Algal Bloom Risk Metric References

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62-302.531 Numeric Interpretations of Narrative Nutrient Criteria.

(1) The narrative water quality criteria for nutrients in paragraphs 62-302.530(47)(a) and (b), F.A.C., applies to all Class I, Class II, and Class III waters.

(2) The narrative water quality criterion for nutrients in paragraph 62-302.530(47)(b), F.A.C., shall be numerically interpreted for both nutrients and nutrient response variables in a hierarchical manner as follows:

(a) Where a site specific numeric interpretation of the criterion in paragraph 62-302.530(47)(b), F.A.C., has been established by the Department, this numeric interpretation shall be the primary interpretation. If there are multiple interpretations of the narrative criterion for a waterbody, the most recent interpretation established by the Department shall apply. A list of the site specific numeric interpretations of paragraph 62-302.530(47)(b), F.A.C., may be obtained from the Department's internet site at http://www.dep.state.fl.us/water/wqssp/swq-docs.htm or by writing to the Florida Department of Environmental Protection, Water Quality Standards and Program, 2600 Blair Stone Road, MS #6511, Tallahassee, FL 32399-2400.

1. The primary site specific interpretations are as follows:

a. Total Maximum Daily Loads (TMDLs) adopted under Chapter 62-304, F.A.C., that interpret the narrative water quality criterion for nutrients in paragraph 62-302.530(47)(b), F.A.C., for one or more nutrients or nutrient response variables,

b. Site specific alternative criteria (SSAC) for one or more nutrients or nutrient response variables as established under Rule 62-302.800, F.A.C.,

c. Estuary-specific numeric interpretations of the narrative nutrient criterion established in Rule 62-302.532, F.A.C., or

d. Other site specific interpretations for one or more nutrients or nutrient response variables that are formally established by rule or final order by the Department, such as a Reasonable Assurance Demonstration pursuant to Rule 62-303.600, F.A.C., or Level II Water Quality Based Effluent Limitations (WQBEL) established pursuant to Rule 62-650.500, F.A.C. To be recognized as the applicable site specific numeric interpretation of the narrative nutrient criterion, the interpretation must establish the total allowable load or ambient concentration for at least one nutrient that results in attainment of the applicable nutrient response variable that represents achievement of the narrative nutrient criterion for the waterbody. A site specific interpretation is also allowable where there are documented adverse biological effects using one or more Biological Health Assessments, if information on chlorophyll *a* levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicate there are no imbalances in flora and a stressor identification study demonstrates that the adverse biological effects are not due to nutrients.

2. For the primary site specific interpretations in subparagraph 62-302.531(2)(a)1., F.A.C., the notice of rulemaking or other public notice shall state that the Department is establishing a site specific interpretation for the receiving waterbody, and offer an opportunity for a public meeting and public comment.

(b) If site specific numeric interpretations, as described in paragraph 62-302.531(2)(a), F.A.C., above, have not been established for a waterbody, but there is an established, quantifiable cause-and-effect relationship between one or more nutrients and nutrient response variables linked to a value that protects against an imbalance in the natural populations of the aquatic flora or fauna, then the numeric values for the nutrients or nutrient response variables, set forth in this paragraph (2)(b), shall be the applicable interpretations. Absent a numeric interpretation as established in paragraph 62-302.531(2)(a), F.A.C., site specific numeric interpretations are established as follows:

1. For lakes, the applicable numeric interpretations of the narrative nutrient criterion in paragraph 62-302.530(47)(b), F.A.C., for chlorophyll *a* are shown in the table below. The applicable interpretations for TN and TP will vary on an annual basis, depending on the availability of chlorophyll *a* data and the concentrations of nutrients and chlorophyll *a* in the lake, as described below. The applicable numeric interpretations for TN, TP, and chlorophyll *a* shall not be exceeded more than once in any consecutive three year period.

a. If there are sufficient data to calculate the annual geometric mean chlorophyll *a* and the mean does not exceed the chlorophyll *a* value for the lake type in the table below, then the TN and TP numeric interpretations for that calendar year shall be the annual geometric means of lake TN and TP samples, subject to the minimum and maximum limits in the table below. However, for lakes with color ≥ 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit shall be the 0.49 mg/L TP streams threshold for the region; or

b. If there are insufficient data to calculate the annual geometric mean chlorophyll *a* for a given year or the annual geometric mean chlorophyll *a* exceeds the values in the table below for the lake type, then the applicable numeric interpretations for TN and TP shall be the minimum values in the table below.

Long Term Geometric Mean	Annual	Minimum calculated numeric	Maximum calculated numeric

Lake Color and Alkalinity	Geometric Mean Chlorophyll *a*	interpretation		interpretation	
		Annual Geometric Mean Total Phosphorus	Annual Geometric Mean Total Nitrogen	Annual Geometric Mean Total Phosphorus	Annual Geometric Mean Total Nitrogen
≥ 40 Platinum Cobalt Units	20 µg/L	0.05 mg/L	1.27 mg/L	0.16 mg/L[1]	2.23 mg/L
≤ 40 Platinum Cobalt Units and ≥ 20 mg/L $CaCO_3$	20 µg/L	0.03 mg/L	1.05 mg/L	0.09 mg/L	1.91 mg/L
≤ 40 Platinum Cobalt Units and ≤ 20 mg/L $CaCO_3$	6 µg/L	0.01 mg/L	0.51 mg/L	0.03 mg/L	0.93 mg/L

[1] For lakes with color ≥ 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit shall be the 0.49 mg/L TP streams threshold for the region.

c. For the purpose of subparagraph 62-302.531(2)(b)1., F.A.C., color shall be assessed as true color and shall be free from turbidity. Lake color and alkalinity shall be the long-term geometric mean of all of the data for the period of record, based on a minimum of ten data points over at least three years with at least one data point in each year. If insufficient alkalinity data are available, long-term geometric mean specific conductance values of all of the data for the period of record shall be used, with a value of ≤100 micromhos/cm used to estimate the 20 mg/L $CaCO_3$ alkalinity concentration until such time that alkalinity data are available. Long-term geometric mean specific conductance shall be based on a minimum of ten data points over at least three years with at least one data point in each year.

2. For spring vents, the applicable numeric interpretation of the narrative nutrient criterion in paragraph 62-302.530(47)(b), F.A.C., is 0.35 mg/L of nitrate-nitrite (NO_3 + NO_2) as an annual geometric mean, not to be exceeded more than once in any three calendar year period.

(c) For streams, if a site specific interpretation pursuant to paragraph 62-302.531(2)(a) or (2)(b), F.A.C., has not been established, biological information shall be used to interpret the narrative nutrient criterion in combination with Nutrient Thresholds. The narrative nutrient criterion in paragraph 62-302.530(47)(b), F.A.C., shall be interpreted as being achieved in a stream segment where information on chlorophyll *a* levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition indicates there are no imbalances in flora or fauna, and either:

1. The average score of at least two temporally independent SCIs performed at representative locations and times is 40 or higher, with neither of the two most recent SCI scores less than 35, or

2. The nutrient thresholds set forth in the table below are achieved.

Nutrient Watershed Region	Total Phosphorus Nutrient Threshold[1]	Total Nitrogen Nutrient Threshold[1]
Panhandle West	0.06 mg/L	0.67 mg/L
Panhandle East	0.18 mg/L	1.03 mg/L
North Central	0.30 mg/L	1.87 mg/L
Peninsular	0.12 mg/L	1.54 mg/L
West Central	0.49 mg/L	1.65 mg/L
South Florida	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.

[1]These values are annual geometric mean concentrations not to be exceeded more than once in any three calendar year period.

(3) Except for data used to establish historical chlorophyll *a* levels, chlorophyll *a* data assessed under this chapter shall be measured according to the DEP document titled "Applicability of Chlorophyll *a* Methods" (DEP-SAS-002/10), dated October 24, 2011 (https://www.flrules.org/Gateway/reference.asp?No=Ref-06043), which is incorporated by reference herein. Copies of the chlorophyll *a* document may be obtained by writing to the Florida Department of Environmental Protection, Water Quality Standards Program, 2600 Blair Stone Road, MS #6511, Tallahassee, FL 32399-2400. Chlorophyll *a* data collected after [7-3-12] shall be corrected for or free from the interference of pheophytin.

(4) The loading of nutrients from a waterbody shall be limited as necessary to provide for the attainment and maintenance of water quality standards in downstream waters.

(5) To qualify as temporally independent samples, each SCI shall be conducted at least three months apart. SCIs collected at the same location less than three months apart shall be considered one sample, with the mean value used to represent the sampling period.

(6) To calculate an annual geometric mean for TN, TP, or chlorophyll *a*, there shall be at least four temporally-independent samples per year with at least one sample taken between May 1 and September 30 and at least one sample taken during the other months of the calendar year. To be treated as temporally-independent, samples must be taken at least one week apart.

(7) The numeric interpretation of the narrative nutrient criterion shall be applied over a spatial area consistent with its derivation.

(a) For numeric interpretations based on paragraph 62-302.531(2)(a), F.A.C., the spatial application of the numeric interpretation is as defined in the associated order or rule.

(b) For lakes covered under subparagraph 62-302.531(2)(b)1., F.A.C., the numeric interpretation shall be applied as a lake-wide or lake segment-wide average.

(c) For spring vents covered under subparagraph 62-302.531(2)(b)2., F.A.C., the numeric interpretation shall be applied in the surface water at or above the spring vent.

(d) For streams covered under paragraph 62-302.531(2)(c), F.A.C., the spatial application of the numeric interpretation shall be determined by relative stream homogeneity and shall be applied to waterbody segments or aggregations of segments as determined by the site-specific considerations.

(8) Load-based or percent reduction-based nutrient TMDLs or Level II Water Quality Based Effluent Limitations (WQBELs) pursuant to Chapter 62-650, F.A.C., do not need to be converted into concentration-based nutrient TMDLs or WQBELs to be used as the basis for the numeric interpretation of the narrative criterion. For percent reduction-based nutrient TMDLs, the associated allowable load or concentration is the numeric interpretation of the narrative criterion for the waterbody.

(9) The Commission adopts subsections 62-302.200(4), 62-302.200(16)-(17), 62-302.200(22)-(25), 62-302.200(35)-(37), 62-302.200(39), Rule 62-302.531, and subsection 62-302.532(3), F.A.C., to ensure, as a matter of policy, that nutrient pollution is addressed in Florida in an integrated, comprehensive and consistent manner. Accordingly, these rules shall be effective only if EPA approves these rules in their entirety, concludes rulemaking that removes federal numeric nutrient criteria in response to the approval, and determines, in accordance with 33 U.S.C. §1313(c)(3), that these rules sufficiently address EPA's January 14, 2009 determination. If any provision of these rules is determined to be invalid by EPA or in any administrative or judicial proceeding, then the entirety of these rules shall not be implemented.

Rulemaking Authority 403.061, 403.062, 403.087, 403.504, 403.704, 403.804 FS. Law Implemented 403.021, 403.061, 403.067, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708 FS. History–New 7-3-12, 2-17-16.
Editorial Note: Rule 62-302.531 will become effective upon approval by EPA in its entirety, conclusion of rulemaking by EPA to repeal its federal numeric nutrient criterion for Florida, and EPA's determination that Florida's rules address its January 2009 determination that numeric nutrient criteria are needed in Florida.

Factors Influencing the Abundance of Blue-Green Algae in Florida Lakes[1]

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Canfield, D. E., Jr., E. Phlips, and C. M. Duarte. 1989. Factors influencing the abundance of blue-green algae in Florida lakes. Can. J. Fish. Aquat. Sci. 46: 1232–1237.

Phytoplankton samples collected from 165 Florida lakes were examined to determine relationships between blue-green algal abundance and environmental conditions. Blue-green algal biomass in the Florida samples was weakly correlated ($r = -0.34$) with water transparency and the concentration of total nitrogen (TN) ($r = 0.47$) and total phosphorus (TP) ($r = 0.33$). The relative contribution of blue-green algae to total phytoplankton biomass, however, did not decrease with TN/TP>29. Blue-green algal biomass was strongly correlated ($r = 0.90$) to total algal biomass, and blue-green algae became consistently dominant when total algal biomass exceeded 100 mg/L.

On a examiné des échantillons de phytoplancton recueillis dans 165 lacs de Floride pour déterminer les relations existant entre l'abondance des algues bleues et les conditions du milieu. On a trouvé qu'il y avait une faible corrélation de la biomasse des algues bleues présentés dans les échantillons de Floride avec la transparence de l'eau ($r = -0,34$), de même qu'avec la concentration d'azote total ($r = 0,47$) et de phosphore total ($r = 0,33$). La proportion relative des algues bleues par rapport à la biomasse totale du phytoplancton n'a cependant pas diminué lorsque le rapport AT/PT était supérieur à 29. On a établi une forte corrélation ($r = 0,90$) entre la biomasse des algues bleues et la biomasse totale des algues; on a trouvé aussi que les algues bleues constituaient à tout coup le groupe d'algues dominantes lorsque la biomasse totale des algues dépassait 100 mg/L.

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Many of the undesirable consequences of lake eutrophication are linked to the development of excessive populations of blue-green algae (e.g. Lund 1969; Reynolds and Walsby 1975; Gregor and Rast 1980). Extensive research on blue-green algae has generated several hypotheses concerning the relationship between environmental conditions and blue-green algal abundance: (1) the concentrations of monovalent cations (sodium and potassium) influence blue-green algal abundance (Provasoli 1969); (2) blue-green algae become dominant because of their ability to use bicarbonate more efficiently than other algal species, thereby enabling them to photosynthesize at lower carbon dioxide concentrations than other algal species (King 1970; Shapiro 1973, 1984; Paerl and Ustach 1982); (3) the contribution of blue-green algae to the biomass of phytoplankton is influenced by the underwater light climate (Mur et al. 1978; Smith 1985, 1986); (4) eutrophic waters are more likely to have planktonic blue-green algae than oligotrophic waters (e.g. Lund 1969; Wetzel 1975; Trimbee and Prepas 1987); and (5) the relative abundance of blue-green algae is primarily determined by ratios of nitrogen to phosphorus in the water (Schindler 1977; Smith 1983).

Many Florida lakes are mesotrophic or eutrophic due to edaphic factors (Canfield 1981; Canfield and Hoyer 1988). Blooms of blue-green algae are common in many of these lakes and some of the blooms reach enormous (310 km^2) sizes as happened in Lake Okeechobee during 1986 (Jones 1987). Consequently, there is a great deal of interest in manipulating environmental conditions (e.g. nutrient control; alterations of N/P) in order to control nuisance blue-green algal blooms. Our purpose here is to evaluate some of the more prominent hypotheses (see above) regarding the factors influencing the abundance of blue-green algae as they may apply to Florida lakes.

Methods

Phytoplankton data presented in this study were collected during a limnological survey of 165 FLorida lakes that spanned a wide range of tropic and chemical conditions (Canfield 1981, 1983; Canfield et al. 1985). Phytoplankton were sampled once in the spring (March to June) and once in the summer (July and August) of 1980. On each sampling date, surface water (0.5 m) samples were collected at each lake from three midlake locations. At larger lakes like Lake Okeechobee, samples were collected from three near-shore, open-water areas. Prior to being transported to the laboratory for analysis, water samples were placed on ice and algal samples were preserved with Lugol's solution and stored in the dark (APHA 1976).

At the laboratory, pH was measured by use of an Orion Model 601A pH meter calibrated against buffers at 4.0, 7.0, and 10.0. Total alkalinity (mg/L as $CaCO_3$) was determined by titration with 0.02 N sulfuric acid (APHA 1976). All samples were titrated to a pH of 4.5 to standardize titrations and avoid interference from silicates, phosphates, and other materials (APHA

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1976). Reported alkalinities, therefore, may be slightly greater than true alkalinities in some lakes because the equivalence point occurs at pH >4.5 in low alkalinity samples and many Florida lakes have low total alkalinities. Carbon dioxide concentrations were calculated using the equation of Saunders et al. (1962). All CO_2 values were corrected for water temperature. Specific conductance (microSiemens per centimetre at 25°C) was measured by using a Yellow Springs Instrument Company Model 31 conductivity bridge. Total phosphorus concentrations (milligrams per cubic metre) were determined by using the procedures of Murphy and Riley (1962) with a persulfate digestion (Menzel and Corwin 1965). Total nitrogen concentrations (milligrams per cubic metre) were determined by using the modified Kjeldahl technique described by Nelson and Sommers (1975).

Water samples were analyzed for color, sodium, and potassium following filtration through Gelman Type A-E glass fiber filters. Color (Pt–Co units) was determined by using the platinum–cobalt method and Nessler tubes (APHA 1976). Sodium and potassium concentrations (milligrams per litre) were determined by flame photometry (APHA 1976).

The concentration of plankton algae in each lake was estimated by measuring chlorophyll *a* concentrations. A measured volume of lake water was filtered through a Gelman Type A-E glass fiber filter. Filters were stored over desiccant and frozen until analyzed. Chlorophyll *a* concentrations (milligrams per cubic metre) were determined by the methods of Richards and Thompson (1952) and Yentsch and Menzel (1963). Chlorophyll *a* values were calculated using the equations of Parsons and Strickland (1963) without corrections for phaeophytin.

Total algal volumes in the phytoplankton samples were calculated from cell counts and size measurements. Algal samples were concentrated by centrifugation prior to microscopical examination in a Palmer cell. At least 20 random microscopic fields were examined for each sample. Additional fields were counted when cell counts were less than 100 cells. A Nikon phase-contrast microscope was used at 400 ×. Algae were identified to genus and cell volume estimated from cell dimensions by approximations to the nearest geometrical shape (Edler 1979). Phytoplankton biomass was estimated from total biovolume by assuming a specific density of 1.

We used sampling dates as our unit of analysis. Because the limnological variables we sampled spanned several orders of magnitude, all data except the relative biomass of blue-green algae were transformed to their natural logarithms prior to statistical analysis. The relative biomass of blue-green algae was estimated as their percent contribution to the total community biomass. This variable was arcsin transformed prior to statistical analysis.

Results and Discussion

The lakes sampled represented a wide range of trophic conditions, water chemistry, phytoplankton biomass, and community structure (Canfield 1983; Canfield et al. 1985; Canfield and Hoyer 1988). The lakes, however, tended to be eutrophic (mean chlorophyll $a = 18$ mg/m^3). Water transparency was generally low (mean Secchi disc = 1.8 m) because of high algal biomass and color (mean color = 52 Pt–Co units) concentrations (Canfield and Hodgson 1983).

The contention that high concentrations of monovalent cations (sodium and potassium) favor blue-green algal dominance (Provasoli 1969) was not supported by our data. Neither the absolute concentration of sodium and potassium, nor their relative concentration (as the ratio of sodium + potassium to specific conductance) were significantly correlated to the relative abundance of blue-green algae.

Water transparency was weakly ($r = -0.34$; $p<0.01$) correlated to the relative biomass of blue-green algae. Although previous investigators have stressed that underwater light climate should be estimated using both Secchi disc transparency and the depth of the mixed layer, the possible effects of the depth of the mixed layer were not determined because this study used data from individual sampling dates rather than growing season averages. Most Florida lakes also have very shallow (<3 m) mean depths and are well mixed. The negative relationship between water transparency and the relative biomass of blue-green algae, however, agrees with Smith (1986), but the interpretation of this pattern is confounded by the negative relationship ($r = -0.49$; $p<0.01$) between water transparency and total phytoplankton biomass. The possible spurious nature of the correlation between water transparency and the relative biomass of blue-green algae is manifested by the lack of any significant correlation between the relative abundance of blue-green algae and Secchi disc transparency once the total biomass of phytoplankton is considered (partial r between blue-green algal biomass and Secchi transparency = 0.09, $p>0.05$; partial r between blue-green algal biomass and total phytoplankton biomass = 0.65, $p<0.01$). Despite the significant contribution of humic substances to light extinction in many Florida lakes (Canfield and Hodgson 1983), color was not significantly correlated $r = -0.07$; $p>0.05$) to the proportion of blue-green algae in our samples.

We found a weak ($r = -0.52$; $p<0.05$) correlation between the relative abundance (biomass) of blue-green algae and the total concentration of dissolved carbon dioxide. This suggests that carbon dioxide concentrations may influence the relative biomass of blue-green algae in Florida lakes. The weakness of this relationship, however, indicates that other factors are influencing the biomass of blue-green algae in the lakes.

The concept that blue-green alge tend to dominate in lakes receiving an abundant nutrient supply (Smith 1985, 1986; Sommer et al. 1986; Trimbee and Prepas 1987) was only partially supported by our data because both total nitrogen ($r = 0.47$; $p<0.05$) and total phosphorus ($r = 0.33$; $p<0.05$) were weakly correlated to the total biomass of blue-green algae (Fig. 1). The relative biomass of blue-green algae was also weakly correlated to total nitrogen ($r = 0.45$; $p<0.05$) and total phosphorus ($r = 0.26$; $p<0.05$) concentrations (Fig. 1).

The lack of strong direct correlations between nutrient concentrations and both total and relative blue-green algal biomass (Fig. 1) may result because we used data from individual sampling dates. Smith (1983, 1986) and Trimbee and Prepas (1987) based their conclusions on growing season averages, but our results do not seem to be peculiar to Florida lakes. Although blue-green algae are often found in eutrophic or hypereutrophic lakes, blue-green algae can also contribute significantly to phytoplankton biomass in mesotrophic and oligotrophic lakes (Fig. 1; Siegfried 1985; Stockner and Antia 1986). Conversely, eutrophic lakes may be dominated by other algal groups such as diatoms and green algae (Pavoni 1963; Findenegg 1966; Wetzel 1966; Jackson 1969; Januszko 1971; Lund 1973; Reynolds 1973a, b; Reynolds and Walsby 1975; Vincent 1980). The evidence that blue-green algae can dominate the cell numbers and production of algal communities of oligotrophic lakes and seas is now rapidly expanding as new methodologies allow the

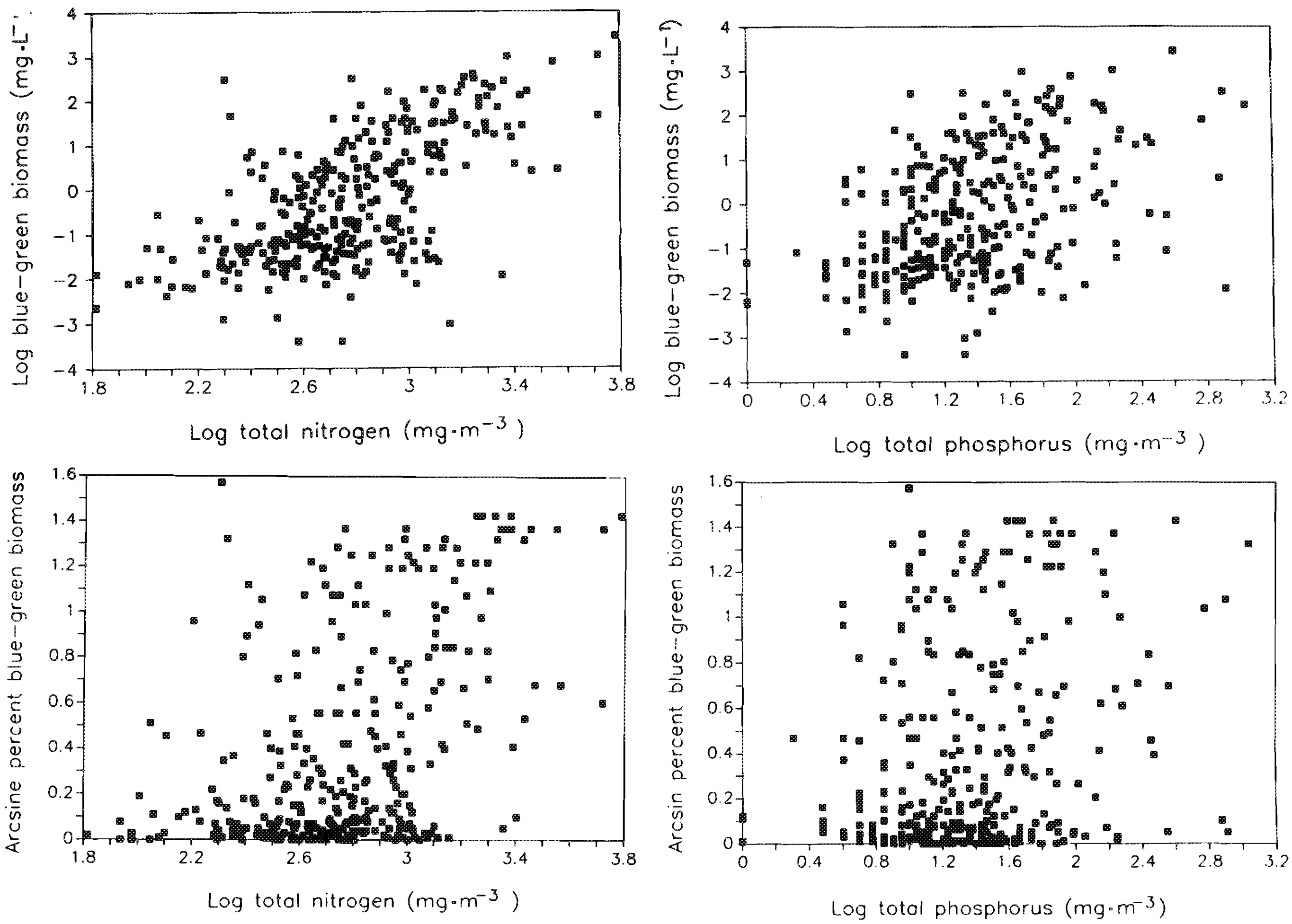

FIG. 1. Relationships between blue-green algal biomass and percent blue-green biomass with total nitrogen and total phosphorus concentrations in Florida lakes.

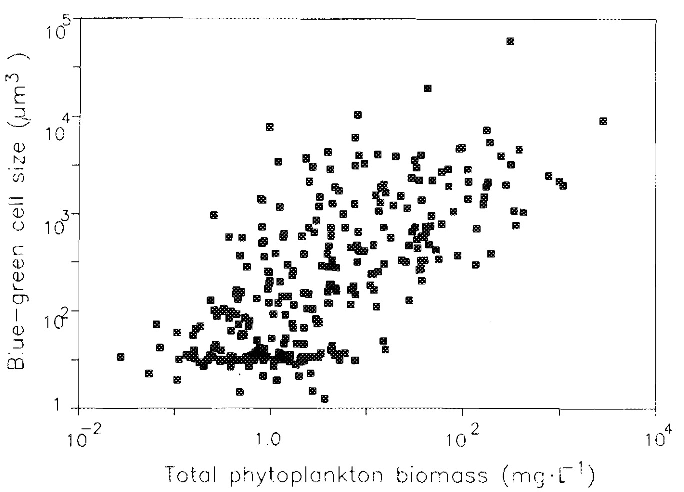

FIG. 2. Relationship between the mean size of blue-green algae and total phytoplankton biomass in Florida lakes.

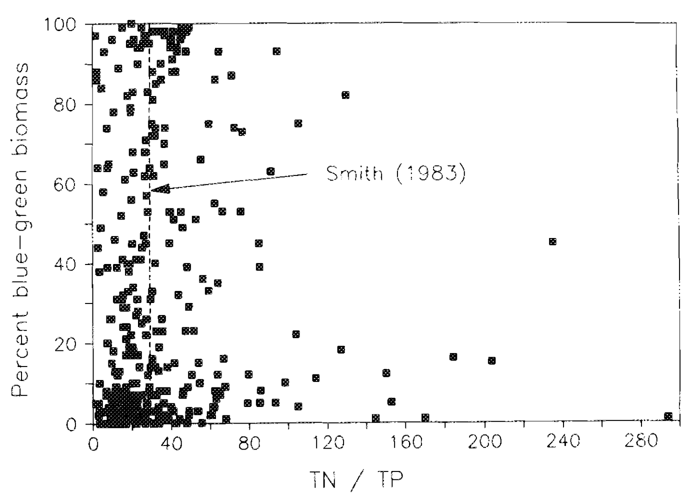

FIG. 3. Relationship between the TN/TP ratio and the relative abundance of blue-green algae in Florida lakes. The solid line shows the TN/TP ratio of 29 proposed by Smith (1983) to separate lakes with a high abundance of blue-green algae from lakes with a low abundance.

counting of small (ca. 1 μm^3) blue-green algae (Li et al. 1983; Stockner and Antia 1986; Stockner 1988). Although we did not consider picoplankton-size organisms in our lake survey, we found a relationship ($r=0.61$; $p<0.01$) between mean blue-green algal size and total phytoplankton biomass (Fig. 2). This suggests that the shift towards small blue-green algae as lakes become more oligotrophic is not restricted only to picoplankton-size species, but reflects instead a gradual change from large to small algae.

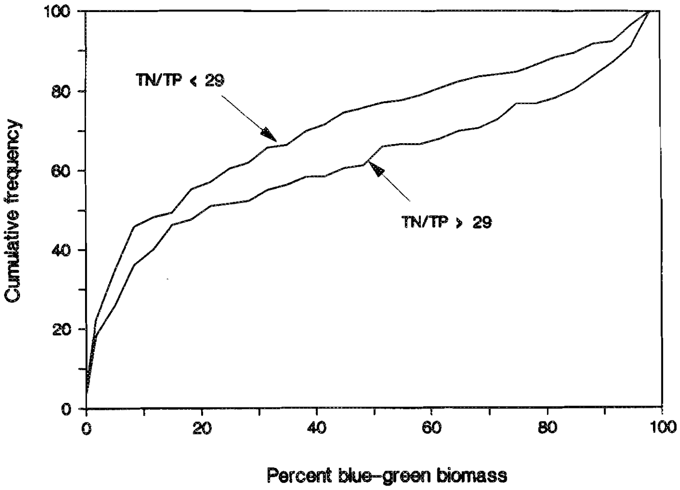

FIG. 4. Cumulative distribution of the relative (percent) biomass of blue-green algae for lakes with TN/TP ratios lower and greater than 29 by weight.

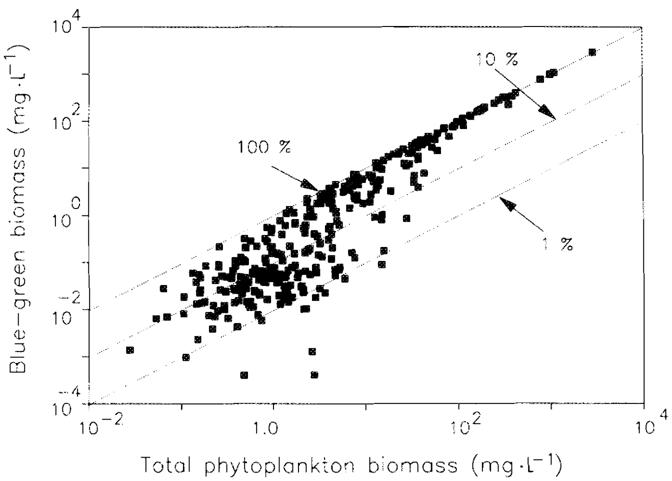

FIG. 5. Relationship between blue-green algal biomass and total phytoplankton biomass in Florida lakes. The dotted lines show the lines for which the biomass of blue-green algae equals 100, 10, and 1% of the total phytoplankton biomass.

Smith (1983) proposed that the relative contribution of blue-green algae to total phytoplankton biomass is not dependent on absolute nutrient concentrations, but rather on the ratio (by weight) of total nitrogen (TN) to total phosphorus (TP) (TN/TP). He suggested that the contribution of blue-green algae to the algal community in lakes is reduced for TN/TP greater than 29 and increases dramatically below ths ratio. Although our analyses are based on individual sampling dates rather than growing season averages, our data fail to support Smith's (1983) conclusion because many lakes with TN/TP greater than 29 have blue-green algae as the dominant phytoplankton species (Fig. 3). Further, comparison of the cumulative frequency distributions of the relative biomass of blue-green algae for lake waters with TN/TP greater than 29 and lake waters with TN/TP less than 29 indicates a weak, but significant (Kolgomorov–Smirnov test: $p<0.05$), tendency for waters with TN/TP lower than 29 to have a lower percentage of blue-green algae (Fig. 4). We, therefore, cannot support with our data the hypothesis that blue-green algae are less abundant when TN/TP exceeds 29 (also see Sommer et al. 1986: McQueen and Lean 1987).

Our results and recent evidence from a whole-lake nitrogen fertilization experiment (Lathrop 1988) suggest that the role of low TN/TP in favoring the dominance of blue-green algae has been overemphasized. The TN/TP hypothesis has been justified in part on the basis that blue-green algae are better competitors for nitrogen than other species of phytoplankton (Smith 1983) or that some blue-green algae fix nitrogen (Schindler 1977). The reason for the failure of the postulated importance of TN/TP may be that not all blue-green algae are better competitors for nitrogen (Healey 1985; Suttle and Harrison 1988) or that few eutrophic lakes exhibit a long-term absence of free inorganic nitrogen. It is more likely that short term and local depletions of nitrogen stimulate nitrogen fixation, rather than any particular average nutrient ratio. In addition, many species of bloom-forming blue-green algae (e.g. *Microcystis* spp., *Oscillatoria* spp., and *Lyngbya* spp.) do not exhibit N_2 fixation under aerobic conditions (Fay 1981; Duerr et al. 1982) and conversely nitrogen fixing species like *Anabaena flos-aquae* have high rates of growth using ammonium or nitrate as a source of nitrogen (Kerry et al. 1988; Phlips et al. 1989). The ability of some blue-green algae to compete for nitrogen or to fix nitrogen, therefore, may be a weak argument for postulating blue-green algae dominance under a TN/TP values less than 29.

Although our results suggest that blue-green algae do not necessarily tend to dominate as nutrient levels increase or in response to a specific TN/TP, there is a relationship between blue-green algal biomass and total phytoplankton biomass (milligrams per litre) in the Florida data that can be described by:

(1) $\ln \text{blue-green biomass} = 1.37 \ln \text{total biomass} - 2.33$
$R^2=0.81$; $n=307$; SE intercept $=0.09$; SE slope $=0.037$; $p<0.05$.

This relationship suggests that blue-green algae tend to make up a higher fraction of the phytoplankton biomass as the total biomass increases (Ho: slope $=1$, *t*-test $p<0.05$). Equation (1) is not influenced by the date of sampling or lake water temperature as would be suggested from the work of McQueen and Lean (1987) on Lake St. George (Ontario, Canada). Examination of the scatter plot for the relationship between blue-green algal biomass and total phytoplankton biomass (Fig. 5), however, reveals that there is not a uniform trend across the entire range of algal biomass. Instead, blue-green algae may represent any proportion of the total algal biomass below a total biomass of about 50 to 100 mg/L, but they become consistently dominant at biomass values greater than 100 mg/L (Fig. 5). This further indicates that although blue-green algae tend to be dominant in hypereutrophic lakes in Florida, they do not necessarily tend to be rare in oligotrophic lakes.

Blue-green algae thrive in virtually all aquatic habitats because they have, as a group, an extraordinary functional and structural heterogeneity (Carr and Whitton 1973; Fogg et al. 1973). They benefit not only from their photsynthetic ability, but from their chemotrophic and heterotrophic capabilities. This heterogeneity is a reflection of their unique place in the taxonomic mosaic and their extended evolutionary history. Our inability to adequately explain patterns in the dominance of blue-green algae through the examination of one or a few environmental variables is, therefore, not surprising.

We believe that the simple empirical models that now exist in the literature to explain blue-green algal dominance (e.g. Smith 1983, 1985, 1986, 1987; Trimbee and Prepas 1987) should be further tested to assess their general applicability. This testing is especially needed before the models are made an integral part of the strategies for lake management (see Lathrop 1988). The strong demand for models that predict the occurrence and magnitude of algal blooms, however, must not be ignored and all efforts to develop predictive models, whatever their nature, should be encouraged.

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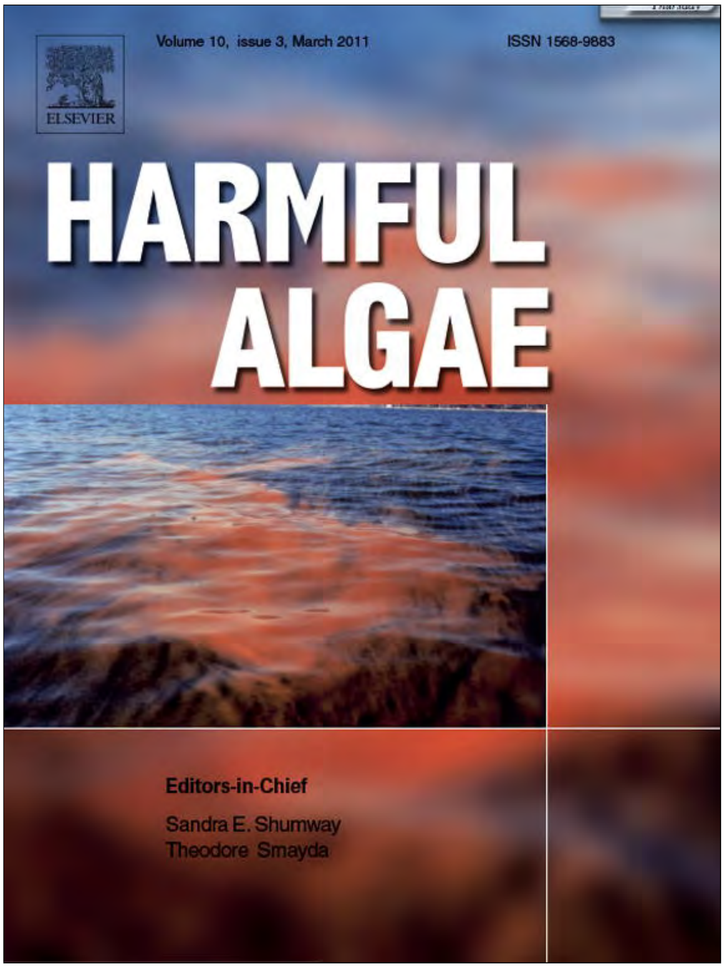
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Scales of temporal and spatial variability in the distribution of harmful algae species in the Indian River Lagoon, Florida, USA

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ABSTRACT

This paper describes the results of a harmful algal bloom (HAB) monitoring effort in the Indian River Lagoon. The goal of the study was to describe spatial and temporal variability in the distribution, frequency of occurrence, and composition of HABs, along with an examination of potential driving factors, such as hydrologic conditions and nutrient concentrations. Six sampling sites in the northern lagoon were selected for the study. The composition and abundance of the phytoplankton community was determined microscopically. Water column parameters measured in the study included salinity, water temperature, Secchi depth, total phosphorus, and total nitrogen.

Dinoflagellates, diatoms or cyanobacteria dominated the phytoplankton communities in terms of biovolume at all six sampling sites. Five potential toxin producing species were observed at bloom levels during the study period, including the diatom *Pseudo-nitzschia calliantha* and the dinoflagellates *Pyrodinium bahamense* var. *bahamense*, *Prorocentrum rathymum*, *Cochlodinium polykrikoides*, and *Karlodinium veneficum*. The saxitoxin-producing dinoflagellate *P. bahamense* var. *bahamense* had the highest biovolume observed over the study period, $33.9 \times 10^6\ \mu m^3\ ml^{-1}$, and was present in almost half of the samples collected. Three non-toxic HAB species were observed at bloom levels of biovolume, including *Akashiwo sanguinea*, *Peridinium quinquecorne*, and *Kryptoperidinium foliaceum*. As part of this study, a statistical approach to estimating the probability of detecting HAB events was explored, using three common and important HAB species in the IRL, *P. bahamense* var. *bahamense*, *A. sanguinea* and *P. calliantha*, as exemplars. The potential driving factors for HAB events are discussed within the context of the hydrological, meteorological and watershed characteristics of the lagoon.

1. Introduction

Global increases in cultural eutrophication and the potential for climate change, have heightened concerns over future threats to the integrity of coastal phytoplankton communities (Paerl, 1988; Hallegraeff, 2003; Phlips, 2002; Cloern, 2001; Smetacek and Cloern, 2008), such as increases in the frequency and intensity of harmful algal blooms (HABs) (Nixon, 1995; Smayda, 1989, 1997; Anderson et al., 1998; Sellner et al., 2003; Glibert and Burkholder, 2006). In response, long-term monitoring programs have been established to document bloom dynamics in ecosystems at risk, and build data bases of information from which models can be developed to predict future trends in HABs (Andersen, 1996; Smayda, 1997; Sellner et al., 2003; Franks, 2008; Zingone et al., 2010). One of the major challenges in designing such monitoring programs is dealing with variability in HAB events that span a wide range of spatial and temporal scales (Andersen, 1996; Chang and Dickey, 2008; Cullen, 2008).

This paper describes the results of a HAB monitoring study in the northern and central Indian River Lagoon (IRL) in Florida. The

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goal of the study was to describe spatial and temporal variability in the distribution, frequency of occurrence, intensity and composition of HABs, and examine how different spatial and temporal scales of sampling affect the detection of HAB events. The IRL, which spans over 220 km of the east coast of Florida, is characterized by a number of sub-basins with different environmental characteristics and algal populations (Phlips et al., 2002, 2010; Badylak and Phlips, 2004). While HAB events have been observed throughout the IRL, areas subject to long water residence time in the northern lagoon have been particularly prone to intense blooms (Phlips et al., 2004, 2010), and were the focus of this study. Of particular concern is the repeated occurrence of intense blooms of the toxic dinoflagellate *Pyrodinium bahamense* var. *bahamense* (Phlips et al., 2006), which has been linked to the appearance of saxitoxin in the tissues of certain fish species in the IRL (Landsberg et al., 2006; Abbott et al., 2009). The results of the study highlight the importance of differences in growth, longevity and ecological strategies of individual HAB species in defining their distribution and probability of detection. Possible driving factors for HAB events are also discussed, including the importance of meteorological conditions, in relation to shifts in salinity, temperature and nutrient concentration.

2. Methods

2.1. Site description

Six sampling sites were selected for the study, three in the northern and central Indian River Lagoon, and three in adjacent intra-coastal lagoons linked to the IRL via canals and waterways, the Mosquito Lagoon (1 site) and the Banana River (2 sites) (Fig. 1). For simplification the overall study region is described as the Northern Indian River Lagoon, or NIRL. The sampling sites included: (1) in the southern Mosquito Lagoon, near a canal which links the Mosquito Lagoon to the northern-most reach of the IRL; (2) in the IRL, near the city of Titusville; (3) in the northern Banana River, (4) in the IRL, near the city of Cocoa; (5) in the central Banana River, near the city of Cocoa Beach, and (6) in the central IRL, near the city of Melbourne. Mean depths at Sites 1 and 4 were near 1 m. Mean depths at Sites 2, 3, and 5 were 1.7–1.9 m. Mean depth at Site 6 was near 2.5 m.

The entire NIRL region is microtidal and has long water residence times, with average estimated mean water half-lives (standardized to unit volume of water) ranging from several weeks at the southern most site (Site 6), 1–2 months at Sites 1, 2, 4 and 5, and up to five months at Site 3 (Sheng and Davis, 2003; Steward et al., 2005; Reyier et al., 2008; D. Christian, unpublished data).

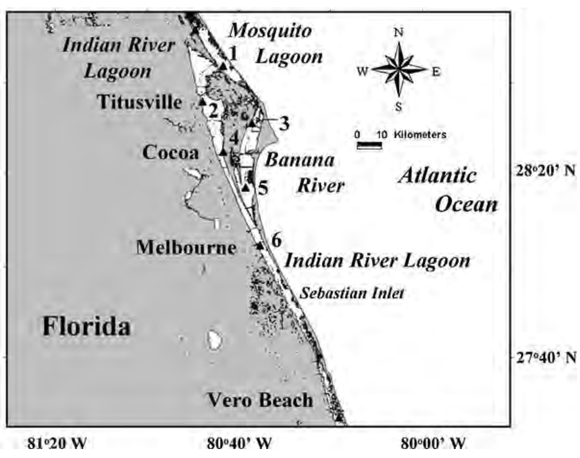

Fig. 1. Locations of the six sampling sites.

Watersheds draining different regions of the IRL basin vary in size and land-use characteristics (Adkins et al., 2004). Sites 1 and 3 are associated with relatively small watersheds, with high waterbody/watershed area ratios, and a high proportion of undeveloped wetlands. Sites 4 and 5 also have relatively high basin/watershed area ratios, but are characterized by significant urban/residential areas and light industry (Steward et al., 2005). Sites 4 and 6 are located in basins associated with somewhat larger watersheds, including urban and agricultural land uses.

2.2. Field and laboratory procedures

Salinity and temperature were measured with YSI or Hach/Hydrolab environmental multi-probes. Water was collected at the sampling sites using a vertical integrating sampling tube that captures water evenly from the surface to within 0.1 m of the bottom. Split phytoplankton samples were preserved on site, one with Lugol's and the other with gluteraldehyde in 0.1 M sodium cacodylate buffer. Additional aliquots of water were frozen for determination of total nitrogen and total phosphorus, using the persulfate digestion method (APHA, 1989; Parsons et al., 1984).

2.3. Phytoplankton analysis

General phytoplankton composition was determined using the Utermöhl method (Utermöhl, 1958). Samples preserved in Lugol's were settled in 19 mm diameter cylindrical chambers. Phytoplankton cells were identified and counted at 400× and 100× with a Leica phase contrast inverted microscope. At 400×, a minimum of 100 cells of a single taxon and 30 grids were counted. If 100 cells were not counted by 30 grids, up to a maximum of 100 grids were counted until 100 cells of a single taxon was reached. At 100×, a total bottom count was completed for taxa >30 μm in size. Light microscopy was aided by other techniques for proper identification, such as the squash technique (Steidinger, 1979) and scanning electron microscopy (Badylak et al., 2004).

Fluorescence microscopy was used to enumerate picoplanktonic cyanobacteria at 1000× magnification (Phlips et al., 1999). Subsamples of seawater were filtered onto 0.2 μm Nuclepore filters and mounted between a microscope slide and cover slip with immersion oil. If not analyzed immediately, slides were stored in a freezer and counted at within 72 h.

Cell biovolumes were estimated by assigning combinations of geometric shapes to fit the characteristics of individual taxa (Smayda, 1978). Specific phytoplankton dimensions were measured for at least 30 randomly selected cells. Species which vary in size, such as many diatom species, were placed into size categories.

For the purpose of description and discussion, 'blooms' were defined as phytoplankton biovolumes for individual species which fell within the top 5% of biovolumes observed over the study period for all individual species, i.e. $>10^6\ \mu m^3\ ml^{-1}$.

2.4. Statistical methods

Basic statistical procedures (i.e. determination of mean values, standard deviations, Pearson Correlation Coefficients) were carried out using SAS v9.2 (SAS Institute, Cary, North Carolina, USA).

As part of this study, a statistical approach was explored for estimating the probability of detecting blooms, given different sampling intervals. When systematic sampling is used, that is when measurements are taken on a regularly recurring schedule, the probability that a particular bloom will be observed during the study is a function of the length of time (L) that the phytoplankton species is at bloom levels, the number and temporal dispersion of the blooms, and the time interval between sampling dates (I). The probability that a systematic sample regime S (the set of dates on which measurements are taken) at time interval I intersects a bloom in period B (the set of contiguous dates on which the bloom occurs) of length L is given by:

$$P(S \cap B) = \begin{cases} \frac{L}{I} & L < I \\ 1 & L \geq I^* \end{cases}$$

For example, if a 10-day bloom occurs during a study in which a two-week sampling design is used, the probability of the bloom being observed is 0.714 (=10/14) if the start date of the systematic sample is random. To provide approximations for estimating the effect of sampling interval and bloom length on the probability of detecting a HAB event, the observed biovolumes of the dinoflagellate *P. bahamense* var. *bahamense*, *Akashiwo sanguinea*, and the diatom *Pseudo-nitzschia calliantha* were used to predict the daily values for dates on which sampling was not performed. To obtain a complete daily time series for the study period, a non-parametric smoothing function was used to fit a cubic spline to the observed biovolumes for each species at each station. The cubic spline method uses a set of third-degree polynomials spliced together such that the resulting curve is continuous and smooth at the splices (knot points). An example of the predicted time series for a single station for *P. bahamense* is shown in Fig. 11.

Dinoflagellate blooms were defined as biovolumes above 10^6 μm^3 ml^{-1}. For the diatom *P. calliantha* the bloom threshold level was based on the cell density above which health warnings are administered in many countries around the world, i.e. 200 cells ml^{-1} (Andersen, 1996), equivalent to a biovolume of 0.06×10^6 μm^3 ml^{-1}. The simulated bloom lengths for *P. bahamense* over all of the stations were 4, 10, 11, 13, 14, 16, 18, 24, 25, 32, 70, 92, and 149 days. Using the simulated time series which incorporate lengths of blooms as well as the temporal distribution of the blooms, the probability of observing a bloom was estimated by systematically sampling from these daily time series using different intersampling intervals (I). We used intervals of one, two, four and eight weeks. Sampling was done by using every possible start date for a systematic sample of a given intersampling interval so that all possible systematic samples for each I were performed. The probability of intersecting a bloom of a particular length during the study period was calculated using the set of systematic samples with the same interval. All analyses were done using R (R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org).

GIS images of HAB distribution were generated using the Arc Map Spatial Analyst Extension feature of Arc View 9.3 (ESRI, Redlands, California, USA), to illustrate the spatial distribution of single-species blooms using supplemental monitoring data. Interpolations were done using Inverse Distance Weighting (IDW).

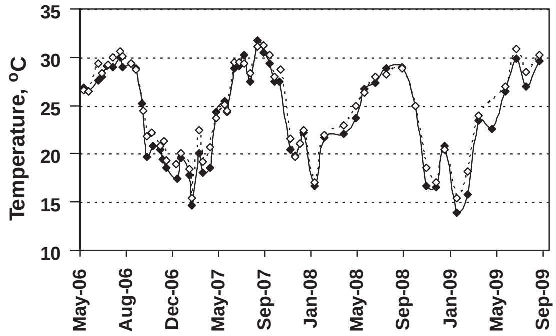

Fig. 2. Surface water temperatures at Sites 2 (closed circles) and 6 (open circles).

3. Results

3.1. Physical-chemical and meteorological characteristics

Water temperatures over the study period reflected the subtropical climate of central Florida, with temperatures in excess of 20 °C through most of the study period (Fig. 2). In the Spring of 2006 there was an early increase in water temperature due to exceptionally high air temperatures in April station (U. S. National Climate Data Center, www.ncdc.noaa.gov).

Monthly rainfall totals ranged from 0 to 39 cm at the Titusville meteorological station and from 0.2 to 68 cm at the Melbourne meteorological station (U. S. National Climate Data Center, www.ncdc.noaa.gov) (Fig. 3). Rainfall was generally greater from May through October (the wet season) than November through April (the dry season). The wet seasons included in the study period had different rainfall patterns. Monthly rainfall totals in the wet season of 2006 were near, to somewhat above, 'normal' from May through September. In 2007, monthly rainfall totals during

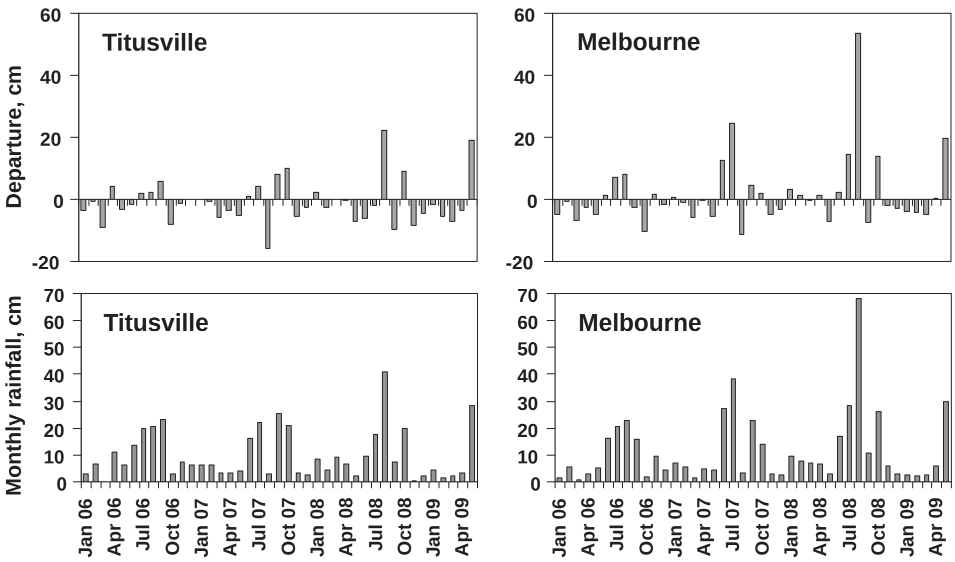

Fig. 3. Monthly rainfall totals (cm) at meteorological stations in Titusville (bottom left frame) and Melbourne (bottom right frame), and departure from normal (cm) in Titusville (top left frame) and Melbourne (top right frame) (after U. S. National Climate Data Center, Florida Climatological Record).

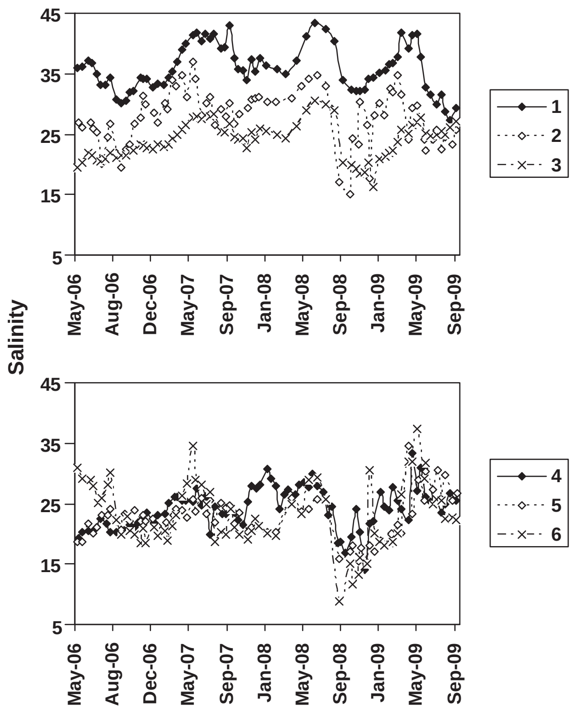

Fig. 4. Surface water salinities at the six sites in the NIRL.

the wet season varied from well-below normal in May, the last month of a six-month drought period, to well above average in June, July and September, particularly at the Melbourne meteorological station, which had large rainfall peaks in June and July. In 2008, monthly rainfall totals were above normal most of the wet season at the Melbourne meteorological station, including well above normal totals in July, August and October. The August peak was associated with the passage of tropical storm Fay. At the Titusville meteorological station rainfall was only above normal in August and October, with the remainder of the wet season being below normal.

Salinities for the study period ranged from near 10 at Site 6 near Melbourne to 42 at Sites 1 in the Mosquito Lagoon (Fig. 4). The timing and extent of salinity variation differed between sites. The most prominent feature shared by all sites was a sharp decline in salinity associated with very high rainfall in the summer/fall of 2008.

Mean water column transparency values, expressed as Secchi disk depths, were near 1.5 m at all sites except Site 4. Mean Secchi depth at Site 4 was 0.6 m, reflecting the shallow depth (<1.0 m) and high potential for sediment re-suspension.

Mean total nitrogen (TN) concentrations at Sites 1 through 6 were 1070 μg N l^{-1} (Std = 298), 1083 μg N l^{-1} (Std = 313), 1226 μg N l^{-1} (Std = 280), 1134 μg N l^{-1} (Std = 303), 1167 μg N l^{-1} (Std = 318), and 809 μg N l^{-1} (Std = 298), respectively. Temporal patterns of TN concentration were similar at all sites, with declining values through the drought period from the fall of 2006 through the Spring of 2007. Increases in TN in the summer and fall of 2007 coincided with increases in rainfall. Increases in TN concentrations also coincided with high rainfall experienced in the late summers/early fall of 2008 at all six sites. The positive relationships between TN concentration, rainfall and freshwater inflow were reflected in the significant negative correlations between salinity and TN at most sites (Table 1).

Mean total phosphorus (TP) concentrations at Sites 1 through 6 were 38 μg P l^{-1} (Std = 17), 45 μg P l^{-1} (Std = 16), 39 μg P l^{-1} (Std = 13), 93 μg P l^{-1} (Std = 48), 48 μg P l^{-1} (Std = 16), and 55 μg P l^{-1} (Std = 19), respectively. Temporal variability of TP concentration was less predictable than TN concentration.

Table 1
Pearson correlation coefficients for relationships between salinity, chlorophyll *a*, total phosphorus (TP), and total nitrogen (TN) at the six sampling sites. Coefficients shown in italics were not significant at the $p = 0.05$ level.

Site	Salinity ×		Chlorophyll *a* ×	
	TN	TP	TN	TP
1	*−0.04*	0.26	0.20	*0.16*
2	−0.47	−0.28	0.34	0.46
3	−0.42	*0.12*	0.21	0.34
4	*−0.15*	*−0.08*	0.27	0.43
5	−0.45	*0.16*	*0.11*	0.51
6	−0.46	0.21	0.38	*0.06*

Correlations between TP and salinity varied by site and were not significant at Sites 3–5 (Table 1), suggesting that other factors may significantly contribute to variability in TP, such as internal loading processes (e.g. sediment resuspension).

Mean chlorophyll *a* concentrations at Sites 1 through 6 were 6.2 μg l^{-1} (Std = 35), 8.0 μg l^{-1} (Std = 5.6), 8.6 μg l^{-1} (Std = 5.7), 16.4 μg l^{-1} (Std = 12.2), 10.0 μg l^{-1} (Std = 7.7), and 11.9 μg l^{-1} (Std = 9.3), respectively. Chlorophyll *a* concentrations were positively correlated to TP and TN at Sites 2–5 (Table 1), but the correlation coefficients for TN were lower than for TP. At Sites 1 and 6, chlorophyll *a* concentrations were only correlated to TN.

3.2. Phytoplankton biomass

Mean total phytoplankton biovolumes at Sites 1 through 6 were 2.31×10^6 μm^3 ml^{-1} (Std = 2.45×10^6), 2.68×10^6 μm^3 ml^{-1} (Std = 3.15×10^6), 3.58×10^6 μm^3 ml^{-1} (Std = 2.88×10^6), 4.91×10^6 μm^3 ml^{-1} (Std = 5.69×10^6), 5.21×10^6 μm^3 ml^{-1} (Std = 7.14×10^6), and 4.23×10^6 μm^3 ml^{-1} (Std = 19×10^6), respectively. The mean values for all six sites were subject to large standard deviations, reflecting the periodic appearance of blooms (Fig. 5). Dinoflagellates, diatoms or cyanobacteria dominated the phytoplankton communities during bloom conditions in terms of biomass (i.e. expressed as biovolume), as illustrated by the time series of phytoplankton biovolume (Fig. 5). Although major blooms were relatively rare at Site 1, they were typically dominated by diatoms, including *P. calliantha*, *Chaetoceros simplex* and *Dactyliosolen fragilissimus* (Fig. 5). At Site 2, the largest blooms were dominated by dinoflagellates, typically involving the HAB species *P. bahamense* var. *bahamense* and *A. sanguinea* (Fig. 5). A mixture of dinoflagellate and diatom blooms was observed at Site 3, including the dinoflagellates *P. bahamense* var. *bahamense* and *A. sanguinea*, and the diatoms *P. calliantha*, *D. fragilissimus* and *Cerataulina pelagica*. As in the case of Site 2, blooms at Site 4 were dominated either by the diatom *D. fragilissimus* or by the dinoflagellates *P. bahamense* var. *bahamense*, *Karlodinium veneficum*, *Kryptoperidinium foliaceum*, *Peridinium quinquecorne* and *Prorocentrum rathymum*. At Site 5, the highest phytoplankton biovolumes observed over the study period frequently involved the dinoflagellate *P. bahamense* var. *bahamense* and three diatom species, i.e. *C. pelagica*, *D. fragilissimus* and *Rhizosolenia setigera* (Fig. 5). At Site 6, many of the peaks in phytoplankton biovolume were dominated by diatoms, including *Leptocylindrus minimus*, Leptocylindrus danicus, *C. pelagica*, *D. fragilissimus* and *R. setigera* (Fig. 5). Several blooms of *P. bahamense* var. *bahamense* and *A. sanguinea* were also observed at Site 6 in 2006.

3.3. HAB species

Twenty-four phytoplankton taxa that appear on major lists of harmful algal bloom (HAB) species (Landsberg, 2002; FWC, 2009; IOC, 2009) were observed over the study period (Table 2). Among the 24 HAB species, 16 are considered potential toxin producers, while the remaining eight have been associated with other harmful

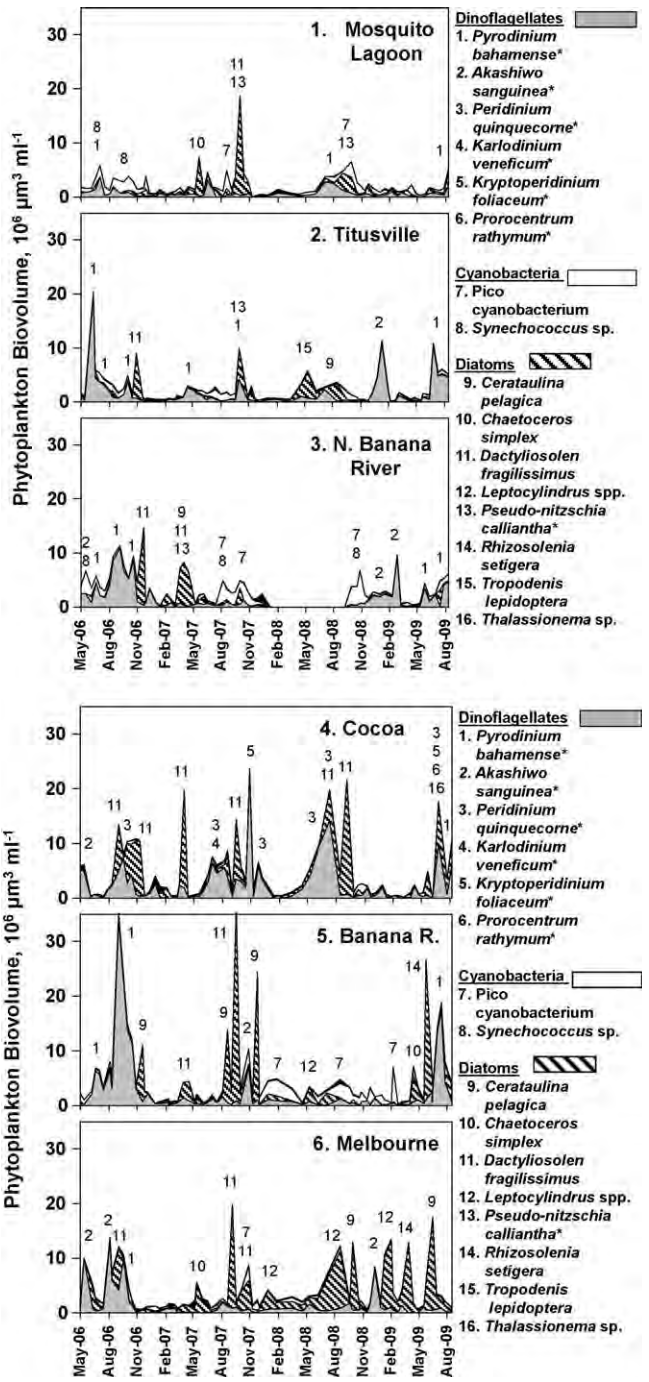

Fig. 5. Biovolume contribution of the major phytoplankton groups to total phytoplankton biovolume. The major groups include dinoflagellates (grey), diatoms (cross hatch) and cyanobacteria (white), and other (black), which includes the remainder of the phytoplankton taxa observed in each sample. The species associated with some of the major peaks in biovolume are shown as numbers above the peaks. Species with '*' indicates a HAB species.

effects, such as hypoxia. Eight of the HAB species were observed at bloom levels of biomass (defined as biovolumes > 10^6 µm³ ml^{-1}); including the diatom *P. calliantha*, and the dinoflagellates *P. bahamense* var. *bahamense*, *A. sanguinea*, *P. quinquecorne*, *K. foliaceum*, *K. veneficum*, *Cochlodinium polykrikoides* and *P. rathymum* (Table 2).

The HAB species most commonly observed at bloom levels of biovolume was *P. bahamense* var. *bahamense* (Table 2). The saxitoxin-producing dinoflagellate had the highest biovolume observed over the study period, 33.9 × 10^6 µm³ ml^{-1}, and was observed at bloom levels in 51 samples, primarily during the summer and fall of 2006 and 2008 (Fig. 5). *A. sanguinea* was the HAB species with the second largest number of bloom observations, i.e. 17 (Table 2). The most intense blooms of *A. sanguinea* were observed in three time windows, the spring of 2006, fall of 2007 and winter of 2009 (Fig. 5). The only HAB diatom commonly observed at bloom levels was *P. calliantha* (Table 2), a potential domoic acid producing diatom (Landsberg, 2002). *K. veneficum*, a dinoflagellate associated with the production of the icthyotoxic karlotoxins (Landsberg, 2002), was the most frequently observed HAB species during the study period, appearing in 272 of 419 samples (Table 2), but seldom reached bloom levels.

Five other HAB species were observed at cell densities greater than 100 cells ml^{-1}; including the dinoflagellates *Prorocentrum minimum* and *Takayama tasmanica*; the diatom *Pseudo-nitzschia turgidula*; and the haptophytes *Chrysochromulina* spp. and *Prymnesium* spp. (Table 2). None of the latter five species were observed at bloom levels of biovolume, although *Chrysochromulina* spp. came close at Site 4 in the Summer of 2007, with a biovolume of 0.88 × 10^6 µm³ ml^{-1}.

A number of potentially toxic species were occasionally observed, generally at densities below 100 cells ml^{-1}. Included in this list were two potentially toxic species from the genus *Karenia*, i.e. mikimotoi and brevis, as well as the potentially toxic raphidophyte *Chattonella* spp. (Table 2). The potential PSP-producing species *Alexandrium monilatum* was observed in four samples, but at densities below 10 cells ml^{-1}. Although cell densities for these HAB species were relatively low, there were some observations that exceeded thresholds of concern established by management organizations. For example, the observation of *K. brevis* at 50 cells ml^{-1} on June 9, 2007 at Site 1 is 10-fold higher than the alert threshold established by the Florida Fish and Wildlife Commission (FWC, 2009).

3.4. The distribution of major bloom-forming species

Many of the major bloom-forming phytoplankton species were widely distributed through the NIRL, but bloom events of certain species were more spatially restricted. The most prominent HAB dinoflagellate *P. bahamense* var. *bahamense*, was observed at bloom levels at all six sites (Fig. 6). Blooms of *A. sanguinea* were also widely distributed, appearing at Sites 2–6 (Fig. 6). Similarly, blooms of the major non-HAB diatoms and cyanobacteria were widely distributed throughout the NIRL, as exemplified by the distribution of *D. fragilissimus* and picoplanktonic cyanobacteria (Fig. 6). Some other bloom-forming HAB species showed spatially biased distribution. The HAB diatom *P. calliantha* was only observed at bloom levels at Sites 1–3. Some HAB dinoflagellates were only observed at bloom levels at Site 4, including *K. veneficum*, *K. foliaceum*, and *P. quinquecorne* (Fig. 6).

From an ecophysiological perspective, many of the bloom-forming phytoplankton in the NIRL were observed over a wide range of salinities, as exemplified by the HAB species *P. bahamense* var. *bahamense*, *A. sanguinea*, *P. calliantha*, and *P. quinquecorne* (Fig. 7). The major non-HAB diatoms, such a *D. fragilissimus*, and picoplanktonic cyanobacteria were also euryhaline in their distribution (Fig. 7). Peak levels of biomass were commonly observed at mid-range salinities (i.e. 20–30 psu) (Fig. 7).

The distribution of major bloom-forming phytoplankton species according to water temperature showed some disparities (Fig. 8). The tropical dinoflagellate *P. bahamense* var. *bahamense* was not observed at significant concentrations below 20 °C, and blooms were generally confined to temperatures above 25 °C. Blooms of *P. quinquecorne* were similarly most abundant above 25 °C. By contrast, blooms of *A. sanguinea* were observed at temperatures from 12 to 30 °C, as were blooms of picoplanktonic cyanobacteria and the diatom *D. fragilissimus*.

Table 2
Species of phytoplankton observed during the study period, which appear on Harmful Algal Bloom lists (FWC, 2009; IOC, 2009). First column shows the number of samples containing the species, out of a total of 410 samples. The second column shows the highest biovolume observed for each species and the third column the highest cell density. The final column shows the number of 'bloom' ($>10^6$ μm^3 ml^{-1}) observations for each species. The first column shows group identities; 'Df' for dinoflagellates (*Dinophyceae*), 'Di' for diatoms (*Bacillariophyceae*), 'R' for raphidiophytes (*Raphidophyceae*) and 'H' haptophytes (*Prymnesiophyceae*).

HAB species	Group	Obs.	Maximum biovolume 10^6 μm^3 ml^{-1}	Maximum density cells ml^{-1}	Bloom Obs.
Pyrodinium bahamense[a]	Df	198	33.94	928	51
Akashiwo sanguinea[b]	Df	186	12.55	176	17
Peridinium quinquecorne[a]	Df	44	10.35	1,556	11
Pseudo-nitzschia calliantha[a]	Di	90	5.07	16,780	5
Kryptoperidinium foliaceum[b]	Df	34	22.66	3848	5
Karlodinium veneflcum[a]	Df	274	3.93	4485	3
Prorocentrum rathymum[a]	Df	39	16.68	944	1
Cochlodinium polykrikoides[a]	Df	56	1.21	39	1
Gonyaulax polygramma[b]	Df	97	0.50	11	0
Prorocentrum minimum[a]	Df	72	0.48	302	0
Gyrodinium instriatum[b]	Df	52	0.14	5	0
Oxyphysis oxytoxides[b]	Df	50	0.39	26	0
Takayama tasmanica[a]	Df	39	0.25	127	0
Chrysochromulina spp.[a]	H	35	0.88	5980	0
Pseudo-nitzschia turgidula[a]	Di	23	0.52	2431	0
Takayama pulchella[a]	Df	17	0.12	60	0
Gonyaulax spinifera[b]	Df	13	0.02	2	0
Chattonella spp.[a]	R	12	0.12	20	0
Prorocentrum lima[a]	Df	11	0.03	1	0
Prymnesium spp.[a]	H	9	0.01	290	0
Karenia mikimotoi[a]	Df	6	0.13	30	0
Alexandrium monilatum[a]	Df	5	0.05	3	0
Karenia brevis[a]	Df	2	0.22	50	0
Gyrodinium impudicum[b]	Df	1	0.01	1	0

[a] Refers to potentially toxic species.
[b] Refers to species associated with other harmful effects, such as fish kills not necessarily associated with toxins.

In addition to the more general distribution patterns of bloom-forming species, the frequent and widespread presence of *P. bahamense* var. *bahamense* provided an opportunity to examine more specific spatial issues. For example, in a limited test of vertical stratification of HAB species, the distribution of *P. bahamense* var. *bahamense* was examined on several sampling dates during a bloom event at Site 2. On the first sampling date, clear skies prevailed, and *P. bahamense* var. *bahamense* densities were four-fold higher in the bottom water sample (depth = 2 m) than in the surface or mid-column (depth = 1 m) water samples

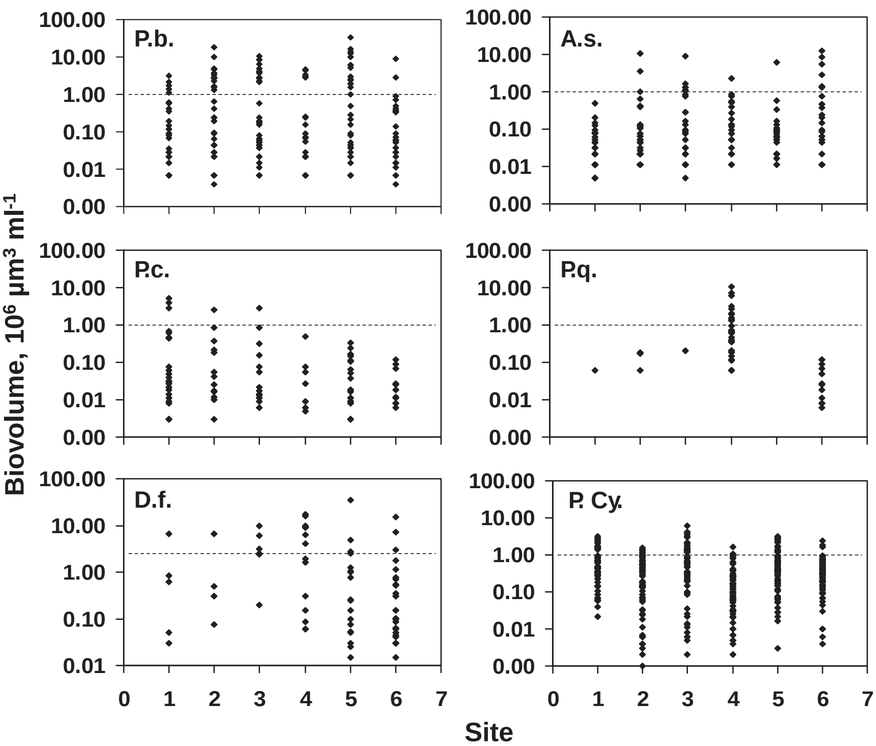

Fig. 6. Spatial distribution of observations of four HAB species (P.b., *Pyrodinium bahamense* var. *bahamense*; A.s., *Akashiwo sanguinea*; P.c., *Pseudo-nitzschia calliantha*; P.q., *Peridinium quinquecorne*), and two non-HAB taxa (D.f., *Dactyliosolen fragilissimus*; P.cy., *Picoplanktonic cyanobacteria*), in terms of biovolume.

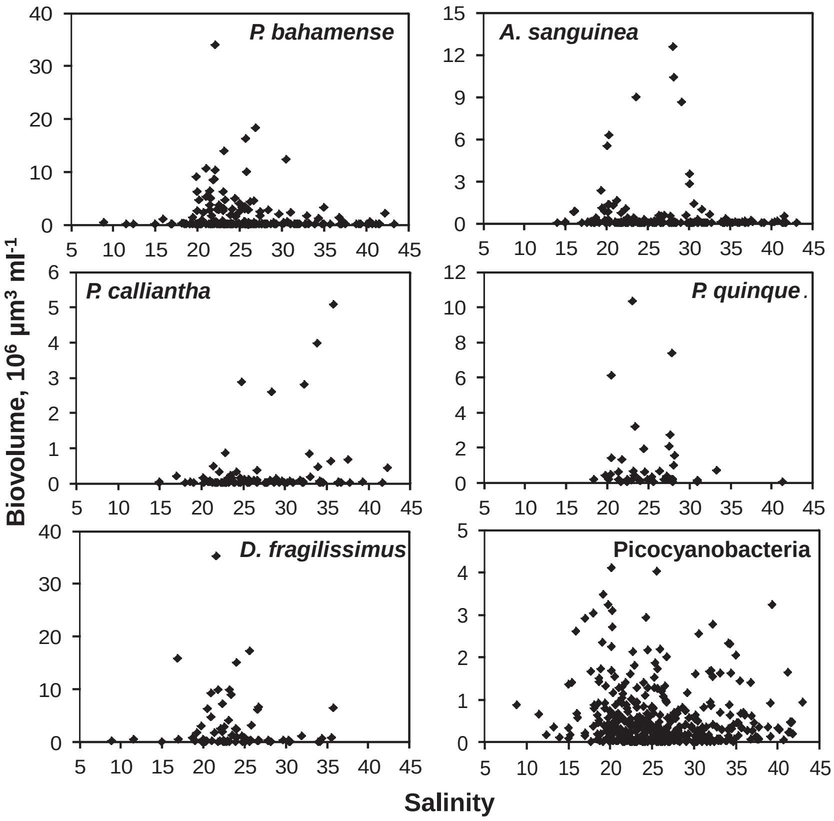

Fig. 7. Distribution of observations of four HAB species (*Pyrodinium bahamense* var. *bahamense*, *Akashiwo sanguinea*, *Pseudo-nitzschia calliantha*, and *Peridinium quinquecorne*), and two non-HAB taxa (*Dactyliosolen fragilissimus* and *Picoplanktonic cyanobacteria*) in relation to salinity.

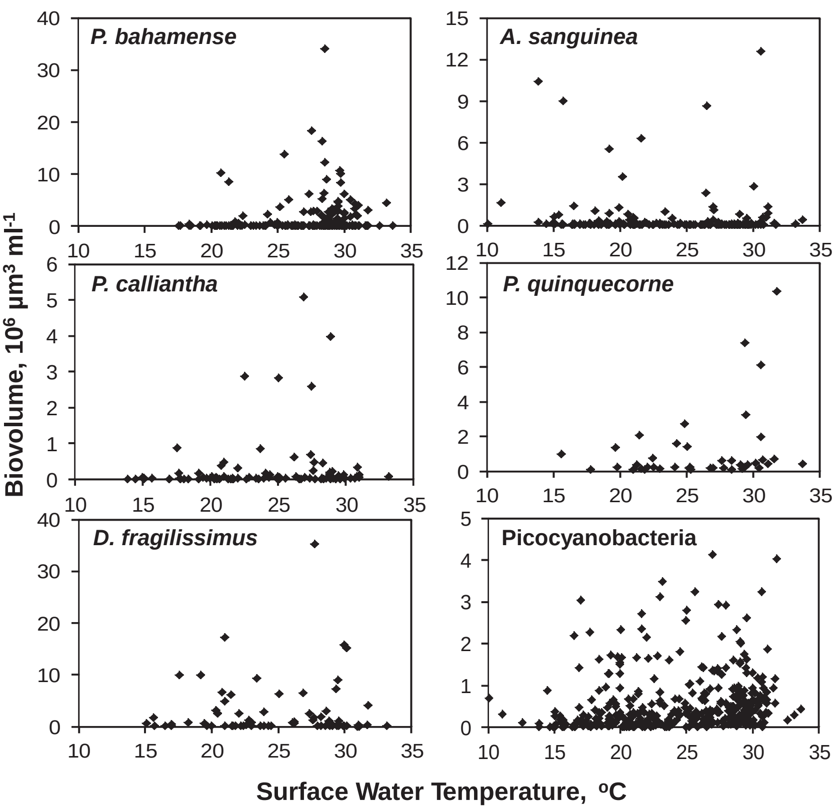

Fig. 8. Distribution of observations of four HAB species (*Pyrodinium bahamense* var. *bahamense*, *Akashiwo sanguinea*, *Pseudo-nitzschia calliantha*, and *Peridinium quinquecorne*), and two non-HAB taxa (*Dactyliosolen fragilissimus* and *Picoplanktonic cyanobacteria*) in relation to water temperature.

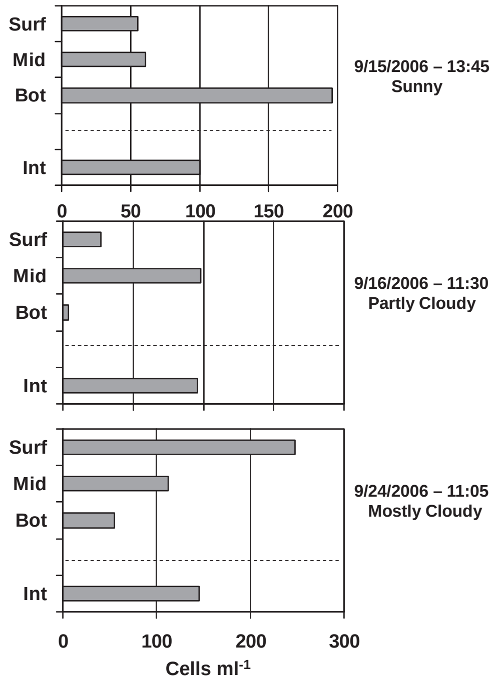

Fig. 9. The distribution of *Pyrodinium bahamense* var. *bahamense* cells (cells ml^{-1}) in the water column at Site 2. The mid-water column (Mid) was at 1 m and the bottom (Bot) at 2 m. The integrated value (Int) was determined from a whole water column sample.

(Fig. 9). On the second sampling date conditions were partly cloudy, and *P. bahamense* var. *bahamense* were highest in the mid-water column sample. On the third sampling date mostly cloudy conditions prevailed, and *P. bahamense* var. *bahamense* densities were highest in the surface water sample. *P. bahamense* var. *bahamense* densities in integrated water column samples were relatively similar on all three sampling dates, indicating that the overall densities were similar throughout the 10-day test period.

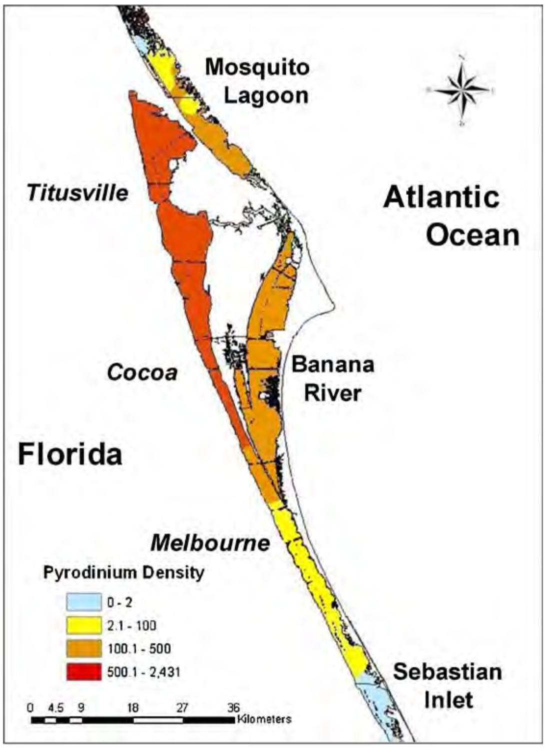

Fig. 10. Spatial distribution of *Pyrodinium bahamense* var. *bahamense* blooms in the northern Indian River Lagoon, Banana River and southern Mosquito Lagoon from July to October 2009. Maximum cell densities over the time period at 19 sites distributed around the study region were used to generate the GIS contours.

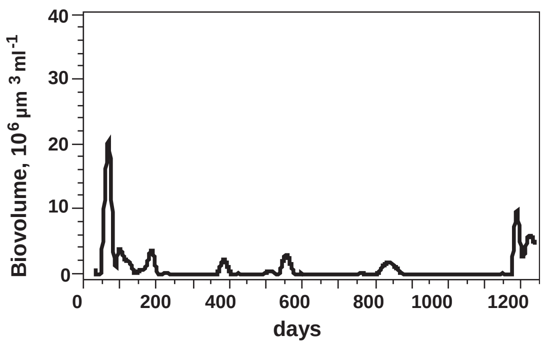

Fig. 11. Predicted daily time series of biovolume (10^6 μm^3 ml^{-1}) for *Pyrodinium bahamense* var. *bahamense* at Station 2 using cubic splines. The cutoff for blooms is defined as a biovolume greater than 10^6 μm^3 ml^{-1}.

The availability of supplemental phytoplankton monitoring data for the late summer and early fall of 2009 provided an opportunity to examine in greater detail the geographical extent of a *P. bahamense* var. *bahamense* bloom in the NIRL in greater detail (Fig. 10). The GIS contour image of the peak cell densities for the August through October bloom period of 2009 revealed a region of peak cell densities in the northern IRL proper, from near Cocoa northward, although significant densities (i.e. >100 cells ml^{-1}) extended into the southern Mosquito Lagoon, the Banana River Lagoon, to near Site 6.

The occurrence of peak *P. bahamense* var. *bahamense* abundances in the NIRL and sharp decline south of Melbourne (Site 6) has been a repeating pattern since 2001 (Phlips et al., 2006, 2010), but not without exception. In the summer of 2004 a *P. bahamense* var. *bahamense* bloom uncharacteristically appeared in the Sebastian Inlet region of the IRL, well south of Melbourne, just after the passage of Hurricane Charley. On July 22 no *P. bahamense* var. *bahamense* cells were observed in the region, while cell densities were 775 cells ml^{-1} at Melbourne (Site 6). One week after Hurricane Charley on August 25 concentrations dropped to 391 cells ml^{-1} at Melbourne and went up to 100 cells ml^{-1} near the Sebastian Inlet. It is likely that the bloom near the Sebatian Inlet was not a local event, but resulted from wind-driven displacement of *P. bahamense* var. *bahamense* from the Melbourne region southward to Sebastian during the hurricane. This observation highlights the potential importance of wind-driven circulation on the distribution of blooms.

A similar non-indigenous HAB event was observed in the fall of 2007, when the toxic dinoflagellate *Karenia brevis* was observed in the Mosquito Lagoon (Site 1), as a result of tidally driven incursion of coastal water containing a bloom of the alga.

3.5. Detecting HAB species and bloom events

Three of the most prominent HAB species in the IRL were included in a test of bloom detection probabilities using a non-parametric smoothing function to fit a cubic spline to the observed biovolumes or cell densities at each site, as described in the methods section; i.e. the dinoflagellates *P. bahamense* var. *bahamense* and *A. sanguinea*, and the diatom *P. calliantha*. To determine the effects of sampling interval and bloom period length on the probability of detecting HAB events, daily time series were generated for blooms of the three selected HAB species. Dinoflagellate blooms were defined as biovolumes above 10^6 μm^3 ml^{-1}. For the diatom *P. calliantha* the bloom threshold

Table 3
Predicted number of blooms (count), mean and standard deviation (Std) of the length of a bloom, standard error of the mean (SEM) bloom length, and the proportion of days (*P*) during the study period which met the definition of a bloom event. Daily biovolumes or cells ml^{-1} were predicted at each of the six stations over the study period, May 2006 to August 2009, using cubic splines (see text) fitted to biweekly observations. Blooms were identified as the days when the predicted value exceeded the cutoff for an event where an event is defined as a biovolume over 1×10^6 μm^3 ml^{-1} for *P. bahamense* and *A. sanguinea* and over 200 cells ml^{-1} for *P. calliantha*.

Statistic	*P. bahamense*	*A. sanguinea*	*P. calliantha*
Count	22	11	27
Mean	40.27	26.09	28.48
Std	31.15	12.53	20.61
SEM	6.64	3.78	3.97
Min	12	2	2
Max	151	42	94
P	0.123	0.040	0.106

level was based on the cell density above which health warnings are administered in many countries around the world, i.e. 200 cells ml^{-1} (Andersen, 1996), equivalent to a biovolume of 0.06×10^6 μm^3 ml^{-1}. An example of a predicted time series is shown in Fig. 11. The mean bloom lengths and timing of the blooms are shown in Table 3. Mean lengths of time over which the three species exceeded the bloom thresholds were 26.09, 28.48, and 40.27 days for *A. sanguinea*, *P. calliantha*, and *P. bahamense* var. *bahamense*, respectively.

The probability of observing a bloom of a given length was strongly influenced by sampling interval (Fig. 12). The effect of sampling interval was inversely related to the mean length of

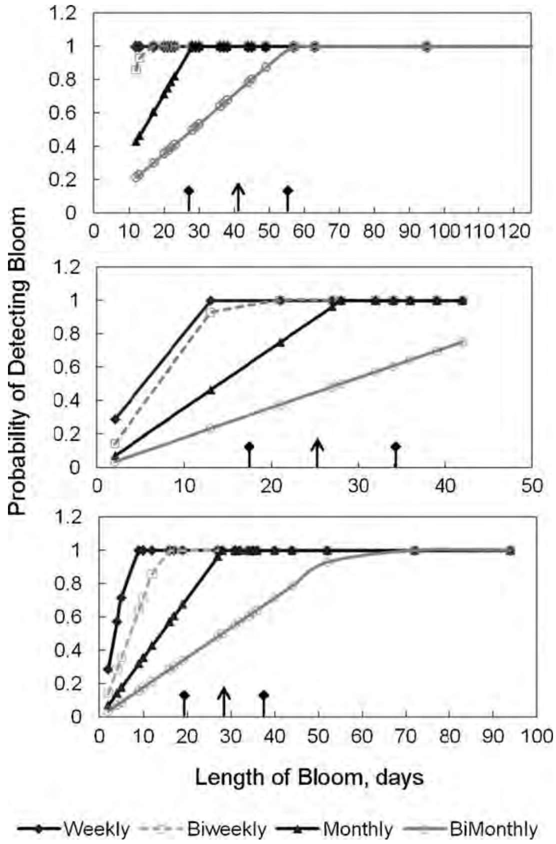

Fig. 12. Plot of the probability of a bloom being observed as a function of the length of time the bloom exists and the time interval between systematic samples. The three panels are for *Pyrodinium bahamense* var. *bahamense* (top), *Akashiwo sanguinea* (middle), and *Pseudo-nitzschia calliantha* (bottom). The arrows indicate the mean bloom length and the diamond markers are the 95% confidence intervals around the means.

blooms. Using the 95% confidence interval around the mean values for bloom length, the probability of detecting a *P. bahamense* var. *bahamense* bloom was 1.00 for sampling intervals of 1–2 weeks, and 0.85–1.00 for monthly sampling intervals (Table 3). At a sampling interval of two months (bi-monthly), the probability of detection went down to 0.45–1.00. For *A. sanguinea*, a species with shorter–lived blooms, the probability of detection was 0.95–1.00 for one and two-week sampling intervals, 0.55–1.00 for monthly sampling intervals, but only 0.20–0.55 for bi-monthly sampling intervals. The probabilities of bloom detection for *P. calliantha* were similar to *A. sanguinea*; 1.00 for one- to two-week sampling intervals, 0.70–1.00 for monthly sampling intervals, and 0.25–0.70 for bi-monthly sampling intervals.

Precisely defining the probability of detecting blooms of species that did not span more than one sampling date in a row over the sampling period was not feasible. For example, *K. foliaceum* appeared at bloom levels several times at Site 4, but bloom levels were never sustained for more than one sampling date. Hence for some of the HAB species observed in this study, we have likely missed several short duration blooms due to the two-week sampling interval. The probability that all blooms of such species would be missed during the study is a complicated calculation that depends not only on the sampling interval and the lengths of the blooms but also on the number of blooms and the number of days between blooms. The resolution of this problem would require a longer–term data series.

4. Discussion

Spatial and temporal variability in the abundance and composition of phytoplankton during bloom events can be viewed on various levels of taxonomic organization, but for the purpose of this discussion it is useful to begin by examining variability of total phytoplankton biomass at the sub-basin scale, before proceeding toward an examination of the dominant bloom-forming groups and harmful algae bloom (HAB) species. Spatial and temporal variability can also be viewed from the perspective of the probability of detecting bloom events involving different species, given different monitoring strategies.

4.1. Temporal and spatial patterns in phytoplankton biomass

From a temporal perspective, phytoplankton blooms in the northern Indian River Lagoon (NIRL) were most abundant from the late spring to early fall, but winter blooms were common, reflecting the subtropical character of central Florida's climate. A similar lack of consistent seasonal periodicity of blooms has been observed in other south Florida ecosystems, such as Florida Bay (Phlips et al., 1999; Briceño and Boyer, 2010; Winder and Cloern, 2010). Seasonal changes in light availability and temperature, which are major factors in defining phytoplankton production and biomass in temperate and boreal ecosystems (Cushing, 1959; Sommer et al., 1986), are less critical in controlling seasonal biomass potential in sub-tropical ecosystems (Harris, 1986; Winder and Cloern, 2010), and their role may be more important in guiding species composition and succession than setting biomass thresholds.

One of the driving factors for temporal trends of phytoplankton biomass in the NIRL is rainfall. Elevated rainfall totals during the wet season are associated with increased nutrient loads in the NIRL, as indicated by the negative relationship between salinity and concentrations of total nitrogen. In regions of the lagoon with high hydraulic residence time, such periods of increased load are correlated to bloom intensity, while in regions with short water residence time, such as near the Sebastian Inlet, changes in load have less impact on phytoplankton biomass (Phlips et al., 2004, 2010).

From a spatial perspective, differences in average phytoplankton biovolumes among the six sampling sites in the NIRL can be viewed in terms of both basin and watershed characteristics. The southern Mosquito Lagoon (Site 1) had the lowest average phytoplankton biovolume and bloom frequency. The region is fed by water inflows from relatively small and pristine watersheds, yielding lower nutrient loads than other regions of the NIRL (Adkins et al., 2004). The region is also characterized by shallow mean depths (i.e. <1.5 m) and extensive seagrass populations (Fletcher and Fletcher, 1995), increasing competition for nutrients by algal populations associated with seagrass, which can reach high biomass levels in the early spring (Virnstein and Carbonara, 1985). Virnstein and Carbonara (1985) observed drift algae standing crops as high as 400 g dry wt. m^{-2}, along with seagrass biomass of up to 300 g dry wt. m^{-2} in the IRL.

The Mosquito Lagoon, as well as the rest of the NIRL, also contain significant populations of clams, mussels and other filter-feeding invertebrates (Mikkelsen et al., 1995), as reflected by the presence of a bivalve harvesting industry (Busby, 1986). Concentrations of certain filter-feeding bivalves, such as clams and mussels, can be particularly high in seagrass communities of the NIRL (Mikkelsen et al., 1995). From a spatial perspective, the Mosquito Lagoon is one of the regions in the NIRL with high bivalve densities (http://www.dep.state.fl.us/coastal/sites/mosquito/management/public_use.htm). These benthic communities represent a potential source of top-down pressure on phytoplankton populations in the NIRL. The importance of benthic grazers on phytoplankton dynamics has been demonstrated for other shallow ecosystems, such as San Francisco Bay (Cloern, 1982). In terms of the importance of zooplankton grazing in the NIRL, preliminary evidence suggests that rates are lower than phytoplankton growth potential (Phlips et al., 2002). The specific magnitude of planktonic and benthic grazing pressures in the NIRL is difficult to quantify due to the lack of sufficient faunal abundance and composition data.

The sites with the next to highest mean phytoplankton biovolumes were Site 2 near Titusville and Site 3 in the Northern Banana River. Both sites are located in regions with shallow mean depths (i.e. around 2 m) and significant seagrass and drift algae populations, but are also characterized by very long water residence times (i.e. average half water replacement rate, or $R_{50} > 100$ days), and watersheds with moderate human influence (Adkins et al., 2004; Reyier et al., 2008; Gao, 2009). Nitrogen and phosphorus loads to most of the NIRL have increased by at least 30% and 50%, respectively since the 1940s (Steward and Green, 2007), likely contributing to bloom potential.

The three sites with the highest mean phytoplankton biovolume and greatest frequency of bloom events during the study period, Sites 4–6, were located in regions of the IRL with markedly different physical characteristics. Site 4 was located in an isolated very shallow (i.e. 1 m) embayment, Site 5 was located in a broad shallow (i.e. 2 m) basin in the central Banana River Lagoon, and Site 6 was located in a broad, somewhat deeper (i.e. 2–3 m), basin with lower seagrass densities and subject to inflows from a major tidal creek, as reflected by the exceptionally variable salinities. Despite these distinctions, the three regions share one important feature, their close proximity to watersheds with significant human development and associated anthropogenic enhancement of nutrient inputs (Adkins et al., 2004; Gao, 2009). Nutrient loads in the central Banana River Lagoon and central Indian River Lagoon (which includes Site 6) have experienced larger increases of nitrogen (TN) and phosphorus (TP) loads since the 1940s than the rest of the NIRL, i.e. 85% for TN and 161–183% for TP (Steward and Green, 2007). Estimates of TN and TP loads per acre of basin area in the regions containing Sites 4, 5 and 6 are three-fold higher than in the basins associated with Sites 2 and 3 (Gao, 2009).

In summary, the spatial and temporal patterns of total phytoplankton biomass in the NIRL reflect the variable influences of watershed nutrient loads, climatic variability and water residence time. In line with the general hypothesis forwarded by Cloern and Jassby (2010), the high frequency of bloom events in the southern half of the NIRL is suggestive of the influence of nutrient-enriched inputs from the watershed. The inter-annual variability in the intensity of blooms in the NIRL over the past decade reflect shifts in climatic conditions, principally rainfall, which affect the intensity of nutrient loads and freshwater flushing rates (Phlips et al., 2004, 2010). For example, a study of water residence times in the north-central Indian River Lagoon (Site 6) from 1997 to 1998 showed an R_{50} (50% water exchange) of five days during a high rainfall period in 1997 (a strong El Niño year), to an R_{50} of 20 days in the low rainfall summer of 1998 (David Christian, unpublished data). Underlying the spatial and temporal differences in nutrient loads and water residence time, the very shallow bathymetry and extensive communities of benthic flora and fauna in the NIRL represent a significant potential for top-down control of phytoplankton and nutrient competition for planktonic primary producers.

4.2. Temporal and spatial patterns in bloom composition

Interest in defining the ecological basis for spatial and temporal differences in phytoplankton community structure has grown out of the observations of a number of researchers in the 1960s and 1970s (Hutchinson, 1961; Grime, 1977; Tilman, 1977; Margalef, 1978; Smayda, 1980). The ability to divide phytoplankton taxa into functional groups, which relate to their adaptability to different environmental scenarios, is a valuable tool in defining the causes of blooms and developing predictive capacity. Recent efforts to classify phytoplankton according to their ecophysiological "traits" have focused attention on both autogenic and allogenic considerations, such as differences in nutrient acquisition, light adaptation, temperature preference, susceptibility to grazing, and reproductive strategies (Riegman, 1998; Sommer et al., 1986; Grover, 1991; Burkholder et al., 2008; Litchman and Klausmeier, 2008; Smayda, 2008). It is useful to view variability in the composition of phytoplankton blooms in the NIRL from the perspective of the relationships between key traits and shifting environmental conditions.

Two environmental features that help define the dominant bloom-forming phytoplankton taxa in the NIRL are wide salinity variation and pulsed nutrient inputs. Salinities in most of the NIRL vary between 10 and 35 psu, except at Site 1 in the southern Mosquito Lagoon. It is therefore not surprising that the major bloom-forming species in the NIRL are euryhaline. Blooms were often associated with mid-range salinities (i.e. 20–30 psu), which likely reflects the positive influence of freshwater inputs from the watershed on nutrient loads and the concurrence of the wet season with warmer water temperatures.

The pulsed nature of nutrient loads to the NIRL is a product of relatively small size of the watersheds that feed the estuary, resulting in episodic loads of small to moderate size, depending on rainfall conditions. Such conditions should favor species with nutrient storage capacity (Grover, 1991; Litchman and Klausmeier, 2008), or mixotrophic capabilities which provide access to organic sources of nutrients (Burkholder et al., 2008). It is generally believed that diatoms have greater storage capacities than dinoflagellates, chlorophytes or cyanobacteria, particularly in terms of nitrogen (Litchman and Klausmeier, 2008), which is a commonly limiting nutrient in the NIRL, particularly in the north-central (Site 6), central and southern IRL (Phlips et al., 2002). Based on this observation, it might be expected that diatoms would play a dominate role in blooms, however, both diatoms and dinoflagellates play major roles in phytoplankton blooms, and picoplanktonic cyanobacteria are periodically important (Phlips et al., 2010). In 2006 large-celled dinoflagellates dominated most blooms at all sampling sites in the NIRL, but from 2007 to 2009 shifts in dominance between diatoms and dinoflagellates varied by region and year. Clearly, the forces that define competition between phytoplankton groups in the NIRL vary over time and space, including the potential for phosphorus limitation in the NIRL (Phlips et al., 2002), which is reflected in the observed correlations between concentrations of chlorophyll *a* and TP.

It is possible to speculate on the environmental factors that contributed to the widespread dominance of dinoflagellates during blooms throughout the NIRL in 2006. Two coinciding climatic conditions in 2006 are noteworthy, an early spring increase in water temperature, related to well-above average air temperatures in April, and relatively moderate summer storm activity compared to 2007 and 2008, which yields lower freshwater flushing rates and more stable water column conditions. Most of the dinoflagellate blooms of 2006 were dominated by one of two HAB species, *P. bahamense* var. *bahamense* and *A. sanguinea*. Both species are common features of phytoplankton communities in the NIRL (Phlips et al., 2010; Badylak et al., 2004). The two species share several important features; i.e. large size (40–60 μm in diameter), low maximum growth rates (near or below one doubling per day) (Phlips unpublished data; Usup and Azanza, 1998; Matsubara et al., 2007), motility, tolerance to a wide range of salinities (Phlips et al., 2006; Matsubara et al., 2007), and the ability to form resting cysts (Sombrito et al., 2004; Badylak and Phlips, unpublished data). The existence of seed banks of the two species in the NIRL, combined with the early Spring warm up of 2006, may have provided a jump start for the dinoflagellate blooms, in terms of the germination of cysts. This may be particularly true for the dominant dinoflagellate in the NIRL, *P. bahamense* var. *bahamense*, which is a tropical species that prefers water temperature greater than 25 °C (Phlips et al., 2006). Anomalous warm temperature periods have been associated with dinoflagellate blooms in other ecosystems, such as San Francisco Bay (Cloern et al., 2005) and the Neuse River estuary in North Carolina (Hall et al., 2008).

The importance of *P. bahamense* and *A. sanguinea* through the summer of 2006 was also promoted by more stable hydrologic conditions and longer water residence times than in 2007–2008, providing a favorable environment for these slower growing dinoflagellates. The success of dinoflagellates in 2006 also indicates their ability to compete for pulses of nutrients or revert to alternative sources of nutrition. Although dinoflagellates are not generally considered to have as large a storage capacity for nutrients as diatoms (Litchman and Klausmeier, 2008), the large size of *P. bahamense* and *A. sanguinea* may make them better competitors than smaller dinoflagellate species. This hypothesis is supported by the concept that internal nutrient reserve capacities are not just correlated to the physiological characteristics of different species, but also their size (Grover, 1991; Stolte and Riegman, 1996). *P. bahamense* and *A. sanguinea* also exhibit other characteristics which may provide selective advantages under nutrient-limited conditions, such as the mixotrophic growth capabilities of *A. sanguinea* (Burkholder et al., 2008), and the presence of alkaline phosphatase activity in *P. bahamense* (Gonzáles-Gil et al., 1998), allowing it to maintain substantial growth using polyphosphates, rather than just orthophosphate.

