Prioritizing Future Actions Related to Impaired Lakes and the FDEP TMDL Program

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Submitted To:

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List of Acronyms

AGM	Annual Geometric Mean
ARPET	Aquatic Restoration Prioritization and Evaluation Tool
BMP	Basin Management Plan
BMAP	Basin Management Action Plan
CHLAC	chlorophyll-a, corrected
CHLAcomb	combined parameter of corrected and uncorrected chlorophyll-a
CHL-A	chlorophyll-a
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FFWCC	Florida Fish and Wildlife Conservation Commission
FMA	Fish Management Area
FWRA	Florida Watershed Restoration Act
GFBT	Great Florida Birding Trail
IWR	Impaired Waters Rule
LA	Load Allocation
mg/L	milligram per liter
MS4	Municipal Separate Storm Sewer Systems
MOS	Margin of Safety
NNC	Numeric Nutrient Criteria
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point source

PLRG	Pollutant Load Reduction Goal
PCU	Platinum Cobalt Units
RAP	Reasonable Assurance Plan
R^2	Coefficient of Variation
SFWMD	South Florida Water Management District
STORET	Storage and Retrieval Database
SWFWMD	Southwest Florida Water Management District
SWIM	Surface Water Improvement and Management Program
SWUCA	Southern Water Use Caution Area
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
µg/L	microgram per liter
WLA	Waste Load Allocations
WQMP	Water Quality Management Plan

Executive Summary

Section 303(d) of the Clean Water Act (CWA) requires that states develop impaired waters lists to identify rivers, lakes, coastal waters, and estuaries that do not meet water quality standards. Total Maximum Daily Loads (TMDLs) have been adopted by the United States Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP) for these water bodies and specify the maximum amount of a pollutant that a water body can receive and still meet water quality standards. Polk County‟s (County) Municipal Separate Storm Sewer Systems (MS4) permit requires the permitee to prioritize waters with established TMDLs and initiate storm event monitoring with respect to the TMDL. For a water body with an adopted Basin Management Action Plan (BMAP), National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the requirements of adopted TMDLs. For water bodies with an FDEP adopted TMDL or an EPA established TMDL but without a BMAP, FDEP requires approval of a final prioritization report. This report has been prepared to provide the final list of TMDLs, the prioritization factors, the prioritized list, and the associated schedule for related activities to Polk County.

Polk County is evaluating lakes with nutrient-related TMDLs to identify whether additional review by FDEP is appropriate prior to implementation of potentially costly water quality improvement projects. The County contracted with the Atkins team to review TMDLs for 23 lakes and support the development of the prioritization factors and a prioritization list for 97 water bodies. This report presents:

- A comprehensive review of 23 lake TMDLs in Polk County
- Locally-derived water quality targets for each of the 97 lakes
- Probable impairment status for each of the 97 lakes using the most current state standard (numeric nutrient criteria or NNC)
- A protocol to prioritize 97 publicly accessible lakes within Polk County for additional restoration or protection efforts

The TMDLs for many of Polk County‟s lakes require some level of revision prior to implementing associated proposed nutrient load reductions. For example, proposed nutrient concentration targets for some TMDLs have been shown to be too high to result in the predicted reductions in chlorophyll-a (chl-a) concentrations. Nutrient and chl-a targets for other TMDLs have been shown to be too low and represent “better” lake conditions than historically occurred, resulting in unrealistic expectations for water quality improvements.

Overall, site-specific nutrient concentration targets calculated for these lakes were more stringent than FDEP NNC criteria and suggest that additional efforts are needed to meet water quality goals for chl-a, above and beyond those based on NNC. However, the anticipated water quality improvements in lakes Shipp, May, and Lulu have not been documented following the achievement of load reduction targets set out in their TMDLs, potentially due in large part to total phosphorus (TP) targets that were too high to result in expected reductions in chl-a.

Eighteen lakes previously designated by FDEP as impaired for elevated nutrients (based on Trophic State Index (TSI)) were identified as unimpaired when using NNC to measure impairment. Independently, FDEP reviewed the water quality for these lakes and confirmed their unimpaired status using NNC. Two of these lakes (Alfred and Kissimmee) have or are in the process of establishing TMDLs. Of the 97 lakes examined for this project, 62 were found to be impaired due to at least one nutrient parameter using the NNC, although only 21 of the 62 have draft or final TMDLs developed.

A matrix was developed to assign priority to each of the 97 publicly accessible lakes for prioritizing potential future water quality restoration actions (**Figure ES-1**). Thirty-four lakes were selected (based on the prioritization process used) as a short list from which to select a smaller number of lakes for the development of water quality management plans to identify potential water quality restoration projects (**Table ES-1**). Of the thirty-four lakes, it is recommended that the County initially evaluate the following lakes for the development of water quality management plans: Little Crooked, Arbuckle, Weohyakapka, Mattie, Deer, Grassy, Ariana, Sears, Lena, Crooked, Daisy, and Tennessee, based solely on the results of the ranking process.

A meeting of County staff with FDEP staff from the regulatory, TMDL and BMAP sections to discuss the results of this project is also recommended.

Figure ES 1. Summary of prioritization matrix development.

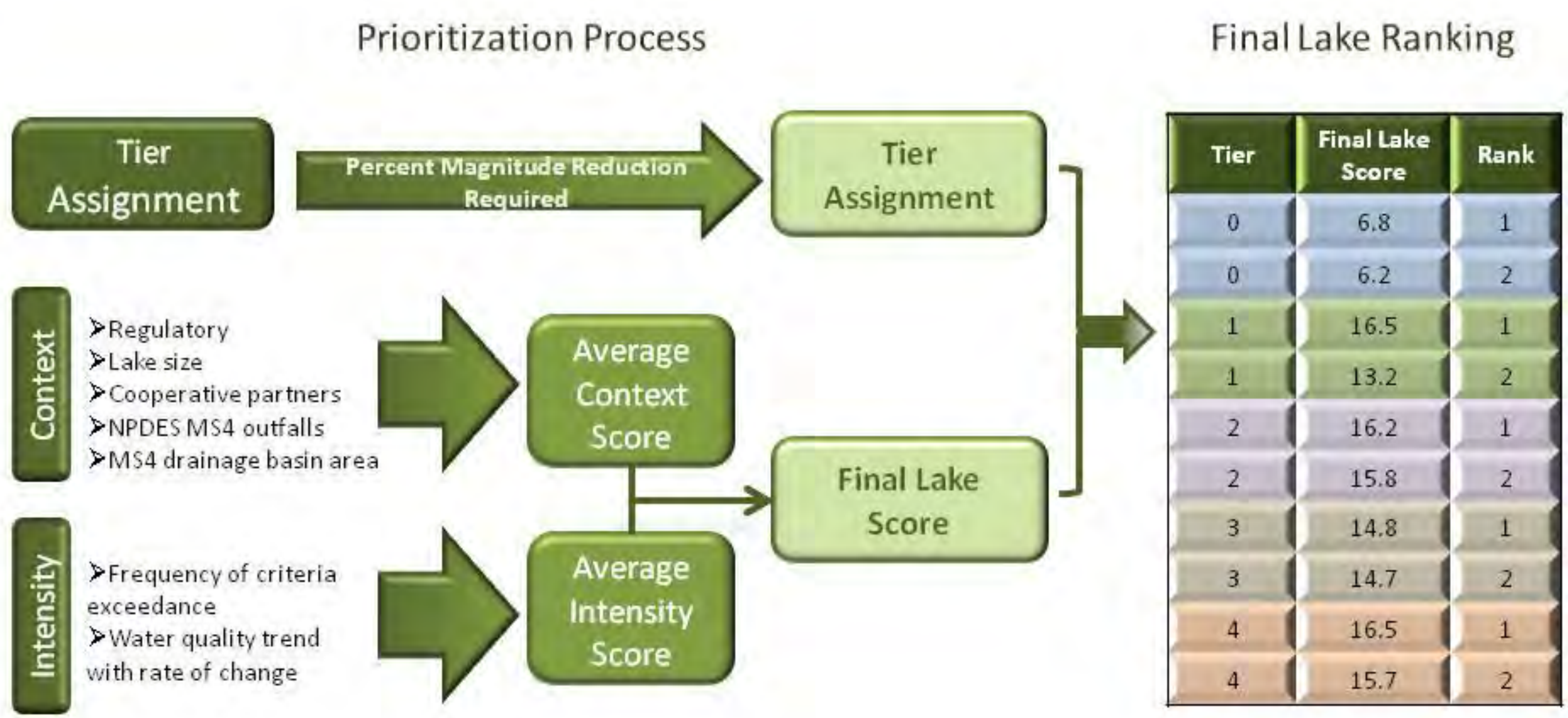

Table ES 1. Recommended "next steps" for each of the ninety-seven evaluated Polk County lakes.

Rank	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
	Percent TN, TP or chl-a concentration reduction required to meet NNC				
	None	<20	20-<40	40-<60	≥60
1	LITTLE CROOKED	IDYLWILD	CANNON	SEARS	CRYSTAL
2	THOMAS	SPRING	JESSIE	CONINE	BLUE
3	ECHO	ARBUCKLE	DEER	LENA	DAISY
4	WINTERSET	WEOHYAKAPKA	HARTRIDGE	SHIPP	TENNESSEE
5	SUMMIT	MATTIE	GRASSY	CROOKED	DEESON
6	PANSY	HAMILTON	MARIANNA	MUD	GIBSON
7	MARTHA	NED	SMART	ANNIE	SADDLE CREEK PARK
8	SILVER	BUCKEYE	LULU	MAY	SOMERSET
9	MARIE	OTIS	ROCHELLE	CLINCH	STAHL
10	MENZIE		ARIANA	MCLEOD	AGNES
11	MIRIAM		MIDDLE HAMILTON	WAILES	BUFFUM
12	DAVENPORT		MIRROR	EAGLE	JOHN
13	LINK		JULIANA	ALFRED	HOLLINGSWORTH
14	SWOOPE		HOWARD	EASY	PARKER
15	TIGER		HATCHINEHA		BANANA
16	CONFUSION		REEDY		HANCOCK
17	ELBERT		FANNIE		HICKORY
18	WIRE		LITTLE HAMILTON		PIERCE
19	LOWERY		ELOISE		CARTER ROAD PARK
20	TRACY		HAINES		MARION
21	CRYSTAL		CYPRESS		HUNTER
22			ROSALIE		GARFIELD
23			EVA		BONNY
24			ROY		TENOROC
25			MAUDE		
26			KISSIMMEE		
27			LIVINGSTON		
28			LITTLE AGNES		
29			SURVEYORS		

Legend:
- No action (water quality is fine)
- No action (waiting development of WQMP)
- Insufficient data
- Existing WQMP
- No MS4
- Select for WQMP development

1 Introduction/Purpose

Section 303(d) of the Clean Water Act requires that states develop impaired waters lists to identify rivers, lakes, coastal waters, and estuaries that do not meet water quality standards. TMDLs have been adopted by the EPA and FDEP for these water bodies and specify the maximum amount of a pollutant that a water body can receive and still meet water quality standards. A TMDL is "the sum of the individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources" (40 CFR 130.2 and 130.70). Discharges from MS4s are included as part of the wasteload allocations. An MS4 that contributes a pollutant of concern to an impaired waterbody or a waterbody with an approved TMDL is assigned a WLA necessary to reduce pollutant loads and meet the TMDL. The MS4 program is implemented under the NPDES stormwater permitting program and is intended to address the water quality goal of the CWA, i.e. "not cause or contribute to exceedance of water quality standards".

Polk County‟s MS4 permit requires the permitee to prioritize waters with established TMDLs and initiate storm event monitoring with respect to the TMDL. For a water body with an adopted BMAP, NPDES permits must be consistent with the requirements of adopted TMDLs. For water bodies with an adopted FDEP TMDL or an EPA established TMDL but without a BMAP, FDEP requires approval of a final prioritization report that includes the final list of adopted FDEP TMDLs or EPA established TMDLs, the prioritization factors, the prioritized list, and the associated schedule for related activities.

There are challenges to developing and implementing TMDLs. FDEP (2008) cites (after Environmental Law Institute 2008), the top four barriers to TMDL development as:

1. Inappropriate water quality standards and water body classification system; Florida, like nearly all states, adopted its water quality standards in the 1970s as a means of permitting point sources of pollution, not protecting ambient water quality or aquatic ecological systems
2. Lack of data and information linking water quality impacts to causes or sources
3. Insufficient time and flexibility
4. Insufficient resources for BMAP implementation

Similarly, the top three barriers to TMDL implementation identified by the Environmental Law Institute (2008) include:

1. Lack of financial resources
2. Lack of data, information, and knowledge linking water quality impacts to causes or sources; understanding pollutant fate and transport, especially nutrient dynamics, that occur within individual water bodies
3. Lack of scientific data on the pollutant removal performance of Best Management Practices (BMPs) for non-point sources (NPSs), particularly for agricultural BMPs

In recognition of these challenges, Polk County is evaluating lakes with nutrient-related TMDLs to identify whether additional review by FDEP is appropriate prior to implementation of potentially costly water quality improvement projects. The County has contracted with Atkins to review 23 TMDLs and support the development of the prioritization factors and prioritization list for water bodies with an adopted FDEP TMDL or an EPA established TMDL but without a BMAP, pursuant to the County‟s MS4 permit (FDEP permit number FLS000015-003). Polk County has included an additional 74 lakes for prioritization in support of its own water quality protection and restoration efforts. Consequently, a total of 97 publicly accessible lakes are addressed for this project. Three specific tasks were undertaken by Atkins in support of Polk County‟s efforts and are briefly outlined below.

Task 1: Meeting with FDEP senior staff

The first objective of this project was to meet with FDEP senior staff in the TMDL and BMAP programs to review existing TMDLs. The meeting focused on developing a consensus with respect to the process by which Polk County is addressing TMDLs, to ensure that the approach is locally relevant and scientifically sound, and that implications to the County‟s MS4 permits are addressed and provided to FDEP for considered in any future actions by FDEP.

Task 2: Review of TMDLs for 23 Polk County lakes

The second objective of this project was to review draft and final nutrient-related TMDLs for lakes in Polk County and evaluate the appropriateness of the TMDLs using locally relevant data as available.

For most TMDLs, a mechanistic model was used to develop the water quality targets and load reductions recommended for water quality improvements. The application of mechanistic models may not be appropriate for many lakes reviewed because sufficient data to quantify both the internal and external processes were not available at the time of TMDL development. Therefore, model assumptions made may not adequately address the nutrient effects and could result in inappropriate water quality targets. The implementation of these TMDLs could lead to time and resources spent on projects unlikely to bring about water quality improvements.

Task 3: Prioritization of lakes for further action

The third objective was to prioritize 97 publicly accessible lakes within Polk County for additional water quality restoration or protection efforts. Both context and intensity criteria were used to characterize and score each lake. These scores will assist in developing a priority ranking for future actions and comply with the MS4 permit requirements.

2 Approach/rationale to water quality priorities development

The first step to reviewing TMDLs and developing a list of priority water bodies was to develop consensus with FDEP with respect to an acceptable process by which the County can preserve and protect water quality and natural resources. The approach should be locally relevant and scientifically sound, and take into consideration implications with respect to the County‟s MS4 permits. On March 24, 2014, Polk County, FDEP, and staff from Atkins and Environmental Scientists and Associates (ESA) met to discuss the County resources available for water quality restoration, and review nutrient impaired water bodies currently listed on the 303(d) list and associated nutrient-related TMDLs (**Figure 1**). Upon conclusion of the meeting, FDEP indicated that they would carefully review the results of the comprehensive TMDL review proposed by the County (Task 2) and discrepancies in the impairment designation of water bodies due to the change in water quality criteria (Task 3). FDEP was amenable to working with the County to seek a mutually agreeable resolution based upon concurrent data assessment and TMDL review.

As such, this report documents the findings of the comprehensive TMDL review performed for 23 lakes in the County. Locally-derived water quality targets were developed for the 97 publicly accessible lakes with sufficient data to develop relationships between Total Nitrogen (TN) or TP and chl-a. Results of these locally-derived nutrient concentration target values were compared and contrasted to NNC criteria used by FDEP and the EPA for setting water quality targets for Florida lakes. Finally, impairment status was evaluated using locally-derived nutrient targets, nutrient targets based on NNC criteria, and FDEP TSI targets. The FDEP TSI targets are the basis for the existing nutrient-related TMDLs for these lakes.

Additionally, prioritization factors and a protocol to prioritize the lakes for additional restoration or protection efforts were developed. Context and intensity factors were used to characterize and score each lake. As part of this effort, the probable impairment status was determined using the current state standard (NNC) which allowed for an evaluation of the appropriateness of existing impairments.

2.1. Review of Polk County lake TMDLs

Draft and final TMDLs from both FDEP and the EPA were reviewed for those lakes on the Verified Impaired List for nutrient enrichment. Prior efforts have documented concerns regarding TMDL implementation. For example, the Draft TMDL for Lake Hancock (FDEP 2005) includes the following concerns: 1) groundwater seepage into Lake Hancock does not appear possible since the lake is perched higher than the surficial aquifer, yet groundwater seepage is a major component of the nutrient load in the TMDL; 2) the nitrogen budget for Lake Hancock does not account for the significant amount of nitrogen fixation in the lake (Tomasko et al. 2009); and 3) internal phosphorus loads from the organic rich sediments are likely a much more important influence on the lake‟s water quality than nutrient loads from the watershed, which are the focus of the draft TMDL.

Reviews of the TMDLs for Banana Lake, Lake Hunter, and Lake Parker indicate concerns similar to those identified in the Lake Hancock draft TMDL.

Previous work on the Winter Haven Chain of Lakes (PBS&J 2008) concluded the use of the TSI for setting water quality targets was inconsistent with conditions in high color lakes. High color lakes exhibited no relationship between either TN and chl-a or TP and chl-a concentrations. For low color lakes, relationships were found between TN and chl-a and TP and chl-a, but target TN and TP values derived using empirical relationships differed dramatically from target TN and TP values based in TSI calculations. For the Northern Chain of Lakes, measured groundwater inflow rates were similar to rates used in FDEP‟s water budget estimates, but measured phosphorus flux from groundwater was much higher than model inputs. The under-reported nutrient loading rates due to groundwater suggest that the stormwater inflow (as a nutrient source) is overstated in those TMDLs.

Based on these previous reports, the nutrient-related TMDLs for all of Polk County‟s lakes were reviewed with particular attention to: 1) appropriateness of water quality targets for chl-a and nutrients; 2) consideration of internal lake processes such as sediment resuspension and in-situ nitrogen-fixation; 3) likelihood of proposed nutrient targets reducing concentrations of chl-a; and 4) whether or not the nutrient loading model includes enough untested assumptions that TMDL implementation should be delayed until those loads are better understood or documented.

A total of 23 lake TMDL reports (draft and final) prepared by FDEP or EPA were reviewed for Polk County (**Figure 1**). The TMDL reviews were restricted to lakes with a nutrient-related impairment, such as exceedance of the guidance related to TSI. Copies of each TDML can be downloaded from the FDEP website (http://www.dep.state.fl.us/water/tmdl/). The TMDLs reviewed were developed for the following lakes:

Lake Ariana North
Lake Alfred
Banana Lake
Lake Bonny
Lake Cannon
Crystal Lake
Lake Cypress
Deer Lake
Lake Haines
Lake Hancock
Lake Hollingsworth
Lake Howard
Lake Hunter
Lake Idylwild
Lake Jessie
Lake Kissimmee
Lake Lena
Lake Lulu
Lake May
Lake Mirror
Lake Parker
Lake Shipp
Lake Smart

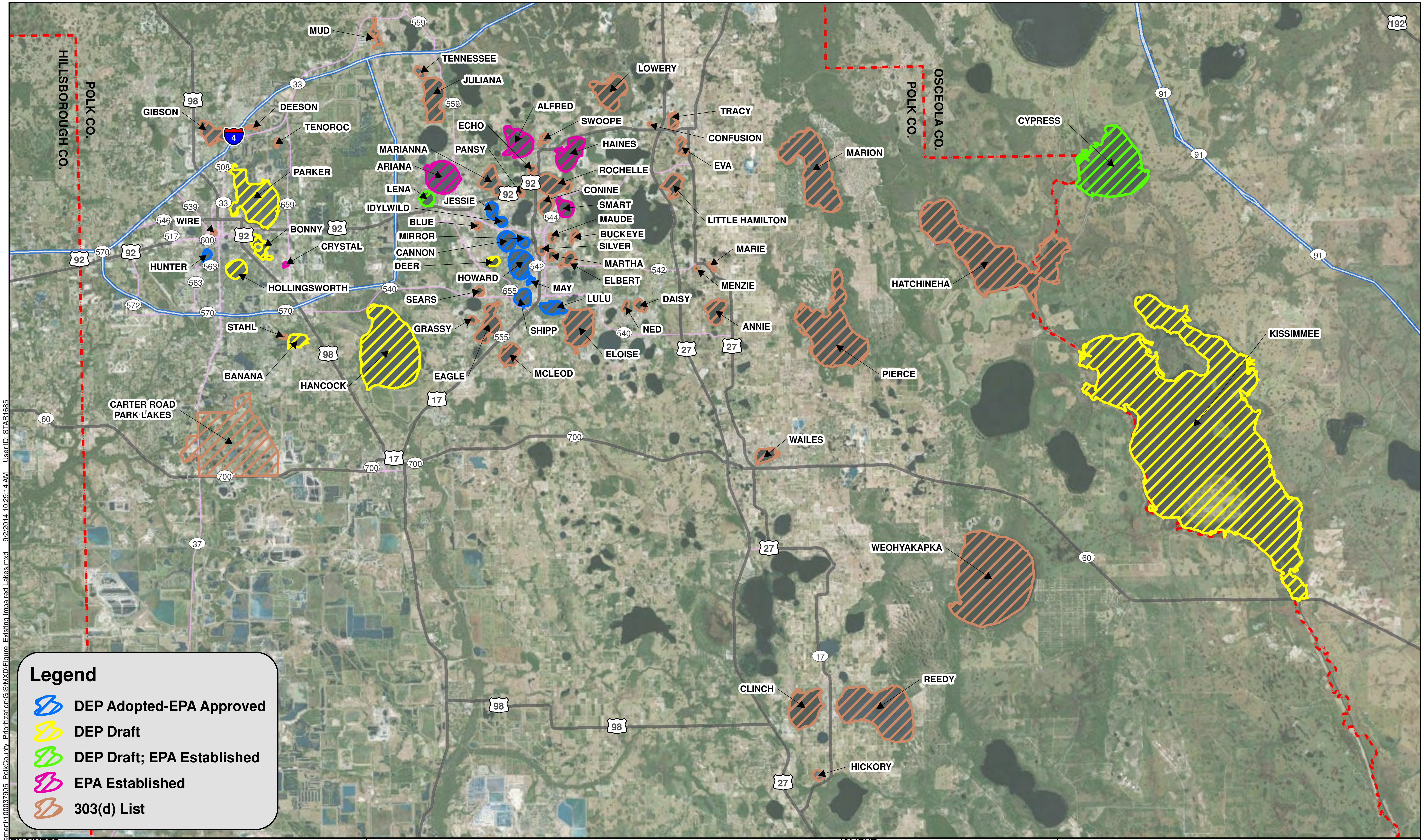

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Figure 1. Map of nutrient impaired water bodies currently listed on the 303(d) list and lakes with existing nutrient-related TMDLs

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J:\Watershed Management\100037905_PolkCounty_Prioritization\GIS\MXD\Figure_Existing Impaired Lakes.mxd 9/2/2014 10:29:14 AM User ID: STAR1685

2.2. Empirically-derived nutrient targets for water quality

Empirically-derived, site-specific water quality targets were developed for the 97 publicly accessible lakes with sufficient data to establish relationships between TN or TP and chl-a. Targets were developed using lake-specific correlations between nutrients and chl-a, an indicator of the amount of algae within the water. The current water quality targets are based on the color and alkalinity for each lake.

Correlation determination

A comprehensive dataset was compiled to evaluate nutrient impairment for each lake using correlation analysis between chl-a and either TN or TP. Data were limited to the period of 1983 to 2013. Annual geometric means (AGM) and individual data for nutrients were used to develop empirically-derived water quality targets.

Annual geometric mean

The FDEP NNC is based on the calculation of the AGM for TN, TP, and chl-a oncentrations. To be consistent with the measure of comparison used by FDEP and the most recent FDEP TMDLs (e.g. Lake Hollingsworth, Deer Lake, Lake Bonny, and Lake Lena), the relationship between the AGMs of each parameter was used. A geometric mean is a measure of average calculated by using the product of a set of numbers and is used when the data are interrelated, i.e. the calculated number is influenced by the previous number and affects the subsequent numbers. Data sufficiency for the calculation of the annual geometric mean was consistent with the FDEP NNC requirements (F.A.C. 62-302.531). The analysis was completed for lakes with a minimum of five annual data points. For example, Lake Mariana (WBID 1521L) had 19 data points included in the TN:chl-a correlation analysis and eight data points included in the TP:chl-a correlation analysis. Data were log-transformed prior to analysis to account for non-normal distribution of data.

Individual data

To establish a water quality target comparable with individual sampling events, this analysis was based on the relationship between data from individual sampling events for all data over the period of analysis (in contrast to the AGM approach). A modified chl-a variable (chlacomb) was created whereby the chlac (corrected chlorophyll [i.e.,corrected for phaeophytin]) variable was combined with chl-a, uncorrected results. In other words, chl-a, uncorrected results were used in instances in which chlac were unavailable. In 2007, FDEP modified the 62-303, F.A.C such that chl-a data collected from September 2007 forward were required to be chlac in order to be included in the assessment of water quality. Data collected prior to September 2007 were exempt from this requirement. The analysis was completed for lakes with a minimum of 20 data points. The initial correlations between nutrients and chlacomb were reviewed and outlier data were removed from analysis. In comparison to the AGM approach, Lake Mariana (WBID 1521L) had 164 data points included in the TN:chlcomb correlation analysis and 160 data points included in the TP:chlcomb correlation analysis.

2.3. Impairment determination using TSI vs NNC

Until 2013, FDEP used the TSI for the determination of nutrient imbalances in lakes and estuaries in the State of Florida. Recently, the FDEP has developed lake-specific NNC method which has been approved by EPA. The following section addresses the differences in the two methods.

2.3.1 Trophic State Index (TSI)

TSI was used by FDEP to determine nutrient impairment for lakes and estuaries until the adoption of the NNC in 2012. TSI is calculated based on the calculated nutrient limitation (e.g. nitrogen, phosphorus or co-limited; **Table 1**). In order to violate the TSI guidance criteria, a single year‟s exceedance during a specified period of record was necessary. In regards to data sufficiency, one sample was required from each quarter of the calendar year. Specific to lakes, TSI targets were allocated based upon color classification. High color lakes (color > 40 platinum-cobalt units (PCU)) had a TSI threshold of 60 TSI which roughly equates to “do not exceed” values for chl-a of 20 µg/L, TP of 0.07 mg/L and TN of 1.2 mg/L. A low color lake (color ≤ 40 PCU) had a TSI threshold of 40 TSI which roughly equates to ”do not exceed” values for chl-a of 5.0 µg/L, TP of 0.02 mg/L and TN of 0.45 mg/L. Low color lakes with paleolimnological work which indicate historically mesotrophic water quality conditions could qualify for a TSI of 60. Several of the lakes within the Winter Haven Chain of Lakes were subject to a revision in TSI based on paleolimnological work.

2.3.2 Numeric Nutrient Criteria (NNC)

The FDEP NNC was implemented in 2013 to determine chl-a, TN and/or TP impairment for lakes. Each lake must first be classified as a low (color ≤40 PCU) or high color (color > PCU) lake. Low color lakes are further classified as acidic (alkalinity ≤ 20 mg/L) or alkaline (alkalinity > 20 mg/L). The appropriate NNC criteria are then assigned based upon the chl-a concentration on an annual basis for each color/alkalinity lake classification (**Table 2**). The minimum or maximum chl-a criterion is assigned based on the AGM for a given year. For example:

- If the annual geometric chl-a concentration exceeds 20 µg/L in a designated high color lake, the TP and TN criteria are 0.05 and 1.27 mg/L for that year, respectively
- If, however, the chl-a concentration is below the 20 µg/L criteria, the TP and TN criteria are 0.16 and 2.23 mg/L, respectively
- The TN, TP, and chl-a criteria are compared to the AGM of each parameter. More than one exceedance in any three-year period denotes an impaired water body. A minimum of four temporally independent sampling events are required in the calendar year to calculate the annual geometric mean, with at least one occurring during the period from May to September and October to April

Table 1. TSI equations and associated targets (from FDEP 1996).

For lakes: 0-59 is good, 60-69 is fair, 70-100 is poor.
For estuaries: 0-49 is good, 50-59 is fair, 60-100 is poor.

Trophic State Index	Chlorophyll CHLA/ micrograms per liter (μg/1)	Total Phosphorus TP/ milligrams of phosphorus per liter (mgP/1)	Total Nitrogen TN/ milligrams of nitrogen per liter (mgN/1)
0	0.3	0.003	0.06
10	0.6	0.005	0.10
20	1.3	0.009	0.16
30	2.5	0.01	0.27
40	5.0	0.02	0.45
50	10.0	0.04	0.70
60	20.0	0.07	1.2
70	40	0.12	2.0
80	80	0.20	3.4
90	160	0.34	5.6
100	320	0.58	9.3

Trophic State Index equations that generate the above criteria (LN = Natural Log):

$CHLA_{TSI} = 16.8 + [14.4 \times LN(CHLA)]$

$TN_{TSI} = 56 + [19.8 \times LN(TN)]$

$TN2_{TSI} = 10 \times [5.96 + 2.15 \times LN(TN + .0001)]$

$TP_{TSI} = [18.6 \times LN(TP \times 1000)] - 18.4$

$TP2_{TSI} = 10 \times [2.36 \times LN(TP \times 1000) - 2.38]$

* *Limiting nutrient considerations for calculating* $NUTR_{TSI}$:

If $TN/TP > 30$ then $NUTR_{TSI} = TP2_{TSI}$

If $TN/TP < 10$ then $NUTR_{TSI} = TN2_{TSI}$

If $10 < TN/TP < 30$ then $NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2$

$TSI = (CHLA_{TSI} + NUTR_{TSI}{}^{*})/2$

Table 2. Lake NNC chl-a, total nitrogen and total phosphorus criteria (from FDEP 2013a).

Long Term Geometric Mean Lake Color and Alkalinity	Annual Geometric Mean Chlorophyll *a*	Minimum calculated numeric interpretation		Maximum calculated numeric 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 West Central Nutrient Watershed Region, maximum TP limit shall be 0.49 mg/L

Water quality data were queried from the Impaired Waters Rule (IWR) Run 47 database for the 97 waterbodies of interest. In addition, Polk County water quality data from September 2012 to August 2013 were retrieved from the Florida STOrage and RETrieval (STORET) database to supplement the FDEP IWR database. Data from October 2010 were previously identified as not successfully uploading to STORET and therefore not included in the IWR Run 47 database. The missing October 2010 data were added to the analysis. The data were compiled and evaluated consistent with the rules provided in 62-303, F.A.C. (Identification of Impaired Surface Waters).

Based on correspondence with FDEP, IWR data (IWR and STORET) with any of the following qualifiers were excluded from analysis: presence of material is verified by not quantified (M) and value based on field kit determination (H). Additionally, chlac values with a qualifier of „U" were reported as half the minimum detection limit. Water quality data were reviewed and a daily median value was calculated to eliminate duplicate data entries. A median value was calculated for samples collected at the same location less than four days apart (F.A.C. 62-303.320(4)).

2.4. Prioritization of lakes for further action

In response to the Polk County MS4 permit requirements, prioritization factors were generated and a prioritized list of lakes was developed. The section below details the factors identified to characterize each lake and the protocol applied to rank each lake for future water quality restoration actions.

2.4.1. Tier assignment

Each lake was assigned to a tier based upon the magnitude of the percent reduction required for TN, TP, or chlac concentrations to satisfy the FDEP NNC targets. Five tiers were developed ranging from lakes requiring no reduction in concentration for all parameters (Tier 0) to lakes requiring more than 60 percent concentration reduction for at least one parameter (Tier 4). Lakes assigned to Tier 0 currently meet the state surface water quality criteria. Tier 1 lakes are marginally impaired requiring less than a 20 percent concentration reduction for a given parameter. In contrast, Tier 4 lakes would require a substantial reduction in internal and/or external loads to satisfy the state NNC. The establishment of a tiered ranking allowed for the selection of priority lakes for protection (better water quality) and restoration (poorer water quality).

The annual percent reduction was calculated for each lake for TN, TP, and chlac when sufficient data were present to calculate the annual geometric mean and the existing criterion for a given year was exceeded. The median percent reduction was calculated over the period of 2003-2013 for each lake by parameter. Each lake was assigned to a tier based upon the magnitude of the percent reduction required by parameter (TN, TP, and chlac). An overall tier was assigned to each lake based on the largest tier score assigned between the three parameter classifications (**Table 3, Figure 2**). For example, Lake Juliana (WBID 1484B) was assigned to Tier 2 based on the 23 percent concentration reductions (respectively) in TN and 28 percent concentration reductions in chlac required to meet the NNC.

Table 3. Allocation of tier assignments designated by magnitude of percent reduction required.

Magnitude of Percent Reduction Required	TN Tier	TP Tier	chlac Tier
No reduction	0	0	0
<20	1	1	1
20 to <40	2	2	2
40 to <60	3	3	3
≥60	4	4	4

2.4.2. Context factors for prioritization

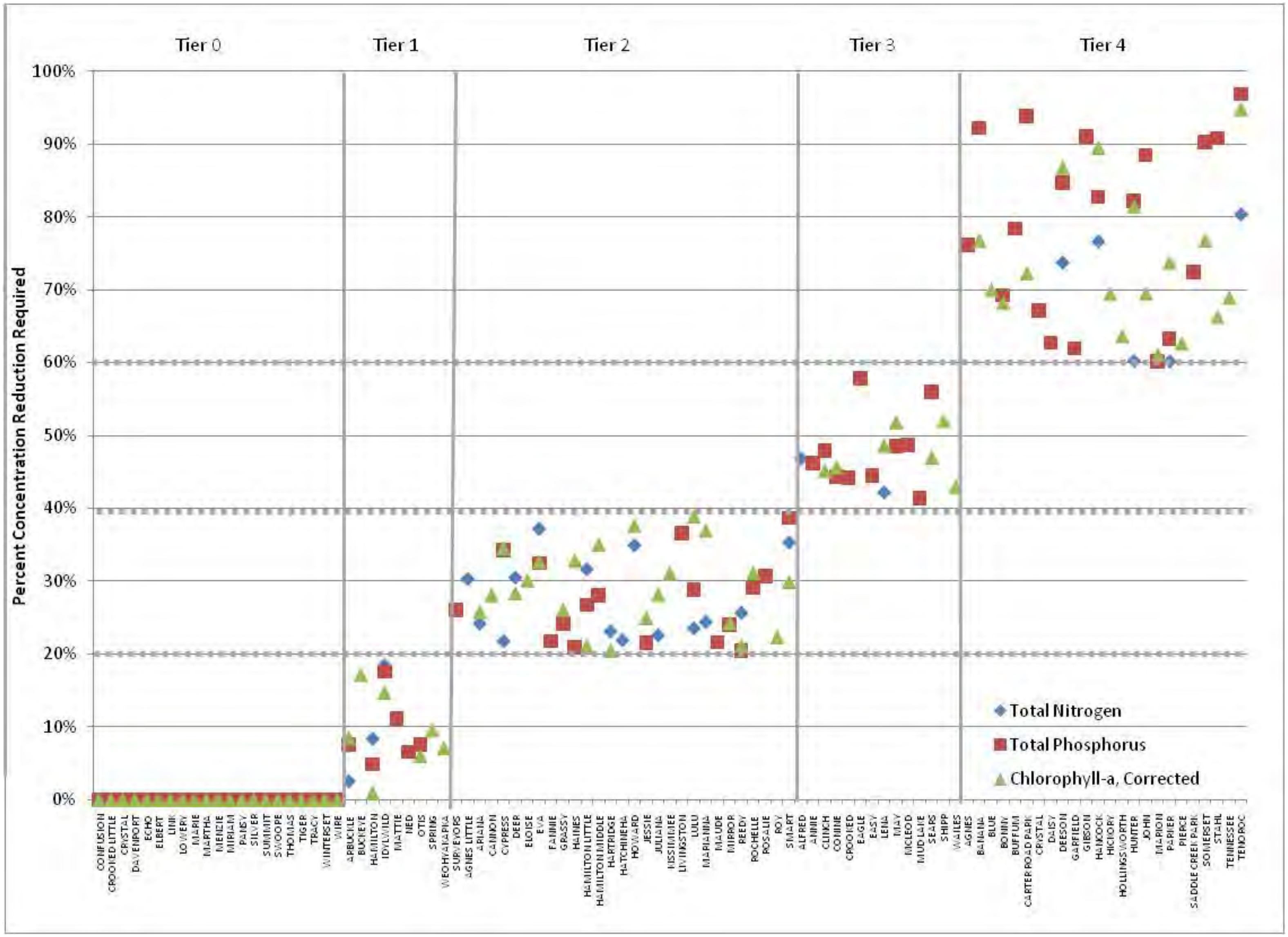
The context of each lake was evaluated by identifying factors which characterize the regulatory status, potential cooperative partners, lake size, potential socio-economic use, number of County M4 outfalls that discharge to the lake, and the portion of the drainage basin draining to the lake via County MS4 outfalls. A brief summary is presented here for of the criteria.

Regulatory

Each lake was classified based upon its current status in regards to regulatory compliance (**Table 4**). The maximum score (10) was assigned to water bodies with adopted TMDLs with a BMAP or Reasonable Assurance Plan (RAP). At this time, none of the lakes evaluated meet these criteria. Several the Polk County water bodies have a water quality management plan (WQMP). This plan identifies potential projects but requires additional feasibility studies prior to implementation. The minimum score (0) was assigned to water bodies which are not considered impaired using the NNC or have insufficient data to evaluate impairment status. TMDL requirements were based on the exceedance of the current water quality standards (NNC) not elevated TSI. Therefore, if a waterbody is currently on the 303(d) list for elevated TSI but was determined to meet the current standards (NNC), a TMDL was not deemed necessary based on the expectation that the waterbody will be removed from the 303(d) list by FDEP. In summary, the following categories were used to assign scores to each lake for the regulatory factor:

- Impaired lakes using NNC which have an adopted TMDL with a BMAP or RAP were assigned a score of 10
- Impaired lakes using NNC which have an FDEP adopted TMDL without a BMAP or which have a PLRG were assigned a score of 8
- Impaired lakes using NNC with existing WQMP were assigned a score of 6
- Impaired lakes using NNC without existing FDEP adopted TMDL were assigned a score of 4
- Lakes which have met the load reductions requirements of the TMDL were assigned a score of 2
- Unimpaired lakes using the NNC regardless of TMDL or 303(d) status or availability of an existing WQMP were assigned a score of 0

Figure 2. Lake tier assignment based on maximum percent concentration reduction required to meet NNC using 2003 to 2013 data.



For example, Lake Juliana (WBID 1484B) was assigned a score of “4” because there is not an existing TMDL and the waterbody exceeds the NNC criteria indicating that it is an impaired waterbody. However, Lake Buckeye (WBID 1488S), currently included on the 303(d) list for elevated TSI, was assigned a score of “0” because the waterbody was confirmed by FDEP to meet the NNC. The regulatory score for each lake can be found in Appendix A1.

Table 4. Score allocation based on regulatory status.

Regulatory Status	Score
TMDL Adopted with BMAP; RAP	10
TMDL Adopted with no BMAP; PLRG	8
WQMP	6
TMDL required	4
TMDL met	2
No TMDL Required; Unimpaired using NNC; INS	0

INS=insufficient data

Lake size

Lake size was used as a proxy for the potential magnitude of restoration funding required to achieve significant benefits (**Table 5**). Smaller lakes (<50 acres) were assigned the maximum score (10). Larger lakes (>1000 acres) were assigned the lowest priority score (2). Smaller lakes were assigned a greater priority to facilitate water quality improvements in as many water bodies as possible based on the limited water quality restoration funds available. For example, Lake Juliana (WBID 1484B) was assigned a lake size score of “4” based on its lake size of 917 acres. The lake size score for all lakes are listed in Appendix A2.

Table 5. Score allocation based upon lake size.

Lake Size (acres)	Score
<50	10
50-100	8
100-250	6
250-1000	4
>1000	2

Cooperative partners

Potential cooperative partners were quantified for each lake to identify the number of funding sources (direct or in-kind) potentially available for water quality restoration projects (**Table 6**). The numbers of potential cooperative partners (e.g. Polk County, Osceola County, City, SWFWMD SWIM, FDEP SWUCA, and FDOT) were designate based on whether the lakes geographic location is within the jurisdiction of a potential partner. The maximum score (10) was assigned to lakes with greater than 5 cooperative partners. The minimum score (1) was assigned to lakes with only one jurisdictional entity. All lakes are located within the South Florida Water Management District (SFWMD) or Southwest Florida Water Management District (SWFWMD) boundaries. However, those within the Surface Water Improvement and Management Program (SWIM) or Southern Water Use Caution Area (SWUCA) were identified as potentially available for additional supplemental funding. For example, Lake Juliana (WBID 1484B) was assigned a cooperative partners score of "4" because the lake is found with Polk County, City of Auburndale, and SWUCA jurisdiction. The cooperative partner score for each lake can be found in Appendix A3.

Table 6. Score allocation based on the number of cooperative partners.

Cooperative Partners	Score
More than five	10
Five	8
Four	6
Three	4
Two	2
One	1

includes Polk County, Osceola County, SWIM, SWUCA, Municipalities, SWFWMD, SFWMD, and FDOT

Socio-economic

The socio-economic classification for each lake relates primarily to recreational use and was calculated using a modified technique developed by the Florida Fish and Wildlife Conservation Commission (FFWCC, **Table 7**). The Aquatic Restoration Prioritization and Evaluation Tool (ARPET) was developed to provide an analytical process for identifying high priority water bodies for FFWCC aquatic habitat restoration and enhancement projects (FFWCC 2014). ARPET used an integration of socio-economics, fish and wildlife, and management emphasis. A modification of the socio-economic importance factor was used to rank the Polk County lakes (**Table 7**). The values for each criterion were summed and divided by the number of criteria (**Table 8**). The maximum score (10) was assigned to lakes with a calculated socio-economic value of 0.81 to 1.0. The minimum score (2) was assigned to lakes with a calculated socio-economic value of 0 to 0.2. For example, Lake Juliana (WBID 1484B) was assigned a socio-economic score of "4" based on the 0.29 calculated socio-economic value. The socio-economic score for each lake can be found in Appendix A4.

Table 7. Parameters used to determine socio-economic use for each Polk County lake.

Parameter / Dataset	Description	Scoring Method	Value Codes	Data Source
Boat Ramps	FFWCC, County, and City improved ramps on public lakes	Total count of "no fee" and "fee" ramps for each lake. Lakes with "access only" will be included, but receive no points.	0 boat ramps = 0 pts 1 boat ramp = 0.2 pts 2 boat ramps = 0.4 pts 3 boat ramps = 0.6 pts 4 boat ramps = 0.8 pts >5 boat ramps = 1 pt	AHRES Compilation: FFWCC Boating and Waterways, FWRI, DFFM, AHRES (December 2011)
Existing Recreational Trails	Trails that are paved/unpaved for multi-use (hike, bike, paddle) within 1 mile of the lake.	The total linear distance (miles) of trail within 1 mile buffer of the lake boundary.	<1 mile = 0.2 pts 1-3 miles =0.4 pts >3 – 4 miles = 0.6 pts >4 – 5 miles = 0.8 pts > 5 = 1 pt	FGDL - University of Florida GeoPlan (September 2011)
Great Florida Birding Trails (GFBT)	Birding trail access points that are within 1 mile of the lake.	Presence/Absence of trail in 1 mile buffer of lake boundary.	Presence GFBT = 1 pt Absence = 0 pts	FFWCC/Office of Public Access - Mark Kiser (November 2010)
Fish Management Areas (FMA)	A lake established for the management of freshwater fish.	Identify each lake as Presence/Absence.	Presence FMA = 1 pt Absence = 0 pt	FFWCC/FWRI (February 2010)
FFWCC Permitted Bass Tournaments	The total number of tournaments permitted on the lake between 2007-2013.	Total number of tournaments	1 - 10 = 0.2 pts 11- 25 = 0.4 pts 26 - 50 = 0.6 pts 51 - 100 = 0.8 pts >100 = 1 pt	AHRES Compilation: DFFM
Population	The total population density within 10 miles of each lake utilizing the 2010 Florida Census Blocks.	Population within 10 mile radius of lake boundary.	<40,000 = 0.2 pts 40,000-<80,000=0.4 pts 80,000- <120,000= 0.6 pts 120,000- <160,000= 0.8 pts > 160,000= 1 pt	FGDL - US Census Bureau (2010 Census Blocks in Florida)
Recreational Facilities	The total number of recreational facilities available adjacent to the lake (excluding Boat ramps)	Total number of recreational facilities	0 facilities=0 1 to 3 facilities=.02 4 to 7 facilities=0.4 8 to 11 facilities=0.6 12 to 15 facilities=0.8 >15 facilities=1	Polk County

Table 8. Score allocation based upon calculated socio-economic value.

Calculated Socio-Economic Value	Score
0.81-1.0	10
0.61-.8	8
0.41-.6	6
0.21-0.4	4
0-0.2	2

NPDES MS4 outfalls

The FDEP TMDL program has identified the NPDES stormwater discharges as a potential source for pollutant loads to impaired water bodies. Modifications to the permitted discharges (e.g. MS4) to an impaired waterbody have been identified as a method to reduce loadings from stormwater as required in a TMDL. The County has the responsibility to manage pollutant loads discharging from their MS4 outfalls. As such, the number of Polk County MS4 discharges to each lake was determined (**Table 9**). Those lakes without Polk County MS4 discharges were assigned a score of “0”. Lakes with a higher number of MS4 discharges were assigned a higher score. For example, Lake Juliana (WBID 1484B) was assigned a NPDES MS4 outfall score of “2” because three County MS4 outfalls were identified which discharge to the lake. The NPDES MS4 outfall scores for all lakes are listed in Appendix A5.

Table 9. Score allocation based on the number of Polk County MS4 discharges to the lake.

No. of County MS4 discharges to lake	Score
No County MS4 to lake	0
1 to 3	2
4 to 6	4
7 to 10	6
11 to 19	8
≥20	10

MS4 drainage basin area as percentage of lake drainage basin

The total lake drainage basin and MS4 subbasins were delineated for each lake that was examined (AMEC 2014). The contribution of runoff from MS4 outfalls into each lake was calculated as the percentage of the total drainage basin (**Table 10**). The minimum score (0) was assigned to lakes without permitted MS4 outfalls. The maximum score (10) was assigned to lakes in which ≥50 percent of a lake‟s drainage basin discharges through MS4 outfalls. For example, Lake Juliana (WBID 1484B) was assigned a MS4 area as percentage of drainage basin score of “6” because 12 percent of the lake drainage basin was attributed to MS4 drainage. The MS4 drainage basin area score for each lake can be found in Appendix A5.

Table 10. Score allocation based on the MS4 drainage basin area as a percentage of the total drainage basin.

MS4 area as percentage of drainage basin	Score
No County MS4 to lake	0
1 to <5	2
5 to <10	4
10 to <25	6
25 to <50	8
≥ 50	10

Context weight factors

The relative importance of each context factor to lake prioritization was designated as low, medium or high (**Table 11**). The designation allowed the County to quantify the influence of factors on the lake prioritization. For example, the regulatory requirement factor was classified to have a “high” relative importance due to the legal implications of TMDL implementation. In contrast, the cooperative partner factor was classified to have “low” relative importance because the number of partners was not considered paramount to water quality restoration project implementation. Weight factors were applied to each factor based upon the relative importance classification. The weighted score for each factor was calculated by multiplying the raw factor score by the weighted value. Factors identified with a “low” relative importance were assigned a weighted value of “0.5”. Factors identified with a “medium” relative importance were assigned a weighted value of “1.0”. Factors identified with a “high” relative importance were assigned a weighted value of “1.5”.

