge rate (84 cfs), golf course drainage/influence, geographic location
Outfall 4	R-64, 7th Avenue North	Geographic and spatial contribution from sub-basin
Outfall 6	R-65, Between 4th & 6th Avenue North and west of South Lake Drive	High discharge rates (82.3 cfs), geographic location and spatial contribution from sub-basin
Outfall 7	Between R-66 & R-67, 3rd Avenue North	Geographic location and spatial contribution from sub-basin
Outfall 8	R-67, 1st Avenue North	High discharge rate and spatial contribution from sub-basin
Outfall 10	R-69, 2nd Avenue South	Geographic location (Project's south limit)

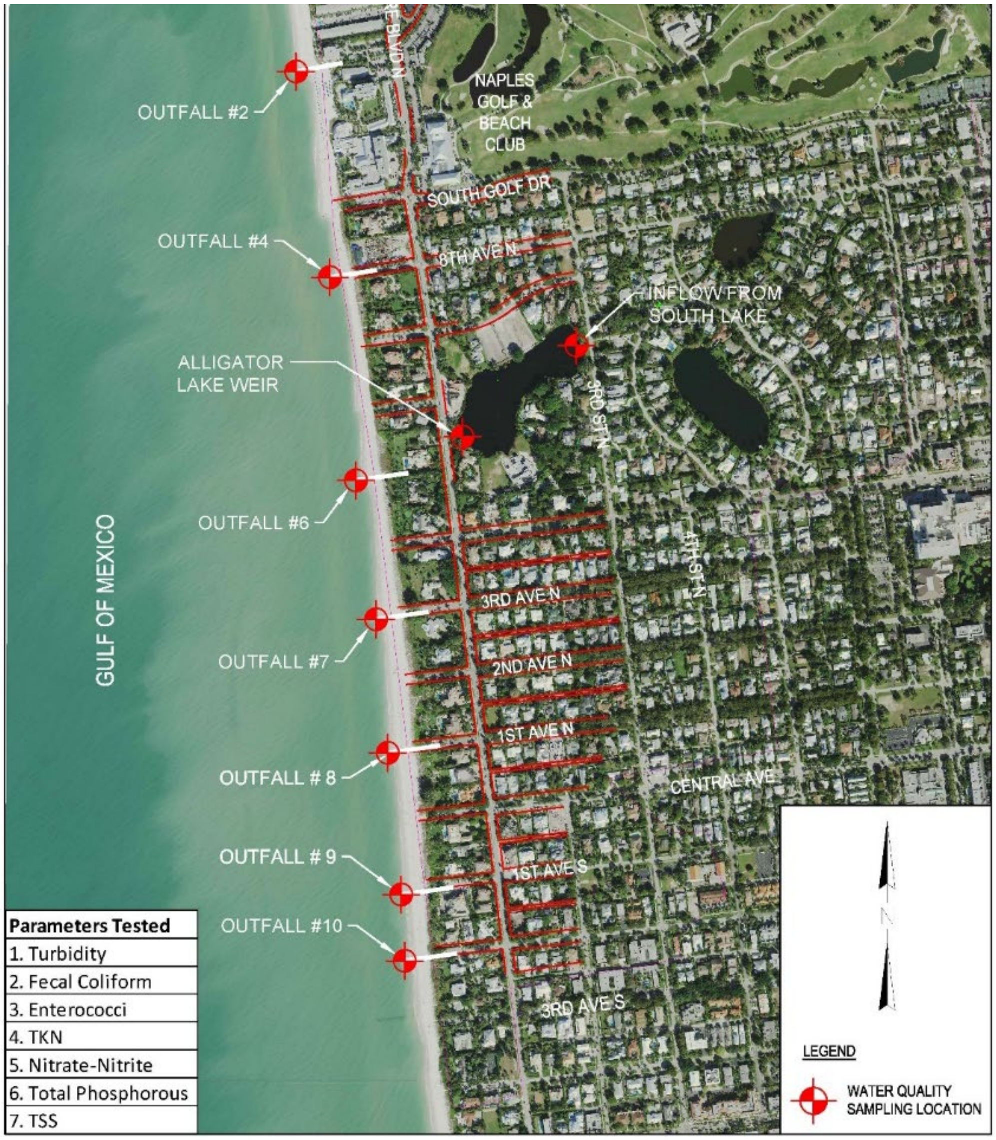


Figure 7 - Water Quality Sampling Locations (2016-17)

The sampling methods were developed, and ECE strived to meet the following criteria:

- Minimal to no rainfall in the area for 7 days
- A rainfall event of at least 0.5” occurring in an 8 hour period
- Safe conditions for sampling (e.g. daylight, no lightning strikes nearby, low waves)

Sampling occurred at the seaward terminus of the outfall, and at 50 ft and 100 ft down-current of the outfall. The goal was to capture the worst-case conditions that would result in contamination near to shore and thus not allow for significant diffusion/dispersion. At Outfalls #2 and #6 (highest flow rates), additional testing was conducted approximately 2-3 hours after the initial testing to help determine the magnitude of reduction in loading occurring over time.

Additional considerations included:

- Samples taken during an onshore wind from the north were preferable to avoid upwelling. Therefore, all samples were taken at 11 am or later.
- Similar to the protocol followed by the State of Florida Department of Health, samples were taken in approximately 3 ft of water at a depth approximately 1-2 ft below the water surface.
- Samples from stagnant waters at each location were avoided.
- For one of the four sampling events, grab samples were collected after five (5) significant rainfall events producing a cumulative excess of two (2) inches of rainfall within the outfall project area.

A total of four (4) sampling events were conducted in 2016-2017. The objective initially was to identify the pollutant loads (i.e. "worst case conditions") associated with the first rainfall following a period of 45 – 60 days with little or no rainfall, and subsequently to determine if these pollutant loads were reduced during the more frequent summer rainfall events. The sample sites and testing were focused on understanding the levels of pollutants discharged to the Gulf of Mexico, and the scale of the pollutant loads. The results of the 2016-2017 sampling are provided in Appendix B. A summary of the water quality data is presented in Table 4**.**

Table 4 - 2016-2017 Baseline Water Quality Sampling at Beach Outfalls (1)

Pollutant		6	AL Weir	4	7	8	9	10	Outfalls 4 & 7-10
TSS (mg/l)	Min	33.0	2.0	50	20.0	30.5	-	883.0	20
	Max	226.0	29.7	50	20.0	30.5	-	883.0	883
	Geometric Mean	86.4	8.0	50	20.0	30.5	-	883.0	72.0
TN (mg/l)	Min	0.92	1.08	0.77	1.19	0.85	0.81	0.66	0.66
	Max	1.43	1.82	1.02	1.24	1.11	0.81	0.78	1.24
	Geometric Mean	1.15	1.46	0.88	1.21	0.97	0.81	0.72	0.92
TP (mg/l)	Min	0.16	0.06	0.029	0.26	0.17	-	0.05	0.029
	Max	0.16	0.11	0.029	0.26	0.17	-	0.05	0.255
	Geometric Mean	0.16	0.08	0.029	0.26	0.17	-	0.05	0.091

(1) Outfall samples collected at the outfall pipe.
(2) High TSS measurement at Outfall 9 & 10 was due to wave-induced suspended sediment during sample collection – these were excluded from the reporting in this table.

State of Florida Department of Health

The State of Florida Department of Health (DOH) routinely tests shoreline water quality and issues beach closure notifications. Three areas near and within the project area are regularly monitored by the DOH for bacteria: (1) Doctor's Pass (north of the pass and north of the project area); (2) Lowdermilk Beach Park (within the project area, between Outfalls 1 and 2, near R-61); and (3) Naples Pier (south of the project area) (Table **5** and Figure **8**). Historically, no beach closures have been issued for the City of Naples beaches. Sampling at the Naples Pier occurs during good weather at the seaward edge of the pier approximately 1000ft from the shoreline and outside of the mixing zone of the current outfalls when there is no/low discharge.

Table 5 - Department of Health Sampling Locations

Sampling Location	Location (WGS 84)		General Location Relative to Project
	Latitude	Longitude	
Doctor's Pass	26° 10' 41" N	81° 48' 54" W	North
Lowdermilk Park Beach	26° 09' 44" N	81° 48' 40" W	Within
Naples Pier	26° 07' 54" N	81° 48' 24" W	South