Another important consideration in the competition between diatoms and dinoflagellates in the NIRL is top-down control. Resistance to grazing can be an important element in the success of HAB species (Turner and Tester, 1997; Turner, 2006; Smayda, 2008). The effects of differences in growth potential between species can be significantly amplified or counteracted by differences in susceptibility to grazing (Riegman, 1998). The large size and motility of *P. bahamense* var. *bahamense* and *A. sanguinea* may provide some resistance to grazing pressure. In addition, the toxin production capabilities (Landsberg et al., 2006; Abbott et al., 2009) and armored character of *P. bahamense* var. *bahamense* may further decrease loss rates due to grazing. A recent study of plankton dynamics in Tampa Bay on the west coast of Florida provides preliminary indications that the abundance of certain zooplankton species may be depressed during major blooms of *P. bahamense* var. *bahamense* (Badylak and Phlips, 2008), supporting the importance of top-down issues in their dynamics. Resistance to grazing losses may help to explain the observed longevity of *P. bahamense* var. *bahamense* blooms relative to other bloom species in the NIRL (see Section 4.4), and Tampa Bay (Badylak and Phlips, 2008).

Regional differences in the relative importance of dinoflagellates and diatoms in blooms after 2006 can be viewed from the perspective of the unique characteristics of individual basins within the NIRL and regional differences in rainfall during the study period. The southern Mosquito Lagoon (Site 1) has the most pristine watershed among the sub-basins in the NIRL (Adkins et al., 2004), which helps to explain the low bloom intensity observed at Site 1. The region is also characterized by the highest mean salinity, and the smallest variability in salinity, which may have contributed to the success of certain marine HAB diatoms, such as the HAB diatom *P. calliantha*.

Moving further south in the NIRL, into regions of increasing human influence, shifts in dominant species from mostly dinoflagellates in 2006 to a mixture of diatoms and dinoflagellates in 2007 and 2008, particularly in the central Banana River Lagoon (Site 5) and the north-central Indian River Lagoon (Site 6), coincided with an increase in the intensity of wet season rainfall events. It may be hypothesized that the increasing frequency of diatom dominance in blooms at Sites 5 and 6 in 2007 and 2008 was related to increased nutrient loads and flushing rates associated with rainfall events, providing a favorable environment for faster growing diatoms. A similar increase in rainfall events was not observed in the northern end of the NIRL (i.e. Sites 2 and 3) in 2007 and 2008. In terms of nutrient availability there are also preliminary indications that temporal and regional differences in silica levels may play a role in the competition between diatoms and dinoflagellates. Nutrient data from the late 1990s indicates that silica concentrations during extended low rainfall periods dip below 1 mg l^{-1}, suggesting a potential for limitation of diatom growth, while concentrations during high rainfall periods exceeded 10 mg l^{-1}, primarily in the central Banana River Lagoon (Site 5) and north-central Indian River Lagoon (Site 6).

In conclusion, defining the causes for the periodicity and species shifts in bloom events involves a wide range of potential driving factors, and is thereby a "challenging task" (Winder and Cloern, 2010). In the NIRL, the relatively small temporal variation in temperature and light availability, along with very shallow depths and little influence from tidal water exchange with the open ocean, focuses attention on the roles of climatic variability, watershed characteristics and differences in the structure of key biological components, such as seagrasses, benthic algae and benthic filter-feeding invertebrates, as driving factors for phytoplankton succession.

4.3. Other HAB species

Three HAB dinoflagellates, *P. quinquecorne*, *K. veneficum* and *K. foliaceum*, were only observed at bloom levels at Site 4, indicating a unique set of driving factors. From a physical perspective, the site is located in the shallowest and most hydrologically isolated bays included in this study. The very shallow depth and restricted horizontal mixing of water the rest of the NIRL provide the hydrologically stable conditions conducive for dinoflagellate blooms (Margalef, 1978; Smayda and Reynolds, 2001). The site also had twice the mean TP concentration as the other five sites in the study, suggesting the presence of local sources of nutrients or organic material, including internal sources associated with the sediments. The unique bloom characteristics at Site 4 may also reflect the distribution of dinoflagellate cyst banks.

Among the other HAB species observed in the IRL, small unarmored dinoflagellates and flagellates were well represented, and occasionally numerically abundant, although they were not observed at bloom levels of biovolume; including *Takayama* spp., *Prymnesium* spp., *Chrysochromulina* spp., *Karenia* spp., *Chattonella* spp. and *K. veneficum*. Some of these taxa have been categorized as r-selected, in part due to their small size and relatively high growth rates (Smayda, 1997; Reynolds, 2006). However, in terms of dominance during major bloom events they appear to be generally outcompeted by larger-celled dinoflagellate or diatom species, as described above. They also compete with other, even smaller, fast growing picoplanktonic cyanobacteria or small-celled centric diatoms, both of which are common features in the IRL (Badylak and Phlips, 2004; Phlips et al., 2010), and other shallow estuaries in Florida (Phlips et al., 1999; Murrell and Lores, 2004). The overall dominance of larger-celled forms is related to several characteristics of the NIRL, including long water residence times and pulsed nutrient inputs. The dominance hierarchy may also be influenced by the greater susceptibility of smaller taxa to grazing losses associated with zooplankton and benthic filter feeding invertebrates (Turner and Tester, 1997; Turner, 2006), which are abundant in the IRL.

4.4. Detecting HAB events

HAB monitoring efforts are faced with the challenge of defining sampling regimes that have a reasonable probability of discovering important species and detecting bloom events within specified spatial and temporal boundaries (Andersen, 1996; Smayda, 1997; Chang and Dickey, 2008; Cullen, 2008; Franks, 2008). Due to the shallowness of the NIRL, it was possible to use a water column integrating device for sampling, thereby limiting the potential of missing key phytoplankton in the water column due to vertical stratification, as observed in this study for *P. bahamense* var. *bahamense*.

In terms of geographical differences in the distribution of HAB species, basin specific disparities in the composition and intensity of blooms were observed in the NIRL. For example, the largest blooms of the potentially toxic diatom *P. calliantha* were observed in the Mosquito Lagoon. Blooms of the HAB species *P. quinquecorne*, *K. veneficum* and *K. foliaceum* were only observed at one of six sites (i.e. Site 4). Conversely, the spatial distribution of *P. bahamense* var. *bahamense* blooms extended over most of the NIRL, by contrast to the general absence of blooms in the central and southern regions of the Indian River Lagoon (Phlips et al., 2006, 2010). However, major climatic events or trends can result in departures from the more typical spatial distributions of HAB species. The importance of this caveat is illustrated by the sudden appearance of a *P. bahamense* var. *bahamense* bloom in the central IRL following the passage of Hurricane Charley in 2004, likely due to wind and rain-driven movement of water in the lagoon from north to south.

From a temporal perspective, sampling intervals obviously affect the probability of detecting HABs. Bloom-forming HAB species have maximum growth rates ranging from 0.25 to 3.5 doublings per day (Smayda, 1997; Stolte and Garcés, 2006; Burkholder et al., 2008), therefore species can reach bloom levels, starting from baseline concentrations, within 2–4 weeks, assuming ideal growth conditions, and no major loss processes. Given these assumptions biweekly sampling should provide a reasonable probability of capturing a bloom event, although absolute peaks of abundance may be missed. However, the dynamics of phytoplankton are related to more than just growth potential, and include a myriad of factors which impact the timing, and length of bloom events, such as nutrient limitation, sub-saturating light flux, grazing and other loss processes, such as dilution or export of phytoplankton biomass or premature death of cells due to pathogens (Smayda, 1997, 2008).

The importance of growth cycle characteristics of individual species in defining the probability of detecting blooms is illustrated by a comparison of three important HAB species in the IRL; *P. bahamense* var. *bahamense*, *A. sanguinea* and *P. calliantha*. The mean length of *P. bahamense* var. *bahamense* blooms in the NIRL is almost twice that of either *P. calliantha* or *A. sanguinea* blooms. In the case of *P. calliantha*, comparatively high growth rate may lead to more rapid depletion of bioavailable nutrients and collapse of blooms. In addition, both *P. calliantha* and *A. sanguinea* may be more strongly influenced by top-down control by zooplankton and benthic invertebrate filter feeders than *P. bahamense* var. *bahamense*.

As part of this study, a statistical approach was explored to estimate the probability of detecting HAB events given different sampling intervals. The probability is related to the characteristic longevity of blooms, frequency of bloom events, and the seasonal preferences of different species. The tropical species *P. bahamense* var. *bahamense* is largely absent from the NIRL during mid-winter months, but is a common feature in the northern lagoon from late spring through summer (Phlips et al., 2006, 2010). The application of probability statistics to *P. bahamense* var. *bahamense* blooms shows that twice monthly or monthly sampling yield high probabilities of detecting bloom events (i.e. >0.85). By contrast, blooms of *A. sanguinea* and *P. calliantha* were generally shorter in duration, lowering the probability of detection at one month sampling intervals to as low as 0.50 and 0.70, respectively. The power of the statistical approach to defining the probability of detecting HAB events depends on the availability of information on the characteristic seasonality, longevity and frequency of blooms of specific species. Therefore, the power of the approach can be improved over time with the availability of long time series data and improved understanding of the ecological strategies and capabilities of key species in specific ecosystems.

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62-302.532 Estuary-Specific Numeric Interpretations of the Narrative Nutrient Criterion.

(1) Estuary-specific numeric interpretations of the narrative nutrient criterion in paragraph 62-302.530(47)(b), F.A.C., are in the table below. The concentration-based estuary interpretations are open water, area-wide averages. Numeric values listed below for nutrient and nutrient response values do not apply to wetlands or to tidal tributaries that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions unless specifically provided by name below. The interpretations expressed as load per million cubic meters of freshwater inflow are the total load of that nutrient to the estuary divided by the total volume of freshwater inflow to that estuary. The numeric values listed below will be superseded if, pursuant to subsection 62-302.531(2), F.A.C., a more recent numeric interpretation of the narrative nutrient criterion in paragraph 62-302.530(47)(b), F.A.C., such as a Level II Water Quality Based Effluent Limitation (WQBEL), Site Specific Alternative Criterion (SSAC), Total Maximum Daily Load (TMDL), or Reasonable Assurance Demonstration, is established by the Department.

Estuary	Total Phosphorus	Total Nitrogen	Chlorophyll *a*
(a) Clearwater Harbor/St. Joseph Sound	Criteria expressed as annual geometric mean (AGM) values are not to be exceeded more than once in a three year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. St. Joseph Sound	0.05 mg/L as AGM	0.66 mg/L as AGM	3.1 µg/L as AGM
2. Clearwater North	0.05 mg/L as AGM	0.61 mg/L as AGM	5.4 µg/L as AGM
3. Clearwater South	0.06 mg/L as AGM	0.58 mg/L as AGM	7.6 µg/L as AGM
(b) Tampa Bay	Criteria expressed as ton/million cubic meters of water are annual totals and are not to be exceeded more than once in a three year period. Criteria expressed as annual means are arithmetic means and are not to be exceeded more than once in a three year period. For criteria expressed as the long-term average of annual means, the long-term average shall be based on data from the most recent seven-year period and shall not be exceeded. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Old Tampa Bay	0.23 tons/million cubic meters of water	1.08 tons/million cubic meters of water	9.3 µg/L as annual mean
2. Hillsborough Bay	1.28 tons/million cubic meters of water	1.62 tons/million cubic meters of water	15.0 µg/L as annual mean
3. Middle Tampa Bay	0.24 tons/million cubic meters of water	1.24 tons/million cubic meters of water	8.5 µg/L as annual mean
4. Lower Tampa Bay	0.14 tons/million cubic meters of water	0.97 tons/million cubic meters of water	5.1 µg/L as annual mean
5. Boca Ciega North	0.18 tons/million cubic meters of water	1.54 tons/million cubic meters of water	8.3 µg/L as annual mean
6. Boca Ciega South	0.06 tons/million cubic meters of water	0.97 tons/million cubic meters of water	6.3 µg/L as annual mean
7. Terra Ceia Bay	0.14 tons/million cubic meters of water	1.10 tons/million cubic meters of water	8.7 µg/L as annual mean
8. Manatee River Estuary	0.37 tons/million cubic meters of water	1.80 tons/million cubic meters of water	8.8 µg/L as annual mean
9. Alafia River Estuary	0.86 mg/L as long-term average of annual means	See subsection 62-304.605(2), F.A.C.	15.0 µg/L as annual mean

(c) Sarasota Bay	Criteria expressed as annual geometric mean (AGM) values for nutrients and annual arithmetic means for chlorophyll *a* are not to be exceeded more than once in a three year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Palma Sola Bay	0.26 mg/L as AGM	0.93 mg/L as AGM	11.8 µg/L as annual mean
2. Sarasota Bay (Total Phosphorus and Chlorophyll *a*)	0.19 mg/L as AGM	See paragraph 62-302.532(1)(i), F.A.C.	6.1 µg/L as annual mean
3. Roberts Bay	0.23 mg/L as AGM	0.54 mg/L as AGM	11.0 µg/L as annual mean
4. Little Sarasota Bay	0.21 mg/L as AGM	0.60 mg/L as AGM	10.4 µg/L as annual mean
5. Blackburn Bay	0.21 mg/L as AGM	0.43 mg/L as AGM	8.2 µg/L as annual mean
(d) Charlotte Harbor/Estero Bay	Criteria expressed as annual means are arithmetic means and are not to be exceeded more than once in a three year period. For criteria expressed as long-term averages, the long-term average shall be based on data from the most recent seven-year period and shall not be exceeded. Criteria expressed as annual geometric means (AGM) are not be exceeded more than once in a three year period. For criteria expressed as not to be exceeded in more than 10 percent of the samples, the criteria shall be assessed over the most recent seven year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Dona and Roberts Bay	0.18 mg/L as annual mean	0.42 mg/L as annual mean	4.9 µg/L as annual mean
2. Upper Lemon Bay	0.26 mg/L as annual mean	0.56 mg/L as annual mean	8.9 µg/L as annual mean
3. Lower Lemon Bay	0.17 mg/L as annual mean	0.62 mg/L as annual mean	6.1 µg/L as annual mean
4. Charlotte Harbor Proper	0.19 mg/L as annual mean	0.67 mg/L as annual mean	6.1 µg/L as annual mean
5. Pine Island Sound	0.06 mg/L as annual mean	0.57 mg/L as annual mean	6.5 µg/L as annual mean
6. San Carlos Bay	0.045 mg/L as long-term average	0.44 mg/L as long-term average	3.7 µg/L as long-term average
7. Tidal Myakka River	0.31 mg/L as annual mean	1.02 mg/L as annual mean	11.7 µg/L as annual mean
8. Tidal Peace River	0.50 mg/L as annual mean	1.08 mg/L as annual mean	12.6 ug/L as annual mean
9. Matlacha Pass	0.08 mg/L as annual mean	0.58 mg/L as annual mean	6.1 µg/L as annual mean
10. Estero Bay (including Tidal Imperial River)	0.07 mg/L as annual mean	0.63 mg/L as annual mean	5.9 µg/L as annual mean
11. Little Hickory Bay	0.070 mg/L as AGM	0.63 mg/L as AGM	5.9 mg/L as AGM
12. Water Turkey Bay	0.057 mg/L as AGM	0.47 mg/L as AGM	5.8 µg/L as AGM
13. Moorings Bay	0.040 mg/L, not to be exceeded in more than ten percent of the samples	0.85 mg/L, not to be exceeded in more than ten percent of the samples	8.1 µg/L as AGM
14. Upper Caloosahatchee River Estuary	0.086 mg/L as long-term average	See subsection 62-304.800(2), F.A.C.	4.2 µg/L as long-term average
15. Middle Caloosahatchee River Estuary	0.055 mg/L as long-term average	See subsection 62-304.800(2), F.A.C.	6.5 µg/L as long-term average
16. Lower Caloosahatchee River Estuary	0.040 mg/L as long-term average	See subsection 62-304.800(2), F.A.C.	5.6 µg/L as long-term average
(e) Tidal Cocohatchee River/Ten Thousand Islands	Criteria expressed as annual geometric means (AGM) not to be exceeded more than once in a three year period.		
1. Tidal Cocohatchee River	0.057 mg/L as AGM	0.47 mg/L as AGM	5.8 µg/L as AGM
2. Collier Inshore	0.032 mg/L as AGM	0.25 mg/L as AGM	3.1 µg/L as AGM
3. Rookery Bay/Marco	0.046 mg/L as AGM	0.30 mg/L as AGM	4.9 µg/L as AGM

Island			
4. Naples Bay	0.045 mg/L as AGM	0.57 mg/L as AGM	4.3 µg/L as AGM
5. Inner Gulf Shelf	0.018 mg/L as AGM	0.29 mg/L as AGM	1.6 µg/L as AGM
6. Middle Gulf Shelf	0.016 mg/L as AGM	0.26 mg/L as AGM	1.4 µg/L as AGM
7. Outer Gulf Shelf	0.013 mg/L as AGM	0.22 mg/L as AGM	1.0 µg/L as AGM
8. Blackwater River	0.053 mg/L as AGM	0.41 mg/L as AGM	4.1 µg/L as AGM
9. Coastal Transition Zone	0.034 mg/L as AGM	0.61 mg/L as AGM	3.9 µg/L as AGM
10. Gulf Islands	0.038 mg/L as AGM	0.44 mg/L as AGM	3.4 µg/L as AGM
11. Inner Waterway	0.033 mg/L as AGM	0.69 mg/L as AGM	5.2 µg/L as AGM
12. Mangrove Rivers	0.021 mg/L as AGM	0.71 mg/L as AGM	3.7 µg/L as AGM
13. Ponce de Leon	0.024 mg/L as AGM	0.52 mg/L as AGM	3.0 µg/L as AGM
14. Shark River Mouth	0.022 mg/L as AGM	0.75 mg/L as AGM	2.2 µg/L as AGM
15. Whitewater Bay	0.026 mg/L as AGM	0.82 mg/L as AGM	4.1 µg/L as AGM
(f) Florida Bay	Criteria expressed as annual geometric means (AGM) are not to be exceeded more than once in a three year period.		
1. Central Florida Bay	0.019 mg/L as AGM	0.99 mg/L as AGM	2.2 µg/L as AGM
2. Coastal Lakes	0.045 mg/L as AGM	1.29 mg/L as AGM	9.3 µg/L as AGM
3. East Central Florida Bay	0.007 mg/L as AGM	0.65 mg/L as AGM	0.4 µg/L as AGM
4. Northern Florida Bay	0.010 mg/L as AGM	0.68 mg/L as AGM	0.8 µg/L as AGM
5. Southern Florida Bay	0.009 mg/L as AGM	0.64 mg/L as AGM	0.8 µg/L as AGM
6. Western Florida Bay	0.015 mg/L as AGM	0.37 mg/L as AGM	1.4 µg/L as AGM
(g) Florida Keys	Criteria expressed as annual geometric means (AGM) are not to be exceeded more than once in a three year period.		
1. Back Bay	0.009 mg/L as AGM	0.25 mg/L as AGM	0.3 µg/L as AGM
2. Backshelf	0.011 mg/L as AGM	0.23 mg/L as AGM	0.7 µg/L as AGM
3. Lower Keys	0.008 mg/L as AGM	0.21 mg/L as AGM	0.3 µg/L as AGM
4. Marquesas	0.008 mg/L as AGM	0.21 mg/L as AGM	0.6 µg/L as AGM
5. Middle Keys	0.007 mg/L as AGM	0.22 mg/L as AGM	0.3 µg/L as AGM
6. Oceanside	0.007 mg/L as AGM	0.17 mg/L as AGM	0.3 µg/L as AGM
7. Upper Keys	0.007 mg/L as AGM	0.18 mg/L as AGM	0.2 µg/L as AGM
(h) Biscayne Bay	Criteria expressed as annual geometric means (AGM) are not to be exceeded more than once in a three year period.		
1. Card Sound	0.008 mg/L as AGM	0.33 mg/L as AGM	0.5 µg/L as AGM
2. Manatee Bay – Barnes Sound	0.007 mg/L as AGM	0.58 mg/L as AGM	0.4 µg/L as AGM
3. North Central Inshore	0.007 mg/L as AGM	0.31 mg/L as AGM	0.5 µg/L as AGM
4. North Central Outer-Bay	0.008 mg/L as AGM	0.28 mg/L as AGM	0.7 µg/L as AGM
5. Northern North Bay	0.012 mg/L as AGM	0.30 mg/L as AGM	1.7 µg/L as AGM
6. South Central Inshore	0.007 mg/L as AGM	0.48 mg/L as AGM	0.4 µg/L as AGM
7. South Central Mid-Bay	0.007 mg/L	0.35 mg/L as AGM	0.2 µg/L as AGM
8. South Central Outer-Bay	0.006 mg/L as AGM	0.24 mg/L as AGM	0.2 µg/L as AGM
9. Southern North Bay	0.010 mg/L as AGM	0.29 mg/L as AGM	1.1 µg/L as AGM
(i) Sarasota Bay	For TN, the annual geometric mean target is calculated from monthly arithmetic mean color by region and season. Annual geometric means shall not be exceeded more than once in a three year period. The Sarasota Bay regions are defined as north (Manatee County) and south (Sarasota County). The wet season for Sarasota Bay is defined as July through October and the dry season is defined as all other months of the year. The seasonal region targets are calculated using monthly color data and shall be calculated as follows:		

	NW_i=Ln[(13.35-(0.32*CN_i))/3.58] ND_i=Ln[(10.39-(0.32*CN_i))/3.58] SW_i=Ln[(8.51-(0.32*$CS_{i,}$)/3.58] SD_i=Ln[(5.55-(0.32*CS_i))/3.58] Where, NW_i is the TN target for i^{th} month calculated for the north region during the wet season ND_i is the TN target for i^{th} month calculated for the north region during the dry season SW_i is the TN target for i^{th} month calculated for the south region during the wet season SD_i is the TN target for i^{th} month calculated for the south region during the dry season CN_i is the arithmetic mean color during the i^{th} month within the north region During the wet season, CN_i shall be set to 41 PCU if the monthly arithmetic mean color is greater than 41 PCU During the dry season, CN_i shall be set to 32 PCU if the monthly arithmetic mean color is greater than 32 PCU CS_i is the arithmetic mean color during the i^{th} month within the south region During the wet season, CS_i shall be set to 26 PCU if the monthly arithmetic mean color is greater than 26 PCU During the dry season, CS_i shall be set to 16 PCU if the monthly arithmetic mean color is greater than 16 PCU The annual TN target is calculated as the geometric mean of all monthly regional and season targets as follows: $$e^{\sum_i^{12}\left(\frac{NWi+NDi+SWi+SDi}{24}\right)}$$ Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.

(j) Clam Bay (Collier County)	No more than 10 percent of the individual Total Phosphorus (TP) or Total Nitrogen (TN) measurements shall exceed the respective TP Upper Limit or TN Upper Limit.		
	TP Upper Limit (mg/L) = $e^{(-1.06256-0.0000328465*Conductivity (\mu S))}$		TN Upper Limit (mg/L) = 2.3601 – 0.0000268325*Conductivity (µS)
Estuary	Total Phosphorus	Total Nitrogen	Chlorophyll *a*
(k) Perdido Bay	Criteria expressed as annual geometric means (AGM) are not to be exceeded more than once in a three year period. For all other bay segments, the criteria shall not be exceeded in more than 10 percent of the measurements and shall be assessed over the most recent seven year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Big Lagoon	0.036 mg/L as AGM	0.61 mg/L as AGM	6.4 µg/L
2. Upper Perdido Bay	0.102 mg/L	1.27 mg/L	11.5 µg/L
3. Central Perdido Bay	0.103 mg/L	0.97 mg/L	7.5 µg/L
4. Lower Perdido Bay	0.110 mg/L	0.78 mg/L	6.9 µg/L
(l) Pensacola Bay	For bay segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For criteria expressed as the long-term average of annual means, the long-term average shall be based on data from the most recent seven-year period and shall not be exceeded. For all other bay segments, the criteria shall not be exceeded in more than 10 percent of the measurements. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Lower Escambia Bay	0.076 mg/L	0.56 mg/L as AGM	6.8 µg/L as AGM
2. East Bay	0.084 mg/L	0.83 mg/L	4.0 µg/L as AGM
3. Upper Pensacola Bay	0.084 mg/L	0.77 mg/L	6.0 µg/L as AGM
4. Lower Pensacola Bay	0.024 mg/L as AGM	0.48 mg/L as AGM	3.9 µg/L as AGM
5. Santa Rosa Sound	0.022 mg/L as AGM	0.41 mg/L as AGM	3.4 µg/L as AGM
6. Blackwater Bay	0.082 mg/L	0.61 mg/L	11.3 µg/L
7. Upper Escambia Bay and Judges Bayou	See subsection 62-304.330(10), F.A.C.	See subsection 62-304.330(10), F.A.C.	7.4 µg/L as long-term average of annual means
(m) Choctawhatchee Bay	For bay segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other bay segments, the criteria shall not be exceeded in more than 10 percent of the measurements. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Alaqua Bayou	0.027 mg/L as AGM	0.41 mg/L as AGM	4.0 µg/L as AGM
2. Basin Bayou	0.019 mg/L as AGM	0.31 mg/L as AGM	4.7 µg/L
3. Boggy Bayou	0.015 mg/L as AGM	0.33 mg/L as AGM	3.0 µg/L as AGM
4. East Bay	0.027 mg/L as AGM	0.46 mg/L as AGM	4.4 µg/L as AGM
5. Garnier Bayou	0.017 mg/L as AGM	0.91 mg/L as AGM	4.0 µg/L as AGM
6. LaGrange Bayou	0.029 mg/L as AGM	0.58 mg/L as AGM	5.1 µg/L as AGM
7. Middle Bay	0.020 mg/L as AGM	0.36 mg/L as AGM	3.1 µg/L as AGM
8. Rocky Bayou	0.016 mg/L as AGM	0.33 mg/L as AGM	3.1 µg/L as AGM
9. West Bay	0.049 mg/L as AGM	0.54 mg/L as AGM	4.1 µg/L as AGM
(n) St. Andrew Bay	Criteria for all bay segments are expressed as annual geometric mean (AGM) values not to be exceeded more than once in a three year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		

1. East Bay	0.016 mg/L as AGM	0.33 mg/L as AGM	3.9 µg/L as AGM
2. North Bay	0.014 mg/L as AGM	0.28 mg/L as AGM	3.1 µg/L as AGM
3. St. Andrew Bay	0.019 mg/L as AGM	0.34 mg/L as AGM	3.7 µg/L as AGM
4. West Bay	0.017 mg/L as AGM	0.35 mg/L as AGM	3.8 µg/L as AGM
5. Crooked Island Sound	0.019 mg/L as AGM	0.34 mg/L as AGM	3.7 µg/L as AGM
(o) St. Joseph Bay	Criteria for all bay segments are expressed as annual geometric mean (AGM) values not to be exceeded more than once in a three year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
St. Joseph Bay	0.021 mg/L as AGM	0.34 mg/L as AGM	3.8 µg/L as AGM
(p) Apalachicola Bay and Alligator Harbor	For bay segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other bay segments, the criteria shall not be exceeded in more than 10 percent of the measurements and shall be assessed over the most recent seven year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Apalachicola Bay	0.063 mg/L as AGM	0.84 mg/L as AGM	8.4 µg/L as AGM
2. St. George Sound	0.083 mg/L	0.92 mg/L	6.1 µg/L as AGM
3. East Bay	0.101 mg/L	1.12 mg/L	9.7 µg/L as AGM
4. St. Vincent Sound	0.116 mg/L	1.10 mg/L	17.4 µg/L
5. Apalachicola Offshore	0.032 mg/L	0.57 mg/L	8.2 µg/L
6. Alligator Habor	0.028 mg/L as AGM	0.42 mg/L as AGM	6.0 µg/L as AGM
Estuary	Total Phosphorus	Total Nitrogen	Chlorophyll a
(q) Loxahatchee River Estuary	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other estuary segments, the criteria shall not be exceeded in more than 10 percent of the measurements and shall be assessed over the most recent seven year period.		
1. Lower Loxahatchee	0.032 mg/L as AGM	0.63 mg/L as AGM	1.8 µg/L as AGM
2. Middle Loxahatchee	0.030 mg/L as AGM	0.80 mg/L as AGM	4.0 µg/L as AGM
3. Upper Loxahatchee	0.075 mg/L as AGM	1.26 mg/L as AGM	5.5 µg/L as AGM
4. Loxahatchee River Estuary (Southwest Fork)	0.075 mg/L as AGM	1.26 mg/L as AGM	5.5 µg/L as AGM
(r) Lake Worth Lagoon	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other estuary segments, the criteria shall not be exceeded in more than 10 percent of the measurements.		
1. Northern Lake Worth Lagoon	0.044 mg/L as AGM	0.54 mg/L as AGM	2.9 µg/L as AGM
2. Central Lake Worth Lagoon	0.049 mg/L as AGM	0.66 mg/L as AGM	10.2 µg/L
3. Southern Lake Worth Lagoon	0.050 mg/L as AGM	0.59 mg/L as AGM	5.7 µg/L as AGM
(s) Halifax River Estuary and Tomoka River Estuary	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. Criteria expressed as annual means are not to be exceeded in any year.		
1. Lower Halifax River Estuary	0.142 mg/L as AGM	0.72 mg/L as AGM	6.2 µg/L as AGM
2. Upper Halifax River Estuary	See subsection 62-304.435(5), F.A.C.	See subsection 62-304.435(5), F.A.C.	9.0 µg/L as annual mean

3. Tomoka River Estuary	0.132 mg/L as AGM	1.24 mg/L as AGM	7.2 µg/L as AGM
4. Tomoka Basin	0.105 mg/L as AGM	1.20 mg/L as AGM	7.1 µg/L as AGM
(t) Guana River/Tolomato River/Matanzas River (GTM) Estuary	Criteria for all estuary segments are expressed as annual geometric mean values (AGM) not to be exceeded more than once in a three year period.		
1. Tolomato	0.105 mg/L as AGM	0.65 mg/L as AGM	6.6 µg/L as AGM
2. North Matanzas	0.110 mg/L as AGM	0.55 mg/L as AGM	4.0 µg/L as AGM
3. South Matanzas	0.111 mg/L as AGM	0.53 mg/L as AGM	5.5 µg/L as AGM
4. Pellicer Creek Estuary	0.123 mg/L as AGM	1.10 mg/L as AGM	4.3 µg/L as AGM
(u) Nassau River Estuary	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other estuary segments, the criteria shall not be exceeded in more than 10 percent of the measurements.		
1. Ft. George River Estuary	0.107 mg/L as AGM	0.60 mg/L as AGM	5.9 µg/L as AGM
2. Lower Nassau	0.107 mg/L as AGM	0.80mg/L as AGM	17.5 µg/L
3. Middle Nassau	0.137 mg/L as AGM	0.83 mg/L as AGM	17.1 µg/L
4. Upper Nassau	0.191 mg/L as AGM	1.29 mg/L as AGM	4.7 µg/L as AGM
(v) Suwannee, Waccasassa, and Withlacoochee River Estuaries	For estuary segments with criteria expressed as single value annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For estuary segments with criteria expressed as a salinity dependent equation, the annual nutrient criteria are expressed as annual geometric means applied to individual monitoring stations by solving the applicable equation below using the annual arithmetic average salinity (AASal) in practical salinity units (PSU) for the station. The AASal shall be calculated as the annual mean of the salinity measurements for each station made in conjunction with the collection of the nutrient samples. For criteria expressed as a salinity dependent equation, no more than 10 percent of the monitoring stations within the segment shall exceed the limit (expressed as AGM) on an annual basis, more than once in a three year period.		
1. Suwannee Offshore	TP as AGM = -0.0035*AASal + 0.1402	TN as AGM = -0.0328*AASal + 1.4177	5.7 µg/L as AGM
2. Waccasassa Offshore	0.063 mg/L as AGM	0.69 mg/L as AGM	5.6 µg/L as AGM
3. Withlacoochee Offshore	TP as AGM = -0.0021*AASal + 0.0942	TN as AGM = -0.0183*AASal + 0.9720	4.9 µg/L as AGM
(w) Springs Coast (Crystal River to Anclote River)	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period.		
1. Anclote Offshore	0.014 mg/L as AGM	0.42 mg/L as AGM	1.7 µg/L as AGM
2. Anclote River Estuary	0.063 mg/L as AGM	0.65 mg/L as AGM	3.8 µg/L as AGM
3. Aripeka and Hudson Offshore	0.008 mg/L as AGM	0.45 mg/L as AGM	0.8 µg/L as AGM
4. Chassahowitzka NWR	0.015 mg/L as AGM	0.55 mg/L as AGM	2.0 µg/L as AGM
5. Chassahowitzka Offshore	0.011 mg/L as AGM	0.46 mg/L as AGM	1.5 µg/L as AGM
6. Chassahowitzka River Estuary	0.021 mg/L as AGM	0.44 mg/L as AGM	3.9 µg/L as AGM
7. Crystal Offshore	0.034 mg/L as AGM	0.40 mg/L as AGM	2.4 µg/L as AGM
8. Crystal River Estuary	0.047 mg/L as AGM	0.37 mg/L as AGM	4.4 µg/L as AGM
9. Homosassa Offshore	0.012 mg/L as AGM	0.46 mg/L as AGM	1.3 µg/L as AGM
10. Homosassa River Estuary	0.028 mg/L as AGM	0.51 mg/L as AGM	7.7 µg/L as AGM
11. Pithlachascotee Offshore	0.010 mg/L as AGM	0.47 mg/L as AGM	1.0 µg/L as AGM

12. Pithlachascotee River Estuary	0.034 mg/L as AGM	0.65 mg/L as AGM	4.0 µg/L as AGM
13. St. Martins Marsh	0.031 mg/L as AGM	0.51 mg/L as AGM	3.2 µg/L as AGM
14. Weeki Wachee Offshore	0.017 mg/L as AGM	0.54 mg/L as AGM	1.2 µg/L as AGM
15. Weeki Wachee River Estuary	0.019 mg/L as AGM	0.60 mg/L as AGM	1.9 µg/L as AGM
16. Anclote Bayou	0.063 mg/L as AGM	0.65 mg/L as AGM	3.8 µg/L as AGM
17. Kings Bay	See subsection 62-304.645(17), F.A.C.	See subsection 62-304.645(17), F.A.C.	5.7 µg/L as AGM
(x) Big Bend and Apalachee Bay	For bay segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other bay segments, the criteria shall not be exceeded in more than 10 percent of the measurements and shall be assessed over the most recent seven year period. Nutrient and nutrient response values do not apply to tidally influenced areas that fluctuate between predominantly marine and predominantly fresh waters during typical climatic and hydrologic conditions.		
1. Ochlockonee River Estuary	0.067 mg/L	0.86 mg/L	9.2 µg/L
2. Ochlockonee/Alligator Harbor Offshore	0.032 mg/L	0.57 mg/L	8.2 µg/L
3. St. Marks River Estuary	0.044 mg/L	0.70 mg/L	6.0 µg/L
4. St. Marks Offshore (includes Oyster and Dickerson Bays)	0.045 mg/L	0.63 mg/L	8.0 µg/L
5. Aucilla River Estuary	0.080 mg/L	0.89 mg/L	2.2 µg/L
6. Aucilla Offshore	0.025 mg/L	0.60 mg/L	9.5 µg/L
7. Econfina River Estuary	0.101 mg/L as AGM	1.14 mg/L as AGM	4.9 µg/L as AGM
8. Econfina Offshore	0.042 mg/L as AGM	0.65 mg/L as AGM	3.7 µg/L as AGM
9. Fenholloway River Estuary	839 lbs/day, as an annual average, based on Level II WQBEL	5,573 lbs/day, as an annual average, based on Level II WQBEL	4.6 µg/L as AGM
10. Fenholloway Offshore	0.059 mg/L as AGM	0.68 mg/L as AGM	4.1 µg/L as AGM
11. Spring Warrior Offshore	0.047 mg/L	0.67 mg/L	8.3 µg/L
12. Steinhatchee River Estuary	0.062 mg/L as AGM	0.86 mg/L as AGM	3.9 µg/L as AGM
13. Steinhatchee Offshore	0.021 mg/L as AGM	0.45 mg/L as AGM	3.3 µg/L as AGM
14. Horseshoe Beach Offshore	0.021 mg/L as AGM	0.45 mg/L as AGM	3.3 µg/L as AGM
15. Cedar Key	0.060 mg/L as AGM	0.79 mg/L as AGM	10.9 µg/L as AGM
(y) Intracoastal Waterway (ICWW)	For ICWW segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. Criteria expressed as kg/year and annual means are not to be exceeded in any year. For all other ICWW segments, the criteria shall not be exceeded in more than 10 percent of the measurements and shall be assessed over the most recent seven year period.		
1. Gulf ICWW between Choctawhatchee Bay and St. Andrew Bay	0.108 mg/L	1.13 mg/L	6.6 µg/L
2. Gulf ICWW between St.	0.108 mg/L	1.13 mg/L	6.6 µg/L

Andrew Bay and St. Joseph Bay			
3. ICWW between Roberts Bay and Lemon Bay	0.253 mg/L as AGM	0.59 mg/L as AGM	4.0 µg/L as AGM
4. Central Broward County ICWW	0.045 mg/L as AGM	0.80 mg/L as AGM	2.7 µg/L as AGM
5. North Broward County ICWW	0.059 mg/L as AGM	0.79 mg/L as AGM	3.0 µg/L as AGM
6. North Central Broward County ICWW	0.048 mg/L as AGM	0.88 mg/L as AGM	3.3 µg/L as AGM
7. South Broward County ICWW	0.043 mg/L as AGM	0.70 mg/L as AGM	2.0 µg/L as AGM
8. Palm Beach County ICWW	0.146 mg/L	1.17 mg/L	13.4 µg/L
9. ICWW between North Lake Worth Lagoon and Lower Loxahatchee River	0.035 mg/L as AGM	0.66 mg/L as AGM	4.7 µg/L as AGM
10. ICWW Palm Coast	73,142 kg/year	798,913 kg/year	4.5 µg/L as annual mean
11. ICWW from North Tolomato River to St. Johns River	0.191 mg/L as AGM	1.27 mg/L	10.2 µg/L
(z) St. Lucie Estuary	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For criteria expressed as long-term averages, the long-term average shall be based on data from the most recent seven-year period and shall not be exceeded.		
1. St. Lucie Estuary	See subsection 62-304.705(1), F.A.C.	See subsection 62-304.705(1), F.A.C.	5.9 µg/L as AGM
2. Upper North Fork St. Lucie River	See subsection 62-304.705(2), F.A.C.	See subsection 62-304.705(2), F.A.C.	6.7 µg/L as AGM
3. Lower North Fork St. Lucie River	See subsection 62-304.705(3), F.A.C.	See subsection 62-304.705(3), F.A.C.	7.4 µg/L as AGM
4. Lower South Fork St. Lucie River	See subsection 62-304.705(6), F.A.C.	See subsection 62-304.705(6), F.A.C.	6.7 µg/L as AGM
5. Upper South Fork St. Lucie River	See subsection 62-304.705(7), F.A.C.	See subsection 62-304.705(7), F.A.C.	5.0 µg/L as AGM
6. Manatee Creek	0.081 mg/L as long-term average	0.72 mg/L as long-term average	5.9 µg/L as AGM
(aa) Indian River Lagoon, Banana River Lagoon, and Mosquito Lagoon	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other estuary segments, the criteria shall not be exceeded in more than 10 percent of the measurements and shall be assessed over the most recent seven year period.		
1. Indian River Lagoon between Loxahatchee River up to and including Hobe Sound	0.021 mg/L as AGM	0.49 mg/L as AGM	2.0 µg/L as AGM
2. Indian River Lagoon between Hobe Sound and St. Lucie	0.060 mg/L as AGM	0.63 mg/L as AGM	6.9 µg/L
3. Indian River Lagoon from St. Lucie Estuary to	0.070 mg/L as AGM	0.72 mg/L as AGM	4.7 µg/L as AGM

Ft. Pierce Inlet			
4. Indian River Lagoon from Ft. Pierce Inlet to Indian River County Line	0.070 mg/L as AGM	0.72 mg/L as AGM	4.7 µg/L as AGM
5. Central Indian River Lagoon	See subsections 62-304.520(7) and (8), F.A.C.	See subsections 62-304.520(7) and (8), F.A.C.	5.9 µg/L as AGM
6. North Indian River Lagoon	See subsections 62-304.520(3)-(6), F.A.C.	See subsections 62-304.520(3)-(6), F.A.C.	6.4 µg/L as AGM
7. Sebastian River Estuary	63,991 pounds/year, not to be exceeded in any year	323,382 pounds/year, not to be exceeded in any year	5.9 µg/L as AGM
8. Banana River Lagoon	See subsections 62-304.520(9) and (10), F.A.C.	See subsections 62-304.520(9) and (10), F.A.C.	7.3 µg/L as AGM
9. Newfound Harbor	See subsection 62-304.520(11), F.A.C.	See subsection 62-304.520(11), F.A.C.	7.3 µg/L as AGM
10. Sykes Creek Estuary	See subsection 62-304.520(13), F.A.C.	See subsection 62-304.520(13), F.A.C.	7.3 µg/L as AGM
11. Mosquito Lagoon: Oak Hill to the Southern Terminus	0.034 mg/L as AGM	1.14 mg/L as AGM	2.5 µg/L as AGM
12. Mosquito Lagoon: Edgewater to Oak Hill	0.048 mg/L as AGM	0.65 mg/L as AGM	3.4 µg/L as AGM
13. Mosquito Lagoon: Ponce de Leon to Edgewater	0.049 mg/L as AGM	0.51 mg/L as AGM	4.0 µg/L as AGM
(bb) Lower St. Johns River and Tributaries (predominantly marine)	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For criteria expressed as the long-term average of annual means, the long-term average shall be based on data from the most recent seven-year period and shall not be exceeded.		
Lower St. Johns River and Tributaries (predominantly marine)	722,834 kilograms/year	See subsection 62-304.415(2), F.A.C.	5.4 µg/L as long-term average of annual means
(cc) St. Marys River	For estuary segments with criteria expressed as annual geometric means (AGM), the values shall not be exceeded more than once in a three year period. For all other estuary segments, the criteria shall not be exceeded in more than 10 percent of the measurements and shall be assessed over the most recent seven year period.		
1. Lower St. Marys River	0.181 mg/L	0.77 mg/L as AGM	12.9 µg/L
2. Middle St. Marys River	0.113 mg/L as AGM	1.12 mg/L as AGM	8.0 µg/L
3. Upper St. Marys River	0.093 mg/L as AGM	1.35 mg/L as AGM	3.0 µg/L as AGM

(2) Criteria for chlorophyll *a* in open ocean coastal waters, derived from satellite remote sensing techniques, are provided in the table below. In each coastal segment specified in the Map of Florida Coastal Segments, dated May 13, 2013 (http://www.flrules.org/Gateway/reference.asp?No=Ref-03017), which is incorporated by reference herein, the Annual Geometric Mean remotely sensed chlorophyll *a* value, calculated excluding *Karenia brevis* blooms (>50,000 cells/L), shall not be exceeded more than once in a three year period. The annual geometric means provided in the table below are based on measurements using the SeaWiFS satellite. Achievement of these criteria shall be assessed only by using satellite remote sensing data that are processed in a manner consistent with the derivation of the criteria. Data selection and preparation shall be consistent with the process described in Section 1.4.3 and Section 1.4.4, pages 14 through 17, in the report titled "Technical Support Document for U.S. EPA's Proposed Rule for Numeric Nutrient Criteria for Florida's Estuaries, Coastal Waters, and South Florida Inland Flowing Waters, Volume 2: Coastal Waters," U.S. Environmental Protection Agency, November 30, 2012

(http://www.flrules.org/Gateway/reference.asp?No=Ref-03018), the specified pages of which are incorporated by reference herein. If MODIS or MERIS satellite data are used, the data shall be normalized using the standardization factors provided in the table below, consistent with the process described in Section 1.6.3, pages 26 through 33 (http://www.flrules.org/Gateway/reference.asp?No=Ref-03019), in the above referenced EPA document, the specified pages of which are incorporated herein. A copy of the Map of Florida Coastal Segments and the referenced pages from EPA's document above are available by writing to the Florida Department of Environmental Protection, Water Quality Standards Program, 2600 Blair Stone Road, MS #6511, Tallahassee, FL 32399-2400.

Coastal Segment	Annual Geometric Mean Remotely Sensed Chlorophyll *a*	MODIS Standardization Factor	MERIS Standardization Factor
1	2.45	0.54	-0.71
2	2.65	0.99	-0.07
3	1.48	0.41	-0.22
4	1.20	0.26	-0.30
5	1.09	0.15	-0.28
6	1.07	0.29	-0.01
7	1.17	0.33	-0.02
8	1.27	0.38	-0.05
9	1.09	0.20	-0.07
10	1.13	0.41	-0.07
11	1.14	0.31	-0.05
12	1.21	0.41	-0.05
13	1.53	0.50	-0.13
14	1.80	0.69	0.01
15	2.80	0.68	0.58
16	2.49	-0.14	0.27
17	3.57	0.08	1.41
18	5.62	0.50	0.03
19	4.90	0.50	0.31
20	4.33	-0.02	-0.69
21	4.06	-0.63	-1.09
22	4.54	-0.46	-0.17
23	3.40	-1.21	-0.67
24	3.41	-2.37	0.01
25	3.11	-2.84	0.05
26	3.00	-4.16	-0.36
27	3.05	-1.77	-0.81
28	3.41	-2.13	-0.61
29	4.55	-0.83	-0.74
30	4.32	-0.74	-0.04
31	3.77	-0.29	-0.90
32	4.30	0.17	-0.47
33	5.98	0.10	0.80
34	4.63	-0.77	-0.32
35	4.14	0.42	-0.83
37	1.01	0.39	0.59
38	0.26	-0.04	-0.03
39	0.27	-0.02	0.00
40	0.25	-0.03	-0.01
41	0.21	-0.06	-0.01
42	0.21	-0.03	0.03
43	0.21	-0.02	0.04
44	0.20	-0.02	0.01

45	0.21	-0.04	0.02
46	0.26	-0.05	-0.01
47	0.58	-0.10	0.03
48	1.09	0.03	0.09
49	1.48	0.39	0.36
50	1.85	0.21	0.32
51	1.72	0.23	0.31
52	1.73	0.05	0.58
53	1.87	0.00	0.47
54	1.66	-0.13	0.31
55	1.60	0.18	0.71
56	2.12	0.11	0.39
57	2.83	0.44	0.84
58	2.63	0.09	0.40
59	2.34	0.06	0.33
60	2.17	0.07	0.29
61	2.01	-0.20	-0.06
62	1.93	0.18	-0.11
63	1.90	-0.69	-0.20
64	2.13	-0.79	-0.20
65	1.96	-0.72	-0.13
66	1.95	-0.85	-0.40
67	2.06	-0.33	-0.53
68	2.51	-0.47	-0.08
69	2.86	-0.60	-0.22
70	2.88	-1.39	-0.32
71	3.62	-2.00	-0.38
72	3.80	-1.38	-0.40
73	3.94	-0.28	-0.49
74	4.36	-0.16	-1.17

(3) Estuarine and marine areas for the estuaries listed in subsection 62-302.532(1), F.A.C., are delineated in the maps of the Florida Estuary Nutrient Regions, dated October 2014 and October 2015 (http://www.flrules.org/Gateway/reference.asp?No=Ref-06050), which are incorporated by reference herein. Copies of these maps may be obtained by writing to the Florida Department of Environmental Protection, Water Quality Standards Program, 2600 Blair Stone Road, MS #6511, Tallahassee, FL 32399-2400.

(4) To calculate an annual geometric or arithmetic mean for TN, TP, or chlorophyll *a*, there shall be at least four temporally-independent samples per year with at least one sample taken between May 1 and September 30 and at least one sample taken during the other months of the calendar year. To be treated as temporally-independent, samples must be taken at least one week apart.

Rulemaking Authority 403.061, 403.062, 403.087, 403.504, 403.704, 403.804 FS. Law Implemented 403.021(11), 403.061, 403.087, 403.088, 403.141, 403.161, 403.182, 403.502, 403.702, 403.708 FS. History–New 7-3-12, Amended 12-20-12, 8-1-13, 8-20-13, 6-7-15, 2-17-16

Editorial Note: Paragraphs 62-302.532(1)(a)-(j) became effective on 7-3-12, and paragraphs 62-302.532(1)(k)-(p) became effective on 12-20-12, 20 days after filing the rule certification packages for these numeric nutrient criteria. In accordance with Section 4 of 2013-71, Laws of Florida, and subsection 62-302.531(9), F.A.C., paragraphs 62-302.532(1)(q)-(w), subsections 62-302.532(2) and (4), and the maps delineating these Florida Estuary Nutrient Regions in subsection 62-302.532(3) will become effective upon approval by EPA in their entirety, conclusion of rulemaking by EPA to repeal its federal numeric nutrient criterion for Florida, and EPA's determination that Florida's rules address its January 2009 determination that numeric nutrient criteria are needed in Florida.

Lake Okeechobee Basin Management Action Plan

Division of Environmental Assessment and Restoration
Water Quality Restoration Program
Florida Department of Environmental Protection

with participation from the
Lake Okeechobee Stakeholders

January 2020

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https://www.floridadep.gov/

Acknowledgments

The *Lake Okeechobee Basin Management Action Plan* was prepared as part of a statewide watershed management approach to restore and protect Florida's water quality. It was prepared by the Florida Department of Environmental Protection with participation from the Lake Okeechobee stakeholders identified below.

Type of Governmental or Private Entity	Participant
Counties	Glades Hendry Highlands Martin Okeechobee Orange Osceola Palm Beach Polk
Municipalities	City of Avon Park City of Edgewood City of Kissimmee City of Okeechobee City of Orlando City of Sebring Town of Windermere
Government entities and special districts	Avon Park Air Force Range Okeechobee Utility Authority Istokpoga Marsh Watershed Improvement District Reedy Creek Improvement District Spring Lake Improvement District South Florida Conservancy District Valencia Water Control District
Agencies	Florida Department of Agriculture and Consumer Services South Florida Water Management District Florida Department of Transportation (FDOT) District 1 FDOT District 4 FDOT District 5

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List of Acronyms and Abbreviations

ACF	Autocorrelation Function
ac-ft	Acre-Feet
BMAP	Basin Management Action Plan
BMP	Best Management Practice
CDBG	Community Development Block Grant
CDS	Continuous Deflective Separation (Unit)
CIB	Curb Inlet Basket
CR	County Road
CWA	Clean Water Act
DEO	Florida Department of Economic Opportunity
DEP	Florida Department of Environmental Protection
DO	Dissolved Oxygen
DOR	Florida Department of Revenue
DWM	Dispersed Water Management
EPA	U.S. Environmental Protection Agency
F.A.C.	Florida Administrative Code
FDACS	Florida Department of Agriculture and Consumer Services
FDOH	Florida Department of Health
FDOT	Florida Department of Transportation
FEMA	Federal Emergency Management Agency
F.S.	Florida Statutes
FSAID	Florida Statewide Agricultural Irrigation Demand
FWM	Flow Weighted Mean
FY	Fiscal Year
FYN	Florida Yards and Neighborhoods
GIS	Geographic Information System
HOA	Homeowner Association
HWTT	Hybrid Wetland Treatment Technology
IMWID	Istokpoga Marsh Watershed Improvement District
lbs/ac	Pounds per Acre
lbs/yr	Pounds Per Year
LET	Load Estimation Tool
LOW	Lake Okeechobee Watershed
LOWCP	Lake Okeechobee Watershed Construction Project
LOWPP	Lake Okeechobee Watershed Protection Plan
MAPS	Managed Aquatic Plant System
mgd	Million Gallons Per Day
mg/L	Milligrams per Liter
MS4	Municipal Separate Storm Sewer System
MSTU	Municipal Services Taxing Unit
mt/yr	Metric Tons Per Year
N/A	Not Applicable

NEEPP	Northern Everglades and Estuaries Protection Program
NEPES	Northern Everglades Payment for Environmental Services
NNC	Numeric Nutrient Criteria
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRP	Nutrient Reduction Plan
NSBB	Nutrient-Separating Baffle Box
O&M	Operations and Maintenance
OAWP	Office of Agricultural Water Policy
OCHCD	Orange County Housing and Community Development
OCUD	Orange County Utilities Division
OSTDS	Onsite Sewage Treatment and Disposal System
OUC	Orlando Utilities Commission
POR	Period of Record
PSA	Public Service Announcement
QA/QC	Quality Assurance/Quality Control
RCID	Reedy Creek Improvement District
RFI	Request for Information
ROC	Regional Operations Center
SFER	South Florida Environmental Report
SFWMD	South Florida Water Management District
SLID	Spring Lake Improvement District
SR	State Road
STA	Stormwater Treatment Area
STORET	Storage and Retrieval (Database)
SWET	Soil and Water Engineering Technology, Inc.
SWMP	Stormwater Management Program
SWFWMD	Southwest Florida Water Management District
TBD	To Be Determined
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TRA	Targeted Restoration Area
UAL	Unit Area Load
UF–IFAS	University of Florida Institute of Food and Agricultural Sciences
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WAM	Watershed Assessment Model
WBID	Waterbody Identification (Number)
WCD	Water Control District
WIN	Watershed Information Network
WPB	West Palm Beach
WRF	Water Reclamation Facility
WWTF	Wastewater Treatment Facility
WY	Water Year

Executive Summary

Background

Lake Okeechobee is the largest lake in the southeastern United States and is vital to the state of Florida and its residents. A shallow, eutrophic lake, it covers approximately 730 square miles, with an average depth of 9 feet (Florida Department of Environmental Protection [DEP] 2001). This multipurpose waterbody provides drinking water for urban areas, irrigation water and frost protection for agricultural lands, recharge for aquifers, fresh water for the Everglades, habitat for fish and wildlife, flood control, navigation, and many recreational activities (DEP 2001). Lake Okeechobee and the associated Lake Okeechobee Watershed (LOW) are primarily located in subtropical south-central Florida in Glades, Hendry, Highlands, Martin, Okeechobee, Orange, Osceola, Palm Beach, and Polk Counties. The LOW is divided into 9 subwatersheds (see **Figure ES-1**).

Lake Okeechobee and its watershed have been subjected to hydrologic, land use, and other anthropogenic modifications over the past century that have degraded its water quality and affected the water quality of the connected Caloosahatchee and St. Lucie Rivers and Estuaries. To help address the nutrient impairment, DEP adopted a total maximum daily load (TMDL) to identify the target load for total phosphorus (TP) discharges to the lake. This basin management action plan (BMAP) represents the joint efforts of multiple stakeholders to identify where nutrients, both nitrogen and phosphorus, can be reduced through regulatory and nonregulatory programs, incentive-based programs, and the implementation of projects that will ultimately achieve the TP TMDL for Lake Okeechobee and help reduce nitrogen in the lake and connected estuaries.

Total Maximum Daily Loads

TMDLs are water quality targets designed to address verified impairments for specific pollutants, such as phosphorus. DEP identified Lake Okeechobee as impaired by TP in 1998. In August 2001, DEP adopted the TP TMDL in the LOW as a target for the lake's restoration. The TMDL proposed a load of 140 metric tons per year (mt/yr) of TP to Lake Okeechobee. The attainment of the TMDL will be calculated using a 5-year rolling average of the monthly loads calculated from measured flow and concentration values. Of the 140 mt/yr, 35 mt/yr of TP are estimated to fall directly on the lake through atmospheric deposition; therefore, the remaining 105 mt/yr of TP is the load allocation for the LOW and its associated land uses to meet the Lake Okeechobee TMDL. As authorized by Subparagraph 403.067(7)(a)2., Florida Statutes (F.S.), the 105 mt/yr of TP is allocated to the entire LOW.

As part of the overall restoration strategy, DEP is prioritizing the development of TMDLs for local waterbodies in the LOW. This approach enhances the overall BMAP because, in most cases, the nutrient reductions needed to achieve local waterbody TMDLs are greater than what is needed for Lake Okeechobee from the same area.

Lake Okeechobee BMAP

DEP first adopted the Lake Okeechobee BMAP in December 2014 to implement the TP TMDL in the LOW. BMAPs are designed to be implemented in a phased approach and, at the end of each five-year phase, a review is completed and submitted to the Legislature and Governor. The 5-Year Review for the initial BMAP is included here as **Chapter 2**, and recommendations have been incorporated into this updated BMAP.

In addition, in January 2019, Executive Order 19-12 (Item C) included a requirement to update and secure all restoration plans, within one year, for waterbodies impacting south Florida communities, including the Lake Okeechobee BMAP. This 2020 BMAP provides information on changes since the 2014 BMAP was adopted, including updates to the modeling, subwatershed loading targets, and management actions to achieve nutrient reductions, and a revised monitoring plan to continue to track trends in water quality.

Summary of Load Reductions

DEP asked the stakeholders to provide information on management actions, including projects, programs, and activities, that would reduce nutrient loads from the LOW. Management actions were required by the original BMAP to address nutrient loads to the lake and had to meet several criteria to be considered eligible for credit. Through June 30, 2019, 215 projects were completed, and an additional 51 projects were underway or planned. A Request for Information (RFI) was released in October 2019 to solicit additional projects from public and private entities in the LOW. Based on the load estimation tool (LET) developed from the Watershed Assessment Model (WAM), the completed activities are estimated to achieve total reductions of 95.54 mt/yr or 210,636 pounds per year (lbs/yr) of TP, which is 19.4 % of the reductions needed to meet the TMDL. **Figure ES-2** shows progress towards the TP TMDL load reductions based on projects completed through June 30, 2019.

To achieve the TMDL in 20 years, stakeholders must identify and submit additional local projects and the Coordinating Agencies (DEP, Florida Department of Agriculture and Consumer Services [FDACS], and South Florida Water Management District [SFWMD]) must identify additional regional projects as well as determine the significant funding that will be necessary. Enhancements to programs addressing basinwide sources will also be required. In addition, the legacy phosphorus contribution in the watershed must be addressed through further studies and projects targeted at this source. Once this additional information is provided, the Coordinating Agencies will address these constraints and estimate the time needed to achieve the TMDL in a future BMAP update. Due to the fact that necessary local and regional nutrient reduction projects are still being identified, and as a result of insufficient agricultural BMP enrollment, BMP implementation verification, and other management strategies, it does not seem practicable to achieve reductions sufficient to meet the TMDL within 20 years.

Source Requirements

This BMAP sets TP and total nitrogen (TN) effluent limits in the LOW for individually permitted domestic wastewater facilities and their associated rapid-rate land application (RRLA) effluent disposal systems and reuse activities, unless the owner or operator can demonstrate reasonable assurance that the discharge, associated RRLA, or reuse activity would not cause or contribute to an exceedance of TMDLs or water quality standards. In U.S. Census–designated urbanized areas and urban clusters, local governments and utilities are also directed to develop master wastewater treatment feasibility analyses to identify specific areas to be sewered within 20 years of BMAP adoption. In areas not targeted for sewering, local governments should identify alternative methods to address loads from septic systems. The intent of the master wastewater treatment feasibility analysis is to identify noncentral sewered areas so further steps can be taken with alternative treatment options for those areas. Sources of funding to address nutrient loading from septic systems should also be identified.

Agricultural nonpoint sources are the predominant contributor of TP loading to Lake Okeechobee. Attainment of the TMDL is largely contingent upon addressing the agricultural loading to the lake. The Lake Okeechobee BMAP was originally adopted in December 2014, and many agricultural producers have enrolled and are implementing best management practices (BMPs). However, enrollment still falls well short of the full enrollment requirement under law, and for those producers that have enrolled, onsite verification of BMP implementation is insufficient. This insufficiency in agricultural BMP enrollment and implementation verification is a constraint to achieving the TMDL in 20 years, and to address this constraint it is paramount that FDACS carries out its statutory authority and fulfills its statutory obligations by more actively engaging agricultural nonpoint sources to enroll in BMPs and by adequately verifying BMP implementation. FDACS has requested funding for additional positions to enable it to undertake these activities at least every two years.

FDACS is responsible for verifying that all eligible landowners are enrolled in appropriate BMP programs, and within one year of the adoption of this BMAP DEP needs FDACS to provide a list of all agricultural landowners in the LOW with their enrollment status. DEP also needs FDACS to perform regular onsite inspections of all agricultural operations enrolled under a BMP manual to ensure that these practices are being properly implemented. Ideally, these inspections would occur at least every two years.

Further reductions beyond the implementation of required agricultural owner–implemented BMPs will be necessary to achieve the TMDL. As such, pursuant to Subsection 373.4595(3), F.S., where water quality problems are detected for agricultural nonpoint sources despite the appropriate implementation of adopted BMPs, a reevaluation of the BMPs shall be conducted pursuant to Subsection 403.067(7), F.S. If the reevaluation determines that the BMPs or other measures require modification, the applicable rule will be revised to require implementation of the modified practice.

Further reductions can also be achieved through the implementation of additional agricultural projects or activities. The Coordinating Agencies (DEP, FDACS, and SFWMD) will work together to identify cost-share practices and other projects that can be undertaken to achieve these nutrient reductions and identify and implement additional projects and activities in priority targeted restoration areas (TRAs). These additional projects and activities are to be implemented in conjunction with the BMP Program, which needs to achieve full enrollment with verification to ensure that the BMAP goals are achieved. FDACS will also collect nitrogen and phosphorus fertilization records during implementation verification visits from each agricultural producer enrolled in BMPs and provide an annual summary to DEP and SFWMD of aggregated fertilizer use in the BMAP area.

Within five years of the adoption of this BMAP, DEP will evaluate any entity located in the BMAP area that serves a minimum resident population of at least 1,000 individuals who are not currently covered by a municipal separate storm sewer system (MS4) permit and designate eligible entities as regulated MS4s, in accordance with Chapter 62-624, F.A.C. DEP and the water management districts are planning to update the stormwater design and operation requirements in Environmental Resource Permit rules and incorporate the most recent scientific information available to improve nutrient reduction benefits.

Water Quality Monitoring

The updated BMAP monitoring network includes 331 stations sampled by local entities, DEP, SFWMD, and U.S. Geological Survey (USGS). Fifty of the stations are proposed as part of expanded SFWMD monitoring and 1 is proposed as part of the Reedy Creek Improvement District monitoring, to improve monitoring in basins throughout the LOW. The monitoring network was revised into tiers as follows: (1) Tier 1 stations are the primary/priority stations used in periodic water quality analyses to track BMAP progress and water quality trends over the long term in the basin, (2) Tier 2 stations will provide secondary information that can be used to help focus and adaptively manage implementation efforts, and (3) Tier 3 stations are the gauges where flow and/or stage are monitored, generally by USGS. The monitoring stations are not specifically BMAP stations—i.e., they are designed for other purposes—but some of the data collected at these sites are used to monitor the effectiveness of BMAP implementation.

BMAP Cost

The project costs provided for the BMAP may include capital costs as well as those associated with construction and routine operations and maintenance and monitoring. Many BMAP projects were built to achieve multiple objectives and not just nutrient reductions. Funds for some projects have already been spent, others have been obligated to ongoing projects, and the remainder are yet to be appropriated.

The funding sources for the projects range from local public and private contributions to state and federal legislative appropriations. DEP will continue to work with stakeholders to explore new opportunities for funding assistance to ensure that the activities listed in this BMAP can be maintained at the necessary level of effort and that additional projects can be constructed.

Figure ES-1. Lake Okeechobee subwatersheds

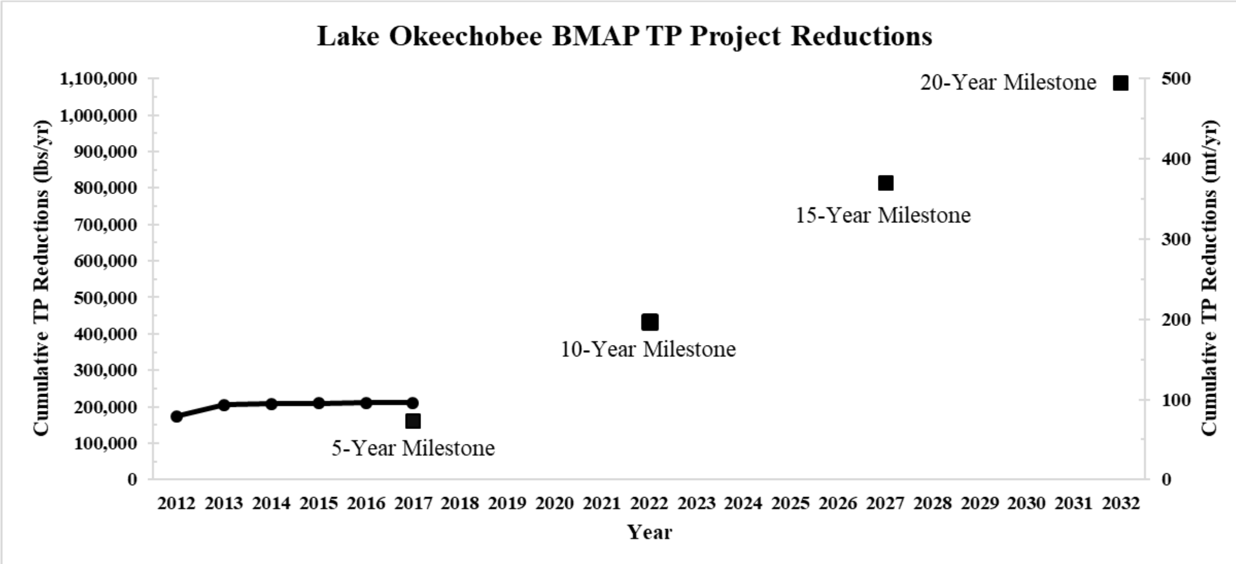

Figure ES-2. Estimated progress towards meeting the TP TMDL allocated to the Lake Okeechobee Watershed with projects completed through June 30, 2019

Chapter 1. Background Information

1.1. Water Quality Standards and Total Maximum Daily Loads (TMDLs)

Florida's water quality standards are designed to ensure that surface waters fully support their designated uses, such as drinking water, aquatic life, recreation, and agriculture. Lake Okeechobee is designated as a Class I water, with uses including public water supply, recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Most surface waters in Florida, including those in the Lake Okeechobee Watershed (LOW), which ultimately reach Lake Okeechobee, are categorized as Class III waters. **Table 1** lists all designated use classifications for Florida surface waters.

Table 1. Designated use attainment categories for Florida surface waters

[1] Class I, I-Treated, and II waters additionally include all Class III uses.

Classification	Description
Class I[1]	**Potable water supplies**
Class I-Treated[1]	Treated potable water supplies
Class II[1]	Shellfish propagation or harvesting
Class III	**Fish consumption, recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife**
Class III-Limited	Fish consumption, recreation or limited recreation, and/or propagation and maintenance of a limited population of fish and wildlife
Class IV	Agricultural water supplies
Class V	Navigation, utility, and industrial use (*no current Class V designations*)

Section 303(d) of the federal Clean Water Act (CWA) requires that every two years each state must identify its "impaired" waters, including estuaries, lakes, rivers, and streams, that do not meet their designated uses. Florida Department of Environmental Protection (DEP) staff in the Division of Environmental Assessment and Restoration are responsible for assessing Florida's waters for inclusion on the Verified List of Impaired Waters (when a causative pollutant for the impairment has been identified) and Study List (when a causative pollutant has not been identified and additional study is needed). These lists are then provided to the U.S. Environmental Protection Agency (EPA) as an annual update to the state "303(d) list." In 1998, DEP identified Lake Okeechobee as impaired for total phosphorus (TP).

1.1.1. Lake Okeechobee TMDL

A TMDL is the maximum amount of a specific pollutant that a waterbody can assimilate while maintaining its designated uses, and in August 2001, DEP adopted the Lake Okeechobee TMDL for TP. The TMDL is an annual TP load to Lake Okeechobee of 140 metric tons per year (mt/yr) (308,647 pounds per year [lbs/yr]), of which 35 mt/yr (77,162 lbs/yr) is estimated to fall directly on the lake through atmospheric deposition. The remaining 105 mt/yr (231,485 lbs/yr) of TP are allocated to the 9 subwatersheds in the LOW, as authorized by Subparagraph 403.067(7)(a)2., Florida Statutes (F.S.). The attainment of the TMDL will be calculated using a 5-year rolling average based on the monthly loads calculated from measured flow and concentration values.

Because there were no National Pollutant Discharge Elimination System (NPDES) facilities that directly discharged into the lake at that time, the adopted TMDL assigned all reductions to the permitted and unpermitted nonpoint source inflows to the lake.

1.2. Lake Okeechobee Basin Management Action Plan (BMAP)

DEP implements TMDLs through permits and BMAPs; the latter contain strategies to reduce and prevent pollutant discharges through various cost-effective means. During the watershed restoration process, DEP and the affected stakeholders jointly develop BMAPs or other implementation approaches. Stakeholder involvement is critical to the success of the watershed restoration program and varies with each phase of implementation to achieve different purposes. The BMAP development process is structured to achieve cooperation and consensus among a broad range of interested parties, including the South Florida Water Management District (SFWMD), Florida Department of Agriculture and Consumer Services (FDACS), and stakeholders representing other agencies, governments, and interested parties.

The Florida Watershed Restoration Act, Subparagraph 403.067(7)(a)1., F.S., establishes an adaptive management process for BMAPs that continues until the TMDL is met. This approach allows for incrementally reducing loadings through the implementation of projects and programs, while simultaneously monitoring and conducting studies to better understand water quality dynamics (sources and response variables) in each impaired waterbody. The original Lake Okeechobee BMAP was adopted in December 2014. Section 373.4595, F.S., calls for a review of the BMAP to be completed and submitted to the Legislature and Governor every five years. This document includes the initial 5-Year Review (**Chapter 2**). In January 2019, Executive Order 19-12 (Item C) included a requirement to update and secure all restoration plans, within one year, for waterbodies impacting south Florida communities, including the Lake Okeechobee BMAP, and this document updates the 2014 BMAP. **Figure 1** shows the LOW BMAP area which is divided into 9 subwatersheds that are further divided into 64 "basins" (**Figure 2**). This adaptive management process will continue until the TMDL is met.

The final *2019 South Florida Environmental Report (SFER) – Volume I, Chapter 8B* prepared by SFWMD, reports the 5-year average (based on data from water year [WY] 2014 to WY2018 [May 1, 2013–April 30, 2018]) annual TP load from the watershed as 598 mt/yr (1,318,364 lbs/yr). Therefore, to achieve the allowable TMDL load of 105 mt/yr, the TP required reduction is 493 mt/yr (1,086,879 lbs/yr). The TP required reduction was assigned to each subwatershed based on the contribution of the total load from that subwatershed as listed in **Table 2**. The 5-year average annual TP load from the watershed is updated annually in the SFER.

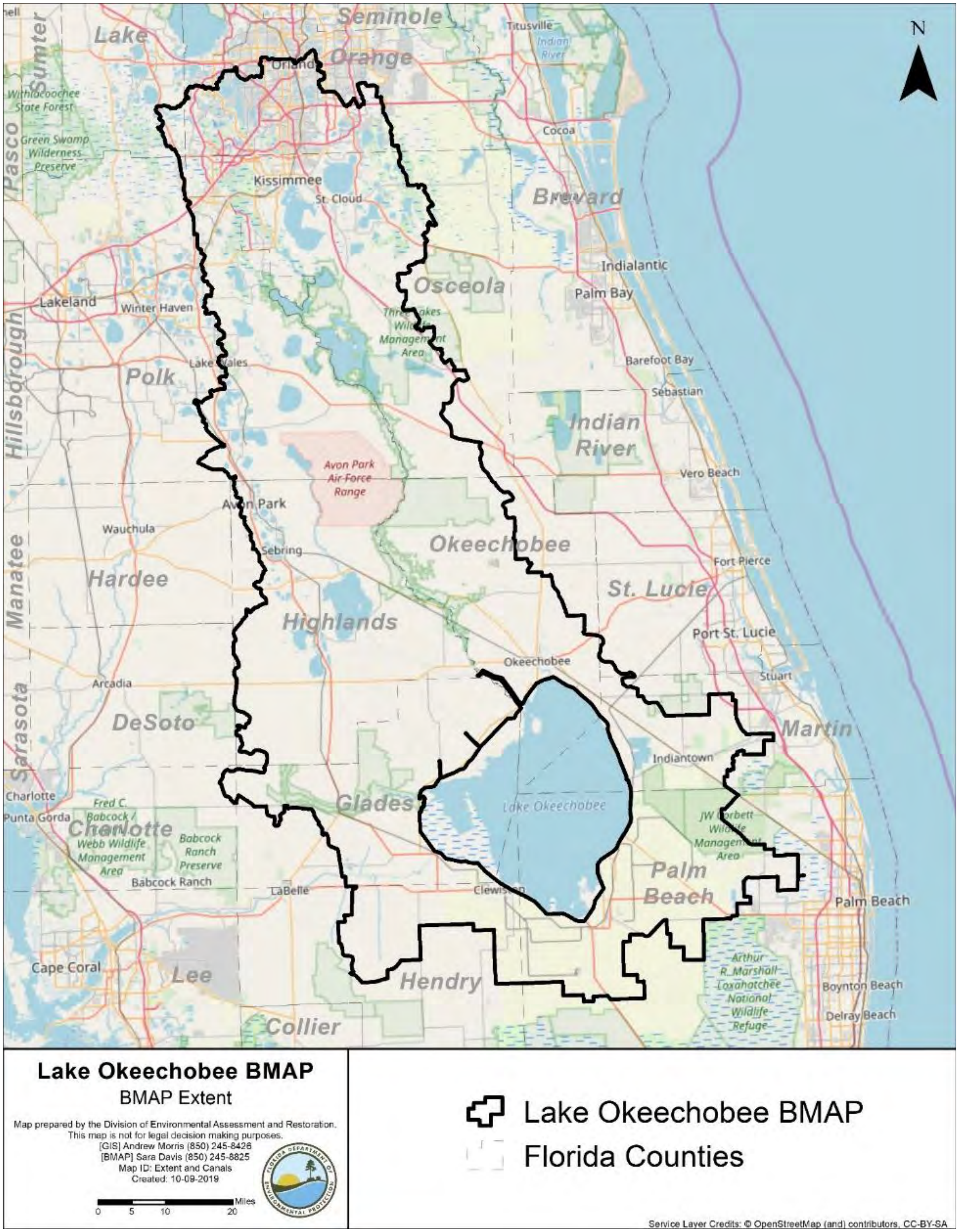

Figure 1. LOW BMAP area

Figure 2. LOW subwatersheds and basins

Table 2. Load reductions and targets by subwatershed

Subwatershed	WY2014–WY2018 TP Load (mt/yr)	% Contribution of Load	TP Load Required Reduction (mt/yr)	TP Target (mt/yr)
Fisheating Creek	72.4	12	59.7	12.7
Indian Prairie	102.5	17	84.5	18.0
Lake Istokpoga	47.7	8	39.3	8.4
Lower Kissimmee	125.9	21	103.8	22.1
Taylor Creek/Nubbin Slough	113.6	19	93.7	19.9
Upper Kissimmee	90.5	15	74.6	15.9
East Lake Okeechobee	16.8	3	13.9	2.9
South Lake Okeechobee	29.0	5	23.9	5.1
West Lake Okeechobee	<0.1	<<1	0.0	0.0
Total	**598.4**	**100**	**493.4**	**105.0**

1.2.1. Pollutant Sources

There are various sources of pollution in the LOW. Nonpoint (i.e., diffuse) sources in the watershed contribute the majority of the TP and total nitrogen (TN) loads to Lake Okeechobee and include agricultural and urban stormwater runoff. Several reports (SFWMD; DEP; FDACS; periodic Lake Okeechobee Watershed Protection Plan [LOWPP] updates) document more detailed information regarding phosphorus and nitrogen inputs from the LOW. **Table 3** summarizes the percent contribution of TP and TN loads to Lake Okeechobee from each land use category in each subwatershed as determined by the Watershed Assessment Model (WAM) load estimation tool (LET) discussed in **Subsection 2.2.2**. The subsections below discuss the sources included in this BMAP in more detail.

Table 3. Summary of TP and TN loads by WAM land use category by subwatershed

Subwatershed	Land Use Category	TP Load (% contribution)	TN Load (% contribution)
Fisheating Creek	Urban	1.3	4.7
Fisheating Creek	Agriculture	64.7	57.2
Fisheating Creek	Natural	34.0	38.1
Indian Prairie	Urban	2.5	9.9
Indian Prairie	Agriculture	84.9	73.8
Indian Prairie	Natural	12.6	16.3
Lake Istokpoga	Urban	52.5	24.0
Lake Istokpoga	Agriculture	20.7	57.4
Lake Istokpoga	Natural	26.8	18.6
Lower Kissimmee	Urban	3.0	7.4
Lower Kissimmee	Agriculture	62.9	51.7
Lower Kissimmee	Natural	34.2	40.9
Taylor Creek/Nubbin Slough	Urban	13.2	18.3
Taylor Creek/Nubbin Slough	Agriculture	82.6	75.1
Taylor Creek/Nubbin Slough	Natural	4.2	6.7
Upper Kissimmee	Urban	21.0	36.4
Upper Kissimmee	Agriculture	37.3	43.9
Upper Kissimmee	Natural	41.7	19.7
East Lake Okeechobee	Urban	5.4	9.4

Subwatershed	Land Use Category	TP Load (% contribution)	TN Load (% contribution)
East Lake Okeechobee	Agriculture	75.0	61.2
East Lake Okeechobee	Natural	19.6	29.4
South Lake Okeechobee	Urban	7.5	8.0
South Lake Okeechobee	Agriculture	91.6	90.6
South Lake Okeechobee	Natural	0.9	1.4
West Lake Okeechobee	Urban	9.9	7.8
West Lake Okeechobee	Agriculture	83.2	83.7
West Lake Okeechobee	Natural	6.9	8.5

1.2.1.1. Agricultural Nonpoint Sources

The primary agricultural land uses in the LOW are improved pastures, unimproved pastures, citrus groves, and woodland pastures. Other agricultural land uses include field crops (e.g., sugar cane), dairies, croplands and pasture, row crops, tree nurseries, specialty farms, and ornamentals. Per Section 403.067, F.S., all agricultural nonpoint sources in the BMAP area are statutorily required either to implement appropriate best management practices (BMPs) or to conduct water quality monitoring that demonstrates compliance with state water quality standards.

Per Section 403.067, F.S., when DEP adopts a BMAP that includes agriculture, it is the agricultural landowner's responsibility to implement BMPs adopted by FDACS to help achieve load reductions or demonstrate through monitoring, per Chapter 62-307, F.A.C., that water quality standards are already being met. To date, FDACS' Office of Agricultural Water Policy (OAWP) has adopted BMP manuals by rule for cow/calf, citrus, vegetable and agronomic crops, nurseries, equine, sod, dairy, poultry, and specialty fruit and nut operations.

To enroll in the BMP Program, landowners first meet with OAWP to determine the BMPs that are applicable to that individual operation. The landowner must then submit to OAWP a Notice of Intent (NOI) to implement the BMPs on the BMP checklist from the applicable BMP manual. Because many agricultural operations are diverse and are engaged in the production of multiple commodities, a landowner may be required to sign multiple NOIs for a single parcel.

OAWP is required to verify that landowners are implementing the BMPs identified in their NOIs. Rule 5M-1.008, Florida Administrative Code (F.A.C.), outlines the procedures used to verify the implementation of agricultural BMPs. BMP implementation is verified through annual surveys submitted by producers enrolled in the BMP Program and site visits by OAWP staff. Producers not implementing BMPs according to the process outlined in Chapter 5M-1, F.A.C., are referred to DEP for enforcement action after attempts at remedial action are exhausted.

FDACS staff conduct site visits to verify that all BMPs are being implemented correctly and to review nutrient and irrigation management records. In addition, OAWP verifies that cost-share items are being implemented correctly. Site visits are prioritized based on the date the NOI was signed, the date of the last BMP verification site visit, whether a survey was completed by the producer for the most recent year, and whether the operation has received cost-share funding. FDACS has requested funding for additional positions to enable it to undertake these onsite inspections at least every two years and provide information it obtains to DEP, subject to any confidentiality restrictions.

Pursuant to Subsection 373.4595(3), F.S., where water quality problems are detected for agricultural nonpoint sources despite the appropriate implementation of adopted BMPs, a reevaluation of the BMPs shall be conducted pursuant to Subsection 403.067(7), F.S. If the reevaluation determines that the BMPs or other measures require modification, the applicable rule will be revised to require implementation of the modified practice. Continuing water quality problems may be detected through the monitoring component of the BMAP and other DEP and SFWMD activities. If a reevaluation of the BMPs is needed, FDACS will also include DEP, SFWMD and other partners in the process. **Section 3.1.1** provides further details on the reevaluation of existing practices.

For the BMAP, the implementation of agricultural BMPs will be documented based on participation in FDACS' BMP Program or SFWMD's Chapter 40E-63, F.A.C., as applicable. Under the SFWMD program, all agricultural and nonagricultural lands are required to implement BMPs and monitor discharges to determine TP loading. FDACS' BMP Program rules provide the presumption of compliance to those agricultural landowners.

Table 4 and **Table 5** summarize the agricultural land use enrolled in BMP programs for the entire LOW and by subwatershed, respectively. Enrollment is as of June 30, 2019, and the agricultural acreage in each subwatershed is based on the Florida Statewide Agricultural Irrigation Demand (FSAID) VI database. As new BMAPs are developed or existing BMAP areas are expanded, overlap among BMAPs is increasing. In the Lake Okeechobee BMAP area, 268,269 agricultural acres are also included in the BMAPs for Caloosahatchee (2020 update) or St. Lucie. While calculations, allocations, and projects are specific to each BMAP, the number of acres from the individual BMAP reports, if added, exceeds the total acres in the three BMAP areas. **Appendix B** provides more information on agricultural activities in the LOW.

Table 4. Summary of agricultural land use acreage enrolled in the BMP Program in the Lake Okeechobee BMAP area

Category	Acres
FSAID VI agricultural acres in the BMAP	1,728,292
Total agricultural acres enrolled	1,335,172
% of FSAID VI agricultural acres enrolled	77 %

Table 5. Agricultural land use acreage enrolled in the BMP Program in the Lake Okeechobee BMAP area by subwatershed

Subwatershed	Total FSAID VI Agricultural Acres	Agricultural Acres Enrolled	% Agricultural Acres Enrolled
Fisheating Creek	189,488	171,662	91
Indian Prairie	221,785	182,376	82
Lake Istokpoga	118,901	93,115	78
Lower Kissimmee	219,817	175,318	80
Taylor Creek/Nubbin Slough	140,181	118,761	85

Subwatershed	Total FSAID VI Agricultural Acres	Agricultural Acres Enrolled	% Agricultural Acres Enrolled
Upper Kissimmee	260,175	126,633	49
East Lake Okeechobee	101,510	56,644	56
South Lake Okeechobee	333,231	292,512	88
West Lake Okeechobee	143,204	118,151	83
Total	**1,728,292**	**1,335,172**	**77**

UNENROLLED AGRICULTURAL ACREAGE

Agricultural land use designation is not always indicative of current agricultural activity and consequently presents challenges to estimating load allocations accurately as well as enrolling every agricultural acre in an appropriate BMP manual. To characterize unenrolled agricultural acres, OAWP identified FSAID VI features outside of the BMP enrollment areas using geographic information system (GIS) software (see **Appendix B** for details). **Table 6** summarizes the results of that analysis.

Table 6. Summary of unenrolled agricultural land use acreage in the Lake Okeechobee BMAP area

Note: Due to geometric variations between shapefiles used in the unenrolled agricultural lands analysis performed by OAWP, the unenrolled agricultural acres differ from subtraction of the FSAID VI Agricultural Acres in the BMAP and the Total Agricultural Acres Enrolled referenced in **Table 5**.

Category	Acres
Unenrolled agricultural acres	393,571
Acres identified within slivers of unenrolled agricultural areas	15,889
Lands without enrollable agricultural activity (e.g., tribal lands, residential development, and parcels with Florida Department of Revenue [DOR] use codes 70-98)	117,299
Total lands with potentially enrollable agricultural activities	**260,384**

As of June 30, 2019, OAWP had enrolled 1,335,172 agricultural acres in BMPs. Considering the results of the analysis shown in **Table 6**, the total acreage with the potential to have agricultural activities that can be enrolled in FDACS' BMP Program in the watershed is 1,595,104 acres. Using this adjusted agricultural acreage, 84 % of agricultural acres have been enrolled.

Analyzing land use data and parcel data is a valuable first step in identifying the agricultural areas that provide the greatest net benefits to water resources for enrollment in FDACS' BMP Program, as well as prioritizing implementation verification visits in a given basin. OAWP will continue to enroll agricultural lands in the BMP Program, focusing on intensive operations, including irrigated acreage, dairies and nurseries, parcels greater than 50 acres in size, and agricultural parcels adjacent to waterways.

The next step to help prioritize the enrollment efforts could use the parcel loading information derived from the WAM. This effort could help FDACS identify specific parcels with the highest modeled nutrient loading. These parcels could then be targeted for enrollment and implementation of BMPs, as well as the verification of BMP implementation.

AQUACULTURE

Under the CWA, aquaculture activities are defined as a point source. Starting in 1992, DEP and/or the water management districts regulated all aquaculture facilities through a general fish farm permit authorized by Section 403.814, F.S. In 1999, the Florida Legislature amended Chapter 597, F.S., Florida Aquaculture Policy Act, to create a program within FDACS requiring Floridians who sell aquatic species to annually acquire an Aquaculture Certificate of Registration and implement Chapter 5L-3, F.A.C., Aquaculture BMPs. Permit holders must be certified every year.

However, as with agricultural land use in Florida, aquaculture facilities are frequently in and out of production. The facilities for which acreages were provided in the original BMAP may no longer be in operation and there may be new companies in different parts of the basin. In the LOW, 663 acres of aquaculture are under certification with FDACS' Division of Aquaculture as of September 2019. For purposes of the BMAP, OAWP delineated the aquaculture facilities using parcel data. Since the acreages were not delineated to just the tank, pond, or pool areas, in most cases these calculations overestimate the acreages of aquaculture activity.

1.2.1.2. Municipal Separate Storm Sewer Systems (MS4s)

Many of the municipalities in the basin are regulated by the Florida NPDES Stormwater Program. An MS4 is a conveyance or system of conveyances, such as roads with stormwater systems, municipal streets, catch basins, curbs, gutters, ditches, constructed channels, or storm drains.

If an MS4 permittee is identified as a contributor in the BMAP, the permitted MS4 must undertake projects specified in the BMAP. The BMAP projects required to be undertaken by MS4s are detailed for each subwatershed in **Chapter 4**. Phase I and Phase II MS4s are required to implement stormwater management programs to reduce pollutants to the maximum extent practicable and address applicable TMDL allocations. Phase I MS4 permits include assessment practices to determine the effectiveness of stormwater management programs (SWMP), which can include water quality monitoring. Both Phase I and Phase II MS4 permits include provisions for the modification of SWMP activities, at the time of permit renewal, for consistency with the assumptions and requirements of the adopted BMAP.

PHASE I MS4 STORMWATER PERMIT REQUIREMENTS

Table 7 lists the local governments in the LOW designated as Phase I MS4s. Phase I MS4 permittees were subject to a two-part application process requiring (1) the development of a proposed SWMP that would meet the standard of reducing discharged pollutants to the maximum extent practicable, and (2) the incorporation of the SWMP into an individual permit issued to the MS4 operator. The stormwater management programs for Phase I MS4s include, but are not limited to, the following measures:

- Identify major outfalls and pollutant loadings.

- Detect and eliminate nonstormwater discharges (illicit discharges) to the system.
- Reduce pollutants in runoff from industrial, commercial, and residential areas.
- Control stormwater discharges from new development and redevelopment areas.
- Ensure flood control projects assess the impacts to water quality of receiving waters.
- Implement a program to reduce the stormwater discharge of pollutants related to the storage and application of pesticides, herbicides, and fertilizers.
- Implement an assessment program to determine program effectiveness.

Additionally, in accordance with Section 403.067, F.S., if an MS4 permittee is identified in an area with an adopted BMAP or BMAP in development, the permittee must comply with the adopted provisions of the BMAP that specify activities to be undertaken by the permittee. If the permittee discharges stormwater to a waterbody with an adopted TMDL pursuant to Chapter 62-304, F.A.C., then the permittee must revise its stormwater master plan to address the assigned wasteload in the TMDL.

Table 7. Entities in the LOW designated as Phase I MS4s

Permittee	Permit Number
Orange County and copermittees:	**FLS000011**
City of Belle Isle	FLS266795
City of Edgewood	FLS266817
Florida Department of Transportation (FDOT) District 5	FLS266876
Valencia Water Control District (WCD)	FLS266868
City of Orlando	**FLS000014**
Palm Beach County and copermittees:	**FLS000018**
City of Belle Glade	FLS643459
FDOT District 4	FLS266493
City of South Bay	FLS645281
Indian Trail Improvement District	FLS606723
Polk County and copermittees:	**FLS000015**
City of Davenport	FLS266621
Town of Dundee	FLS266639
City of Frostproof	FLS266663
City of Haines City	FLS266671
Town of Hillcrest Heights	FLS266698
City of Lake Wales	FLS266736
FDOT District 1	FLS266779
Reedy Creek Improvement District (RCID)	**FLS000010**

PHASE II MS4 STORMWATER PERMIT REQUIREMENTS

Table 8 lists the Phase II MS4s in the LOW as of October 2019. Under a generic permit, the operators of regulated Phase II MS4s must develop a SWMP that includes BMPs with measurable goals and a schedule for implementation to meet the following six minimum control measures:

- **Public Education and Outreach –** Implement a public education program to distribute educational materials to the community or conduct equivalent outreach activities about the impacts of stormwater discharges on water bodies and the steps that the public can take to reduce pollutants in stormwater runoff.
    - *Public Participation/Involvement* **–** Implement a public participation/involvement program that complies with state and local public notice requirements.
- **Illicit Discharge Detection and Elimination –** Subsection 62-624.200(2), F.A.C., defines an illicit discharge as "*…any discharge to an MS4 that is not composed entirely of stormwater…*," except discharges under an NPDES permit, or those listed in rule that do not cause a violation of water quality standards. Illicit discharges can include septic/sanitary sewer discharge, car wash wastewater, laundry wastewater, the improper disposal of auto and household toxics, and spills from roadway accidents.
    - Develop, if not already completed, a storm sewer system map showing the location of all outfalls, and the names and location of all surface waters of the state that receive discharges from those outfalls.
    - To the extent allowable under state or local law, effectively prohibit, through an ordinance or other regulatory mechanism, nonstormwater discharges into the storm sewer system and implement appropriate enforcement procedures and actions.
    - Develop and implement a plan to detect and address nonstormwater discharges, including illegal dumping, to the storm sewer system.
    - Inform public employees, businesses, and the general public of hazards associated with illegal discharges and the improper disposal of waste.
- **Construction Site Runoff Control –**
    - Implement a regulatory mechanism to require erosion and sediment controls, as well as sanctions to ensure compliance, to reduce pollutants in any stormwater runoff to the Phase II MS4 from construction activity that results in a land disturbance greater than or equal to an acre. Construction activity disturbing less than one acre must also be included if that

construction activity is part of a larger common plan of development or sale that would disturb one acre or more.

- Develop and implement requirements for construction site operators to implement appropriate erosion and sediment control BMPs.
- Implement requirements for construction site operators to control waste such as discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste at the construction site that may cause adverse impacts to water quality.
- Develop and implement procedures for site plan review that incorporate the consideration of potential water quality impacts.
- Develop and implement procedures for receiving and considering information submitted by the public.
- Develop and implement procedures for site inspection and the enforcement of control measures.

- **Postconstruction Runoff Control –** Implement and enforce a program to address the discharges of postconstruction stormwater runoff from areas with new development and redevelopment. (**Note**: In Florida, Environmental Resource Permits issued by the water management districts typically serve as a Qualifying Alternative Program for purposes of this minimum control measure.)
- **Pollution Prevention/Good Housekeeping –** Implement an operations and maintenance program that has the ultimate goal of preventing or reducing pollutant runoff from MS4 operator activities, such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, stormwater system maintenance, and staff training in pollution prevention.

The "NPDES Generic Permit for Discharge of Stormwater from Phase II MS4s," Paragraph 62-621.300(7)(a), F.A.C., also requires that if the permittee discharges stormwater to a waterbody with an adopted TMDL pursuant to Chapter 62-304, F.A.C., then the permittee must revise its SWMP to address the assigned wasteload in the TMDL. Additionally, in accordance with Section 403.067, F.S., if an MS4 permittee is identified in an area with an adopted BMAP or BMAP in development, the permittee must comply with the adopted provisions of the BMAP that specify activities to be undertaken by the permittee.

DEP can designate an entity as a regulated Phase II MS4 if its discharges meet the requirements of the rule and are determined to be a significant contributor of pollutants to surface waters of the state in accordance with Rule 62-624.800, F.A.C. A Phase II MS4 can be designated for regulation when a TMDL has been adopted for a waterbody or segment into which the MS4 discharges the pollutant(s) of concern. If an MS4 is designated as a regulated Phase II MS4, it is subject to the conditions of the "NPDES Generic Permit for Stormwater Discharges from Phase II MS4s."

Table 8. Entities in the LOW designated as Phase II MS4s as of October 2019

Permittee	Permit Number
Glades County	FLR04E137
Hendry County	FLR04E138
Highlands County	FLR04E148
Martin County	FLR04E013
Okeechobee County	FLR04E140
Osceola County	FLR04E012
City of Avon Park	FLR04E150
City of Clewiston	FLR04E134
City of Kissimmee	FLR04E064
City of Sebring	FLR04E149
City of St. Cloud	FLR04E112
FDOT District 1 – Highlands County	FLR04E147
FDOT Florida's Turnpike Enterprise	FLR04E049
Town of Windermere	FLR04E063

1.2.1.3. Septic Systems

Based on 2019 data from the Florida Department of Health (FDOH), there are 124,176 known or likely septic systems located throughout the LOW (**Figure 3**). **Table 9** summarizes the number of septic systems by subwatershed.

Table 9. Septic system counts by subwatershed

Subwatershed	Number of Septic Systems
Fisheating Creek	467
Indian Prairie	2,095
Lake Istokpoga	30,787
Lower Kissimmee	924
Taylor Creek/Nubbin Slough	11,085
Upper Kissimmee	61,264
East Lake Okeechobee	12,562
South Lake Okeechobee	2,699
West Lake Okeechobee	2,293
Total	**124,176**

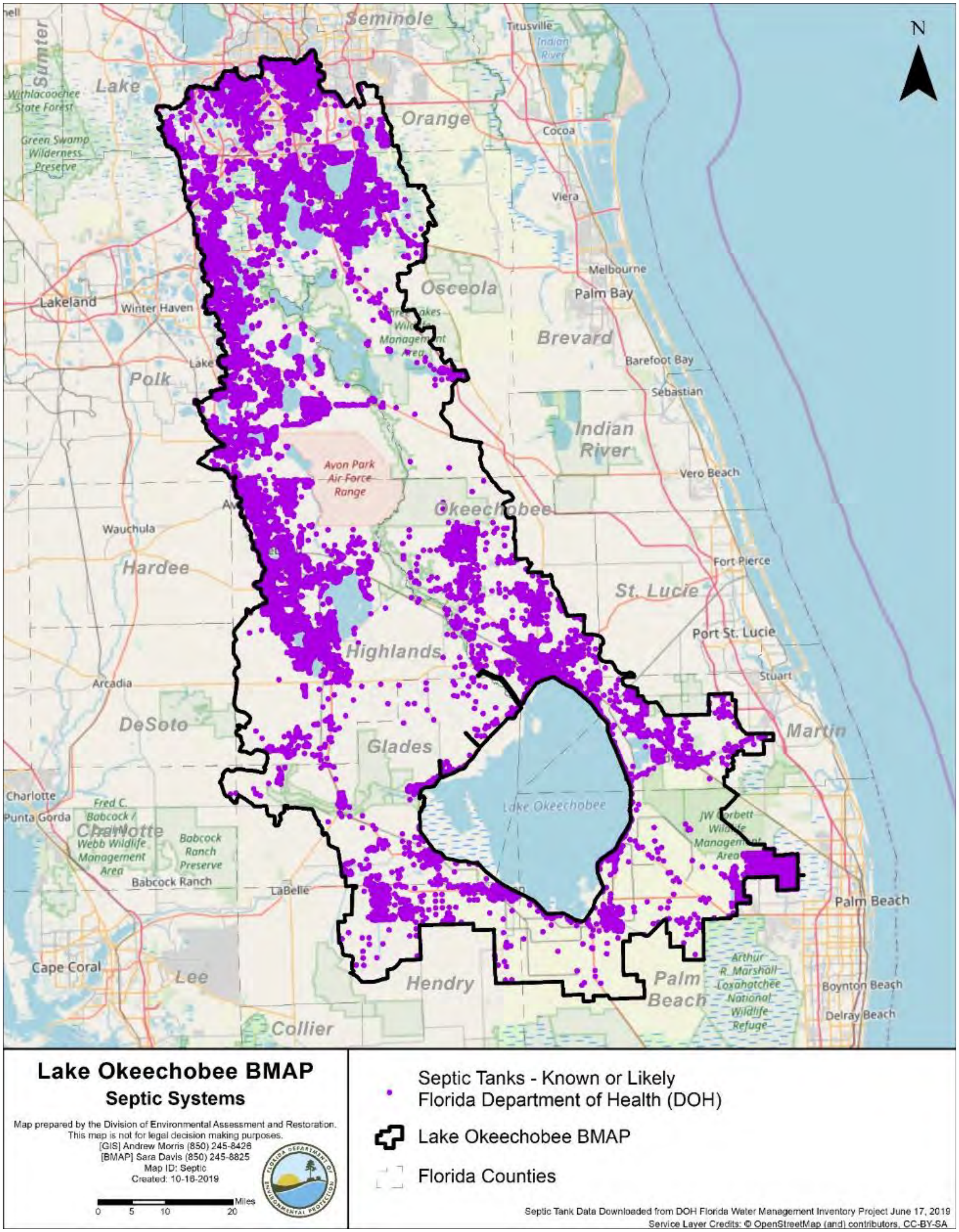

Figure 3. Location of septic systems in the LOW

1.2.1.4. Urban Nonpoint Sources

Subsubparagraph 403.067(7)(b)2.f., F.S., prescribes the pollutant reduction actions required for nonagricultural pollutant sources that are not subject to NPDES permitting. "Non-MS4 sources" must also implement the pollutant reduction requirements detailed in a BMAP and are subject to enforcement action by DEP or a water management district if they fail to implement their responsibilities under the BMAP. **Table 10** lists the nonpoint sources in the LOW.

Table 10. Urban nonpoint sources in the LOW

Type of Entity	Participant
Municipalities	City of Moore Haven City of Okeechobee City of Pahokee Town of Lake Placid Village of Highland Park Village of Indiantown
Government entities and special districts	Avon Park Air Force Range Barron WCD Clewiston Drainage District Collins Slough WCD Coquina Water Management District Devils Garden WCD Disston Island Conservancy District East Beach WCD East Hendry County Drainage District East Shore WCD Flaghole Drainage District Henry Hillard WCD Highlands Glades Drainage District Istokpoga Marsh Watershed Improvement District (IMWID) Northern Palm Beach County Improvement District Pahokee Drainage District Pelican Lake WCD Ritta Drainage District South Florida Conservancy District South Shore Drainage District Spring Lake Improvement District (SLID) Sugarland Drainage District

1.2.1.5. Wastewater Treatment Facilities (WWTFs)

The TMDL identified 190 domestic and industrial WWTFs in the LOW, none of which directly discharged to the lake. Many of the discharges were through wells to groundwater. Therefore, these facilities were not assigned a wasteload allocation. As of December 2019, there were 254 individually permitted wastewater facilities or activities in the LOW. Of these, 26 hold NPDES permits and therefore are authorized, within the limitations of their permits, to discharge directly to surface waters within the LOW. The remaining 228 do not have authorization to discharge directly to surface waters.

1.2.2. Assumptions

The water quality impacts of BMAP implementation are based on several fundamental assumptions about the pollutants targeted by the TMDLs, modeling approaches, waterbody response, and natural processes. The following assumptions were used during the BMAP process:

- Certain BMPs were assigned provisional nutrient reduction benefits for load reductions in this BMAP iteration while additional monitoring and research are conducted to quantify their effectiveness. These estimated reductions may change in future BMAP iterations, as additional information becomes available.

- Nutrient reduction benefits of the stakeholders' projects were calculated using the best available methodologies. Project-specific monitoring, where available, will be used to verify the calculations, and reduction benefits may be adjusted as necessary.

1.2.3. Considerations

This BMAP requires stakeholders to implement projects to achieve reductions within the specified period. However, the full implementation of the BMAP will be a long-term, adaptively managed process. While some of the BMAP projects and activities were recently completed or are currently ongoing, several projects require more time to design, secure funding, and construct. Regular follow-up and continued coordination and communication by the stakeholders will be essential to ensure the implementation of management strategies and assessment of incremental effects.

During the BMAP process, several items were identified that should be addressed in future watershed management cycles to ensure that future BMAPs use the most accurate information:

- **Land Uses –** The loading estimates in the BMAP are based on land uses at a particular point in time, allowing the model to be validated and calibrated. The loading estimates for this BMAP iteration were based on the WAM, which used 2009 land use data updated by SFWMD during 2013 to refine the land use categories. This dataset is referred to in this document as the 2009 land use. WAM updates in this BMAP will allow for the differentiation of phosphorus loading from various land use types.

- **Watershed Boundaries –** The 2014 BMAP focused on the six subwatersheds north of the lake because the WAM at that time did not include the full watershed. This BMAP update includes all nine subwatersheds and uses information from the 2017 WAM to help with load estimation.

- **Chapter 40E-61, F.A.C. –** SFWMD has initiated rulemaking to revise Chapter 40E-61, F.A.C., to ensure its objectives are consistent with Sections 373.4595 and 403.067, F.S.

- **Complexity of Problem –** DEP acknowledges the complexity of the dynamics that affect the water quality of Lake Okeechobee and its watershed; therefore, this BMAP is designed to encompass a wide variety of projects that will cumulatively act to significantly reduce nutrient loads. In September 2019, DEP released a Request for Information (RFI) to obtain new proposals for restoration projects and technologies to be implemented in the LOW. **Appendix E** lists the projects and technologies submitted through this RFI for each of the nine subwatersheds and the lake itself. Resources will be needed to implement these projects throughout the watershed.

