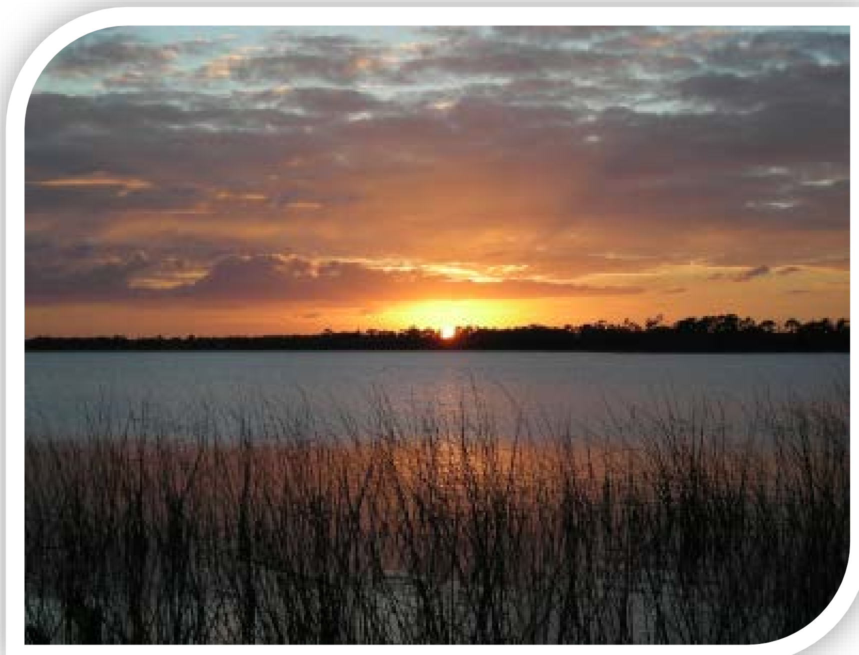
2019

Annual Lakes Report

Presented by the Lakes Advisory Committee



CITY OF WINTER HAVEN
Public Works Department
Natural Resources Division

City of Winter Haven Natural Resources

Mission:

Maintain and improve local natural resources through management based on a sound understanding of social, economic, and ecological systems.

Vision:

To be the premier knowledge base for local natural resources, with an engaged public, supporting natural systems through a community ethic.

Purpose:

Balance the needs of diverse user groups to sustain natural resources the community can be proud of.

Values:

Courteous, Cognizant, Cooperative, Resourceful, Responsive, Accurate, Adaptive

Executive Summary

The Chain of Lakes City is a moniker that highlights Winter Haven's most unique and impressive natural features while cleverly alluding to a theme of connectivity in our community. As the local waterbodies are physically connected via canals, pipes, wetlands, so too is our town's economic, cultural, and ecologic well-being tied to the health of the lakes. Proper management of these systems is absolutely necessary to ensure that Winter Haven remains a place of enriched lifestyle for residents and visitors alike.

Developing a successful lake management strategy requires an understanding of the factors that impact lake health. Winter Haven's Natural Resources staff have developed evaluation metrics based on water quality, hydrology, and biology and a standardized methodology to track comprehensive health of our lakes over time. This integrated, data-driven approach allows for objective prioritization and accurate prescription of best management practice implementation for the 37 public lakes in the study area. The purpose of this report is to provide background information on these metrics, an analysis of the most recent data, and to highlight the management strategies the City is utilizing to maintain and improve lake health. It is our hope that by sharing this information with the public, we can increase community understanding and support to protect these natural resources and safeguard Winter Haven's namesake.

An overview of the primary lake health metrics and their changes from 2018 to 2019 can be found on pages 87 – 91. A review of aggregate lake health scores indicates that 62% of the lakes in the area exhibited improvement in some manner, 19% remained static, while the remaining 19% demonstrated deterioration from 2018 to 2019. With regards to water quality, 43% of lakes are currently meeting regulatory water quality targets while over 40% of the lakes exhibit significant improving trends in chlorophyll-a, total nitrogen, total phosphorus, and water clarity. Hydrologically, 2019 was a wet year with a total of 55 inches of rainfall—a fair amount above Winter Haven's long-term average of 51 inches. This influx of water resulted in a continuation of above-average lake and groundwater levels in the area (pp. 40, 51, 61, 70, & 80). It is likely that these hydrologic conditions partially contributed to this water quality improvement. Concerning lake biological health, overall aquatic vegetation abundance and diversity increased in 2019 over the previous year. Aquatic plants provide water quality benefits as well as habitat for fish and wildlife and are necessary for lakes to thrive. It must be noted that an expansion of invasive plants contributed to the overall increase in abundance. This is likely the result of a brief moratorium on the Florida Fish and Wildlife Commission's aquatic weed treatment efforts in the early part of 2019. Smart, tactical management of invasive plants is crucial to maintaining healthy biological communities.

The City employs various structural and non-structural best management practices aimed at improving water quality. While each is detailed in the Management Strategies section of the report, a few underwent some noteworthy progress in 2019. First, Natural Resources and Utilities partnered to develop an educational water science curriculum for the Cypress Junction Montessori (p. 116). This pilot program focuses on bringing functional expertise to students with the goal to assist local teachers on scientific subjects. Next, the City selected a contractor to begin construction of the Lake Conine Treatment Wetland towards the end of 2019 (p. 101). This constructed wetland has been designed to treat stormwater runoff from a 400 acre drainage basin. The project is scheduled to be completed in early 2021. Finally, the Public Works Department has set in motion the ability to perform street sweeping service in-house (p. 108). This will allow for more efficient and tactical stormwater treatment in the downtown drainage basins.

With every iteration of this report, City staff have attempted to grow and develop the manner in which information is disseminated. In the 2018 report, we introduced the Lake Health Index: a standardized scoring rubric used to prioritize lakes with greater management needs. For the 2019 report, we have distilled critical insights down to one-page water quality management plans for each lake. While these plans aren't meant to replace the information in the report proper, they do provide an at-a-glance breakdown of how the City plans to tackle lake-specific challenges. These plans can be found at the end of the report in the appendix.

Finally, special recognition must be made for the Lakes Advisory Committee. This report would not have been possible without the guidance, advice, and support of local citizens with the passion to protect our natural resources. In addition, we'd like to thank you, our readers. We hope the information contained herein allows for a deeper, more meaningful understanding of the factors that affect the health of our lakes. Please don't hesitate to contact the City Natural Resources Division if you have questions, suggestions, or wish to support lake management efforts in the Winter Haven area.

Sincerely,

Devon Moore

City of Winter Haven
Natural Resources Division
Environmental Scientist

How to Navigate this Document

Section	Description
1. Introduction	Purpose of the report Background info on the evaluation metrics Background info on the area lakes
2. Data Presentation & Analysis	Figures & Tables Current lake health data & trends Insights into lake health impacts
3. Management Strategies	Background on strategies the City is using to improve lake health Current management practices & successes Future strategic goals
4. Appendix	Additional & supplementary data References List of figures & tables
5. Water Quality Management Plans	Stats and info on individual lakes Primary challenges affecting water quality Unique strategic goals for each waterbody

Contents

1- Introduction

1.1 Purpose

The lakes of the greater Winter Haven area are considered some of its most important natural assets. The utilization of these waterbodies by visitors and residents alike have cemented their role as economic and social resources. Our lakes also impart environmental benefits such as fish and wildlife habitat, water storage, and flood protection. By virtue of this, one of the primary objectives of the City's Natural Resources Division is to monitor their overall wellness and to implement best management practices that will ensure the continued enjoyment of their benefits by our diverse user groups.

The purpose of this report, therefore, is to present a more comprehensive outlook on the characteristics that comprise lake health as well as provide a detailed list of management strategies aimed at improving water quality. In using this holistic assessment approach, the City can prioritize waterbodies based on their condition and implement specific management practices geared toward each lake's individual characteristics. Using methods and techniques that are technically sound, yet presented in a manner that is accessible ensures that the information contained herein can be understood and applied by the scientific community as well as the general public.

Lastly, this annual report serves to document the City's evolving approach to environmental stewardship. As we continue to gain a better understanding of our natural systems, we hope to use that knowledge to refine our analytical methods and management practices. The principles we learn today will certainly drive how we preserve our lakes for the future.

1.2 Background on the Waterbodies

The lakes of the Winter Haven area are located within the Winter Haven Ridge and Polk Uplands geographic regions of Central Florida. The regional topography indicates that the Winter Haven lakes are at the top of the Peace River watershed in what is known as the Peace Creek sub-basin. As such, these waterbodies are a major contributor of surface and groundwater flow to the Peace River which flows to the Gulf of Mexico at Charlotte Harbor (Figure 1-1). The lakes chosen for this evaluation discharge directly or indirectly to the Peace Creek Canal—a major tributary that flows south of the Winter Haven area from Lake Hamilton and then west to join with Saddle Creek to become the Peace River (Figure 1-2).

There are numerous waterbodies in the municipal limits of Winter Haven and surrounding unincorporated Polk County. For the purposes of this study, the 37 lakes chosen for analysis were selected based on the following criteria:

- *Possess improved public access (i.e. boat ramp or navigable entry point)*
- *Located within or adjacent to City limits; or discharge directly to a waterbody within City limits*
- *Discharge surface water to the Peace Creek Canal; either directly or via a series of conveyances*
- *Possess a sufficient record of water quality and/or hydrologic data*

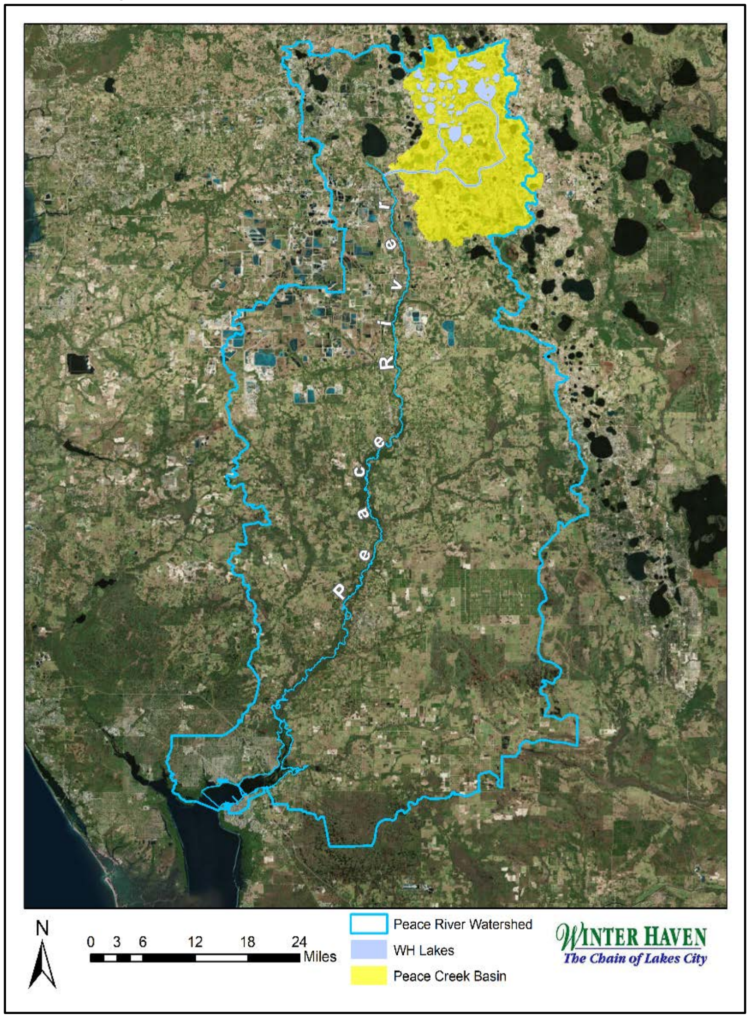


Figure 1-1. Map of Peace River & Peace Creek Watersheds

The lakes discussed in this report have been grouped based on their geographic location, flow pathways, or other common characteristics such as shared connections to other waterbodies. However, it is noteworthy that each lake's health and management goals are considered separately. The five lake groups have been designated the following: North Chain of Lakes, North Central Lakes, South Chain of Lakes, South Central Lakes, & Outlying Lakes.

One of the primary lake grouping categories is shared flow pathway to the Peace River via the numerous canals, ditches, and pipes in the area. The movement of water through these connections is determined by water control structures put in place primarily to conserve water in the lakes at desirable levels. The control structures can be grouped into active or passive categories. Active structures rely on the deliberate opening/closing of a gating mechanism to allow water to pass through the flow-way. These active control structures allow the managing authority to adjust the desired surface level of the upstream waterbody, whereas passive structures include weirs or pipes set at the lake's maximum desired water level—only allowing for the overflow of water above that set level. The Southwest Florida Water Management District (SWFWMD) and Lakes Region Lake Management District (LRLMD) maintain the majority of structures in the Winter Haven area, however there exist a couple passive structures managed by Polk County (Table 1-1).

Control Structure ID	Contributing Waterbody	Managing Organization	Lake Group	Maximum Desired Elevation (NGVD29)
P-5	Lake Henry	SWFWMD	North Chain of Lakes	126.00
P-6	Lake Smart	SWFWMD	North Chain of Lakes	128.50
P-7	Lake Fannie	SWFWMD	North Chain of Lakes	125.50
P-8	Lake Hamilton	SWFWMD	North Chain of Lakes	121.25
Lulu-CS	Lake Lulu	LRLMD	South Chain of Lakes	132.00
Silver-CS	Lake Silver	LRLMD	North Central Lakes	146.50
Martha-CS	Lake Martha	LRLMD	North Central Lakes	142.00
Maude-CS	Lake Maude	LRLMD	North Central Lakes	140.50
Idyl-CS	Lake Idyl	LRLMD	North Central Lakes	132.00
Link-CS	Lake Link	LRLMD	South Central Lakes	128.00
Mariam-CS	Lake Mariam	LRLMD	South Central Lakes	124.75
Mariana-CS	Lake Mariana	LRLMD	Outlying Lakes	137.50
Blue-CS	Lake Blue	Polk County	Outlying Lakes	148.86
Deer-CS	Lake Deer	Polk County	Outlying Lakes	138.61

Table 1-1. Control structure elevations, contributing waterbodies, and managing agencies of study area lakes.

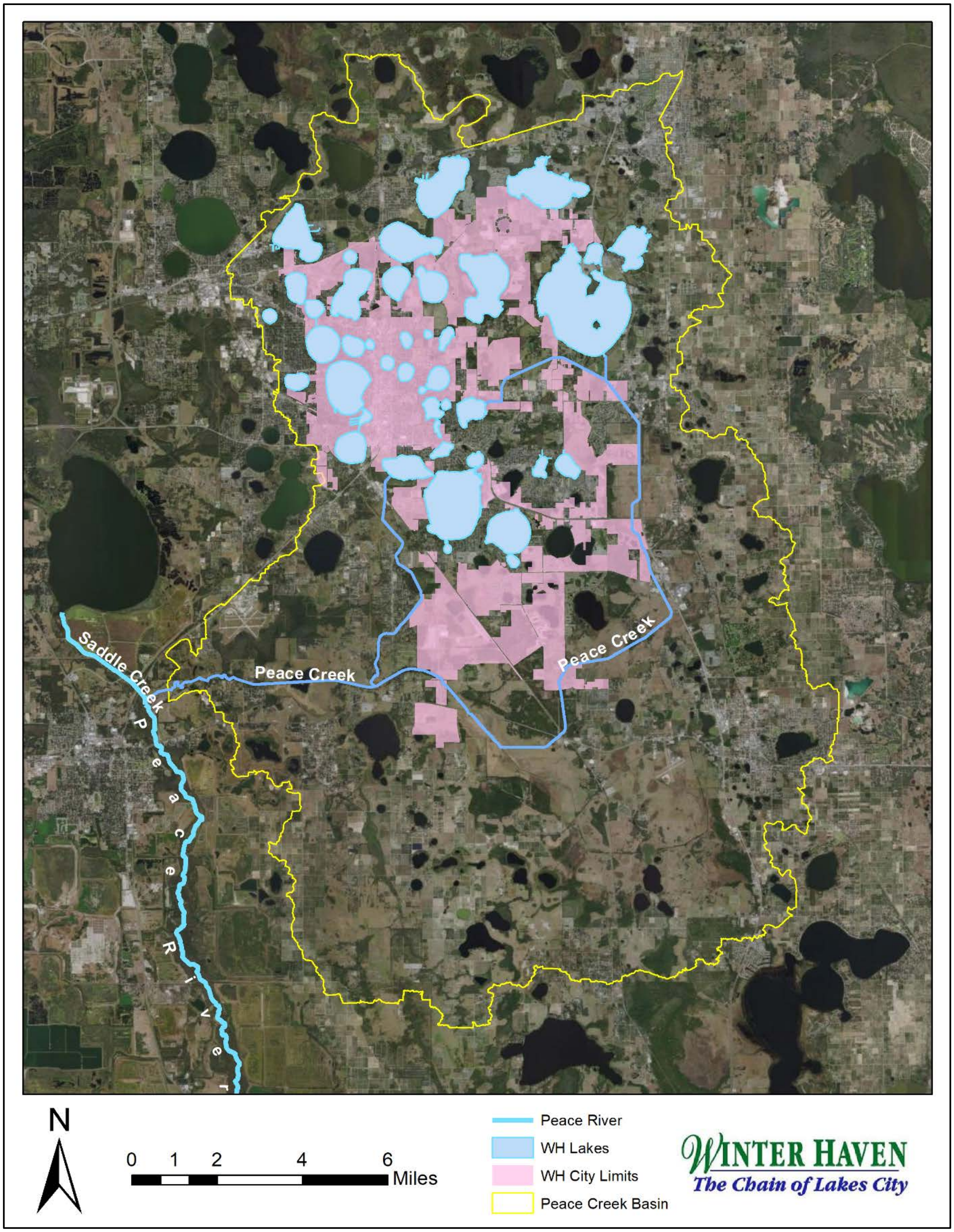


Figure 1-2. Map of the Peace Creek sub-basin, City of Winter Haven limits, contributing lakes and flow-ways.

North Chain of Lakes

The Winter Haven Chain of Lakes have historically been grouped into the distinct Northern and Southern sections that are separated by a boat lock system to allow for navigation between the two. The Northern Chain is made up of the following 9 waterbodies:

- *Lake Conine*
- *Lake Fannie*
- *Lake Haines*
- *Lake Hamilton*
- *Little Lake Hamilton*
- *Middle Lake Hamilton*
- *Lake Henry*
- *Lake Rochelle*
- *Lake Smart*

The Southwest Florida Water Management District (SWFWMD) manages the surface level of the Northern Chain of Lakes via a series of active water control structures. For the purposes of water conservation and flood control, the SWFWMD sets maximum desired levels at each of these structures—discharging water to the Peace Creek Canal when surface levels exceed the upper limits [1]. In this system, water flows from West to East toward the terminal discharge point at Lake Hamilton (Figure 1-3). Lakes Conine, Haines, Rochelle, and Smart are all held roughly equal via a series of navigable canals. The P-6 water control structure, located downstream of Lake Smart, maintains the desired surface level for these four lakes. From Smart, water discharges to Lake Fannie which is controlled by the P-7 structure. Discharge from Lake Fannie flows to the Hamilton Chain (Lakes Hamilton, Little Hamilton, & Middle Hamilton) where the P-8 control structure maintains water in these three lakes before discharging to the Peace Creek Canal. In addition to these 8 waterbodies, Lake Henry discharges to Hamilton via the P-5 structure. However, because Lake Henry lacks public access and a means of water quality data collection, it has been excluded from this study.

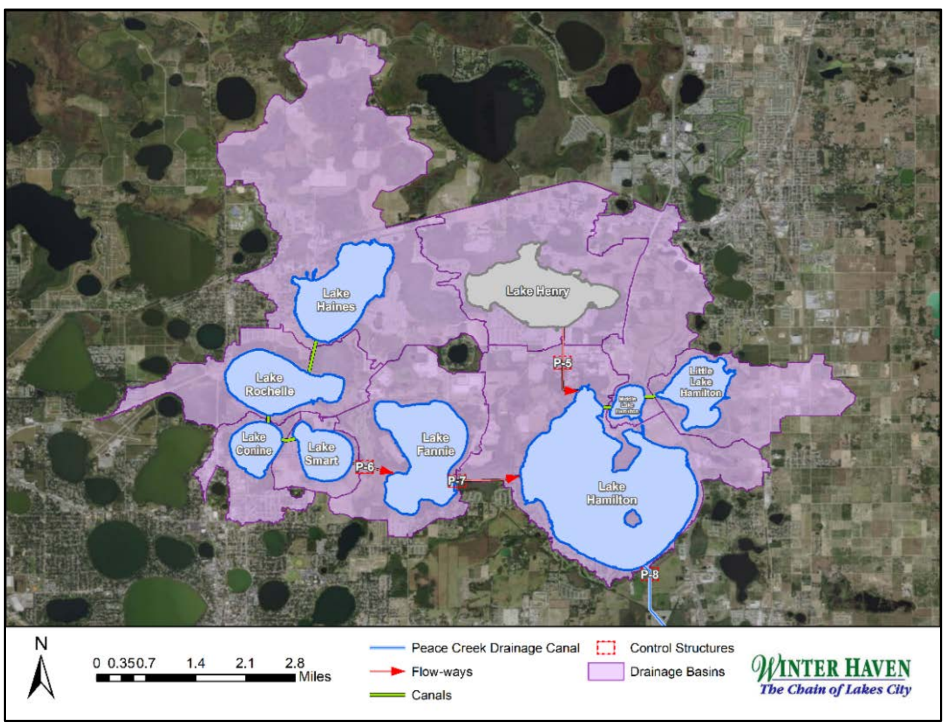


Figure 1-3. Map of North Chain of Lakes, Flow Pathways & Drainage Basins

Southern Chain of Lakes

Spanning the majority of the City of Winter Haven boundary, the Southern Chain of Lakes is composed of the following 14 waterbodies:

- *Lake Cannon*
- *Lake Eloise*
- *Lake Hartridge*
- *Lake Howard*
- *Lake Idylwild*
- *Lake Jessie*
- *Lake Lulu*
- *Lake May*
- *Lake Mirror*
- *Lake Roy*
- *Lake Shipp*
- *Lake Summit*
- *Lake Winterset*
- *Spring Lake*

The entirety of the Southern Chain is connected via a series of navigable canals. Many of these canals were constructed in the early 1900's, in part as a means to transport citrus through the region [2]. A passive control structure located on the southern shore of Lake Lulu and managed by the Lake Region Lakes Management District (LRLMD), maintains the surface level of this entire chain. From this structure, the Southern Chain discharges to the Wahneta Farms Drainage Canal; travelling south until it joins with the final stretch of the Peace Creek near the City of Bartow (Figure 1-4).

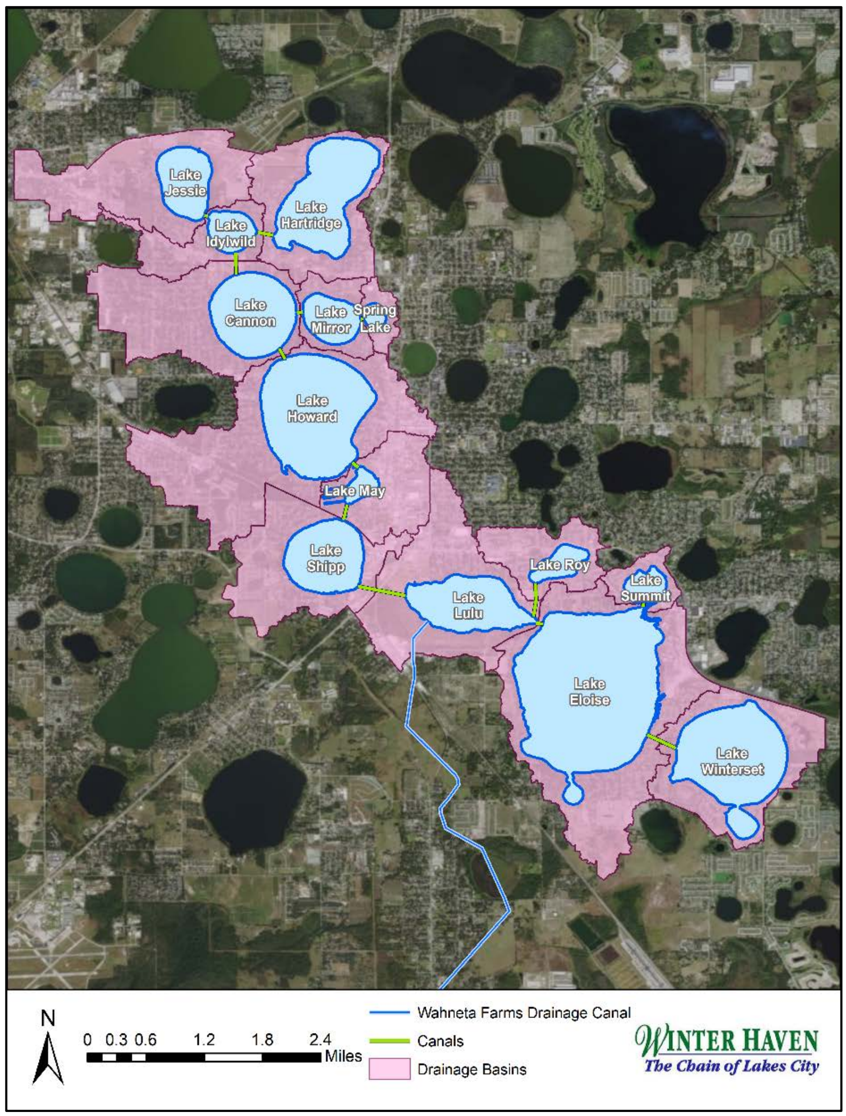


Figure 1-4. Map of South Chain of Lakes, Flow Pathways & Drainage Basins

North Central Lakes

This series of lakes is grouped due to its distinctly separate flow pathway and its location relative to the other lake groups. The following 5 lakes make up the North Central group:

- *Lake Buckeye*
- *Lake Idyl*
- *Lake Martha*
- *Lake Maude*
- *Lake Silver*

Beginning in the heart of downtown Winter Haven, water flows from Lake Silver to Martha, Maude, Idyl, and Buckeye, respectively (Figure 1-5). The ditches and pipes that connect these lakes also act as passive water control structures maintained by the LRLMD. At the downstream end of this lake group, overflow from Lake Buckeye discharges north to Lake Fannie through a natural wetland area.

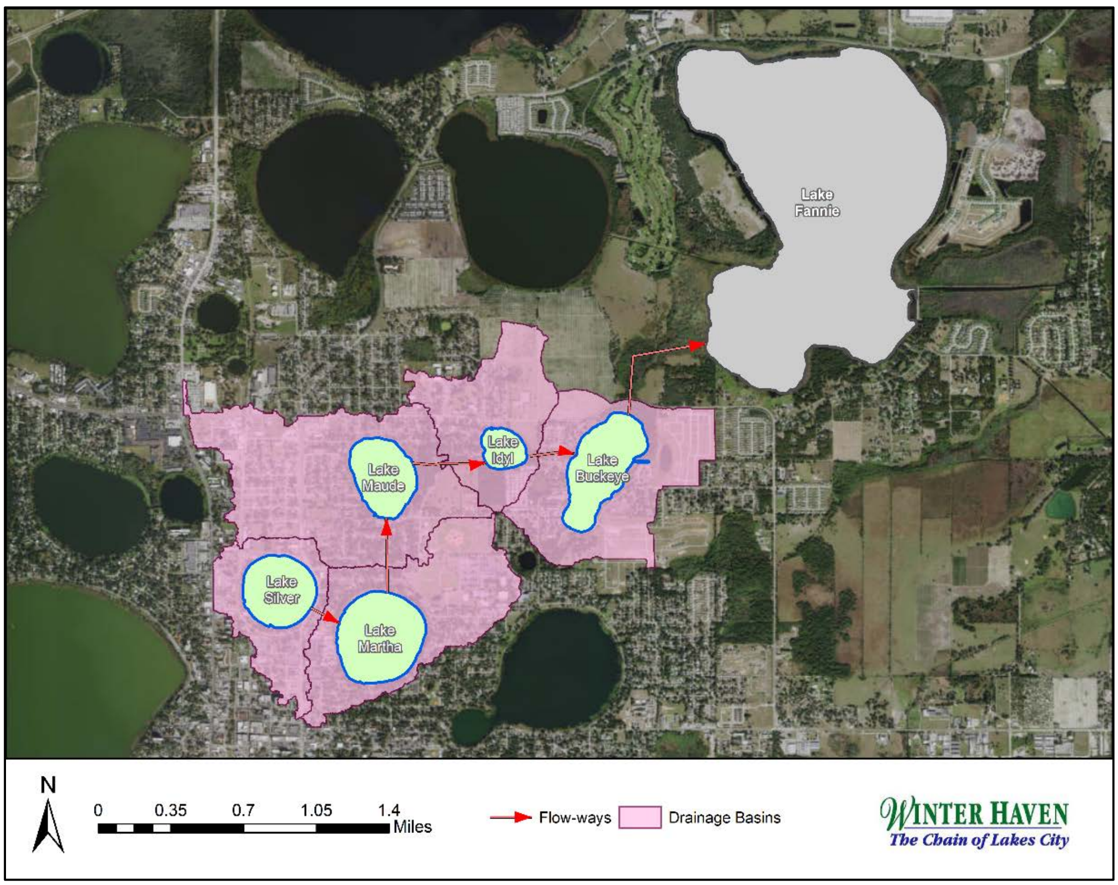


Figure 1-5. Map of North Central Lakes, Flow Pathways & Drainage Basins

South Central Lakes

Similar to the North Central group, the South Central Lakes are categorized based on their relative location and historic flow pathway. Comprised of the following 4 waterbodies, the South-Central group contributes surface flow to the Peace Creek Canal:

- *Lake Elbert*
- *Lake Link*
- *Lake Mariam*
- *Lake Otis*

Starting at Lake Elbert, water flows through an underground pipe to Lakes Otis and Link which are connected via a navigable canal. From Link, surface water is conveyed via another pipe to Lake Mariam which discharges to a small ditch that travels east until it meets with the Peace Creek Canal (Figure 1-6). Again, weirs control the maximum desired surface level of these lakes for the purposes of flood prevention and water conservation.

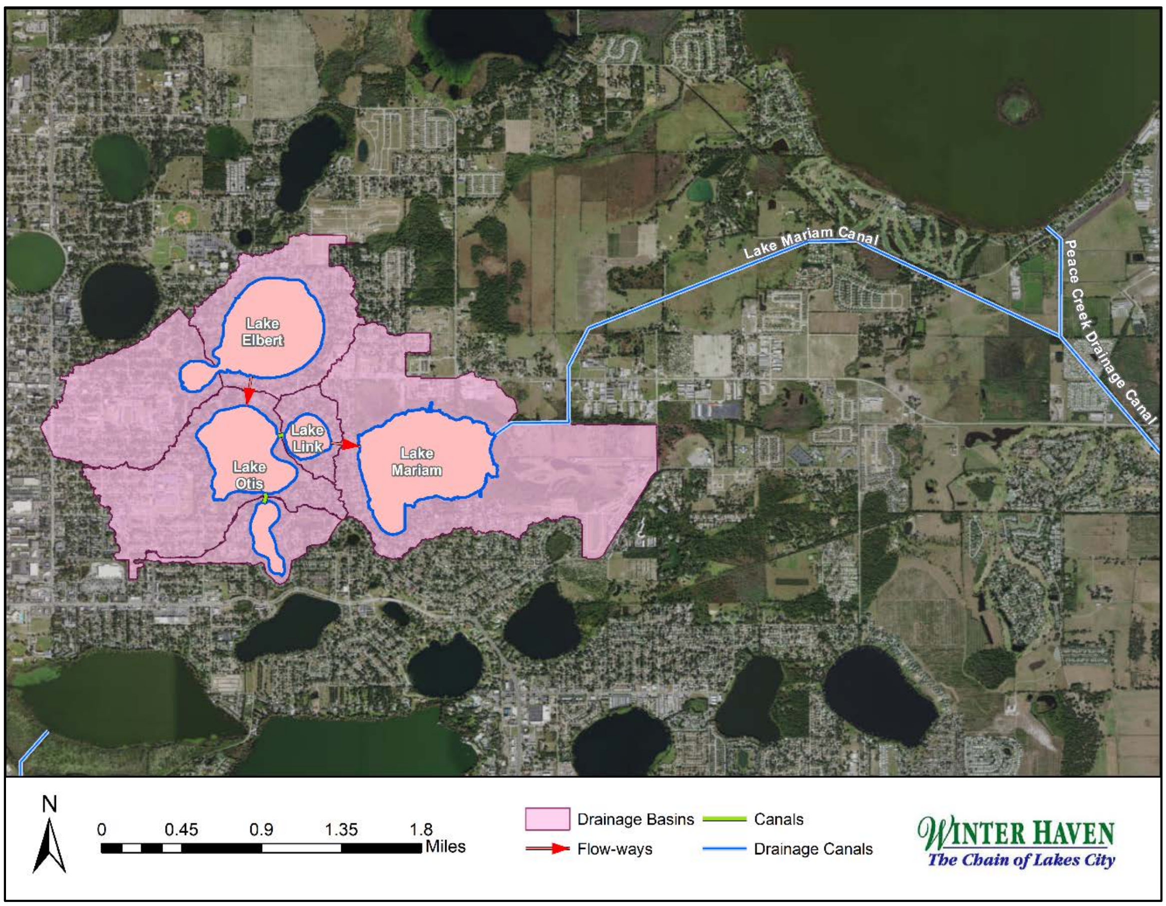


Figure 1-6. Map of South Central Lakes, Flow Pathways & Drainage Basins

Outlying Lakes

The Outlying lakes are made up of isolated waterbodies that don't discharge directly to the Peace Creek Canal, but still meet the other selection criteria presented at the beginning of this section. These lakes are also located at the periphery of the other lake groups. The 6 lakes in this category include:

- *Lake Blue*
- *Lake Daisy*
- *Lake Deer*
- *Lake Mariana*
- *Lake Ned*
- *Lake Pansy*

The lakes in this group are mostly separate systems that flow into other area waterbodies (Figure 1-7). Lakes Blue and Deer, located west of downtown Winter Haven, both discharge to the Southern Chain of Lakes (Lake Cannon) via underground stormwater pipes managed by Polk County. Located in the City of Auburndale, Lake Mariana was selected due to its contribution to the Southern Chain through a ditch and pipe system as well, which discharges into Lake Jessie. Lake Pansy doesn't appear to possess any man-made conveyances to other lakes. However, there is evidence to suggest that Lakes Pansy and Rochelle share a surface water connection via the wetland area between them. Because Pansy lacks a dedicated control structure, the surface level required for flow to occur is not well known. Lakes Ned and Daisy are located in Southeastern Winter Haven. They share a surface water connection, but have no confirmed connections to other lakes or the Peace Creek. However, since they are public lakes abutting City limits, they have been included in this analysis.