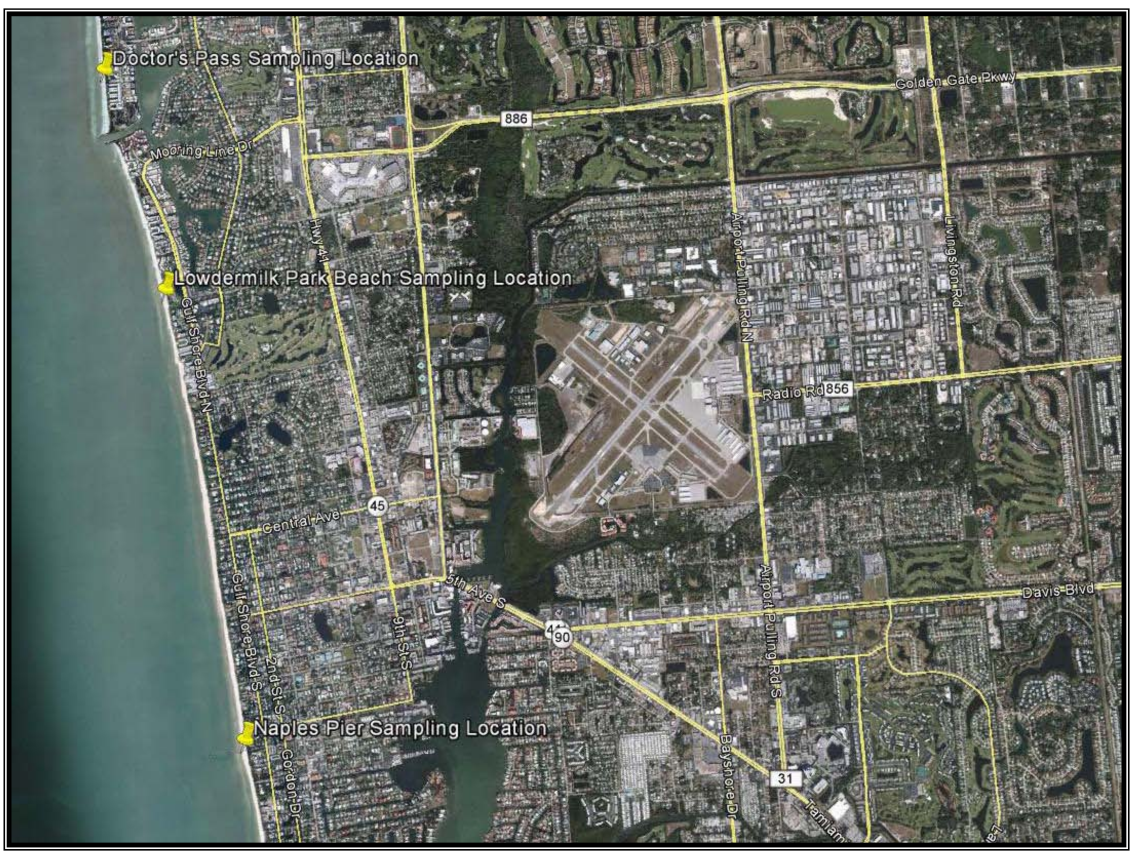


Figure 8 – Florida Health Department's Bacteria Sampling Locations

2.3. Upstream Water Quality and Sediment Sampling

Additional sampling was conducted by the City in September 2020 (upstream catch basin sediments) and ECE in November 2020 (upstream water quality) to supplement the available baseline data. The sampling quantified the types and concentrations of pollutants that presently discharge through the City's beach outfall pipes (#2-10) and the variability of these pollutants between the upstream lakes, stormwater system and the beach discharge.

A single collection event was conducted by the City in September 2020, which included sediment sampling from existing City of Naples catch basins with filter inserts to establish the characteristics of the sediments in stormwater run-off. The following parameters were tested:

- EPA 9056 test (Inorganic Anions by Ion Chromatography) to better identify the pollutant constituents within the TSS (2-3 samples within catch basins).
- TSS: fixed solids vs. volatile solids
- TSS: fixed solids fraction of fines and D_{50}

The September 2020 Sediment Sampling results are provided in Appendix D, and the results are summarized in Table 6.

Table 6 – City of Naples September 2020 Catch Basin Sediment Sampling

Constituent		Nitrate/Nitrite	Volatile Solids	Fixed Solids	D_{50} Grain Size	Percent Fines
Sediment	Min to Max	0.3 to 6.1	6.6 to 59	41 to 93	0.2 to 1.48	1.8 to 37.0
	Geometric Mean	0.9	19.5	68.2	0.5	6.9

A water sampling event was conducted by ECE in November 2020, which included water quality sampling from existing City of Naples catch basins to investigate water quality characteristics in upstream portions of the system. The November 2020 event tested the following parameters at 11 locations:

- TSS and Turbidity
- Enterococci Bacteria
- Total Phosphorus and Ortho-Phosphate
- TKN, Nitrate + Nitrate as N, Total Nitrogen

Results of the November 2020 Water Quality Sampling are provided in Attachment B. A summary of upstream water quality sampling results is presented in Table 7.

Table 7 – 2020 Upstream Sampling Geometric Means					
Pollutant	**3-Lake System Basin 5/6**	**Basin 7**	**Basin 8**	**South System - Basins 7-10**	**FDEP AVG(1)**
TSS (mg/l)	14.1	446.0	8.7	47.1	37.5
TN (mg/l)	1.55	20.93	0.42	4.91	2.07
TP (mg/l)	0.12	2.54	0.25	0.79	0.327

(1) EMC's for Florida's general land use categories Single Family Residential (FDEP, 2018)

2.4. **Summary of Bacteria Sampling**

A number of water quality sampling events were conducted between 2016 and 2020 including samples from within the Lakes, within the upstream pipe network and at the beach outfalls. The bacteria level results are summarized in Table 8. For the two inlets and one swale sampled for enterococcus in June and July of 2020, three of the five samples exceeded the method detection limit, and the remaining two were more than ten times the concentration of the proposed water quality goal. Quarterly sampling within the existing system, specifically with samples collected at the inlet grate during rainfall events, is proposed to understand the source of the high bacteria levels (e.g. from flow into the system or bacteria growth in pipes).

Table 8 – 2016 to 2020 Enterococci Sampling Results				
Location	Range (#/100 mL)			Geometric Mean
North Lake	161	to	1,290	372
South Lake	42	to	983	171
North & South Lakes Combined	42		1,290	238
Alligator Lake	20	to	11,199	328
Outfall 6	10	to	19,000	1,178
Alligator Lake & Outfall 6	10	to	19,000	394
Outfall 4	1,700	to	22,000	6,116
Upstream Basin 7	720	to	24,196	5,109
Outfall 7	6,600	to	52,000	18,526
Basin 7	720	to	52,000	7,849
Upstream Basin 8	31	to	24,196	3,210
Outfall 8	38,000	to	41,000	39,472
Basin 8	31	to	41,000	7,408
Outfall 9	400	to	400	400
Outfall 10	10	to	4,400	210

High bacteria levels at the beach outfalls are likely due to staging in the box culverts within the existing system that provides an ideal environment for bacteria growth. The proposed system will ensure that there is not stagnant water within the pipe network by designing the system to have continuous positive flow to the pump station. Therefore, the high bacteria levels shown in Table 8 would not be indicative of the expected bacteria loading within the new system because a significant source of the bacterial growth would be removed. Further upstream testing of water flowing into the inlet grates are planned to occur in June-July 2021 and August-September 2021 to better understand the expected bacteria levels entering the pipes and thereby the rebuilt pipe network.

3. Rainfall, Runoff and Pre-Project Annual Pollutant Loads

The basis for pollutant removal effectiveness is measured by comparing pre- and post-project pollutant loading. The pre-project loading depends directly on runoff, which depends on rainfall and land use characteristics. The post-project loading directly depends on runoff and performance of Best Management Practices (BMPs).

Runoff is a function of precipitation and soil conditions / land cover (i.e. percolation versus runoff, described by the annual runoff coefficient). This section provides an overview of local rainfall and land use which are then used to determine predicted water quality of the runoff given State standards.

3.1 Rainfall

The State of Florida BMP Trains model, discussed later in this report, requires the input of the mean annual rainfall and the meteorological zone. The meteorological zones are based on a cluster analysis to identify areas with similar annual rainfall and runoff values. The City of Naples is located within the "Florida Zone 4" cluster (Figure **9**).

The State of Florida conducted a study in 2007 to estimate the mean annual rainfall for throughout Florida based on data collected between 1971 and 2000 (Figure **10**). This study estimates the mean annual rainfall for the City of Naples at 53 inches per year.

ECE conducted an updated assessment of rainfall of Southwest Florida, inclusive of the City of Naples, for the period 2003-2019. The results indicate a mean annual rainfall 48 and 59 inches, with the gauge location nearest to the Project Site receiving an average of 59 inches per year which is greater than the mean reported by Harper (2007) (Table **9**). As such, a mean annual rainfall of 59 inches was applied to the water quality evaluation as described herein.

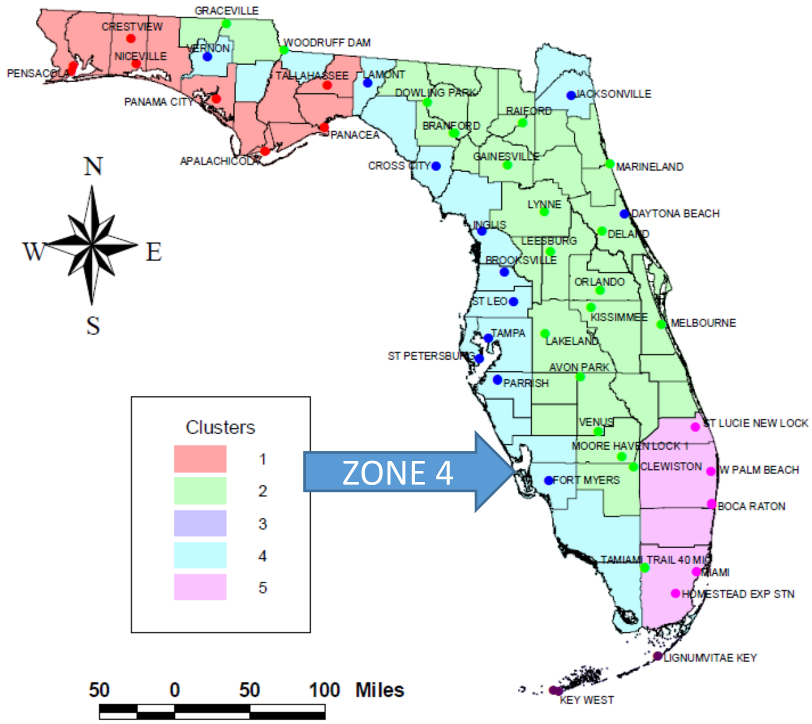


Figure 9 - Meteorological Zones Identified Using Cluster Analysis (Harper, 2007)