Table 11. Relative importance and weighted value assigned to each context factor.

Factor	Relative Importance	Weighted Value
Regulatory Requirements	High	1.5
Lake Size	Medium	1.0
Recreational Use	Medium	1.0
MS4 Discharges to Lake	Medium	1.0
MS4 Sub-basin Contribution	Medium	1.0
Cooperative Partners	Low	0.5

2.4.3. Intensity factors for prioritization

Intensity factors were developed to quantify the water quality status using existing water quality data for each lake. The frequency of exceedance of state standards and water quality trends were used to characterize the current water quality condition. A brief summary of each of the factors is provided below:

Frequency of exceedance

The number of times a lake exceeded the existing annual criteria for TN, TP, and chlac was calculated over the period of 2003-2013. Each lake was assigned a ranking based upon the frequency of exceedances by parameter (TN, , and chlac). The overall frequency ranking was assigned based on the largest tier score assigned between the three parameter classifications (**Table 12**). The maximum score (10) was assigned to lakes with an exceedance frequency of 21 to 40 percent for all three parameters because lakes within this category are considered marginally impaired and degradation in water quality may be intermittent. The minimum score (0) was assigned to lakes with no data or lakes that never exceeded the criteria for all three parameters. Lakes with 81 to 100 percent exceedance were assigned a score of "2" to account for consistent exceedances of the water quality criteria, suggest a chronic water quality issue that may require substantial funding to address and may have a reduced likelihood of improvement. For example, Lake Juliana (WBID 1484B) was assigned a percent frequency of exceedance score of "8" because TN and chlac concentrations exceeded the annual criteria 45 and 55 percent of the time over the period of 2003-2013, respectively. The percent frequency of exceedance score for each lake can be found in Appendix A.

Table 12. Score allocation based on the frequency of times a parameter exceed the NNC.

Percent Frequency of Exceedance (2003-2013)	TN Score	TP Score	chlac Score
1-20	4	4	4
21-40	10	10	10
41-60	8	8	8
61-80	6	6	6
81-100	2	2	2
0 or ND	0	0	0

ND- No Data

Water quality trend

A seasonal Kendall-Tau trend test was used to evaluate the presence of increasing or decreasing trends in TN, TP, and/or chlac for each lake (Helsel et al. 2005). A minimum of 30 data points was required for the analysis. If a significant improvement in water quality (decreasing trend) was identified, the predicted year in which the lake would meet the target was calculated using the trend equation. Each lake was classified based upon the impairment designation using the NNC combined and results of the trend test for each parameter (TN, TP, and chlac). The overall ranking for rate of change was assigned based on the largest score assigned between the three parameter classifications (**Table 13**). The water quality trend was extrapolated forward to predict whether the water quality criteria would be met, or violated, within ten years. An unimpaired lake with an increasing (declining water quality) trend that is expected to violate the criteria within 10 years was assigned the maximum score (10). Similarly, an impaired lake with a decreasing (improving) trend which is expected to meet the criteria within 10 years was assigned the maximum score (10). These two categories were assigned the greatest rank as implementation of water quality restoration projects was deemed to have a substantial impact on improving the water quality. Unimpaired lakes with a decreasing (improving) trend or no trend were assigned the minimum score (0). For example, Lake Juliana (WBID 1484B) was assigned a water quality trend and rate score of "10" because the waterbody is impaired when compared to the NNC and decreasing TP trends indicate an improvement in water quality within 10 years. The water quality trend and rate score for each lake can be found in Appendix A.

Table 13. Score allocation based on the water quality trend and rate of improvement or decline.

Water Quality Trend with Rate	TN Score	TP Score	chlac Score
Unimpaired, increasing (declining) within 10 years	10	10	10
Impaired, decreasing (improving) trend within 10 years	10	10	10
Impaired, increasing (declining) or no trend	8	8	8
Impaired, decreasing (improving) trend over 10 years	6	6	6
Unimpaired, increasing (declining) over 10 years	4	4	4
INS for Impairment determination; decreasing (improving) trend	2	2	2
Unimpaired, decreasing (improving) or no trend	2	2	2
Insufficient data or no trend	0	0	0

2.4.4. Final lake prioritization

Average scores for both the context and intensity factors were calculated. The overall context factor score was calculated by averaging the total weighted scores for all context factors. The overall intensity factor score was calculated by averaging all intensity factors. The final lake score is the sum of the overall context and overall intensity score. The individual lakes were ranked within tier groups. Lakes with the higher final lake scores were assigned higher priority. For example, the average context and intensity scores for Lake Juliana (WBID 1484B) are 4.0 and 9.0, respectively. The overall final lake score for the lake is 13.0. **Table 14** presents the average context and intensity and final lake score for each lake. Results of the prioritization process to assign priority to each of the ninety-seven publicly accessible lakes for potential future water quality restoration actions are presented in Section 3.2.2.

Table 14. Average context and intensity scores and final lake scores.

WBID	Lake Name	Average Context Score	Average Intensity Score	Final Lake Score
1466	AGNES	3.7	8	11.7
1466A1	LITTLE AGNES	1.5	2	3.5
1488D	ALFRED	1.8	3	4.8
1539C	ANNIE	2.7	9	11.7
1685A	ARBUCKLE	3.2	9	12.2

Table 14. Average context and intensity scores and final lake scores (Cont'd).

WBID	Lake Name	Average Context Score	Average Intensity Score	Final Lake Score
1501B	ARIANA	4.3	9	13.3
1549B	BANANA	4.8	6	10.8
1521Q	BLUE	6.7	9	15.7
1497E	BONNY	3.7	5	8.7
1488S	BUCKEYE	3.5	3	6.5
1677C	BUFFUM	2.7	9	11.7
1521H	CANNON	7.2	9	16.2
1610	CARTER ROAD PARK	4.3	6	10.3
1706	CLINCH	4.0	7	11.0
15003	CONFUSION	2.2	1	3.2
1488U	CONINE	5.7	9	14.7
1663	CROOKED	4.0	8	12.0
1663B	LITTLE CROOKED	1.8	5	6.8
1406B	CRYSTAL	2.2	0	2.2
1497A	CRYSTAL	6.5	10	16.5
3180A	CYPRESS*	2.0	9	11.0
1539R	DAISY	6.0	9	15.0
1436A	DAVENPORT	3.5	0	3.5
1521P	DEER	5.7	10	15.7
1449A	DEESON	4.8	9	13.8
1623M	EAGLE	4.7	6	10.7
1619B	EASY	2.0	2	4.0
1488Z	ECHO	4.3	1	5.3
1548	ELBERT	1.7	1	2.7
1521B	ELOISE	4.3	8	12.3
15101	EVA	3.0	5	8.0
14882	FANNIE	3.3	9	12.3
1622	GARFIELD	3.2	6	9.2
1497D	GIBSON	5.2	8	13.2
1623M1	GRASSY	4.3	10	14.3
1488C	HAINES	4.3	7	11.3
15041	HAMILTON	1.5	7	8.5
15001	LITTLE HAMILTON	3.3	9	12.3
15002	MIDDLE HAMILTON	4.2	9	13.2
1623L	HANCOCK	4.7	6	10.7
1521I	HARTRIDGE	5.8	9	14.8
1472B	HATCHINEHA	2.7	10	12.7
1730	HICKORY*	2.7	8	10.7
1549X	HOLLINGSWORTH	3.0	8	11.0
1521F	HOWARD	4.8	8	12.8

Table 14. Average context and intensity scores and final lake scores (Cont'd).

WBID	Lake Name	Average Context Score	Average Intensity Score	Final Lake Score
1543	HUNTER	4.3	5	9.3
1521J	IDYLWILD	6.5	10	16.5
1521K	JESSIE	6.8	9	15.8
1549E	JOHN	4.2	7	11.2
1484B	JULIANA	4.0	9	13.0
3183B	KISSIMMEE*	2.2	3	5.2
1501	LENA	4.7	9	13.7
1539Y	LINK	2.3	1	3.3
1730B	LIVINGSTON	1.0	3	4.0
2890A	LOWERY*	1.5	1	2.5
1521	LULU	4.7	9	13.7
1521L	MARIANNA	5.3	9	14.3
1532B	MARIE	2.7	1	3.7
1480	MARION	3.2	7	10.2
1488P	MARTHA	2.3	2	4.3
1476	MATTIE	3.3	8	11.3
1488Q	MAUDE	2.3	4	6.3
1521E	MAY	3.3	8	11.3
1588A	MCLEOD	3.0	8	11.0
1539Z	MENZIE	2.7	1	3.7
1539X	MIRIAM	2.7	1	3.7
1521G	MIRROR	4.2	9	13.2
1467	MUD	3.8	8	11.8
1539Q	NED	5.0	3	8.0
1539D	OTIS	1.7	3	4.7
1488Y	PANSY	2.3	2	4.3
1497B	PARKER	5.0	6	11.0
1532A	PIERCE	3.3	7	10.3
1685D	REEDY	3.7	9	12.7
1488B	ROCHELLE	4.5	9	13.5
1573C	ROSALIE	2.8	7	9.8
1521O	ROY	4.3	3	7.3
1497J	SADDLE CREEK PARK	5.8	7	12.8
1501W	SEARS	4.8	10	14.8
1521D	SHIPP	4.3	8	12.3
1488G	SILVER	2.3	2	4.3
1488A	SMART	3.8	10	13.8
1549F	SOMERSET	5.8	7	12.8
1521G1	SPRING	4.2	9	13.2
1549B1	STAHL	5.8	7	12.8

Table 14. Average context and intensity scores and final lake scores (Cont'd).

WBID	Lake Name	Average Context Score	Average Intensity Score	Final Lake Score
1521M	SUMMIT	3.5	1	4.5
1647	SURVEYORS	1.3	2	3.3
1488V	SWOOPE	2.3	1	3.3
1484A	TENNESSEE	5.0	10	15.0
1497C	TENOROC*	2.3	2	4.3
1501X	THOMAS	5.2	1	6.2
1573A	TIGER	1.2	2	3.2
14921	TRACY	1.5	1	2.5
1619A	WAILES	3.0	8	11.0
1573E	WEOHYAKAPKA	4.1	8	12.1
1521A	WINTERSET	3.7	1	4.7
1537	WIRE*	2.7	0	2.7

*Lakes not sampled by Polk County PNRD

3 Results

3.1 TMDL review

Detailed reports of the TMDLs reviewed are available in Appendix B. Summaries of relevant concerns for the 23 lakes with TMDLs are provided below.

Lake Ariana North

The primary issue with the TMDL for Lake Ariana North (EPA 2010) is the water quality target on which the TMDL is based. The TMDL for Lake Ariana North is based on attainment of a TSI target of 35, which is more protective than the typical TSI impairment level of 40. Prior work on low color lakes in Polk County has shown that a TSI target of 60 is more appropriate (FDEP 2007 and EPA 2006b). A TSI target of 35 results in water quality targets that are inappropriately low, and most likely unattainable.

Lake Alfred

Similar to Lake Ariana North, the primary issue with the TMDL for Lake Alfred is the water quality target on which the TMDL is based (EPA 2010). The TMDL for Alfred is based on attainment of a TSI target of 35, which is more protective than the TSI impairment level of 40. Prior work on low color lakes in Polk County has shown that a TSI target of 60 is more appropriate (FDEP 2007 and EPA 2006b). A TSI target of 35 results in water quality targets that are inappropriately low, and most likely unattainable.

Banana Lake

The waters of Banana Lake have much higher concentrations of TN and TP than initial water quality model results indicated. Consequently, the water quality model relied on a process termed “internal loading” (presumably from historical industrial and domestic wastewater point source loadings) that was not measured or explicitly described. Similar to Lake Hancock (below), resuspension of phosphorus-rich bottom sediments from prior point source loads could be a significant source of the excess and unaccounted for TP in the lake. Also, nitrogen-fixation by cyanobacteria in Banana Lake could be a significant source of the excess and unaccounted for TN. Neither resuspension of TP-rich sediments nor nitrogen fixation are processes included in the TMDL report (FDEP 2005a). As such, these two sources do not appear to be processes through which load allocation credits could be applied. TMDLs for locations such as Banana Lake, where historical point source loads are a significant and ongoing nutrient source, should include a mechanism through which nutrient reduction via sediment removal and/or inactivation would earn credit at least as much as load reductions focused on stormwater runoff.

Lake Bonny

The TMDL for Lake Bonny is based on empirically-derived relationships (i.e. based directly on data rather than a mechanistic model) that a comparison to NNC criteria, and refined further using results from paleolimnological studies (FDEP 2014a). The TMDL also allows for the possibility that in-lake activities such as enhanced management of submerged aquatic vegetation, whole-lake aeration, etc. can be used to achieve water quality goals. The combination of using actual data, rather than mechanistic water quality models and consideration of in-lake processes makes the TMDL for Lake Bonny more realistic than most other TMDLs for Polk County.

Lake Cannon

The water quality targets developed for the Lake Cannon TMDL are based on TSI, not NNC (FDEP 2007). However, a prior study in the Winter Haven Chain of Lakes indicated a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a, i.e. the nutrient concentrations that equate to a TSI score of 60 are likely to bring about a chl-a concentration with a TSI score much higher than 60 (PBS&J 2008). Also, the water quality model used for the Lake Cannon TMDL was calibrated via modifying TP settling rates, although locally measure rates are not available. Based on available data from Lakes Shipp, May, and Lulu (all of which had similarly challenging TMDLs) water quality in Lake Cannon is not likely to improve, at least not to an unimpaired condition, should the existing TMDL be fully implemented, as the nutrient concentration targets are not likely to bring about a chl-a concentration equivalent to the anticipated chl-a concentration.

Crystal Lake

Similar to the TMDLs for Lake Ariana North and Lake Alfred, the TMDL for Crystal Lake is based on a TSI target of 35, 5 units more protective than the designated TSI impairment level of 40 (EPA 2010). However, prior work on low color lakes in Polk County suggests a TSI target of 60 is more appropriate (FDEP 2007 and EPA 2006b). A TSI target of 35 results in water quality targets that are inappropriately low, and most likely unattainable.

Lake Cypress

The TMDL for Lake Cypress does not appear to address the importance of the change in lake levels (2 feet of decline) that occurred in the 1960s with the completion of the Cypress-Hatchineha Canal (EPA 2011). However, recently approved modifications to the Lake Cypress TMDL allow for the pursuit of water quality goals for Lake Cypress via hydrologic restoration (Tom Frick, personal communication) that are consistent with ongoing efforts to restore the lost wet weather storage capacity of the Upper Kissimmee Chain of Lakes. If hydrologic restoration of the Lake Cypress watershed does not bring about the water quality improvements anticipated, stormwater projects may be required. It should also be noted that the vast majority of the Lake Cypress watershed as well as the lake itself is outside the boundaries of Polk County.

Deer Lake

Similar to Lake Bonny, the TMDL for Deer Lake is based on empirically-derived relationships, which were then compared to NNC criteria (FDEP 2014b). The TMDL also allows for the possibility that in-lake activities such as enhanced management of submerged aquatic vegetation, whole-lake aeration, etc. can be used to achieve water quality goals. The combination of using available data, rather than mechanistic water quality models, and the consideration of in-lake processes, makes the TMDL more realistic than most other TMDLs for Polk County. However, it appears that the estimation of TP concentration reductions required to meet NNC criteria used in the development of the TMDL may be in error: further discussion can be found in the Appendix B. This potential discrepancy should be verified, and corrected if necessary.

Lake Haines

The TMDL for Lake Haines does not appear to address or note the basis for what appears to be a substantial reduction in chl-a from the early 1990s to the early 2000s (EPA 2006b). If a lake management action was involved, it is important to identify the action and better incorporate it into the TMDL. Groundwater seepage rates and groundwater loading estimates for both TN and TP are available for Lake Haines. However, those data were collected after the TMDL was developed, and a revised TMDL is not yet available (nor is a revision scheduled) to incorporate the locally-based groundwater nutrient budget. There is a large discrepancy between the external TP load reductions called for in the TMDL (70 percent based on TSI values) vs. the TP concentration reduction required to meet NNC guidance (21 percent), suggesting a revised TMDL may be appropriate.

Lake Hancock

The TMDL for Lake Hancock, developed in 2005, remains a draft document (FDEP 2005b). Similar to the TMDL for Banana Lake, the waters of Lake Hancock have much higher levels of TN and TP than indicated in initial water quality model results, and so the water quality model invoked a process termed “internal loading” that was never measured nor fully described. A prior study in Lake Hancock have shown that bottom resuspension of phosphorus-rich sediments are a significant source of the excess and unaccounted for TP in the lake, and that nitrogen-fixation by cyanobacteria are a significant source of the excess and unaccounted for TN (Tomasko et al. 2009). Neither resuspension of TP rich bottom sediments nor nitrogen fixation processes are included in the draft TMDL. As such, those two sources do not appear to be processes through which load allocation credits could be applied.

Lake Hollingsworth

Similar to Lake Bonny and Deer Lake, the TMDL for Lake Hollingsworth is based on empirically-derived relationships, which are then compared to NNC criteria, and results are further refined based on paleolimnological studies (FDEP 2014c). The TMDL also allows for the possibility that in-lake activities such as enhanced management of submerged aquatic vegetation, whole-lake aeration, can be used to achieve water quality goals. The combination of the empirical approach rather than a mechanistic water quality model, and the consideration of in-lake processes, makes the TMDL for Lake Hollingsworth more realistic than most other TMDLs for Polk County.

Lake Howard

Similar to Lake Cannon, the water quality targets developed for the Lake Howard TMDL are based on TSI, not NNC (FDEP 2007). However, a prior study in the Winter Haven Chain of Lakes has indicated a discrepancy between TSI values for nutrients and TSI values for the biological indicator of chl-a (PBS&J 2008). Also, the water quality model used for the Lake Howard TMDL was calibrated via modifying the rate coefficients of biological processes that have not been locally measured. Based on monitoring data from Lakes Shipp, May, and Lulu (all of which had similarly challenging TMDLs), water quality is not likely to improve in Lake Howard, at least not to an unimpaired condition, should the TMDL be fully implemented.

Lake Hunter

The TMDL for Lake Hunter is based on the attainment of water quality targets developed using a series of complex equations dependent, either directly or indirectly, on relationships that have not been verified (FDEP 2004). Consequently, re-evaluation of the Lake Hunter TMDL appears appropriate, with a particular focus on developing, if possible, empirically-derived water quality targets for nutrient concentrations. In addition, there is evidence that the relationship between TN and chl-a in Lake Hunter is mostly influenced by nitrogen-fixing cyanobacteria, rather than TN loads, as nitrogen concentrations in the lake include many values that are much higher than those which could be produced by urban stormwater runoff (as presented in Section 3.2). There is not a statistically significant correlation between TP and chl-a in Lake Hunter, although TP reductions are included as part of the TMDL. The TMDL also does not account for the potential role of in-lake processes for both TN and TP. Further, the influence of septic tank systems on the TN load is assumed, not measured, and is at odds with estimates of such loads in other TMDLs which have suggested a much more moderate impact of septic tank systems on downstream nutrient loads.

Lake Idylwild

Similar to Lakes Cannon and Howard, the water quality targets developed for the Lake Idylwild TMDL are based on TSI, not NNC (FDEP 2007). However, the previously described study for the Winter Haven Chain of Lakes has shown that there is a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a (PBS&J 2008). Also, the water quality model used in the TMDL for Lake Idylwild was calibrated via modifying TP settling rates, which have not been locally measured. Based on monitoring data from Lakes Shipp, May, and Lulu (all of which had similarly problematic TMDLs), in our opinion there is a heightened probability that water quality in Lake Idylwild would not likely improve, at least to an unimpaired condition, should the TMDL be fully implemented.

Lake Jessie

As in Lakes Cannon, Howard and Idylwild, the water quality targets developed for the Lake Jessie TMDL are based on TSI, not NNC (FDEP 2007). However, the previously described study for the Winter Haven Chain of Lakes has shown that there is a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a (PBS&J 2008). Also, the water quality model used in the TMDL for Lake Jessie was calibrated via modifying rate coefficients of biological processes which have not been locally measured. Based on monitoring data from lakes Shipp, May, and Lulu (all of which had similarly problematic TMDLs) there is a heightened probability that water quality would not likely improve in Lake Jessie, at least to an unimpaired condition, should the TMDL be fully implemented.

Lake Kissimmee

A complicating factor related to the TMDL for Lake Kissimmee is that when water quality is characterized using NNC, Lake Kissimmee is not impaired for nutrients, at least not during the period of 2000 to 2012 (FDEP 2013b). Therefore, a TMDL based on the use of TSI appears to be problematic, as the State of Florida"s updated nutrient impairment techniques suggest that water quality is not impaired for nutrients. Although there are statistically significant relationships between both TN and chl-a and also between TP and chl-a, the relationships have low R^2 values, suggesting that factors other than nutrient availability are more important influencers of algal biomass than nutrients alone (see Tables 15 and 16). Additionally, Lake Kissimmee is an in-line waterbody, essentially a wide segment of the Kissimmee River, so water quality is significantly affected by nutrient inputs from the entire upstream basin. The TMDL for Lake Kissimmee is based on the achievement of TMDL obligations in lakes that are located farther upstream in the Upper Kissimmee Chain of Lakes system; including lakes which themselves have problematic TMDLs (e.g. Lake Cypress).

Lake Lena

Similar to Lakes Bonny and Hollingsworth and Deer Lake, the TMDL developed for Lake Lena is based on empirically-derived relationships, which are then compared to NNC criteria (FDEP 2014d). The TMDL also allows for the possibility that in-lake processes can be used to achieve water quality goals. The combination of using actual data rather than mechanistic water quality models, and the consideration of in-lake activities such as enhanced management of submerged aquatic vegetation, whole-lake aeration, makes the TMDL more realistic than most. However, and as in the TMDL for Deer Lake, it appears that the TMDL for Lake Lena includes an error involving the estimation of TP concentration reductions required to meet NNC criteria, as further discussed in Appendix B.

Lake Lulu

As in Lakes Cannon, Howard, Idylwild and Jessie, the TMDL for Lake Lulu is based on water quality targets derived from the use of TSI, not NNC (FDEP 2007). A prior study has determined that Lake Lulu has shown little evidence of improvement in water quality, even though the County‟s obligations with respect to the TMDL for the lake appear to have been met (PBS&J 2008). Prior studies on the Winter Haven Chain of Lakes have shown that TSI values for nutrients do not correspond well with expected chl-a values (based on TSI) (PBS&J 2008). This disconnect could be related to the use of a complex mechanistic water quality model that was calibrated via the modification of TP settling rates, which have not been locally measured, and therefore are not necessarily representative of the Lake Lulu internal processes.

Lake May

As in Lakes Cannon, Howard, Idylwild, Jessie and Lulu, the TMDL for Lake May is based on water quality targets derived from the use of TSI, not NNC (FDEP 2007). A prior study has determined that Lake May has shown little evidence of improvement in water quality, even though the County‟s obligations with respect to the TMDL for the lake appear to have been met (PBS&J 2008). A prior study on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correspond well with expected chl-a values (based on TSI) (PBS&J 2008). This disconnect could be related to the use of a complex mechanistic water quality model that was calibrated via the modification of TP settling rates, which have not been locally measured, and therefore are not necessarily representative of the Lake May internal processes.

Lake Mirror

As in Lakes Cannon, Howard, Idylwild, Jessie and May, the water quality targets in the Lake Mirror TMDL are based on TSI, not NNC (FDEP 2007). However, a prior study in the Winter Haven Chain of Lakes has shown that there is a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a (PBS&J 2008). Also, the water quality model used in the TMDL for Lake Mirror was calibrated via modifying rate coefficients of biological processes which have not been locally measured. Based on monitoring data from Lakes Shipp, May, and Lulu (all of which had similarly problematic TMDLs), it is our opinion that there is a heightened probability that water quality in Lake Mirror would not likely improve, at least to an unimpaired condition, should the TMDL be fully implemented.

Lake Parker

Lake Parker contains higher levels of TN and TP than initial water quality model results indicated (FDEP 2005c). Consequently, the water quality model relied on a process termed “internal loading” that was not measured, but is meant to account for all “excess” nutrient loads. Similar to Lake Hancock and Banana Lake, these internal loads are likely due to resuspension of phosphorus-rich bottom sediments from prior point source loads for TP, and nitrogen-fixation by cyanobacteria for TN. Neither resuspension of TP-rich sediments nor nitrogen fixation are processes included in the TMDL report. As such, these two sources do not appear to be processes through which load allocation credits could be applied. The TMDL for Lake Parker, where historical point source loads are a significant and ongoing nutrient source from sediments, should include a mechanism through which nutrient reduction via sediment removal and/or inactivation would earn credit at least as much as load reductions focused on stormwater runoff.

Lake Shipp

As in Lakes Cannon, Howard, Idylwild, Jessie, Lulu and May, the TMDL for Lake Shipp is based on water quality targets derived from the use of TSI, not NNC (FDEP 2007). A prior study has determined that Lake Shipp shows little evidence of improvement in water quality, even though the lake appears to have already met its TMDL obligations (PBS&J 2008). Prior studies on the Winter Haven Chain of Lakes have shown that TSI values for nutrients do not correspond well with expected values (based on TSI) for chl-a (PBS&J 2008). This disconnect could be related to the use of a complex mechanistic water quality model that was calibrated via the modification of TP settling rates, which have not been locally measured, and therefore are not necessarily representative of the Lake Shipp internal processes.

Lake Smart

The TMDL for Lake Smart does not fully account for the obvious improvements in water quality in Lake Smart after the whole-lake alum treatment that was applied to the “upstream” waterbody of Lake Conine (EPA 2006b). The TMDL for Lake Smart includes evidence of an approximate 50 percent decline in chl-a concentrations in the lake that appear to be related to the Lake Conine project, but that improvement was associated with an activity that occurred outside the geographic boundaries of the Lake Smart watershed, as shown in the TMDL. Similar to Lake Haines, groundwater seepage rates and groundwater loading estimates for both TN and TP are available for Lake Smart, but those data were collected after the TMDL was developed; the groundwater seepage estimates of the TMDL for Lake Smart appear to underestimate the actual load of TN and TP from groundwater sources.

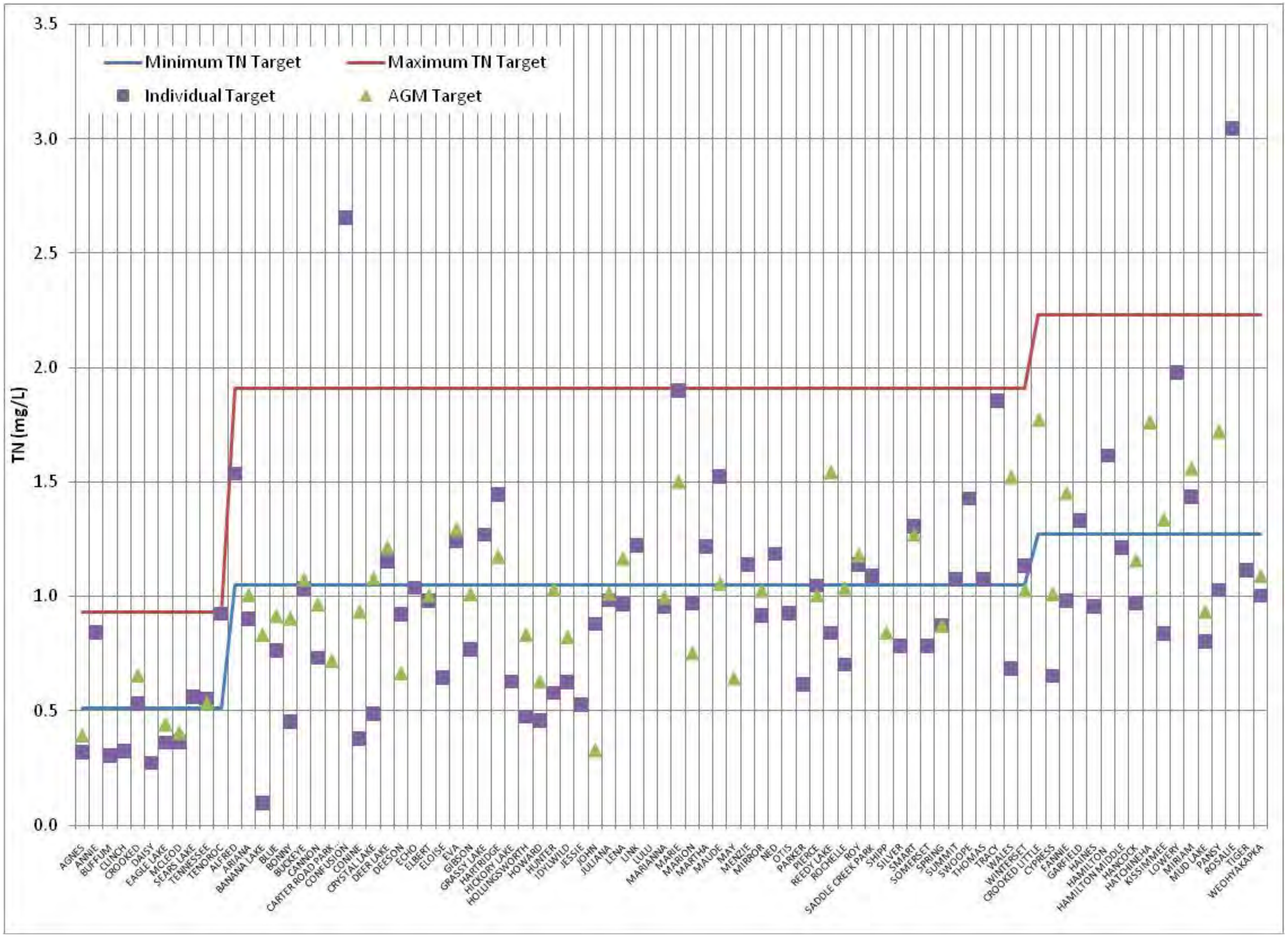
3.2 Empirically-derived nutrient targets for water quality

Lake-specific nutrient concentration targets were developed for Polk County lakes independent of FDEP NNC. Correlations (R^2 values) between nutrient (TN or TP) and chl-a concentrations were developed and lake-specific targets were calculated for those correlations that were significant (p-value ≤ 0.05). Results from the AGM and individual data approach are provided in **Tables 15 and 16** and in **Figures 3 and 4**. The R^2 value indicates the measure of confidence in the correlation between the parameters evaluated. A low R^2 value can indicate that the correlation between the independent and dependent variable is weak (i.e. there is a large amount of unexplained variability) or that the fit of the data to the model is poor. The empirically-derived, lake-specific TN or TP targets (AGM and individual) were compared to the FDEP NNC criteria (minimum and maximum targets) based upon lake-type designation (e.g. clear, acidic; **Tables 15 and 16**).

- Min TP or TN NNC AGM Target: default minimum FDEP NNC criteria for lakes with AGM chlac concentrations that exceed the AGM chlac target
- Max TP or TN NNC AGM Target: default maximum FDEP NNC criteria for lakes with AGM chlac concentrations that are below the AGM chlac target
- AGM TP or TN Target: empirically-derived, lake-specific target calculated from significant correlation with chlac using AGM over the period of 1983 to 2013
- Individual TP or TN Target: empirically-derived, lake-specific target calculated from significant correlation with chlac using all data from 1983 to 2013

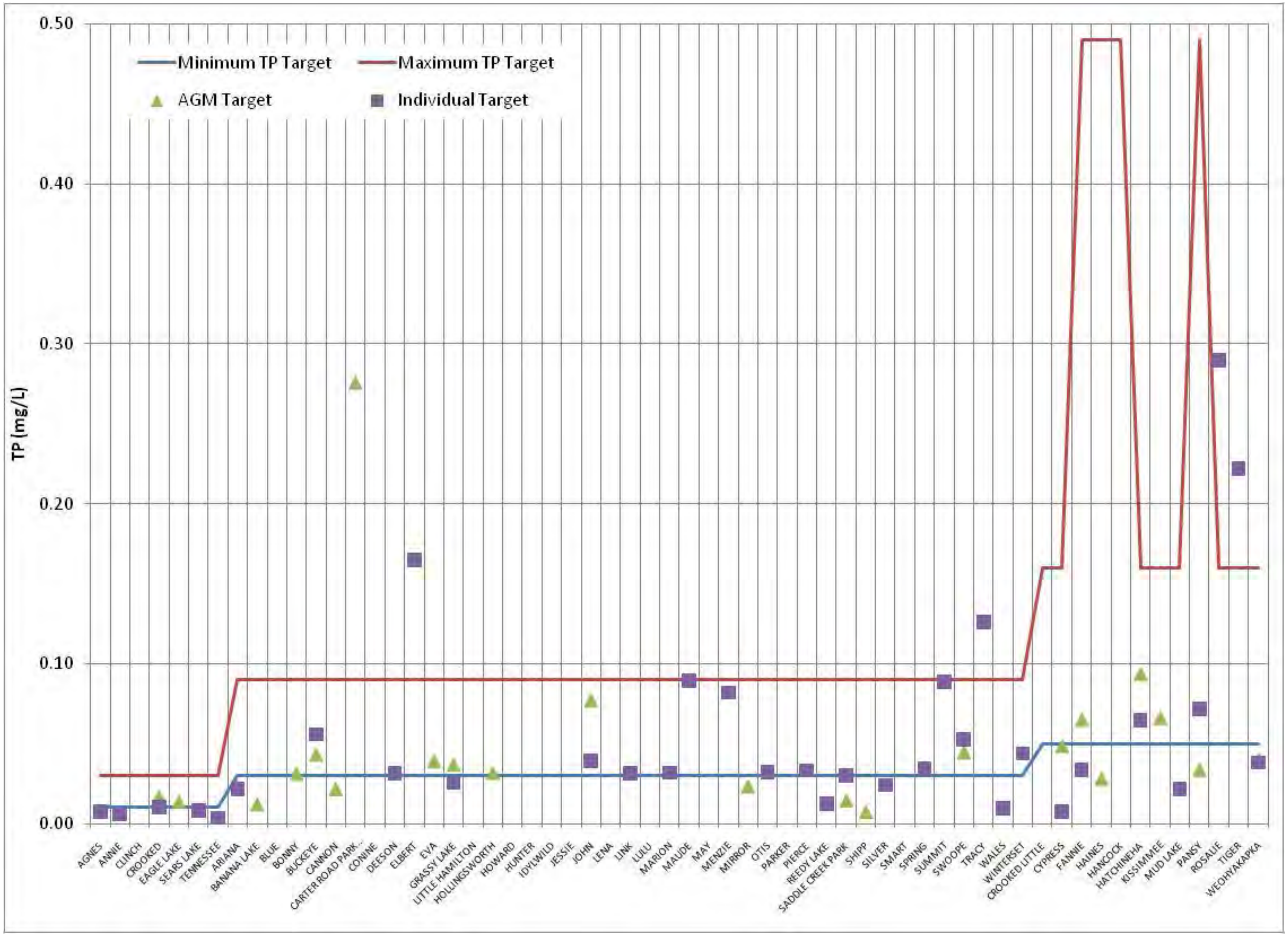
For example, Lake Bonny is classified as a clear, alkaline lake (color ≤ 40 PCU and alkalinity >20 mg/L $CaCO_3$) within the West Central Region. The FDEP NNC chl-a target for Lake Bonny is 20 µg/L, and the minimum and maximum targets are 1.05 and 1.91 mg/L for TN and 0.03 and 0.09 mg/L for TP (**Figures 3 and 4**). The minimum or maximum criteria are assigned based on the annual geometric chl-a concentration for a given year. If the annual geometric chl-a concentration exceeds 20 µg/L, the TP and TN criteria are 0.03 and 1.05 mg/L for that year, respectively. However, if the chl-a concentration is below the 20 µg/L criteria, the TN and TP criteria are 1.91 and 0.09 mg/L, respectively. The empirically-derived AGM lake-specific TN and TP targets are 0.91 and 0.03 mg/L, respectively (**Tables 15 and 16**). The empirically-derived individual lake-specific TN target was 0.45 mg/L, after the removal of influential high TN concentrations (values greater than 2.4 mg/L were removed for analysis; **Table 15**). A significant correlation between chlacomb and TP was identified; however, the solution of the resulting linear equation to calculate the target TP was negative. Therefore, the TP target for Lake Bonny using the individual data was reported as “na” (equation not applicable). While the TP target is similar between the NNC and empirically-derived, AGM target, both the AGM (0.91 mg/L) and individual (0.45 mg/L) TN targets are lower than the min and max NNC AGM TN targets (1.05 and 1.91 mg/L, respectively).

Figure 3. Empirically-derived, lake-specific water quality TN targets for selected Polk County lakes.*



*Only lakes with sufficient data and significant correlations to calculate the targets are presented.

Figure 4. Empirically-derived, lake-specific water quality TP targets for selected Polk County lakes.*



*Only lakes with sufficient data and significant correlations to calculate the targets are presented.

Table 15. Empirically-derived, lake-specific water quality TN targets for selected Polk County lakes.

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TN AGM NNC Target (mg/L)		AGM TN and chlac		Individual TN and chlacomb	
					Min	Max	R^2	Lake-Specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1466	AGNES	Clear	Acidic	6	0.51	0.93	0.46	0.39	0.34	0.32
1466A1	LITTLE AGNES	Clear	Acidic	6	0.51	0.93	ins	ins	ins	ins
1488D	ALFRED	Clear	Alkaline	20	1.05	1.91	0.44	ns	0.52	1.54
1539C	ANNIE	Clear	Acidic	6	0.51	0.93	ins	ins	0.69	0.84
1685A	ARBUCKLE	Colored		20	1.27	2.23	0.01	ns	ns	ns
1501B	ARIANA	Clear	Alkaline	20	1.05	1.91	0.88	1.01	0.47	0.90
1549B	BANANA LAKE*	Clear	Alkaline	20	1.05	1.91	0.79	0.83	0.11	0.10
1521Q	BLUE	Clear	Alkaline	20	1.05	1.91	0.44	0.92	0.65	0.76
1497E	BONNY*	Clear	Alkaline	20	1.05	1.91	0.91	0.90	0.20	0.45
1488S	BUCKEYE	Clear	Alkaline	20	1.05	1.91	0.61	1.08	0.58	1.04
1677C	BUFFUM	Clear	Acidic	6	0.51	0.93	ins	ins	0.30	0.31
1521H	CANNON	Clear	Alkaline	20	1.05	1.91	0.64	0.97	0.33	0.73
1610	CARTER ROAD PARK LAKES	Clear	Alkaline	20	1.05	1.91	0.49	0.72	0.35	na
1706	CLINCH	Clear	Acidic	6	0.51	0.93	0.38	ins	0.30	0.32
15003	CONFUSION	Clear	Alkaline	20	1.05	1.91	0.19	ns	0.11	2.66
1488U	CONINE	Clear	Alkaline	20	1.05	1.91	0.53	0.94	0.22	0.38
1663	CROOKED	Clear	Acidic	6	0.51	0.93	0.51	0.66	0.17	0.53
1663B	LITTLE CROOKED	Colored		20	1.27	2.23	0.54	1.77	ns	ns
1406B	CRYSTAL	Clear	Acidic	6	0.51	0.93	ins	ins	ins	
1497A	CRYSTAL LAKE	Clear	Alkaline	20	1.05	1.91	0.74	1.08	0.28	0.49
3180A	CYPRESS	Colored		20	1.27	2.23	0.49	1.01	0.27	0.65
1539R	DAISY	Clear	Acidic	6	0.51	0.93	0.04	ns	0.04	0.27
1436A	DAVENPORT	Colored		20	1.27	2.23	ins	ins	ins	ins

Table 15. Empirically-derived, lake-specific water quality TN targets for selected Polk County lakes (Cont'd)

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TN AGM NNC Target (mg/L)		AGM TN and chlac		Individual TN and chlacomb	
					Min	Max	R^2	Lake-Specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1521P	DEER LAKE	Clear	Alkaline	20	1.05	1.91	0.54	1.21	0.38	1.15
1449A	DEESON	Clear	Alkaline	20	1.05	1.91	0.94	0.67	0.48	0.92
1623M	EAGLE LAKE	Clear	Acidic	6	0.51	0.93	0.46	0.44	0.38	0.36
1619B	EASY	Clear	Acidic	6	0.51	0.93	ins	ins	0.19	inverse
1488Z	ECHO	Clear	Alkaline	20	1.05	1.91	ns	ns	0.34	1.04
1548	ELBERT	Clear	Alkaline	20	1.05	1.91	0.43	1.01	0.39	0.98
1521B	ELOISE	Clear	Alkaline	20	1.05	1.91	ns	ns	0.29	0.64
15101	EVA	Clear	Alkaline	20	1.05	1.91	0.78	1.29	0.63	1.24
14882	FANNIE	Colored		20	1.27	2.23	0.62	1.45	0.24	0.98
1622	GARFIELD	Colored		20	1.27	2.23	ns	ns	0.20	1.33
1497D	GIBSON	Clear	Alkaline	20	1.05	1.91	0.63	1.01	0.56	0.77
1623M1	GRASSY LAKE	Clear	Alkaline	20	1.05	1.91	ns	ns	0.56	1.27
1488C	HAINES	Colored		20	1.27	2.23	ns	ns	0.74	0.95
15041	HAMILTON	Colored		20	1.27	2.23	ns	ns	0.36	1.61
15002	MIDDLE HAMILTON	Colored		20	1.27	2.23	ins	ins	0.28	1.21
15001	LITTLE HAMILTON	Clear	Alkaline	20	1.05	1.91	ins	ins	ns	ns
1623L	HANCOCK	Colored		20	1.27	2.23	0.91	1.16	0.53	0.97
1521I	HARTRIDGE	Clear	Alkaline	20	1.05	1.91	0.59	1.18	0.16	1.45
1472B	HATCHINEHA	Colored		20	1.27	2.23	0.29	1.76	ns	ns
1730	HICKORY LAKE*	Clear	Alkaline	20	1.05	1.91	ns	ns	0.60	0.63
1549X	HOLLINGSWORTH*	Clear	Alkaline	20	1.05	1.91	0.87	0.83	0.26	0.48
1521F	HOWARD	Clear	Alkaline	20	1.05	1.91	0.46	0.63	0.31	0.46
1543	HUNTER*	Clear	Alkaline	20	1.05	1.91	0.93	1.03	0.16	0.58

Table 15. Empirically-derived, lake-specific water quality TN targets for selected Polk County lakes (Cont'd)

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TN AGM NNC Target (mg/L)		AGM TN and chlac		Individual TN and chlacomb	
					Min	Max	R^2	Lake-Specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1521J	IDYLWILD	Clear	Alkaline	20	1.05	1.91	0.56	0.82	0.21	0.63
1521K	JESSIE	Clear	Alkaline	20	1.05	1.91	ns	ns	0.45	0.53
1549E	JOHN	Clear	Alkaline	20	1.05	1.91	0.80	0.33	0.53	0.88
1484B	JULIANA	Clear	Alkaline	20	1.05	1.91	0.80	1.01	0.13	0.98
3183B	KISSIMMEE	Colored		20	1.27	2.23	0.14	1.34	0.37	0.84
1501	LENA	Clear	Alkaline	20	1.05	1.91	0.71	1.17	0.18	0.97
1539Y	LINK	Clear	Alkaline	20	1.05	1.91	ins	ins	0.43	1.22
1730B	LIVINGSTON	Colored		20	1.27	2.23	ins	ins	ns	ns
2890A	LOWERY	Colored		20	1.27	2.23	ns	ns	0.19	1.98
1521	LULU	Clear	Alkaline	20	1.05	1.91	ns	ns	0.06	na
1521L	MARIANNA	Clear	Alkaline	20	1.05	1.91	0.66	1.00	0.52	0.96
1532B	MARIE	Clear	Alkaline	20	1.05	1.91	0.66	1.50	0.25	1.90
1480	MARION	Clear	Alkaline	20	1.05	1.91	0.59	0.75	0.66	0.97
1488P	MARTHA	Clear	Alkaline	20	1.05	1.91	ns	ns	0.41	1.22
1476	MATTIE	Colored		20	1.27	2.23	0.52	inverse	ns	ns
1488Q	MAUDE	Clear	Alkaline	20	1.05	1.91	0.65	1.06	0.09	1.53
1521E	MAY	Clear	Alkaline	20	1.05	1.91	0.50	0.64	0.16	na
1588A	MCLEOD	Clear	Acidic	6	0.51	0.93	0.59	0.41	0.32	0.36
1539Z	MENZIE	Clear	Alkaline	20	1.05	1.91	ins	ins	0.45	1.14
1539X	MIRIAM	Colored		20	1.27	2.23	0.81	1.56	0.45	1.44
1521G	MIRROR	Clear	Alkaline	20	1.05	1.91	0.61	1.03	0.47	0.92
1467	MUD	Colored		20	1.27	2.23	0.85	0.93	0.50	0.80
1539Q	NED	Clear	Alkaline	20	1.05	1.91	ns	ns	0.34	1.19

Table 15. Empirically-derived, lake-specific water quality TN targets for selected Polk County lakes (Cont'd)

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TN AGM NNC Target (mg/L)		AGM TN and chlac		Individual TN and chlacomb	
					Min	Max	R^2	Lake-Specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1539D	OTIS	Clear	Alkaline	20	1.05	1.91	ins	ins	0.40	0.92
1488Y	PANSY	Colored		20	1.27	2.23	0.43	1.72	0.37	1.03
1497B	PARKER*	Clear	Alkaline	20	1.05	1.91	ns	ns	0.13	0.61
1532A	PIERCE	Clear	Alkaline	20	1.05	1.91	0.82	1.01	0.67	1.05
1685D	REEDY LAKE	Clear	Alkaline	20	1.05	1.91	0.53	1.54	0.17	0.84
1488B	ROCHELLE	Clear	Alkaline	20	1.05	1.91	0.55	1.04	0.25	0.70
1573C	ROSALIE	Colored		20	1.27	2.23	ns	ns	0.06	3.05
1521O	ROY	Clear	Alkaline	20	1.05	1.91	0.55	1.18	0.55	1.14
1497J	SADDLE CREEK PARK	Clear	Alkaline	20	1.05	1.91	ns	ns	0.59	1.09
1501W	SEARS LAKE	Clear	Acidic	6	0.51	0.93	ins	ins	0.50	0.56
1521D	SHIPP	Clear	Alkaline	20	1.05	1.91	0.59	0.84	0.18	na
1488G	SILVER	Clear	Alkaline	20	1.05	1.91	ns	ns	0.66	0.78
1488A	SMART	Clear	Alkaline	20	1.05	1.91	0.82	1.27	0.26	1.31
1549F	SOMERSET	Clear	Alkaline	20	1.05	1.91	ns	ns	0.37	0.78
1521G1	SPRING	Clear	Alkaline	20	1.05	1.91	0.67	0.87	0.42	0.87
1549B1	STAHL	Clear	Alkaline	20	1.05	1.91	ns	ns	ns	ns
1521M	SUMMIT	Clear	Alkaline	20	1.05	1.91	ns	ns	0.35	1.07
1647	SURVEYORS	Colored		20	1.27	2.23	ns	ns	0.09	inverse
1488V	SWOOPE	Clear	Alkaline	20	1.05	1.91	ns	ns	0.40	1.43
1484A	TENNESSEE	Clear	Acidic	6	0.51	0.93	0.83	0.54	0.73	0.55
1497C	TENOROC*	Clear	Acidic	6	0.51	0.93	ins	ins	0.60	0.92
1501X	THOMAS	Clear	Alkaline	20	1.05	1.91	ins	ins	0.43	1.07
1573A	TIGER	Colored		20	1.27	2.23	ns	ns	0.53	1.11

Table 15. Empirically-derived, lake-specific water quality TN targets for selected Polk County lakes (Cont'd)

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TN AGM NNC Target (mg/L)		AGM TN and chlac		Individual TN and chlacomb	
					Min	Max	R^2	Lake-Specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
14921	TRACY	Clear	Alkaline	20	1.05	1.91	ins	ins	0.53	1.86
1619A	WALES	Clear	Alkaline	20	1.05	1.91	0.94	1.52	0.56	0.68
1573E	WEOHYAKAPKA	Colored		20	1.27	2.23	0.80	1.09	0.48	1.00
1521A	WINTERSET	Clear	Alkaline	20	1.05	1.91	0.76	1.03	0.43	1.13
1537	WIRE	Clear	Alkaline	20	1.05	1.91	ins	ins	ins	ins

*Individual data regression completed after all TN values greater than 2.4 mg/L removed; ins=insufficient data; ns=not significant; na=equation not applicable

Table 16. Empirically-derived, lake-specific water quality TP targets for selected Polk County lakes.