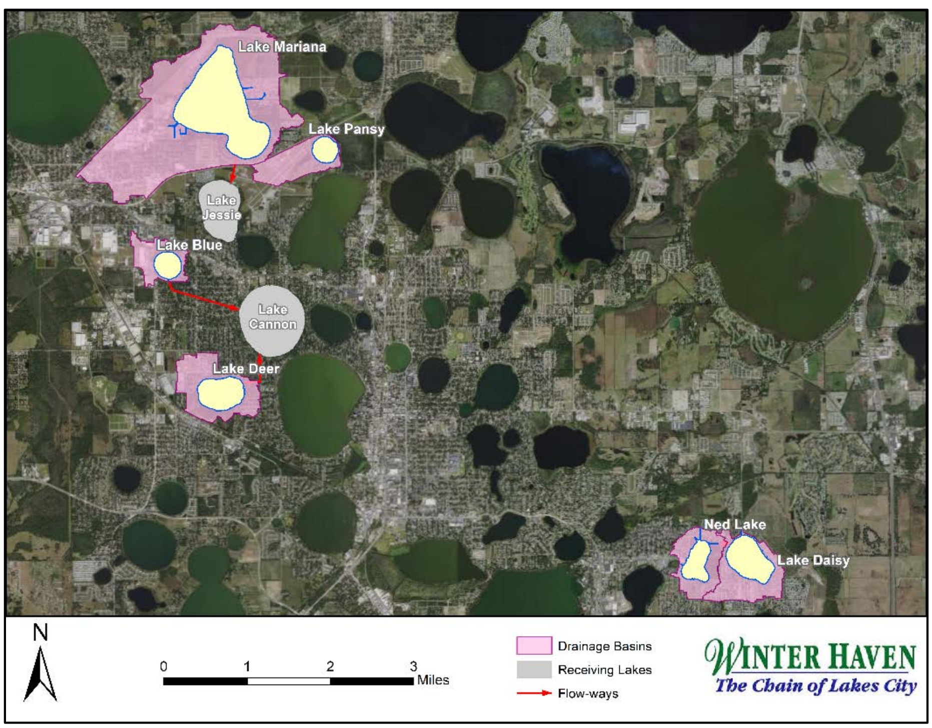


Figure 1-7. Map of Outlying Lakes, Flow Pathways & Drainage Basins

1.3 Background on the Metrics

Just as a person's well-being is reliant on multiple factors such as physical health, genetic predispositions, and individual mental health; so are the facets of limnology built upon complex, dynamic relationships. While significant insights can be gained by studying the individual components, a more comprehensive approach is needed to identify systemic issues and prescribe effective solutions. For the purposes of this study, focus will be placed on understanding the interactions amongst water quality, hydrology, and ecology.

Water Quality

Out of context, the term "water quality" can be misinterpreted. At face value, it simply refers to the relative perceived condition of a water source based on a selection of its physical and chemical characteristics. Different user groups may often judge a lake based on what they consider good or bad qualities. An attribute such as a waterbody's color or trophic state can have a different connotation to swimmers than it would to anglers or nature enthusiasts. Managing these waterbodies in a way that strikes a balance between usability and ecological health ensures that the greatest number of people can take advantage of the benefits our lakes have to offer.

In the context used by the scientific community and regulatory agencies, water quality refers to specific chemical characteristics of a waterbody and how they affect its intended use. The following are some of the parameters adopted by the Federal and State government that the City uses as water quality indicators. Throughout the following sections, the core water quality metrics used in the City's analysis will be described in the context of overall lake health.

Primary Water Quality Metrics

Chlorophyll-a (Chla): *Measured as the concentration of the primary photosynthetic pigment of plants and algae in the water column, Chla is used to estimate algal abundance and can represent the trophic state or biological productivity of a waterbody.*

Nutrient Concentrations: *Measured as the concentration of total nitrogen (TN) and total phosphorus (TP) in the water column, TN and TP are the primary nutrients that contribute to anthropogenic eutrophication.*

Water Clarity: *Measured as Secchi depth, or the maximum depth in the water column that a Secchi disk remains visible to the naked eye. Clarity can be used to measure both suspended and dissolved matter in the water column. Turbidity and true color are separate parameters that impact overall water clarity.*

Regulatory Background

A major effort by State and Federal environmental agencies in recent decades was the development of an objective set of standards and a regulatory system that acts to reduce anthropogenic impacts to waterbodies. These impacts primarily come from the discharge of pollutants such as bacteria, heavy metals, and nutrients. For the purposes of this report, the focus will be placed on nutrient pollution as these are the primary catalysts of lake eutrophication and the main impairment parameters observed in the study area. On the geologic time scale (thousands of years), lakes go through a natural process called eutrophication or increase in productivity. However, many anthropogenic sources of pollution can expedite this process until lakes become hypereutrophic—a productive state that facilitates harmful algal blooms (HABs), fish kills, and unrestricted growth of nuisance or invasive plants.

In 2011, under section 303(d) of the Clean Water Act, the US Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP) established sets of Numeric Nutrient Criteria (NNC) for all of Florida's Surface waters. These criteria are based on a waterbody's intended use classification, estimated pre-disturbance conditions, natural trophic state, and the human-related influences that contribute to eutrophication.

FDEP Intended Use Classifications

- **Class I**: *Potable Water Supply*
- **Class II**: *Shellfish Propagation & Harvesting*
- **Class III**: *Recreation; Propagation, & Maintenance of a Healthy, Well-Balanced Population of Fish & Wildlife*
- **Class IV**: *Agricultural Water Supply*
- **Class V**: *Navigation, Utility, & Industrial Use*

The NNC are specific chemical concentration goals that waterbodies must meet for their intended use classification, of which all of the Winter Haven lakes fall under Class III. Chlorophyll-a (Chla), a measure of algal abundance, is generally used as a response metric for a waterbody's trophic state; with high Chla concentrations indicating an increased trophic status. The EPA and FDEP have established that the two main drivers of eutrophication in freshwater systems are TN and TP. These nutrients are often the limiting component for Chla increase as illustrated by their correlative relationships (Figure 1-8). Based on the correlations in this figure, an increase in either TN or TP lead to an increase in Chla. As a result NNC thresholds were established as a means to determine if a waterbody is impaired. Once impairment has been established, action is taken to reduce concentrations back to acceptable levels.

In addition to the parameters mentioned above, additional chemical characteristics can impact how a lake responds to increased nutrient concentrations. FDEP further categorizes freshwater lakes based on long term concentrations of True Color and Total Alkalinity. True Color, measured in Platinum-Cobalt Units (PCU), is indicative of the amount of dissolved tannins and other organic compounds present in the water column.

Color partly affects the depth light can reach in the water column, impacting the growth of aquatic plants as well as algae. Total Alkalinity or water hardness, measured in milligrams per liter of Calcium Carbonate (mg/L $CaCO_3$), indicates a waterbody's ability to neutralize acids and buffer against changes in pH. Generally, lakes with more alkalinity can support more productivity which is why this metric is used to classify lakes [3]. Due to the increased presence of underlying carbonate rock (limestone) in this region of Florida, the majority of Winter Haven's lakes possess relatively high natural alkalinity.

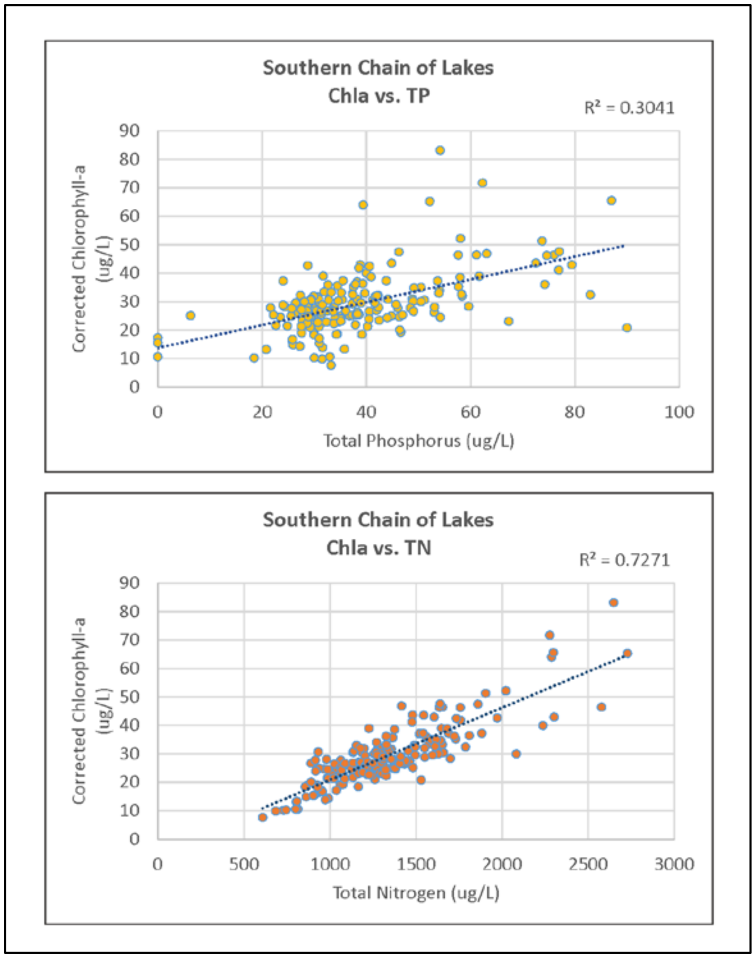


Figure 1-8. Linear Regression of Chlorophyll-a vs. Total Phosphorus & Total Nitrogen

In order to simplify the NNC impairment determination process, a flow chart was developed by City staff as a step-by-step guide (Figure 1-9) [4]. The initial step of the assessment process involves categorization of lakes based on the long-term geometric mean true color and total alkalinity concentrations. Winter Haven's lakes generally fall into two categories: colored lakes (>40 PCU) and clear/alkaline lakes (<40 PCU & >20 mg/l $CaCO_3$) These categories are subject to individual thresholds for the annual geometric mean (AGM) concentrations of Chla, TN, & TP. Once a lake is categorized, annual Chla concentration is assessed. If the AGM Chla exceeds the NNC threshold, or if there is insufficient data to determine Chla impairment, the AGM TN & TP concentrations are subject to the minimum impairment limit for that year. If there is no Chla exceedance, AGM TN & TP concentrations are subject to the maximum limit. In order to assess long-term water quality trends, 7.5 years of AGM concentrations are evaluated. If the Chla, TN, or TP threshold is exceeded more than once in any consecutive 3 year period, then the waterbody is placed on the verified impaired list. By this process, a lake can be considered impaired for nutrients in response to exceedances by Chla, TN, and/or TP.

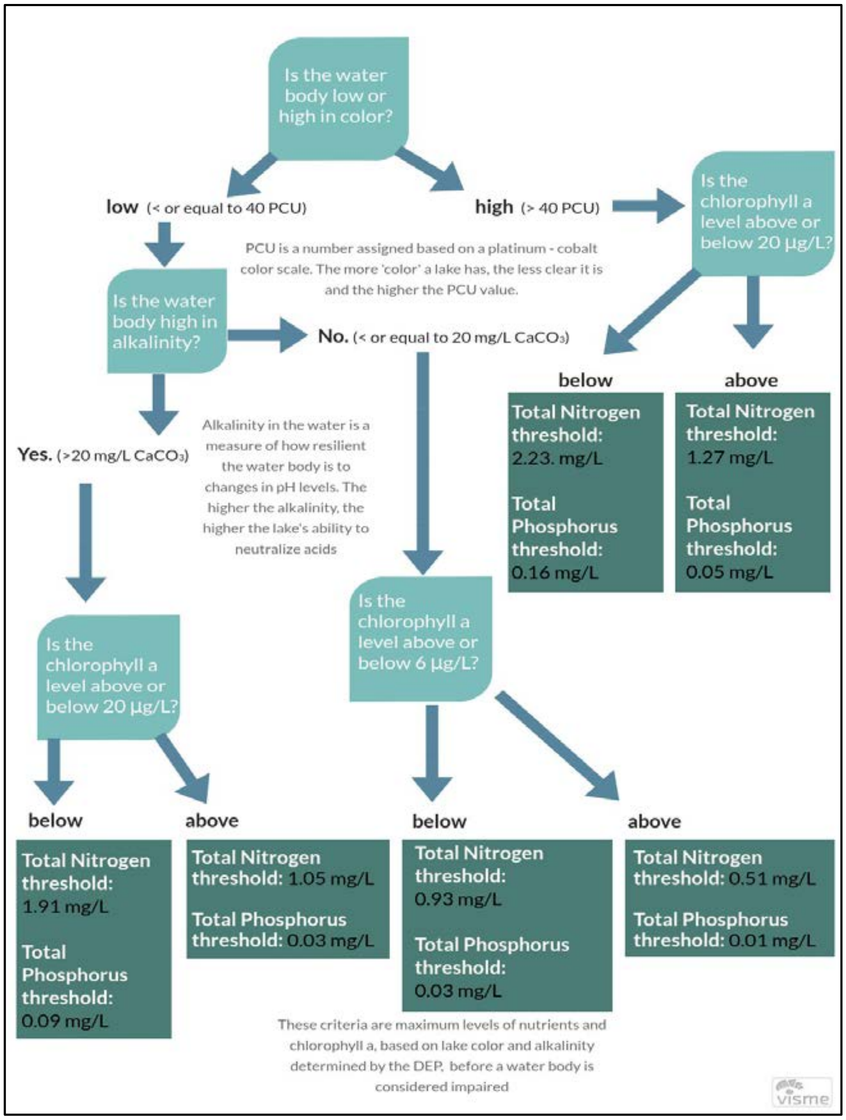


Figure 1-9. NNC Impairment Determination Flowchart

After a waterbody is assessed with a nutrient impairment, the FDEP develops pollutant reduction goals for stakeholders that contribute surface water or groundwater to that waterbody. Referred to as a Total Maximum Daily Load (TMDL), the reduction goals represent the total allowable amount of pollutant that can be discharged to a waterbody per day and still meet the intended use. TMDLs are established for the pollutant of concern which is typically the nutrient of impairment, but can also be the limiting nutrient(s). A nutrient is considered limiting if present in lower relative concentrations than other nutrients or if it would be the first to be used up through natural processes. When a limiting nutrient is depleted, plant and algal growth cannot continue regardless of the presence of other nutrients. Depending on the ratio of nitrogen to phosphorus, a lake may be considered phosphorus-limited, nitrogen-limited, or co-limited. According to UF/IFAS, the majority of Florida lakes are phosphorus limited [5]. Knowledge of the limiting nutrient can assist lake managers in determining what management practices to focus on to improve water quality.

In order to establish appropriate nutrient reduction goals that will lead to water quality improvement, the FDEP must estimate the current pollutant loading rate of point sources and non-point sources in weight of nutrient per year (e.g. lbs/year of TP). Point sources refer to discharge from wastewater treatment plants and **M**unicipal **S**eparate **S**torm **S**ewer **S**ystems (MS4s). Non-point sources refer to the introduction of pollutants through surface runoff, atmospheric deposition, groundwater, sediments, and any other sources that don't possess a discreet entry point. Calculating the current loading rate for each stormwater outfall is accomplished by incorporating estimated annual runoff volumes, size of the contributing drainage areas, land uses, and their respective average loading rates for each pollutant per storm event—referred to as event mean concentrations (EMCs).

With a developed TMDL clearly outlining reduction goals for all relevant loading sources, the next step is the creation of a Basin Management Action Plan (BMAP) or Water Quality Management Plan that mandates stakeholder compliance of the TMDL through the implementation of best management practices (BMPs). BMP is a blanket term that refers to any structural or non-structural practice or initiative that contributes to water quality improvement. The same BMPs aren't applicable for every scenario, therefore the development of BMAPs requires a thorough understanding of the unique challenges associated with individual waterbodies. Successful reduction of pollutant concentrations below the impairment thresholds for an extended period will allow FDEP to remove waterbodies from the verified impaired list to a study list to be monitored for long-term compliance. Once deemed stable in an unimpaired status, waterbodies can then be delisted until such a time they exceed NNC thresholds again.

The FDEP evaluates nutrient impairment of State waterbodies via a cyclical assessment schedule. Impairment determination incorporates the most recent 7.5 years of quality controlled data. Due to the large number of waterbodies in the State and FDEP staffing limitations, statewide annual re-evaluations of impairment aren't feasible. Using the FDEP methodology, the City of Winter Haven has begun evaluating NNC exceedances of local lakes on a yearly basis. The ability to evaluate individual lake exceedances at an annual frequency is beneficial in that it provides insights into the incremental changes in water quality. While impairment doesn't typically change from year to year, extrapolation of the water quality trends can allow for predictions of when NNC goals will be met or exceeded in the future.

Nutrient Cycles

Nitrogen (N) and Phosphorus (P) have been established as the primary pollutants of concern from an anthropogenic standpoint, but each is involved in a complex natural cycle within lake ecosystems. Both nitrogen and phosphorus enter aquatic systems through similar external pathways: surface runoff, groundwater infiltration, and atmospheric deposition (i.e. air and precipitation). Nitrogen is typically present in three forms: organic N, inorganic N, and atmospheric N. Typically, only the inorganic, mineral form of N is biologically available for plants and algae to uptake. Most inorganic N is derived from a microbial process called mineralization that converts it from organic forms. Bioavailable N can also be introduced via anthropogenic sources such as fertilizers and wastewater. One of the more important aspects of the nitrogen cycle is denitrification—a process by which soil bacteria in anoxic conditions can convert inorganic N to atmospheric N; effectively removing it from the aquatic environment.

Similarly to nitrogen, phosphorus also cycles in and out of inorganic (bioavailable) and organic (unavailable) forms. Plants and algae uptake inorganic P from the water column and sediments and convert it into organic P as it's incorporated into their cellular structure. When plant and algal cells die or are eaten, the remains are left to decompose on lake bottoms. Bacteria convert the organic P to inorganic P which can return to the water column depending on the current TP gradient in the lake. This process, called phosphorus flux, can allow large amounts of P to be stored and released periodically over long periods of time—facilitating a continual source of TP. Unlike the nitrogen cycle, phosphorus doesn't undergo a bacterial transformation to an atmospheric form; meaning the only effective means to reduce TP in aquatic environments is through the physical removal of plants, animals, or sediments (muck removal). Due to the large costs associated with these strategies, it's often more economically feasible to develop methods to lock phosphorus in the sediments or prevent it from entering aquatic environments altogether.

Underscoring the concepts of phosphorus flux and nitrogen mineralization is the concern regarding internal nutrient loading. The presence of legacy nutrients originating from historic wastewater or industrial discharges and deposits of phosphatic soils can exacerbate eutrophication. These legacy nutrients require special consideration in planning BMPs as even a significant reduction of stormwater input may not have much effect on water quality if the majority of loading originates from the underlying sediments.

Additional Parameters & Considerations

Trophic state was mentioned previously as a concept describing a waterbody's level of primary productivity. Productivity is a term that relates to the amount of plants, algae, and wildlife a waterbody can support. Trophic status is broken down into several classes (Figure 1-10) [6]:

Trophic States

- **Oligotrophic:** *Low productivity*
- **Mesotrophic:** *Low-moderate productivity*
- **Eutrophic:** *Moderate-High productivity*
- **Hypereutrophic:** *Very high productivity*

As stated above, lakes naturally increase in productivity as they age due to the deposition of sediments over time. Generally, oligotrophic lakes are fairly clear, relatively deeper, and possess smaller populations of plants and fish. Eutrophic lakes, on the other hand, are often highly colored or turbid due to increased amounts of organic sediments. These lakes are typically shallower and have higher natural nutrient concentrations—as such they can support more plants, algae, and wildlife. Mesotrophic waterbodies fit the middle ground between these two while hypereutrophic waterbodies fall on the extreme side of eutrophic. Due to an overabundance of nutrients in hypereutrophic lakes, they are often associated with harmful algal blooms, fish kills, and the unrestricted growth of invasive or nuisance plants. Impairment regulations attempt to set achievable nutrient targets to reduce lake trophic state or prevent further anthropogenic eutrophication.

Prior to the use of the current NNC system, FDEP relied on a ranked system known as the Trophic State Index (TSI) to determine impairment [7]. The index ranks trophic state from low to high productivity on a scale from 1 – 100; calculated using concentrations of TN, TP, total chlorophyll, and Secchi depth. It was determined that a combined trophic state metric cannot always accurately represent the overall quality of a lake. A waterbody with high average TSI values may not be preferable for swimming or skiing, but it could still easily meet the intended use for other forms of recreation such as fishing or kayaking [3].

Paleolimnology, or the ecological study of historic lake conditions, can provide insights into the pre-disturbance trophic state of inland waterbodies. By testing the layers of sediment that have accumulated on the lake floor, inferences regarding historic phosphorus and chlorophyll concentrations can be made. Several studies performed on Winter Haven area lakes have shown that several of these waterbodies were naturally eutrophic prior to human development in the region [8] [9].

Water clarity is a metric that indicates the depth light can penetrate in the water column. This parameter is measured by lowering a Secchi disk into the water column until it is no longer visible. Unlike true color, clarity is impacted by the dissolved *and* suspended particulate matter in the water column. This includes algae, turbidity, and color imparted by dissolved solids. Turbidity or total suspended solids (TSS) is the component of water clarity associated with particulate matter. Often, recreational user groups misconstrue clarity as a mark of water cleanliness. Since many components factor into the overall clarity metric, an unclear lake may not always suffer from water quality issues. Due to this, Secchi depth is no longer used as an impairment determination parameter. Nevertheless, clarity can still provide insights into general water quality trends.

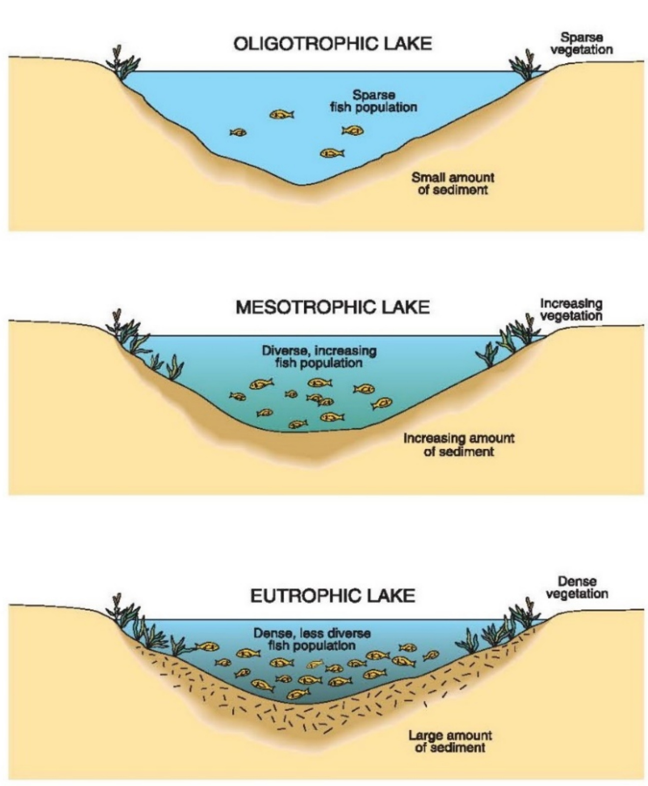


Figure 1-10. Diagram of Lake Trophic States [6].

Hydrology

In the simplest terms, hydrology is the study of the pathways that water takes through our environment. Water's journey is long and varied and each molecule travels the Earth in one way or another. The way water enters, leaves, and interacts with our lakes plays a large part in their overall health. The following metrics are the primary hydrologic response variables and characteristics that are assessed by the City and other environmental agencies. While the metrics listed below are not direct indicators of lake health, they are useful for determining underlying causes of poor water quality and/or biological health. In addition, management practices can be tailored to specific waterbodies based on their unique hydrologic characteristics. In the health and wellness analogy, hydrology is akin to a patient's medical history—something that cannot be changed, but can point to underlying issues that can be managed.

Primary Hydrologic Metrics

Surface Level: *The elevation of a waterbody's surface measured in feet above sea level. Also known as lake stage, surface level changes over time in response to environmental stimuli such as precipitation and groundwater influence.*

Pollutant Loading: *The amount of pollution that can enter a waterbody via stormwater flow, pollutant load is typically estimated based on precipitation, land use, and surface runoff potential (imperviousness).*

Rainfall

Precipitation in all its forms (rain, snow, sleet, hail) is one of the main drivers of the hydrologic cycle. Winter Haven is a great example of the importance of precipitation as our local hydrologic system is completely rainfall driven. The topography of the Winter Haven Ridge and Polk Uplands regions essentially place these lakes on a hilltop where surface water naturally migrates downstream toward the Peace River. Rainfall in this area is responsible for fluctuations in lake levels as well as the recharge of groundwater reservoirs.

Precipitation can reach a lake directly or via surface runoff from the surrounding land. The total area that contributes stormwater runoff to a waterbody is referred to as that lake's drainage basin. In a natural system the effective drainage basin of a lake is relatively small. Abundance of vegetation and a lack of impervious surfaces cause much of that stormwater to infiltrate into the groundwater system before it reaches the lake. Installation of "gray" infrastructure such as stormwater pipes or concrete ditches and swales can significantly alter a lake's drainage basin—often increasing the volume of direct stormwater flow. This can cause issues such as rapid surface level fluctuations as well as increased nutrient loading. Restoring some of the natural drainage pathways can be accomplished through the implementation of "green" infrastructure BMPs that reduce runoff and increase stormwater storage and infiltration.

Groundwater

There are two primary tiers of groundwater in Florida: the upper layer known as the surficial aquifer, and the deeper Floridan aquifer, confined under a layer of impermeable clay. Measurement of the elevation above sea level of the upper surface of each aquifer is the accepted method for determining their current water quantity. The surficial aquifer level is referred to as the water table. Since the Upper Floridan is a confined aquifer, its level is measured as the potentiometric surface, or the level at which water will rise in a well pipe due to the pressure exerted on it. Where there are breaks or perforations in this confining layer, water can be exchanged with the surface. Fluctuations of both the surficial and Upper Floridan levels can significantly impact lake surface levels (Figure 1-11). During periods of time or locations where the aquifer surfaces are high, water may flow to the surface via the bottom of lakes. Of course, the opposite occurs when the water table and potentiometric surface are low.

The Upper Floridan Aquifer is the sole municipal water source for the City of Winter Haven. As one of the fastest growing metropolitan regions in the Country [10], the potential hydrologic impacts of water use must be considered not only for the ecological outlook of our lakes, but also for the future of our drinking water supply. The primary hydrologic strategies for this area include promoting rapid recharge of the Upper Floridan and the long-term storage, treatment, and slow infiltration of surface waters in areas where fast recharge isn't feasible.

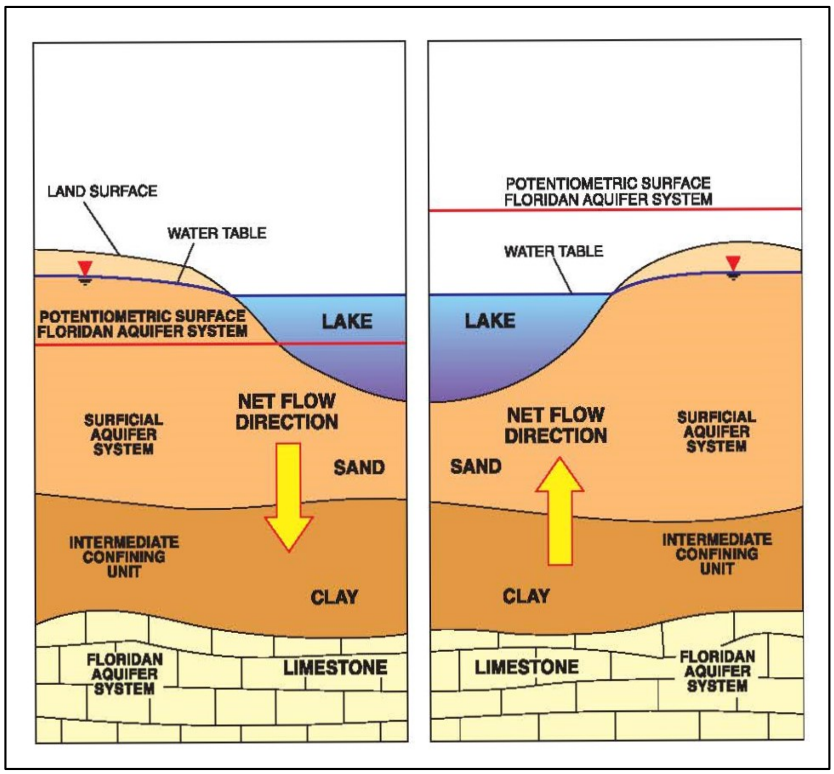


Figure 1-11. Diagram of Groundwater Interactions

Soil Type

The types of soils found in lake drainage basins can significantly impact hydrology. The United States Department of Agriculture (USDA) has classified soils on public and private lands into several hydrologic groups based on sediment types (e.g. sand, clay, loam) and their respective water infiltration rates. This information has long been used in site development and engineering for projects across the country since the early 1900s. Environmental scientists can also utilize soils data to determine how well water filters into various sediments.

USDA Hydrologic Soil Groups

- **Group A:** *Soils consisting mostly of excessively drained sands or gravel with a high infiltration rate when thoroughly wet.*
- **Group B:** *Soils consisting of moderately well-drained course or fine texture sediments with a moderate infiltration rate when thoroughly wet.*
- **Group C:** *Soils consisting of fine textures having a layer that impedes the downward movement of water with a slow infiltration rate when thoroughly wet.*
- **Group D:** *Soils consisting chiefly of clays or clay layers near the surface or over nearly impervious material with a very slow infiltration rate.*
- **Dual Groups:** *(A/D, B/D, C/D) Mixed soils with no dominant type where the designation applies to 'drained'/'undrained' areas.*

The proportion of each soil group making up a given lake drainage basin can indicate the pre-development infiltration potential in that basin. This information can also be used to determine adequate locations for BMPs that promote groundwater recharge or treatment of stormwater. The majority of the Winter Haven area consists of Class A or A/D soils, however notice that the proportion of A/D soils increases further from the downtown area (Figure 1-12). It can be inferred that stormwater infiltration BMPs will be more effective in the City center with surface water storage/treatment being relegated to the less well-drained lower elevations at the periphery of the downtown area.