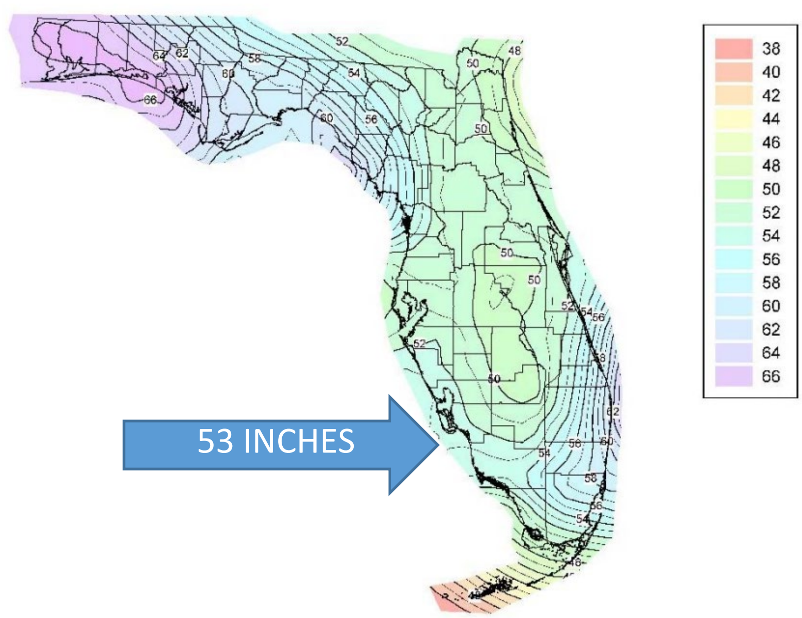


Figure 10- Isopleths of Mean Annual Precipitation in Florida from 1971-2000 (Harper, 2007)

Table 9 - Southwest Florida Annual Rainfall (2003-2019)

Year	Annual Rainfall Totals (in)			
	Naples		Ft. Myers[1]	Punta Gorda[1]
	Naples Municipal Airport[1,2]	Golden Gate High School[3]		
2003	71.1	74.6	70.6	62.9
2004	40.2	55.7	61.8	50.1
2005	63.4	66.1	74.5	58
2006	50.2	46.2	56.3	51.1
2007	35	40.5	47	30
2008	48.3	60.3	60.1	48.8
2009	33.9	56.8	39.9	45.4
2010	44.6	57.1	53.1	54.5
2011	38.2	55.8	65.8	47.1
2012	37.9	52.1	49.6	56.3
2013	49.3	64.5	53.8	66.9
2014	50.7	60.4	42.3	54.8
2015	39.7	47.1	60.9	51.6
2016	44.6	69.6	63.9	62.4
2017	68.5	78	61.5	51.8
2018	50.1	55.5	52.1	63.3
2019	44.9	n.d.	60.4	57.7
Mean Annual Rainfall	**48**	**59**	**57**	**54**

Data Source(s):

1. https://www.ncdc.noaa.gov/cdo-web/
   Naples Municipal Airport Station
   Ft. Myers Field Airport Station
   Punta Gorda Airport Station
2. http://www.weatherunderground.com/history - Naples Municipal Airport Station
3. http://climatecenter.fsu.edu/ - Golden Gate High School Station; Golden Gate gauge removed in 2019

3.2 Land Use

The performance efficiency and effectiveness of stormwater BMPs are directly linked to the quantity (volume or flow rate) and quality (i.e. concentration of pollutants) of the stormwater runoff. Both stormwater quality and quantity depend on land use within the catchment area.

The State of Florida general land use categories are described below in Table **10**. The Project Area can be described as Single-Family Residential.

Table 10 - General Land Use Categories for Runoff Characterization Data (Harper, 2007)

Land Use	Description
Low-Density Residential	Rural areas with lot sizes greater than 1 acre or less than one dwelling unit per acre; internal roadways associated with the homes are also included.
Single-Family Residential	Typical detached home community with lot sizes generally less than 1 acre and dwelling densities greater than one dwelling unit per acre; internal roadways associated with the homes are also included.
Multi-Family Residential	Residential land use consisting primarily of apartments, condominiums, and cluster-homes; internal roadways associated with the homes are also included.
Low-Intensity Commercial	Areas which receive only a moderate amount of traffic volume where cars are parked during the day for extended periods of time; these areas include universities, schools, professional office sites, and small shopping centers; internal roadways associated with the development are also included.
High-Intensity Commercial	Land use consisting of commercial areas with high levels of traffic volume and constant traffic moving in and out of the area; includes downtown areas, commercial sites, regional malls, and associated parking lots; internal roadways associated with the development are also included.

3.3 Runoff Coefficient

The runoff coefficient (Rational C Value) estimates the percentage of rainfall which becomes runoff by using the NDCIA (non-DCIA curve number for the portion of the basin which is not directly connected to impervious area) and the DCIA percentage (the percentage of the basin that includes directly-connected impervious area). The NDCIA and DCIA percentage were previously estimated for the project, after undergoing a sensitivity analysis, during the pre- and post-project stormwater modeling by ECE. The non-DCIA curve number is estimated as 80, and a DCIA percentage is estimated as 30. The resulting Rational C Value is therefore 0.388 for Florida Zone 4 (e.g the percentage of rainfall that becomes runoff) (Harper, 2007).

3.4 Drainage Areas

The drainage areas for each sub-catchment, 5-10, are provided in Table 11. The annual runoff is the estimated as the drainage area multiplied by the mean annual rainfall and the runoff coefficient.

Table 11 - Catchment Areas and Runoff Estimates

Pre-Project Annual Loading	Catchment Area (Ac)[1]	Runoff (Ac-Ft/Yr)
EMC (mg/l)		
Sub-Basin 5 & 6	165 (156)	247
Sub-Basin 7	22 (33)	33
Sub-Basin 8	30 (51)	45
Sub-Basin 9	6	8
Sub-Basin 10	9	13
Sub-Basins 5-6	165 (156)	247
Sub-Basins 7-10	67 (100)	100
Total (Sub-Basins 2-10)	232 (256)	346

(1) Numbers in parentheses are acreages reported in 2020 Design Plans. ***See Table 14.***

The runoff volume for each catchment area has been calculated for a range of rainfall events as present in Table 12.

Table 12 – Runoff Volumes							
LEVEL OF SERVICE	**RAINFALL (IN)**	**VOLUME (MG)**			**SIMULATED AREAS (AC)**		
		LAKE SYSTEM	**SOUTH SYSTEM**	**TOTAL**	**LAKE SYSTEM**	**SOUTH SYSTEM**	**TOTAL**
5YR-1HR	2.8	3.73	1.78	5.51	167.01	72.39	239.40
5YR-24HR	5.5	17.77	8.08	25.86			
25YR-72HR	11.5	43.43	19.33	62.76			

3.5 Event Mean Concentration (EMC)

Runoff concentrations are expressed in terms of the Event Mean Concentration (EMC) which is described as the ratio of pollutant loading and runoff volume. EMCs for General Land Use Categories in Florida are provided in Table **13**.

Guidelines for EMC for bacteria are not readily available; however, onsite testing indicates EMC of 300 cfu/100mL for baseflow (as documented at the upstream weir in Alligator Lake) and upwards of 38,000 cfu/100mL during storm flow that is likely from the box culvert that connects to the Gulf. All loading values for bacteria are provided as cfu/100 mL.

Table 13 - EMCs for General Land Use Categories in Florida

Land Use	Typical Runoff Concentration (Mg/L)						
	Total N	Total P	BOD	TSS	Copper	Lead	Zinc
Low-Density Residential	1.61	0.191	4.7	23	0.0084	0.0024	0.031
Single-Family*	2.07	0.327	7.9	37.5	0.016	0.004	0.062
Multi-Family	2.32	0.52	11.3	77.8	0.009	0.006	0.086
Low-Intensity Commercial	1.18	0.179	7.7	57.5	0.018	0.005	0.094
High-Intensity Commercial	2.4	0.345	11.3	69.7	0.015	--	0.16

*Typical detached home community with lot sizes generally less than 1 acre and dwelling densities greater than one dwelling unit per acre; and internal roadways associated with the homes are also included.

The EMCs included in Table **13** are recommended by FDEP in absence of site specific data. These typical runoff concentrations were compared to measured levels to ensure that an appropriate range was considered; however, site specific data was utilized for this analysis.

3.6 <u>Pre-Project Annual Pollutant Loading</u>

Pre-Project annual pollutant loading is estimated based on the annual runoff volume multiplied by the EMC. The pre-project annual pollutant loadings for TSS, TN, TP and bacteria are estimated using the EPA Simple Method. The site-specific data was used to calculate the pre-project loading.

$$L = 0.266 * RO * EMC * A \quad [for\ TSS, TN\ and\ TP]$$

Where L = annual load (lbs/yr), RO = Average Annual Runoff (Ac-in/yr), A = Catchment Area (ac), EMC = Event Mean Concentration (mg/l)

$$L = 1.03x10 - 3 * RO * C * A\ [\,for\ bacteria]$$

Where L = annual load (billion colonies), RO = Average Annual Runoff (Ac-in/yr), A = Catchment Area (ac), C = Bacteria Concentration (col/100ml)

Table 14 - Estimated Pre-Project Annual Loadings

Pre-Project Annual Loading	Catchment Area	Runoff	TSS	TP	TN	Entero-cocci
	(Ac)	(Ac-Ft/Yr)	lbs/yr	lbs/yr	lbs/yr	Billion Colonies
EMC (mg/l)			11.91	0.17	1.76	300*
Lake System (Basins 5/6)	165 (156)	275	8,704	127	1,303	
EMC (mg/l)			47.1	0.79	4.91	300*
South System (Basins 7-10)	67 (100)	111	14,163	238	1,476	
Total (Sub-Basins 5-10)	232	385	22,867	364	2,779	

*300 cfu/100 ml (base flow)

NOTES:

(1) Sub-basin 5 & 6 was increased by 9 ac resulting from removal of 19 ac along S. Golf Drive (conveys to sub-basin 3 and NPS) and adding 28 ac from sub-basins 7 & 8 associated with 3rd Street (2nd Ave S to 3rd Ave N).