- **Legacy Phosphorus –** DEP recognizes that legacy phosphorus is present in Lake Okeechobee and in the LOW as a result of past anthropogenic activities, and this watershed load has the potential to be transported to Lake Okeechobee. The Coordinating Agencies (DEP, FDACS, and SFWMD) and stakeholders will identify projects and management strategies that will address the legacy load.

- **Attenuation Factors –** Attenuation factors were calculated for each of the LOW subwatersheds using the 2017 WAM outputs. These factors were applied during the project credit calculation process to determine the nutrient reduction benefits to Lake Okeechobee.

- **Other TMDLs in the LOW –** As part of the overall restoration strategy, DEP is prioritizing waterbody TMDLs in the LOW. DEP has adopted nutrient TMDLs for Lake Kissimmee (waterbody identification [WBID] number 3183B), Lake Cypress (WBID 3180A), Lake Holden (WBID 3168H), Lake Jackson (WBID 3183G), and Lake Marian (WBID 3184) that became effective in December 2013. The dissolved oxygen (DO) TMDL for C-44 Canal (WBID 3218) and C-23 Canal (WBID 3200) became effective in March 2009. The nutrient TMDL for Lake Persimmon (WBID 1938E) became effective in November 2018. The DO TMDLs for the S-4 Basin (WBID 3246), C-19 Canal (WBID 3237E), Lake Hicpochee (WBID 3237C), Townsend Canal (WBID 3235L), and Long Hammock Creek (WBID 3237B) became effective in August 2019 and will be addressed as part of the Caloosahatchee River and Estuary BMAP.

  DEP also has nutrient TMDLs in development for Lake Glenada (WBID 1813L), Red Water Lake (WBID 1938F), Lake Placid (WBID 1938C), and Lake Istokpoga (WBID 1856B). For Reedy Lake (WBID 1685D), Lake Ida (WBID 1685E), Hickory Lake (WBID 1730), Lake Clinch (WBID 1706), and

Lake Adelaide (WBID 1730D), DEP held a public rule development workshop in August 2019, with anticipated adoption by 2020.

In addition, DEP will perform site-specific studies of 28 waterbodies in the Kissimmee, Taylor Creek, and Istokpoga Basins. The statewide priority list is posted on the DEP website.

- **TN –** Although the Lake Okeechobee TMDL only addresses TP, TN is of particular importance to the Northern Everglades and Estuaries system, including the Caloosahatchee and St. Lucie Estuaries, which receive flows directly from Lake Okeechobee. Each of these estuaries has a TMDL and a BMAP in place to address TN; therefore, DEP has calculated project reduction benefits for TN to track TN management efforts in the LOW that will directly or indirectly benefit the lake and downstream waters. In addition, DEP is evaluating TN concentrations compared with benchmark concentrations to help prioritize basins for restoration activities.

- **Previous Restoration Efforts –** DEP recognizes that stakeholders throughout the watershed have implemented stormwater management projects as well as statutorily mandated diversions away from Lake Okeechobee prior to 2009 and that these efforts have benefited water quality.

- **Estuary BMAP Overlap –** Portions of the LOW overlap with the watersheds for the Caloosahatchee River and Estuary and St. Lucie River and Estuary. The projects in these overlap areas are included in both this BMAP and the applicable estuary BMAP. The benefits of these projects will vary by BMAP as the reductions are calculated for the waterbody that is the focus of the BMAP.

Chapter 2. 5-Year Review

The BMAP, which is adopted by Secretarial Order, implements phased TP reductions according to Subparagraph 403.067(7)(a)1., F.S., for the loading generated in the LOW. This first 5-Year Review was prepared to update the status of implementation and provide recommendations for the updated BMAP. The sections below summarize the progress made to date, updates to the BMAP model, the targeted restoration area (TRA) approach for the BMAP update, water quality monitoring revisions, and established milestones. The updates and recommendations identified during the 5-Year Review are incorporated into this BMAP update.

2.1. Progress to Date

During the development of the BMAP update, DEP asked the stakeholders to provide information on activities and projects that would reduce nutrient loading to achieve the BMAP milestones and ultimately attain the TMDL. The outputs from the 2017 WAM were used to develop an LET for the calculation of existing loads and nutrient reduction benefits associated with stakeholder projects (see **Section 2.2** for details). Management strategies and projects are being implemented by the local stakeholders and Coordinating Agencies.

Chapter 4 includes projects and other management strategies that were completed, planned, or ongoing since January 1, 2009, as well as those currently under development by the Coordinating Agencies (DEP, SFWMD, and FDACS) and other initiatives. Public-private partnerships and regional projects represent a number of management strategies in the LOW. Municipal, regional, state, and federal agencies, as well as agricultural producers, have responsibilities under the BMAP to implement structural and nonstructural activities to reduce TP loads to Lake Okeechobee.

Responsible entities submitted these projects and activities to DEP with the understanding that these would be included in the BMAP, thus setting the expectation for each entity to implement the proposed projects and activities to achieve the assigned project load reduction estimates in the period specified for each project. This list of projects is meant to be flexible enough to allow for changes that may occur over time, provided that the reduction is still met within the specified period. DEP must first approve any change in listed projects and activities, or the deadline to complete these actions. Substituted projects must result in equivalent or greater nutrient reductions than expected from the original projects.

Projects had to meet several criteria to be considered eligible for nutrient reduction benefits under the BMAP. All projects, programs, and activities were required to address TP loads. Only projects completed, planned, or ongoing since January 1, 2009, were eligible for BMAP nutrient reduction benefits. While DEP recognizes that significant stakeholder actions were implemented in the LOW prior to 2009, the intent of this BMAP is to focus on current, planned, and future projects to reduce TP loads. Projects were only given nutrient reduction benefits for the portion of the load reduction over and above any permit requirements.

DEP annually reviews each entity's progress towards completing projects listed in the BMAP to achieve the TMDL. **Table 11** lists the number of projects that each entity committed to in the BMAP and annual progress reports, along with the project status projects as of June 30, 2019. Through June 30, 2019, 215 projects were completed, and an additional 51 projects were underway or planned. Based on the LET, the completed activities are estimated to achieve total reductions of 95.54 mt/yr or 210,636 pounds per year (lbs/yr) of TP, which is 19.4 % of the reductions needed to meet the TMDL. **Table 12** summarizes the reductions achieved by each entity based on modeled estimates of projects completed as of June 30, 2019.

Table 11. Projects to achieve the TMDL as of June 30, 2019

Entity	Completed	Underway	Planned	Canceled	Total
Avon Park Air Force Range	1	0	0	0	1
City of Avon Park	1	0	0	2	3
City of Edgewood	3	0	0	0	3
City of Kissimmee	6	2	1	0	9
City of Okeechobee	2	0	2	0	4
City of Orlando	15	0	1	1	17
City of Sebring	2	0	0	0	2
Coordinating Agencies	8	9	2	1	20
FDACS/Agriculture	24	0	0	0	24
FDOT District 1	3	0	0	0	3
FDOT District 4	5	1	0	0	6
FDOT District 5	25	11	0	0	36
Glades County	2	0	2	0	4
Highlands County	7	0	0	0	7
IMWID	0	2	0	0	2
Okeechobee County	7	0	0	0	7
Orange County	44	10	2	3	59
Osceola County	31	2	0	0	33
Polk County	4	0	0	0	4
RCID	2	0	0	0	2
SFWMD	20	2	1	0	23
SLID	1	0	0	1	2
Town of Windermere	1	0	0	0	1
Valencia WCD	1	0	1	0	2
Total	**215**	**39**	**12**	**8**	**274**

Table 12. Reductions towards the TMDL as of June 30, 2019

Subwatershed	TP Reduction to Date (lbs/yr)	TP Reduction to Date (mt/yr)
Fisheating Creek	31,652	14.36
Indian Prairie	45,077	20.45
Lake Istokpoga	5,595	2.54
Lower Kissimmee	12,245	5.55
Taylor Creek/Nubbin Slough	51,437	23.33
Upper Kissimmee	36,234	16.44
East Lake Okeechobee	8,911	4.04
South Lake Okeechobee	18,309	8.30
West Lake Okeechobee	1,176	0.53
Total	**210,636**	**95.54**
Total Required Reductions	**1,086,879**	**493.00**
Total Reductions Achieved (%)	**19.4 %**	**19.4 %**

2.2. BMAP Modeling

Since the BMAP was adopted in 2014, the Lake Okeechobee WAM has been updated and revised. WAM was developed to evaluate the impact of alternative land uses and management practices associated with the implementation of BMPs and nutrient load reduction projects for the LOW. It is a process-based model that can be used to perform hydrologic and water quality analysis to carry out the following (Soil and Water Engineering Technology, Inc. [SWET] 2017a):

- Simulate flows and nutrient loads for existing land uses, soils, and land management practices.
- Analyze the hydrologic and water quality impacts on streams and lakes for management scenarios, such as land use changes, the implementation of BMPs, or the addition of regional stormwater treatment areas (STAs).
- View and analyze the simulated flow and concentrations for every source cell and stream reach in the LOW under the ArcGIS platform.
- Prioritize geographic areas to focus BMP efforts.

To enhance the WAM tool for this BMAP update and other uses, the Coordinating Agencies contracted with SWET to update and recalibrate WAM to existing conditions using the latest land use, soils, hydrography, control projects, and weather databases for the six northern subwatersheds and to extend the model to include the three southern subwatersheds (SWET 2017a).

Since the previous WAM for the subwatersheds north of the lake was developed, several of the model datasets have received significant updates, including land use, hydrography, topography, drainage boundary, rainfall, flow, hydraulic structure, and TN and TP concentration data. The

WAM period of record (POR) was also extended through 2013 using the latest available rainfall, temperature, and other meteorological data. In addition, the model domains were modified to be consistent with the most current subwatershed boundaries provided by the Coordinating Agencies. Finally, shoreline reaches for all major lakes to separate flow and loads from source cells that directly discharge to the lake and other reaches draining to the lake were added to the model, as this information is useful for budget analyses (SWET 2017a).

For the LOW, the updated model used the 2009 SFWMD land use coverage, as updated in 2013 by SFWMD to refine the land use classifications. Simulation data were reported and analyzed on a daily, monthly, and annual basis to determine flows, TP and TN concentrations, and TN and TP loads from each of the six subwatersheds north of Lake Okeechobee. SWET also recalibrated the model. The model was run from 1975 through 2013; however, the validation period was limited to 2003 through 2013 because the existing land use conditions were the most representative for this period. The calibration period was split to cover the first three years (2003–05) and the last three years (2011–13) with the middle five years (2006–10) serving as the verification period (SWET 2017a).

In addition to the updates completed for the northern six subwatersheds, the WAM domain was extended to include the East, South, and West Lake Okeechobee Subwatersheds. The model domain was expanded and then the calibration, verification, and goodness-of-fit processes were completed for the three southern subwatersheds. These updates provide information for the entire LOW, used in this BMAP to estimate project load reductions. The updated WAM also provides a tool for assessing various abatement strategies that can be implemented throughout the LOW (SWET 2017b).

2.2.1. Evaluation of Predrainage Conditions

During the development of the initial BMAP, stakeholders requested that the Coordinating Agencies evaluate loads to Lake Okeechobee under predrainage conditions, i.e., conditions that existed prior to agricultural and urban development. Therefore, in 2018, SWET used the updated WAM to develop estimates of water and nutrient loadings to the lake under predrainage conditions. To simulate the predrainage conditions, a variety of sources, including descriptions of the area from the 1800s and aerial photography from the mid-1900s, were consulted, and existing land use, hydrography, and soils datasets were modified based on these sources.

All nonnative land uses were converted to the best available estimates of native land cover, man-made hydrologic features were removed, and sloughs and streams were added to reflect estimated natural conditions. The original natural topography has been altered in many places, particularly in the southern part of the watershed; therefore, a topographic dataset reflecting predrainage conditions that was developed for the Natural System Regional Simulation Model was obtained from SFWMD to use in the model setup. The literature was reviewed to develop estimates of nutrient concentrations in runoff and recharge to groundwater from native land covers that were not impacted by human development.

Simulations of the pristine conditions in all 9 subwatersheds were run with WAM over calendar years 1994 through 2013, and the overall discharge volume of water, nutrient loads, and flow-weighted concentrations to Lake Okeechobee were calculated. The estimates from the WAM simulations based on rainfall over the period from WY1995–WY2013 are that, on average, 1.8 million acre-feet (ac-ft) of water were discharged into Lake Okeechobee each year, carrying nutrient loads into the lake of almost 2,400 mt/yr of TN and 80 mt/yr of TP. Flow-weighted concentrations of TN and TP in water entering the lake were 1.05 and 0.036 milligrams per liter (mg/L), respectively (SWET 2018).

2.2.2. Development of the LET

DEP developed the LET for the northern Lake Okeechobee BMAP subwatersheds in 2014. It provided the spatial TN and TP source loads and determined how much of those loads ultimately reach Lake Okeechobee. The purpose of the LET is to provide the stakeholders with the ability to evaluate the relative benefits of projects based on their location in the LOW. The LET was originally developed for the northern six subwatersheds based on the 2012 WAM. This version of the LET did not have the ability to separate surface versus groundwater flows through the watershed stream network to their associated outlet locations into Lake Okeechobee.

Therefore, as part of the contract to update the WAM in 2017, SWET was tasked with updating the LET using the 2017 WAM that included all nine subwatersheds. This updated LET was to provide separate estimates of TN and TP loads for surface and groundwater at the source cells, after attenuation to the nearest stream/reach, and loads from the source cells that ultimately reach Lake Okeechobee. The updated version was used in this BMAP to update the estimated load reduction benefits from the BMAP projects.

2.2.3. Subwatershed Attenuation Rates

Based on a comparison of the source loads and loads that reach the lake from each subwatershed within the LET, attenuation factors were calculated for each of the LOW subwatersheds. These factors were applied during the project credit calculation process (where project base loads were not already attenuated) to determine the nutrient reduction benefits to Lake Okeechobee. **Table 13** lists the attenuation rates used for each subwatershed in the LOW.

Table 13. Attenuation factors in the LOW by subwatershed

Subwatershed	TP Attenuation Rate	TN Attenuation Rate
Fisheating Creek	0.38	0.70
Indian Prairie	0.03	0.37
Lake Istokpoga	0.69	0.64
Lower Kissimmee	0.38	0.68
Taylor Creek/Nubbin Slough	0.21	0.40
Upper Kissimmee	0.47	0.67
East Lake Okeechobee	0.66	0.70
South Lake Okeechobee	0.90	0.53
West Lake Okeechobee	0.93	0.90

2.3. LOW Construction Project

The Coordinating Agencies (DEP, SFWMD, and FDACS) have been working together to identify restoration measures for the LOW to meet the intent of the Northern Everglades and Estuaries Protection Program (NEEPP). In accordance with Paragraph 373.4595(3)(a), F.S., the Coordinating Agencies, led by SFWMD, developed the LOWPP (SFWMD et al. 2007), which includes the Lake Okeechobee Research and Water Quality Monitoring Plan and the Lake Okeechobee Watershed Construction Project (LOWCP). The LOWPP contains an integrated management strategy based on watershed and in-lake remediation activities.

The purpose of the LOWCP is to provide an overall strategy to protect and restore surface water resources by improving hydrology and water quality for the Northern Everglades ecosystem to support the BMAP in achieving the TP TMDL for Lake Okeechobee. To date, the LOWCP has evolved through two phases. Phase I (outlined in the 2007 LOWPP Update) was intended to bring immediate TP load reductions to the lake with a subset of specific projects. Phase II (also known as the Phase II Technical Plan; SFWMD et al. 2008) identified regional construction projects and onsite measures, practices, and regulations intended to prevent or reduce pollution at the source and to increase storage north of the lake to attenuate and reduce flows to Lake Okeechobee.

In early 2019, SFWMD worked closely with the Coordinating Agencies to prepare the proposed initiatives and projects (known as management measures) in the LOWCP and establish the recommended modifications and updates to the LOWCP. The draft LOWCP 2020 Update was also provided to LOW stakeholders to review and comment on the proposed projects via a public workshop as well as an interactive, dedicated website for the update. In accordance with Subparagraph 373.4595(3)(a)(1)c, F.S., SFWMD provided the LOWCP 2020 Update to DEP in August 2019. **Chapter 4** includes the measures from the LOWCP for Lake Okeechobee and each of the subwatersheds of the LOW. Additional details about the update can be found on the SFWMD LOWPP website. The complete LOWPP 2020 Update will be published by SFWMD in the final *2020 SFER – Volume I, Appendix 8A-1*.

2.3.1. Coordinating Agencies' Projects and Initiatives

During the first five years of BMAP implementation, a host of restoration activities in the LOW progressed. Pursuant to Paragraph 373.4595(3)(b), F.S., the Coordinating Agencies developed an interagency agreement in March 2017 that outlines each agency's role and responsibilities in the implementation of the LOWPP and BMAP as set forth in Sections 373.4595 and 403.0678, F.S. Subsequently, the Coordinating Agencies have prepared Annual Work Plans to further define and update as needed the specific tasks of the agencies outlined in the interagency agreement. In addition to site-specific projects, the Coordinating Agencies continued work on other initiatives to achieve nutrient reductions in the LOW. **Table 14** provides an update on the status of those initiatives listed in the Lake Okeechobee BMAP.

Table 14. Coordinating Agencies' initiatives

Initiative	Explanation	Start Date	Update
Lake Okeechobee Watershed Restoration Project (LOWRP)	SFWMD reinitiated formulation of storage components of LOWRP, with U.S. Army Corps of Engineers (USACE) as federal partner.	Summer 2016	LOWRP contains 3 components of Comprehensive Everglades Restoration Plan that will identify regional-scale features north of Lake Okeechobee to improve quantity, timing, and distribution of flows to better manage lake water levels, reduce freshwater discharges to Caloosahatchee and St. Lucie Estuaries, increase spatial extent and functionality of wetland habitat, and increase availability of water supply to existing legal water users of Lake Okeechobee. These objectives will be achieved through storage of water in a wetland attenuation feature and aquifer storage and recovery wells, and restoration of approximately 4,800 acres of wetlands in the LOW. Work by USACE and SFWMD on the LOWRP planning effort commenced in June 2016. Tentatively selected plan was identified in May 2018, and tentatively selected plan was subsequently optimized to become Recommended Plan. Planning process is anticipated to take 46 months to complete. After planning process, future work is contingent on congressional authorization and appropriations.
Implemented BMP Verification	FDACS and DEP are developing plan for BMP verification.	Spring 2015	FDACS is currently working with DEP to identify possible sites with owner-implemented and cost-share BMPs.
Cost-Share BMP Effectiveness Review	FDACS and DEP are developing approach to evaluate effectiveness of various types of cost-share projects.	Fall 2015	In late 2015, FDACS contracted with SWET to assess treatment efficiencies (TP and TN reductions in concentration and loads) as well as storage capacities of various common cost-share BMPs in LOW. TP and TN reductions for evaluated cost-share BMPs were provided to DEP, so revised nutrient-reduction benefits can be attributed to cost-share BMPs in this BMAP. FDACS will also use TP and TN reductions and storage capacities to review future cost-share applications and maximize nutrient reduction potential that can be achieved with available cost-share dollars. Report was finalized in summer 2016 and includes expected nutrient reductions and cost ranges.
SFWMD Regulatory Nutrient Source Control Program	Chapter 40E-61, F.A.C.	Fall 2019	SFWMD has initiated rulemaking to revise Chapter 40E-61, F.A.C., to ensure objectives are consistent with Sections 373.4595 and 403.067, F.S.
Water Quality Monitoring	As DEP develops monitoring plan for BMAP, consideration is being given to areas with on-the-ground projects/ BMPs to evaluate water quality improvements.	Fall 2018	BMAP monitoring plan stations have been verified, with data providers and locations confirmed, and appropriate updates made to revised monitoring network. DEP is working with additional potential data providers to evaluate possible inclusion of new monitoring sites. Based on mapped locations of projects and BMPs, Coordinating Agencies are working to optimize monitoring efforts. As a result of these efforts, SFWMD is expanding monitoring efforts in the LOW to include more locations, greater frequency, and more parameters.

Initiative	Explanation	Start Date	Update
In-Lake Strategies: Muck Scraping and Tilling	In Lake Okeechobee	Fall 2014	Initiative has potential for inclusion as BMAP project(s) during low lake levels if drought conditions occur and if project logistics (e.g., planning, permitting, contracting) can be implemented in timely fashion for work to be conducted. SFWMD Low Water Level Habitat Enhancement Plan drafted for lake in November 2015 may inform this initiative. SFWMD draft plan (November 2015) was submitted to DEP in March 2016.

2.4. Water Quality Analysis

DEP completed a water quality analysis to assist in tracking TP trends in the LOW. This analysis, five years into BMAP implementation, was used to identify the locations where trends exist. The results provide an initial look at the status of water quality in waterbodies in the BMAP area. Future analyses will investigate the drivers of these trends to help focus activities and projects and will include a longer period with more available data.

The majority of data for the analysis was received from SFWMD, and any additional station data were retrieved from the DEP Watershed Information Network (WIN) Database. Monitoring stations in the BMAP area were grouped into tiers based on data provider and station type. Only Tier 1 and Tier 2 stations (described in **Subsection 3.3.2**) with adequate data availability and sampling frequencies were used in the analysis, and some refinements to the monitoring network have been made since this analysis was completed. Furthermore, Tier 1 data are based on grab samples in combination with autosampler data (time or flow composited) and generally have associated flow monitoring, while Tier 2 data are often from grab samples.

Datasets from stations with less than 50 % of available data for the POR were not included in the analysis. This data availability requirement is based on a review of the literature regarding the data requirements necessary for trend analysis. The station datasets were divided into 2 groups based on the number of sampled data points (on a monthly basis) relative to the total potential number of months in the POR. The first group contained stations with greater than 50 % of available data points, and the second group contained stations with less than 50 % of available data points. Only the stations with more than 50 % of available data were assessed for this analysis. Stations with less data may be used in future analyses, provided more data become available and they can meet data quality requirements.

The POR selected for this analysis was May 1, 2008, to April 30, 2018 (WY2009–WY2018). The 10-year POR includes a period prior to BMAP adoption in December 2014 that could be used to track progress from the implementation of a number of load reduction projects. Analyzing data based on water year is a standard practice among the Coordinating Agencies and allows for consistent reporting and analysis. In future reviews at the 10- and 15-year milestones, additional data will be available that will allow for the further analysis of long-term trends.

Trends in TP flow weighted mean (FWM) concentrations and load data provided by SFWMD were assessed for Tier 1 structure stations. Trends in TP concentrations were assessed for Tier 2 stations. The results of the trend analysis are summarized below, and **Appendix C** describes in more detail the methods used to retrieve, process, and perform the analysis.

The nonparametric Seasonal Kendall test was used to identify monotonic trends in the nutrient data for each station. The effects of seasonal patterns and serial correlation in the data series were taken into account in the analysis to avoid false positive or false negative indications of trend significance. It should be noted that while the trends may be statistically significant, they may not be ecologically significant. A statistically significant trend in a dataset with slope closer to zero will likely not show a measurable impact within a reasonable period (i.e., years to decades).

Trends for Tier 1 structure stations were assessed in terms of FWM and loads. The results for the Seasonal Kendall trend analysis for Tier 1 station FWM and loads are summarized in **Table 15** and **Table 16**, respectively, and shown in **Figure 4** and **Figure 5**, respectively. Out of the 23 Tier 1 stations analyzed, 11 showed significant trends for FWM, while 14 stations showed significant trends for loads. Differences in trend results across the type of parameter measured (FWM versus load) were found when analyzing nutrient loads for each structure station. Eight stations showed a significant trend for TP load, varying between positive and negative, but no significant trend for FWM. Conversely, 5 stations showed a significant trend for FWM, but no significant trend for load. Five stations (S-135, S-4, S-65, S-65E, and S-72) showed significantly increasing trends for both FWM and TP load.

The results of the Seasonal Kendall trend analysis of TP concentrations for Tier 2 stations are summarized in **Table 17** and shown in **Figure 6**. Of the 58 Tier 2 stations analyzed, 19 showed significant trends for TP concentrations, 9 of which were significantly increasing and 10 of which were significantly decreasing.

Table 15. Seasonal Kendall trend analysis results for TP FWMs at Tier 1 stations

Notes: P-values listed in **bold** indicate statistical significance ($p<0.05$).
TP measured in mg/L.
[1] Even if the p-value is statistically significant, the result may not be ecologically significant. For example, if a trend is statistically significantly declining (negative trend) but the slope is near zero, then it may not be realistic to assume that an improvement in water quality by reductions in TP may positively impact the ecological system in a measurable way.
[2] Series with serial correlation (as per autocorrelation analysis results) used the adjusted P-value for serial correlation.
[3] A decreasing trend may suggest an improvement in water quality. An increasing trend may suggest a decline in water quality.

Station	Subwatershed	Tau	P-Value	Adjusted P-Value	Slope[1]	Selected P-value[2]	Serial Correlation	Trend[3]
C10A	East Lake Okeechobee	0.253	0.0150	0.1683	0.0043	**0.015**	No	**Significantly Increasing**
FECSR78	Fisheating Creek	0.085	0.2453	0.4692	0.0025	0.245	No	No Significant Trend
INDUSCAN	South Lake Okeechobee	-0.010	0.9277	0.9518	-0.0002	0.928	No	No Significant Trend
L59W	Indian Prairie	-0.241	0.0039	0.1456	-0.0156	**0.004**	No	**Significantly Decreasing**
L60E	Indian Prairie	-0.052	0.5612	0.7368	-0.0021	0.561	No	No Significant Trend
L60W	Indian Prairie	0.019	0.8204	0.8585	0.0004	0.859	Yes	No Significant Trend
L61E	Indian Prairie	-0.167	0.0936	0.3040	-0.0030	0.094	No	No Significant Trend
S127	Indian Prairie	-0.161	0.0907	0.3922	-0.0081	0.091	No	No Significant Trend

Station	Subwatershed	Tau	P-Value	Adjusted P-Value	Slope[1]	Selected P-value[2]	Serial Correlation	Trend[3]
S129	Indian Prairie	-0.407	0.0000	0.0476	-0.0048	**0.048**	Yes	**Significantly Decreasing**
S131	Indian Prairie	-0.070	0.4372	0.6523	-0.0008	0.652	Yes	No Significant Trend
S133	Taylor Creek/Nubbin Slough	-0.137	0.1789	0.4760	-0.0047	0.179	No	No Significant Trend
S135	Taylor Creek/Nubbin Slough	0.346	0.0002	0.0817	0.0093	**0.000**	No	**Significantly Increasing**
S154	Taylor Creek/Nubbin Slough	0.137	0.1366	0.3377	0.0107	0.137	No	No Significant Trend
S154C	Taylor Creek/Nubbin Slough	-0.124	0.1175	0.3789	-0.0114	0.118	No	No Significant Trend
S191	Taylor Creek/Nubbin Slough	0.391	0.0000	0.0086	0.0243	**0.009**	Yes	**Significantly Increasing**
S308C	East Lake Okeechobee	0.233	0.0036	0.1338	0.0071	**0.004**	No	**Significantly Increasing**
S4	South Lake Okeechobee	0.303	0.0001	0.0856	0.0177	**0.000**	No	**Significantly Increasing**
S65	Upper Kissimmee	0.237	0.0010	0.0544	0.0021	**0.001**	No	**Significantly Increasing**
S65E	Lower Kissimmee	0.293	0.0001	0.0139	0.0074	**0.000**	No	**Significantly Increasing**
S68	Lake Istokpoga	0.266	0.0003	0.0785	0.0040	0.079	Yes	No Significant Trend
S71	Lake Istokpoga	0.107	0.1464	0.2646	0.0051	0.146	No	No Significant Trend
S72	Indian Prairie	0.202	0.0056	0.0560	0.0105	**0.006**	No	**Significantly Increasing**
S84	Indian Prairie	0.190	0.0090	0.1120	0.0067	**0.009**	No	**Significantly Increasing**

Table 16. Seasonal Kendall trend analysis results for TP loads at Tier 1 stations

Notes: P-values listed in **bold** indicate statistical significance ($p<0.05$).
TP loads measured in kilograms.
[1] Even if the p-value is determined to be statistically significant, the result may not be ecologically significant. For example, if a trend is statistically significantly declining (negative trend) but the slope is near zero, then it may not be realistic to assume that an improvement in water quality by reductions in TP may positively impact the ecological system in a measurable way.
[2] Series with serial correlation (as per autocorrelation analysis results) used the P-value adjusted for serial correlation.
[3] A decreasing trend may suggest an improvement in water quality. An increasing trend may suggest a decline in water quality.

Station	Subwatershed	Tau	P-Value	Adjusted P-Value	Slope[1]	Selected P-value[2]	Serial Correlation	Trend[3]
C10A	East Lake Okeechobee	0.009	0.9109	0.9458	0.0000	0.911	No	No Significant Trend
FECSR78	Fisheating Creek	0.248	0.0006	0.0708	44.2000	**0.001**	No	**Significantly Increasing**
INDUSCAN	South Lake Okeechobee	-0.169	0.0192	0.0086	-1.3920	**0.019**	No	**Significantly Decreasing**
L59W	Indian Prairie	0.091	0.2117	0.4382	3.8870	0.438	Yes	No Significant Trend

Station	Subwatershed	Tau	P-Value	Adjusted P-Value	Slope[1]	Selected P-value[2]	Serial Correlation	Trend[3]
L60E	Indian Prairie	0.176	0.0131	0.1134	0.4175	**0.013**	No	**Significantly Increasing**
L60W	Indian Prairie	0.231	0.0014	0.0065	1.4160	**0.001**	No	**Significantly Increasing**
L61E	Indian Prairie	0.001	0.9556	0.9685	0.0000	0.956	No	No Significant Trend
S127	Indian Prairie	0.133	0.0575	0.2777	0.4762	0.058	No	No Significant Trend
S129	Indian Prairie	0.002	1.0000	1.0000	0.0000	1.000	No	No Significant Trend
S131	Indian Prairie	0.165	0.0204	0.2017	0.8327	**0.020**	No	**Significantly Increasing**
S133	Taylor Creek/Nubbin Slough	0.291	0.0000	0.0554	15.2800	**0.000**	No	**Significantly Increasing**
S135	Taylor Creek/Nubbin Slough	0.380	0.0000	0.0137	20.7900	**0.014**	Yes	**Significantly Increasing**
S154	Taylor Creek/Nubbin Slough	0.187	0.0072	0.1408	0.0270	**0.007**	No	**Significantly Increasing**
S154C	Taylor Creek/Nubbin Slough	0.017	0.8353	0.8972	0.0000	0.835	No	No Significant Trend
S191	Taylor Creek/Nubbin Slough	0.083	0.2465	0.4680	0.0427	0.468	Yes	No Significant Trend
S308C	East Lake Okeechobee	-0.033	0.6597	0.7983	-3.1330	0.660	No	No Significant Trend
S4	South Lake Okeechobee	0.178	0.0139	0.0470	6.3680	**0.014**	No	**Significantly Increasing**
S65	Upper Kissimmee	0.244	0.0007	0.0345	197.8000	**0.001**	No	**Significantly Increasing**
S65E	Lower Kissimmee	0.293	0.0001	0.0192	595.2000	**0.000**	No	**Significantly Increasing**
S68	Lake Istokpoga	0.183	0.0114	0.2363	174.7000	**0.011**	No	**Significant Increasing**
S71	Lake Istokpoga	0.115	0.1153	0.4178	89.2500	0.418	Yes	No Significant Trend
S72	Indian Prairie	0.163	0.0247	0.2663	138.3000	**0.025**	No	**Significantly Increasing**
S84	Indian Prairie	0.170	0.0188	0.2255	160.8000	**0.019**	No	**Significantly Increasing**

Table 17. Seasonal Kendall trend analysis results for TP concentrations at Tier 2 stations

Notes: P-values listed in **bold** indicate statistical significance ($p<0.05$).
TP measured in mg/L.

[1] Even if the p-value is determined to be statistically significant, the result may not be ecologically significant. For example, if a trend is statistically significantly declining (negative trend) but the slope is near zero, then it may not be realistic to assume that an improvement in water quality by reductions in TP may positively impact the ecological system in a measurable way.
[2] Series with serial correlation (as per autocorrelation analysis results) used the P-value adjusted for serial correlation.
[3] A decreasing trend may suggest an improvement in water quality. An increasing trend may suggest a decline in water quality.

Station	Subwatershed	Tau	P-Value	Adjusted P-Value	Slope[1]	Selected P-value[2]	Serial Correlation	Trend[3]
AB27343014	Lake Istokpoga	0.096	0.2168	0.3458	0.0030	0.346	Yes	No Significant Trend
ABOGGN	Upper Kissimmee	0.251	0.0064	0.0302	0.0007	**0.006**	No	**Significantly Increasing**
AR06333013	Lake Istokpoga	-0.058	0.4380	0.7287	-0.0005	0.729	Yes	No Significant Trend
AR18343012	Lake Istokpoga	0.114	0.1583	0.2549	0.0021	0.255	Yes	No Significant Trend
BH04392912	Fisheating Creek	-0.413	0.0000	0.0118	-0.0285	**0.012**	Yes	**Significantly Decreasing**
BN03332911	Lake Istokpoga	-0.291	0.0001	0.0226	-0.0392	**0.023**	Yes	**Significantly Decreasing**
BN08332912	Lake Istokpoga	-0.226	0.0037	0.1545	-0.0798	**0.004**	No	**Significantly Decreasing**
BNSHINGLE	Upper Kissimmee	-0.157	0.0556	0.2949	-0.0013	0.295	Yes	No Significant Trend
BS-59	Upper Kissimmee	-0.098	0.4080	0.6328	-0.0002	0.408	No	No Significant Trend
CL18273011	Upper Kissimmee	-0.255	0.0321	0.1305	-0.0015	**0.032**	No	**Significantly Decreasing**
CREEDYBR	Upper Kissimmee	-0.196	0.0670	0.2630	-0.0030	0.263	Yes	No Significant Trend
CY05353444	Lower Kissimmee	-0.026	0.7678	0.7829	-0.0022	0.783	Yes	No Significant Trend
DLMARNCR	Upper Kissimmee	-0.050	0.6841	0.7923	-0.0005	0.684	No	No Significant Trend
ET05253114	Upper Kissimmee	-0.262	0.0133	0.1262	-0.0009	0.126	Yes	No Significant Trend
ET06253113	Upper Kissimmee	-0.196	0.0113	0.0617	-0.0028	**0.011**	No	**Significantly Decreasing**
FE20393013	Fisheating Creek	0.144	0.1781	0.3790	0.0146	0.178	No	No Significant Trend
FE21392913	Fisheating Creek	-0.311	0.0050	0.0616	-0.0124	0.062	Yes	No Significant Trend
FE26362812	Fisheating Creek	-0.069	0.4703	0.6584	-0.0013	0.470	No	No Significant Trend
GA09393011	Fisheating Creek	-0.398	0.0000	0.0251	-0.0326	**0.025**	Yes	**Significantly Decreasing**
HP06393242	Indian Prairie	0.155	0.1928	0.1979	0.0086	0.198	Yes	No Significant Trend
HP11373132	Indian Prairie	0.424	0.0004	0.0451	0.0053	**0.045**	Yes	**Significantly Increasing**
HP15373112	Indian Prairie	0.224	0.0350	0.1408	0.0194	0.141	Yes	No Significant Trend
HP22373112	Indian Prairie	-0.321	0.0015	0.0076	-0.0218	**0.008**	Yes	**Significantly Decreasing**
HP25373013	Indian Prairie	-0.037	0.6375	0.7282	-0.0011	0.728	Yes	No Significant Trend

Station	Subwatershed	Tau	P-Value	Adjusted P-Value	Slope[1]	Selected P-value[2]	Serial Correlation	Trend[3]
IP09383232	Indian Prairie	0.180	0.1339	0.0894	0.0095	0.134	No	No Significant Trend
KR05373311	Lower Kissimmee	0.168	0.1534	0.1248	0.0193	0.153	No	No Significant Trend
KR16373414	Taylor Creek/Nubbin Slough	0.294	0.0019	0.0361	0.0200	**0.036**	Yes	**Significantly Increasing**
KR17373513	Taylor Creek/Nubbin Slough	0.203	0.0255	0.1766	0.0095	0.177	Yes	No Significant Trend
KR24353114	Lower Kissimmee	-0.326	0.0012	0.0475	-0.0139	**0.048**	Yes	**Significantly Decreasing**
KREA 01	Lower Kissimmee	-0.037	0.7771	0.7797	-0.0030	0.780	Yes	No Significant Trend
KREA 04	Lower Kissimmee	-0.061	0.6129	0.7429	-0.0019	0.743	Yes	No Significant Trend
KREA 14	Lower Kissimmee	0.026	0.8684	0.8953	0.0024	0.868	No	No Significant Trend
KREA 17A	Lower Kissimmee	0.232	0.0139	0.1324	0.0163	**0.014**	No	**Significantly Increasing**
KREA 22	Lower Kissimmee	-0.043	0.6448	0.7214	-0.0003	0.645	No	No Significant Trend
KREA 23	Lower Kissimmee	-0.276	0.0038	0.0511	-0.0050	**0.004**	No	**Significantly Decreasing**
KREA91	Lower Kissimmee	-0.224	0.0024	0.0874	-0.0035	**0.002**	No	**Significantly Decreasing**
KREA92	Lower Kissimmee	0.248	0.0010	0.0423	0.0020	**0.001**	No	**Significantly Increasing**
KREA93	Lower Kissimmee	0.066	0.3902	0.5585	0.0008	0.559	Yes	No Significant Trend
KREA94	Lower Kissimmee	0.086	0.2574	0.4369	0.0010	0.437	Yes	No Significant Trend
KREA97	Lower Kissimmee	-0.206	0.0060	0.1370	-0.0022	0.137	Yes	No Significant Trend
KREA98	Lower Kissimmee	0.084	0.2555	0.5383	0.0005	0.538	Yes	No Significant Trend
LB29353513	Taylor Creek/Nubbin Slough	0.079	0.3974	0.5749	0.0131	0.397	No	No Significant Trend
LI02362923	Lake Istokpoga	0.094	0.3378	0.3580	0.0005	0.338	No	No Significant Trend
LV14322813	Lake Istokpoga	-0.043	0.7122	0.7604	-0.0033	0.760	Yes	No Significant Trend
MS08373611	Taylor Creek/Nubbin Slough	0.257	0.0156	0.1978	0.0660	0.198	Yes	No Significant Trend
OK09353212	Lower Kissimmee	-0.167	0.0830	0.2218	-0.0067	0.083	No	No Significant Trend
OT34353513	Taylor Creek/Nubbin Slough	0.167	0.1309	0.2019	0.0218	0.202	Yes	No Significant Trend
PA10313112	Upper Kissimmee	0.137	0.1338	0.3620	0.0026	0.362	No	No Significant Trend

Station	Subwatershed	Tau	P-Value	Adjusted P-Value	Slope[1]	Selected P-value[2]	Serial Correlation	Trend[3]
PB24392912	Fisheating Creek	0.113	0.1467	0.2500	0.0062	0.250	No	No Significant Trend
PL01382911	Lake Istokpoga	0.346	0.0000	0.0058	0.0336	**0.006**	Yes	**Significantly Increasing**
RD08322913	Lake Istokpoga	0.454	0.0000	0.0026	0.0050	**0.003**	Yes	**Significantly Increasing**
TCNS 204	Taylor Creek/Nubbin Slough	0.016	0.9010	0.9236	0.0032	0.901	No	No Significant Trend
TCNS 207	Taylor Creek/Nubbin Slough	0.060	0.6268	0.6732	0.0025	0.673	Yes	No Significant Trend
TCNS 213	Taylor Creek/Nubbin Slough	0.047	0.6155	0.6843	0.0018	0.616	No	No Significant Trend
TCNS 214	Taylor Creek/Nubbin Slough	0.500	0.0000	0.0015	0.0426	**0.000**	No	**Significantly Increasing**
TCNS 217	Taylor Creek/Nubbin Slough	0.116	0.1418	0.3598	0.0060	0.142	No	No Significant Trend
TCNS 220	Taylor Creek/Nubbin Slough	0.239	0.0275	0.1118	0.0331	**0.028**	No	**Significantly Increasing**
TCNS 222	Taylor Creek/Nubbin Slough	0.109	0.2146	0.3497	0.0073	0.350	Yes	No Significant Trend

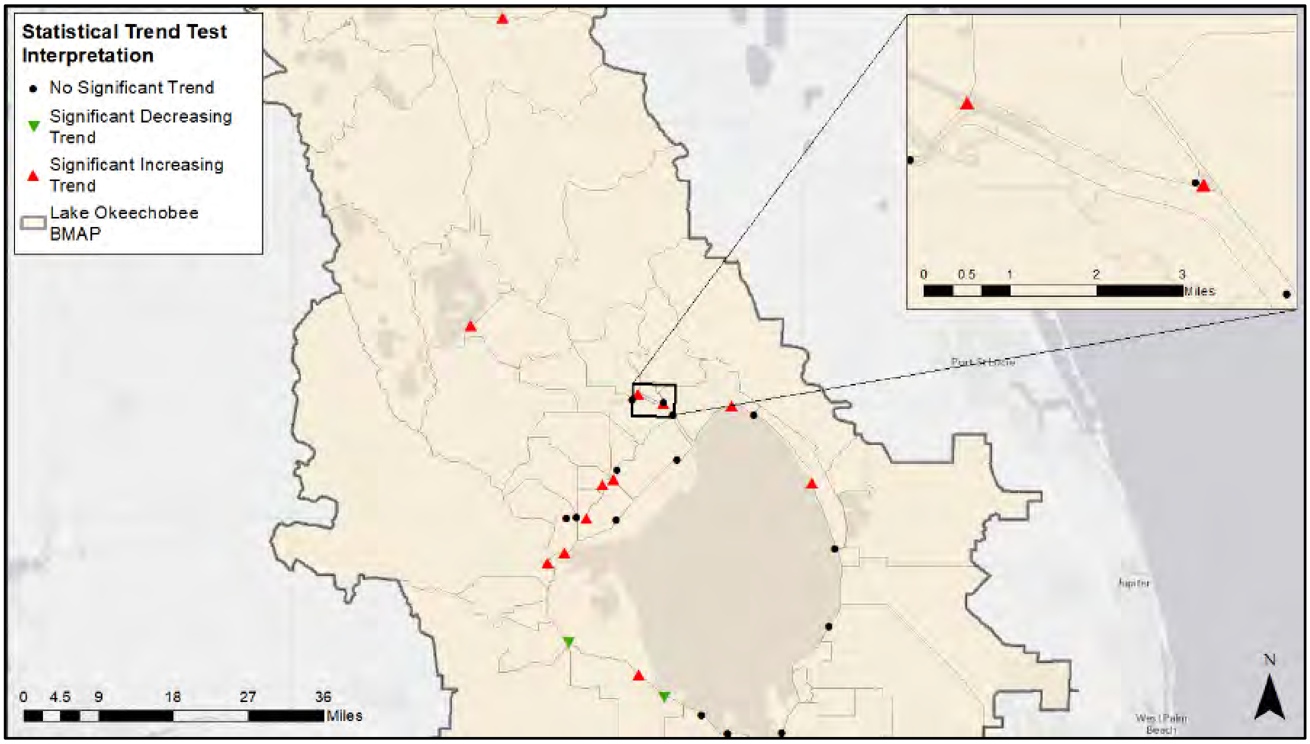

Figure 4. Tier 1 stations monthly TP load analysis

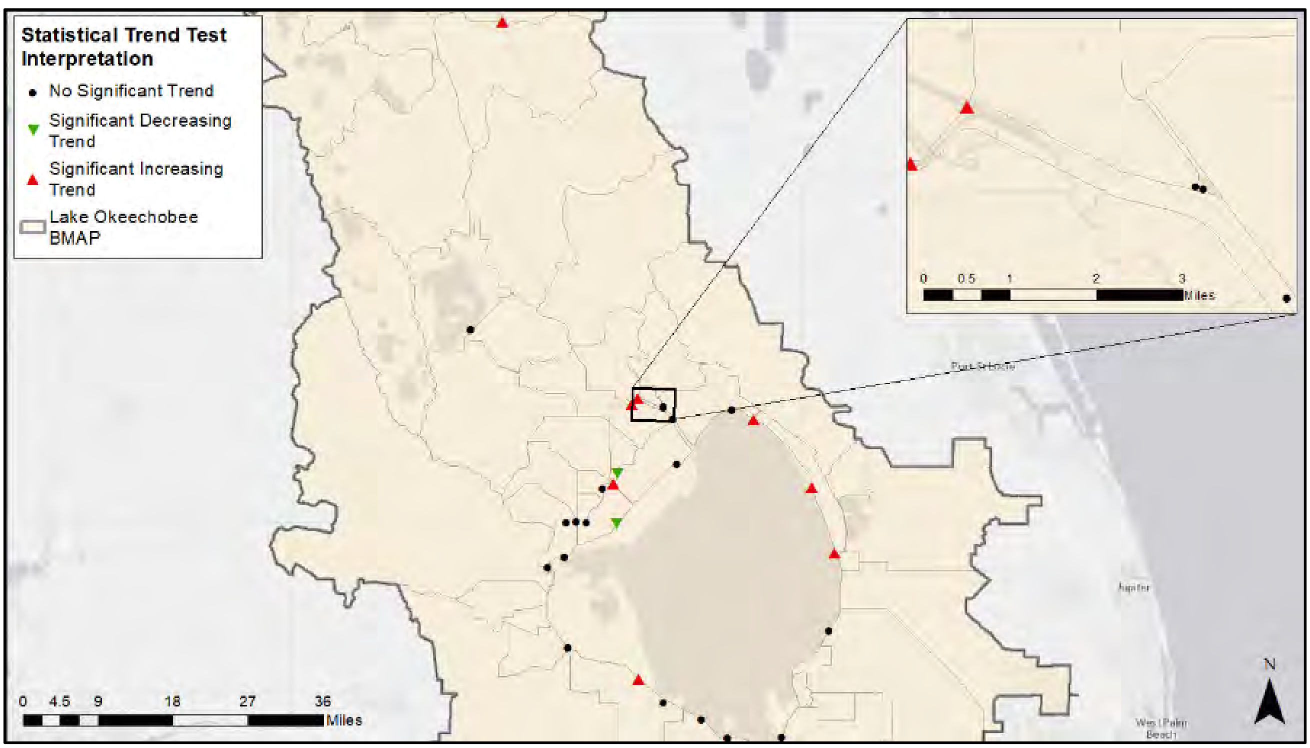

Figure 5. Tier 1 stations monthly TP FWM analysis

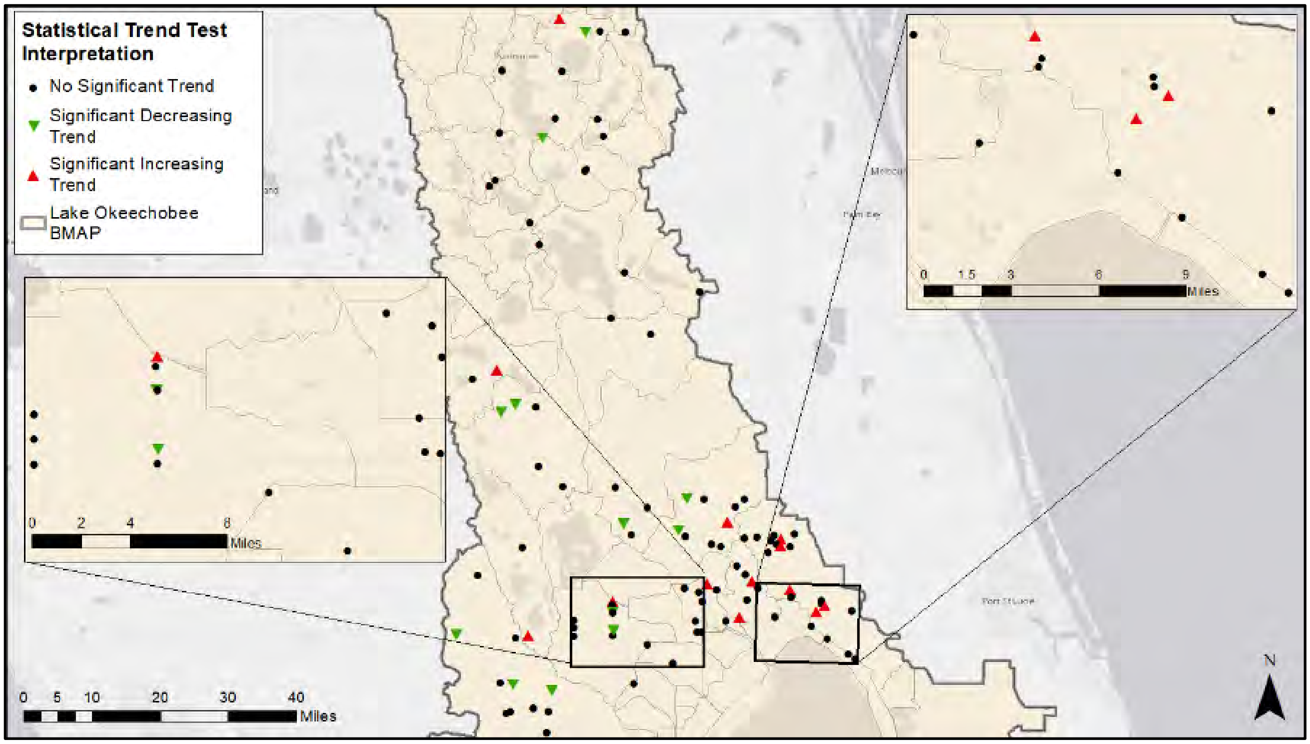

Figure 6. Tier 2 stations monthly TP concentration analysis

2.5. 5-Year Review Conclusions

2.5.1. Milestones

The 5-Year Review documents progress and allows for stakeholder involvement in the methods of assessing progress and revising the BMAP as appropriate. The projects and activities in the BMAP are key to reducing TP in the watershed and lake. The estimated benefits of these implemented activities should be tracked to show stakeholder efforts by determining a percentage towards the total required reductions to be achieved at each milestone.

Agricultural nonpoint sources are the predominant contributor of TP loading to Lake Okeechobee. Attainment of the TMDL is largely contingent upon addressing the agricultural loading to the lake. The Lake Okeechobee BMAP was originally adopted in December 2014, and many agricultural producers have enrolled and are implementing BMPs. However, enrollment still falls well short of the full enrollment requirement under law, and for those producers that have enrolled, onsite verification of BMP implementation is insufficient. This insufficiency in agricultural BMP enrollment and implementation verification is a constraint to achieving the TMDL in 20 years, and to address this constraint it is paramount that FDACS carries out its statutory authority and fulfills its statutory obligations by more actively engaging agricultural nonpoint sources to enroll in BMPs and by adequately verifying BMP implementation. FDACS has requested funding for additional positions to enable it to ensure full BMP enrollment and implementation verification.

In addition to completing agricultural BMP enrollment and implementation, to reach the TMDL in 20 years, stakeholders must submit additional local projects and the Coordinating Agencies (DEP, FDACS, and SFWMD) must identify additional regional projects as well as determine the significant funding that will be necessary. Constraints to having this information available at this time include the need to determine appropriate locations, identify funding sources, design the projects, obtain funding, secure permits, and construct the projects.

Enhancements to programs addressing basinwide sources will also be required, as discussed in **Section 3.1**. In addition, the legacy phosphorus contribution in the watershed must be addressed through further studies and projects targeted at this source. The Coordinating Agencies will evaluate studies and assist with identifying projects targeted at reducing this source. Once this additional information is provided, the Coordinating Agencies will address these constraints and estimate the time needed to achieve the TMDL in a future BMAP update. Due to the fact that necessary local and regional nutrient reduction projects are still being identified, and as a result of insufficient agricultural BMP enrollment, BMP implementation verification, and other management strategies, it does not seem practicable to achieve reductions sufficient to meet the TMDL within 20 years. Until these deficiencies and constraints are addressed, DEP is unable to decisively determine when the TMDL will be achieved.

The following percent reduction goals are proposed for each milestone and may be adjusted as more information is obtained and constraints are addressed:

- 5-year milestone (Years 1 to 5, including projects completed after January 1, 2009): 15 % or 163,032 lbs/yr (74.0 mt/yr) TP.
- 10-year milestone (Years 6 to 10): 40 % or 434,752 lbs/yr (197.2 mt/yr) TP. Based on study results, reset 15-year, 20-year, and future 5-year milestones, as needed.
- 15-year milestone (Years 11 to 15): 75 % or 815,159 lbs/yr (369.7 mt/yr) TP.
- 20-year milestone (Years 16 to 20): 100 % or 1,086,879 lbs/yr (493.0 mt/yr) TP.

Figure 7 shows the 5-, 10-, 15-, and 20-year milestones as well as the cumulative TP reductions over time as projects are completed in each reporting period.

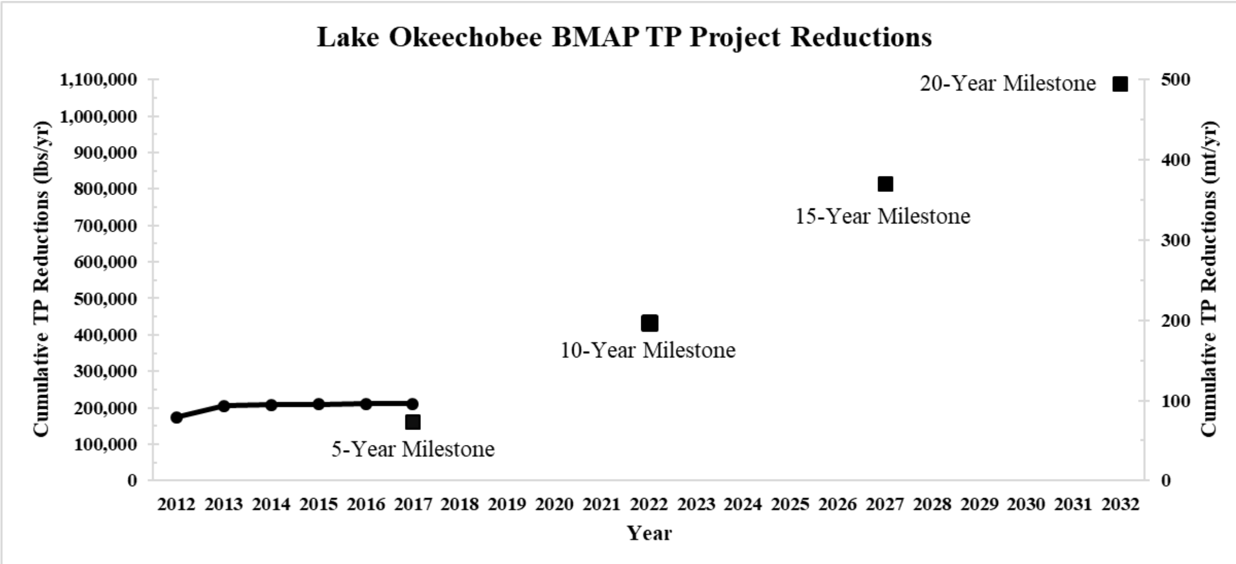

Figure 7. Estimated progress towards the Lake Okeechobee BMAP TP milestones with projects completed through June 30, 2019

2.5.2. New Project Approach

Land uses in the LOW are predominately agricultural, and a new approach is needed to solicit projects and ideas to achieve nutrient reductions throughout the watershed. **Chapter 3** includes proposed measures to address the sources in the LOW, as well as the new approach used to carry out some of the projects included in this BMAP.

Chapter 3. Restoration Approach

3.1. Basinwide Sources Approach

3.1.1. Agriculture

When DEP adopts a BMAP that includes agriculture, it is the agricultural landowner's responsibility to implement BMPs adopted by FDACS to help achieve load reductions or demonstrate through monitoring that they are already meeting water quality standards. FDACS is responsible for verifying that all eligible landowners are enrolled in appropriate BMP programs, and within one year of the adoption of this BMAP, DEP needs FDACS to provide a list of all unenrolled landowners in the LOW with their enrollment status. DEP also needs FDACS to perform regular onsite inspections of all agricultural operations enrolled under a BMP manual to ensure that these practices are being properly implemented. Ideally, these inspections would occur at least every two years. From these inspections, FDACS will provide DEP and SFWMD an annual summary of aggregated fertilizer use in the BMAP area, quantifying total applications and providing information on application reductions by subwatershed. FDACS has requested funding for additional positions to enable it to undertake these activities at least every two years.

Although it is anticipated that additional enrollment in agricultural BMPs along with more frequent implementation verification site visits by FDACS will increase nutrient reductions from agricultural nonpoint sources, it is also recognized that further reductions, beyond the implementation of required owner-implemented BMPs, will be necessary to achieve the TMDL. As such, pursuant to Subsection 373.4595(3), F.S., FDACS has committed to updating its existing BMP manuals to incorporate updated BMPs based on the latest scientific and technical research. To expedite further reductions DEP needs these updates to occur no more than five years from adoption of this BMAP.

Further nutrient reductions can be achieved through implementation of additional agricultural projects or activities. The Coordinating Agencies will continue to collaborate to identify cost-share practices and other projects that can be undertaken to achieve these nutrient reductions and identify and implement additional projects and practices in priority TRAs.

SFWMD is implementing projects that encourage low-input agriculture and water quality improvement technologies. FDACS also provides funding to some agricultural operations to add other practices beyond owner-implemented BMPs. Examples include drainage improvements, fencing, water control structures, precision agriculture technology, and fertigation. The Coordinating Agencies will also investigate the possibility of implementing other incentive-based programs—such as providing incentives for producers to transition to less-intensive crops, changing land use to fallow or native landscape, or changing the type of cropping system–that would reduce nutrient loading in the BMAP area.

Other reductions associated with the implementation and modification of BMPs may be realized through ongoing studies, data collection, and water management district initiatives. These additional projects and activities are to be implemented in conjunction with the BMP Program, which needs to achieve full enrollment with verification to ensure that the BMAP goals are achieved.

3.1.2. Septic Systems

In U.S. Census–designated urbanized areas and urban clusters, local governments and utilities will develop master wastewater treatment feasibility analyses that include provisions to address loads from existing and new septic systems (e.g., sewering, advanced septic system retrofits, prohibiting the installation of new conventional septic systems). The analyses must identify specific areas to be sewered within 20 years of BMAP adoption. Sources of funding to address nutrient loading from septic systems will also be identified in the analyses. The feasibility analyses will be completed and submitted to DEP within 3 years of BMAP adoption, so that the analyses can inform the selection of management strategies and projects as part of the next 5-year review of the BMAP.

Based on data from FDOH, there are 124,176 known and likely septic systems located throughout the LOW. Of these, 93,827 are located within U.S. Census (2010)–designated urbanized areas or urban clusters. The TN and TP estimated loads from septic systems in urbanized areas are summarized in **Table 18**. These loads were calculated based on 2014–2018 U.S. Census Bureau data for the average number of people per household for each county in the LOW with an estimated wastewater flow of 70 gallons per day per person and TN and TP nutrient concentrations in the effluent from the EPA *Onsite Wastewater Treatment Systems Manual* (2002). This resulted in an average effluent load leaving the septic system of 15 lbs/yr of TN and 1.5 lbs/yr of TP per septic system. The reductions from addressing these septic systems will be less than the estimated load depending on how they are addressed (i.e., connecting to central sewer sends the wastewater to a treatment facility, which does not remove 100 % of the nutrient load). This effluent load will also attenuate as it travels through the watershed to Lake Okeechobee, so the benefits at the lake will be lower than these effluent loads. Furthermore, stakeholders will submit projects describing how septic loads are addressed as part of BMAP reporting.

Table 18. Septic system counts by subwatershed and estimated effluent loads

Subwatershed	Total Number of Septic Systems	Number of Septic Systems in the Urbanized Areas and Urban Clusters	Estimated TN Load from Urbanized Septic Systems (lbs/yr)	Estimated TP Load from Urbanized Septic Systems (lbs/yr)
Fisheating Creek	467	3	20,574	1,990
Indian Prairie	2,095	129	39	4
Lake Istokpoga	30,787	23,132	278,139	26,899
Lower Kissimmee	924	0	0	0
Taylor Creek/Nubbin Slough	11,085	7,577	377,387	36,498
Upper Kissimmee	61,264	48,746	469,866	45,442
East Lake Okeechobee	12,562	11,339	13,330	1,289
South Lake Okeechobee	2,293	869	177,199	17,137
West Lake Okeechobee	2,699	2,032	125,086	12,097
Total	**124,176**	**93,827**	**1,461,619**	**141,356**

3.1.3. Stormwater

Stormwater from urban areas is a considerable source of nutrient loading to Lake Okeechobee, and many of these areas are already regulated under the NPDES Stormwater Program. MS4 permittees are required to develop and implement a stormwater management program. Urban areas located in the BMAP area that are not currently covered by an MS4 permit also significantly contribute, individually or in aggregate, to nutrient loading. Therefore, the NPDES Stormwater Program will, within five years of BMAP adoption, evaluate any entity located in the BMAP area that serves a minimum resident population of at least 1,000 individuals that are not currently covered by an MS4 permit and designate eligible entities as regulated MS4s, in accordance with Chapter 62-624, F.A.C.

DEP and the water management districts are planning to update the stormwater design and operation requirements in Environmental Resource Permit rules. These revisions will incorporate the most recent scientific information available to improve nutrient reduction benefits.

3.1.4. Wastewater Treatment

DEP issues permits for facilities and activities to discharge wastewater to surface waters and ground waters of the state. DEP is authorized by the EPA to issue permits for discharges to surface waters under the NPDES Program. Permits for discharges to ground waters are issued by DEP under state statutes and rules. These wastewater discharge permits establish specific limitations and requirements based on the location and type of facility or activity releasing industrial or domestic wastewaters from a point source.

New and existing domestic wastewater facilities and their associated rapid-rate land applications (RRLAs) and reuse activities, must meet the stringent nutrient wastewater limitations set forth in this BMAP. Any such new facilities, their RRLAs, and reuse activities (those commencing after the adoption of this BMAP) must be capable of meeting the requirements of this BMAP at the time of permit issuance. For existing domestic wastewater facilities and their associated RRLAs and reuse activities, DEP shall modify the permit limitations and requirements to be consistent with this BMAP at the time of the next permit renewal. In some cases, the owner or operator may require additional time to meet the modified limitations in the renewed permit, in which case, the permit may also establish a compliance schedule not to exceed four and half years after the effective date of the permit.

In areas where there is anticipated growth in human population, adequate treatment capacity of domestic wastewater is essential. Domestic wastewater is treated through either WWTFs or onsite sewage treatment and disposal systems (OSTDS), commonly referred to as septic systems. Where sewer lines are available, Florida law (Section 381.00655, F.S.) requires a development or property owner to abandon the use of OSTDS and connect to sanitary sewer lines.

This BMAP requires all individually permitted domestic wastewater facilities and their associated RRLAs and reuse activities to meet the effluent limits listed in **Table 19** and **Table 20**, unless the owner or operator can demonstrate reasonable assurance that the effluent would not cause or contribute to an exceedance of the TMDLs or water quality standards. To demonstrate reasonable assurance, the owner or operator must provide relevant water quality data, physical circumstances, or other site-specific credible information needed to show the facility would not cause or contribute to the nutrient loading to the BMAP area. This demonstration may include factors such as dilution; site-specific geological conditions; research/studies, including dye tracer tests; and modeling. Should DEP concur with the reasonable assurance demonstration request, the effluent requirements established here may be modified for the owner or operator or waived. New effluent standards will take effect at the time of permit issuance.

Table 19 and **Table 20** list the TP and TN effluent limits, respectively, adopted for this BMAP that apply to domestic wastewater facilities and their RRLAs and reuse activities, unless the owner or operator can demonstrate reasonable assurance as listed above. The limits for direct surface discharges apply to individually NPDES-permitted facilities. The limits for RRLA effluent disposal systems apply at the compliance well located at the edge of the zone of discharge for domestic wastewater facilities, RRLAs, or reuse activities having sites such as rapid infiltration basins and absorption fields. The limits for all domestic wastewater discharges not addressed by the direct surface discharge and RRLA limits are specified in the last column of the tables. These limits are applied as an annual average.

Short-term or intermittent discharges are not significant sources of TN or TP in the LOW, and are not subject to the limits in **Table 19** and **Table 20.** Intermittent, rainfall-driven, diffuse overflow releases of wastewater from ponds or basins designed to hold precipitation from a 25-year**,** 24-hour rainfall event or less frequent rainfall event and that infrequently reaches surface waters are considered insignificant sources of TN and TP. The owners or operators of cooling pond reservoirs must operate each spillway gate either during regular operation or on a test basis to protect the structural integrity of the reservoir. Because of the short duration and low volume of wastewater released during spillway gate testing, releases either on an annual or semi-annual basis are considered insignificant sources of TN and TP.

As of December 2019, there were 254 individually permitted wastewater facilities or activities in the BMAP area. Of these, 26 hold NPDES permits and therefore are authorized, within the limitations of their permits, to discharge directly to surface waters within the LOW. The remaining 228 do not have authorization to discharge directly to surface waters.

Additionally, new or renewed wastewater permits in the BMAP area must require at least quarterly sampling of the effluent discharge at the point of discharge or edge of mixing zone for TP and TN and the reporting of sampling results in the discharge monitoring reports submitted to DEP.

Table 19. TP effluent limits

mgd = Million gallons per day

Permitted Average Daily Flow (mgd)	TP Concentration Limits for Direct Surface Discharge (mg/L)	TP Concentration Limits for RRLA Effluent Disposal System (mg/L)	TP Concentration Limits for All Other Disposal Methods, Including Reuse (mg/L)
Greater than or equal to 0.5	1	1	6
Less than 0.5 and greater than or equal to 0.1	1	3	6
Less than 0.1	6	6	6

Table 20. TN effluent limits

mgd = Million gallons per day

Permitted Average Daily Flow (mgd)	TN Concentration Limits for Direct Surface Discharge (mg/L)	TN Concentration Limits for RRLA Effluent Disposal System (mg/L)	TN Concentration Limits for All Other Disposal Methods, Including Reuse (mg/L)
Greater than or equal to 0.5	3	3	10
Less than 0.5 and greater than or equal to 0.1	3	6	10
Less than 0.1	10	10	10

3.2. TRA Approach

3.2.1. Overview

To better prioritize and focus resources to most efficiently achieve restoration in the LOW, DEP developed the TRA approach. This approach used measured data collected throughout the watershed to evaluate TP and TN concentrations, as well as flow, in the basins in each of the LOW subwatersheds. The measured nutrient concentrations were compared with selected benchmarks to identify those basins that should be the highest priority for restoration. This advisory process is not intended to be a management strategy under Chapter 403.067, F.S. The benchmarks are not intended to measure progress towards restoration; they were only used to prioritize resources. The overall approach implemented the following steps:

1. **Identify smaller areas (e.g., basins) for focused restoration.**
2. **Delineate each area and locate relevant water quality stations:**
    a. Obtain existing data for TN, TP, and flow.
    b. Recommend additional monitoring where data are lacking.
    c. Supplement with information from water quality models where appropriate.

3. **Determine benchmarks for evaluating water quality and water storage:**
    a. Consider the applicable numeric nutrient criteria (NNC) (e.g., peninsular for streams) and consult the LOWCP for indications of water quality and/or flow issues.
    b. Rely on existing SFWMD information for water storage needs.
4. **Review measured data:**
    a. Calculate most recent 5-year average TN and TP concentrations (WY2014–WY2018).
    b. Compare concentrations with established benchmarks.
    c. Consult FWM concentrations and unit area loads, where available, to better understand conditions.
5. **Identify criteria for implementation and funding, and describe restoration types (e.g., water quality, flow) recommended for each TRA:**
    a. Calculate expected reductions from existing and recommended projects using measured data wherever possible.
    b. Identify where additional projects are necessary.
6. **Prioritize areas where new projects would have the most impact on overall restoration:**
    a. Use water quality (TN and TP) and flow data.
    b. Compare with benchmarks for each basin,
7. **Publish an RFI to solicit additional projects and evaluate responses based on benchmarks established for each TRA.**

Chapter 4 includes the results of the TRA approach for each of the subwatersheds and the lake itself. **Table E-1** in **Appendix E** lists the projects received from the RFI.

Future steps in this approach include the following:

- Evaluate progress in TRAs annually by comparing measured data with benchmarks and TMDL targets for the subwatersheds.
- Use responses from RFIs and existing project lists, combined with the prioritized areas and recommended restoration needs, to inform future budget requests for DEP.
- Update existing water quality models based on expanded monitoring efforts.

3.2.2. Evaluation

Chapter 4 summarizes the results of the TRA evaluation process for the basins in each subwatershed of the LOW. For each basin, a priority was assigned based on the TP concentration, TN concentrations, and flows. These priorities were set to help focus resources and projects in the basins that are in most need of improvement. Basins were assessed and prioritized as follows (see **Figure 8**):

1. **Assess the five-year average concentration at representative stations and compare with the NNC benchmark:**
   a. Priority 1: Concentration is two times greater than the NNC.
   b. Priority 2: Concentration is greater than the NNC but less than two times the NNC.
   c. Priority 3: Concentration is less than or equal to the NNC.
2. **Assess the five-year average FWM concentration and compare with the NNC benchmark. This step is weighted above Step 1; therefore, the results for the FWM concentrations would supersede the priorities from Step 1:**
   a. Priority 1: FWM concentration is two times greater than the NNC.
   b. Priority 2: FWM concentration is greater than the NNC but less than two times the NNC.
   c. Priority 3: FWM concentration is less than or equal to the NNC.
3. **Assess the attenuated unit area load (UAL), which is the average load per acre in each subwatershed from the LET, and compare it with the subwatershed UAL calculated target (derived from the loading in the final *2019 SFER – Volume I, Chapter 8B*. and the subwatershed targets described in Section 5.4). This step is weighted above Step 2 where data are available; therefore, results would increase or decrease the priority accordingly:**
   a. Priority increases: UAL is greater than 50 % above the subwatershed target UAL.
   b. Priority decreases: UAL is less than the subwatershed target UAL.
   c. Priority remains unchanged: UAL is above the subwatershed target UAL, but less than 50 %.
4. **Assess the water quality trends from the water quality analysis (Section 2.4) for statistical significance. This step is weighted above Step 3 where data are available; therefore, the results would increase or decrease the priority accordingly:**
   a. Priority increases: Trend is significantly increasing.

b. Priority decreases: Trend is significantly decreasing.

c. Priority remains unchanged: No significant trend is detected.

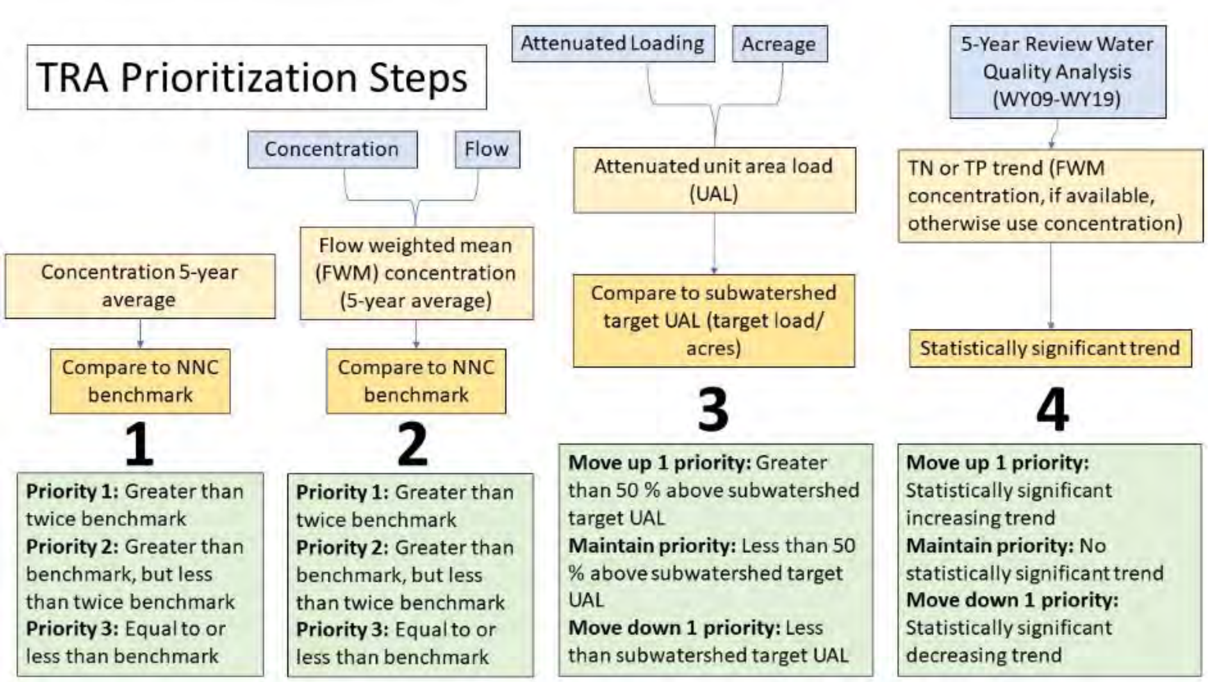

Figure 8. Summary of the TRA prioritization process

3.3. Water Quality Monitoring Plan

To help prioritize monitoring and track BMAP progress, the BMAP monitoring network is being revised, as discussed below, to implement a new tiered system for the sampling stations, remove some stations from the network, and add new monitoring locations.

3.3.1. Objectives and Parameters

The Lake Okeechobee BMAP monitoring plan was designed to enhance the understanding of basin loads, identify areas with high nutrient concentrations, and track water quality trends. The information gathered through the monitoring plan measures progress toward achieving the TMDLs and provides a better understanding of watershed loading. The BMAP monitoring plan consists of ambient water quality sampling, sampling at discharge structures, and flow monitoring.

Focused objectives are critical for a monitoring strategy to provide the information needed to evaluate implementation success. The primary and secondary objectives of the monitoring strategy for the LOW, described below, are used to evaluate the success of the BMAP, help interpret the data collected, and provide information for potential future refinements of the BMAP.

Primary Objective

- To continue to track trends in TP loads and concentrations by subwatershed and basin.

Secondary Objectives

- To continue to track trends in TN loads and concentrations by subwatershed and basin.
- To continue to identify areas in the watershed with elevated TP and TN loading to better focus management efforts.
- To continue to measure the effectiveness of individual or collective projects in reaching TMDL target-pollutant loadings.

To achieve the objectives above, the monitoring strategy focuses on the following suggested parameters:

- Alkalinity.
- Ammonia (N).
- BOD.
- Carbon – Organic.
- Carbon – Total.
- Chlorophyll a.
- Color.
- DO.
- DO Saturation.
- Flow.
- Nitrate-Nitrite (N).
- Nitrogen – Total Kjeldahl.
- Nitrogen – Total.
- Orthophosphate (P)
- pH.
- Phosphorus – Total.
- Specific Conductance/ Salinity.
- Temperature, Water.
- Total Suspended Solids.
- Turbidity.

3.3.2. Monitoring Network

The monitoring network comprises a tiered system for the sampling stations, as follows:

- Tier 1 stations are the primary/priority stations used in periodic water quality analyses to track BMAP progress and water quality trends over the long term in the basin. Tier 1 stations consist of only SFWMD water control structure stations that measure water quality and flow at each station. These stations will be used to calculate annual TP and TN loads for each subwatershed or basin.

- Tier 2 stations will provide secondary information that can be used to help focus and adaptively manage implementation efforts. These include SFWMD ambient stations, which are mostly open-water stations, and do not record flow data. Tier 2 also includes the monitoring associated with the Lake Tohopekaliga Nutrient Reduction Plan (NRP) (CDM 2011).

- Tier 3 consists of U.S. Geological Survey (USGS) gauges where flow and/or stage are monitored.

Figure 9 shows the stations included in each of these tiers. In addition to monitoring throughout the LOW, various agencies also sample stations in Lake Okeechobee. **Chapter 4** includes additional information about the BMAP monitoring network and stations used in the TRA process.

3.3.3. Data Management and Quality Assurance/Quality Control (QA/QC)

The STOrage and RETrieval (STORET) Database served as the primary repository of ambient water quality data for the state until DEP transitioned to WIN in 2017. BMAP data providers have agreed to upload ambient water quality data at least once every six months on the completion of the appropriate QA/QC checks and have begun uploading data to WIN instead of STORET. Data must be collected following DEP standard operating procedures, and the results must be analyzed by a National Environmental Laboratory Accreditation Program–certified laboratory.

In addition to ambient water quality data, flow data are used to track loading trends for the BMAP. Data collected by USGS are available through its website, and some flow data are also available through the SFWMD corporate environmental database, DBHYDRO.

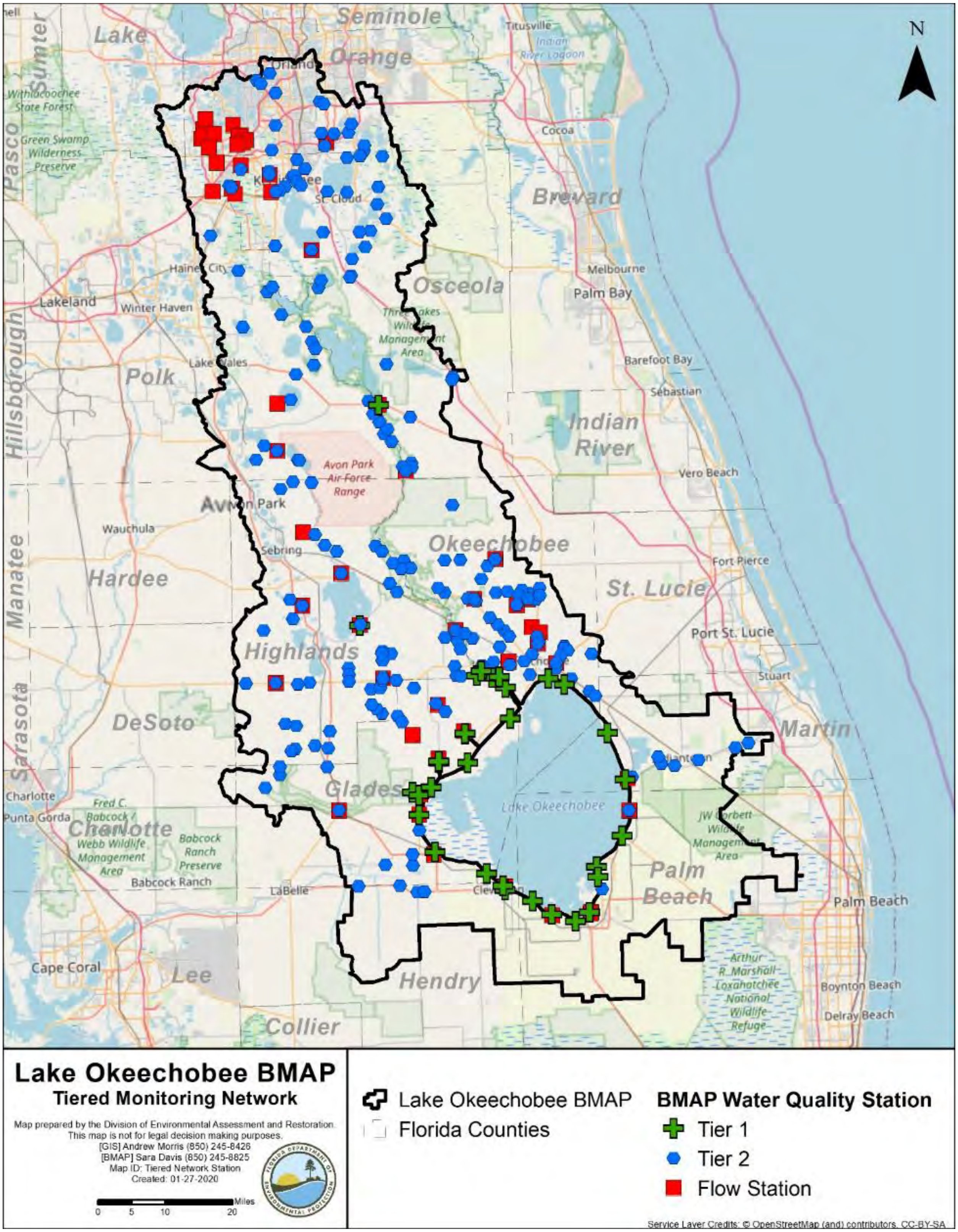

Figure 9. Lake Okeechobee BMAP monitoring network

Chapter 4. Subwatersheds

Section 4.1 through **Section 4.10** provide specific information on the nine subwatersheds and within Lake Okeechobee. The land use summaries are based on the 2009 land use in WAM, and **Appendix B** provides additional details on agricultural land uses. Monitoring network stations in the subwatershed or the lake are provided along with designations for the basin where the station is located, monitoring entity, BMAP monitoring network tier, whether the station is a representative site for the TRA approach discussed in **Section 3.2**, and whether additional data are needed for the TRA approach in that basin or at that station. The TN, TP, and flow priority results of the TRA evaluation are provided for basins in each subwatershed. Finally, all projects identified as part of this BMAP update are provided by subwatershed. The table of existing and planned projects lists those projects submitted by stakeholders to help meet their obligations under the BMAP. Future projects have been identified by stakeholders to help meet the remaining reductions needed; however, many of these projects are conceptual, in early design stages, or have not been fully funded. Information in the tables was provided by the lead entity and is subject to change as the project develops and more information becomes available. **Appendix E** lists projects and technologies submitted as part of the RFI.

DEP will also be monitoring and working to achieve the subwatershed targets identified in **Table 21**. DEP will use this information to identify problem areas and sources that are not meeting the target, acknowledge them through annual reporting and public engagement, and focus resources accordingly (i.e., regulatory programs through permitting decisions, compliance and enforcement, and nutrient reduction projects).

Table 21. Load reductions and targets by subwatershed

Subwatershed	WY2014–WY2018 TP Load (mt/yr)	% Contribution of Load	TP Load Required Reduction (mt/yr)	TP Target (mt/yr)
Fisheating Creek	72.4	12	59.7	12.7
Indian Prairie	102.5	17	84.5	18.0
Lake Istokpoga	47.7	8	39.3	8.4
Lower Kissimmee	125.9	21	103.8	22.1
Taylor Creek/Nubbin Slough	113.6	19	93.7	19.9
Upper Kissimmee	90.5	15	74.6	15.9
East Lake Okeechobee	16.8	3	13.9	2.9
South Lake Okeechobee	29.0	5	23.9	5.1
West Lake Okeechobee	0.0	0	0.0	0.0
Total	**598.4**	**100**	**493.4**	**105.0**

4.1. Fisheating Creek Subwatershed

The Fisheating Creek Subwatershed covers more than 318,000 acres of the LOW and comprises 2 basins. As shown in **Table 22**, agriculture makes up the majority of the subwatershed with 54.7 % of the area, followed by wetlands with 23.8 %. Stakeholders in the Fisheating Creek Subwatershed are Glades County and Highlands County.

Table 22. Summary of land uses in the Fisheating Creek Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	5,581	1.8
2000	Agriculture	174,019	54.7
3000	Upland Nonforested	14,163	4.5
4000	Upland Forests	45,809	14.4
5000	Water	1,050	0.3
6000	Wetlands	75,623	23.8
7000	Barren Land	1,025	0.3
8000	Transportation, Communication, and Utilities	774	0.2
	Total	**318,044**	**100.0**

4.1.1. Water Quality Monitoring

In the Fisheating Creek Subwatershed, the BMAP monitoring network includes water quality stations in both of the basins. **Table 23** summarizes the water quality monitoring stations in the subwatershed, and **Figure 10** shows the station locations. **Table 23** also includes indications of which stations have recently been added as part of SFWMD expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the station to better align with the BMAP.

Table 23. Water quality monitoring stations in the Fisheating Creek Subwatershed

[1] Water quality data are collected by SFWMD and flow data are collected by USGS at these stations.

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Fisheating Creek/L-61	No	SFWMD	L61W	1	Not applicable (N/A)
Fisheating Creek/L-61	Yes	SFWMD	FECSR78	1	Sufficient TN and TP data
Nicodemus Slough North	Yes	SFWMD	CULV5	1	Sufficient TN and TP data
Fisheating Creek/L-61	No	SFWMD/ USGS	02255600[1]	2	N/A
Fisheating Creek/L-61	No	SFWMD/ USGS	02256500[1]	2	N/A
Fisheating Creek/L-61	No	SFWMD	BH04392912	2	N/A
Fisheating Creek/L-61	No	SFWMD	BH32382914	2	N/A
Fisheating Creek/L-61	No	SFWMD	FE03382911	2	N/A
Fisheating Creek/L-61	No	SFWMD	FE20393013	2	N/A
Fisheating Creek/L-61	No	SFWMD	FE21392913	2	N/A
Fisheating Creek/L-61	No	SFWMD	FE21392914	2	N/A
Fisheating Creek/L-61	No	SFWMD	FE26362812	2	N/A
Fisheating Creek/L-61	No	SFWMD	FE29403212	2	Proposed station as part of SFWMD expanded monitoring
Fisheating Creek/L-61	No	SFWMD	FE32372814	2	N/A
Fisheating Creek/L-61	No	SFWMD	GA09393011	2	N/A
Fisheating Creek/L-61	No	SFWMD	GG05403011	2	N/A
Fisheating Creek/L-61	No	SFWMD	GT07402911	2	Proposed station as part of SFWMD expanded monitoring

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Fisheating Creek/L-61	No	SFWMD	HS06402911	2	Proposed station as part of SFWMD expanded monitoring
Fisheating Creek/L-61	No	SFWMD	PB24392912	2	N/A
Fisheating Creek/L-61	No	SFWMD	RS23402811	2	Proposed station as part of SFWMD expanded monitoring
Fisheating Creek/L-61	No	USGS	02255600[1]	3	N/A
Fisheating Creek/L-61	No	USGS	02256500[1]	3	N/A
Fisheating Creek/L-61	No	USGS	02257000	3	N/A
Nicodemus Slough North	No	USACE	CULV5	3	N/A

Figure 10. Locations of the water quality monitoring stations in the Fisheating Creek Subwatershed

4.1.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the Fisheating Creek Subwatershed is 72.4 mt/yr. A reduction of 59.7 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 12.7 mt/yr.

Table 24 summarizes the basin evaluation results for the Fisheating Creek Subwatershed. Both basins in the subwatershed have TN concentrations greater than the benchmark. The Fisheating Creek/L-61 Basin also has TP concentrations above the benchmark. Based on evaluations made by SFWMD in the LOWCP update, flow was determined not to be an issue in the Nicodemus Slough North Basin but may be an issue in the Fisheating Creek/L-61 Basin. **Table 25** lists the TRA prioritization results for the Fisheating Creek Subwatershed**,** with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 24. Basin evaluation results for the Fisheating Creek Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL, pounds per acre (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
3	Nicodemus Slough North	1.61	2.01	0.32	Insufficient Data	0.07	0.05	0.02	Insufficient Data	No
4	Fisheating Creek/L-61	1.79	1.47	1.32	No Significant Trend	0.17	0.18	0.33	Significant Increasing	Maybe

Table 25. TRA evaluation results for the Fisheating Creek Subwatershed

Basin	Station	TP Priority	TN Priority	Flow Priority
Fisheating Creek/L-61	FECSR78	1	1	2
Nicodemus Slough North	CULV5	3	1	3

4.1.3. Projects

The sections below summarize the existing and planned and future projects for the Fisheating Creek Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.1.3.1. Existing and Planned Projects

Table 26 summarizes the existing and planned projects provided by the stakeholders for the Fisheating Creek Subwatershed.

Table 26. Existing and planned projects in the Fisheating Creek Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual Operations and Maintenance (O&M)	Funding Source	Funding Amount	DEP Contract Agreement Number
Coordinating Agency	N/A	CA-06	Legislative Cost-Share Appropriation Program (Dairy Projects)	FDACS conducted 3 rounds of solicitations for dairy project proposals. First solicitation was in fall 2014; 7 projects were funded, of which 1 is still under construction. Second solicitation for dairy projects occurred in fall 2015.	Dairy Remediation	Underway	To be determined (TBD)	TBD	TBD	TBD	TBD	Fisheating Creek/L-61	TBD	Not provided	Not provided	FDACS	Not provided	N/A
Coordinating Agency	Natural Resources Conservation Service (NRCS)	CA-12	PL-566 Funded/ Fisheating Creek Structure	NRCS began wetland restoration work on Phase I (~10,000 acres) of Fisheating Creek project in 2019; this phase is expected to be completed in 2020. NRCS received SFWMD permit to initiate work on remaining acres (~24,000) in 2020. NRCS has committed $14 million to restoration project and by mid-2020 should have idea whether that will be enough to also address water control structure.	Control Structure	Planned	TBD	TBD	TBD	1,888.6	0.86	Fisheating Creek/L-61	TBD	$14,000,000	TBD	NRCS	$14,000,000	N/A
FDACS	Private Landowner	FDACS-04	Fisheating Creek	Floating aquatic vegetation treatment.	Floating Islands/ Managed Aquatic Plant System (MAPS)	Completed	2016	10,242.6	4.65	1,981.5	0.90	Fisheating Creek/L-61	45,000	$3,311,070	$1,435,790	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-07	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – Fisheating Creek. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	59,236.0	26.87	6,096.8	2.77	Fisheating Creek	171,662	TBD	TBD	FDACS	TBD	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual Operations and Maintenance (O&M)	Funding Source	Funding Amount	DEP Contract Agreement Number
FDACS	Agricultural Producers	FDACS-16	Cost-Share Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	9,125.6	4.14	1,688.3	0.77	Fisheating Creek	37,797	TBD	TBD	FDACS	TBD	N/A
Glades County	N/A	GC-01	Education and Outreach	Florida Yards and Neighborhoods (FYN); landscaping, irrigation, and fertilizer ordinances; public service announcements (PSAs), pamphlets, website, and illicit discharge program.	Education Efforts	Completed	N/A	361.7	0.16	15.9	0.01	Fisheating Creek/L-61, Nicodemus Slough North	2,241.2	Not provided	$5,500	Glades County	Not provided	N/A
Highlands County	University of Florida Institute of Food and Agricultural Sciences (UF–IFAS)	HC-01	Education and Outreach	FYN, landscaping and irrigation ordinances, PSAs, and pamphlets.	Education Efforts	Completed	N/A	2,056.2	0.93	49.6	0.02	Fisheating Creek/L-61	5,171.9	Not provided	Not provided	Highlands County	Not provided	N/A
SFWMD	N/A	SFWMD-18	XL Ranch (Lightsey)	Storage of 887 ac-ft of water through above-ground impoundment and pasture.	DWM (dispersed water management)	Completed	2012	TBD	TBD	278.0	0.13	Fisheating Creek/L-61	3,227.0	$61,396	$137,000	Florida Legislature	Florida Legislature – $137,000	N/A
SFWMD	N/A	SFWMD-20	La Hamaca (Blue Head Ranch)	Storage of 3,462 ac-ft of water through pasture.	DWM	Completed	2017	TBD	TBD	1,867.8	0.85	Fisheating Creek/L-61	5,020.0	$193,750	$361,200	Florida Legislature	Florida Legislature – $361,200	N/A
SFWMD	N/A	SFWMD-21	Nicodemus Slough	Storage of 33,860 ac-ft of water through above-ground impoundment and pasture.	DWM	Completed	2015	TBD	TBD	19,674.1	8.92	Nicodemus Slough North	15,906.0	$4,900,000	$2,500,000	Florida Legislature	Florida Legislature – $2,500,000	N/A

4.1.3.2. Future Projects

Table 27 lists the future projects provided by the stakeholders for the Fisheating Creek Subwatershed.

Table 27. Future projects in the Fisheating Creek Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Highlands County	Coordinating Agencies	F-01	Smart Fertilizer	Watershedwide ban on fertilizer use during certain portion of year for residential use.	Enhanced Public Education	Planned	TBD	TBD	TBD	TBD	TBD	Fisheating Creek/L-61	TBD	TBD
Highlands County	Coordinating Agencies	F-02	Happy Planters	Replanting grant for vegetation loss on waterbodies.	Creating/Enhancing Living Shoreline	Planned	TBD	TBD	TBD	TBD	TBD	Fisheating Creek/L-61	TBD	TBD
Coordinating Agency	N/A	F-03	Fisheating Creek Marsh Watershed Project	DWM.	DWM	Conceptual	TBD	TBD	TBD	6,287.6	2.85	Fisheating Creek/L-61	TBD	TBD
Coordinating Agency	N/A	F-04	Fisheating Creek	Alternative water storage and disposal interim project.	Stormwater Reuse	Conceptual	TBD	TBD	TBD	330.8	0.15	Fisheating Creek/L-61	TBD	TBD

4.2. Indian Prairie Subwatershed

The Indian Prairie Subwatershed covers more than 276,500 acres of the LOW and is made up of 11 basins. As shown in **Table 28**, agriculture makes up the largest portion of the subwatershed, with 79.9 % of the area, followed by wetlands with 12.1 %. Stakeholders in the Indian Prairie Subwatershed are Glades County, Highlands County, and IMWID.

Table 28. Summary of land uses in the Indian Prairie Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	5,201	1.9
2000	Agriculture	220,921	79.9
3000	Upland Nonforested	5,677	2.1
4000	Upland Forests	3,776	1.4
5000	Water	3,588	1.3
6000	Wetlands	33,602	12.1
7000	Barren Land	3,663	1.3
8000	Transportation, Communication, and Utilities	150	0.1
	Total	**276,578**	**100.0**

4.2.1. Water Quality Monitoring

In the Indian Prairie Subwatershed, the BMAP monitoring network includes water quality stations in all 11 of the basins. **Table 29** summarizes the water quality monitoring stations in the subwatershed, and **Figure 11** shows the station locations. **Table 29** also includes indications of which stations have recently been added as part of SFWMD expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the station to better align with the BMAP.

Table 29. Water quality monitoring stations in the Indian Prairie Subwatershed

[1] Water quality data are collected by SFWMD and flow data are collected by USGS at these stations

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
C-40	Yes	SFWMD	S72	1	Sufficient TN and TP data
C-41	Yes	SFWMD	S71	1	Sufficient TN and TP data
C-41A	Yes	SFWMD	S84	1	Sufficient TN and TP data
L-48	Yes	SFWMD	S127	1	Sufficient TN and TP data
L-49	Yes	SFWMD	S129	1	Sufficient TN and TP data
L-59E	No	SFWMD	C38W	1	N/A
L-59E	Yes	SFWMD	L59E	1	Sufficient TN and TP data
L-59W	No	SFWMD	G208	1	N/A
L-59W	Yes	SFWMD	L59W	1	Sufficient TN and TP data
L-60E	Yes	SFWMD	L60E	1	Sufficient TN and TP data
L-60W	Yes	SFWMD	L60W	1	Sufficient TN and TP data
L-61E	Yes	SFWMD	L61E	1	Sufficient TN and TP data
S-131	Yes	SFWMD	S131	1	Sufficient TN and TP data
In canal to lake	No	SFWMD	G207	1	N/A
C-40	No	SFWMD	IP09383232	2	N/A
C-40	No	SFWMD	IP24383214	2	N/A

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
C-40	No	SFWMD	IP29383313	2	Proposed station as part of SFWMD expanded monitoring
C-41	No	SFWMD	HP06393242	2	N/A
C-41	No	SFWMD	HP11373132	2	N/A
C-41	No	SFWMD	HP15373112	2	N/A
C-41	No	SFWMD	HP22373112	2	N/A
C-41	No	SFWMD	HP23373111	2	N/A
C-41	No	SFWMD	HP24373013	2	N/A
C-41	No	SFWMD	HP25373013	2	N/A
C-41	No	SFWMD	HP34373124	2	N/A
C-41	No	SFWMD	HP35373113	2	N/A
C-41	No	SFWMD	HP36373013	2	N/A
C-41	No	SFWMD	02273230[1]	2	N/A
C-41	No	SFWMD	HP09383151	2	Proposed station as part of SFWMD expanded monitoring
C-41	No	SFWMD	HP10383112	2	Proposed station as part of SFWMD expanded monitoring
C-41	No	SFWMD	HP21383121	2	Proposed station as part of SFWMD expanded monitoring
C-41	No	SFWMD	HP27383124	2	Proposed station as part of SFWMD expanded monitoring
C-41	No	SFWMD	HP28383112	2	Proposed station as part of SFWMD expanded monitoring
C-41	No	SFWMD	HP36383112	2	Proposed station as part of SFWMD expanded monitoring
C-41	No	SFWMD	IP01383122	2	Proposed station as part of SFWMD expanded monitoring
C-41A	No	SFWMD	SD28373312	2	N/A
C-41A	No	SFWMD	SD33373314	2	N/A
C-41A	No	SFWMD	SD34373313	2	N/A
C-41A	No	SFWMD	SD13373111	2	Proposed station as part of SFWMD expanded monitoring
C-40	No	USGS	02258800	3	N/A
C-40	No	USGS	02259100	3	N/A
C-41	No	USGS	02257750	3	N/A
C-41	No	USGS	02257790	3	N/A
C-41	No	USGS	02273230	3	N/A

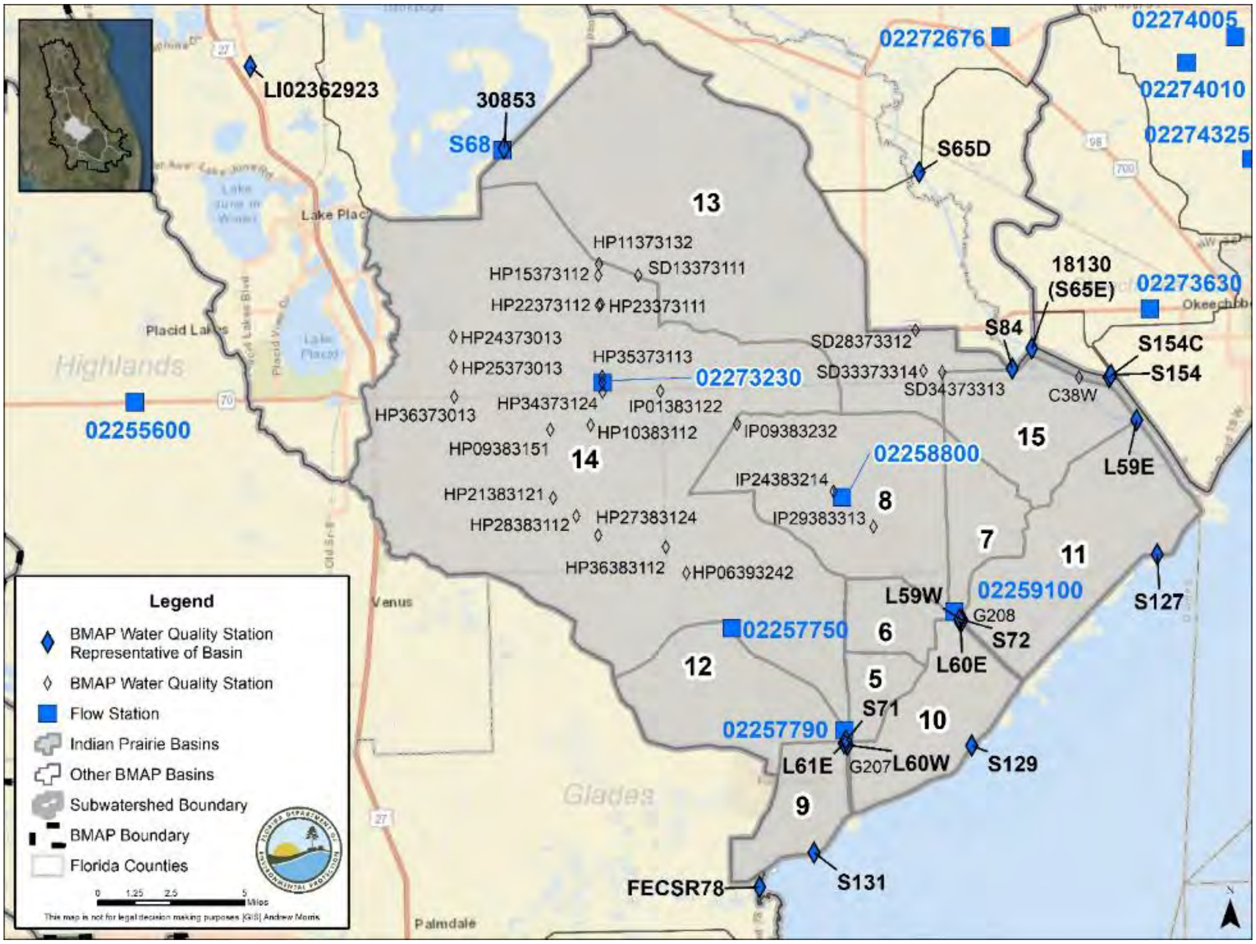

Figure 11. Locations of the water quality monitoring stations in the Indian Prairie Subwatershed

4.2.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the Indian Prairie Subwatershed is 102.5 mt/yr. A reduction of 84.5 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 18.0 mt/yr.