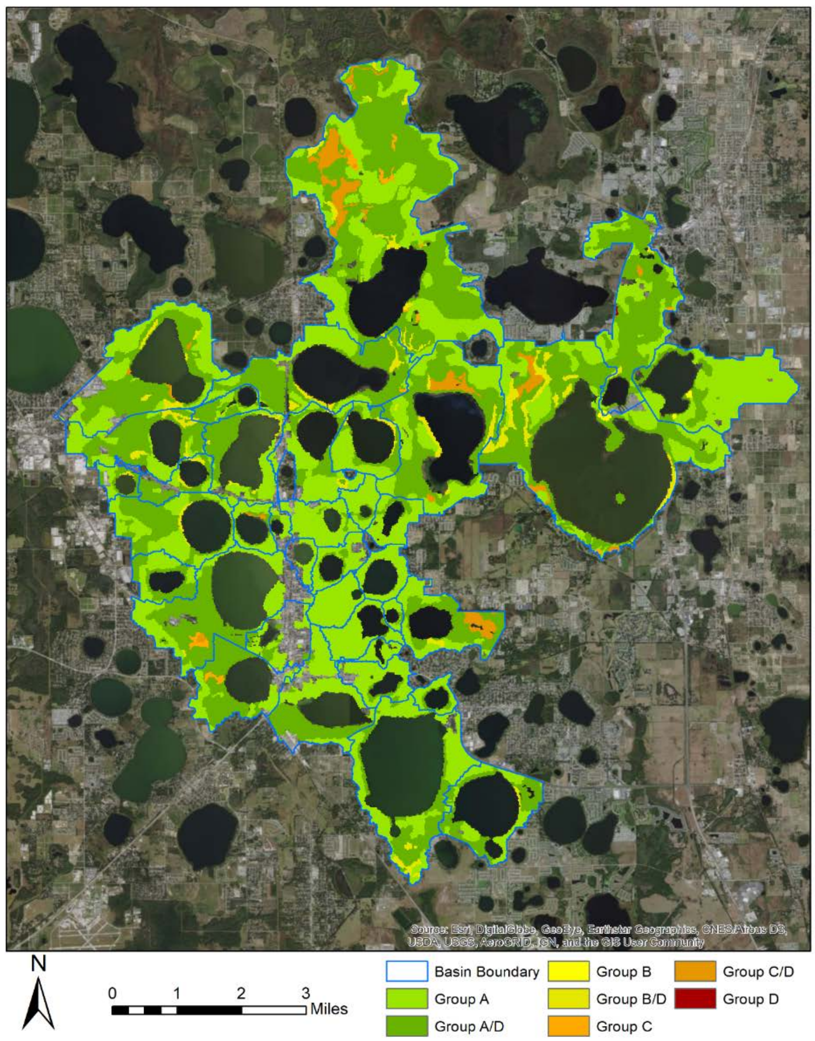


Figure 1-12. Hydrologic Soil Groups of the Winter Haven Lakes

Pollutant Loading

Identifying pollution hotspots in our waterbodies is the primary purpose of pollutant load determination. Focusing management efforts on areas with relatively high pollutant loads can only be done through quantification. Nonpoint pollutant loads such as septic leaching into groundwater are difficult to estimate, however it is still useful to identify areas of high septic density to develop management plans around them. For point sources or stormwater drainage basins with few discharge points, it may be more feasible to sample during storm events and calculate an average pollutant load during a typical year. Larger or more complex watersheds may require mathematical models to estimate loading. Due to the number of lakes and individual drainage sub-basins in the Winter Haven area, the City has elected to model stormwater pollutant loads for the 37 lakes under consideration.

In the realm of stormwater pollutant load modelling, there are a number of methods that take into account various factors that can influence loading rates. The 'Simple Method', developed by Thomas Schueler in 1987, is an EPA approved model that utilizes rainfall volume and land use area to estimate the annual load of various pollutants such as TN, TP, suspended solids, and heavy metals [21]. Tied to each land use are average impervious percentages to determine runoff rates as well as event mean concentrations (EMCs) which denote average loading rates for each pollutant per storm event. The result of this modelling work is the ability to estimate annual loads of nutrients from each sub-basin to prioritize the implementation of BMPs in high-loading hotspots. For example, the annual total nitrogen loading rates in Lake Silver's sub-basins are indicative of increase pollutant loading from the urban commercial land uses (Figure 1-13).

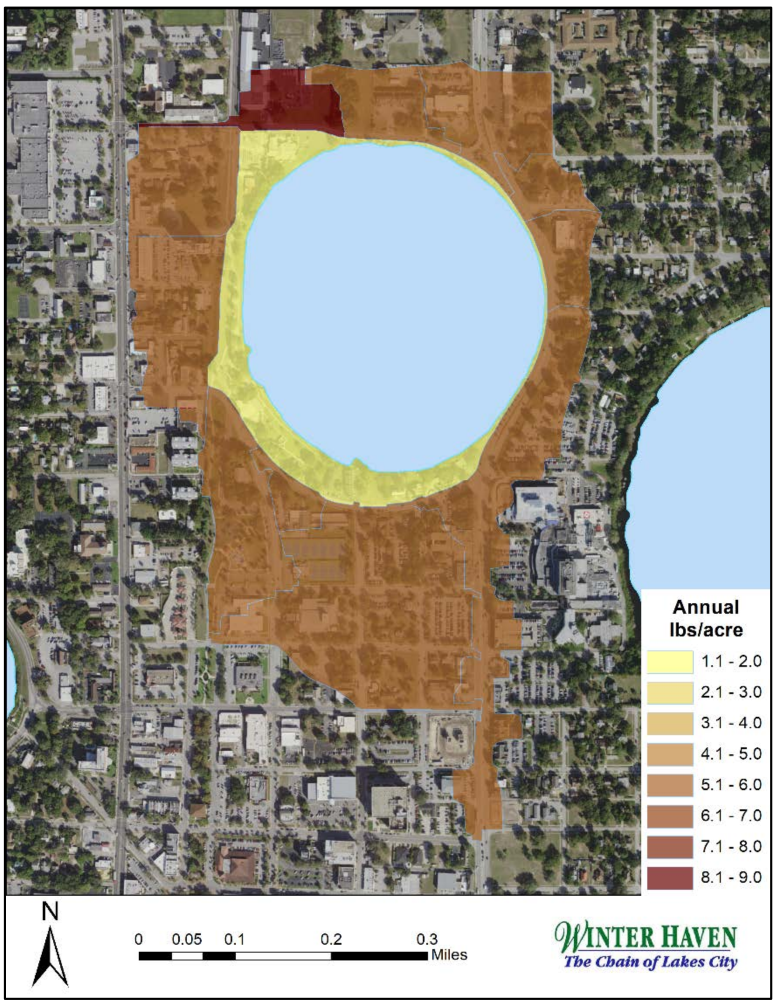


Figure 1-13. Annual Total Nitrogen Loads to Lake Silver in lbs/acre

The calculated loading rates displayed here are raw values that exclude nutrient load reductions from stormwater best management practices. There are numerous privately owned BMPs within each drainage basin, however the estimated load reduction they confer is not always documented. City land development code require a match of pre and post development runoff volumes [22]. By design, these BMPs capture the majority of runoff. However, many parcels that were developed prior to the initiation of these ordinances have no stormwater management BMPs implemented. By identifying where raw pollutant loads are highest and where there are no documented BMPs, staff are able to pinpoint specific communities where new stormwater practices will have the greatest effect. This strategy is most effective in Winter Haven's residential urban center where aging stormwater infrastructure and high density of impervious surfaces funnel untreated stormwater directly to lakes. Redevelopment of urban residential areas is slow or nonexistent and so retrofitting green infrastructure projects like raingardens or infiltration pipes are some of the few viable means to reduce pollutant loading.

Ecology

Ecology is a subsection of biology that focuses on the study of living organisms and their interactions with one another and their environment. An understanding of these biological communities is necessary to meet the intended use requirements for Class III waterbodies, referenced earlier in this document.

> **Class III**: *Recreation; Propagation, & Maintenance of a Healthy, Well-Balanced Population of Fish & Wildlife*

One of the main components of any ecosystem is the presence of primary producers (i.e. plants and algae). These photosynthetic organisms provide multiple benefits for the aquatic environment. The management of non-algal plants, or macrophytes, ensures that their populations remain healthy and well-balanced. The quantity and quality of vegetation in a waterbody respond to and impact the response of both hydrologic and water quality metrics. In addition, a healthy plant community will also provide habitat and food sources of native fish and wildlife. It is for this reason that the City decided to focus on aquatic vegetation as a vital component of lake health.

Primary Ecological Metrics

Biological abundance: *The quantity of vegetation growing in a waterbody can be estimated through the use of remote monitoring methods. Percent area coverage (PAC) and biological volume (BV) represent the respective 2-dimensional and 3-dimensional quantification of plant matter relative to a waterbody's size.*

Species Composition: *Ecological surveys are performed to estimate the overall population of aquatic plants in each lake. A count of each species present during a survey allows for the evaluation of diversity, dominant taxa, and the ratio of natives to invasives.*

Species Diversity: *Species diversity is a measure of the overall richness (number of unique species) and evenness (relative species proportion) of a lake's biological community. Multiple indices are used to evaluate overall diversity.*

Aquatic Plant Types

Of the different types of primary producers in aquatic environments, both microscopic algae and macrophytes (large aquatic plants) fill a similar ecological role as an oxygen-producing food source for primary consumers. A healthy balance of each is necessary for a functioning, diverse aquatic community. However, macrophytes provide additional ecological benefits such as their role as habitat for aquatic fauna. Based on their various fundamental growth strategies, aquatic macrophytes are separated into three categories: submerged aquatic vegetation (SAV), emergent aquatic vegetation (EAV), and free-floating vegetation (FV) (Figure 1-14).

Submerged plants grow completely under the water's surface and are usually rooted in the benthic sediments. Since the main body of the plant is supported by water, SAV isn't hampered by the energy requirements needed to develop rigid support structures to keep them upright. Due to this, SAV species typically grow relatively quickly. However, this evolutionary strategy ties the growth of submerged plants to the availability of sunlight—meaning that water clarity, bathymetry, and surface level can significantly impact available real estate where SAV can grow. Common examples of SAV in our lakes include eel grass (*Vallisneria americana*) and the invasive species hydrilla (*Hydrilla verticillata*).

Emergent plants are similar to SAV in that they are rooted in the benthic substrate, however the main photosynthetic body of the plant grows above or floats on the water's surface. This adaptation negates some of the issues associated with light availability, however these plants must put more energy into structural components that allow them to rise above the surface. In addition, the growing depth of EAV is limited by the capacity to transport air and nutrients to their root systems—meaning that most species are relegated to the shallow margins of lakes. Duck potato (*Sagittaria lancifolia*) and cattail (*Typhus spp.*) are a couple examples of emergent plants.

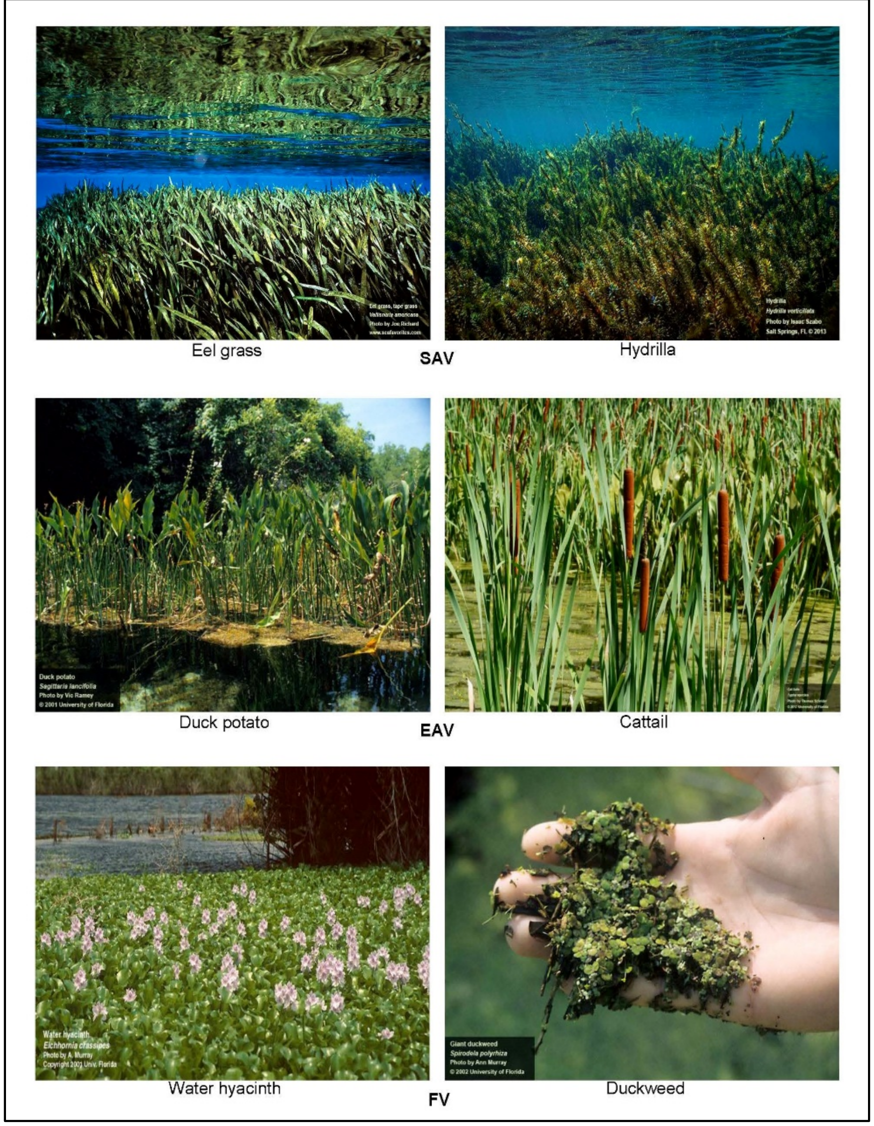


Figure 1-14. Examples of Aquatic Vegetation Categories

Floating plants are unique in that they have evolved beyond the need to root into the underlying substrate. To prevent them from sinking, most are small in size while some species possess adaptations that create buoyancy. The ability to float negates many of the challenges that SAV and EAV must contend with. By virtue of this, some of the most prolific invasive plant species in Florida are floating plants. Examples of FV species are water hyacinths (*Eichhornia crassipes*) and duckweeds (*Lemnoideae spp.*).

Vegetation Quantity

The areas of saturated or inundated ground along the peripheries of some lakes can support emergent vegetation. These areas, known as wetlands, are a unique habitat area that many species of wildlife rely on. Wetlands can act as a pollutant sink as well as a source of beneficial chemical components [12]. Surface water that comes into contact with wetland areas deposits sediments, nutrients, and other contaminants. Also, most forested wetlands provide a source of dissolved organic compounds that impart color to the water column. Figure 1-15 illustrates the correlation between surface level and true color in a system with surrounding wooded wetland area and one without significant wetlands. Lake Haines, with its surrounding wetlands elicits a much stronger relationship between surface level and color than Lake Blue which lacks any substantial forested wetland area. Reductions in wetland connectivity through land development or surface level alteration can diminish these benefits. Identification and restoration of historic wetland connections is one management strategy that can be employed to improve water quality.

For submerged vegetation, the area within a lake that can support the growth of SAV is referred to as the littoral zone. This area, measured as the percent of area covered (PAC), is limited by the depth that light can penetrate in the water column. As such, the size of the littoral zone is determined by lake morphology, water clarity, and the unique requirements of the species of plants that inhabit it. Since most SAV species are rooted, they contribute to the stabilization of the benthic sediments [13]. Therefore, it can be inferred that greater PAC generally equates to lower potential suspended sediment concentrations. Unofficial state that a range of 15 – 30 PAC is generally considered a conservative target for beneficial wildlife habitat.

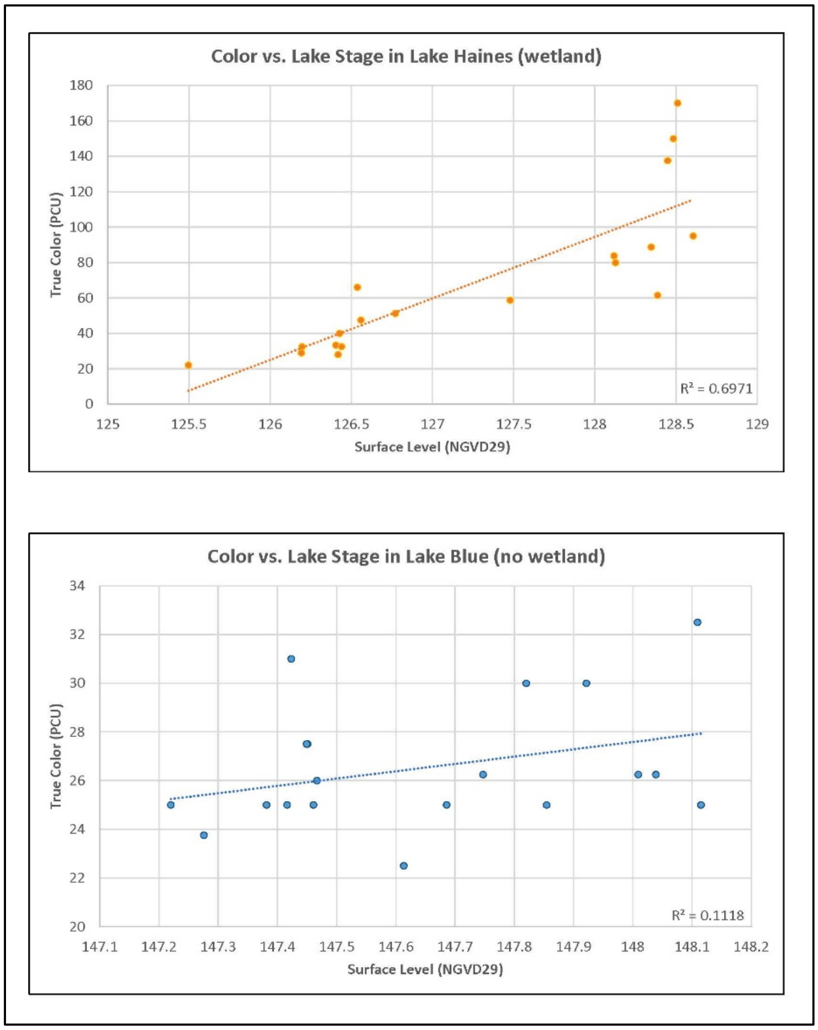


Figure 1-15. Correlation between Wetlands and True Color in Lake Haines & Lake Blue

One additional benefit of SAV in lakes is their increased capacity to uptake nutrients directly from the water column compared to most emergent species [14]. Monitoring the total quantity of SAV can help determine a lake's ability to buffer against changes in nutrient concentrations. The use of SONAR mapping technology allows for the 3-dimensional quantification of SAV. By finding the difference between depth to bottom and depth to vegetation, the volume of water inhabited by plants can be calculated. This metric, known as biological volume, or biovolume (BV), is often recorded as a percentage in relation to total lake volume. The City has been recording the annual changes in BV in most study area lakes since 2016.

Vegetation Diversity

Species diversity is a complex metric that takes into account the number of species present (richness) as well as the relative proportion of each species (evenness). Since each individual plant can't feasibly be counted, scientists can use a variety of survey methods to identify what a representative sample of the overall population looks like. Using a point-intercept method to sample regularly spaced points across a lake's area, the City can record not only the estimated number (frequency) of each species, but also their relative spatial distribution.

Species frequency can be used to identify a waterbody's dominant taxa as well as to calculate species richness and evenness (Figure 1-16). The resulting scores, referred to as diversity index values, can be used to evaluate the health of vegetation communities. Ecologically, a healthy population is a diverse and evenly distributed one. As an example, a lake that is dominated by one or two species is at a substantially greater risk of collapse than one with numerous, equally abundant species. Common sources of collapse include climatic changes, pests and diseases as well as competition from invasive species. Since species diversity is such a complex metric, no single index can adequately represent diversity in all cases. Moreover, some indices make assumptions regarding the population being studied and are applicable only in specific scenarios. For the intents and purposes of this study, these indices are only used to compare the changes in vegetation communities over time and not for comparing the diversity of one lake to another:

Primary Species Diversity Indices [15]

- **R2**: known as *Menhinick's richness index, represents the number of unique species sampled in a given site or area. This index is reliant upon sampling effort, therefore it is useful only for comparing richness of the same site over time (assuming sample size remains constant).*
- **E3**: *One of many popular indices that represent how evenly the species in a population are distributed. E3 ranks a sample from 0 – 1 where the index approaches 1 when all species are present in equal proportions.*
- **H**: *Referred to as Shannon's Diversity Index, this metric incorporates concepts of richness and evenness. H represents the uncertainty of sampling the same species multiple times in a row; as such this value increases as a population becomes more diverse.*

In the realm of vegetation management, knowing where a given species is located is equally as important as understanding the diversity dynamics of the local population. Where a particular plant species is commonly found can provide information about its optimal growing conditions (e.g. light, depth, or substrate). It can also be used as a handy method for tracking invasive species such as hydrilla and water hyacinth. These plants have few natural checks that would limit their growth in this region and can outcompete most natives; often to the detriment of navigation and ecological diversity.

The City of Winter Haven does not actively manage invasive aquatic species in public waterbodies, however it provides support to the organizations that do. The Florida Fish and Wildlife Commission (FWC) is the governing body with jurisdiction over treatment of waters of the State. Through funding from FWC, Polk County assists in the treatment of invasive plants in this area using various methods including herbicide, mechanical removal, and biological controls. Excluding physical removal methods, the treatment of invasive species can facilitate reintroduction of nutrients as the treated plants decompose. Fortunately, the release of nutrients can be mitigated by limiting treatment area and intensity. The City's monitoring efforts allow for the early detection of invasives so that they may be managed before their populations expand and require large scale treatment. This concept of early detection and rapid response is critical to the maintenance of species diversity and overall ecological health. Since complete eradication of invasives is often not a feasible goal, reduction of invasive presence to a maintenance state is the general target. These targets are typically based on percent of lake surface area covered and are species specific. Since the point-intercept survey methods aren't the most applicable means of measuring species area, the City considers reduction in invasive frequency an adequate indicator of improvement.

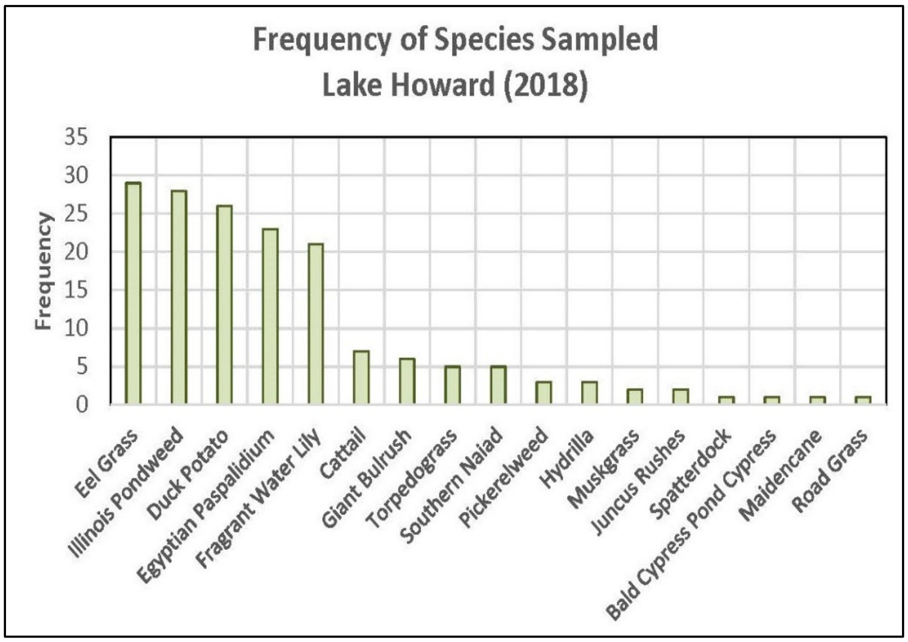


Figure 1-16. Species Frequency Chart of Aquatic Vegetation in Lake Howard

2- Data Presentation & Analysis

Acknowledgements

The City of Winter Haven would like to recognize the following organizations for providing support with data collection and analysis. The water quality data used in this analysis is sourced via the Polk Water Atlas which is curated by the University of South Florida (USF) with funding through the Coastal & Heartland National Estuary Program (CHNEP); water quality data is collected quarterly by the Polk County Natural Resources Division. Surface level datasets have been sourced from the Southwest Florida Water Management District (SWFWMD) and the Lake Region Lakes Management District (LRLMD). Bathymetric and biological survey data for Lakes Hamilton, Middle Hamilton, and Little Hamilton were collected by the Florida Fish and Wildlife Conservation Commission (FWC) via their Invasive Plant Management Section. Watershed soils data was obtained from the Natural Resources Conservation Service's Soil Survey Geographic Database (SSURGO). Land use data for pollutant loading calculations is from the 2017 SWFWMD land use survey GIS layer. All other data have either been collected by City of Winter Haven staff or are cited directly in the report. Much of the analysis and data visualization presented here has been made possible through ESRI ArcMap, Microsoft Excel, and the Tableau data visualization software.

Summary

Using the concepts and metrics detailed in the previous section, the following is a presentation of the chemical, hydrologic, and ecological data collected by various environmental agencies and organizations. For the purposes of organization and readability, the data has been arranged by the lake groups established in section 1.2. These groups are based on their drainage pathways and spatial distribution, however, not all lakes within a group may exhibit similar responses to environmental stimuli. No doubt, comparisons can be made between lakes and/or lake groups, but the focus of this report is on site-specific evaluations. Consideration of each waterbody's unique characteristics is necessary to develop effective management strategies aimed at maintaining and improving lake health.

This evaluation has been performed by reviewing various water quality and ecological criteria in order to ascertain the relative health of each waterbody. Each criterion is assigned a value indicating whether the target waterbody is meeting the recommended standard and/or exhibiting improvement. The individual criterion values are then aggregated, resulting in a semi-quantitative lake health score that can be used to prioritize management of lakes within the study area. The following are the individual lake health criteria:

- *Water Quality Criteria*
    - *NNC Impairments*
        - *Chlorophyll-a*
        - *Total Nitrogen*
        - *Total Phosphorus*
    - *Chlorophyll-a Trends*
    - *Total Nitrogen Trends*
    - *Total Phosphorus Trends*
    - *Clarity Trends*
- *Biological Criteria*
    - *Vegetation Abundance*
    - *Invasive Species Percentage*
    - *Species Diversity*
        - *Menhenick Richness Index (R2)*
        - *Hill Evenness Index #3 (E3)*
        - *Shannon's Diversity Index (H)*

NNC Impairments: For the impairment indicator, a score of 1 is given for each metric not determined to be impaired, while 0 is assigned to any currently impaired metrics. Each metric score is combined for a possible score of 3 which indicates a lake without any impairments. Impairment is determined as more than one consecutive Annual Geometric Mean (AGM) exceedance of NNC thresholds in any 3-year period during the 7.5 year assessment period.

Water Quality Trends: Each water quality metric is evaluated on monotonic trend direction (+/-) and statistical significance (p-value ≤ 0.05) based on AGM values for each parameter (Chla, TN, TP, and Secchi depth) from 2000 to 2019. Significant improving trends are assigned a score of 3; non-significant improving trends are given a score of 2; non-significant deteriorating trends are scored as a 1; and significant deteriorating trends are scored as a 0.

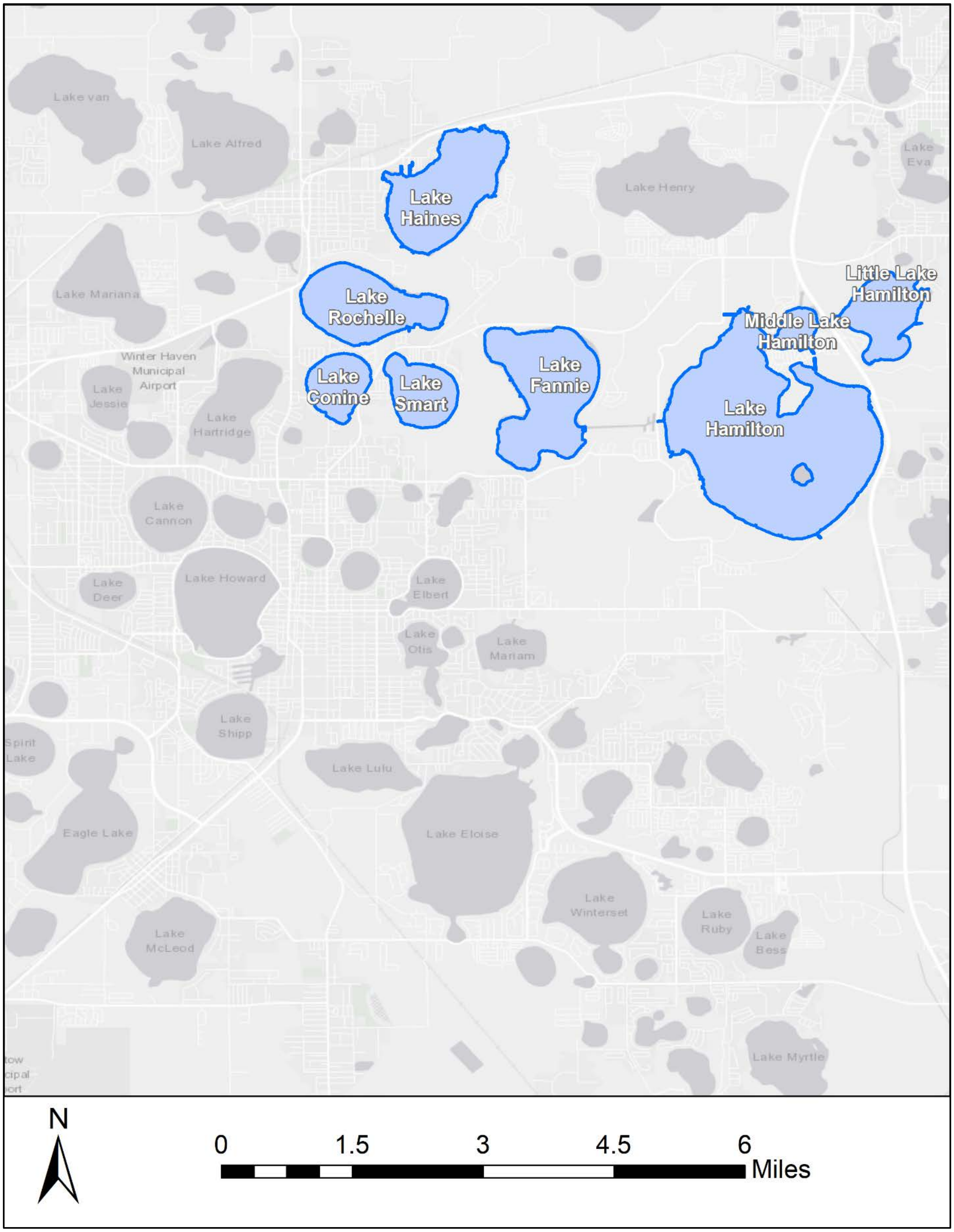
Vegetation Abundance: Abundance is scored based on percent area coverage (PAC) values as determined by SONAR mapping. A score of 3 is given to lakes with PACs exceeding 30%; between 30% and 15% receives a score of 2; a 1 is assigned to lakes between 15% and 2.5%; a score of 0 is given to lakes with less than 2.5% PAC.

Invasive Species Percentage: Invasive indicator scores are based on species frequency numbers as a percent of sample for each waterbody. Scores are assigned for total percentage of invasive species managed by environmental agencies. A score of 3 is assigned to lakes with no managed invasive presence; a 2 is given to lakes with less than 2.5% total invasive percentage; lakes with between 2.5% and 10% are given a score of 1; while 0 scores are given to lakes with greater than 10% total invasive percentage of the sample.

Species Diversity: Diversity scores are assigned per lake based on a measurable increase or decrease of index values. A score of 1 is given to each of the three indices (R2, E3, H) exhibiting an increase from the previous year to the current; 0 scores are assigned to indices exhibiting a decrease from the previous year. For each waterbody, index scores are combined for a total possible score of 3. As more data is collected, baseline diversity values can be calculated for each waterbody. Comparisons to these baseline values will allow for a more robust evaluation of relative vegetation community diversity.

Lake Health Score: The individual lake health indicator scores are averaged for each waterbody. The resulting value represents each lake's annual relative health on a scale of 0 to 3 with 3 being an exceptionally healthy waterbody. This lake health score methodology was not developed to be an official evaluation metric, but is intended to be used to track overall changes in the Winter Haven area lakes over time. Since many of the individual indicator criteria are based on a binary scale, the overall lake health metric does not incorporate magnitude. As a result, these scores are not applicable as absolute measurements of overall lake condition, only as a means to compare the lakes within the study area. Moreover, this metric is meant to be evaluated annually which means that lake health index values will fluctuate due to environmental or anthropogenic stimuli—these values are not static.

2.1 North Chain of Lakes



The Winter Haven North Chain of Lakes (NCOL) is made up of eight waterbodies: Lakes Conine, Fannie, Haines, Hamilton, Rochelle, Smart, Little Hamilton, and Middle Hamilton. While Lake Henry is also considered part of this Chain, it has been excluded from this study due to a lack of public access and means to collect water quality data. The primary surface water contributors and Municipal Separate Storm Sewer System (MS4) permit holders within the NCOL watersheds include the Florida Department of Transportation, Polk County, and the cities of Winter Haven, Lake Alfred, and Haines City. As recently as 1992, Lake Conine received wastewater discharge from the City's Wastewater Treatment Plant #2. Currently, Lakes Conine, Haines, and Rochelle possess FDEP Nutrient TMDLs which were established in 2018.

Water Quality

In order to determine water quality impairment, the NCOL waterbodies were categorized based on long-term geometric mean true color and total alkalinity concentrations. Of the nine waterbodies, Lakes Fannie, Haines, Hamilton, and Middle Hamilton were determined to be highly colored while Lakes Conine, Rochelle, Smart, and Little Hamilton were categorized as clear, alkaline waterbodies. Annual geometric mean (AGM) chlorophyll-a (Chla), total nitrogen (TN), and total phosphorus (TP) concentrations between 2011 and 2019 were evaluated to determine impairment status. The AGM concentrations are displayed in Tables 4-1 through 4-3 located in the Appendix. Based on this dataset, Lakes Conine, Hamilton, Rochelle, Little Hamilton, and Middle Hamilton are impaired for Chla, TN, and TP exceedances during the 7.5 year assessment period. Lake Haines remains impaired for Chla and TN exceedances, but TP has consistently remained below NNC thresholds for the last 7.5 years. Lake Fannie Chla, TN, and TP concentrations have dropped below exceedance thresholds for the requisite amount of time to remove it from provisional impaired status.