(2) Sub-basin 7 was reduced by 11 acres, redirected 9 acres at 3rd Street (3-Lake System) and removing Beach Dune (2 ac).

(3) Sub-basin 8 was reduced by 21 ac, redirected 20 at ac 3rd Street (3-Lake System) and removing Beach Dune (1 ac).

4. WQ Treatment Components

ECE evaluated the effectiveness of stand-alone water quality treatment BMPs (alternatives) and then evaluated the effectiveness of multiple BMPs in series using the State of Florida methodology and the ECE modified BMPTrains Model as a basis to build an optimized Trains model that includes TSS. Percent reduction in annual pollutant loads, as described herein, are based on the pre-project annual loading of the project areas as a whole (i.e. 3-Lake System (Sub-Basins 5-6) and South System (Sub-Basins 7-10)). Load removal efficiencies as a percent removal of influent and effluent at the individual treatment systems are also specified.

The performance of stormwater BMPs are commonly expressed in terms of removal efficiency (%) for the purpose of comparing between BMP types. This metric is also used to compute expected post-project loads such as with the Trains Model. In practice, pollutant removal performance varies with pollutant load, and a BMP will typically remove a large percentage of total load when concentrations are high compared to when influent concentrations are low. Water quality BMPs are presented below in the order of the proposed treatment train. Removal rates are based on independently tested results. Where deemed appropriate, values were adjusted to a lower removal efficiency (more conservative estimate) based on site specific conditions.

4.1 Street Sweeping (Increased Frequency)

Street sweeping proactively clears leaves, debris, sediments and other organic and inorganic matter that is suspended by runoff and flows into the stormwater system during rainfall events. An increase in street sweeping from once per month to twice per month was evaluated to estimate the TSS, TN and TP removal efficiencies with the following assumptions:

- Curb Miles within Project Area: 13.8 (Phase 1)
- Dry weight removal: 0.062 lbs per foot (FSA, 2011/2019)
- Annual Reduction (lbs) per year (FSA, 2019) (Table 15).
- Construction Costs: $0
- Annual Maintenance Costs: $45/mile x 12 events (net increase) (FSA, 2011/2019; City of Naples, 2018) = 13.8 miles * $45/mile x 12 events/yr = $7,452/yr
- 20-Year Total Costs: $149,040 for 3-Lake and South Systems.

Table 15- Pollutant Removal Efficiencies for Increased Street Sweeping (Net Increase)

Area	Annual Reduction (lbs/yr) / (Percent)			20-Yr Costs per lb		
	TSS	TN	TP	TSS	TN	TP
3-Lake System	836 9.6%	20 1.5%	13 10.0%	$5	$226	$353
South System	557 3.9%	14 1.0%	9 3.9%	$5	$209	$327
Total	1393 7.3%	34 1.2%	22 6.0%	$5	$219	$342

4.2 3-Lake System Increase in Wet Detention

Wet detention systems allow the suspended sediments and nutrients to settle out as the flow velocity drops. It is particularly effective for phosphorus removal which is ultimately absorbed into the lake sediments. An increase in wet detention is achieved by a proposed adjustable height weir in Alligator Lake which would increase the water levels in upstream lakes. The increase in wet detention of 9 inches (previously modelled 6") in the 3-lake system was evaluated to estimate the TSS, TN and TP removal efficiencies with the following assumptions:

- Surface Area of Lakes: 12.2 acres
- Permeant Pool Volume: 9.15 ac-ft (FDEP, 2018)

- Annual Reduction (lbs) per year (FDEP, 2018) (Table **16**).
- Percent Removal (Influent to Effluent): 18% TSS, 59% TP, 34% TN (FDEP, 2018)
- Construction Costs: $5,000 (adjustable weir)
- Annual Maintenance Costs: $1,000 (weir cleaning)
- 20-Year Total Costs: $25,000 3-Lake System.

Table 16 - Pollutant Removal Efficiencies for Increased Wet Detention in 3-Lake System

Area	Annual Reduction (lbs/yr) / (Percent)			20-Yr Costs per lb		
	TSS	TN	TP	TSS	TN	TP
3-Lake System	1,567 18%	443 34%	75 59%	$1	$3	$17

4.3 <u>3-Lake System Aluminum Weir Screen</u>

An aluminum screen at the new weir is proposed to protect the pipe system from floatable debris including coconuts and sticks. The removal of organic material will reduce nutrient loads within the system. The increase in wet detention of 9 inches (previously modelled 6") in the 3-lake system was evaluated to estimate the TSS, TN and TP removal efficiencies with the following assumptions:

- Surface Area of Lakes: 12.2 acres
- Annual Reduction (lbs) per year (Table **17**).
- Percent Removal (Influent to Effluent): 6% TSS, 22% TP, 22% TN
- Construction Costs: $18,000
- Annual Maintenance Costs: $500 (cleaning of screen)
- 20-Year Total Costs: $28,000 for 3-Lake System.

Table 17 - Pollutant Removal Efficiencies for Weir Screen in 3-Lake System

Area	Annual Reduction (lbs/yr) / (Percent)			20-Yr Costs per lb		
	TSS	TN	TP	TSS	TN	TP
3-Lake System	500 6%	287 22%	28 22%	$3	$5	$50

4.4 <u>Hydrodynamic Separators</u>

Hydrodynamic separators use gravity to remove sediment from stormwater flows. Hydrodynamic separators at strategic locations were to estimate the TSS, TN and TP removal efficiencies with the following assumptions:

- Two Downstream Defenders by Hydro International (or equal): 3rd Ave N and 3rd St and 7th Ave N (3-Lake System)
- % Removal of Hydrodynamic Seperator (Influent to Effluent): 80% to 90% (for 0.35 to 0.48 mm mean grain size) TSS, 22% TP, 22% TN (FDEP, 2018) (manufactures documented higher load removals).
- Annual Reduction (lbs) per year (FDEP, 2018) in Table **18**
- Construction Costs: $109,900/ea for Downstream Defender
- Annual Maintenance Costs: $1,250/ea **=** $2,500/yr
- 20-Year Total Costs: ***$269,800***

Table 18 - Pollutant Removal Efficiencies for Hydrodynamic Separators

Area	Annual Reduction (lbs/yr) / (Percent)			20-Yr Costs per lb		
	TSS	TN	TP	TSS	TN	TP
3-Lake System - Hydrodynamic Separators	2,145 80%	88 22%	9 22%	$6	$153	$1,573

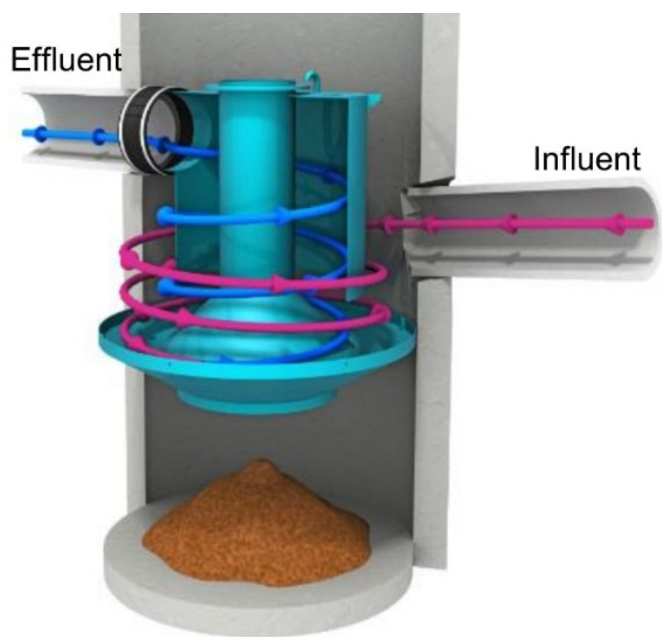


Figure 11 - Downstream Defender

4.5 <u>Catch Basin Inserts</u>

Catch basin inserts are filters that capture and retain sediment, debris, and other contaminants before they enter the stormwater system improving the water quality of the incoming runoff.

Catch Basin Inserts (Grate Inlet Skimmer Baskets (GISB) by Suntree or approved equal) were assessed to estimate the TSS, TN and TP removal efficiencies with the following assumptions:

- 63 total GISBs plus Weir Modifications at Alligator Lake
- Annual Reduction (lbs) per year (FDOT, 2019) (Table **19**).
- Construction Costs: $2,810/inlet, totaling $177,030
- Annual Maintenance Costs: $69/basin (FSA, 2011/2019) plus $500/yr for weir cleanout = 63 GISBs * $69/GISB = $4,347/yr
- 20-Year Total Costs: $263,970.