Table 30 summarizes the basin evaluation results for the subwatershed. The TN concentrations in Basins C-40, C-41, L-48, L-59E, L-59W, L-60E, L-60W, and L-61E are greater than the benchmark, as are the TP concentrations in Basins C-40, C-41, L-48, L-59E, L-59W, L-60E, and L-61E. In addition, based on evaluations made by SFWMD in the LOWCP update, flow is an issue in the C-41A Basin, it may be an issue in Basins L-59E, L-59W, L-60E, L-60W, and L-61E, but is not an issue in the other basins. **Table 31** lists the TRA prioritization results for the Indian Prairie Subwatershed, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 30. Basin evaluation results for the Indian Prairie Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
5	L-60W	1.64	1.64	2.63	No Significant Trend	0.12	0.13	0.32	No Significant Trend	Maybe
6	L-60E	1.65	1.83	5.10	Significant Decreasing	0.18	0.22	0.94	No Significant Trend	Maybe
7	L-59W	1.74	1.97	16.91	Significant Decreasing	0.23	0.27	3.54	Significant Decreasing	Maybe
8	C-40	2.07	2.79	3.78	Insufficient Data	0.23	0.44	0.87	Significant Increasing	No
9	S-131	1.39	1.47	3.00	Significant Decreasing	0.09	0.10	0.30	No Significant Trend	No
10	L-49	1.46	1.51	2.73	Significant Decreasing	0.05	0.05	0.15	Significant Decreasing	No
11	L-48	1.95	2.08	3.22	Significant Decreasing	0.13	0.19	0.45	No Significant Trend	No
12	L-61E	2.36	1.44	5.49	No Significant Trend	0.13	0.14	0.83	No Significant Trend	Maybe
13	C-41A	1.42	1.98	10.24	Insufficient Data	0.07	0.45	1.22	Significant Increasing	Yes
14	C-41	2.82	3.46	3.29	Insufficient Data	0.21	0.15	0.62	Insufficient Data	No
15	L-59E	2.82	2.34	2.06	Insufficient Data	0.20	0.17	0.22	Insufficient Data	Maybe

Table 31. TRA evaluation results for the Indian Prairie Subwatershed

Basin	Station	TP Priority	TN Priority	Flow Priority
C-40	S72	1	1	3
C-41	S71	1	1	3
C-41A	S84	1	1	1
L-48	S127	1	2	3
L-49	S129	3	3	3
L-59E	L59E	2	1	2
L-59W	L59W	2	2	2
L-60E	L60E	1	2	2
L-60W	L60W	1	1	2
L-61E	L61E	1	1	2
S-131	S131	2	3	3

4.2.3. Projects

The sections below summarize the existing and planned and future projects for the Indian Prairie Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.2.3.1. Existing and Planned Projects

Table 32 summarizes the existing and planned projects provided by the stakeholders for the Indian Prairie Subwatershed.

Table 32. Existing and planned projects in the Indian Prairie Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Coordinating Agency	N/A	CA-01	Brighton Valley DWM	Estimated to provide net annual average benefit of 39,765 ac-ft of treated water via passthrough system.	DWM	Underway	2019	37,917.2	17.20	6,843.4	3.10	C-41	8,200.0	$42,642,088	$3,125,000 (years 1-4) $3,000,000 (years 5-10)	FDACS/ Florida Legislature	$11,500,000	N/A
Coordinating Agency	N/A	CA-03	Inactive Dairies – Lagoon Remediation	See CA-02.	Dairy Remediation	Completed	Not provided	Not provided	Not provided	Not provided	Not provided	Indian Prairie	Not provided	Not provided	Not provided	FDACS	Not provided	N/A
Coordinating Agency	N/A	CA-07	Legislative Cost-Share Appropriation Program (Dairy Projects)	See CA-06.	Dairy Remediation	Underway	TBD	TBD	TBD	TBD	TBD	Indian Prairie	TBD	Not provided	Not provided	FDACS	Not provided	N/A
Coordinating Agency	FDOT	CA-15	State Road (SR) 710 Regional Project	See FDOT4-01.	Stormwater System Rehabilitation	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	TBD	TBD	TBD	FDOT	TBD	N/A
FDACS	Agricultural Producers	FDACS-08	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – Indian Prairie. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	114,031.0	51.72	23,104.1	10.48	Indian Prairie	182,376	TBD	TBD	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-17	Cost-Share BMP Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	7,600.5	3.45	1,993.2	0.90	Indian Prairie	28,429	TBD	TBD	FDACS	TBD	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Glades County	N/A	GC-02	Education and Outreach	FYN; landscaping, irrigation, and fertilizer ordinances; PSAs, pamphlets, website, and illicit discharge program.	Education Efforts	Completed	N/A	4,301.2	1.95	40.7	0.02	L-60W, L-60E, L-59W, C-40, S-131, L-49, L-48, L-61E, C-41A. C-41, L-59E	3,649.7	Not provided	$5,500	Glades County	Not provided	N/A
Highlands County	UF-IFAS	HC-02	Education and Outreach	FYN, landscaping and irrigation ordinances, PSAs, and pamphlets.	Education Efforts	Completed	N/A	1,979.5	0.90	68.1	0.03	C-41A, C-41, L-59E	4,771.6	Not provided	Not provided	Highlands County	Not provided	N/A
IMWID	DEP/ SFWMD/ FDACS/ IMWID	IMWID-01	IMWID Phase I (DWM Project in Two Phases)	Construct above-ground impoundment with storage capacity of 950 ac-ft/yr.	DWM	Underway	2020	N/A	N/A	1,817.7	0.82	C-41	308.0	$15,437,146	TBD	DEP/ SFWMD/ FDACS	DEP funding – $4,600,000/ FDACS funding – $2,414,000/ SFWMD funding – $8,423,146	S0650
IMWID	DEP/ SFWMD/ FDACS/ IMWID	IMWID-02	IMWID Phase II (DWM Project in Two Phases)	Construct above-ground impoundment with storage capacity of 1,200 ac-ft/yr.	DWM	Underway	2023	N/A	N/A	2,459.3	1.12	C-41	400.0	$4,450,000	TBD	DEP/ FDACS	DEP funding – $450,000/ FDACS funding – $4,000,000	NF023
SFWMD	N/A	SFWMD-10	Lykes West Waterhole Marsh	Project pumps excess water from C-40 Canal for phosphorus removal via uptake in wetlands and associated marshes before it enters Lake Okeechobee.	DWM	Completed	2006	31,945.0	14.49	12,403.2	5.63	C-41	2,370.0	$50,000	$470,238	Florida Legislature	Florida Ranchlands Environmental Services Project – $470,238	N/A
SFWMD	N/A	SFWMD-12	Buck Island Ranch (Northern Everglades Payment for Environmental Services [NEPES]-1)	Storage of 1,573 ac-ft of water through pasture.	DWM	Completed	2012	TBD	TBD	3,336.0	1.51	C-41	1,048.0	$1,725	$173,600	Florida Legislature	Florida Legislature – $173,600	N/A
SFWMD	N/A	SFWMD-23	Buck Island Ranch Wildlife Management Area NEPES-2	Component 1 – Storage of 620 ac-ft of water through pasture. Component 2 – Nutrient removal of 1,567 lbs of phosphorus on forage lands	DWM	Completed	2015	TBD	TBD	1,565.0	0.71	C-41	1,048.0	$2,259,600	$163,500	Florida Legislature	Florida Legislature – $163,500	N/A

4.2.3.2. Future Projects

Table 33 lists the future projects provided by the stakeholders for the Indian Prairie Subwatershed.

Table 33. Future projects in the Indian Prairie Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Highlands County	Coordinating Agencies	F-05	Smart Fertilizer	Watershedwide ban on fertilizer use during certain portion of year for residential use.	Enhanced Public Education	Planned	TBD	TBD	TBD	TBD	TBD	C-41A, C-41, L-59E	TBD	TBD
Highlands County	Coordinating Agencies	F-06	Happy Planters	Replanting grant for vegetation loss on waterbodies.	Creating/ Enhancing Living Shoreline	Planned	TBD	TBD	TBD	TBD	TBD	C-41A, C-41, L-59E	TBD	TBD
Highlands County	Coordinating Agencies	F-07	IMWID Phase III	Continue purchasing property for current water quality project. Still need 500 acres to get estimated 90 % reduction.	DWM	Conceptual	500	TBD	TBD	TBD	TBD	C-41	TBD	TBD
Coordinating Agency	N/A	F-08	Pearce/Hartman Property	Alternative water storage and disposal interim project.	Stormwater Reuse	Conceptual	TBD	TBD	TBD	1,582.5	0.72	L-48, L-59E	TBD	TBD
Coordinating Agency	N/A	F-09	Buckhead Ridge Property	Alternative water storage and disposal interim project.	Stormwater Reuse	Conceptual	TBD	TBD	TBD	23.5	0.00	L-48	TBD	TBD
Coordinating Agency	N/A	F-10	Harney Pond	Alternative water storage and disposal interim project.	Stormwater Reuse	Conceptual	TBD	TBD	TBD	27.8	0.01	C-41	TBD	TBD
Coordinating Agency	N/A	F-11	Indian Prairie	Alternative water storage and disposal interim project.	Stormwater Reuse	Conceptual	TBD	TBD	TBD	47.0	0.02	TBD	TBD	TBD
Coordinating Agency	N/A	F-12	S-68 STA	STA.	STA	Conceptual	TBD	TBD	TBD	17,107.9	7.76	C-41	TBD	TBD
Coordinating Agency	N/A	F-13	Istokpoga/ Kissimmee Reservoir and STA	Reservoir and STA..	STAs	Conceptual	TBD	TBD	TBD	19,246.4	8.73	C-41	TBD	TBD
Coordinating Agency	N/A	F-14	West Water Hole Expansion	Public-private partnership project will treat and remove phosphorus and nitrogen from regional system by adding 500 acres to existing project.	DWM	Conceptual	TBD	TBD	TBD	2,138.5	0.97	C-40	TBD	TBD

4.3. Lake Istokpoga Subwatershed

The Lake Istokpoga Subwatershed covers more than 394,000 acres of the LOW and is made up of 4 basins. As shown in **Table 34**, agriculture covers 33.1 % of the area, followed by urban and built-up with 16.5 %. Stakeholders in the subwatershed are the City of Avon Park, City of Frostproof, City of Sebring, Highlands County, Polk County, SLID, Town of Hillcrest Heights, Town of Lake Placid, and Village of Highland Park.

Table 34. Summary of land uses in the Lake Istokpoga Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	64,880	16.5
2000	Agriculture	130,399	33.1
3000	Upland Nonforested	27,597	7.0
4000	Upland Forests	44,330	11.2
5000	Water	58,141	14.7
6000	Wetlands	63,824	16.2
7000	Barren Land	563	0.1
8000	Transportation, Communication, and Utilities	4,472	1.1
	Total	**394,206**	**100.0**

4.3.1. Water Quality Monitoring

In the Lake Istokpoga Subwatershed, the BMAP monitoring network includes water quality stations in all four of the basins. **Table 35** summarizes the water quality monitoring stations in the subwatershed, and **Figure 12** shows the station locations. **Table 35** also includes indications of which stations have recently been added as part of SFWMD expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the station to better align with the BMAP.

Table 35. Water quality monitoring stations in the Lake Istokpoga Subwatershed

[1] Water quality data are collected by SFWMD and flow data are collected by the USGS at these stations

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Lake Istokpoga	No	SFWMD	S68	1	N/A
Arbuckle Creek	Yes	SFWMD	02270500 (30854)[1]	2	Sufficient TN and TP data
Arbuckle Creek	No	SFWMD	AB27343014	2	N/A
Arbuckle Creek	No	SFWMD	AR06333013	2	N/A
Arbuckle Creek	No	SFWMD	AR18343012	2	N/A
Arbuckle Creek	No	SFWMD	AR21343013	2	Proposed station as part of SFWMD expanded monitoring
Arbuckle Creek	No	SFWMD	BN03332911	2	N/A
Arbuckle Creek	No	SFWMD	BN08332912	2	N/A

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Lake Arbuckle	Yes	DEP Southwest Regional Operations Center (ROC)	274119812344	2	Sufficient TN and TP data
Lake Arbuckle	Yes	Polk County Natural Resources Division	Arbuckle1	2	Sufficient TN and TP data
Lake Arbuckle	No	SFWMD	LV14322813	2	N/A
Lake Arbuckle	No	SFWMD	RD01322813	2	Proposed station as part of SFWMD expanded monitoring
Lake Arbuckle	No	SFWMD	RD08322913[1]	2	N/A
Lake Istokpoga	Yes	SFWMD	02273198 (30853)	2	Sufficient TN and TP data
Josephine Creek	No	SFWMD	JO33352914	2	Proposed station as part of SFWMD expanded monitoring
Josephine Creek	No	SFWMD	JO16362914	2	Proposed station as part of SFWMD expanded monitoring
Josephine Creek	Yes	SFWMD	LI02362923[1]	2	Sufficient TP data; SFWMD will include TN in expanded monitoring
Josephine Creek	No	SFWMD	PL01382911	2	N/A
Arbuckle Creek	No	USGS	02270000	3	N/A
Arbuckle Creek	No	USGS/SFWMD	02270500/ARBUCK[1]	3	N/A
Lake Arbuckle	No	USGS/SFWMD	02269520[1]	3	N/A
Lake Istokpoga	No	USGS	S68	3	N/A
Josephine Creek	No	USGS/SFWMD	02271500[1]	3	N/A

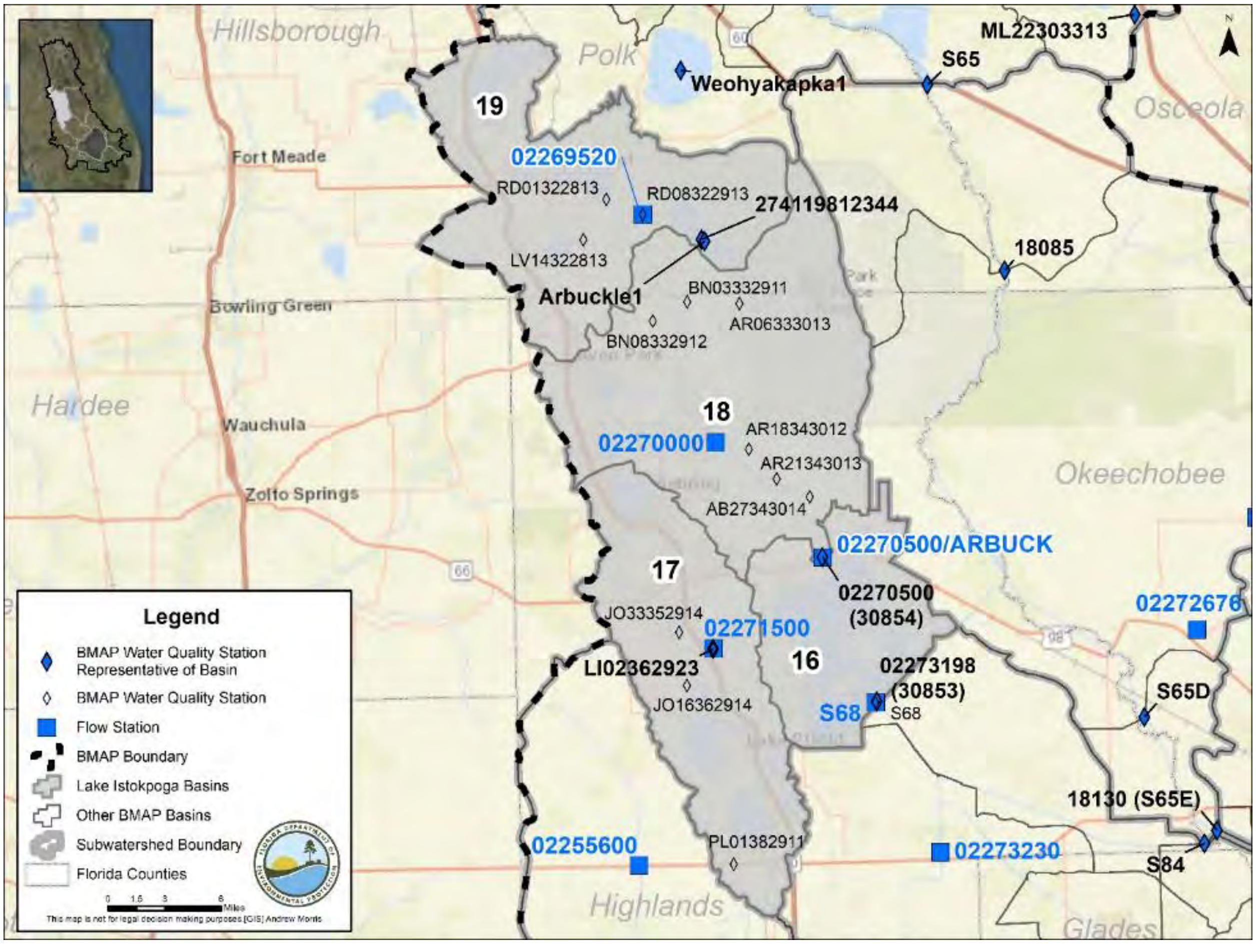

Figure 12. Locations of the water quality monitoring stations in the Lake Istokpoga Subwatershed

4.3.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the Lake Istokpoga Subwatershed is 47.7 mt/yr. A reduction of 39.3 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 8.4 mt/yr.

Table 36 summarizes the basin evaluation results for the subwatershed. The Lake Istokpoga Basin TN concentrations are greater than the benchmark, and the Arbuckle Creek TP concentrations are higher than the benchmark. Based on evaluations of the subwatershed made by SFWMD in the LOWCP update, additional investigations are needed to determine whether flow is an issue. **Table 37** lists the TRA prioritization results for the Lake Istokpoga Subwatershed, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 36. Basin evaluation results for the Lake Istokpoga Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
16	Lake Istokpoga	1.61	1.53	1.55	Insufficient Data	0.09	0.09	0.08	Significant Increasing	Maybe
17	Josephine Creek	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.06	Insufficient Data	Insufficient Data	No Significant Trend	Maybe
18	Arbuckle Creek	1.31	Insufficient Data	Insufficient Data	Insufficient Data	0.12	Insufficient Data	Insufficient Data	Insufficient Data	Maybe
19	Lake Arbuckle	1.02	Insufficient Data	Insufficient Data	Insufficient Data	0.08	Insufficient Data	Insufficient Data	Insufficient Data	Maybe

Table 37. TRA evaluation results for the Lake Istokpoga Subwatershed

*SFWMD determined that additional investigations are needed regarding whether water quantity is an issue in this subwatershed.
Insufficient data = Available data were not at the frequency needed for evaluation.

Basin	Station	TP Priority	TN Priority	Flow Priority
Arbuckle Creek	30854	3	3	*
Josephine Creek	LI02362923	3	Insufficient Data	*
Lake Arbuckle	ARBUCKLE1-274119812344	3	3	*
Lake Istokpoga	30853	2	1	*

4.3.3. Projects

The sections below summarize the existing and planned and future projects for the Lake Istokpoga Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.3.3.1. Existing and Planned Projects

Table 38 summarizes the existing and planned projects provided by the stakeholders for the Lake Istokpoga Subwatershed.

Table 38. Existing and planned projects in the Lake Istokpoga Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
City of Avon Park	N/A	AP-01	Avon Park Street Sweeping	Street sweeping.	Street Sweeping	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	N/A	Not provided	Not provided	City of Avon Park	Not provided	N/A
City of Avon Park	N/A	AP-02	Lake Tulane Stormwater Improvement Project	Runoff will be captured in series of swales that will allow runoff to percolate into sandy soils, preventing further degradation of Lake Tulane.	Grass Swales Without Swale Blocks or Raised Culverts	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	32.1	Not provided	Not provided	City of Avon Park/ Southwest Florida Water Management District (SWFWMD)	Not provided	N/A
City of Avon Park	N/A	AP-03	Lake Isis Stormwater Improvement Project	Runoff will be captured in lakeside swale and redesigned pond that will allow runoff to percolate into sandy soils, preventing further degradation of Lake Isis.	Wet Detention Pond	Completed	Completed	0.2	0.0	0.2	0.00	Lake Arbuckle	37.1	Not provided	Not provided	City of Avon Park/ SWFWMD	Not provided	N/A
Coordinating Agency	N/A	CA-08	Legislative Cost-Share Appropriation Program (Dairy Projects)	See CA-05.	Dairy Remediation	Underway	TBD	TBD	TBD	TBD	TBD	Lake Istokpoga	TBD	Not provided	Not provided	FDACS	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDACS	Agricultural Producers	FDACS-09	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – Lake Istokpoga. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	72,156.8	32.73	1,652.6	0.75	Lake Istokpoga	93,115	TBD	TBD	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-18	Cost-Share BMP Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	7,987.3	3.62	286.2	0.13	Lake Istokpoga	13,644	TBD	TBD	FDACS	TBD	N/A
Highlands County	UF-IFAS	HC-03	Education and Outreach	FYN, landscaping and irrigation ordinances, PSAs, and pamphlets.	Education Efforts	Completed	N/A	11,712.3	5.31	2,368.7	1.07	Lake Istokpoga, Josephine Creek, Arbuckle Creek, Lake Arbuckle	57,004.5	Not provided	Not provided	Highlands County	Not provided	N/A
Highlands County	FDOT/ SWFWMD	HC-05	Lake June Stormwater Project	Install 450 feet of 24-inch French drain in 4 contributing basins.	Online Retention BMPs	Completed	2018	127.4	0.06	92.7	0.04	Josephine Creek	42.0	$530,000	Not provided	SWFWMD/ Highlands County	SWFWMD – $440,000/ County – $90,000	N/A
Highlands County	SWFWMD	HC-06	Lake Clay Stormwater Project	600 feet of 24-inch online French drain for parking lot subbasin; 300 feet of 24-inch online French drain will treat street subbasin.	On-line Retention BMPs	Completed	2013	259.4	0.12	20.2	0.01	Josephine Creek	24.7	$330,000	$1,973	SWFWMD/ Highlands County	SWFWMD – $330,000/ County – $1,973	N/A
Highlands County	Highlands Soil and Water Conservation District/ FDOT/ SWFWMD	HC-07	Lake McCoy Stormwater Project	Replace 420 feet of concrete sluiceway with grassy swales, ditch blocks and drop box.	Online Retention BMPs	Completed	2018	29.9	0.01	9.8	0.00	Josephine Creek	9.9	$134,479	TBD	Highlands Soil and Water Conservation District/ FDOT/ SWFWMD	SWFMWD – $100,859/ Soil and Water Conservation District – $33,620	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Polk County	Extension Office/ County Utilities/ Lakes Education Action Drive/ Municipal Agencies	PC-01	Education and Outreach	FYN, fertilizer ordinance, PSAs, pamphlets, website, and Illicit Discharge Program.	Education Efforts	Completed	N/A	824.2	0.37	186.2	0.08	Lake Arbuckle, Arbuckle Creek	12,720.9	N/A	$2,000	Polk County	$2,000	N/A
City of Sebring	DEP/ SWFWMD/ Highlands County	SEB-01	Little Lake Jackson Offline Alum Injection Stormwater Treatment	Stormwater is diverted through underground culvert, alum is injected, and water settles for 7 days in detention pond. Treated water is released to Little Lake Jackson.	Alum Injection Systems	Completed	2011	TBD	TBD	TBD	TBD	Josephine Creek	Not provided	$231,494	$18,500	DEP/ SWFWMD/ City of Sebring/ Highlands County	Not provided	N/A
City of Sebring	Not provided	SEB-02	Street Sweeping	Street sweeping to collect 602,940 lbs/yr of material. In 2018, 992,000 lbs of material were collected.	Street Sweeping	Completed	N/A	122.2	0.06	67.5	0.03	Arbuckle Creek, Josephine Creek	N/A	Not provided	$35,000	City of Sebring	Not provided	N/A
SFWMD	N/A	SFWMD-11	Rafter T Ranch	Storage of 1,298 ac-ft of water through above-ground impoundment and pasture.	DWM	Completed	2014	TBD	TBD	769.9	0.35	Arbuckle Creek	2,602.0	$1,627,360	$162,736	Florida Legislature	Florida Legislature – $743,477	N/A
SLID	DEP	SLID-01	SLID Improvements Phases 1–3	Treatment of runoff through STA.	STAs	Completed	2016	426.7	0.19	140.5	0.06	Josephine Creek	2,327.7	$3,671,712	$60,000	SLID/ DEP/ Florida Legislature	SLID – $69,267/ DEP – $3,186,445/ Legislature – $416,000	G0377
SLID	N/A	SLID-02	SLID Improvements Phase 4	Modification of existing STA (Project SLID-1) to include bypass weir to direct more water to STA.	STAs	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	N/A	N/A	N/A	N/A	N/A

4.3.3.2. Future Projects

Table 39 lists the future projects provided by the stakeholders for the Lake Istokpoga Subwatershed.

Table 39. Future projects in the Lake Istokpoga Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Highlands County	Coordinating Agencies	F-15	Smart Fertilizer	Watershedwide ban on fertilizer use during certain portion of year for residential use.	Enhanced Public Education	Planned	TBD	TBD	TBD	TBD	TBD	Lake Istokpoga, Josephine Creek, Arbuckle Creek, Lake Arbuckle	TBD	TBD
Highlands County	Coordinating Agencies	F-16	Happy Planters	Replanting grant for vegetation loss on waterbodies.	Creating/ Enhancing Living Shoreline	Planned	TBD	TBD	TBD	TBD	TBD	Lake Istokpoga, Josephine Creek, Arbuckle Creek, Lake Arbuckle	TBD	TBD
Highlands County	Coordinating Agencies	F-17	Arbuckle Creek Supports Istokpoga	Property for sale at mouth of Arbuckle Creek not only contains creek itself but decent-sized piece of land on east side of the creek. Maybe purchase this land and run portion of Arbuckle Creek through series of filtering ponds before release into Istokpoga. These areas are often turned into parks as well.	DWM	Conceptual	TBD	TBD	TBD	TBD	TBD	Arbuckle Creek	TBD	TBD
City of Sebring	N/A	F-18	Lakeview Dr. Roadway and Drainage Improvements	Repair/replace/rehab drainage infrastructure and roadway.	Stormwater System Rehabilitation	Planned	TBD	TBD	TBD	TBD	TBD	Josephine Creek	TBD	TBD

4.4. Lower Kissimmee Subwatershed

The Lower Kissimmee Subwatershed covers more than 429,000 acres of the LOW and is made up of 3 basins. As shown in **Table 40**, agriculture is the largest portion of the subwatershed with 51.3 % of the area, followed by wetlands with 21.0 %. Stakeholders in the subwatershed are Highlands County, Osceola County, and Polk County.

Table 40. Summary of land uses in the Lower Kissimmee Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	11,061	2.6
2000	Agriculture	220,226	51.3
3000	Upland Nonforested	77,511	18.1
4000	Upland Forests	25,065	5.8
5000	Water	3,432	0.8
6000	Wetlands	90,035	21.0
7000	Barren Land	1,583	0.4
8000	Transportation, Communication, and Utilities	277	0.1
	Total	**429,190**	**100.0**

4.4.1. Water Quality Monitoring

In the Lower Kissimmee Subwatershed, the BMAP monitoring network includes water quality stations in all three of the basins. **Table 41** summarizes the water quality monitoring stations in the subwatershed, and **Figure 13** shows the station locations. **Table 41** also includes indications of which stations have recently been added as part of SFWMD expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the station to better align with the BMAP.

Table 41. Water quality monitoring stations in the Lower Kissimmee Subwatershed

[1] Water quality data are collected by SFWMD and flow data are collected by USGS at these stations

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
S-65E	Yes	SFWMD	18130 (S65E)	1	Sufficient TN and TP data
Kissimmee River	No	SFWMD	02272676[1]	2	N/A
Kissimmee River	No	SFWMD	CY05353444	2	N/A
Kissimmee River	No	SFWMD	CY06363411	2	N/A
Kissimmee River	No	SFWMD	CY17353413	2	N/A
Kissimmee River	No	SFWMD	KR24353114	2	N/A
Kissimmee River	No	SFWMD	KR29353334	2	N/A
Kissimmee River	No	SFWMD	KR30353214	2	N/A
Kissimmee River	No	SFWMD	KR30353312	2	N/A
Kissimmee River	No	SFWMD	KR32343214	2	Proposed station as part of SFWMD expanded monitoring
Kissimmee River	No	SFWMD	KREA 01[1]	2	N/A
Kissimmee River	No	SFWMD	KREA 04	2	N/A
Kissimmee River	No	SFWMD	KREA 22	2	N/A
Kissimmee River	No	SFWMD	KREA 23	2	N/A
Kissimmee River	No	SFWMD	KREA 93	2	N/A
Kissimmee River	No	SFWMD	KREA 94	2	N/A
Kissimmee River	No	SFWMD	KREA 98	2	N/A

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Kissimmee River	No	SFWMD	KREA 100	2	Proposed station as part of SFWMD expanded monitoring
Kissimmee River	No	SFWMD	OK09353212	2	N/A
Kissimmee River	Yes	SFWMD	S65D	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Kissimmee River	No	SFWMD	SM21333314	2	Proposed station as part of SFWMD expanded monitoring
S-65A	Yes	SFWMD	18085 (S65A)	2	Sufficient TN and TP data
S-65A	No	SFWMD	AM22323213	2	Proposed station as part of SFWMD expanded monitoring
S-65A	No	SFWMD	AM27323211	2	Proposed station as part of SFWMD expanded monitoring
S-65A	No	SFWMD	BB16313214	2	N/A
S-65A	No	SFWMD	BM15313111	2	Proposed station as part of SFWMD expanded monitoring
S-65A	No	SFWMD	IC35313112	2	Proposed station as part of SFWMD expanded monitoring
S-65A	No	SFWMD	KR23313113	2	Proposed station as part of SFWMD expanded monitoring
S-65A	No	SFWMD	KREA 91	2	N/A
S-65A	No	SFWMD	KREA 92	2	N/A
S-65A	No	SFWMD	KREA 97	2	N/A
S-65E	No	SFWMD	KR05373311	2	N/A
S-65E	No	SFWMD	KR36363312	2	N/A
S-65E	No	SFWMD	KREA 14	2	N/A
S-65E	No	SFWMD	KREA 17A	2	N/A
S-65E	No	SFWMD	KREA 41A	2	N/A
Kissimmee River	No	USGS	02272650[1]	3	N/A
Kissimmee River	No	USGS	02272676[1]	3	N/A
Kissimmee River	No	SFWMD	S65_S	3	N/A
Kissimmee River	No	SFWMD	S-65D	3	N/A
S-65A	No	SFWMD	S65A_S	3	N/A

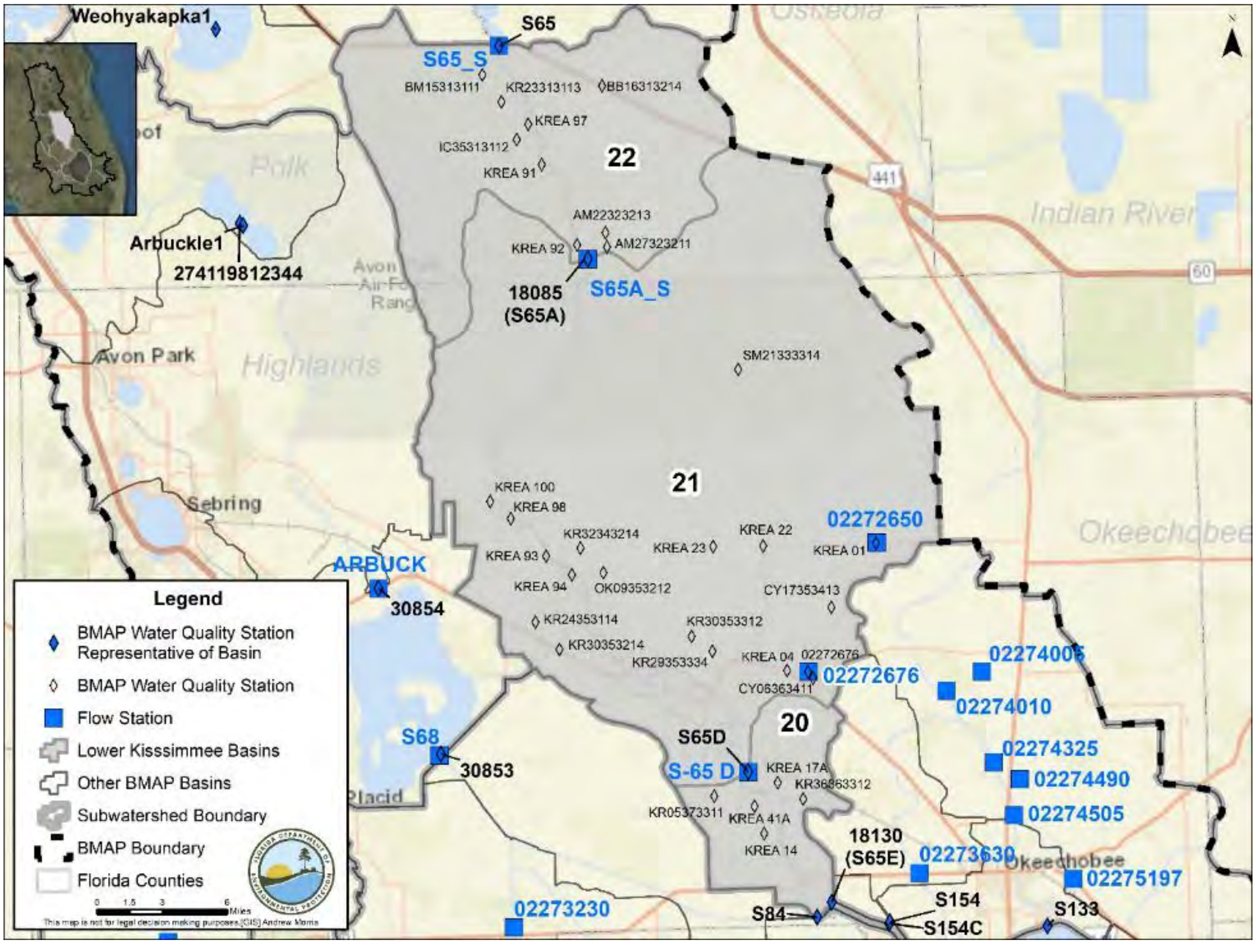

Figure 13. Locations of the water quality monitoring stations in the Lower Kissimmee Subwatershed

4.4.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the Lower Kissimmee Subwatershed is 125.9 mt/yr. A reduction of 103.8 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 22.1 mt/yr.

Table 42 summarizes the basin evaluation results for the subwatershed. Both basins in the subwatershed have TN concentrations greater than the benchmark. None of the three basins has TN or TP concentrations above the benchmarks. Based on evaluations made by SFWMD in the LOWCP update, flow was determined not to be an issue in any of the basins. **Table 43** lists the TRA prioritization results for the Lower Kissimmee Subwatershed, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 42. Basin evaluation results for the Lower Kissimmee Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
20	S-65E	1.34	1.04	1.08	Significant Decreasing	0.10	0.20	0.40	Significant Increasing	No
21	Kissimmee River	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.10	Insufficient Data	Insufficient Data	Insufficient Data	No
22	S-65A	1.22	Insufficient Data	Insufficient Data	Insufficient Data	0.08	Insufficient Data	Insufficient Data	Insufficient Data	No

Table 43. TRA evaluation results for the Lower Kissimmee Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

Basin	Station	TP Priority	TN Priority	Flow Priority
Kissimmee River	S65D	3	Insufficient Data	3
S-65A	18085	3	3	3
S-65E	S65E	1	3	3

4.4.3. Projects

The sections below summarize the existing and planned and future projects for the Lower Kissimmee Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.4.3.1. Existing and Planned Projects

Table 44 summarizes the existing and planned projects provided by the stakeholders for Lower Kissimmee Subwatershed.

Table 44. Existing and planned projects in the Lower Kissimmee Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Coordinating Agency	N/A	CA-05	El Maximo Ranch DWM (formerly Latt Maxcy DWM)	Estimated to provide net annual average benefit of 32,675 ac-ft of treated water via pass-through system.	DWM	Underway	2020	TBD	TBD	2,733.6	1.24	S-65A	7,030.0	Not provided	$3,863,204	FDACS	Not provided	N/A
Coordinating Agency	N/A	CA-09	Legislative Cost-Share Appropriation Program (Dairy Projects)	See CA-05.	Dairy Remediation	Underway	TBD	TBD	TBD	TBD	TBD	Lower Kissimmee	TBD	Not provided	Not provided	FDACS	Not provided	N/A
Coordinating Agency	N/A	CA-17	Alternative Water Supply Projects – Joe Hall, Raulerson and Sons Ranch	Stormwater recycling project.	Stormwater Reuse	Completed	2010	TBD	TBD	45.1	0.02	S-65D	Not provided	Not provided	Not provided	Not provided	Not provided	N/A
Coordinating Agency	N/A	CA-18	Alternative Water Supply Projects – David H. Williams Sod & Cattle	Stormwater irrigation project.	Stormwater Reuse	Completed	2010	TBD	TBD	20.5	0.01	S-65D	Not provided	Not provided	Not provided	Not provided	Not provided	N/A
Coordinating Agency	N/A	CA-19	Alternative Water Supply Projects – Four K Ranch, Inc., Lippincott Farm	Stormwater recycling project.	Stormwater Reuse	Completed	2010	TBD	TBD	4.1	0.00	S-65D	Not provided	Not provided	Not provided	Not provided	Not provided	N/A
Coordinating Agency	N/A	CA-20	Alternative Water Supply Projects – Haynes and Susan Williams, 101 Ranch	17.2-acre reservoir and 44-acre reservoir.	Stormwater Reuse	Completed	2010	TBD	TBD	4.1	0.00	S-65D	Not provided	Not provided	Not provided	Not provided	Not provided	N/A
FDACS	Agricultural Producers	FDACS-10	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – Lower Kissimmee. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	75,818.4	34.39	9,366.6	4.25	Lower Kissimmee	175,318	TBD	TBD	FDACS	TBD	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDACS	Agricultural Producers	FDACS-19	Cost-Share BMP Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	16,070.1	7.29	1,842.2	0.84	Lower Kissimmee	27,257	TBD	TBD	FDACS	TBD	N/A
Highlands County	UF–IFAS	HC-04	Education and Outreach	FYN, landscaping and irrigation ordinances, PSAs, and pamphlets.	Education Efforts	Completed	N/A	771.3	0.35	85.8	0.04	Kissimmee River, S-65E	2,436.4	Not provided	Not provided	Highlands County	Not provided	N/A
Osceola County	N/A	OSC-11	Education and Outreach	FYN; landscaping, irrigation, fertilizer, and pet waste management ordinances; PSAs; pamphlets; website; and illicit discharge program.	Education Efforts	Completed	N/A	12.7	0.01	4.2	0.00	S-65A, Kissimmee River	165.6	Not provided	$5,000	Osceola County	$5,000	N/A
Polk County	Extension Office/ County Utilities/ Lakes Education Action Drive/ Municipal Agencies	PC-02	Education and Outreach	FYN, fertilizer ordinance, PSAs, pamphlets, website, and Illicit Discharge Program.	Education Efforts	Completed	N/A	917.6	0.42	31.9	0.01	Kissimmee River, S-65A	5,616.7	N/A	$3,000	Polk County	$3,000	N/A
SFWMD	N/A	SFWMD-04	Otter Slough Restoration	Completed project included 5 ditch plugs and removal of 2 berms to help attenuate regional stormwater runoff, as well as provide nutrient reductions because of plant uptake from overland flows.	Hydrologic Restoration	Completed	2009	TBD	TBD	10.9	0.00	Lake Kissimmee	500.0	N/A	$0	N/A	N/A	N/A
SFWMD	USACE	SFWMD-05	Kissimmee River Restoration	Restore ecological integrity by restoring 40 miles of meandering river and more than 12,000 acres of wetlands through the design and construction of physical project features coupled with application of optimized hydrologic conditions.	Hydrologic Restoration	Underway	2020	9,934.8	4.5	1,369.9	0.6	S-65A, S-65BC, S-65D	25,000.0	$780,000,000	N/A	USACE	USACE – $780,000,000	N/A
SFWMD	N/A	SFWMD-13	Dixie West	Storage of 315 ac-ft of water through pasture.	DWM	Completed	2012	TBD	TBD	451.4	0.20	S-65E	495.0	$548,000	$51,500	Florida Legislature	Florida Legislature – $51,500	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
TBDTBD223.90.10**SFWMD**	N/A	SFWMD-17	Willaway Cattle and Sod	Storage of 229 ac-ft of water through above-ground impoundment.	DWM	Completed	2013	TBD	TBD	153.9	0.07	Kissimmee River	69.0	$344,279	$1,878	Florida Legislature	Florida Legislature – $1,878	N/A
SFWMD	N/A	SFWMD-19	Triple A Ranch	Storage of 397 ac-ft of water through above-ground impoundment.	DWM	Completed	2015	TBD	TBD	2,733.6	1.24	Kissimmee River	106.0	$607,186	$30,000	Florida Legislature	Florida Legislature – $30,000	N/A

4.4.3.2. Future Projects

Table 45 lists the future projects provided by the stakeholders for the Lower Kissimmee Subwatershed.

Table 45. Future projects in the Lower Kissimmee Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Highlands County	Coordinating Agencies	F-19	Smart Fertilizer	Watershedwide ban on fertilizer use during certain portion of year for residential use.	Enhanced Public Education	Planned	TBD	TBD	TBD	TBD	TBD	Kissimmee River, S-65E	TBD	TBD
Highlands County	Coordinating Agencies	F-20	Happy Planters	Replanting grant for vegetation loss on waterbodies.	Creating/ Enhancing Living Shoreline	Planned	TBD	TBD	TBD	TBD	TBD	Kissimmee River, S-65E	TBD	TBD

4.5. Taylor Creek/Nubbin Slough Subwatershed

The Taylor Creek/Nubbin Slough Subwatershed covers almost 198,000 acres of the LOW and is made up of 5 basins. As shown in **Table 46**, agriculture is the predominate land use with 71.6 % of the area, followed by urban and built-up with 9.2 %. Stakeholders in the subwatershed are the City of Okeechobee, Coquina Water Management District, FDOT District 1, FDOT District 4, Martin County, and Okeechobee County.

Table 46. Summary of land uses in the Taylor Creek/Nubbin Slough Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	18,126	9.2
2000	Agriculture	141,605	71.6
3000	Upland Nonforested	2,699	1.4
4000	Upland Forests	4,519	2.3
5000	Water	2,401	1.2
6000	Wetlands	17,486	8.8
7000	Barren Land	1,545	0.8
8000	Transportation, Communication, and Utilities	813	0.4
9000	Inactive Dairy	8,602	4.3
	Total	**197,796**	**100.0**

4.5.1. Water Quality Monitoring

In the Taylor Creek/Nubbin Slough Subwatershed, the BMAP monitoring network includes water quality stations in all five of the basins. **Table 47** summarizes the water quality monitoring stations in the subwatershed, and **Figure 14** shows the station locations. **Table 47** also includes indications of which stations have recently been added as part of SFWMD expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the station to better align with the BMAP.

Table 47. Water quality monitoring stations in the Taylor Creek/Nubbin Slough Subwatershed

[1] Water quality data are collected by SFWMD and flow data are collected by USGS at these stations.

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
S-133	Yes	SFWMD	S133	1	Sufficient TN and TP data
S-135	Yes	SFWMD	S135	1	Sufficient TN and TP data
S-154	Yes	SFWMD	S154	1	Sufficient TN and TP data
S-154C	Yes	SFWMD	S154C	1	Sufficient TN and TP data
S191	Yes	SFWMD	S191	1	Sufficient TN and TP data
S-133	No	SFWMD	LM29373514	2	Proposed station as part of SFWMD expanded monitoring
S-133	No	SFWMD	TC09373513	2	Proposed station as part of SFWMD expanded monitoring
S-154	No	SFWMD	KR16373414	2	N/A
S-154	No	SFWMD	KR17373513	2	N/A
S-154	No	SFWMD	KREA 20	2	N/A
S-154	No	SFWMD	KREA 25	2	N/A

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
S-154	No	SFWMD	KREA 28	2	N/A
S-154	No	SFWMD	KREA 30 A	2	N/A
S-154	No	SFWMD	TS26363411	2	N/A
S-154	No	SFWMD	TS36363411	2	N/A
S-154C	No	SFWMD	KR20373413	2	N/A
S191	No	SFWMD	02275197[1]	2	N/A
S191	No	SFWMD	LB29353513	2	N/A
S191	No	SFWMD	MS05373613	2	N/A
S191	No	SFWMD	MS08373611	2	N/A
S191	No	SFWMD	MS08373624	2	N/A
S191	No	SFWMD	OT29353514	2	N/A
S191	No	SFWMD	OT32353511	2	N/A
S191	No	SFWMD	OT34353513	2	N/A
S191	No	SFWMD	TC03373511	2	N/A
S191	No	SFWMD	TC27353413	2	N/A
S191	No	SFWMD	TCNS 201	2	N/A
S191	No	SFWMD	TCNS 204	2	N/A
S191	No	SFWMD	TCNS 207	2	N/A
S191	No	SFWMD	TCNS 209	2	N/A
S191	No	SFWMD	TCNS 213	2	N/A
S191	No	SFWMD	TCNS 214	2	N/A
S191	No	SFWMD	TCNS 217	2	N/A
S191	No	SFWMD	TCNS 220	2	N/A
S191	No	SFWMD	TCNS 222	2	N/A
S191	No	SFWMD	TCNS 228	2	N/A
S191	No	SFWMD	TCNS 230	2	N/A
S191	No	SFWMD	TCNS 233	2	N/A
S191	No	SFWMD	TCNS 249	2	N/A
S-154	No	USGS	02273630	3	N/A
S191	No	USGS	02274005	3	N/A
S191	No	USGS	02274010[1]	3	N/A
S191	No	USGS	02274325	3	N/A
S191	No	USGS	02274490[1]	3	N/A
S191	No	USGS	02274505[1]	3	N/A
S191	No	USGS	02275197[1]	3	N/A

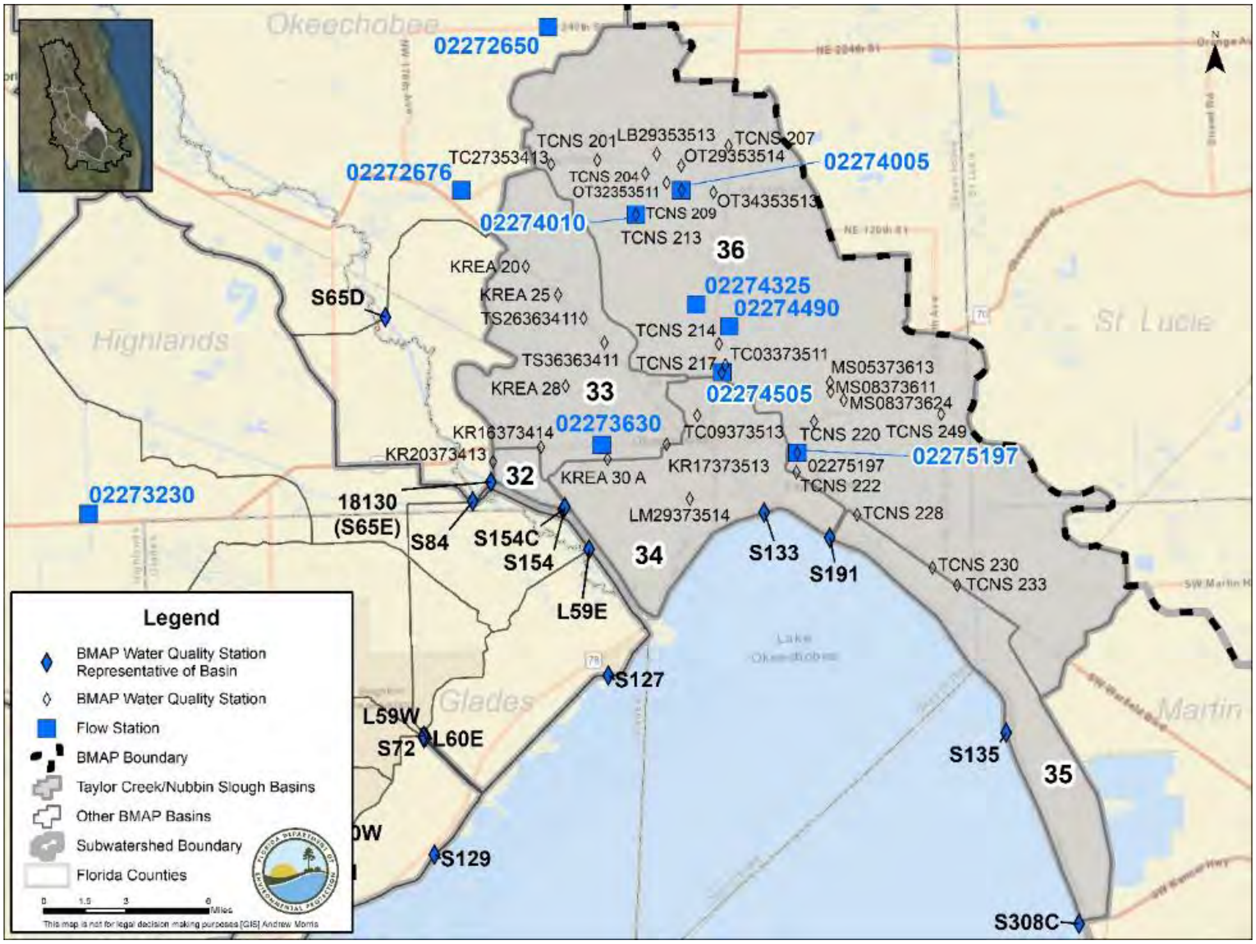

Figure 14. Locations of the water quality monitoring stations in the Taylor Creek/ Nubbin Slough Subwatershed

4.5.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the Taylor Creek/Nubbin Slough Subwatershed is 113.6 mt/yr. A reduction of 93.7 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 19.9 mt/yr.

Table 48 summarizes the basin evaluation results for the Taylor Creek/Nubbin Slough Subwatershed. All five basins have TN concentrations higher than the benchmark. The S-154C, S-154, S-133, and S191 Basins also have TP concentrations higher than the benchmark. Based on evaluations made by SFWMD in the LOWCP update, flow was determined not to be an issue in the S-135 basin. **Table 49** lists the TRA prioritization results for the Taylor Creek/Nubbin Slough Subwatershed, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 48. Basin evaluation results for the Taylor Creek/Nubbin Slough Subwatershed

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
32	S-154C	2.18	2.50	5.98	No Significant Trend	0.49	0.71	2.23	No Significant Trend	Maybe
33	S-154	1.70	2.04	2.96	No Significant Trend	0.27	0.54	1.03	No Significant Trend	Maybe
34	S-133	1.88	1.75	3.16	No Significant Trend	0.20	0.24	0.56	No Significant Trend	Maybe
35	S-135	1.55	1.55	4.83	No Significant Trend	0.11	0.14	0.59	Significant Increasing	No
36	S191	1.81	1.92	2.66	No Significant Trend	0.49	0.62	1.12	Significant Increasing	Maybe

Table 49. TRA evaluation results for the Taylor Creek/Nubbin Slough Subwatershed

Basin	Station	TP Priority	TN Priority	Flow Priority
S-133	S133	1	1	2
S-135	S135	1	1	3
S-154	S154	1	1	2
S-154C	S154C	1	1	2
S191	S191	1	1	2

4.5.3. Projects

The sections below summarize the existing and planned and future projects for the Taylor Creek/Nubbin Slough Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.5.3.1. Existing and Planned Projects

Table 50 summarizes the existing and planned projects provided by the stakeholders for the Taylor Creek/Nubbin Slough Subwatershed.

Table 50. Existing and planned projects in the Taylor Creek/Nubbin Slough Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Coordinating Agency	N/A	CA-02	Inactive Dairies – Lagoon Remediation	FDACS worked with dairy in LOW to partially remediate its lagoon. Soil was spread on field for crops to use nutrients, and stormwater was routed to remediated pond and reused to minimize discharges and groundwater withdrawals.	Dairy Remediation	Completed	Not provided	Not provided	Not provided	Not provided	Not provided	S-133	79.1	$643,593	Not provided	FDACS	Not provided	N/A
Coordinating Agency	N/A	CA-04	Lakeside Ranch Phase II	Phase II Includes southern STA and pump station (S-191), also known as Phase III in 2018 Ops Plan, to manage rim canal levels during high flow and potentially recirculate lake water back to STA for further TP removal.	STAs	Underway	2021	TBD	TBD	13,236.5	6.00	S-133	66.7	$1,112,005	Not provided	Federal Emergency Management Agency (FEMA)/ DEO	Not provided	N/A
Coordinating Agency	N/A	CA-10	Legislative Cost-Share Appropriation Program (Dairy Projects)	See CA-06.	Dairy Remediation	Underway	TBD	TBD	TBD	TBD	TBD	S-133	TBD	Not Provided	Not provided	FDACS	Not provided	N/A
Coordinating Agency	FDOT	CA-14	SR 710 Regional Project	Feasibility study was completed. FDOT is reviewing several conceptual designs. Coordinating Agencies are also reviewing study to determine whether multiple program initiatives can be aligned for greater project impact.	Study	Completed	N/A	N/A	N/A	N/A	N/A	S-133	39.5	$1,485,917	Not provided	FEMA	Not provided	N/A
City of Okeechobee	SFWMD/ DEP	CO-01	Centennial Park Stormwater Drainage Construction	Upgrade stormwater infrastructure by constructing nutrient-separating baffle box (NSBB), bioswale, and removing and replacing pipe.	Baffle Boxes – First Generation (hydrodynamic separator)	Completed	2018	2.2	0.00	0.0	0.00	S-154	17.3	$786,665	Not provided	DEO	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
City of Okeechobee	N/A	CO-02	South 4th St. Stormwater Drainage Construction	Upgrade stormwater infrastructure by constructing NSBB, bioswale, and removing and replacing pipe.	Baffle Boxes – First Generation (hydrodynamic separator)	Planned	TBD	275.3	0.12	10.0	0.00	S-133	20.0	$749,410	Not provided	Florida Legislature	Not provided	N/A
City of Okeechobee	DEP	CO-03	SE 8th Stormwater Drainage Construction	Upgrade stormwater infrastructure by constructing NSBB, bioswale, and removing and replacing pipe.	Baffle Boxes – First Generation (hydrodynamic separator)	Planned	2020	18.2	0.01	0.6	0.00	S-133	0.0	$157,143	Not provided	Florida Legislature	Not provided	N/A
City of Okeechobee	N/A	CO-04	Citywide Street Sweeping	Remove turbidity and excess nutrients from runoff.	Street Sweeping	Completed	N/A	TBD	TBD	TBD	TBD	S-191	118.0	$26,900,000	$141,882	USACE/ SFWMD	USACE – $26,900,000/ SFWMD – $141,882	N/A
FDACS	SFWMD	FDACS-01	Lemkin Creek	Hybrid wetland treatment technology (HWTT) is combination of wetland and chemical treatment technologies designed mainly to remove phosphorus at subbasin and parcel scales.	HWTT	Completed	2009	806.4	0.37	489.8	0.22	S-191	1,522	$635,970	$253,910	FDACS	TBD	N/A
FDACS	SFWMD	FDACS-02	Wolff Ditch	HWTT is combination of wetland and chemical treatment technologies designed mainly to remove phosphorus at subbasin and parcel scales.	HWTT	Completed	2009	1,420.8	0.64	1,043.6	0.47	S-135	1,930	$1,036,070	$412,380	FDACS	TBD	N/A
FDACS	SFWMD	FDACS-03	Grassy Island	HWTT is combination of wetland and chemical treatment technologies designed mainly to remove phosphorus at subbasin and parcel scales.	HWTT	Completed	2010	9,891.0	4.49	4,171.2	1.89	S-154	37,802	$5,041,338	$1,252,58 0	FDACS	TBD	N/A
FDACS	Private Landowner	FDACS-05	Nubbin Slough	HWTT is combination of wetland and chemical treatment technologies designed mainly to remove phosphorus at subbasin and parcel scales.	HWTT	Completed	2008	1,128.6	0.51	1,160.5	0.53	S-133	2,000	$900,260	$216,500	FDACS	TBD	N/A
FDACS	Private Landowner	FDACS-06	Mosquito Creek	HWTT is combination of wetland and chemical treatment technologies designed mainly to remove phosphorus at subbasin and parcel scales.	HWTT	Completed	2008	2,638.8	1.20	1,318.5	0.60	S-133	5,000	$1,263,920	$275,110	FDACS	TBD	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDACS	Agricultural Producers	FDACS-11	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – Taylor Creek/Nubbin Slough. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	73,699.4	33.43	12,995.2	5.89	S-133	118,761	TBD	TBD	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-20	Cost-Share Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	12,290.6	5.57	4,397.2	1.99	S-133	35,026	TBD	TBD	FDACS	TBD	N/A
FDOT District 1	N/A	FDOT1-01	SR 70 from 34th Avenue to 80th Avenue	6 wet detention ponds.	Wet Detention Pond	Completed	2018	35.5	0.02	37.4	0.02	S-154	17.3	$786,665	Not provided	DEO	Not provided	N/A
FDOT District 1	N/A	FDOT1-02	SR 70 from 80th Ave. to St. Lucie County Line	3 wet detention ponds and 3 dry retention swales.	Wet Detention Pond	Completed	2018	24.4	0.01	9.6	0.00	S-133	20.0	$749,410	Not provided	Florida Legislature	Not provided	N/A
FDOT District 1	N/A	FDOT1-03	Street Sweeping	Street sweeping.	Street Sweeping	Completed	N/A	144.1	0.07	120.2	0.05	S-133	0.0	$157,143	Not provided	Florida Legislature	Not provided	N/A
FDOT District 4	N/A	FDOT4-04	Public Education	Pamphlets.	Education Efforts	Completed	N/A	0.7	0.00	0.1	0.00	S-191	118.0	$26,900,000	$141,882	USACE/ SFWMD	USACE – $26,900,000/ SFWMD – $141,882	N/A
Okeechobee County	DEO	OK-01B	Douglas Park South	Addition of dry detention area to serve 73.5 acres of original 150-acre drainage area.	Dry Detention Pond	Completed	2009	38.0	0.02	5.4	0.00	S-191	773.0	N/A	$196,548	USACE/ SFWMD	N/A	N/A
Okeechobee County	FEMA/ DEO	OK-02	Oak Park	Roadside swales with raised inlets and 2 hydrodynamic separators.	Grass Swales with Swale Blocks or Raised Culverts	Completed	2016	47.0	0.02	5.9	0.00	S-135	919.0	$22,800,000	$132,704	Florida Legislature	USACE – $22,800,000/ SFWMD – $132,704	N/A
Okeechobee County	FEMA/ City of Okeechobee	OK-03	Southwest 21st St.+	Dry detention roadside swales with raised inlets and 1 hydrodynamic separator.	Grass Swales with Swale Blocks or Raised Culverts	Completed	2013	0.6	0.00	0.1	0.00	S-154	See SFWMD-14.	See SFWMD-14.	See SFWMD-14.	See SFWMD-14.	Included in SFWMD-14.	N/A
Okeechobee County	FEMA	OK-04	Southwest Drainage Area Improvements	Dry detention roadside swales with raised inlets and 2 hydrodynamic separators.	Grass Swales with Swale Blocks or Raised Culverts	Completed	2011	1.0	0.00	0.2	0.00	S-133	79.1	$643,593	Not provided	DEO	Not provided	N/A
Okeechobee County	DEO	OK-05	Okeechobee County 2008 Disaster Recovery Community Development Block Grant (CDBG)	Culvert upgrades and dry detention area to improve water quality and alleviate need for funding.	Stormwater System Rehabilitation	Completed	2014	5.6	0.00	0.8	0.00	S-133	66.7	$1,112,005	Not provided	FEMA/ DEO	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Okeechobee County	Not provided	OK-06	Southwest Drainage Area Improvements Whidden Ditch (Phase III)	Ditch and culvert upgrades to improve stormwater conveyance to Rim Canal.	Stormwater System Rehabilitation	Completed	2017	TBD	TBD	TBD	TBD	S-133	2.5	$483,893	Not provided	FEMA/ City of Okeechobee/ County	Not provided	N/A
Okeechobee County	Not provided	OK-07	Lock 7 Bypass Culvert System	Installation of parallel culvert system along Rim Canal to improve conveyance.	Stormwater System Rehabilitation	Completed	2016	0.0	0.00	0.0	0.00	S-133	39.5	$1,485,917	Not provided	FEMA	Not provided	N/A
SFWMD	USACE	SFWMD-01	Taylor Creek	Taylor Creek STA is 2-celled STA.	STA	Completed	2008	TBD	TBD	3,483.3	1.6	S-154	17.3	$786,665	Not provided	DEO	Not provided	N/A
SFWMD	USACE	SFWMD-02	Nubbin Slough	Nubbin Slough STA is larger of 2 pilot STAs constructed north of lake; 2-celled enclosure.	STA	Completed	2015	TBD	TBD	9,230.8	4.2	S-133	20.0	$749,410	Not provided	Florida Legislature	Not provided	N/A
SFWMD	USACE	SFWMD-03	Lakeside Ranch Phase I	Phase I included northern STA and inflow pump station (S-650), which began operating in 2012.	STA	Completed	2012	TBD	TBD	12,191.6	5.5	S-133	0.0	$157,143	Not provided	Florida Legislature	Not provided	N/A
SFWMD	N/A	SFWMD-14	Dixie Ranch	Storage of 856 ac-ft of water through pasture.	DWM	Completed	2012	TBD	TBD	261.9	0.12	S-65E	3,771.0	$507,500	$146,500	Florida Legislature	Florida Legislature – $146,500	N/A
SFWMD	N/A	SFWMD-15	Dixie Ranch	See SFWMD-14.	DWM	Completed	2012	TBD	TBD	513.7	0.23	S-191	118.0	$26,900,000	$141,882	USACE/ SFWMD	USACE – $26,900,000/ SFWMD – $141,882	N/A

4.5.3.2. Future Projects

Table 51 lists the future projects provided by the stakeholders for the Taylor Creek/Nubbin Slough Subwatershed.

Table 51. Future projects in the Taylor Creek/Nubbin Slough Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Coordinating Agency	N/A	F-21	Grassy Island Flow Equalization Basin	Flow equalization basin to provide inflows needed to maintain wetland vegetation at Taylor Creek STA.	Regional Stormwater Treatment	Conceptual	TBD	TBD	TBD	1,741.7	0.79	S-191	TBD	TBD
Coordinating Agency	N/A	F-22	Lemkin Creek Urban Stormwater Facility	Alternatives consist of shallow impoundment and shallow wetland treatment system.	Regional Stormwater Treatment	Conceptual	TBD	TBD	TBD	1,915.8	0.87	S-133	TBD	TBD
Coordinating Agency	N/A	F-23	Okeechobee County East/West Stormwater Conveyance Project	DWM.	DWM	Conceptual	TBD	TBD	TBD	557.3	0.25		TBD	TBD
Coordinating Agency	N/A	F-24	Brady Ranch STA	STA.	STA	Conceptual	TBD	TBD	TBD	8,708.3	3.95	S-191	TBD	TBD
Coordinating Agency	N/A	F-25	C-38 Reservoir Assisted STA	Treat water from 3 priority basins.	STA	Conceptual	TBD	TBD	TBD	TBD	TBD	S-154, S-154C, S-133	TBD	TBD
Landowner	TBD	F-26	Urban Regional Basin STA in Southwest Okeechobee County	Provide additional water quality and stormwater detention area for urbanized area. Regional drainage system fed from Highway 70 and urbanized residential area. Regional onsite drainage canal and expansion for additional water quality are available.	BMP Treatment Train	Conceptual	500	TBD	TBD	TBD	TBD	S-191	$350,000	$7,500
FDOT D1	N/A	F-27	443172-1	SR 15 (US 98) from SE 36th Ave. to SE 38th Ave.	Stormwater System Rehabilitation	Planned	TBD	TBD	TBD	TBD	TBD	S-133	TBD	TBD
FDOT D1	N/A	F-28	439032-1	US 98/US 441 from SW 23rd St. to SW 14th St..	Wet Detention Pond	Planned	TBD	TBD	TBD	TBD	TBD	S-133	TBD	TBD

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Okeechobee Utility Authority	TBD	F-29	Treasure Island Septic to Sewer	Elimination of up to 2,430 connections.	OSTDS Phase Out	Conceptual	TBD	18,396.0	8.34	0.0	0.00	S-133	$24,300,000	TBD
Okeechobee Utility Authority	TBD	F-30	Southwest Wastewater Service Area	Elimination of up to 738 connections.	OSTDS Phase Out	Conceptual	TBD	5,628.0	2.55	0.0	0.00	S-133	$13,950,000	TBD
Okeechobee Utility Authority	TBD	F-31	Pine Ridge Park Septic to Sewer	Elimination of up to 80 connections.	OSTDS Phase Out	Conceptual	TBD	630.0	0.29	0.0	0.00	S-133	$1,500,000	TBD
Okeechobee Utility Authority	TBD	F-32	Okee-Tantie Wastewater Improvements	Elimination of up to 633 connections.	OSTDS Phase Out	Conceptual	TBD	4,788.0	2.17	0.0	0.00	S-133	$10,500,000	TBD

4.6. Upper Kissimmee Subwatershed

The Upper Kissimmee Subwatershed covers more than 1,000,000 acres of the LOW and is made up of 25 basins. As shown in **Table 52**, wetlands cover 34.6 % of the subwatershed, followed by agriculture at 26.1 %. Stakeholders in the subwatershed are Avon Park Air Force Range, City of Belle Isle, City of Davenport, City of Edgewood, City of Haines City, City of Kissimmee, City of Lake Wales, City of Orlando, City of St. Cloud, FDOT District 5, Turnpike Enterprise, Orange County, Osceola County, Polk County, RCID, Town of Dundee, Town of Windermere, and Valencia WCD.

Table 52. Summary of land uses in the Upper Kissimmee Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	216,916	21.1
2000	Agriculture	268,628	26.1
3000	Upland Nonforested	59,930	5.8
4000	Upland Forests	71,457	6.9
5000	Water	25,743	2.5
6000	Wetlands	355,682	34.6
7000	Barren Land	5,235	0.5
8000	Transportation, Communication, and Utilities	24,834	2.4
	Total	**1,028,425**	**100.0**

4.6.1. Water Quality Monitoring

In the Upper Kissimmee Subwatershed, the BMAP monitoring network includes water quality stations in 23 of the 25 basins. **Table 53** summarizes the water quality monitoring stations in the subwatershed, and **Figure 15** shows the station locations. **Table 53** also includes indications of which stations have recently been added as part of SFWMD or RCID expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the stations to better align with the BMAP. New monitoring stations will be needed in two basins where no representative site exists.

Table 53. Water quality monitoring stations in the Upper Kissimmee Subwatershed

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Lake Kissimmee	Yes	SFWMD	S65	1	Sufficient TN and TP data
Alligator Lake	No	SFWMD	AL11263113	2	Proposed station as part of SFWMD expanded monitoring
Alligator Lake	No	SFWMD	AL24263113	2	Proposed station as part of SFWMD expanded monitoring
Alligator Lake	No	SFWMD	AL34263113	2	Proposed station as part of SFWMD expanded monitoring
Alligator Lake	No	SFWMD	CO35253112	2	Proposed station as part of SFWMD expanded monitoring

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Alligator Lake	Yes	SFWMD	LG32263124	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Boggy Creek	Yes	SFWMD	ABOGGN	2	Sufficient TN and TP data
Boggy Creek	No	Orange County	Boggy Creek A (Tradeport)	2	N/A
Boggy Creek	No	Orlando/Orange County	Boggy Creek B (SR 527A)	2	Lake Tohopekaliga NRP station
Boggy Creek	No	Orlando/Orange County	Boggy Creek @ 527A City of Orlando Site (bcb)	2	Lake Tohopekaliga NRP station
Boggy Creek	No	City of Orlando	Lake Fran	2	Lake Tohopekaliga NRP station
Boggy Creek	No	City of Orlando	Lake Mare Prairie	2	Lake Tohopekaliga NRP station
Boggy Creek	No	City of Orlando	Mud Lake	2	Lake Tohopekaliga NRP station
Catfish Creek	Yes	SFWMD	34008 (ROMCUT)	2	Sufficient TN and TP data
East Lake Tohopekaliga	Yes	SFWMD	BS-59	2	Sufficient TN and TP data
East Lake Tohopekaliga	No	SFWMD	ET05253114	2	N/A
East Lake Tohopekaliga	No	Osceola County	ET05253114	2	Lake Tohopekaliga NRP station
East Lake Tohopekaliga	No	SFWMD	ET06253113	2	N/A
Horse Creek	Yes	Polk County Natural Resources Division	Horse Crk2	2	Increase collection frequency for TN and TP
Lake Conlin	N/A	N/A	N/A	2	No site available
Lake Cypress	Yes	SFWMD	4002 (C03)	2	Sufficient TN and TP data
Lake Gentry	No	SFWMD	CL19273123	2	Proposed station as part of SFWMD expanded monitoring
Lake Gentry	Yes	SFWMD	GENTRYDTCH	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Lake Hart	No	SFWMD	AJ33243122	2	Proposed station as part of SFWMD expanded monitoring
Lake Hart	No	City of Orlando	Buck Lake	2	Lake Tohopekaliga NRP station
Lake Hart	No	Orange County	HART: Lake Hart Outflow at S-62 (Clap Sims Duda)	2	N/A
Lake Hart	Yes	SFWMD	MJ01253123	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Lake Hatchinea	Yes	SFWMD	EC-37	2	Sufficient TP data; SFWMD will add TN in expanded monitoring

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Lake Hatchinea	No	SFWMD	HL08283014	2	Proposed station as part of SFWMD expanded monitoring
Lake Jackson	Yes	SFWMD	LJACKDSCH	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Lake Kissimmee	No	SFWMD	LK04313114	2	Proposed station as part of SFWMD expanded monitoring
Lake Kissimmee	No	SFWMD	PA10313112	2	N/A
Lake Marian	No	SFWMD	ML22303311	2	Proposed station as part of SFWMD expanded monitoring
Lake Marian	Yes	SFWMD	ML22303313	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Lake Marion	Yes	DEP Watershed Monitoring Section	51242	2	Increase collection frequency for TN and TP
Lake Myrtle	N/A	N/A	N/A	2	No site available
Lake Pierce	Yes	Polk County Natural Resources Division	Pierce1	2	Increase collection frequency for TN and TP
Lake Rosalie	Yes	SFWMD	KUB009	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Lake Tohopekaliga	No	City of Kissimmee	Bass Slough at Boggy Creek	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	City of Kissimmee	Bass Slough at Timothy Lane	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	SFWMD	BNSHINGLE	2	N/A
Lake Tohopekaliga	Yes	SFWMD	CL18273011	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Lake Tohopekaliga	No	City of Kissimmee	East City Ditch Outfall	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	Osceola County	JUDGES_DCH	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	SFWMD	LT32263013	2	N/A
Lake Tohopekaliga	No	City of Kissimmee	Mill Slough at Mill Run Blvd.	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	City of Kissimmee	Mill Slough Outfall	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	Osceola County	PARTIN_CNL	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	Osceola County	RUNNYMEDE	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	City of Kissimmee	Shingle Creek at John Young Pkwy.	2	Lake Tohopekaliga NRP station
Lake Tohopekaliga	No	City of Kissimmee	West City Ditch at Hacienda Circle	2	Lake Tohopekaliga NRP station

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Lake Weohyakapka	No	SFWMD	LR14302912	2	Proposed station as part of SFWMD expanded monitoring
Lake Weohyakapka	Yes	Polk County Natural Resources Division	Weohyakapka1	2	Increase collection frequency for TN and TP
Lower Reedy Creek	Yes	SFWMD	CREEDYBR	2	Sufficient TN and TP data
Marion Creek	Yes	SFWMD	DLMARNCR	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Marion Creek	Yes	SFWMD	DLONDNCR	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
S63A	No	SFWMD	CL06283112	2	N/A
S63A	Yes	SFWMD	CL06283111	2	Sufficient TP data; SFWMD will add TN in expanded monitoring
Shingle Creek	Yes	Orange County Environmental Protection Division	SCD	2	Sufficient TN and TP data
Shingle Creek	No	Orange County	Shingle Creek (Central FL Pkwy.)	2	N/A
Shingle Creek	No	City of Kissimmee	Shingle Creek at Town Center Blvd.	2	Lake Tohopekaliga NRP station
Shingle Creek	No	City of Kissimmee	Shingle Creek at Yates Rd.	2	Lake Tohopekaliga NRP station
Shingle Creek	No	Orlando/Orange County	Shingle Creek City of Orlando	2	Lake Tohopekaliga NRP station
Shingle Creek	No	City of Orlando	Turkey Lake (North)	2	Lake Tohopekaliga NRP station
Shingle Creek	No	City of Orlando	Turkey Lake (South)	2	Lake Tohopekaliga NRP station
Tiger Lake	Yes	DEP Central ROC	G4CE0070 (Tiger1-G4CE0070)	2	Sufficient TN and TP data
Tiger Lake	Yes	Polk County Natural Resources Division	Tiger1 (Tiger1-G4CE0070)	2	Sufficient TN and TP data
Upper Reedy Creek	No	RCID	C-12E (C-12E-RC-13H)	2	N/A
Upper Reedy Creek	No	RCID	RC-13H (C-12E-RC-13H)	2	N/A
Upper Reedy Creek	Yes	RCID	RC-13L	2	Proposed station (RCID)
Boggy Creek	No	USGS	02262900	3	N/A
Lake Kissimmee	No	SFWMD	S65_S	3	N/A
Lake Tohopekaliga	No	SFWMD	S61_S	3	N/A
Lake Weohyakapka	No	USGS	02268390	3	N/A
Shingle Creek	No	USGS	02263800	3	N/A
Shingle Creek	No	USGS	02264495	3	N/A
Upper Reedy Creek	No	USGS	02263869	3	N/A

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
Upper Reedy Creek	No	USGS	02264000	3	N/A
Upper Reedy Creek	No	USGS	02264003	3	N/A
Upper Reedy Creek	No	USGS	02264030	3	N/A
Upper Reedy Creek	No	USGS	02264051	3	N/A
Upper Reedy Creek	No	USGS	02264060	3	N/A
Upper Reedy Creek	No	USGS	02264100	3	N/A
Upper Reedy Creek	No	USGS	02266025	3	N/A
Upper Reedy Creek	No	USGS	02266200	3	N/A
Upper Reedy Creek	No	USGS	02266205	3	N/A
Upper Reedy Creek	No	USGS	02266291	3	N/A
Upper Reedy Creek	No	USGS	02266293	3	N/A
Upper Reedy Creek	No	USGS	02266295	3	N/A
Upper Reedy Creek	No	USGS	02266300	3	N/A
Upper Reedy Creek	No	USGS	02266480	3	N/A
Upper Reedy Creek	No	USGS	02266496	3	N/A
Upper Reedy Creek	No	USGS	02266500	3	N/A

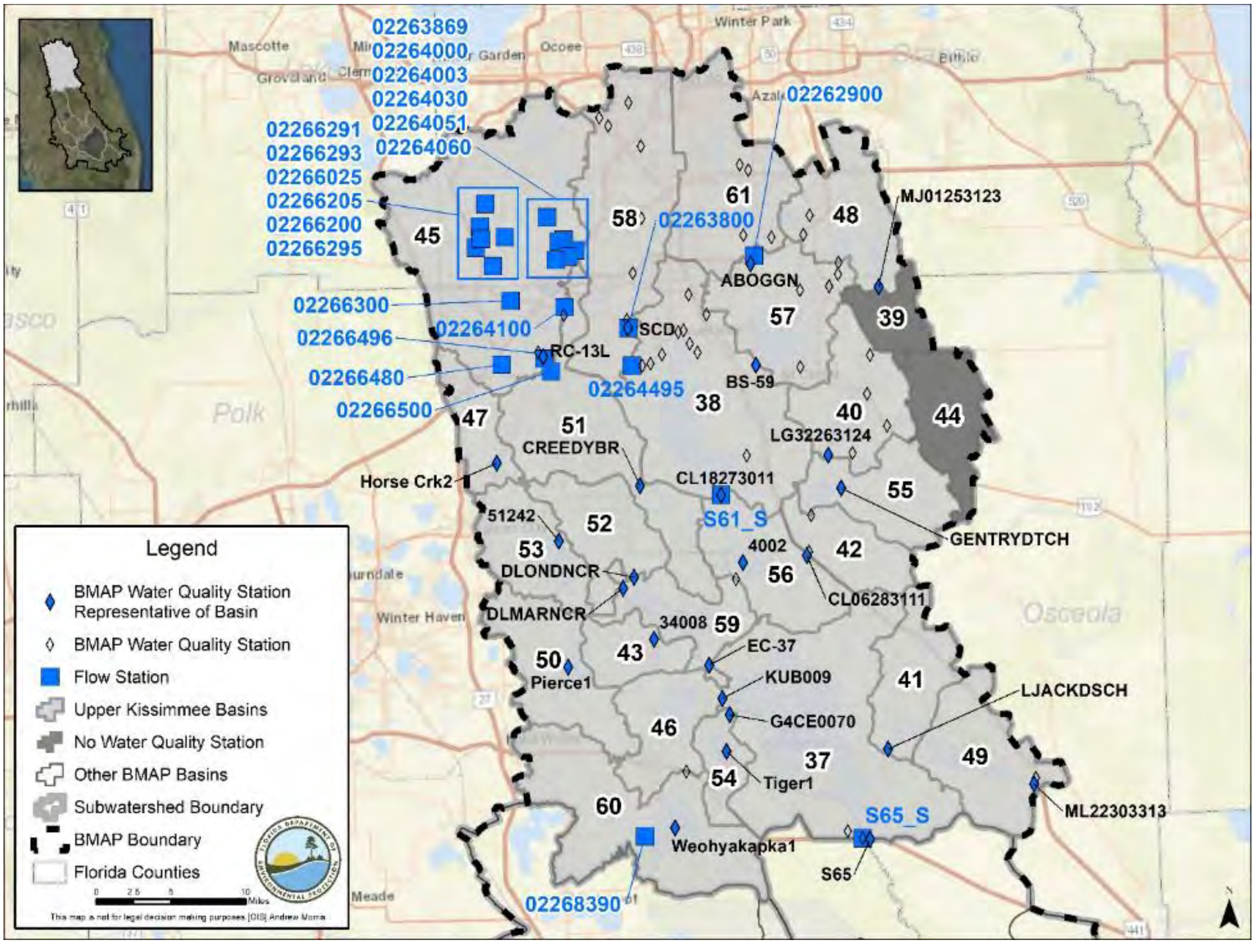

Figure 15. Locations of the water quality monitoring stations in the Upper Kissimmee Subwatershed

4.6.2. Basin Evaluation Results

The current TP load, based on data from WY2014–WY2018 for the Upper Kissimmee Subwatershed, is 90.5 mt/yr. A reduction of 74.6 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 15.9 mt/yr.

Table 54 summarizes the basin evaluation results for the Upper Kissimmee Subwatershed. For the basins with sufficient data, Catfish Creek and Lake Pierce have TN concentrations greater than the benchmark, and Lake Marian and Tiger Lake have TP concentrations greater than the benchmark. Based on evaluations made by SFWMD in the LOWCP update using the S65_S station, flow was determined not to be an issue in this subwatershed. The TRA prioritization results for the Upper Kissimmee Subwatershed are listed in **Table 55**, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 54. Basin evaluation results for the Upper Kissimmee Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
37	Lake Kissimmee	1.37	1.22	1.00	Insufficient Data	0.08	0.08	0.10	Significant Increasing	No
38	Lake Tohopekaliga	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.04	Insufficient Data	Insufficient Data	Significant Decreasing	Insufficient Data
39	Lake Myrtle	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
40	Alligator Lake	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
41	Lake Jackson	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.08	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
42	S63A	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
43	Catfish Creek	1.78	Insufficient Data	Insufficient Data	Insufficient Data	0.07	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
44	Lake Conlin (closed basin)	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
45	Upper Reedy Creek	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.04	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
46	Lake Rosalie	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.08	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
47	Horse Creek (closed basin)	1.32	Insufficient Data	Insufficient Data	Insufficient Data	0.07	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
48	Lake Hart	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.02	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
49	Lake Marian	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	1.28	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
50	Lake Pierce	1.97	Insufficient Data	Insufficient Data	Insufficient Data	0.05	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
51	Lower Reedy Creek	1.21	Insufficient Data	Insufficient Data	Insufficient Data	0.09	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
52	Marion Creek	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.10	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
53	Lake Marion	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.07	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
54	Tiger Lake	0.87	Insufficient Data	Insufficient Data	Insufficient Data	0.14	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
55	Lake Gentry	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.07	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
56	Lake Cypress	1.17	Insufficient Data	Insufficient Data	Insufficient Data	0.05	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
57	East Lake Tohopekaliga	0.71	Insufficient Data	Insufficient Data	Insufficient Data	0.02	Insufficient Data	Insufficient Data	No Significant Trend	Insufficient Data
58	Shingle Creek	0.61	Insufficient Data	Insufficient Data	Insufficient Data	0.05	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
59	Lake Hatchineha	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data	0.07	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
60	Lake Weohyakapka	0.87	Insufficient Data	Insufficient Data	Insufficient Data	0.03	Insufficient Data	Insufficient Data	Insufficient Data	Insufficient Data
61	Boggy Creek	0.63	Insufficient Data	Insufficient Data	Insufficient Data	0.04	Insufficient Data	Insufficient Data	Significant Increasing	Insufficient Data

Table 55. TRA evaluation results for the Upper Kissimmee Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

Basin	Station	TP Priority	TN Priority	Flow Priority
Alligator Lake	S60	Insufficient Data	Insufficient Data	Insufficient Data
Boggy Creek	ABOGGN	2	3	Insufficient Data
Catfish Creek	34008	3	3	Insufficient Data
East Lake Tohopekaliga	BS-59	3	3	Insufficient Data
Horse Creek (closed basin)	Horse Crk2	3	3	Insufficient Data
Lake Conlin (closed basin)		Insufficient Data	Insufficient Data	Insufficient Data
Lake Cypress	4002	3	3	Insufficient Data
Lake Gentry	GENTRYDTCH	3	Insufficient Data	Insufficient Data
Lake Hart	MJ01253123	3	Insufficient Data	Insufficient Data
Lake Hatchineha	EC-37	3	Insufficient Data	Insufficient Data
Lake Jackson	LJACKDSCH	3	Insufficient Data	Insufficient Data
Lake Kissimmee	S65	1	2	3
Lake Marian	ML22303313	2	Insufficient Data	Insufficient Data
Lake Marion	51242	3	Insufficient Data	Insufficient Data
Lake Myrtle		Insufficient Data	Insufficient Data	Insufficient Data
Lake Pierce	Pierce1	3	3	Insufficient Data
Lake Rosalie	KUB009	3	Insufficient Data	Insufficient Data
Lake Tohopekaliga	CL18273011	3	Insufficient Data	Insufficient Data
Lake Weohyakapka	Weohyakapka1	3	3	Insufficient Data
Lower Reedy Creek	CREEDYBR	3	3	Insufficient Data
Marion Creek	DLMARNCR-DLONDNCR	3	Insufficient Data	Insufficient Data
S63A	S63A	Insufficient Data	Insufficient Data	Insufficient Data
Shingle Creek	SCD	3	3	Insufficient Data
Tiger Lake	Tiger1-G4CE0070	3	3	Insufficient Data
Upper Reedy Creek	C-12E-RC-13H	3	Insufficient Data	Insufficient Data

4.6.3. Projects

The sections below summarize the existing and planned and future projects for the Upper Kissimmee Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.6.3.1. Existing and Planned Projects

Table 56 summarizes the existing and planned projects provided by the stakeholders for the Upper Kissimmee Subwatershed.

Table 56. Existing and planned projects in the Upper Kissimmee Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Avon Park Air Force Range	N/A	AFR-01	Cancellation of Cattle Lease	Land use change from agriculture to natural.	Land Use Change	Completed	2018	1,902.8	0.86	606.5	0.28	Arbuckle Creek	23,996.3	N/A	N/A	N/A	N/A	N/A
Coordinating Agency	N/A	CA-11	Legislative Cost-Share Appropriation Program (Dairy Projects)	See CA-05.	Dairy Remediation	Underway	TBD	TBD	TBD	TBD	TBD	Upper Kissimmee	TBD	Not provided	Not provided	FDACS	Not provided	N/A
Coordinating Agency	N/A	CA-13	Rolling Meadows Wetland Restoration Phase II	Land has been acquired and conceptual plan recommended. Implementation of Phase II is contingent on success of Phase I and future legislative funding. Schedule: If approved and funded, project completion is anticipated in 2 to 3 years.	Wetland Restoration	Planned	TBD	TBD	TBD	10.6	0.00	Catfish Creek	580.0	TBD	TBD	TBD	TBD	N/A
Coordinating Agency	N/A	CA-16	Sumica DWM	DWM.	DWM	Completed	Not provided	TBD	TBD	37.4	0.02	Tiger Lake	Not provided	Not provided	Not provided	Not provided	Not provided	N/A
City of Edgewood	N/A	EW-01	Water Quality Awareness Program	Water quality education and awareness articles in city quarterly newsletter. Water quality–related informational brochures, fliers, and other publications displayed at city hall for the public.	Education Efforts	Completed	N/A	32.0	0.01	18.2	0.01	Boggy Creek	N/A	N/A	$1,000	City of Edgewood	$1,000	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
City of Edgewood	Orange County	EW-02	Street Sweeping	Orange County performs weekly sweeping of 15.6 miles of streets within city limits	Street Sweeping	Completed	N/A	18.2	0.01	18.7	0.01	Boggy Creek	N/A	N/A	N/A	Orange County	N/A	N/A
City of Edgewood	Orange County	EW-03	Catch Basin Inlet Cleaning	Orange County performs monthly cleaning of storm inlet baskets for debris removal	Catch Basin Inserts	Completed	N/A	2.4	0.00	2.4	0.00	Boggy Creek	N/A	N/A	N/A	Orange County	N/A	N/A
FDACS	Agricultural Producers	FDACS-12	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – Upper Kissimmee. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	77,891.3	35.33	4,654.4	2.11	Upper Kissimmee	126,633	TBD	TBD	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-21	Cost-Share Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	8,305.5	3.77	731.9	0.33	Upper Kissimmee	12,178	TBD	TBD	FDACS	TBD	N/A
FDOT District 5	N/A	FDOT5-01	239266-B SR 15 (Hoffner Rd.) from north of Lee Vista Blvd. to west of SR 436 (Pond 2)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2019	0.1	0.00	0.0	0.00	Boggy Creek	4.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-02	239266-A SR 15 Hoffner Ave. from east of SR 436 to Conway Rd. (Pond 1)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2019	0.9	0.00	0.0	0.00	Boggy Creek	7.4	Not provided	Not provided	Florida Legislature	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDOT District 5	N/A	FDOT5-03	239266-C SR 15 Hoffner Ave. from west of SR 436 to Conway Rd. (Pond 3)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2019	5.9	0.00	0.8	0.00	Boggy Creek	4.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-04	239266-D SR 15 Hoffner Ave. from west of SR 436 to Conway Rd. (Pond 4)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2019	11.8	0.01	1.5	0.00	Boggy Creek	23.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-05	239535-F SR 50 from Good Homes Rd. to Pine Hills Rd. (Pond 4)	Add lanes and reconstruct.	Dry Detention Pond	Completed	2014	40.4	0.02	14.8	0.01	Shingle Creek	207.6	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-06	416518-A Interstate (I) 4 Braided Ramp from US 192 Interchange to Osceola Pkwy. Interchange (Pond SE-1)	New road construction.	Wet Detention Pond	Completed	2014	6.0	0.00	0.9	0.00	Upper Reedy Creek	14.8	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-07	416518-B Interstate-4 Braided Ramp from US 192 Interchange to Osceola Pkwy. Interchange (Pond SE-2)	New road construction.	Wet Detention Pond	Completed	2014	1.7	0.00	0.3	0.00	Upper Reedy Creek	4.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-08	239682-A SR 500 (US 17-92) from Aeronautical Dr. to Budinger Ave. (Pond 1)	Add lanes and rehabilitate pavement.	Wet Detention Pond	Underway	2020	11.2	0.01	2.2	0.00	Lake Tohopekaliga	12.4	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-09	239682-B SR 500 (US 17-92) from Aeronautical Dr. to Budinger Ave. (Pond 2)	Add lanes and rehabilitate pavement.	Wet Detention Pond	Underway	2020	20.8	0.01	1.7	0.00	Lake Tohopekaliga	9.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-10	239682-C SR 500 (US 17-92) from Aeronautical Dr. to Budinger Ave. (Pond 3)	Add lanes and rehabilitate pavement.	Wet Detention Pond	Underway	2020	9.6	0.00	2.1	0.00	Lake Tohopekaliga	9.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-11	239682-D SR 500 (US 17-92) from Aeronautical Dr. to Budinger Ave. (Pond 4)	Add lanes and rehabilitate pavement.	Wet Detention Pond	Underway	2020	12.6	0.01	5.3	0.00	Lake Tohopekaliga	34.6	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-12	418403-A, B SR 600 (US 17-92) John Young Pkwy. (JYP) from south of Portage St. to north of Vine St. (US 192) (Ponds East and West)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2019	2.8	0.00	0.8	0.00	Lake Tohopekaliga	2.5	Not provided	Not provided	Florida Legislature	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDOT District 5	N/A	FDOT5-13	239454-A widening of SR 436 from SR 528 to SR 552 (Pond A)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2010	1.6	0.00	0.9	0.00	Boggy Creek	59.3	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-14	239635-A New Bridge SR 500 at Reedy Creek (Pond 1)	New bridge.	Dry Detention Pond	Completed	2010	0.7	0.00	0.1	0.00	Lower Reedy Creek	2.5	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-15	239635-B New Bridge SR 500 at Reedy Creek (Pond 2)	New bridge.	Wet Detention Pond	Completed	2010	3.0	0.00	0.3	0.00	Lower Reedy Creek	4.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-16	239663-A Widening of SR 530 from SR 535 to Hoagland Blvd. (Pond 1)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2010	2.7	0.00	0.5	0.00	Shingle Creek	19.8	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-17	239663-B Widening of SR 530 from SR 535 to Hoagland Blvd. (Pond 2)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2010	6.7	0.00	1.0	0.00	Shingle Creek	17.3	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-18	239663-C Widening of SR 530 from SR 535 to Hoagland Blvd. (Pond 3)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2010	16.9	0.01	3.6	0.00	Shingle Creek	14.8	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-19	239663-D Widening of SR 530 from SR 535 to Hoagland Blvd. (Pond 4)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2010	4.5	0.00	2.1	0.00	Shingle Creek	12.4	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-20	242436-A SR 400 Ramps at Gore Ave. Retention Pits (Ponds 1 and 2)	Ramps.	Dry Detention Pond	Completed	2011	3.1	0.00	0.4	0.00	Boggy Creek	4.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-21	242484-A Widening of SR 400 from Universal Blvd. to South St. (Pond 4)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2011	3.2	0.00	0.8	0.00	Boggy Creek	19.8	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-22	405515-A and B SR 400 Wet Detention Pond (Ponds 1 and 2)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2011	0.5	0.00	0.6	0.00	Shingle Creek	9.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-23	410732-B SR 400 Swales	Add lanes and reconstruct.	Grass Swales Without Swale Blocks or Raised Culverts	Completed	2010	0.7	0.00	0.3	0.00	Shingle Creek	32.1	Not provided	Not provided	Florida Legislature	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDOT District 5	N/A	FDOT5-24	Street Sweeping	Street sweeping to collect 1,507,453 lbs/yr of material.	Street Sweeping	Completed	N/A	280.2	0.13	288.3	0.13	Lake Tohopekaliga, Upper Reedy Creek, Lower Reedy Creek, Shingle Creek, Boggy Creek, Alligator Lake	N/A	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-25	Education and Outreach	Funding for Orange County Water Atlas website, and illicit discharge inspection and training program.	Education Efforts	Completed	N/A	67.8	0.03	19.5	0.01	Lake Kissimmee, Lake Tohopekaliga, Alligator Lake, Lake Jackson, S63A, Lake Conlin (closed basin), Upper Reedy Creek, Lake Rosalie, Horse Creek (closed basin), Lake Hart, Lake Marian, Lake Pierce, Lower Reedy Creek, Lake Marion, Tiger Lake, Lake Gentry, Lake Cypress, East Lake Tohopekaliga, Shingle Creek, Lake Weohyakapka, Boggy Creek	12,414.5	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-26	2396831 Pond 6 (SR 500 widening from Eastern Ave. to Nova Rd.)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2017	65.5	0.03	11.7	0.01	Alligator Lake	19.1	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-27	2396831 Pond 7 (SR 500 widening from Eastern Ave. to Nova Rd.)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2017	79.3	0.04	6.9	0.00	Alligator Lake	23.2	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-28	407143-4 Ponds WDA 2A and 2B (SR 482 widening from west of Turkey Lake Rd. to east of Universal Blvd.)	Add lanes and reconstruct.	Wet Detention Pond	Underway	2019	16.0	0.01	3.6	0.00	Shingle Creek	42.0	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-29	407143-4 Pond WDA 3 (SR 482 widening from west of Turkey Lake Rd. to east of Universal Blvd.)	Add lanes and reconstruct.	Wet Detention Pond	Underway	2019	7.7	0.00	2.4	0.00	Shingle Creek	27.2	Not provided	Not provided	Florida Legislature	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDOT District 5	N/A	FDOT5-30	407143-4 Pond WDA 4 (SR 482 widening from west of Turkey Lake Rd. to east of Universal Blvd.)	Add lanes and reconstruct.	Wet Detention Pond	Underway	2019	17.9	0.01	7.1	0.00	Shingle Creek	39.5	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-31	407143-6 SR 482 (Sand Lake Rd.) at John Young Pkwy. – Overpass over Sand Lake	Overpass over Sand Lake at John Young Pkwy. (2 wet detention ponds for FM 407143-1).	Wet Detention Pond	Underway	2019	4.3	0.00	2.4	0.00	Shingle Creek	32.1	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-32	239714-SR 600 from west of Poinciana to County Road (CR) 535 (Pond 1)	Add lanes and reconstruct.	Wet Detention Pond	Underway	2021	1.7	0.00	1.1	0.00	Shingle Creek	13.0	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-33	239714-SR 600 from west of Poinciana to CR 535 (Pond 2)	Add lanes and reconstruct.	Wet Detention Pond	Underway	2021	1.4	0.00	0.8	0.00	Shingle Creek	13.3	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-34	239714-SR 600 from west of Poinciana to CR 535 (Pond 3)	Add lanes and reconstruct.	Wet Detention Pond	Underway	2021	0.4	0.00	0.2	0.00	Shingle Creek	4.0	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-35	239304-SR 530 from Lake C/L to east of Secret Lake Dr. (Pond 1)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2014	1.1	0.00	0.4	0.00	Upper Reedy Creek	11.0	Not provided	Not provided	Florida Legislature	Not provided	N/A
FDOT District 5	N/A	FDOT5-36	239304-SR 530 from Lake C/L to east of Secret Lake Dr. (Pond 5)	Add lanes and reconstruct.	Wet Detention Pond	Completed	2014	1.1	0.00	0.4	0.00	Upper Reedy Creek	11.9	Not provided	Not provided	Florida Legislature	Not provided	N/A
City of Kissimmee	N/A	KS-01	Education and Outreach	PSAs, pamphlets, website, and Illicit Discharge Program.	Education Efforts	Completed	N/A	253.0	0.11	92.8	0.04	Shingle Creek, Lake Tohopekaliga, East Lake Tohopekaliga	9,197.2	$65,000	$45,000	City of Kissimmee	$110,000	N/A
City of Kissimmee	N/A	KS-02	Street Sweeping	Complete 6,573 miles of street sweeping and collect 3,100 cubic yards of debris.	Street Sweeping	Completed	N/A	1,320.5	0.60	1,359.9	0.62	Shingle Creek, Lake Tohopekaliga, East Lake Tohopekaliga	N/A	$50,000	$50,000	City of Kissimmee	$100,000	N/A
City of Kissimmee	TBD	KS-03	Lake Tivoli	Treatment for older existing development as well as future online development; treatment provides 2.5 times proposed percent impervious area.	Online Retention BMPs	Underway	TBD	TBD	TBD	TBD	TBD	Lake Tohopekaliga	135.9	$300,000	TBD	TBD	TBD	N/A

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City of Kissimmee	N/A	KS-04	Lakefront Park Redevelopment - Swales/ Rain Gardens	Swale/rain garden system with 2.07 acres of dry detention.	Grass Swales Without Swale Blocks or Raised Culverts	Completed	2015	2.3	0.00	0.1	0.00	Lake Tohopekaliga	12.4	$500,000	Not provided	City of Kissimmee	$500,000	N/A
City of Kissimmee	N/A	KS-05	Lakefront Park Redevelopment Baffle Boxes	3 NSBBs and 3 filter boxes in lakefront park area. Will install up to additional 2 baffle boxes in next 5 years.	Baffle Boxes – Second Generation	Completed	2015	4.0	0.00	0.2	0.00	Lake Tohopekaliga	12.4	$394,267	Not provided	City of Kissimmee	$394,267	N/A
City of Kissimmee	N/A	KS-06	Martin Luther King Blvd. Phase III from Thacker Ave. to Dyer Blvd.	Construction of dry detention with specific standards (side slopes, littoral zones) per Federal Aviation Administration for reduction of bird strikes.	Grass Swales Without Swale Blocks or Raised Culverts	Completed	2015	1.0	0.0	0.1	0.0	Lake Tohopekaliga	5.5	$1,500,000	$1,500	City of Kissimmee	$1,501,500	N/A
City of Kissimmee	DEP	KS-07	Emory Ave. Stormwater Management Pond	Offline stormwater pond to provide extra storage to alleviate flooding. Pond will also catch first flush during rain events to help provide water quality treatment to West City Ditch.	Wet Detention Pond	Completed	2017	0.1	0.0	0.0	0.0	Lake Tohopekaliga	TBD	$500,000	$1,000	DEP	$500,000	S0725
City of Kissimmee	NRCS	KS-08	Mill Slough Restoration	Restored eroded banks and removed excess silt that was washed from bank along with removal of downed trees.	Shoreline Stabilization	Underway	2019	TBD	TBD	TBD	TBD	Lake Tohopekaliga	TBD	$1,857,026	TBD	NRCS/ City of Kissimmee	$1,434,974	N/A
City of Kissimmee	DEP	KS-09	Woodside Drainage Improvement	Project would reduce flooding and improve water quality entering Shingle Creek Basin.	Wet Detention Pond	Planned	2021	TBD	TBD	TBD	TBD	Lake Tohopekaliga	TBD	TBD	TBD	DEP/ City of Kissimmee	TBD	TBD

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Orange County	N/A	OC-01	Education and Outreach	FYN; landscaping, irrigation, fertilizer, and pet waste management ordinances; PSAs; pamphlets; Water Atlas website; and illicit discharge program.	Education Efforts	Completed	N/A	14,785.3	6.71	9,192.1	4.17	Upper Reedy Creek, Shingle Creek, Boggy Creek, Lake Tohopekaliga, East Lake Tohopekaliga, Lake Hart, Lower Reedy Creek	66,065.8	$225,000	$6,988	Orange County	$225,000 and $6,988 annually	N/A
Orange County	N/A	OC-02	Lake Conway Street Sweeping	Street sweeping of 5,011 curb miles annually.	Street Sweeping	Completed	N/A	212.9	0.10	157.9	0.07	Boggy Creek	N/A	$94,217	$94,217	Lake Conway Taxing District (Municipal Services Taxing Unit [MSTU])	$94,217 annually	N/A
Orange County	N/A	OC-03	Lake Holden Street Sweeping	Street sweeping of 829 curb miles annually.	Street Sweeping	Completed	N/A	35.3	0.02	26.0	0.01	Boggy Creek	N/A	$15,587	$15,587	Lake Holden Taxing District (MSTU)	$15,587 annually	N/A
Orange County	N/A	OC-04	Lake Jessamine Street Sweeping	Street sweeping of 734 curb miles annually.	Street Sweeping	Completed	N/A	31.0	0.01	23.3	0.01	Boggy Creek	N/A	$13,801	$13,801	Lake Jessamine Taxing District (MSTU)	$13,801 annually	N/A
Orange County	N/A	OC-05	Shingle/Boggy/Hart Basin Street Sweeping	Countywide street sweeping (about 13,000 curb miles).	Street Sweeping	Completed	N/A	176.2	0.08	130.4	0.06	Shingle Creek, Boggy Creek, Lake Hart	N/A	$404,000	$404,000	Orange County	$404,000 Annually	N/A
Orange County	N/A	OC-07	Lake Conway Curb Inlet Basket (CIB) Existing	Curb or grate inlet filter baskets (116) to collect 16,169 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2015	3.6	0.00	3.7	0.00	Boggy Creek	71.0	$112,000	$13,269	Lake Conway Taxing District (MSTU)	Not provided	N/A
Orange County	N/A	OC-09	Lake Pineloch CIB	Curb or grate inlet filter baskets (23) to collect 4,158 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	0.9	0.00	0.9	0.00	Boggy Creek	14.0	$18,000	$2,677	Orange County	Not provided	N/A
Orange County	N/A	OC-10	Lake Anderson CIB	Curb or grate inlet filter baskets (11) to collect 3,364 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	$10,000	$1,280	Lake Anderson MSTU	Not provided	N/A
Orange County	N/A	OC-11	Lake Holden CIB	Curb or grate inlet filter baskets (115) to collect 27,602 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	6.2	0.00	6.1	0.00	Shingle Creek	72.0	$41,000	$13,386	Lake Holden Taxing District (MSTU)	Not provided	N/A
Orange County	N/A	OC-12	Lake Jessamine CIB	Curb or grate inlet filter baskets (92) to collect 13,025 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	2.9	0.00	2.9	0.00	Boggy Creek	63.0	$110,000	$10,708	Lake Jessamine Taxing District (MSTU)	Not provided	N/A