A snapshot of the 2019 AGM Chla, TN, TP, and Secchi depth values for the NCOL is displayed in Figure 2-1. Also represented are each lake's long-term mean and normal range (+/- 1 standard deviation) derived from the period between 2000 and 2019. Comparison of 2019 water quality levels with long-term values indicates that the majority of these waterbodies are currently exhibiting below average Chla, TN, and TP concentrations as well as above average water clarity. Lake Hamilton is the only lake in this group experiencing poorer water quality with regards to Chla, TN, and Secchi depth than its long-term averages. However, one positive note is that current TP concentrations for Lake Hamilton are actually much lower than the 19 year mean. This decline in TP has shifted the nutrient balance in Hamilton to a strictly phosphorus limited system for the last three years. The management implication for this shift could be that further reduction of TP sources in the drainage basin may limit the growth of algae and work to reduce Chla concentrations.

To determine whether each lake is experiencing overall water quality improvement or deterioration, analysis of the long-term trends was performed. The monotonic (directional) trend test involves linear regressions of AGM Chla, TN, TP, and Secchi depth from 2000 to 2019 (Table 2-1). The magnitude of the correlation coefficient (R^2) was not factored into the lake health criterion, however the regression direction (Increasing/Decreasing) and statistical significance (p-value ≤ 0.05) were used to determine the trend relationship and validity respectively (see Table 4-4 in Appendix for regression statistics).

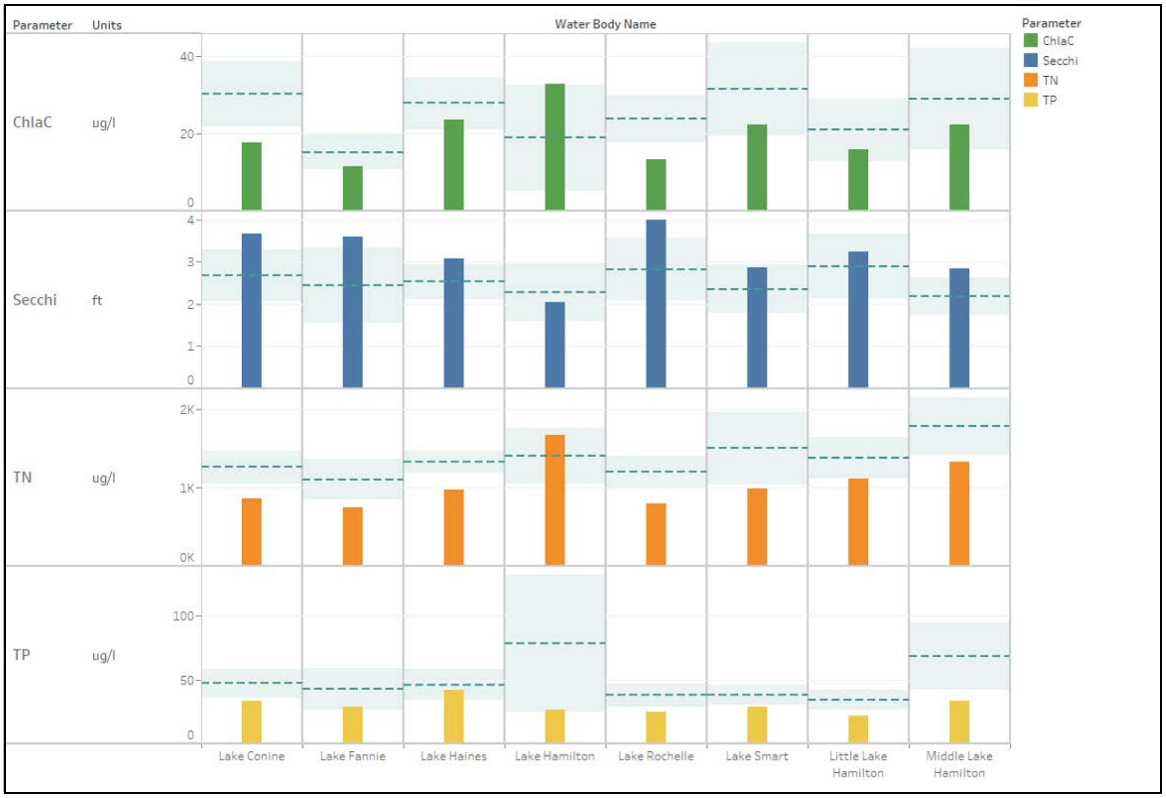


Figure 2-1. 2019 AGM Chla, TN, TP, & Secchi depth values for the North Chain of Lakes; dotted line represents long-term mean and the shaded area refers to the standard deviation range.

Chlorophyll-a Trends: Lake Hamilton is the only waterbody in this group exhibiting a significant increasing trend in Chla, while Lake Rochelle is the only lake showing a decreasing trend from 2000 – 2019.

Total Nitrogen Trends: Lake Hamilton currently exhibits a significant increasing trend in TN. Lakes Haines and Rochelle are both significantly trending downward in TN.

Total Phosphorus Trends: Lakes Conine, Hamilton, Rochelle, Smart, and Middle Hamilton exhibit significant declining TP trends. No lakes in this group are trending upward in TP.

Water Clarity Trends: Between 2000 and 2019, Lakes Conine, Fannie, Haines, and Rochelle displayed significant improving trends in water clarity. Only Lake Hamilton possesses a significant deteriorating trend in clarity over this time frame.

Despite existing impairments, the majority of waterbodies in the Northern Chain are experiencing some form of improvement in the four primary water quality parameters. If current trends continue, Lakes Conine, Haines, and Rochelle are likely to drop below nutrient impairment thresholds. However, greater focus will need to be placed on the management strategies impacting the Lake Hamilton chain. Even with the decline of TP, the sources of pollutants causing the increase in TN and Chla must be identified—whether they be from external or internal loading. Since much of the area draining to Lake Hamilton is outside municipal limits, the City must work with other stakeholders in the area to identify and limit the sources of pollutant loading to these lakes.

Waterbody	Parameter	Trend Direction	Significance	Index Score
Lake Conine	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing	Not Significant	2
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Lake Fannie	Chla	Decreasing	Not Significant	2
	TN	Decreasing	Not Significant	2
	TP	Decreasing	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
Lake Haines	Chla	Decreasing	Not Significant	2
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
Lake Hamilton	Chla	Increasing (Deteriorating)	Significant	0
	TN	Increasing (Deteriorating)	Significant	0
	TP	Decreasing (Improving)	Significant	3
	Secchi	Decreasing (Deteriorating)	Significant	0
Lake Rochelle	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Lake Smart	Chla	Decreasing	Not Significant	2
	TN	Decreasing	Not Significant	2
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing	Not Significant	2
Little Lake Hamilton	Chla	Increasing	Not Significant	1
	TN	Increasing	Not Significant	1
	TP	Decreasing	Not Significant	2
	Secchi	Decreasing	Not Significant	1
Middle Lake Hamilton	Chla	Increasing	Not Significant	1
	TN	Decreasing	Not Significant	2
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing	Not Significant	2

Table 2-1. 2019 North Chain of Lakes WQ Trends for Chla, TN, TP, & Secchi Depth and their representative lake health index scores

Hydrology

As part of the hydrologic cycle, lake surface levels (SL) fluctuate on a regular basis. Hydrographs of monthly SLs from 2000 – 2019 indicate annual fluctuations that correspond with wet and dry season rainfall; with long-term ups and downs that correspond with extended periods of drought and excess rainfall (Figure 2-2). To the right of the hydrographs are box & whisker plots depicting each waterbody's median and normal range (25th – 75th quartile). Annual rainfall for 2019 was 55 inches—well over the average yearly total of 51.65 inches. Since 2014, lake levels have remained consistently above the median. In 2017, the Southwest Florida Water Management District (SWFWMD) updated their control structure operations guidelines to improve water storage, recreational use, and minimize flooding, all while meeting minimum flows to the Peace Creek [1]. The strategy is to hold more water in these lakes year round, only discharging downstream prior to intense storm events (e.g. hurricanes).

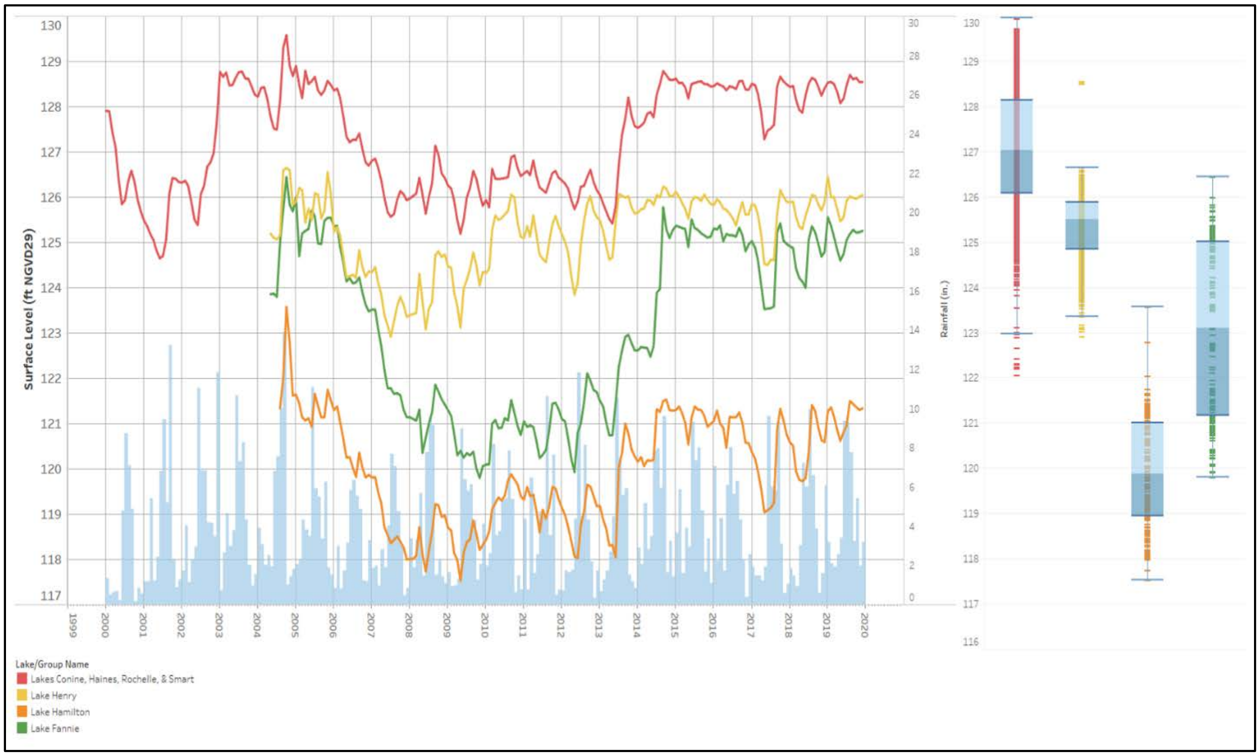


Figure 2-2. North Chain of Lakes hydrograph with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

The level of impact that hydrologic fluctuations have on water quality varies from lake to lake dependent on each waterbody's unique characteristics such as morphology and surrounding land use [23]. This was analyzed in-depth in the previous Lakes Report and will not be covered again here, however most Northern Chain lakes exhibited significant relationships between surface level and at least one or more parameters from 2000 – 2018 (Table 4-5; in appendix). The only waterbody in this group that had no significant relationships was Lake Hamilton. This may be due to multiple factors, but it should be noted that as the largest waterbody in the study area in terms of volume and surface area and it being the most downstream point in this lake group, Lake Hamilton likely does not flush as rapidly as other waterbodies. To support this, Lake Hamilton exhibited sweeping water quality improvements based on AGM Chla, TN, TP, and Secchi depth values from 2017 to 2019. This scenario coincides with consistently above-average surface levels which may have led to increased flushing and a dilution of Chla, TN, and TP in the lake. Further hydrologic analysis will be undertaken to better understand the impacts of retention time on lake water quality.

Pollutant load modelling was conducted for all drainage basins/sub-basins contributing to the North Chain of Lakes. The purpose of this modelling is to identify areas of relatively high TN and TP loading where management efforts can be focused. Lakes closer to the City center are surrounded by older developments and stormwater infrastructure which typically equate to multiple distinct drainage sub-basins. Due to the North Chain of Lake's more rural surroundings and newer developmental regulations, stormwater is usually treated onsite (e.g. retention ponds) and individual drainage basins are difficult to differentiate. The rural land uses in these basins also allow for greater infiltration of stormwater compared to urban areas. As a result, areal pollutant loads are relatively lower than in any of the other lake groups.

The hotspots for both TN and TP loading are congregated near the southernmost lakes in this group due to the greater density of residential and commercial land uses (Figure 2-3). The residential development hotspots west of Lake Smart and South of Lake Fannie have implemented retention BMPs to capture stormwater before it can enter each waterbody. In order to address loads to Lake Conine from the residential and commercial lands to the south, the City is in the process of constructing a treatment wetland that will capture and treat urban stormwater before discharging to the lake.

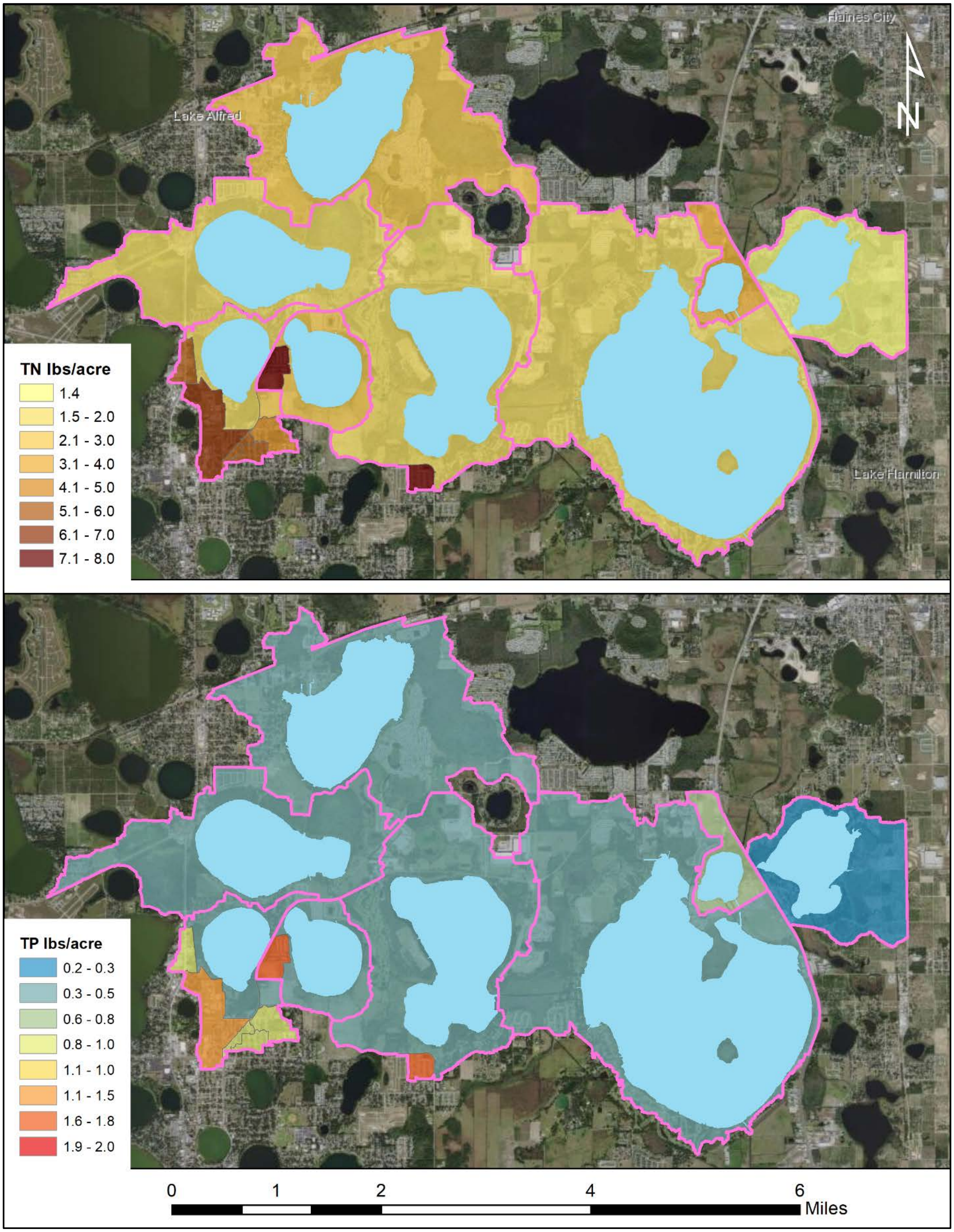


Figure 2-3. Areal TN & TP Loading for individual drainage basins in the North Chain of Lakes.

Ecology

The abundance and diversity of each lake's aquatic vegetation community can provide insights into overall lake health. By virtue of this, the City of Winter Haven has incorporated aquatic vegetation monitoring as part of its overall lake management strategy. City staff began conducting vegetation monitoring surveys on a few select lakes in 2016. Now, surveys have been conducted on all lakes for two consecutive years.

The aquatic plants of the Northern Chain have been categorized into three groups—submerged aquatic vegetation (SAV), floating vegetation (FV) and emergent aquatic vegetation (EAV). The Northern Chain of Lakes are mix of SAV and EAV dominant waterbodies. Lakes Conine, Haines, and Rochelle have an almost equal mix of submerged and emergent plants. While the other lakes in this group are EAV dominant, their SAV proportion is only slightly lower than the average distribution for all lakes in the study area at roughly 40% (Figure 2-4).

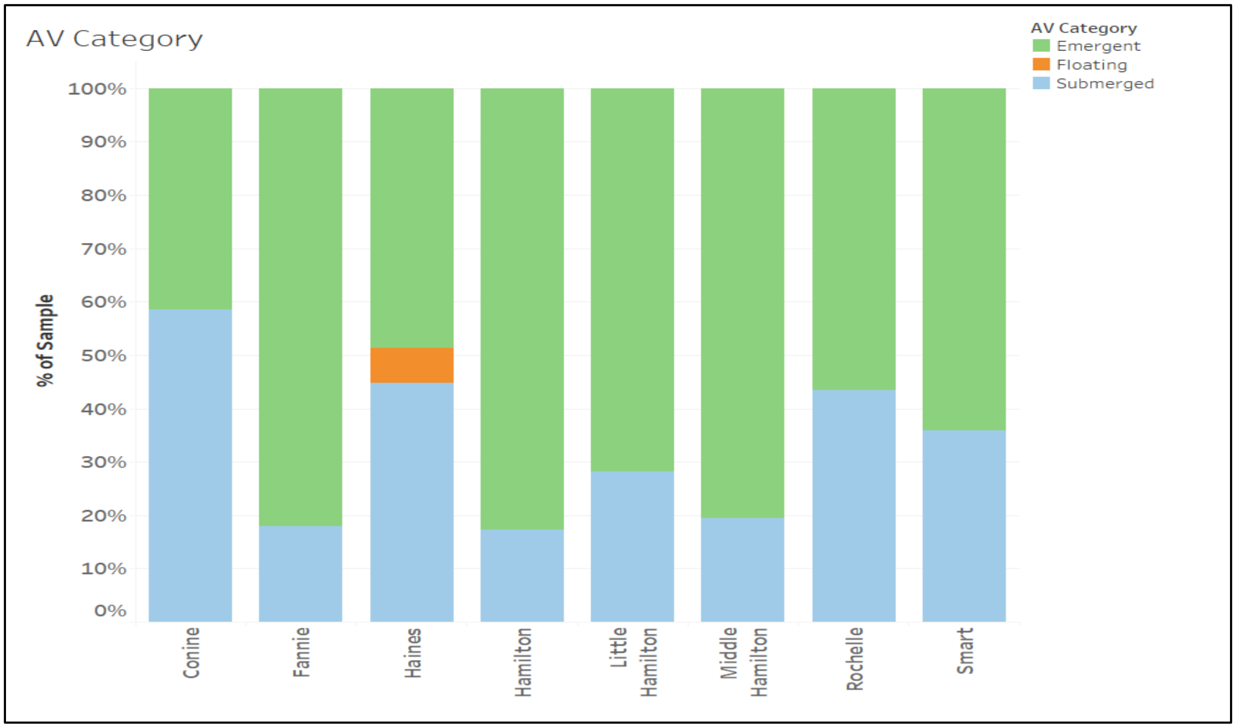


Figure 2-4. North Chain of Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

Aquatic vegetation abundance has been measured using two metrics—percent area cover (PAC) which relates to the total area of each lake with rooted vegetation and percent biovolume (% BV) which equates to total lake volume inhabited by vegetation. The data used to quantify abundance was collected via SONAR as part of the City's monitoring efforts. With regards to lake health, favorable PAC levels fall at or above a target of 15%. This target, selected by the Florida Fish and Wildlife Commission (FWC) as adequate for fish habitat, is also important for sediment stabilization and nutrient uptake. Alternatively, % BV is representative of SAV abundance and nutrient absorption potential. The City scores PAC for the lake health index using the following rubric:

- Score of 3: ≥ 30%
- Score of 2: 15% - 30%
- Score of 1: 2.5% - 15%
- Score of 0: < 2.5%

In 2019, the majority of the NCOL maintained vegetation abundance above the 15% minimum target (Figure 2-5). Lakes Conine, Rochelle, and Smart underwent a substantial increase in vegetation abundance since the previous 2018 survey and now score a 3 in abundance. Lakes Haines, Fannie, Little Hamilton, and Middle Hamilton received a score of 2 for their 2019 PAC values. Since Lake Hamilton remains below the 15% target, it received a score of 1.

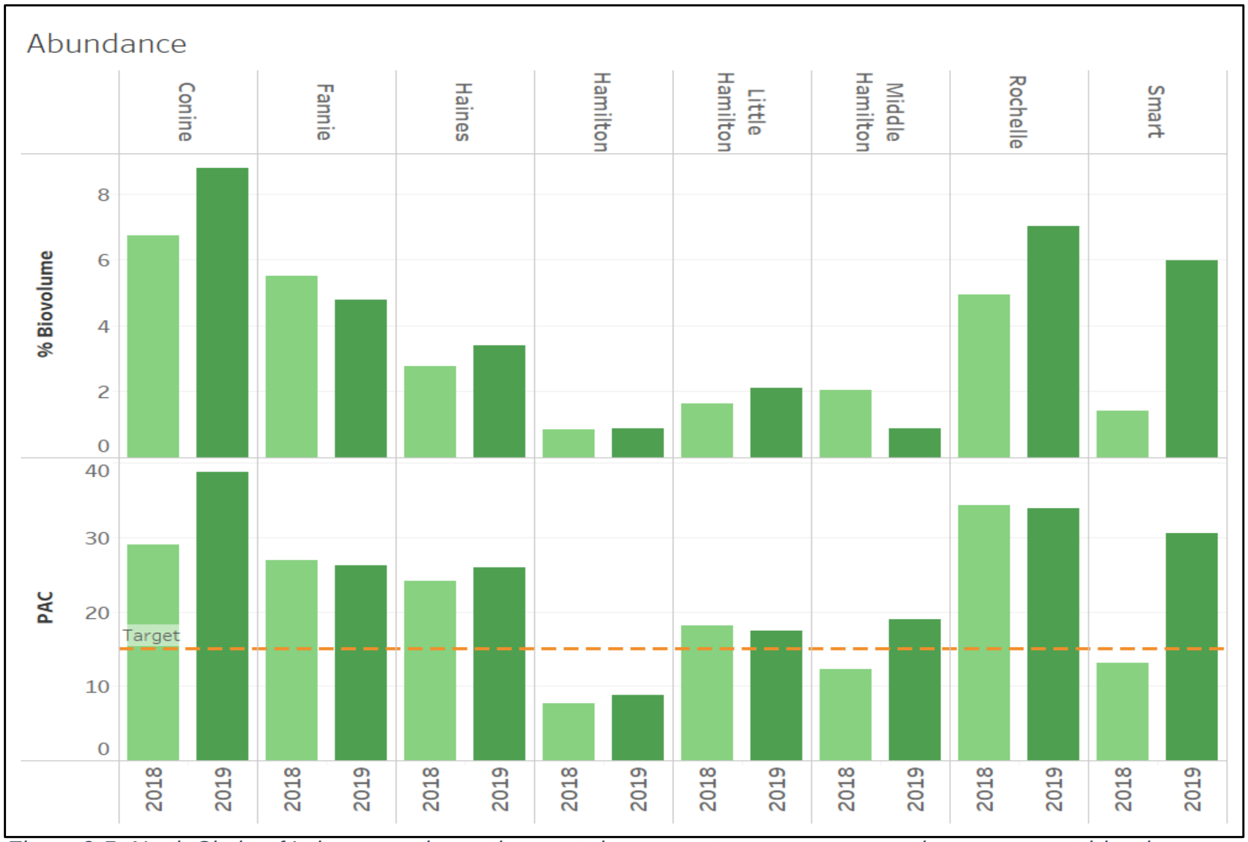


Figure 2-5. North Chain of Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

The percentage of invasive species is an important lake health indicator as an increase in invasive abundance can negatively impact navigation, recreation, and some aquatic habitats. The primary invasives that are managed by local and state organizations in this lake group include hydrilla (*Hydrilla verticillata)*, burhead sedge (*Oxycaryum cubense)*, and water hyacinth (*Eichhornia crassipes*). In 2019, Lakes Haines and Rochelle experienced a substantial increase in invasive presence (Figure 2-6). A water hyacinth population explosion on Haines catapulted this waterbody into a 0 score for this year. The proliferation of hydrilla in Lake Rochelle also place it in the 0 score range. An increase of invasives in Middle Hamilton and Smart place them in 1 score territory. Lake Conine's invasive percent changed little and so it remains with a score of 1. A reduction of hydrilla in Lake Fannie has increased its score from 0 to 1. Lakes Hamilton and Little Hamilton continue to possess very little invasive species presence; Hamilton received a score of 2, while a lack of measured invasives in Little Hamilton earns this waterbody a 3 score for 2019.

Changes in species diversity contribute to the final vegetative health indicator. Observation of an increase or decrease in each of the three index values constitutes an

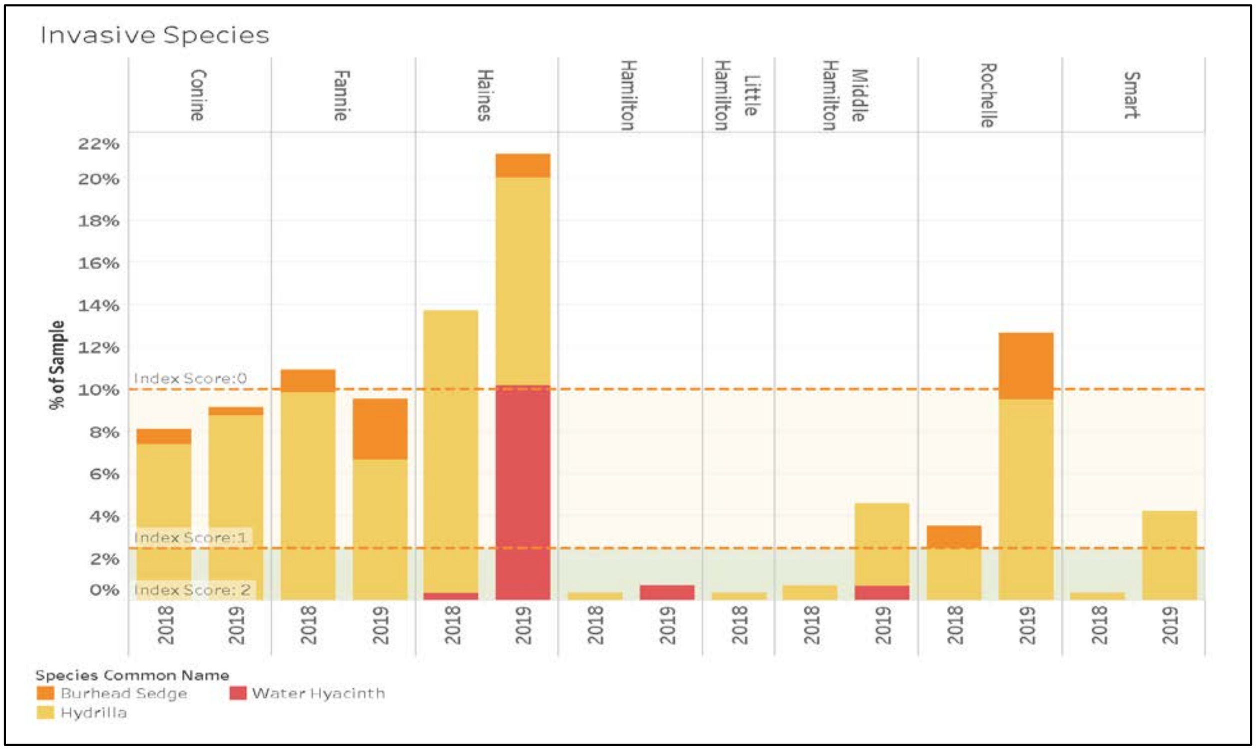


Figure 2-6. North Chain of Lakes annual percentage of managed invasive species.

improvement or deterioration respectively (Figure 2-7). It must be stressed that these index values are dependent on site-specific sampling effort—as such, these values are not be used to compare one lake to another. An annual increase in each index confers a point toward the diversity score, while a decrease equates to a point subtraction.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Conine, Fannie, and Haines exhibited an increase in species richness from 2018 to 2019; Lakes Hamilton, Little Hamilton, Middle Hamilton, Rochelle, and Smart underwent a decrease in richness during this time period.

Hill's Evenness #3 (E3): Species evenness is preferred over one or two dominant species as it improves community resilience. Lakes Fannie, Haines, Hamilton, Middle Hamilton, and Smart showed an increase in species evenness in 2019. Lakes Conine, Little Hamilton, and Rochelle experienced a decrease an evenness.

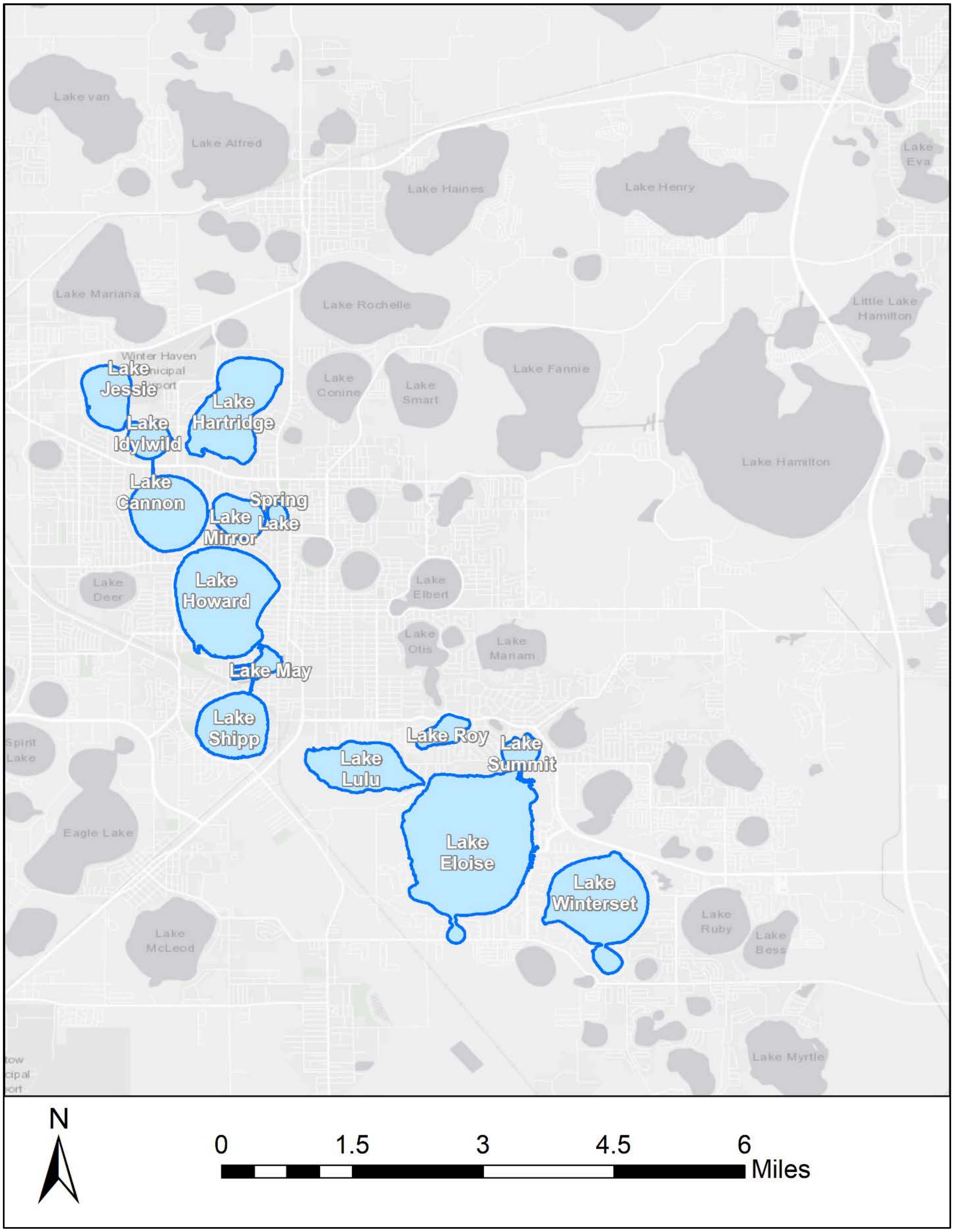
Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Lakes Haines, Hamilton, Little Hamilton, Middle Hamilton, Rochelle, and Smart all underwent an overall increase in diversity in 2019. Alternatively, Lakes Conine and Fannie experienced a decrease in this metric.