Table 19- Pollutant Removal Efficiencies for GISBs

Area	Annual Reduction (lbs/yr) / (Percent)			20-Yr Costs per lb		
	TSS	TN	TP	TSS	TN	TP
South System	6,300 85%	465 60%	88 71%	$2	$28	$149
Total	6,300 85%	465 60%	88 71%	$2	$28	$149

Figure 12- Catch Basin Filter Insert (Suntree)

4.6 <u>Swales & Media Filtration</u>

Swale regrading and cleanout are proposed along 1st, 2nd and 3rd Avenue, west of 3rd Street, with the addition of 1st Avenue South swale improvements in review. These swales improvements will increase percolation reducing runoff and organics at Gulf Shore Boulevard. Where the swales flow into the stormwater system, media filtration is proposed. Media filtration in swales, such as Bold and Gold, creates an anaerobic environment to biologically remove nitrogen and absorb phosphorus as well as trap sediments within the filtration layers. Media filtration removal rates for TSS, TN and TP were estimated with the following assumptions:

- Swales with Media Filtration where swale connects to pipe system (using Bold and Gold Media or equal) trenches: Along 1st, 2nd & 3rd Ave N. ***– Estimate is. $20,000 ea with $500 per year for total annual maintenance for 3 systems.***
- West Indian Mahogany trees provide a large canopy and are a natural resource valued by the community. An arborist will be engaged to evaluate trenching impacts on root systems and will be on site during construction. Other measures to protect the trees have been considered in the design. Specifically, pipes will remain in place with grouting at 2nd Avenue line to prevent impacts.
- Annual Reduction (lbs) per year (FDEP, 2018) (Table **20**).
- 20-Year Total Costs: ***$70,000***

Table 20 - Pollutant Removal Efficiencies for Media Filters

Area	Annual Reduction (lbs/yr) / (Percent)			20-Yr Costs per lb		
	TSS	TN	TP	TSS	TN	TP
South System – ***Media Filters***	2,688 80%	203 58%	50 88%	$1	$17	$71

4.7 SPS Screening Chamber (2nd Generation Nutrient Separating Baffle Box)

The Nutrient Separating Baffle Box utilizes a hydrodynamic separation and screens to capture and store debris and suspended sediments. The debris storage is outside of the flow area so that nutrients from the debris removed do not leech into the stormwater. The SPS screening chamber estimate of the TSS, TN and TP removal efficiencies is based on the following assumptions:

- NSBB by Suntree (or Equal): South Pump Station
- % Removal (Influent to Effluent): 60% TSS, 15.5% TP, 19.05% TN by (FDEP, 2018) (product manufacturer documented higher load removals).
- Annual Reduction (lbs) per year (FDEP, 2018) (Table **21**).
- Construction Costs: $175,300
- Annual Maintenance Costs: ***$5,000/yr***
- 20-Year Total Costs: ***$275,300*** for 3-Lake and South System.

Table 21 - Pollutant Removal Efficiencies for NSBBs

Area	Annual Reduction (lbs/yr) / (Percent)			20-Yr Costs per lb		
	TSS	TN	TP	TSS	TN	TP
3-Lake System	5,223 60%	248 19.05%	19.6 15.50%	$2	$34	$428
South System	8,498 60%	281 19.05%	36.8 15.50%	$0.63	$19	$146
Total	13,720 60%	529 19.05%	56 15.50%	$1.00	$26	$244

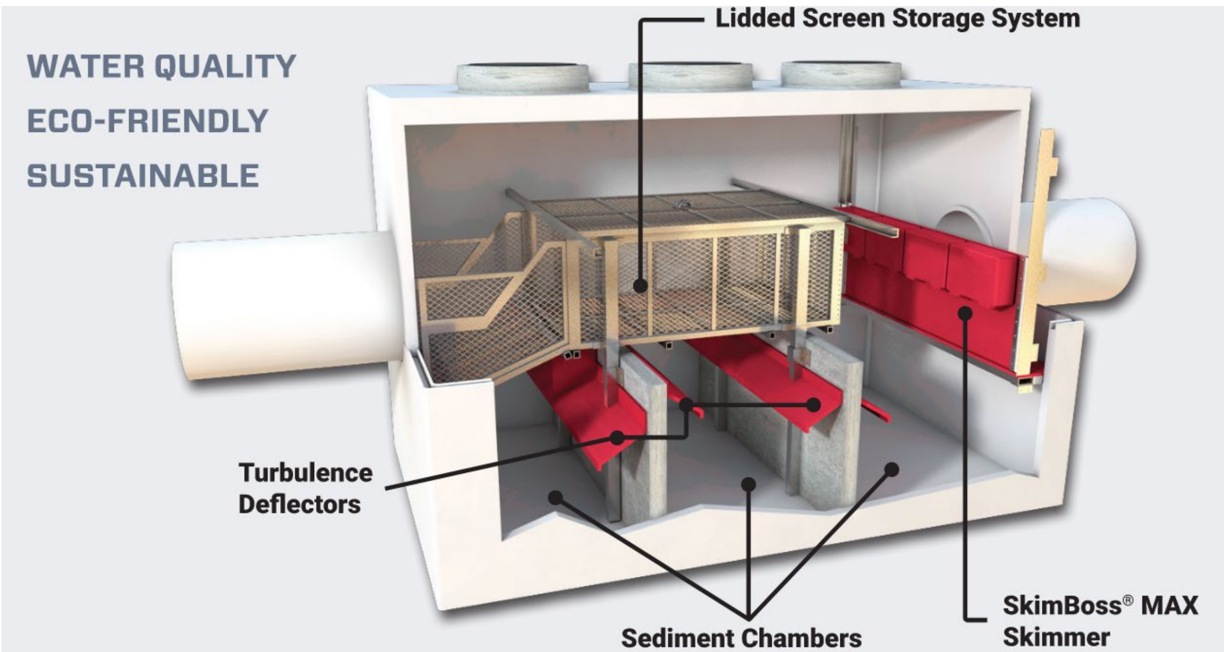


Figure 13– Screening Chamber (Nutrient Separating Baffle Box, by SunTree)

4.8 UV Treatment

UV treatment is highly effective for reducing bacteria loading by disrupting RNA and DNA chains therefore preventing reproduction and ending the bacteria life cycle. UV Treatment immediately after the South Pump Station is designed as an option for the Project. The proposed system has the following characteristics:

- Aquionics InLine W 36000+ (or Equal): South Pump Station
- % Removal (Influent to Effluent): 70,000 cfu/100ml reduced to to 70 cfu/100ml capacity for enterococci (Aquionics, 2020) at 15 CFS.

- Annual Reduction (Billion Colonies) per year (Table **22**).
- Construction Costs: $877,780 (UV Treatment Unit)
- An additional $672,000 in construction costs to enable UV treatment are included with the pump station.
- Annual Maintenance Costs: ***$10,000-$15,000/yr***
- 20-Year Total Costs: $1.3M for 3-Lake System and South System Combined

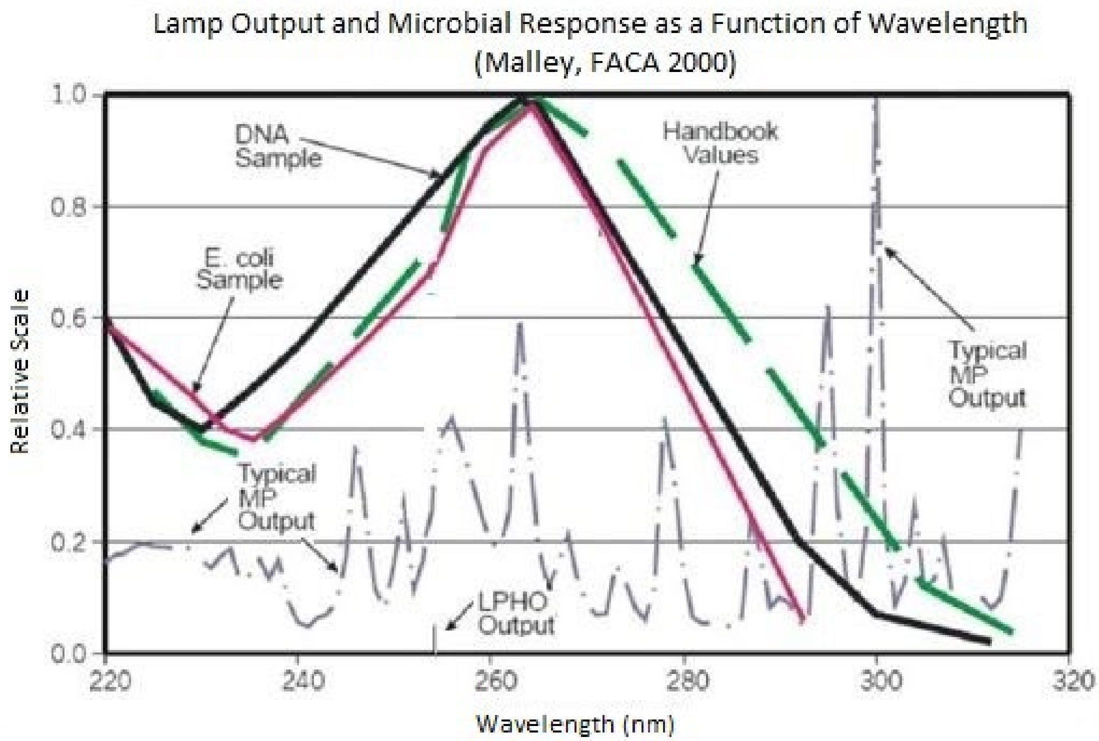


Figure 14 - Microbial Response to Light

As shown in Figure **14**, microbes decrease significantly as the light wavelength increases. The proposed UV array uses UVC Germicidal lights which operate at a wavelength of 200-280nm to kill bacteria by disrupting the RNA and DNA chains and preventing cell reproduction.