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TP NNC AGM Target (mg/L)		AGM TP and chlac		Individual TP and chlacomb	
					Min	Max	R^2	Lake-specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1466	AGNES	Clear	Acidic	6	0.01	0.03	0.34	ns	0.18	0.01
1466A1	LITTLE AGNES	Clear	Acidic	6	0.01	0.03	ins	ins	ins	ins
1488D	ALFRED	Clear	Alkaline	20	0.03	0.09	ins	ins	ns	ns
1539C	ANNIE	Clear	Acidic	6	0.01	0.03	ins	ins	0.17	0.01
1685A	ARBUCKLE	Colored		20	0.05	0.16	0.47	inverse	ns	ns
1501B	ARIANA	Clear	Alkaline	20	0.03	0.09	0.72	0.02	0.15	0.02
1549B	BANANA LAKE	Clear	Alkaline	20	0.03	0.09	0.42	0.01	0.20	na
1521Q	BLUE	Clear	Alkaline	20	0.03	0.09	0.49	ns	0.36	na
1497E	BONNY	Clear	Alkaline	20	0.03	0.09	0.93	0.03	0.82	na
1488S	BUCKEYE	Clear	Alkaline	20	0.03	0.09	0.62	0.04	0.20	0.06
1677C	BUFFUM	Clear	Acidic	6	0.01	0.03	ins	ins	ns	ns
1521H	CANNON	Clear	Alkaline	20	0.03	0.09	0.49	0.02	0.11	na
1610	CARTER ROAD PARK LAKES	Clear	Alkaline	20	0.03	0.09	0.33	0.28	0.05	na
1706	CLINCH	Clear	Acidic	6	0.01	0.03	ns	ns	0.05	na
15003	CONFUSION	Clear	Alkaline	20	0.03	0.09	ins	ins	ns	ns
1488U	CONINE	Clear	Alkaline	20	0.03	0.09	0.05	ns	0.25	na
1663	CROOKED	Clear	Acidic	6	0.01	0.03	0.58	0.02	0.08	0.01
1663B	LITTLE CROOKED	Colored		20	0.05	0.16	0.22	ns	ns	ns
1406B	CRYSTAL	Clear	Acidic	6	0.01	0.03	ins	ins	ins	
1497A	CRYSTAL LAKE	Clear	Alkaline	20	0.03	0.09	0.08	ns	ns	ns
3180A	CYPRESS	Colored		20	0.05	0.16	0.47	0.05	0.22	0.01
1539R	DAISY	Clear	Acidic	6	0.01	0.03	0.02	ns	ns	ns
1436A	DAVENPORT	Colored		20	0.05	0.16	ins	ins	ins	ins

Table 16. Empirically-derived, lake-specific water quality TP targets for selected Polk County lakes (Cont'd).

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TP NNC AGM Target (mg/L)		AGM TP and chlac		Individual TP and chlacomb	
					Min	Max	R^2	Lake-specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1521P	DEER LAKE	Clear	Alkaline	20	0.03	0.09	0.20	ns	ns	Ns
1449A	DEESON	Clear	Alkaline	20	0.03	0.09	ins	ins	0.25	0.03
1623M	EAGLE LAKE	Clear	Acidic	6	0.01	0.03	0.59	0.01	0.02	na
1619B	EASY	Clear	Acidic	6	0.01	0.03	ins	ins	ns	ns
1488Z	ECHO	Clear	Alkaline	20	0.03	0.09	0.09	ns	ns	ns
1548	ELBERT	Clear	Alkaline	20	0.03	0.09	0.19	ns	0.04	0.16
1521B	ELOISE	Clear	Alkaline	20	0.03	0.09	0.00	ns	ns	ns
15101	EVA	Clear	Alkaline	20	0.03	0.09	0.73	0.04	ns	ns
14882	FANNIE	Colored		20	0.05	0.49	0.53	0.06	0.05	0.03
1622	GARFIELD	Colored		20	0.05	0.49	ins	ns	ns	ns
1497D	GIBSON	Clear	Alkaline	20	0.03	0.09	0.45	ns	ins	ins
1623M1	GRASSY LAKE	Clear	Alkaline	20	0.03	0.09	0.96	0.04	0.13	0.03
1488C	HAINES	Colored		20	0.05	0.49	0.57	0.03	0.26	na
15041	HAMILTON	Colored		20	0.05	0.49	0.95	inverse	0.04	inverse
15002	MIDDLE HAMILTON	Colored		20	0.05	0.49	ins	ins	ns	ns
15001	LITTLE HAMILTON	Clear	Alkaline	20	0.03	0.09	ins	ins	ns	ns
1623L	HANCOCK	Colored		20	0.05	0.49	0.02	ns	0.06	na
1521I	HARTRIDGE	Clear	Alkaline	20	0.03	0.09	0.01	ns	ns	ns
1472B	HATCHINEHA	Colored		20	0.05	0.16	0.25	0.09	0.24	0.06
1730	HICKORY LAKE	Clear	Alkaline	20	0.03	0.09	0.81	ns	ns	ns
1549X	HOLLINGSWORTH	Clear	Alkaline	20	0.03	0.09	0.61	0.03	0.33	na
1521F	HOWARD	Clear	Alkaline	20	0.03	0.09	0.39	ns	0.02	na
1543	HUNTER	Clear	Alkaline	20	0.03	0.09	0.04	ns	0.04	na
1521J	IDYLWILD	Clear	Alkaline	20	0.03	0.09	0.01	ns	0.03	na

Table 16. Empirically-derived, lake-specific water quality TP targets for selected Polk County lakes (Cont'd).

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TP NNC AGM Target (mg/L)		AGM TP and chlac		Individual TP and chlacomb	
					Min	Max	R^2	Lake-specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1521K	JESSIE	Clear	Alkaline	20	0.03	0.09	0.06	ns	0.02	Na
1549E	JOHN	Clear	Alkaline	20	0.03	0.09	0.58	0.08	0.27	0.04
1484B	JULIANA	Clear	Alkaline	20	0.03	0.09	0.48	ns	ns	ns
3183B	KISSIMMEE	Colored		20	0.05	0.16	0.15	0.07	0.06	na
1501	LENA	Clear	Alkaline	20	0.03	0.09	0.48	ns	0.05	na
1539Y	LINK	Clear	Alkaline	20	0.03	0.09	ins	ins	0.13	0.03
1730B	LIVINGSTON	Colored		20	0.05	0.16	ins	ins	ns	ns
2890A	LOWERY	Colored		20	0.05	0.16	0.00	ns	ns	ns
1521	LULU	Clear	Alkaline	20	0.03	0.09	0.17	ns	0.02	na
1521L	MARIANNA	Clear	Alkaline	20	0.03	0.09	0.04	ns	ns	ns
1532B	MARIE	Clear	Alkaline	20	0.03	0.09	0.08	ns	ns	ns
1480	MARION	Clear	Alkaline	20	0.03	0.09	0.12	ns	0.52	0.03
1488P	MARTHA	Clear	Alkaline	20	0.03	0.09	ins	ins	ns	ins
1476	MATTIE	Colored		20	0.05	0.16	0.06	ns	ns	ns
1488Q	MAUDE	Clear	Alkaline	20	0.03	0.09	ins	ins	0.10	0.09
1521E	MAY	Clear	Alkaline	20	0.03	0.09	0.54	ns	0.07	na
1588A	MCLEOD	Clear	Acidic	6	0.01	0.03	0.27	ns	ns	ns
1539Z	MENZIE	Clear	Alkaline	20	0.03	0.09	ins	ins	0.11	0.08
1539X	MIRIAM	Colored		20	0.05	0.49	0.07	ns	ns	ns
1521G	MIRROR	Clear	Alkaline	20	0.03	0.09	0.67	0.02	0.11	na
1467	MUD	Colored		20	0.05	0.16	0.41	ns	0.24	0.02
1539Q	NED	Clear	Alkaline	20	0.03	0.09	0.00	ns	ns	ns
1539D	OTIS	Clear	Alkaline	20	0.03	0.09	ins	ins	0.14	0.03
1488Y	PANSY	Colored		20	0.05	0.49	0.66	0.03	0.11	0.07

Table 16. Empirically-derived, lake-specific water quality TP targets for selected Polk County lakes (Cont'd).

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TP NNC AGM Target (mg/L)		AGM TP and chlac		Individual TP and chlacomb	
					Min	Max	R^2	Lake-specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1497B	PARKER	Clear	Alkaline	20	0.03	0.09	0.02	ns	0.14	Na
1532A	PIERCE	Clear	Alkaline	20	0.03	0.09	0.42	ns	0.60	0.03
1685D	REEDY LAKE	Clear	Alkaline	20	0.03	0.09	0.39	ns	0.10	0.01
1488B	ROCHELLE	Clear	Alkaline	20	0.03	0.09	0.04	ns	ns	ns
1573C	ROSALIE	Colored		20	0.05	0.16	0.31	ns	0.05	0.29
1521O	ROY	Clear	Alkaline	20	0.03	0.09	0.16	ns	ns	ns
1497J	SADDLE CREEK PARK	Clear	Alkaline	20	0.03	0.09	0.72	0.01	0.32	0.03
1501W	SEARS LAKE	Clear	Acidic	6	0.01	0.03	ins	ins	0.55	0.01
1521D	SHIPP	Clear	Alkaline	20	0.03	0.09	0.42	0.01	0.08	na
1488G	SILVER	Clear	Alkaline	20	0.03	0.09	0.07	ns	0.60	0.02
1488A	SMART	Clear	Alkaline	20	0.03	0.09	0.17	ns	0.39	na
1549F	SOMERSET	Clear	Alkaline	20	0.03	0.09	0.12	ns	ns	ns
1521G1	SPRING	Clear	Alkaline	20	0.03	0.09	0.74	ns	0.24	0.03
1549B1	STAHL	Clear	Alkaline	20	0.03	0.09	0.02	ns	ns	ns
1521M	SUMMIT	Clear	Alkaline	20	0.03	0.09	0.27	ns	0.03	0.09
1647	SURVEYORS	Colored		20	0.05	0.49	ns	ns	0.18	inverse
1488V	SWOOPE	Clear	Alkaline	20	0.03	0.09	0.61	0.04	0.12	0.05
1484A	TENNESSEE	Clear	Acidic	6	0.01	0.03	ins	ins	0.22	0.00
1497C	TENOROC	Clear	Acidic	6	0.01	0.03	ins	ins	ns	ns
1501X	THOMAS	Clear	Alkaline	20	0.03	0.09	ins	ins	ns	ns
1573A	TIGER	Colored		20	0.05	0.16	0.46	ns	0.16	0.22
14921	TRACY	Clear	Alkaline	20	0.03	0.09	ins	ins	0.19	0.13
1619A	WALES	Clear	Alkaline	20	0.03	0.09	0.40	ns	0.10	0.01

Table 16. Empirically-derived, lake-specific water quality TP targets for selected Polk County lakes (Cont'd).

WBID	Waterbody Name	Color Status	Akalinity	chlac Target (µg/L)	TP NNC AGM Target (mg/L)		AGM TP and chlac		Individual TP and chlacomb	
					Min	Max	R^2	Lake-specific Target (mg/L)	R^2	Lake-specific Target (mg/L)
1573E	WEOHYAKAPKA	Colored		20	0.05	0.16	0.82	0.04	0.41	0.04
1521A	WINTERSET	Clear	Alkaline	20	0.03	0.09	0.51	ns	0.24	0.04
1537	WIRE	Clear	Alkaline	20	0.03	0.09	ins	ins	ins	ins

ins=insufficient data; ns=not significant; na=equation not applicable

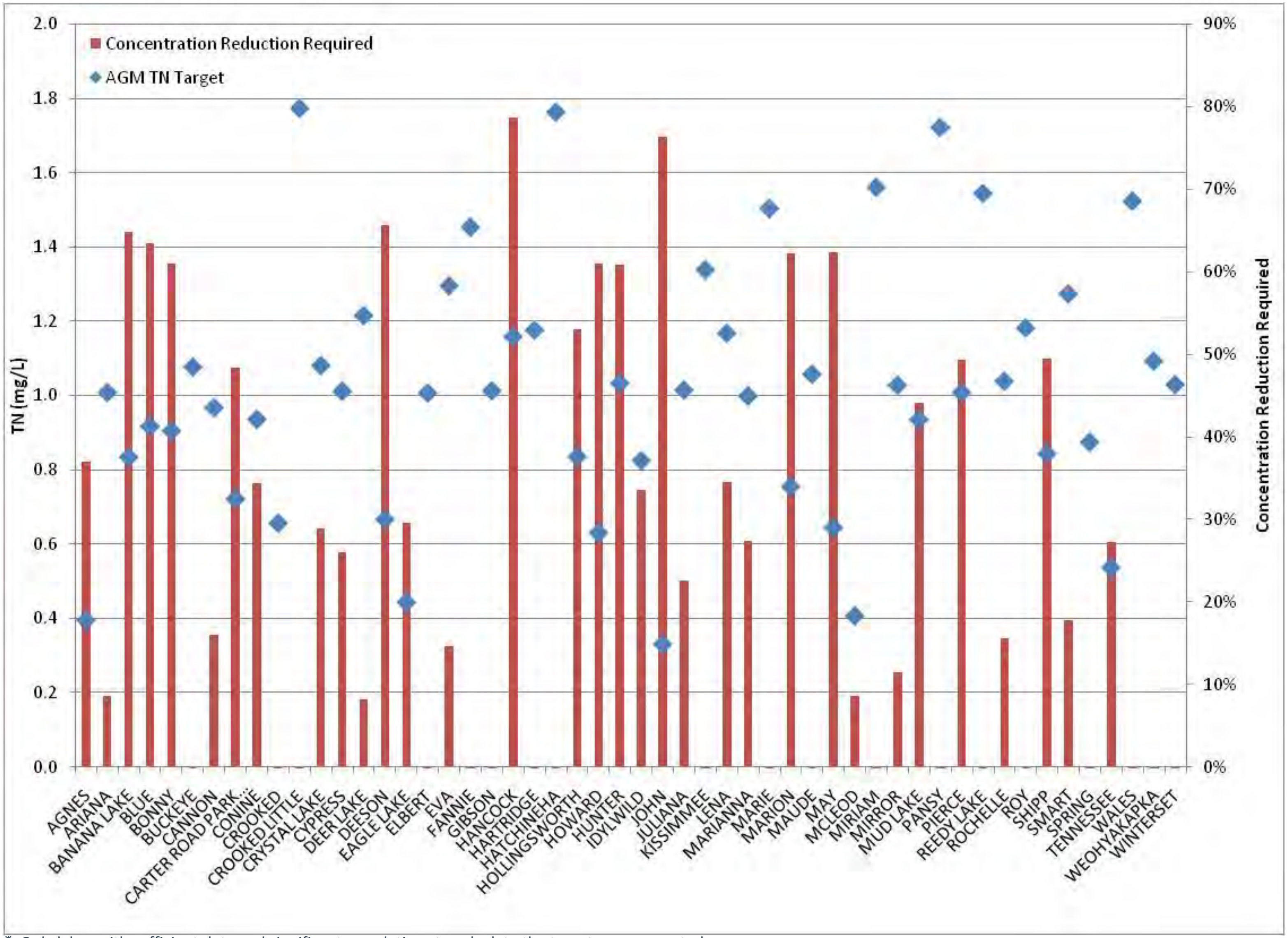
For some lakes, inverse correlations were identified which would indicate that chl-a concentrations were declining as nutrient concentrations were increasing. Where inverse correlations were identified, the empirically-derived targets were not calculated even if the correlation was significant. The disconnect between nutrients and phytoplankton could be due to elevated color within the water column which inhibits phytoplankton ability to photosynthesis and use available nutrients. Additionally, the range in nutrient and chl-a concentrations could be small, resulting in insufficient variation to determine a causative relationship. Also, it is important to note that this report has examined the relationships between nutrients (both TN and TP) for nearly 100 lakes using statistical analyses to develop data-driven water quality targets. Using an alpha value of 0.05 as the threshold for determining statistically significance, it is likely that approximately 5 percent of determinations of significance are due to chance alone. With nearly 200 analyses conducted, perhaps 10 of these determinations of significance would be Type I errors; i.e. instances where the statistical test suggests a relationship between nutrients and the chl-a, when in fact there is no such relationship .

Prior to the establishment of locally-derived targets, additional review of the water quality dynamics are required to identify the internal and/or external processes which resulted in the inverse relationship.

The annual percent reductions required to meet the empirically-derived AGM targets were calculated for each lake for TN and TP when sufficient data were present to calculate the AGM. The median percent reduction was calculated over the period of 2003-2013 for each lake, for each parameter. Based on the empirically-derived AGM targets for Lake Bonny, a 61 and 69 percent concentration reduction in TN and TP would be required (**Figures 5 and 6; Tables 17 and 18**). The site-specific AGM targets were calculated based on the assumption that the chl-a targets of 20 µg/L for clear, alkaline (color ≤ 40 PCU and alkalinity >20 mg/L $CaCO_3$) and high color (color >40 PCU) lakes and chl-a target of 6 µg/L for clear, acidic lakes (color ≤ 40 PCU and alkalinity ≤ 20 mg/L $CaCO_3$) are appropriate.

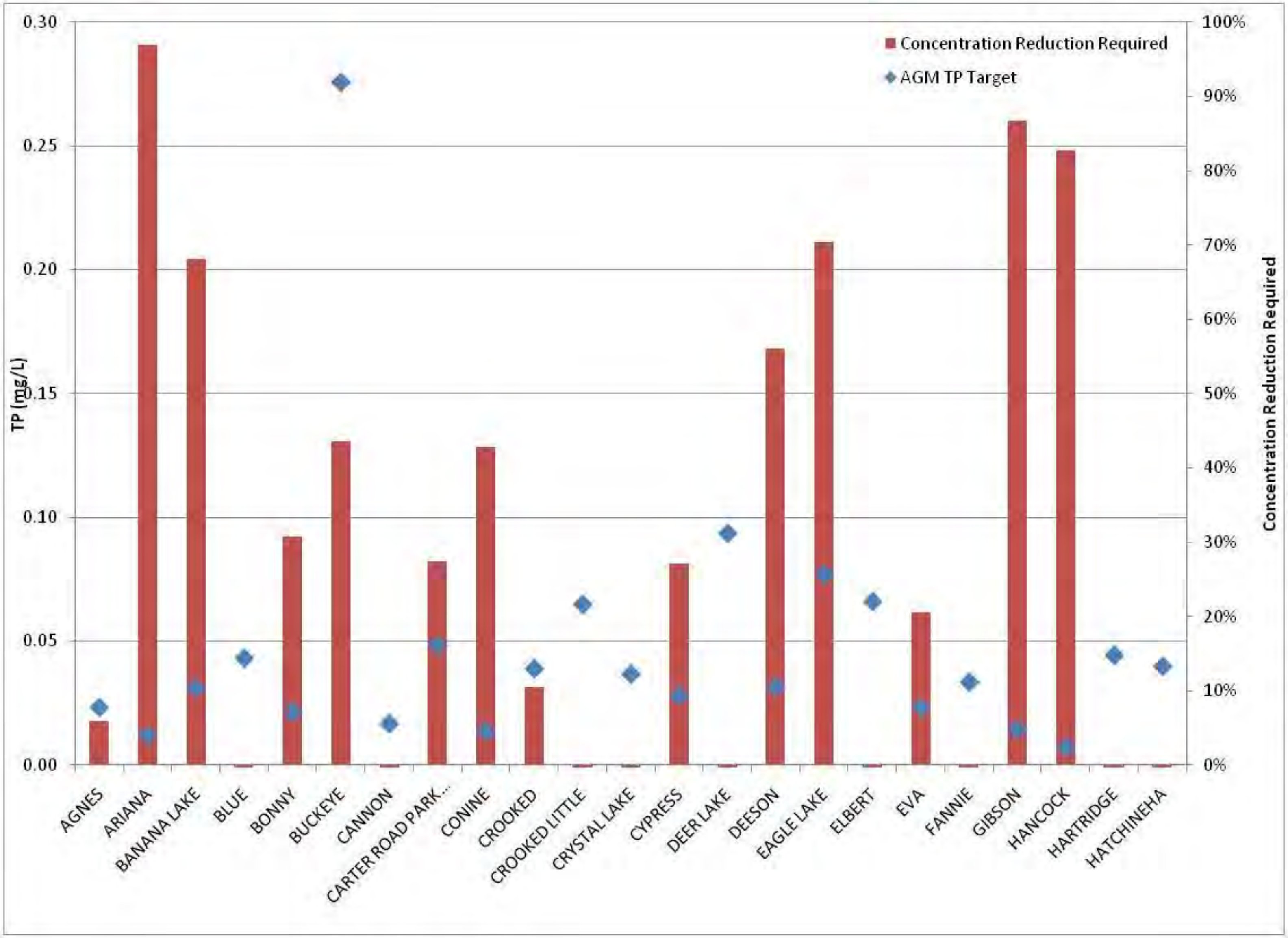
In general, the site-specific targets developed were more stringent than the FDEP NNC criteria. This could require additional efforts to meet water quality goals, above and beyond those based on NNC. However, the lack of water quality improvement in lakes Shipp, May, and Lulu, after meeting their load reduction targets set out in their TMDLs, is based in large part on the TMDLs having TP targets too high to result in their expected chl-a targets.

Figure 5. Empirically-derived annual geometric mean TN target and the percent concentration reduction required to meet the derived TN target. *



* Only lakes with sufficient data and significant correlations to calculate the targets are presented.

Figure 6. Empirically-derived annual geometric mean TP target and the percent concentration reduction required to meet the derived TP target. *



*Only lakes with sufficient data and significant correlations to calculate the targets are presented.

Table 17. Percent concentration reduction required to meet locally-derived AGM TN target.

WBID	Waterbody Name	Lake-specific AGM TN Target (mg/L)	Percent concentration reduction required
1466	AGNES	0.39	37
1501B	ARIANA	1.01	9
1549B	BANANA LAKE	0.83	65
1521Q	BLUE	0.92	63
1497E	BONNY	0.90	61
1488S	BUCKEYE	1.08	0
1521H	CANNON	0.97	16
1610	CARTER ROAD PARK LAKES	0.72	48
1488U	CONINE	0.94	34
1663	CROOKED	0.66	0
1663B	LITTLE CROOKED	1.77	0
1497A	CRYSTAL LAKE	1.08	29
3180A	CYPRESS	1.01	26
1521P	DEER LAKE	1.21	8
1449A	DEESON	0.67	66
1623M	EAGLE LAKE	0.44	30
1548	ELBERT	1.01	0
15101	EVA	1.29	15
14882	FANNIE	1.45	0
1497D	GIBSON	1.01	0
1623L	HANCOCK	1.16	79
1521I	HARTRIDGE	1.18	0
1472B	HATCHINEHA	1.76	0
1549X	HOLLINGSWORTH	0.83	53
1521F	HOWARD	0.63	61
1543	HUNTER	1.03	61
1521J	IDYLWILD	0.82	34
1549E	JOHN	0.33	76
1484B	JULIANA	1.01	23
3183B	KISSIMMEE	1.34	0
1501	LENA	1.17	35
1521L	MARIANNA	1.00	27
1532B	MARIE	1.50	0
1480	MARION	0.75	62
1488Q	MAUDE	1.06	0
1521E	MAY	0.64	62
1588A	MCLEOD	0.41	9
1539X	MIRIAM	1.56	0
1521G	MIRROR	1.03	12

Table 17. Percent concentration reduction required to meet locally-derived AGM TN target (Cont'd).

WBID	Waterbody Name	Lake-specific AGM TN Target (mg/L)	Percent concentration reduction required
1467	MUD	0.93	44
1488Y	PANSY	1.72	0
1532A	PIERCE	1.01	49
1685D	REEDY LAKE	1.54	0
1488B	ROCHELLE	1.04	16
1521O	ROY	1.18	0
1521D	SHIPP	0.84	49
1488A	SMART	1.27	18
1521G1	SPRING	0.87	0
1484A	TENNESSEE	0.54	27
1619A	WALES	1.52	0
1573E	WEOHYAKAPKA	1.09	0
1521A	WINTERSET	1.03	0

Table 18. Percent concentration reduction required to meet locally-derived AGM TP target.

WBID	Waterbody Name	Lake-specific AGM TP Target	Percent concentration reduction required
1501B	ARIANA	0.02	6
1549B	BANANA LAKE	0.01	97
1497E	BONNY	0.03	68
1488S	BUCKEYE	0.04	0
1521H	CANNON	0.02	31
1610	CARTER ROAD PARK LAKES	0.28	44
1663	CROOKED	0.02	0
3180A	CYPRESS	0.05	27
1623M	EAGLE LAKE	0.01	43
15101	EVA	0.04	11
14882	FANNIE	0.06	0
1623M1	GRASSY LAKE	0.04	0
1488C	HAINES	0.03	27
1472B	HATCHINEHA	0.09	0
1549X	HOLLINGSWORTH	0.03	56
1549E	JOHN	0.08	70
3183B	KISSIMMEE	0.07	0
1521G	MIRROR	0.02	21

Table 18. Percent concentration reduction required to meet locally-derived AGM TP target (Cont'd).

WBID	Waterbody Name	Lake-specific AGM TP Target	Percent concentration reduction required
1497J	SADDLE CREEK PARK	0.01	87
1521D	SHIPP	0.01	83
1488V	SWOOPE	0.04	0
1573E	WEOHYAKAPKA	0.04	0

Evidence of Cyanobacteria presence

The presence of cyanobacteria within lakes can complicate management actions required to restore water quality. First, a correlation between TN and chl-a that is usually used as evidence of the need to reduce external TN loads could be "backwards" in the sense that cyanobacteria could be creating TN, rather than vice versa. Also, prior work in Lakes Hancock and Jesup have shown that the resuspension of TP-rich bottom sediments is the most important nutrient impact, rather than external loads of either TN or TP. Consequently, a screening tool to determine lakes with significant levels of cyanobacteria was developed, based on differences between actual and predicted TN concentrations in lakes with high levels of chl-a.

The highest TN concentrations from stormwater runoff are typically in the range of 2.4 to 2.8 mg/L (Harper and Baker 2007). Therefore, in-lake TN concentrations greater than 2.4 mg/L indicate a source of nitrogen to the lake beyond that which can be explained by stormwater runoff alone. Elevated TN concentrations (>2.4 mg/L) could be due to the presence of a cyanobacteria population capable of nitrogen-fixation, thereby able to generate nitrogen directly from the atmosphere. In-lake TN concentrations were reviewed for evidence of cyanobacteria presence in the lake by calculating the frequency of data points which exceeded 2.4 mg/L. Lakes with greater than thirty percent of TN concentrations above 2.4 mg/L were classified to potentially have a cyanobacteria population influencing nutrient concentrations within the lake (**Table 19**).

Table 19. List of lakes with potentially significant cyanobacteria population.

WBID	Lake	Percent of values greater than 2.4 mg/L
1623L	Hancock	93
1497B	Parker	73
1549B	Banana	64
1730	Hickory	49
1497E	Bonny	42
1497C	Tenoroc	40
1543	Hunter	35

3.3 Impairment designation using NNC

FDEP previously classified water bodies in Polk County as impaired or unimpaired based on a comparison of water quality to TSI. FDEP includes impaired water bodies in their 303(d) which ultimately requires the development of a TMDL. The impairment status of each of the 97 lakes was re-evaluated as part of this project to the water quality to the 2012 FDEP NNC.

Eighteen lakes previously designated as impaired for elevated nutrients (based on TSI) by FDEP were subsequently identified as unimpaired or had insufficient data for assessment when compared to the FDEP NNC as part of this project (**Table 20**). In response to the March 24, 2014 meeting between the County and FDEP, FDEP agreed to perform an independent review of the water quality status for those lakes on the 303(d) list for elevated TSI but identified as unimpaired when using the FDEP NNC criteria. On April 24th and May 2nd, 2014, FDEP provided the results of their independent analysis; concluding that 18 of the lakes previously listed on the 303(d) list for elevated TSI have water quality conditions which satisfy the water quality criteria within the NNC or insufficient data to perform the analysis (lakes Wire and Tenoroc). As such, it is recommended that the County coordinate with FDEP to investigate steps to delist those waterbodies that meet the FDEP NNC criteria for the 2003 to 2013 period. Two of these lakes (Alfred and Kissimmee) have, or are in the process of establishing, TMDLs.

Seventeen lakes not included on the 303(d) list for elevated TSI were found to be unimpaired when compared to the FDEP NNC for the three parameters: chl-a, TN, or TP (**Table 21, Figure 7**). The data for two of these lakes were insufficient to evaluate at least one of the parameters to determine an impairment designation. For those two lakes (lakes Thomas and Livingston), parameters with sufficient data for analysis were found to not be impaired. Three lakes had insufficient data to evaluate the water quality status for all parameters: Crystal (1406B), Davenport, and Easy. At least one parameter was found to be impaired in the remaining 62 lakes (**Table 22, Figure 8**). Thirteen of the lakes found to be impaired when compared to the FDEP NNC (using data from 2003 to 2013) are not currently list on the FDEP 303(d) list for elevated TSI or chl-a.

Table 20. List of impaired (TSI) lakes that are unimpaired when compared to FDEP NNC criteria (using the 2003-2013 data)*.

WBID	Waterbody Name	303(d) list	Meets FDEP NNC?	TMDL Status
1488D	ALFRED	Nutrients (TSI)	Yes	EPA Established
1488S	BUCKEYE	Nutrients (TSI)	Yes	None
15003	CONFUSION	Nutrients (TSI)	Yes	None
1488Z	ECHO	Nutrients (TSI)	Yes	None
1548	ELBERT	Nutrients (TSI)	Yes	None
3183B	KISSIMMEE	Nutrients (TSI)	Yes	DEP Draft
2890A	LOWERY	Nutrients (TSI)	Yes	None
1532B	MARIE	Nutrients (TSI)	Yes	None
1488P	MARTHA	Nutrients (TSI)	Yes	None

Table 20. List of impaired (TSI) lakes that are unimpaired when compared to FDEP NNC criteria (using the 2003-2013 data)*.

WBID	Waterbody Name	303(d) list	Meets FDEP NNC?	TMDL Status
1488Q	MAUDE	Nutrients (TSI)	Yes	None
1539Z	MENZIE	Nutrients (TSI)	Yes	None
1539Q	NED	Nutrients (TSI)	Yes	None
1488Y	PANSY	Nutrients (TSI)	Yes	None
1488G	SILVER	Nutrients (TSI)	Yes	None
1488V	SWOOPE	Nutrients (TSI)	Yes	None
1497C	TENOROC	Nutrients (TSI)	ins	None
14921	TRACY	Nutrients (TSI)	Yes	None
1537	WIRE	Nutrients (TSI)	ins	None

ins=insufficient data to perform analysis;*water quality status was confirmed by FDEP

Table 21. List of lakes that meet water quality standards when compared to FDEP NNC criteria (using 2003 to 2013 data)*.

WBID	Waterbody Name	303(d) list	NNC Impairment Designation		
			TN	TP	CHLAC
1466A1	LITTLE AGNES	No	N	N	N
1663B	LITTLE CROOKED	No	N	N	N
1406B	CRYSTAL	No	ins	ins	ins
1436A	DAVENPORT	No	ins	ins	ins
1619B	EASY	No	ins	ins	ins
15041	HAMILTON	No	N	N	N
1539Y	LINK	No	N	N	N
1730B	LIVINGSTON	No	N	ins	N
1539X	MIRIAM	No	N	N	N
1539D	OTIS	No	N	N	N
1573C	ROSALIE	No	N	N	N
1521O	ROY	No	N	N	N
1521M	SUMMIT	No	N	N	N
1647B	SURVEYORS	No	N	N	N
1501X	THOMAS	No	N	N	ins
1573A	TIGER	No	N	N	N
1521A	WINTERSET	No	N	N	N

N= Not impaired; ins=insufficient data to perform analysis; *None of these lakes are on the 303(d) list for elevated nutrients.

Table 22. List of lakes that are impaired when compared to FDEP NNC criteria (using 2003 to 2013 data).

WBID	Waterbody Name	303(d) list	TMDL Status	NNC Impairment Designation		
				TN	TP	CHLAC
1466	AGNES	No	None	Y	Y	Y
1539C	ANNIE	Nutrients (TSI)	None	Y	Y	ins
1685A	ARBUCKLE	No	None	Y	Y	Y
1501B	ARIANA	Nutrients (TSI)	EPA Established	Y	N	Y
1549B	BANANA	Nutrients (TSI)	DEP Draft	Y	Y	Y
1521Q	BLUE	Nutrients (TSI)	None	Y	Y	Y
1497E	BONNY	Nutrients (TSI)	DEP Draft	Y	Y	Y
1677C	BUFFUM	No	None	Y	Y	Y
1521H	CANNON	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1610	CARTER ROAD PARK LAKES	Nutrients (Chlorophyll-a)	None	Y	Y	Y
1706	CLINCH	Nutrients (TSI)	None	Y	Y	Y
1488U	CONINE	Nutrients (TSI)	None	Y	Y	Y
1663	CROOKED	No	None	Y	Y	Y
1497A	CRYSTAL	Nutrients (TSI)	EPA Established	Y	Y	Y
3180A	CYPRESS	Nutrients (TSI)	DEP Draft; EPA Established	Y	Y	Y
1539R	DAISY	Nutrients (TSI)	None	Y	Y	N
1521P	DEER	Nutrients (TSI)	DEP Draft	Y	Y	Y
1449A	DEESON	Nutrients (TSI)	None	Y	Y	Y
1623M	EAGLE	Nutrients (TSI)	None	Y	Y	Y
1521B	ELOISE	Nutrients (TSI)	None	Y	Y	Y
15101	EVA	Nutrients (TSI)	None	Y	Y	Y
14882	FANNIE	No	None	Y	Y	Y
1622	GARFIELD	No	None	N	Y	ins
1497D	GIBSON	Nutrients (TSI)	None	Y	Y	Y
1623M1	GRASSY	Nutrients (TSI)	None	Y	Y	Y

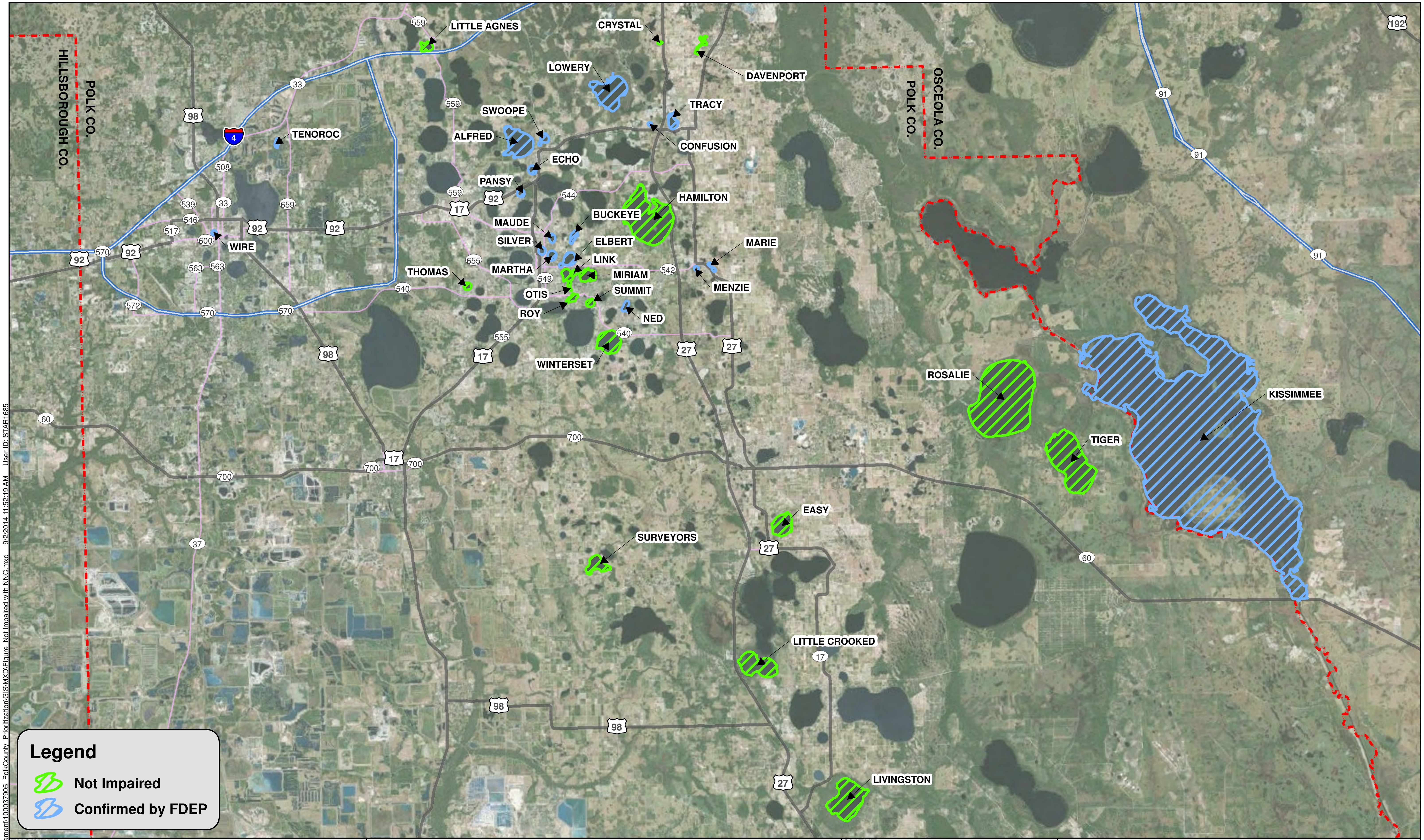
Table 22. List of lakes that are impaired when compared to FDEP NNC criteria (using 2003 to 2013 data) (Cont'd).

WBID	Waterbody Name	303(d) list	TMDL Status	NNC Impairment Designation		
				TN	TP	CHLAC
1488C	HAINES	Nutrients (TSI)	EPA Established	Y	Y	Y
15002	MIDDLE HAMILTON	No	None	Y	ins	Y
15001	LITTLE HAMILTON	Nutrients (TSI)	None	Y	Y	Y
1623L	HANCOCK	Nutrients (TSI)	DEP Draft	Y	Y	Y
1521I	HARTRIDGE	No	None	Y	Y	Y
1472B	HATCHINEHA	Nutrients (TSI Trend)	None	Y	Y	Y
1730	HICKORY	Nutrients (TSI)	None	Y	Y	Y
1549X	HOLLINGSWORTH	Nutrients (TSI)	DEP Draft	Y	Y	Y
1521F	HOWARD	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1543	HUNTER	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1521J	IDYLWILD	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1521K	JESSIE	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1549E	JOHN	No	None	Y	Y	Y
1484B	JULIANA	Nutrients (TSI)	None	Y	Y	Y
1501	LENA	Nutrients (TSI)	DEP Draft; EPA Established	Y	Y	Y
1521	LULU	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1521L	MARIANNA	Nutrients (TSI)	None	Y	Y	Y
1480	MARION	Nutrients (TSI)	None	Y	Y	Y
1476	MATTIE	No	None	N	Y	N
1521E	MAY	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1588A	MCLEOD	Nutrients (TSI)	None	Y	Y	Y
1521G	MIRROR	Nutrient	DEP Adopted-EPA Approved	Y	N	Y
1467	MUD	Nutrients (TSI)	None	Y	Y	Y
1497B	PARKER	Nutrients (TSI)	DEP Draft	Y	Y	Y
1532A	PIERCE	Nutrients (TSI)	None	Y	Y	Y

Table 22. List of lakes that are impaired when compared to FDEP NNC criteria (using 2003 to 2013 data) (Cont'd).

WBID	Waterbody Name	303(d) list	TMDL Status	NNC Impairment Designation		
				TN	TP	CHLAC
1685D	REEDY	Nutrients (TSI)	None	Y	N	Y
1488B	ROCHELLE	Nutrients (TSI)	None	Y	Y	Y
1497J	SADDLE CREEK PARK	No	None	Y	Y	Y
1501W	SEARS	Nutrients (TSI)	None	Y	Y	Y
1521D	SHIPP	Nutrient	DEP Adopted-EPA Approved	Y	Y	Y
1488A	SMART	Nutrients (TSI)	EPA Established	Y	ins	Y
1549F	SOMERSET	No	None	Y	Y	Y
1521G1	SPRING	No	None	N	N	Y
1549B1	STAHL	Nutrients (TSI)	None	Y	Y	Y
1484A	TENNESSEE	Nutrients (TSI)	None	Y	Y	Y
1619A	WAILES	Nutrients (TSI)	None	Y	Y	Y
1573E	WEOHYAKAPKA	Nutrients (Historic TSI)	None	N	N	Y

N=Not impaired; Y=Impaired; ins=insufficient data to perform analysis



J:\Watershed Management\100037905_PolkCounty_Prioritization\GIS\MXD\Figure_Not Impaired with NNC.mxd 9/2/2014 11:52:19 AM User ID: STAR1685

ENGINEER

ATKINS
4030 WEST BOY SCOUT BLVD
SUITE 700
TAMPA, FLORIDA 33607
800-477-7275

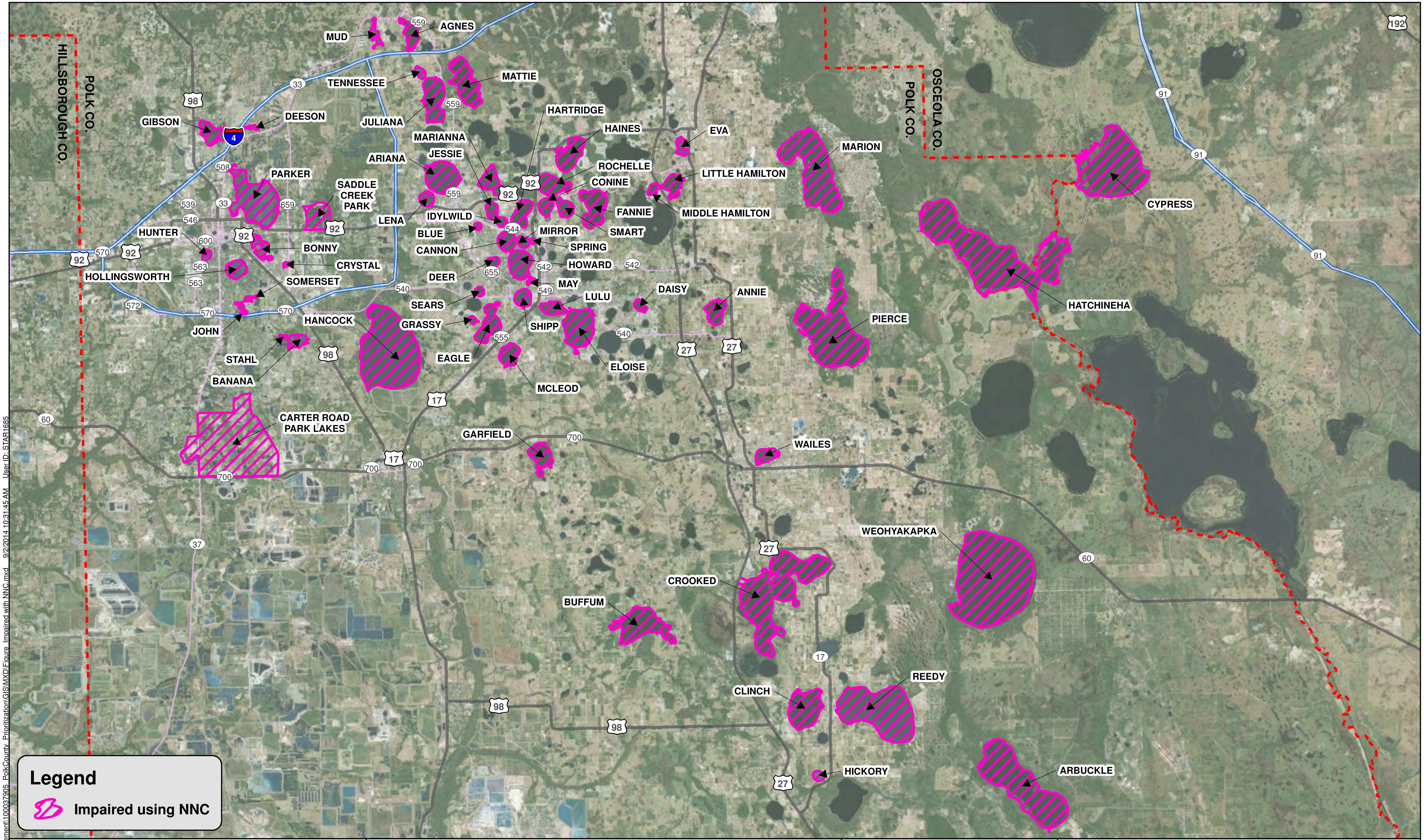
Figure 7. Map of lakes that are unimpaired when compared to FDEP NNC criteria (using 2003 to 2013 data).

CLIENT:

POLK COUNTY
NATURAL RESOURCES
4177 BEN DURRANCE ROAD
P.O. BOX 9005, DRAWER PW06
BARTOW, FLORIDA 33831
863-534-7377

0 2 4 8 Miles

N



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ENGINEER

ATKINS

4030 WEST BOY SCOUT BLVD
SUITE 700
TAMPA, FLORIDA 33607
800-477-7275

Figure 8. Map of lakes that are impaired when compared to FDEP NNC criteria (using 2003 to 2013 data).

CLIENT:

POLK COUNTY

NATURAL RESOURCES
4177 BEN DURRANCE ROAD
P.O. BOX 9005, DRAWER PW06
BARTOW, FLORIDA 33831
863-534-7377

0 2 4 8 Miles

N

3.4 Prioritization of lakes for further action

The County‟s 97 publicly accessible lakes were evaluated and prioritized to address requirements related to waterbodies with TMDLs and pursuant to the County‟s MS4 permit (**Figure 9**). The individual lakes were ranked within tier groups (as discussed in section 2.3.1.1). Lakes with the highest final lake score are recommended for initial consideration for future water quality restoration projects. Lake prioritization results for the 97 publicly accessible lakes in Polk County are presented in **Table 23**.

A summary of information available related to the regulatory status, locally-derived targets, priority ranking and recommendations are provided for each the 97 publicly accessible lakes in Polk County evaluated for this project. Lake-specific summaries are presented by Tier and rank.

Figure 9. Summary of prioritization matrix development.