Figure 2-7. North Chain of Lakes annual index values for species richness, evenness, and diversity.

Analysis of these ecological metrics provides interesting insights. Vegetation abundance has implications for water quality, however an increase in abundance may be due to invasive species proliferation. Similarly, species diversity may increase or decrease over time, but the index metrics don't discriminate based on native or invasive. For example, Middle Lake Hamilton underwent an increase in plant abundance, species evenness and overall diversity. However, these improvements were due in part to the increase of hydrilla and water hyacinth. Incidentally, the treatment of invasive species results in a decrease in abundance and potential diversity; and can lead to the degradation of water quality (in the case of herbicide treatment). However, allowing these invasive species to dominate a lake's ecosystem can result in greater losses, both in the form of recreational and navigational potential and in community resiliency as a few dominant species come to squeeze out the beneficial natives. Striking this balance is one of the most difficult challenges for lake managers.

Due to increased public objection over herbicide use, the FWC has elected to utilize biological control in the Northern Chain. Triploid grass carp will have been released as of early 2020 to supplement the herbicide treatment of hydrilla in this Chain. Further monitoring will be crucial to determine their effectiveness.

2.2 South Chain of Lakes



The Winter Haven South Chain of Lakes (SCOL) is made up of 14 waterbodies: Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, Mirror, Roy, Shipp, Summit, Winterset, and Spring. The major surface water and MS4 contributors to the SCOL include the City of Winter Haven, FDOT and Polk County. In addition, Lakes Eloise, Howard, Jessie, Lulu, May, and Shipp have all received historic wastewater discharges from multiple sources including the City of Winter Haven and various commercial and industrial processing facilities [20]. In 2007, Nutrient TMDLs were developed for several Southern Chain waterbodies. However, due to new guidelines, the FDEP developed new TMDLs for Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, and Shipp in 2018.

Water Quality

Water quality impairment is one of the primary lake health indicators that is also monitored closely by the FDEP. Through assessment of the long-term geometric mean true color and total alkalinity of the SCOL, it was determined that all 14 waterbodies fall into the low color, high alkalinity category and are subject to the NNC thresholds established for that group. Impairment status was determined through analysis of the annual geometric mean (AGM) Chla, TN, and TP concentrations between 2011 and 2019 displayed in Tables 4-1 through 4-3 in the Appendix. Impairment is a scored criterion in the overall lake health index. A lake with no impairments is granted a score of 3, however a point is subtracted for each parameter exhibiting NNC impairment during the assessment period.

Impairment

Chlorophyll-a: The following waterbodies were determined to be impaired based on Chla exceedances: Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, and Shipp.

Total Nitrogen: Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, and Shipp experienced more than one consecutive TN exceedance from 2011 to 2019 and were determined to be impaired.

Total Phosphorus: Lakes Eloise, Jessie, Lulu, May, and Shipp exceeded TP thresholds multiple years to meet impairment status. Since the previous report, TP concentrations in Lakes Cannon and Hartridge have dropped below impairment thresholds.

The 2019 AGM Chla, TN, TP, and Secchi depth values for the SCOL as well as the long-term mean and normal range (+/- 1 standard deviation) were calculated based on data from 2000 to 2019 (Figure 2-8). This data represents a snapshot of the most recent annual data. In 2019, Lake Hartridge was the only waterbody to possess above-average Chla concentrations, while Hartridge and Jessie were the only lakes with above-average TN concentrations. All lakes exhibited below-average AGM TP concentrations, while only Cannon, Hartridge, and Jessie showed lower-than-average Secchi depths.

In order to determine if long-term monotonic (directional) trends in water quality are occurring, AGM Chla, TN, TP, and Secchi depth were plotted against time in years. The resulting regression analyses show direction (+/-), magnitude (R^2), and statistical significance (p-value ≤ 0.05) of each lake's water quality trends (Table 2-2). While the

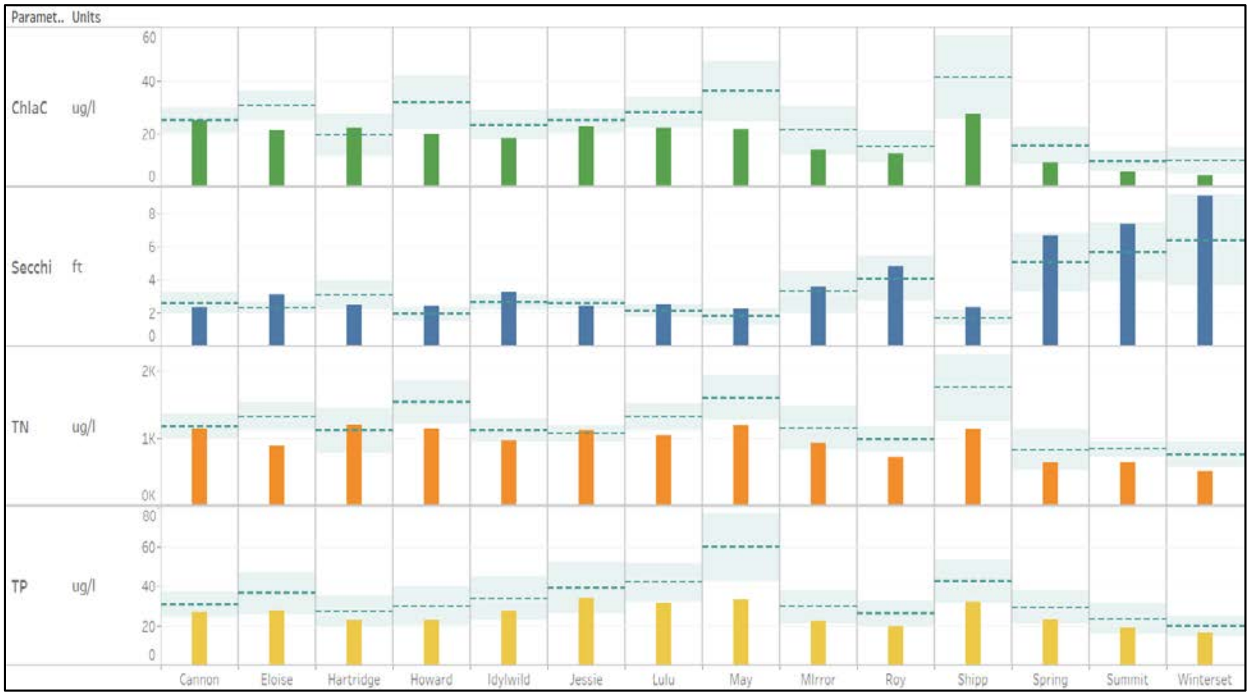


Figure 2-8. 2019 AGM Chla, TN, TP, & Secchi depth values for the South Chain of Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

magnitude of these linear relationships is useful to determine the strength of these trends, only direction and significance are used in the lake health evaluation (see Table 4-4 in appendix for regression statistics).

Chlorophyll-a Trends: Of the 14 SCOL waterbodies, Lakes Howard, Lulu, May, Mirror, Roy, Shipp, Summit, Winterset and Spring exhibited significant decreasing Chla trends from 2000 - 2019. Lake Hartridge is the only waterbody that exhibited a significant increase in Chla.

Total Nitrogen Trends: Lakes Cannon, Howard, May, Mirror, Roy, Shipp, Summit, Winterset, and Spring showed significant decreasing TN trends. Again, Lake Hartridge is the only waterbody in this group that underwent a significant TN increase.

Total Phosphorus Trends: No SCOL waterbodies exhibited significant increasing trends in TP. Significant decreasing TP trends are shown for Lakes Lulu, May, Mirror, Roy, Shipp, Winterset, and Spring.

Water Clarity Trends: With regards to Secchi depth, all Southern Chain lakes except Hartridge and Jessie exhibited an increasing trend. Lake Hartridge AGMs are indicative of a significant downward trend in water clarity.

Based on impairment and trend data, most Southern Chain waterbodies are improving in at least one primary water quality parameter. With that, greater focus must be placed on the increasing trends in Lake Hartridge. All nutrient sources, including septic systems and internal legacy sediments, must be considered to determine the primary contributors to the decline in water quality.

Waterbody	Parameter	Trend Direction	Significance	Index Score
Lake Cannon	Chla	Decreasing	Not Significant	2
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
Lake Eloise	Chla	Decreasing	Not Significant	2
	TN	Decreasing	Not Significant	2
	TP	Decreasing	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
Lake Hartridge	Chla	Increasing (Deteriorating)	Significant	0
	TN	Increasing (Deteriorating)	Significant	0
	TP	Increasing	Not Significant	1
	Secchi	Decreasing (Deteriorating)	Significant	0
Lake Howard	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
Lake Idylwild	Chla	Decreasing	Not Significant	2
	TN	Increasing	Not Significant	1
	TP	Decreasing	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
Lake Jessie	Chla	Increasing	Not Significant	1
	TN	Increasing	Not Significant	1
	TP	Decreasing	Not Significant	2
	Secchi	Increasing	Not Significant	2
Lake Lulu	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing	Not Significant	2
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Lake May	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Lake Mirror	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Lake Roy	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Lake Shipp	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Lake Summit	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
Lake Winterset	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3
Spring Lake	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing (Improving)	Significant	3

Table 2-2. 2019 South Chain of Lakes WQ Trends for Chla, TN, TP, & Secchi Depth and their representative lake health index scores

Hydrology

The South Chain of Lakes are connected via a series of navigable canals. As a result, individual surface levels are held at roughly the same elevation. A hydrograph of the SCOL monthly SLs and rainfall from 2000 to 2019 shows short and long-term fluctuations in lake level in response to rainfall (Figure 2-9). Box and whisker plot shows overall variability for this lake group. The upper and lower reaches of the boxplot correspond with the respective 75th and 25th percentile surface elevations. SCOL surface levels have been consistently above the median (central boxplot line) since mid-2014—except for a brief period at the height of the 2017 dry season. Surface levels were depressed from 2006 until 2014 due to eight years of consistently below-average rainfall.

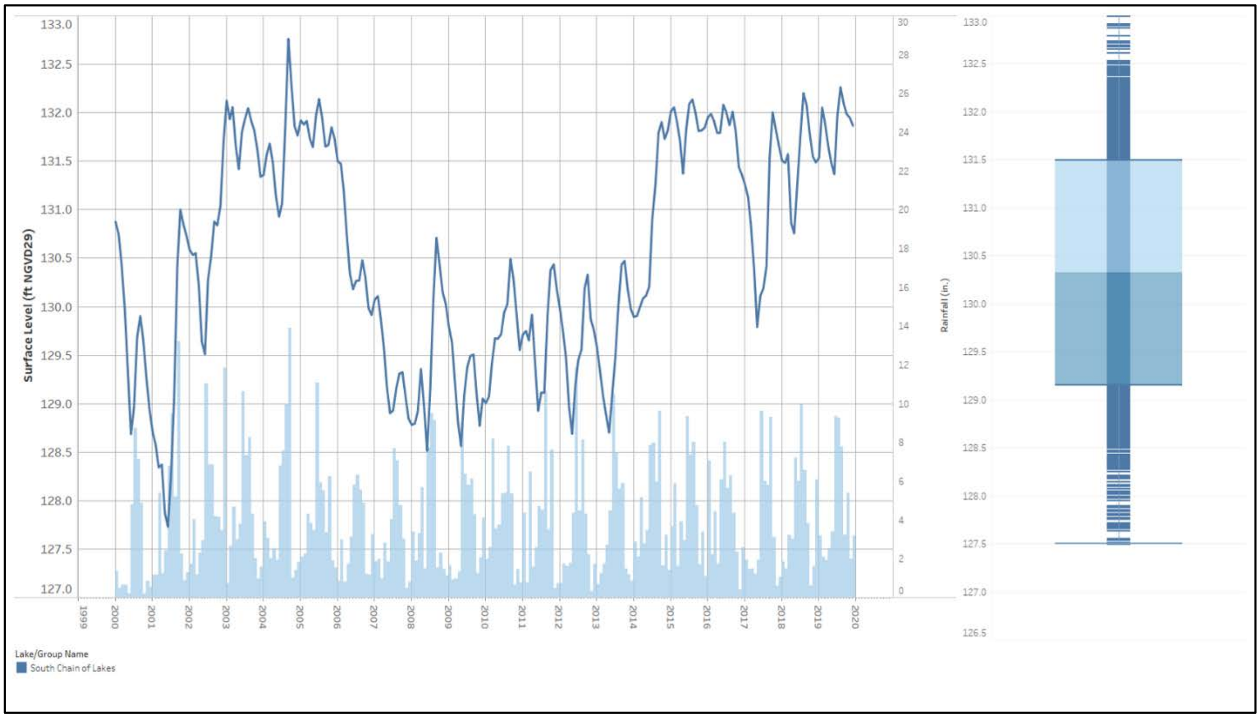


Figure 2-9. South Chain of Lakes hydrograph with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

The relationship between surface level and each primary water quality metric was assessed in-depth within the 2018 Lakes Report (Table 4-5; in appendix). It was determined that Lake May showed relationships between SL and each primary water quality metric. Lakes Idylwild and Roy also experienced significant relationships amongst SL and Chla, TN, and Secchi depth. Lakes Jessie, Lulu, and Shipp also exhibited significant relationships between SL and one or two water quality parameters. Despite the nature of this lake group to hydrologically fluctuate as one entity, the impacts that changes in SL have on water quality vary significantly—likely due to each waterbody's unique morphological and biological characteristics [23]. That said, maintaining lake levels near to the maximum desired management level of 132.0 ft above sea level should provide the greatest benefit to majority of this group.

The Southern Chain of Lakes extends from the north to the south of the Winter Haven City limits. As such, stormwater pollutant loading varies considerably from lake to lake. Lakes Eloise, Hartridge, Jessie, Summit, and Winterset possess minimal stormwater infrastructure data which has limited staff's ability to delineate individual sub-basins. Conversely, the waterbodies close to the City center possess multiple distinct stormwater systems.

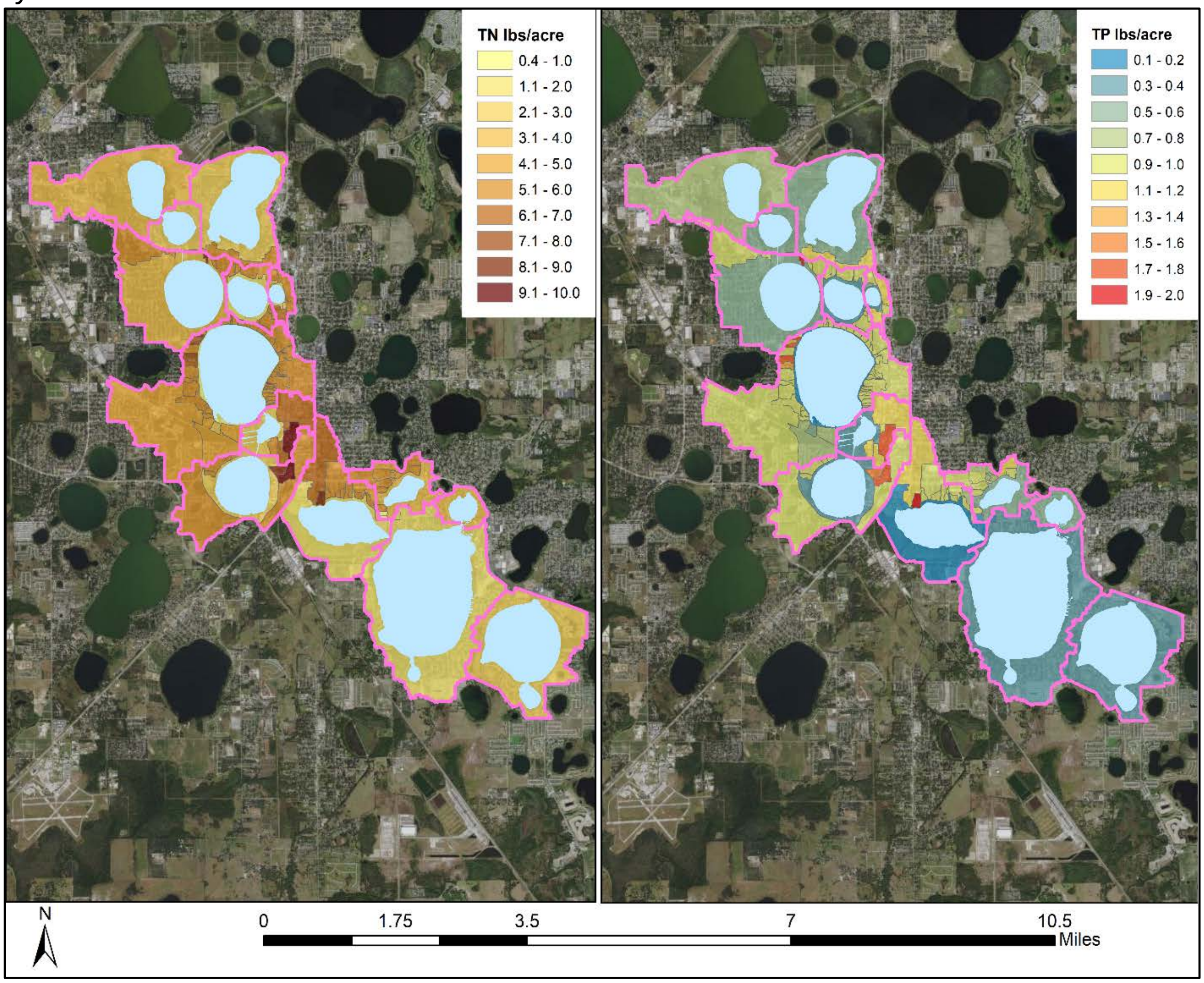


Figure 2-10. Areal TN & TP Loading for individual drainage basins in the South Chain of Lakes.

At first glance, the lowest areal TN and TP loads are located in the drainage basins of the peripheral lakes listed above (Figure 2-10). These basins primarily consist of low-medium density residential and open lands with moderate to high soil infiltration rates and the inclusion of stormwater BMPs in the form of retention/detention ponds. With a few exceptions, some of the highest loading rates are present in Lulu, May, and Shipp basins. These areas have a greater proportion of commercial and industrial land uses as well as a greater percentage of impervious surfaces—leading to increased runoff volume and pollutant concentrations. The previously mentioned exception are the basins located in older residential areas around Lakes Howard, Cannon, Mirror, and Spring. These neighborhoods were constructed prior to regulations mandating on-site stormwater management. As a result, much of the stormwater flows directly to these lakes without any treatment. In most of these drainage basins, the City has implemented several structural and non-structural BMPs including alum injection, street sweeping, and green infrastructure to capture or lock-down nutrients before they can disperse into the lakes. In the future, quantifying these nutrient reduction programs will be required to develop a nutrient budget for all lakes in the study area.

Ecology

As a major component of the lake health evaluation process, aquatic vegetation abundance and diversity data have been collected for the South Chain of Lakes. Vegetation surveys were initially performed in 2016 on Lakes Lulu, Mirror, Spring, Summit, and Winterset. In 2017 data were collected from Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, May, Roy, and Shipp while 2018 marks the first year that vegetation surveys were performed on all lakes within the study area. As a result, data representing multiple years is available for analysis of the SCOL.

Understanding the distribution of emergent (EAV), submerged (SAV), and floating (FV) plants can help to answer questions that relate water quality and hydrology to the biological components of these waterbodies. Overall, the SCOL possesses an exceptional proportion of submerged vegetation compared with other lakes in the area, with >30% SAV in the majority (Figure 2-11). Due to the nutrient adsorption capabilities of submerged vegetation, it comes as no surprise that most Southern Chain lakes are experiencing significant water quality improvements.

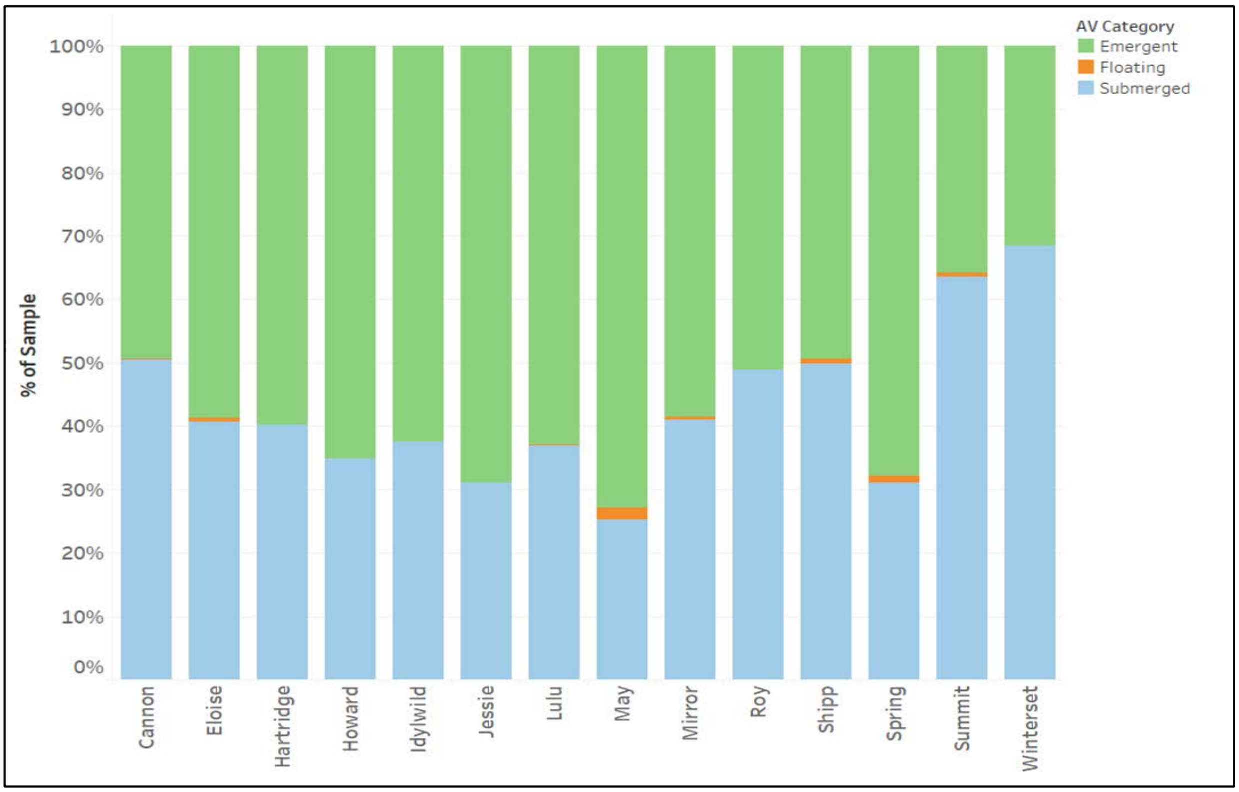


Figure 2-11. South Chain of Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

Measurements of percent area cover (PAC) and percent biovolume (% BV) indicate that the majority of the SCOL possessed excellent vegetation abundance (Figure 2-12). In 2019, every Southern Chain waterbody exceeded the 15% PAC target, with all but Eloise, Howard, and Roy above the 30% exceptional abundance threshold. All except Lakes Summit and Roy underwent an increase in PAC and % BV. For vegetation abundance, all received a score of 2 or 3 for the lake health index.

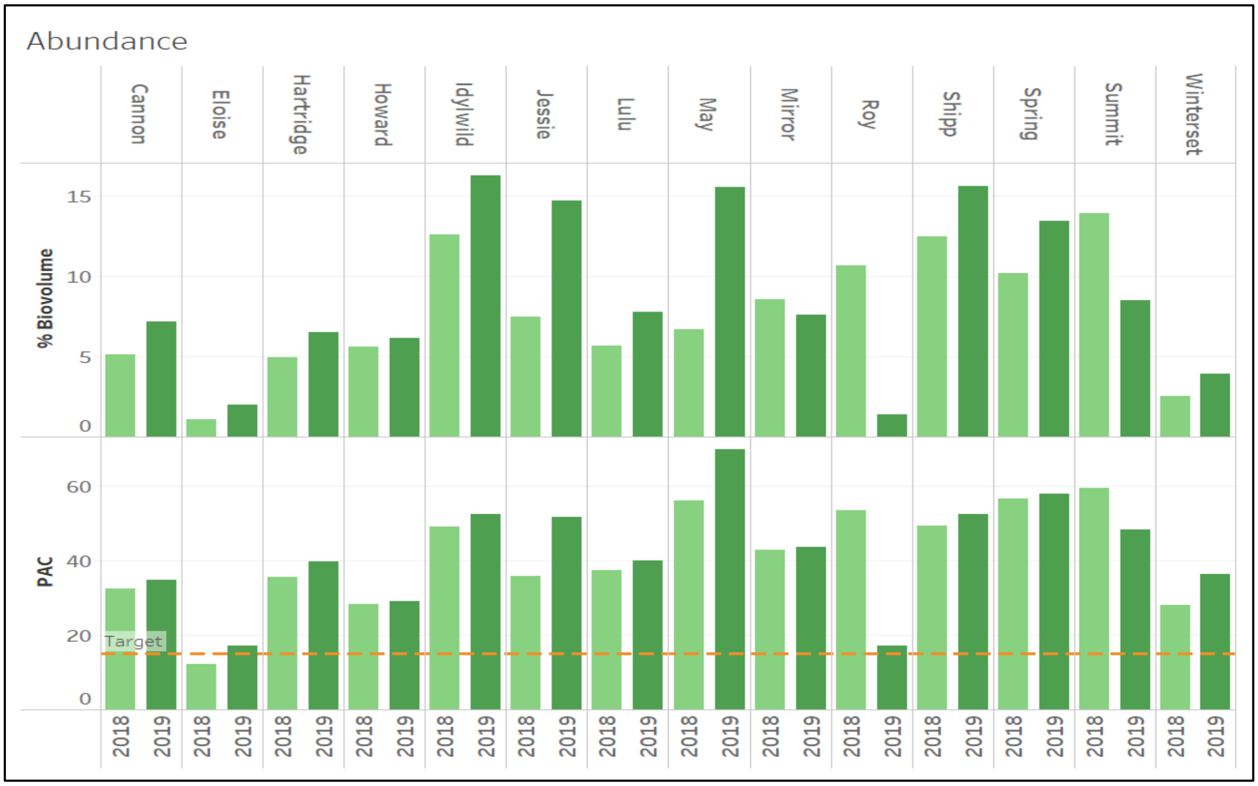


Figure 2-12. South Chain of Lakes annual aquatic vegetation percent area coverage and mean percent biovolume

Due to most invasive species' proclivity to rapidly expand, there's no doubt that changes in their abundance can significantly impact the overall vegetation abundance in a waterbody. The primary species that are treated regularly in the Southern Chain include hydrilla (*Hydrilla verticillata*), burhead sedge (*Oxycaryum cubense*), and water hyacinths (*Eichhornia crassipes*). Eight of the Southern Chain lakes underwent an increase in invasive percentage from 2018 to 2019 (Figure 2-13). Also illustrated are the invasive score thresholds for the lake health index; keep in mind that a score of 3 is only earned if no invasives were sampled during the survey.

Due to a lack of observed invasive species in 2019, Lake Howard received a score of 3 for this metric. A decrease or no change in the hydrilla percentages below the 2.5% threshold in Lakes Cannon, Lulu, Roy, and Summit equate to a score of 2. Lakes Eloise, Hartridge, Idylwild, Jessie, May, Mirror, Shipp, and Spring all score a 1 as a result of their 2019 invasive percentages; most of which increased from the previous year. Lake Winterset, unfortunately due to a significant increase in hydrilla, received a 0 score for the lake health index. This data shows that even with regular assessments and rapid treatments, invasives have a tendency to undergo population explosions in a short period of time. Treatment of these plants is needed to ensure that these waterways remain open for recreational use. That said, extra emphasis is being placed on alternative methods for aquatic weed control in the State. The City is committed to working with FWC to limit the negative impacts of invasive treatment by advocating for the most appropriate methods for the area.

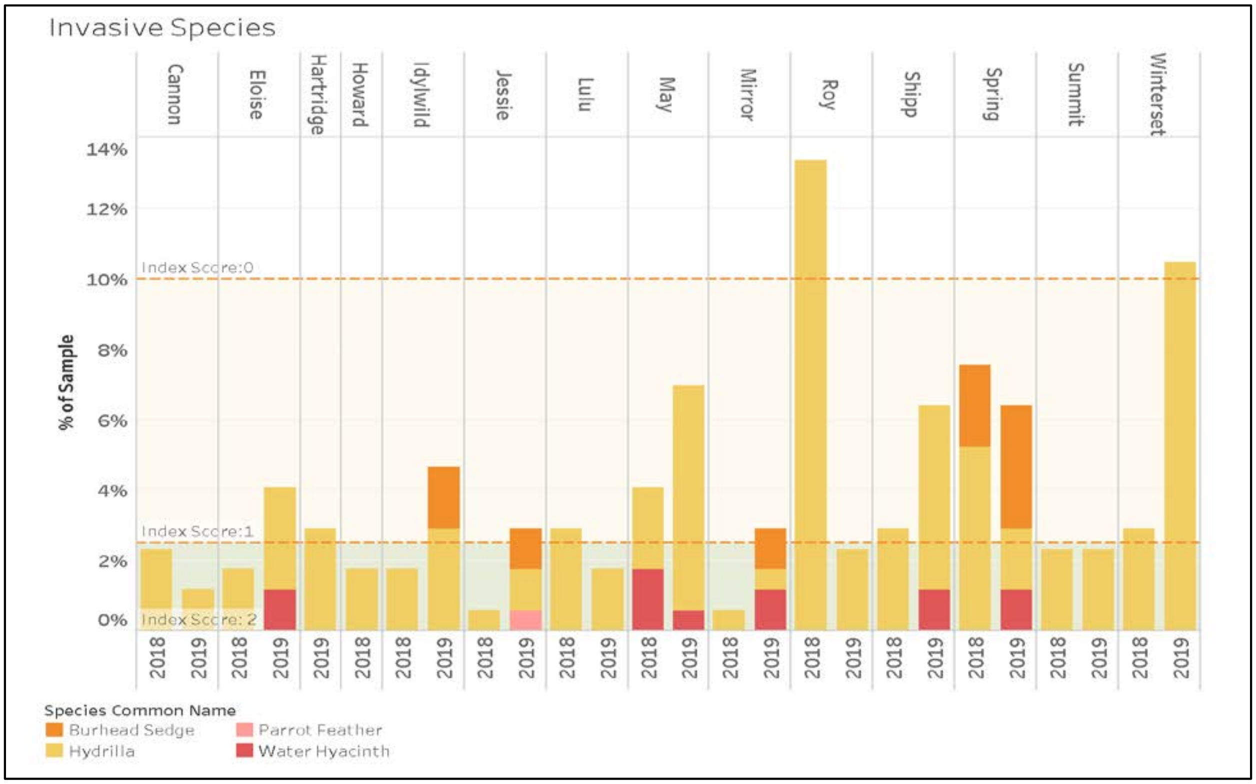


Figure 2-13. South Chain of Lakes annual percentage of managed invasive species.

Species diversity index values for the South Chain of Lakes were calculated using at least two years of survey data. Species richness, evenness, and uncertainty index values constitute the overall species diversity for the SCOL (Figure 2-14). An increase or decrease in each index value from the previous year contribute to this lake health criterion, for a total possible score of 3 if increases are observed for each diversity index.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Eloise, Hartridge, Howard, Idylwild, Jessie, May, Mirror, Spring, Summit, and Winterset exhibited an increase in species richness from 2018 to 2019; Lakes Cannon, Lulu, Roy, and Shipp underwent a decrease in richness during this time period.

Hill's Evenness #3 (E3): An increase in species evenness is preferred as it correlates to improvement in community resilience. Lakes Howard, Jessie, Lulu, May, Roy, Spring, and Winterset showed an increase in species evenness in 2019. Lakes Cannon, Eloise, Hartridge, Idylwild, Mirror, and Summit experienced a decrease an evenness. No change in evenness was observed in Lake Shipp, however it receives a point for not exhibiting a decline.