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Orange County	N/A	OC-13	Lake Floy CIB	Curb or grate inlet filter baskets (10) to collect 4,835 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	1.1	0.00	1.1	0.00	Shingle Creek	6.0	$10,000	$1,164	Lake Floy MSTU	Not provided	N/A
Orange County	N/A	OC-14	Lake Cane CIB	Curb or grate inlet filter baskets (14) to collect 3,845 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	0.9	0.00	0.8	0.00	Shingle Creek	11.0	$14,000	$1,629	Orange County	Not provided	N/A
Orange County	N/A	OC-15	Lake Odell CIB	Curb or grate inlet filter baskets (3) to collect 904 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	0.2	0.00	0.2	0.00	Shingle Creek	2.0	$3,000	$349	Orange County	Not provided	N/A
Orange County	Not provided	OC-16	Lake Tyler CIB	Curb or grate inlet filter baskets (10).	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	1.1	0.00	1.1	0.00	Shingle Creek	7.0	$11,000	$1,164	Not provided	Not provided	Not provided
Orange County	N/A	OC-17	Lake Down/Windermere CIB	Curb or grate inlet filter baskets (51) to collect 16,934 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2014	3.8	0.00	3.8	0.00	Shingle Creek	34.0	$56,000	$16,063	Windermere Water and Navigation Control District (MSTU)	Not provided	N/A
Orange County	N/A	OC-18	Lake Tibet CIB	Curb or grate inlet filter baskets (92) to collect 13,494 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	3.1	0.00	3.0	0.00	Upper Reedy Creek	58.0	$31,000	Not provided	Windermere Water and Navigation Control District (MSTU)	Not provided	N/A
Orange County	N/A	OC-19	Lisa Waterway Continuous Deflective Separation (CDS) Unit	Treats runoff from Orange Ave.	Hydrodynamic Separators	Completed	2008	2.6	0.00	1.7	0.00	Boggy Creek	Not provided	$225,000	$6,988	Lake Conway Taxing District (MSTU)	Not provided	N/A
Orange County	Not provided	OC-20	Randolph Ave. CDS Unit	Treats runoff from Randolph Ave.	Hydrodynamic Separators	Completed	Not provided	0.0	0.0	0.0	0.0	Boggy Creek	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided
Orange County	Not provided	OC-21	Randolph Ave. Stormceptor™	Stormceptor™.	Hydrodynamic Separators	Completed	Prior to 2014	0.0	0.0	0.0	0.0	Boggy Creek	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided
Orange County	Not provided	OC-22	Randolph (Hansel) Ave. Pond	Retrofit of wet detention pond – increased residence time, pond depth.	Wet Detention Pond	Completed	2019	0.1	0.0	0.0	0.0	Boggy Creek	Not provided	Not provided	Not provided	Orange County Public Works/ Lake Conway Taxing District (MSTU)	Not provided	Not provided
Orange County	FDOT District 5/ City of Edgewood	OC-23	Lake Mary Jess Pond	Wet retention pond created from canal.	Wet Detention Pond	Completed	2013	9.3	0.00	10.7	0.00	Boggy Creek	27.2	$534,795	$6,000	FDOT District 5/ City of Edgewood	Not provided	N/A

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Orange County	N/A	OC-24	Lake Odell Sediment Sump	Small sump collects sediment from roadway, with estimated 12,000 lbs/yr of material.	Control Structure	Completed	2014	2.1	0.00	2.2	0.00	Shingle Creek	N/A	$33,300	$1,500	Orange County	Not provided	N/A
Orange County	SJRWMD	OC-25	Lake Jennie Jewell NSBB	Construct second-generation NSBB containing media. Improve headwall and forebay prior to discharge to lake.	Baffle Boxes – Second Generation with Media	Completed	2018	103.7	0.05	0.6	0.00	Boggy Creek	24.7	$312,511	$2,500	SJRWMD/ Orange County	SJRWMD – $119,600/ County – $192,911	N/A
Orange County	N/A	OC-26	Lake Anderson Alum Treatment System	Storm pond enhancement with alum.	Alum Injection Systems	Completed	2017	782.5	0.35	13.3	0.01	Boggy Creek	170.5	$345,166	$16,900	Orange County/ Lake Anderson MSBU	Not provided	N/A
Orange County	N/A	OC-27	Lake Jessamine Surface Alum	Whole-lake alum treatment.	Alum Injection Systems	Completed	2013	108.1	0.05	14.0	0.01	Boggy Creek	294.1	$246,000	Not provided	Lake Jessamine Taxing District (MSTU)	Not provided	N/A
Orange County	DEP	OC-28	Lake Down Alum Treatment Facility	Installation of offline alum injection facility on upstream portion of Butler Chain of Lakes to address phosphorus loading to chain and downstream.	Alum Injection Systems	Completed	2016	317.8	0.14	35.6	0.02	Upper Reedy Creek	378.1	$2,000,000	$15,000	Windermere Water and Navigation Control District (MSTU)/ DEP	MSTU – $1,053,000/ DEP 319 – $790,000	G0335
Orange County	N/A	OC-29	Lake Conway Hydrologic and Nutrient Study	Identify nutrient sources.	Study	Underway	2019	N/A	N/A	N/A	N/A	Boggy Creek	N/A	$172,000	N/A	Lake Conway Taxing District (MSTU)	$224,097	N/A
Orange County	N/A	OC-30	Lake Jennie Jewel CIB Installation	Install baskets in stormwater inlets.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2015	2.0	0.00	2.0	0.00	Boggy Creek	N/A	$9,360	$1,200	Orange County	$93,600 and $1,200 annually	N/A
Orange County	N/A	OC-31	Jewell-Gatlin NSBB	Construct NSBB containing media.	Baffle Boxes – Second Generation with Media	Canceled	N/A	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	N/A	N/A	N/A	N/A	N/A
Orange County	N/A	OC-32	Lake Gem Mary Loading Assessment	Identify impairment sources and recommend BMPs.	Study	Underway	2019	N/A	N/A	N/A	N/A	Boggy Creek	N/A	$162,517	N/A	Orange County	$162,517	N/A
Orange County	DEP	OC-33	Lake Conway Old Dominion Rd. NSBB	Treat stormwater from Lake Conway Woods.	Baffle Boxes – Second Generation with Media	Completed	2015	TBD	TBD	TBD	TBD	Boggy Creek	39.5	$173,513	$4,258	Lake Conway Taxing District (MSTU)	DEP – $141,679/ MSTU – $31,834	LP4803F

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Orange County	N/A	OC-34	Lake Conway Pershing CDS	Treat stormwater from Pershing Ave.	Hydrodynamic Separators	Completed	Not provided	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$5,072	Lake Conway Taxing District (MSTU)	MSTU – $5,072 annually	N/A
Orange County	N/A	OC-35	Lake Conway Cullen Lakeshore CDS	Treat stormwater from Cullen Lake shore.	Hydrodynamic Separators	Completed	Prior to 2007	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$5,677	Lake Conway Taxing District (MSTU)	MSTU – $5,677 annually	N/A
Orange County	N/A	OC-36	Lake Jessamine 608 Viscaya NSB1	Treat stormwater from Viscaya Ave.	Baffle Boxes – Second Generation with Media	Completed	2015	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$1,175	Lake Jessamine Taxing District (MSTU)	MSTU – $1,175 annually	N/A
Orange County	N/A	OC-37	Lake Jessamine 616 Viscaya NSB1	Treat stormwater from Viscaya Ave.	Baffle Boxes – Second Generation with Media	Completed	2015	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$1,404	Lake Jessamine Taxing District (MSTU)	MSTU – $1,404 annually	N/A
Orange County	N/A	OC-38	Lake Jessamine Silvera Ave. NSB1	Treat stormwater from Silvera Ave.	Baffle Boxes – Second Generation with Media	Completed	2015	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$2,076	Lake Jessamine Taxing District (MSTU)	MSTU – $2,076 annually	N/A
Orange County	N/A	OC-39	Lake Tyler Apts. 8 CDS	Treat stormwater from Lake Tyler Apts.	Hydrodynamic Separators	Completed	2008	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$2,952	Orange County	County – $2,952 annually	N/A
Orange County	N/A	OC-40	Lake Tyler Apts. 9 CDS	Treat stormwater from Lake Tyler Apts.	Hydrodynamic Separators	Completed	2008	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$5,445	Orange County	County – $5,445 annually	N/A
Orange County	N/A	OC-41	Hidden Cove Apts. 7 CDS	Treat stormwater from Hidden Cove Apts.	Hydrodynamic Separators	Completed	2008	TBD	TBD	TBD	TBD	Boggy Creek	Not provided	Not provided	$3,333	Orange County	County – $3,333 annually	N/A
Orange County	N/A	OC-42	Lake Tibet Houston Pl. NSBB	Treat stormwater from Houston Place.	Baffle Boxes – Second Generation with Media	Completed	2017	TBD	TBD	TBD	TBD	Upper Reedy Creek	Not provided	Not provided	$2,329	Butler MSTU	MSTU – $2,329 annually	N/A
Orange County	N/A	OC-43	Lake Down Subbasin 9 NSBB	Treat stormwater from Subbasin 9 in Lake Down.	Baffle Boxes – Second Generation	Completed	2017	TBD	TBD	TBD	TBD	Upper Reedy Creek	411.0	$390,000	$8,125	Butler MSTU/ SFWMD	Not provided	N/A
Orange County	N/A	OC-44	Lake Jessamine Hydrologic Nutrient Budget Study	Hydrologic and nutrient budget study.	Study	Completed	2012	N/A	N/A	N/A	N/A	Boggy Creek	N/A	$105,886	N/A	Lake Jessamine Taxing District (MSTU)	Not provided	N/A
Orange County	N/A	OC-45	Anderson St. Sweeping	Sweeping of 31.8 curb miles annually.	Street Sweeping	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	N/A	Not provided	$770	Lake Anderson Taxing District (MSTU)	MSTU – $770 annually	N/A
Orange County	N/A	OC-46	Bass Lake CIB	Collect 1,572 lbs/yr of material in 6 CIBs.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2008	1.0	0.00	1.0	0.00	Boggy Creek	4.0	$5,430	$470	Bass Lake Taxing District (MSTU)	MSTU – $5,430 plus $470 annually	N/A
Orange County	N/A	OC-47	Jennie Jewel Alum	In-lake application of alum and buffer.	Alum Injection Systems	Completed	2019	35.6	0.02	1.1	0.00	Boggy Creek	69.2	$138,605	N/A	Orange County Board of County Commissioners/ SJRWMD	$119,600.00 (Bundled with OC-25)	N/A

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Orange County	N/A	OC-48	LaGrange CIB	Collect 2,290 lbs/yr of material.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	2014	2.0	0.00	1.0	0.00	Boggy Creek	5.0	$7,200	$940	LaGrange Taxing District (MSTU)	MSTU – $7,200 plus $940 annually	N/A
Orange County	N/A	OC-49	Lake Christie NSBB	Install NSBB fitted with bioactivated media.	Baffle Boxes – Second Generation with Media	Completed	2018	TBD	TBD	TBD	TBD	Shingle Creek	81.5	$150,000	$1,500	Orange County	$151,500.00	N/A
Orange County	N/A	OC-50	Lake Pineloch NSBB	Construct treatment train consisting of online NSBB and offline upflow filter	Baffle Boxes – Second Generation with Media	Planned	2020	TBD	TBD	TBD	TBD	Boggy Creek	109.0	$841,992	$1,500	TBD	TBD	N/A
Orange County	N/A	OC-51	Shingle Creek Hydro/ Nutrient Assessment	Conduct nutrient/hydro assessment and produce ranked list of BMPs.	Study	Underway	2019	N/A	N/A	N/A	N/A	Shingle Creek	N/A	$134,958	N/A	Orange County	$134,958	N/A
Orange County	N/A	OC-52	Boggy Creek B-14 Pipeline (Segment B)	Replace structures and failing 60-inch corrugated metal pipe.	Stormwater System Rehabilitation	Completed	2016	TBD	TBD	TBD	TBD	Boggy Creek	N/A	$172,840	N/A	Orange County	$172,840	N/A
Orange County	N/A	OC-53	Bonnie Brook Erosion Control	Remove failing fabriform revetment and install new reinforced concrete channel lining and riprap in segments of Lake Ellenor Outfall Canal and Westridge Outfall Canal.	Shoreline Stabilization	Completed	2017	TBD	TBD	TBD	TBD	Shingle Creek	Not provided	$387,412	N/A	Orange County	$387,412	N/A
Orange County	N/A	OC-54	B-14 Wheatberry Court	Repair existing slope failure areas and install turf reinforcement mat to stabilize slope.	Shoreline Stabilization	Underway	2019	TBD	TBD	TBD	TBD	Boggy Creek	TBD	$60,000	N/A	Orange County	$113,710	N/A
Orange County	N/A	OC-55	Boggy Creek B-14 Pipeline (Segments A, C, and D)	Replace 4,500 linear feet of failing 60-inch corrugated metal pipe.	Stormwater System Rehabilitation	Underway	2021	TBD	TBD	TBD	TBD	Boggy Creek	TBD	$3,100,000	N/A	Orange County	$3,100,000	N/A

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Orange County	N/A	OC-56	Lake Hickorynut Hydro/Nutrient Source Assessment	Assess hydrological and nutrient pollutant sources, allocate source loading, produce ranked list of BMPs for consideration.	Study	Underway	43983	N/A	N/A	N/A	N/A	Upper Reedy Creek	800.0	$199,179	$0	Orange County Board of County Commissioners	$199,179	N/A
Orange County	N/A	OC-57	Lake Gem Mary Alum Treatment Design	Size alum application of Lake Gem Mary.	Alum Injection Systems	Underway	43800	TBD	TBD	TBD	TBD	Boggy Creek	14.0	$63,672	$0	Orange County Board of County Commissioners	$63,672	N/A
Orange County	N/A	OC-58	Lake Gem Mary Alum Treatment	In-lake alum surface water treatment.	Alum Injection Systems	Planned	TBD	543.0	0.25	12.1	0.01	Boggy Creek	61.8	TBD	$0	Orange County Board of County Commissioners	TBD	N/A
Orange County	N/A	OC-59	Shingle Creek Feasibility Study	Determine constructability of BMPs intended to improve water quality and/or impound water.	Study	Underway	TBD	N/A	N/A	N/A	N/A	Shingle Creek	TBD	$197,354	$0	Orange County Board of County Commissioners	$197,354	N/A
Orange County	N/A	OC-60	Holden Heights Community Improvements Phase IV	Project includes new gravity sewer to replace aging septic tank systems. This is joint Orange County Utilities (OCUD), Orange County Public Works, Orange County Housing and Community Development (OCHCD), and Orlando Utilities Commission (OUC) project with CDBG funding provided through OCHCD.	OSTDS Phase Out	Underway	2019	494.8	0.22	0.0	0.00	Shingle Creek	N/A	Not provided	N/A	CDBG funding provided through OCHCD	Not provided	N/A

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Orange County	N/A	OC-61	Hamlin Water Reclamation Facility (WRF)	Hamlin WRF project consists of design and construction of new physical, biological, and chemical treatment facilities for raw sewage with annual average daily flow capacity of 5 mgd. WRF will be designed to meet effluent goals of advanced WRF.	WWTF Nutrient Reduction	Underway	2023	TBD	TBD	TBD	TBD	Shingle Creek	N/A	Not provided	N/A	OCUD Capital Improvements Program Budget	Not provided	N/A
City of Orlando	SFWMD	ORL-01	18th St./ Parramore Ave. Baffle Box	Baffle box installed to remove gross pollutants, including organic debris, sediment and litter. 1.5 cubic yards per year of material collected.	Baffle Boxes – Second Generation	Completed	2009	2.6	0.00	0.1	0.00	Boggy Creek	2.5	$578,138	Not provided	SFWMD/ City of Orlando Streets and Stormwater Division	City – $289,069/ SFWMD – $289,069	N/A
City of Orlando	SFWMD	ORL-02	19th St./ Parramore Ave. Baffle Box	Baffle box installed to remove gross pollutants, including organic debris, sediment and litter. 1 cubic yd/yr of material collected.	Baffle Boxes – Second Generation	Completed	2009	7.6	0.00	0.1	0.00	Boggy Creek	12.4	N/A	Not provided	SFWMD/ City of Orlando Streets and Stormwater Division	N/A	N/A
City of Orlando	DEP	ORL-03	Pine St./ Orange Blossom Trail Corridor Stormwater Improvements	Installation of 1,800 linear feet of stormwater pipe from Pine St. to Lake Lorna Doone, including baffle box.	Baffle Boxes – Second Generation	Completed	2010	1.8	0.00	1.0	0.00	Boggy Creek	9.9	$942,710	Not provided	DEP/ City of Orlando Streets and Stormwater Division	City – $471,355/ DEP – $471,355	Not provided
City of Orlando	OUC	ORL-04	Lake Holden Terrace/Albert Shores Sanitary Components	Sanitary infrastructure installed for septic tank conversions. 11 of 77 homes converted.	Wastewater Service Area Expansion	Completed	2012	320.2	0.15	0.0	0.00	Boggy Creek	N/A	$3,522,911	Not provided	City of Orlando/ OUC	Not provided	N/A

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City of Orlando	OUC	ORL-05	Lake Holden Terrace/Albert Shores Stormwater Components	2 baffle boxes and 1 Storm Flo unit installed in stormwater infrastructure for capturing organic debris, sediment, and litter; stormwater infrastructure added to alleviate flooding. 20.5 cubic yds/yr of material collected.	Baffle Boxes – Second Generation	Completed	2012	1,587.2	0.72	98.4	0.04	Boggy Creek	69.2	N/A	Not provided	City of Orlando/ OUC	Not provided	N/A
City of Orlando	DEP	ORL-06	Lake Angel Drainage Improvements	Expand permanent pool volume of Lake Angel and install 3 baffle boxes in main inflow pipes.	Wet Detention Pond	Completed	2015	22.0	0.01	0.6	0.00	Boggy Creek	101.3	$1,239,249	Not provided	DEP/ City of Orlando Streets and Stormwater Division	City – $948,249/ DEP – $291,000	Not provided
City of Orlando	N/A	ORL-07	Cemex – South Division Ave. Roadway and Drainage Improvements	Pave unimproved access road to industrial park and install baffle box to capture sediment; install curbing along additional areas of Division Ave. to allow street sweepers to effectively capture more sediment in Lake Holden Basin.	Baffle Boxes – Second Generation	Canceled	N/A	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	N/A	N/A	N/A	N/A	N/A
City of Orlando	N/A	ORL-08	Lake Pineloch Basin Inlet Baskets	32 inlet baskets installed to remove gross pollutants, including organic debris, sediment, and litter. 44 cubic yds/yr of material collected.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	Not provided	14.2	0.01	14.0	0.01	Boggy Creek	Not provided	$40,480	$11,735	City of Orlando Streets and Stormwater Division	Not provided	N/A

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City of Orlando	N/A	ORL-09	Clear Lake Basin Inlet Baskets	29 inlet baskets installed to remove gross pollutants, including organic debris, sediment and litter. 25.25 cubic yds/yr of material collected.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	Not provided	16.6	0.01	16.4	0.01	Shingle Creek	Not provided	$8,550	$8,332	City of Orlando Streets and Stormwater Division	Not provided	N/A
City of Orlando	N/A	ORL-10	Lake Lorna Doone Basin Inlet Baskets	16 inlet baskets installed to remove gross pollutants, including organic debris, sediment and litter. 32.6 cubic yds/yr of material collected.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	Not provided	16.2	0.01	16.0	0.01	Shingle Creek	Not provided	$17,755	$8,673	City of Orlando Streets and Stormwater Division	Not provided	N/A
City of Orlando	N/A	ORL-11	Lake Mann Basin Inlet Baskets	44 inlet baskets installed to remove gross pollutants, including organic debris, sediment and litter. 23 cubic yds/yr of material collected.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	Not provided	27.4	0.01	27.0	0.01	Shingle Creek	Not provided	$48,826	$3,566	City of Orlando Streets and Stormwater Division	Not provided	N/A
City of Orlando	N/A	ORL-13	Rock Lake Basin Inlet Baskets	10 inlet baskets installed to remove gross pollutants, including organic debris, sediment and litter. 21 cubic yds/yr of material collected.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	Not provided	10.3	0.00	10.2	0.00	Shingle Creek	Not provided	$8,550	$9,706	City of Orlando Streets and Stormwater Division	Not provided	N/A
City of Orlando	N/A	ORL-14	Lake Sunset Basin Inlet Baskets	8 inlet baskets installed to remove gross pollutants, including organic debris, sediment and litter. 15 cubic yds/yr of material collected.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	Not provided	18.7	0.01	18.4	0.01	Shingle Creek	Not provided	$8,550	$11,451	City of Orlando Streets and Stormwater Division	Not provided	N/A

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City of Orlando	N/A	ORL-15	Walker Lagoon Basin Inlet Baskets	16 inlet baskets installed to remove gross pollutants, including organic debris, sediment and litter. 35.1 cubic yds/yr of material collected.	Catch Basin Inserts/Inlet Filter Cleanout	Completed	Not provided	16.4	0.01	16.2	0.01	Shingle Creek	Not provided	$17,755	$7,049	City of Orlando Streets and Stormwater Division	Not provided	N/A
City of Orlando	N/A	ORL-16	Street Sweeping	Street sweeping within all public roads within city limits. 22,325.2 cubic yds/yr of material collected.	Street Sweeping	Completed	N/A	212.5	0.10	218.9	0.10	Shingle Creek, Boggy Creek	N/A	Not provided	$850,000	City of Orlando Streets and Stormwater Division	$850,000	N/A
City of Orlando	N/A	ORL-17	Education and Outreach	FYN; landscaping, irrigation, fertilizer, and pet waste management ordinances; PSAs; pamphlets; website; and illicit discharge program.	Education Efforts	Completed	N/A	2,852.2	1.29	1,311.6	0.59	Shingle Creek, Boggy Creek	32,625.2	$51,500	Not provided	City of Orlando Streets and Stormwater Division	Not provided	N/A
City of Orlando	N/A	ORL-18	Lizzie Rogers Park Baffle Box	Relocation of drainage outfall into Lake Sunset with addition of baffle box.	Baffle Boxes – Second Generation	Planned	2020	5.2	0.00	0.2	0.00	Shingle Creek	7.4	TBD	TBD	City of Orlando Streets and Stormwater Division	Not provided	N/A
Osceola County	N/A	OSC-01	Narcoossee Rd. IB Ponds 2 and 3	Roadway widening.	Wet Detention Pond	Completed	2011	9.4	0.00	0.9	0.00	East Lake Tohopekaliga	126.0	Not provided	$4,195	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-02	Narcoossee Rd. III Ponds C3A and C3B	Roadway widening.	Wet Detention Pond	Completed	2012	2.8	0.00	0.6	0.00	East Lake Tohopekaliga	29.7	Not provided	$4,195	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-03	Narcoossee Rd. III Pond D3	Roadway widening.	Wet Detention Pond	Completed	2012	8.9	0.00	0.6	0.00	East Lake Tohopekaliga	22.2	Not provided	$4,195	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-04	Narcoossee Rd. III Pond E1	Roadway widening.	Wet Detention Pond	Completed	2012	5.1	0.00	0.7	0.00	East Lake Tohopekaliga	12.4	Not provided	$4,195	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-05	Neptune Rd. I – Ponds 100, 200, and 300	Road improvement.	Wet Detention Pond	Completed	2010	1,334.0	0.61	59.3	0.03	Lake Tohopekaliga	229.8	Not provided	$4,195	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-06	Old Wilson Rd. Pond D002-P	Road improvement.	Online Retention BMPs	Completed	2012	17.1	0.01	0.0	0.00	Upper Reedy Creek	64.2	Not provided	Not provided	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-07	Old Wilson Rd. Pond D004-P	Road improvement.	Online Retention BMPs	Completed	2012	18.7	0.01	0.4	0.00	Upper Reedy Creek	32.1	Not provided	Not provided	Osceola County	Not provided	N/A

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Osceola County	N/A	OSC-08	Old Wilson Rd. Pond E002-P	Road improvement.	Online Retention BMPs	Completed	2012	16.0	0.01	0.6	0.00	Upper Reedy Creek	27.2	Not provided	Not provided	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-09	Stewart St. Regional Pond Retrofit	Regional pond retrofit.	Wet Detention Pond	Completed	2009	2,835.3	1.29	336.6	0.15	Lake Tohopekaliga	2,241.2	Not provided	Not provided	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-10	Education and Outreach	FYN; landscaping, irrigation, fertilizer, and pet waste management ordinances; PSAs; pamphlets; website; and illicit discharge program.	Education Efforts	Completed	N/A	18,018.4	8.17	8,940.3	4.06	Lake Kissimmee, Lake Tohopekaliga, Lake Myrtle, Alligator Lake, Lake Jackson, S63A, Lake Conlin, Upper Reedy Creek, Horse Creek, Lake Marian, Lower Reedy Creek, Marion Creek, Lake Gentry, Lake Cypress, East Lake Tohopekaliga, Shingle Creek, Lake Hatchineha	73,437.0	Not provided	$60,000	Osceola County	$60,000	N/A
Osceola County	Homeowner Association (HOA)	OSC-12	East Lake Reserve Stormwater Reuse	Stormwater reuse for landscape irrigation from Pond A1 (9.1A).	Stormwater Reuse	Completed	Not provided	439.0	0.20	18.5	0.01	East Lake Tohopekaliga	126.0	Not provided	Not provided	HOA	Not provided	N/A
Osceola County	N/A	OSC-13	Neptune Rd. Stormwater Reuse	Stormwater reuse for landscape irrigation from Ponds 100/101 and 300.	Stormwater Reuse	Completed	Not provided	124.7	0.06	5.9	0.00	Lake Tohopekaliga	34.6	$640,690	$26,000	Osceola County	Not provided	N/A
Osceola County	HOA	OSC-14	Bellalago and Isles of Bellalago Stormwater Reuse	Stormwater reuse for landscape irrigation (197A).	Stormwater Reuse	Completed	Not provided	2,221.5	1.01	118.2	0.05	Lake Tohopekaliga	1,354.1	Not provided	Not provided	HOA	Not provided	N/A
Osceola County	Private	OSC-15	Poinciana Commerce Center Reuse	Stormwater reuse for landscape irrigation from Pond 1.	Stormwater Reuse	Completed	Not provided	7.5	0.00	0.4	0.00	Lower Reedy Creek	7.4	Not provided	Not provided	Private	Not provided	N/A

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Osceola County	Private	OSC-16	Kissimmee Bay Reuse	Stormwater reuse; 20-year duration for 84.5 acres of golf course and 5-year duration for 45.5 acres of landscape irrigation.	Stormwater Reuse	Completed	Not provided	441.9	0.20	31.0	0.01	East Lake Tohopekaliga	266.9	Not provided	Not provided	Private	Not provided	N/A
Osceola County	Private	OSC-17	Remington Reuse	Stormwater reuse for golf course irrigation from Ponds 12, 13, 14A, and 14B.	Stormwater Reuse	Completed	Not provided	205.0	0.09	11.4	0.01	East Lake Tohopekaliga	170.5	Not provided	Not provided	Private	Not provided	N/A
Osceola County	Private	OSC-18	Eagle Lake Reuse	Stormwater reuse for turf irrigation.	Stormwater Reuse	Completed	Not provided	892.2	0.40	48.9	0.02	Lake Tohopekaliga, Upper Reedy Creek	427.5	Not provided	Not provided	Private	Not provided	N/A
Osceola County	Private	OSC-19	La Quinta Inn Reuse	Stormwater reuse for turf irrigation.	Stormwater Reuse	Completed	Not provided	49.4	0.02	2.4	0.00	Shingle Creek	17.3	Not provided	Not provided	Private	Not provided	N/A
Osceola County	DEP/ SFWMD	OSC-20	Lake Toho Regional Water Storage Facility (Judge Farms)	Construction of regional stormwater pond and alternative water supply reservoir.	STA	Underway	2020	20,415.0	9.26	747.7	0.34	Lake Tohopekaliga	5,888.5	TBD	TBD	County/ DEP/ SFWMD/ Toho Water Authority	County – $32,850,000/ DEP – $1,750,000 SFWMD – $400,000	LP49021 and S0806

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Osceola County	N/A	OSC-21	Street Sweeping	Monthly street sweeping.	Street Sweeping	Completed	N/A	38.1	0.02	39.3	0.02	Lake Kissimmee, Arbuckle Creek, Lake Tohopekaliga, Lake Myrtle, Alligator Lake, Lake Arbuckle, Lake Jackson, S-63A, Catfish Creek, Lake Conlin, Upper Reedy Creek, Lake Rosalie, Horse Creek, Lake Hart, Lake Pierce, Lower Reedy Creek, Marion Creek, Lake Marion, Tiger Lake, Lake Gentry, Lake Cypress, East Lake Tohopekaliga, Shingle Creek, Lake Hatchineha, Lake Weohyakapka	N/A	Not provided	$60,000	Osceola County	$60,000	N/A
Osceola County	N/A	OSC-22	Buenaventura Lakes Golf Course Ponds	2 new lakes at golf course.	Wet Detention Pond	Completed	Not provided	5.4	0.00	3.8	0.00	Lake Tohopekaliga	518.9	Not provided	Not provided	Osceola County	Not provided	N/A
Osceola County	N/A	OSC-23	Slaman	Conservation areas.	Land Preservation	Completed	2008	18.5	0.01	3.0	0.00	Alligator Lake	29.7	Not provided	$1,500	Osceola County	$1,500	N/A
Osceola County	N/A	OSC-24	Jim Yates	Conservation areas.	Land Preservation	Completed	2009	487.8	0.22	45.3	0.02	East Lake Tohopekaliga	126.0	Not provided	$3,750	Osceola County	$3,750	N/A
Osceola County	N/A	OSC-25	Udstad	Conservation areas.	Land Preservation	Completed	2008	12.2	0.01	2.3	0.00	Shingle Creek	4.9	Not provided	$3,500	Osceola County	$3,500	N/A
Osceola County	N/A	OSC-26	Proctor	Conservation areas.	Land Preservation	Completed	2009	138.5	0.06	14.5	0.01	Lake Tohopekaliga	34.6	Not provided	$1,750	Osceola County	$1,750	N/A
Osceola County	N/A	OSC-27	Twin Oaks	Conservation areas.	Land Preservation	Completed	2009	4.0	0.00	0.5	0.00	East Lake Tohopekaliga	2.5	Not provided	$16,500	Osceola County	$16,500	N/A
Osceola County	N/A	OSC-28	Cherokee Point	Conservation areas.	Land Preservation	Completed	2005	2,468.3	1.12	289.6	0.13	Lake Tohopekaliga, Upper Reedy Creek	1,354.1	Not provided	$21,800	Osceola County	$21,800	N/A
Osceola County	HOA	OSC-29	Encantada Resort	Stormwater reuse for landscape irrigation from pond.	Stormwater Reuse	Completed	Not provided	55.6	0.03	1.7	0.00	Upper Reedy Creek	56.8	Not provided	Not provided	HOA	Not provided	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Osceola County	HOA	OSC-30	Cypress Palms Condos	Stormwater reuse for landscape irrigation from pond.	Stormwater Reuse	Completed	Not provided	13.0	0.01	1.1	0.00	Shingle Creek	12.4	Not provided	Not provided	HOA	Not provided	N/A
Osceola County	HOA	OSC-31	Lake Pointe	Stormwater reuse for landscape irrigation from pond.	Stormwater Reuse	Completed	Not provided	280.8	0.13	41.4	0.02	East Lake Tohopekaliga	12.4	Not provided	Not provided	HOA	Not provided	N/A
Osceola County	HOA	OSC-32	Traditions at Westside	Stormwater reuse for landscape irrigation from pond.	Stormwater Reuse	Completed	Not provided	10.1	0.00	1.1	0.00	Upper Reedy Creek	27.2	Not provided	Not provided	HOA	Not provided	N/A
Osceola County	N/A	OSC-33	Hoagland Blvd. Phase III	Road widening	Hydrodynamic Separators	Underway	2020	0.0	0.00	0.4	0.00	Shingle Creek, Upper Kissimmee	7.4	$16,000	$2,400	Osceola County	$16,000	N/A
Polk County	Extension Office/ County Utilities/ Lakes Education Action Drive/ Municipal Agencies	PC-03	Education and Outreach	FYN, fertilizer ordinance, PSAs, pamphlets, website, and Illicit Discharge Program.	Education Efforts	Completed	N/A	7,601.3	3.45	4,769.7	2.16	Lake Kissimmee, Catfish Creek, Upper Reedy Creek, Lake Rosalie, Horse Creek, Lake Pierce, Lower Reedy Creek, Marion Creek, Lake Marion, Tiger Lake, Lake Hatchineha, Lake Wohyakapka	50,849.1	N/A	$2,000	Polk County	$2,000	N/A
Polk County	SFWMD	PC-04	Sumica Preserve Water Storage/ Hydrologic Restoration	Construction of gravel berm to store water onsite for wetland restoration.	Wetland Restoration	Completed	2010	464.6	0.21	31.8	0.01	Tiger Lake	4,240.3	$42,850	$13,000	Polk County/ SFWMD	County – $21,425/ SFWMD – $21,245	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Reedy Creek Improvement District	Walt Disney World	RCID-01	Education and Outreach	Landscaping, irrigation, and fertilizer ordinances; PSAs, pamphlets, website, Illicit Discharge Program, inspection program; equivalent FYN program to address needs of visitors, Walt Disney World employees, and neighboring property owners.	Education Efforts	Completed	N/A	883.8	0.40	164.3	0.07	Upper Reedy Creek	7,769.0	Not provided	Not provided	RCID	Not provided	N/A
Reedy Creek Improvement District	Walt Disney World	RCID-02	Propertywide Street Sweeping	Street sweeping of more than 220,000 lane miles annually.	Street Sweeping	Completed	N/A	405.2	0.18	417.1	0.19	Upper Reedy Creek	N/A	Not provided	Not provided	RCID	Not provided	N/A
SFWMD	DEP	SFWMD-06	Phase I Rolling Meadows	Restore historical Lake Hatchineha floodplain wetlands and habitat in Rolling Meadows property, which was purchased jointly with DEP.	Wetland Restoration	Completed	2016	TBD	TBD	350.5	0.16	Catfish Creek	1,900.0	$43,200,000	$150,000	DEP	DEP – $150,000	N/A
SFWMD	N/A	SFWMD-07	Gardner-Cobb Marsh	Project includes various activities (ditch plugs, berm removal, exotic vegetation treatment, and culvert replacement) to help attenuate regional stormwater runoff. May provide ancillary water quality benefits because of nutrient plant uptake from overland flows in marsh.	Hydrologic Restoration	Planned	TBD	TBD	TBD	330.7	0.15	Lake Kissimmee	1,832.0	$79,073	$55,000	Florida Legislature	Florida Legislature – $55,000	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
SFWMD	N/A	SFWMD-08	Rough Island	Completed project included various activities (e.g., ditch plugs, ditch filling, exotic removal) to help attenuate regional stormwater runoff and provide incidental nutrient reductions because of plant uptake from overland flows.	Hydrologic Restoration	Completed	2009	TBD	TBD	2.8	0.00	Lake Kissimmee	7,200.0	Included in SFWMD-05.	Included in SFWMD-05.	Included in SFWMD-05.	Included in SFWMD-05.	N/A
SFWMD	N/A	SFWMD-09	Oasis Marsh Restoration	Completed project included filling 4 ditches, totaling 2.4 acres in size, with 3,144 cubic yds of sediments from an adjacent levee to restore floodplain function of 77 acres of wetlands and reconnect them to the littoral zone of Lake Kissimmee.	Wetland Restoration	Completed	2010	TBD	TBD	1,051.6	0.48	Upper Reedy Creek	23.5	$566,889	Not provided	Windermere/ SFWMD	Windermere – $391,889/ SFWMD – $175,000	N/A
SFWMD	N/A	SFWMD-16	Lost Oak Ranch	Storage of 374 ac-ft of water through pasture.	DWM	Completed	2013	TBD	TBD	150.9	0.07	Shingle Creek	3,417.5	N/A	$1,000	Valencia WCD	$1,000	N/A

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
SFWMD	USACE	SFWMD-22	Kissimmee River Headwaters Revitalization	Increase stages and change operating schedule of 3 headwaters lakes to provide appropriate flow patterns to restored Kissimmee River and floodplain. This is also expected to improve quantity and quality of littoral habitat in headwater lakes.	Hydrologic Restoration	Underway	2020	TBD	TBD	3,049.7	1.38	Shingle Creek	107.1	$62,750	$328,214	Valencia WCD	$62,750	N/A
Town of Windermere	SFWMD	TW-01	First Ave. and Forest St. Drainage Improvements	Construct vegetated swales, exfiltration trench systems, and oil/grit separation units to treat stormwater runoff into Wauseon Bay, which is directly connected to Lake Butler, Outstanding Florida Water.	BMP Treatment Train	Completed	2018	TBD	TBD	TBD	TBD	Lake Kissimmee	1,832.0	$79,073	$55,000	Florida Legislature	Florida Legislature – $55,000	N/A
Valencia WCD	N/A	VWCD-01	Water Quality Awareness Program	Water quality education and awareness articles posted on Orange County website.	Education Efforts	Completed	N/A	24.3	0.01	10.2	0.00	Lake Kissimmee	7,200.0	Included in SFWMD-05.	Included in SFWMD-05.	Included in SFWMD-05.	Included in SFWMD-05.	N/A
Valencia WCD	N/A	VWCD-02	C-4 Outfall	Replace existing outfall structure draining to C-4 Canal. Reline existing storm pipes at outfall. Provide flow-calming weir in C-4 Canal	Control Structure	Planned	2020	0.0	0.00	0.0	0.00	Upper Reedy Creek	23.5	$566,889	Not provided	Windermere/ SFWMD	Windermere – $391,889/ SFWMD – $175,000	N/A

4.6.3.2. Future Projects

Table 57 lists the future projects provided by the stakeholders for the Upper Kissimmee Subwatershed.

Table 57. Future projects in the Upper Kissimmee Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Polk County	SWFWMD/ NRCS/ FDOT	F-33	Crooked Lake Surface Water Restoration	Block old agricultural ditches through wetland for rehydration.	Hydrologic Restoration	Planned	4,660	1,241	0.56	2,020	0.92	Lake Arbuckle	$804,150	$4,000
Polk County	SWFWMD	F-34	Sunset Trail Water Quality Improvements (Crooked Lake Basin)	Divert roadway runoff to treatment area.	BMP Treatment Train	Planned	75	36	0.02	20	0.01	Lake Arbuckle	TBD	TBD
Polk County	DEP	F-35	Lake Rosalie Canal Restoration (Lake Kissimmee State Park)	Restore historical flow patterns to adjacent wetlands.	Hydrologic Restoration	Conceptual	600	8	0.00	8	0.00	Lake Rosalie	TBD	TBD
Polk County	City Davenport	F-36	Restoration of Lake Play and Nearby Wetlands	Water quality treatment, habitat enhancement.	Hydrologic Restoration	Conceptual	TBD	18	0.01	16	0.01	Horse Creek	TBD	TBD

4.6.4. Lake Tohopekaliga NRP

Within the Lake Okeechobee BMAP boundary, restoration efforts have been ongoing under the Lake Tohopekaliga NRP. This plan, accepted by DEP in December 2011, includes many efforts that parallel those in the Lake Okeechobee BMAP, and some that benefit Lake Okeechobee in addition to benefiting Lake Tohopekaliga. Stakeholders are providing updates on NRP project efforts as part of the Lake Okeechobee BMAP progress reports. **Section 4.6.1** lists the NRP monitoring stations, and the projects are included in the tables in **Section 4.6.3**. Additional details on the Lake Tohopekaliga NRP can be obtained by contacting DEP's Division of Environmental Assessment and Restoration, Watershed Assessment Section.

4.7. East Lake Okeechobee Subwatershed

The East Lake Okeechobee Subwatershed covers more than 239,000 acres of the LOW and is made up of 2 basins. As shown in **Table 58**, agriculture is the largest portion of the subwatershed with 42.9 % of the area, followed by wetlands with 23.6 %. Stakeholders in the subwatershed are FDOT District 4, Hendry County, Indian Trail Improvement District, Martin County, Palm Beach County, and Village of Indiantown.

Table 58. Summary of land uses in the East Lake Okeechobee Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	23,846	10.0
2000	Agriculture	102,425	42.9
3000	Upland Nonforested	8,978	3.8
4000	Upland Forests	32,277	13.5
5000	Water	9,560	4.0
6000	Wetlands	56,481	23.6
7000	Barren Land	1,978	0.8
8000	Transportation, Communication, and Utilities	3,468	1.5
	Total	**239,013**	**100.0**

4.7.1. Water Quality Monitoring

In the East Lake Okeechobee Subwatershed, the BMAP monitoring network includes water quality stations in both of the basins. **Table 59** summarizes the water quality monitoring stations in the subwatershed, and **Figure 16** shows the station locations. **Table 59** also includes indications of which stations have recently been added as part of SFWMD expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the station to better align with the BMAP.

Table 59. Water quality monitoring stations in the East Lake Okeechobee Subwatershed

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
C-44/Basin 8/S-153	Yes	SFWMD	S308C	1	Sufficient TN and TP data; only consider when flowing to lake
C-44/Basin 8/S-153	No	SFWMD	C44SC2	2	Proposed station as part of SFWMD expanded monitoring
C-44/Basin 8/S-153	No	SFWMD	C44SC5	2	Proposed station as part of SFWMD expanded monitoring
C-44/Basin 8/S-153	No	SFWMD	C44SC14	2	Proposed station as part of SFWMD expanded monitoring
C-44/Basin 8/S-153	No	SFWMD	C44SC19	2	Proposed station as part of SFWMD expanded monitoring
C-44/Basin 8/S-153	No	SFWMD	C44SC23	2	Proposed station as part of SFWMD expanded monitoring
C-44/Basin 8/S-153	No	SFWMD	C44SC24	2	Proposed station as part of SFWMD expanded monitoring
C-44/Basin 8/S-153	No	SFWMD	S153	2	Proposed station as part of SFWMD expanded monitoring

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
L-8	Yes	SFWMD	5147 (C10A)	2	Biweekly sampling only if flowing; otherwise monthly
C-44/Basin 8/S-153	No	USGS	02276877	3	N/A
L-8	No	USGS	265501080364900	3	N/A

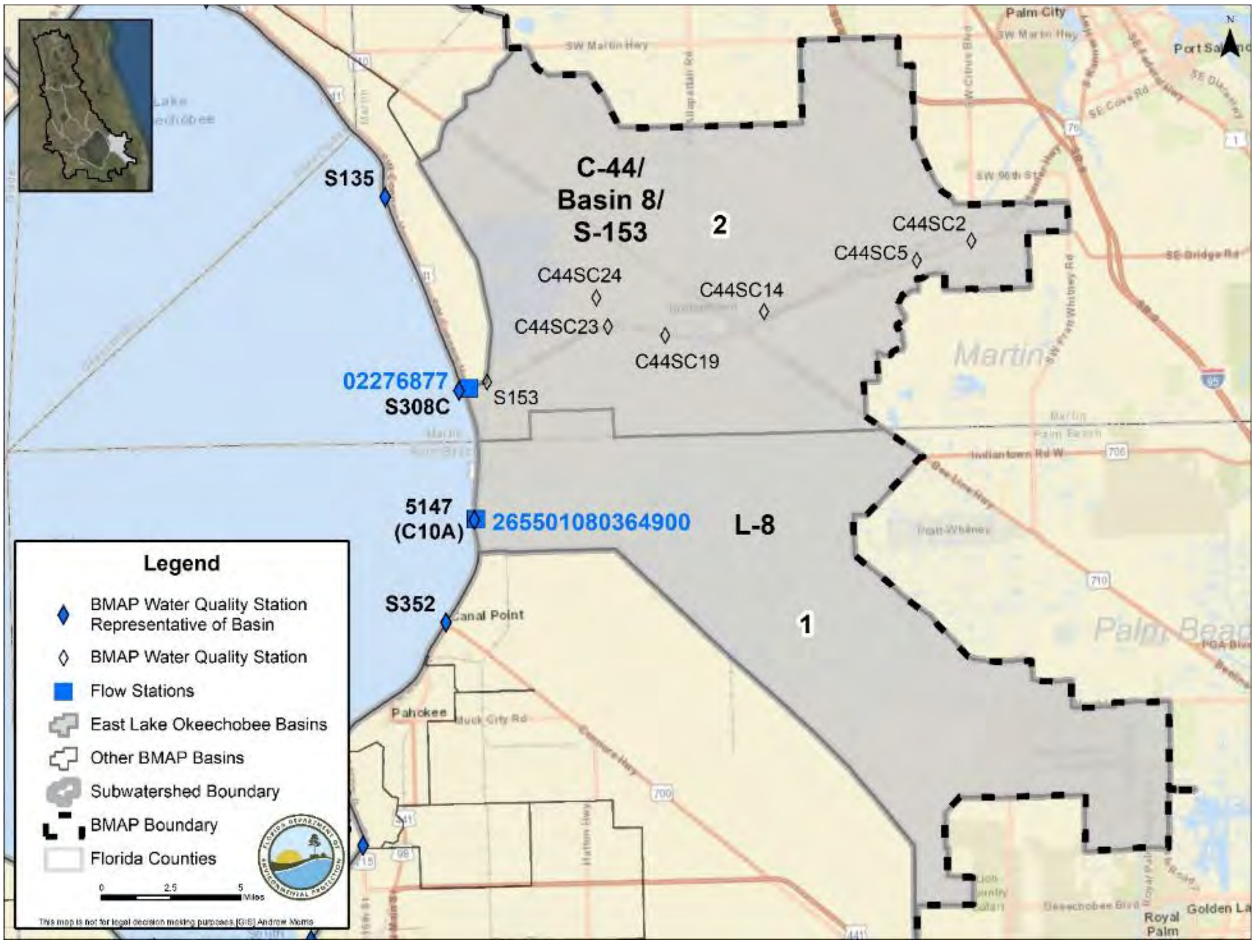

Figure 16. Locations of the water quality monitoring stations in the East Lake Okeechobee Subwatershed

4.7.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the East Lake Okeechobee Subwatershed is 16.8 mt/yr. A reduction of 13.9 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 2.9 mt/yr.

Table 60 summarizes the basin evaluation results for the East Lake Okeechobee Subwatershed. The concentrations in the two basins are variable, depending on the flow to the lake from the subwatershed. Based on evaluations made by SFWMD in the LOWCP update, flow was determined not to be an issue in the subwatershed. **Table 61** lists the TRA prioritization results for the subwatershed, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 60. Basin evaluation results for the East Lake Okeechobee Subwatershed

Variable = Flows to the lake in this area are inconsistent and the concentrations are variable.
Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
1	L-8	Variable	1.64	0.66	No Significant Trend	Variable	0.15	0.05	Significant Increasing	No
2	C-44/Basin 8/S-153	Variable	2.28	0.32	Insufficient Data	Variable	0.25	0.05	Significant Increasing	No

Table 61. TRA evaluation results for the East Lake Okeechobee Subwatershed

Basin	Station	TP Priority	TN Priority	Flow Priority
C-44/Basin 8/S-153	S308C	1	1	3
L-8	5147	1	1	3

4.7.3. Projects

The sections below summarize the existing and planned and future projects for the East Lake Okeechobee Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.7.3.1. Existing and Planned Projects

Table 62 summarizes the existing and planned projects provided by the stakeholders for the East Lake Okeechobee Subwatershed.

Table 62. Existing and planned projects in the East Lake Okeechobee Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
Coordinating Agency	FDOT	CA-15	State Road (SR) 710 Regional Project	See FDOT4-01.	Stormwater System Rehabilitation	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	Canceled	TBD	TBD	TBD	FDOT	TBD	N/A
FDACS	Agricultural Producers	FDACS-13	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – East Lake Okeechobee. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	81,011.0	36.75	8,554.6	3.88	All East Lake Okeechobee	56,644	TBD	TBD	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-22	Cost-share Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	1,326.0	0.60	82.5	0.04	All East Lake Okeechobee	2,798	TBD	TBD	FDACS	TBD	N/A
FDOT District 4	N/A	FDOT4-01	FM# 432705-1 / SR 710	SR-710/Beeline Highway widening from 2 to 4 lanes.	Grass swales without swale blocks or raised culverts	Underway	2019	23.9	0.01	1.6	0.00	C-44/ Basin 8/ S-153	145.8	Not provided	Not provided	Not provided	Not provided	N/A
FDOT District 4	N/A	FDOT4-02	Public Education	Pamphlets.	Education Efforts	Completed	N/A	3.3	0.00	0.3	0.00	C-44/ Basin 8/ S-153, L-8	711.7	Not provided	Not provided	Not provided	Not provided	N/A
FDOT District 4	N/A	FDOT4-05	Street Sweeping	Continued sweeping.	Street Sweeping	Completed	N/A	541.8	0.25	283.3	0.13	C-44/ Basin 8/ S-153	N/A	Not provided	Not provided	Not provided	Not provided	N/A
FDOT District 4	N/A	FDOT4-06	Catch Basin Clean-Out	Continued cleanout.	BMP Cleanout	Completed	N/A	TBD	TBD	TBD	TBD	C-44/ Basin 8/ S-153	N/A	Not provided	Not provided	Not provided	Not provided	N/A

4.7.3.2. Future Projects

No future projects were provided by the stakeholders for the East Lake Okeechobee Subwatershed.

4.8. South Lake Okeechobee Subwatershed

The South Lake Okeechobee Subwatershed covers more than 363,000 acres of the LOW and is made up of 9 basins. As shown in **Table 63**, the predominate land use is agriculture with 92.5 % of the subwatershed, followed by urban and built-up with 3.7 %. Stakeholders in the subwatershed are the City of Belle Glade, City of Clewiston, City of Pahokee, City of South Bay, FDOT District 4, Hendry County, Palm Beach County, East Beach WCD, East Hendry County Drainage District, East Shore WCD, Highlands Glades Drainage District, Northern Palm Beach County Improvement District, Pahokee Drainage District, Pelican Lake WCD, Ritta Drainage District, South Shore Drainage District, and South Florida Conservancy District.

Table 63. Summary of land uses in the South Lake Okeechobee Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	13,432	3.7
2000	Agriculture	335,878	92.5
3000	Upland Nonforested	1,369	0.4
4000	Upland Forests	150	0.0
5000	Water	3,645	1.0
6000	Wetlands	2,331	0.6
7000	Barren Land	3,346	0.9
8000	Transportation, Communication, and Utilities	2,992	0.8
	Total	**363,143**	**100.0**

4.8.1. Water Quality Monitoring

In the South Lake Okeechobee Subwatershed, the BMAP monitoring network includes water quality stations in all nine of the basins. **Table 64** summarizes the water quality monitoring stations in the subwatershed, and **Figure 17** shows the station locations.

Table 64. Water quality monitoring stations in the South Lake Okeechobee Subwatershed

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
715 Farms (Culv 12A)	Yes	Sugar Farms Co-Op	S274 (C12A)	1	Only TP collected when flowing to lake
East Beach WCD (Culv 10)	Yes	East Beach WCD	S273 (C-10)	1	Only TP collected when flowing to lake
S2	Yes	SFWMD	S2	1	TP and TN collected when flowing to lake
S2	No	SFWMD	S351	1	N/A
S-3	Yes	SFWMD	S3	1	Sufficient TN and TP data
S-3	No	SFWMD	S354	1	N/A
S-4	No	SFWMD	INDUSCAN	1	N/A
S-4	No	SFWMD	S169	1	N/A
S-4	Yes	SFWMD	S4	1	Sufficient TN and TP data
S-5A Basin (S-352-West Palm Beach [WPB] Canal)	Yes	SFWMD	S352	1	Sufficient TN and TP data
South Florida Conservancy District (S-236)	Yes	South Florida Conservancy District/SFWMD	S-236	1	Sufficient TN and TP data

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
South Shore Drainage District (Culv 4A)	Yes	South Shore Drainage District	C-4A	1	Only TP collected when flowing to lake
East Shore WCD (Culv 12)	Yes	East Shore WCD	S275 (C-12)	2	Only TP collected when flowing to lake
S2	No	USGS	02280500	3	N/A
S2	No	USGS	02283500	3	N/A
S-3	No	USGS	02286400	3	N/A
S-4	No	USGS	264514080550700	3	N/A

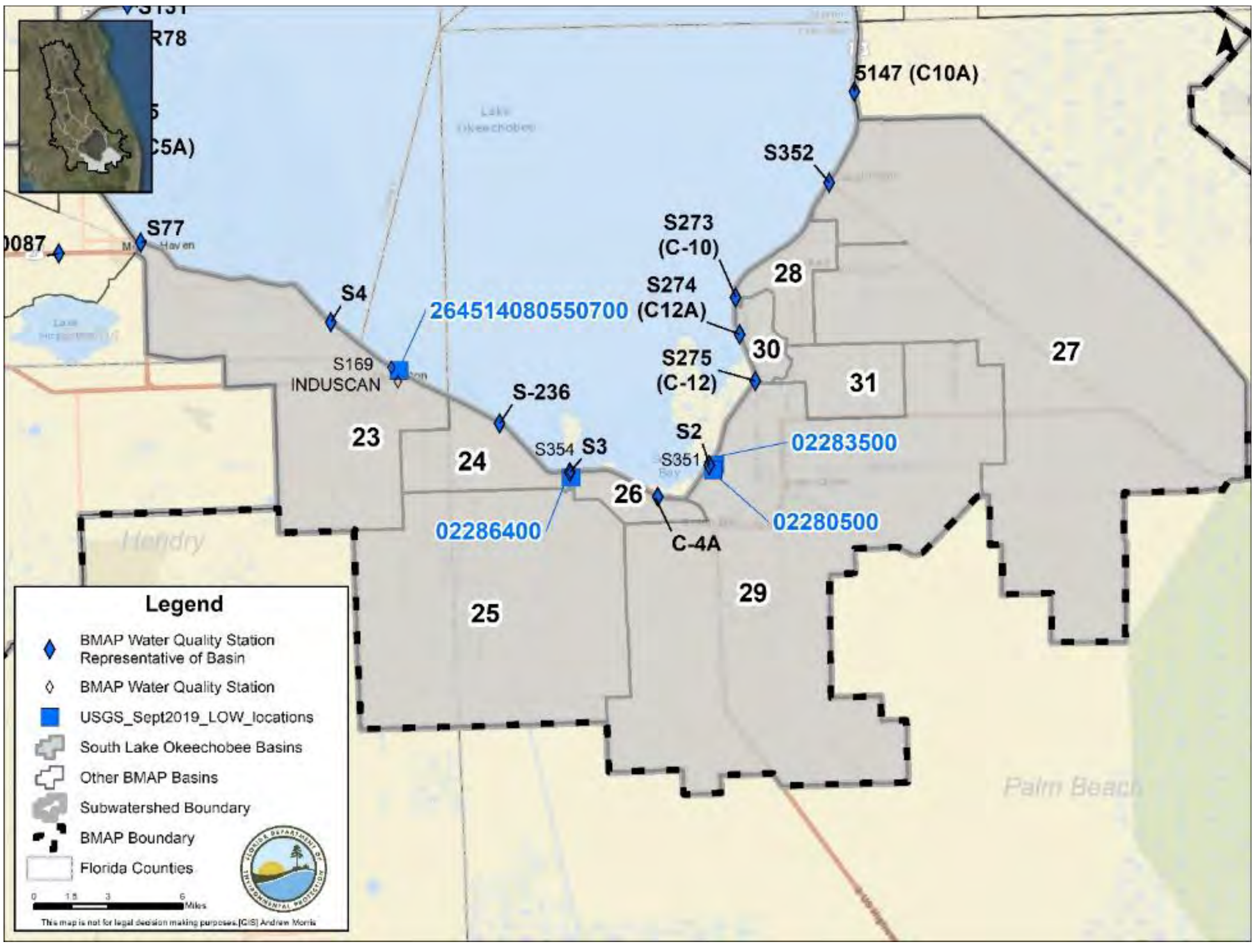

Figure 17. Locations of the water quality monitoring stations in the South Lake Okeechobee Subwatershed

4.8.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the South Lake Okeechobee Subwatershed is 29.0 mt/yr. A reduction of 23.9 mt/yr is required to help achieve the TMDL and meet the subwatershed target of 5.1 mt/yr.

Table 65 summarizes the basin evaluation results for the South Lake Okeechobee Subwatershed. The concentrations in the nine basins are variable depending on the flow to the lake from the subwatershed. Based on evaluations made by SFWMD in the LOWCP update, flow was determined not to be an issue in the subwatershed. **Table 66** lists the TRA prioritization results for the South Lake Okeechobee Subwatershed, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 65. Basin evaluation results for the South Lake Okeechobee Subwatershed

Variable = Flows to the lake in this area are inconsistent and the concentrations are variable.
Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
23	S-4	Variable	2.93	3.55	No Significant Trend	Variable	0.37	0.09	Significant Increasing	No
24	South FL Conservancy Drainage District (S-236)	Variable	2.63	0.11	Insufficient Data	Variable	0.22	0.00	Insufficient Data	No
25	S-3	Variable	4.56	1.11	Insufficient Data	Variable	0.21	0.01	Insufficient Data	No
26	South Shore/ So. Bay Drainage District (Culv 4A)	Variable	3.00	0.07	Insufficient Data	Variable	0.28	0.00	Insufficient Data	No
27	S-5A Basin (S-352-WPB Canal)	Variable	9.40	0.04	Insufficient Data	Variable	0.27	0.00	Insufficient Data	No
28	East Beach Drainage District (Culv 10)	Variable	3.43	0.11	Insufficient Data	Variable	0.78	0.01	Insufficient Data	No
29	S2	Variable	6.14	2.00	Insufficient Data	Variable	0.25	0.02	Insufficient Data	No
30	715 Farms (Culv 12A)	Variable	Insufficient Data	No flow	Insufficient Data	Variable	Insufficient Data	Insufficient Data	Insufficient Data	No
31	East Shore Drainage District (Culv 12)	Variable	Insufficient Data	No flow	Insufficient Data	Variable	Insufficient Data	Insufficient Data	Insufficient Data	No

Table 66. TRA evaluation results for the South Lake Okeechobee Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

Basin	Station	TP Priority	TN Priority	Flow Priority
715 Farms (Culv 12A)	S274 (C12A)	Insufficient Data	Insufficient Data	3
East Beach Drainage District (Culv 10)	S273	2	1	3
East Shore Drainage District (Culv 12)	S275	Insufficient Data	Insufficient Data	3
S2	S2	2	1	3
S-3	S3	3	1	3
S-4	S4	1	1	3
S-5A Basin (S-352-WPB Canal)	S352	2	2	3
South Florida Conservancy Drainage District (S-236)	S236	3	1	3
South Shore/ So. Bay Drainage District (Culv 4A)	C4A	2	2	3

4.8.3. Projects

The sections below summarize the existing and planned and future projects for the South Lake Okeechobee Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.8.3.1. Existing and Planned Projects

Table 67 summarizes the existing and planned projects provided by the stakeholders for the South Lake Okeechobee Subwatershed.

Table 67. Existing and planned projects in the South Lake Okeechobee Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDACS	Agricultural Producers	FDACS-14	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – South Lake Okeechobee. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	311,617.0	141.35	18,273.7	8.29	All South Lake Okeechobee	292,512	TBD	TBD	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-23	Cost-share Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	376.3	0.17	48.2	0.02	All South Lake Okeechobee	752	TBD	TBD	FDACS	TBD	N/A
FDOT District 4	N/A	FDOT4-03	Public Education	Pamphlets.	Education Efforts	Completed	N/A	32.5	0.01	1.4	0.00	South Florida Conservancy Drainage District (S-236), S-3, South Shore/ So. Bay Drainage District (Culv 4A), S-5A Basin (S-352-WPB Canal), East Beach Drainage District (Culv 10), S2, 715 Farms (Culv 12A), East Shore Drainage District (Culv 12)	1,954.6	Not provided	Not provided	Not provided	Not provided	N/A

4.8.3.2. Future Projects

No future projects were provided by the stakeholders for the South Lake Okeechobee Subwatershed.

4.9. West Lake Okeechobee Subwatershed

The West Lake Okeechobee Subwatershed covers more than 204,000 acres of the LOW and is made up of 3 basins. As shown in **Table 68**, the predominate land use is agriculture with 66.2 % of the subwatershed, followed by wetlands with 14.4 %. Stakeholders in the subwatershed are the City of Moore Haven, Glades County, Barron WCD, Clewiston Drainage District, Collins Slough WCD, Devils Garden WCD, Disston Island Conservancy District, Flaghole Drainage District, Henry Hillard WCD, and Sugarland Drainage District.

Table 68. Summary of land uses in the West Lake Okeechobee Subwatershed

Level 1 Land Use Code	Land Use Description	Acres	% Total
1000	Urban and Built-Up	7,457	3.7
2000	Agriculture	135,032	66.2
3000	Upland Nonforested	5,894	2.9
4000	Upland Forests	20,659	10.1
5000	Water	2,166	1.1
6000	Wetlands	29,317	14.4
7000	Barren Land	2,084	1.0
8000	Transportation, Communication, and Utilities	1,485	0.7
	Total	**204,094**	**100.0**

4.9.1. Water Quality Monitoring

In the West Lake Okeechobee Subwatershed, the BMAP monitoring network includes water quality stations in all three of the basins. **Table 69** summarizes the water quality monitoring stations in the subwatershed, and **Figure 18** shows the station locations. **Table 69** also includes indications of which stations have recently been added as part of SFWMD expanded monitoring and recommendations to change the location, frequency, or parameters sampled for the station to better align with the BMAP.

Table 69. Water quality monitoring stations in the West Lake Okeechobee Subwatershed

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
East Caloosahatchee	Yes	SFWMD	S77	1	Sufficient TN and TP data
East Caloosahatchee	No	SFWMD	CRFW01	2	Proposed station as part of SFWMD expanded monitoring
East Caloosahatchee	No	SFWMD	CRFW02	2	Proposed station as part of SFWMD expanded monitoring
East Caloosahatchee	No	SFWMD	CRFW03	2	Proposed station as part of SFWMD expanded monitoring
East Caloosahatchee	No	SFWMD	CRFW05	2	Proposed station as part of SFWMD expanded monitoring
East Caloosahatchee	No	SFWMD	CRFW30	2	Proposed station as part of SFWMD expanded monitoring

Basin	Representative Site?	Entity	Station ID	Tier	Data Needs
East Caloosahatchee	No	SFWMD	S-47D (CRFW33)	2	Proposed station as part of SFWMD expanded monitoring
Hicpochee North	Yes	DEP South ROC	G3SD0087	2	Increase collection frequency for TN and TP
Nicodemus Slough North	Yes	SFWMD	5158 (C5A)	2	Increase collection frequency for TN and TP – biweekly sampling when flowing
East Caloosahatchee	No	USGS	02292010	3	N/A

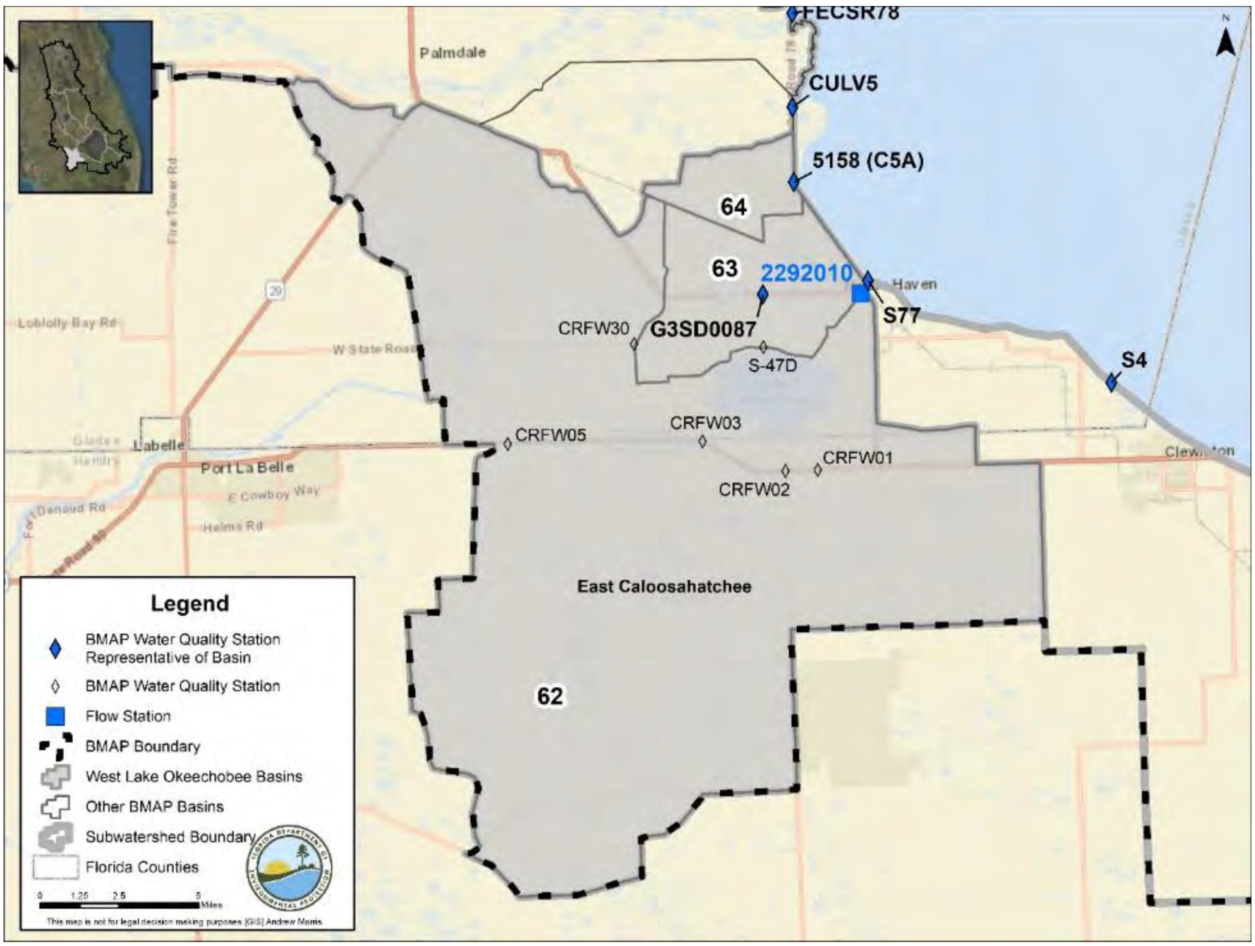

Figure 18. Locations of the water quality monitoring stations in the West Lake Okeechobee Subwatershed

4.9.2. Basin Evaluation Results

The current TP load based on data from WY2014–WY2018 for the West Lake Okeechobee Subwatershed is 0 mt/yr. Therefore, reductions are not required to help achieve the TMDL.

Table 70 summarizes the basin evaluation results for the subwatershed. The concentrations in the three basins are variable depending on the flow to the lake from the subwatershed. Based on evaluations made by SFWMD in the LOWCP update, flow was determined not to be an issue in the basins. **Table 71** lists the TRA prioritization results for the subwatershed, with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 70. Basin evaluation results for the West Lake Okeechobee Subwatershed

Variable = Flows to the lake in this area are inconsistent and the concentrations are variable.
Insufficient data = Available data were not at the frequency needed for evaluation.

TRA ID	Basin Name	TN (mg/L) (Benchmark – 1.54)	TN FWM Concentration (mg/L)	TN UAL (lbs/ac)	TN Trend Analysis	TP (mg/L) (Benchmark – 0.12)	TP FWM Concentration (mg/L)	TP UAL (lbs/ac)	TP Trend Analysis	Flow
62	East Caloosahatchee	Variable	2.72	0.00	Insufficient Data	Variable	0.20	0.00	Insufficient Data	No
63	Hicpochee North	Variable	Insufficient Data	Insufficient Data	Insufficient Data	Variable	Insufficient Data	Insufficient Data	Insufficient Data	No
64	Nicodemus Slough South	Variable	6.54	0.03	Insufficient Data	Variable	0.09	0.00	Insufficient Data	No

Table 71. TRA evaluation results for the West Lake Okeechobee Subwatershed

Insufficient data = Available data were not at the frequency needed for evaluation.

Basin	Station	TP Priority	TN Priority	Flow Priority
East Caloosahatchee	S77	3	3	3
Hicpochee North	G3SD0087	3	Insufficient Data	3
Nicodemus Slough South	C5A	2	1	3

4.9.3. Projects

The sections below summarize the existing and planned and future projects for the West Lake Okeechobee Subwatershed that were provided for the BMAP. The existing and planned projects are a BMAP requirement, while future projects will be implemented as funding becomes available for project implementation. **Appendix A** provides additional details about the projects and the terms used in these tables.

4.9.3.1. Existing and Planned Projects

Table 72 summarizes the existing and planned projects provided by the stakeholders for the West Lake Okeechobee Subwatershed.

Table 72. Existing and planned projects in the West Lake Okeechobee Subwatershed

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Estimated Completion Date	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Acres Treated	Cost Estimate	Cost Annual O&M	Funding Source	Funding Amount	DEP Contract Agreement Number
FDACS	Agricultural Producers	FDACS-15	BMP Implementation and Verification	Enrollment and verification of BMPs by agricultural producers – West Lake Okeechobee. Acres treated based on FDACS OAWP June 2019 Enrollment and FSAID VI. Reductions were estimated using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	17,069.1	7.74	1,135.0	0.51	All West Lake Okeechobee	118,151	TBD	TBD	FDACS	TBD	N/A
FDACS	Agricultural Producers	FDACS-24	Cost-share Projects	Cost-share projects paid for by FDACS. Acres treated based on FDACS OAWP June 2019 Enrollment. Reductions estimated by DEP using 2019 BMAP LET.	Agricultural BMPs	Completed	N/A	908.4	0.41	50.1	0.02	All West Lake Okeechobee	5,595	TBD	TBD	FDACS	TBD	N/A
Glades County	N/A	GC-03	Glades County Caloosahatchee River and Estuary Area Wastewater Grant	Elimination of aging and/or failing existing septic systems in City of Moore Haven. Project also provides for increased conveyance capacity for additional homes and businesses.	OSTDS Phase Out	Planned	2021	252.0	0.11	0.0	0.00	Hicpochee North	86.5	$891,848	$12,240	GAA	$891,848.00	LP22023
Glades County	N/A	GC-04	Glades County Business Park Wetlands	Wetland maintenance and planting agreement	Wetland Restoration	Planned	2021	0.0	0.00	0.0	0.00	Hicpochee North	8.8	$42,395	Not provided	Glades County	$42,395	N/A

4.9.3.2. Future Projects

No future projects were provided by the stakeholders for the West Lake Okeechobee Subwatershed.

4.10. In-Lake Strategies

The Lake Okeechobee BMAP is established to address loads from the LOW; however, the treatment of legacy loads in the lake is also important for restoration. This section documents in-lake treatment strategies and water quality monitoring. These are not management strategies within the meaning of Section 403.067, F.S., and are provided for informational purposes. Additional information on water quality in Lake Okeechobee can be found in the latest SFER, published annually on the SFWMD website.

4.10.1. Water Quality Monitoring

Figure 19 shows the locations of the in-lake monitoring stations. These stations are not part of the BMAP monitoring network but are monitored to evaluate in-lake water quality. Additional information on in-lake monitoring is reported annually in the SFER.

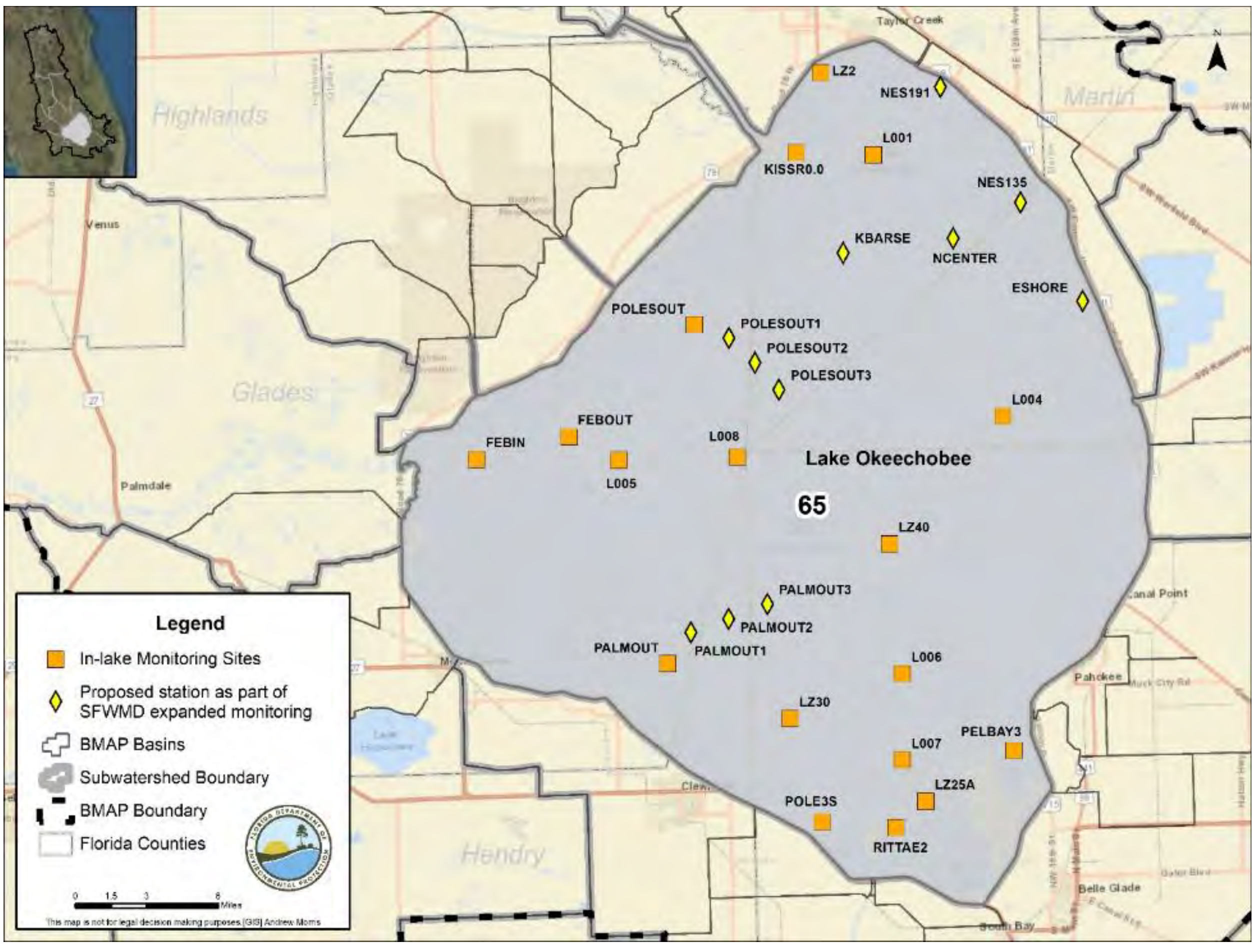

Figure 19. Locations of the water quality monitoring stations in Lake Okeechobee

4.10.2. Projects

The 2014 Lake Okeechobee BMAP lists the in-lake strategies of muck scraping and tilling as a BMAP initiative. Additional projects that were added as part of this BMAP are included in the sections below.

4.10.2.1. Existing and Planned Projects

Pursuant to the NEEPP (Section 373.4595, F.S.), the Lake Okeechobee Internal Phosphorus Management Program is a component of the LOWPP. In accordance with Paragraph 373.4595(3)(d), F.S., this legislation requires SFWMD, in cooperation with the Coordinating Agencies and interested parties, to evaluate the feasibility of Lake Okeechobee internal phosphorus load removal projects. The evaluation must be based on technical feasibility, as well as economic considerations, and consider all reasonable methods of phosphorus removal. Relevant information resulting from the Lake Okeechobee Internal Phosphorus Management Program is covered in the LOWPP 2020 Update (to be published by March 1, 2020, as Appendix 8A-1 of the final *2020 SFER – Volume I*), with a brief overview provided below.

Internal phosphorus loading from sediments in Lake Okeechobee is primarily affected by two factors: (1) the depth of resuspendable sediment, and (2) the distribution of that sediment once entrained in the water column. Prior studies have focused on the plausibility of reducing resuspension, both through the capping and removal of sediment (SFWMD 2003). However, to date there has been little focus on evaluating options for reducing distribution. Consequently, a modeling effort by SFWMD is planned in fiscal year (FY) 2020 to assess the effects of increasing the height of natural rock barriers in the southern portions of the lake to isolate turbid pelagic water from nearshore areas. Using a hydrocirculation model, several alternative heights and locations of rock formation are being evaluated for their effects on circulation patterns and turbidity in the lake's southern portion at various stages and wind directions.

The properties of in-lake sediments (e.g., depth, nutrient content, exchange rates, uptake capacity, and distribution of easily resuspended mud) have been historically monitored, but these have not been studied for more than a decade (SFWMD 2007). To address this need, a proposed effort is planned in FY 2020–21 to reassess the sediment properties and distribution in the lake to determine how Hurricane Irma (which made landfall in Florida on September 10, 2017) affected the location and depths of resuspendable sediments, as well as nutrient content, exchange rates, and uptake capacity.

Long-term water quality monitoring in the lake suggests the depth of resuspendable sediments—and subsequently, water column turbidity—has increased since the 2004–05 hurricanes, possibly affecting the burial rates of phosphorus, soil/water interface properties, light penetration, and other factors. Updating sediment maps will also help improve lake circulation models by further reducing uncertainties and allowing better predictions of the effects of any mitigation strategies, such as future dredging or mud isolation projects.

4.10.2.2. Future Projects

Table 73 lists the future in-lake projects included in the LOWCP.

Table 73. Future in-lake projects

Lead Entity	Partners	Project Number	Project Name	Project Description	Project Type	Project Status	Acres Treated	TN Reduction (lbs/yr)	TN Reduction (mt/yr)	TP Reduction (lbs/yr)	TP Reduction (mt/yr)	Basin	Cost Estimate	Cost Annual O&M
Coordinating Agency	N/A	F-37	In-Lake Strategies	Low stage muck scraping, and tilling	Muck Removal/ Restoration Dredging	Conceptual	TBD	TBD	TBD	TBD	TBD	In-lake	TBD	TBD
Coordinating Agency	N/A	F-38	In-Lake Strategies	New concepts and technologies for in-lake phosphorus treatment.	Muck Removal/ Restoration Dredging	Conceptual	TBD	TBD	TBD	TBD	TBD	In-lake	TBD	TBD

Chapter 5. Summary

5.1. TRA Evaluation Results

Table 74 summarizes the results of the TRA evaluation process that were presented by subwatershed in **Chapter 4** for the basins in the LOW. For each basin, a priority was assigned based on the TP and TN concentrations and flows. These priorities were set to help focus resources and projects in the basins that are in most need of improvement. Priorities were set with 1 the highest priority, 2 the next highest priority, and 3 a priority as resources allow.

Table 74. Summary of the TRA evaluation results

*SFWMD determined that additional investigations are needed regarding whether water quantity is an issue in this subwatershed.
Insufficient data = Available data were not at the frequency needed for evaluation.

Subwatershed	Basin	Station	TP Priority	TN Priority	Flow Priority
Fisheating Creek	Fisheating Creek/L-61	FECSR78	1	1	2
Fisheating Creek	Nicodemus Slough North	CULV5	3	1	3
Indian Prairie	C-40	S72	1	1	3
Indian Prairie	C-41	S71	1	1	3
Indian Prairie	C-41A	S84	1	1	1
Indian Prairie	L-48	S127	1	2	3
Indian Prairie	L-49	S129	3	3	3
Indian Prairie	L-59E	L59E	2	1	2
Indian Prairie	L-59W	L59W	2	2	2
Indian Prairie	L-60E	L60E	1	2	2
Indian Prairie	L-60W	L60W	1	1	2
Indian Prairie	L-61E	L61E	1	1	2
Indian Prairie	S-131	S131	2	3	3
Lake Istokpoga	Arbuckle Creek	30854	3	3	*
Lake Istokpoga	Josephine Creek	LI02362923	3	Insufficient Data	*
Lake Istokpoga	Lake Arbuckle	ARBUCKLE1-274119812344	3	3	*
Lake Istokpoga	Lake Istokpoga	30853	2	1	*
Lower Kissimmee	Kissimmee River	S65D	3	Insufficient Data	3
Lower Kissimmee	S-65A	18085	3	3	3
Lower Kissimmee	S-65E	18130 (S65E)	1	3	3
Taylor Creek/ Nubbin Slough	S-133	S133	1	1	2
Taylor Creek/ Nubbin Slough	S-135	S135	1	1	3
Taylor Creek/ Nubbin Slough	S-154	S154	1	1	2
Taylor Creek/ Nubbin Slough	S-154C	S154C	1	1	2
Taylor Creek/ Nubbin Slough	S191	S191	1	1	2
Upper Kissimmee	Alligator Lake	S60	Insufficient Data	Insufficient Data	Insufficient Data

Subwatershed	Basin	Station	TP Priority	TN Priority	Flow Priority
Upper Kissimmee	Boggy Creek	ABOGGN	2	3	Insufficient Data
Upper Kissimmee	Catfish Creek	34008	3	3	Insufficient Data
Upper Kissimmee	East Lake Tohopekaliga	BS-59	3	3	Insufficient Data
Upper Kissimmee	Horse Creek (closed basin)	Horse Crk2	3	3	Insufficient Data
Upper Kissimmee	Lake Conlin (closed basin)	None	Insufficient Data	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Cypress	4002	3	3	Insufficient Data
Upper Kissimmee	Lake Gentry	GENTRYDTCH	3	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Hart	MJ01253123	3	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Hatchineha	EC-37	3	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Jackson	LJACKDSCH	3	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Kissimmee	S65	1	2	3
Upper Kissimmee	Lake Marian	ML22303313	2	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Marion	51242	3	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Myrtle	None	Insufficient Data	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Pierce	Pierce1	3	3	Insufficient Data
Upper Kissimmee	Lake Rosalie	KUB009	3	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Tohopekaliga	CL18273011	3	Insufficient Data	Insufficient Data
Upper Kissimmee	Lake Weohyakapka	Weohyakapka1	3	3	Insufficient Data
Upper Kissimmee	Lower Reedy Creek	CREEDYBR	3	3	Insufficient Data
Upper Kissimmee	Marion Creek	DLMARNCR-DLONDNCR	3	Insufficient Data	Insufficient Data
Upper Kissimmee	S63A	S63A	Insufficient Data	Insufficient Data	Insufficient Data
Upper Kissimmee	Shingle Creek	SCD	3	3	Insufficient Data
Upper Kissimmee	Tiger Lake	Tiger1 (Tiger1-G4CE0070)	3	3	Insufficient Data
Upper Kissimmee	Upper Reedy Creek	C-12E (C-12E-RC-13H)	3	Insufficient Data	Insufficient Data
East Lake Okeechobee	C-44/Basin 8/S-153	S308C	1	1	3
East Lake Okeechobee	L-8	5147 (C10A)	1	1	3
West Lake Okeechobee	East Caloosahatchee	S77	3	3	3

Subwatershed	Basin	Station	TP Priority	TN Priority	Flow Priority
West Lake Okeechobee	Hicpochee North	G3SD0087	3	Insufficient Data	3
West Lake Okeechobee	Nicodemus Slough South	5158 (C5A)	2	1	3
South Lake Okeechobee	715 Farms (Culv 12A)	S274 (C12A)	Insufficient Data	Insufficient Data	3
South Lake Okeechobee	East Beach Drainage District (Culv 10)	S273 (C10)	2	1	3
South Lake Okeechobee	East Shore Drainage District (Culv 12)	S275	Insufficient Data	Insufficient Data	3
South Lake Okeechobee	S2	S2	2	1	3
South Lake Okeechobee	S-3	S3	3	1	3
South Lake Okeechobee	S-4	S4	1	1	3
South Lake Okeechobee	S-5A Basin (S-352-WPB Canal)	S352	2	2	3
South Lake Okeechobee	South Florida Conservancy Drainage District (S-236)	S236	3	1	3
South Lake Okeechobee	South Shore/ So. Bay Drainage District (Culv 4A)	C4A	2	2	3

5.2. RFI Responses

To further identify restoration projects for this BMAP, DEP implemented an RFI in October 2019 to generate additional restoration projects or activities from both the public and private sectors. The effort was open to any interested parties who could propose a viable project for restoration and could be considered for inclusion in the final Lake Okeechobee BMAP for funding consideration.

Overall, the RFI process generated 34 responses from the private sector. Submittals ranged from on-the-ground projects, such as STAs, to technologies that could be implemented in both aquatic and terrestrial environments. All submittals were reviewed, and **Appendix E** provides a summary of the submittals. Resources will be needed to implement any of these projects throughout the watershed, and they are being considered for DEP funding. Additional details on all responses are on file with DEP.

5.3. Future Growth

To ensure that this BMAP effort can achieve and ultimately maintain the goal of meeting TMDL requirements, the overall restoration strategy must include actions and planning for future growth and development. New development primarily falls into two general source categories: (1) urban and (2) agriculture. Nutrient impacts from new development are addressed through a variety of mechanisms as well as other provisions of Florida law.

While the majority of the restoration projects and programs listed in this BMAP address current loading, the need to plan and implement sound management strategies to address additional population growth in the BMAP area must be considered. DEP has included in this BMAP specific elements to address all current and future WWTF effluent, septic systems, and stormwater sources. Broader laws—such as local land development regulations, comprehensive plans, ordinances, incentives, Environmental Resource Permit requirements, and consumptive use permit requirements—all provide additional mechanisms and avenues for protecting water resources and reducing the impact of new development and other land use changes as they occur.

The recommendations presented in **Chapter 3** should be considered by local governments during master planning and land use decision-making efforts. At the time of BMAP development and adoption, many of these recommendations are not required by statute, but it is anticipated that some, if not all, of the recommendations may be a part of future legislative mandates and future BMAP iterations.

It should also be noted that any additional loading, such as from land use changes from low to high density, or any increase in intensity of use (that may include additional nutrient loadings), will be evaluated during future BMAP review efforts. If an increase in loading has occurred, additional restoration actions will be required to remediate impacts. DEP recommends that all local governments revise their planning and land use ordinance(s) to adequately address all future growth, and consider limitations on growth in sensitive areas, such as lands with a direct hydrologic connection to impaired waterbodies, wetland areas, or coastal areas.

5.4. Compliance

The TMDL sets an annual TP load to Lake Okeechobee of 140 mt/yr (308,647 lbs/yr), of which 35 mt/yr (77,162 lbs/yr) is estimated to fall directly on the lake through atmospheric deposition. The remaining 105 mt/yr (231,485 lbs/yr) of TP are allocated to the entire LOW. The attainment of the TMDL is calculated based on a 5-year rolling average using the monthly loads calculated from measured flow and concentration values.

In addition to overall compliance with the TMDL (i.e., 140 and 105 mt/yr of TP for the lake and entire watershed, respectively), DEP will be monitoring and working to achieve the subwatershed targets identified in **Table 75**. DEP will use this information to identify problem areas and sources that are not meeting the target, acknowledge them through annual reporting and public engagement, and focus resources (regulatory programs through permitting decisions, compliance and enforcement, and nutrient reduction projects) accordingly. This is a key component to the ultimate strategy for restoring the lake.

The final *2019 SFER – Volume I, Chapter 8B* prepared by SFWMD, reports the 5-year average (based on data from WY2014–WY2018 [May 1, 2013–April 30, 2018]) annual TP load from the watershed as 598 mt/yr (1,318,364 lbs/yr). Therefore, to achieve the allowable TMDL load of 105 mt/yr, the TP required reductions are 493 mt/yr (1,086,879 lbs/yr). The TP required reductions were assigned to each subwatershed based on the contribution of the total load from that subwatershed (**Table 75**), and **Table 76** lists the progress towards those reductions with projects completed through June 30, 2019. DEP will refer to the 5-year average TP load reported annually in the SFER to update the estimated load reductions needed to achieve the TMDL and to track progress towards the TMDL.

Table 75. Load reductions and targets by subwatershed

Subwatershed	WY2014–WY2018 TP Load (mt/yr)	% Contribution of Load	TP Load Required Reduction (mt/yr)	TP Target (mt/yr)
Fisheating Creek	72.4	12	59.7	12.7
Indian Prairie	102.5	17	84.5	18.0
Lake Istokpoga	47.7	8	39.3	8.4
Lower Kissimmee	125.9	21	103.8	22.1
Taylor Creek/Nubbin Slough	113.6	19	93.7	19.9
Upper Kissimmee	90.5	15	74.6	15.9
East Lake Okeechobee	16.8	3	13.9	2.9
South Lake Okeechobee	29.0	5	23.9	5.1
West Lake Okeechobee	0.0	0	0.0	0.0
Total	**598.4**	**100**	**493.4**	**105.0**

Table 76. Load reductions achieved through June 30, 2019, by subwatershed

Subwatershed	TP Load Required Reduction (mt/yr)	TP Reduction Through June 30, 2019 (mt/yr)	TP Reductions Achieved Through June 30, 2019 (%)
Fisheating Creek	59.7	14.4	24.1
Indian Prairie	84.5	20.5	24.3
Lake Istokpoga	39.3	2.5	6.4
Lower Kissimmee	103.8	5.6	5.4
Taylor Creek/Nubbin Slough	93.7	23.3	24.9
Upper Kissimmee	74.6	16.4	22.0
East Lake Okeechobee	13.9	4.0	28.8
South Lake Okeechobee	23.9	8.3	34.7
West Lake Okeechobee	0.0	0.5	N/A
Total	**493.4**	**95.5**	**19.4**

Chapter 6. References

CDM. 2011. *Lake Tohopekaliga Nutrient Reduction Plan*.

Florida Department of Environmental Protection. 2001. *Total maximum daily load for total phosphorus in Lake Okeechobee*. Tallahassee, FL.

Soil and Water Engineering Technology, Inc. 2016. *Estimation of total phosphorus and nitrogen load reductions associated with FDACS Lake Okeechobee cost-share BMP Program*. Tasks 1 and 2. --

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Appendices

Appendix A. BMAP Projects Supporting Information

The project tables in this BMAP list the implementation status of the BMAP projects as of June 30, 2019. The tables list the attenuated TP and TN reductions (in lbs/yr and mt/yr) attributable to each individual project. These projects were submitted to DEP by responsible entities with the understanding that the projects and activities would be included in the BMAP, thus setting the expectation for each entity to implement the proposed projects and activities to achieve the assigned load reduction estimates in the specified time.

However, the list of projects is meant to be flexible enough to allow for changes that may occur over time. During the annual review of BMAP implementation efforts, project-specific information may be revised and updated, resulting in changes to the estimated reductions for those projects. The revisions may increase or decrease estimated reductions, and DEP will work with stakeholders to address revisions as they are identified.

The project status column is standardized into the following four categories:

- **Canceled**: Project or activity that was planned but will no longer take place. This category includes the cessation of ongoing activities.
- **Completed**: Project, activity, or task that is finished. This category includes fully implemented activities (i.e., ongoing activities) that must continue to maintain assigned credits indefinitely (such as street sweeping, BMP clean-out, catch basin cleanout, public education, fertilizer cessation/reduction, and vegetation harvesting).
- **Planned**: Project or activity that is conceptual or proposed.
- **Underway**: Project or activity that has commenced or initiated but is not completed and is not yet reducing nutrient loads from the treated area.

Prior to reporting project information, DEP contacts each lead entity to gather new information on projects and confirm previously reported information. The terms used throughout the project tables are defined as follows:

- **Not provided**: Denotes that information was requested by DEP but was not provided by the lead entity.
- **TBD**: To be determined. Denotes that information is not currently available but will be provided by the stakeholder when it is available.
- **N/A**: Not applicable. Denotes that information for that category is not relevant to that project.

- **0: Zero.** Denotes the numeric value for that category as zero.

The project tables are based on current information, and project details may be updated as further information becomes available.

This BMAP requires stakeholders to implement their projects to achieve reductions as soon as practicable. However, the full implementation of the BMAP will be a long-term process. While some of the projects and activities listed in the BMAP were recently completed or are currently ongoing, several projects require more time to design, secure funding, and construct. Unlike the existing and planned projects, these future projects are not yet considered commitments of the entities but rather are intended for future BMAP credit, pending the availability of funding and other resources.

Although BMAP implementation is a long-term process, the goal of this BMAP is to achieve the TMDL within 20 years from BMAP adoption. It is understood that all waterbodies can respond differently to the implementation of reduced loadings to meet applicable water quality standards. Continued coordination and communication by the stakeholders will be essential to ensure that management strategies continue to meet the implementation milestones.

DEP requested information from stakeholders on future projects and also released an RFI to obtain proposals for restoration projects and technologies with the potential for additional load reductions in the basin. Funding has not yet been identified for many of these future and RFI projects, and the additional funding of projects is a key part of making the reductions required to achieve the TMDL. The future project tables in **Chapter 4** will be updated as project details are refined and funding is obtained.

Appendix B. Agricultural Enrollment and Reductions

(Language in this appendix was provided by FDACS.)

All agricultural nonpoint sources in the Lake Okeechobee BMAP area are statutorily required either to implement FDACS-adopted BMPs or to conduct water quality monitoring prescribed by DEP or the applicable water management district. Under Paragraph 403.067(7)(c), F.S., the implementation of FDACS-adopted, DEP-verified BMPs, in accordance with FDACS rules, provides a presumption of compliance with state water quality standards for the pollutants addressed by the BMPs.

FDACS Role in BMP Implementation and Followup

When DEP adopts a BMAP that includes agriculture, it is the agricultural landowner's responsibility to implement BMPs adopted by FDACS to help achieve load reductions. To date, FDACS OAWP has adopted BMP manuals by rule[1] for cow/calf, citrus, vegetable and agronomic crops, nurseries, equine, sod, dairy, poultry, and specialty fruit and nut operations. All OAWP BMP manuals are periodically revised, updated, and subsequently reviewed and preliminarily verified by DEP before readoption. OAWP intends to update BMP manuals every five years.

To enroll in the BMP Program, landowners must meet with OAWP to determine the BMPs that are applicable to their operation. The landowner must submit a NOI to implement the BMPs on the BMP checklist from the applicable BMP manual to OAWP. Because many agricultural operations are diverse and are engaged in the production of multiple commodities, a landowner may sign multiple NOIs for a single parcel.

OAWP is required to verify that landowners are implementing BMPs identified in their NOIs. Procedures used to verify the implementation of agricultural BMPs are outlined in Rule 5M-1.008, F.A.C. BMP implementation is verified using annual surveys submitted by producers enrolled in the BMP Program and site visits by OAWP. Producers not implementing BMPs according to the process outlined in Title 5M-1, F.A.C., are referred to DEP for enforcement action after attempts at remedial action are exhausted.

BMP verification site visits are conducted to verify that all BMPs are being implemented correctly and to review nutrient and irrigation management records. In addition, OAWP verifies that cost-share items are being implemented correctly. Site visits are prioritized based on the date the NOI was signed, the date of the last BMP verification site visit, whether a survey was completed by the producer for the most recent year, and whether the operation has received cost-share funding. FDACS is to conduct an onsite inspection of each producer implementing BMPs at least every two years and provide information it obtains to DEP, subject to any confidentiality restrictions.

[1] https://www.fdacs.gov/Agriculture-Industry/Water/Agricultural-Best-Management-Practices

Section 403.067, F.S. requires that, where water quality problems persist despite the proper implementation of adopted agricultural BMPs, FDACS must reevaluate the practices, in consultation with DEP, and modify them if necessary. Continuing water quality problems will be detected through the monitoring component of the BMAP and other DEP and SFWMD activities. If a reevaluation of the BMPs is needed, FDACS will also include SFWMD and other partners in the process.

Adopted BMAP Agricultural Land Use and Enrollment

Land use data are helpful as a starting point for estimating agricultural acreage, determining agricultural nonpoint source loads, and developing strategies to reduce those loads in a BMAP area, but there are inherent limitations in the available data. The time of year when land use data are collected (through aerial photography) affects the accuracy of photo interpretation. Flights are often scheduled during the winter months because of better weather and reduced leaf canopies. While these are favorable conditions for capturing aerial imagery, they make photo interpretation for determining agricultural land use more difficult because agricultural lands are often fallow in the winter months and can result in inappropriate analysis of the photo imagery.

There is also a significant variation in the frequency with which various sources of data are collected and compiled, and older data are less likely to capture the frequent changes that often typify agricultural land use. In addition, it is not always apparent that an agricultural activity is being conducted on the land. Consequently, DEP relies on local stakeholder knowledge and coordination with FDACS to verify agricultural acreage and BMP implementation.

FDACS uses the FSAID geodatabase to estimate agricultural acreages statewide. FSAID is derived from water management district land use data and is refined using county property appraiser data, OAWP BMP enrollment data, U.S. Department of Agriculture data for agriculture such as the Cropland Data Layer and Census of Agriculture, FDACS Department of Plant Industry citrus data, and water management district water use and permitting data, as well as field verification performed by USGS, the water management districts, and OAWP. Ongoing mapping and ground-truthing efforts of the FSAID dataset provide the best available data on the status of irrigated and nonirrigated agricultural lands in Florida.

In terms of NOIs, enrolled acreage fluctuates when parcels are sold, when leases end or change hands, or when production areas downsize or production ceases, among other reasons. When crop types on a specific parcel change, additional NOIs may be required for any new commodities being produced on the parcel, and this could result in a reduction in enrolled acreage. OAWP BMP enrollments are delineated in GIS using county property appraiser parcels. Nonproduction areas such as forest, roads, urban structures, and water features are often included within the parcel boundaries. Conversely, agricultural lands in the FSAID only include areas identified as agriculture. To estimate the agricultural acres enrolled in the BMP Program, OAWP overlays FSAID and BMP enrollment data within GIS to calculate the acres of agricultural land in an enrolled parcel.

To address the greatest resource concerns, OAWP prioritizes the enrollment of agricultural land uses. The highest priority parcels comprise all intensive operations, including dairies and nurseries, parcels greater than 50 acres in size, and agricultural parcels adjacent to waterways.

When considering agricultural land uses and associated nonpoint source loads, it is important to note that the Lake Okeechobee BMAP boundary overlaps portions of both the Caloosahatchee and St. Lucie River and Estuary BMAP areas. The total agricultural acreage represented by the overlap between watersheds is 268,269, which comprises 16 % of the agricultural acreage in the Lake Okeechobee BMAP. **Table B-1** through **Table B-12** list the agricultural acreage in each subwatershed, based on FSAID VI, that is enrolled in each OAWP BMP Program commodity or in LOWPP enrollments. LOWPP enrollments were made before OAWP adopted commodity-specific BMP manuals and are being reincorporated over time under the appropriate manuals, mostly cow/calf. The acreages in these tables may differ from the WAM 2009 land use acreages provided for each subwatershed in **Chapter 4**. **Figure B-1** shows the parcels enrolled in the OAWP BMP Program by commodity in the Lake Okeechobee BMAP area, however compliance with Section 403.067, F.S. is based on the NOIs and site visits described in **Section 1.2.1.1**.

Table B-1. Summary of agricultural land use acreage enrolled in the BMP Program in the Lake Okeechobee BMAP area

Category	Acres
FSAID VI agricultural acres in the BMAP area	1,728,292
Total agricultural acres enrolled	1,335,172
% of FSAID VI agricultural acres enrolled	77 %

Table B-2. Agricultural land use acreage enrolled in the BMP Program in the Lake Okeechobee BMAP by subwatershed

Subwatershed	Total FSAID VI Agricultural Acres	Agricultural Acres Enrolled	% of Agricultural Acres Enrolled
Fisheating Creek	189,488	171,662	91
Indian Prairie	221,785	182,376	82
Lake Istokpoga	118,901	93,115	78
Lower Kissimmee	219,817	175,318	80
Taylor Creek/Nubbin Slough	140,181	118,761	85
Upper Kissimmee	260,175	126,633	49
East Lake Okeechobee	101,510	56,644	56
South Lake Okeechobee	333,231	292,512	88
West Lake Okeechobee	143,204	118,151	83
Total	**1,728,292**	**1,335,172**	**77**

Table B-3. Agricultural land use acreage enrolled in the Lake Okeechobee BMAP by BMP Program

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	124,646
Conservation Plan	148,941
Cow/Calf	495,742
Dairy	17,764
Equine	456
LOWPP	63,937
Multiple Commodities	78,089
Nursery	3,579
Poultry	38
Row/Field Crops	385,931
Specialty Fruit and Nut	815
Sod	15,234
Total	**1,335,172**

Enrollment Information by Subwatershed

Table B-4 through **Table B-12** provide additional details about enrollment in the nine subwatersheds.