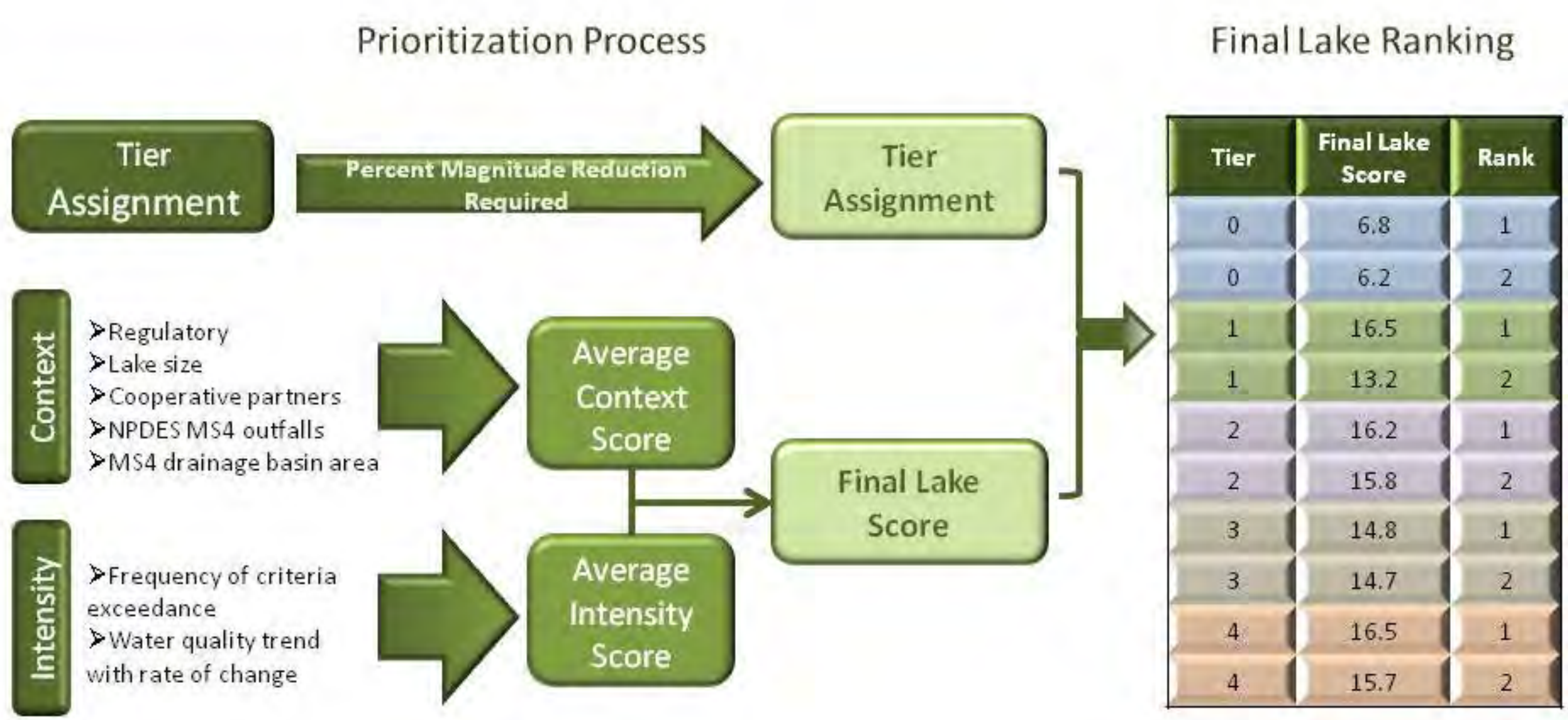


Table 23. Priority rankings within each Tier for the 97 publicly accessible lakes within Polk County.

Rank	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
	Percent TP, TN or chlac Concentration Reduction Required				
	None	<20	20-<40	40-<60	≥60
1	LITTLE CROOKED*	IDYLWILD*	CANNON*	SEARS*	CRYSTAL(1497A)*
2	THOMAS*	SPRING	JESSIE*	CONINE*	BLUE*
3	ECHO*	ARBUCKLE*	DEER*	LENA*	DAISY*
4	WINTERSET*	WEOHYAKAPKA*	HARTRIDGE*	SHIPP*	TENNESSEE*
5	SUMMIT*	MATTIE*	GRASSY*	CROOKED*	DEESON*
6	PANSY	HAMILTON	MARIANNA*	MUD*	GIBSON*
7	MARTHA	NED*	SMART	ANNIE*	SADDLE CREEK PARK*
8	SILVER	BUCKEYE*	LULU*	MAY	SOMERSET*
9	MARIE	OTIS	ROCHELLE*	CLINCH*	STAHL*
10	MENZIE		ARIANA*	MCLEOD*	AGNES*
11	MIRIAM*		MIDDLE HAMILTON*	WAILES	BUFFUM*
12	DAVENPORT*		MIRROR	EAGLE*	JOHN
13	LINK		JULIANA*	ALFRED*	HOLLINGSWORTH
14	SWOOPE		HOWARD*	EASY*	PARKER*
15	TIGER*		HATCHINEHA*		BANANA*
16	CONFUSION		REEDY*		HANCOCK*
17	ELBERT		FANNIE*		HICKORY+
18	WIRE+		LITTLE HAMILTON*		PIERCE*
19	LOWERY*+		ELOISE*		CARTER ROAD PARK*
20	TRACY		HAINES*		MARION*
21	CRYSTAL (1406B)		CYPRESS+		HUNTER
22			ROSALIE*		GARFIELD*
23			EVA		BONNY*
24			ROY		TENOROC+
25			MAUDE		
26			KISSIMMEE+		
27			LIVINGSTON		
28			LITTLE AGNES		
29			SURVEYORS		

*Polk County MS4 outfall present; +Lakes not Sampled by Polk County PNRD

Lakes assigned to Tier 0

Little Crooked Lake (WBID 1663B)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN target using annual geometric mean (AGM; 1983-2013) is 1.77 mg/L (based on chl-a target of 20 µg/L).
- No concentration reduction is required to meet the locally-derived AGM TN target.
- Correlation between TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #1 of 21 within Tier 0.
- Two County MS4 outfalls account for 1 percent of the lake‟s drainage area.
- Trends in TN indicate declining water quality.
- Medium-large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Investigate increasing trend in TN.
- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Thomas Lake (WBID 1501X)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for TN or TP. Insufficient data are available to evaluate chl-a for impairment status.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #2 of 21 within Tier 0.
- Twenty County MS4 outfalls account for 66 percent of the lake"s drainage area.
- Trend in TP indicates improving water quality.
- Small-medium lake with limited recreational use and predominantly urban watershed.

Recommendations

- Continue existing water quality improvement projects and monitoring programs. Review water quality data in 5 years.

Lake Echo (WBID 1488Z)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.
- Three County MS4 outfalls discharge to the lake; permit-specified load may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a was not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #3 of 21 within Tier 0.
- Three County MS4 outfalls account for 100 percent of the lake‟s drainage area.
- TP trend indicates improving water quality.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendation

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Winterset (WBID 1521A)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.03 and 0.03 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN and TP targets.

Priority Ranking

- Assigned lake priority #4 of 21 within Tier 0.
- Seven County MS4 outfalls account for 10 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Small lake with limited recreational use and predominantly urban watershed.

Recommendation

- Existing water quality management plans are available; no water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvements; review water quality status in five years.

Photograph of Lake Winterset.

Lake Summit (WBID 1521M)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP targets using AGM (1983-2013) were not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #5 of 21 within Tier 0.
- Three County MS4 outfalls account for 14 percent of the lake‟s drainage area.
- Trends in TN and TP indicate improving water quality.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Photograph of Lake Summit.

Lake Pansy (WBID 1488Y)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) were 1.72 and 0.03 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN or TP target.

Priority Ranking

- Assigned lake priority #6 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TP indicates water quality is improving. Trend in TN indicates water quality is degrading.
- Small-medium lake with moderately-low recreational use and predominantly developed watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- Investigate increasing trend in TN.
- Review and evaluate existing water quality management plan (PBS&J 2011) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Lake Pansy.

Lake Martha (WBID 1488P)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.
- Correlation between TN and chl-a using AGM (1983-2013) is not significant.

Priority Ranking

- Assigned lake priority #7 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TN and chl-a indicates degrading water quality.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- Investigate degrading trends in water quality.
- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Lake Martha.

Lake Silver (WBID 1488G)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #8 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TN indicates declining water quality. No trends in TP or chl-a were identified.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendation

- Investigate increasing trend in TN.
- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- Review and evaluate existing water quality management plan (PBS&J 2011) for potential selection of projects for implementation.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Photograph of Lake Silver.

Lake Marie (WBID 1532B)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) was 1.50 mg/L (based on chl-a target of 20 µg/L), respectively.
- Empirically-derived TP target using AGM (1983-2013) was not significant (based on chl-a target of 20 µg/L).
- No concentration reduction is required to meet locally-derived AGM TN target.

Priority Ranking

- Assigned lake priority #9 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- There were no trends in TN, TP, or chl-a.
- Small lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Menzie (WBID 1539Z)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #10 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- No trends in water quality were identified.
- Small lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Miriam (WBID 1539X)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.56 mg/L for TN and is not significant for TP (based on chl-a target of 20 µg/L).
- No concentration reduction is required to meet locally-derived AGM TN target.

Priority Ranking

- Assigned lake priority #11 of 21 within Tier 0.
- One County MS4 outfall accounts for 6 percent of the lake‟s drainage area.
- Trend in TP indicates improving water quality.
- Medium lake with limited recreational use with both residential and undeveloped areas.

Recommendations

- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Davenport (WBID 1436A)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients based on insufficient data

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #12 of 21 within Tier 0.
- Ten County MS4 outfalls account for about 1 percent of the lake‟s drainage area.
- Insufficient data to evaluate trends in water quality.
- Small lake with limited recreational use and predominantly urban watershed.

Recommendations

- Continue existing water quality improvement projects and monitoring programs; review water quality data in 5 years.

Lake Link (WBID 1539Y)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #13 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- No trends in water quality were identified.
- Small lake with limited recreational use and predominantly urban watershed.

Recommendations

- No water quality improvement actions are recommended at this time.
- Continue existing water quality improvement projects and monitoring programs; review water quality data in 5 years.

Lake Swoope (WBID 1488V)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) was not significant for TN and 0.04 mg/L for TP (based on chl-a target of 20 µg/L).
- No concentration reduction was required to meet locally-derived AGM TP target.

Priority Ranking

- Assigned lake priority #14 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TP indicates improving water quality.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Tiger Lake (WBID 1573A)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) is not significant.

Priority Ranking

- Assigned lake priority #15 of 21 within Tier 0.
- One County MS4 outfall accounts for less than 1 percent of the lake"s drainage area.
- Trends in TP, TN, and chl-a indicate declining water quality.
- Large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Monitor and investigate degrading water quality trend.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Confusion (WBID 15003)

Regulatory Implications

- Designated by FDEP as impaired for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN and chl-a not found using AGM (1983-2013).
- Correlation between TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #16 of 21 within Tier 0.
- No County MS4 outfalls discharge to the lake.
- Trend in TP indicates improving water quality.
- Small lake with limited recreational use and predominantly urban watershed.

Recommendation

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Elbert (WBID 1548)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) was 1.01 mg/L (based on chl-a target of 20 µg/L).
- No concentration reduction is required to meet locally-derived AGM TN target.
- Correlation between TP and chl-a was not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #17 of 21 within Tier 0.
- No County MS4 outfalls discharge to the lake.
- TN trend indicates improving water quality.
- Medium lake with limited recreational use and entirely developed (residential) watershed.

Recommendation

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Photograph of Lake Elbert.

Lake Wire (WBID 1537)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients based on insufficient data.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) was not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #18 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- Insufficient data to evaluate trends in water quality.
- Small lake with moderately limited recreational use and predominantly urban watershed.

Recommendation

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No action is recommended until completion of anticipated development of the Water Quality Management Plan by the City of Lakeland.
- Continue existing water quality improvement projects and monitoring programs; review water quality data in 5 years.

Lake Lowery (WBID 2890A)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.
- One County MS4 outfall discharges to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP targets using AGM (1983-2013) were not significant (based on chl-a target of 20 μg/L).

Priority Ranking

- Assigned lake priority #19 of 21 within Tier 0.
- One County MS4 outfall accounts for less than 1 percent of the lake‟s drainage area.
- Trend in chl-a indicates improving water quality.
- Medium-large lake with limited recreational use and predominantly undeveloped watershed with limited residential and agriculture, and extensive wetlands.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Tracy (WBID 14921)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #20 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- Trend in chl-a indicates improving water quality.
- Medium lake with limited recreational use and predominantly urban watershed.

Recommendation

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Crystal Lake (WBID 1406B)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients based on insufficient data.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #21 of 21 within Tier 0.
- There are no County MS4 outfalls discharging to the lake.
- Insufficient data to evaluated trends in water quality.
- Small lake with limited recreational use and predominantly urban watershed.

Recommendations

- No water quality improvement actions are recommended at this time.
- Continue existing water quality improvement projects and monitoring programs; review water quality data in 5 years.

Lakes assigned to Tier 1

Lake Idylwild (WBID 1521J)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring a reduction in stormwater loads of TP by 63 percent.
- Studies in the Winter Haven Chain of Lakes show that there is a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of TMDL load reductions for Lakes Shipp, May, and Lulu; TMDLs for those lakes were based on similar modelling as was done for Lake Idylwild.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 19 percent, 18 percent, and 15 percent concentration reductions, respectively.
- Seven County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) was 0.82 mg/L (based on chl-a target of 20 µg/L), respectively.
- Empirically-derived TP target using AGM (1983-2013) was not significant (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 34 percent.

Priority Ranking

- Assigned lake priority #1 of 9 within Tier 1.
- Seven County MS4 outfalls account for 10 percent of the lake‟s drainage area.
- Trend in TN indicates water quality is improving.
- Small-medium lake with moderately limited recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Spring Lake (WBID 1521G1)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on chl-a, requiring 10 percent concentration reduction.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.87 and 0.03 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN target is 17 percent.
- No concentration reduction is required to meet locally-derived AGM TP target.

Priority Ranking

- Assigned lake priority #2 of 9 within Tier 1.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TP indicates improving water quality.
- Small lake with moderately limited recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Arbuckle (WBID 1685A)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a, requiring 3 percent, 8 percent, and 9 percent concentration reductions, respectively.
- There are five County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Inverse correlation between TP and chl-a using AGM (1983-2013) was determined; empirically-derived target was not calculated.
- Correlation between TN and chl-a was not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #3 of 9 within Tier 1.
- Five County MS4 outfalls account for less than 1 percent of the lake‟s drainage area.
- No trends in water quality were identified.
- Large lake with moderate recreational use and predominantly undeveloped watershed including significant protected areas.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Weohyakapka (WBID 1573E)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on chl-a requiring 7 percent concentration reduction.
- Seven County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.09 and 0.04 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN and TP target.

Priority Ranking

- Assigned lake priority #4 of 9 within Tier 1.
- Seven County MS4 outfalls account for 13 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate declining water quality.
- Large lake with moderately limited recreational use has significant undeveloped areas, however, the Community of Nalcrest and other residential areas also exist in the basin.

Recommendation

- Investigate degrading trends in water quality.
- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Mattie (WBID 1488Q)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TP requiring 11 percent concentration reductions.
- One County MS4 outfall discharges to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Inverse correlation between TN and chl-a using AGM (1983-2013) was determined; empirically-derived target was not calculated.
- Correlation between TP and chl-a using AGM (1983-2013) is not significant.

Priority Ranking

- Assigned lake priority #5 of 9 within Tier 1.
- One County MS4 outfalls accounts for 19 percent of the lake‟s drainage area.
- Trend in TN and TP indicates declining water quality.
- Large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Hamilton (WBID 15041)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) was 1.43 mg/L (based on chl-a target of 20 µg/L).
- Inverse correlation between TP and chl-a using AGM (1983-2013) was determined; empirically-derived target was not calculated.
- No concentration reduction is required to meet locally-derived AGM TN target.

Priority Ranking

- Assigned lake priority #6 of 9 within Tier 1.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TP indicates water quality is improving. Trends in TN and chl-a indicate water quality is declining.
- Large lake with moderately limited recreational use and predominantly urban watershed.

Recommendations

- Investigate degrading water quality trends for TN and chl-a.
- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Lake Hamilton.

Ned Lake (WBID 1539Q)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP targets using AGM (1983-2013) were not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #7 of 9 within Tier 1.
- Eight County MS4 outfalls account for 76 percent of the lake‟s drainage area.
- Trend in TP indicates improving water quality.
- Small-medium lake with moderately limited recreational use and predominantly urban watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Buckeye (WBID 1488S)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.
- One County MS4 outfall discharges to the lake; permit-specified load reductions maybe required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP targets using AGM (1983-2013) are 1.08 and 0.04 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN or TP targets.

Priority Ranking

- Assigned lake priority #8 of 9 within Tier 1.
- One County MS4 outfall accounts for 10 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Small-medium lake with limited recreational use and predominantly urban watershed.

Recommendation

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Otis (WBID 1539D)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #9 of 9 within Tier 1.
- There are no County MS4 outfalls discharging to the lake.
- There were no trends in TN, TP, or chl-a.
- Medium lake with limited recreational use and predominantly urban watershed.

Recommendations

- Continue existing water quality improvement projects and monitoring programs; review water quality data in 5 years.

Lakes assigned to Tier 2

Lake Cannon (WBID 1521H)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring reduction in stormwater loads of TP by 54 percent.
- Studies in the Winter Haven Chain of Lakes show a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of TMDL load reductions for Lakes Shipp, May, and Lulu; TMDLs for those lakes were based on similar modelling as was done for Lake Cannon.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 11 percent, 9 percent, and 28 percent concentration reductions, respectively.
- Twenty-one County MS4 outfalls to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) are 0.97 and 0.02 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target are 16 and 36 percent, respectively.

Priority Ranking

- Assigned lake priority #1 of 29 within Tier 2.
- Twenty-one County MS4 outfalls account for 62 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Jessie (WBID 1521K)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring a reduction in stormwater loads of TP by 50 percent.
- Studies in the Winter Haven Chain of Lakes show that there is a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of TMDL load reductions for Lakes Shipp, May, and Lulu; TMDLs for those lakes were based on similar modelling as was done for Lake Jessie.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 10 percent, 22 percent, and 25 percent concentration reductions, respectively.
- Ten County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #2 of 29 within Tier 2.
- Ten County MS4 outfalls account for 59 percent of the lake‟s drainage area.
- Trends in TP and chl-a indicate water quality is improving.
- Medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Deer Lake (WBID 1521P)

Regulatory Implications

- Draft TMDL established by FDEP (2014) is based on empirically-derived relationships that are then compared to NNC and then further refined. The TMDL calls for reductions in TN concentrations in the lake of 12 percent, but no reductions in TP, possibly an error.
- TMDL allows for the incorporation of in-lake processes such as sediment resuspension and management of submerged aquatic vegetation.
- TMDL implementation appears to be warranted with BMAP efforts focusing on determining the types of projects that would be appropriate to meet water quality goals outlined in the TMDL and a review of the need for reductions in TP concentrations.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 31 percent, 11 percent, and 28 percent concentration reductions, respectively.
- Nine County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 1.21 mg/L (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 9 percent.
- Correlation between TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #3 of 29 within Tier 2.
- Nine County MS4 outfalls account for 100 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Hartridge (WBID 1521I)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 23 percent, 2 percent, and 21 percent concentration reductions, respectively.
- Eleven County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 1.18 mg/L (based on chl-a target of 20 μg/L).
- Empirically-derived TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 μg/L).
- No concentration reduction is required to meet locally-derived AGM TN target.

Priority Ranking

- Assigned lake priority #4 of 29 within Tier 2.
- Eleven County MS4 outfalls account for 20 percent of the lake‟s drainage area.
- Trends in TN and chl-a indicate water quality is declining.
- Medium-large lake with moderate recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Lake Hartridge.

Grassy Lake (WBID 1623M1)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 32 percent, 24 percent, and 26 percent concentration reductions, respectively.
- Three County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TP target using AGM (1983-2013) is 0.04 mg/L (based on chl-a target of 20 µg/L).
- Empirically-derived TN target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).
- No concentration reduction is required to meet locally-derived AGM TP target.

Priority Ranking

- Assigned lake priority #5 of 29 within Tier 2.
- Three County MS4 outfalls account for 10 percent of the lake‟s drainage area.
- Trend in TP indicates water quality is improving.
- Small-medium lake with limited recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Mariana (WBID 1521L)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 24 percent, 9 percent, and 37 percent concentration reductions, respectively.
- Four County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 1.00 mg/L (based on chl-a target of 20 µg/L).
- Empirically-derived TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 27 percent.

Priority Ranking

- Assigned lake priority #6 of 29 within Tier 2.
- Four County MS4 outfalls account for 50 percent of the lake"s drainage area.
- Trends in TP and TN indicate declining water quality.
- Medium-large lake with limited recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Lake Mariana.

Lake Smart (WBID 1488A)

Regulatory Implications

- Final TMDL established by EPA (2006) is based on a TSI target of 60 requiring reductions in stormwater loads of TP by 70 percent.
- TMDL does not address the basis for a substantial reduction in chl-a from the whole-lake alum treatment of the upstream waters of Lake Conine. The water quality model does not fully include the factor(s) that resulted in such a positive response of water quality.
- TMDL implementation is not recommended until the discrepancy is resolved between the amounts of TP reductions derived using NNC vs. estimates in the TMDL. The BMAP process should focus on deriving locally-derived water quality targets and incorporating existing information on groundwater seepage into loading model estimate and the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN and chl-a requiring 35 percent and 30 percent concentration reductions, respectively. Insufficient data to evaluate TP for impairment status.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.27 mg/L for TN and is not significant for TP (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 18 percent.

Priority Ranking

- Assigned lake priority #7 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TP and chl-a indicate improving water quality.
- Medium-large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Lulu (WBID 1521)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring a reduction in stormwater loads of TP by 55 percent.
- Studies in the Winter Haven Chain of Lakes show a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of prior TMDL load reductions.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 24 percent, 29 percent, and 39 percent concentration reductions, respectively.
- Twelve County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP targets using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #8 of 29 within Tier 2.
- Twelve County MS4 outfalls account for 24 percent of the lake‟s drainage area.
- Trends in TP and chl-a indicate improving water quality.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Rochelle (WBID 1488B)

Regulatory Implications

- Designated as impaired by FDEP for nutrients in 2004 based on elevated TSI.
- Final TMDL established by EPA (2006) is based on a TSI target of 60 that would require a 70 percent reduction in external TP loads.
- Proposed TP load reduction (TMDL) based on model results; however, no empirically-based correlation between TP and chl-a was reported.
- External TMDL review (see Appendix A) indicated locally-derived rate coefficients were not used in the WASP model.
- TMDL implementation not recommended; BMAP development should take into consideration lake-specific data and trends.
- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 18 percent, 29 percent, and 31 percent concentration reductions, respectively.
- Five County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.04 mg/L for TN and is not significant for TP (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 15 percent.

Priority Ranking

- Assigned lake priority #9 of 29 within Tier 2.
- Five County MS4 outfalls account for 4 percent of the lake‟s drainage area.
- Trends in TP and chl-a indicate water quality is improving. Trends in TN indicate water quality is declining.
- Medium-large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Ariana (WBID 1501B)

Regulatory Implications

- Final TMDL established by EPA (2010) is based on a TSI target of 35 requiring reductions in stormwater loads of TN and TP of 55 and 49 percent, respectively, and a 50 percent reduction in nutrient loads from sediments.
- A TSI target of 60 is appropriate, as lakes in this region were historically mesotrophic to slightly eutrophic.
- TMDL implementation is not recommended; BMAP efforts should focus on the development of more realistic water quality targets.
- Impairment evaluation using NNC method indicates impairment based on TN and chl-a, requiring 24 percent and 26 percent concentration reductions, respectively.
- Three County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN or TP target using AGM (1983-2013) is 1.01 and 0.01 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 8 percent and 19 percent, respectively.

Priority Ranking

- Assigned lake priority #10 of 29 within Tier 2.
- Three County MS4 outfalls account for 8 percent of the lake‟s drainage area.
- Trends in TN and chl-a indicate declining water quality. Trend in TP indicates improving water quality.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Middle Lake Hamilton (WBID 15002)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN and chl-a requiring 17 percent, 28 percent, and 35 percent concentration reductions, respectively.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #11 of 29 within Tier 2.
- One County MS4 outfall accounts for 4 percent of the lake‟s drainage area.
- Trend in chl-a indicates water quality is declining.
- Medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Mirror (WBID 1521G)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring a reduction in stormwater loads of TP by 28 percent.
- Studies in the Winter Haven Chain of Lakes show a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of TMDL load reductions for Lakes Shipp, May, and Lulu; TMDLs for those lakes were based on similar modelling as was done for Lake Mirror.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN and chl-a requiring 12 percent and 24 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.03 and 0.02 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 11 percent and 31 percent, respectively.

Priority Ranking

- Assigned lake priority #12 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TP and chl-a indicate improving water quality.
- Medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- No actions recommended until completion of anticipated development of Water Quality Management Plan by the City of Lakeland.
- Continue existing water quality improvement projects and monitoring programs.

Lake Juliana (WBID 1484B)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 23 percent, 3 percent, and 28 percent concentration reductions, respectively.
- Three County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.01 and 0.02 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 23 percent and 29 percent, respectively.

Priority Ranking

- Assigned lake priority #13 of 29 within Tier 2.
- Three County MS4 outfalls account for 12 percent of the lake‟s drainage area.
- Trend in TP indicates water quality is improving. Trends in TN and chl-a indicate water quality is declining.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Howard (WBID 1521F)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring a reduction in stormwater loads of TP by 63 percent.
- Studies in the Winter Haven Chain of Lakes show a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of TMDL load reductions for Lakes Shipp, May, and Lulu; TMDLs for those lakes were based on similar modelling as was done for Lake Howard.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 35 percent, 16 percent, and 38 percent concentration reductions, respectively.
- Four County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.63 and 0.01 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 61 percent and 67 percent, respectively.

Priority Ranking

- Assigned lake priority #14 of 29 within Tier 2.
- Four County MS4 outfalls account for less than 1 percent of the lake"s drainage area.
- Trends in TP and chl-a indicate water quality is improving.
- Medium-large lake with moderate recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Hatchineha (WBID 1472B)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on TSI trend, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 22 percent, 17 percent, and 19 percent concentration reductions, respectively.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.76 and 0.09 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN or TP target.

Priority Ranking

- Assigned lake priority #15 of 29 within Tier 2.
- One County MS4 outfall accounts for less than 1 percent of the lake‟s drainage area.
- Trend in TP indicates water quality is improving.
- Large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Reedy Lake (WBID 1685D)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN and chl-a requiring 26 percent and 21percent concentration reductions, respectively.
- Seven County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.54 and 0.03 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN or TP target.

Priority Ranking

- Assigned lake priority #16 of 29 within Tier 2.
- Seven County MS4 outfalls account for 3 percent of the lake‟s drainage area.
- Trends in TP, TN, and chl-a indicate water quality is declining.
- Large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Fannie (WBID 14882)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 9 percent, 22 percent, and 11 percent concentration reductions, respectively.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

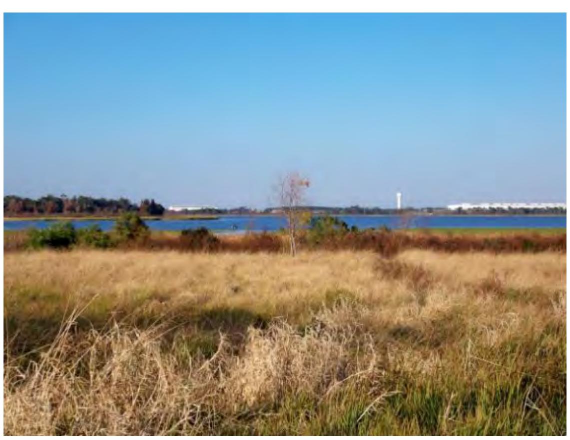
- Empirically-derived TN and TP target using AGM (1983-2013) is 1.45 and 0.06 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN or TP target.

Priority Ranking

- Assigned lake priority #17 of 29 within Tier 2.
- One County MS4 outfall accounts for 2 percent of the lake‟s drainage area.
- Trend in TN indicates declining water quality.
- Medium-large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.



Photograph of Lake Fannie.

Little Lake Hamilton (WBID 15001)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 32 percent, 27 percent, and 21 percent concentration reductions, respectively.
- Three County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #18 of 29 within Tier 2.
- Three County MS4 outfalls account for 2 percent of the lake‟s drainage area.
- Trend in TN indicates water quality is declining.
- Medium-large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Little Lake Hamilton.

Lake Eloise (WBID 1521B)

Regulatory Implications

- Designated as impaired by FDEP for nutrients in 2004 based on elevated TSI.
- Final TMDL established by EPA (2006) based on a TSI target of 60, which would require a 70 percent reduction in external TP loads.
- Proposed TP load reduction (TMDL) based on model results; however, no empirically-based correlation between TP and chl-a was reported.
- External TMDL review (see Appendix A) indicated locally-derived rate coefficients were not used in the WASP model.
- TMDL implementation not recommended; BMAP development should take into consideration lake-specific data and trends.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 12 percent, 17 percent, and 30 percent concentration reductions, respectively.
- Nine County MS4 outfalls to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #19 of 29 within Tier 2.
- Nine County MS4 outfalls account for 4 percent of the lake‟s drainage area.
- TP trends indicate improving water quality.
- Large lake with moderately-low recreational use and predominately developed (residential) watershed.

Recommendation

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Haines (WBID 1488C)

Regulatory Implications

- Final TMDL established by EPA (2006) is based on a TSI target of 60 requiring reductions in stormwater loads of TP by 70 percent.
- TMDL does not address the basis for a substantial reduction in chl-a from the early 1990s to the early 2000s and the water quality model might not fully include the factor(s) that resulted in the noted trend in water quality.
- TMDL implementation is not recommended until the discrepancy is resolved between the amounts of TP reductions derived using NNC vs. estimates in the TMDL. The BMAP process should focus on developing locally-derived water quality targets and incorporating existing information on groundwater seepage into loading model estimates and the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 8 percent, 21 percent, and 33 percent concentration reductions, respectively.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TP target using AGM (1983-2013) is 0.03 mg/L (based on chl-a target of 20 µg/L).
- Empirically-derived TN target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TP target is 22 percent.

Priority Ranking

- Assigned lake priority #20 of 29 within Tier 2.
- One County MS4 outfall accounts for less than 1 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate water quality is improving.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Cypress (WBID 3180A)

Regulatory Implications

- Draft TMDL established by FDEP (2011) is based on a TSI target of 60 requiring reductions in stormwater loads of TN and TP by 7 and 53 percent, respectively.
- Draft TMDL does not appear to address the importance of the approximate 2 foot change in lake levels that occurred in the 1960s with the completion of the Cypress-Hatchineha Canal and the impacts of hydrologic alterations on water quality.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of planned hydrologic restoration projects in the Upper Kissimmee Chain of Lakes, which may be able to restore water quality to an unimpaired condition.
- If future hydrologic restoration of Lake Cypress watershed does not result in the water quality improvements anticipated a focus on stormwater projects might be required.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 22 percent, 34 percent, and 35 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.01 and 0.05 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN or TP target is 26 and 25 percent, respectively.

Priority Ranking

- Assigned lake priority #21 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Rosalie (WBID 1573C)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #22 of 29 within Tier 2.
- Eleven County MS4 outfalls account for 2 percent of the lake‟s drainage area.
- Trend in TN and TP indicates water quality is declining.
- Large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- No water quality improvement actions are recommended at this time.
- Monitor degrading trend in TN and TP.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Eva (WBID 15101)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 37 percent, 32 percent, and 33 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.29 and 0.04 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 15 percent and 8 percent, respectively.

Priority Ranking

- Assigned lake priority #23 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TN and chl-a indicate declining water quality.
- Medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Roy (WBID 1521O)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.18 mg/L for TN and insignificant for TP (based on chl-a target of 20 µg/L).
- No concentration reduction is required to meet locally-derived AGM TN target.

Priority Ranking

- Assigned lake priority #24 of 29 within Tier 2.
- Ten County MS4 outfalls account for 16 percent of the lake‟s drainage area.
- Trend in TP indicates water quality is improving.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Maude (WBID 1488Q)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 1.06 mg/L (based on chl-a target of 20 µg/L).
- Correlation between TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.
- No concentration reduction is required to meet locally-derived AGM TN target.

Priority Ranking

- Assigned lake priority #25 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TN indicates declining water quality.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time. Monitor degrading trend in TN concentrations.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Photograph of Lake Maude.

Lake Kissimmee (WBID 3183B)

Regulatory Implications

- Final TMDL produced by FDEP (2011) is based on a TSI target of 60 requiring reductions in stormwater loads of TN and TP by 5 and 25 percent, respectively.
- A complicating factor is when water quality is characterized using NNC Lake Kissimmee does not appear to be impaired for nutrients.
- The current TMDL requires load reductions throughout the Upper Kissimmee Chain of Lakes watershed, but newly adopted NNC guidance suggests that water quality is not problematic in Lake Kissimmee.
- TMDL is based on the achievement of TMDL obligations in lakes located farther upstream in the Upper Kissimmee Chain of Lakes system including lakes that have problematic TMDLs (e.g. Lake Cypress).
- The County should work with FDEP in the BMAP process to ensure that the most appropriate water quality targets and restoration strategies are selected and pursued during TMDL implementation.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.34 and 0.07 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN or TP target.

Priority Ranking

- Assigned lake priority #26 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- Trends in chl-a indicate water quality is improving. Trends in TP indicate water quality is declining.
- Large lake with high recreational use and predominantly undeveloped watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.
- Monitor degrading trend in TP.

Lake Livingston (WBID 1730B)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #27 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- No trends in water quality were identified.
- Large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Continue existing water quality improvement projects and monitoring programs; review water quality data in 5 years.
- No water quality improvement actions are recommended at this time.

Little Lake Agnes (WBID 1466A1)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #28 of 28 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- Insufficient data to evaluated trends in water quality.
- Medium lake with limited recreational use and predominantly urban watershed.

Recommendations

- Continue existing water quality improvement projects and monitoring programs. Review water quality data in 5 years.

Surveyors Lake (WBID 1647)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients.

Locally-derived Targets

- Correlation between TN or TP and chl-a was not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #29 of 29 within Tier 2.
- There are no County MS4 outfalls discharging to the lake.
- No trends in water quality identified.
- Medium-large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lakes assigned to Tier 3

Sears Lake (WBID 1501W)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 30 percent, 56 percent, and 47 percent concentration reductions, respectively.
- Six County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #1 of 14 within Tier 3.
- Six County MS4 outfalls account for 30 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Small-medium lake with limited recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Conine (WBID 1488U)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 27 percent, 44 percent, and 46 percent concentration reductions, respectively.
- Nine County MS4 outfalls to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 0.94 mg/L (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 34 percent.
- Correlation between TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #2 of 14 within Tier 3.
- Nine County MS4 outfalls account for 19 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Lake Conine.

Lake Lena (WBID 1501)

Regulatory Implications

- Draft TMDL established by FDEP (2014) is based on empirically-derived relationships that are compared to NNC and then further refined. The TMDL calls for reductions in TN concentrations in the lake of 42 percent, but no reduction in TP concentrations, possibly an error.
- TMDL allows for the incorporation of in-lake processes such as sediment resuspension and management of submerged aquatic vegetation.
- TMDL implementation appears to be warranted with BMAP efforts focusing on determining the types of projects that would be appropriate to meet water quality goals outlined in the TMDL and a review of the need for any reductions in TP concentrations.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 42 percent, 16 percent, and 49 percent concentration reductions, respectively.
- Four County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.17 and 0.02 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 34 percent and 44 percent, respectively.

Priority Ranking

- Assigned lake priority #3 of 14 within Tier 3.
- Four County MS4 outfalls account for 40 percent of the lake‟s drainage area.
- Trend in TP indicates water quality is improving.
- Medium lake with limited recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Shipp (WBID 1521D)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring a reduction in stormwater loads of TP by 65 percent.
- Studies in the Winter Haven Chain of Lakes show a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of prior TMDL load reductions.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 37 percent, 28 percent, and 52 percent concentration reductions, respectively.
- Two County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.84 and 0.01 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 50 percent and 76 percent, respectively.

Priority Ranking

- Assigned lake priority #4 of 14 within Tier 3.
- Two County MS4 outfalls account for 37 percent of the lake‟s drainage area.
- Trends in TP and chl-a indicate improving water quality.
- Medium-large lake with moderate recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Crooked Lake (WBID 1663)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 22 percent, 44 percent, and 16 percent concentration reductions, respectively.
- Seven County MS4 outfalls to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.66 and 0.02 mg/L (based on chl-a target of 6 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN or TP target.

Priority Ranking

- Assigned lake priority #5 of 14 within Tier 3.
- Seven County MS4 outfalls account for 3.9 percent of the lake‟s drainage area.
- Trends in TN and chl-a indicate declining water quality.
- Large lake with moderate recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Mud Lake (WBID 1467)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 39 percent, 41 percent, and 34 percent concentration reductions, respectively.
- Two County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.93 and 0.03 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 44 percent and 57 percent, respectively.

Priority Ranking

- Assigned lake priority #6 of 14 within Tier 3.
- Two County MS4 outfalls account for 6 percent of the lake‟s drainage area.
- Trend in TN indicates declining water quality.
- Medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Annie (WBID 1539C)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN and TP requiring 38 percent and 46 percent concentration reductions, respectively. Insufficient data were available to evaluate chl-a for impairment.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #7 of 14 within Tier 3.
- One County MS4 outfall accounts for less than 1 percent of the lake‟s drainage area.
- Trends in TP, TN, and chl-a indicate improving water quality.
- Medium-large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake May (WBID 1588A)

Regulatory Implications

- Final TMDL produced by FDEP (2007) is based on a TSI target of 60 requiring a reduction in stormwater loads of TP by 58 percent.
- Studies in the Winter Haven Chain of Lakes show a discrepancy between TSI values for nutrients and those for the biological indicator of chl-a. This discrepancy may be responsible for the lack of system responses to the implementation of prior TMDL load reductions.
- TMDL implementation is not recommended; BMAP efforts should focus on the implementation of projects outlined in the Winter Haven Chain of Lakes Water Quality Management Plan (PBS&J 2010).
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 39 percent, 49 percent, and 52 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.64 and 0.02 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 63 percent and 66 percent, respectively.

Priority Ranking

- Assigned lake priority #8 of 14 within Tier 3.
- There are no County MS4 outfalls discharging to the lake.
- Trend in TP indicates improving water quality. Trend in TN indicates declining water quality.
- Small lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Review and evaluate existing water quality management plan for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Clinch (WBID 1706)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 24 percent, 48 percent, and 45 percent concentration reduction, respectively.
- Seven County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #9 of 14 within Tier 3.
- Seven County MS4 outfalls account for 11 percent of the lake‟s drainage area.
- No trends in water quality were identified.
- Large lake with limited recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake McLeod (WBID 1588A)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 3 percent, 49 percent, and 19 percent concentration reductions, respectively.
- Three County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 0.41 mg/L (based on chl-a target of 6 µg/L).
- Empirically-derived TP target using AGM (1983-2013) is not significant (based on chl-a target of 6 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 8 percent.

Priority Ranking

- Assigned lake priority #10 of 14 within Tier 3.
- Three County MS4 outfalls account for less than 1 percent of the lake‟s drainage area.
- No trends in water quality were identified.
- Medium-large lake with limited recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Wailes (WBID 1619A)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 27 percent, 7 percent, and 43 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.52 and 0.02 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN target.
- Concentration reduction required to meet locally-derived AGM TP target is 29 percent.

Priority Ranking

- Assigned lake priority #11 of 14 within Tier 3.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TN and chl-a indicate declining water quality.
- Medium large lake with moderate recreational use and predominantly urban watershed.

Recommendation

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Eagle Lake (WBID 1623M)

Regulatory Implications

- Currently designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 20 percent, 58 percent, and 38 percent concentration reductions, respectively.
- Eight County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.44 and 0.01 mg/L (based on chl-a target of 6 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 30 percent and 58 percent, respectively.

Priority Ranking

- Assigned lake priority #12 of 13 within Tier 3.
- Eight County MS4 outfalls account for 18 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Medium-large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Alfred (WBID 1488D)

Regulatory Implications

- Final TMDL established by EPA (2010) is based on a TSI target of 35 requiring reductions in stormwater loads of TN and TP by 68 and 55 percent, respectively, and a 60 percent reduction in nutrient loads from sediments.
- A TSI target of 60 is appropriate as lakes in this region were historically mesotrophic to slightly eutrophic.
- TMDL implementation is not recommended; BMAP efforts should focus on the development of more realistic water quality targets.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients.
- Three County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN and chl-a not found using AGM (1983-2013).
- Correlation between TP and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #13 of 14 within Tier 3.
- Three County MS4 outfalls account for less than 1 percent of the lake"s drainage area.
- TP trends indicate improving water quality.
- Medium-large lake with limited recreational use and predominantly undeveloped watershed.

Recommendation

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

Lake Easy (WBID 1619B)

Regulatory Implications

- Currently designated as not impaired by FDEP.
- Impairment evaluation using NNC method indicates the lake is unimpaired for nutrients based on insufficient data.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #14 of 24 within Tier 3.
- Eight County MS4 outfalls account for less than 1 percent of the lake‟s drainage area.
- Insufficient data to evaluate trends in water quality.
- Medium-large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Continue existing water quality improvement projects and monitoring programs; review water quality data in 5 years.

Lakes assigned to Tier 4

Crystal Lake (WBID 1497A)

Regulatory Implications

- Final TMDL established by EPA (2010) is based on a TSI target of 35 requiring reductions in stormwater loads of TN and TP by 51 and 79 percent, respectively, and a 75 percent reduction in nutrient loads from sediments.
- A TSI target of 60 is appropriate as lakes in this region were historically mesotrophic to slightly eutrophic.
- TMDL implementation is not recommended; BMAP efforts should focus on the development of more realistic water quality targets.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 31 percent, 67 percent, and 59 percent concentration reductions, respectively.
- Five County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 1.08 mg/L (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived TN target is 29 percent.
- Correlation between TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #1 of 24 within Tier 4.
- Five County MS4 outfalls account for 57 percent of the lake‟s drainage area.
- Trends in TN and chl-a indicate declining water quality. Trend in TP indicates improving water quality.
- Small lake with limited recreational use and predominantly urban watershed.

Recommendations

- No actions recommended until completion of anticipated development of Water Quality Management Plan by the City of Lakeland.
- Continue existing water quality improvement projects and monitoring programs.

Lake Blue (WBID 1521B)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 58 percent, 55 percent, and 70 percent concentration reductions, respectively.
- Twelve County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 0.92 mg/L (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 63 percent.
- Correlation between TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #2 of 24 within Tier 4.
- Twelve County MS4 outfalls that account for 56 percent of the lake‟s drainage area.
- Trends in TN and chl-a indicate declining water quality. Trend in TP indicates improving water quality.
- Small-medium lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Review and evaluate existing water quality management plan (PBS&J 2010) for potential selection of projects for implementation.
- Continue existing water quality improvement projects and monitoring programs.

Lake Daisy (WBID 1539R)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN and TP requiring 5 percent and 63 percent concentration reductions, respectively.
- Seven County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TN or TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #3 of 24 within Tier 4.
- Seven County MS4 outfalls account for 44 percent of the lake‟s drainage area.
- Trend in TP indicates improving water quality.
- Medium lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Photograph of Lake Daisy.

Lake Tennessee (WBID 1484A)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 34 percent, 51 percent, and 69 percent concentration reductions, respectively.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 0.54 mg/L (based on chl-a target of 6 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 27 percent.
- Correlation between TP and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #4 of 24 within Tier 4.
- One County MS4 outfall accounts for 20 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate improving water quality.
- Small lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Deeson (WBID 1449A)

Regulatory Implications

- Currently designated as impaired for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 74 percent, 85 percent, and 87 percent concentration reductions, respectively.
- Five County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 0.67 mg/L (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 65 percent.
- Correlation between TP and chl-a using AGM (1983-2013) could not be determined due to insufficient data.

Priority Ranking

- Assigned lake priority #5 of 24 within Tier 4.
- Five County MS4 outfalls account for 12 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate declining water quality.
- Small lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Gibson (WBID 1497D)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 33 percent, 91 percent, and 48 percent concentration reductions, respectively.
- Seventeen County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.01 and 0.06 mg/L (based on chl-a target of 20 µg/L), respectively.
- No concentration reduction is required to meet locally-derived AGM TN target.
- Concentration reduction required to meet locally-derived AGM TP target is 46 percent.

Priority Ranking

- Assigned lake priority #6 of 24 within Tier 4.
- Seventeen County MS4 outfalls account for 43 percent of the lake‟s drainage area.
- Trend in TP indicates improving water quality. Trend in chl-a indicates declining water quality.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- No actions recommended until completion of anticipated development of Water Quality Management Plan by the City of Lakeland.
- Continue existing water quality improvement projects and monitoring programs.

Saddle Creek Park (WBID 1497J)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 30 percent, 72 percent, and 54 percent concentration reductions, respectively.
- Twenty-five County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is not significant for TN and is 0.01 mg/L for TP (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TP target is 91 percent.

Priority Ranking

- Assigned lake priority #7 of 24 within Tier 4.
- Twenty-five County MS4 outfalls account for 13 percent of the lake‟s drainage area.
- No trends in TN, TP, or chl-a.
- Medium-large lake with moderately high recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Somerset Lake (WBID 1549F)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 44 percent, 90 percent, and 77 percent concentration reductions, respectively.
- Two County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.42 mg/L for TN and is not significant for TP (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 78 percent.

Priority Ranking

- Assigned lake priority #8 of 24 within Tier 4.
- Two County MS4 outfalls account for 60 percent of the lake‟s drainage area.
- Trend in TN indicates declining water quality.
- Small lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Stahl Lake (WBID 1549B1)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 50 percent, 91 percent, and 66 percent concentration reductions, respectively.
- Six County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN or TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #9 of 24 within Tier 4.
- Six County MS4 outfalls account for 74 percent of the lake‟s drainage area.
- Trend in TP indicates improving water quality. Trend in chl-a indicates declining water quality.
- Small lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Investigate degrading chl-a trends.
- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Agnes (WBID 1466)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and impairment designation
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 19 percent, 76 percent, and 44 percent concentration reductions, respectively.
- Six County MS4 outfalls to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 0.39 mg/L (based on chl-a target of 6 μg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 38 percent.
- Correlation between TP and chl-a not found using AGM (1983-2013).

Priority Ranking

- Assigned lake priority #10 of 24 within Tier 4.
- Six County MS4 outfalls account for 2 percent of the lake‟s drainage area.
- TP and chl-a trends indicate improving water quality.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendation

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Buffum (WBID 1677C)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 43 percent, 78 percent, and 51 percent concentration reductions, respectively.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Correlation between TP or TN and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #11 of 24 within Tier 4
- One County MS4 outfall accounts for 2 percent of the lake‟s drainage area.
- Trend in TN indicates declining water quality
- Large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake John (WBID 1549E)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 25 percent, 88 percent, and 70 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.33 and 0.08 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived TN and TP target is 76 percent and 69 percent, respectively.

Priority Ranking

- Assigned lake priority #12 of 24 within Tier 4.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TN and chl-a indicate water quality is declining.
- Small lake with moderate recreational use and predominantly urban watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Hollingsworth (WBID 1549X)

Regulatory Implications

- Draft TMDL established by FDEP (2014) is based on empirically-derived relationships that are then compared to NNC and then further refined. The TMDL calls for reductions in TN and TP concentrations in the lake of 52 and 57, respectively.
- The TMDL allows for the incorporation of in-lake processes such as sediment resuspension and management of submerged aquatic vegetation.
- TMDL implementation appears to be warranted, with BMAP efforts focusing on determining the types of projects that would be appropriate to meet water quality goals outlined in the TMDL.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 41 percent, 58 percent, and 64 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.83 and 0.03 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 53 percent and 58 percent, respectively.

Priority Ranking

- Assigned lake priority #13 of 24 within Tier 4.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TP, TN, and chl-a indicate water quality is improving.
- Medium-large lake with moderate recreational use and predominantly urban watershed.

Recommendations

- No actions recommended until completion of anticipated development of Water Quality Management Plan by the City of Lakeland.
- Continue existing water quality improvement projects and monitoring programs.

Lake Parker (WBID 1497B)

Regulatory Implications

- Draft TMDL established by FDEP (2005) is based on a TSI target of 72.9, which would require reductions of stormwater loads of both TN and TP of 57 percent.
- The load reduction goals in the TMDL are unattainable and problematic, as nutrient concentrations in the lake are substantially higher than in stormwater runoff to the lake.
- Likely that resuspension of phosphorus-rich sediments is a significant source of the excess and unaccounted for TP and that nitrogen-fixation by cyanobacteria could be a significant source of the excess and unaccounted for TN.
- TMDL implementation is not recommended until and unless the role of TP-rich sediments and nitrogen fixation are processes included in the TMDL.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 60 percent, 63 percent, and 74 percent concentration reductions, respectively.
- Fifteen County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.98 mg/L for TN and not significant for TP (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 63 percent.