Table 22- Pollutant Removal Efficiencies for UV Treatment

Area	Annual Reduction Billion Colonies / (Percent)	20-Yr Costs per Billion Colonies
	Enterococci	
3-Lake System	1,008	$53
South System	407	$122

Bacteria removal via UV treatment depends on stormwater flow rate, the UV dose delivered by lamps, and the incoming water quality (e.g. algal turbidity and other contaminants can reduce UV transmittance). UV Transmittance readings within Alligator Lake indicate that 3-4 log removal is not likely under current conditions, due to high levels of organic deposits fronting the Alligator Lake Weir structure. Recent testing of Alligator Lake UV transmittance (May 2021, Appendix A), show UV transmittance values alongside concurrent TSS sampling results. Evaluation of UV transmittance (UVT) following construction of the new stormwater system is required to reassess design basis and the percent removal rates. Aquionics in line systems are typically designed to achieve "3-4 log removal" of bacteria. For 3 log removal, an incoming bacteria level of 10,000 colonies/100mL would be reduced to 10 colonies/100mL, and for 4 log removal, the outflow would be 1 colony/100mL.

Table 23 - Parameters Effecting UV Removal of Bacteria

Parameter	Influence / Effect	Typical Range
UV Percent Transmittance	Measure of UV absorption Effects system sizing requirements	50 – 70 % - WW 85 – 95 % - DW
Turbidity	Measure of light scattering Effects disinfection performance	< 5 NTU recommended
Minerals Coagulants	Can cause scaling on quartz sleeves Effects UV transmission	Fe < 0.1 mg/l Mn <0.1 mg/l
Suspended Solids	Absorbs UV light & shields bacteria Effects disinfection performance	< 30mg/l recommended < 10 mg/l preferred

With a UV system operating at 3-4 log removal, the outflow would be reduced to 5-50 colonies/100mL which is within the DoH limits for a Class II water body. The bacteria loading in the proposed stormwater system upstream of the UV treatment is expected to be lower than historic loading because the proposed system is designed to have positive continuous flow, and therefore bacteria is not expected to grow due to water stagnation in the pipe system. See Appendix J for further descriptions of the UV system's design parameters and design details for the proposed UV system.

5. BMP in Series

The individual BMPs were identified and strategically sited in the appropriate location within the proposed stormwater system to maximize reductions in pollutants of concern. Simulating the drainage discharge to the lake system and the south pipe network to the south pump station for pollutant loading using the City's baseline data results in the removal rates shown in Table **24** below and in Figure **15**. The total volume of water reaching the pump station based upon the hydraulic model developed for the Project is 68% Lake System and 32% South System through the swales and roadways. These relative ratios of loading after removal by the upstream treatment components proposed to be implemented are described in Section 7 below.

BMPs in series were assessed to estimate the TSS, TN and TP removal efficiencies for the Project (Sub-Basins 5-10) with the following assumptions:

- 63 Catch Basin Inserts (GISB by Suntree or equal)
- 3 media filtration swales (Bold and Gold media, or equal)
- 2 Hydrodynamic Separators (Downstream Defender by Suntree of equal) at 3rd Ave N and 3rd St & at 7th Ave N (by North Lake).
- Increased frequency of street sweeping from once per month to twice per month for all roads within the basin boundaries and implemented by the City beginning in 2020.
- 2nd Generation Baffle Box (NSBB by Suntree or equal) at the South Pump Station
- UV Treatment System (Aquionics InLine 36000+ or equal)
- Reduction (lbs) per year (FDOT, 2020) (Table **24**).
- Construction Costs: $812,630 ($1.69M with optional UV treatment)
- Annual Maintenance Costs: $22,300 ($37,000/yr with optional UV treatment)
- 20-Year Total Costs: $1.3M ($2.4M with optional UV treatment) (does not consider future value conversions).

Table 24 - Pollutant Removal Efficiencies for South System BMPs in Series

Area	Annual Reduction (lbs/yr) / (Percent)			Costs per lb Removed		
	TSS	TN	TP	TSS	TN	TP
3-Lake System	6,871	805	98	$4	$36	$296
	79%	62%	77%			
South System	12,174	828	157	$2	$26	$138
	86%	56%	66%			

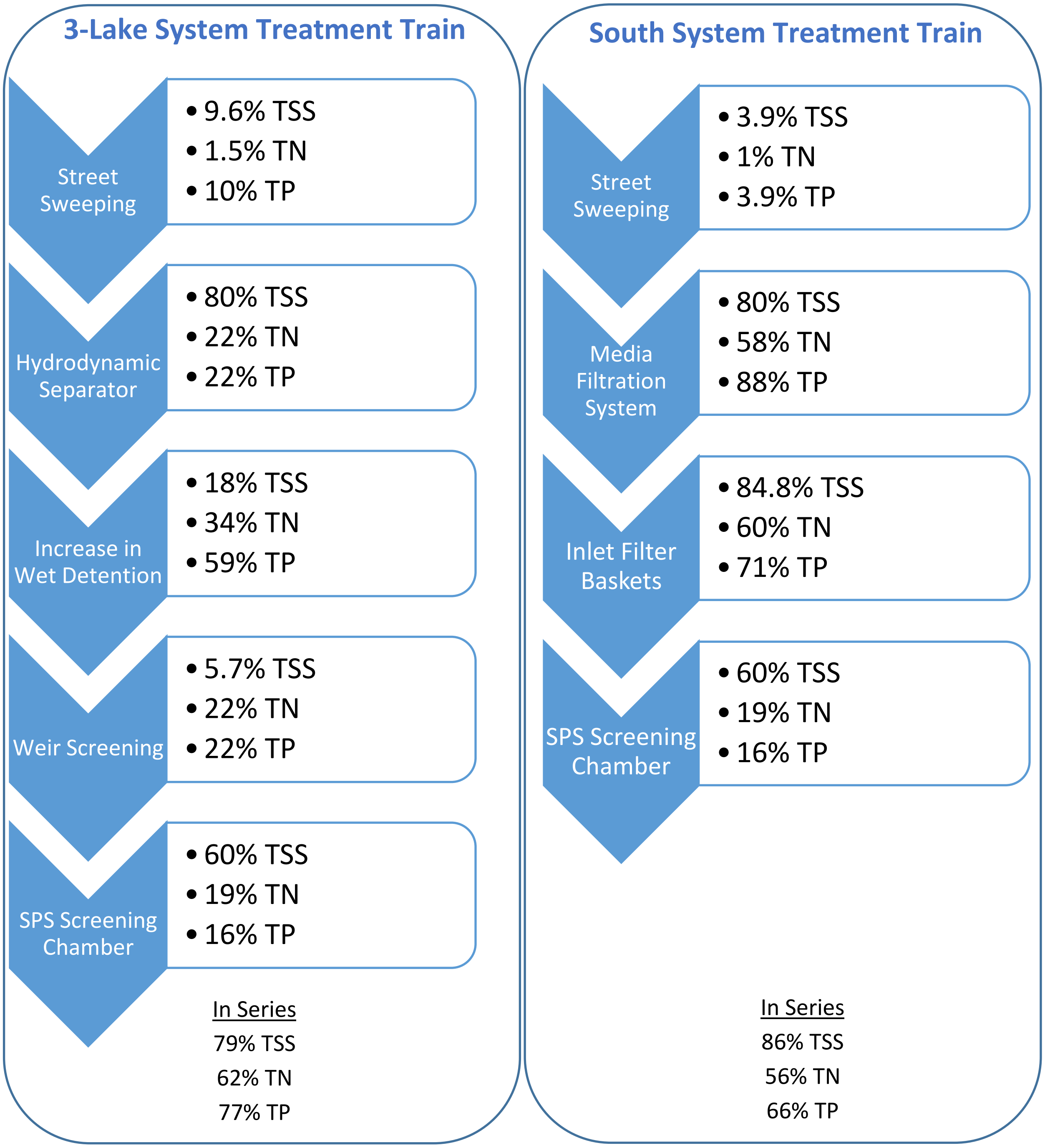


Figure 15 - Water Quality Treatment Train with Reduction Percentages

6. Water Quality Removal Efficiencies and Performance with Recommendations

Average pollutant concentrations for the existing basins are summarized in Table 25 for average upstream concentrations and estimated BMP Treatment Train removal efficiencies. Ranges of pollutant concentration are reported as plus or minus twenty percent (±20%) of the mean concentrations. Range estimates will be refined with additional sampling data.

Importantly, BMPs are additional measures to target specific water quality parameters for improvement. The upgrade of the existing, from an aging, gravity based stormwater system to the proposed, continuous flow system are expected to provide significant water quality improvements to the present loads measured at locations in Figure 16**.** Table 25 and Figure 16 will be updated at 90% design upon receipt of further testing data. The BMP Trains model does not include treatment of bacteria, and has been excluded in Table 25. Estimates of bacteria concentrations in the discharge will be presented at the 90% design after further testing is performed.