Table B-4. Agricultural land use acreage enrolled in the BMP Program in the Fisheating Creek Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	9,266
Conservation Plan	54,432
Cow/Calf	99,517
Dairy	874
LOWPP	956
Multiple Commodities	5,709
Nursery	290
Row/Field Crops	597
Total	**171,662**

Table B-5. Agricultural land use acreage enrolled in the BMP Program in the Indian Prairie Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	14,155
Conservation Plan	72,866
Cow/Calf	66,389
Dairy	93
LOWPP	5,609
Multiple Commodities	16,900
Nursery	122
Row/Field Crops	2,639
Sod	3,603
Total	**182,376**

Table B-6. Agricultural land use acreage enrolled in the BMP Program in the Lake Istokpoga Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	45,231
Conservation Plan	1,629
Cow/Calf	34,070
Dairy	2,231
LOWPP	843
Multiple Commodities	5,880
Nursery	169
Row/Field Crops	606
Specialty Fruit and Nut	107
Sod	2,349
Total	**93,115**

Table B-7. Agricultural land use acreage enrolled in the BMP Program in the Lower Kissimmee Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	7,104
Conservation Plan	8,754
Cow/Calf	110,922
Dairy	2,969
LOWPP	20,131
Multiple Commodities	17,661
Nursery	196
Row/Field Crops	7,581
Total	**175,318**

Table B-8. Agricultural land use acreage enrolled in the BMP Program in the Taylor Creek/Nubbin Slough Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	3
Conservation Plan	2
Cow/Calf	65,441
Dairy	11,459
Equine	339
LOWPP	28,273
Multiple Commodities	6,206
Nursery	1,903
Poultry	38
Row/Field Crops	4,564
Sod	533
Total	**118,761**

Table B-9. Agricultural land use acreage enrolled in the BMP Program in the Upper Kissimmee Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	32,056
Cow/Calf	68,539
LOWPP	2,644
Multiple Commodities	12,633
Nursery	181
Row/Field Crops	3,779
Specialty Fruit and Nut	687
Sod	6,114
Total	**126,633**

Table B-10. Agricultural land use acreage enrolled in the BMP Program in the East Lake Okeechobee Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	1,022
Cow/Calf	20,359
Equine	117
LOWPP	2,209
Multiple Commodities	3,263
Nursery	587
Row/Field Crops	27,802
Sod	1,284
Total	**56,644**

Table B-11. Agricultural land use acreage enrolled in the BMP Program in the South Lake Okeechobee Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Cow/Calf	499
LOWPP	2,099
Multiple Commodities	1,488
Nursery	123
Row/Field Crops	288,303
Total	**292,512**

Table B-12. Agricultural land use acreage enrolled in the BMP Program in the West Lake Okeechobee Subwatershed

Related OAWP BMP Programs	Agricultural Acres Enrolled
Citrus	15,811
Conservation Plan Rule	11,256
Cow/Calf	30,005
Dairy	138
LOWPP	1,174
Multiple Commodities	8,348
Nursery	9
Row/Field Crops	50,060
Sod	1,351
Total	**118,151**

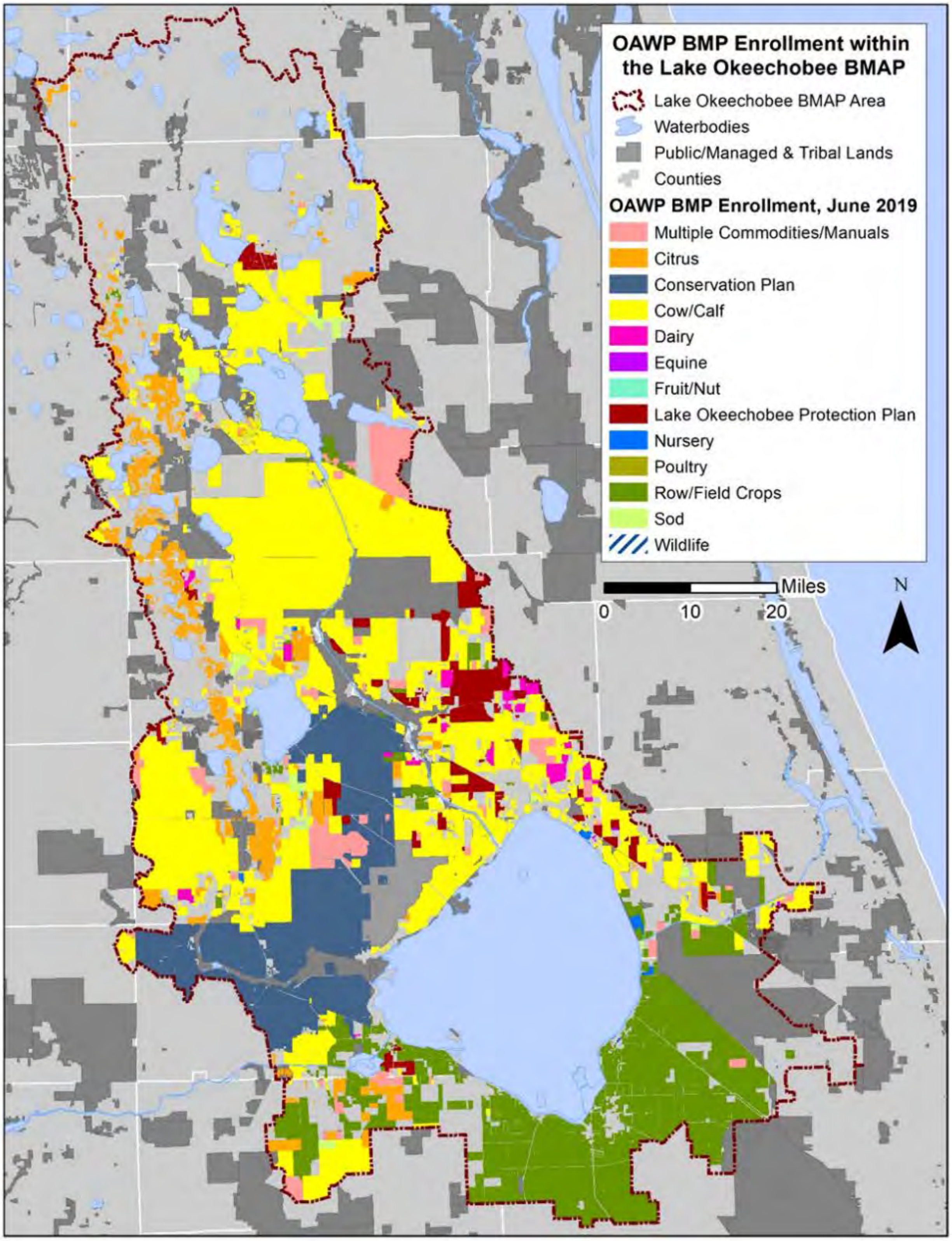

Figure B-1. BMP enrollment in the Lake Okeechobee BMAP area as of June 2019

Unenrolled Agricultural Acreage

Since the adoption of the NEEPP, FDACS' goal has been to enroll 100 % of the agricultural acres in the BMP Program. As of June 2019, 77 % of the agricultural acres in the Lake Okeechobee BMAP area are enrolled in FDACS BMP Program and are implementing practices designed to improve water quality. While achieving 100 % enrollment is a laudable goal, the analysis of various land use databases has identified land uses classified as agriculture that are difficult to enroll or where there is a limit to the BMPs that can effectively be implemented onsite. This has required the prioritization and specific identification of agricultural lands that can be enrolled in FDACS' BMP Program.

To address the greatest resource concerns, OAWP has prioritized BMP enrollment by focusing on more intensive operations, including irrigated acreage, dairies and nurseries, parcels greater than 50 acres in size, and agricultural parcels adjacent to waterways. As of June 2019, 87 % of irrigated agricultural acres in the Lake Okeechobee BMAP area were enrolled in FDACS' BMP programs.

As these priorities are met, OAWP has identified additional enrollment priorities, typically comprising smaller irrigated agricultural operations ranging from 30 to 50 acres and other targeted areas. Those larger, more intensive operations that have not enrolled are being referred to DEP to either develop individual monitoring plans pursuant to Chapter 62-307, F.A.C., or be subject to enforcement actions under DEP's regulatory authority.

General Considerations

As new BMAPs are developed or existing BMAP areas are expanded, overlap among BMAPs is increasing. In the Lake Okeechobee BMAP area, 16 % of the agricultural acres are also included in the BMAPs for the Caloosahatchee River and Estuary (2020 update) or St. Lucie River and Estuary. While calculations, allocations, and projects are specific to each BMAP, it should be noted that the number of acres from the individual BMAP reports, if added, exceeds the total acres in the three BMAP areas. The Lake Okeechobee BMAP boundary encompasses 169,184 acres of unenrolled agricultural land use, and 55,258 acres of the unenrolled agriculture in this BMAP are also identified in other BMAPs.

Although land use data have been used as the basis for prioritizing FDACS enrollment efforts, many land use issues not captured by these databases affect FDACS enrollment efforts. Many areas within the Lake Okeechobee BMAP area experience rapid land use changes, especially at the urban/rural boundary. Agricultural lands are regularly converted to residential, industrial, commercial, or multiuse properties, but still appear in various databases as pasture or other rural lands. While these lands are likely to be developed in the near future, the agricultural land use classifications require these properties to comply with the BMP enrollment requirements.

Additionally, the counties' methods of classifying small acreages as agricultural lands can affect the BMP enrollment process. Along with these changes, there are also large agricultural parcels being subdivided but remaining classified as "agriculture." This "urban agriculture"—also called residential agriculture, rural residential, rural estates, equine communities, ranchettes, rural homesteads, and other descriptive names for homes with some acreage and agricultural zoning—

present a particular challenge for FDACS, since the BMP manuals are not designed for the enrollment of these properties in BMPs targeted for bona fide agricultural production areas.

Further, thousands of acres of open land, scrub land, unimproved pasture, and grazing land exist without a readily identifiable agricultural production activity that will fit within the framework of existing FDACS BMP manuals. Also, these types of parcels are usually controlled by many different individuals (for example, an initial analysis indicates approximately 16,000 different entities control the parcels whose size is less than 50 acres). The increasing number of these smaller parcels with nontraditional agricultural production represents a growing component of unenrolled acreage. It will be necessary to develop a suite of options to apply to these properties or develop a new classification that may subject these types of areas to alternative methods to ensure their nutrient loading contribution is being appropriately identified and reduced.

Another challenging area includes those agricultural lands that are inactive or fallow—i.e., lands that, on the day the FDACS representative visits, display no enrollable agricultural activity. These lands may be part of a rotation implemented by a landowner, scheduled for development, listed for sale, etc. The land use information FDACS receives is consistently improving the classification of these areas, but policy options remain limited in scope to ensure the implementation of practices aimed at reducing nutrient inputs from these areas.

Characterization of Unenrolled Agricultural Lands

To characterize unenrolled agricultural acres, OAWP identified FSAID VI features outside of the BMP enrollment areas within GIS. As previously mentioned, OAWP BMP enrollments are initially delineated based on county property appraiser parcel data, even if the entire parcel is not agriculture, to allow BMPs to be tied to the specific parcels where agricultural activities are occurring. FSAID agricultural lands are delineated based on land use features identified as agriculture and represent a more refined analysis of those areas actually in agricultural production.

Because of differences in their spatial geometries when they are combined or compared, the boundaries often do not align precisely, creating "slivers." Slivers are not enrollable because they are an artifact of the geospatial analysis and do not represent lands with active agricultural practices. For example, a sliver can represent the area between the boundary of a parcel and the beginning of a road, canal, easement, etc. Slivers are often associated with previously enrolled agricultural operations but because of the delineation differences, these slivers are not captured within the enrolled parcel during geoprocessing. When characterizing unenrolled agricultural lands, slivers are excluded. **Figure B-2** shows an example of a sliver created when performing geospatial analysis.

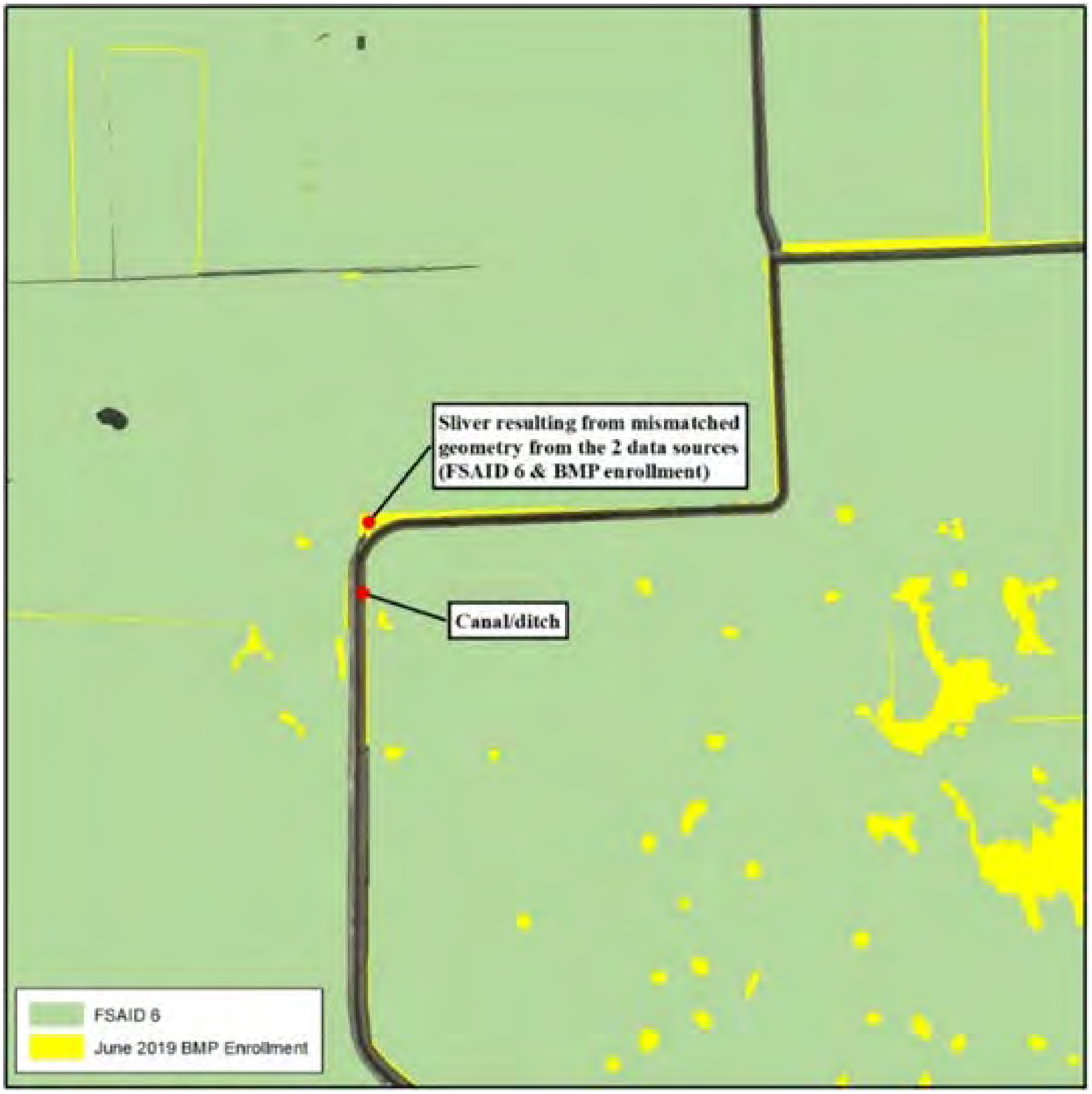

Figure B-2. GIS example of a sliver in the Lake Okeechobee BMAP area

OAWP used property appraiser data and manually reviewed aerial imagery to characterize unenrolled lands in the BMAP area. Lands under tribal ownership are not subject to the requirements of Section 403.067, F.S.; yet areas within the sovereign lands of the Seminole Tribe of Florida are identified as unenrolled agricultural lands. Other large areas that are identified as agricultural land use but are unlikely to have enrollable agricultural activities include lands owned by the state (Board of Trustees of the Internal Improvement Trust Fund), and SFWMD. It is possible that these lands, in whole or in part, may be leased to other entities that conduct agricultural activities, but such leasing is infrequent. If leasing occurs, the leasing entity will be required to enroll in the BMP Program. Ongoing coordination between FDACS, DEP's Division of State Lands, and SFWMD is needed to ensure that any public lands that are leased for the purposes of agricultural activities are required to implement and enroll in FDACS BMP program as a condition of the lease. Other lands that may be classified as agriculture but are unlikely to have enrollable agricultural activities include lands that may be part of a restoration project or water storage project. Future analysis and coordination with SFWMD will be needed to identify which areas may have enrollable agriculture in the areas identified for restoration and water storage projects.

Other smaller parcels that have been identified as nonagricultural but have features that cause them to be identified as agricultural lands in various databases, include those lands associated with utilities, telecommunication companies, churches, FDOT rights-of-way, and airports. DOR uses code numbers 70 through 98 to identify these types of lands.

Those agricultural lands that have been identified as "fallow," "former [ag]," and "abandoned," as well as brush land/scrub land/open land, comprise 16 % of the total unenrolled agricultural acres in the Lake Okeechobee BMAP area. These acres are still classified as agricultural land for the purposes of the BMAP nutrient load assessment. There are a variety of potential options to account for these lands, such as enrollment as "temporarily inactive" operations to capture some of these lands—particularly those that were previously enrolled and are planned to resume production. Another option may be to note the inactive acres at the time of a field visit and perform periodic reassessment on a cyclical basis. The possibility for DEP and FDACS to calculate nutrient reduction credits or adjust nutrient loading rates may also provide opportunities to present more accurate estimates and establish priorities.

Another factor considered in the prioritization of BMP enrollment is the number of agricultural acres on the parcel. Analyzing the number of agricultural acreages on the parcel and commodity type can give an idea of the efforts that are needed to enroll these areas in FDACS' BMP Program and also identify the areas most in need of enrollment. **Figure B-3** summarizes the agricultural acres distributed by agricultural acreage found on each parcel.

Further analysis was done to characterize the parcels that contain 50 acres of agriculture or greater and those parcels with less than 50 acres of agriculture; 179,887 acres of the 260,384 acres of land identified as having potential agricultural activity are found on parcels that contain 50 acres of agriculture or greater. **Figure B-4** shows the types of agricultural land use based on FSAID VI found on parcels that contain 50 acres of agriculture or greater. Grazing land comprises 56 % of this acreage.

Of the land identified as agriculture, 80,496 acres are found on parcels with less than 50 acres of agriculture. **Figure B-5** shows the types of agricultural land use found on parcels with less than 50 acres of agriculture. Grazing land comprises 55 % of this acreage. For these parcels, OAWP will prioritize the more intensive agricultural operations, such as sugarcane, citrus, and other row crops, for enrollment.

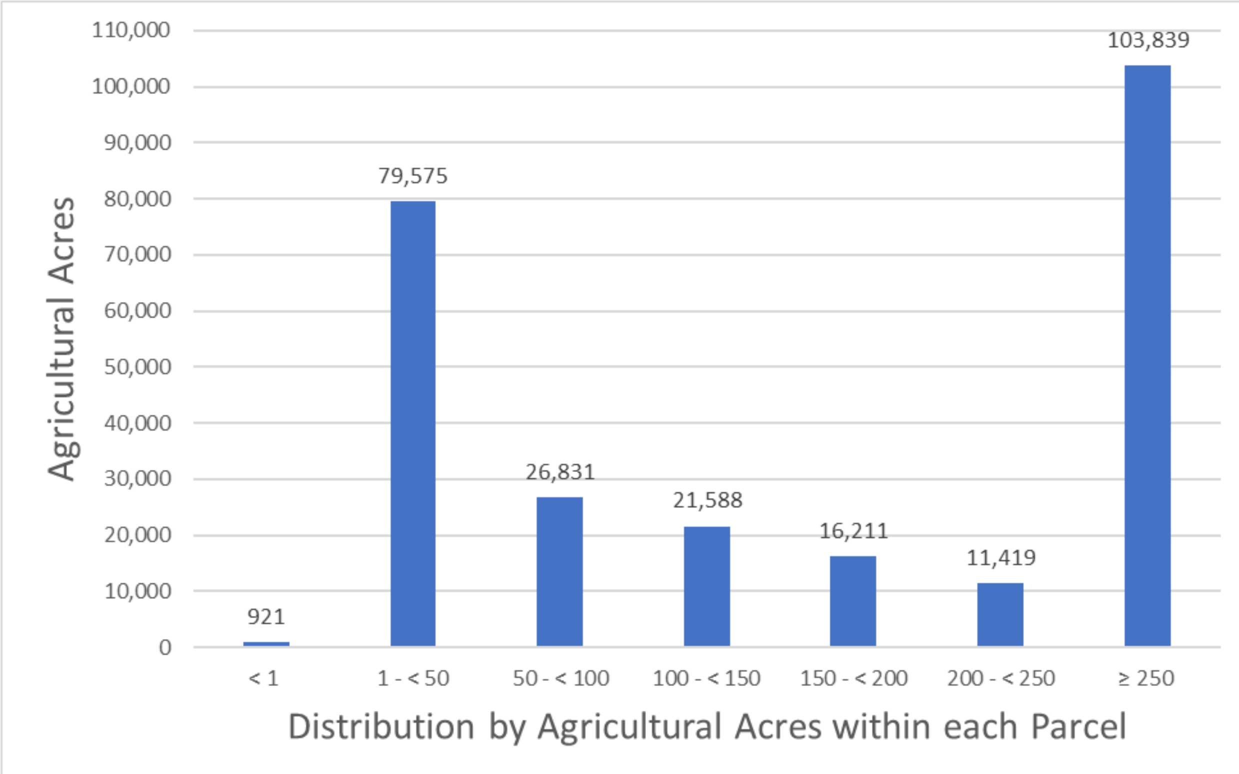

Figure B-3. Distribution of agricultural acreage on parcels with potential agricultural activity

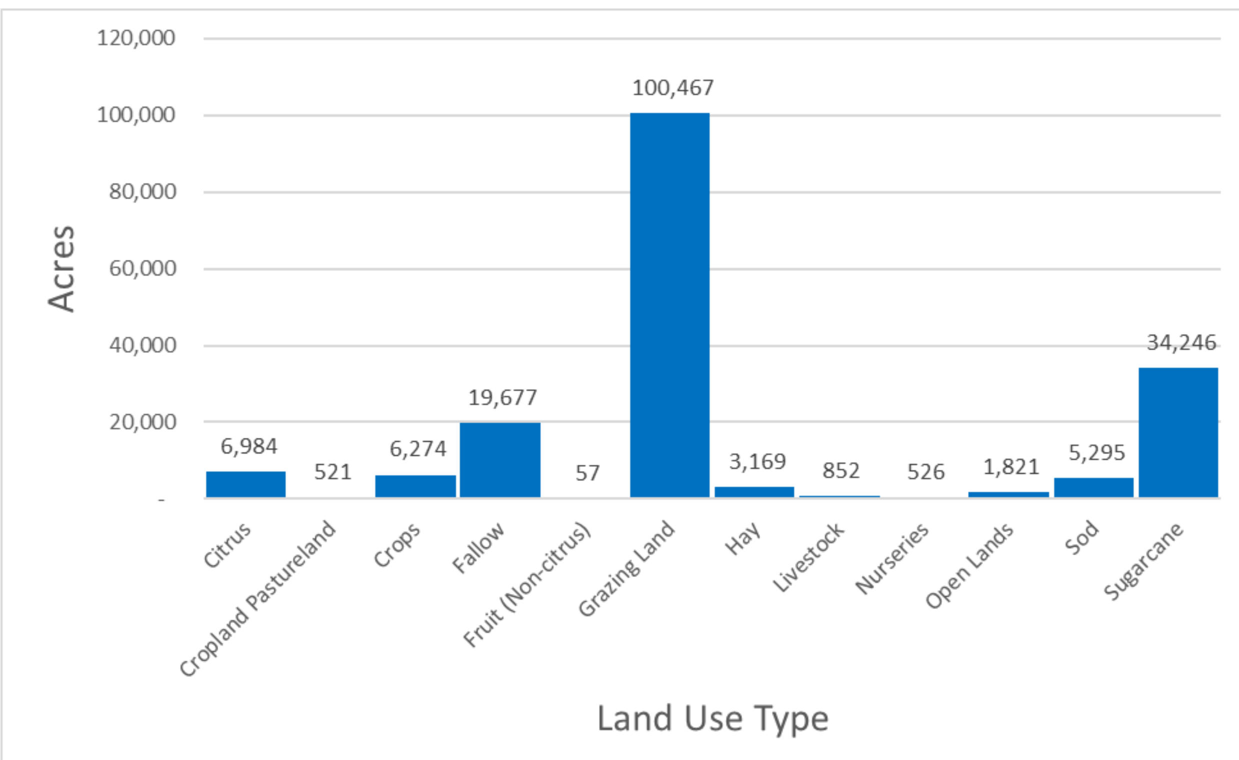

Figure B-4. Agricultural lands on parcels with 50 acres of agriculture and greater

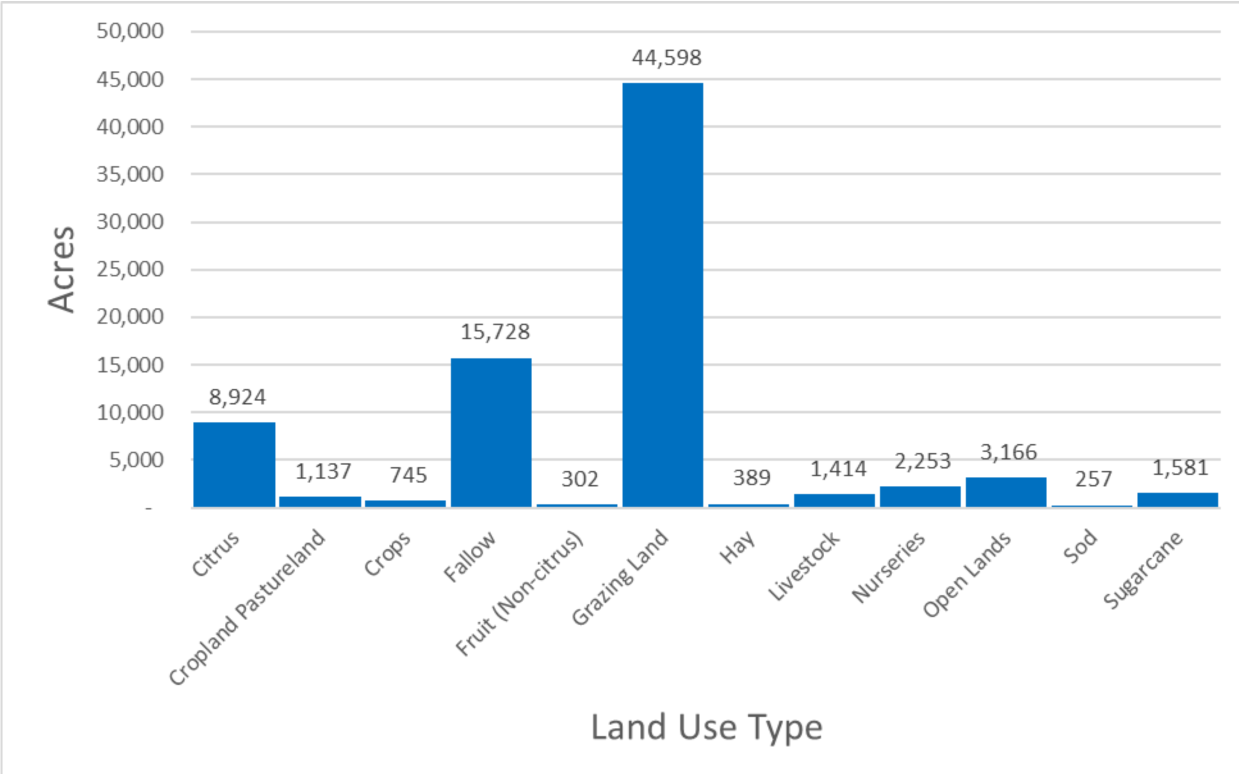

Figure B-5. Agricultural land uses on parcels with less than 50 acres of agriculture

Table B-13 lists the total acreage associated with the identified slivers and the lands that are not likely to have enrollable agricultural activities, along with a remaining total of unenrolled agricultural acres in the BMAP area. **Figure B-6** through **Figure B-7** summarize the unenrolled agricultural acres in the Lake Okeechobee BMAP area by acres of agriculture within the parcels. However, they do not include acreages or parcels associated with slivers or lands that are not likely to have enrollable agricultural activities.

Table B-13. Summary of unenrolled agricultural land use acreage in the Lake Okeechobee BMAP area

Note: Due to geometric variations between shapefiles used in the unenrolled agricultural lands analysis performed by OAWP, the unenrolled agricultural acres differ from subtraction of the FSAID VI Agricultural Acres in the BMAP and the Total Agricultural Acres Enrolled referenced in Table B-2.

Category	Acres
Unenrolled agricultural acres	393,571
Acres identified within slivers of unenrolled agricultural areas	15,889
Lands without enrollable agricultural activity (e.g., tribal lands, residential development, and parcels with DOR use codes 70-98)	117,299
Total lands with potentially enrollable agricultural activities	**260,384**

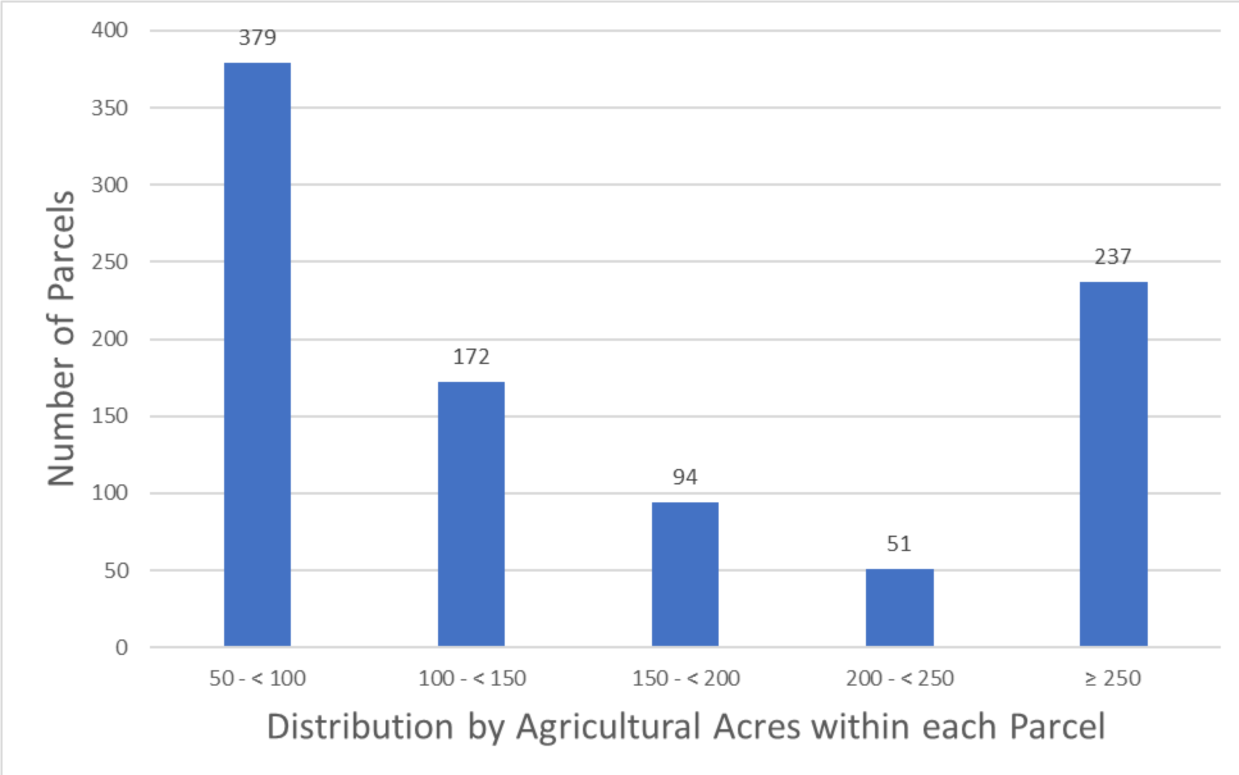

Figure B-6. Number of parcels with 50 acres of agriculture and greater

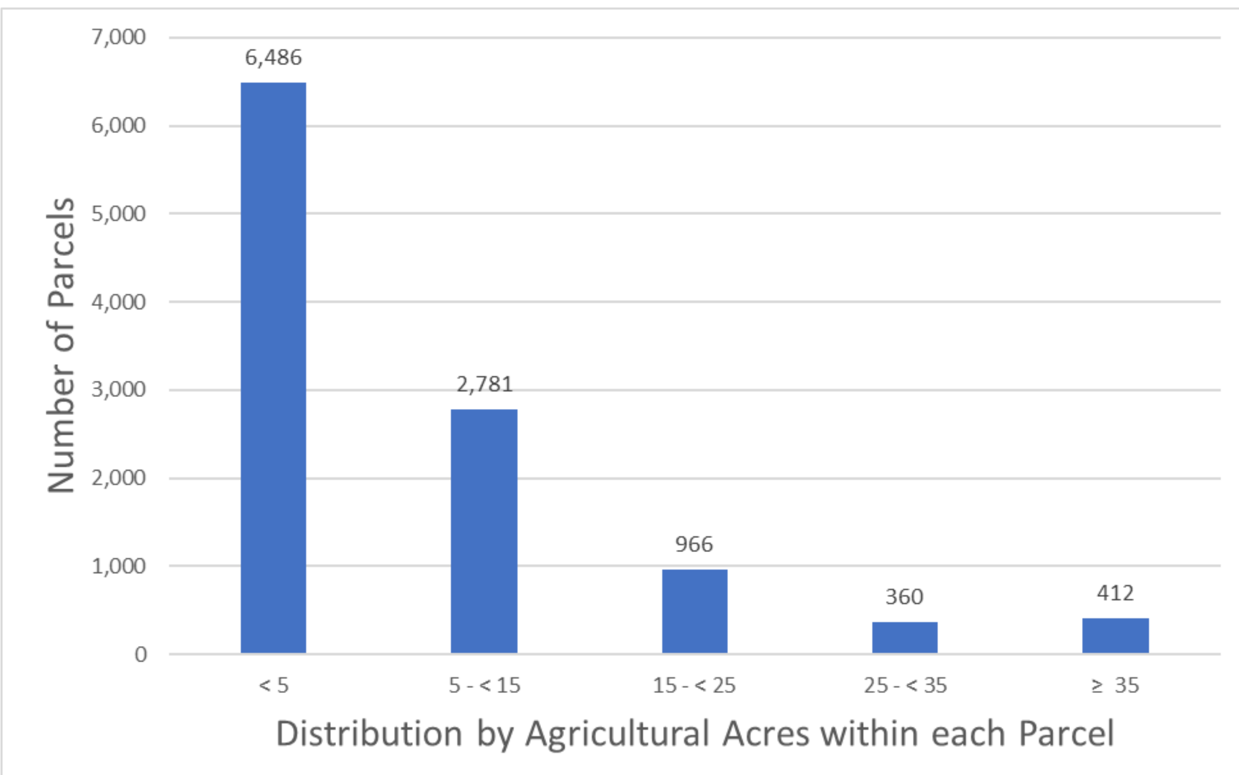

Figure B-7. Number of parcels with less than 50 acres of agriculture

Unenrolled agriculture characterization information for each individual subwatershed, including the distribution of agricultural acres within each parcel and land use type, is presented in **Figure B-8** through **Figure B-25**.

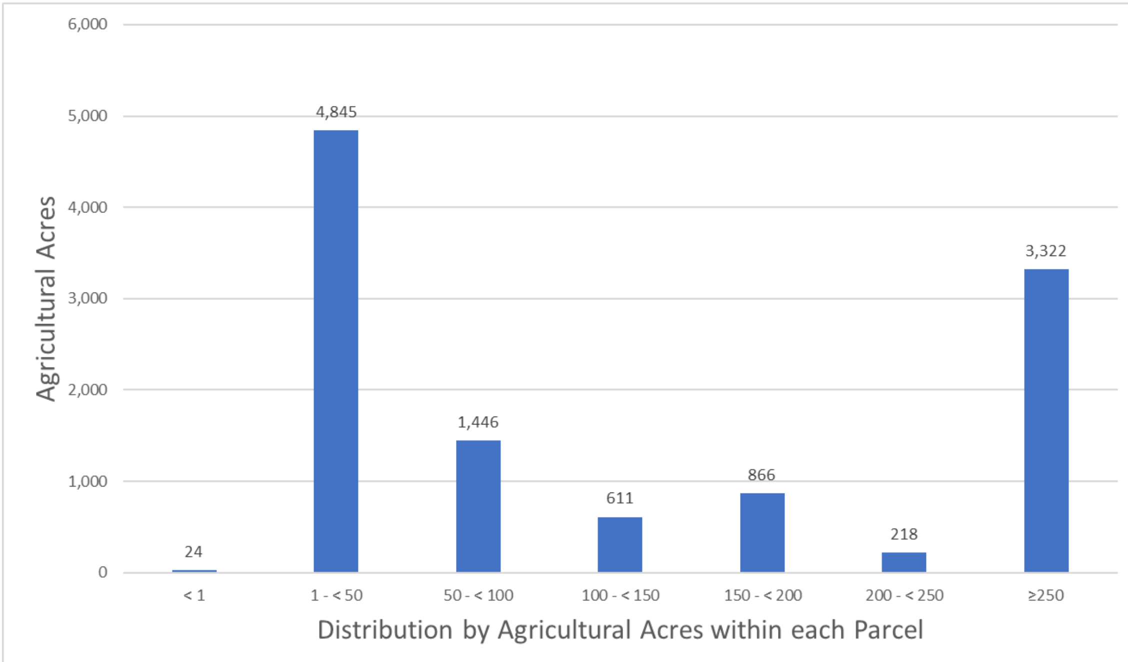

Figure B-8. Distribution by agricultural acres within each parcel, Fisheating Creek Subwatershed

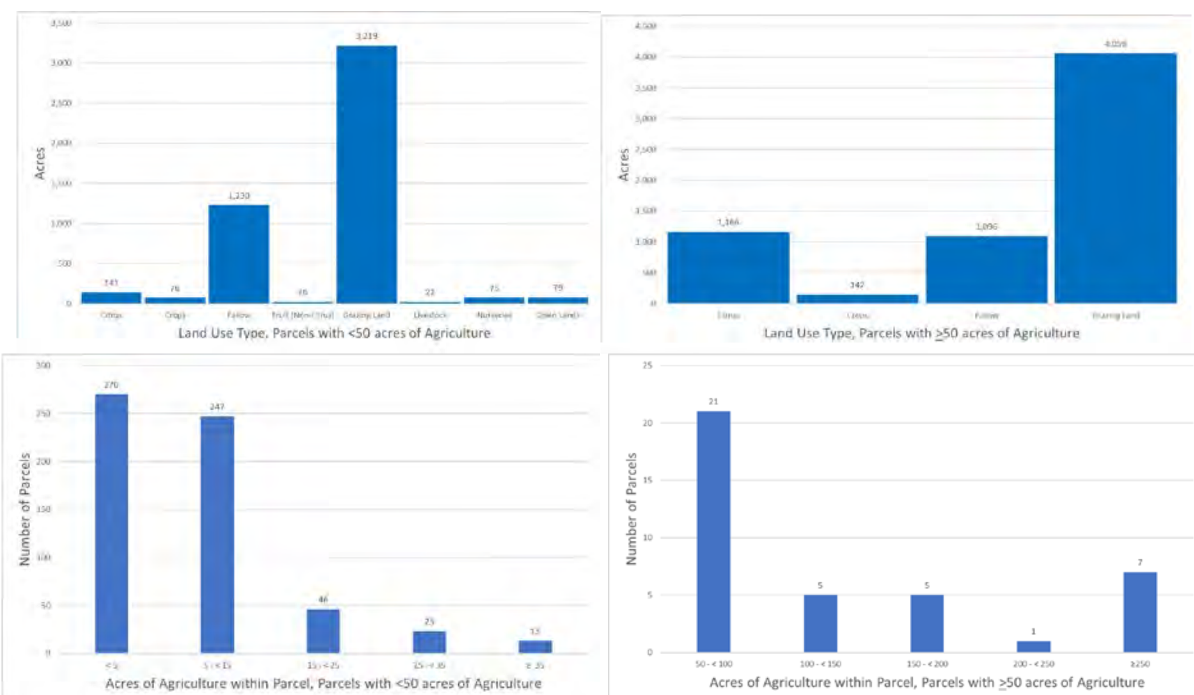

Figure B-9. Land use type and distribution of agricultural acreage, Fisheating Creek Subwatershed

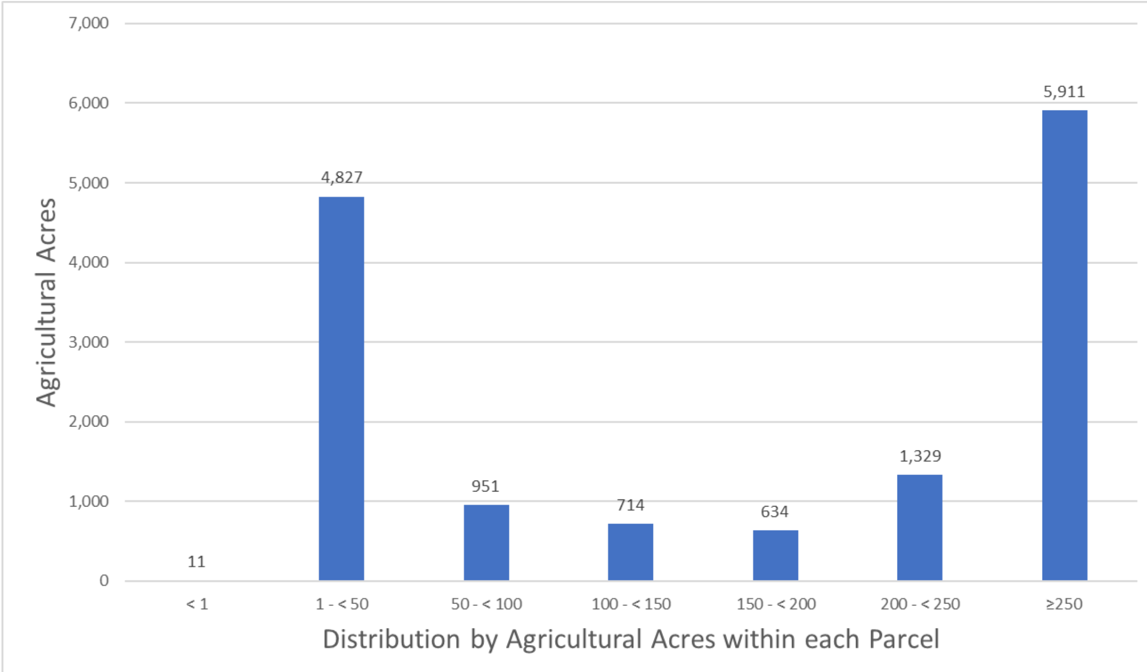

Figure B-10. Distribution by agricultural acres within each parcel, Indian Prairie Subwatershed

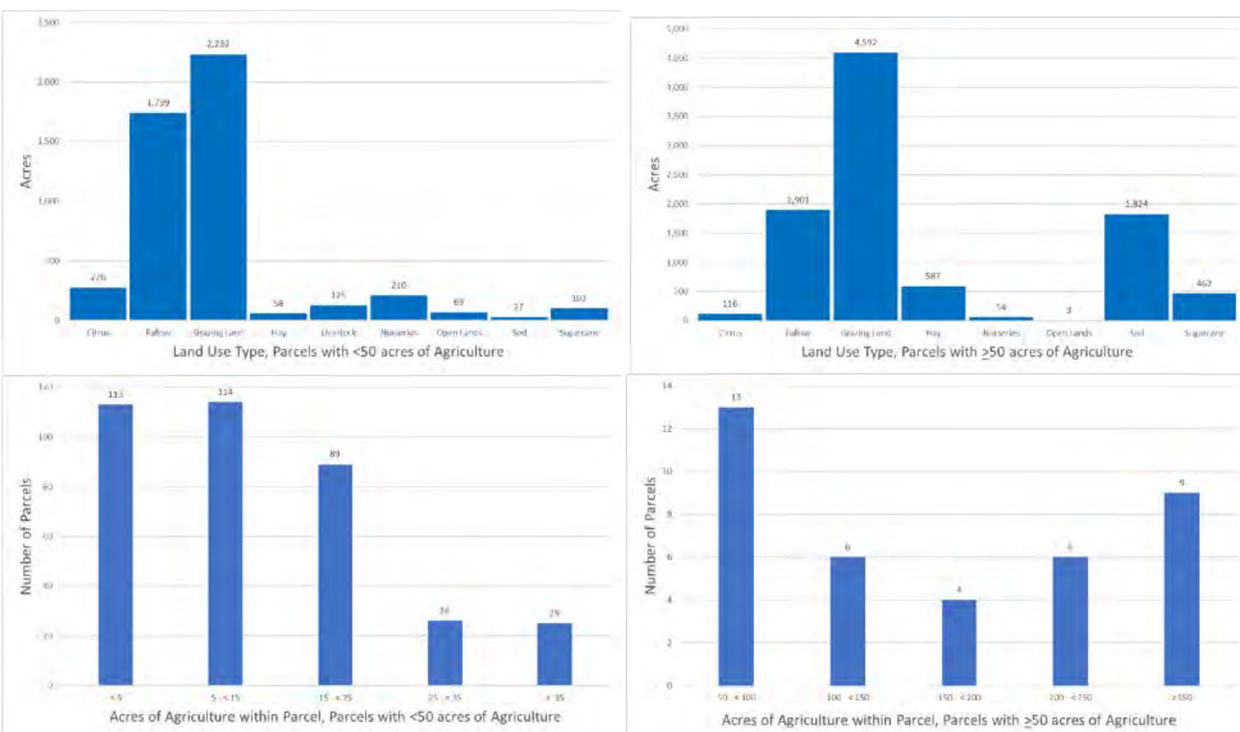

Figure B-11. Land use type and distribution of agricultural acreage, Indian Prairie Subwatershed

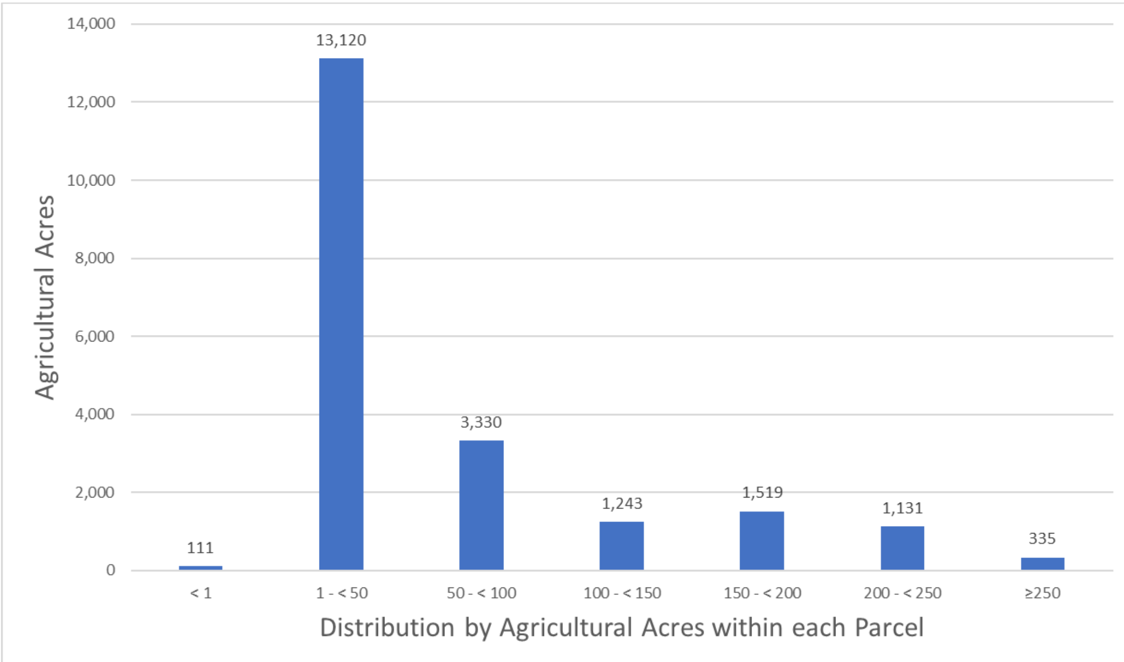

Figure B-12. Distribution by agricultural acres within each parcel, Lake Istokpoga Subwatershed

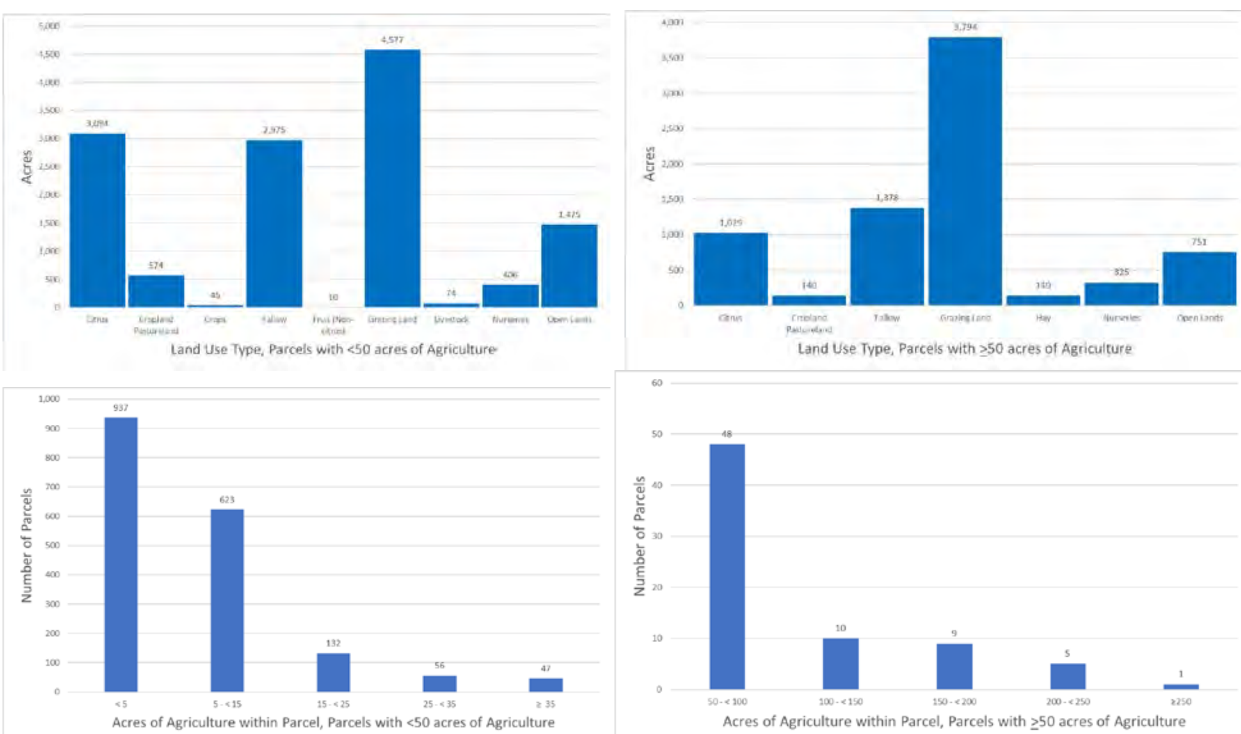

Figure B-13. Land use type and distribution of agricultural acreage, Lake Istokpoga Subwatershed

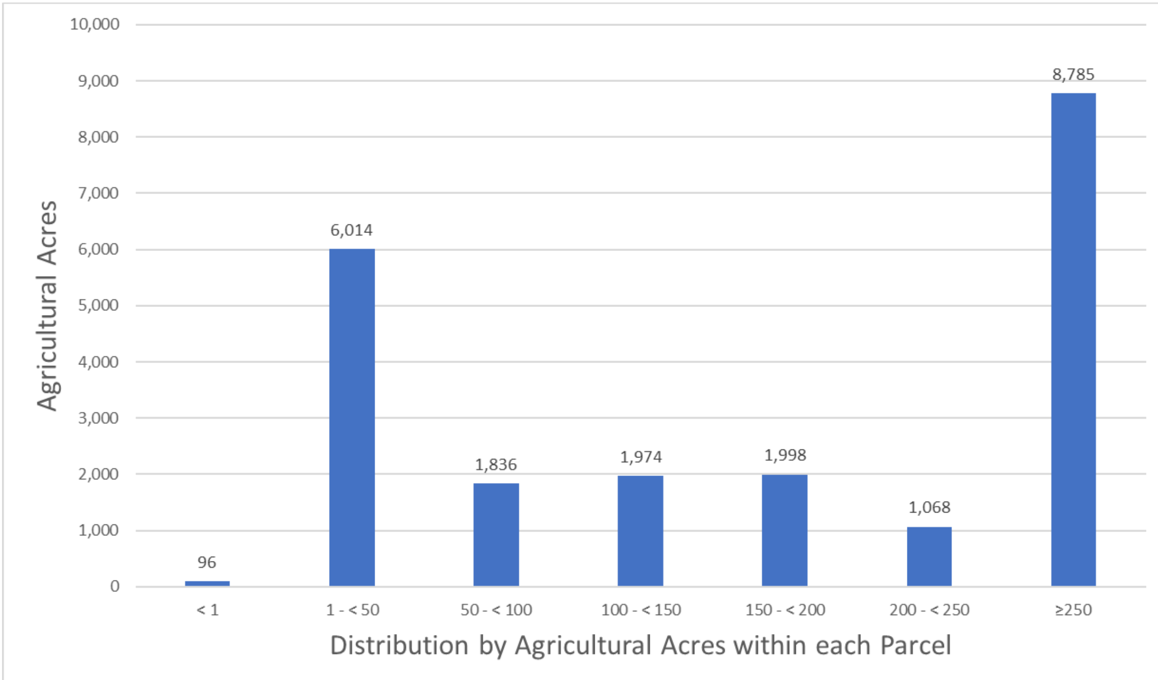

Figure B-14. Distribution by agricultural acres within each parcel, Lower Kissimmee Subwatershed

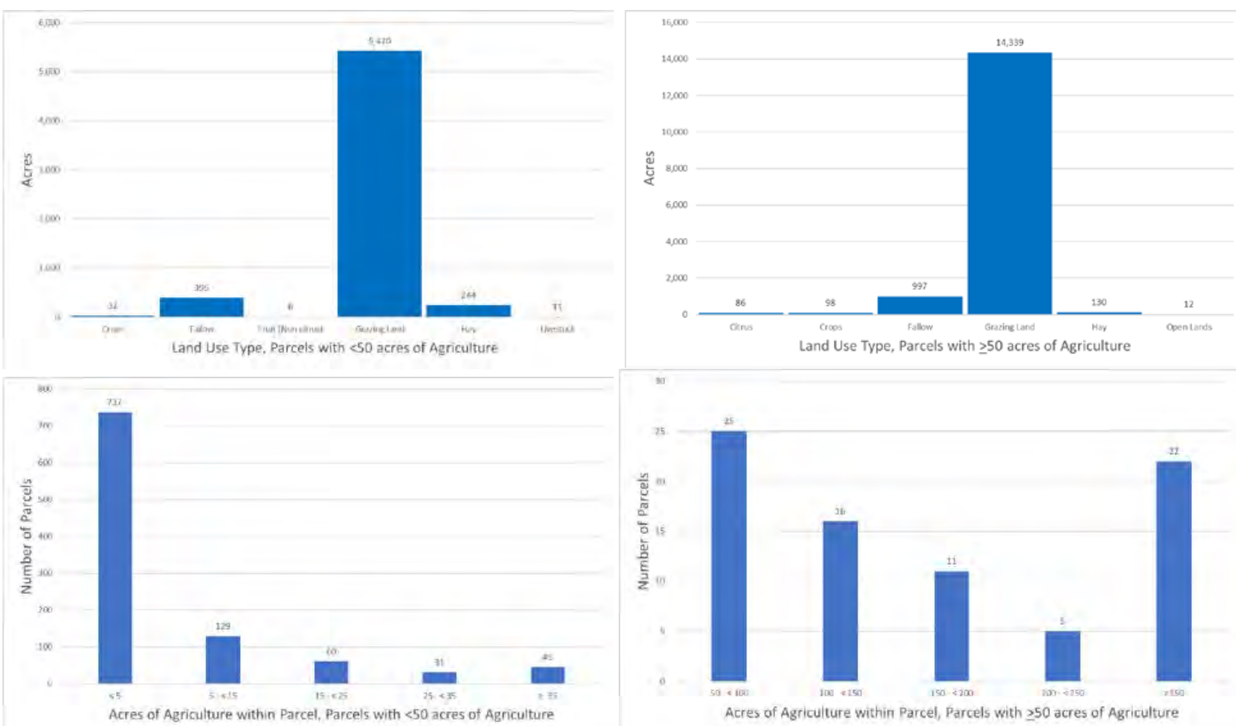

Figure B-15. Land use type and distribution of agricultural acreage, Lower Kissimmee Subwatershed

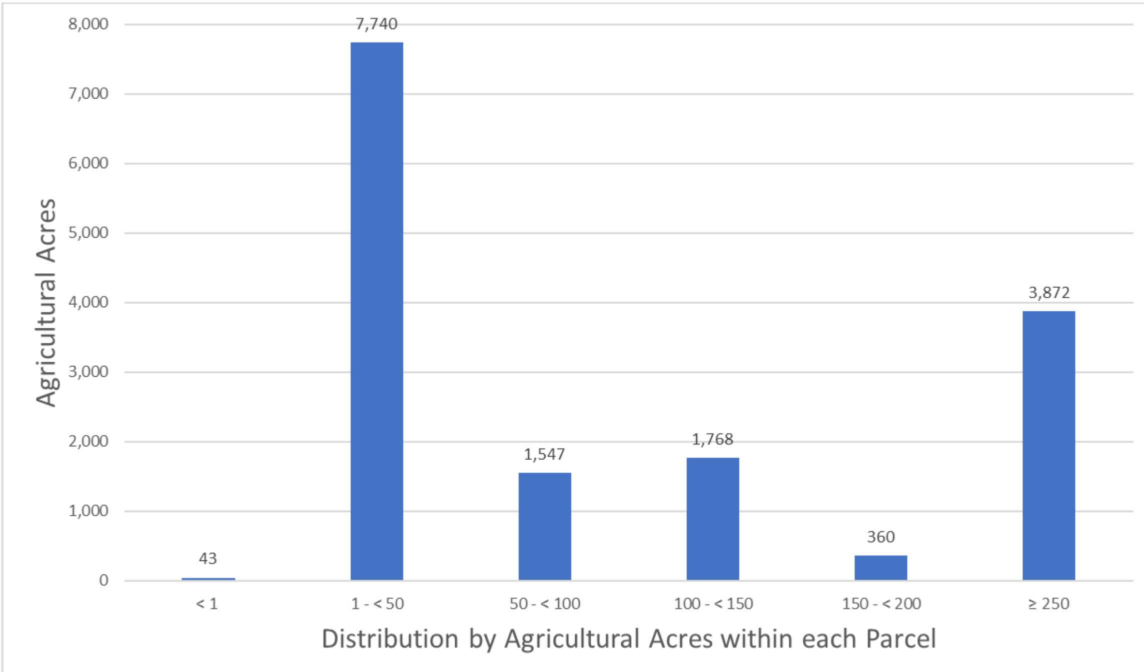

Figure B-16. Distribution by agricultural acres within each parcel, Taylor Creek/Nubbin Slough Subwatershed

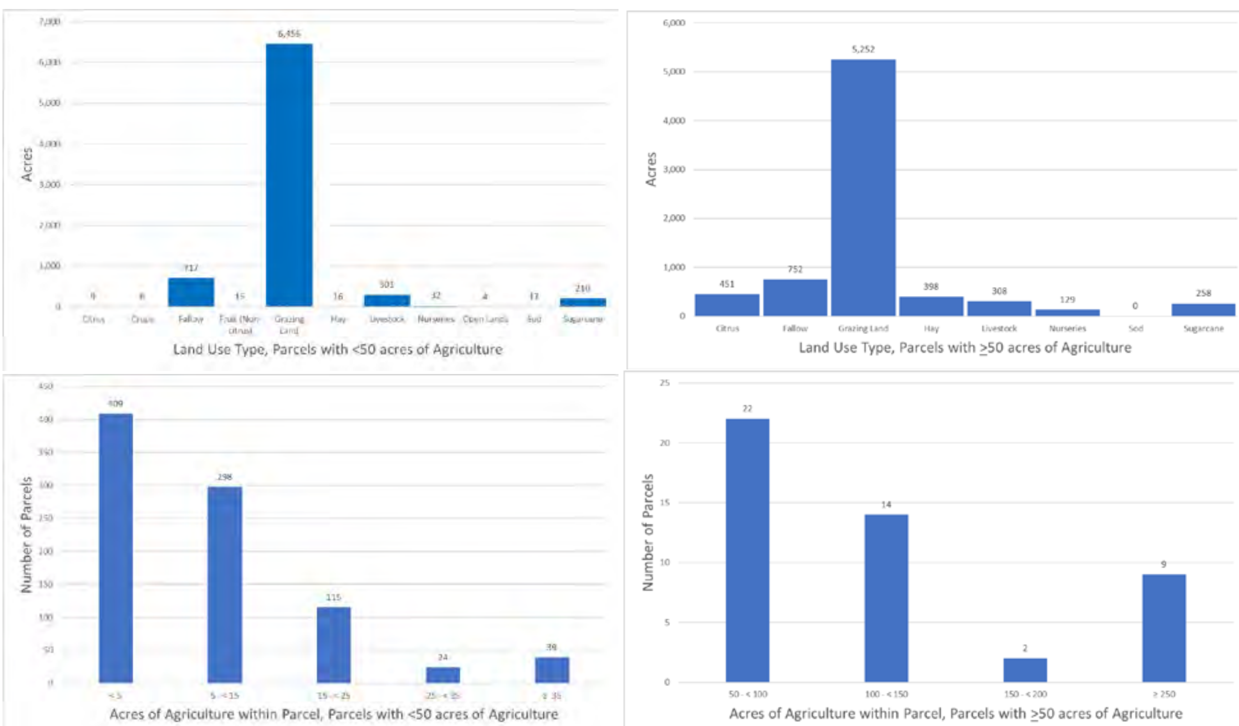

Figure B-17. Land use type and distribution of agricultural acreage, Taylor Creek/Nubbin Slough Subwatershed

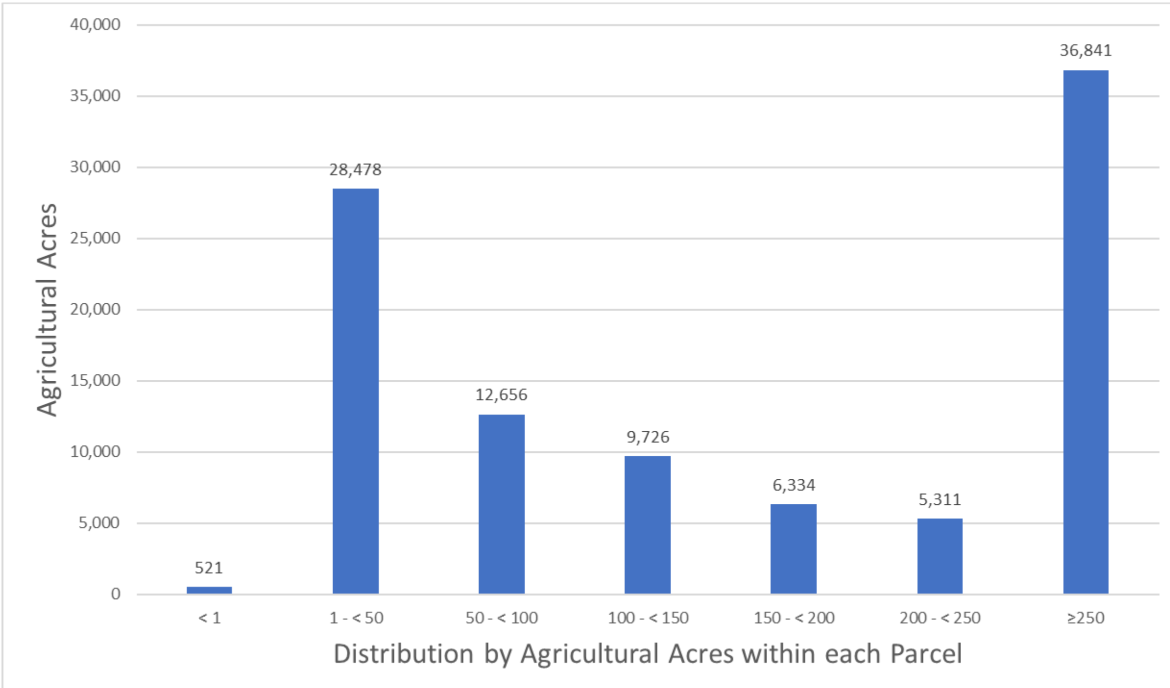

Figure B-18. Distribution by agricultural acres within each parcel, Upper Kissimmee Subwatershed

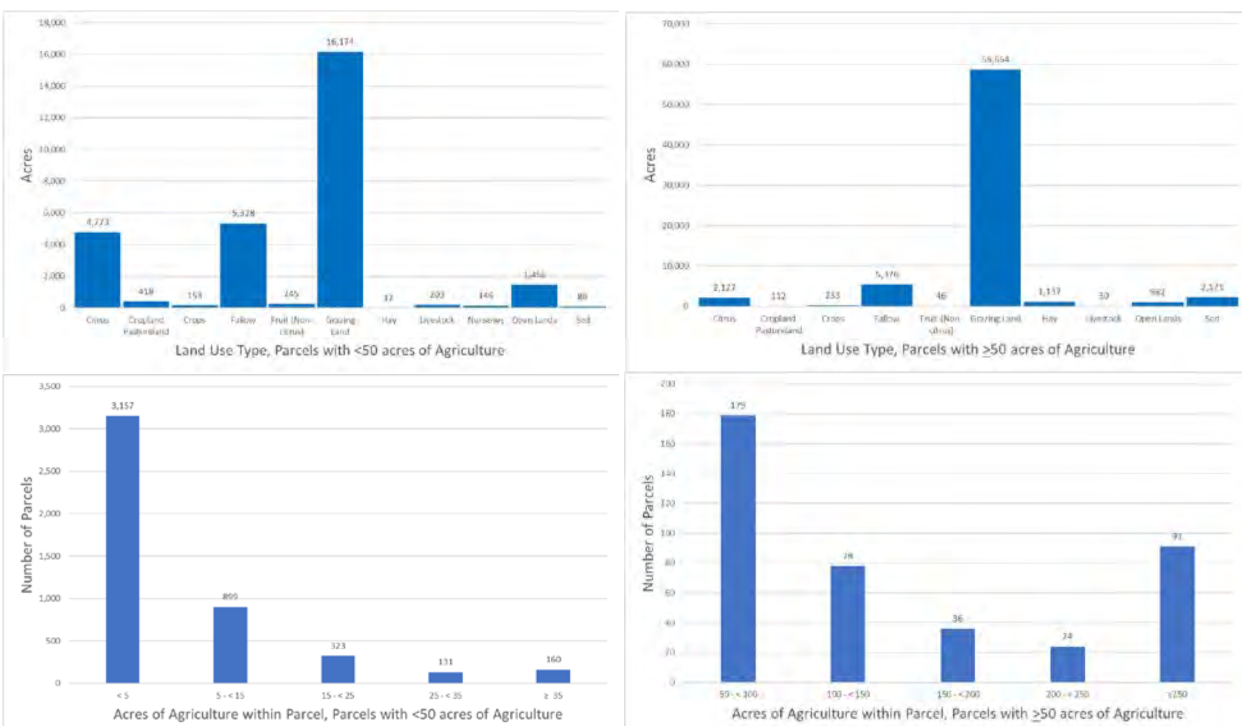

Figure B-19. Land use type and distribution of agricultural acreage, Upper Kissimmee Subwatershed

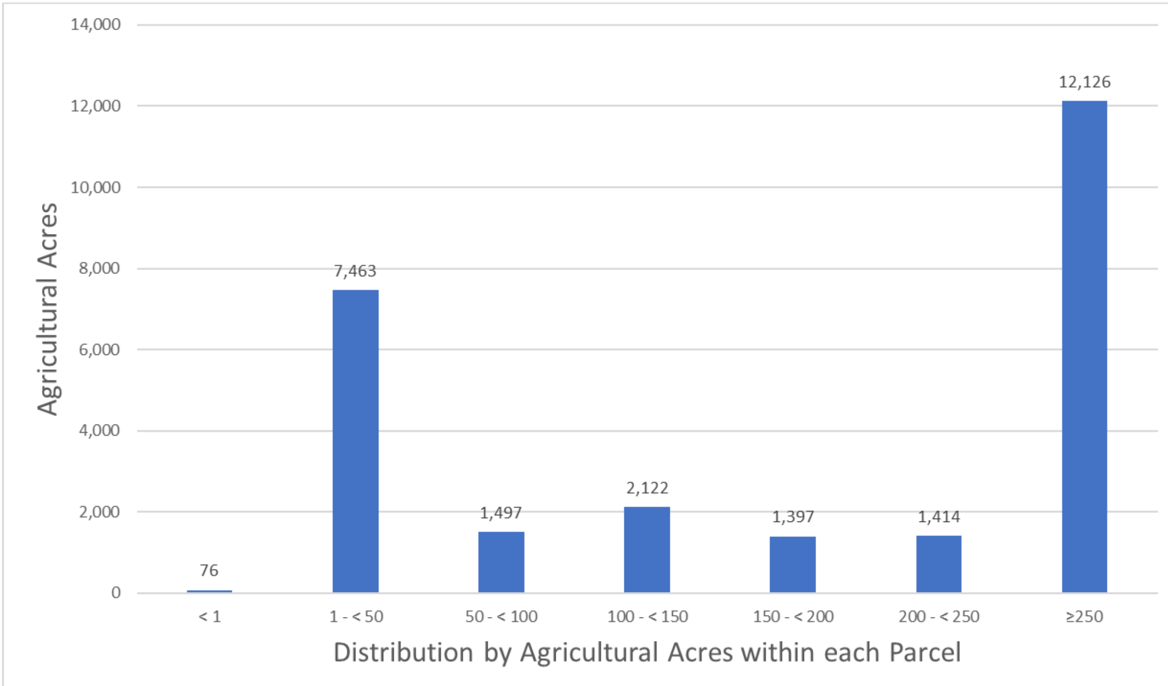

Figure B-20. Distribution by agricultural acres within each parcel, East Lake Okeechobee Subwatershed

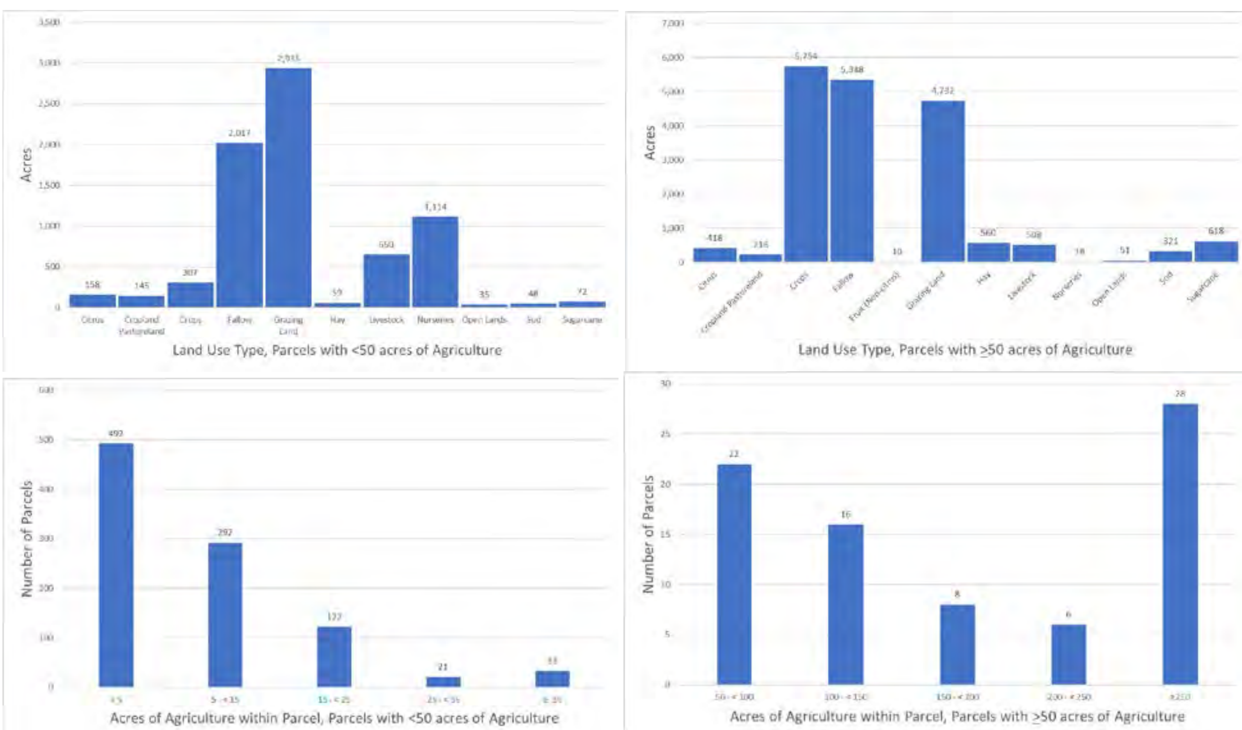

Figure B-21. Land use type and distribution of agricultural acreage, East Lake Okeechobee Subwatershed

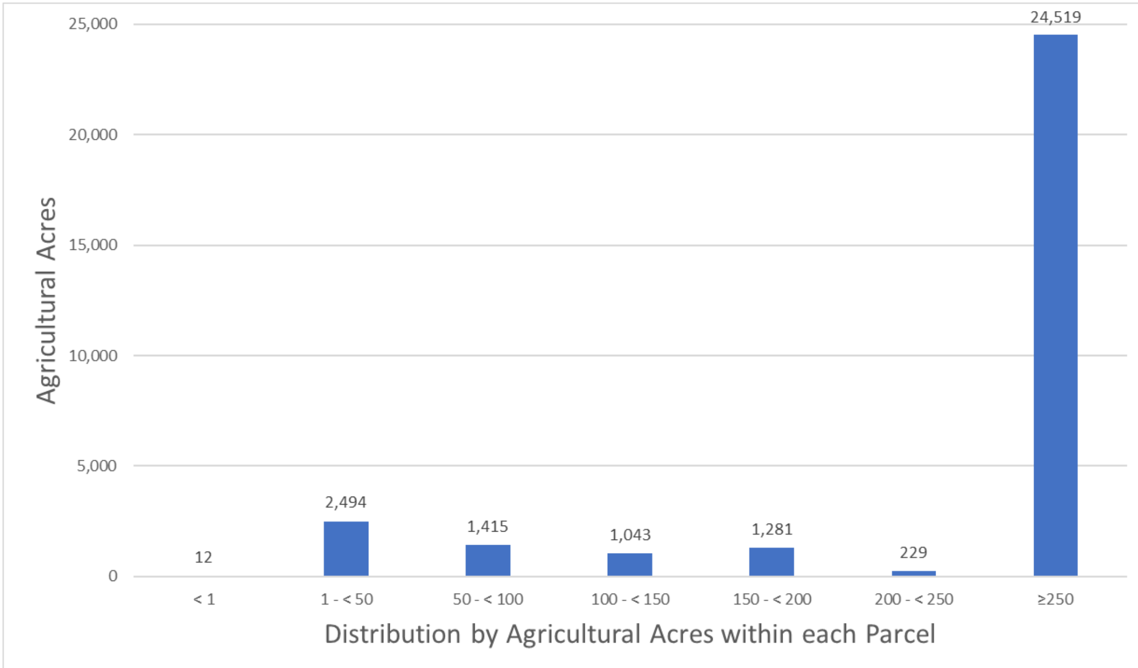

Figure B-22. Distribution by agricultural acres within each parcel, South Lake Okeechobee Subwatershed

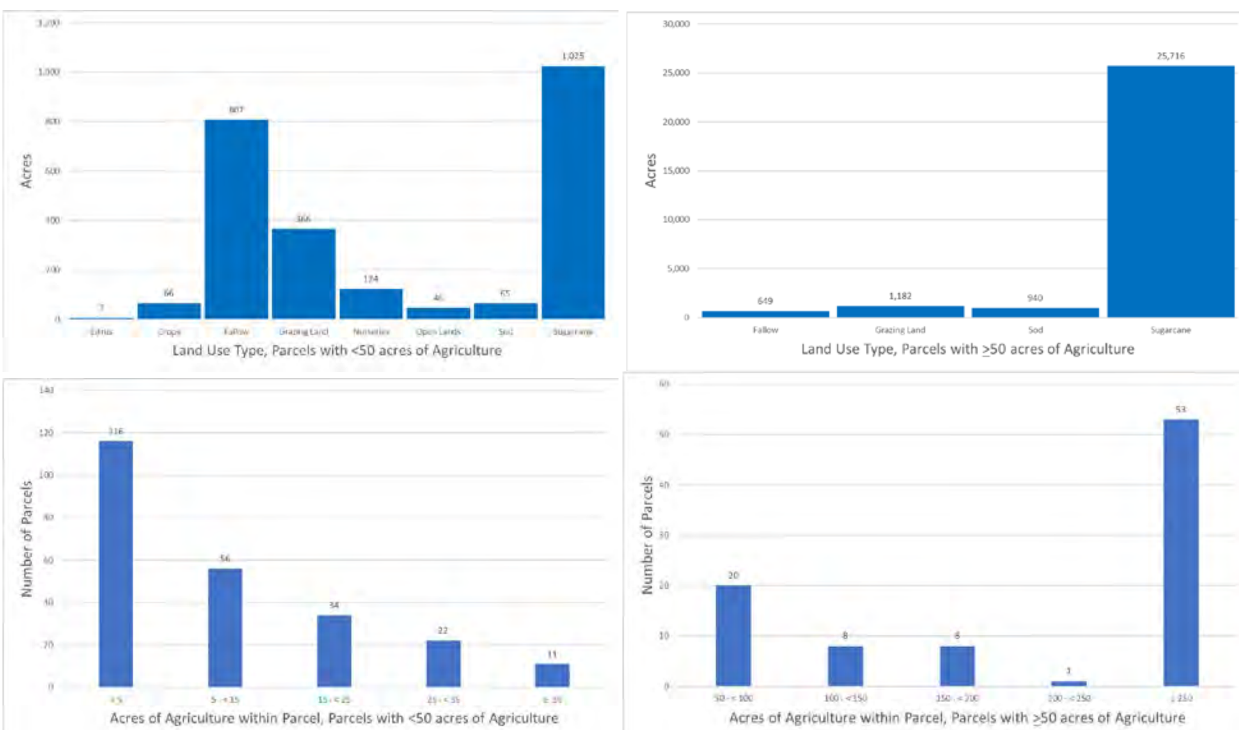

Figure B-23. Land use type and distribution of agricultural acreage, South Lake Okeechobee Subwatershed

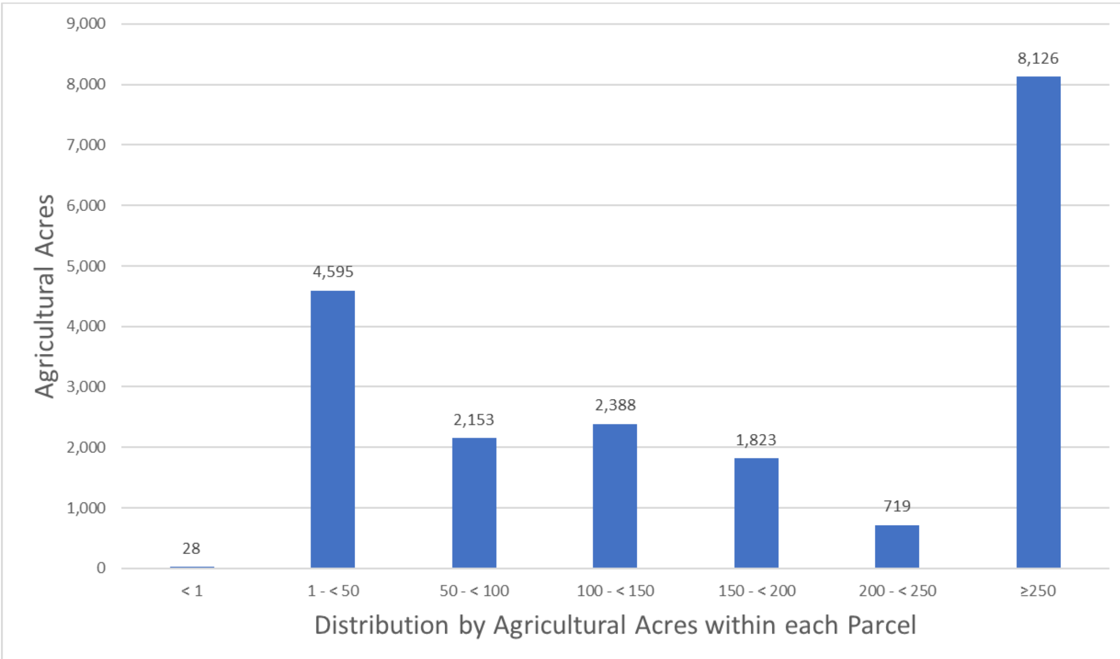

Figure B-24. Distribution by agricultural acres within each parcel, West Lake Okeechobee Subwatershed

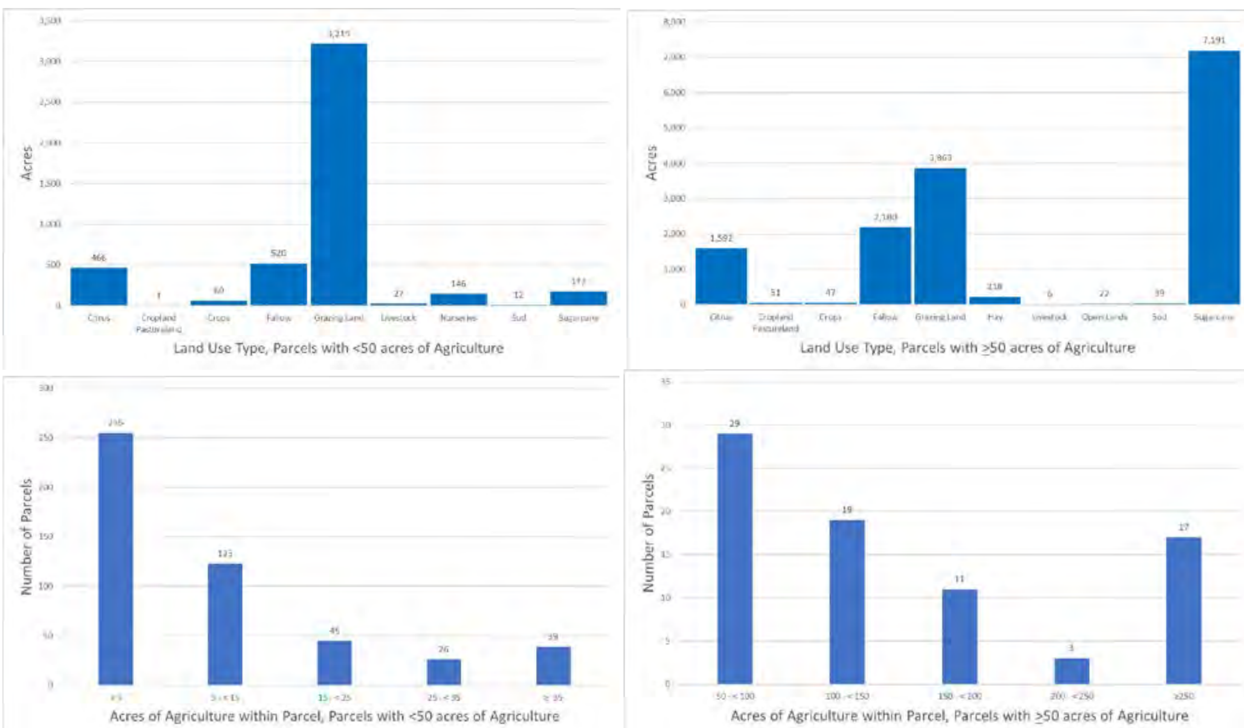

Figure B-25. Land use type and distribution of agricultural acreage, West Lake Okeechobee Subwatershed

Future Efforts

BMAP loads and allocations, as well as water supply projections, are based primarily on land use data. Maintaining the most accurate agricultural land use dataset is critical to planning and policy decisions. Although crop changes, technology advances, and land ownership/lessee changes related to agricultural operations create dynamic environments and difficulties in estimating impacts from specific operations, FDACS and DEP continue to coordinate and develop ways to improve accuracy.

Additional characterizations of the agricultural land uses need to be conducted for each of the subwatersheds in the Lake Okeechobee BMAP area. As the DEP analysis identifies the nutrient loading estimates for each associated subwatershed, FDACS will be able to better focus enrollment and cost-share efforts on those subwatersheds with the highest estimated loads and characterize the land uses with agricultural production that is consistent with FDACS' BMP Program.

Analyzing land use data and parcel data is a valuable first step in identifying the agricultural areas that provide the greatest net benefits to water resources for enrollment in FDACS' BMP Program, as well as to prioritize implementation verification visits in a given subwatershed. The next step to refine the enrollment efforts will have the parcel loading information derived from WAM converted to a format that can easily be analyzed with the land use and parcel geodatabases. This effort will help FDACS identify those specific parcels with the highest modeled nutrient loading. These parcels would then be prioritized for enrollment and implementation of BMPs, as well as site visits for the verification of BMP implementation.

Additional Factors Related to Agricultural Lands and Measuring Progress

Legacy loading, including loading as a result of the operation of the regional water management system and associated infrastructure, can present an additional challenge to measuring progress in many of areas of Florida with adopted BMAPs. Based on research, initial verification by DEP, and long-term trends in water quality in the BMAP area, it is expected that current efforts, such as BMP implementation, will continue to provide improvements in overall water quality despite the impacts from legacy loads. Recognition that there is naturally occurring phosphorus in the system is important when evaluating solutions, as the ubiquity of the source, limitations for treatment, and uncertainty of proportion compared with anthropogenic sources may mask or overwhelm gains achieved through BMP implementation and other site-specific efforts.

While the implementation of BMPs will improve the water quality in the basin, it is not reasonable to assume that BMP implementation alone can overcome the issues of legacy loads, conversion to more urban environments, and the effects of intense weather events. BMP implementation is one of several complex and integrated components in managing the water resources of a watershed. Additional regional projects, precisely located and operated, will be needed to achieve the TMDL for the LOW.

Collaboration between DEP, the water management districts, and other state agencies, as well as local governments, federal partners, and agricultural producers, is critical in identifying projects and programs, as well as locating funding opportunities to achieve allocations provided for under this BMAP. To improve water quality while retaining the benefits agricultural production provides to local communities, wildlife enhancement, and preservation of natural areas requires a commitment from all stakeholders to implementing protective measures in a way that maintain the viability of agricultural operations.

Recommended Updates to Land Use

DEP and OAWP have identified land use–related issues that consistently occur during BMAP development and/or updates. One of these issues is the differentiation between what is classified as agricultural land use in the TMDL or BMAP model and what is no longer agricultural land use.

OAWP has developed a methodology to identify agricultural land use changes. Using GIS, OAWP compared the 2009 SFWMD BMAP modeled land use with the latest FSAID land use and OAWP BMP enrollment data. OAWP identified areas classified as agriculture by the BMAP modeled land use that do not overlap with the latest FSAID or OWAP BMP enrollment data. OAWP reviewed the output of this overlay analysis by using county property appraiser data and aerial imagery to determine if the nonoverlapping areas were still in production. OAWP identified 13,407 acres, classified as agriculture in the 2009 SFWMD land use used in WAM, that are now other land use types such as residential, industrial, or commercial (see **Table B-14**). Often the analyses show changes that have occurred more rapidly than any land use data can capture, such as the transition to residential development. The land use changes are provided to DEP as a GIS shapefile with a description of the information in the county property appraiser database and aerial imagery reflected for refinement of the acreage and loading allocated to agriculture in a BMAP area.

In addition to identifying land use changes in BMAP modeled land use, OAWP regularly reviews FSAID data, at times daily or weekly, as it performs other job functions. Any edits or changes are reviewed and considered for inclusion in the next iteration of the FSAID.

Table B-14. Agricultural land use change by subwatershed

Subwatershed	Acres
Fisheating Creek	1,448
Indian Prairie	5,605
Lake Istokpoga	2,181
Lower Kissimmee	2,411
Taylor Creek/Nubbin Slough	N/A
Upper Kissimmee	N/A
East Lake Okeechobee	855
West Lake Okeechobee	907
South Lake Okeechobee	N/A

Potential Site-Specific Nutrient Management Measures in Addition to BMPs

Beyond enrolling producers in the OAWP BMP Program and verifying implementation, OAWP will also work with producers to identify a suite of agricultural projects and research agricultural technologies that could be implemented on properties where they are deemed technically feasible and if funding is made available. FDACS executes contracts with soil and water conservation districts and other partners to administer cost-share funds and provide technical and administrative support for these districts and other partners. Cost-share funding is being used to implement higher level BMPs, innovative technologies, and regional projects to provide the next added increment of improving and protecting water quality.

Table B-15 identifies the agricultural technologies that received cost-share assistance in the Lake Okeechobee BMAP area and the associated nutrient reductions based on the 2016 SWET report. Using the nutrient reductions from the report, OAWP developed a methodology to estimate nutrient reductions for NOIs that have received cost-share funding. The NOI boundary, based on county property appraiser parcel data, was considered the area treated by the cost-share agricultural technology or project. For parcels with more than one cost-share project, OAWP identified the order of treatment to determine the reductions for the multiple projects and created a workbook that provided the cost-share agricultural technologies and the formulas to estimate the nutrient reductions.

Table B-15. Cost-share project types and associated nutrient reductions recommended by OAWP

[1] Reductions for this measure were not incorporated as part of this exercise.
[2] Reductions for this measure are from Table 5 in the 2016 SWET Report (Bottcher 2016). Each project is 1 unit..

Project Types	TN Reductions (%)	TP Reductions (%)
Chemigation/fertigation	20	20
Composting and/or storage project	N/A	N/A
Crop implements	N/A	N/A
Dairy work	50	50
Drainage improvements, mole drain, ditch cleaning	10	15
Engineering, surveying, planning, modeling	N/A	N/A
Fence	10	10
Irrigation improvements, automation	20	20
Precision agriculture technology	30	10
Retention, detention, tailwater recovery, berms (vegetable and agronomic crops, citrus)	64	70
Retention, detention, tailwater recovery, berms (cow/calf)	25	18
Structure for water control/culvert	17	29
Weather station[1]	20	5
Well, pipeline, trough, pond, heavy use protection[2]	186 lbs/yr/unit	50 lbs/yr/unit

Appendix C. Water Quality Data Processing and Analysis Methods

For the 5-Year Review of the Lake Okeechobee BMAP, trend analyses were conducted on available data from Tier 1 and Tier 2 stations for the period from May 1, 2008, to April 30, 2018. Data were provided by SFWMD and retrieved from WIN and processed according to the procedure outlined in the next section.

The nonparametric Seasonal Kendall test was used to identify monotonic trends in the data. This statistical technique was chosen because data are not required to conform to a particular distribution and the results are robust against outliers and gaps in the data record. **Section 3.3.3** summarizes the results of the Seasonal Kendall analysis, and details of the techniques are provided below.

Data Management and Processing

The POR for this analysis was May 1, 2008, to April 30, 2018, to allow a sufficient data record for trend analysis including periods before and after BMAP adoption in December 2014, and to remain consistent with the established water year in the region (May 1–April 30).

TP was the only parameter used in this analysis, and SFWMD provided TP data for the Tier 1 and Tier 2 stations. Data from the last four months of WY2018 for Station KREA98 were appended from data retrieved from WIN. **Table C-1** and **Table C-2** list the POR and data availability for the monthly series of TP data for each station. The data provided by SFWMD were already preprocessed per standard SFWMD quality control protocols.

Data retrieved from WIN were further processed with standard quality control checks and statistical diagnostics, including removing data with fatal qualifier codes, the assessment of temporal independence, and serial correlation. After quality control processing was completed, monthly aggregated values were calculated for each month with more than one sampling event. The monthly series was the final dataset used in statistical and trend analysis. Specific data processing and steps and methodology are provided in the following sections.

Statistical Analyses

The Seasonal Kendall test was used to identify monotonic trends in the TP load (Tier 1), FWM (Tier 1), or concentration (Tier 2) data, which were dependent on station type. The USGS Fortran code for the Seasonal Kendall test was used to compute a tau, raw p-value, and slope for each parameter series using months as "seasons." The program also provides a p-value adjusted for covariance caused by serial correlation.

Autocorrelation function (ACF) analysis was conducted on the monthly TP series for each station to identify the presence of seasonality and serial correlation. If a series showed significant autocorrelation at the 12-month lag, it was considered to exhibit serial correlation, and the adjusted p-value was selected as the representative p-value for the series. If no serial correlation was detected, then the raw p-value was reported. Trends in the data series were considered statistically significant if the appropriate p-value was less than 0.05, with a positive Sen slope indicating an increasing trend and a negative Sen slope indicating a decreasing trend.

Data Download

Station data were provided by SFWMD to assess TP concentrations for Tier 2 stations and TP FWMs and loads at Tier I structure stations for the designated POR of May 1, 2008, through April 30, 2018.

Data Processing (in order of operation)

- The majority of data processing was conducted by SFWMD for the final *2019 SFER – Volume I, Chapter 8B* prepared by SFWMD. Data processing conducted by SFWMD included the calculations of monthly surface water flows and nutrient (TP and TN) loads for the major drainage basins into Lake Okeechobee, as well as discharges from Lakes Istokpoga and Kissimmee. Data were based on stations where flows are continuously monitored and TP and TN samples are collected weekly, if flowing; otherwise monthly at a minimum. Basin load and flow data were used to estimate nutrient FWM concentrations. The SFER lists annual flows and nutrient loads to Lake Okeechobee for each water year.

- Few data points downloaded for WY2018 for KREA98 were subject to the following data processing:
  - Data Qualifiers:
    - Data with result qualifiers of "G," "H," "K," "L," "N," "O," "Q," "V," "Y," or "?" were not used in the analysis, as per Table 1, Data Qualifier Codes, in Rule 62-160.700, F.A.C., Quality Assurance, and recent DEP decisions.
    - Only grab samples were used in the analysis of concentration data.
    - Both grab and automatic composite samples were used in the analysis of FWM and load data (as calculated and provided by SFWMD from flow and concentration data).
    - Data with a result qualifier of "J" were reviewed.
    - Data with a result qualifier of "U" were reviewed:
      - If not already present, a result qualifier of "U" was assigned to any data with a result value of "*Non-Detect."
      - Data with a result value of "*Not Reported" were deleted unless they also had a value qualifier of "U."
      - Data with a result qualifier of "U" were processed in accordance with Subsection 62-303.320(12), F.A.C., Aquatic Life-Based Water Quality Criteria Assessment. Results with the "U" data

qualifier code reported by a laboratory were assessed as half the reported result or half the criterion (whichever was lower).

- Sample Depth:
  - Samples were not filtered by sample depth.
- Nutrient Characteristic Selection:
  - TP: "Phosphorus as P," "Phosphorus-Total."
- Accounting for Duplicate Samples:
  - If samples were found to share the same station, characteristic, date, and time, they were flagged and reviewed.
  - The median of the duplicate samples was used as the reported value.

- Temporal Processing:
  - Monthly Time Series: If multiple data points existed within a month, the monthly median was calculated for each month.
- Processing for Statistical Tests:
  - Data were processed according to the needs of each statistical test (ACF or trend) and formatted for use in the R statistical program or USGS Fortran code.
  - Sampling Frequency:
    - Monthly data series were used for analysis.
    - Stations were separated into 2 analysis groups based on whether they had more or less than 50 % of available points.
    - Only station datasets with greater than 50 % of available data points were used for analysis.

Trend Analysis

- ACF:
  - Conducted to analyze seasonal patterns or serial correlation (using monthly seasons).
  - For the purposes of Seasonal Kendall analysis, statistically significant correlation on the 12th month lag was considered to be representative of serial correlation.
- Seasonal Kendall Tau Test:
  - Statistical Test Description: A nonparametric statistical test that does not require data to conform to a specific distribution and is not sensitive to outliers or data gaps.
    - Identifies monotonic trends in the datasets.

- Yields statistical significance value and direction of trend (increasing or decreasing).
- Accounts for seasonal data patterns (using months as seasons).

o Use in Trend Analysis:

- Serial correlation was identified with ACFs prior to trend analysis.
- USGS Fortran code for Seasonal Kendall Tau Test was used to produce tau, p-value, adjusted p-value, and Sen slope:
  - Raw p-value was used for series with no serial correlation detected.
  - Adjusted p-value was used if serial correlation was identified.
- Tau, p-value, and slope were used to interpret the significance and direction of a monotonic trend.

Table C-1. POR for Tier 1 stations monthly TP FWM and load data series

Station	FWM Start Date	FWM End Date	FWM Count	Load Start Date	Load End Date	Load Count
C10A	5/1/2008	4/1/2018	72	5/1/2018	4/1/2018	120
FECSR78	5/1/2018	4/1/2018	120	5/1/2018	4/1/2018	120
INDUSCAN	5/1/2008	4/1/2018	105	5/1/2018	4/1/2018	120
L59W	5/1/2008	4/1/2018	98	5/1/2018	4/1/2018	120
L60E	7/1/2008	3/1/2018	94	5/1/2018	4/1/2018	120
L60W	5/1/2008	4/1/2018	112	5/1/2018	4/1/2018	120
L61E	5/1/2008	4/1/2018	77	5/1/2018	4/1/2018	120
S127	8/1/2008	1/1/2018	83	5/1/2018	4/1/2018	120
S129	8/1/2008	2/1/2018	98	5/1/2018	4/1/2018	120
S131	7/1/2008	3/1/2018	92	5/1/2018	4/1/2018	120
S133	8/1/2008	2/1/2018	77	5/1/2018	4/1/2018	120
S135	7/1/2008	2/1/2018	84	5/1/2018	4/1/2018	120
S154	7/1/2008	3/1/2018	87	5/1/2018	4/1/2018	120
S154C	7/1/2008	4/1/2018	107	5/1/2018	4/1/2018	120
S191	6/1/2018	1/1/2018	97	5/1/2018	4/1/2018	120
S308C	5/1/2008	4/1/2018	104	5/1/2018	4/1/2018	120
S4	7/1/2008	4/1/2018	105	5/1/2018	4/1/2018	120
S65	5/1/2018	4/1/2018	120	5/1/2018	4/1/2018	120
S65E	5/1/2018	4/1/2018	118	5/1/2018	4/1/2018	120
S68	5/1/2018	4/1/2018	115	5/1/2018	4/1/2018	120
S71	5/1/2018	4/1/2018	118	5/1/2018	4/1/2018	120
S72	5/1/2018	4/1/2018	119	5/1/2018	4/1/2018	120
S84	5/1/2018	4/1/2018	119	5/1/2018	4/1/2018	120

Table C-2. POR for Tier 2 stations monthly TP concentration data series

Notes: Stations KREA91, KREA92, KREA93, KREA94, KREA97, and KREA98 are in-river sites.
SFWMD water quality stations KREA01, TCNS 213, TCNS 214, and TCNS 217 are colocated with USGS flow monitoring stations.

Station	Start Date	End Date	Count	% Available Data
AB27343014	5/9/2008	4/12/2018	110	91.67
ABOGGN	12/8/2009	1/9/2018	83	69.17
AR06333013	5/9/2008	4/12/2018	117	97.50
AR18343012	5/9/2008	4/12/2018	104	86.67
BH04392912	5/13/2008	12/21/2017	84	70.00
BN03332911	5/9/2008	4/12/2018	118	98.33
BN08332912	5/9/2008	4/12/2018	108	90.00
BNSHINGLE	5/19/2008	4/24/2018	100	83.33
BS-59	5/19/2008	4/24/2018	62	51.67
CL18273011	7/21/2011	4/17/2018	61	50.83
CREEDYBR	5/19/2008	4/24/2018	71	59.17
CY05353444	5/12/2008	4/17/2018	101	84.17
DLMARNCR	6/19/2012	4/30/2018	68	56.67
ET05253114	7/9/2008	2/14/2018	71	59.17
ET06253113	5/14/2008	1/22/2018	109	90.83
FE20393013	5/13/2008	12/21/2017	72	60.00
FE21392913	5/13/2008	9/22/2017	68	56.67
FE26362812	7/8/2008	3/6/2018	86	71.67
GA09393011	5/13/2008	3/6/2018	103	85.83
HP06393242	5/9/2011	3/16/2018	63	52.50
HP11373132	6/18/2008	9/22/2017	61	50.83
HP15373112	6/27/2008	11/16/2017	72	60.00
HP22373112	5/5/2008	12/21/2017	76	63.33
HP25373013	5/5/2008	4/5/2018	114	95.00
IP09383232	5/9/2011	10/5/2017	62	51.67
KR05373311	5/7/2008	2/2/2018	64	53.33
KR16373414	5/27/2008	4/24/2018	83	69.17
KR17373513	5/12/2008	4/24/2018	88	73.33
KR24353114	6/19/2008	4/12/2018	76	63.33
KREA 01	5/5/2008	11/22/2017	65	54.17
KREA 04	7/7/2008	4/12/2018	67	55.83
KREA 14	7/8/2008	1/19/2018	61	50.83
KREA 17A	7/8/2008	2/2/2018	83	69.17
KREA 22	5/5/2008	2/14/2018	91	75.83
KREA 23	7/7/2008	12/28/2017	82	68.33
KREA91	5/5/2008	12/13/17	116	96.67
KREA92	5/5/2008	12/13/17	112	93.33
KREA93	5/6/2008	12/12/17	114	95.00
KREA94	5/6/2008	12/12/17	114	95.00
KREA97	5/5/2008	12/13/17	114	95.00
KREA98	5/6/2018	4/10/18	118	98.33
LB29353513	6/30/2008	4/17/2018	87	72.50
LI02362923	6/1/2011	4/5/2018	81	67.50
LV14322813	9/2/2008	2/1/2018	70	58.33
MS08373611	6/30/2008	2/22/2018	70	58.33
OK09353212	5/12/2008	2/14/2018	82	68.33
OT34353513	5/20/2008	1/5/2018	68	56.67
PA10313112	7/24/2008	3/13/2018	88	73.33
PB24392912	5/13/2008	2/21/2018	110	91.67

Station	Start Date	End Date	Count	% Available Data
PL01382911	6/25/2008	3/6/2018	105	87.50
RD08322913	5/9/2008	4/12/2018	119	99.17
TCNS 204	6/2/2008	2/14/2018	77	64.17
TCNS 207	7/7/2008	2/14/2018	65	54.17
TCNS 213	7/7/2008	12/28/2017	91	75.83
TCNS 214	5/5/2008	4/24/2018	69	57.50
TCNS 217	5/5/2008	4/24/2018	108	90.00
TCNS 220	6/3/2008	4/24/2018	67	55.83
TCNS 222	5/6/2008	4/24/2018	93	77.50

Appendix D. Stations Used in Five-Year Rolling Average TP Load Calculation

The SFER, prepared by SFWMD, reports annually on the TP load to Lake Okeechobee by water year and for the latest five-year average. The reported load is based on the locations shown in **Figure D-1** through **Figure D-4**, and further analysis is available in the final *2019 SFER – Volume I, Chapter 8B* (which documents water flow, TP load, and TP FWM concentrations in each subwatershed of the LOW) and in the final *2019 SFER – Volume III, Appendix 4-1*.