Priority Ranking

- Assigned lake priority #14 of 24 within Tier 4.
- Fifteen County MS4 outfalls account for 5 percent of the lake‟s drainage area.
- Trend in TP indicates water quality is improving.
- Large lake with moderately high recreational use and predominantly urban watershed.

Recommendations

- No actions recommended until completion of anticipated development of Water Quality Management Plan by the City of Lakeland.
- Elevated in-lake TN concentrations (>2.4 mg/L) indicate potential presence of cyanobacteria.
- Continue existing water quality improvement projects and monitoring programs.

Banana Lake (WBID 1549B)

Regulatory Implications

- Draft TMDL established by FDEP (2005) is based on a TSI target of 60 requiring reductions in stormwater loads of TN and TP by 79 and 80 percent, respectively.
- The load reduction goals in the TMDL are unattainable and problematic; lake nutrient concentrations are substantially higher than in stormwater runoff.
- Likely that resuspension of phosphorus-rich sediments is a significant source of the excess and unaccounted for TP and that nitrogen-fixation by cyanobacteria could be a significant source of the excess and unaccounted for TN.
- TMDL implementation is not recommended unless the role of TP-rich sediments and nitrogen fixation processes are included.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 56 percent, 92 percent, and 77 percent concentration reductions, respectively.
- Seven County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.83 and 0.01 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 65 percent and 97 percent, respectively.

Priority Ranking

- Assigned lake priority #15 of 24 within Tier 4.
- Seven County MS4 outfalls that account for 15 percent of the lake‟s drainage area.
- Trends in TP and TN indicate improving water quality.
- Medium-large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake. Elevated in-lake TN concentrations (>2.4 mg/L) indicate potential presence of cyanobacteria.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Hancock (WBID 1623L)

Regulatory Implications

- Draft TMDL established by FDEP (2014) is based on empirically-derived relationships that are compared to NNC and then further refined. The TMDL calls for reductions in TN and TP concentrations in the lake of 52 and 57 percent, respectively.
- The TMDL allows for the incorporation of in-lake processes such as sediment resuspension and management of submerged aquatic vegetation.
- TMDL implementation appears to be warranted with BMAP efforts focusing on determining the types of projects that would be appropriate to meet water quality goals outlined in the TMDL.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 77 percent, 83 percent, and 90 percent concentration reductions, respectively.
- Forty-two County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 1.16 mg/L (based on chl-a target of 20 µg/L).
- Empirically-derived TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 79 percent.

Priority Ranking

- Assigned lake priority #16 of 24 within Tier 4.
- Forty-two County MS4 outfalls account for 4 percent of the lake"s drainage area.
- Trend in TP indicates water quality is improving. Trends in TN and chl-a indicate water quality is declining.
- Large lake with moderate recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake. Elevated in-lake TN concentrations (>2.4 mg/L) indicate potential presence of cyanobacteria.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Hickory Lake (WBID 1730)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 57 percent, 8 percent, and 69 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TP target using AGM (1983-2013) is 0.02 mg/L (based on chl-a target of 20 µg/L).
- Empirically-derived TN target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TP target is 39 percent.

Priority Ranking

- Assigned lake priority #17 of 24 within Tier 4.
- There are no County MS4 outfalls discharging to the lake.
- No trends in water quality were identified.
- Medium lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake. Elevated in-lake TN concentrations (>2.4 mg/L) indicate potential presence of cyanobacteria.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Pierce (WBID 1685D)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 52 percent, 51 percent, and 63 percent concentration reductions, respectively.
- Two County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 1.01 and 0.02 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN and TP target is 49 percent and 67 percent, respectively.

Priority Ranking

- Assigned lake priority #18 of 24 within Tier 4.
- Two County MS4 outfalls account for 1 percent of the lake‟s drainage area.
- Trends in TP, TN, and chl-a indicate water quality is declining.
- Large lake with moderate recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Carter Road Park (WBID 1610)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated chl-a, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 25 percent, 94 percent, and 72 percent concentration reduction, respectively.
- Fifteen County MS4 outfalls to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.72 and 0.28 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN or TP target is 48 percent and 43 percent, respectively.

Priority Ranking

- Assigned lake priority #19 of 24 within Tier 4.
- Fifteen County MS4 outfalls account for 14 percent of the lake‟s drainage area.
- Trend in TN indicates improving water quality.
- Large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Marion (WBID 1480)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 47 percent, 60 percent, and 61 percent concentration reductions, respectively.
- One County MS4 outfall to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 0.75 mg/L (based on chl-a target of 20 µg/L).
- Correlation between TP and chl-a not found using AGM (1983-2013).
- Concentration reduction required to meet locally-derived AGM TN target is 62 percent.

Priority Ranking

- Assigned lake priority #20 of 24 within Tier 4.
- One County MS4 outfall accounts for 3 percent of the lake‟s drainage area.
- Trends in TN, TP, and chl-a indicate declining water quality.
- Large lake with moderately-low recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Hunter (WBID 1543)

Regulatory Implications

- Final TMDL produced by FDEP (2004) is based on attaining water quality targets dependent upon a series of complex equations that are dependent on numerous assumed relationships that have not been measured. These target water quality values require reductions in stormwater loads of TN and TP by 80 percent each along with the elimination of septic tank systems in the watershed.
- The relationship between TN and chl-a appears to be due to the production of TN by nitrogen-fixing cyanobacteria, rather than chl-a being controlled by TN loads. There is no statistically significant correlation between TP and chl-a.
- TMDL implementation is not recommended; BMAP efforts should focus on the development of empirically-derived nutrient concentrations and better quantifying the role of TP-rich sediments and nitrogen fixation by cyanobacteria.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 60 percent, 82 percent, and 81 percent concentration reductions, respectively.

Locally-derived Targets

- Empirically-derived TN target using AGM (1983-2013) is 1.03 mg/L (based on chl-a target of 20 µg/L).
- Empirically-derived TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).
- Concentration reduction required to meet locally-derived AGM TN target is 61 percent.

Priority Ranking

- Assigned lake priority #21 of 24 within Tier 4.
- There are no County MS4 outfalls discharging to the lake.
- Trends in TN and chl-a indicate water quality is declining.
- Small-medium lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- No actions recommended until completion of anticipated development of Water Quality Management Plan by the City of Lakeland.
- Elevated in-lake TN concentrations (>2.4 mg/L) indicate potential presence of cyanobacteria.
- Continue existing water quality improvement projects and monitoring programs.

Lake Garfield (WBID 1622)

Regulatory Implications

- Currently designated as not impaired by FDEP; however, a TMDL is anticipated upon FDEP evaluation and probable impairment designation using the NNC.
- Impairment evaluation using NNC method indicates impairment based on TP requiring 62 percent concentration reductions.
- Five County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is not significant (based on chl-a target of 20 µg/L).

Priority Ranking

- Assigned lake priority #22 of 24 within Tier 4.
- Five County MS4 outfalls account for 2 percent of the lake‟s drainage area.
- Trend in TP indicates declining water quality.
- Medium-large lake with limited recreational use and predominantly undeveloped watershed.

Recommendations

- Evaluate internal and external nutrient loads to the lake.
- Develop and implement water quality management plan which presents potential water quality improvement projects.
- Continue existing water quality improvement projects and monitoring programs.

Lake Bonny (WBID 1497E)

Regulatory Implications

- Draft TMDL established by FDEP (2014) is based on empirically-derived relationships that are compared to NNC and then further refined. The TMDL calls for reductions in TN and TP concentrations in the lake of 64 percent and 60 percent, respectively.
- TMDL allows for the incorporation of in-lake processes such as sediment resuspension and management of submerged aquatic vegetation.
- TMDL implementation appears to be warranted with BMAP efforts focusing on determining the types of projects appropriate to meet water quality goals.
- Impairment evaluation using NNC method indicates impairment based on TN, TP, and chl-a requiring 55 percent, 69 percent, and 68 percent concentration reductions, respectively.
- Three County MS4 outfalls discharge to the lake; permit-specified load reductions may be required to meet TMDL-defined water quality target.

Locally-derived Targets

- Empirically-derived TN and TP target using AGM (1983-2013) is 0.90 and 0.03 mg/L (based on chl-a target of 20 µg/L), respectively.
- Concentration reduction required to meet locally-derived AGM TN or TP target is 61 percent and 69 percent, respectively.

Priority Ranking

- Assigned lake priority #23 of 24 within Tier 4.
- Three County MS4 outfalls account for 8 percent of the lake‟s drainage area.
- No trends in water quality were identified.
- Medium-large lake with moderately-low recreational use and predominantly urban watershed.

Recommendations

- No actions recommended until completion of anticipated development of Water Quality Management Plan by the City of Lakeland.
- Elevated in-lake TN concentrations (>2.4 mg/L) indicate potential presence of cyanobacteria.
- Continue existing water quality improvement projects and monitoring programs.

Lake Tenoroc (WBID 1497C)

Regulatory Implications

- Designated as impaired by FDEP for nutrients based on elevated TSI, TMDL is anticipated.
- Impairment evaluation using NNC method confirmed by FDEP indicates the lake is unimpaired for nutrients based on insufficient data.

Locally-derived Targets

- Correlation between TN or TP and chl-a using AGM (1983-2013) not determined due to insufficient data.

Priority Ranking

- Assigned lake priority #24 of 24 within Tier 4.
- There are no County MS4 outfalls discharging to the lake.
- Trends in water quality were not determined due to insufficient data.
- Medium lake with moderate recreational use and predominantly undeveloped watershed.

Recommendations

- Coordinate with FDEP for delisting from 303(d) based upon unimpaired nutrient status using NNC.
- No water quality improvement actions are recommended at this time.
- Elevated in-lake TN concentrations (>2.4 mg/L) indicate potential presence of cyanobacteria.
- Continue monitoring program and existing water quality improvement projects; review water quality status in five years.

4 Conclusions/Recommendations

4.1 FDEP involvement

Based on a meeting between Polk County and FDEP staff in Tallahassee (March 2014) it was agreed that FDEP would provide the County with comments on this report, and share any comments or concerns. In addition to review of this report, items that require FDEP action include the following: 1) FDEP should work with Polk County to enact the appropriate regulatory response up to and including removing lakes that are on the Verified Impaired list using TSI, but are not impaired using FDEP‟s recently adopted NNC criteria from the Verified Impaired list, and 2) FDEP should work with Polk County to revise problematic TMDLs, lest limited resources be spent on projects that are unlikely to bring about the desired water quality response.

To ensure that the County‟s limited resources are directed to lakes where there is a likely probability of success, this report also prioritizes lakes on the Verified Impaired List and/or lakes with draft or final TMDLs. The County and FDEP should develop an approach wherein both entities work in a coordinated fashion so that limited resources are not being spent on duplicative efforts, and so that lakes that are not on the County‟s priority list get attention from either FDEP or other entities.

4.2 TMDL Review: Related to TMDL implementation

The majority of TMDLs for Polk County Lakes require some level of revision prior to implementing their proposed nutrient load reductions. In some lakes, the proposed nutrient concentration targets have been previously shown to be too high to result in the chl-a concentrations that are expected with TMDL implementation, such as in Lakes Shipp, May, and Lulu. In other TMDLs, the nutrient and chl-a targets have been previously shown to be too low to be realistic goals, as they represent lake conditions "cleaner" than historical conditions (e.g. Lakes Ariana North and Crystal).

Many of the TMDLs examined are based on the use of complex mechanistic water quality models. While such models are useful and necessary in many situations, they are often "calibrated" for local conditions through the modification of biological rate processes that have never been locally measured. Consequently, the validity of model calibration techniques cannot be independently assessed. What is known, however, is that implementation of TMDL obligations that were developed based on the use of mechanistic water quality models has not resulted in the expected improvement to unimpaired water quality conditions for Lakes Shipp, May, and Lulu (PBS&J 2008).

In some lakes, the influence of in-lake processes such as sediment re-suspension, internal nutrient fluxes, etc. have been included in TMDL reports without local data to support the rates used in the assessments (e.g. Banana Lake, Lake Hancock). In other lakes, data exist for such in-lake processes, but the data have not yet been incorporated into the appropriate TMDLs (e.g. Lakes Haines and Smart). In other TMDLs, the removal of

nutrient loads from septic tanks is included as a necessary action without local data to support such an expense.
It is recommended that Polk County communicate its concerns to FDEP, and that the County request that FDEP work with the County to resolve the issues listed here. Very few lake TMDLs (e.g Lakes Bonny, Deer, Hollingsworth and Lena) are scientifically defensible enough to provide confidence that the implementation of proposed load reductions is likely to produce the response that both the County and FDEP wish to see – a lake that experiences sufficient improvements in water quality so as to no longer be considered impaired.

4.3 Lake prioritization

There are 554 freshwater lakes in Polk County. The County currently implements a water quality monitoring program which collects and analyses samples quarterly within ninety-one of the 97 lakes evaluated for this report. Sixty-two of the ninety-seven lakes evaluated are potentially impaired when compared to the FDEP NNC. As previously noted, the County does not have the resources to fully address all the regulatory compliance criteria that may be relevant to impaired lakes and streams within its jurisdiction. As such, a mechanism was developed to assign priority to each of the ninety-seven publicly accessible lakes for potential future water quality restoration actions.

The results of the lake prioritization matrix were evaluated and each lake was identified regarding the recommended "next step" (**Table 24**). Five lakes require the collection of additional water quality data prior the development of a water quality management plan (Davenport, Tracy, Crystal (1406B), Little Agnes, and Tenoroc). It is recommend that the water quality status of each these lakes be reviewed in five years after the collection of additional data. Twenty-five of the lakes were identified to have good existing water quality with no evidence of degradation; therefore, no immediate actions are recommended. A re-evaluation of water quality status is recommended in five years to identify potential degradation. Seven lakes are included in a future work plan funded by the City of Lakeland to develop a WQMP (Mirror, Crystal (1497A), Gibson, Parker, Hollingsworth, Bonny and Hunter). As such, no immediate action is recommended until the completion of the anticipated WQMP. Nineteen were identified to have existing WQMPs with potential projects identified. A review of the existing plans is recommended for potential project selection to address water quality concerns. Seven lakes have water quality concerns but no existing County MS4 outfall. Thirty-four lakes were selected (based on the prioritization process used) as a short list from which to select a smaller number of lakes for the development of water quality management plans to identify potential water quality restoration projects for the lakes. Of the thirty-four lakes, it is recommended that the County initially evaluate the following lakes for the development of water quality management plans: Little Crooked, Arbuckle, Weohyakapka, Mattie, Deer, Grassy, Ariana, Sears, Lena, Crooked, Daisy, and Tennessee, based solely on the results of the ranking process.

Table 24. Recommended "next steps" for each of the ninety-seven evaluated Polk County lakes.

Rank	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
	Percent TN, TP or chl-a concentration reduction required to meet NNC				
	None	<20	20-<40	40-<60	≥60
1	LITTLE CROOKED	IDYLWILD	CANNON	SEARS	CRYSTAL
2	THOMAS	SPRING	JESSIE	CONINE	BLUE
3	ECHO	ARBUCKLE	DEER	LENA	DAISY
4	WINTERSET	WEOHYAKAPKA	HARTRIDGE	SHIPP	TENNESSEE
5	SUMMIT	MATTIE	GRASSY	CROOKED	DEESON
6	PANSY	HAMILTON	MARIANNA	MUD	GIBSON
7	MARTHA	NED	SMART	ANNIE	SADDLE CREEK PARK
8	SILVER	BUCKEYE	LULU	MAY	SOMERSET
9	MARIE	OTIS	ROCHELLE	CLINCH	STAHL
10	MENZIE		ARIANA	MCLEOD	AGNES
11	MIRIAM		MIDDLE HAMILTON	WAILES	BUFFUM
12	DAVENPORT		MIRROR	EAGLE	JOHN
13	LINK		JULIANA	ALFRED	HOLLINGSWORTH
14	SWOOPE		HOWARD	EASY	PARKER
15	TIGER		HATCHINEHA		BANANA
16	CONFUSION		REEDY		HANCOCK
17	ELBERT		FANNIE		HICKORY
18	WIRE		LITTLE HAMILTON		PIERCE
19	LOWERY		ELOISE		CARTER ROAD PARK
20	TRACY		HAINES		MARION
21	CRYSTAL		CYPRESS		HUNTER
22			ROSALIE		GARFIELD
23			EVA		BONNY
24			ROY		TENOROC
25			MAUDE		
26			KISSIMMEE		
27			LIVINGSTON		
28			LITTLE AGNES		
29			SURVEYORS		

Legend:
- No action (water quality is fine)
- No action (waiting development of WQMP)
- Insufficient data
- Existing WQMP
- No MS4
- Select for WQMP development

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Appendix A. Prioritization factor scores

A.1. Regulatory scores

Each lake was classified based upon its current status in regards to regulatory compliance (**Table A1**).

Table A 1. Individual lake regulatory factor score.

WBID	Lake Name	Regulatory Requirement Score	TMDL Status	Existing WQMP	NNC Impairment Status
1466	AGNES	4	Required	No	Impaired
1466A1	LITTLE AGNES	0	None	No	Not impaired
1488D	ALFRED	0	EPA Established	No	Not impaired*
1539C	ANNIE	4	Required	No	Impaired
1685A	ARBUCKLE	4	Required	No	Impaired
1501B	ARIANA	8	EPA Established	No	Impaired
1549B	BANANA	4	DEP Draft	No	Impaired
1521Q	BLUE	6	Required	Yes	Impaired
1497E	BONNY	4	DEP Draft	No	Impaired
1488S	BUCKEYE	0	None	No	Not impaired*
1677C	BUFFUM	4	Required	No	Impaired
1521H	CANNON	8	DEP Adopted-EPA Approved	Yes	Impaired
1610	CARTER ROAD PARK	4	Required	No	Impaired
1706	CLINCH	4	Required	No	Impaired
15003	CONFUSION	0	None	No	Not impaired*
1488U	CONINE	6	Required	Yes	Impaired
1663	CROOKED	4	Required	No	Impaired
1663B	LITTLE CROOKED	0	None	No	Not impaired
1406B	CRYSTAL	0	None	No	Not impaired
1497A	CRYSTAL	8	EPA Established	No	Impaired
3180A	CYPRESS	4	DEP Draft; EPA Established	No	Impaired
1539R	DAISY	6	Required	Yes	Impaired
1436A	DAVENPORT	0	None	No	Not impaired
1521P	DEER	4	DEP Draft	No	Impaired
1449A	DEESON	4	Required	No	Impaired
1623M	EAGLE	4	Required	No	Impaired

Table A1. Individual lake regulatory factor score (Cont'd).

WBID	Lake Name	Regulatory Requirement Score	TMDL Status	Existing WQMP	NNC Impairment Status
1619B	EASY	0	None	No	Not impaired
1488Z	ECHO	0	None	No	Not impaired*
1548	ELBERT	0	None	No	Not impaired*
1521B	ELOISE	6	Required	Yes	Impaired
15101	EVA	4	Required	No	Impaired
14882	FANNIE	4	Required	No	Impaired
1622	GARFIELD	4	Required	No	Impaired
1497D	GIBSON	4	Required	No	Impaired
1623M1	GRASSY	4	Required	No	Impaired
1488C	HAINES	8	EPA Established	Yes	Impaired
15041	HAMILTON	0	None	No	Not impaired
15001	LITTLE HAMILTON	4	Required	No	Impaired
15002	MIDDLE HAMILTON	6	Required	Yes	Impaired
1623L	HANCOCK	4	DEP Draft	No	Impaired
1521I	HARTRIDGE	6	Required	Yes	Impaired
1472B	HATCHINEHA	4	Required	No	Impaired
1730	HICKORY	4	Required	No	Impaired
1549X	HOLLINGSWORTH	4	DEP Draft	No	Impaired
1521F	HOWARD	8	DEP Adopted-EPA Approved	Yes	Impaired
1543	HUNTER	8	DEP Adopted-EPA Approved	No	Impaired
1521J	IDYLWILD	8	DEP Adopted-EPA Approved	Yes	Impaired
1521K	JESSIE	8	DEP Adopted-EPA Approved	Yes	Impaired
1549E	JOHN	4	Required	No	Impaired
1484B	JULIANA	4	Required	No	Impaired
3183B	KISSIMMEE	0	DEP Draft	No	Not impaired*
1501	LENA	4	DEP Draft; EPA Established	No	Impaired
1539Y	LINK	0	None	No	Not impaired
1730B	LIVINGSTON	0	None	No	Not impaired
2890A	LOWERY	0	None	No	Not impaired*
1521	LULU	2	DEP Adopted-EPA Approved	Yes	Impaired
1521L	MARIANNA	6	Required	Yes	Impaired

Table A1. Individual lake regulatory factor score (Cont'd).

WBID	Lake Name	Regulatory Requirement Score	TMDL Status	Existing WQMP	NNC Impairment Status
1532B	MARIE	0	None	No	Not impaired*
1480	MARION	4	Required	No	Impaired
1488P	MARTHA	0	None	No	Not impaired*
1476	MATTIE	4	Required	No	Impaired
1488Q	MAUDE	0	None	No	Not impaired*
1521E	MAY	2	DEP Adopted-EPA Approved	Yes	Impaired
1588A	MCLEOD	4	Required	No	Impaired
1539Z	MENZIE	0	None	No	Not impaired*
1539X	MIRIAM	0	None	No	Not impaired
1521G	MIRROR	8	DEP Adopted-EPA Approved	Yes	Impaired
1467	MUD	4	Required	No	Impaired
1539Q	NED	0	None	No	Not impaired*
1539D	OTIS	0	None	No	Not impaired
1488Y	PANSY	0	None	Yes	Not impaired*
1497B	PARKER	4	DEP Draft	No	Impaired
1532A	PIERCE	4	Required	No	Impaired
1685D	REEDY	4	Required	No	Impaired
1488B	ROCHELLE	6	Required	Yes	Impaired
1573C	ROSALIE	0	None	No	Not impaired
1521O	ROY	0	None	Yes	Not impaired
1497J	SADDLE CREEK PARK	4	Required	No	Impaired
1501W	SEARS	4	Required	No	Impaired
1521D	SHIPP	2	DEP Adopted-EPA Approved	Yes	Impaired
1488G	SILVER	0	None	No	Not impaired*
1488A	SMART	8	EPA Established	Yes	Impaired
1549F	SOMERSET	4	Required	No	Impaired
1521G1	SPRING	6	Required	Yes	Impaired
1549B1	STAHL	4	Required	No	Impaired
1521M	SUMMIT	0	None	Yes	Not impaired
1647	SURVEYORS	0	None	No	Not impaired
1488V	SWOOPE	0	None	No	Not impaired*
1484A	TENNESSEE	4	Required	No	Impaired

Table A1. Individual lake regulatory factor score (Cont'd).

WBID	Lake Name	Regulatory Requirement Score	TMDL Status	Existing WQMP	NNC Impairment Status
1497C	TENOROC	0	None	No	Not impaired*
1501X	THOMAS	0	None	No	Not impaired
1573A	TIGER	0	None	No	Not impaired
14921	TRACY	0	None	No	Not impaired*
1619A	WAILES	4	Required	No	Impaired
1573E	WEOHYAKAPKA	4	Required	No	Impaired
1521A	WINTERSET	0	None	No	Not impaired
1537	WIRE	0	None	No	Not impaired*

* FDEP confirmed impairment status

A.2. Lake size scores

Lake size was used as a proxy for the potential magnitude of restoration funding required to achieve significant benefits. Each lake was classified based upon its lake size (**Table A2**).

Table A 2. Individual lake size factor score.

WBID	Waterbody Name	Area (acres)	Score
1466	AGNES	373	4
1466A1	LITTLE AGNES	109	6
1488D	ALFRED	753	4
1539C	ANNIE	437	4
1685A	ARBUCKLE	3779	2
1501B	ARIANA	1040	2
1549B	BANANA	255	4
1521Q	BLUE	53	8
1497E	BONNY	268	4
1488S	BUCKEYE	70	8
1677C	BUFFUM	1434	2
1521H	CANNON	334	4
1610	CARTER ROAD PARK	6169	2
1706	CLINCH	1210	2
15003	CONFUSION	15	10
1488U	CONINE	238	6
1663	CROOKED	4287	2
1663B	LITTLE CROOKED	762	4
1406B	CRYSTAL	14	10
1497A	CRYSTAL	27	10
3180A	CYPRESS	4045	2
1539R	DAISY	128	6
1436A	DAVENPORT	44	10
1521P	DEER	116	6
1449A	DEESON	45	10
1623M	EAGLE	647	4
1619B	EASY	415	4
1488Z	ECHO	69	8
1548	ELBERT	172	6
1521B	ELOISE	1161	2
15101	EVA	171	6
14882	FANNIE	755	4
1622	GARFIELD	663	4
1497D	GIBSON	480	4
1623M1	GRASSY	57	8
1488C	HAINES	724	4

Table A2. Individual lake size factor score (Cont'd).

WBID	Waterbody Name	Area (acres)	Score
15041	HAMILTON	2158	2
15001	LITTLE HAMILTON	368	4
15002	MIDDLE HAMILTON	106	6
1623L	HANCOCK	4529	2
1521I	HARTRIDGE	437	4
1472B	HATCHINEHA	6611	2
1730	HICKORY	101	6
1549X	HOLLINGSWORTH	354	4
1521F	HOWARD	623	4
1543	HUNTER	94	8
1521J	IDYLWILD	97	8
1521K	JESSIE	190	6
1549E	JOHN	35	10
1484B	JULIANA	917	4
3183B	KISSIMMEE	34006	2
1501	LENA	207	6
1539Y	LINK	26	10
1730B	LIVINGSTON	1173	2
2890A	LOWERY	900	4
1521	LULU	303	4
1521L	MARIANNA	497	4
1532B	MARIE	30	10
1480	MARION	3025	2
1488P	MARTHA	84	8
1476	MATTIE	1082	2
1488Q	MAUDE	55	8
1521E	MAY	43	10
1588A	MCLEOD	398	4
1539Z	MENZIE	20	10
1539X	MIRIAM	194	6
1521G	MIRROR	124	6
1467	MUD	151	6
1539Q	NED	63	8
1539D	OTIS	137	6
1488Y	PANSY	50	8
1497B	PARKER	2103	2
1532A	PIERCE	3809	2
1685D	REEDY	3516	2
1488B	ROCHELLE	580	4
1573C	ROSALIE	3915	2
1521O	ROY	66	8
1497J	SADDLE CREEK PARK	725	4

Table A2. Individual lake size factor score (Cont'd).

WBID	Waterbody Name	Area (acres)	Score
1501W	SEARS	79	8
1521D	SHIPP	281	4
1488G	SILVER	52	8
1488A	SMART	274	4
1549F	SOMERSET	33	10
1521G1	SPRING	24	10
1549B1	STAHL	32	10
1521M	SUMMIT	62	8
1647	SURVEYORS	291	4
1488V	SWOOPE	86	8
1484A	TENNESSEE	23	10
1497C	TENOROC	107	6
1501X	THOMAS	54	8
1573A	TIGER	2141	2
14921	TRACY	135	6
1619A	WAILES	302	4
1573E	WEOHYAKAPKA	7018	2
1521A	WINTERSET	565	4
1537	WIRE	25	10

A.3. Cooperative partners scores

Potential cooperative partners were quantified for each lake in order to identify the number of funding sources (direct or in-kind) potentially available for water quality restoration projects (**Table A3**).

Table A 3. Individual cooperative partner factor score.

WBID	Waterbody Name	Total Cooperative Partners	Cooperative Partner Score
1466	AGNES	3	4
1466A1	LITTLE AGNES	2	2
1488D	ALFRED	4	6
1539C	ANNIE	3	4
1685A	ARBUCKLE	2	2
1501B	ARIANA	3	4
1549B	BANANA	4	6
1521Q	BLUE	2	2
1497E	BONNY	3	4
1488S	BUCKEYE	4	6
1677C	BUFFUM	3	4
1521H	CANNON	4	6
1610	CARTER ROAD PARK	3	4
1706	CLINCH	3	4
15003	CONFUSION	2	2
1488U	CONINE	4	6
1663	CROOKED	3	4
1663B	LITTLE CROOKED	2	2
1406B	CRYSTAL	2	2
1497A	CRYSTAL	2	2
3180A	CYPRESS	3	4
1539R	DAISY	4	6
1436A	DAVENPORT	2	2
1521P	DEER	3	4
1449A	DEESON	2	2
1623M	EAGLE	3	4
1619B	EASY	3	4
1488Z	ECHO	3	4
1548	ELBERT	3	4
1521B	ELOISE	4	6
15101	EVA	3	4
14882	FANNIE	3	4
1622	GARFIELD	2	2
1497D	GIBSON	2	2
1623M1	GRASSY	3	4
1488C	HAINES	5	8

Table A3. Individual cooperative partner factor score (Cont'd).

WBID	Waterbody Name	Total Cooperative Partners	Cooperative Partner Score
15041	HAMILTON	4	6
15001	LITTLE HAMILTON	3	4
15002	MIDDLE HAMILTON	3	4
1623L	HANCOCK	3	4
1521I	HARTRIDGE	3	4
1472B	HATCHINEHA	3	4
1730	HICKORY	3	4
1549X	HOLLINGSWORTH	3	4
1521F	HOWARD	4	6
1543	HUNTER	3	4
1521J	IDYLWILD	4	6
1521K	JESSIE	4	6
1549E	JOHN	4	6
1484B	JULIANA	3	4
3183B	KISSIMMEE	2	2
1501	LENA	3	4
1539Y	LINK	3	4
1730B	LIVINGSTON	3	4
2890A	LOWERY	2	2
1521	ULU	4	6
1521L	MARIANNA	4	6
1532B	MARIE	3	4
1480	MARION	4	6
1488P	MARTHA	3	4
1476	MATTIE	3	4
1488Q	MAUDE	3	4
1521E	MAY	4	6
1588A	MCLEOD	3	4
1539Z	MENZIE	3	4
1539X	MIRIAM	3	4
1521G	MIRROR	4	6
1467	MUD	2	2
1539Q	NED	3	4
1539D	OTIS	3	4
1488Y	PANSY	3	4
1497B	PARKER	3	4
1532A	PIERCE	3	4
1685D	REEDY	3	4
1488B	ROCHELLE	5	8
1573C	ROSALIE	2	2

Table A3. Individual cooperative partner factor score (Cont'd).

WBID	Waterbody Name	Total Cooperative Partners	Cooperative Partner Score
1521O	ROY	3	4
1497J	SADDLE CREEK PARK	2	2
1501W	SEARS	2	2
1521D	SHIPP	4	6
1488G	SILVER	3	4
1488A	SMART	4	6
1549F	SOMERSET	4	6
1521G1	SPRING	3	4
1549B1	STAHL	4	6
1521M	SUMMIT	2	2
1647	SURVEYORS	3	4
1488V	SWOOPE	3	4
1484A	TENNESSEE	3	4
1497C	TENOROC	3	4
1501X	THOMAS	2	2
1573A	TIGER	2	2
14921	TRACY	2	2
1619A	WAILES	3	4
1573E	WEOHYAKAPKA	1	1
1521A	WINTERSET	3	4
1537	WIRE	3	4

A.4. Socio-economic scores

The socio-economic classification was calculated for each lake and relates primarily to recreational use (**Table A4**).

Table A 4. Individual lake socio-economic factor score.

WBID	Waterbody Name	Calculated Socio-Economic Value	Socio-Economic Score
1466	AGNES	0.26	4
1466A1	LITTLE AGNES	0.20	2
1488D	ALFRED	0.17	2
1539C	ANNIE	0.17	2
1685A	ARBUCKLE	0.49	6
1501B	ARIANA	0.31	4
1549B	BANANA	0.31	4
1521Q	BLUE	0.23	4
1497E	BONNY	0.31	4
1488S	BUCKEYE	0.17	2
1677C	BUFFUM	0.09	2
1521H	CANNON	0.37	4
1610	CARTER ROAD PARK	0.20	2
1706	CLINCH	0.14	2
15003	CONFUSION	0.17	2
1488U	CONINE	0.34	4
1663	CROOKED	0.57	6
1663B	LITTLE CROOKED	0.09	2
1406B	CRYSTAL	0.14	2
1497A	CRYSTAL	0.20	2
3180A	CYPRESS	0.06	2
1539R	DAISY	0.31	4
1436A	DAVENPORT	0.14	2
1521P	DEER	0.34	4
1449A	DEESON	0.17	2
1623M	EAGLE	0.26	4
1619B	EASY	0.14	2
1488Z	ECHO	0.23	4
1548	ELBERT	0.20	2
1521B	ELOISE	0.26	4
15101	EVA	0.26	4
14882	FANNIE	0.29	4
1622	GARFIELD	0.17	2
1497D	GIBSON	0.23	4

Table A4. Individual lake socio-economic factor score (Cont'd).

WBID	Waterbody Name	Calculated Socio-Economic Value	Socio-Economic Score
1623M1	GRASSY	0.20	2
1488C	HAINES	0.29	4
15041	HAMILTON	0.29	4
15001	LITTLE HAMILTON	0.26	4
15002	MIDDLE HAMILTON	0.26	4
1623L	HANCOCK	0.46	6
1521I	HARTRIDGE	0.46	6
1472B	HATCHINEHA	0.37	4
1730	HICKORY	0.11	2
1549X	HOLLINGSWORTH	0.51	6
1521F	HOWARD	0.49	6
1543	HUNTER	0.37	4
1521J	IDYLWILD	0.26	4
1521K	JESSIE	0.29	4
1549E	JOHN	0.49	6
1484B	JULIANA	0.29	4
3183B	KISSIMMEE	0.83	10
1501	LENA	0.17	2
1539Y	LINK	0.14	2
1730B	LIVINGSTON	0.11	2
2890A	LOWERY	0.14	2
1521	LULU	0.29	4
1521L	MARIANNA	0.17	2
1532B	MARIE	0.23	4
1480	MARION	0.29	4
1488P	MARTHA	0.29	4
1476	MATTIE	0.14	2
1488Q	MAUDE	0.29	4
1521E	MAY	0.37	4
1588A	MCLEOD	0.20	2
1539Z	MENZIE	0.23	4
1539X	MIRIAM	0.17	2
1521G	MIRROR	0.37	4
1467	MUD	0.23	4
1539Q	NED	0.31	4
1539D	OTIS	0.14	2
1488Y	PANSY	0.23	4
1497B	PARKER	0.66	8

Table A4. Individual lake socio-economic factor score (Cont'd).

WBID	Waterbody Name	Calculated Socio-Economic Value	Socio-Economic Score
1532A	PIERCE	0.51	6
1685D	REEDY	0.34	4
1488B	ROCHELLE	0.37	4
1573C	ROSALIE	0.34	4
1521O	ROY	0.31	4
1497J	SADDLE CREEK PARK	0.71	8
1501W	SEARS	0.17	2
1521D	SHIPP	0.49	6
1488G	SILVER	0.31	4
1488A	SMART	0.31	4
1549F	SOMERSET	0.23	4
1521G1	SPRING	0.31	4
1549B1	STAHL	0.14	2
1521M	SUMMIT	0.34	4
1647	SURVEYORS	0.11	2
1488V	SWOOPE	0.23	4
1484A	TENNESSEE	0.23	4
1497C	TENOROC	0.43	6
1501X	THOMAS	0.17	2
1573A	TIGER	0.17	2
14921	TRACY	0.17	2
1619A	WAILES	0.54	6
1573E	WEOHYAKAPKA	0.37	4
1521A	WINTERSET	0.26	4
1537	WIRE	0.29	4

A.5. NPDES MS4 outfalls and MS4 drainage basin area as percentage of lake drainage basin

The FDEP TMDL program has identified the NPDES stormwater discharges as a potential source for pollutant loads to impaired water bodies. The total lake drainage basin and MS4 subbasins were delineated for each lake that was examined (AMEC 2014). The number of Polk County MS4 outfalls to each lake was identified and the MS4 drainage basin area as a percentage of lake drainage basin was calculated. A score was assigned to each lake for each factor (**Table A5**).

Table A 5. Individual lake NPDES outfall factor and MS4 area as percent basin scores.

WBID	Lake Name	Number of County MS4 outfalls	NPDES MS4 outfall Score	MS4 area as percent basin total	MS4 area as percent basin score
1466	AGNES	6	4	2	2
1466A1	LITTLE AGNES	0	0	0	0
1488D	ALFRED	3	2	0	0
1539C	ANNIE	1	2	0	0
1685A	ARBUCKLE	5	4	0	0
1501B	ARIANA	3	2	7	4
1549B	BANANA	7	6	15	6
1521Q	BLUE	12	8	56	10
1497E	BONNY	3	2	8	4
1488S	BUCKEYE	1	2	10	6
1677C	BUFFUM	1	2	2	2
1521H	CANNON	21	10	62	10
1610	CARTER ROAD PARK	15	8	14	6
1706	CLINCH	7	6	11	6
15003	CONFUSION	0	0	0	0
1488U	CONINE	9	6	19	6
1663	CROOKED	7	6	4	2
1663B	LITTLE CROOKED	2	2	1	2
1406B	CRYSTAL	0	0	0	0
1497A	CRYSTAL	5	4	56	10
3180A	CYPRESS*	0	0		0
1539R	DAISY	7	6	44	8
1436A	DAVENPORT	10	6	1	2
1521P	DEER	9	6	100	10
1449A	DEESON	5	4	12	6
1623M	EAGLE	8	6	18	6
1619B	EASY	2	2	1	2
1488Z	ECHO	3	2	100	10

Table A5. Individual lake NPDES outfall factor and MS4 area as percent basin scores (Cont'd).

WBID	Lake Name	Number of County MS4 outfalls	NPDES MS4 outfall Score	MS4 area as percent basin total	MS4 area as percent basin score
1548	ELBERT	0	0	0	0
1521B	ELOISE	9	6	4	2
15101	EVA	0	0	0	0
14882	FANNIE	1	2	2	2
1622	GARFIELD	5	4	2	2
1497D	GIBSON	17	8	43	8
1623M1	GRASSY	3	2	10	6
1488C	HAINES	1	2	0	0
15041	HAMILTON	0	0	0	0
15001	LITTLE HAMILTON	3	2	1	2
15002	MIDDLE HAMILTON	1	2	4	2
1623L	HANCOCK	42	10	4	2
1521I	HARTRIDGE	11	8	20	6
1472B	HATCHINEHA	1	2	0	0
1730	HICKORY*	0	0	0	0
1549X	HOLLINGSWORTH	0	0	0	0
1521F	HOWARD	4	4	0	0
1543	HUNTER	0	0	0	0
1521J	IDYLWILD	7	6	10	6
1521K	JESSIE	10	6	59	10
1549E	JOHN	0	0	0	0
1484B	JULIANA	3	2	12	6
3183B	KISSIMMEE*	0	0	0	0
1501	LENA	4	4	40	8
1539Y	LINK	0	0	0	0
1730B	LIVINGSTON	0	0	0	0
2890A	LOWERY*	1	2	0	0
1521	LULU	12	8	24	6
1521L	MARIANNA	4	4	50	10
1532B	MARIE	0	0	0	0
1480	MARION	1	2	3	2
1488P	MARTHA	0	0	0	0
1476	MATTIE	1	2	19	6
1488Q	MAUDE	0	0	0	0
1521E	MAY	0	0	0	0
1588A	MCLEOD	3	2	1	2

Table A5. Individual lake NPDES outfall factor and MS4 area as percent basin scores (Cont'd).

WBID	Lake Name	Number of County MS4 outfalls	NPDES MS4 outfall Score	MS4 area as percent basin total	MS4 area as percent basin score
1539Z	MENZIE	0	0	0	0
1539X	MIRIAM	1	2	6	4
1521G	MIRROR	0	0	0	0
1467	MUD	2	2	6	4
1539Q	NED	8	6	76	10
1539D	OTIS	0	0	0	0
1488Y	PANSY	0	0	0	0
1497B	PARKER	15	8	5	4
1532A	PIERCE	2	2	1	2
1685D	REEDY	7	6	3	2
1488B	ROCHELLE	5	4	4	2
1573C	ROSALIE	11	8	2	2
1521O	ROY	10	6	16	6
1497J	SADDLE CREEK PARK	25	10	13	6
1501W	SEARS	6	4	30	8
1521D	SHIPP	2	2	37	8
1488G	SILVER	0	0	0	0
1488A	SMART	0	0	0	0
1549F	SOMERSET	2	2	60	10
1521G1	SPRING	0	0	0	0
1549B1	STAHL	6	4	74	10
1521M	SUMMIT	3	2	14	6
1647	SURVEYORS	0	0	0	0
1488V	SWOOPE	0	0	0	0
1484A	TENNESSEE	1	2	20	6
1497C	TENOROC*	0	0	0	0
1501X	THOMAS	20	10	66	10
1573A	TIGER	1	2	0	0
14921	TRACY	0	0	0	0
1619A	WAILES	0	0	0	0
1573E	WEOHYAKAPKA	7	6	13	6
1521A	WINTERSET	7	6	10	6
1537	WIRE*	0	0	0	0

A.6. Frequency of exceedance scores

The number of times a lake exceeded the existing annual criteria for TN, TP, and chlac was calculated over the period of 2003-2013. Each lake was assigned a ranking based upon the frequency of exceedances by parameter (TN, TP, and chlac). The overall ranking was assigned based on the largest tier score assigned between the three parameter classifications (**Table A6**).

Table A 6. Individual lake percent frequency of exceedance factor score.

WBID	Lake Name	Percent Frequency of Exceedance			Individual Rank			Overall rank
		TN	TP	chlac	TN	TP	chlac	
1466	AGNES	82	73	73	2	6	6	6
1466A1	LITTLE AGNES	9	0	20	4	0	4	4
1488D	ALFRED	9	0	9	4	0	4	4
1539C	ANNIE	64	55	9	6	8	4	8
1685A	ARBUCKLE	18	27	18	4	10	4	10
1501B	ARIANA	36	0	55	10	0	8	10
1549B	BANANA	91	91	91	2	2	2	2
1521Q	BLUE	82	55	82	2	8	2	8
1497E	BONNY	82	82	82	2	2	2	2
1488S	BUCKEYE	0	0	9	0	0	4	4
1677C	BUFFUM	64	67	33	6	6	10	10
1521H	CANNON	73	45	82	6	8	2	8
1610	CARTER ROAD PARK	100	100	100	2	2	2	2
1706	CLINCH	73	73	64	6	6	6	6
15003	CONFUSION	0	0	0	0	0	0	0
1488U	CONINE	73	55	73	6	8	6	8
1663	CROOKED	55	55	55	8	8	8	8
1663B	LITTLE CROOKED	0	0	0	0	0	0	0
1406B	CRYSTAL	0	0	0	0	0	0	0
1497A	CRYSTAL	64	36	64	6	10	6	10
3180A	CYPRESS	55	78	78	8	6	6	8
1539R	DAISY	27	36	9	10	10	4	10
1436A	DAVENPORT	0	0	0	0	0	0	0
1521P	DEER	45	36	45	8	10	8	10
1449A	DEESON	45	33	56	8	10	8	10
1623M	EAGLE	91	91	100	2	2	2	2
1619B	EASY	9	17	17	4	4	4	4
1488Z	ECHO	0	0	0	0	0	0	0
1548	ELBERT	0	0	0	0	0	0	0
1521B	ELOISE	73	82	91	6	2	2	6
15101	EVA	82	82	82	2	2	2	2

Table A6. Individual lake percent frequency of exceedance factor score (Cont'd).

WBID	Lake Name	Percent Frequency of Exceedance			Individual Rank			Overall rank
		TN	TP	chlac	TN	TP	chlac	
14882	FANNIE	27	18	27	10	4	10	10
1622	GARFIELD	18	82	0	4	2	0	4
1497D	GIBSON	91	91	73	2	2	6	6
1623M1	GRASSY	27	20	20	10	4	4	10
1488C	HAINES	91	18	82	2	4	2	4
15041	HAMILTON	9	9	9	4	4	4	4
15001	LITTLE HAMILTON	18	22	22	4	10	10	10
15002	MIDDLE HAMILTON	36	9	36	10	4	10	10
1623L	HANCOCK	82	82	82	2	2	2	2
1521I	HARTRIDGE	36	27	45	10	10	8	10
1472B	HATCHINEHA	36	36	36	10	10	10	10
1730	HICKORY	45	50	63	8	8	6	8
1549X	HOLLINGSWORTH	91	73	91	2	6	2	6
1521F	HOWARD	73	18	73	6	4	6	6
1543	HUNTER	91	91	91	2	2	2	2
1521J	IDYLWILD	45	36	73	8	10	6	10
1521K	JESSIE	45	45	73	8	8	6	8
1549E	JOHN	82	91	73	2	2	6	6
1484B	JULIANA	45	18	55	8	4	8	8
3183B	KISSIMMEE	9	10	10	4	4	4	4
1501	LENA	73	55	73	6	8	6	8
1539Y	LINK	0	0	0	0	0	0	0
1730B	LIVINGSTON	0	20	0	0	4	0	4
2890A	LOWERY	0	0	0	0	0	0	0
1521	LULU	82	55	73	2	8	6	8
1521L	MARIANNA	82	27	91	2	10	2	10
1532B	MARIE	0	0	0	0	0	0	0
1480	MARION	91	64	91	2	6	2	6
1488P	MARTHA	0	0	0	0	0	0	0
1476	MATTIE	0	43	0	0	8	0	8
1488Q	MAUDE	0	9	0	0	4	0	4
1521E	MAY	73	45	73	6	8	6	8
1588A	MCLEOD	18	45	55	4	8	8	8
1539Z	MENZIE	0	0	0	0	0	0	0
1539X	MIRIAM	0	0	0	0	0	0	0
1521G	MIRROR	55	18	45	8	4	8	8
1467	MUD	55	55	91	8	8	2	8

Table A6. Individual lake percent frequency of exceedance factor score (Cont'd).

WBID	Lake Name	Percent Frequency of Exceedance			Individual Rank			Overall rank
		TN	TP	chlac	TN	TP	chlac	
1539Q	NED	0	9	0	0	4	0	4
1539D	OTIS	0	13	13	0	4	4	4
1488Y	PANSY	0	0	0	0	0	0	0
1497B	PARKER	91	82	82	2	2	2	2
1532A	PIERCE	73	91	73	6	2	6	6
1685D	REEDY	64	9	27	6	4	10	10
1488B	ROCHELLE	73	55	64	6	8	6	8
1573C	ROSALIE	0	9	0	0	4	0	4
1521O	ROY	9	0	9	4	0	4	4
1497J	SADDLE CREEK PARK	73	88	100	6	2	2	6
1501W	SEARS	36	30	20	10	10	4	10
1521D	SHIPP	91	64	91	2	6	2	6
1488G	SILVER	0	0	0	0	0	0	0
1488A	SMART	27	22	33	10	10	10	10
1549F	SOMERSET	73	64	73	6	6	6	6
1521G1	SPRING	9	0	27	4	0	10	10
1549B1	STAHL	64	64	64	6	6	6	6
1521M	SUMMIT	0	0	0	0	0	0	0
1647B	SURVEYORS	0	10	10	0	4	4	4
1488V	SWOOPE	0	0	0	0	0	0	0
1484A	TENNESSEE	64	45	36	6	8	10	10
1497C	TENOROC	9	100	100	4	2	2	4
1501X	THOMAS	0	0	0	0	0	0	0
1573A	TIGER	0	0	0	0	0	0	0
14921	TRACY	0	0	0	0	0	0	0
1619A	WAILES	45	18	55	8	4	8	8
1573E	WEOHYAKAPKA	0	0	45	0	0	8	8
1521A	WINTERSET	0	0	0	0	0	0	0
1537	WIRE	0	0	0	0	0	0	0

A.7. Water quality trend scores

A seasonal Kendall-Tau trend test was used to evaluate increasing or decreasing trends in TN, TP, and chlac for each lake. The individual score for each lake is provided below (**Table A7**).

Table A 7. Individual lake water quality trend with rate of change factor score.