Table 25 - Estimated Removal Efficiencies and Discharge Concentrations

Pollutant	**Range(1)(2)**	**3-Lake System(4)**		**South System(4)(6)**		**Discharge Concentration "Goals" Based on Trains Model**		
		Baseline (5)	Removal (3)	Baseline (5)	% Removal (3)	3-Lake Discharge	South System Discharge	Discharge
TSS (mg/l)	Lower Mean Upper	9.35 11.69 14.03	78%	37.68 47.10 56.52	86%	**2.67**	**6.72**	**4**
TN (mg/l)	Lower Mean Upper	1.40 1.75 2.10	62%	3.93 4.91 5.89	56%	**0.67**	**2.15**	**1.15**
TP (mg/l)	Lower Mean Upper	0.14 0.17 0.21	77%	0.63 0.79 0.95	66%	**0.04**	**0.27**	**0.11**

NOTES:
1) Lower and Upper ranges of pollutant concentrations computed as mean +/- 20%
2) Ranges will be refined as water quality database updated with additional sampling
3) Removal percentages computed according to BMPTrains model methodology
4) 3-Lake System Baseline was established based on the geometric mean of the South Lake data (2017-2020)
5) South System Baseline was established based on the geometric mean of the 2020 upstream sampling.
6) Discharge assumes 68% Lake System water and 32% South System Water

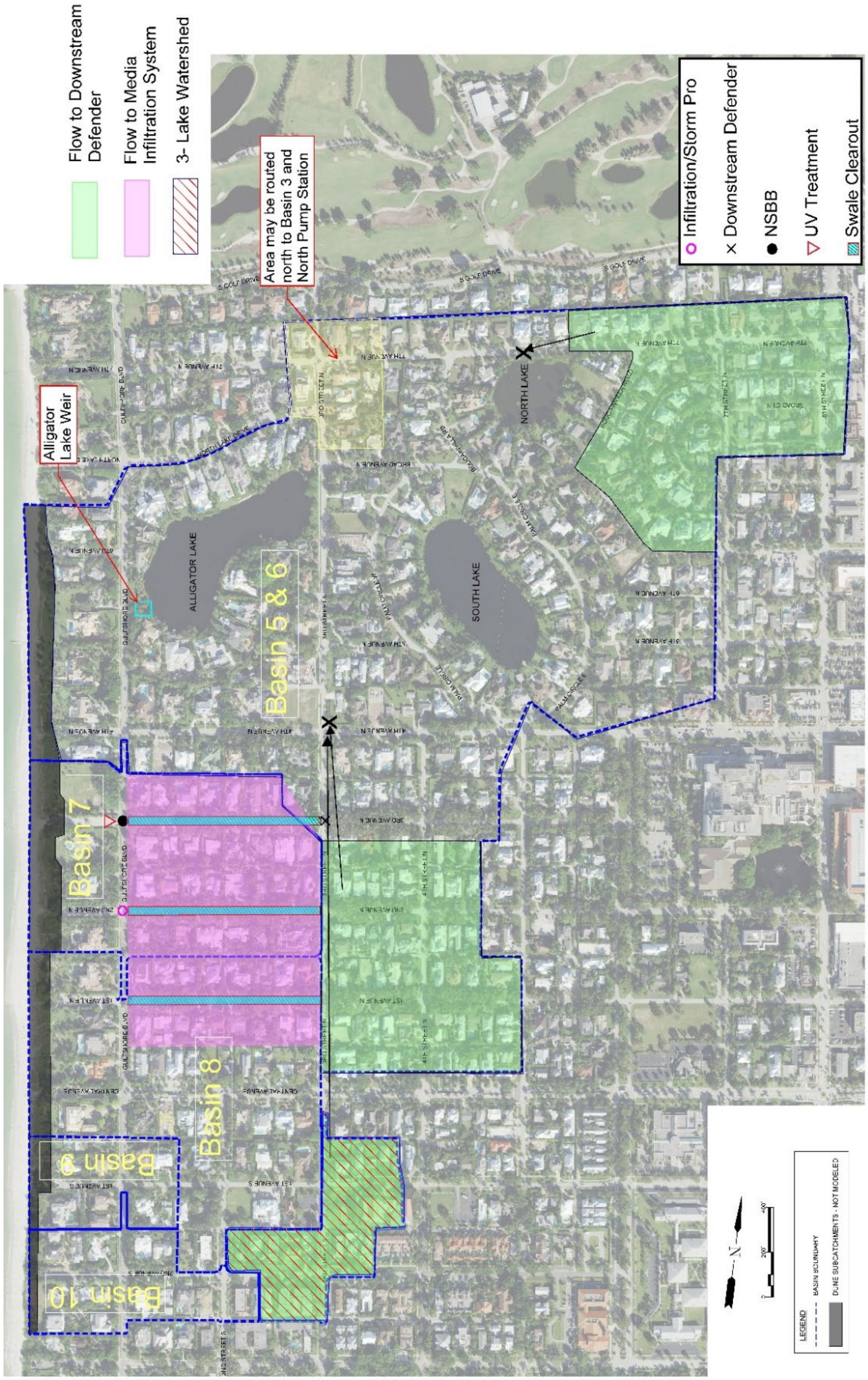


Figure 16– Phase 1 Treatment Train

The combined percent removal for TSS assuming 68% flow from the 3-Lake System and 32% flow from the South System is 83% compared to current levels. The combined percent removal of total nitrogen is 59%, and the combined percent removal of total phosphorus is 70% as shown in Table **26**.

Table 26 - Estimated Discharge % Removal

Pollutant	Discharge with 68% of Flow from 3-Lake and 32% of Flow from South System		
	Combined - No Treatment	Discharge with BMP Treatment Train	% Removal
TSS (mg/l)	23.17	4	84%
TN (mg/l)	2.76	1.15	59%
TP (mg/l)	0.37	0.11	70%

6.1. **Water Quality Improvement Goals**

Enterococci

Florida administrative code 62-302.530 defines the surface water quality criteria for a range of water bodies. For enterococci, the monthly geometric mean cannot exceed 35 CFU/100mL (if a minimum of 10 samples are taken per month) and the 10% threshold value cannot exceed 130 CFU/100mL during any 30-day period for a Class III water body. Due to the high rainfalls in the summer and variable water quality in the Gulf of Mexico, it is recommended that compliance, and monitoring samples be collected monthly at the pump station prior to discharge and quarterly at the discharge site at the limits of the mixing zone and at the discharge pipe during a discharge event, to assess success. Bacteria sampling is proposed to occur on a monthly basis, and the proposed standard is the 20% threshold value for exceedance in any 2 year period is 130 CFU/100mL. This means that over a two year period, no more than 4 samples may result in bacteria concentrations greater than 130 CFU/100mL.

To meet this goal, a significant reduction in bacteria loading at the pump station will be required. This will be partially achieved by (1) replacing of aging infrastructure which currently provides an environment conducive to bacteria growth, (2) continuous positive flow to prevent stagnation, and (3) by mixing stormwater at the pump station to be 68% from the lakes and 32% stormwater pipes. If further reductions in bacteria are required following removal and replacement of the existing stormwater system, UV treatment at the South Pump Station would be evaluated.

Sampling sites recommended include: at the Pump Station's (PS) wet well; upstream discharge points at Alligator Lake and the South System trunk line (before stormwater enters the PS); and offshore at the discharge site (in the mixing zone). If PS wet well bacteria levels are not reduced to acceptable levels by the replacement of the aging stormwater infrastructure or the mixing zone bacteria levels are elevated above background, installation of the UV system would be evaluated.

Total Suspended Solids (TSS)

Florida does not identify a TSS limit for discharge into Class III waters; however, TSS is a pollutant of concern. The proposed stormwater system has been designed to reduce the discharge of suspended sediments (1) to prevent impacts to hardbottom near stormwater discharge and (2) because TSS include organic and inorganic matter of which the volatile organic components contributes to nutrient loads as decay occurs. If the organic fraction of the sediments remains in the system, these pollutants will break down releasing dissolved nitrogen and phosphorus, and increase nutrient loading, as was found from the 2020 testing of the City's catch basins sediments.

If a UV system is determined to be required to manage the bacteria loading, the UV system will require low suspended sediments and associated turbidity levels to allow for maximum UV transmittance. The operational limit of the proposed UV system is 30mg/L of TSS; therefore, the proposed maximum loading of TSS goal should be less than 30 mg/l and a goal of 10-20 mg/l is recommended. Further testing of the relation of TSS concentrations to turbidity (NTUs) will be conducted to refine the maximum loading goal.

TSS in Basins 5/6, 8, 9 and 10 largely meet the above TSS criteria; however, Basin 7's TSS loading will require higher levels of reduction. Continuous flows to the pump station's force main, improved swales and media filtration before flows enter the pipes, road grades and slopes, and the pipe sizes and the basins have been designed to current standards to prevent water staging which will reduce the sediment load. The design of the stormwater system will prevent sedimentation, and mixing of lake and pipe water will further reduce suspended solids concentration at the discharge. Additional grates will remove suspended and floating debris (coconuts, limbs and leaf mass) loads at both the lake and south system intakes. Additional measures to reduce suspended solids are proposed as part of the best management practices treatment train as assessed and further evaluated in Sections 4 and 5 above.

Numeric Nutrient Criteria (NNC)

The State has not established standards for nutrient (total nitrogen and total phosphorus) loading for the part of the Gulf of Mexico where the stormwater system discharges. The loading rates have been evaluated and used in the Water Quality Removal Trains Model based on the baseline data for the drainage basins existing pollutant levels and site conditions. The predicted discharge pollutant levels based on this model is 1.15 mg/l for TN and 0.11 mg/l for TP based on the nutrient removal percentages specific to the proposed water quality improvement components.

By comparison, Florida Administrative Code 62-302.532(e)(2) specifies a maximum of 0.25mg/L for Nitrogen and 0.032mg/L for Phosphorus within the Collier Inshore Estuary which is in the vicinity of the project site. The Collier Inshore Estuary standards for NNC are not recommended as discharge goals for maximum nutrient concentration at the pump's wet well; however, the Estuary standards provide an estimate of the Gulf of Mexico's (Gulf) background pollutant concentration levels near the monitoring site. It is estimated nutrient levels at the pump station's wet well, before discharge to the Gulf of Mexico, will be 1.15 mg/l TN and 0.11 TP, and after discharging to the Gulf these nutrient levels will be further reduced by 90% within the mixing zone (150 ft radius of diffusers) and equivalent to the Gulf.