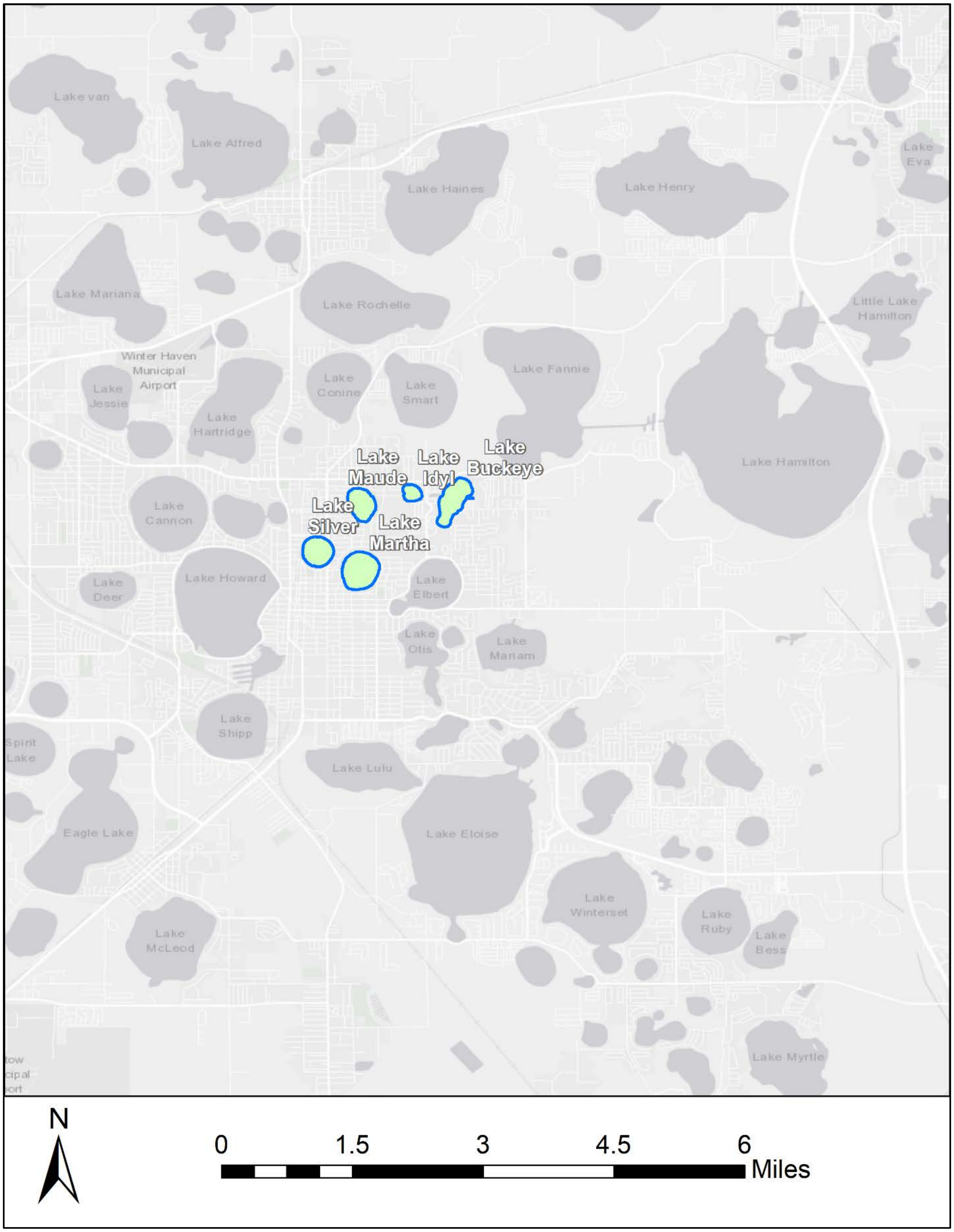
Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Lakes Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, Mirror, Shipp, Spring, Summit, and Winterset all underwent an overall increase in diversity in 2019. Only Lakes Cannon and Roy experienced a decrease in this index value.

These lake health metrics provide insights into where management efforts should be focused. With the majority of the Southern Chain possessing TMDLs or considered impaired by regulatory standards, it is comforting to know that the majority are exhibiting improvement of multiple water quality parameters. Interestingly, the waterbodies with the higher areal pollutant loadings are all ones undergoing sweeping water quality improvement. Granted, many of these urban stormwater sources have been mitigated through BMPs like street sweeping or raingardens. This anecdotally supports that stormwater BMPs make a difference. Alternatively, the deteriorating water quality in Lake Hartridge, coupled with its lack of direct high-intensity stormwater loads provide evidence to suggest that alternative pollutant sources are the culprit of its current situation. The high density of septic systems in its watershed could be a possible scapegoat, however more analysis is needed to better understand the impacts.

Collectively, this lake group's vegetation community is robust and generally healthy. A strong SAV community helps to buffer against increased nutrient loads. However, the urban environment surrounding these lakes presents challenges regarding invasive treatment. A lack of adjacent public land around the SCOL makes the removal of plant material challenging. The interconnectedness of these lakes also limits the FWCs ability to employ grass carp as a biological control. These reasons are why early detection and rapid herbicide response is often the only way to keep nuisance plants like hydrilla at bay. Perhaps new technologies may allow more environmentally friendly methods to emerge.

Figure 2-14. South Chain of Lakes annual index values for species richness, evenness, and diversity.

2.3 North Central Lakes



The Winter Haven North Central Lakes (NCL) are a group of waterbodies connected by overflow conveyances and can contribute surface water to the North Chain of Lakes by discharging to Lake Fannie during high water periods. The group of five lakes include Lakes Buckeye, Idyl, Martha, Maude, and Silver. The major surface water and MS4 contributors to the NCL are the City of Winter Haven, the FDOT, and Polk County. None of these lakes currently possess a TMDL.

Water Quality

Determination of water quality impairment is one of the ways that environmental agencies such as the FDEP can monitor general improvement of lake health. As such it is one of the most important indicators that the City keeps track of. Using long-term geometric mean true color and total alkalinity values, all five lakes in the NCL were determined to fall in the low color, high alkalinity category and are subject to the appropriate NNC thresholds for this classification. Impairment status was determined through analysis of the annual geometric mean (AGM) Chla, TN, and TP concentrations between 2011 and 2019 (Tables 4-1 through 4-3 in the Appendix). Lake health index scores for this criterion are based on the collective impairments for a given waterbody. A score of 3 is given to lakes with no impairment, while a point is subtracted for an impairment in each of the 3 NNC parameters. Within this lake group, Lake Idyl is the only waterbody exhibiting impairment, however, it was determined to be impaired for Chla, TN, and TP due to multiple consecutive exceedances in the last few years.

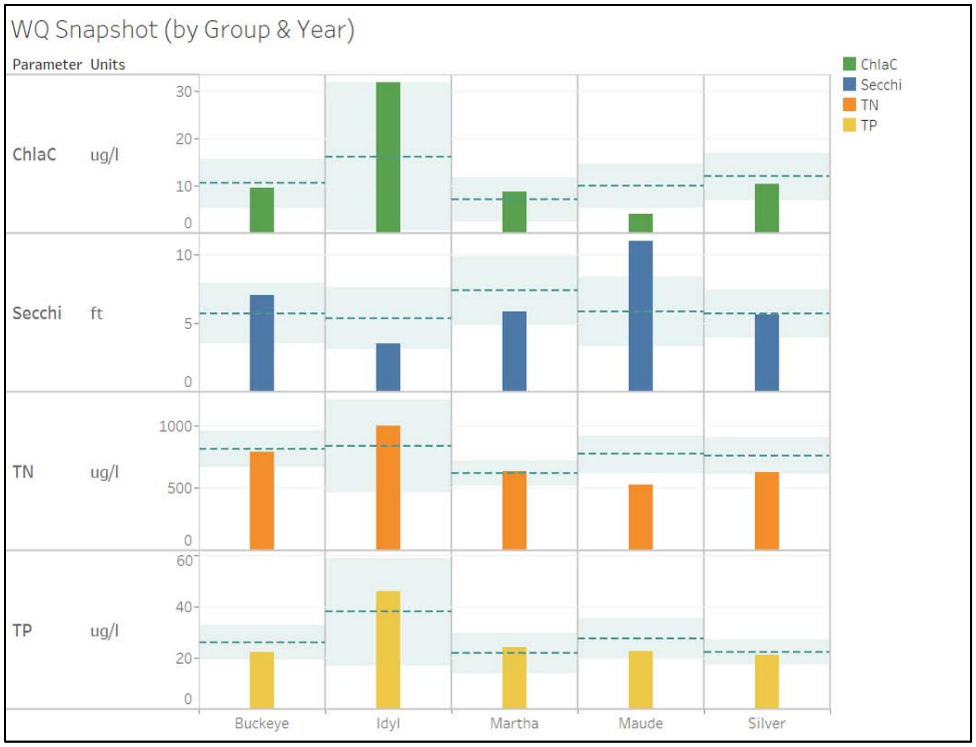


Figure 2-15. 2019 AGM Chla, TN, TP, & Secchi depth values for the North Central Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

2019 AGM Chla, TN, TP, and Secchi depth values with each lake's long-term average and normal range (+/- 1 standard deviation) are used to compare current water quality conditions with historic values. Based on this comparison, it can be observed that Lakes Buckeye, Maude, and Silver are currently experiencing at or above-average clarity and below average Chla, TN, and TP concentrations (Figure 2-15). Alternatively, Lakes Idyl and Martha are both experiencing poorer water quality with below average Secchi depths and at or above-average Chla, TN, and TP concentrations.

Evaluation of water quality trends is an important lake health indicator that can be utilized to indicate general improvement or deterioration. Trend analysis was performed by plotting AGM Chla, TN, TP, and Secchi depth values against time in years from 2000 – 2019 (Table 2-3). The resulting linear regression statistics were then used to determine trend direction (+/-) and significance (p-value ≤ 0.05) (Table 4-4 in appendix).

Chlorophyll-a Trends: Lakes Buckeye and Maude are currently exhibiting significant decreasing Chla trends while Lake Martha's trend is increasing signficantly.

Total Nitrogen Trends: Similar to Chla trends, Lakes Buckeye and Maude are experiencing significant decreasing trends in TN. Lake Martha is exhibiting a significant increasing regression over time.

Total Phosphorus Trends: With regards to TP, Lakes Buckeye and Martha are exhibiting significant trends—trend direction for Buckeye is decreasing while TP is increasing in Martha.

Clarity Trends: Lakes Buckeye and Maude are experiencing a significant increasing Secchi depth trend. Lake Martha's Secchi depth is decreasing significantly.

Waterbody	Parameter	Trend Direction	Significance	Index Score
Lake Buckeye	Chla	Decreasing (Improving)	Significant	3
Lake Buckeye	TN	Decreasing (Improving)	Significant	3
Lake Buckeye	TP	Decreasing (Improving)	Significant	3
Lake Buckeye	Secchi	Increasing (Improving)	Significant	3
Lake Idyl	Chla	Increasing	Not Significant	1
Lake Idyl	TN	Increasing	Not Significant	1
Lake Idyl	TP	Increasing	Not Significant	1
Lake Idyl	Secchi	Decreasing	Not Significant	1
Lake Martha	Chla	Increasing (Deteriorating)	Significant	0
Lake Martha	TN	Increasing (Deteriorating)	Significant	0
Lake Martha	TP	Increasing (Deteriorating)	Significant	0
Lake Martha	Secchi	Decreasing (Deteriorating)	Significant	0
Lake Maude	Chla	Decreasing (Improving)	Significant	3
Lake Maude	TN	Decreasing (Improving)	Significant	3
Lake Maude	TP	Decreasing	Not Significant	2
Lake Maude	Secchi	Increasing (Improving)	Significant	3
Lake Silver	Chla	Decreasing	Not Significant	2
Lake Silver	TN	Decreasing	Not Significant	2
Lake Silver	TP	Decreasing	Not Significant	2
Lake Silver	Secchi	Decreasing	Not Significant	1

Table 2-3 2019 North Central Lakes WQ Trends for Chla, TN, TP, & Secchi Depth and their representative lake health index scores

Hydrology

The North Central Lakes are linearly connected via a series of passive overflow structures. As a result, each lake undergoes separate surface level fluctuations; only discharging downstream when surface levels exceed their respective control structures. Unlike other lake groups, rainfall does not appear to be a heavy influence on surface level fluctuations. Aside from the seasonal fluctuations, expressed as a high and low point during a given year, only a couple of these waterbodies show long-term fluctuations coincident with changes in annual rainfall (Figure 2-16). Lakes Maude, Idyl, and Buckeye exhibit little to no long-term variation; SLs did not recede during the 2006 – 2014 drought, nor did they show recovery over the last 5 years.

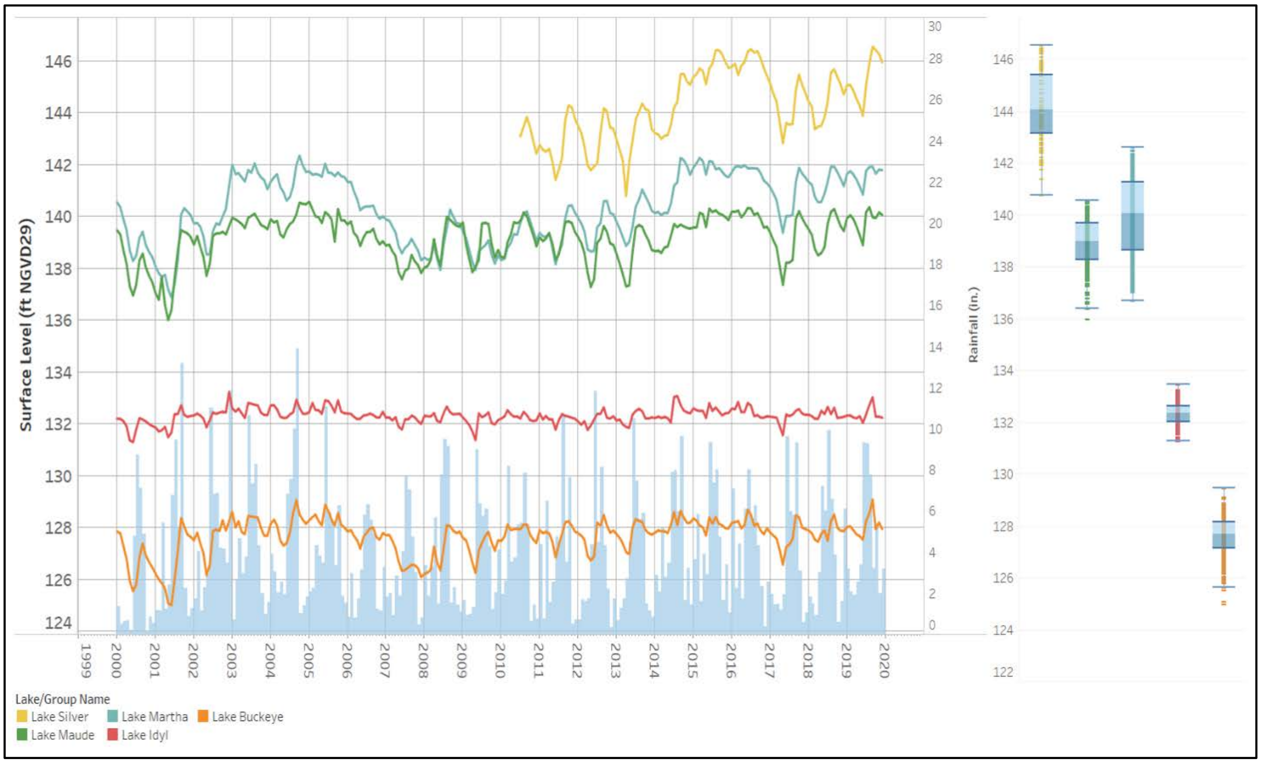


Figure 2-16. North Central Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

Incidentally, surface level fluctuations do not correlate strongly with water quality changes in this lake group as evidenced in the linear regression analysis performed for the previous lakes report—only Lake Martha exhibited a significant positive correlation between lake level and Chla (Table 4-5; in appendix). This is likely due to the lack of long-term water level fluctuations in several of these lakes. No doubt the anthropogenic changes to the drainage characteristics in the area have led to the current hydrological regime. Further analysis is needed to determine if the absence of long-term SL variation has had negative impacts on the ecology or water quality in these lakes.

Pollutant loading rates vary considerably from lake to lake in this group. As water moves through this group of waterbodies, the surrounding topography and land uses change as well. The commercial and residential land uses give way to more open and agricultural types as you move from the City center—providing changes to the impervious percentage within each drainage basin. Additionally, the older residential areas near downtown transition into newer developments which bring greater on-site stormwater treatment with them. The higher areal loads are aggregated in these urban residential areas, with the highest originating from commercial land uses (Figure 2-17). While the downtown area does receive stormwater load reduction from street sweeping and green infrastructure, there are a couple hotspot areas around Lakes Maude and Idyl that lack structural BMPs. These hotspots were identified through the City's Stormwater Assessment and Improvement Project as needing infrastructure improvements to address both water quality and flooding issues. Staff are currently pursuing funding to design and implement these improvements in the near future.

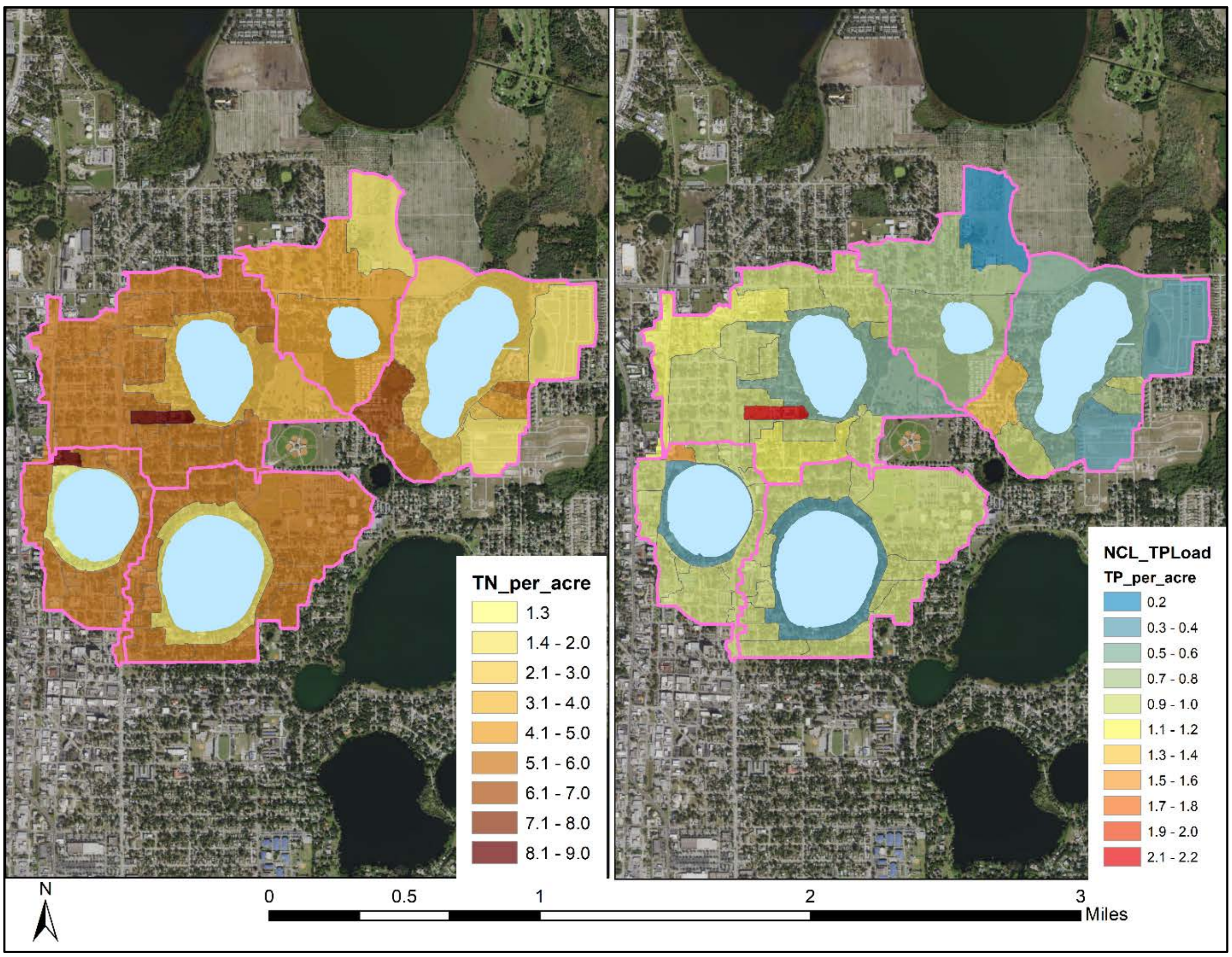


Figure 2-17. Areal TN & TP Loading for individual drainage basins in the North Central Lakes.

Ecology

As part of the City's vegetation monitoring program, each waterbody in the North Central Lakes group was surveyed annually from 2017 to 2019. Monitoring efforts include SONAR mapping to quantify abundance of submerged aquatic vegetation (SAV) and some emergent aquatic vegetation (EAV) species. Additionally, point-intercept sampling is performed to identify the relative proportion of each species present. The City can then use this data to better understand how much and what types of vegetation are present in each lake.

Calculating the relative proportions of each vegetation type allows for general inferences to be made regarding the health of each waterbody. A healthy balance of EAV and SAV is indicative of good species diversity and habitat for aquatic fauna. Dominance by emergent or floating types is not always cause for alarm, however in most instances where this is the case, water quality issues are typically observed. In the North Central Lakes group, Lakes Buckeye and Maude possess majority SAV species, while Lakes Idyl, Martha, and Silver are dominated by EAV (Figure 2-18). What should also be noted here is that Lakes Idyl, Martha, and Silver effectively possess little to no SAV presence. It is not wholly understood why these lakes lack submerged plant communities, however the City is constantly seeking information to discover the underlying cause(s). For instance, in Lake Idyl, detritus and muck can be found throughout the waterbody. This type of sediment difficult for most species to gain a foothold in except for spatterdock (*Nuphar advena*); which is why it is the dominant species in this lake. Alternatively, Lake Martha appears to have a fair amount of sandy sediment, however no submerged species have been documented there in at least the last 5 years. The lack of SAV still remains a mystery.

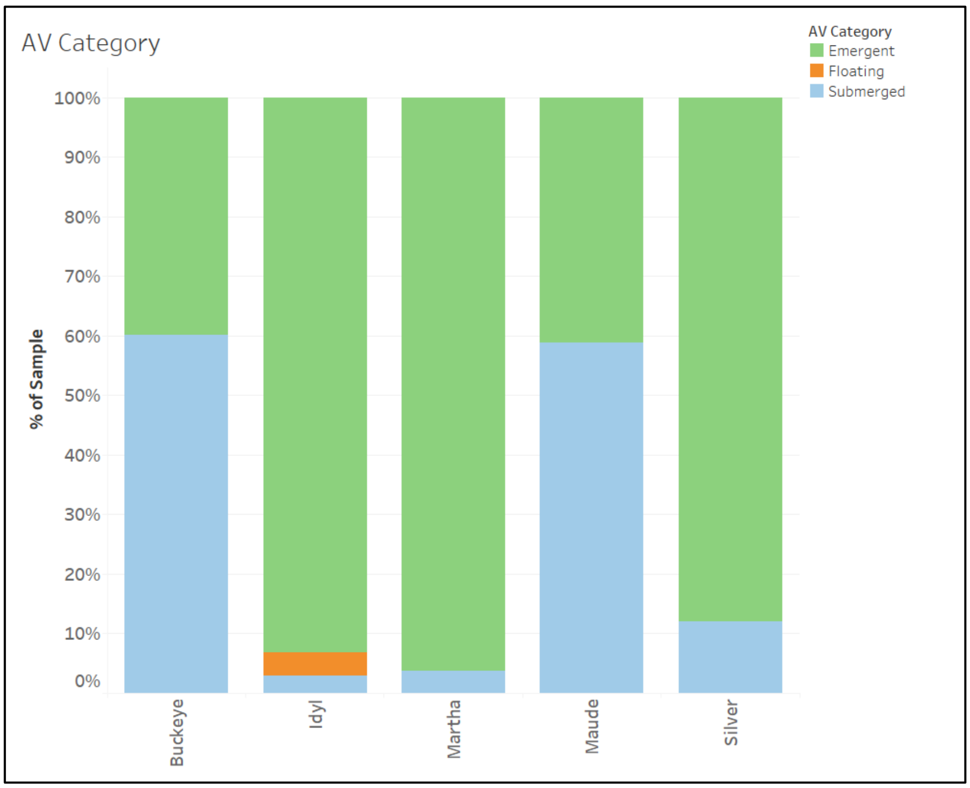


Figure 2-18. North Central Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

Monitoring vegetation abundance with SONAR yields two metrics: percent area cover (PAC) and percent biological volume (% BV). These criteria, PAC and % BV, quantify how much vegetation is present relative to a waterbody's surface area and volume respectively. As a value representing the amount of rooted vegetation, PAC is an important lake health indicator. In the majority of cases, PAC is comprised of SAV species which not only help to stabilize lake sediments, but actively pull nutrients from the water column. In 2019, Lakes Buckeye and Maude possessed PAC values well over 90% which likely contribute significantly to their excellent water quality (Figure 2-19). As a result they received abundance scores of 3 for the lake health index. Lake Idyl underwent a significant decrease in both %BV and PAC—dropping it below the 15% target. Similarly, very little aquatic vegetation was detected in Lake Martha and Silver; however they both exhibited a slight increase in %BV and PAC from 2018. Due to PAC levels between 2.5% and 15% in Lakes Idyl, Martha, and Silver, all three receive a score of 1.

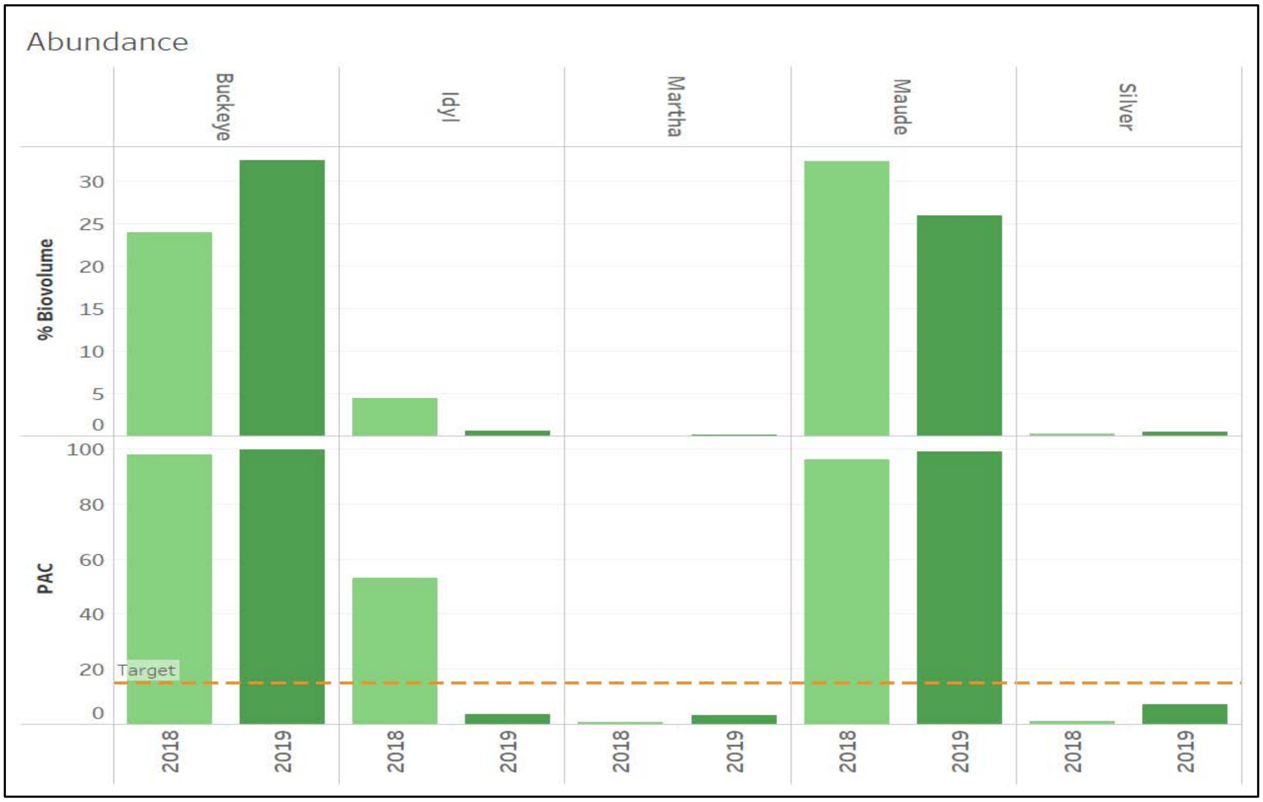


Figure 2-19. North Central Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

Monitoring efforts afford a look into the presence of invasive species in the Winter Haven area lakes. Management of invasive species depends on knowledge of their density and location in order to prescribe the most effective treatment options. Tracking percentages of these managed invasives also provides a means to measure treatment effectiveness with the goal of bringing each lake into a managed state. From 2018 to 2019, the total percentage of invasive species in Lake Buckeye decreased. However, this was not sufficient to improve its score from a 0. The percentage of invasives detected in the other lakes in this group also increased from the previous year (Figure 2-20). Water hyacinths

(*Eichhornia crassipes*) in Lake Idyl were successfully managed, however burhead sedge (*Oxycaryum cubense*) increased to the point to score this lake at a 1. Lake Martha and Maude also experienced an uptick in burhead sedge from the previous year—yield scores of 0 and 2 respectively.

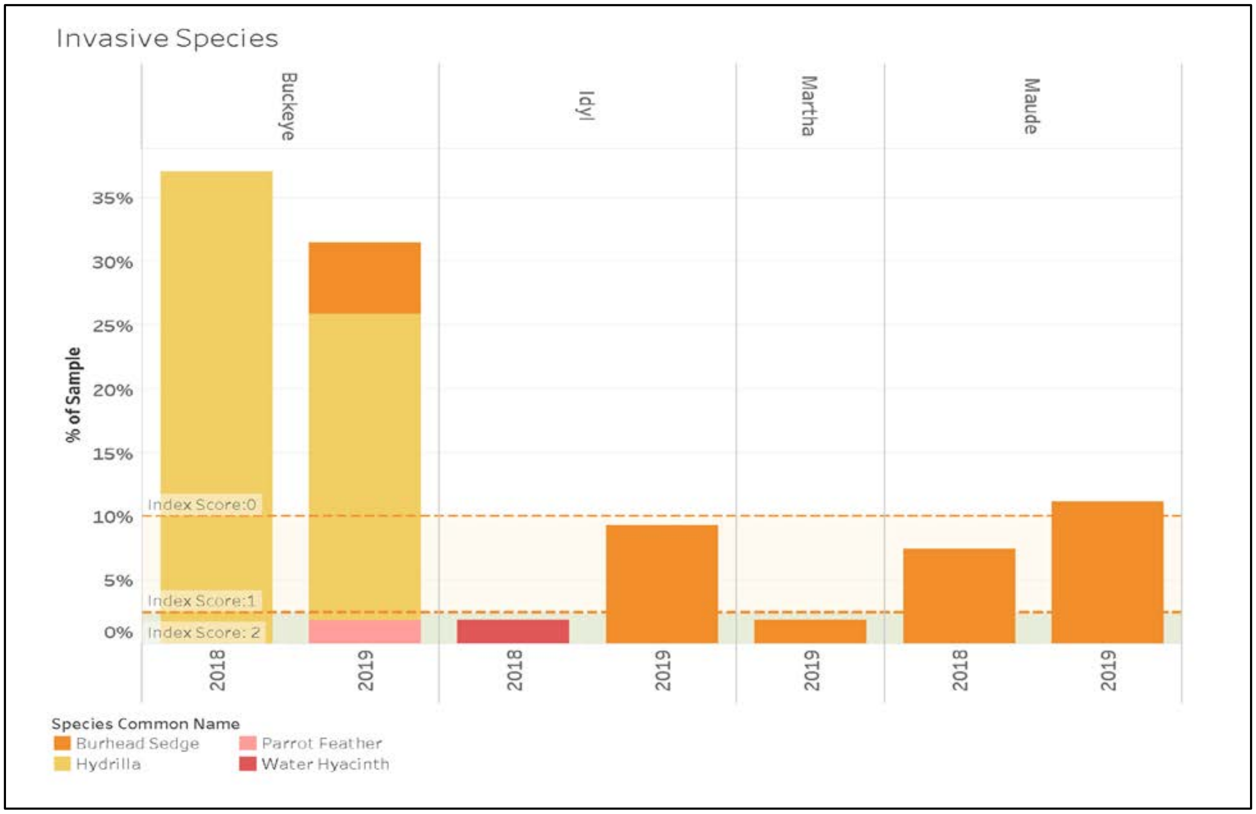


Figure 2-20. North Central Lakes annual percentage of managed invasive species.

Collection of species data allows for the calculation of diversity index scores. As one of the lake health indicators, a change in diversity index values from year to year shows general improvement or deterioration of the aquatic plant community of each lake. The indices used for this evaluation include species richness (R2), evenness (E3), and overall diversity (H). Scoring species diversity is determined by a measurable increase or decrease from the previous year (Figure 2-21). A point is conferred for an increase in each diversity index, for a total possible score of 3.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Buckeye and Martha exhibited an increase in species richness from 2018 to 2019; Lakes Idyl, Maude, and Silber underwent a decrease in richness during this time period.