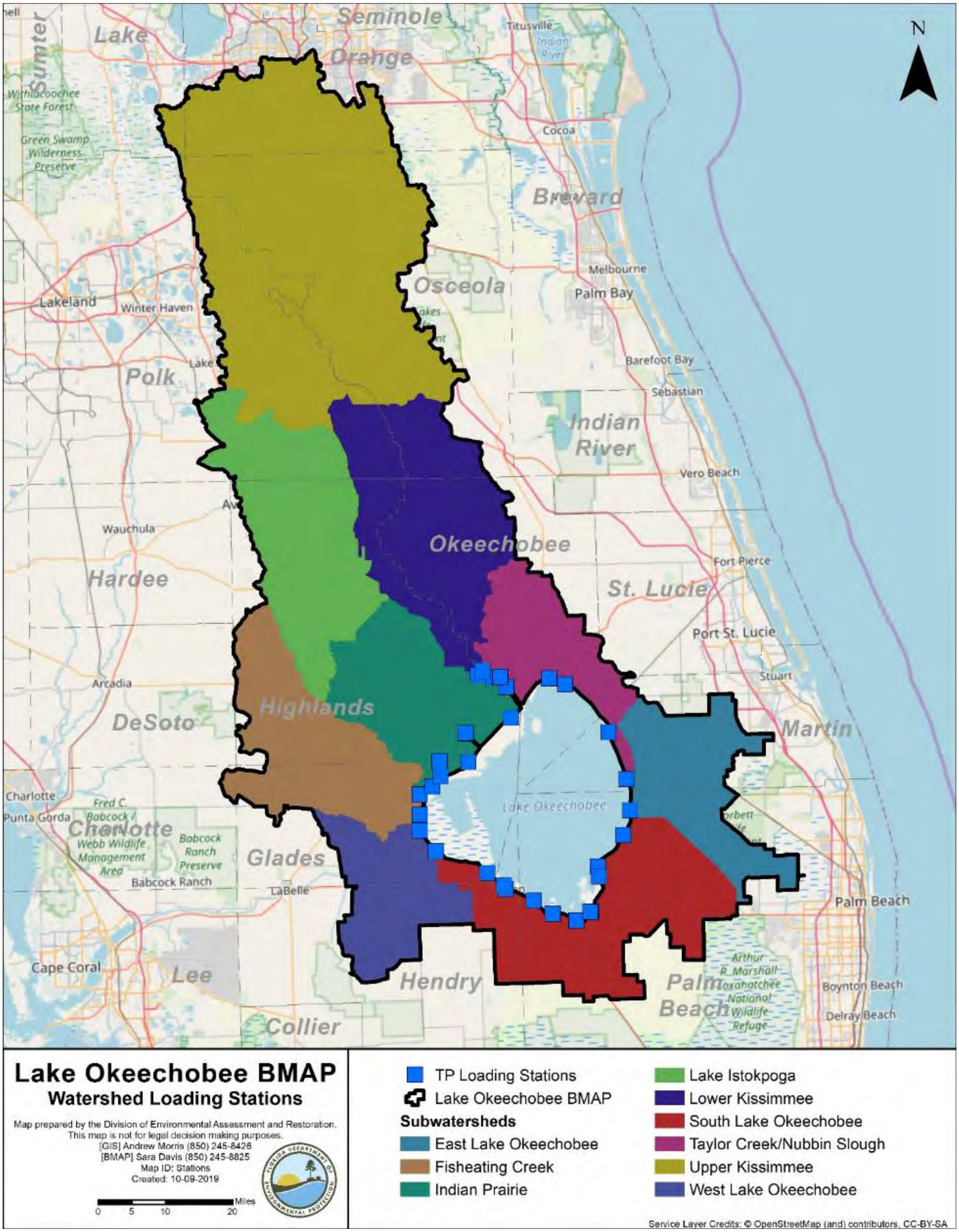

Figure D-1. Stations used to determine the five-year rolling average TP load for the LOW

Figure D-2. Stations used to determine the five-year rolling average TP load for the LOW (zoomed in on north stations)

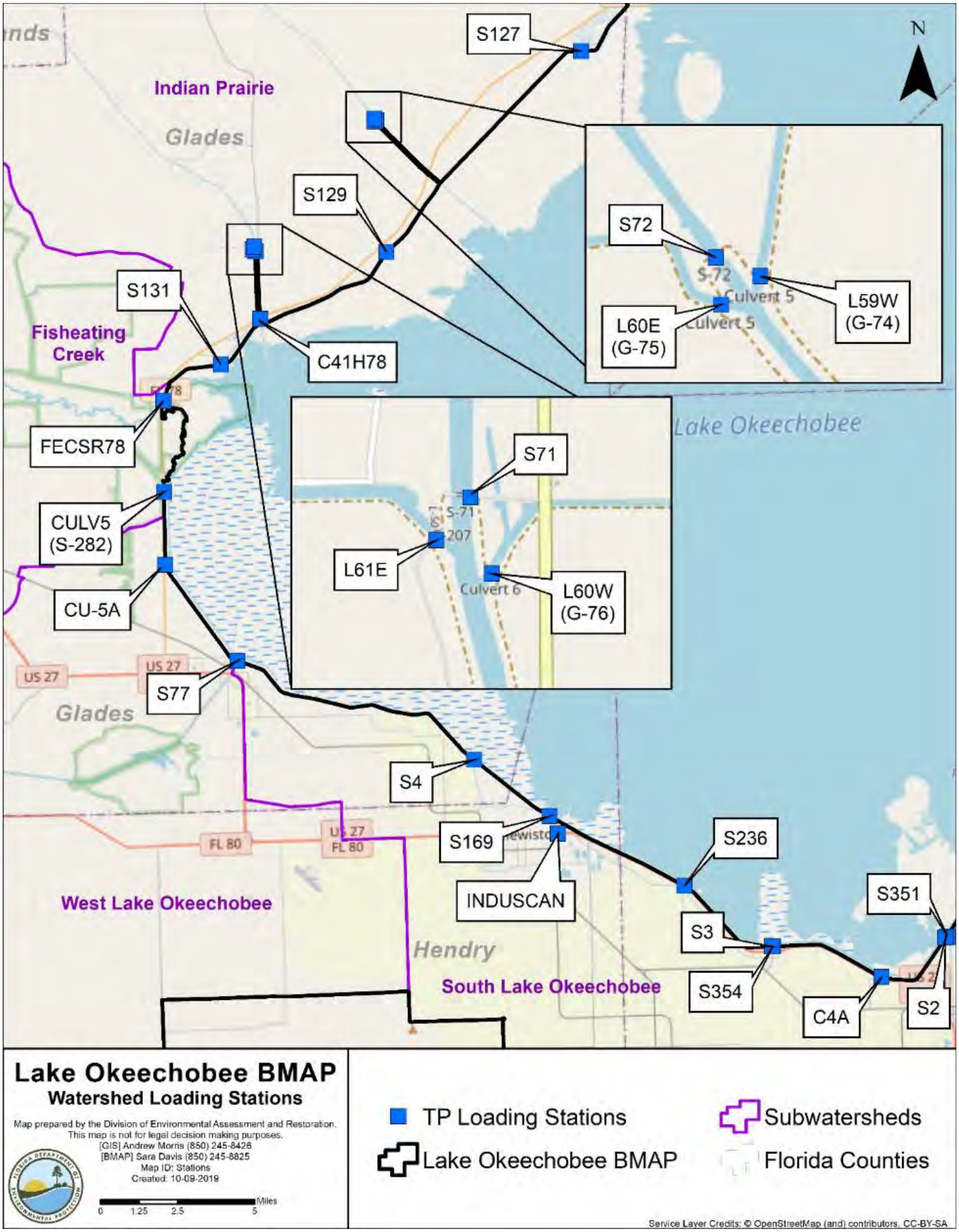

Figure D-3. Stations used to determine the five-year rolling average TP load for the LOW (zoomed in on west stations)

Figure D-4. Stations used to determine the five-year rolling average TP load for the LOW (zoomed in on east stations)

Appendix E. RFI Responses

To further identify restoration projects for this BMAP, DEP released an RFI in October 2019 to generate additional restoration projects or activities from both the public and private sectors. The effort was open to any interested parties who could propose a viable project for restoration and could be considered for inclusion in the final Lake Okeechobee BMAP for funding consideration.

Overall, the RFI process generated 34 responses from the private sector. Submittals ranged from structural projects to new and emerging technologies. All submittals were reviewed; **Table E-1** summarizes the submittals. The TRA IDs and basin names reference the maps for each subwatershed and the lake in **Chapter 4**. Resources will be needed to implement any of these projects throughout the watershed, and they are being considered for DEP funding. Additional details on all responses are on file with DEP.

Table E-1. Summary of responses received for RFI 2020012

Location Information	Submitted by	Project Name	Project Type
TRA 1 (L-8)	The Colinas Group	Mayaca Materials STA	Storage/STA
TRA ID 2 (C 44/Basin 8/S 153)	The MilCor Group, Inc.	Caulkins-Troup Water Farm	Storage/STA
TRA ID 2 (C 44/Basin 8/S 153)	The MilCor Group, Inc.	Caulkins-Greenridge Water Farm	Storage/STA
TRA ID 14 (C-41)	EHS Support	Two Bar G Farms STA	Storage/STA
TRA IDs: 14 (C-41) and 36 (S-191) Can also treat TRA IDs 13, 21, 33, and 65	AquaFiber Technologies Corporation	AquaFiber Algae Harvesting	Algae-harvesting technology
TRA IDs: 32 (S-154C) and 34 (S-133) Can also treat TRA IDs 13, 21, 33, and 65	Ecosystem Investment Partners	Dual-cell STAs	Storage/STA
TRA ID 33 (S-154)	Family Tree Enterprises Limited Partnership, LLLP	The Dixie Ranch Stormwater Pond and Ditches	Storage/STA
TRA ID 33 (S-154)	HydroMentia Technologies	Algal Turf Scrubber	Algae filtration technology
TRA ID 36 (S-191)	Sustainable Water Investment Group, LLC	Phosphorus Elimination System Upgrade of Taylor Creek STA	Storage/STA
TRA ID 54 (Tiger Lake)	ECO2	Super Oxygenation	In-lake treatment
TRA ID 62 (East Caloosahatchee)	Lykes Bros. Inc.	Turkey Branch Above-Ground Impoundments	Storage/STA
TRA ID 65 (in-lake)	Atkins	Quantification of Sediment Nutrient Recycling to Guide Implementation of In Situ Nutrient Sequestration	Monitoring
TRA ID 65 (in-lake)	Ensynox	Ensynox Enzyme	Bioremediation treatment technology
TRA ID 65 (in-lake)	Green Wave Innovative Solutions, LLC	Chara filter	Algae filtration technology

Location Information	Submitted by	Project Name	Project Type
TRA IDs: 1,2,9,23,24,26,27,28,30, 34,35,65	Beta Analytic	Dissolved Nitrate Isotopic Monitoring	Monitoring
TRA IDs: 3,4,16,17,18,19,21,37,38 ,39,40,41,43,44,45,46,47 ,48,49,50,51,52,53,54,55 ,56,57,58,59,60,61,62,63 ,64	Eco Librium	Water Cleanser	Technology
TRA IDs: 32,33,34,35,36	AECOM Technical Services, Inc.	Nutrient Inceptor Removal System (NIRS)	Algae-harvesting technology
TRA IDs: 3-8, 11-16, 32-36, 43,49,50,54, 65	Equilibrium Sciences, LLC	ExtraGro™	Bioremediation/ land application technology
TRA IDs: 3-8,11,12,14,15,16,18,32-36,43,49,50,54	UltraTech International	Ultra-Archaea and Ultra-PhosFilter	Bioremediation treatment technology
TRA IDs: 4,6,7,8,11,12,14,15,18,3 2,33,34,36,49,54	ESSRE	Nano-Enhanced Adsorbent Media (NEAM)	Technology
TRA IDs: 6,7,8,32,33,36,65	Nclear, Inc	TPX™ Phosphorus Removal Media	Technology
TRA IDs: 7,8,14,15,32,33,34,36,49	Water Warriors	Poseidon™ Carbonate Pellets	Technology
TRA IDs: 8,14,32,33,36,65	Phosphorus Free	Phosphorus Free Water Solutions	Technology
TRA IDs: 1-64 Also visited two dairy farms and found acceptable sites.	ECS	Bold & Gold Filtration Media	Biosorption activated media
TRA IDs: 1-64	Higgins Env	A-Pod	Technology
TRA IDs: 1-64	LatAm Services	LatAm Services Technology	Bioremediation/ land application technology
TRA IDs: 1-64	PDS Health, Inc	PDS Health Technology	Algae-harvesting technology
TRA IDs: 1-65	Peace USA	Nualgi	Algae-harvesting technology
TRA IDs: 1-65	Universal Engineering Sciences, Inc.	Universal Engineering Sciences Bioremediation	Bioremediation treatment technology
TRAs with tillable land	HSC Organics	HSC Organics Soil Treatment	Bioremediation/ land application technology
Not Provided	Freytech	Environmental Balance Device	Technology
Not Provided	OxSolve, LLC	OxSolve Aeration System	Technology
Not Provided	SFS SOS	Salvation Farming Solutions Salvation Ocean Solutions	Technology

Total Maximum Daily Load
for Total Phosphorus
Lake Okeechobee, Florida

Prepared by:

Florida Department of Environmental Protection

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Submitted to:

U.S. Environmental Protection Agency, Region IV

Atlanta Federal Building
61 Forsyth Street
Atlanta, GA 30303

August 2001

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ACRONYM LIST

BMP	Best Management Practice
C&SF	Central & South Florida Project
CERP	Comprehensive Everglades Restoration Project
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEP	Florida Department of Environmental Protection
DIP	Dissolved Inorganic Phosphorus
EAA	Everglades Agricultural Area
EPA	U.S. Environmental Protection Agency
FAMS	Florida Atmospheric Mercury Study
IAP	Interim Action Plan
KOE	Kissimmee-Okeechobee-Everglades System
LOTAC	Lake Okeechobee Technical Advisory Council
MOS	Margin of Safety
MSL	Mean Sea Level
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
RASTA	Reservoir Assisted Stormwater Treatment Area
RCWP	Rural Clean Waters Program
SFERWG	South Florida Ecosystem Restoration Working Group
SFWMD	South Florida Water Management District
STA	Stormwater Treatment Area
SWIM	Surface Water Improvement and Management Program
TBEL	Technology-Based Effluent Limitation
TCNS	Taylor Creek Nubbin Slough
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USACE	United States Army Corps of Engineers
WCA	Water Conservation Areas
WMD	Water Management District
WOD	Works of the District
WQBEL	Water Quality-Based Effluent Limitation
WQL	Water Quality Limit

EXECUTIVE SUMMARY

Lake Okeechobee is a large, shallow eutrophic lake located in subtropical south central Florida that is designated a Class I water (potable water supply). It is a large multipurpose lake providing drinking water for urban areas, irrigation water for agricultural lands, recharge for aquifers, freshwater for the Everglades, habitat for fish and waterfowl, flood control, navigation, and many recreational opportunities. High phosphorus loadings resulting from man-induced hydrologic and land use modifications over the past 60 years have degraded the water quality of the lake.

This TMDL proposes an annual load of 140 metric tons of phosphorus to Lake Okeechobee to achieve an in-lake target phosphorus concentration of 40 ppb in the pelagic zone of the lake. This restoration target will support a healthy lake system, restore the designated uses of Lake Okeechobee and allow the lake to meet applicable water quality standards. The annual load was determined using computer models developed with guidance from the Lake Okeechobee TMDL Technical Advisory Committee. The entire load is allocated to the sum of all nonpoint sources. Currently, there are no point sources discharging directly to Lake Okeechobee.

The implementation of the TMDL will follow a phased approach consistent with Section 373.4595, Florida Statutes, Lake Okeechobee Protection Program, which addresses the restoration of Lake Okeechobee. Phase I includes immediately initiating activities within the Lake Okeechobee watershed to achieve the phosphorus load reductions as set forth in the South Florida Water Management District's Technical Pub 81-2. It is also the planning period for all activities to be implemented in Phase II. Phase II will include the implementation of additional phosphorus reductions in the watershed following management activities outlined in the Lake Okeechobee Protection Program to achieve the phosphorus TMDL for the lake of 140 metric tons. Phase III includes evaluating phosphorus reductions and monitoring up to this point and comparing the results to the water quality target.

INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) directs each State to develop Total Maximum Daily Loads (TMDLs) for each water quality limited (WQL) segment reported according to Section 303(d). A TMDL reflects the total pollutant loading, from all contributing sources, that a water segment can receive, such that its capacity to assimilate the pollutant load is not exceeded and that the water body can still meet applicable water quality standards and its designated use, taking into account seasonal variation and a margin of safety. The elements of a TMDL are described in Section 303(d) of the CWA and in 40 CFR 130.2, 130.6 and 130.7. Lake Okeechobee was identified on the 1998 303(d) list, submitted to EPA by the Florida Department of Environmental Protection (FDEP), as being water quality limited (use impaired) by nutrients (particularly, phosphorus), dissolved oxygen, un-ionized ammonia, chlorides, coliforms, and iron. This document establishes a TMDL for phosphorus for Lake Okeechobee.

In addition to the Clean Water Act requirements, the state has enacted legislation (403.067 Florida Statutes (1999)), which provides a framework for how TMDLs will be developed in Florida. According to the legislation, the state is to develop a phosphorus TMDL for Lake Okeechobee.

BACKGROUND

Description of Water Body

Lake Okeechobee is a large, shallow eutrophic lake located in subtropical south central Florida and is a major feature of the Kissimmee-Okeechobee-Everglades (KOE) system (Figure 1). The KOE system is a continuous hydrologic system extending from Central Florida south to Florida Bay. Lake Okeechobee is the largest freshwater lake in Florida and the second largest freshwater lake within the contiguous United States, covering approximately 730 square miles. Since 1992, the lake has had an average lakewide depth of nine feet. The lake has a maximum storage capacity of 1.05 trillion gallons (at a depth of 19 feet). Lake Okeechobee is a multipurpose reservoir providing drinking water for urban areas, irrigation water for agricultural lands, recharge for aquifers, freshwater for the Everglades, habitat for fish and waterfowl, flood control, navigation, and many recreational opportunities (SFWMD 1997).

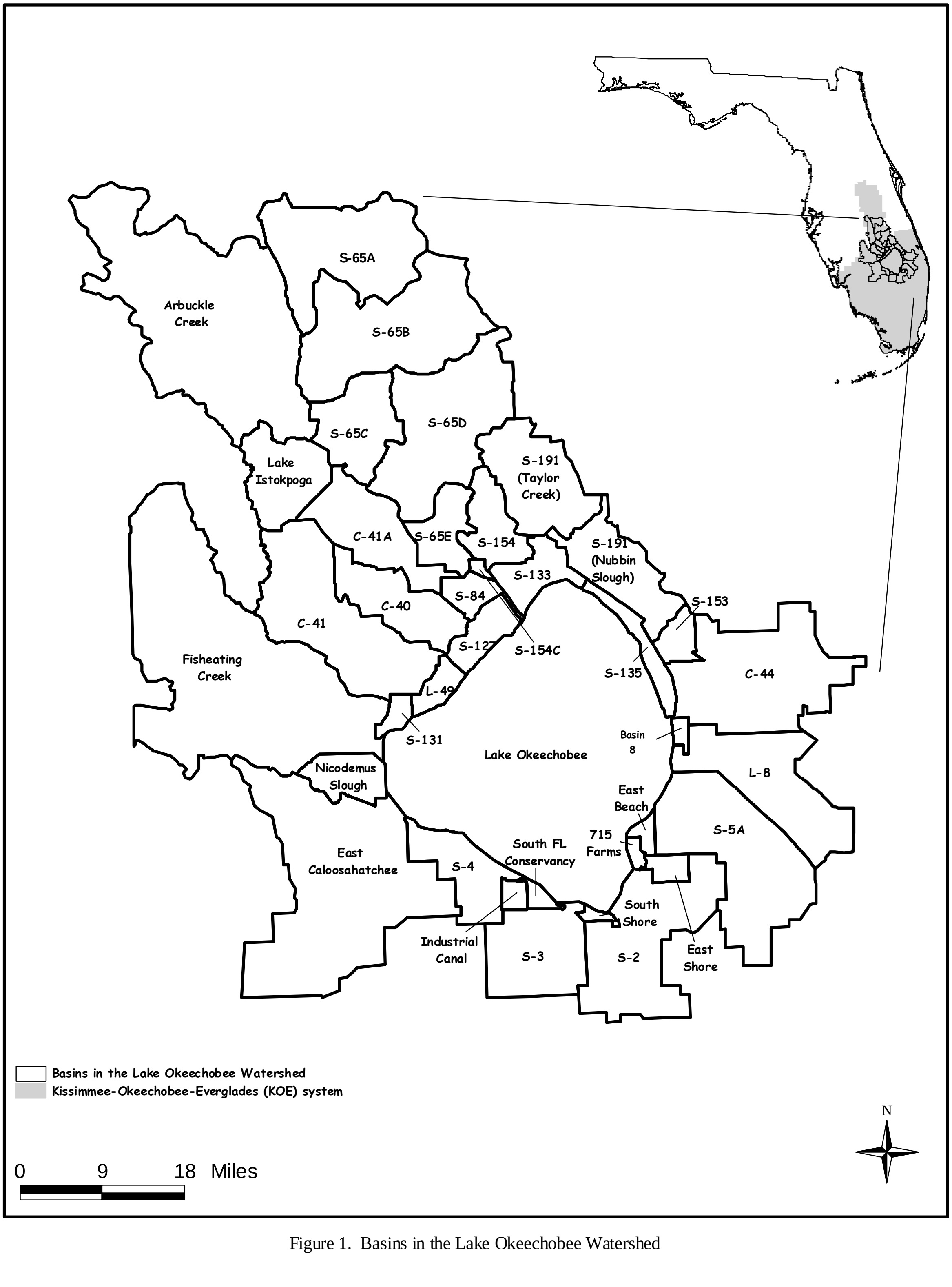


Figure 1. Basins in the Lake Okeechobee Watershed

Two hundred years ago, a large percentage of the lake bottom in Lake Okeechobee may have been covered with sand, whereas today, much of that area is overlain by organic mud (Brezonik and Engstrom 1997). The upper 10 cm of that mud is estimated to contain over 30,000 metric tons of phosphorus that has accumulated over the last 50 years (Olila and Reddy 1993). The rates of mud sediment accumulation and phosphorus deposition both have increased significantly in the last 50 years (Brezonik and Engstrom 1997).

At low lake stages (less than 15 feet), Lake Okeechobee is a spatially heterogeneous system with five distinct ecological zones: littoral, transition, edge, north and center (Figure 2) (Phlips et al. 1995). The ecological zones differ based on local water chemistry (total phosphorus, total nitrogen, chlorophyll *a* concentrations, limiting nutrient status), frequency of algal blooms, and light availability (Havens 1994). The ecological zones are closely associated with the different sediment types that have formed at the bottom of the lake. Sediment can affect the ecology of the lake with the resuspension of mud into the water column, which then affects light availability to plants and algae in the lake. The littoral zone, characterized by emergent and submergent vegetation, covers an area of approximately 150 square miles (25% of the lake's surface area), and is primarily located along the western shore of the lake (Havens et al. 1996b, SFWMD 1997). The littoral zone is typically found in areas underlain by rock. The littoral zone is sensitive to nutrient loading and light availability (Havens et al. 1999). The edge (near-shore) zone is located in the southern and western portions of the lake, between the littoral and transition zones, and is characterized by lower total phosphorus, more frequent nutrient limitation than in the other open-water zones (Aldridge et al. 1995), and frequent periods of light limitation (Steinman et al. 1997, Hwang et al. 1998). This ecological zone has developed in areas overlying sand and peat. The edge zone also is most sensitive to changing lake water levels and nutrient loading, displaying transitions between clear water with macrophyte dominance at low lake stage and turbid water with phytoplankton dominance at high stage (Havens et al. 2000). The north zone is located in the northeastern portion of the lake and around the center ecological zone. This area receives high phosphorus loading from the Taylor Creek/Nubbin Slough, S-154 and Kissimmee River basins and is characterized by high total phosphorus concentrations and nitrogen-limited phytoplankton growth. The center zone also has high total phosphorus and high chlorophyll *a* concentrations, while photosynthetic growth is typically light-limited (except in the mid-summer) due to the resuspension of the mud sediments below (Phlips et al. 1997). The transition zone is located between the north and edge zones and has moderate concentrations of total phosphorus. This zone is mostly found overlying sand sediment (SFWMD 1997).

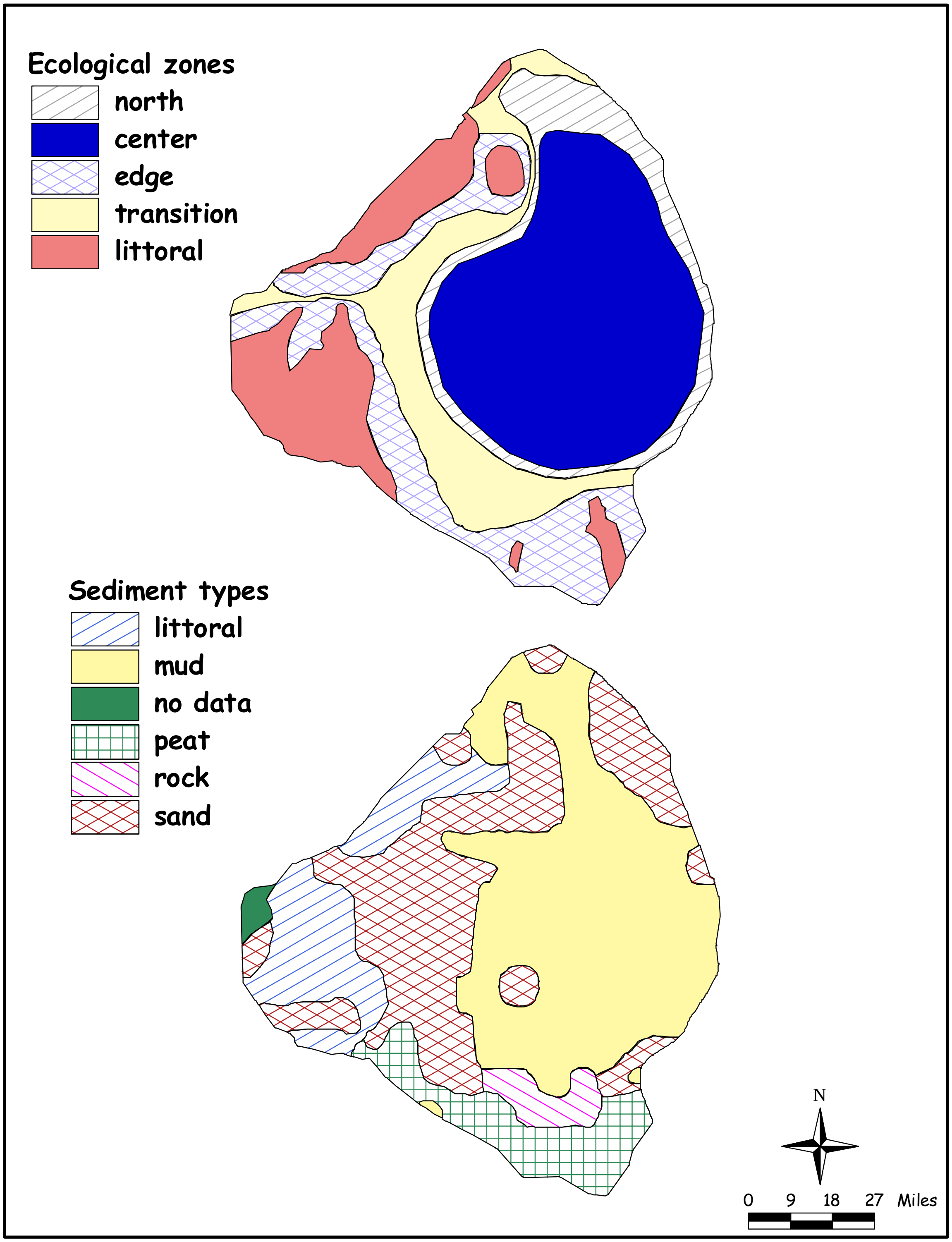


Figure 2. Ecological Zones and Sediment Types in Lake Okeechobee

Hydrology

Lake Okeechobee's drainage basin covers more than 4,600 square miles. The lake's watershed boundary has been defined under the Surface Water Improvement and Management (SWIM) program as those basins that are direct tributaries to the lake, including upstream tributaries and/or basins from which water is released or pumped into the lake on a regular basis (Figure 1). Forty-one basins fall within this boundary. Major hydrologic inputs into the lake include rainfall (39 %), the Kissimmee River (31 %), Fisheating Creek, and Taylor Creek/Nubbin Slough and numerous smaller inflows, such as discharges from the Everglades Agricultural Area (EAA), Harney Pond basin, Indian Prairie Creek basin. Major hydrologic outputs include evapotranspiration (66 %), the Caloosahatchee River to the west (12 %), the St. Lucie Canal (C-44) to the east (4 %), and four agricultural canals which discharge south into the Everglades region (Miami, North New River, Hillsboro, and West Palm Beach canals) (18%) (SFWMD 1997). Lake Okeechobee receives an average of 53 inches of rainfall per year. Approximately, 75% of this rain comes during the summer convective storms (May to October) (Purdam et al. 1998).

Water movement and currents in Lake Okeechobee are influenced by wind patterns (direction and velocity) and water depth. Distinct circulation patterns are formed on the surface and at the bottom of the lake (SFWMD 1997). The water found at the bottom of the lake typically moves south, with the presence of one clockwise circulation gyre. The water at the surface is influenced by multiple circulation gyres also moving clockwise (SFWMD 1997, Sheng 1993). The residence time (not including evapotranspiration) of water in Lake Okeechobee is approximately 3 years (SFWMD 1997). The residence time in the lake varies with rainfall, storage in the lake and outflows.

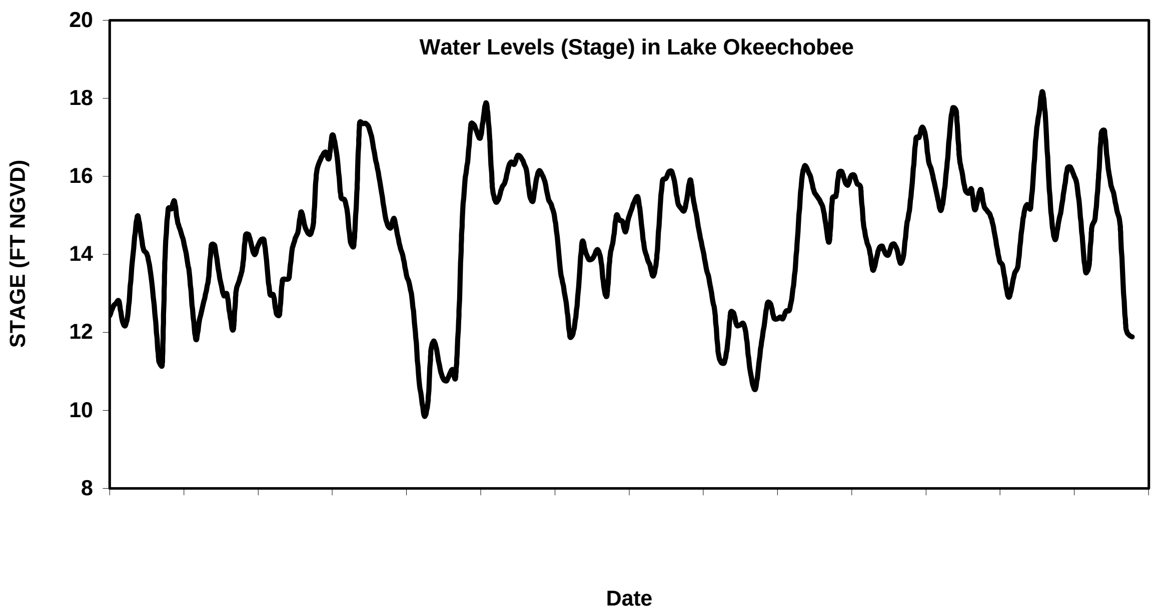
The hydrology of the Kissimmee-Okeechobee-Everglades drainage system has been greatly modified with diking and dredging to create farmland, control flooding, provide navigation, and facilitate greater water storage capacity (SFWMD 1997). The Lake Okeechobee watershed has little relief and a water table that is near the soil surface during the wet season. This area was once composed of large quantities of wetlands (Blatie 1980). Prior to human modification, the littoral zone of Lake Okeechobee was connected to the Everglades marsh and would deliver sheet flow runoff to the Everglades (Brooks 1974, Tebeau 1984). During 1926 and 1928, flooding resulted in the loss of life and property, which then resulted in the establishment of the Okeechobee Flood Control District to manage the water levels in the lake. In the 1930s, after the construction of a flood control levee (Herbert Hoover Dike) and a rim canal around the lake to control flooding, the lake levels were managed in a manner that resulted in the surface elevation being lowered from 19 ft to 17 ft, mean sea level (MSL) (Purdum et al. 1998). At present, virtually all flows into and out of the lake are managed through 140 miles of canals, control structures (gates, locks, and pumps) and levees, which were completed in the late 1950s, as part of the Central and South Florida (C&SF) Flood Control Project. The South Florida Water Management District (SFWMD), in conjunction with the United States Army Corps of Engineers (USACE), regulates these structures and canals (SFWMD 1997). This modified system has improved flood control and supplied irrigation water, however it has negatively affected the water quality of Lake Okeechobee by expediting the delivery of stormwater runoff to Lake Okeechobee.

The USACE has developed a lake regulation schedule primarily to provide flood protection during the wet season and secondarily to store water for irrigation, urban uses and deliveries to natural systems for the dry season. This schedule determines the timing and quantity of water releases from Lake Okeechobee based on its water level (Otero and Floris 1994). Regional rainfall patterns have caused the lake's levels to vary greatly over the last 60 years. The regulation schedule exacerbates the already existing problem of fluctuating lake levels. Prior to any hydrologic modifications, the lake had maximum water levels around 20 ft to 21 ft MSL. High water levels would result in water flooding adjacent wetlands, which could increase the surface area of the lake. The levee constructed in 1932 at the south end of lake was the only water control structure on Lake Okeechobee, and at this time the lake generally averaged 19 ft MSL.

The construction of the levee limited the size of the lake causing more dramatic ecological effects from the high water levels. From 1932 to 1950, the lake exhibited high average water levels (17 ft MSL) and low inter-year variability. From 1950 to 1960, the lake had lower water levels (maximums: 14 ft wet season, 15.5 dry season) and higher inter-year variability. From the

1960s to 1971, the northern portion of the Lake Okeechobee watershed experienced man-induced hydrological changes, including the channelization of the lower Kissimmee River, and the draining of 40,000 to 50,000 acres of floodplain wetlands for the development of agriculture (Loftin et al. 1990). These modifications upstream of Lake Okeechobee resulted in higher lake levels, which submerged the littoral zone of the lake reducing fish-spawning grounds and waterfowl feeding and nesting areas. In the 1970s, the maximum water level was increased (15.5 ft – wet season, 17.5 ft – dry season) creating longer periods of high water (Purdum et al. 1998). The current regulatory schedule (WSE) has the goal of reducing inter-year variability and also reducing pulse releases of freshwater from the lake to the Caloosahatchee and St. Lucie estuaries (LORSS 1996). Figure 3 illustrates changing water levels over time.

Figure 3. Annual average stage in Lake Okeechobee



WATER QUALITY CHARACTERIZATION

Use Impairment

According to FDEP's 1998 303(d) list, the water quality of Lake Okeechobee is impaired due to phosphorus, dissolved oxygen, iron, un-ionized ammonia, coliforms and chlorides. High phosphorus concentrations are the predominant reason for impairment, and at this time phosphorus is the sole pollutant considered for TMDL analysis. Elevated phosphorus loadings to the lake and high internal phosphorus concentrations have intensified the eutrophication of the lake, resulting in the development of widespread algal blooms in the lake. For example, an algal bloom in 1986 affected 25% of the lake as the wind blew the algal bloom into the near-shore zone (Jones 1987).

According to Rule 62-302 Florida Administrative Code (F.A.C.), Lake Okeechobee is designated a Class I water, which is a potable water supply. The State of Florida has a narrative criterion for nutrients, and according to this water quality criterion (Section 62-302.530(48) F.A.C.), nutrient concentrations of a water body shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. The development of seasonal blooms of blue-green algae (Cichra et al. 1995) and the shift in the composition of benthic macroinvertebrates toward more pollutant-tolerant species (oligochaetes) (Warren et al. 1995) are considered to be imbalances. Algal blooms in Lake Okeechobee have caused die-offs of macroinvertebrate communities due to toxic by-products of algal decay (Jones 1986), and they could threaten other ecological and societal values of the ecosystem. The algal species that occur during blooms (*Anabaena circinalis*, *Microcystis aeurginosa*, and *Aphanizomenon flos-aquae*) can sometimes produce toxic chemicals that harm fish and wildlife (Carmichael et al. 1985). Dense blooms of algae in a lake also can affect the quality of drinking water by creating taste and odor problems and contributing to the development of high levels of trihalomethane precursors (Heiskary and Walker 1988, Barica 1993).

Eutrophication

Researchers have observed an increased rate of eutrophication in Lake Okeechobee from 1973 to the present. Symptoms of this eutrophication include the following: 1) increases in algal bloom frequency since the mid-1980s (with an algal bloom being defined as chlorophyll *a* concentrations greater than 40 μg/L) (Maceina 1993, Carrick et al. 1994, Havens et al. 1995b), 2) increases in the dominance of blue-green algae following a shift in the TN:TP ratio (Smith et al. 1995), 3) increases in the lake water concentration of total phosphorus, 4) and increases in average chlorophyll *a* concentrations (Havens et al. 1995). Phosphorus is considered the key nutrient contributing to the eutrophication of the lake (Federico et al. 1981). Increases in total phosphorus concentrations in the lake, coupled with decreases in nitrogen loading from reduced backpumping from the Everglades Agricultural Area, have shifted the TN:TP ratio from greater than 25:1 in the 1970s to around 15:1 in the 1990s. This shift has created conditions more favorable for the proliferation of nitrogen-fixing blue-green algae, which are responsible for the blooms occurring in the lake (Smith et al. 1995).

Other studies could be cited to show that lake Okeechobee has been affected by phosphorus enrichment. Phosphorus enrichment is so great that phytoplankton growth is not limited by phosphorus, but by nitrogen (Aldridge et al. 1995). This type of secondary nutrient limitation induced by excessive phosphorus enrichment is a consequence of eutrophication (Schelske 1984). It can be demonstrated in Lake Okeechobee by bioassays (Aldridge et al. 1995) or from low concentrations of dissolved inorganic nitrogen that control phytoplankton growth (Schelske 1989).

According to Havens et al. (1995a), lake-wide algal bloom frequencies increased from 1980 to 1992. During the early 1980s, algal blooms only occurred in 8 months of the year, and during the 1990s have been occurring in all 12 months of the year (Havens et al. 1995a). Algal bloom frequencies increase with higher phosphorus concentrations and when there is high light penetration (Phlips et al. 1995). Algal blooms are seasonally and spatially controlled by wind-driven sediment resuspension and high summer temperatures. For example, bloom frequency in the pelagic zone is correlated with high temperature and high light transparency (Havens et al. 1995a). Blooms occur more frequently at the northern pelagic stations (L001 and L002) and in the western pelagic (L005 and L008) due to increased light availability. The lowest frequencies of blooms occur at the center of the pelagic zone (L004 and L006) because of low light transparency due to the resuspension of sediment. Overall, the highest frequency of blooms is seen in June. This is most likely due to lower wind velocities, reduced sediment resuspension, and greater underwater irradiances during summer (Havens et al. 1995a).

Phosphorus Trends in the Water Column

Total phosphorus concentrations within the pelagic region of the lake have been increasing since the early 1970s (Figure 4). The total phosphorus concentrations that currently exist in the lake are in excess of the amount needed for a healthy ecosystem. The in-lake total phosphorus concentrations have doubled over the last 50 years as a result of increased inputs from the watershed. The construction of canals and structures, as part of the C&SF Project, facilitated the delivery of stormwater runoff from intensive land uses that have developed in the surrounding watershed (Harvey and Havens 1999). During the last five years, the average concentration of total phosphorus in the pelagic region of Lake Okeechobee was approximately 100 ppb. However, perturbations of the system, such as hurricanes, have shown spikes of total phosphorus in the water column of ~400 ppb. Near-shore total phosphorus concentrations are generally lower than concentrations found in the pelagic region (Havens 1997).

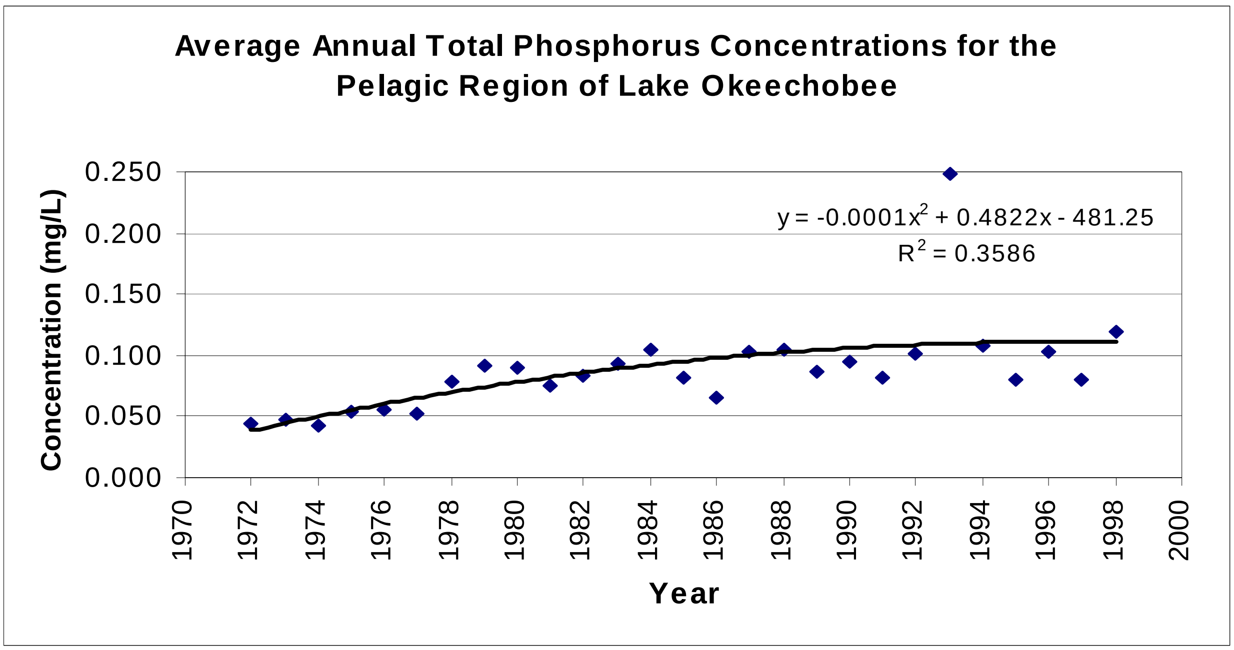


Figure 4. Annual average phosphorus concentrations in the pelagic region of Lake Okeechobee (A trend line was created from the annual average total phosphorus concentrations.)

Phosphorus trends in sediments

The concentration of phosphorus in the sediments of Lake Okeechobee has also been increasing. Prior to the 1950s, the lake bottom was comprised primarily of sand with low phosphorus concentrations (Harvey and Havens 1999). According to Engstrom and Benzonik (1993), phosphorus accumulation rates have increased between the 1950s and 1980s. This additional phosphorus accumulation has resulted in the development of mud sediments. High phosphorus loading to the lake saturates the sediments with phosphorus, which then decreases the lake's capacity to assimilate phosphorus (James et al. 1995). It is estimated that the top 10 cm of the lake sediments contain approximately 30,000 metric tons of phosphorus that has accumulated over the last 75 years. Phosphorus loading rates from the sediments to the water column are as large as 0.7 mg phosphorus/m^2/day for mud zone and 1.1 mg phosphorus/m^2/day for marsh sediments (Reddy et al. 1995b).

Currently, this internal phosphorus loading from the mud zone to the water column through diffusive fluxes is equal to the external phosphorus loading to the water column on an annual basis (Reddy et al. 1995b). A portion of the stored phosphorus becomes a significant source to the water column when this active phosphorus-laden sediment layer is resuspended into the water column by wind and waves.

The total amount of phosphorus stored in the soils of the Lake Okeechobee watershed is directly related to the intensity of land uses: unimpacted-44gP/m^2, forage-46gP/m^2, pasture-102gP/m^2, intensive agricultural areas-766gP/m^2, streams-116gP/m^2 and wetlands-75gP/m^2 (Reddy et al. 1995a). Total phosphorus concentrations found in the soils in the agricultural areas of the Taylor Creek/Nubbin Slough basins have increased 50 to 60 times as a result of phosphorus loading from manure (Graetz and Nair 1995). The phosphorus content of pastures in the Lake Okeechobee watershed has increased 3 to 4 times the background concentration. Phosphorus retention in upland sediments is at 85%; however, continuous loading of phosphorus to these soils is further decreasing the retention capacity for phosphorus in these soils (Reddy et al. 1995a).

Annual Phosphorus Mass Balance

$$\Delta R = \text{Inputs} - \text{Losses}$$

$$\Delta R = MI + AI - (SL + MO)$$

$$\text{where } SL = SU - IL$$

ΔR = Annual change in phosphorus reservoir (water mass)

MI = Monitored Inputs

AI = Atmospheric Inputs

SL = System Loss (including sedimentation and littoral zone storage)

MO = Monitored Outflows

SU = System Uptake of phosphorus (biological, chemical and physical processes)

IL = Internal Loading (recycling)

Within Lake Okeechobee, the net losses of phosphorus to the sediments from the water column can be determined by comparing measured total phosphorus inputs and outputs. The net losses have changed over time relative to loads, in that the lake now assimilates phosphorus at about 1/3 of the capacity that it did in the 1970s.

CURRENT LAKE-WIDE PHOSPHORUS LOADING

Between 1995 and 2000, phosphorus loading rates to Lake Okeechobee have averaged approximately 641 metric tons/year, with approximately 400 metric tons/year accumulating into the sediments of the lake. While the sediments provide a sink for phosphorus, a portion of the phosphorus stored in the top 10 cm of the lake's sediments is being added back into the water column at a rate almost equal to the external loading of phosphorus to the lake on an annual basis. To address excess phosphorus loadings to Lake Okeechobee and rehabilitate the ecological condition of the lake, phosphorus loading targets for each of the contributing basins within the watershed were established by the South Florida Water Management District's Works of the District permitting program, which were then adopted through the SWIM Act of 1989 (SFWMD 1989). In an effort to achieve an in-lake total phosphorus concentration of 40 ppb, a 40% reduction in phosphorus loading was specified based on the SFWMD's Technical Pub 81-2, (Federico et al. 1981). According to the 2001 SWIM plan update, to achieve the in-lake phosphorus concentration target, the total phosphorus load to the lake needs to be less than 423 metric tons/year (SFWMD 2001). Since 1995, phosphorus loading rates have exceeded the SWIM target by over 200 metric tons/year (SFWMD 2001). Currently, 14 of the 29 basins are exceeding their phosphorus loading targets. Four of the basins exceeding the SWIM targets have been identified as the key contributors of phosphorus in the watershed: Taylor Creek/Nubbin Slough (TCNS) and the three Kissimmee River basins (S-154, S-65D, and S-65E). Table 1 and Table 2 provide the phosphorus loading targets for each basin, along with their current phosphorus loading rates. The tables refer to "uncontrollable sources", which are sources and basins that are not under the regulatory authority of the SFWMD Works of the District (WOD) permitting program, while "controllable sources" are under the WOD program.

Table 1. Current annual average phosphorus loading rates and target annual phosphorus loading rates (based on 5-year rolling average) for each basin based on SWIM concentration targets during the years 1994 to 1998 (nd = no data) (Harvey and Havens 1999).

Basin	Discharge	Area	**SWIM Target**	**SWIM Target Load**	Actual	Actual Load	Over Target
Controllable Sources	(acre-ft)/yr	(sq. mi)	**TP (ppm)**	**(short tons/yr)**	TP (ppm)	(short tons/yr)	(short tons/yr)
715 Farms (Culv 12A)	12,758	4	0.18	3.1	0.1	1.7	-1.4
C-40 Basin (S-72) – S68	16,069	87	0.18	3.9	0.2	10.5	6.6
C-41 Basin (S-71) – S68	52,768	176	0.18	12.9	0.18	32.3	19.4
S-84 Basin (C41A) – S68	66,759	180	0.1	9.1	0.05	12.9	3.9
S-308C (St. Lucie-C-44)	41,480	190	0.18	10.2	0.13	8.9	-1.2
Culvert 10	11,612	10	0.18	2.8	0.53	9.8	7
Culvert 12	15,075	13	0.13	2.7	0.18	3.6	1
Fisheating Creek	256,761	462	0.18	62.8	0.18	60.7	-2.1
Industrial Canal	21,878	23	0.18	5.4	0.09	2.8	-2.6
L-48 Basin (S-127)	31,088	32	0.18	7.6	0.21	9.4	1.8
L-49 Basin (S-129)	0	19	0.18	0	0.09	2	2
L-59E	nd	15	0.16	nd	nd	nd	nd
L-59W	nd	15	0.16	nd	nd	nd	nd
L-60E	nd	6	0.1	nd	nd	nd	nd
L-60W	nd	6	0.1	nd	nd	nd	nd
L-61E	nd	22	0.09	nd	nd	nd	nd
L-61W	nd	22	0.09	nd	nd	nd	nd
TCNS (S-191)	116,022	188	0.18	28.4	0.57	94.2	65.8
S-131 Basin	11,992	11	0.15	2.4	0.12	1.9	-0.5
S-133 Basin	30,004	40	0.18	7.3	0.16	7.2	-0.2
S-135 Basin	30,097	28	0.16	6.5	0.1	4.3	-2.2
S-154 Basin	23,428	37	0.18	5.7	0.76	22.8	17
S-2	34,629	166	0.16	7.5	0.18	9	1.5
S-3	13,429	101	0.15	2.7	0.18	3.9	1.1
S-4	40,921	66	0.18	10	0.18	11.1	1.1
S65E – S65	364,526	749	0.18	89.2	0.18	91.5	2.3
S-236	9,716	15	0.09	1.2	0.1	1.5	0.3
Culvert 4A	8,954	7	0.08	1	0.09	1.1	0.2
Culvert 5	nd	28	0.06	nd	nd	nd	nd
Controllable Totals	1,209,967			282.7		403.4	120.7
<u>Uncontrollable Sources</u>							
Rainfall					0.03	71	
S65 (Lake Kissimmee)	1,139,602				0.08	119.4	
Lake Istokpoga (S-68)	342,212				0.04	22.4	
S5A Basin	0					0	
E. Caloosahatchee (S-77)	0					0	
L-8 Basin (Culv 10A)	60,922				0.1	8.3	
Uncontrollable Totals	1,542,737					221	
Average Total Loadings						624.3	
Vollenweider Target						458.7	
Over-Target Loads				Concentration based		120.7	
				Vollenweider		165.7	

Table 2. Current annual average phosphorus loading rates and target annual phosphorus loading rates (based on 5-year rolling average) for each basin based on SWIM concentration targets during the years 1995 to 1999 (nd = no data) (SFWMD 2001).

Basin	Discharge	Area	SWIM Target	SWIM Target Load	Actual	Actual Load
Controllable Sources	(acre-ft)/yr	(sq. mi)	TP (ppb)	(tons/yr)	TP (ppb)	(tons/yr)
715 Farms (Culv 12A)	13,679	4	180	3.3	95	1.8
C-40 Basin (S-72) – S68	15,534	87	180	3.8	503	10.6
C-41 Basin (S-71) – S68	52,630	176	180	12.9	433	30.9
S-84 Basin (C41A) – S68	66,211	180	100	9.0	152	13.7
S-308C (St. Lucie-C-44)	22,219	190	180	5.4	197	5.9
East Beach DD (Culvert 10)	14,184	10	180	3.5	616	11.9
East Shore DD (Culvert 12)	15,699	13	130	2.8	162	3.5
Fisheating Creek	249,378	462	180	60.9	176	59.7
Industrial Canal	21,236	23	180	5.2	97	2.8
L-48 Basin (S-127)	31,629	32	180	7.7	231	9.9
L-49 Basin (S-129)	17,157	19	180	4.2	92	2.1
L-59E	nd	15	160	nd	nd	nd
L-59W	nd	15	160	nd	nd	nd
L-60E	nd	6	100	nd	nd	nd
L-60W	nd	6	100	nd	nd	nd
L-61E	nd	22	90	nd	nd	nd
L-61W	nd	22	90	nd	nd	nd
TCNS (S-191)	113,467	188	180	27.7	653	100.6
S-131 Basin	10,815	11	150	2.2	116	1.7
S-133 Basin	28,302	40	180	6.9	183	7.0
S-135 Basin	26,445	28	160	5.7	117	4.2
S-154 Basin	31,885	37	180	7.8	828	35.8
S-2	28,612	166	160	6.2	194	7.5
S-3	12,087	101	150	2.5	215	3.5
S-4	39,872	66	180	9.7	216	11.7
S65E – S65	348,214	749	113	53.4	200	94.7
S-236		15	90	nd	nd	nd
South Shore/South Bay DD (Culvert 4A)	8,840	7	80	1.0	17	0.2
Nicodemus Slough (Culvert 5)	nd	28	60	1.0	nd	nd
Controllable Totals	1,168,122			242.0	265	420.0
Uncontrollable Sources						
Rainfall	1,893,356				0.03	71.0
S65 (Lake Kissimmee)	993,997				0.08	116.3
Lake Istokpoga (S-68)	344,506				0.04	27.3
S5A Basin	0					0.0
E. Caloosahatchee (S-77)	0					0.0
L-8 Basin (Culv 10A)	48,437				0.1	5.5
Uncontrollable Totals						
Average Total Loadings						641.0
Basin Target						463.0
Vollenweider Target						423.0

PHOSPHORUS LOADING SOURCES IN THE WATERSHED

Human activities occurring within the Lake Okeechobee watershed have contributed to the high external phosphorus loading rates. Sources of pollution to the watershed include both point and nonpoint sources.

Point Sources

Several point sources exist in the Lake Okeechobee watershed; however, none of these discharges directly to the lake, and many of the discharges are through wells to the ground water. Point sources include discharges of effluent from domestic and industrial wastewater treatment facilities (Table 3). These discharges require wastewater permits from FDEP that serve as the National Pollutant Discharge Elimination System (NPDES) permit for the facility if it discharges to surface waters. These permits typically include FDEP approved water quality-based effluent limits (WQBEL) or technology-based effluent limits (TBEL) for surface water discharges.

Nonpoint Sources

Nonpoint sources, which are related to different types of land uses and are driven by rainfall and runoff, are the dominant pollution sources in the Lake Okeechobee watershed (Table 3). Agricultural activities surrounding the lake are the principal land uses in the area and are responsible for discharging large quantities of nutrients to the waters within the watershed through stormwater runoff (Anderson and Flaig 1995). Approximately, 50% of the Lake Okeechobee watershed is used for agriculture (Figure 5). Cattle and dairy pasturelands are the primary agricultural activities north and northwest of the lake, while cropland (sugarcane and vegetables) dominates to the south and east of the lake (SFWMD 1989). The most intensive land use in the watershed is dairy farming, which began in the 1950s (Reddy et al. 1995a).

Residential septic tank systems within the watershed are another source of nonpoint source pollution that delivers contaminants (bacteria and toxic household chemicals) and nutrients to Lake Okeechobee (Environmental Science and Engineering 1993).

Other land uses in the watershed consist of Wetlands (16%), Upland Forests (10%), Water (7%), Rangeland (7%), Urban and Built-up (10%), Barren Land (1%), and Transportation and Utilities

(1%) (Figure 5). While urban land uses make up 10% of total area, they only contribute 3% of the total phosphorus load in the watershed (SFWMD 97). Appendix 1 provides a more detailed distribution of land uses, using Level 2 land use for each of the basins in the Lake Okeechobee watershed.

Table 3. Sources of Pollution in the Lake Okeechobee Watershed (SFWMD 1997)

Sources of Pollution	Type	Total Number Permitted
Industrial Wastewater Facilities	Point	69
Domestic Wastewater Facilities (Municipal and Private)	Point	121
Dairies	Nonpoint	29
Works of the District (Agricultural, Industrial, Commercial, NPS BMPs)	Nonpoint	688
Stormwater Runoff Locations Measured by Surface Water Management (Stormwater Management Systems)	Nonpoint	470
Waste Disposal Systems (landfills)	Nonpoint	16

Out-of-Basin Sources

The importation of phosphorus, as feed, fertilizer and detergents, to support various agricultural activities is a major source of phosphorus to the watershed. Ninety-eight percent of the phosphorus imported to the watershed supports agricultural activities, while the remaining two-percent supports human activities. When this is further broken down, fertilizers account for 73% of the amount imported, dairy feed accounts for 16%, while beef feed supplements, human food and detergents account for the remaining 11% (Fluck et al. 1992). Land use activities that are responsible for the largest percentages of annual phosphorus imports to the watershed include improved pasture (47% of total imports), sugar mills (15%), dairies (14%), sugarcane fields (13%) and truck crops (7%) (Fluck et al. 1992). There is a high correlation between phosphorus imports (animal feed and fertilizers) to the watershed and phosphorus loading to the lake (Boggess et al. 1995). Annually, an average of 8% of the net phosphorus imported to the watershed reaches Lake Okeechobee (Fluck et al. 1992). There are also phosphorus sources

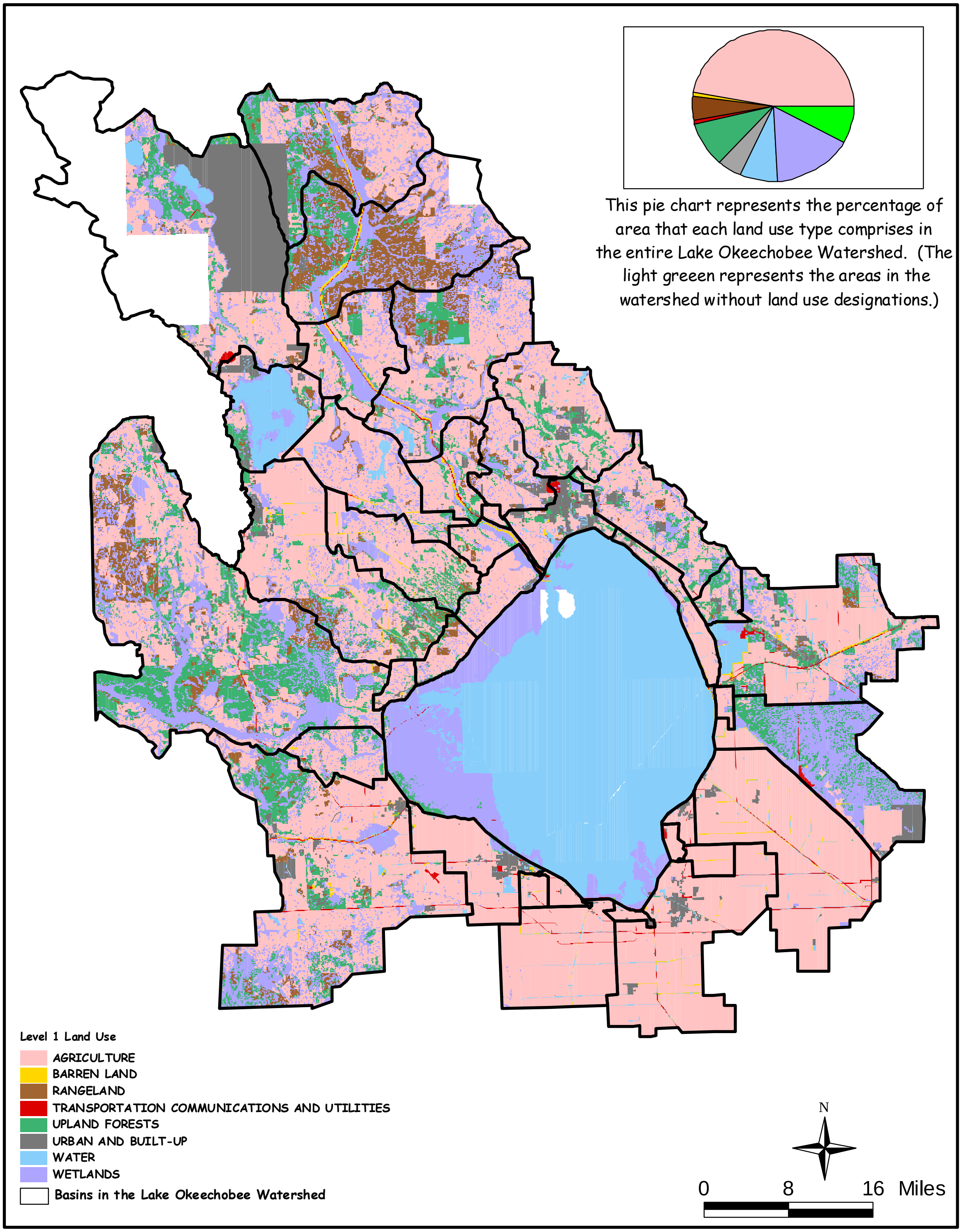


Figure 5. Land Use (Level 1) in the Lake Okeechobee Watershed (SFWMD 1995)

coming into the watershed from the Upper Chain-of-Lakes and Lake Istokpoga. A new phosphorus budget is currently being constructed to reflect more recent trends on phosphorus sources in the watershed; however, it will not be completed for another 18 months.

Atmospheric Loading

Another source of phosphorus loading to Lake Okeechobee is dry and wet atmospheric deposition. Phosphorus loading in South Florida is monitored through the Florida Atmospheric Mercury Study (FAMS). Wet deposition phosphorus loading rates average around 10 mgP/m^2-yr, while dry deposition phosphorus loading rates range from 10 mgP/m^2-yr to 20 mgP/m^2-yr (Pollman 2000). Based on data presented by Curtis Pollman, the Lake Okeechobee Technical Advisory Committee (2000) recommended that 18 mgP/m^2-yr is an appropriate atmospheric loading of phosphorus over the open lake.

FACTORS AFFECTING PHOSPHORUS CONCENTRATIONS IN LAKE OKEECHOBEE

The high phosphorus concentrations in Lake Okeechobee are the result of watershed management activities, lake management activities and in-lake processes (SFWMD 1997). Several of these conditions and activities together exacerbate the phosphorus problems in Lake Okeechobee.

External Loadings

As discussed in previous sections, phosphorus enrichment and the increase in the frequency of high chlorophyll *a* concentrations (algal blooms) are a result of excessive phosphorus loading to Lake Okeechobee from upstream activities in the watershed (Reddy and Flaig 1995). However, reducing external phosphorus loads to the lake according to the SWIM targets will not reduce the in-lake total phosphorus concentration to 40 ppb largely due to the phosphorus currently stored in the lake’s sediments and external sources not controlled under the SFWMD's Works of the District permitting program. In order for the lake to reach the 40 ppb in-lake phosphorus target, additional reductions in phosphorus loading to the lake need to be achieved and/or the phosphorus load in the sediments needs to be controlled in some manner.

High Water Levels

High water levels in the lake have been documented to exacerbate the symptoms of cultural eutrophication (Canfield and Hoyer 1988, Havens 1997). There is a strong correlation between yearly-average total phosphorus concentrations, near-shore algal bloom frequencies, and water levels. Two ecological processes may interactively explain this phenomenon. First, when water levels are high, there is reduced growth of submerged plants in the near-shore zone, and therefore, less competition for phosphorus between plants and phytoplankton. Phytoplankton sequester nearly all of the available nutrients and give rise to blooms. Second, when water levels are high, there is greater transport of phosphorus-rich water from the mid-lake region into the near-shore area by underwater currents. At low lake stages a shallow rock reef that separates the near-shore area from mid-lake prevents this transport. A third mechanism is that littoral flooding results in internal phosphorus loading from dead vegetation. Dierberg (1993) showed this phosphorus load to be of relatively low importance, and that the littoral zone is largely a sink, rather than a source of phosphorus.

Wind Effects

A fourth factor that affects the high total phosphorus concentrations in the water column of the pelagic zone involves wind effects on sediment resuspension. The almost daily wind-driven resuspension of the phosphorus-laden active layer of sediment in the pelagic zone increases phosphorus concentrations in the water column (Havens et al. 1996a). Wind and total phosphorus concentrations have a high correlation (r^2=0.78). The highest sediment resuspension in Lake Okeechobee occurs in the winter (Grimard and Jones 1982, Carrick et al. 1994).

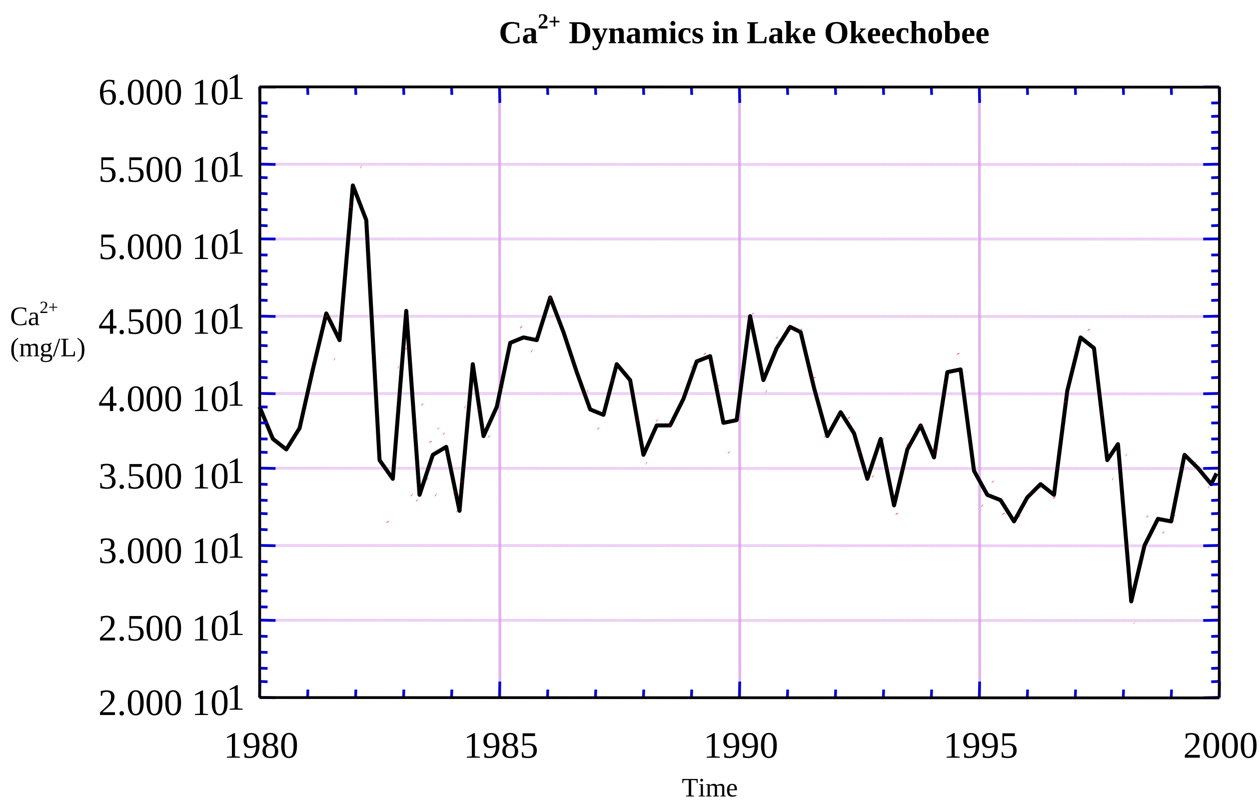
Internal Loadings from Sediment

Another factor involves the internal phosphorus loading from the consolidated organic muds at the center of the lake bottom. Sixty percent of the pelagic bottom is composed of these consolidated organic muds, which store approximately 30,000 metric tons of phosphorus within the upper 10 cm of the mud that have accumulated over the last 75 years. This phosphorus is typically bound to calcium, other organic matter or iron at the sediment surface. The diffusive flux of phosphorus between the sediment surface and water column is controlled by iron solubility (Olila and Reddy 1993). Under reducing conditions (iron is in the form of Fe^{2+}), phosphorus is released at high rates from the sediment active zone into the water column. Under conditions of low dissolved oxygen, the levels of phosphorus in the water column could increase from 50 ppb to over 100 ppb. This condition could contribute to the algal blooms that occur in summer months (Havens et al. 1995). Despite a slight decline in external phosphorus loading in the late 80s and early 90s from the implementation of the FDEP Dairy Rule in 1987, internal phosphorus loading has kept the concentration of total phosphorus in the water column at 90 ppb to 100 ppb since the 1980s (Harvey and Havens 1999). This is a common effect seen in shallow lakes with a long history of excessive external phosphorus inputs (Sas 1989).

Potential Role of Calcium

Over time, Ca^{2+} has been declining in the water column of Lake Okeechobee. From 1980 to 2000, Ca^{2+} has declined by an average of 15 mg/L (Figure 6). Phosphorus tends to bind to calcium forming calcium phosphate (hydroxyapatite), which is a sink for phosphorus. As the amount of Ca^{2+} declines because of the supersaturation of hydroxyapatite, dissolved inorganic phosphorus increases because it is being released back into the water column. Therefore, calcium concentrations are positively correlated with the phosphorus settling rate.

Figure 6. Change in Ca^{2+} over time (Pollman 2000)



Biological Processes

Biological processes also affect the phosphorus dynamics and phosphorus concentrations found in Lake Okeechobee. The biological processes that occur in the lake are complex and produce feedback loops and non-linear responses (Havens and Schelske 2001). Macrophytes affect the phosphorus dynamics by removing phosphorus from the water column through their roots and providing a sink for the phosphorus. The larger the macrophyte population, the larger the sink. Additionally, the roots of macrophytes stabilize the sediments, thereby reducing the resuspension of phosphorus-laden sediments (Vermaat et al. 2000). Lake Okeechobee experiences high levels of turbidity, which are in part a result of a loss of submerged aquatic vegetation from years of high water levels (Havens 1997).

Benthic invertebrates also affect the cycling of phosphorus. Phosphorus can be released into the water column from the sediments through bioturbation and feeding activities of various invertebrates (Van Rees et al. 1996) and benthic feeding fish (Moss et al. 1997). In addition, some macroinvertebrates, such as mussels, are able to remove phosphorus from the watershed through filtration (Nalepa and Fahnenstiel 1995).

Over time, a larger portion of the total phosphorus in the water column has been found in the dissolved form. This dissolved phosphorus is utilized by the phytoplankton. However, from years of high phosphorus loading to the lake, the amount of dissolved phosphorus that is available exceeds the demand, and as a result the dissolved phosphorus in the water column is lost to the sediments. As more phosphorus is incorporated into the sediments, the lake is losing its ability to assimilate phosphorus. Another mechanism of phosphorus loss involves the storage of soluble phosphorus from within the sediment-water interface as polyphosphates in algal cells (Carrick et al. 1993).

HISTORIC AND CURRENT PROGRAMS, GROUPS AND MANAGEMENT PLANS TO ADDRESS WATER QUALITY PROBLEMS IN THE LAKE OKEECHOBEE WATERSHED

Interim Action Plan (IAP)

The Interim Action Plan (IAP) was implemented in 1979 to reduce the nutrient loads coming to Lake Okeechobee from the backpumping of the Everglades Agricultural Area (EAA).

Alternatively, the water from the EAA was to be diverted south into the Water Conservation Areas (WCAs). The goal of IAP was to reduce nitrogen loading to the lake by 90%. The IAP was successful in meeting this goal, which also helped to reduce phosphorus inputs to the lake from the EAA. Water is still occasionally pumped from the EAA to the lake during periods of high rainfall (Harvey and Havens 1999).

Surface Water Improvement and Management (SWIM)

In 1987, the Florida Legislature passed the SWIM Act, Sections 373.451-373.4595, F.S., which required the Water Management Districts (WMDs) to develop plans and programs for the improvement and management of surface waters that have been degraded, altered, or are in danger of being degraded. The SWIM Act required a 40% reduction in phosphorus flowing into Lake Okeechobee to achieve the in-lake phosphorus reduction goal of 40 ppb, based on the South Florida Water Management District's Technical Publication 81-2, by July 1992. According to the 1989 Interim Lake Okeechobee SWIM Plan, all inflows to the lake are required to meet total phosphorus concentrations of 180 ppb or lower. Tables 1 and 2 depict the total phosphorus concentration targets established for each basin.

Lake Okeechobee Technical Advisory Council II (LOTAC II)

LOTAC II was created by the Florida Legislature through the SWIM Act of 1987 with the purpose of investigating the adverse affects of past diversions of water and the potential effects of future diversions on indigenous wildlife and vegetation within the environmentally sensitive areas surrounding Lake Okeechobee. The council reported to the Legislature by March 1, 1988 with findings and recommendations of permanent solutions to eliminate the adverse effects. This investigation included the St. Lucie and Caloosahatchee watersheds and Everglades National Park (LOTAC II 1988).

Works of the District (WOD) Permitting Program

To achieve the reduction goals established in the SWIM Plan, the SFWMD adopted the Works of the District (WOD) Permitting Program (Rule 40E-61). This program established a permitting process for non-dairy land uses within the Lake Okeechobee watershed and established discharge limits for runoff from different land uses based on the in-lake phosphorus target of 40 ppb

(SFWMD 1989). For example, the total phosphorus concentration limit for improved cattle pasture is 350 ppb. The SFWMD works with landowners to help them meet their discharge limits by identifying best management practices (BMPs) or other measures to reduce the total phosphorus concentration in runoff. Figure 7 illustrates the WOD permit locations.

FDEP Dairy Rule and Dairy Buy-Out Program

In 1987, the FDEP adopted Chapter 62-670 to establish treatment requirements to reduce total phosphorus concentrations in runoff coming from animal feeding operations and dairy farms in the Lake Okeechobee watershed. Waste treatment systems were to be constructed to treat runoff and wastewater from barns and high-intesity milk herd holding areas. According to the rule, all 49 dairies in the Lake Okeechobee drainage basin had to sell and remove their cattle or else comply with the rule by 1991. The Dairy Buy-Out Program allowed owners of dairies to sell their dairy if they were unable or unwilling to comply with the FDEP Dairy Rule. In 1997, 23 dairies were eliminated, while 26 came into compliance due to the Dairy Rule, Dairy Buy-Out Program and the Save Our Rivers Program.

Taylor Creek Headwaters Project and Taylor Creek Nubbin Slough (TCNS) Rural Clean Waters Program (RCWP)

A variety of best management practices (BMPs) were implemented to reduce phosphorus loading from the Taylor Creek and Nubbin Slough basins. These BMPs included fencing cows away from streams, animal wastewater disposal on croplands, and utilization of wetlands for nutrient removal. More detailed information on the BMPs is available in Anderson and Flaig (1995).

Lake Okeechobee Action Plan

The Lake Okeechobee Issue Team, formed by the South Florida Ecosystem Restoration Working Group, a multi-agency group working on South Florida environmental issues, was formed in 1998 to develop an Action Plan to protect and enhance the ecological and societal values of Lake

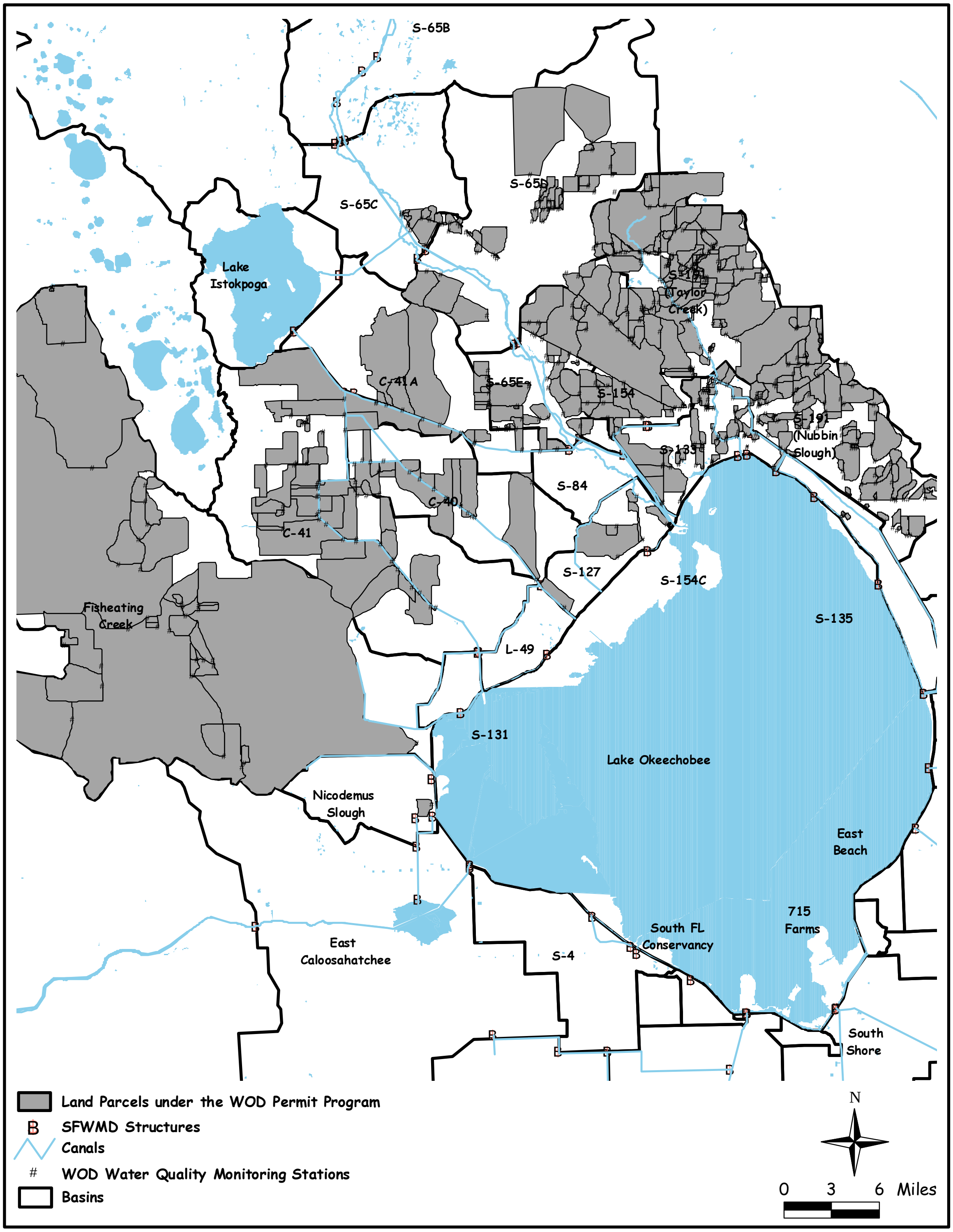


Figure 7. Works of the district (WOD) permits and monitoring locations

Okeechobee. The primary focus of the Action Plan (Harvey and Havens 1999) was to reduce in-lake phosphorus concentrations to 40 ppb (the target established by the SWIM Plan). The Action Plan provides strategies and options for reducing phosphorus inputs to Lake Okeechobee from its surrounding watershed. It also provides a summary of current on-going and projected future projects that could reduce phosphorus loading in the watershed. These projects include the construction of reservoir assisted stormwater treatment areas (RASTAs) to attenuate peak flows, development of a phosphorus budget for the watershed, reclamation of isolated wetlands, elimination of importing residuals into the watershed, analysis for and implementation of additional measures for phosphorus controls, and implementation of a sediment removal feasibility study.

Lake Okeechobee TMDL Technical Advisory Committee

In February of 2000, the department established the Lake Okeechobee TMDL technical advisory committee (TAC) to provide scientific input to assist in the development of a phosphorus TMDL for Lake Okeechobee. Discussion included the appropriate in-lake phosphorus concentration target, biotic responses to phosphorus loading, the in-lake cycling of phosphorus with emphasis on the role of sediments in phosphorus cycling, tools currently available for modeling the Lake Okeechobee system, and the formulation of a method for determining allowable phosphorus loading to the lake. The eight member TAC met seven times over the year. The TAC determined that the restoration target would be 40 ppb for the pelagic zone of the lake. It is assumed that the littoral zone would be protected with this restoration target for the pelagic zone.

Lake Okeechobee Protection Program (Section 373.4595, F.S.)

The Lake Okeechobee Protection Program provides a plan for restoring and protecting Lake Okeechobee using a watershed-based approach to reduce phosphorus loadings to the lake and downstream receiving waters. The Legislature intends for this section and s. 403.067, F.S., to provide a reasonable means of achieving and maintaining compliance with state water quality standards in Lake Okeechobee. The act outlines several plans and projects that are to be implemented to restore Lake Okeechobee. The first is the development and implementation of the Lake Okeechobee Protection Plan by January 1, 2004, which will address the reduction of phosphorus loads to Lake Okeechobee from both internal and external sources using a phased program of implementation. The initial phase of phosphorus load reductions will be based on the South Florida Water Management District's (SFWMD) Technical Publication 81-2 and the SFWMD's WOD program. Subsequent phases of phosphorus load reductions will be based on the TMDL established in accordance with s. 403.067, F.S. Components of the Lake Okeechobee Protection Plan to reduce phosphorus loads to the lake are outlined below.

- Lake Okeechobee Construction Project

  The purpose of the Lake Okeechobee Construction Project is to improve the hydrology and water quality of Lake Okeechobee and downstream receiving waters. Phase I of the construction project includes the design and construction of the Grassy Island Ranch and New Palm Dairy stormwater treatment facilities and two of the isolated wetland restoration projects as components of the Lake Okeechobee Water Retention/Phosphorus Removal Critical Project. Additionally, by January 31, 2002, the SFWMD shall design and complete implementation of the Lake Okeechobee Tributary Sediment Removal Pilot Project. The fourth component of Phase I includes initiating the design process for the Taylor Creek/Nubbin Slough Reservoir Assisted Stormwater Treatment Area. Phase II includes the development of an implementation plan for the Lake Okeechobee Construction Project. The implementation plan will identify the Lake Okeechobee Construction Projects to be constructed, identify size and location, provide a construction schedule, provide a land acquisition schedule, provide a detailed schedule of costs, and identify impacts on wetlands and state-listed species expected to be associated with construction of these projects.

- Lake Okeechobee Watershed Phosphorus Control Program

  The Lake Okeechobee Watershed Phosphorus Control Program is designed to be a multifaceted approach to reducing phosphorus loads by improving the management of phosphorus sources within the Lake Okeechobee watershed through continued implementation of existing regulations and best management practices (BMPs), development and implementation of improved BMPs, improvement and restoration of the hydrologic function of natural and managed systems, and utilization of alternative technologies for nutrient reduction. This section includes the development of an interagency agreement for the development and evaluation of agricultural and nonagricultural BMPs by March of 2001. It also includes rule development by FDACS for interim measures, BMPs, conservation plans, nutrient management plans, or other measures necessary for Lake Okeechobee phosphorus load reduction. The program also addresses nonagricultural nonpoint source BMPs. By January 2001, FDEP is to develop interim measures, BMPs or other measures necessary for Lake Okeechobee phosphorus load reduction resulting from nonagricultural nonpoint sources. Other components of the program include the development and submission of agricultural use plans from entities disposing domestic wastewater residuals and rulemaking for conservation or nutrient management plans of animal manure application.

- Lake Okeechobee Research and Water Quality Monitoring Program
  By January 2001, the Lake Okeechobee Research and Water Quality Monitoring Program is to be established by the SFWMD. The program requires that all total phosphorus data be evaluated to develop a water quality baseline of existing conditions in Lake Okeechobee. The program also includes 1) the development of a Lake Okeechobee water quality model that represents phosphorus dynamics of the lake, 2) the determination of the relative contribution of phosphorus from all identifiable sources and all primary and secondary land uses, 3) an assessment of the sources of phosphorus from the Upper Kissimmee Chain-of-Lakes and Lake Istokpoga and their relative contribution to the water quality of Lake Okeechobee, 4) an assessment of current water management practices within the Lake Okeechobee watershed and develop recommendations for structural and operational improvements, 5) and an evaluation of the feasibility of alternative nutrient reduction technologies.
- Lake Okeechobee Exotic Species Control Program
  This program requires the coordinating agencies to identify the exotic species that threaten the native flora and fauna within the Lake Okeechobee watershed and develop and implement measures to protect the native flora and fauna by June 1, 2002.
- Lake Okeechobee Internal Phosphorus Management Program
  By July 1, 2003, in cooperation with coordinating agencies and interested parties, the SFWMD is to complete a Lake Okeechobee internal phosphorus load removal feasibility study. If any removal methods are found to be technically and economically feasible, then the SFWMD will immediately pursue the design, funding and permitting for implementing the removal method.

- Annual Progress Report

  Every January 1, beginning on January 1, 2001, the SFWMD shall submit to the Governor, the President of the Senate, and the Speaker of the House of Representatives annual progress reports regarding implementation of this section, s. 373.4595, F.S. The annual progress report will include a summary of water quality and habitat conditions in Lake Okeechobee and its surrounding watershed, and an update on the status of the Lake Okeechobee Construction Project.

- Lake Okeechobee Protection Permits

  This section of the legislation requires that all structures discharging into or from Lake Okeechobee must obtain permits. All permits obtained through the act will be in lieu of other permits under chapter 373 and chapter 403, except for 403.0885, F.S. Owners and operators that have existing structures that discharge into and from the lake are required to apply for 5-year permits to operate and maintain such structures within 90 days of completion of the diversion plans set forth in FDEP's Consent Orders 91-0694, 91-0707, 91-0706, 91-0705, and RT50-205564. As of September 1, 2000, owners or operators of all other existing structures, which discharge into or from the lake are required to apply for 5-year permits from FDEP to operate and maintain the structures. By January 1, 2004, the SFWMD shall submit to FDEP a permit modification to the Lake Okeechobee structure permits to incorporate any changes needed to achieve state water quality standards, including the TMDL established in accordance with s. 403.067, F.S.

Section 403.067, F.S. Establishment and Implementation of Total Maximum Daily Loads (TMDLs)

Section 403.067, F.S. provides the framework for how the state will approach developing TMDLs. The legislation instructs FDEP to adopt by rule a methodology for determining those waters that are impaired and provides guidance for the calculation, allocation and implementation of a TMDL. The total maximum daily load calculations for each water body or water body segment are to be adopted by rule by the secretary pursuant to ss. 120.536(1), 120.54 and 403.805. Section 403.067 recognizes Lake Okeechobee as impaired without using the methodology that the state is going to use to determine impairment. This is significant, as this methodology is currently undergoing rulemaking.

AVAILABLE AMBIENT MONITORING DATA

Since the late 1960s, water quality has been monitored in Lake Okeechobee by many agencies, including the South Florida Water Management District (SFWMD), Florida Department of Environmental Protection (FDEP), United States Army Corps of Engineers (USACE), United States Environmental Protection Agency (USEPA), county governments, universities, and private organizations. The SFWMD has been the primary agency responsible for continuous monitoring in Lake Okeechobee since the early 1970s. The SFWMD monitoring stations are shown in Figure 8. Constituents monitored at these stations vary among physical parameters, nutrients, metals, and select biotic communities. Additionally, monitoring is conducted at most inflows and outflows to the lakes at the structures. Data from near-shore stations were used to establish the in-lake total phosphorus concentration goal of 40 ppb. Stations L001 to L008 within the pelagic zone of the lake are being used to monitor the in-lake phosphorus concentration. The near-shore stations were used in the Walker and Pollman models to develop the TMDL.

TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

In-lake Phosphorus Concentration Target

In order to establish or calculate a Total Maximum Daily Load (TMDL), a waterbody specific concentration target is established, above which the waterbody is unable to meet its designated uses. In the case of Lake Okeechobee, that target was determined to be 40 ppb for total phosphorus in the pelagic zone of the lake. The target was developed using chlorophyll *a* as an indicator of algal biomass, which in turn acts as a surrogate for indicating excessive nutrient concentrations. Based on several published journal articles, algal blooms (chlorophyll *a* concentrations greater than 40 *u*g/l (Havens et al. 1995, Walker and Havens 1995)) occur as a result of excessive phosphorus levels in the lake. These algal blooms pose a significant threat to many of the uses of the lake including drinking water, habitat, nesting, fishing and swimming.

Total phosphorus and chlorophyll *a* concentrations are found to be highly correlated in the near-shore areas to the south and north/west (Walker and Havens 1995). In the south littoral and the pelagic zones, the frequency of algal blooms greatly increased when mean phosphorus

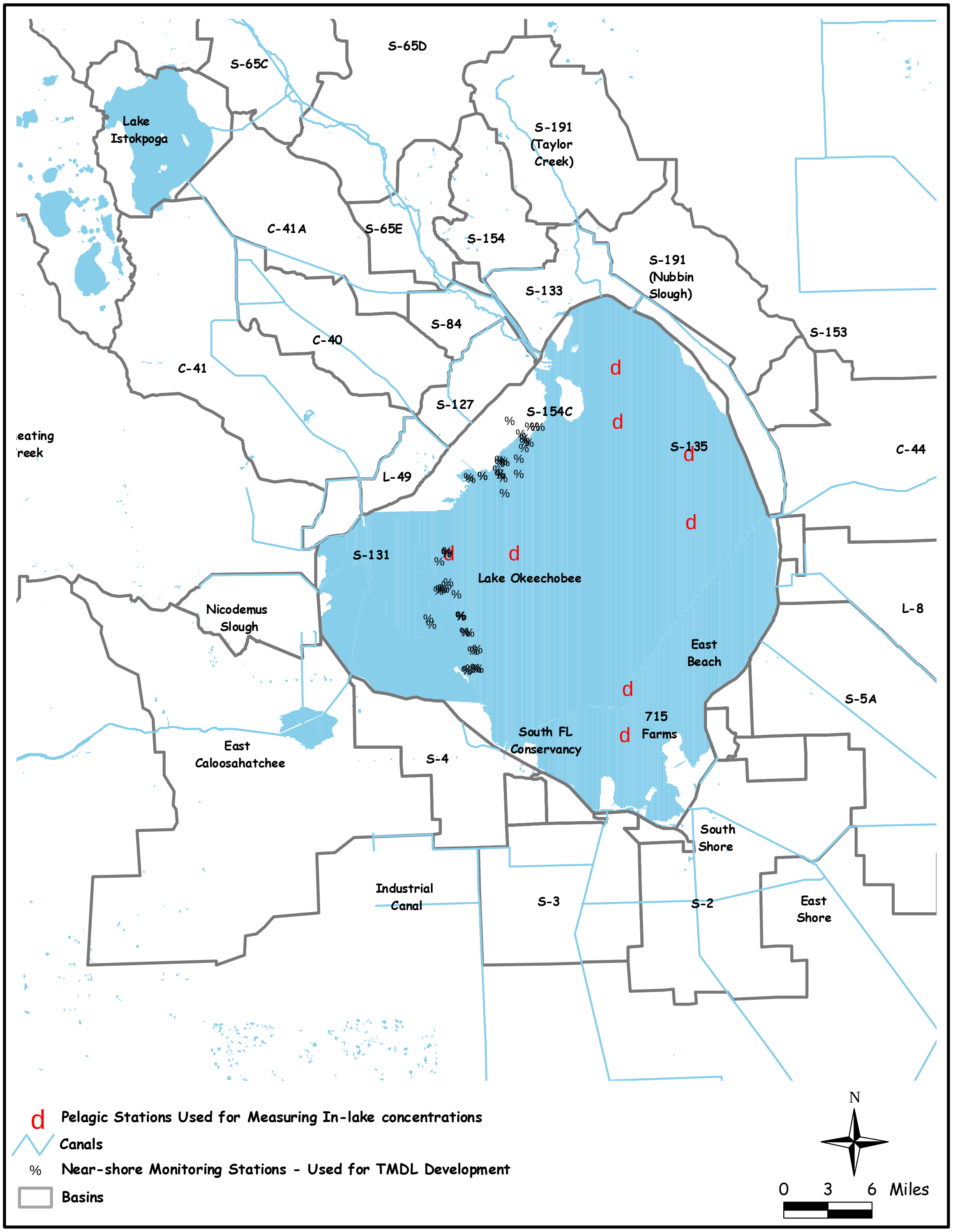


Figure 8. SFWMD Station and Structure Locations in Lake Okeechobee

concentrations exceeded 40 ppb. When total phosphorus is less than 30 ppb, bloom conditions are rare, however, between 30 ppb and 60 ppb total phosphorus, the frequency of blooms steeply increases (Walker and Havens 1995). Figure 9 illustrates the change in algal bloom frequency versus change in mean phosphorus concentrations for three areas of the lake.

Additional studies also suggest a restoration target around 40 ppb. In Havens and James (1997), the existing South Florida Water Management District (SFWMD) concentration target was evaluated considering historical "pre-impact" phosphorus concentration data and the heterogeneity of algal responses to in-lake phosphorus concentrations. Based on this study, the total phosphorus concentration target to return the lake to a less-impacted condition was found to be between 26 ppb and 92 ppb. However, on closer inspection of this range, the Lake Okeechobee Issue Team and the TMDL Technical Advisory Committee noted that values towards the mid-point (30 to 50 ppb) were the most appropriate from a scientific standpoint. In another study, James and Havens (1996) conducted a regression analysis to derive a total phosphorus concentration goal to achieve a desired algal bloom frequency. From this study, the regression model provided a near-littoral zone total phosphorus concentration goal of between 36 ppb and 52 ppb. Another regression model generated by using the historic low chlorophyll *a* concentration produced a total phosphorus concentration goal of between 40 ppb to 75 ppb ($r^2=0.88$, $\alpha<0.05$).

The total phosphorus concentration target produced by these different analysis methods all encompass the 40 ppb concentration target. The Lake Okeechobee TMDL Technical Advisory Committee, after considering information regarding the 40 ppb concentration target (including what is discussed above) also supports a phosphorus concentration of 40 ppb in the pelagic zone of the lake. The 40 ppb goal for the entire pelagic region is considered to be a conservative goal that introduces a margin of safety into the TMDL. This reflects the fact that under high lake stage conditions, total phosphorus concentrations are relatively homogeneous across the open-water region, but when lake stages are low, the near-shore area displays considerably lower total phosphorus than the open water zone. Hence, if 40 ppb is met at the eight pelagic stations (which represent the mid-lake) we can expect total phosphorus concentrations of below 40 ppb in the near-shore during certain years.

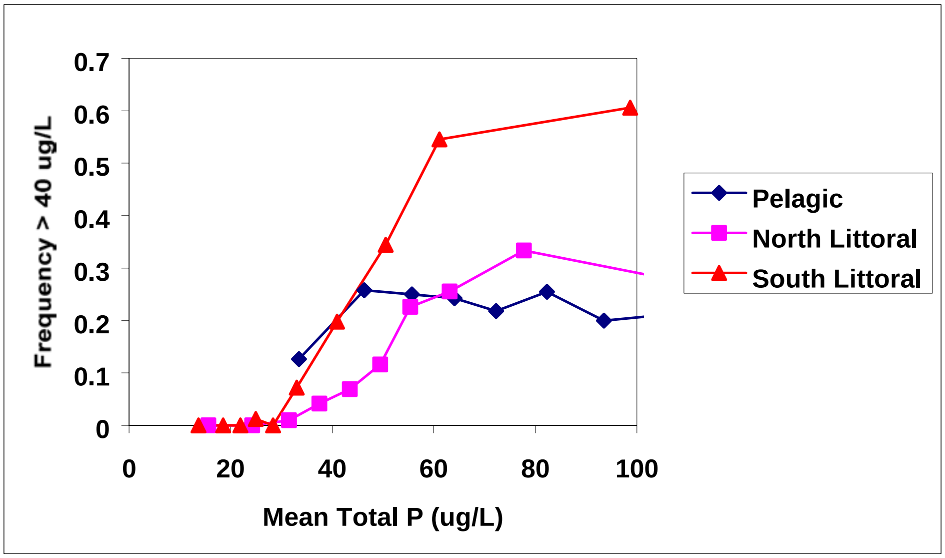


Figure 9. Mean total phosphorus versus of algal blooms over 40 μg/L (Walker and Havens 1995)

Calculation

The total annual phosphorus load to Lake Okeechobee that will meet the in-lake target restoration goal of 40 ppb in the pelagic zone (based on water quality stations L001 – L008) is 140 tonnes, including atmospheric deposition, which accounts for 35 tonnes/yr. The attainment of the TMDL will be calculated using a 5-year rolling average using the monthly loads calculated from measured flow and concentration values. This load was determined using the results from two different models presented to FDEP from the Lake Okeechobee TMDL Technical Advisory Committee. The models are discussed in Appendix 2 and 3. The TMDL is defined as follows:

$$\text{TMDL} = \sum\text{Point Sources} + \sum\text{Nonpoint Sources} + \text{Margin of Safety}$$

$$\text{TMDL} = 140 \text{ metric tons/yr}$$

Load Allocation

This load will be allocated to the sum of all nonpoint sources. For this TMDL, all existing direct inflows into Lake Okeechobee are considered to be nonpoint sources (Figure 10). This includes the phosphorus load from atmospheric deposition, which is currently estimated at 35 metric tons/year. No portion of the TMDL will be allocated to point sources. Currently, there are no point sources to the lake. See Appendix 2 for more information on phosphorus loads from rainfall. Future allocations may be revised based on new research and data as they become available (refer to the implementation section). From the equation above:

$\sum$Point Sources = 0

$\sum$Nonpoint Sources = 140 (atmospheric deposition will be accounted for in this section)

Margin of Safety = implicit by using conservative parameters

Critical Condition Determination

This TMDL establishes the maximum annual load for phosphorus for Lake Okeechobee. The models include and represent critical conditions by utilizing a 26-year data set. Using a broad time frame as in this case allows the range of flow and meteorological conditions that can occur in Lake Okeechobee to be considered.

Margin of Safety (MOS)

A margin of safety (MOS) is required as part of a TMDL in recognition that there are many uncertainties in scientific and technical understanding of the chemical and biological processes that occur in Lake Okeechobee. The MOS is intended to account for such uncertainties in a conservative manner that protects the environment. According to EPA's guidance, a MOS can be achieved through reserving a portion of the load for the future, or using conservative assumptions in calculating the load. In the case of Lake Okeechobee, the MOS is accounted for by using a conservative estimate for the in-lake total phosphorus concentration target of 40 ppb. A specific load is not reserved for the margin of safety (See Section on In-lake Phosphorus Concentration Target).

Seasonal Variation

Long-term (26 year) data for flow and total phosphorus concentrations used in the modeling process account for interannual and long-term variations that have occurred within Lake Okeechobee. Also, variations in flow are accounted for in the expression of the TMDL as an annual flow weighted average over several years.

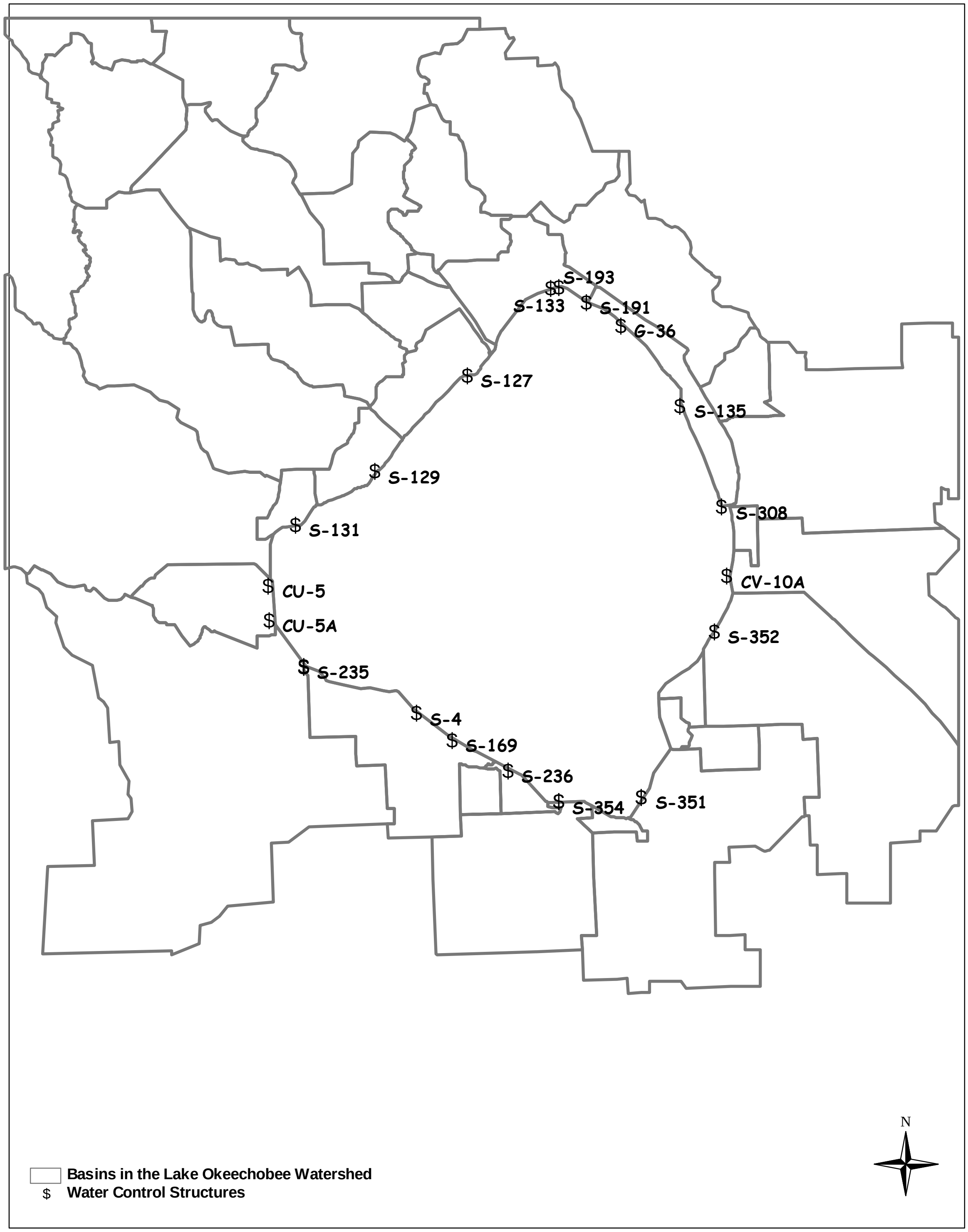


Figure 10. Location of Structures in the Lake Okeechobee Watershed

IMPLEMENTATION PLAN

In order to achieve phosphorus reductions necessary to meet the TMDL for Lake Okeechobee, the state will implement a phased approach. Phased implementation is necessary because the processes involving phosphorus cycling in Lake Okeechobee and the surrounding watershed are not fully understood. The phosphorus dynamics within Lake Okeechobee sediments are also not fully understood, except that the contribution of phosphorus from the sediments to the water column is significant. As a result, predictive modeling for the recovery of the lake uses conservative assumptions because the degree of uncertainty cannot be precisely quantified until more data become available. Additionally, limited information exists on the nature of nonpoint source stormwater runoff, including the performance of phosphorus removal techniques based on Best Management Practices (BMPs) and Reservoir Assisted Storage Treatment Areas (RASTAs), and thus only estimates of phosphorus removal can be made. Even with the above uncertainties, it is imperative that the state moves forward with phased water quality management activities to restore the water quality and ecology of Lake Okeechobee. The phased TMDL allows progress to be checked against measurable interim targets. This process will include monitoring and re-assessing the TMDL within five years, as more information becomes available to ensure attainment of water quality standards (USEPA 1991). For example, we may observe a faster recovery of the lake than anticipated, and perhaps an increase in phosphorus assimilative capacity, if past biological trends associated with eutrophication (e.g., blue-green and oligochaete dominance) are reversed. This might lead to adjustment of the TMDL. This phased implementation will be consistent with the phased management activities outlined in section 373.4595, F.S., relating to the restoration of Lake Okeechobee.