Nitrogen and phosphorus loadings in Basins 5/6, 7, 8, 9 and 10 are estimated to be reduced by approximately 59% and 70% for existing nitrogen and phosphorus concentrations respectively. Reduction in sedimentation (TSS) within the system will reduce nutrient loading as well as additional measures to reduce total nitrogen and total phosphorus, as discussed in Section 4 as part of the best management practices treatment train.

6.2. Water Quality BMPs Estimated Removal Efficiencies & Costs

The Phase 1 Project includes structural BMP's that will function as a BMP treatment train to remove targeted pollutants. Estimates of individual BMP removal efficiencies are presented in Section 5 of this report, as well as the estimated overall performance. Table 27 summarizes the overall Phase 1 project BMP efficiency estimates as well as anticipated installation and 20-year maintenance costs. Importantly, these removal quantities and associated 20-year costs per pound were calculated in series. ***The quantities in Table 27 are lower than for the individual BMPs because as the stormwater moves through the treatment train, there is progressively less contaminant to remove***.

Table 27 - Estimated BMP Performance and Cost

	BMP	Annual Reduction (lbs/yr & %) TSS	TN	TP	Costs: Construction	Annual Maintenance ($/yr)	20-Yr Costs per lb removed: TSS	TN	TP
	SPS Screening Chamber	**5,733** **60.0%**	**269.7** **19.1%**	**20.09** **15.5%**	**$175,300**	**$5,000**	**$2**	**$51**	**$685**
	Aluminum Screen	**279** **5.7%**	**173.5** **22.0%**	**9.58** **22.0%**	**$18,000**	**$500**	**$5**	**$8**	**$146**
3-Lake System	**Street Sweeping**	836 9.6%	19.8 1.5%	12.71 10.0%	$0	$4,484	$5	$226	$353
3-Lake System	**Wet Detention**	1,067 18.0%	406.3 34.0%	62.63 59.0%	$5,000	$1,000	$1	$3	$20
3-Lake System	**Hydrodynamic Separators**	1,939 80.0%	8838 22.0%	7.72 22.0%	$219,800	$2,500	$7	$153	$1,749
3-Lake System	**3-Lake Sub-Total:**	3,842	514.4	83.06	224,800	$7,984	$5	$37	$231
South System	**Street Sweeping**	557 3.9%	14.3 1.0%	9.15 3.9%	$0	$2,989	$5	$209	$327
South System	**Catch Basin Filter Baskets**	6,052 84.8%	460.2 60.0%	85.07 71.0%	$177,030	$4,347	$2	$29	$155
South System	**Filter Media**	2,582 80.0%	201.2 58.0%	47.68 88.0%	$60,000	$500	$1	$17	$73
South System	**Swales**				$157,500				
South System	**South Sub-Total:**	9,191	675.7	141.9	$394,530	$7,836	$3	$41	$194
	Total costs (excluding aluminum screen & screening chamber)				**$619,330**				
		Annual Reduction (%) **Enterococci**			**Costs** **Construction**	**Annual Maintenance ($/yr)**			
	UV Treatment	50-99%			$877,784	$15,000			
	Total:				**$1.69 M**	**$35k**			

Notes:

(1) Removal quantities are evaluated as cumulative removal; as the water progresses through the treatment train, the pollutant loading decreases. The removal rates in Table 27 are consistent with the individual removal rates, but because the incoming water quality is improved, a reduced amount (lb) of pollutant is removed as the water progresses through the treatment train.
(2) Street sweeping to occur under separate line item in City budget, not as part of the water quality improvement project, SPS Screening Chamber and Aluminum Weir Screen are required to protect pumps.
(3) Swales will improve conveyance, increase percolation and reduce deposits of organic matter. Values for reduction in contaminant loading not included in Trains model.

The Proposed BMP Treatment Train Flow Chart with estimated removal efficiencies is shown in Figure **15.** A map depicting the locations for individual BMPs is depicted in Figure 16. The Treatment Train model will be updated at the 90% design phase to incorporate additional upstream sampling within the south system and lake system.

7. WQ Monitoring and Adaptive Management Plan

This evaluation and report serves as the technical basis for development of a Water Quality Monitoring and Adaptive Management Plan, to be designed with local community input and direction from City Council. A comprehensive pre- and post-construction monitoring will continue to expand the water quality database through a comprehensive monitoring program. The expanded baseline data for the existing south system will provide for future adjustments to achieve the objectives and commitments of the project as established by City. To understand the background pollutant levels and variability in the Gulf and to compare to the stormwater discharge, an YSI or similar water quality monitoring instrument is mounted on the seabed to continuously (30 to 60 minutes intervals) measure pollutant levels of TSS and nutrients (TN and TP) for comparison and analysis. Post-construction monitoring of nutrients, total suspended sediments and bacteria sampling sites recommended include: at the Pump Station's (PS) wet well; upstream discharge points at Alligator Lake and the South System trunk line (before stormwater enters the PS); and offshore at the discharge site (in the mixing zone).

7.1. <u>**Monitoring Plan Components**</u>

Discharge to the Gulf will be monitored at the pump station prior to discharge, and before and after UV treatment, if a UV system is installed to determine the bacteria loads and removal efficiencies to assess the improvements after replacement of the stormwater system. ECE, in consultation with the City and the community, will assess and recommend the City's goals for pollutant reductions for turbidity, total suspended solids, total dissolved nitrogen, total dissolved phosphorus, and Enterococci. After these goals are established, when monitoring thresholds are exceeded, the City will initiate review and the potential for adaptive management changes. These pollutant reduction goals will be used to evaluate project success.

The proposed Adaptive Management Plan will include:

1. Strategies for water quality improvement and actions for implementation.
2. Predictions for the effectiveness of the water quality improvements, on a continuous annual basis and through re-evaluation every 3 years.
3. Methodology for adapting the plan according to future water quality sampling data.
4. Assessment of discharge waters' pollutant loads monthly for the first year, and quarterly thereafter.
5. System-wide monitoring monthly at the pump station and quarterly upstream and at the discharge site for bacteria, TSS and nutrients pre-construction and for the first year post-construction with reassessment of monitoring frequency after the first year.

7.2. Additional Water Quality Improvement Measures to be Considered in Adaptive Management

The water quality improvement goals may not be fully achieved by the new stormwater system, and additional measures may be considered to allow for further improvements if required. The proposed UV system may not be included in the initial stormwater system; however, the pump station site will include piping and electrical capacity as well as space for the UV treatment system and may be added following initial construction when the need is established and requirement for further reductions in bacteria levels are identified.

North Lake has the highest pollutant loads within the 3-Lake system. To reduce the pollutants in North Lake, work is scheduled for FY 2024-25 to remove the accumulated sediments from the lake which contribute to nutrient loads and reduce flushing. The City is discussing accelerating construction of the North Lake improvements, depending on available budget in the City's capital improvement program. Stormwater that presently discharges to North Lake will be redirected to South Golf Drive, and the North Pump Station in FY 2022-23.

These measures are expected to contribute to a measurable reduction of TSS, nitrogen and phosphorus levels. If nutrient loading continues to be high, alum treatment may be considered; however, pH monitoring must be incorporated to ensure that changes in pH are acceptable.

8. Summary and Recommendations to Improve Water Quality

Water quality testing from 2016-2020 has documented levels of contaminants that require management. The removal of the gravity driven, aging stormwater pipes which result in stagnation and bacteria growth and replacement with a new system designed to have continuous positive flow will significantly reduce sedimentation, and therefore nutrient levels, as well as bacteria loading within the discharge. In addition, a number of targeted water quality improvement best management practices are recommended. These water quality improvement components and BMPs are summarized in Table 28.

Table 28: Summary of Recommendations

	BMP	Description	Construction Cost	Cost Line Item
3-Lake System	Street Sweeping(1)	Increased street sweeping from monthly to fortnightly	-	11.1.1
3-Lake System	Wet Detention	Increase in lake elevation by 9" using an adjustable weir	$5,000	11.1.2
3-Lake System	Weir Screening	Remove floatables with aluminum screen	$18,500	11.1.2
3-Lake System	Hydrodynamic Separators	Centripetal separation to remove TSS and nutrients	$219,800	11.1.3
3-Lake System		3-Lake Sub-Total:	$242,800	
	BMP	**Description**	**Construction Cost**	**Cost Line Item**
South System	Street Sweeping(1)	Increased street sweeping from monthly to fortnightly	-	11.2.1
South System	Catch basin filter basket inserts	Filter basket inserts to inlets to capture debris, TSS and nutrients	$177,030	11.2.2
South System	Swales	Regrading to reestablish percolation and remove sedimentation	$157,500	11.2.3
South System	Media filtration systems	Placed at the interface between swales and pipe network to capture TSS and nutrients	$60,000	11.2.4
South System		South Sub-Total:	$394,530	
SPS Screening Chamber		Uses flow over screens to remove debris, sediments and organic matter to reduce nutrients	$175,300	11.3.1
		Total:	$812,630	

(1) Increased street sweeping is provided in the City's operational budget
(2) Schedule of quantities and estimate of costs report line item reference.

Within this BMP treatment train, reduction of suspended sediments between 84%, reduction of total nitrogen between 59% and reduction of total phosphorus of 70% are anticipated. With these reductions, discharge from the pump station is expected to be significantly improved from the pre-project condition.

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