Hill's Evenness #3 (E3): An increase in species evenness is preferred as it correlates to improvement in community resilience. Lakes Idyl, Martha, and Silver showed an increase in species evenness in 2019. Lakes Buckeye and Maude experienced a decrease an evenness.

Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Lakes Buckeye, Martha, and Silver all underwent an overall increase in diversity in 2019. Lakes Idyl and Maude experienced a decrease.

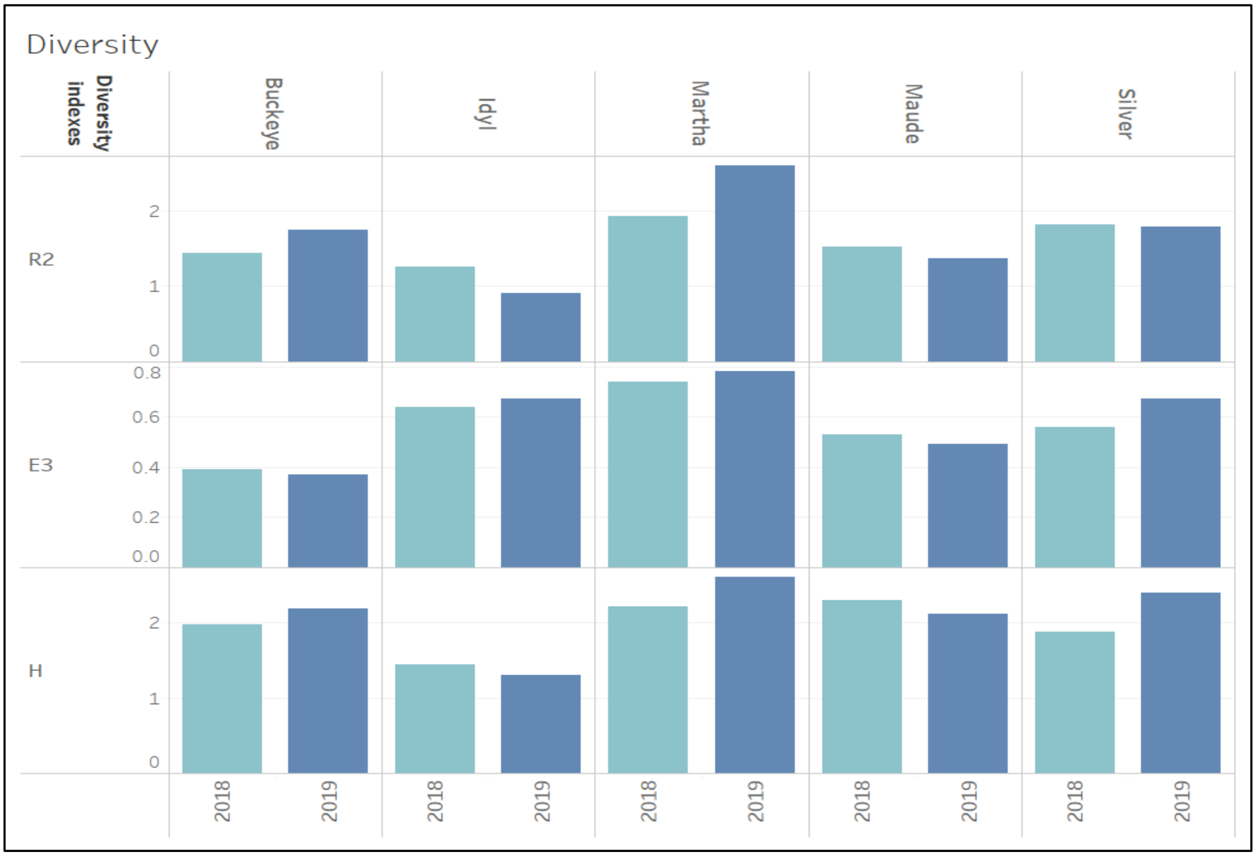
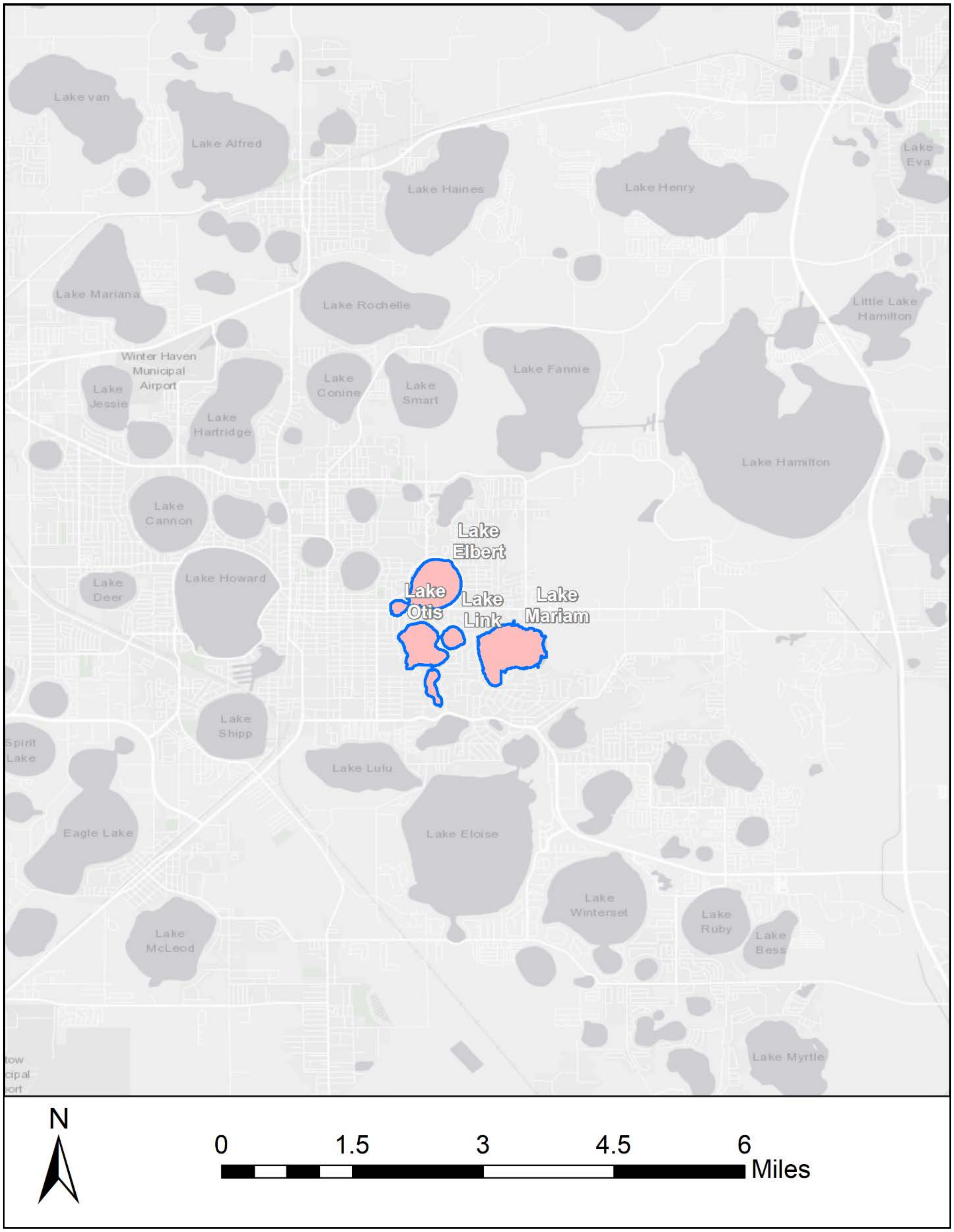


Figure 2-21. North Central Lakes annual index values for species richness, evenness, and diversity

With regards to vegetation management in this chain, the primary concern remains the lack of SAV species in Lakes Idyl, Martha, and Silver. Due to the ability of submerged vegetation to uptake nutrients directly from the water column as well as its sediment stabilization benefits, promoting the growth of SAV should work to improve water quality in these waterbodies. The Natural Resources Division is currently looking into SAV planting methodologies to seed growth of species such as eelgrass (*Vallisneria americana*) in Lake Martha as well as shoreline stabilization with emergent plants to reduce erosion in Lake Silver.

2.4 South Central Lakes



The Winter Haven South Central Lakes (SCL) is comprised of four waterbodies: Lakes Elbert, Link, Mariam, and Otis. Connected by a series of overflow conveyances, these lakes may contribute surface flow to the Peace Creek Drainage Canal via a discharge point to the east of Lake Mariam. The City of Winter Haven, FDOT, and Polk County all contribute surface water to and hold Municipal Separate Storm Sewer System (MS4) permits for stormwater discharge to the SCL. None of the waterbodies in this group currently possess a TMDL.

Water Quality

In order to determine water quality impairment, the South Central waterbodies were categorized based on long-term geometric mean true color and total alkalinity concentrations. Lakes Elbert, Link, and Otis are all considered clear, high alkalinity waterbodies, while Lake Mariam was determined to be highly colored. Impairment was determined via exceedance of the Numeric Nutrient Criteria (NNC) thresholds by annual geometric mean (AGM) Chla, TN, and TP concentrations between 2011 and 2019. The AGM concentrations during this time period are displayed in Tables 4-1 through 4-3 in the Appendix. Based on this methodology, Lake Otis was determined to be impaired for Chla. No other impairments were determined for this lake group. As a result, Lake Otis receives a lake health score of 2 while the other lakes in this group receive a score of 3 in the water quality impairment criterion.

A snapshot of the 2019 AGM Chla, TN, TP, and Secchi depth values for the SCL with the long-term (2000 – 2019) mean and normal range (+/- 1 standard deviation) for each waterbody (Figure 2-22). Lake Elbert is currently exhibiting poorer water quality with above average Chla and TN as well as below average Secchi depth. Lakes Link, Mariam, and Otis all display at or below average Chla, TN, and TP in addition to Secchi depths within the normal range.

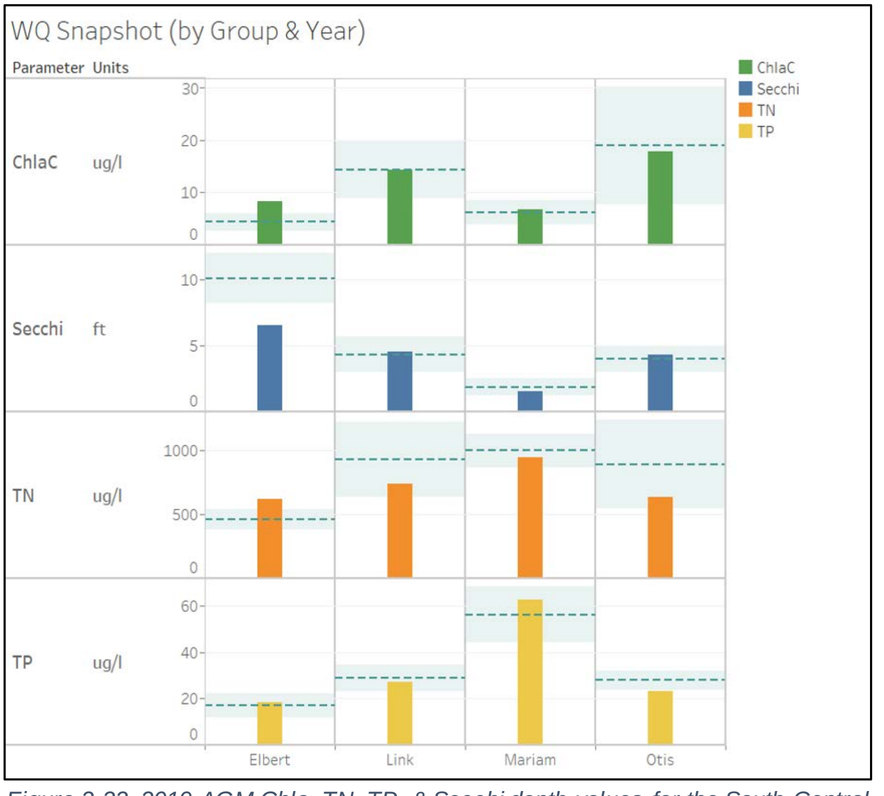


Figure 2-22. 2019 AGM Chla, TN, TP, & Secchi depth values for the South Central Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

Water quality trend evaluation was performed by plotting AGM Chla, TN, TP, and Secchi depth against time, in years, from 2000 to 2019 (Table 2-4). Monotonic trend direction (+/-) and statistical significance (p-value ≤ 0.05) were determined based on the resulting linear regression statistics (Table 4-4 in Appendix). The trend information, including the associated lake health index scoring, is presented in Table 2-4. The only significant water quality trends include increasing Chla and TN trends in Lake Elbert and a decreasing TN trend in Lake Link.

Waterbody	Parameter	Trend Direction	Significance	Index Score
Lake Elbert	Chla	Increasing (Deteriorating)	Significant	0
	TN	Increasing (Deteriorating)	Significant	0
	TP	Increasing	Not Significant	1
	Secchi	Decreasing	Not Significant	1
Lake Link	Chla	Decreasing	Not Significant	2
	TN	Decreasing (Improving)	Significant	3
	TP	Decreasing	Not Significant	2
	Secchi	Increasing	Not Significant	2
Lake Mariam	Chla	Decreasing	Not Significant	2
	TN	Decreasing	Not Significant	2
	TP	Decreasing	Not Significant	2
	Secchi	Increasing	Not Significant	2
Lake Otis	Chla	Decreasing	Not Significant	2
	TN	Decreasing	Not Significant	2
	TP	Decreasing	Not Significant	2
	Secchi	Increasing	Not Significant	2

Table 2-4. 2019 South Central Lakes WQ Trends for Chla, TN, TP, & Secchi Depth and their representative lake health index scores

Hydrology

Similar to the North Central Lakes group, the South Central waterbodies are connected via a series of passive overflow structures and conveyances; Lakes Link and Otis are connected by a navigable canal which means they are held at the same elevation. Flow downstream only occurs when water levels exceed the passive control structure elevations on each lake. Incidentally, the pipe connecting Lake Elbert to Otis was originally designed to utilize a pump, however one was never installed. Consequently, water cannot flow from Lake Elbert naturally. Monthly surface level (SL) and rainfall readings for the SCL from 2000 to 2019 as well as box-and-whisker plots detail each lake's relative variability. Since rainfall drives the hydrology of the area, SCL surface levels track fairly consistently with annual precipitation above and below the Winter Haven area average of 51.6 inches (Figure 2-23). Of the lakes in this group, Lake Elbert experiences significantly more variation in SL. This is likely due to the relative size of its drainage basin and the fact that it may never reach levels in which it overflows to Lake Otis. All 4 waterbodies in this group experienced impacts from the drought period from 2006 to 2014 and a subsequent recovery after annual rainfall totals returned to normal.

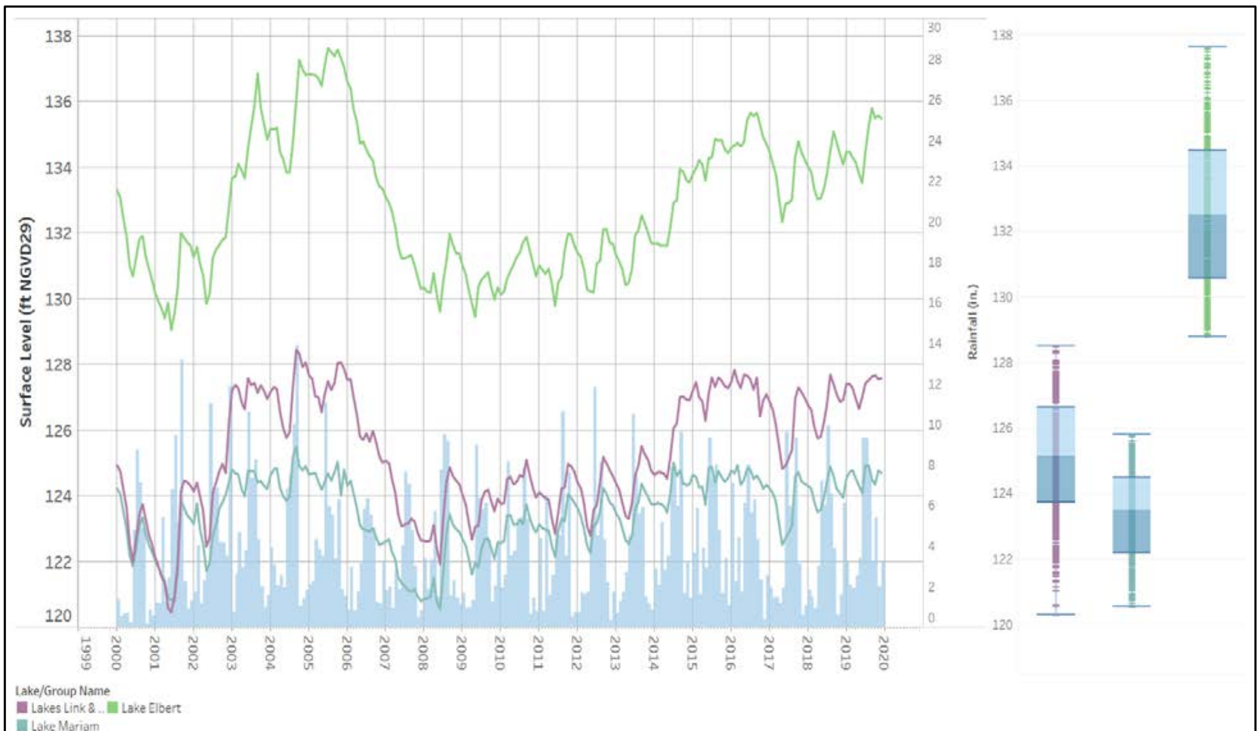


Figure 2-23. South Central Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Monthly rainfall totals indicate hydrologic response to precipitation.

Based on linear regression analysis performed in the previous lakes report, Lakes Elbert, Link and Otis all exhibit correlations between surface level and more than one primary water quality parameter (Table 4-5; in appendix). Lake Mariam showed no such relationships which may be a result of its position at the most downstream point of this lake group. As the final discharge point, Mariam likely only flushes during extremely wet periods. This is evidenced by the lower overall SL variability—shown as the smaller interquartile range in the boxplot.

Stormwater pollutant loads for this drainage basin originate mostly from institutional (from two educational facilities) and medium-density residential land uses. As a result, areal nutrient loads are roughly average for the study area. The sub-basins around Lake Elbert and west of Lake Otis are where the higher loading areas are located in this lake group (Figure 2-24). These basins are located within City limits and were identified as priority basins for regular street sweeping as a pollutant load reduction BMP. In addition, the City has installed some green infrastructure in these watersheds with more planned for the future. Lower loading values have been determined in the sub-basins east of Lakes Link and Mariam. These watersheds generally consist of a mix between residential and open/agricultural lands.

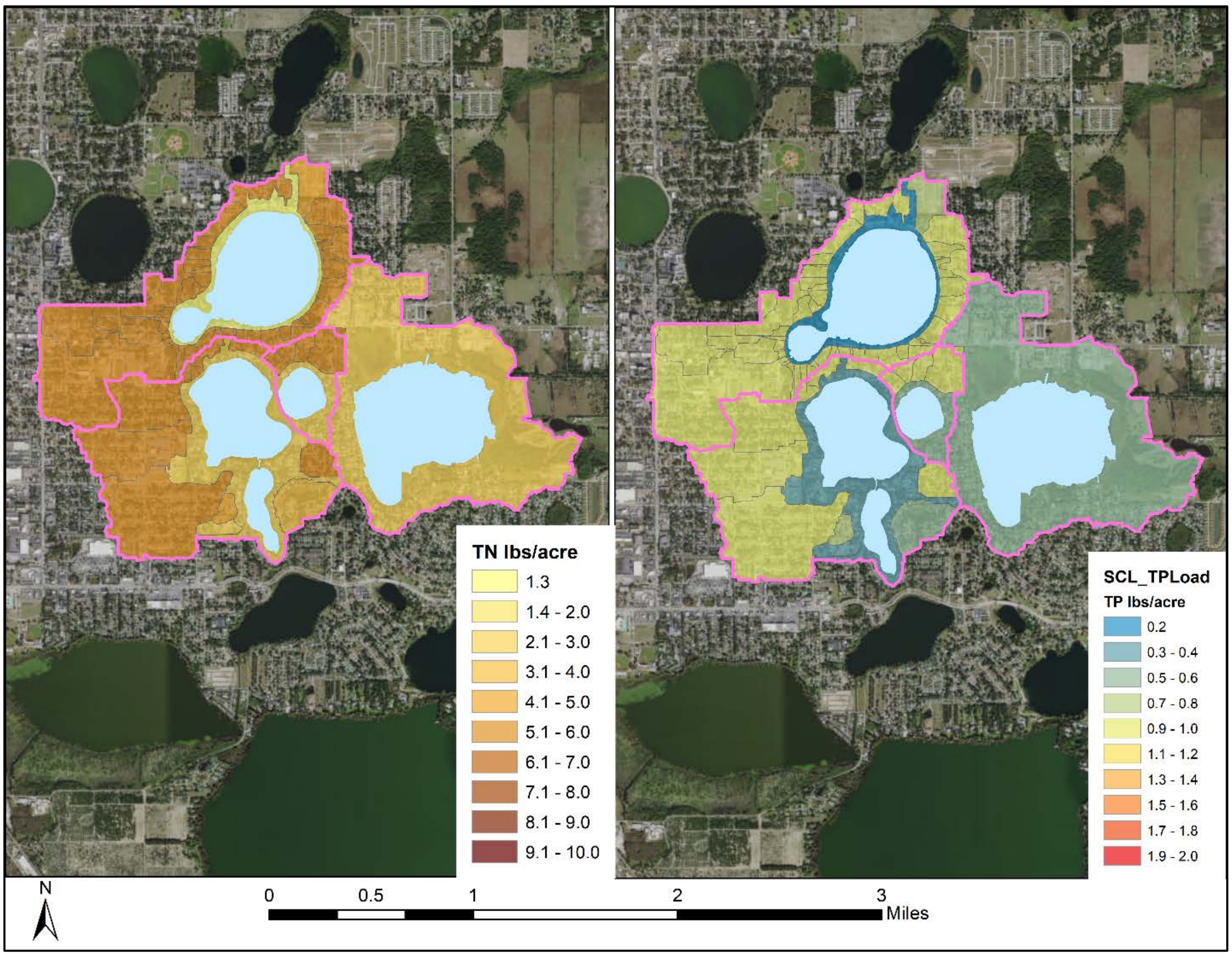


Figure 2-24. Areal TN & TP Loading for individual drainage basins in the South Central Lakes.

Ecology

The City of Winter Haven's ecological monitoring program involves annual surveys of aquatic vegetation found in the study area lakes. Survey methods include point-intercept sampling to determine the representative species present in each waterbody as well as SONAR mapping which provides data relating to the abundance of submerged and some emergent species. Lakes Elbert, Otis, and Mariam have been surveyed annually since 2017. Due to extremely high surface levels in 2019, staff were unable to pilot the survey vessel under the bridge to Lake Link. As a result, no vegetation survey data was collected for this year.

Analyzing the proportion of each vegetation type found in a given lake is useful to determine the general vegetation community at a glance. Ideally, waterbodies should possess a healthy mix of submerged aquatic vegetation (SAV) and emergent aquatic vegetation (EAV). However, due to the unique characteristics and environmental stimuli found in each lake, an equal mix is not always indicative of a healthy waterbody. Lake Elbert appears to have an extremely robust SAV community with a dominant 60% proportion (Figure 2-25). Lakes Link and Otis possess a majority of EAV species, but with strong SAV communities at roughly 25% of the total population. Emergent vegetation is clearly the dominant type found in Lake Mariam, as there has been no SAV present in the last three surveys.

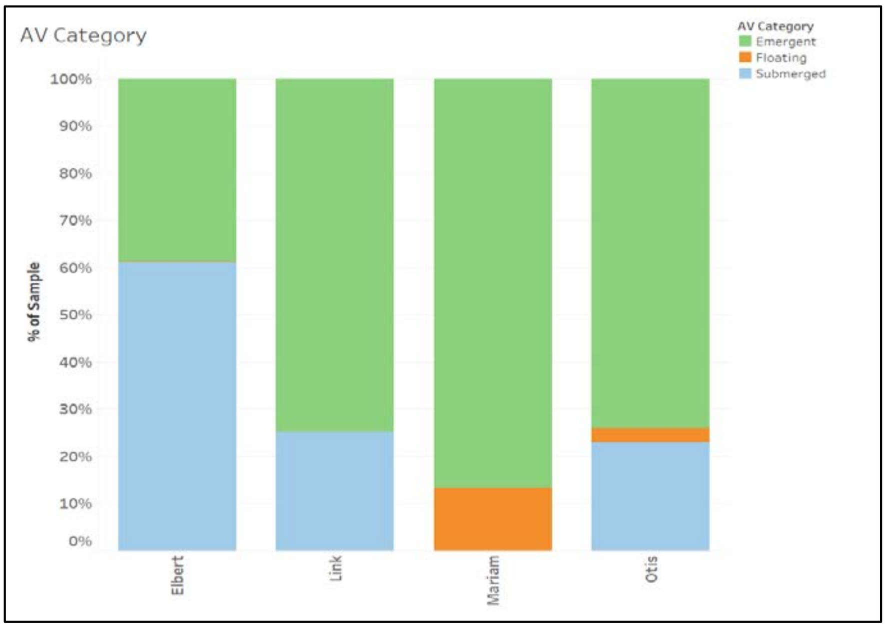


Figure 2-25. South Central Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

Measures of vegetation abundance are useful metrics that can provide insights into sediment stabilization, fish habitat, as well as nutrient absorption potential. The primary measures used by the City include percent area coverage (PAC) and average percent biological volume (% BV). Tracking changes in these metrics over time allows lake managers to determine if rooted vegetation communities are increasing or receding. Lake health index scoring for this criterion is based on 2019 PAC values in relation to set minimum targets (Figure 2-26).

2019 PAC values remained relatively high for Lake Elbert. A score of 3 is earned for PAC above 30%. Both Lake Mariam and Otis showed a moderate increase in vegetation abundance from 2018 to 2019. With PACs between 15% and 30%, they receive a score of 2. Due to the lack of 2019 vegetation data for Lake Link, this metric will not be evaluated in this year's lake health index. However, it is likely that in the absence of any major invasive treatments in this lake, it is likely that vegetation abundance remained at or exceeded 2018 values.

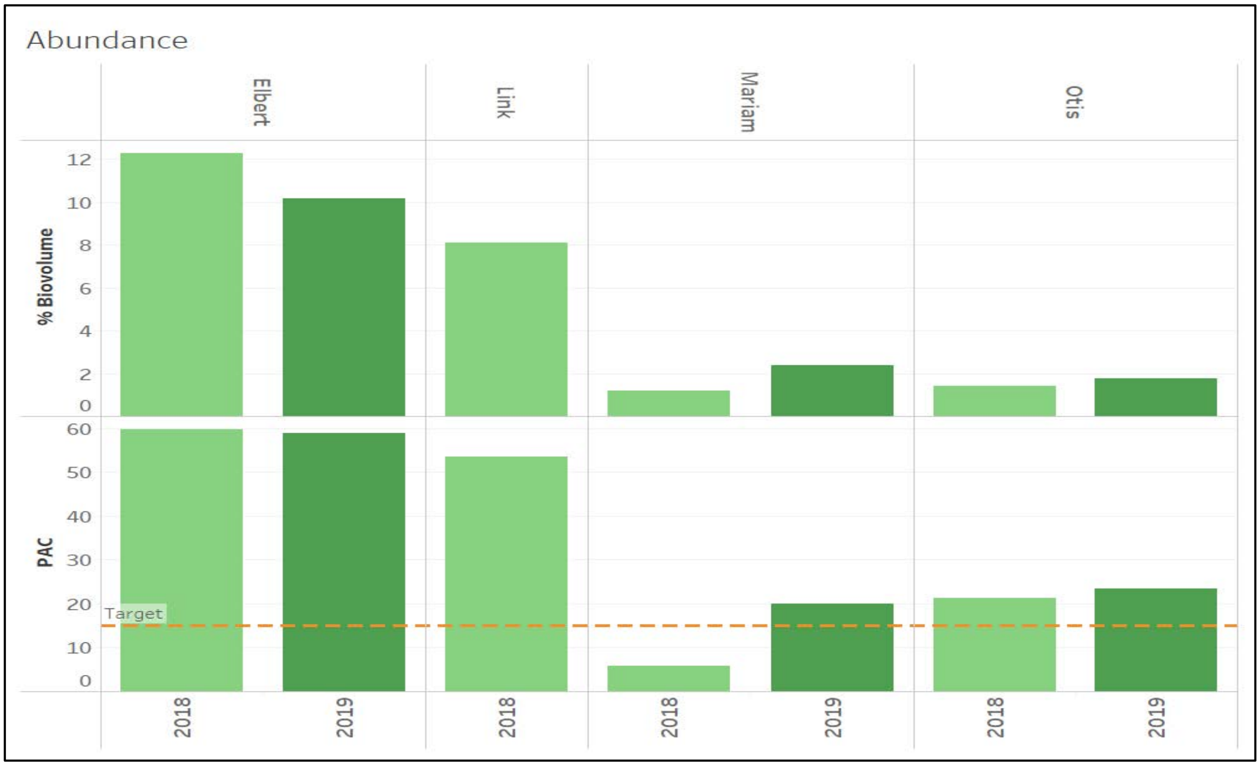


Figure 2-26. South Central Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

Ideally, a perfectly healthy biological community would be free from invasive species. In addition to causing ecological harm to native species, wholesale treatment of invasive plants can release a considerable amount of nutrients into the water column as they decompose. The City's response is to promote early detection and rapid response measures that seek to reduce these nutrient releases by limiting the amount of vegetation treated at one time. The data collected by the City has been used to score lake health based on the percentage of managed invasives observed. The managed species found in this lake group include hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichhornia crassipes*), and burhead sedge (*Oxycaryum cubense*).

From 2018 to 2019, Lakes Elbert, Mariam, and Otis all exhibited an increase in invasive percentage (Figure 2-27). Lakes Elbert and Mariam maintain a score of 0 from the previous year. Due to a significant increase in burhead sedge in Lake Otis, it has received a score of 0, downgraded from the previous year. Since no vegetation data was collected for Lake Link, the invasive metric will not be calculated as part of overall lake health index.

Based on criterion scores from the other lakes in this group, it is likely that invasive percentage has increased in Lake Link in 2019. This will be confirmed with a follow-up survey in 2020.

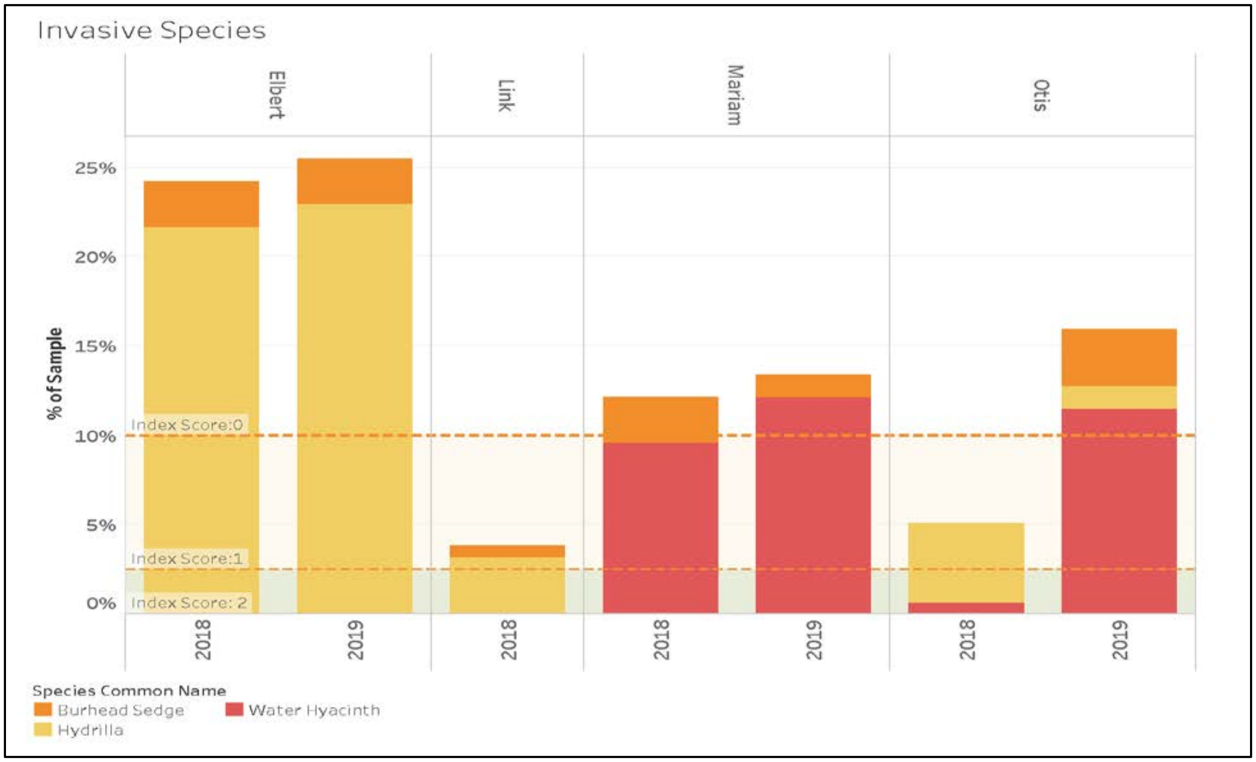


Figure 2-27. South Central Lakes annual percentage of managed invasive species.