WBID	Waterbody Name	NNC Impairment Status	TN		TP		chlac		WQ trend scored
			Trend	Score	Trend	Score	Trend	Score	
1466	AGNES	Impaired	ns	8	decreasing	6	decreasing	10	10
1466A1	LITTLE AGNES	Not impaired	ns	0	ns	0	ns	0	0
1488D	ALFRED	Not impaired*	ns	2	decreasing	2	ns	2	2
1539C	ANNIE	Impaired	decreasing	10	decreasing	10	decreasing	2	10
1685A	ARBUCKLE	Impaired	ns	8	ns	8	ns	8	8
1501B	ARIANA	Impaired	increasing	8	decreasing	2	increasing	8	8
1549B	BANANA	Impaired	decreasing	6	decreasing	10	ns	8	10
1521Q	BLUE	Impaired	increasing	8	decreasing	10	increasing	8	10
1497E	BONNY	Impaired	ns	8	ns	8	ns	8	8
1488S	BUCKEYE	Not impaired*	decreasing	2	decreasing	2	decreasing	2	2
1677C	BUFFUM	Impaired	increasing	8	ns	8	ns	8	8
1521H	CANNON	Impaired	decreasing	10	decreasing	10	decreasing	10	10
1610	CARTER ROAD PARK	Impaired	decreasing	10	ns	8	ns	8	8
1706	CLINCH	Impaired	ns	8	ns	8	ns	8	8
15003	CONFUSION	Not impaired*	ns	2	decreasing	2	ins	2	2
1488U	CONINE	Impaired	decreasing	10	decreasing	10	decreasing	6	10
1663	CROOKED	Impaired	increasing	8	ns	8	increasing	8	8
1663B	LITTLE CROOKED	Not impaired	increasing	10	ns	2	ns	2	2
1406B	CRYSTAL	Not impaired	ins	0	ins	0	ins	0	0

Table A7. Individual lake water quality trend with rate of change factor score (Cont'd).

WBID	Waterbody Name	NNC Impairment Status	TN		TP		chlac		WQ trend scored
			Trend	Score	Trend	Score	Trend	Score	
1497A	CRYSTAL	Impaired	increasing	8	decreasing	10	increasing	8	10
3180A	CYPRESS	Impaired	decreasing	10	decreasing	10	decreasing	10	10
1539R	DAISY	Impaired	ns	8	decreasing	6	ns	2	6
1436A	DAVENPORT	Not impaired	ns	0	ns	0	ns	0	0
1521P	DEER	Impaired	decreasing	10	decreasing	10	decreasing	6	10
1449A	DEESON	Impaired	increasing	8	increasing	8	increasing	8	8
1623M	EAGLE	Impaired	decreasing	10	decreasing	6	decreasing	10	10
1619B	EASY	Not impaired	ns	0	ns	0	ns	0	0
1488Z	ECHO	Not impaired*	ns	2	decreasing	2	ns	2	2
1548	ELBERT	Not impaired*	decreasing	2	ns	2	ns	2	2
1521B	ELOISE	Impaired	ns	8	decreasing	10	ns	8	10
15101	EVA	Impaired	increasing	8	ns	8	increasing	8	8
14882	FANNIE	Impaired	increasing	8	ns	8	ns	8	8
1622	GARFIELD	Impaired	ns	2	increasing	8	ns	0	8
1497D	GIBSON	Impaired	ns	8	decreasing	10	increasing	8	10
1623M1	GRASSY	Impaired	ns	8	decreasing	10	ns	8	10
1488C	HAINES	Impaired	decreasing	10	decreasing	10	decreasing	10	10
15041	HAMILTON	Not impaired	increasing	10	decreasing	2	increasing	4	4
15001	LITTLE HAMILTON	Impaired	increasing	8	ns	8	ns	8	8
15002	MIDDLE HAMILTON	Impaired	ns	8	ns	2	increasing	8	8
1623L	HANCOCK	Impaired	increasing	8	decreasing	10	increasing	8	10
1521I	HARTRIDGE	Impaired	increasing	8	ns	8	increasing	8	8

Table A7. Individual lake water quality trend with rate of change factor score (Cont'd).

WBID	Waterbody Name	NNC Impairment Status	TN		TP		chlac		WQ trend scored
			Trend	Score	Trend	Score	Trend	Score	
1472B	HATCHINEHA	Impaired	ns	8	decreasing	10	ns	8	10
1730	HICKORY	Impaired	ns	8	ns	8	ns	8	8
1549X	HOLLINGSWORTH	Impaired	decreasing	10	decreasing	10	decreasing	10	10
1521F	HOWARD	Impaired	ns	8	decreasing	10	decreasing	6	10
1543	HUNTER	Impaired	increasing	8	ns	8	increasing	8	8
1521J	IDYLWILD	Impaired	ns	8	decreasing	10	ns	8	10
1521K	JESSIE	Impaired	ns	8	decreasing	10	decreasing	10	10
1549E	JOHN	Impaired	increasing	8	ns	8	increasing	8	8
1484B	JULIANA	Impaired	increasing	8	decreasing	10	increasing	8	10
3183B	KISSIMMEE	Not impaired*	ns	2	increasing	2	decreasing	2	2
1501	LENA	Impaired	ns	8	decreasing	10	ns	8	10
1539Y	LINK	Not impaired	ns	2	ns	2	ns	2	2
1730B	LIVINGSTON	Not impaired	ns	2	ns	2	ns	2	2
2890A	LOWERY	Not impaired*	ns	2	ns	2	decreasing	2	2
1521	LULU	Impaired	ns	8	decreasing	10	decreasing	6	10
1521L	MARIANNA	Impaired	increasing	8	ns	8	increasing	8	8
1532B	MARIE	Not impaired*	ns	2	ns	2	ns	2	2
1480	MARION	Impaired	increasing	8	increasing	8	increasing	8	8
1488P	MARTHA	Not impaired*	increasing	4	ns	2	increasing	4	4
1476	MATTIE	Impaired	increasing	4	increasing	8	ns	2	8
1488Q	MAUDE	Not impaired*	increasing	4	ns	2	ns	2	2
1521E	MAY	Impaired	increasing	8	decreasing	6	ns	8	8

Table A7. Individual lake water quality trend with rate of change factor score (Cont'd).

WBID	Waterbody Name	NNC Impairment Status	TN		TP		chlac		WQ trend scored
			Trend	Score	Trend	Score	Trend	Score	
1588A	MCLEOD	Impaired	ns	8	ns	8	ns	8	8
1539Z	MENZIE	Not impaired*	ns	2	ns	2	ns	2	2
1539X	MIRIAM	Not impaired	ns	2	decreasing	2	ns	2	2
1521G	MIRROR	Impaired	ns	8	decreasing	2	decreasing	10	10
1467	MUD	Impaired	increasing	8	ns	8	ns	8	8
1539Q	NED	Not impaired*	ns	2	decreasing	2	ns	2	2
1539D	OTIS	Not impaired	ns	2	ns	2	ns	2	2
1488Y	PANSY	Not impaired*	increasing	4	decreasing	2	ns	2	2
1497B	PARKER	Impaired	ns	8	decreasing	10	ns	8	10
1532A	PIERCE	Impaired	increasing	8	increasing	8	increasing	8	8
1685D	REEDY	Impaired	increasing	8	increasing	4	increasing	8	8
1488B	ROCHELLE	Impaired	increasing	8	decreasing	10	decreasing	10	10
1573C	ROSALIE	Not impaired	increasing	4	increasing	10	ns	2	10
1521O	ROY	Not impaired	ns	2	decreasing	2	ns	2	2
1497J	SADDLE CREEK PARK	Impaired	ns	8	ns	8	ns	8	8
1501W	SEARS	Impaired	decreasing	10	decreasing	10	decreasing	10	10
1521D	SHIPP	Impaired	ns	8	decreasing	10	decreasing	6	10
1488G	SILVER	Not impaired*	increasing	4	ns	2	ns	2	2
1488A	SMART	Impaired	ns	8	decreasing	2	decreasing	10	10
1549F	SOMERSET	Impaired	increasing	8	ns	8	ns	8	8
1521G1	SPRING	Impaired	ns	2	decreasing	2	ns	8	8

Table A7. Individual lake water quality trend with rate of change factor score (Cont'd).

WBID	Waterbody Name	NNC Impairment Status	TN		TP		chlac		WQ trend scored
			Trend	Score	Trend	Score	Trend	Score	
1549B1	STAHL	Impaired	ns	8	decreasing	6	increasing	8	8
1521M	SUMMIT	Not impaired	decreasing	2	decreasing	2	ns	2	2
1647	SURVEYORS	Not impaired	ns	0	ns	0	ns	0	0
1488V	SWOOPE	Not impaired*	ns	2	decreasing	2	ns	2	2
1484A	TENNESSEE	Impaired	decreasing	10	decreasing	10	decreasing	10	10
1497C	TENOROC	Not impaired*	ins	0	ins	0	ins	0	0
1501X	THOMAS	Not impaired	ns	2	decreasing	2	ns	2	2
1573A	TIGER	Not impaired	increasing	4	increasing	2	increasing	4	4
14921	TRACY	Not impaired*	ns	2	ns	2	decreasing	2	2
1619A	WAILES	Impaired	increasing	8	ns	8	increasing	8	8
1573E	WEOHYAKAPKA	Impaired	increasing	2	increasing	4	increasing	8	8
1521A	WINTERSET	Not impaired	decreasing	2	decreasing	2	decreasing	2	2
1537	WIRE	Not impaired*	ins	0	ins	0	ins	0	0

ns=not significant; ins=insufficient data; *FDEP confirmed

Appendix B. TMDL Review

Technical Memorandum as prepared by David Tomasko, Ph.D. which summarizes a review that was conducted of the draft and final nutrient TMDL reports for Polk County.

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Technical Memorandum

date September 17, 2014

to Emily Keenan, Pam Latham
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4030 West Boy Scout Boulevard, Suite 700
Tampa, FL 33607

from David Tomasko, Ph.D.

subject Appendix B – TMDL Review

This Technical Memorandum summarizes a review that was conducted of the draft and final Total Maximum Daily Load (TMDL) reports for Polk County lakes by both the Florida Department of Environmental Protection (FDEP) and the US Environmental Protection Agency (EPA). The TMDLs reviewed were those related to impairments from nutrients and their impacts to lakes. Each TMDL was assessed in terms of the basis for impairment, the water quality targets used in the TMDL, the assumptions associated with the various pollutant loading models, and a brief summary as to whether or not Polk County should view the TMDL as being sufficient for implementation. The TMDLs are reviewed here in alphabetical order (disregarding the letter "L" used in the word "lake").

Lake Alfred (WBID 1488D) TMDL

Basis for Impairment

Lake Alfred is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was identified as impaired for nutrients pursuant to EPA commitments related to the 1998 Consent Decree (Florida Wildlife Federation et al. v. Carol Browner et al., Civil Action No. 4: 98CV356-WS). In that Consent Decree, the EPA committed to developing TMDLs for a number of waterbodies, including a TMDL that addresses Lake Alfred, Crystal Lake, and Lake Ariana (EPA 2010).

The TMDL for Lake Alfred used water quality data from 1985 to 2009 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were available. However, the vast majority of the water quality data collected in Lake Alfred was from the 11 year period of 1999 to 2009. The TMDL (EPA 2010) determined that sufficient data were available to characterize water quality for the entire period of 1985 to 2009. As Lake Alfred was determined to be a low color lake (platinum cobalt units [PCU] < 40) the threshold for impairment was set at a TSI value of 40. Although annual average values are not shown in the TMDL report (EPA 2010) the vast majority of TSI values calculated exceeded 40, which was determined to be sufficient evidence to support Lake Alfred being classified as impaired.

TMDL Summary

Water quality targets

The TSI target for Lake Alfred was based on a determination that the lake was a low color lake (< 40 PCU) and so a target TSI value of 40 was the threshold value above which the lake would be declared "impaired" for nutrients. However, the TMDL produced by FDEP for the Winter Haven Southern Chain of Lakes (FDEP 2007) and the TMDL for Lakes Haines and Smart (EPA 2006b) both use a TSI value of 60 as the threshold for determining water quality impairment, even for lakes classified as low color. The two TMDLs (FDEP 2007 and EPA 2006b) used results from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions, which are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) not the TSI value of 40 used for Lake Alfred. It should be noted that of the five lakes studied by Whitmore and Brenner (1995) four of them (Lakes Conine, Hartridge, Howard and May) were consistently low color lakes and the other one (Lake Haines) had annual mean color levels less than 40 PCU on 6 of 11 years. Clearly, the conclusion that a TSI target of 60 is more appropriate than a TSI target of 40 is relevant for low color lakes in Polk County, such as Lake Alfred.

Using a TSI target value of 40, the chlorophyll-a target value is 5 µg/L, vs. 20 µg/L with a TSI target of 60. For TN, values are 0.45 and 1.2 mg/L, respectively, for TSI targets of 40 and 60. For TP, target values are 0.02 and 0.07 for TSI targets of 40 and 60, respectively. The decision by the EPA (2010) to use a TSI value of 40 to determine impairment status, compared to the more locally appropriate TSI target of 60, resulted in impairment thresholds that are 75, 63, and 71 percent lower for chlorophyll-a, TN and TP, respectively, than TSI targets based on local paleolimnological studies (i.e., Whitmore and Brenner 1995). To add a margin of safety to the TMDL, it was determined that nutrient load reductions should actually be based on the attainment of a target TSI value of 35, which is 5 units below the chosen TSI target of 40 (EPA 2010). A TSI target of 35 would be even harder to meet than an impairment status criterion of 40 for TSI.

In addition to issues related to having a TMDL that is based on overly stringent criteria, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Alfred) until the adoption of Numeric Nutrient Concentration (NNC) criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Alfred.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used to establish the TMDL for Lake Alfred (EPA 2010). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature

- As affected by light intensity
- As affected by phosphorus concentrations

- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Alfred, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Alfred on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Alfred itself.

The TMDL for Lake Alfred calls for reductions in nutrient loads from both “benthic fluxes” and stormwater runoff. While there are actual measurements of groundwater seepage available for Lakes Conine, Haines, Rochelle and Smart (PBS&J 2009) there are no measurements made of benthic flux in Lake Alfred. Without differentiating between TN and TP, the TMDL for Lake Alfred (EPA 2010) calls for a 60 percent reduction in benthic nutrient flux rates. In addition, the TMDL calls for 68 and 55 percent reductions in stormwater loads for TN and TP, respectively. Using an empirical approach to target setting, there is a statistically significant correlation found between TN and Chl-a in Lake Alfred, with a r-square value of 0.52, suggesting that variation in concentrations of TN explain approximately 52 percent of the variation in concentrations of Chl-a. There is, however, no statistically significant relationship between TP and Chl-a in Lake Alfred.

Based on an examination of water quality data during the Verified Impaired time period for Lake Alfred (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 7 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 23 and 10 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Alfred is based on linking a GIS-based pollutant loading model output with WASP as the water quality model. The pollutant loading model used was the Watershed Assessment Model (WAM) which predicts stormwater loads of nutrients based on inputting data on rainfall, soils, and land use classifications. WAM has the ability to attenuate stormwater loads via features such as wetlands, depressional areas, and model input related to the distribution of Best Management Practices (BMPs) within the watershed.

The TMDL for Lake Alfred is based on output from the Watershed Assessment Model (WAM) with the WASP water quality model. WAM estimates stormwater pollutant loads via GIS-based inputs of data on land use classifications (using FLUCCS) and soils, as driven by rainfall. WAM also allows for the attenuation of generated pollutant loads via wetlands and/or BMPs, if such data are available in GIS for the watershed.

WAM allows for the simulation of surface flows and groundwater inflow on a daily basis, and these daily flow estimates can be "processed" in the model via information related to topographical relief, channel configurations, etc. This feature allows for loads to be attenuated along the pathway from the watershed to the conveyance system and then on to the water body of interest. Literature-derived "attenuation algorithms" are applied to the calculated stormwater inflows.

The ability of WAM to attenuate modeled loads via BMPs, wetlands and stream channels is an important improvement over more simplistic pollutant loading models. However, the pollutant loading model as described in the TMDL is not actually "calibrated" via comparison of model output of stormwater loads to measured data. As is the case with other pollutant loading models used in Polk County, there does not appear to be an exercise within the TMDL for which model output on pollutant loads is compared to measured data. Instead, the pollutant loading model and the water quality model are "calibrated" against in-lake concentrations. More often than not, this model calibration effort is accomplished via the modification of rate coefficients that have never been locally measured.

The TMDL for Lake Alfred calls for reductions in of 60 percent for TN and TP loads from benthic fluxes, based on modeling. And while there are actual measurements of groundwater seepage available for the nearby waterbodies of Lakes Conine, Haines, Rochelle and Smart (PBS&J 2009), there are no similar measurements available for Lake Alfred.

The TMDL for Lake Alfred (EPA 2010) appears to be problematic for a number of reasons:

- The TMDL for Lake Alfred is based on the attainment of a TSI target of 35, which would give a 5 unit margin of safety over the chosen TSI impairment level of 40
- However, prior work on low color lakes in Polk County (i.e., Conine, Hartridge, Howard and May; Whitmore and Brenner 1995) has shown that a TSI target of 60 is more appropriate, as lakes in this portion of Central Florida were historically mesotrophic to eutrophic
- Consequently, the water quality targets for Chl-a, TN and TP are inappropriately low, and most likely unattainable

- Perhaps related to the utilization of an inappropriately strict water quality target, the TMDL calls for unrealistic reductions in benthic fluxes (which were not measured) and stormwater runoff

- When using lake data and NNC guidance, the amount of improvement in water quality required for Lake Alfred to reach unimpaired status is much more realistic and attainable, suggesting a modified target setting process could result in more realistic lake improvement strategies

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Alfred (EPA 2010).

Lake Ariana North (WBID 1501B) TMDL

Basis for Impairment

Lake Ariana North is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The north portion of the wider Lake Ariana system lake was identified as impaired for nutrients pursuant to EPA commitments related to the 1998 Consent Decree (Florida Wildlife Federation et al. v. Carol Browner et al., Civil Action No. 4: 98CV356-WS). In that Consent Decree, the EPA committed to developing TMDLs for a number of waterbodies, including a TMDL that addresses Lake Ariana North, Crystal Lake, and Lake Ariana (EPA 2010).

The TMDL for Lake Ariana North used water quality data from 1976 to 2009 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were available. However, the vast majority of the water quality data collected in Lake Ariana North was from the 25 year period of 1985 to 2009. The TMDL (EPA 2010) determined that sufficient data were available to characterize water quality for the entire period of 1985 to 2009. As Lake Ariana North was determined to be a low color lake (platinum cobalt units [PCU] < 40) the threshold for impairment was set at a TSI value of 40. Although annual average values are not shown in the TMDL report (EPA 2010) the vast majority of TSI values calculated exceeded 40, which was determined to be sufficient evidence to support Lake Ariana North being classified as impaired.

TMDL Summary

Water Quality Targets

The TSI target for Lake Ariana North was based on a determination that the lake was a low color lake (< 40 PCU) and so a target TSI value of 40 was the threshold value above which the lake would be declared “impaired” for nutrients. However, the TMDL produced by FDEP for the Winter Haven Southern Chain of Lakes (FDEP 2007) and the TMDL for Lakes Haines and Smart (EPA 2006b) both use a TSI value of 60 as the threshold for determining water quality impairment, even for lakes classified as low color. The 10 lakes covered by those two TMDLs (FDEP 2007 and EPA 2006b) both were informed by a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions, which are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) not the TSI value of 40 used for Lake Ariana North. It should be noted that of the five lakes studied by Whitmore and Brenner (1995) four of them

(Lakes Conine, Hartridge, Howard and May) were consistently low color lakes and the other one (Lake Haines) had annual mean color levels less than 40 PCU on 6 of 11 years. Clearly, the conclusion that a TSI target of 60 is more appropriate than a TSI target of 40 is relevant for low color lakes in Polk County, such as Lake Ariana North.

Using a TSI target value of 40, the chlorophyll-a target value is 5 µg/L, vs. 20 µg/L with a TSI target of 60. For TN, values are 0.45 and 1.2 mg/L, respectively, for TSI targets of 40 and 60. For TP, target values are 0.02 and 0.07 for TSI targets of 40 and 60, respectively. The decision by the EPA (2010) to use a TSI value of 40 to determine impairment status, compared to the more locally appropriate TSI target of 60, results in impairment thresholds that are 75, 63, and 71 percent lower for chlorophyll-a, TN and TP, respectively, than TSI targets based on local paleolimnological studies (i.e., Whitmore and Brenner 1995). To add a margin of safety to the TMDL, it was determined that nutrient load reductions should actually be based on the attainment of a target TSI value of 35, which is 5 units below the chosen TSI target of 40 (EPA 2010). A TSI target of 35 would be even harder to meet than an impairment status criterion of 40 for TSI.

In addition to issues related to having a TMDL that is based on overly stringent criteria, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Ariana North) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Ariana North.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used to establish the TMDL for Lake Ariana North (EPA 2010). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)

- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments

- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Ariana North, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Ariana North on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Ariana North itself.

The TMDL for Lake Ariana North calls for reductions in nutrient loads from both "benthic fluxes" and stormwater runoff. While there are actual measurements of groundwater seepage available for Lakes Conine, Haines, Rochelle and Smart (PBS&J 2009) there are no measurements made of benthic flux in Lake Ariana North. Without differentiating between TN and TP, the TMDL for Lake Ariana North (EPA 2010) calls for a 50 percent reduction in benthic nutrient flux rates. In addition, the TMDL calls for 55 and 49 percent reductions in stormwater loads for TN and TP, respectively. Using an empirical approach to target setting, there is a statistically significant correlation found between TN and Chl-a in Lake Ariana North, with a r-square value of 0.47, suggesting that variation in concentrations of TN explain approximately 47 percent of the variation in concentrations of Chl-a. There is also a statistically significant correlation found between TP and Chl-a in Lake Ariana North, with a r-square value of 0.15, suggesting that variation in concentrations of TP explains about 15 percent of the variation in concentrations of Chl-a.

Based on an examination of water quality data during the Verified Impaired time period for Lake Ariana North (IWR run 47) the mean reduction in Chl-a concentrations required to meet NNC criteria was estimated at 21 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 11 and 6 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Ariana North is based on output from the Watershed Assessment Model (WAM) with the WASP water quality model. WAM estimates stormwater pollutant loads via GIS-based inputs of data on land use classifications (using FLUCCS) and soils, as driven by rainfall. WAM also allows for the attenuation of generated pollutant loads via wetlands and/or BMPs, if such data are available in GIS for the watershed.

WAM allows for the simulation of surface flows and groundwater inflow on a daily basis, and these daily flow estimates can be "processed" in the model via information related to topographical relief, channel configurations, etc. This feature allows for loads to be attenuated along the pathway from the watershed to the conveyance system and then on to the water body of interest. Literature-derived "attenuation algorithms" are applied to the calculated stormwater inflows.

The ability of WAM to attenuate modeled loads via BMPs, wetlands and stream channels is an important improvement over more simplistic pollutant loading models. However, the pollutant loading model as described in the TMDL is not actually "calibrated" via comparison of model output of stormwater loads to measured data. As is the case with other pollutant loading models used in Polk County, there does not appear to be an exercise within the TMDL for which model output on pollutant loads is compared to measured data of flows and concentrations. Instead, the pollutant loading model and the water quality model are "calibrated" against in-lake concentrations. More often than not, this model calibration effort is accomplished via the modification of rate coefficients that have never been locally measured.

The TMDL for Lake Ariana North calls for reductions in of 50 percent for TN and TP loads from benthic fluxes, based on modeling. And while there are actual measurements of groundwater seepage available for the nearby waterbodies of Lakes Conine, Haines, Rochelle and Smart (PBS&J 2009), there are no similar measurements available for Lake Ariana North.

The TMDL for Lake Ariana North (EPA 2010) appears to be problematic for a number of reasons:

- The TMDL for Lake Ariana North is based on the attainment of a TSI target of 35, which would give a 5 unit margin of safety over the chosen TSI impairment level of 40
- However, prior work on low color lakes in Polk County (i.e., Conine, Hartridge, Howard and May; Whitmore and Brenner 1995) has shown that a TSI target of 60 is more appropriate, as lakes in this portion of Central Florida were historically mesotrophic to eutrophic
- Consequently, the water quality targets for Chl-a, TN and TP are inappropriately low, and most likely unattainable
- Perhaps related to the utilization of an inappropriately strict water quality target, the TMDL calls for unrealistic reductions in benthic fluxes (which were not measured) and stormwater runoff
- When using lake data and NNC guidance, the amount of improvement in water quality required for Lake Ariana North to reach unimpaired status is much more realistic and attainable, suggesting a modified target setting process could result in more realistic lake improvement strategies, compared to management actions called for in the TMDL

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Ariana North (EPA 2010).

Banana Lake (WBID 1549B) TMDL

Basis for Impairment

Banana Lake and Banana Lake Canal were verified as impaired for nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code). The lake and canal were included on the Verified List of impaired waters that was adopted by Secretarial Order on June 17, 2005. Banana Lake and Banana Lake Canal were also listed as being impaired for dissolved oxygen (DO) during the Verified Period for Group 3 waterbodies. Banana Lake is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

The Draft TMDL for Banana Lake (FDEP 2005a) and Final TMDL from EPA (2006a) used water quality data from January 1, 1997 to June 30, 2004. The annual average value for color averaged 39.7 platinum cobalt units (PCU). Although this would normally result in Banana Lake being declared "impaired" if TSI values exceeded

40, the target TSI value for TMDL development was set at 62.8, based on a 5 TSI unit increase over the estimated historical TSI value of 57.8. During those years with sufficient data to calculate annual average TSI values, the target TSI value of 62.8 was exceeded each year (1997, 1998, 1999 and 2001). The average TSI value for all years with sufficient data for determining annual averages was 84.5. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Banana Lake easily exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The Draft and Final TMDLs for Banana Lake (FDEP 2005a and EPA 2006a, respectively) determined that there were no current permitted wastewater treatment plant (WWTP) discharges to the lake. For non-point sources, the TMDL (FDEP) noted that stormwater systems owned and operated by local governments and the Florida Department of Transportation are covered by an NPDES MS4 permit.

The water quality target setting process for Banana Lake used at a target TSI value based on the use of linked watershed and water quality response models to determine water quality conditions prior to human impacts. An "acceptable" amount of water quality deterioration was then applied to allow for target setting. The Banana Lake TMDL (FDEP 2005a) used the Watershed Assessment Model (WAM; Soil and Water Engineering Technology, Inc., 2005) to estimate pollutant loads, and WAM output was then the input for the BATHTUB model (Quantitative Environmental Analysis, LLC, 2005) to simulate water quality within Banana Lake.

The WAM model was run with natural land uses (and no point source discharges) to estimate pollutant loads from an undeveloped watershed, and then loads were then input into BATHTUB to estimate a "natural background" TSI value. Based on this approach, a natural background TSI value of 57.8 was derived. An increase of 5 TSI units above natural background (62.8) was then used as the target TSI value for load reduction estimates, and load reductions required to get Banana Lake from its current condition to a TSI target of 62.8 were then developed.

The TMDL for Banana Lake calls for 79 and 80 percent load reductions for Total Nitrogen (TN) and Total Phosphorus (TP), respectively. Since there are no current point source discharges into Banana Lake, external load reductions of such a magnitude are impossible to bring about with any known technology of stormwater treatment, even if applied to 100 percent of the watershed of the lake. While there is a statistically significant correlation found between TN and Chl-a in Banana Lake, quite a few of the TN values are higher than 2.8 mg/L, and cannot be ascribed to stormwater loads alone, as those values are higher than the highest Event Mean Concentration (EMC) values shown for both urban and agricultural land uses in Harper and Baker (2007). Instead, it is more likely that the highest TN concentrations are likely reflecting the influence of nitrogen fixation by cyanobacteria, as has been previously documented in Lake Hancock (Tomasko et al. 2009) and Lake Jesup (PBS&J 2006). There is also a statistically significant relationship between TP and Chl-a. The r-square value of the relationship between TP and Chl-a is 0.20, suggesting that 20 percent of the variation in Chl-a values is explained by variation in concentrations of TP.

Based on an examination of water quality data during the Verified Impaired time period for Banana Lake (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 52 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 34 and 76 percent, respectively. However, TN concentrations in Banana Lake are likely elevated via nitrogen-fixation by cyanobacteria.

Pollutant Loading Model

The pollutant loading model for the Banana Lake TMDLS (FDEP 2005a) used the Watershed Assessment Model (WAM) which predicts stormwater and groundwater loads of nutrients based on inputting data on rainfall, soils, and land use classifications. WAM has the ability to attenuate stormwater loads via features such as wetlands, depressional areas, and model input related to the distribution of Best Management Practices (BMPs) within the watershed.

The TMDL for Banana Lake is based on output from the Watershed Assessment Model (WAM) with the WASP water quality model. WAM estimates stormwater pollutant loads via GIS-based inputs of data on land use classifications (using FLUCCS) and soils, as driven by rainfall. WAM also allows for the attenuation of generated pollutant loads via wetlands and/or BMPs, if such data are available in GIS for the watershed.

WAM allows for the simulation of surface flows and groundwater inflow on a daily basis, and these daily flow estimates can be "processed" in the model via information related to topographical relief, channel configurations, etc. This feature allows for loads to be attenuated along the pathway from the watershed to the conveyance system and then on to the water body of interest. Literature-derived "attenuation algorithms" are applied to the calculated stormwater inflows.

The ability of WAM to attenuate modelled loads via BMPs, wetlands and stream channels is an important improvement over more simplistic pollutant loading models. However, the pollutant loading model as described in the TMDL is not actually "calibrated" via comparison of model output of stormwater loads to measured data. As is the case with other pollutant loading models used in Polk County, there does not appear to be an exercise within the TMDL for which model output on pollutant loads is compared to measured data of flows and concentrations. Instead, the pollutant loading model and the water quality model are "calibrated" with in-lake concentrations. More often than not, this model calibration effort is accomplished via the modification of rate coefficients that have never been locally measured.

The first model runs for "existing conditions" gave rise to results where the measured TN values were often twice as high model output. In the years 2000 and 2001, average measured TN values were more than four-times higher than model output. For TP, an even more severe discrepancy was found; measured TP values were often eight-times higher than model output. Clearly, the combination of WAM and BATHTUB did not sufficiently characterize the water quality of Banana Lake.

In accommodate the discrepancy between model output and measured data for existing conditions, model calibration for TN and TP was achieved by "…invoking BATHTUB's internal loading rate functions for both TN and TP to match the measured in-lake mass" (FDEP 2005a). This term "internal loading rate" is not fully described, but the TMDL report states that this internal loading rate is meant to include not only in-lake processes such as nitrogen fixation (for TN) but "…all other missing mass." Figures 5.1 and 5.2 in the TMDL report show the differences between the initial model runs of TN and TP, respectively, vs. measured data, and also how the calibration step of invoking internal loading results in model output that exactly matches measured data. In essence, the TMDL for Banana Lake used a two-step process: (1) initial model runs resulted in significant underestimates of the TN and TP concentrations in the lake, (2) a model factor referred to as internal loading was then used to "calibrate" model output so that modeled and measured data would exactly coincide.

With any model, the term “calibration” refers to the process through which the modification of a state variable or rate coefficient is conducted in an attempt to better align model output and measured data. Ideally, model calibration would involve relatively minor adjustment to model components, using stare variables or rate coefficients that had been measured directly, hopefully in a somewhat similar environment. In the case of the Banana Lake TMDL, model calibration was not based on any measured processes (e.g., bottom resuspension, in-situ nitrogen fixation) from any nearby lake. In fact, it appears that calibration involved simply using the term “internal process” as a substitute for all the potential reasons why model output and measured values differed by so much. Since measured data on TN and TP were often 4 to 8 times higher than model output, this seriously compromises the validity of the TMDL. The lack of sufficient knowledge of the actual mechanisms behind the discrepancies between modeled and measured TN and TP values could result in a TMDL model that is calibrated via the modification of model variables that are not representative of actual field conditions.

Four main considerations suggest that the TMDL for Banana Lake requires significant review prior to implementation: 1) measured water quality has 4 to 8 times the level of TN and TP, respectively, vs. initial model runs, 2) calibration of the water quality model was accomplished via the inclusion of a term called “Internal loading” that is neither fully explained as to its processes, nor is it derived from actual measurements of any processes in Banana Lake, 3) based on prior work in Lake Hancock (Tomasko et al. 2009) it is likely that bottom resuspension of phosphorus-rich sediments could be a significant source of the excess and unaccounted for TP concentration in the lake, and 4) based on prior work in Lake Hancock (Tomasko et al., 2009) it is likely that nitrogen-fixation by cyanobacteria within Banana Lake could be a significant source of the excess and unaccounted for TN concentrations in the lake.

Since neither bottom resuspension of TP-rich sediments nor in-situ nitrogen fixation have been measured in Banana Lake, the model calibration effort included in the TMDL (FDEP 2005) is problematic. In terms of meeting TMDL obligations, since neither bottom resuspension of TP rich sediments nor nitrogen fixation are processes included in the water quality model, they are not processes through which TMDL load allocation credits could be applied.

Further work is justified, focusing on the discrepancies above, prior to the investment of time and resources to implement the TMDL for Banana Lake (FDEP 2005).

Lake Bonny (WBID 1497E) TMDL

Basis for Impairment

Lake Bonny is classified as a Class III freshwater waterbody, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the verified impairments (nutrients) for this water is the state of Florida’s nutrient criterion in Paragraph 62-302.530(47) (b), Florida Administrative Code (F.A.C.).

FDEP had determined that Lake Bonny was impaired for nutrients based on elevated annual average Trophic State Index (TSI) values during the cycle 1 verification period for Group 3 basins (January 1997 to June 2004). At that time, the methodology used by FDEP was that total nitrogen (TN), total phosphorus (TP), and chlorophyll-a were used to calculate annual average TSI values to interpret Florida’s narrative nutrient criteria. For high color lakes, an exceedance of an annual average TSI value of 60 in any one year of the verified period was sufficient for being declared impaired for nutrients. Even though Lake Bonny is a low color lake (FDEP 2014) prior work in the

Winter Haven Chain of Lakes had shown that many lakes in Polk County are naturally mesotrophic to eutrophic (Whitmore and Brenner 1995); therefore a TSI target value of 60 is more appropriate. From 1996 to 2002, every annual average TSI value exceeded the impairment threshold of 60. In the more recent cycle 2 verification period (January 2002 to June 2009) annual mean TSI values also exceeded the threshold of 60.

Florida has newly adopted lake criteria for total nitrogen (TN), total phosphorous (TP) and chlorophyll-a (62-302.531, F.A.C.). While EPA has reviewed and approved the new numeric nutrient criteria (NNC) in terms of its scientific validity, the NNC are not fully adopted by EPA, pending the opportunity for third party interveners to comment on the proposed new rules. While FDEP has not formally examined Lake Bonny using NNC, a preliminary assessment by FDEP has found that Lake Bonny would still be impaired with NNC, as it is with the use of Trophic State Index (TSI).

TMDL Summary

Water Quality Targets

Lake Bonny is classified as a lake with low color (<40 PCU) and high alkalinity (>20 mg/L $CaCO_3$). The new chlorophyll a NNC for low color, high alkalinity lakes is an annual geometric mean value of 20 μg/L, which is not to be exceeded more than once in any consecutive three-year period. As Lake Bonny exceeded NNC guidance for chlorophyll-a, it's default threshold values for TN and TP would be 1.05 and 0.03 mg/L, respectively, using NNC.

However, a more detailed assessment was conducted to develop TN and TP targets for Lake Bonny. For TN, a regression equation that examined the relationship between TN and chlorophyll-a was used to derive the TN concentration that would result in a chlorophyll-a value of 20 μg/L. Based on the derived equation, a TN concentration of 0.89 mg/L would be expected to result in a chlorophyll-a concentration of 20 μg/L. That TN concentration was used as the target for Lake Bonny.

The selection of a TP target for Lake Bonny was complicated by a discrepancy between two different approaches to setting targets. The TN target of 0.89 mg/L was chosen based on the correlation between TN and chlorophyll-a, and solving the equation for the TN target that corresponds to a chlorophyll-a concentration of 20 μg/L. Using this approach for TP, the target TP value for Lake Bonny would be approximately 0.025 mg/L. However, a paleolimnological study conducted on Lake Bonny (Whitmore and Brenner 2002) determined that TP values would have historically been somewhere between 0.032 and 0.043 mg/L, values 28 and 72 percent higher than the derived TP target (based on a chlorophyll-a vs. TP relationship) described above. FDEP's guidance is that no water quality standard can be stricter than conditions in an undisturbed condition, therefore it was concluded (FDEP 2014) that the derived value of 0.025 mg TP/L was inappropriate. Instead, the higher of the two values for "historical" TP values from the paleolimnological study (Whitmore and Brenner 2002) was used, and the TP target for Lake Bonny was thus set at 0.043 mg/L.

Pollutant Loading Model

As opposed to most of the TMDLs produced by FDEP, the TMDL for Lake Bonny is empirically derived based on relationships between nutrients and chlorophyll-a, as modified with results from paleolimnological studies. Consequently, there are no requirements that reduced nutrient concentrations have to be achieved by acting on external loads of TN and TP. While the TMDL for Lake Bonny summarized land use within the lake's watershed, there are no estimates of external loads to the lake. Instead, lake management activities to meet the TMDL targets for TN and TP can be based solely on reducing nutrient concentrations by acting on internal processes such as bottom resuspension, by increasing the uptake of nutrients via submerged aquatic vegetation, or by increasing the role of wetlands as a moderating influence on the transformation of nutrients into algal biomass. While this approach may seem counter-intuitive to those who are more familiar with "traditional" TMDLs, it is consistent with data from the lake itself. For example, Figure 5.3 in the TMDL shows a strong inverse relationship between rainfall and chlorophyll-a values on an annual basis; years with the highest quantities of external stormwater loads do not have the worst water quality, they have the best water quality, on average. As such, acting on external stormwater loads alone is not likely to bring about improvements in water quality. By not focusing on external loads (in fact, not even quantifying them) the TMDL allows lake managers to act on those factors that are most important to the lake's water quality.

The percent reductions in TN and TP are based on the following equation:

$$\frac{[\text{Measured exceedance} - \text{target}] \times 100}{\text{Measured exceedance}}$$

The term "measured exceedance" as used in the TMDL for Lake Bonny (FDEP 2014) refers to the median values of the annual geometric mean values for TN and TP values that exceeded the water quality targets of 0.89 mg TN/L and 0.04 mg TP/L. The TMDL (FDEP 2014) lists a geometric mean value of 2.46 mg TN/L; a 64 percent reduction in TN concentrations is thus required to meet the target TN value of 0.89 mg/L. With a geometric mean value of 0.10 mg TP/L, a 60 percent reduction in concentrations is required to meet the target TP value of 0.04 mg/L.

The TMDL for Lake Bonny (2011) appears to be less problematic than most of the other TMDLs for Polk County lakes. The TMDL is based on empirically-derived relationships, which are then compared to NNC criteria and results from paleolimnological studies. The TMDL also allows for the possibility that in-lake processes can be used to achieve water quality goals, a major oversight for most other TMDLs. The combination of using actual data, rather than overly complex mechanistic models, and the inclusion of in-lake processes makes the TMDL more realistic than most. It will be a serious challenge for Polk County to achieve the water quality improvements laid out in this TMDL, but the targets are more realistic than those of most other TMDLs.

Lake Cannon (WBID 1521H) TMDL

Basis for Impairment

Lake Cannon is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Cannon is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. Sufficient data were available for all years except 2003. The annual average TSI value exceeded the established target of 60 in 8 of those 11 years with a mean annual average TSI value of 61.9. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Cannon easily exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Cannon) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Cannon.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake Cannon (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)

- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms

- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Cannon, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Cannon on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Cannon itself.

The TMDL for Lake Cannon calls for a 54 percent reduction in external TP loads. There is a statistically significant correlation found between TP and Chl-a in Lake Cannon, with an r-square value of 0.49, suggesting that 49 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Cannon (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 26 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 11 and 10 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Cannon (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake Cannon, the TMDL (FDEP 2007) calls for a 54 percent reduction in stormwater loads. It was noted as well that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has control over; they are not responsible for reducing other nonpoint source loads in their jurisdiction.

The pollutant loading model for the Lake Cannon TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005). The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$POFF = RCOEF * WFLOW^{WASPRO}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$POFF = RCOEF * WFLOW$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from “average” EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that "There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999." As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP's TMDL (PBS&J 2009).

For the eight lakes included in FDEP's 2007 TMDL for the Southern Chain of Lakes (including Lake Cannon) WASP was "calibrated" for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake Cannon requires significant review prior to implementation: 1) the water quality targets used are based on TSI, not NNC, 2) prior work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured, and 4) despite the fact that Lakes Shipp, May and Lulu (also in the Winter Haven Chain of Lakes) have met or exceeded the TP reduction targets contained in their individual TMDLs, there is no evidence of improved water quality in those three lakes (PBS&J 2008).

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Cannon (FDEP 2007).

Crystal Lake (WBID 1497A) TMDL

Basis for Impairment

Crystal Lake is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was identified as impaired for nutrients pursuant to EPA commitments related to the 1998 Consent Decree (Florida Wildlife Federation et al.

v. Carol Browner et al., Civil Action No. 4: 98CV356-WS). In that Consent Decree, the EPA committed to developing TMDLs for a number of waterbodies, including a TMDL that addresses Lake Alfred, Crystal Lake, and Lake Ariana (EPA 2010).

The TMDL for Crystal Lake used water quality data from 1992 to 2007 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were available. The majority of the water quality data collected in Crystal Lake was collected over the entire 16 year period of 1992 to 2007. The TMDL (EPA 2010) determined that sufficient data were available to characterize water quality for the entire period of 1992 to 2007. As Crystal Lake was determined to be a low color lake (platinum cobalt units [PCU] < 40) the threshold for impairment was set at a TSI value of 40. Although annual average values are not shown in the TMDL report (EPA 2010) every TSI value calculated exceeded 40, which was determined to be sufficient evidence to support Crystal Lake being classified as impaired.

TMDL Summary

Water Quality Targets

The TSI target for Crystal Lake was based on a determination that the lake was a low color lake (< 40 PCU) and so a target TSI value of 40 was the threshold value above which the lake would be declared "impaired" for nutrients. However, the TMDL produced by FDEP for the Winter Haven Southern Chain of Lakes (FDEP 2007) and the TMDL for Lakes Haines and Smart (EPA 2006b) both use a TSI value of 60 as the threshold for determining water quality impairment, even for lakes classified as low color. The 10 lakes covered by those two TMDLs (FDEP 2007 and EPA 2006b) both were informed by a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions, which are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) not the TSI value of 40 used for Crystal Lake. It should be noted that of the five lakes studied by Whitmore and Brenner (1995) four of them (Lakes Conine, Hartridge, Howard and May) were consistently low color lakes and the other one (Lake Haines) had annual mean color levels less than 40 PCU on 6 of 11 years. Clearly, the conclusion that a TSI target of 60 is more appropriate than a TSI target of 40 is relevant for low color lakes in Polk County, such as Crystal Lake.

Using a TSI target value of 40, the chlorophyll-a target value is 5 µg/L, vs. 20 µg/L with a TSI target of 60. For TN, values are 0.45 and 1.2 mg/L, respectively, for TSI targets of 40 and 60. For TP, target values are 0.02 and 0.07 for TSI targets of 40 and 60, respectively. The decision by the EPA (2010) to use a TSI value of 40 to determine impairment status, compared to the more locally appropriate TSI target of 60, results in impairment thresholds that are 75, 63, and 71 percent lower for chlorophyll-a, TN and TP, respectively, than TSI targets based on local paleolimnological studies (i.e., Whitmore and Brenner 1995). To add a margin of safety to the TMDL, it was determined that nutrient load reductions should actually be based on the attainment of a target TSI value of 35, which is 5 units below the chosen TSI target of 40 (EPA 2010). A TSI target of 35 would be even harder to meet than an impairment status criterion of 40 for TSI.

In addition to issues related to having a TMDL that is based on overly stringent criteria, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Crystal Lake) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Crystal Lake.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used to establish the TMDL for Crystal Lake (EPA 2010). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of μg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Crystal Lake, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Crystal Lake on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Crystal Lake itself.

The TMDL for Crystal Lake calls for reductions in nutrient loads from both “benthic fluxes” and stormwater runoff. While there are actual measurements of groundwater seepage available for Lakes Conine, Haines, Rochelle and Smart (PBS&J 2009) there are no measurements made of benthic flux in Crystal Lake. Without differentiating between TN and TP, the TMDL for Crystal Lake (EPA 2010) calls for a 75 percent reduction in benthic nutrient flux rates. In addition, the TMDL calls for 51 and 79 percent reductions in stormwater loads for TN and TP, respectively. Using an empirical approach to target setting, there is a statistically significant correlation found between TN and Chl-a in Crystal Lake, with a r-square value of 0.28, suggesting that variation in concentrations of TN explain approximately 28 percent of the variation in concentrations of Chl-a. There is, however, no statistically significant relationship between TP and Chl-a in Crystal Lake.

Based on an examination of water quality data for Crystal Lake from 2003 to 2013 the median reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 59 percent. Also using NNC criteria, the median reduction in TN and TP concentrations required would be 31 and 67 percent, respectively.

Pollutant Loading Model

The TMDL for Crystal Lake is based on linking a GIS-based pollutant loading model output with WASP as the water quality model. The pollutant loading model used was the Watershed Assessment Model (WAM) which predicts stormwater loads of nutrients based on inputting data on rainfall, soils, and land use classifications. WAM has the ability to attenuate stormwater loads via features such as wetlands, depressional areas, and model input related to the distribution of Best Management Practices (BMPs) within the watershed.

The TMDL for Crystal Lake is based on output from the Watershed Assessment Model (WAM) with the WASP water quality model. WAM estimates stormwater pollutant loads via GIS-based inputs of data on land use classifications (using FLUCCS) and soils, as driven by rainfall. WAM also allows for the attenuation of generated pollutant loads via wetlands and/or BMPs, if such data are available in GIS for the watershed.

WAM allows for the simulation of surface flows and groundwater inflow on a daily basis, and these daily flow estimates can be "processed" in the model via information related to topographical relief, channel configurations, etc. This feature allows for loads to be attenuated along the pathway from the watershed to the conveyance system and then on to the water body of interest. Literature-derived "attenuation algorithms" are applied to the calculated stormwater inflows.

The ability of WAM to attenuate modeled loads via BMPs, wetlands and stream channels is an important improvement over more simplistic pollutant loading models. However, the pollutant loading model as described in the TMDL is not actually "calibrated" via comparison of model output of stormwater loads to measured data. As is the case with other pollutant loading models used in Polk County, there does not appear to be an exercise within the TMDL for which model output on pollutant loads is compared to measured data of flows and concentrations. Instead, the pollutant loading model and the water quality model are "calibrated" against in-lake concentrations. More often than not, this model calibration effort is accomplished via the modification of rate coefficients that have never been locally measured.

The TMDL for Crystal Lake calls for reductions of 75 percent for TN and TP loads from benthic fluxes, based on modeling. And while there are actual measurements of groundwater seepage available for the nearby waterbodies of Lakes Conine, Haines, Rochelle and Smart (PBS&J 2009), there are no similar measurements available for Crystal Lake.

The TMDL for Crystal Lake (EPA 2010) appears to be problematic for a number of reasons:

- The TMDL for Crystal Lake is based on the attainment of a TSI target of 35, which would give a 5 unit margin of safety over the chosen TSI impairment level of 40

- However, prior work on low color lakes in Polk County (i.e., Conine, Hartridge, Howard and May; Whitmore and Brenner 1995) has shown that a TSI target of 60 is more appropriate, as lakes in this portion of Central Florida were historically mesotrophic to eutrophic

- Consequently, the water quality targets for Chl-a, TN and TP are inappropriately low, and most likely unattainable

- Perhaps related to the utilization of an inappropriately strict water quality target, the TMDL calls for unrealistic reductions in benthic fluxes (which were not measured) and stormwater runoff

However, when using lake data and NNC guidance, the amount of improvement in water quality required for Crystal Lake to reach unimpaired status is still significant; suggesting that Crystal Lake requires significant improvements in water quality, and that stormwater loads and internal loads could both be significant stressors for the lake.

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Crystal Lake (EPA 2010).