The implementation of the Lake Okeechobee TMDL will occur in three phases.

Phase I

The first phase includes immediately initiating activities within the Lake Okeechobee watershed to achieve the phosphorus load reductions as set forth in the South Florida Water Management District’s Technical Pub 81-2, which is consistent with recommendations from the Legislature. Technical Pub 81-2 and the SWIM plan, recommends a 40 ppb in-lake phosphorus goal, which was then used to calculate, based on a simplified flow-based water quality model (modified Vollenweider (1975)), an acceptable load of phosphorus to the lake. This first phase will include identifying agricultural and nonagricultural nonpoint sources, evaluating existing program, controls and strategies, developing interim measures and BMPs, and implementing BMPs as part of the Lake Okeechobee Watershed Phosphorus Control Program. Additionally, this phase will be a planning and data gathering period for the construction of large RASTAs and isolated wetlands restoration projects, which are projects being conducted in conjunction with the Comprehensive Everglades Restoration Program (CERP). The design goal of the RASTAs is to treat inflows to an effluent phosphorus concentration of 40 ppb. The priority basins targeted for these construction projects include S-191 (Taylor Creek/Nubbin Slough), S-154, and Pools D and E of the Lower Kissimmee River (Figure 11). These basins are considered the priority basins because they are contributing some of the highest loads of phosphorus to Lake Okeechobee and they have particularly high concentrations of phosphorus in their waters. Using this phased approach allows time for construction, designs, water quality evaluations, feasibility studies and other studies described in the legislation.

Phase II

In 2004, the phosphorus reductions achieved in Phase I will be evaluated. Additional phosphorus reduction in the watershed will follow management activities outlined in the Lake Okeechobee Protection Plan that is to be completed by 2004 (section 373.4595, F.S.) to achieve the phosphorus TMDL for the lake of 140 metric tons. At this point, the initial assessment and planning of the Lake Okeechobee Construction Project and the Lake Okeechobee Watershed Phosphorus Control Program should be completed. The information from the assessment and planning activities will guide future management activities, including the actual construction of large-scale construction projects (RASTAs and other treatment wetlands) and implementation of additional BMPs. In addition, the TMDL will be reevaluated by 2006.

Phase III

In 2010 - 2020, the current planned construction projects and management activities will have been completed and implemented. Phosphorus reductions and monitoring will be evaluated and compared to the water quality target (40 ppb in-lake concentration target in the pelagic zone). The TMDL numeric target will be re-calculated if the current phosphorus reduction target is not adequate to meet the water quality restoration goal (40 ppb in-lake total phosphorus concentration). Future construction projects and other management activities will be determined from the results of the construction projects, BMPs implemented and other management activities that have been implemented.

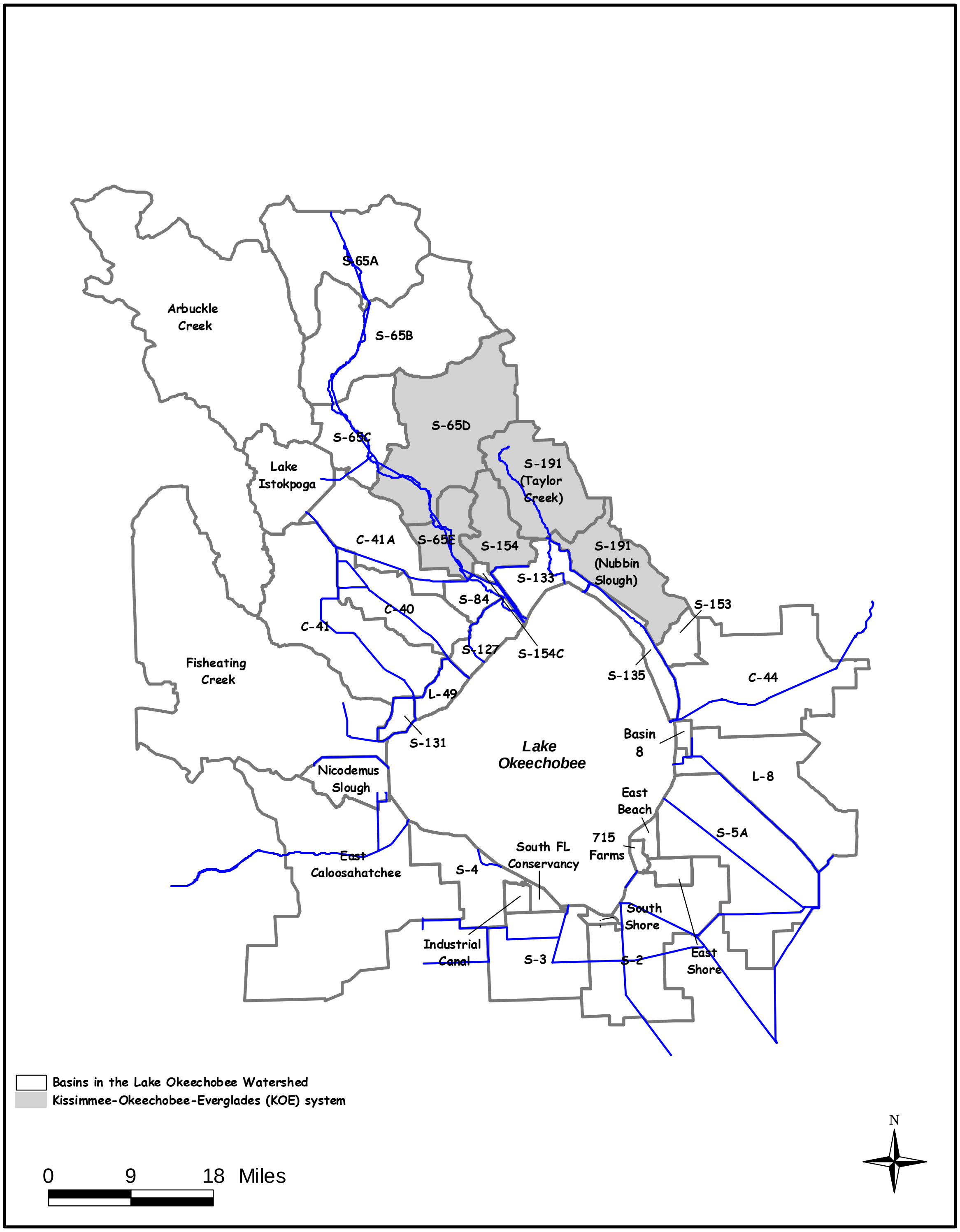


Figure 11. Priority Basins within the Lake Okeechobee Watershed

PUBLIC PARTICIPATION

Public participation was a major focus in the development of the Lake Okeechobee phosphorus TMDL. Within the Lake Okeechobee watershed, there is growing consensus among the stakeholders for immediate implementation of effective control measures. This kind of agreement and cooperation, directed at expeditious action, is essential if Lake Okeechobee is to be restored. Restoration of Lake Okeechobee will require unprecedented cooperation between the public and private sector. The FDEP felt that this cooperation should begin in the initial stages of TMDL development.

During the TMDL development process, eight technical advisory committee (TAC) meetings were held, in which the public was invited to provide input. These meetings were held on 2/15/00, 3/15/00-3/16/00, 4/6/00, 5/3/00, 5/31/00, 6/22/00, 8/1/00, and 10/7/00. The minutes to these minutes are provided in Appendix 4. Additionally, FDEP solicited comments on the Draft TMDL document during September of 2000. These comments are provided in Appendix 5.

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Hurricanes, El Niño and harmful algal blooms in two sub-tropical Florida estuaries: Direct and indirect impacts

Edward J. Phlips[1*], Susan Badylak[1], Natalie G. Nelson[2,3] & Karl E. Havens[1,4]

Future increases in the intensity of hurricanes and El Niño periods predicted by climate change models have focused attention on their role in stimulating harmful algal blooms (HABs). A series of hurricanes that recently impacted Florida (USA) provided a unique opportunity to explore the relationships between hurricanes, El Niño and HABs in two Florida estuaries subject to repeated intense ecosystem disruptive HABs, the Indian River Lagoon and the St. Lucie Estuary. The roles that hurricanes and El Niño play in contributing to HAB events are examined in the context of key structural and functional features of each estuary and their watersheds, including morphology, water residence time and hydrology, such as the influence of Lake Okeechobee discharges into the St. Lucie Estuary. The most direct impact was the increase in rainfall associated with hurricanes and El Niño, resulting in enhanced nutrient loads which drive HABs in the Indian River Lagoon and Lake Okeechobee. Major HABs in Lake Okeechobee also present an indirect threat of freshwater HAB blooms in the St. Lucie Estuary via mandated discharges from the lake into the estuary during high rainfall periods. Conversely, during the absence of HABs in Lake Okeechobee, short water residence times produced by discharges into the St. Lucie Estuary can result in lower bloom intensities.

There is a consensus about the role that human activity plays in nutrient enrichment of aquatic environments as drivers of harmful algal blooms (HABs)[1,2]. There are also growing concerns that anticipated future changes in climatic conditions will increase threats for HABs[2,3]. Among these climatic threats are increases in the intensity and duration of hurricanes and El Niño periods[4–6]. High rainfall and winds associated with storms and elevated rain during El Niño periods in certain regions of the world can impact a range of processes relevant to phytoplankton dynamics and HAB development, including nutrient loads, physical disruption of ecosystems and ecosystem flushing rates[7–10]. These impacts can be exacerbated by human influences on nutrient loads and hydrology[11,12].

A series of hurricanes that recently impacted the peninsula of Florida, and the long record of El Niño/La Niña cycles, provide an opportunity to explore the potential impacts on HABs. The effects of storm and El Niño-driven changes to the hydrology and nutrient status of coastal estuaries can be difficult to define without a basic understanding of the structure and function of both the core estuary and its watershed. For example, storm enhanced watershed runoff can increase external nutrient loads that fuel algal blooms, or contain high HAB biomass from freshwater ecosystems in the watershed, or conversely, in some ecosystems elevated flushing rates can limit the intensity of autochthonous HABs by reducing water residence times. In addition to bringing high rainfall to impacted areas which enhance nutrient loads, the winds associated with storms can cause physical damage (e.g. erosion) or disruption (e.g. sediment re-suspension) of aquatic ecosystems, contributing to internal nutrient loading and re-distribution of nutrient sources and sinks[13,14].

We address these issues and examine the relationships between hurricanes (and more generally tropical cyclones), El Niño periods and HABs in two sub-tropical ecosystems, the St. Lucie Estuary and the Indian River Lagoon (Fig. 1). In subtropical ecosystems, relatively modest seasonal variability in temperature and irradiance can reduce the predictability of seasonal trends in phytoplankton biomass and composition[15]. Consequently,

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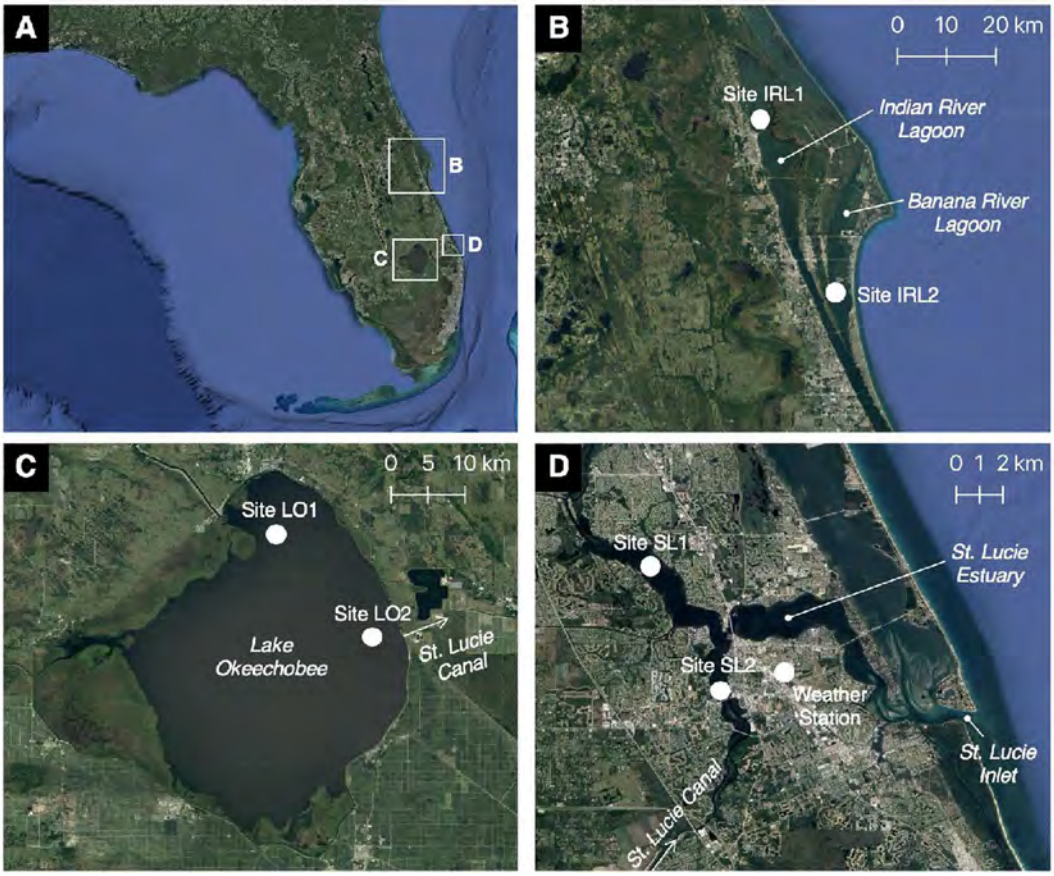

Figure 1. Sampling site maps for the northern Indian River Lagoon (**B**), including the connected Banana River lagoon component, Lake Okeechobee (**C**) and the St. Lucie Estuary (**D**). The top left panel (**A**) shows the location of the three ecosystems in the peninsula of Florida. Maps created using QGIS 3.2.3 with imagery from Google Maps using the XYZ Tiles service. Imagery data providers include LDEO-Columbia, NSF, NOAA, U.S. Navy, NGA, GEBCO, INEGI, SIO, Landsat/Copernicus).

other variables can take on greater importance in driving phytoplankton dynamics, often on longer and less predictable time intervals[16]. Two such factors are multi-year cyclical patterns (e.g. El Niño/La Niña cycles) and stochastic variability in rainfall intensity and wind associated with storm events. Both the St. Lucie Estuary and Indian River Lagoon have experienced significant hurricane activity, but each illustrates a different set of drivers and consequences associated with storm events as it relates to HABs. In the St. Lucie Estuary, hurricanes can indirectly impact HABs by increasing the potential for introduction of high algae biomass from freshwater systems in the watershed (Fig. 2a). In the Indian River Lagoon, both hurricanes and El Niño periods have a direct positive effect on HABs of internal origin (i.e. autochthonous), predominantly through the enhancement of nutrient loads. These relationships are explored within the context of key structural and functional features of each estuary and its watershed, including water residence times, composition of dominant algal species during HABs within and entering the estuary from watersheds and temporal patterns of hydrologic management activities, such as regulated discharges from Lake Okeechobee into the St. Lucie Estuary via the St. Lucie Canal[17,18].

Methods

Site description. In the St. Lucie Estuary, the study focused on two sampling sites in the inner regions of the St. Lucie Estuary, Site SL1 in the North Fork region and Site SL2 in the South Fork region (Fig. 1). The St. Lucie Estuary has an area of 29 km^2 and is shallow throughout (i.e. mean depth 2–2.5 m)[19,20]. In addition to two natural inflows, Ten-mile Creek and Old South Fork, three man-made canals (C-23, C-24 and C-44) were added to the system in the first half of the 20th Century to control hydrology in the region, including the regulation of water releases from Lake Okeechobee into the St. Lucie Canal (C-44) for flood control (Fig. 1). The canals provide an average of 75% of the freshwater discharge into the estuary, and all the inflows are managed by means of water control structures, such as locks, dams and water pumping stations[21]. The shallow depth and relatively small size of the St. Lucie Estuary result in rapid and spatially extensive responses to changes in discharge[22]. Water residence times in the South Fork/North Fork region of the estuary range from 1–16.5 days, based on CH3D hydrodynamic/salinity models[19]. Salinity isoclines can move substantial distances up and down the estuary on time scales of days to weeks, and vertical stratification is generally short-lived. The estuary is microtidal (amplitude <0.5 m)[22].

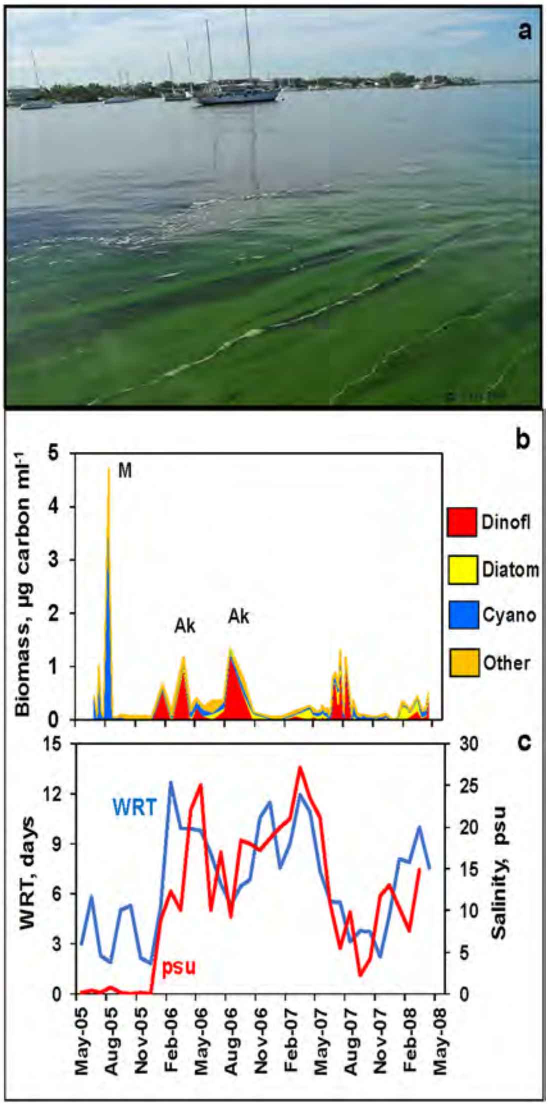

Figure 2. Image of major cyanobacteria bloom in the St. Lucie Estuary in August 2005 (**a**, photo by author E. J. Phlips), phytoplankton biomass time series at Site SL2 in the South Fork of the estuary, divided into four major groupings, i.e. dinoflagellates, diatoms, cyanobacteria and "other" (letters above major bloom indicate dominant species, A – marine dinoflagellate *Akashiwo sanguinea;* M – freshwater cyanobacterium *Microcystis aeruginosa*) (**b**). Salinities (psu) and water residence times for the inner estuary (**c**).

Lake Okeechobee, located in south-central Florida (27°00′ N, 80°50′ W), is the largest lake in the southeast United States (1,730 km^2 surface area). It is shallow (2.7 m mean depth), eutrophic and frequently subject to intense cyanobacteria blooms[17]. It has been impacted repeatedly by hurricanes, sometimes several in the same year. The lake has distinct zones that differ in their ecological structure and function, including a large comparatively deep (i.e. 4–5 m) central zone characterized by flocculent muddy sediments, a shallower (<3 m) perimeter zone characterized by firmer sediments, and a shallow northern perimeter zone subject to the largest external inflows from the water shed[23,24]. In terms of HAB events, blooms often begin in the shallow perimeter regions of the lake because of higher light availability and proximity to external nutrient inputs, but can spread throughout the lake[24]. In order to capture potential variability in conditions, data for two sites were included in these analyses, i.e. Sites LO1 and LO2 in the nearshore region of the lake, near the outflow to the St. Lucie Canal, which flows into the St. Lucie Estuary (Fig. 1).

In the Indian River Lagoon, the study focused on two sampling sites located in two separate sub-basins of the northern Indian River Lagoon subject to frequent HABs: Site IRL1 in the northern Indian River Lagoon near Titusville, and Site IRL2 in the central Banana River Lagoon (Fig. 1). Both sub-basins are microtidal and have long water residence times, with estimated mean water half-lives (i.e. 50% exchange) of 107 days in the northern Indian River Lagoon and 156 days in the central Banana River Lagoon[25,26]. Mean water depths are approximately 2 m in both regions. The sub-basins associated with Sites IRL1 and IRL2 are both characterized by small watersheds (i.e. 35,446 ha and 5628 ha, respectively), relative to the size of the receiving basins (i.e. 16,465 ha and 10,202 ha, respectively), but their watersheds differ in terms of percent distribution of land-uses[27,28]. The sub-basin of Site IRL1 had 65% undeveloped, 24% agricultural and 11% urban/residential land-use areas in 2009[28]. The sub-basin of Site IRL2 had significantly higher urban/residential area at 65%, low agricultural (4%) and 33% undeveloped land-use areas in 2009[28].

Sampling and field collections. Sites SL1 and SL2 in the St. Lucie Estuary were sampled on a weekly basis from May 2005 through April 2008. Sites IRL1 and IRL2 in the northern Indian River Lagoon were sampled monthly from September 1997 to August 2005, and twice monthly from September 2005 through April 2018. Temperature and salinity were measured at the surface and near the bottom at each site with a Hydrolab Quanta environmental multi probe. Water samples for phytoplankton analysis were collected with a vertical integrating sampling tube that captured water from the surface to within 0.1 m of the bottom, to avoid sample bias resulting from vertical stratification of phytoplankton. Duplicate aliquots were preserved on site, one with Lugol's solution and one with buffered glutaraldehyde.

Nutrient and chlorophyll a data. Monthly total Kjeldahl nitrogen and total phosphorus data for Indian River Lagoon (1997–2018) were obtained from the St. Johns River Water Management District (Palatka, Florida). Nitrate, soluble reactive phosphorus, total suspended solids and chlorophyll *a* data for the two sites in Lake Okeechobee (2004–2007) were obtained from the South Florida Water Management District (West Palm Beach, Florida).

Climate, discharge and remotely-sensed cyanobacteria observations. Rainfall data for the Stuart and Titusville (Florida) meteorological stations were obtained from the NOAA Climatological Data for Florida web site (www.ncdc.noaa.gov/IPS). Flow data capturing discharge from Lake Okeechobee into the St. Lucie Canal (Site 02276877) were obtained from the U.S. Geological Survey. Satellite imagery captured by MERIS and Sentinel-3 OLCI were analyzed using the Cyanobacteria Index (CI)[29] for cyanobacteria abundance and distribution in Lake Okeechobee. The CI was calculated from MERIS imagery for dates in 2005, and Sentinel-3 imagery in 2018.

Plankton analysis. General phytoplankton composition was determined using the Utermöhl method[30]. Samples preserved in Lugol's were settled in 19-mm diameter cylindrical chambers. Phytoplankton cells were identified and counted at 400× and 100× with a Leica phase contrast inverted microscope. At 400×, a minimum of 100 cells of a single taxon and 30 grids were counted. If 100 cells of a single taxon were not counted by 30 grids, up to a maximum of 100 grids were counted until 100 cells of a single taxon were reached. At 100×, a total bottom count was completed for taxa >30 µm in size.

Fluorescence microscopy was used to enumerate picoplanktonic cyanobacteria (e.g. *Synechococcus*.spp., spherical picocyanobacteria spp.) at 1000× magnification[31]. Subsamples of seawater were filtered onto 0.2 µm Nuclepore filters and mounted between a microscope slide and cover slip with immersion oil. If not analyzed immediately, samples preserved with buffered glutaraldehyde were refrigerated and counted within 72 h.

Cell biovolumes were estimated by assigning combinations of geometric shapes to fit the characteristics of individual taxa[32,33]. Specific phytoplankton dimensions were measured for at least 30 randomly selected cells. Species which vary substantially in size, such as many diatom species, were placed into size categories. Phytoplankton biomass as carbon values (i.e. µg carbon ml^{-1}) were estimated by using conversion factors for different taxonomic groups applied to biovolume estimates: i.e. 0.065× biovolume of diatoms, 0.22× biovolume of cyanobacteria or nanoplanktonic eukaryotes, and 0.16× biovolume of dinoflagellates or other taxa[34–38].

Statistical and modeling methods. Basic statistical procedures (i.e. determination of mean values, standard deviations, and Spearman's comparison of means) were carried out using SAS v9.2 (SAS Institute, Cary, North Carolina, USA).

Water residence times are expressed as E_{60} values (i.e. time in days for 60% water exchange), otherwise referred to as the e-folding time. Water residence time data for the inner St. Lucie Estuary used in this paper were provided by D. Sun of the South Florida Water Management District (W. Palm Beach, Florida). The St. Lucie Estuary is strongly influenced by tidal water exchange rates as well as freshwater flushing rates, therefore both factors are incorporated into the model formulations of water residence time[19,20]. Water residence time estimates for the study period were based on linear regression relationships developed between historical E_{60} values derived from a hydrodynamic model for 1997–1999[19,20] and rainfall integrated over a period of two weeks prior to the date (i.e. X) of the E_{60} model estimate. Regression for North Fork was $E_{60} = -0.2534X + 17.028$, $R^2 = 0.77$. Regression for South Fork was $E_{60} = -0.0257X + 2.9239$, $R^2 = 0.21$. A number of factors contribute to the lower R^2 of the relationship for South Fork, including the morphology of the estuary and the implications for tidal mixing, very shallow mean depth, small volume compared to North Fork and direct impacts of the flow-regulated discharges from the St. Lucie Canal to South Fork.

Results and discussion

St. Lucie Estuary-Lake Okeechobee connection. The results of a three-year study of the St. Lucie Estuary provide insights into two different ways storms affect HABs, i.e. internal blooms (i.e. autochthonous) of marine species and externally introduced blooms (i.e. allochthonous) of freshwater species[39]. The largest biomass peaks of marine species were observed in late summer/early fall (August-October) of 2006 (Fig. 2b, Supplemental Fig. S1), when salinities and water residence times were comparatively high (Fig. 2c) due to below average rainfall levels (Fig. 3), providing the conditions favorable for accumulation of marine phytoplankton biomass. Millie *et al.*[40] made a similar observation during a one-year study coinciding with a drought period in 2000, when diatom blooms were observed in the inner estuary. Conversely, periods of high rainfall, such as late summer/early fall of 2007, coincided with shorter water residence times, low salinities (Fig. 2c) and lower phytoplankton

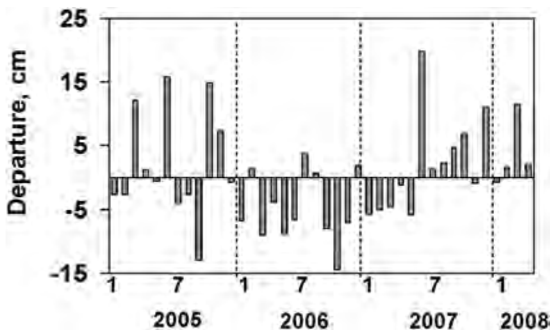

Figure 3. Departure from long-term average monthly rainfall at a weather station in the region of the St. Lucie Estuary at the NOAA meteorological station at Stuart, Florida (www.ncdc.noaa.gov/IPS).

biomass (Fig. 2b), despite the fact that average nutrient levels during the 2006 period (i.e. TP, 0.20 mg L^{-1}; TN, 0.90 mg L^{-1}) were lower than during the same period in 2007 (i.e. TP, 0.25 mg L^{-1}; TN, 1.20 mg L^{-1}). These observations indicate that periods of high rainfall and discharge from the watershed can restrict marine phytoplankton biomass due to diminished water residence times[39], highlighting the potential importance of water residence time in modifying the potential intensity of HABs involving marine species. The impact of water residence time can be compounded by elevated colored dissolved organic matter and tripton (i.e. non-algal particulate matter) in watershed discharge, which can reduce light availability in the water column for phytoplankton. This is reflected by lower mean CDOM and turbidity values in the August-October period of 2006 (i.e. 59 Pt-Co and 7.8 Ntu), than the same period in 2007 (i.e. 127 Pt-Co and 18.5 Ntu). However, the magnitude of potential light limitation for phytoplankton production may be partially mitigated by the shallow mean depths in the St. Lucie Estuary (i.e. mean depths of 2–2.5 m).

In contrast to the relationships described for blooms of marine species, high rainfall periods can be associated with freshwater HAB events in the St. Lucie Estuary, when discharges from Lake Okeechobee into the St. Lucie Estuary via the St. Lucie Canal occur during major HAB events in the lake. The latter scenario was observed in 2005 (Fig. 4a, Supplemental Fig. S2), during a period (2004–2005) when central Florida was impacted by five hurricanes, i.e. Charley, Francis, and Jeanne in 2004, and Dennis and Wilma in 2005[39,41,42] (Fig. 4b, Fig. 5). The storms affected Lake Okeechobee in several important ways relevant to the dynamics of HABs[17,18]. Exceptionally high rainfall resulted in large inflows of nutrient-rich water to the lake from its watershed, as evidenced by large increases in dissolved inorganic nitrogen and soluble reactive phosphorus in the lake (Fig. 4b). The increases in dissolved inorganic nitrogen may have been particularly important since the lake is more prone to nitrogen-limiting conditions for phytoplankton production than phosphorus limitation[43,44]. High winds associated with several of the hurricanes in 2004 caused intense re-suspension of muddy flocculent lake bottom sediments, resulting in high total suspended solids concentrations (Fig. 4c) and low light availability for primary production (i.e. Secchi depths less than 30 cm), as well as a potential for introduction of additional nutrients associated with bottom sediments[39,45,46]. The response of the phytoplankton community to the enhanced inorganic nutrient concentrations was not realized until the summer of 2005 (Fig. 4c), when total suspended solids concentrations declined significantly, providing the additional light necessary to support high phytoplankton production and biomass[17,44,47]. A major lake-wide bloom was observed on the lake in July-August 2005, as evidenced by satellite imagery (Fig. 4a), coinciding with a rapid decline in DIN (Fig. 4b), which reflects the high demand for inorganic nitrogen during blooms (Fig. 4b).

During the major 2005 HAB event in Lake Okeechobee, water levels in the lake were high due to excessive rainfall from the multiple hurricane events. Unlike most natural lake ecosystems, Lake Okeechobee is entirely contained within a man-made dike (i.e. Hoover Dike), built in the early 1900's to prevent flooding in south Florida[48]. The U.S. Army Corps of Engineers is tasked with maintaining specific water levels in the lake to avoid breaching of the dike[49]. However, as an ecosystem with restricted outflows, Lake Okeechobee is characterized by long water residence times, i.e. 3.5 years[50], which enhance the potential for intense HABs, particularly during periods of high external nutrient loads. In the summer of 2005, water levels reached a critical threshold, mandating large releases of water into the St. Lucie Canal, which discharges into the South Fork region of the St. Lucie Estuary (Fig. 1). Discharge rates went up significantly following the hurricane events (Fig. 5)[51]. The high releases in July and August 2005 coincided with a major cyanobacteria bloom in the lake (Fig. 4a), resulting in large influxes of cyanobacteria biomass into the estuary, as evidenced by the cyanobacteria peak in the St. Lucie Estuary (Fig. 2a,b). The biomass was dominated by the toxic freshwater species *Microcystis aeruginosa*, with peak average chlorophyll *a* concentrations observed in the water column of 166 µg L^{-1}, and peak surface scum layer values up to 2,863 µg L^{-1} [39]. The cyanobacteria bloom was also associated with concentrations of the hepatotoxin microcystin in excess of 1,000 µg L^{-1} in surface water grab samples[39], which greatly exceed the World Health Organization guidelines for drinking water and recreational exposure, i.e. 1 µg L^{-1} and 10 µg L^{-1} microcystin, respectively[52,53]. During the discharge period, salinities in the inner half of the estuary were near freshwater levels (Fig. 2c), providing an environment conducive to the survival and continued growth of the toxic algae. The relationship between freshwater discharges from Lake Okeechobee and *Microcystis aeruginosa* blooms in the St. Lucie Estuary highlights how hurricanes can indirectly increase freshwater bloom potential in estuaries with strong connections to human-impacted eutrophic freshwater systems.

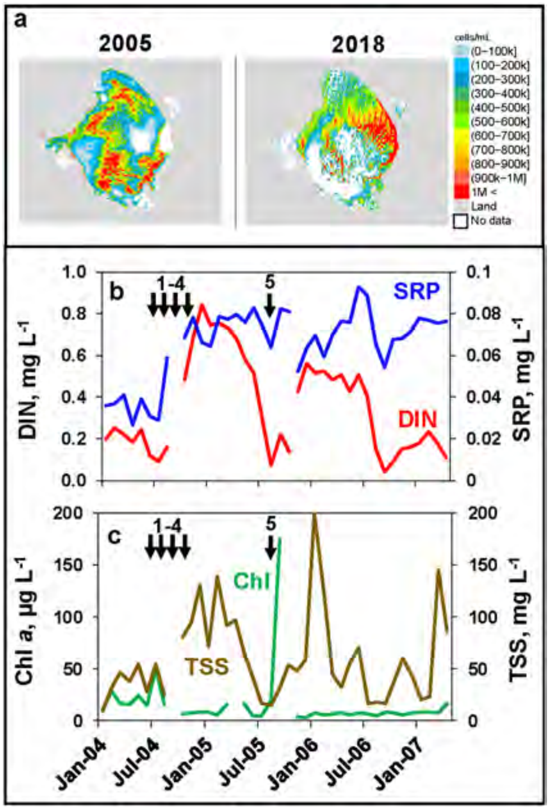

Figure 4. Cyanobacteria concentrations derived from weekly satellite imagery composites of Lake Okeechobee in 2005 (August 13–26) and 2018 (July 1–7) during periods of cyanobacteria blooms in the St. Lucie Estuary (**a**). Dissolved inorganic nitrogen and soluble reactive phosphorus (**b**), chlorophyll *a* and total suspended solids (**c**) concentrations in Lake Okeechobee. Values are means for Sites LO1 and LO2. Arrows indicate the timing of hurricanes that affected south and central Florida in 2004 and 2005.

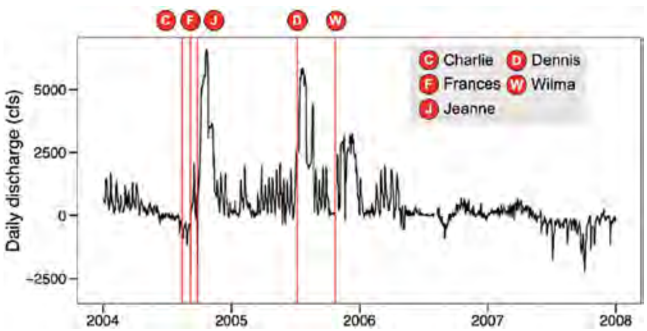

Figure 5. Daily discharge rates from Lake Okeechobee via the St. Lucie Canal. The timing of five hurricane events that impacted the Like Okeechobee region in 2004 and 2005 are shown on the figure.

Intense toxic freshwater cyanobacteria blooms in the St. Lucie Estuary associated with federally-mandated flood control discharges from Lake Okeechobee have been a recurring phenomenon[17,18,39,45,54]. Hurricanes enhance the potential for blooms by elevating nutrient loads to the lake from the watersheds north and west of the lake, which in combination with long water residence times and mandated discharge from the lake, create a "perfect storm" of conditions for the potential introduction of intense HABs into the estuary. Most recently these conditions have led to re-occurrence of intense cyanobacteria blooms in the St. Lucie estuary in 2016 (Fig. 6) and 2018[18,45,54]. As in 2005, both bloom events occurred during a three-year period of strong tropical storm activity in the Lake Okeechobee region, including hurricanes Joaquin and Erika in 2015, Colin, Julia and Mathew in 2016, and Emily and Irma in 2017. The HAB event in Lake Okeechobee in 2018 is shown in a satellite image of Lake Okeechobee taken during the peak of the freshwater HAB blooms in the St. Lucie Estuary (Fig. 4a).

Figure 6. HAB picture of *Microcystis aeruginosa* bloom in the St. Lucie Estuary in 2016 (All Rights Reserved, © p77/ZUMA Press).

Indian River Lagoon. For the Indian River Lagoon ecosystem, a long-term continuous 20-year time-series of phytoplankton composition and biomass dating back to 1997 provides an opportunity not only to examine hurricane effects, but also more general trends in climatic effects on HABs. The northern Indian River Lagoon has repeatedly experienced intense HABs since 1997 (i.e. >2 µg carbon mL^{-1}, or roughly equivalent to >30–50 µg chlorophyll a L^{-1}) (e.g. Fig. 7a), as illustrated by the time-series at Site IRL1 (Figs. 1 and 7b, Supplemental Fig. S3). One of the trends in the time series is the positive relationship between rainfall and peaks in phytoplankton biomass[14,55]. The trend is indicated by the positive linear relationship between bloom biomass peaks of the toxic dinoflagellate *Pyrodinium bahamense* and rainfall prior to the blooms ($R^2 = 0.45$, Supplemental Fig. S4). *P. bahamense* is one of the dominant bloom-forming HAB species in the Indian River Lagoon (Fig. 7b, Supplemental Fig. S3), and a major HAB species in other Florida ecosystems and many tropical ecosystems around the world[56,57]. One of the important cyclical phenomena that affects rainfall in central Florida is El Niño/La Niña periods. El Niño periods are often characterized by higher rainfall than La Niña periods (Fig. 8), particularly during the dry season (i.e. Nov.-April)[58,59]. A comparison of the temporal records of *P. bahamense* biomass and El Niño/La Niña periods (expressed as Multivariate ENSO Index: MEI) further demonstrates the relationship between peak *P. bahamense* biomass and high rainfall El Niño periods (Fig. 7c). The relationship is functionally tied to the positive relationship between nutrient concentrations and rainfall[14,56]. External nutrients enter the northern Indian River Lagoon from a variety of sources, including surface water runoff, groundwater discharge, direct rainfall inputs, septic system leakage, and permitted and accidental releases from sewage treatment systems[60–65]. All of these processes can be enhanced by high rainfall, although the relative importance of the sources can vary by nutrient type. For example, atmospheric contribution to non-point source nitrogen loads are significantly greater (i.e. 32–53%) than for phosphorus loads (i.e. 4–13%) (Gao 2009).

Beyond the general effects of elevated rainfall and nutrient loads on HAB potential, hurricanes can exacerbate the effect in several other ways, as observed in Lake Taihu, China[13]. Intense winds can impact nutrient concentrations through sediment re-suspension and re-mineralization of nutrients from damaged aquatic vegetation (e.g. seagrasses) and damaged terrestrial biomass in the watershed which can potentially be transported into the estuary. Because of long water residence times in the northern Indian River Lagoon (i.e. E_{50} of 100–200 days, 50% half water turnover rates) storm impacts can extend for months. For example, the effects of storm events in July-October (i.e. peak period for tropical activity) can have both short-term and long-term impacts, including elevated nutrient concentrations which can extend into the following year. The phytoplankton biomass time-series for Site 1 in the northern Indian River Lagoon provide an example of the latter phenomena (Fig. 7b. Supplemental Fig. S3). The tropical storm seasons of 2005, 2015 and 2017 all had storms with high rainfall totals[66]. All three years were associated with significant increases in nutrient concentrations (Supplemental Fig. S5) and HABs blooms in the following years, i.e. 2006, 2016 and 2018 (Fig. 7b, Supplemental Fig. S3). In 2006, the bloom involved the toxic dinoflagellate *P. bahamense*[14,56]. In 2016 and 2018, the bloom events also involved the brown tide species *Aureoumbra lagunensis*, as well as other nanoplanktonic eukaryotic algae (Fig. 7a,b, Supplemental Fig. S3)[66].

The dramatically higher bloom biomass peaks in 2016 and 2018 relative to 2006 are the result of a shift in the intensity of blooms that began in the northern Indian River Lagoon in 2011[14]. The shift also involved significant changes in the structure of the ecosystem, such as widespread and major losses of seagrass communities, which may have intensified the response of the phytoplankton community to external and internal nutrient loads[14,66]. It is also possible that high winds associated with storms in 2015 and 2017 contributed to the persistence of the shift by disrupting the stability of surface sediment layers, and limiting seagrass recovery. The trend toward more frequent and intense blooms may be further accentuated if future storms and El Niño become more frequent and are associated with higher rainfall totals, as predicted by some climate models, which tie future increases in ocean water temperatures to increases in atmospheric water content[4–6,67,68]. In this context, the added dimension of temperature increases add up to a triple threat for bloom development, i.e. by enhancing nutrient loads, increasing algal growth rates and promoting dominance by cyanobacteria and other HAB species[1,3,68–71].

Direct versus indirect impacts. The two estuaries highlighted in this study illustrate how the impacts of hurricanes and El Niño periods on HABs not only depend on direct effects on nutrient loads that drive blooms, but also differences in the structure and function of individual ecosystems, such as water residence time, flushing rates, as well as indirect (i.e. allochthonous) introduction of blooms from the watershed. For ecosystems with

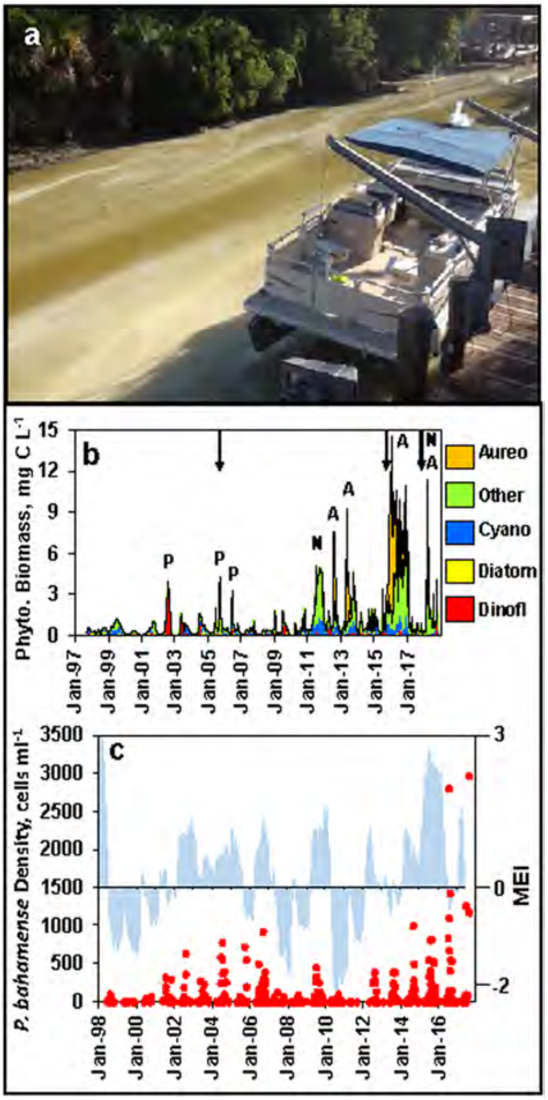

Figure 7. Brown tide event in the northern IRL dominated by *Aureoumbra lagunensis* (**a**, photo by permission from Kelly Young, Volusia County Environmental Management), and phytoplankton biomass for Site IRL1 in the IRL (**b**), divided into four major groupings, i.e. dinoflagellates, diatoms, cyanobacteria, *A. lagunensis* (Aureo) and all "other" taxa (letter above major bloom peaks indicate the dominant species in terms of biomass: i.e. A – *A. lagunensis*, N – unspecified nanoplanktonic eukaryotes, P – *P. bahamense*). Arrows show timing of hurricane/storm events. Panel 'c' *Pyrodinium bahamense* cell densities (red markers) and Multivariate ENSO Index (MEI) (blue) from 1998 to 2017 throughout the northern IRL.

long water residence times and shallow depths, like Lake Okeechobee and the northern Indian River Lagoon, enhanced watershed nutrient loads caused by hurricane and El Niño-related rainfall can directly enhance the potential for autochthonous HAB events. Physical disturbance of sediments by storm events can also enhance internal nutrient loads, as observed in Lake Taihu, China[13]. Similar observations have been made in Florida Bay, a restricted estuary on the southern tip of the Florida peninsula. Three hurricanes impacted Florida Bay in 2005 (i.e. Katrina, Rita and Wilma), resulting in transport of nutrient rich sediments into the eastern bay, increased nutrient load from the bay's watersheds and destruction of mangrove habitat. The hurricane period was followed by intense marine picoplanktonic cyanobacteria blooms from 2005–2008, in part aided by the very long water residence times in the bay[31,72,73].

By contrast, the St. Lucie Estuary presents a different picture, in part because of the shorter and more variable water residence times (i.e. 1–16.5 days)[19,39], and the linkage to bloom-prone Lake Okeechobee. As a result, the greatest potential for autochthonous marine algal blooms occurs during periods of comparatively low rainfall, watershed discharge and nutrient levels, but longer water residence times which permit the accumulation of phytoplankton biomass. Conversely, periods of high rainfall, watershed discharge and nutrient inputs from the watershed can be associated with lower peak phytoplankton biomass levels due to short water residence times. Similar relationships have been observed in two other ecosystems in Florida, the Guana, Tolomato, Matanzas estuary[41,74,75] and Lake George[17,76]. In both ecosystems the strong hurricane seasons of 2004 and 2005 yielded

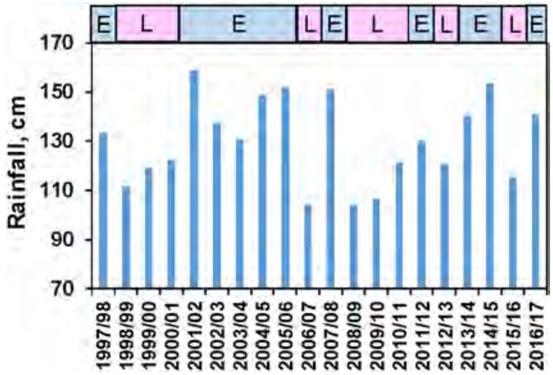

Figure 8. Annual rainfall totals at the NOAA meteorological station at Titusville, Florida, located near Site IRL1 in the northern IRL (www.ncdc.noaa.gov/IPS). The annual values are based on the 12-month period from November-October of each period. Letters in boxes above the figure represent time periods with predominantly El Niño ('E') or La Niña ('L) conditions, based on Multivariate ENSO Index (MEI).

reduced peaks in phytoplankton biomass due to reduced water residence times, despite elevated concentrations of nutrients. The exception to this trend in the St. Lucie Estuary is high rainfall periods associated with high discharges from Lake Okeechobee during intense freshwater HAB events in the lake, leading to freshwater HABs of allochthonous origin in the estuary[18,39]. Similar relationships have been observed in other estuaries[77], such as the Caloosahatchee estuary in Florida[78] and San Francisco Bay[79].

Potential impacts of hurricanes and El Niño periods on HABs are not limited to coastal estuaries and inland lakes, but can extend into nearshore and open ocean environments, particularly in shallow shelf regions. The potential is illustrated by the intense red tide event experienced along the southwest coast of Florida in the summer of 2018[77,80–82]. The toxic dinoflagellate bloom, dominated by *Karenia brevi*s, extended over a broad reach of the inner shelf near several major freshwater outflows from the watershed, including large inputs from the Caloosahatchee River. The red tide resulted in serious impacts to aquatic animal and human health, as described for earlier red tide events in the region, including mass mortalities of marine animals and human health impacts related to exposure to aerosolized neurotoxins produced by *K. brevis* (i.e. brevetoxin)[81,83]. As in the case of the St. Lucie estuary, the Caloosahatchee River was subject to large discharges from Lake Okeechobee in response to the strong hurricane season in 2017 and high rainfall in the spring of 2018. Recent research has shown that periods of high discharge result in significant elevation of nutrient levels in the estuary[82]. It may be hypothesized that such discharges contribute to the nutrient supplies that support red tide events, such as the event observed in 2018[82], highlighting the need for further research on land-sea interactions in relationship to coastal blooms.

Irrespective of the origin of HAB events, they can be disruptive to ecosystem structure and function in many ways, including production of toxins, promotion of hypoxic conditions, shading out of benthic primary producers (e.g. seagrasses) and alteration of food web dynamics[84]. Depending on the species involved, HABs can also pose threats to human and animal health, particularly as it relates to toxin exposure[52,53,81,83,85]. Beyond these direct harmful effects, there are indirect side effects to HAB phenomena, which can have important economic and life-style consequences[86,87]. Except for some inquisitive and committed phycologists, most people find the types of intense algal scums encountered in the St. Lucie Estuary (Figs. 2a and 5) and Indian River Lagoon (Fig. 7a) disturbing and undesirable, leading to impacts on tourism, recreational use and property values. In a sense, the visual imagery of these blooms sends a strong message on the sensitivity of aquatic ecosystems to changes in the environment related to human activities, including cultural eutrophication, hydrological alteration and climate change. These are multi-dimensional problems requiring multi-dimensional solutions based on a clear ecosystem-specific understanding of driving factors and consequences of HABs. The results of this study highlight the important roles that both stochastic (e.g. hurricanes and storms) and cyclical (e.g. El Niño/La Niña patterns) climatic processes can play in HAB dynamics. The anticipated future progressive changes in cultural eutrophication and global climatic conditions, if left unaddressed, will likely exacerbate existing weather-driven HAB instigations. The ecosystems included in this study are exemplary of many subtropical environments which are sensitive to climate changes due to their position in the transition between temperate and tropical environments, as well as high frequency of exposure to tropical storms. Many sub-tropical/tropical regions around the world are also subject to rapid population growth and development, heightening the challenges associated with cultural eutrophication.

Data availability

The data used in this paper were obtained from the South Florida Water Management District for Lake Okeechobee. Nutrient data were obtained from St. Johns River Water Management District for the Indian River Lagoon (Palatka, Florida), as part of project data reporting requirements and should be accessible from the respective Districts.

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Author contributions
Edward Phlips is the primary author of the paper, with contributions from the other three co-authors. Susan Badylak was the lead taxonomist in research of the IRL and St. Lucie estuaries. Natalie Nelson was the major contributor for the geospatial imaging and interpretation in the paper. Karl Havens provided the data and analyses for the Lake Okeechobee data presented. All four authors collaborated in the interpretation of data.

Competing interests
The authors declare no competing interests.

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Modeling residence time with a three-dimensional hydrodynamic model: Linkage with chlorophyll *a* in a subtropical estuary

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ABSTRACT

Residence time calculated with a three-dimensional hydrodynamic model was analyzed together with field measurements of chlorophyll *a* collected through long-term monitoring programs and synoptic-scale water quality mapping in the Caloosahatchee Estuary located in Florida, USA. Freshwater inflows to the estuary are highly managed at the head water control structure. A total of 14 freshwater inflow rates ranging from 0 to 283 $m^3 s^{-1}$ were simulated to represent the whole spectrum of hydrologic and water management conditions. Residence time, reported as the e-folding time, ranged from a few days to more than 60 days, depending on the magnitude of freshwater discharge and location in the estuary. The spatial heterogeneity of residence time indicated that there existed a zone in the estuary where water parcels reside for a longer period of time than in other areas of the estuary. The location of this “residence time maximum” zone progressed further toward the mouth of the estuary with increasing freshwater discharge. The location of peak chlorophyll *a* concentration along the longitudinal axis of the estuary as measured through long-term monitoring and synoptic water quality mapping, also fluctuated with freshwater discharge and coincided with the zone of maximum residence time. The results confirmed the fundamental role of freshwater inflow in the control of residence time and accumulation of phytoplankton biomass. The study helps elucidate how and where phytoplankton respond to freshwater inflows at the head of the estuary.

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1. Introduction

Fate and transport of pollutants in a coastal water body and their effects on the ecosystem involve complex physical, chemical, and biological processes that occur at varying spatial and temporal scales. Residence time is often considered as an important factor affecting these processes (Takeoka, 1984). In the literature, residence time has been documented to explain changes in pollutant concentrations and distributions of plankton in temperate rivers (Basu and Pick, 1996), climatic influences on autochthonous and allochthonous phytoplankton blooms in a subtropical estuary (Phlips et al., 2012), causes and ecological consequences of harmful algal blooms in U.S. Mid-Atlantic coastal waters (Bricelj and Lonsdale, 1997), spatial and temporal variations of dissolved nutrients in a lagoonal patch reef (Andrews and Muller, 1983), and high groundwater seepage rate and relatively good water quality condition of the Indian River Lagoon (Kim, 2003). Its importance as a physical attribute or “filter” to explain in part the diversity of phytoplankton responses to nutrient loading in estuaries has also been recognized (Nixon et al., 1996). Due to the spatially local nature of residence time, it is very useful in identifying and quantifying spatially heterogeneous phenomena and processes in sub-domains of estuaries and ecosystems (Aikman and Lanerolle, 2004). Boynton et al. (1995) further argued that residence time is a sufficiently significant concept that it could form a basis for comparative analyses of nutrient budgets in ecosystems.

Residence time has been traditionally measured through dye studies in the field or evaluated from a crude estimate with the ratio of the volume of the domain of interest to an outgoing flux. In most cases, it is impossible to estimate these timescales in a thorough way by using field data alone. Evaluating residence time as the ratio of volume over flow rate is a rudimentary approximation that is valid only for a steady state flow in a well-mixed domain. Box or tidal prism models are also used to calculate residence time of an estuary (e.g., Miller and McPherson, 1991); yet their weakness is well recognized for applications in heterogeneous estuarine systems (Sheldon and Alber, 2002). In the past couple of decades, with the advancement of sophisticated three-dimensional (3-D) numerical models, numerical simulations are able to provide spatially and temporally extensive flow-field information (for example, water density, temperature, salinity and velocity distributions). High-resolution hydrodynamic models can be used to achieve refined estimates of residence time for the computational regions of application and also to determine the physical

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factors affecting their values and spatial distributions (Aikman and Lanerolle, 2004; Shen and Haas, 2004; Huang, 2007; Shen and Wang, 2007).

The Caloosahatchee Estuary, located on the southwest coast of Florida, is a subtropical estuary that has been the subject of water quantity and water quality concerns since the 1950s. The Caloosahatchee River and Estuary are part of the larger Charlotte Harbor system and have been highly modified over time. The Caloosahatchee River runs 67 km from Lake Okeechobee to the Franklin Lock and Dam (S-79). S-79 separates the freshwater river from the estuary that terminates 42 km downstream at Shell Point (Fig. 1). The Caloosahatchee River has been straightened, deepened, and three water control structures have been added. The last, S-79, was completed in 1966 in part to act as a salinity barrier. The River has been artificially connected to Lake Okeechobee to convey regulatory releases of water to tide to control water level in the Lake. The estuarine portion of the system has also been modified. Seven automobile bridges and one railroad bridge connect the north and south shores of the estuary. A navigation channel has been dredged and in the 1960s a causeway was built across the mouth of San Carlos Bay. Historic oyster bars upstream of Shell Point have been mined and removed for road construction. Tidal range measured at the mouth of the estuary is about 0.8 m. The estuary has a mean water depth of 2.6 m and a surface area of about 63 km^2.

The freshwater inflow to the estuary is highly managed with a high seasonal variance as a result of alterations in the watershed and connection to Lake Okeechobee. During the wet season, extremely high flows, especially releases from Lake Okeechobee, can drive the entire system fresh, causing mortality of marine organisms in the lower estuary and San Carlo Bay. By contrast, the lack of flows during the dry season can allow salt water to intrude up to the head of the estuary at S-79, sometimes reaching 20 psu. Salinity at this high level causes mortality of brackish water organisms that normally inhabit this area (Chamberlain and Doering, 1998). Freshwater flushing is an important mechanism accounting for estuarine mixing and water quality changes in the Caloosahatchee Estuary. Doering et al. (2006) reported that chlorophyll *a* responds to both nutrient loading and freshwater discharge at S-79. There is some evidence that freshwater discharge may modulate or "filter" the response of chlorophyll *a* through a 'wash out' effect. Tolley et al. (2010) also indicated that location and composition of phytoplankton shifted with changing inflow. Under low flows (<28 $m^3 s^{-1}$), larger phytoplankton (diatoms) grow in the upper estuary. Higher flows support growth farther downstream in the lower estuary and are accompanied by an increase in smaller cells (predominately cyanobacteria).

The objective of this paper is to examine the residence time of the Caloosahatchee Estuary calculated with a 3-D hydrodynamic model together with field measurements of chlorophyll *a* collected through long-term monitoring programs and synoptic-scale water quality mapping under varying inflow conditions. The hypothesis presented here is that along the longitudinal direction of the estuary there exists a zone or area where water parcels reside for a longer period of time than in other areas of the estuary. This local "residence time maximum" zone facilitates the growth and accumulation of phytoplankton biomass, thereby determines the location of the chlorophyll *a* concentration maximum in the estuary.

2. Calculation of residence time

2.1. Definition of residence time

While detailed discussion of definition and theory related to residence time has been provided by several workers (e.g., Zimmerman, 1976, 1988; Takeoka, 1984), a variety of terms, such as flushing time, residence time, turnover time, and age of water, are used to describe time scales for transport and removal of materials, and sometimes their calculations do not always use consistent methods. Thus, uses of residence time need clarification to identify the underlying assumptions in the application to avoid misinterpretation or incorrect comparisons of data (Monsen et al., 2002). In this study, a definition similar to Zimmerman (1976) was used: residence time is the time for a certain water mass to remain in a defined region before exiting or the time needed to replace this water mass in that region. The only difference is that Zimmerman (1976) uses a single water particle and we use water mass or a group of particles. The defined region can be the entire estuary or an arbitrarily defined location in the estuary. The defined water mass needs to be identified and separated from any other water masses in the model domain. A traditional way to do this is to use passive or conservative tracers (Deleersnijder et al., 2001; Shen and Haas, 2004; Cucco and Umgiesser, 2006). A concentration of a constant constituent (C_0) is assigned to the defined water mass and zero (0) concentration is assigned to all other water masses. The governing equation for the tracer is the advection diffusion equation in a 3-D form:

$$\frac{\partial c(t,x,y,z)}{\partial t} + v\nabla c(t,x,y,z) = \nabla(D\nabla c(t,x,y,z)) \quad (1)$$

where $c(t,x,y,z)$ is the tracer concentration, v is the velocity field, D is the diffusivity tensor, t is time, and x,y,z define the spatial location. The boundary condition for the tracer was set to zero for all open boundaries including ocean and river boundaries. The initial condition is:

$c_{t=0} = c_0$ for the defined region

$c_{t=0} = 0$ for any other area

The decay of the concentration follows the remnant function of Takeoka (1984) such that $r(t,x,y,z) = c(t,x,y,z)/c_0$. The residence time τ can then be defined as (Takeoka, 1984),

$$\tau = \int_0^{\infty} r(t)\, dt \quad (2)$$

and for every position x, y, z of the domain as:

$$\tau(x,y,z) = \int_0^{\infty} r(x,y,z,t)\, dt \quad (3)$$

If the average concentration for the defined region or at a particular location decreases exponentially with time t such that:

$$\bar{c} = c_0\, e^{-t/T_r} \quad (4)$$

then residence time is the time $t = T_r$, and thus $\bar{c}/c_0 = e^{-1}$, i.e., the average concentration to be reduced to $e^{-1} = 1/2.7$ or 37% of the initial concentration. This time, also called the e-folding time, is a widely used concept to quantify residence time (e.g., Takeoka, 1984; Cucco and Umgiesser, 2006). From this definition it is easy to see that residence time is a function of the location of the defined region and factors affecting flushing such as freshwater discharge.

2.2. The Caloosahatchee Estuary 3-D hydrodynamic model

We used a three-dimensional estuarine hydrodynamic model, based on the curvilinear hydrodynamics three-dimensional code (CH3D), to calculate the residence time. The Caloosahatchee CH3D model has been developed to simulate the hydrodynamics and salinity distribution within the Caloosahatchee Estuary (Qiu et al., 2007). CH3D uses a horizontally boundary-fitted curvilinear grid and vertical sigma grid system capable of simulating complicated hydrodynamic processes including wind-driven, density-driven,

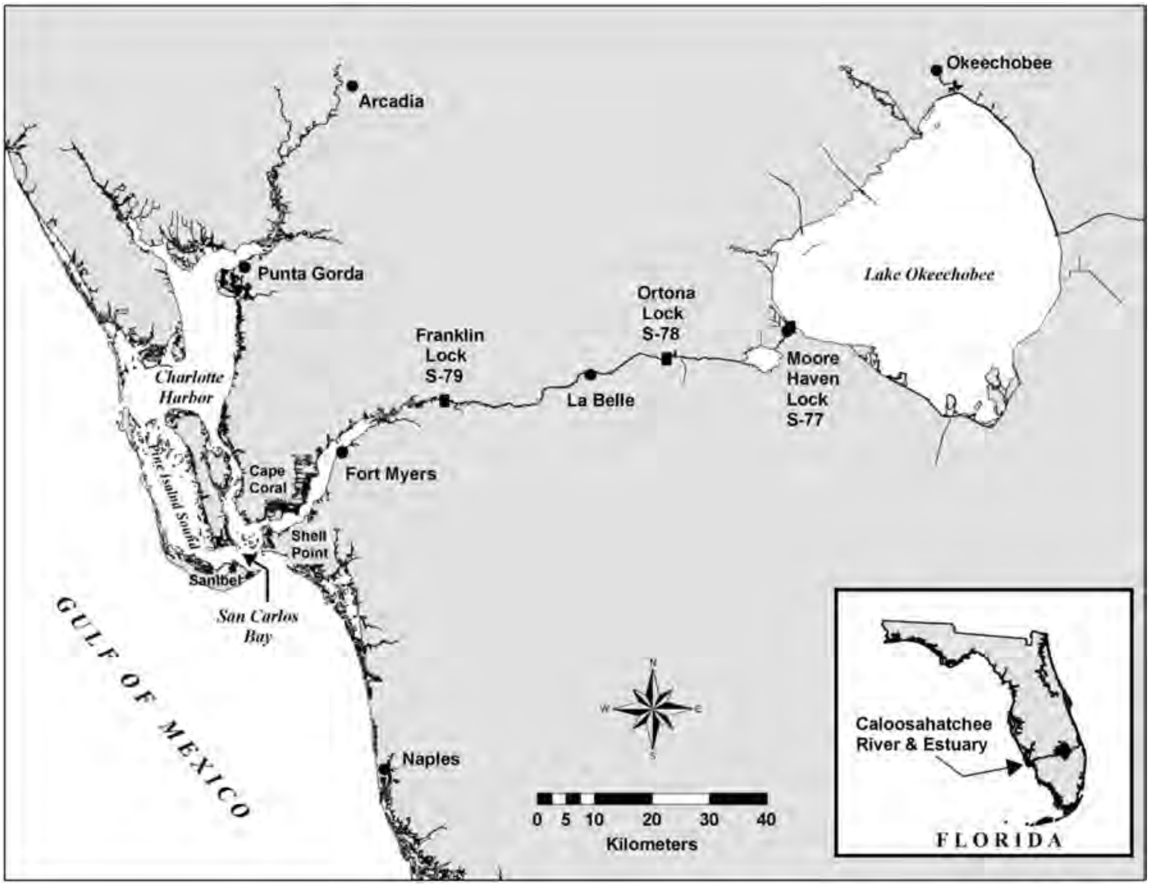

Fig. 1. Location of the Caloosahatchee Estuary.

and tidal circulation. The model contains a robust turbulence closure scheme for accurate simulation of stratified flows in estuaries and lakes (Sheng, 1986, 1987, 1990; Sheng and Villaret, 1989). Detailed derivation of the turbulence closure can be found in Sheng (1986, 1987); Sheng and Villaret (1989), and an abbreviated version is provided in the appendix. The non-orthogonal nature of the model enables it to represent the complex geometry of an estuary such as the Caloosahatchee. The model is driven by external forcing prescribed at the boundaries, including tidal forcing at the ocean boundary, freshwater inflow from controlled structures and runoff from the watershed, and meteorological forcing including wind and rainfall.

The model domain covers the Caloosahatchee Estuary, Charlotte Harbor, Pine Island Sound, San Carlos Bay, Estero Bay, and all the major tributaries (Fig. 2a). The fine model grid permits the representation of the numerous islands, including the islands of the Sanibel Causeway and Estero Bay. Vertically, five evenly spaced sigma-layers enable simulation of vertical stratification within the estuary. The original model development of CH3D in Charlotte Harbor and adjacent areas began in 1999 for the Charlotte Harbor National Estuary Program (Sheng, 2001). The South Florida Water Management District (SFWMD) extended the model calibration to the Caloosahatchee Estuary portion using a 16-month time series (Qiu, 2003). In 2005, the Caloosahatchee portions of the model were calibrated with three years of measured data (2001–2004) from 5 stations in the Caloosahatchee Estuary (Qiu, 2006). Recently, the calibration of the model was further refined using newly collected salinity and tide data (up to March 2011) at 7 stations in the Caloosahatchee Estuary (Fig. 2b). All the salinity and tide data used for model calibration were collected electronically every 15 min. The updated salinity calibration results expressed as the goodness-of-fit parameters including R^2, the root mean square error (RMSE), and the relative RMSE (RRE) were summarized in Table 1. The values of these parameters showed improvement over previous calibrations (Qiu, 2006).

2.3. Computation of residence time using the CH3D model

Using the Caloosahatchee Estuary CH3D model, we conducted a total of 14 simulations to calculate resident time. These simulations represented 14 freshwater inflows ranging from 0 to 283 $m^3 s^{-1}$. This flow range covers the full spectrum (magnitude and frequency) of hydrologic conditions in the watershed and water management operations at S-79 (Table 2). The particular scenario with no S-79 discharge, often occurs during the winter dry season and was included to represent the case when flushing is primarily driven by tides. Flows less than about 14 $m^3 s^{-1}$ typically occur in the dry season. Flows at this low level do not maintain the full salinity gradient (0–35 psu) in the estuary. At flows greater than about 79 $m^3 s^{-1}$, salinity declines in the lower estuary impacting marine seagrasses and oysters typical of this area. Flows greater than 127 $m^3 s^{-1}$, which are typically associated with flood control releases from Lake Okeechobee, lower salinity sufficiently in San Carlos Bay to impact seagrasses there (Chamberlain and Doering, 1998).

In each simulation, a conservative tracer with a concentration of 100 (arbitrary unit) was assigned to the estuary (from S-79 to Shell Point) as the initial condition. Zero concentration was set for any other areas in the model domain. The tracer-based methods have been employed by other workers such as Miller and McPherson (1991), Shen and Haas (2004), and Cucco and Umgiesser (2006). Freshwater inflows to the estuary were imposed at S-79. Tide data

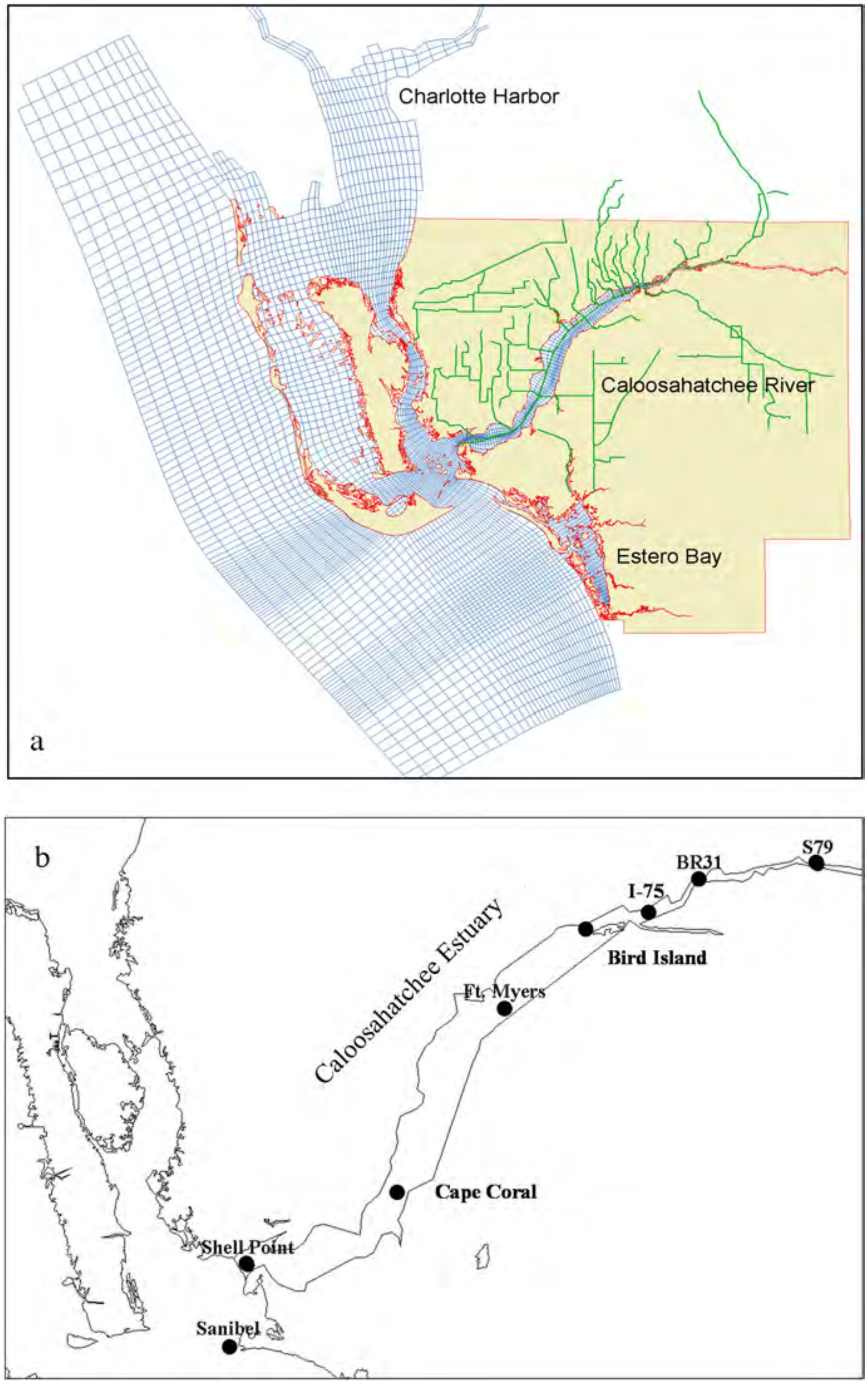

Fig. 2. The Caloosahatchee Estuary 3-D hydrodynamic model: (a) model domain; (b) monitoring stations maintained by the SFWMD.

collected offshore of Naples Bay were used as the tidal boundary condition. The simulation period spanned from 2/1/2000 to 9/30/2000 and was long enough for the model to achieve dynamic equilibrium.

Tracer concentrations were averaged to derive the e-folding time. For simplicity of discussion, two "residence time" terminologies were developed. Following Miller and McPherson (1991), estuary residence time (ERT) was used to describe resident time of the estuary as a whole entity. Since we were also concerned with the transport time scale at a particular location in the estuary, transect residence time (TRT) was introduced to evaluate residence time at the local scale as opposed to ERT of the entire estuary. TRT was defined as the time needed for the concentration across a specific transect perpendicular to the river flow to reach 37% of its initial value. Transects examined in the model were placed at the locations in the estuary were the SFWMD has traditionally monitored salinity and biological resources (Fig. 2, Chamberlain and Doering, 1998).

Due to tidal influence, the time to reach 37% of the initial concentration was not readily discernible as tracer concentrations could oscillate around the 37% of the initial concentration for several tidal cycles. To smooth this tidal effect, hourly concentration data were processed as a daily moving average to derive residence time. Regression analyses were conducted between residence time and freshwater inflow rate for curve fitting of the data.

Table 1
Goodness-of-fit statistics of salinity calibration of the Caloosahatchee Estuary CH3D model.[a]

Location	Layers	R^2	RMSE (psu)	RRE (%)	Data period
S-79	Top	0.89	2.19	8.47	Jan. 1992 to March 2011
	Bottom	0.86	1.97	7.18	
BR31	Top	0.90	1.61	6.83	Jan. 1992 to March 2011
	Bottom	0.82	2.50	10.22	
I-75	Top	0.90	2.12	8.44	Dec 2005 to March 2011
	Bottom	0.90	2.35	9.11	
Ft. Myers	Top	0.92	2.35	8.36	Jan. 1992 to March 2011
	Bottom	0.89	2.82	9.86	
Cape Coral	Top	0.94	2.09	6.34	Aug. 2002 to March 2011
	Bottom	0.94	2.72	8.09	
Shell Point	Top	0.83	3.92	9.49	Jan. 1992 to June 2002 and Jan. 2005 to March 2011
	Bottom	0.78	4.00	9.60	

[a] The mathematical equations of these parameters are given below:

$$R^2 = \left[\frac{\sum_{i=1}^{n} (o_i - \bar{o})(p_i - \bar{p})}{\sqrt{\sum_{i=1}^{n} (o_i - \bar{o})^2 \sum_{i=1}^{n} (p_i - \bar{p})^2}} \right]^2$$

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (o_i - p_i)^2}{n}}$$

$$\mathrm{RRE} = \frac{\sqrt{\sum_{i=1}^{n} (o_i - p_i)^2 / n}}{o_{\max} - o_{\min}} \times 100$$

where n is the number of data point during the period of evaluation, O_i is the observed salinity, $\bar{O}$ is the mean of the observed salinity, O_{max} is the maximum value of observed salinity, O_{min} is the minimum value of observed salinity, P_i is the simulated salinity, and $\bar{P}$ is the mean of the simulated salinity.

3. Chlorophyll *a* data sets

The chlorophyll *a* concentration data were taken from two data sets. The first data set originated from six water quality monitoring programs either conducted or supported by the SFWMD. Descriptions of these monitoring programs are provided by Doering and Chamberlain (1998) and Doering et al. (2006). Briefly, the data set spanned from 1981 through 2003. All samples were taken within the top 0.5 m of the water column using a van Dorn, Kimmerer or similar bottle. All samples were stored on ice until their return to the laboratory. Chlorophyll *a* samples were filtered and analyzed spectrophotometrically in the laboratory within 24 h of collection. The effect of S-79 discharge on the longitudinal position of maximum chlorophyll *a* concentration in the estuary was examined as described by Doering et al. (2006).

The second data set was from a project that used a flow-through system to map water quality parameters along the Caloosahatchee Estuary (Ashton et al., 2012). The flow through system consists of an intake ram attached to the transom of a boat, a flow meter, Trimble Differential Global Position System, YSI 6600 multiparameter water quality instrument, bathymetric profiler and laptop computer with Streamline GEO software. The intake ram was set at 0.5 m depth and fitted with an in-line pump to ensure water flowed through the system when the boat was stopped or moving at low speeds. Mapping surveys commenced just downstream of S-79 and extended downstream to Shell Point. Fifteen fixed sampling stations were established. At each station, discrete water samples were taken for water quality analysis (including chlorophyll *a*) following the SFWMD's Standard Operating Procedures. Laboratory determination of chlorophyll *a* concentrations were used to calibrate in situ values of chlorophyll *a* reported in the field by the optical chlorophyll probe for all surveys. Individual linear regressions were calculated and run between laboratory and in situ chlorophyll *a* concentrations and applied as a correction to the in situ estimates of chlorophyll *a*. Boat speeds averaged 8 knots and each map survey took about 7–9 h. While close to twenty surveys were conducted during the dry season of 2012 and 2013, we selected three cruises in this paper to demonstrate the linkage between residence time and chlorophyll *a* in the estuary.

4. Results and discussion

4.1. Influence of freshwater inflows and location on residence time

Estuary residence time (ERT) decreased with increasing discharge at S-79, following a double-exponential decay function (Fig. 3). ERT was close to 60 days when there were no freshwater

Table 2
Magnitude and frequency of freshwater inflows used for residence time simulations.

Low flows		Medium flows		High flows		Extremely high flows	
($m^3\ s^{-1}$)	$P(Q\leq)$[a]	($m^3\ s^{-1}$)	$P(Q\leq)$	($m^3\ s^{-1}$)	$P(Q\leq)$	($m^3\ s^{-1}$)	$P(Q\leq)$
0	0.09	42	0.67	91	0.82	184	0.93
8	0.41	56	0.73	102	0.84	240	0.97
14	0.48	79	0.79	113	0.85	283	0.98
28	0.60			127	0.87		

[a] Probability of flow not exceeded, $P(Q\leq)$, is based on cumulative frequency distribution of daily flow record measured at S-79 from 1966 to 2012.

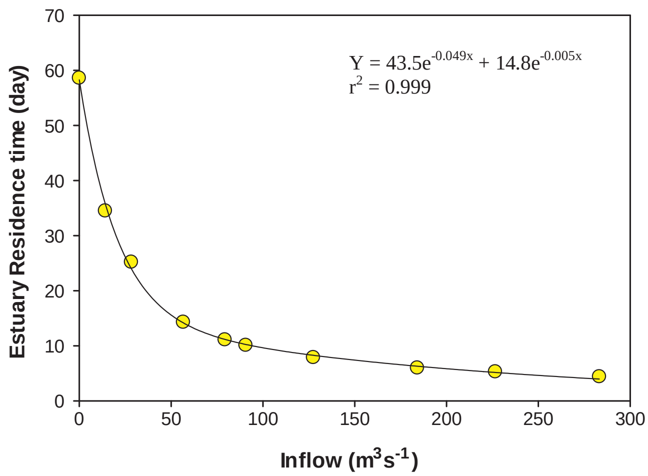

Fig. 3. Estuary residence time under varying inflows at S-79.

discharge, dropped to 14 days when S-79 discharge increased to 57 $m^3 s^{-1}$, and leveled off at 4–8 days when S-79 discharge was larger than 127 $m^3 s^{-1}$. At the local scale, the response of transect residence time (TRT) to varying freshwater discharges changed with locations (Fig. 4). For example, TRT dropped quickly from about 90 to 8 days at BR31 and from about 82 to 25 days at Ft. Myers when S-79 discharge increased from zero to 28 $m^3 s^{-1}$. At Cape Coral, TRT remained around 43 days when S-79 discharge was less than 14 $m^3 s^{-1}$, and dropped to about 10 days when S-79 discharge reached 127 $m^3 s^{-1}$. At Shell Point, TRT stayed around 3 days when S-79 discharge was less than 113 $m^3 s^{-1}$, but increased to 12 days at flow rates of 127 $m^3 s^{-1}$ and retreated to 8 days when flows were greater than 127 $m^3 s^{-1}$. This unusual increase of TRT is likely induced by tracers "washed off" from the upstream area of the estuary.

The varying response of TRT to freshwater inflows at different locations in the estuary can be understood in the context of two flushing forces: freshwater forcing and tidal forcing, acting together in transporting and removing materials from the system (Miller and McPherson, 1991; Wang et al., 2004; Sheldon and Alber, 2006). When there is no freshwater inflow at S-79, tide is the only flushing force. Tidal flushing is strongest at the inlet close to the ocean (Shell Point) and weakest immediately downstream of S-79 (Fig. 4). The influence of tidal exchange becomes weak as the tidal signals are attenuated. In contrast, freshwater flushing is strongest immediately downstream of S-79 but gradually decreases with increasing distance from S-79. The sharp drop in TRT with increasing S-79 discharge at BR31 (Fig. 4) is indicative of the predominance of freshwater flushing in the upper estuary. The higher the S-79 discharges, the further downstream the freshwater impact reaches. Such spatial variation in the relative influence of freshwater and tide on residence time were also noted by Miller and McPherson (1991) and Shen and Haas (2004). The fact that responses of ERT and TRT in the upper estuary to increasing freshwater inflows were both described by exponential decay functions suggested that the residence time of the entire estuary was controlled by a "bottle neck" effect of the upper estuary, particularly at lower flow conditions (<28 $m^3 s^{-1}$). Materials close to the estuary mouth can be quickly flushed out though tidal exchange. The geometry of the estuary also plays a role. The narrow channel (200 m) and small cross-sectional area (120 m^2) in the upper estuary enhances freshwater flushing compared with the wide channel (2500 m) and large cross-sectional area (5000 m^2) near the estuary mouth.

Because of this synergistic interaction between freshwater and tidal flushing, there can be an area or a zone in the estuary where conservative tracers or water parcels reside for a longer period of time than in areas immediately up or downstream. This is verified by the clear reversal pattern of TRT along the longitudinal axis of the estuary (Fig. 5). At a given flow rate, changes in TRT along the estuary transitioned from an upward slope to a downward slope. We introduce a concept called "residence time maximum" to describe this relative and local phenomenon. Specifically, when there was no S-79 discharge, the residence time maximum was located right downstream of S-79, the farthest area from the tidal impact. As S-79 discharges increased, freshwater flushing pushed the "residence time maximum" close to the area near Ft. Myers and then

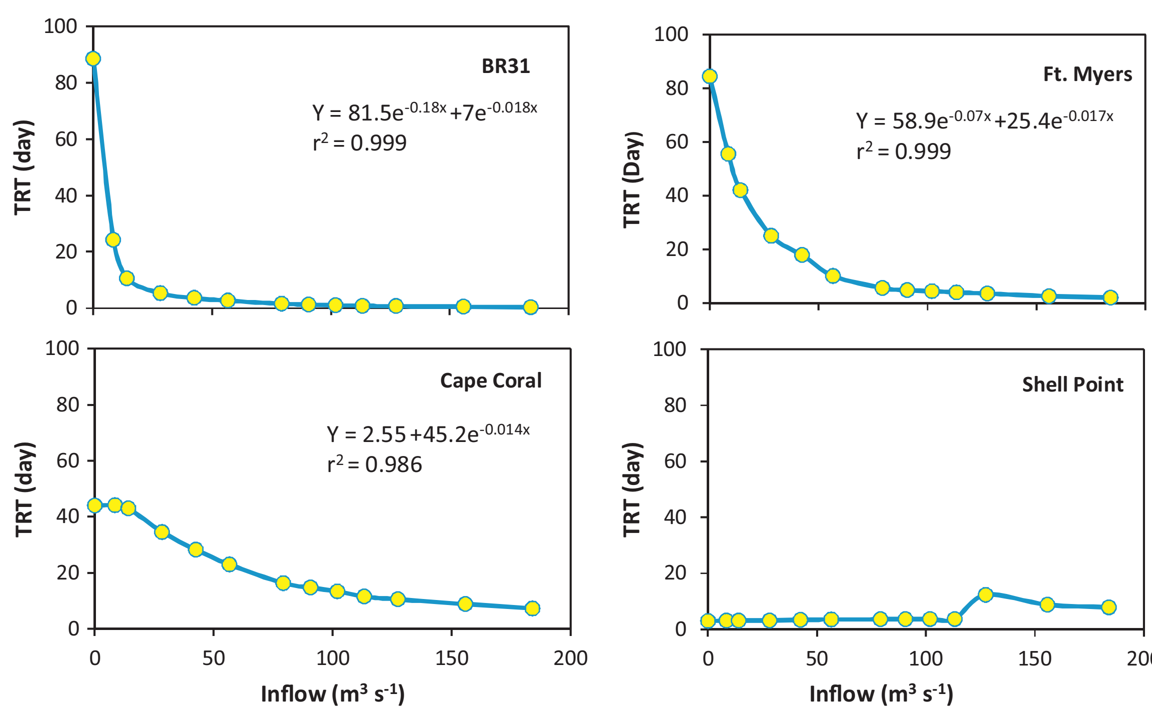

Fig. 4. Transect residence time at selected locations under varying inflows at S-79.

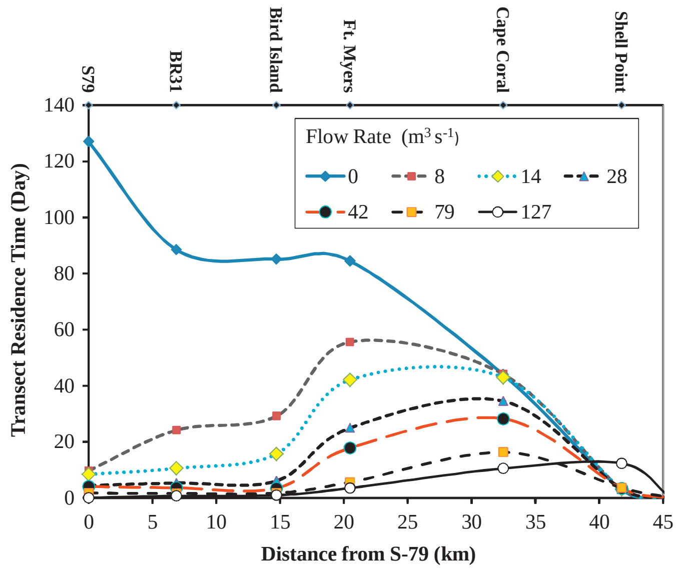

Fig. 5. Change of transect residence time in the longitudinal direction of the estuary.

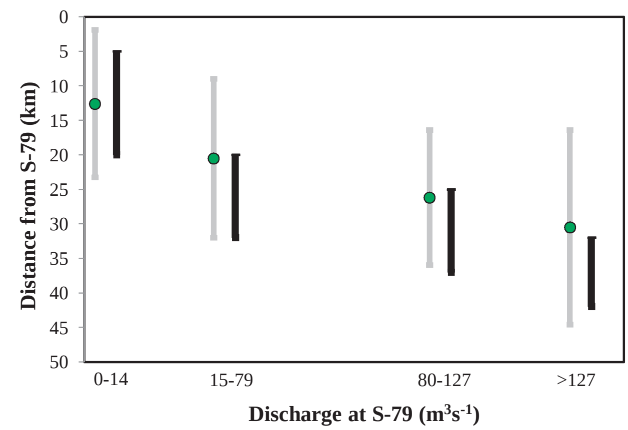

Fig. 6. Locations of chlorophyll *a* maximum concentration (dot with gray bar representing mean ± 1 standard deviation) reported by Doering et al. (2006) and the residence time maximum zone (black bar).

to Cape Coral. At flow rates greater than 28 $m^3 s^{-1}$, the location of residence time maximum continued to reside in this zone in spite of smaller TRT values. At the flow rate of 127 $m^3 s^{-1}$, TRT maximum moved to Shell Point, suggesting that at this high flow rate the transport of tracers from upstream outweighed that flushed out by tidal exchange.

4.2. Linking residence time maximum with spatial variation of chlorophyll a

This "residence time maximum" concept has important water quality implications as long residence time generally facilitates the growth and accumulation of phytoplankton biomass (Phlips et al., 2012). Field data collected in the Caloosahatchee Estuary indicated that the concentration of chlorophyll *a* increased with increasing discharge up to a maximum and then began to decrease (Doering et al., 2006). The location of the peak chlorophyll *a* concentration occurred in the upper estuary at low discharges and moved downstream as discharge increased. It was also note that the magnitude of the maximum chlorophyll *a* concentration decreased with increasing S-79 discharge (Doering and Chamberlain, 1998; Doering et al., 2006;). A similar correlation between the location of peak chlorophyll *a* and river discharge was also found by Sin et al. (1999) in the York River estuary, Virginia.

The location and magnitude of chlorophyll *a* concentration maximum observed by Doering et al. (2006) and Doering and Chamberlain (1998) in this estuary can be explained in part by the "residence time maximum" phenomenon shown in Fig. 5 though phytoplankton productivity can be affected by other factors such as availability of nutrients, light, temperature, and zooplankton grazing (e.g., Basu and Pick, 1996). Fig. 6 compares the location of the chlorophyll *a* maximum reported by Doering et al. (2006) and the location of "residence time maximum" identified in this study. Given the errors of the data, maximum accumulation of chlorophyll *a* coincides with the residence time maximum. The decreasing magnitude of the TRT maximum with increasing S-79 discharge (Fig. 7) is consistent with the decrease of the chlorophyll *a* maximum concentration with increasing S-79 discharge as observed by Doering and Chamberlain (1998). This reduced level of chlorophyll *a* concentration can be partly attributable to enhanced freshwater flushing at the high flow regime and thereby shorter residence time (Phlips et al., 2012). Welsh et al. (1972) also reported that freshwater discharge may modulate or "filter" the response of chlorophyll *a* through a 'wash out' effect.

To further elucidate the relationship between the accumulation of chlorophyll *a* and the location of residence time maximum, temporal changes of tracer concentrations at selected transects were examined (Fig. 7). Note that at the low flow regime (e.g., 8 $m^3 s^{-1}$), the highest concentration was present at Ft. Myers, consistent with the data presented in Fig. 6. This is also consistent with peak chlorophyll *a* concentrations observed in the upper estuary (Doering

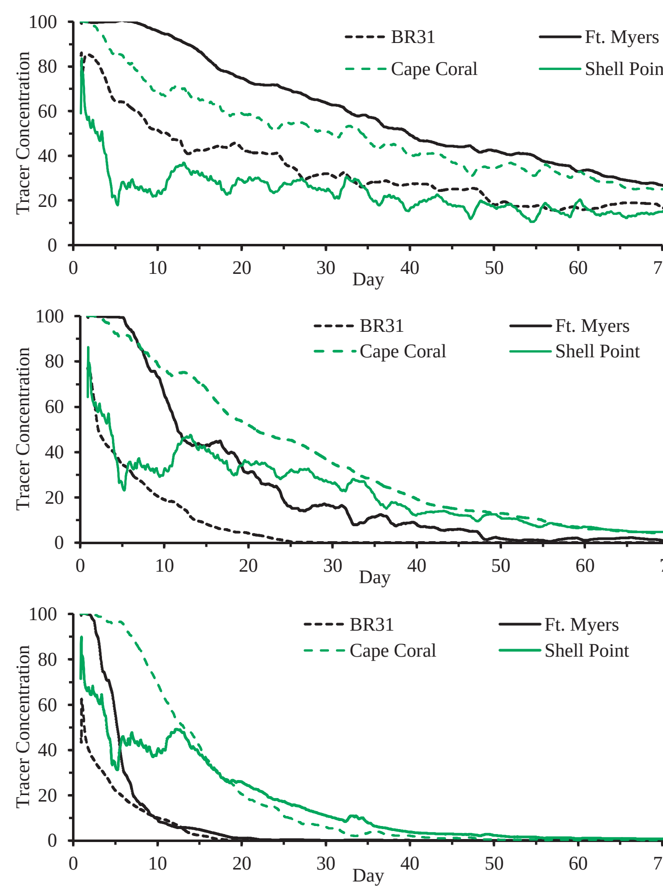

Fig. 7. Change of tracer concentrations (daily moving average) at selected transects in the estuary under the low flow (8 $m^3 s^{-1}$, upper panel), medium flow (42 $m^3 s^{-1}$, middle panel), and high flow (91 $m^3 s^{-1}$, lower panel) conditions.

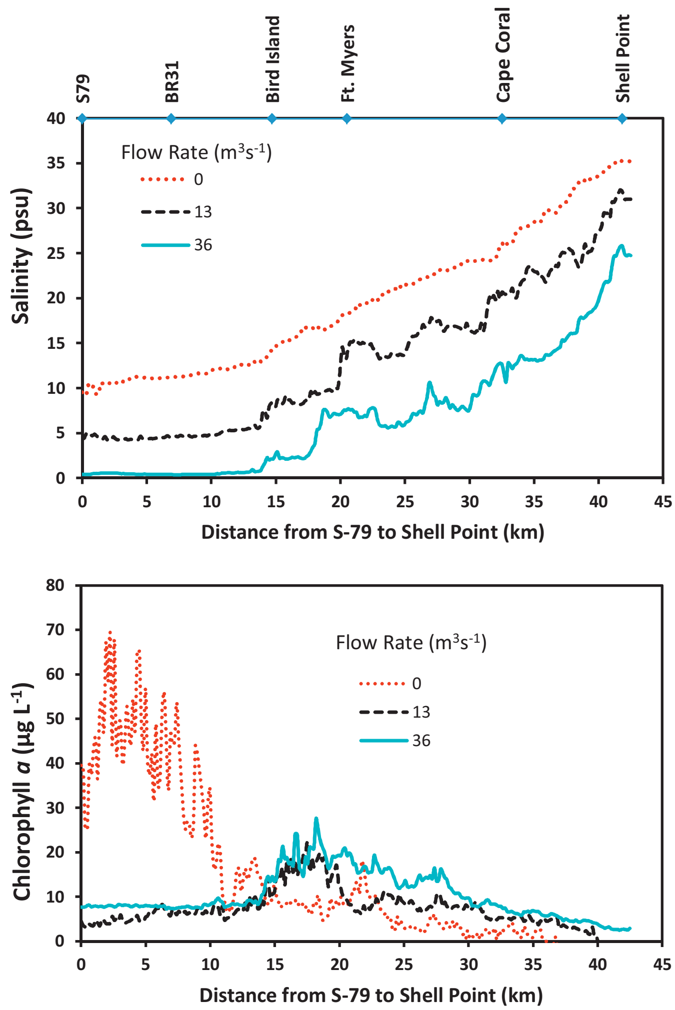

Fig. 8. Mapping surveys of salinity (upper panel) and chlorophyll *a* concentration (lower panel) in the Caloosahatchee Estuary under three inflows at S-79.

et al., 2006). Concentrations at upstream and downstream transects (BR31 and Shell Point) were lower because of stronger flushing by freshwater inflows and tide, respectively. At medium flow (e.g., 42 $m^3 s^{-1}$), concentrations dropped quickly at BR31 because of the increased freshwater flushing in the upper estuary. Concentrations at Cape Coral remained higher than at other transects. As S-79 discharge increased further (91 $m^3 s^{-1}$), concentrations dropped rapidly at BR31 and Ft. Myers with the maximum concentration located at Shell Point 20 days after the simulation. The location of concentration maximum moved downstream as S-79 discharge increased and its magnitude decreased with increasing flow, exhibiting a similar pattern of accumulation of chlorophyll *a* with respect to change in discharge at S-79 observed by Doering et al. (2006).

The linkage between the local residence time maximum and peak chlorophyll *a* concentrations in the estuary can be further verified by the mapping surveys of the flow-through system. These surveys provided a snap shot of the spatial variation in chlorophyll *a* within the entire estuary. Three of the cruises were selected with S-79 discharges during the period of 10 days prior to each survey averaging (1) zero (April 12, 2012), (2) 13 $m^3 s^{-1}$ (February 2, 2012), and (3) 36 $m^3 s^{-1}$ (February 21, 2013) (Fig. 8). While the difference in salinity among the three surveys can be easily understood in the context of mixing with freshwater, changes in the location and extent of peak chlorophyll *a* concentrations are consistent with the "residence time maximum" mechanism. On April 12, 2012 when freshwater releases ceased during the previous 2 weeks, the peak chlorophyll *a* concentration zone (20–70 $\mu g L^{-1}$) was observed immediately downstream of S-79, likely due to poor flushing and long residence time in the area. The high chlorophyll *a* concentrations actually indicated the formation of an algal bloom in the area. With low levels of freshwater releases (e.g., 13 $m^3 s^{-1}$ for the February 2, 2012 survey), the peak chlorophyll *a* concentration zone (10–25 $\mu g L^{-1}$) was observed near Bird Island to Ft. Myers. Further increase in freshwater inflows (e.g., 36 $m^3 s^{-1}$ for the February 21, 2013 survey) extended the peak chlorophyll *a* concentration zone (10–30 $\mu g L^{-1}$) downstream to the area near Cape Coral. The location and extent of peak chlorophyll *a* concentrations with respect to freshwater inflows were consistent with the residence time maximum mechanism and the spatial pattern of chlorophyll *a* reported by Doering et al. (2006).

The practical implication of this linkage is that the location of potential algal blooms can be accordingly predicted for different flow conditions. During the wet season when freshwater discharge is high at S-79, algae blooms are likely to occur in the lower estuary. However, their occurrence may be low as the accumulation and growth of chlorophyll *a* biomass can be suppressed by rapid flushing in spite of high nutrient loading. During the dry season when freshwater discharge at S-79 is low, especially when the temperature starts to increase in the late spring, there is a great potential for phytoplankton blooms in the upper estuary. Discharges at S-79 might be managed in a way to reduce the likelihood of bloom formation.

5. Conclusions

The analysis of residence time calculated with the Caloosahatchee Estuary CH3D model emphasized the fundamental role of freshwater inflows in the control of the magnitude and spatial heterogeneity of this transport time scale. The results confirmed that for a given freshwater inflow, there existed an area or zone along the estuary where water parcels or pollutants can reside for a longer period of time than in adjacent areas of the estuary. The location of this "residence time maximum" zone moved from upstream to downstream in the estuary as freshwater inflows increased. The dynamics of the residence time maximum in part explained spatial variation in peak chlorophyll *a* concentrations with changing freshwater discharge observed in the field by Doering and Chamberlain (1998) and Doering et al. (2006). This linkage between the spatial variation in residence time and chlorophyll *a* levels was further confirmed by the mapping surveys of chlorophyll *a* using the flow-through system. The results help understand where and why phytoplankton tends to bloom in the estuary in response to nutrient loading and freshwater inflows at S-79.

Acknowledgements

We would like to thank Cecilia Conrad, Barbara Welch, Kathy Haunert, and Beth Orlando for their assistance in collecting the water quality mapping data in the field. Critical reviews from two anonymous reviewers were also appreciated.

Appendix A. Turbulence closure in the CH3D model

In the CH3D model, Sheng's equilibrium closure model (Sheng and Villaret, 1989) is used to compute the vertical eddy viscosity and diffusivity. The model is based on the assumption that the local equilibrium condition is valid when time scale of mean flow is much larger than that for turbulence and when turbulence varies little over the turbulence macro-scale. The equilibrium model is significantly simpler than the Reynolds stress model and has been found to give very good results for mean flow, and salinity with little or no tuning on model coefficients (Sheng and Villaret, 1989). The equations for the model are given below:

$$0 = -\overline{u_i'u_k'}\frac{\partial u_j}{\partial x_k} - \overline{u_j'u_k'}\frac{\partial u_i}{\partial x_k} + g_i\frac{\overline{u_j'\rho'}}{\rho_0} + g_j\frac{\overline{u_i'\rho'}}{\rho_0} - 2\varepsilon_{ikj}\Omega_k\overline{u_i'u_j'} - 2\varepsilon_{jlk}\Omega_l\overline{u_k'u_i'} - \frac{q}{\Lambda}\left(\overline{u_i'u_j'} - \delta_{ij}\frac{q^2}{3}\right) - \delta_{ij}\frac{q^3}{12\Lambda} \quad (A.1)$$

$$0 = -\overline{u_i'u_k'}\frac{\partial \rho}{\partial x_j} - \overline{u_j'\rho}\frac{\partial u_i}{\partial x_k} - g_i\frac{\overline{\rho'\rho'}}{\rho_0} - 2\varepsilon_{ikj}\Omega_j\overline{u_k'\rho'} - 0.75q\frac{\overline{u_i'\rho'}}{\Lambda} \quad (A.2)$$

$$0 = 2\overline{u_j'\rho'}\frac{\partial \rho'}{\partial x_j} + \frac{0.45q\overline{\rho'\rho'}}{\Lambda} \quad (A.3)$$

where u is the mean flow velocity component, ρ is the mean water density, u', ρ' are the turbulence fluctuation of velocity and density. Subscripts i,j,k,l take one of the values of 1,2, or 3. Λ is the turbulence length scale, Ω is the Earth rotation, g is gravity and q is root-mean-square turbulent velocity. The above equations contain a total of 5 model coefficients (or invariants, see below). These coefficients were determined from laboratory data, and remain invariant in application of the equilibrium model. q can be determined from the following equation when the mean flow is known (Sheng and Villaret, 1989):

$$b(s+3+4bs)R_i^2 + (bs-A)(1-2b)R_i = 3A^2b^2sQ^4 + A[bs+3b + 7b^2s]R_i - Abs(1-2b)]Q^2 \quad (A.4)$$

where A, b and s are "invariant" and have the values of 0.75, 0.125 and 1.8, respectively, and:

$$Q = \frac{q}{\Lambda\sqrt{(\partial u/\partial z)^2 + (\partial v/\partial z)^2}} \quad (A.5)$$

$$R_i = \frac{(g/\rho_0)(\partial \rho/\partial z)}{(\partial u/\partial z)^2 + (\partial v/\partial z)^2} \quad (A.6)$$

Both Q and R_i are nondimensional, where Q is a measure of turbulence strength against the vertical shear of the mean velocity and R_i, the Richardson number, is a measure of stratification which tends to suppress turbulence production. The total root-mean-square turbulent velocity q can then be obtained from mean flow variables. The vertical eddy viscosity coefficient A_v and the vertical eddy diffusivity coefficient D_v can then be computed from:

$$A_v = \frac{A + \bar{w}\overline{w'w'}}{A - wq^2}\Lambda q \quad (A.7)$$

$$w = \frac{R_i}{AQ^2} \quad (A.8)$$

$$D_v = \frac{bs}{(bs-w)A}\frac{\overline{w'w'}}{q^2}\Lambda q \quad (A.9)$$

$$\bar{w} = \frac{w}{1 - w/bs} \quad (A.10)$$

$$\overline{w'w'} = \frac{1-2b}{3(1-2\bar{w})}q^2 \quad (A.11)$$

The turbulent macro-scale Λ is often assumed to satisfy a number of integral equations. First of all, it is assumed to be a linear function of the vertical distance immediately above the bottom or below the free surface. In addition, it must satisfy the following relationships:

$$\left|\frac{d\Lambda}{dz}\right| \le 0.65 \quad (A.12a)$$

$$\Lambda \le C_1 H \quad (A.12b)$$

$$\Lambda \le C_1 H_p \quad (A.12c)$$

$$\Lambda \le C_2 \delta_{q^2} \quad (A.12d)$$

$$\Lambda \le \frac{q}{N} \quad (A.12e)$$

where C_1 is usually between 0.1 and 0.25, H is the total depth, H_p is the depth of pynocline, C_2, ranging between 0.1 and 0.25 is the fractional cut-off limitation of turbulent macro-scale based on δ_{q2}, the spread of the turbulence determined from the turbulence kinetic energy. And N is the Brunt–Vaisala frequency, defined as:

$$N = \left(-\frac{g}{\rho_0}\frac{\partial \rho}{\partial z}\right)^{1/2} \quad (A.13)$$

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