Lake Cypress (WBID 3180A) TMDL

Basis for Impairment

Lake Cypress is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake itself lies outside of Polk County, but its watershed extends into the County's boundaries. Lake Cypress was initially verified as impaired during Cycle 1 (verified period January 1, 1998 – June 30, 2005) due to excessive nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303, Florida Administrative Code), and was included on the Cycle 1 Verified List of impaired waters for the Kissimmee River Basin that was adopted by Secretarial Order on May 12, 2006. Subsequently, during the Cycle 2 assessment (verified period January 1, 2003 – June 30, 2010), the impairment for nutrients was documented as continuing, as the Trophic State Index (TSI) threshold of 60 was exceeded for five years of the Cycle 2 assessment period.

The TMDL establishes the allowable loadings to the lake that would restore the waterbody so that it meets applicable water quality narrative criteria for nutrients. The Final TMDL for Lake Cypress (FDEP 2011a) used water quality data from 1979 to 2009 to calculate Tropic State Index (TSI) values for the lake, which required the use of data from LakeWatch. Data for Total Nitrogen (TN) and Total Phosphorus (TP) were shown from 1969 and 1968, respectively. Chlorophyll-a data are shown from 1979 to 2009. During the period of 1979 to 2009, annual average TSI values exceeded the established target of 60 in every year except for 1994 and 1995. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Cypress easily exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

For the Lake Cypress TMDL, FDEP (2011) used Hydrologic Simulation Program FORTRAN (HSPF; EPA 2000) model to determine the appropriate nutrient target. The HSPF was first used to estimate existing conditions in the Lake Cypress watershed, and results were then compared to model runs for "background" conditions by setting land uses to natural land use patterns. FDEP's guidance is that if background TSI values can be reliably determined, an increase of 5 TSI units above background will be the water quality target used for TMDL development.

Based on model runs, the HSPF-estimated average TSI value for an undeveloped watershed was 54.9, and that Lake Cypress was historically phosphorus limited (based on an expected TN:TP ratio of 38.5). By adding the 5 unit TSI increase on top of the historical TSI estimate, the target TSI value for Lake Cypress was thus determined to be 59.9 (FDEP 2011a) vs. a default impairment TSI value of 60 that would had been used for other lakes in Central Florida.

However, the use of TSI for water quality target setting is out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, and TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008). The TMDL for Lake Cypress (FDEP 2011a) notes that Lake Cypress would be classified as a high color lake for all but 5 of the last 50 plus years (i.e., 1954 to 2009).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Cypress) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Cypress.

The TMDL for Lake Cypress calls for percent reductions in external TN and TP loads of 7 and 53 percent, respectively. In a review of the TMDL for Lake Cypress, Atkins (2013) found that both TN and TP concentrations were positively correlated with chlorophyll-a concentrations, with r-square values of 0.42 and 0.34, respectively, suggesting that variation in nutrient concentrations explain approximately 30 to 40 percent of the variation in chlorophyll-a concentrations.

Based on an examination of water quality data during the period of 1999 to 2009 for Lake Cypress the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 47 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 26 percent for both nutrients.

Pollutant Loading Model

The water quality target for Lake Cypress is based on a TSI target of 59.9, which is based on the use of HSPF, which determined that the TSI value of Lake Cypress in an undisturbed condition would be 54.9.

Three main approaches were used to determine hydrologic loads to Lake Cypress from both its immediately adjacent watershed and those lakes that are located farther upstream in the Upper Kissimmee Chain of Lakes system. The IMPLND module of HSPF was used to estimate runoff from impervious surfaces of those land areas where FLUCCS indicated there was impervious area. For those portions of the watershed where impervious areas are not expected, the PERLND module of HSPF was used to estimate both runoff and baseflow. The model estimated the amount of pervious area by subtracting the amount of land estimated to have pervious area in each FLUCCS category from the total amount of area, for each sub-basin. Rainfall that was not modeled to turn into surface runoff (for both pervious and impervious land uses) was assigned by the model to become infiltration into soils. The volume of infiltrated soils was then processed via evapotranspiration, discharge as baseflow, or it was "lost" via percolation to deeper aquifers. Rainfall onto the major land use categories of water and wetlands was processed in the model as if those two landscapes were pervious, but with lower rates assigned for infiltration and storage in surface soils.

The RCHES module of HSPF then used output from the PERLND and IMPLND modules to convey flows from those modules, and to account for direct atmospheric deposition onto open waters and evaporation. These estimated flows are then based on rating curves developed by the HSPF user. These flows were then used to estimate stormwater loads, via techniques described below.

For pervious lands, TSS loads were quantified based on estimates of the amount of sediments that are "detached" from the landscape by rainfall, thus becoming available for subsequent "wash-off". For constituents other than TSS, the amount of those pollutants was estimated by the use of a "potency factor". Potency factors were estimates of the amount of non-TSS pollutants that would be expected to be loaded via wash-off as a function of the amount of TSS loaded.

In Table 5.8 of the TMDL (FDEP 2011a) a summary of area-normalized nutrient loads are displayed, in terms of the amount of different forms of pollutants generated per acre of watershed per year. Results are given for different land use types for different soil types. The results shown in Table 5.8 suggest that inorganic forms of both nitrogen and phosphorus are fairly substantial percentages of the total amount of nutrients loaded via stormwater runoff. For example, commercial landscapes on poorly-drained D-type soils are given a TN loading rate of 12.3 lbs. TN / acre / yr. For the same land cover and soil combination, the amount of that load attributed to the inorganic forms of nitrogen of ammonia and nitrate plus nitrite is estimated at 5.3 lbs. TN / acre / yr. Put another way, inorganic nitrogen is estimated to account for 43 percent of the TN load from those areas. In contrast, Smith (2010) summarized the nitrogen makeup of more than 900 Florida stormwater samples and found that dissolved inorganic nitrogen made up only about 31 percent of TN loads from stormwater, a number that matched up well with estimates from Rushton et al. (1997), where inorganic nitrogen made up 28 percent of the TN in stormwater samples. For phosphorus, inorganic forms of phosphorous account for 66 percent of the estimated load of TP from commercial /industrial landscapes on D-type soils, which may be a similar, yet relatively minor, over-estimate as in TN loads.

The nutrient yields (lbs per acre per year) for the urbanized watershed features of the landscape tend to fall within the range of estimates (after conversion to units of kg / ha / yr) developed for most watersheds in the US (i.e., Stacey et al. 2000). These watershed-level loads were then summed and served as input to the water quality model for Lake Cypress, also run in HSPF.

The water quality portion of HSPF "balances" nutrients and chlorophyll-a values via a series of equations where by conversion of loads into phytoplankton biomass is simulated based on modifications of estimated maximum growth rates via adjustments due to water temperature, available light, and the amount of nutrients in the water column <u>in an inorganic form</u>. The amount of nutrients available in an inorganic form is estimated based on model output that uses the following processes:

- Decay of BOD and re-mineralization of nitrogen and phosphorus
- Settling of BOD to the lake bottom
- Phytoplankton growth and uptake of inorganic nutrients
- Respiration rates of phytoplankton
- Phytoplankton death rates
- Phytoplankton settling rates
- Nitrification within lake sediments
- Sediment nutrient fluxes (especially for phosphorus)

Based on discussions with several researchers at the University of Florida, it appears that perhaps only one or two of these rate coefficients have been measured in any Florida Lake. As such, the water quality model is dependent upon the accuracy of multiple and linked biological processes that haven't been measured in Lake Cypress. For the most part, the model's accuracy cannot be independently verified. While it is possible that the goodness of fit between measured data and model output is due to the model having very precisely estimated the many biological processes occurring in Lake Kissimmee, it is also possible that values appear to be aligned due to model errors canceling each other out.

Although there are a number of issues related to the use of water quality models, including the use of HSPF, an additional and significant issue might be related to the relative role of the hydrologic alterations that have occurred within the Kissimmee Chain of Lakes, including impacts to Lake Cypress. The TMDL for Lake Cypress (FDEP 2011a) makes no mention of the approximate two foot reduction in lake levels that occurred in the 1960s (Atkins 2013). Prior work in the Winter Haven Chain of Lakes has shown that water levels can be equally if not more important than stormwater loads in terms of influencing water quality (PBS&J 2008). Also in that report (PBS&J 2008) it was shown that high color lakes like Lake Cypress do not always exhibit a strong relationship between nutrient concentrations and chlorophyll-a levels. While there is a fairly good fit at present between TN and chlorophyll-a, as well as between TP and chlorophyll-a, it is also likely that this "goodness of fit" could be due to Lake Cypress being lowered such that it became disconnected from its adjacent swampy shorelines due to the lowering of the lake level that coincided with the construction of the Cypress-Hatchineha Canal. A revised TMDL for Cypress Lake will include language that allows for the achievement of water quality targets via hydrologic restoration (Tom Frick, personal communication) rather than stormwater reductions alone. If hydrologic restoration does not bring about the improved water quality that is expected (Atkins 2013) then stormwater treatment will then be viewed as the most reasonable approach left for meeting water quality targets for Lake Cypress.

The TMDL for Lake Cypress (FDEP 2011a) appears to be problematic for a number of reasons:

- The TMDL for Lake Cypress does not appear to address the importance of the approximate two foot change in lake levels that occurred in the 1960s with the completion of the Cypress-Hatchineha Canal.
- A revised TMDL for Lake Cypress is expected to allow for the achievement of water quality goals for Lake Cypress via hydrologic restoration (Tom Frick, personal communication) which is anticipated to occur via ongoing and planned activities intended to restore the lost wet weather storage capacity of the Upper Kissimmee Chain of Lakes.
- In the event that hydrologic restoration does not bring about the water quality improvements expected (i.e., Atkins 2013) at that time a renewed focus on stormwater projects might be required.

Further assessment is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Cypress (FDEP 2011a).

Deer Lake (WBID 1521P) TMDL

Basis for Impairment

Deer Lake is classified as a Class III freshwater waterbody, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the verified impairments (nutrients) for this water is the state of Florida's nutrient criterion in Paragraph 62-302.530(47) (b), Florida Administrative Code (F.A.C.).

FDEP had determined that Deer Lake was impaired for nutrients based on elevated annual average Trophic State Index (TSI) values during the cycle 2 verification period for Group 3 basins (January 2002 to June 2009). At that time, the methodology used by FDEP was that total nitrogen (TN), total phosphorus (TP), and chlorophyll-a were used to calculate annual average TSI values to interpret Florida's narrative nutrient criteria. For high color lakes, an exceedance of an annual average TSI value of 60 in any one year of the verified period was sufficient for being declared impaired for nutrients. Even though Deer Lake is a low color lake (FDEP 2014b) prior work in the Winter Haven Chain of Lakes had shown that many lakes in Polk County are naturally mesotrophic to eutrophic (Whitmore and Brenner 1995). However, Deer Lake was assessed using a TSI target of 40, the default target for lakes with color levels less than 40 PCU. Exceeding a TSI of 40 in any one year of the verified period is sufficient for identifying a lake as impaired for nutrients, and the annual mean TSI values exceeded 40 in both 2007 and 2008.

Florida has newly adopted lake criteria for total nitrogen (TN), total phosphorous (TP) and chlorophyll-a (62-302.531, F.A.C.). While EPA has reviewed and approved the new numeric nutrient criteria (NNC) in terms of its scientific validity, the NNC are not fully adopted by EPA, pending the opportunity for third party interveners to comment on the proposed new rules. While FDEP has not formally examined Deer Lake using NNC, but a preliminary assessment by FDEP has found that Deer Lake would still be impaired with NNC, as it is with the use of Trophic State Index (TSI).

TMDL Summary

Water Quality Targets

Deer Lake is classified as a lake with low color (<40 PCU) and high alkalinity (>20 mg/L $CaCO_3$). The new chlorophyll a NNC for low color, high alkalinity lakes is an annual geometric mean value of 20 µg/L, which is not to be exceeded more than once in any consecutive three-year period. Because Deer Lake exceeded NNC guidance for chlorophyll-a, the default threshold values for TN and TP are 1.05 and 0.03 mg/L, respectively, using NNC.

However, a more detailed assessment was conducted to develop TN and TP targets for Deer Lake. For TN, a regression equation that examined the relationship between TN and chlorophyll-a was used to derive the TN concentration that would result in a chlorophyll-a value of 20 µg/L. Based on the derived equation, a TN concentration of 1.42 mg/L would be expected to result in a chlorophyll-a concentration of 20 µg/L. That TN concentration was used as the target for Deer Lake.

The Deer Lake TMDL (FDEP 2014b) states that “Based on an assessment of the lake results as presented in Table 2.1, the TP annual geometric means did not exceed the applicable NNC of 0.03 mg/L in any year.” And that “The available data indicate that the lake TP results are meeting the applicable NNC.” However, the TP data shown in Table 2.1 are all values of 0.03 mg TP/L, which is an unusual number to report (as they are identical) for annual averages. A value of 0.03 mg TP/L is not likely a minimum detection limit, but seems to be a typographical error in Table 2.1 in the TMDL (FDEP 2014). In other parts of the TMDL (e.g., Table 5.1, Figure 5.1) data clearly show that average TP values often exceed the NNC criteria of 0.03 mg TP/L.

Since there was not a statistically significant relationship between TP and Chl-a concentrations in Deer Lake, the TMDL concluded that there was no need for a reduction in TP concentrations in the lake, as opposed to the need for TN reductions. However, the lake does not appear to meet NNC criteria for TP, and the conclusion that it does appears to be in error.

Pollutant Loading Model

As opposed to most of the TMDLs produced by FDEP, the TMDL for Deer Lake is empirically derived based on relationships between TN and chlorophyll-a. Consequently, there are no requirements that reduced nutrient concentrations have to be achieved by acting on external loads of TN. Instead, lake management activities to meet the TMDL targets for TN can be based solely on reducing nutrient concentrations by acting on internal processes such as bottom resuspension, by increasing the uptake of nutrients via submerged aquatic vegetation, or by increasing the role of wetlands as a moderating influence on the transformation of nutrients into algal biomass.

While the TMDL for Deer Lake summarized land use within the lake’s watershed, there are <u>no</u> estimates of external loads to the lake. Instead, lake management activities to meet the TMDL targets for TN and TP can be based solely on reducing nutrient concentrations by acting on internal processes such as bottom resuspension, by increasing the uptake of nutrients via submerged aquatic vegetation, or by increasing the role of wetlands as a moderating influence on the transformation of nutrients into algal biomass. While this approach may seem counter-intuitive to those who are more familiar with "traditional" TMDLs, it is consistent with data from the lake itself. For example, Figure 5.3 in the TMDL shows an inverse relationship between rainfall and chlorophyll-a values on an annual basis; years with the highest quantities of external stormwater loads do not have the worst water quality, they have the best water quality, on average. As such, acting on external stormwater loads alone is not likely to bring about improvements in water quality. By not focusing on external loads (in fact, not even quantifying them) the TMDL allows lake managers to act on those factors that are most important to the lake's water quality.

The percent reductions in TN are based on the following equation:

$$\frac{[\text{Measured exceedance} - \text{target}] \times 100}{\text{Measured exceedance}}$$

The term "measured exceedance" as used in the TMDL for Deer Lake (FDEP 2014) refers to the median values of the annual geometric mean values for TN that exceeded the water quality targets of 1.42 mg TN/L. The TMDL (FDEP 2014) lists a maximum geometric mean value of 1.62 mg TN/L; a 12 percent reduction in TN concentrations is thus required to meet the target TN value of 1.42 mg/L.

The TMDL for Deer Lake (2014b) appears to be less problematic than most of the other TMDLs for Polk County Lakes. The TMDL is based on empirically-derived relationships, which are then compared to NNC criteria. The TMDL also allows for the possibility that in-lake processes can be used to achieve water quality goals, a major oversight for most other TMDLs. The combination of using actual data, rather than overly complex mechanistic models, and the inclusion of in-lake processes makes the TMDL more realistic than most. However, it does appear that the TMDL is in error when it states that TP concentrations meet NNC criteria. As a rough estimate, it would appear that a 30 percent reduction in TP concentrations would be required for Deer Lake to meet NNC guidance for TP. It will be a serious challenge for Polk County to achieve the water quality improvements laid out in this TMDL, but the targets (for both TN and TP) appear to be more realistic than those of most other TMDLs.

Lake Haines (WBID 1488C) TMDL

Basis for Impairment

Lake Haines is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Haines is contained within the TMDL for the Nutrient TMDL for Winter Haven Northern Chain of Lakes, Lake Haines and Lake Smart (EPA 2006b). The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. Sufficient data were available for all years except 2002. The annual average TSI value exceeded the established target of 60 in 10 of those 11 years with a mean annual average TSI value of 69.0. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Haines easily exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Northern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008). The TMDL for Lake Haines (EPA 2006b) notes that Lake Haines would be classified as a high color lake 5 of the 11 years with sufficient data for target setting for nutrient concentrations.

The State of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Haines) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Haines.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Northern Chain of Lakes, which includes Lake Haines (EPA 2006b). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)

- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Haines, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Haines on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Haines itself.

The TMDL for Lake Haines calls for 70 percent reductions in external TP loads. Although a preliminary data analysis effort found a statistically significant correlation found between TP and Chl-a in Lake Haines, the resulting r-square value of 0.26, suggested that only 26 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP. A later and more extensive data analysis using identical reporting techniques as is used by FDEP (rather than all available data) did not find a statistically significant relationship between these two variables.

Based on an examination of water quality data during the Verified Impaired time period for Lake Haines (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 34 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 9 and 4 percent, respectively.

Pollutant Loading Model

The water quality target for Lake Haines is based on a TSI target of 60, which is in turn based on paleolimnological work conducted on a series of lakes in Polk County including Lake Haines (Whitmore and Brenner 1995).

Although there are a number of issues related to the use of mechanistic water quality models, an additional and significant issue might be related to the relative role of groundwater inflows vs. surface water runoff, in terms of the delivery of external nutrient loads. The TMDL for Lake Haines (EPA 2006b) states that "A larger proportion of the load to the Northern Chain of Lakes is derived from ground water, which makes up 29 percent of the total load, as compared to ground water only making up 4 percent of the total load to the Southern Chain of Lakes."

The TMDL for Lake Haines calls for a 70 percent reduction in TP loads. While it is explicitly stated that both surface water and groundwater loads are considered together as the external loads that the 70 percent reduction is intended to address, the actual data collected on groundwater inflow rates (PBS&J 2009) is not included in the TMDL.

The annual groundwater TP loads measured by PBSJ (2009) through direct measurement were much higher than the TMDL results for lakes in the Winter Haven Chain of Lakes. The annual groundwater TP load to Lakes Haines, Conine and Rochelle were 83, 57 and 68% greater than the loads modeled for the TMDL, respectively. In the TMDL, TP concentrations were derived from one well with 3 water quality samples in 6 years for the calculation of groundwater seepage. In contrast, a total of 19, 24, and 22 direct TP measurements were used to calculate the average groundwater concentration to Lakes Haines, Conine and Rochelle. The average TP concentrations calculated by direct measurement were 0.14, 0.05 and 0.10 mg/l for Lakes Haines, Conine and Rochelle, respectively. In contrast, the average TP concentration from the surficial aquifer well at Lake Eloise was 0.021 mg/l.

The TMDL for Lake Haines (EPA 2006b) appears to be problematic for a number of reasons:

- The TMDL for Lake Haines does not appear to address or note the basis for what appears to be a substantial reduction in Chl-a concentrations (Figure 5.1; EPA 2006) from the early 1990s to the early 2000s; if a lake management action was involved, it is important to identify that activity.
- In both a prior report (PBS&J 2008) and data analysis conducted here, there was no evidence of a statistically significant relationship between concentrations of TP and Chl-a in Lake Haines, suggesting that reductions in the concentrations of TP may not have any impact on phytoplankton levels.
- Although groundwater seepage rates and groundwater loading estimates are available for Lake Haines for both TN and TP (PBS&J 2009) those data were collected after the TMDL was developed, and no revised TMDL is yet available to incorporate the locally-collected groundwater nutrient budget.
- The discrepancy between the magnitude of the amount of reduction in external TP loads called for in the TMDL (70 percent) vs. the TP concentration reduction required to meet NNC guidance (4 percent) is more than an order of magnitude difference, suggesting that one or both approaches are problematic.

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Haines (EPA 2006b).

Lake Hancock (WBID 1623L) TMDL

Basis for Impairment

Lake Hancock was verified as impaired for nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code). The lake and Lower Saddle Creek were included on the Verified List of impaired waters that was adopted by Secretarial Order on June 17, 2005. Lake Hancock was listed as being impaired for dissolved oxygen (DO) and nutrient during the Verified Period for Group 3 waterbodies.

Lake Hancock has been characterized as having "poor" water quality, using the State of Florida's Trophic State Index (TSI), since at least 1970 (Polk County 2005), and concerns over poor water quality in the lake have existed as far back as the 1950s (ERD 1999). More recently, Lake Hancock's water quality was verified as impaired for nutrients based on data collected between January 1997 and June 2004 (EPA, 2005). Levels of total nitrogen, total phosphorus and biological oxygen demand exceeded the State of Florida's threshold screening values, all by considerable amounts (FDEP 2005b). The poor water quality in Lake Hancock has prompted a number of reports focusing on strategies to improve its condition.

TMDL Summary

Water Quality Targets

The TMDL for Lake Hancock (FDEP 2005) determined that there were two permitted and current wastewater treatment plant (WWTP) discharges to the lake. For non-point sources, the TMDL (FDEP) noted that stormwater systems owned and operated by local governments and the Florida Department of Transportation are covered by an NPDES MS4 permit.

Based on a paleolimnological study (Brenner et al., 2002) it was determined that Lake Hancock had been hypereutrophic for at least the last 100 years. In prior work for the Winter Haven Chain of Lakes, Whitmore and Brenner (1995) found that the historical conditions for five other lakes in Polk County (Lakes Conine, Haines, Hartridge, Howard and May) were that of lakes that were mesotrophic to eutrophic. As a result, the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007) was based on the attainment of a target TSI value of 60.

The water quality target setting process for Lake Hancock is somewhat unusual, in that the target TSI value was based on the use of linked watershed and water quality response models to determine water quality conditions prior to human impacts, and then an acceptable amount of water quality deterioration was applied to allow for target setting. The Lake Hancock TMDL (FDEP 2005b) used the Watershed Assessment Model (WAM; Soil and Water Engineering Technology, Inc., 2005) to estimate pollutant loads, and WAM output was then the input for the BATHTUB model (Quantitative Environmental Analysis, LLC, 2005) to simulate water quality within Lake Hancock.

The WAM model was then run with natural land uses (and no point source discharges) to estimate pollutant loads from an undeveloped watershed, and then loads were then input into BATHTUB to estimate a "natural background" TSI value.

However, Lake Hancock's water quality is so much worse than even the most hypereutrophic lakes in that target setting was extremely difficult. After running the linked WAM and BATHTUB models, it was decided that the best estimate for a natural background for Lake Hancock would require a lake leakage estimate of 50 percent of current conditions, and the reduction of a "missing mass" estimate of 75 percent of current conditions to estimate historical water quality conditions. These two modifications were invoked because the modelers could only use current conditions to try and calibrate their models, and model calibration invoked changes that were thought to be inaccurate when trying to derive "natural" water quality conditions. In essence, it is suggested (FDEP 2005) that the amount of water loss to the aquifer system is greater now than historically, and that the vast amount of "missing mass" of nutrients needed for model calibration under current conditions would not be required historically.

With these modifications, model runs for historical conditions suggested that the pre-development water quality condition for Lake Hancock would be equivalent to a TSI value of 69.4. FDEP's practice has been that when background conditions can be established, TSI targets can be set at a level of background TSI values plus 5, for a target TSI for Lake Hancock of 74.4.

The TMDL for Lake Hancock calls for 75.2 and 75.5 percent load reductions for Total Nitrogen (TN) and Total Phosphorus (TP), respectively. There are two permitted discharges of point source loads identified in the Lake Hancock TMDL (FDEP 2005b). However, their contribution to the lake's estimated TN and TP loads were only 0.36 and 0.19 percent, respectively.

Since point source discharges into Lake Hancock are so minor (< 1 percent of total loads) the call for external load reductions are of such a magnitude (> 75 percent) that they are impossible to bring about with any known technology of stormwater treatment, even if applied to 100 percent of the watershed of the lake. While there is a statistically significant correlation found between TN and Chl-a in Lake Hancock, quite a few of the TN values are higher than 2.8 mg/L, and cannot be ascribed to stormwater loads alone, as those values are higher than the highest Event Mean Concentration (EMC) values shown for both urban and agricultural land uses in Harper and Baker (2007). Instead, it is more likely that the highest TN concentrations are likely reflecting the influence of nitrogen fixation by cyanobacteria, as has been previously documented in Lake Hancock (Tomasko et al. 2009) and Lake Jesup (PBS&J 2006). There is also a statistically significant relationship between TP and Chl-a. The r-square value of the relationship between TP and Chl-a is 0.06, suggesting that only about 6 percent of the variation in Chl-a values is explained by variation in concentrations of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Hancock (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 89 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 77 and 83 percent, respectively. However, TN concentrations in Lake Hancock are likely elevated via nitrogen-fixation by cyanobacteria.

Pollutant Loading Model

The pollutant loading model for the Lake Hancock TMDLs incorporates standard spreadsheet-derived loading estimate, based on rainfall, runoff, and EMC values for TN and TP. The pollutant loads developed from the Watershed Assessment Model (WAM) were the input into the BATHTUB water quality model, as described above.

WAM predicts stormwater loads of nutrients based on inputting data on rainfall, soils, and land use classifications. WAM has the ability to attenuate stormwater loads via features such as wetlands, depressional areas, and model input related to the distribution of Best Management Practices (BMPs) within the watershed. WAM estimates stormwater pollutant loads via GIS-based inputs of data on land use classifications (using FLUCCS) and soils, as driven by rainfall. WAM also allows for the attenuation of generated pollutant loads via wetlands and/or BMPs, if such data are available in GIS for the watershed.

WAM allows for the simulation of surface flows and groundwater inflow on a daily basis, and these daily flow estimates can be "processed" in the model via information related to topographical relief, channel configurations, etc. This feature allows for loads to be attenuated along the pathway from the watershed to the conveyance system and then on to the water body of interest. Literature-derived "attenuation algorithms" are applied to the calculated stormwater inflows.

The ability of WAM to attenuate modeled loads via BMPs, wetlands and stream channels is an important improvement over more simplistic pollutant loading models. However, the pollutant loading model as described in the TMDL is not actually "calibrated" via comparison of model output of stormwater loads to measured data. As is the case with other pollutant loading models used in Polk County, there does not appear to be an exercise within the TMDL for which model output on pollutant loads is compared to measured data of flows and concentrations. Instead, the pollutant loading model and the water quality model are "calibrated" against in-lake concentrations. More often than not, this model calibration effort is accomplished via the modification of rate coefficients that have never been locally measured.

The first model runs for "existing conditions" where WAM output on pollutant loads were used in BATHTUB, resulted in model runs where measured TN and TP values that were four to seven times higher than high model output. Clearly, the combination of WAM and BATHTUB did not sufficiently characterize the water quality of Lake Hancock.

To accommodate the discrepancy between model output and measured data for existing conditions, model calibration for TN and TP was achieved by the incorporation of a term referred to as the internal loading function. The term "internal loading rate" is not fully described, but the TMDL report states that this internal loading rate is meant to include not only in-lake processes such as sediment resuspension (for TP) and nitrogen fixation (for TN) but "…all other missing mass." Figures 5.1 and 5.2 show the differences between the initial model runs of TN and TP respectively vs. measured data, and also how the calibration step of invoking internal loading results in model output that exactly matches measured data. In essence, the TMDL for Lake Hancock used a two-step process: 1) initial model runs resulted in significant underestimates of the TN and TP concentrations in the lake, 2) a model factor referred to as internal loading was then used to "calibrate" model output so that modeled and measured data would exactly coincide, similar to what was done to calibrate the water quality model for Banana Lake.

With any model, the term "calibration" refers to the process through which the modification of a state variable or rate coefficient is conducted in an attempt to better align model output and measured data. Ideally, model calibration would involve relatively minor adjustment to model components, using state variables or rate coefficients that had been measured directly, hopefully in a somewhat similar environment. In the case of the Lake Hancock TMDL, model calibration was not based on any measured processes (e.g., bottom resuspension, in-situ nitrogen fixation) from any nearby lake. In fact, it appears that calibration involved simply using the term "internal process" as a substitute for all the potential reasons why model output and measured values differed by so much. Since measured data on TN and TP were often many times higher than model output, this seriously compromises the validity of the TMDL. The lack of sufficient knowledge of the actual mechanisms behind the discrepancies between modeled and measured TN and TP values could result in a TMDL model that is calibrated via the modification of model variables that are not representative of actual field conditions.

Four main considerations suggest that the TMDL for Lake Hancock requires significant review prior to implementation: 1) measured water quality has up to seven times the level of TN and TP, respectively, vs. initial model runs, 2) calibration of the water quality model was accomplished via the inclusion of a term called "internal loading" that is neither fully explained as to its processes, nor is it derived from actual measurements of any processes in Lake Hancock, 3) based on prior work in Lake Hancock (Tomasko et al. 2009), it is likely that bottom resuspension of phosphorus-rich sediments could be a significant source of the excess and unaccounted for TP concentration in the lake, and 4) based on prior work in Lake Hancock (Tomasko et al., 2009), it is likely that nitrogen-fixation by cyanobacteria within Lake Hancock could be a significant source of the excess and unaccounted for TN concentrations in the lake.

Neither bottom resuspension of TP-rich sediments nor in-situ nitrogen fixation rates have been incorporated into the TMDL for Lake Hancock, the model calibration effort included in the TMDL (FDEP 2005b) is problematic. In terms of meeting TMDL obligations, since neither bottom resuspension of TP rich sediments nor nitrogen fixation are processes included in the water quality model, they are not processes through which TMDL load allocation credits could be applied.

Further work is justified, focusing on the discrepancies above, prior to the investment of time and resources to implement the TMDL for Lake Hancock (FDEP 2005b).

Lake Hollingsworth (WBID 1549X) TMDL

Basis for Impairment

Lake Hollingsworth is classified as a Class III freshwater waterbody, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the verified impairments (nutrients) for this water is the state of Florida's nutrient criterion in Paragraph 62-302.530(47) (b), Florida Administrative Code (F.A.C.).

FDEP (2014c) had determined that Lake Hollingsworth was impaired for nutrients using the methodology in the Identification of Impaired Surface Waters Rule [IWR, Rule 62-303, Florida Administrative Code, (F.A.C.)] and was included on the Verified List of impaired waters for the Sarasota Bay – Peace River – Myakka River Group 3 Basin that was adopted by Secretarial Order on June 17, 2005. FDEP verified the lake as being impaired for nutrients based on elevated annual average Trophic State Index (TSI) values during the cycle 1 verification period (January 1997 to June 2004). At the time the cycle 1 assessment was performed, the IWR methodology used the water quality variables total nitrogen (TN), total phosphorus (TP), and chlorophyll-a to calculate annual TSI values. An exceedance of an annual average TSI value of 60 in any single year of the verified period is sufficient for identifying a lake as impaired for nutrients. As every annual mean TSI value from 1996 to 2002 exceeded 60 in the cycle 1 period, and also for the cycle 2 period as well (January 2002 to June 2009), Lake Hollingsworth easily met the criteria for being declared impaired for nutrients.

Florida has newly adopted lake criteria for total nitrogen (TN), total phosphorous (TP) and chlorophyll-a (62-302.531, F.A.C.). While EPA has reviewed and approved the new numeric nutrient criteria (NNC) in terms of its scientific validity, the NNC are not fully adopted by EPA, pending the opportunity for third party interveners to comment on the proposed new rules. While FDEP has not formally examined Lake Hollingsworth using NNC, a preliminary assessment by FDEP has found that Lake Hollingsworth would still be impaired with NNC, as it is with the use of Trophic State Index (TSI).

TMDL Summary

Water Quality Targets

Lake Hollingsworth is classified as a lake with low color (<40 PCU) and high alkalinity (>20 mg/L CaCO3). The new chlorophyll-a NNC for low color, high alkalinity lakes is an annual geometric mean value of 20 µg/L, which is not to be exceeded more than once in any consecutive three-year period. As Lake Hollingsworth exceeded NNC guidance for chlorophyll-a, it's default threshold values for TN and TP would be 1.05 and 0.03 mg/L, respectively, using NNC.

However, a more detailed assessment was conducted to develop TN and TP targets for Lake Hollingsworth. For TN, a regression equation that examined the relationship between TN and chlorophyll-a was used to derive the TN concentration that would result in a chlorophyll-a value of 20 µg/L. Based on the derived equation, a TN concentration of 0.86 mg/L would be expected to result in a chlorophyll-a concentration of 20 µg/L. That TN concentration was used as the target for Lake Hollingsworth.

The selection of a TP target for Lake Hollingsworth was complicated by a discrepancy between two different approaches to setting targets. The TN target of 0.86 mg/L was chosen based on the correlation between TN and chlorophyll-a, and solving the equation for the TN target that corresponds to a chlorophyll-a concentration of 20 µg/L. Using this approach for TP, the target TP value for Lake Hollingsworth would be approximately 0.015 mg/L. However, a paleolimnological study conducted on Lake Hollingsworth (Brenner et al. 1999) determined that TP values would have historically been somewhere between 0.020 and 0.036 mg/L, values 33 and 140 percent higher than the derived TP target (based on a chlorophyll-a vs. TP relationship) described above. FDEP's guidance is that no water quality standard can be stricter than conditions in an undisturbed condition, therefore it was concluded (FDEP 2014) that the derived value of 0.015 mg TP/L was inappropriate. Instead, the higher of the two values for "historical" TP values from the paleolimnological study (Brenner et al. 1999) was used, and the TP target for Lake Hollingsworth was subsequently set at 0.036 mg/L.

Pollutant Loading Model

As opposed to most of the TMDLs produced by FDEP, the TMDL for Lake Hollingsworth is empirically derived based on relationships between nutrients and chlorophyll-a, as modified with results from paleolimnological studies. Consequently, there are no requirements that reduced nutrient concentrations have to be achieved by acting on external loads of TN and TP. Instead, lake management activities to meet the TMDL targets for TN and TP can be based solely on reducing nutrient concentrations by acting on internal processes such as bottom resuspension, by increasing the uptake of nutrients via submerged aquatic vegetation, or by increasing the role of wetlands as a moderating influence on the transformation of nutrients into algal biomass.

While the TMDL for Lake Hollingsworth summarized land use within the lake's watershed, there are no estimates of external loads to the lake. Instead, lake management activities to meet the TMDL targets for TN and TP can be based solely on reducing nutrient concentrations by acting on internal processes such as bottom resuspension, by increasing the uptake of nutrients via submerged aquatic vegetation, or by increasing the role of wetlands as a moderating influence on the transformation of nutrients into algal biomass. While this approach may seem counter-intuitive to those who are more familiar with "traditional" TMDLs, it is consistent with data from the lake itself. For example, Figure 5.3 in the TMDL shows a strong inverse relationship between rainfall and chlorophyll-a values on an annual basis; years with the highest quantities of external stormwater loads do not have the worst water quality, they have the best water quality, on average. As such, acting on external stormwater loads alone is not likely to bring about improvements in water quality. By not focusing on external loads (in fact, not even quantifying them) the TMDL allows lake managers to act on those factors that are most important to the lake's water quality.

The percent reductions in TN and TP are based on the following equation:

$$\frac{[\text{Measured exceedance} - \text{target}] \times 100}{\text{Measured exceedance}}$$

The measured exceedances in this case are the medians of the TN and TP annual geometric mean values that exceed the water quality targets. For the existing geometric mean TN value of 1.78 mg/L to achieve the target TN concentration of 0.86 mg/L, a 52 percent reduction in TN concentrations is necessary. A 57 percent reduction in the existing annual geometric mean TP concentration of 0.07 mg/L is needed to meet the target TP concentration of 0.036 mg/L. Based on a statistical relationship from Florida lakes in general, the target of 0.036 mg TP/L derived above was then converted into an annual geometric mean value of 0.033 mg TP/L, which serves as the final TP target for Lake Hollingsworth.

The TMDL for Lake Hollingsworth (2014c) appears to be less problematic than most of the other TMDLs for Polk County Lakes. The TMDL is based on empirically-derived relationships, which are then compared to NNC criteria and results from paleolimnological studies. The TMDL also allows for the possibility that in-lake processes can be used to achieve water quality goals, a major oversight for most other TMDLs. The combination of using actual data, rather than overly complex mechanistic models, and the inclusion of in-lake processes makes the TMDL more realistic than most. It will be a serious challenge for Polk County to achieve the water quality improvements laid out in this TMDL, but the targets are more realistic than those of most other TMDLs.

Lake Howard (WBID 1521F) TMDL

Basis for Impairment

Lake Howard is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303, Florida Administrative Code).

The Final TMDL for Lake Howard is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. For Lake Howard sufficient data were only for the years of 1992 to 1997, and again in 1999. The annual average TSI value exceeded the established target of 60 in 6 of those 7 years, with a mean annual average TSI value of 63.5. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Howard easily exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Howard) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Howard.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake Howard (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity

- As affected by phosphorus concentrations

- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Howard information is available on most, but not all, of the state variables listed above. However, there does not appear to be any local data from Lake Howard on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients, which represent biological processes in mechanistic models such as WASP, do not appear to be available from Lake Howard itself.

The TMDL for Lake Howard calls for 62.5 percent reductions in external TP loads. There is a statistically significant correlation found between TP and Chl-a in Lake Howard, with an r-square value for this correlation of 0.02, suggesting that only 2 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Howard (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 34 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 33 and 15 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Howard (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake Howard, the TMDL (FDEP 2007) calls for a 62.5 percent reduction in stormwater loads. It was noted as well that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has control over; they are not responsible for reducing other nonpoint source loads in their jurisdiction.

The pollutant loading model for the Lake Howard TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005. The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$POFF = RCOEF * WFLOW^{WASPRO}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$POFF = RCOEF * WFLOW$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from "average" EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that "There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999." As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP's TMDL (PBS&J 2009).

For eight lakes included in FDEP's 2007 TMDL for the Southern Chain of Lakes (but not Lake Howard) WASP was "calibrated" for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake Howard requires significant review prior to implementation: 1) the water quality targets used are based on TSI, not NNC, 2) prior work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured, and 4) despite the fact that Lakes Shipp, May and Lulu (also in the Winter Haven Chain of Lakes) have met or exceeded the TP reduction targets contained in their individual TMDLs, there is no evidence of improved water quality in those three lakes (PBS&J 2008).

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Howard (FDEP 2007).

Lake Hunter (WBID 1543) TMDL

Basis for Impairment

Lake Hunter is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the method in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Hunter (FDEP 2004) , adopted by FDEP and approved by EPA, used water quality data from 1988 to 2002 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. As such, TSI values were not calculated in 1988, 1989, 1990, and 1995 due to insufficient data. Annual average TSI values exceeded the threshold value of 60 in all of the years where sufficient data existed (1991 through 1994, and also 1996 to 2002) with an annual average TSI value (for those years with sufficient data) of 79.7. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Hunter easily exceeded the impairment threshold.

TMDL Summary

Water quality targets

The TMDL for Lake Hunter (FDEP 2004) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2004) noted that stormwater systems owned and operated by local governments and the Florida Department of Transportation are covered by a Municipal Separate Storm Sewer System (MS4) National Pollutant Discharge Elimination System (NPDES) permit.

The water quality target setting process for Lake Hunter was inconsistent with other TMDL efforts in Polk County, which have mostly used the mechanistic water quality model components of WASP or BATHTUB nor did it use a more traditional empirical approach whereby nutrient loads (or concentrations) would be compared to a potential response variable such as chlorophyll-a. Instead, chlorophyll-a concentrations, as the primary response variable, were predicted based on a series of equations (FDEP 2004), as shown below:

Chlorophyll-a concentrations in the lake (µg/L) were predicted using the following equation:

$Chla = Cc \times Bx / [(1 + 0.025\ Bx \times G)\ (1 + G \times a)\}$

Where;

Cc is a calibration coefficient (to better fit predicted vs. observed values) set at 1.6

Bx is derived from the following equation:

$Bx = Xpn^{1.33}/4.31$, where:

$Xpn = \{p^{-2} + [(n - 150)/12]^{-2}\}^{-0.5}$, where:

p = concentration of TP (µg/L), and

n = concentration of TN (µg/L)

Where:

G = Zmix (0.14 + 0.0039 Fs), where

Zmix = mean depth of mixed layer (m), and

FS =flushing rate of the lake (estimated elsewhere in the report)

Where:

a – non-algal turbidity (m-1), where:

$a = S^{-1} – 0.025$ (Chla), where:

S = Secchi disk depth, approximated as:

$S = Cs\ 16.2 \times Xpn^{-0.79}$; where

CS is given a value of 1, and Xpn is as defined above

Of the equations shown above which are used to predict chlorophyll-a concentrations in Lake Hunter, the only directly measured water quality parameters in those series of equations are TN, TP and Chl-a. As such, most of the equations used to predict water quality are based, directly or indirectly, on assumptions or derived coefficients that are themselves either assumed or are further derived from additional assumptions. The equations themselves appear to be based on logical assumptions of water quality "behaviour" but they are not locally measured, and they may not be locally relevant. For Lake Hunter, it would appear that nutrient load reduction targets derived in the TMDL might be somewhat spurious.

The TMDL for Lake Hunter calls for 80 percent reductions in the loads of both TN and TP. While there is a statistically significant correlation found between TN and Chl-a in Lake Hunter, the majority of TN values higher than 2.4 mg/L cannot be ascribed to stormwater loads alone, as those values are higher than the highest Event Mean Concentration (EMC) values shown for urban land uses in Harper and Baker (2007). Instead, it is more likely that the highest TN concentrations (>2.4 mg/L) are likely reflecting the influence of nitrogen fixation by cyanobacteria, as has been previously documented in Lake Hancock (Tomasko et al. 2009) and Lake Jesup (PBS&J 2006). A comparison of TP and Chl-a concentrations from IWR Run 47 found no significant correlation between those two parameters.

Based on an examination of water quality data during the Verified Impaired time period for Lake Hunter (IWR Run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 79 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 57 and 79 percent, respectively. However, TN concentrations in Lake Hunter are likely elevated via nitrogen-fixation by cyanobacteria, and there is no clear evidence that TP concentrations correlate with Chl-a concentrations.

Pollutant Loading Model

The pollutant loading model for the Lake Hunter TMDL (FDEP 2004) used the Watershed Management Model (WMM) to estimate loads of TN and TP from stormwater runoff. The volume of stormwater runoff generated is based on the equation:

RL = [Cp + (CI – Cp) IMPL] * I

Where: RL = average surface water runoff;

Cp – pervious runoff coefficient;

CI = impervious area runoff coefficient;

IMPL = fraction of the land use that is impervious; and

I = average rainfall

The volume of stormwater runoff generated is them converted into a loading rate of pollutants via the equation:

ML = EMCL*RLI*K

Where: ML = loading factor for each land use (lbs. per acre per year);

EMCL = land use specific event mean concentration (mg / liter);

RL = average surface water runoff (calculated above); and

K = a unit conversion equation

As such, WMM uses an approach similar to a standard spreadsheet-derived loading estimate, with stormwater pollutant quantities based on GIS-based data on soils and land use, rainfall, estimated runoff, and then EMC values for TN and TP. EMC values came from Harper (2002).

As is the case with other pollutant loading models used in Polk County, there does not appear to be an exercise within the TMDL for which model output on pollutant loads is compared to measured data of flows and concentrations. Instead, the pollutant loading model and the water quality model are "calibrated" against in-lake concentrations. More often than not, this model calibration effort is accomplished via the modification of rate coefficients that have never been locally measured (e.g., TP settling rates).

Additional pollutant loading model elements are included, such as atmospheric deposition, groundwater inflows, and inflows from upstream areas. Septic tanks are assumed (based on Haith et al. 1992) to load potentially significant amounts of TN to the lake, in part due to the model not accounting for denitrification (nitrate loads are removed from groundwater only via plant uptake). Perhaps related to the potentially over-estimated influence of septic tank systems, the TMDL predicts that unimpaired water quality would occur only after TN and TP loads from stormwater are reduced by 80 percent and septic tank systems are replaced with central sewage throughout the watershed. In an earlier TMDL for a different water body, however, it was determined by FDEP that thousands of septic tank systems had a negligible effect on downstream TN loads into Roberts Bay (FDEP 2005c).

Four main considerations suggest that the TMDL for Lake Hunter requires significant review prior to implementation: 1) the water quality targets are dependent upon a series of overly complex equations that are dependent, either directly or indirectly on numerous assumptions, 2) the relationship between TN and Chl-a could be strongly influenced by TN "made" by nitrogen-fixing cyanobacteria, rather than Chl-a being controlled by TN itself, 3) there is no statistically significant correlation between TP and chlorophyll-a, 4) the pollutant loading model appears to not sufficiently account for the potential role of in-lake processes for both TN and TP, and 5) the role of septic tank systems on the TN load is assumed, not measured, and is at odds with estimates of such loads from other systems.

Further work is justified, focusing on the discrepancies above, prior to the investment of time and resources to implement the TMDL for Lake Hunter (FDEP 2004).

Lake Idylwild (WBID 1521J) TMDL

Basis for Impairment

Lake Idylwild is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The final TMDL for Lake Idylwild is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. For Lake Idylwild, sufficient data were available only for the years of 1997 to 1999. The annual average TSI value exceeded the established target of 60 only in one of those three years (1998), with a mean annual average TSI value of 59.8. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Idylwild exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The State of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Idylwild) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Idylwild.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake Idylwild (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Idylwild, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Idylwild on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Idylwild itself.

The TMDL for Lake Idylwild calls for a 43 percent reduction in external TP loads. There is a statistically significant correlation found between TP and Chl-a in Lake Idylwild, with an r-square value of 0.03, suggesting that only 3 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Idylwild (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 22 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 12 and 8 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Idylwild (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake Idylwild, the TMDL (FDEP 2007) calls for a 43 percent reduction in stormwater loads for TP. It was noted as well that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has control over; they are not responsible for reducing other nonpoint source loads in their jurisdiction.

The pollutant loading model for the Lake Idylwild TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005. The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$POFF = RCOEF * WFLOW^{WASPRO}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$POFF = RCOEF * WFLOW$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from "average" EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that "There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999." As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP's TMDL (PBS&J 2009).

For the eight lakes included in FDEP's 2007 TMDL for the Southern Chain of Lakes (including Lake Idylwild) WASP was "calibrated" for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake Idylwild requires significant review prior to implementation: 1) the water quality targets used are based on TSI, not NNC, 2) prior work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured, and 4) despite the fact that Lakes Shipp, May and Lulu (also in the Winter Haven Chain of Lakes) have met or exceeded the TP reduction targets contained in their individual TMDLs, there is no evidence of improved water quality in those three lakes (PBS&J 2008).

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Idylwild (FDEP 2007).

Lake Jessie (WBID 1521K) TMDL

Basis for Impairment

Lake Jessie is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Jessie is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. For Lake Jessie sufficient data were available for the years of 1992, and then 1995 to 1999. The annual average TSI value exceeded the established target of 60 in 5 of those 6 years, with a mean annual average TSI value of 62.2. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Jessie easily exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Jessie and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Jessie) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Jessie.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake Jessie (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton

    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Jessie, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Jessie on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Jessie itself.

The TMDL for Lake Jessie calls for 50 percent reductions in external TP loads. There is a statistically significant correlation found between TP and Chl-a in Lake Jessie, with an r-square value of 0.02, suggesting that only 2 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Jessie (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 27 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 7 and 17 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Jessie (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake Jessie, the TMDL (FDEP 2007) calls for a 50 percent reduction in stormwater loads of TP. It was noted as well that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has control over; they are not responsible for reducing other nonpoint source loads in their jurisdiction.

The pollutant loading model for the Lake Jessie TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005. The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$POFF = RCOEF * WFLOW^{WASPRO}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$POFF = RCOEF * WFLOW$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from "average" EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that "There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999." As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP's TMDL (PBS&J 2009).

For eight lakes included in FDEP's 2007 TMDL for the Southern Chain of Lakes (but not Lake Jessie) WASP was "calibrated" for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake Jessie requires significant review prior to implementation: 1) the water quality targets used are based on TSI, not NNC, 2) prior work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured, and 4) despite the fact that Lakes Shipp, May and Lulu (also in the Winter Haven Chain of Lakes) have met or exceeded the TP reduction targets contained in their individual TMDLs, there is no evidence of improved water quality in those three lakes (PBS&J 2008).

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Jessie (FDEP 2007).

Lake Kissimmee (3183B) TMDL

Basis for Impairment

Lake Kissimmee is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake itself lies outside of Polk County, but its watershed extends into the County's boundaries. Lake Kissimmee was initially verified as impaired during Cycle 1 (verified period January 1998 to June 2005) due to excessive nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303, Florida Administrative Code), and was included on the Cycle 1 Verified List of impaired waters for the Kissimmee River Basin that was adopted by Secretarial Order on May 12, 2006. Subsequently, during the Cycle 2 assessment (verified period January 1, 2003 – June 30, 2010), the impairment for nutrients was documented as continuing, as the Trophic State Index (TSI) threshold of 40 (when color is 40 PCU or less) was exceeded in 2007 and the threshold of 60 (color greater than 40 PCU) in 2008.

The TMDL establishes the allowable loadings to the lake that would restore the waterbody so that it meets applicable water quality narrative criteria for nutrients. The Final TMDL for Lake Kissimmee (FDEP 2011b) used water quality data from 1979 to 2009 to calculate TSI values for the lake. Impairment for nutrients was documented during the Cycle 2 verified period, which was from January 2003 to June 2010. The IWR methodology uses the water quality variables total nitrogen (TN), total phosphorus (TP), and corrected chlorophyll-a to calculate annual average TSI. For Lake Kissimmee, data were sufficient to calculate TSI values for all four seasons in each year of the Cycle 1 verified period (1998 to 2005) and also for the years 2003 to 2009 of the verified period for Cycle 2. During Cycle 1, the annual average value for color (in Platinum Cobalt Units; PCU) was greater than 40 PCU for each year and thus the TSI target of 60 was used. Annual average TSI values exceed 60 during the years 1998, 1999 and 2001. During Cycle 2, the annual average value for color was 38 PCU in 2007 and so the lower TSI target of 40 was used; this target was exceeded by the 2007 TSI value of 59. FDEP (2011b) points out that 2007 was one of only two years, over a 30 year period of record, where annual average values for color were less than 40 PCU. In 2008, color values averaged 57 PCU, and the TSI target went up to 60; that year's annual average value of 64 exceeded the more lenient nutrient standards applicable under high color conditions. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Kissimmee easily exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

For the Lake Kissimmee TMDL, FDEP (2011b) used Hydrologic Simulation Program FORTRAN (HSPF) model to determine the appropriate nutrient target. The HSPF was first used to estimate existing conditions in the Lake

Kissimmee watershed, and results were then compared to model runs for "background" conditions by setting land uses to natural land use patterns. FDEP's guidance is that if background TSI values can be reliably determined, an increase of 5 TSI units above background will be the water quality target used for TMDL development.

Based on model runs, the HSPF-estimated average TSI value for an undeveloped watershed was 52.8, and that Lake Kissimmee was historically phosphorus limited, based on estimated TN: TP ratios of 38.5 from the background condition. By adding the 5 unit TSI increase on top of the historical TSI estimate, the target TSI value for Lake Kissimmee was thus determined to be 57.8 (FDEP 2011b) vs. a default impairment TSI value of 60 that would had been used for other lakes in Central Florida. Also, it is important to note that the TMDL for Lake Kissimmee is based upon the assumption that TN and TP load reductions proposed for the upstream impaired Lakes Marian, Jackson, and Cypress have been achieved.

However, the use of TSI for water quality target setting is out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, and TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008). The TMDL for Lake Kissimmee (FDEP 2011b) notes that Lake Kissimmee would be classified as a high color lake for all but two of the last 30 years (i.e., 1979 to 2009).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Kissimmee) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Kissimmee.

The TMDL for Lake Kissimmee calls for percent reductions in external TN and TP loads of 5 and 25 percent, respectively. In a review of the TMDL for Lake Kissimmee, Atkins (2013) found that both TN and TP concentrations were positively correlated with chlorophyll-a concentrations, with r-square values of 0.034 and 0.058, respectively, suggesting that variation in nutrient concentrations explain only 3 to 6 percent of the variation in chlorophyll-a concentrations.

Based on an examination of water quality data during the period of 1999 to 2009 for Lake Kissimmee the mean reduction in chlorophyll-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 9 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would, again, be 9 percent for both nutrients.

Pollutant Loading Model

The water quality target for Lake Kissimmee is based on a TSI target of 57.8, which is based on the use of HSPF, which determined that the TSI value of Lake Kissimmee in an undisturbed condition would be 52.8.

The TMDL for Lake Kissimmee used the Hydrologic Simulation Program – Fortran (HSPF) model.

The external load assessment conducted using HSPF was intended to determine water quality responses to modeled nutrient loads. The loading characteristics of the various sources of pollutants to Lake Kissimmee by incorporating data on topography, land use/land cover, soil types and rainfall to develop estimates of the volume of stormwater runoff to the lake, as well as the timing, volume and concentrations of pollutants.

Characterizations of the watershed were based on the use of the Florida Land Use, Cover and Forms Classification System (FLUCCS) into nine different land use categories. The various land use/land cover categories were aggregated into nine larger categories, described here: cropland/improved pasture/tree crops (i.e., agriculture), unimproved pasture/woodland pasture (pasture), rangeland/upland forests, commercial/industrial, high density residential (HDR), low density residential (LDR), medium density residential (MDR), water, and wetlands. Land use maps were based on data provided by the South Florida Water Management District in 2000.

Of particular importance to Polk County, the Lake Kissimmee TMDL was based on an estimate that of the total Polk County households within the Lake Kissimmee watershed, 43 percent of those houses were estimated to use septic tank systems, and so the number of houses per sub-basin were then estimated to have a septic tank system load that was associated with approximately 43 percent of those houses not having connections to wastewater collection and either local or regional treatment plants.

Three main approaches were used to determine hydrologic loads to Lake Kissimmee from both its immediately adjacent watershed and those lakes that are located farther upstream in the Upper Kissimmee Chain of Lakes system. The IMPLND module of HSPF was used to estimate runoff from impervious surfaces of those land areas where FLUCCS indicated there was impervious area. For those portions of the watershed where impervious areas are not expected, the PERLND module of HSPF was used to estimate both runoff and baseflow. The model estimated the amount of pervious area by subtracting the amount of land estimated to have pervious area in each FLUCCS category from the total amount of area, for each sub-basin. Rainfall that was not modeled to turn into surface runoff (for both pervious and impervious land uses) was assigned by the model to become infiltration into soils. The volume of infiltrated soils was then processed via evapotranspiration, discharge as baseflow, or it was "lost" via percolation to deeper aquifers. Rainfall onto the major land use categories of water and wetlands was processed in the model as if those two landscapes were pervious, but with lower rates assigned for infiltration and storage in surface soils.

The RCHES module of HSPF then used output from the PERLND and IMPLND modules to convey flows from those modules, and to account for direct atmospheric deposition onto open waters and evaporation. These estimated flows are then based on rating curves developed by the HSPF user. These flows were then used to estimate stormwater loads, via techniques described below.

For pervious lands, TSS loads were quantified based on estimates of the amount of sediments that are "detached" from the landscape by rainfall, thus becoming available for subsequent "wash-off". For constituents other than TSS, the amount of those pollutants was estimated by the use of a "potency factor". Potency factors were estimates of the amount of non-TSS pollutants that would be expected to be loaded via wash-off as a function of the amount of TSS loaded.

In Table 5.9 of the TMDL (FDEP 2011b) a summary of area-normalized nutrient loads are displayed, in terms of the amount of different forms of pollutants generated per acre of watershed per year. Results are given for different land use types for different soil types. The results shown in Table 5.9 suggest that inorganic forms of both nitrogen and phosphorus are fairly substantial percentages of the total amount of nutrients loaded via stormwater runoff. For example, commercial landscapes on poorly-drained D-type soils are given a TN loading rate of 12.3 lbs. TN / acre / yr. For the same land cover and soil combination, the amount of that load attributed to the inorganic forms of nitrogen of ammonia and nitrate plus nitrite is estimated at 5.1 lbs. TN / acre / yr. Put another way, inorganic nitrogen is estimated to account for 41 percent of the TN load from those areas. In contrast, Smith (2010) summarized the nitrogen makeup of more than 900 Florida stormwater samples and found that dissolved inorganic nitrogen made up only about 31 percent of TN loads from stormwater, a number that matched up well with estimates from Rushton et al. (1997), where inorganic nitrogen made up 28 percent of the TN in stormwater samples. For phosphorus, inorganic forms of phosphorous account for 66 percent of the estimated load of TP from commercial /industrial landscapes on D-type soils, which may be a similar, yet relatively minor, over-estimate.

The nutrient yields (lbs per acre per year) for the urbanized watershed features of the landscape tend to fall within the range of estimates (after conversion to units of kg / ha / yr) developed for most watersheds in the US (i.e., Stacey et al. 2000). These watershed-level loads were then summed and served as input to the water quality model for Lake Kissimmee, also run in HSPF.

The water quality portion of HSPF "balances" nutrients and chlorophyll-a values via a series of equations where by conversion of loads into phytoplankton biomass is simulated based on modifications of estimated maximum growth rates via adjustments due to water temperature, available light, and the amount of nutrients in the water column <u>in an inorganic form</u>. The amount of nutrients available in an inorganic form is estimated based on model output that uses the following processes:

- Decay of BOD and re-mineralization of nitrogen and phosphorus
- Settling of BOD to the lake bottom
- Phytoplankton growth and uptake of inorganic nutrients
- Respiration rates of phytoplankton
- Phytoplankton death rates
- Phytoplankton settling rates
- Nitrification within lake sediments
- Sediment nutrient fluxes (especially for phosphorus)

Based on discussions with several researchers at the University of Florida, it appears that perhaps only one or two of these rate coefficients have been measured in any Florida Lake. As such, the water quality model is dependent upon the accuracy of multiple and linked biological processes that haven't been measured in Lake Kissimmee. For the most part, the model's accuracy cannot be independently verified. While it is possible that the goodness of fit between measured data and model output is due to the model having very precisely estimated the many biological processes occurring in Lake Kissimmee, it is also possible that values appear to be aligned due to model errors canceling each other out.

Although there are a number of issues related to the use of water quality models, including the use of HSPF, an additional and significant issue related to the TMDL for Lake Kissimmee is that the lake does not appear to be impaired, when using NNC. Lake Kissimmee would not be declared impaired for nutrients using NNC, as there was only one year (2008) where chlorophyll-a and nutrient concentrations exceeded NNC guidance criteria during the period of 2000 to 2012. Guidance in NNC states that "impairment" is based upon not meeting criteria at least twice in any three year period. As such, a single years' exceedance of NNC criteria during the 13 years of 2000 to 2012 would not be sufficient for Lake Kissimmee to be declared impaired for nutrients.

Prior work in the Winter Haven Chain of Lakes has shown that water levels can be equally if not more important than stormwater loads in terms of influencing water quality (PBS&J 2008). Also in that report (PBS&J 2008) it was shown that high color lakes like Lake Kissimmee do not always exhibit a strong relationship between nutrient concentrations and chlorophyll-a levels, which is supported by the finding of very low r-squared values for the correlations between both TN vs. chlorophyll-a and between TP and chlorophyll-a.

The TMDL for Lake Kissimmee (2011b) appears to be problematic for a number of reasons:

- Using NNC as the State of Florida's current criteria for assessing nutrient impairment, Lake Kissimmee does not appear to be impaired for nutrients, at least not during the period of 2000 to 2012
- The very low r-squared values between nutrient concentrations (both TN and TP) and chlorophyll-a suggest that factors other than nutrient availability are more important influencers of algal biomass in the lake than nutrients alone
- The TMDL for Lake Kissimmee is based on the achievement of TMDL obligations in lakes that are located farther upstream in the Kissimmee Chain of Lakes system, including lakes which themselves have problematic TMDLs (e.g., Lake Cypress)

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Kissimmee (FDEP 2011b).

Lake Lena (WBID 1501) TMDL

Basis for Impairment

Lake Lena is classified as a Class III freshwater waterbody, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the verified impairments (nutrients) for this water is the state of Florida's nutrient criterion in Paragraph 62-302.530(47) (b), Florida Administrative Code (F.A.C.).

FDEP had determined that Lake Lena was impaired for nutrients based on elevated annual average Trophic State Index (TSI) values during the cycle 1 verification period (January 1997 to June 2004). At the time the cycle 1 assessment was performed, the IWR methodology used the water quality variables total nitrogen (TN), total phosphorus (TP), and chlorophyll-a. A single year's exceedance (annual average) of a TSI of 60 is sufficient for identifying a lake as impaired for nutrients. For Lake Lena, the annual mean TSI value exceeded 60 in 2003 during cycle 1. In the more recent cycle 2 verification period (January 2002 to June 2009) annual mean TSI values exceeded 60 in the years 2007 and 2008. Florida has newly adopted lake criteria for total nitrogen (TN), total phosphorous (TP) and chlorophyll-a (62-302.531, F.A.C.). While EPA has reviewed and approved the new numeric nutrient criteria (NNC) in terms of its scientific validity, the NNC are not fully adopted by EPA, pending the opportunity for third party interveners to comment on the proposed new rules. While FDEP has not formally examined Lake Lena using NNC, but a preliminary assessment by FDEP has found that Lake Lena would still be impaired with NNC, as it is with the use of Trophic State Index (TSI).

TMDL Summary

Water Quality Targets

Lake Lena is classified as a lake with low color (<40 PCU) and high alkalinity (>20 mg/L CaCO3). The new chlorophyll a NNC for low color, high alkalinity lakes is an annual geometric mean value of 20 µg/L, which is not to be exceeded more than once in any consecutive three-year period. As Lake Lena exceeded NNC guidance for chlorophyll-a, it's default threshold values for TN and TP are 1.05 and 0.03 mg/L, respectively, using NNC.

However, a more detailed assessment was conducted to develop TN and TP targets for Lake Lena. For TN, a regression equation that examined the relationship between TN and chlorophyll-a was used to derive the TN concentration that would result in a chlorophyll-a value of 20 µg/L. Based on the derived equation, a TN concentration of 1.14 mg/L would be expected to result in a chlorophyll-a concentration of 20 µg/L. That TN concentration was used as the target for Lake Lena.

The Lake Lena TMDL (FDEP 2014d) states that "…the TP annual geometric means did not exceed the applicable NNC of 0.03 mg/L more than once in any consecutive three year period." However, other parts of the TMDL (e.g., Figure 5.1) data clearly show that average TP values often exceed the NNC criteria of 0.03 mg TP/L. Since there was not a statistically significant relationship between TP and Chl-a concentrations in Lake Lena, the TMDL concluded that there was no need for a reduction in TP concentrations in the lake, as opposed to the need for TN reductions. However, the lake does not appear to meet NNC criteria for TP in many years (e.g., Figure 5.1; FDEP 2014) and the conclusion that TP concentrations do not exceed NNC criteria could be incorrect.

Pollutant Loading Model

As opposed to most of the TMDLs produced by FDEP, the TMDL for Lake Lena is empirically derived based on relationships between TN and chlorophyll-a. Consequently, there are no requirements that reduced nutrient concentrations have to be achieved by acting solely on external loads of TN. Instead, lake management activities to meet the TMDL targets for TN can be based on reducing nutrient concentrations by acting on internal processes such as bottom resuspension, by increasing the uptake of nutrients via submerged aquatic vegetation, or by increasing the role of wetlands as a moderating influence on the transformation of nutrients into algal biomass.

While the TMDL for Lake Lena summarized land use within the lake's watershed, there are no estimates of external loads to the lake. Instead, lake management activities to meet the TMDL targets for TN and TP can be based solely on reducing nutrient concentrations by acting on internal processes such as bottom resuspension, by increasing the uptake of nutrients via submerged aquatic vegetation, or by increasing the role of wetlands as a moderating influence on the transformation of nutrients into algal biomass. While this approach may seem counter-intuitive to those who are more familiar with "traditional" TMDLs, it is consistent with data from the lake itself. For example, Figure 5.3 in the TMDL shows a strong inverse relationship between rainfall and chlorophyll-a values on an annual basis; years with the highest quantities of external stormwater loads do not have the worst water quality, they have the best water quality, on average. As such, acting on external stormwater loads alone is not likely to bring about improvements in water quality. By not focusing on external loads (in fact, not even quantifying them) the TMDL allows lake managers to act on those factors that are most important to the lake's water quality.

The percent reductions in TN are based on the following equation:

$$\frac{[\text{Measured exceedance} - \text{target}] \times 100}{\text{Measured exceedance}}$$

The term "measured exceedance" as used in the TMDL for Lake Lena (FDEP 2014d) refers to the median values of the annual geometric mean values for TN that exceeded the water quality targets of 1.42 mg TN/L. The TMDL (FDEP 2014) lists a maximum geometric mean value of 1.98 mg TN/L; a 42 percent reduction in TN concentrations is required to meet the target TN value of 1.14 mg/L.

The TMDL for Lake Lena (2014d) appears to be less problematic than most of the other TMDLs for Polk County Lakes. The TMDL is based on empirically-derived relationships, which are then compared to NNC criteria. The TMDL also allows for the possibility that in-lake processes can be used to achieve water quality goals, a major oversight for most other TMDLs. The combination of using actual data, rather than overly complex mechanistic models, and the inclusion of in-lake processes makes the TMDL more realistic than most. However, it does appear that the TMDL is in error when it states that TP concentrations meet NNC criteria. It will be a serious challenge for Polk County to achieve the water quality improvements laid out in this TMDL, but the targets (for both TN and TP) appear to be more realistic than those of most other TMDLs.

Lake Lulu (WBID 1521) TMDL

Basis for Impairment

Lake Lulu is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Lulu is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. For Lake Lulu, sufficient data were available for all of those years except for 2003. The annual average TSI value exceeded the established target of 60 in 9 of those 10 years, with a mean annual average TSI value of 63.5. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Lulu exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The State of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Lulu) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Lulu.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake Lulu (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
  - As affected by temperature
  - As affected by light intensity
  - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
  - As affected by temperature
  - As affected by light intensity
  - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Lulu, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Lulu on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Lulu itself.

The TMDL for Lake Lulu calls for a 55 percent reduction in external TP loads. There is a statistically significant correlation found between TP and Chl-a in Lake Lulu, with an r-square value of 0.02, suggesting that only 2 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Lulu (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 31 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 24 and 23 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Lulu (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake Lulu, the TMDL (FDEP 2007) calls for a 55 percent reduction in stormwater loads for TP, which has been met by the various stormwater retrofit projects that have been constructed throughout the lake's watershed (PBS&J 2008). Despite meeting its TMDL load reduction goals, Lake Lulu is still impaired for nutrients, and there is little evidence for any improvements in water quality since meeting its TMDL obligations.

The pollutant loading model for the Lake Lulu TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005. The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$\text{POFF} = \text{RCOEF} * \text{WFLOW}^{\text{WASPRO}}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$\text{POFF} = \text{RCOEF} * \text{WFLOW}$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from “average” EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that “There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999.” As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP’s TMDL (PBS&J 2009).

For the eight lakes included in FDEP’s 2007 TMDL for the Southern Chain of Lakes (including Lake Lulu) WASP was “calibrated” for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake Lulu requires significant review, especially since the lake has met its TMDL obligations, without evidence of any improvement in water quality (PBS&J 2008). The reasons for this failure of the TMDL to meet its intended purpose might include the following: 1) the water quality targets used are based on TSI, not NNC, 2) work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), and 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured.

Lake May (WBID 1521E) TMDL

Basis for Impairment

Lake May is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake May is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. For Lake May, sufficient data were available for the years of 1997 to 1999. The annual average TSI value exceeded the established target of 60 in both 1997 and 1998, with a mean annual average TSI value of 63.4. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake May exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The State of Florida used TSI to determine the nutrient impairment status for lakes (including Lake May) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake May.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake May (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton

  - As affected by temperature
  - As affected by light intensity
  - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake May, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake May on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake May itself.

The TMDL for Lake May calls for a 57.5 percent reduction in external TP loads. While there is a statistically significant correlation found between TP and Chl-a in Lake May, the r-square value for this correlation is 0.07, suggesting only approximately 07 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake May (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 51 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 38 and 53 percent, respectively.

Pollutant Loading Model

The TMDL for Lake May (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake May, the TMDL (FDEP 2007) calls for a 57.5 percent reduction in stormwater loads for TP, which has been met by the various stormwater retrofit projects that have been constructed throughout the lake's watershed (PBS&J 2008). Despite meeting its TMDL load reduction goals, Lake May is still impaired for nutrients, and there is little evidence for any improvements in water quality since meeting its TMDL obligations.

The pollutant loading model for the Lake May TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005. The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$POFF = RCOEF * WFLOW^{WASPRO}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$POFF = RCOEF * WFLOW$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from "average" EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that "There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999." As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP's TMDL (PBS&J 2009).

For the eight lakes included in FDEP's 2007 TMDL for the Southern Chain of Lakes (including Lake May) WASP was "calibrated" for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake May requires significant review, especially since the lake has met its TMDL obligations, without evidence of any improvement in water quality (PBS&J 2008). The reasons for this failure of the TMDL to meet its intended purpose might include the following: 1) the water quality targets used are based on TSI, not NNC, 2) work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), and 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured.

Lake Mirror (WBID 1521G) TMDL

Basis for Impairment

Lake Mirror is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Mirror is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. For Lake Mirror, sufficient data were available only for the year 2003. The annual average TSI that year was 69.4. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Mirror exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Mirror) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Mirror.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake Mirror (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments

- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Mirror, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Mirror on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Mirror itself.

The TMDL for Lake Mirror calls for a 27.5 percent reduction in external TP loads. While there is a statistically significant correlation found between TP and Chl-a in Lake Mirror, the r-square value for this correlation is 0.11, suggesting that approximately 11 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Mirror (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 31 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 13 and 9 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Mirror (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake Mirror, the TMDL (FDEP 2007) calls for a 27.5 percent reduction in stormwater loads for TP. It was noted as well that any MS4 permittee is only responsible for reducing the loads associated with stormwater outfalls that it owns or otherwise has control over; they are not responsible for reducing other nonpoint source loads in their jurisdiction.

The pollutant loading model for the Lake Mirror TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005. The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$POFF = RCOEF * WFLOW^{WASPRO}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$POFF = RCOEF * WFLOW$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from “average” EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that "There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999." As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP's TMDL (PBS&J 2009).

For the eight lakes included in FDEP's 2007 TMDL for the Southern Chain of Lakes (including Lake Mirror) WASP was "calibrated" for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake Mirror requires significant review prior to implementation: 1) the water quality targets used are based on TSI, not NNC, 2) prior work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured, and 4) despite the fact that Lakes Shipp, May and Lulu (also in the Winter Haven Chain of Lakes) have met or exceeded the TP reduction targets contained in their individual TMDLs, there is no evidence of improved water quality in those three lakes (PBS&J 2008).

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Mirror (FDEP 2007).

Lake Parker (WBID 1497B) TMDL

Basis for Impairment

Lake Parker was verified as impaired for nutrients using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code). The lake and canal were included on the Verified List of impaired waters that was adopted by Secretarial Order on June 17, 2005. Lake Parker is a Class

III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

The Draft TMDL for Lake Parker (FDEP 2005d) used water quality data from January 1, 1997 to June 30, 2004. The annual average value for color averaged 48.2 platinum cobalt units (PCU). As such, the default target TSI value for TMDL development would have been set at 60, as Lake Parker is considered a high color lake (i.e., color levels in excess of 40 PCU). However, paleolimnological work conducted on Lake Parker concluded that in an undisturbed condition, Lake Parker's water quality would have been equivalent to a TSI value of 68.4. The average TSI value for the years 1997 to 2003 was 83.6, with each year exceeding the target TSI value. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Parker easily exceeded the impairment threshold.

TMDL Summary

Water quality targets

The TMDL for Lake Parker (FDEP 2005d) determined that there were no permitted wastewater treatment plant (WWTP) discharges to the lake, although the lake waters are used for cooling purposes for two power generation facilities. Also, the northern portion of the lake has been substantially altered by phosphate mining activities. For non-point sources, the TMDL (FDEP 2005d) noted that stormwater systems owned and operated by local governments and the Florida Department of Transportation are covered by an NPDES MS4 permit.

The water quality target setting process for Lake Hancock took into account findings from paleolimnological work conducted for Lake Parker. The paleolimnological results suggested an historical TSI value of 68.4. However, the target TSI value was based on the use of linked watershed and water quality response models previously conducted in Lakes Bonny and Gibson, which was then further modified.

The pollutant loading models for Lakes Bonny, Gibson, and Parker were modified to represent historical conditions by setting "leakance" rates to groundwater to 50 percent of current estimates (i.e., the lakes would lose more water historically) and then an estimate of excess nutrients that could not be accounted for in those lakes in their current condition was reduced by 75 percent to represent historical conditions. However, the use of these steps resulted in a TSI score for historical conditions that exceeded the current TSI scores. As a result, FDEP used a natural land use loading estimates alone, which gave rise to a TSI target of 67.9, a value fairly close to the TSI target from paleolimnological work. A 5-unit TSI increase was used to develop the final TSI target value of 72.9 for Lake Parker.

The Lake Parker TMDL (FDEP 2005d) used the Watershed Assessment Model (WAM; Soil and Water Engineering Technology, Inc., 2005) to estimate pollutant loads, and WAM output was then the input for the BATHTUB model (Quantitative Environmental Analysis, LLC, 2005) to simulate water quality within Lake Parker.

The TMDL for Lake Parker calls for 57 percent load reductions for both Total Nitrogen (TN) and Total Phosphorus (TP). Since there are no current point source discharges into Lake Parker, external load reductions of such a magnitude are impossible to bring about with any known technology of stormwater treatment, even if applied to 100 percent of the watershed of the lake. Quite a few of the TN values are higher than 2.8 mg/L, and cannot be ascribed to stormwater loads alone, as those values are higher than the highest Event Mean

Concentration (EMC) values shown for both urban and agricultural land uses in Harper and Baker (2007). Instead, it is more likely that the highest TN concentrations are likely reflecting the influence of nitrogen fixation by cyanobacteria, as has been previously documented in Lake Hancock (Tomasko et al. 2009) and Lake Jessup (PBS&J 2006); TN concentrations in Lake Parker are likely elevated via nitrogen-fixation by cyanobacteria.

Pollutant loading model

The pollutant loading model for the Lake Parker TMDL (FDEP 2005d) incorporates standard spreadsheet-derived loading estimate, based on rainfall, runoff, and EMC values for TN and TP. The pollutant loads developed from the Watershed Assessment Model (WAM) were the input into the BATHTUB water quality model, as described above.

WAM predicts stormwater loads of nutrients based on inputting data on rainfall, soils, and land use classifications. WAM has the ability to attenuate stormwater loads via features such as wetlands, depressional areas, and model input related to the distribution of Best Management Practices (BMPs) within the watershed. WAM estimates stormwater pollutant loads via GIS-based inputs of data on land use classifications (using FLUCCS) and soils, as driven by rainfall. WAM also allows for the attenuation of generated pollutant loads via wetlands and/or BMPs, if such data are available in GIS for the watershed.

WAM allows for the simulation of surface flows and groundwater inflow on a daily basis, and these daily flow estimates can be "processed" in the model via information related to topographical relief, channel configurations, etc. This feature allows for loads to be attenuated along the pathway from the watershed to the conveyance system and then on to the water body of interest. Literature-derived "attenuation algorithms" are applied to the calculated stormwater inflows.

The ability of WAM to attenuate modeled loads via BMPs, wetlands and stream channels is an important improvement over more simplistic pollutant loading models. However, the pollutant loading model as described in the TMDL is not actually "calibrated" via comparison of model output of stormwater loads to measured data. As is the case with other pollutant loading models used in Polk County, there does not appear to be an exercise within the TMDL for which model output on pollutant loads is compared to measured data. Instead, the pollutant loading model and the water quality model are "calibrated" against in-lake concentrations. More often than not the calibration of the linked pollutant loading and water quality models is conducted via the modification of a rate coefficient that has not been locally modelled.

The first model runs for "existing conditions" gave rise to results where measured TN values were often twice as high as model output. In the years 2000 and 2001, average measured TN values as much as three-times higher than model output. For TP, an even more severe discrepancy was found; measured TP values were as much as eight-times higher than model output. Clearly, the combination of WAM and BATHTUB did not sufficiently characterize the water quality of Lake Parker.

In accommodate the discrepancy between model output and measured data for existing conditions, "…the primary calibration for TN and TP was achieved by invoking BATHTUB's internal loading rate functions for both TN and TP to match the measured in-lake mass" (FDEP 2005d). The term "internal loading rate" is meant to include not only in-lake processes such as nitrogen fixation (for TN) but "…all other missing mass." Figures 5.1 and 5.2 show the differences between the initial model runs of TN and TP, respectively, vs. measured data, and also how the calibration step of invoking internal loading results in model output that exactly matches measured data. In essence, the TMDL for Lake Parker used a two-step process: 1) initial model runs resulted in significant underestimates of the TN and TP concentrations in the lake, 2) a model factor referred to as internal loading was then used to "calibrate" model output so that modeled and measured data would exactly coincide.

With any model, the term "calibration" refers to the process through which the modification of a state variable or rate coefficient is conducted in an attempt to better align model output and measured data. Ideally, model calibration would involve relatively minor adjustment to model components, using stare variables or rate coefficients that had been measured directly, hopefully in a somewhat similar environment. In the case of the Lake Parker TMDL, model calibration was not based on any measured processes (e.g., bottom resuspension, in-situ nitrogen fixation) from any nearby lake. Instead, calibration involved using the term "internal process" as a substitute for all the potential reasons why model output and measured values differed by so much. Since measured data on TN and TP were often 3 to 7 times higher than model output, this seriously compromises the validity of the TMDL. The lack of sufficient knowledge of the actual mechanisms behind the discrepancies between modeled and measured TN and TP values could result in a TMDL model that is calibrated via the modification of model variables that are not representative of actual field conditions.

Four main considerations suggest that the TMDL for Lake Parker requires significant review prior to implementation: 1) measured water quality has 3 to 7 times the level of TN and TP, respectively, vs. initial model runs, 2) calibration of the water quality model was accomplished via the inclusion of a term called "Internal loading" that is neither fully explained as to its processes, nor is it derived from actual measurements of any processes in Lake Parker, 3) based on prior work in Lake Hancock (Tomasko et al. 2009) it is likely that bottom resuspension of phosphorus-rich sediments could be a significant source of the excess and unaccounted for TP concentration in the lake, and 4) based on prior work in Lake Hancock (Tomasko et al., 2009) it is likely that nitrogen-fixation by cyanobacteria within Lake Parker could be a significant source of the excess and unaccounted for TN concentrations in the lake.

Since neither bottom resuspension of TP-rich sediments nor in-situ nitrogen fixation have been measured in Lake Parker, the model calibration effort included in the TMDL (FDEP 2005d) is problematic. In terms of meeting TMDL obligations, since neither bottom resuspension of TP rich sediments nor nitrogen fixation are processes included in the water quality model, they are not currently identified as activities though which TMDL reductions could be applied.

Further work is justified, focusing on the discrepancies above, prior to the investment of time and resources to implement the TMDL for Lake Parker (FDEP 2005d).

Lake Shipp (WBID 1521D) TMDL

Basis for Impairment

Lake Shipp is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Shipp is contained within the TMDL for the Winter Haven Southern Chain of Lakes (FDEP 2007), adopted by FDEP and approved by EPA. The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. For Lake Shipp, sufficient data were available for the years of 1997 and then 1999 to 2003. The annual average TSI value exceeded the established target of 60 each of the 6 years, with a mean annual average TSI value of 70.4. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Shipp exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Southern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Haines, Hartridge, Howard and Shipp (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008).

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Shipp) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Shipp.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Southern Chain of Lakes, which includes Lake Shipp (FDEP 2007). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)
- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to “link” the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
  - As affected by temperature
  - As affected by light intensity
  - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
  - As affected by temperature
  - As affected by light intensity
  - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate

- Settling rates of suspended inorganic compounds

In Lake Shipp, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Shipp on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Shipp itself.

The TMDL for Lake Shipp calls for a 65 percent reduction in external TP loads. While there is a statistically significant correlation found between TP and Chl-a in Lake Shipp, the r-square value for this correlation is 0.08, suggesting that 8 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Shipp (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 52 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 41 and 29 percent, respectively.

Pollutant Loading Model

The TMDL for Lake Shipp (FDEP 2007) determined that there were no permitted wastewater treatment facility (WWTF) discharges to the lake. For non-point sources, the TMDL (FDEP 2007) noted that loadings from stormwater discharges permitted under the NPDES stormwater program (i.e. MS4 areas) are expressed as a percent reduction and was set at the same percent reduction needed for nonpoint sources to meet their calculated load allocation goals. For Lake Shipp, the TMDL (FDEP 2007) calls for a 65 percent reduction in stormwater loads for TP, which has been met by the various stormwater retrofit projects that have been constructed throughout the lake's watershed (PBS&J 2008). Despite meeting its TMDL load reduction goals, Lake Shipp is still impaired for nutrients, and there is little evidence for any improvements in water quality since meeting its TMDL obligations.

The pollutant loading model for the Lake Shipp TMDL (FDEP 2007) is based on the Pollutant Load Reduction Goal (PLRG) report (McCary and Ross 2005. The PLRG report estimated TP loads from watershed runoff using the Storm Water Management Model (SWMM). This output was then matched with groundwater inflow estimates based on the U.S. Geological Survey's MODFLOW Program (FDEP 2007) which was then based on the data set described below. The combined loads from SWMM and MODFLOW served as the input to the Water Quality Analysis Simulation Program (WASP) model, which was used to predict water quality in individual lakes.

The watershed boundaries for stormwater runoff were estimated based on the modification of previously derived general basin boundaries, which were supplemented with additional topographic data. The amount of runoff generated within each watershed per given rainfall was based on soil type and land use, both of which were available in GIS formats. The amount of runoff and groundwater inflows were then added to the amount of water directly deposited to each lake via rainfall on lake surfaces to determine freshwater inflows for each lake.

Calculations of nutrient loads from stormwater runoff were determined in SWMM using the equation:

$$POFF = RCOEF * WFLOW^{WASPRO}$$

Where: POFF = runoff load (pounds of nutrient);

RCOEF = wash-off coefficient (concentration of pollutant, mg/L);

WFLOW = sub-basin runoff (acre-feet); and

WASHPO = runoff rate exponent (calibration coefficient).

The runoff rate exponent was set to a value of 1, which simplified the equation to the following:

$$POFF = RCOEF * WFLOW$$

The authors (McCary and Ross 2005) then used Event Mean Concentration (EMC) values for TP from Harper (1994) for RCOEF values to estimate TP loads from stormwater.

Although the hydrology and hydraulics of SWMM and MODFLOW can be quite complex, the equation used to estimate stormwater pollutant loads is basically a restatement of the standard spreadsheet formula for pollutant loading models, where stormwater loads (POFF) are the product of a runoff estimate (WFLOW) multiplied by a literature-derived concentration of pollutants (RCOEF). This approach is similar to prior pollutant loading models produced by Heyl (1992), Tomasko et al. (2001) and others.

Estimates of stormwater loads of TP to the lakes in the Winter Haven Chain of Lakes system are thus limited by the following issues: 1) there were no gaged data available to validate the runoff coefficients used to estimate the volume of water coming off the watershed, and 2) there were no locally measured nutrient concentration data collected as part of the model development to turn runoff volumes into pollutant load estimates. Recently completed and ongoing studies in Lemon Bay (ERD 2004) and Charlotte County (Tomasko, personal communication) have measured nutrient concentration values in stormwater runoff that can be dramatically different from "average" EMC values listed in Harper (1994).

Consequently, while the level of expertise applied to the PLRG model is impressive, stormwater loads to the lakes of the Winter Haven Chain of Lakes system are estimates based on assumed but non-verified rates of runoff multiplied by literature-derived concentrations of pollutants of concern. The stormwater load estimates in the PLRG study (McCary and Ross 2005) then form the basis for the TMDL (FDEP 2007). While these estimates could be accurate, they could also be substantially different than reality. As there are not detailed and local measurements of runoff rates or nutrient concentrations in the Winter Haven Chain of Lakes system, it is impossible to determine if the loading estimates for stormwater runoff are accurate.

For groundwater seepage, McCary and Ross (2005) noted that "There were five surficial wells in Polk County that had water-quality data. Only one of these wells is within the basin boundaries, shown in that report as the surficial well located between Lakes Eloise and Lulu. This well had three recorded data points, sampled on 3/17/1993, 3/4/1996, and 5/25/1999." As such, the data that was used to estimate groundwater seepage rates in the PLRG are elevation data reported for one well. The estimated groundwater seepage volumes estimated using this data set were then multiplied by nutrient concentrations to get nutrient loading rates.

As in the stormwater loading model component of the PLRG (McCary and Ross 2005) there is a paucity of data available to determine if the pollutant load estimates for groundwater seepage accurately reflect actual rates. For Lakes Conine, Fannie, Rochelle and Smart, direct measurements of groundwater nutrient loading differed substantially from estimates for these same lakes in FDEP's TMDL (PBS&J 2009).

For the eight lakes included in FDEP's 2007 TMDL for the Southern Chain of Lakes (including Lake Shipp) WASP was "calibrated" for TP concentrations by modifying the settling rate of TP from the water column into the lake sediments. However, TP settling rates have not been measured in any of the lakes of the Winter Haven Chain of Lakes system. In effect, model calibration was brought about via modifying a process that has not been measured locally, which could lead to spurious results.

Chlorophyll-a was the water quality variable used for model calibration in Lakes Howard and Jessie, as the measured phosphorus values were considered suspect for an unspecified reason. However, the PLRG model (McCary and Ross 2005) included a curious statement that chlorophyll-a concentrations were not used for WASP model calibration because the authors expected chlorophyll-a concentrations to vary significantly over the course of a day as a result of changes in irradiance (McCary and Ross 2005). This belief, that chlorophyll-a concentrations would rise and fall over the course of a day as a result of changes in irradiance, suggests a lack of familiarity with phytoplankton dynamics in lakes, and it is not supported by data collected on a diel basis in Lake Hancock (ERD 2005).

A number of considerations suggest that the TMDL for Lake Shipp requires significant review, especially since the lake has met its TMDL obligations, without evidence of any improvement in water quality (PBS&J 2008). The reasons for this failure of the TMDL to meet its intended purpose might include the following: 1) the water quality targets used are based on TSI, not NNC, 2) work done on the Winter Haven Chain of Lakes has shown that TSI values for nutrients do not correlate very well with expected values (based on TSI) for chlorophyll-a (PBS&J 2008), and 3) the WASP model used for water quality target setting is mostly calibrated via the modification of TP settling rates, which have not been locally measured.

Lake Smart (WBID 1488A) TMDL

Basis for Impairment

Lake Smart is a Class III freshwater lake, with a designated use for recreational purposes and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The lake was verified as impaired for nutrients in 2004 using the methodology in the Identification of Impaired Surface Waters Rule (IWR, Rule 62-303; Florida Administrative Code).

The Final TMDL for Lake Smart is contained within the TMDL for the Nutrient TMDL for Winter Haven Northern Chain of Lakes, Lake Haines and Lake Smart (EPA 2006b). The TMDL used water quality data from 1992 to 2003 to calculate Tropic State Index (TSI) values for those years when data for Total Nitrogen (TN), Total Phosphorus (TP) and Chlorophyll-a (Chl-a) were sufficient to calculate annual averages. Sufficient data were available for the years 1997 to 2000. The annual average TSI value exceeded the established target of 60 in 3 of those 4 years, with a mean annual average TSI value of 62.7. As only a single year's exceedance was sufficient for a lake to be placed on the Verified Impaired list, Lake Smart exceeded the impairment threshold.

TMDL Summary

Water Quality Targets

The TSI target developed for the Northern Chain of Lakes took into account findings from a paleolimnological study conducted on Lakes Conine, Smart, Hartridge, Howard and May (Whitmore and Brenner 1995). The deepest samples, dated at approximately 1860, indicated that the five lakes studied were historically dominated by species of phytoplankton that are indicative of mesotrophic to eutrophic conditions. As such, the best possible outcome of any lake management program would be a return to mesotrophic to eutrophic conditions. Such conditions are typically associated with TSI values in the range of 50 to 60 (Whitmore and Brenner, 1995) and so the SWFWMD Pollutant Load Reduction Goal (PLRG; McCary and Ross 2005) and FDEP (2007) used a TSI target of 60 as the proper lake management goal.

Not only is the use of TSI for water quality target setting out of sync with the current use of Numeric Nutrient Concentration (NNC) criteria for lake characterization, TSI does not seem to be an appropriate water quality target in the Winter Haven Chain of Lakes system (PBS&J 2008). TSI scores for nutrients did not correlate with the expected chlorophyll-a concentration scores in low color lakes in the Winter Haven Chain of Lakes, and in high color lakes, there was no correlation at all between nutrient concentrations and chlorophyll-a concentrations (PBS&J 2008). The TMDL for Lake Smart (EPA 2006b) notes that Lake Smart would be classified as a high color lake in one of the 4 years with sufficient data for target setting for nutrient concentrations.

The state of Florida used TSI to determine the nutrient impairment status for lakes (including Lake Smart) until the adoption of NNC criteria in 2012. The adoption of NNC criteria included a lag period between technical review and approval and formal adoption into rule (FDEP 2012). FDEP's lake-specific NNC criteria were subsequently approved by EPA (2013) although, at this date, final regulatory adoption is dependent upon the outcome of various lawsuits by third party interveners. However, it should be recognized that NNC criteria for lakes have been reviewed and approved by both FDEP (2012) and EPA (2013) on their technical merits. Therefore, nutrient targets derived from the use of NNC guidance should be considered the framework for target setting for water quality in Lake Smart.

In addition to concerns over the use of TSI vs. NNC as a target setting technique for water quality, there are concerns related to the use of EPA's Water Quality Assessment Program (aka WASP) model, which was used in both the SWFWMD's PLRG (McCary and Ross 2005) and the TMDL for the Northern Chain of Lakes, which includes Lake Smart (EPA 2006b). In mechanistic models, there are two main model components, state variables and rate coefficients. State variables refer to water quality parameters such as levels of dissolved oxygen or nutrient concentrations. The standard state variables in WASP include the following (EPA 2006c):

- Ammonia (mg/L)
- Nitrate (mg/L)
- Orthophosphate (mg/L)
- Phytoplankton (expressed as chlorophyll-a in units of µg/L)
- Detrital carbon (mg/L)
- Detrital nitrogen (mg/L)
- Detrital phosphorus (mg/L)

- Chemical biological oxygen demand (3 types, in units of mg DO consumed per unit volume per unit time)
- Dissolved oxygen (mg/L)
- Dissolved organic nitrogen (mg/L)
- Dissolved organic phosphorus (mg/L)
- Total suspended solids (mg/L)

This extensive data set represents water quality parameters that reflect a concentration, not a biological or bio-chemical process. Rate coefficients are then used to "link" the various state variables to each other. The rate coefficients used in WASP7 include the following (EPA 2006c):

- Rates of oxygen exchange between the atmosphere and the water body
- Assimilation rates of inorganic nitrogen by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by nitrogen concentrations
- Assimilation rates of inorganic phosphorus by phytoplankton
    - As affected by temperature
    - As affected by light intensity
    - As affected by phosphorus concentrations
- The relative influence of phytoplankton, suspended inorganic compounds and dissolved organic substances on light attenuation
- Rates of mortality of phytoplankton
- Grazing rates of zooplankton on phytoplankton
- Settling rates of phytoplankton out of the water column
- Rates of decomposition of detritus in lake sediments
- Rates of re-mineralization of organic nitrogen into inorganic forms
- Rates of re-mineralization of organic phosphorus into inorganic forms
- Rates of de-nitrification of nitrate into di-nitrogen gas in sediments
- Rates of nitrification of ammonium into nitrate
- Settling rates of suspended inorganic compounds

In Lake Smart, information is available on most, but not all, of the state variables listed above. However, there do not appear to be any local data from Lake Smart on any of the 17 rate coefficients listed above. Rate coefficients that represent mostly physical processes, such as the mixing of oxygen from the atmosphere into the water column, or the setting rates of inorganic substances, could likely be derived from existing literature with little concern. But those rate coefficients which represent biological processes in mechanistic models such as WASP do not appear to be available from Lake Smart itself.

The TMDL for Lake Smart calls for 70 percent reductions in external TP loads. There is a statistically significant correlation found between TP and Chl-a in Lake Smart, the r-square value for this correlation is 0.39, suggesting that 39 percent of the variation in chlorophyll-a concentrations can be attributed to variation in the abundance of TP.

Based on an examination of water quality data during the Verified Impaired time period for Lake Smart (IWR run 47) the mean reduction in Chl-a concentrations required to meet Numeric Nutrient Concentration (NNC) criteria was estimated at 42 percent. Also using NNC criteria, the average reduction in TN and TP concentrations required would be 31 and 23 percent, respectively.

Pollutant Loading Model

The water quality target for Lake Smart is based on a TSI target of 60, which is in turn based on paleolimnological work conducted on a series of lakes in Polk County (Whitmore and Brenner 1995).

Although there are a number of issues related to the use of mechanistic water quality models, an additional and significant issue might be related to the relative role of groundwater inflows vs. surface water runoff, in terms of the delivery of external nutrient loads. The TMDL for Lake Smart (EPA 2006b) states that "A larger proportion of the load to the Northern Chain of Lakes is derived from ground water, which makes up 29 percent of the total load, as compared to ground water only making up 4 percent of the total load to the Southern Chain of Lakes."

The TMDL for Lake Smart calls for a 70 percent reduction in TP loads. While it is explicitly stated that both surface water and groundwater loads are considered together as the external loads that the 70 percent reduction is intended to address, the actual data collected on groundwater inflow rates for Lake Smart (PBS&J 2009) is not included in the TMDL.

The annual groundwater TP loads measured by PBSJ (2009) through direct measurement were much higher than the TMDL results for lakes in the Winter Haven Chain of Lakes. The annual groundwater TP load to Lakes Haines, Conine and Rochelle were 83, 57 and 68% greater than the loads modeled for the TMDL, respectively. In the TMDL, TP concentrations were derived from one well with 3 water quality samples in 6 years for the calculation of groundwater seepage. In contrast, a total of 19, 24, and 22 direct TP measurements were used to calculate the average groundwater concentration to Lakes Haines, Conine and Rochelle. The average TP concentrations calculated by direct measurement were 0.14, 0.05 and 0.10 mg/l for Lakes Haines, Conine and Rochelle, respectively. In contrast, the average TP concentration from the surficial aquifer well at Lake Eloise was 0.021 mg/l.

The TMDL for Lake Smart (EPA 2006b) appears to be problematic for a number of reasons:, 1) the TMDL for Lake Smart does not fully accommodate the findings, both in that report (Figure 5.2 in EPA 2006) and in the BMAP report conducted for FDEP (PBS&J 2008) that the substantial reduction in Chl-a concentrations that occurred in the late1990s appears to be related to the whole-lake alum treatment of Lake Conine, which is located "upstream" from Lake Smart, 2) the TMDL for Lake Smart shows an approximate 50 percent decline in Chl-a concentrations in the lake (associated with an activity that did not occur within the geographic boundaries within which a 70 percent reduction in external TP loads is required (to meet TMDL obligations), and 3) although groundwater seepage rates and groundwater loading estimates for Lake Smart are available for both TN and TP

(PBS&J 2009) those data were collected after the TMDL was developed, and no revised TMDL is yet available to incorporate the locally-collected groundwater nutrient budget

Further work is justified, focusing on the discrepancies listed above, prior to the investment of time and resources to implement the TMDL for Lake Smart (EPA 2006b).

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