As the final biological lake health indicator, species diversity is essential to ensuring a long-lasting, healthy vegetative community. Species richness, evenness, and overall diversity are all separate metrics incorporated into the diversity score. Tracking changes in this score over time should provide some indication as to ecological trends in Winter Haven's lakes (Figure 2-28). Scoring is based on either an increase or decrease of each index value from 2018 to 2019, for a total possible score of 3. Since no data was collected for Lake Link, this metric will be excluded from the overall lake health calculation.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Elbert and Otis exhibited an increase in species richness while Lake Mariam underwent a decrease from 2018 to 2019.

Hill's Evenness #3 (E3): An increase in species evenness is preferred as it correlates to improvement in community resilience. Lakes Lakes Mariam and Otis showed increasing values, with Lake Elbert decreasing in evenness in 2019.

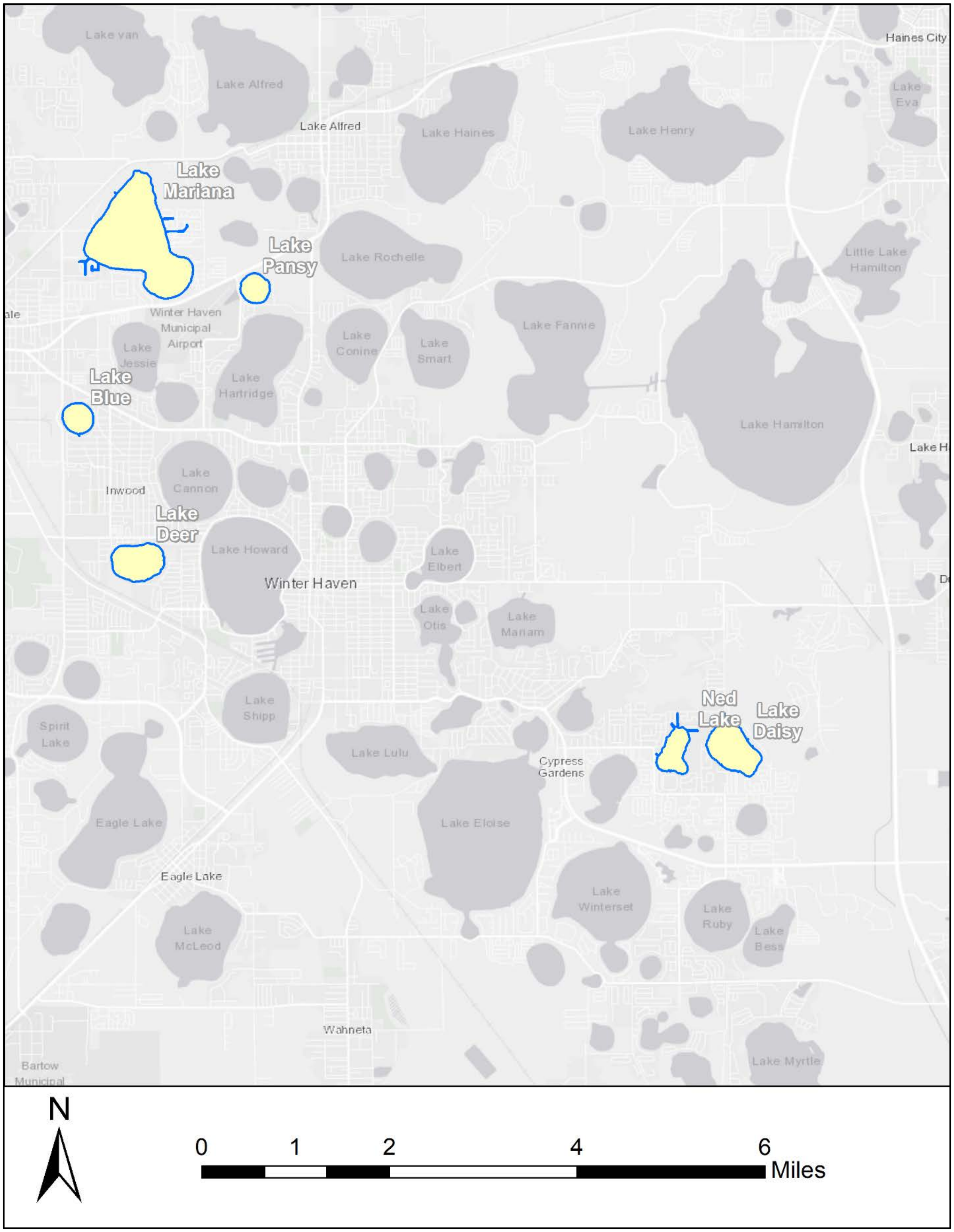
Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Lakes Elbert, Mariam, and Otis exhibited an increase in Shannon's diversity from 2018 to 2019.

Figure 2-28. South Central Lakes annual index values for species richness, evenness, and diversity.

Through analysis of the vegetation data for this lake group, a few things can be concluded. First, focus should be placed on management of Lake Mariam's biological community since it lacks vegetation abundance and an SAV presence. Based on observations while sampling, the primary sediment type in Mariam is organic muck which is not the best benthic habitat to support most native aquatic plants. Therefore, alternative solutions may be necessary to provide nutrient uptake—floating wetlands is one such novel solution that the City has used to treat urban stormwater ponds.

Secondly, a trend of invasive proliferation has been observed not only in this lake group, but amongst the study area as a whole. The species that has shown the most consistent increase in biomass has been burhead sedge. Focused treatment of this species may need to become a priority in the coming year as populations expand. The City plans to work with FWC and Polk County to determine if alternative control strategies will be viable for this plant.

2.5 Outlying Lakes



The Winter Haven Outlying Lakes (OL) group is composed of several seemingly isolated waterbodies located at the periphery of the City. Lakes Blue, Deer, and Mariana all possess known passive overflow connections to the Southern Chain of Lakes. While Lake Pansy has no known conveyances directly connecting it to other lakes in the study area, it is possible during periods of extremely high surface level that water may flow through its adjacent wetland and into the Northern Chain via Lake Rochelle. Lakes Ned and Daisy share a connection, but no known discharge points to other waterbodies. The governmental entities that contribute surface water flow and/or possess Municipal Separate Storm Sewer System (MS4) permits to this lake group include the Cities of Winter Haven and Auburndale, Polk County, and the FDOT. Lakes Blue, Deer, and Mariana possess Nutrient TMDLs developed by the FDEP.

Water Quality

As a lake health indicator, determination of impairment is used by the FDEP to assess whether a waterbody is currently meeting water quality standards that fit with its intended use. Categorizing lakes based on long-term geometric mean true color and total alkalinity is the first step to determine which Numeric Nutrient Criteria (NNC) targets to meet. Within the Outlying Lakes group, Lakes Blue, Deer, Mariana and Ned are considered clear, high alkalinity waterbodies, Lake Pansy was determined to be highly colored, while Lake Daisy is a clear, low alkalinity lake. Impairment scoring is determined by exceedances of NNC thresholds by annual geometric mean (AGM) Chla, TN, and TP concentrations during the assessment period from 2011 to 2019 (Tables 4-1 to 4-3 in appendix). Waterbodies with no impairments are given a score of 3, while a point is deducted for each impaired parameter.

Based on these criteria, Lakes Blue, Deer, and Mariana were all determined to be impaired for Chla, TN, and TP during this period. Lakes Daisy, Ned, and Pansy exhibit no impairments. It should be noted that recent water quality trends place its Chla, TN, and TP concentrations below impairment thresholds for the last six years. Pending continued trends, it is likely that Deer will be meeting its NNC targets by 2021 and eligible for delisting at some point thereafter.

A snapshot of 2019 AGM Chla, TN, TP, and Secchi depth values shows that water quality may be improving in recent years in the OL group (Figure 2-29). Lakes Blue, Daisy, and Pansy experienced Chla concentrations at their respective long-term averages or within their normal range. Lakes Mariana and Ned had Chla concentrations that were above their normal range; while Lake Deer's Chla concentration was well below the average. All OL waterbodies had 2019 TN and TP concentrations at or below the long-term average. Secchi depths were within the normal range for Lakes Blue, Daisy, and Pansy. Lake Deer exhibited Secchi depths well above the long-term average, while Lakes Mariana and Ned had values well below their respective averages. Overall, Lakes Mariana and Ned had generally poorer water quality in 2019, whereas Lake Deer's water quality was much better than its long-term average.

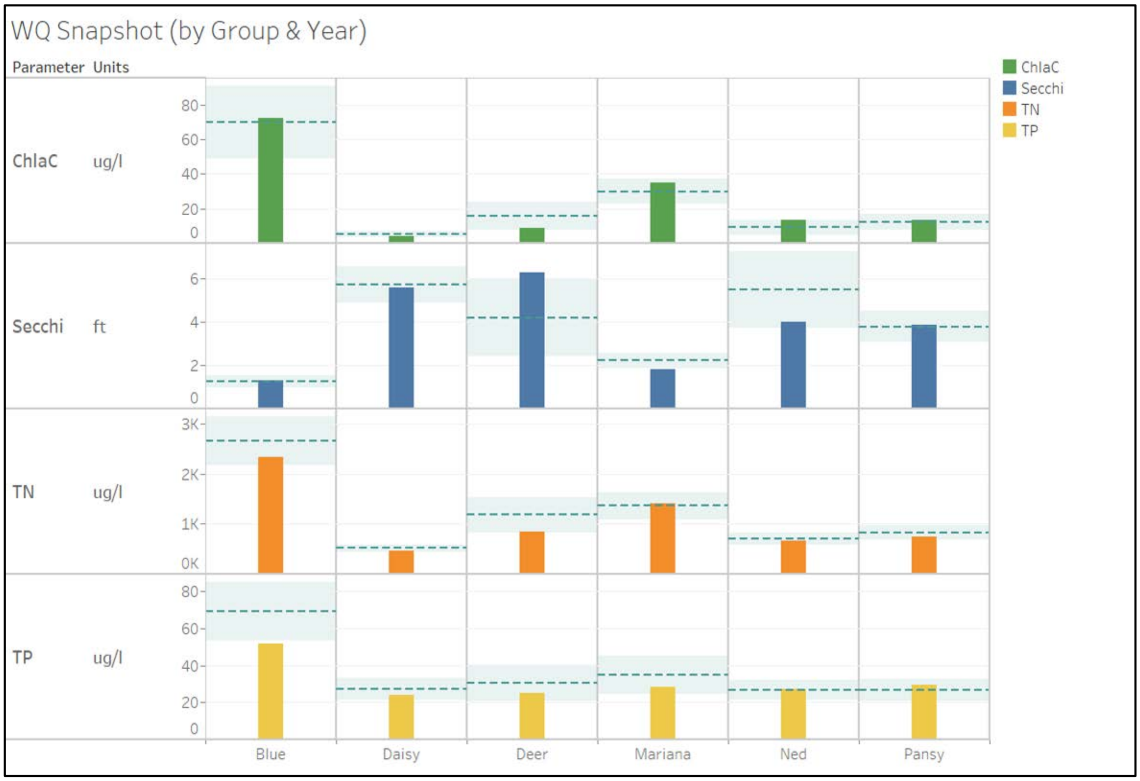


Figure 2-29. 2019 AGM Chla, TN, TP, & Secchi depth values for the Outlying Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

Analysis of the long-term water quality trends was performed by plotting AGM Chla, TN, TP, and Secchi depth against time, in years, from 2000 to 2019 (Table 2-5). Linear regression lines were plotted in order to determine trend direction (+/-) and statistical significance (p-value ≤ 0.05) (Table 4-4 in appendix). By performing these regressions, the resulting statistics indicate whether lakes are improving or declining in each of the four previously mentioned water quality parameters.

Chlorophyll-a Trends: Of the OL group, Lake Daisy exhibits a significant decreasing Chla trend, while Lake Pansy shows a significant increasing trend.

Total Nitrogen Trends: No Outlying Lakes experienced significant TN trends over time.

Total Phosphorus Trends: Lake Ned possesses a significant increasing trend in TP.

Clarity Trends: Lakes Mariana and Ned both exhibit significant decreasing Secchi depth trends over time.

Waterbody	Parameter	Trend Direction	Significance	Index Score
Lake Blue	Chla	Decreasing	Not Significant	2
	TN	Decreasing	Not Significant	2
	TP	Decreasing (Improving)	Significant	3
	Secchi	Increasing	Not Significant	2
Lake Daisy	Chla	Decreasing (Improving)	Significant	3
	TN	Decreasing	Not Significant	2
	TP	Decreasing	Not Significant	2
	Secchi	Increasing	Not Significant	2
Lake Deer	Chla	Decreasing	Not Significant	2
	TN	Decreasing	Not Significant	2
	TP	Decreasing	Not Significant	2
	Secchi	Increasing	Not Significant	2
Lake Mariana	Chla	Increasing	Not Significant	1
	TN	Increasing	Not Significant	1
	TP	Decreasing	Not Significant	2
	Secchi	Decreasing (Deteriorating)	Significant	0
Lake Ned	Chla	Increasing (Deteriorating)	Significant	0
	TN	Decreasing	Not Significant	2
	TP	Increasing (Deteriorating)	Significant	0
	Secchi	Decreasing (Deteriorating)	Significant	0
Lake Pansy	Chla	Increasing (Deteriorating)	Significant	0
	TN	Increasing	Not Significant	1
	TP	Increasing	Not Significant	1
	Secchi	Decreasing	Not Significant	1

Table 2-5. 2019 Outlying Lakes WQ Trends for Chla, TN, TP, & Secchi Depth and their representative lake health index scores

Analysis of this information should inherently place greater focus on the waterbodies that are currently impaired. Lakes Blue, Deer, and Mariana all possess nutrient TMDLs and require the development of BMPs to improve water quality. The Chla, TN, and TP concentrations in Lake Blue are not only magnitudes higher than the other lakes in the study area, but also significantly higher than the regulatory NNC targets. It is likely that no amount of stormwater load reduction will improve conditions in the lake. The City and County will need to determine potential in-lake practices to reduce existing nutrient concentrations.

On the other hand, focus must also be placed on the waterbodies that currently are not impaired but are trending poorly. Lakes Ned and Pansy are currently exhibiting signs of deteriorating water quality. The goal is to enact BMPs to prevent these lakes from becoming impaired. This is where identifying and mitigating potential nutrient sources is the most effective strategy. Due to a lack of traditional stormwater infrastructure in these watersheds, greater focus should be placed on the non-point sources such as septic or internal loading.

Hydrology

Unlike other lake groups, the Outlying Lakes are not connected in a linear fashion, nor are they all located within or adjacent to City boundaries. Each of these waterbodies are essentially isolated systems with little impact on one another. However, they all have the capacity to impact downstream surface waters in the Winter Haven Chain of Lakes; either by discharging during high water periods or through groundwater interaction. Monthly surface level (SL) and rainfall readings from 2000 - 2019 as well as box-and-whisker plots detailing relative variability show short and long-term variability due to precipitation. The data suggests that Lake Daisy flows downstream to Lake Ned as its surface level is consistently higher by roughly a foot. Lake Ned discharged via an overflow structure to Lake Dexter to the west; Lake Dexter was not included in this study since it lacks public access.

The seasonal variations in surface level are clearly evident by the peaks and troughs during each year, but there appears to be a distinct lack of long-term fluctuations in surface level exhibited by all except Lake Pansy (Figure 2-30). It is difficult to say at this time whether this lack of long-term fluctuation is a result of surface level management efforts or if there are other hydrologic impacts at play. Perhaps as a result of the overall lack of surface level variability in this lake group, there are no significant relationships between SL and Chla, TN, TP, or Secchi depth in Lakes Blue, Daisy, Deer, Mariana, or Pansy. There is a significant, yet weak correlation between SL and TN in Lake Ned however (*$R^2 = 0.22; p < 0.05; DF = 19$*). Since these lakes are generally very shallow and

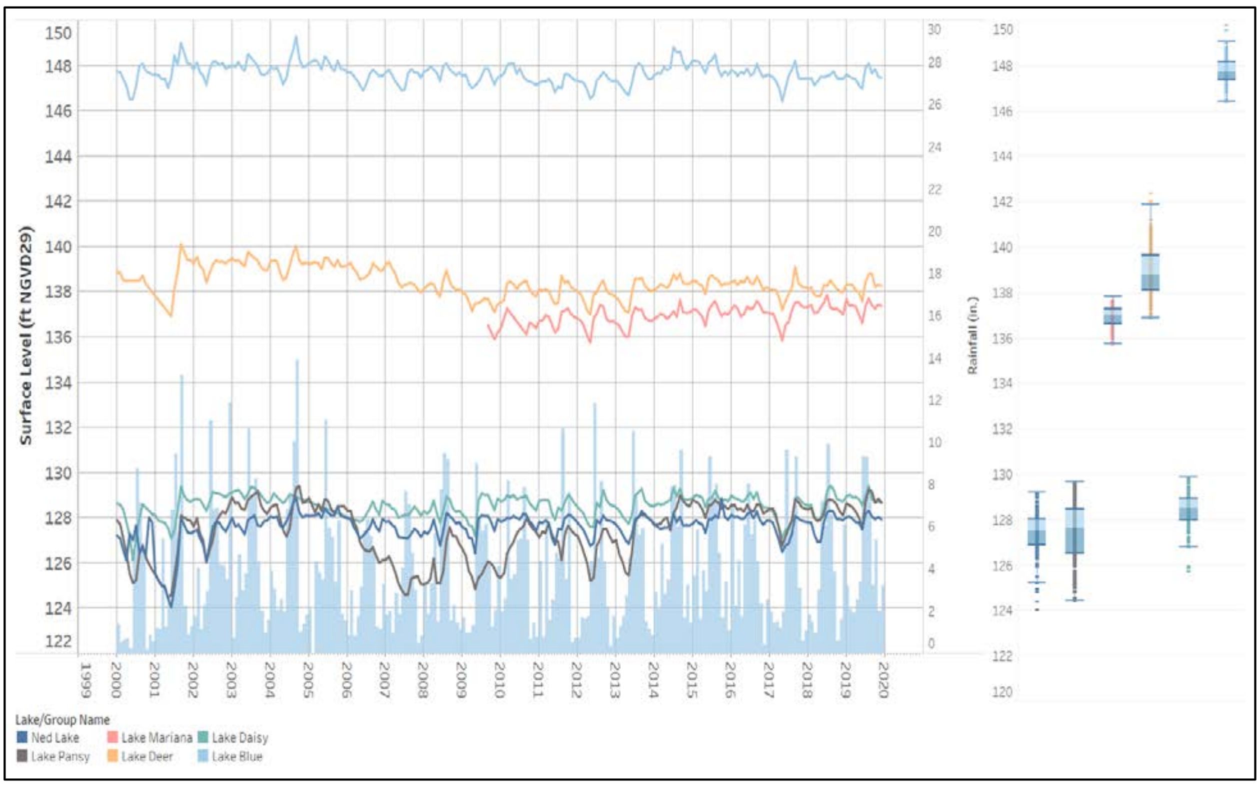


Figure 2-30. Outlying Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Monthly rainfall totals indicate hydrologic response to precipitation.

surrounded by residential areas, a significant change in surface level one way or the other could lead to flooding or a loss of core recreational and ecological functions. Therefore it is unlikely that alterations to hydrologic management levels would be feasible or effective at improving water quality.

Pollutant load model analysis for this lake group indicates that stormwater nutrient loading for the Outlying lakes is roughly average when compared to the other waterbodies in this study area (Figure 2-31). The primary land uses within these drainage basins are residential with some commercial and open land uses as well. Much or all of the land surrounding Lakes Blue, Daisy, Deer, Mariana, and Ned is in unincorporated Polk County which typically has minimal gray stormwater infrastructure. As a result, the discreet drainage pathways are difficult to identify. This also limits the City's ability to mitigate loading through BMPs like street sweeping or green infrastructure. The majority of Lake Pansy's stormwater drains from the Winter Haven airport grounds. Here, the City has implemented detention ponds to limit the amount of nutrient loading from that site.

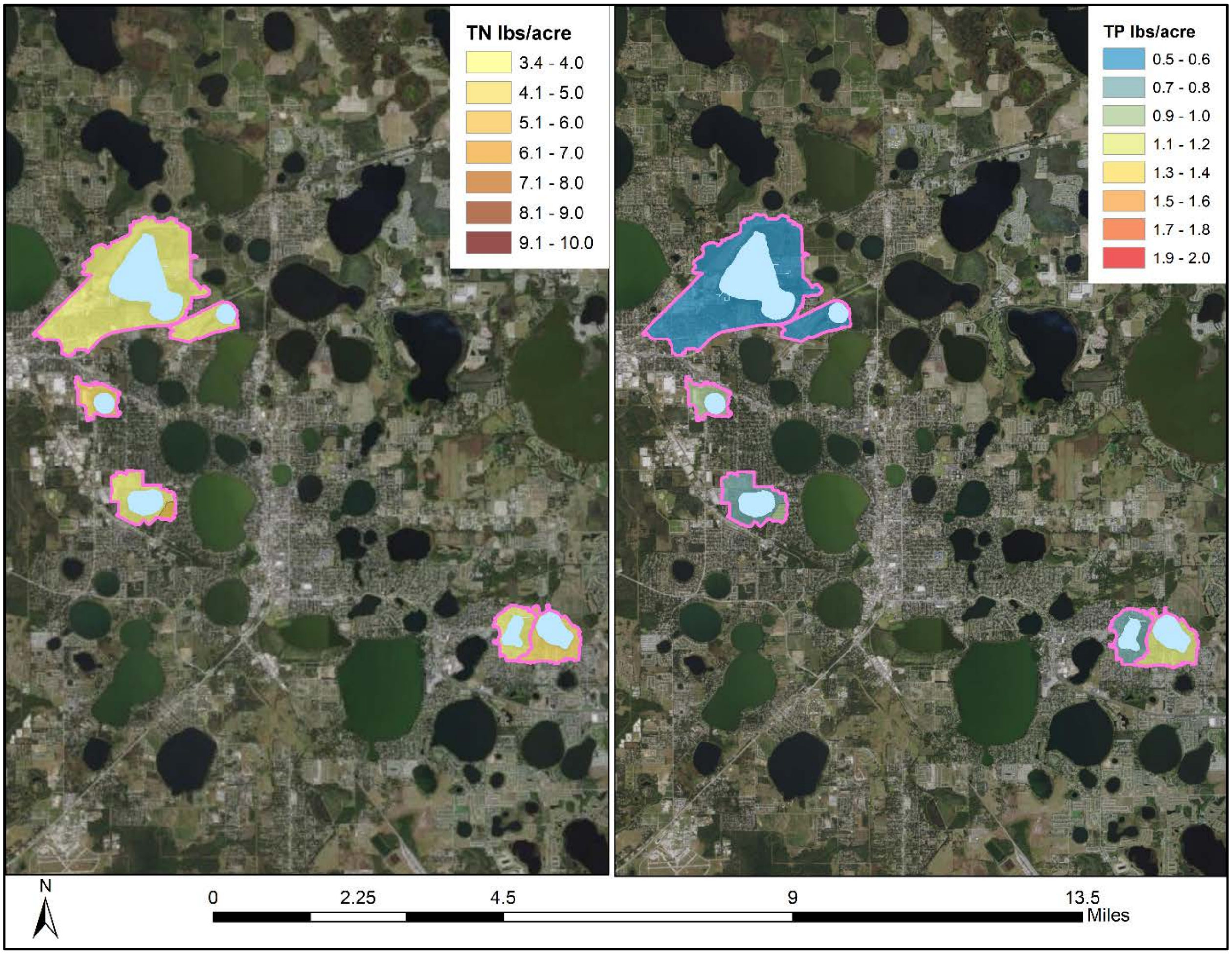


Figure 2-31. Areal TN & TP Loading for individual drainage basins in the Outlying Lakes.

It should be noted that the majority of lakes in this group possess a high density of Onsite Sewage Treatment & Disposal (OSTD) or septic systems within their drainage basins.

Within recent years, septic leachate has become the subject of greater scrutiny as a significant source of nutrients as well as human health hazards in public waterways. Unfortunately, the costs to retrofit or convert these systems to a municipal sewer network are often prohibitively high. That said, if OSTDs are the primary cause of lake health degradation, funding sought after or earmarked for conversion could be well worth the costs. Since many of the residents of these lakes are outside Winter Haven limits, the City should collaborate with Polk County to develop a plan for addressing this potential pollutant source.

Ecology

Ecological evaluation is a major component of the lake health assessment. Aquatic vegetation abundance and diversity measures are used to determine the overall health of each waterbody's biological communities. In order to obtain this information, the City performs annual vegetation surveys using point-intercept sampling and SONAR mapping methods. The City has conducted annual vegetation surveys for each of these lakes since 2017.

Categorizing the vegetation types found in each waterbody allows for general assumptions to be made about the communities found within. These categories include emergent aquatic vegetation (EAV), submerged aquatic vegetation (SAV), and floating vegetation (FV). Lakes Deer and Mariana both possess a healthy balance of EAV and SAV (Figure 2-32). Lakes Blue, Daisy, Ned and Pansy have very little in the way of SAV which equates to these lakes' inability to buffer against spikes in nutrient loading. This means that as pollutant loads increase, there is a greater risk of algal blooms. Lake Blue's inability to support much SAV is expected due to its poor water clarity. Lakes Ned and Pansy possess moderate Secchi depths which should facilitate SAV growth. The lack of SAV in Lake Daisy is peculiar as its Secchi depth rivals that of Lake Deer. Perhaps the benthic sediment is not an ideal substrate. Further analysis is required to determine the cause of this peculiar situation.

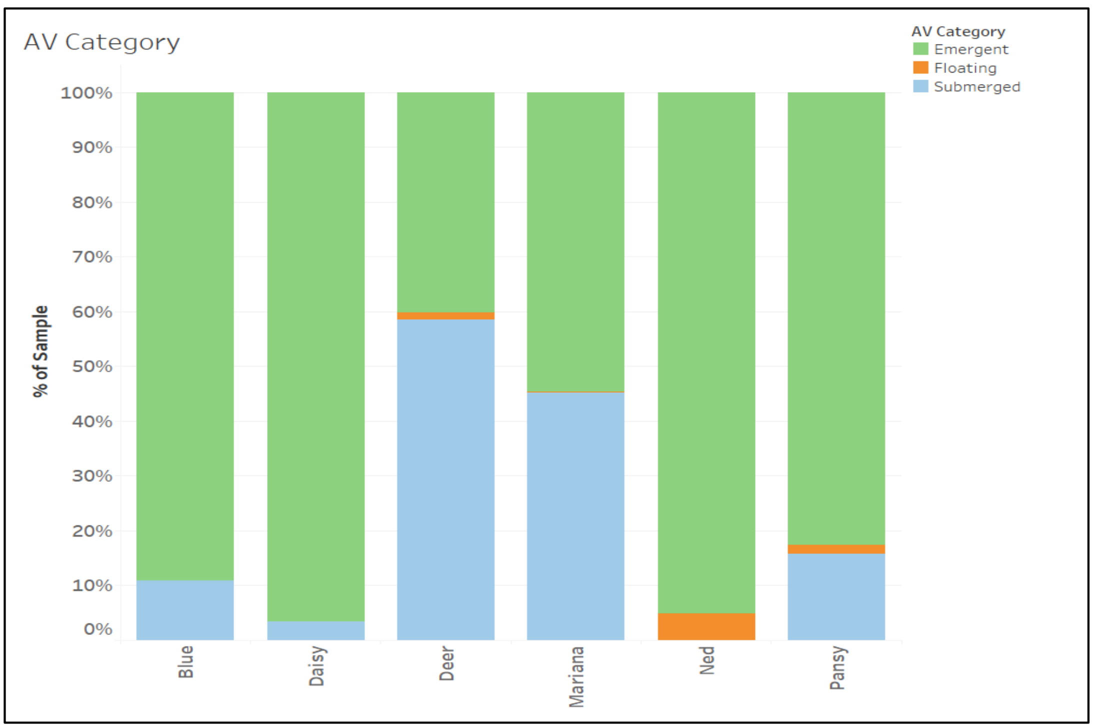


Figure 2-32. Outlying Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

Vegetation abundance data is represented by two primary metrics—percent area cover (PAC) and mean percent biological volume (% BV). These metrics represent the amount of rooted vegetation detected as it relates to lake surface area and volume respectively. State environmental agencies consider a PAC of more than 15% ideal to support healthy fish populations. As a result, the City utilizes this value as a lake health indicator. As of 2019, Lakes Deer and Pansy possessed > 30% coverage—earning them a lake health score of 3 for this criterion (Figure 2-33). Lake Deer, in particular, had a very dense eel grass (*Vallisneria americana*) population which contributed to its high PAC value. The amount of Illinois Pondweed (*Potamogeton illinoensis*) in Lake Mariana contributed to its PAC of 26% which earned it a score of 2. Lakes Blue, Daisy, and Ned all possessed minimal rooted vegetation which resulted in scores of 1.

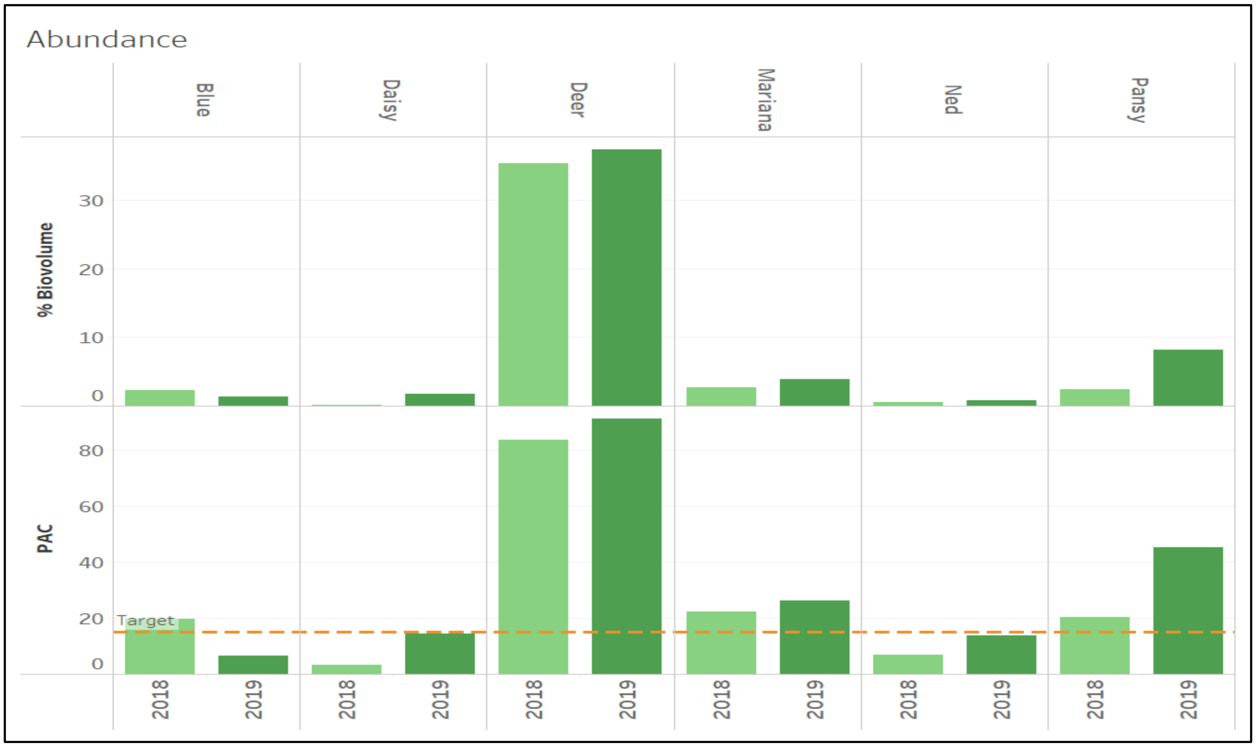


Figure 2-33. Outlying Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

The percentage of invasive species found in the Outlying Lakes from 2018 to 2019 shows that Lake Deer suffered a substantial increase in pest plants in 2019 (Figure 2- 34). Lakes Daisy and Blue are absent from this chart due to their lack of observed invasive species in the last two years—as a result, they score a 3 in this criterion. Lake Deer's surge in invasives was due to an explosion of the hydrilla (*Hydrilla verticillata*) population. This increase earned it an invasive score of 0. Inversely, Lake Mariana underwent a decline in invasive percentage in 2019. A lack of observed invasives in this lake resulted in it receiving a score of 3. Lakes Ned and Pansy each received score of 1 due to their invasive percentages. As of the writing of this report, Lake Deer has undergone a whole-lake herbicide treatment to reduce the hydrilla population. The efficacy of this treatment should be apparent in the data collected in 2020.

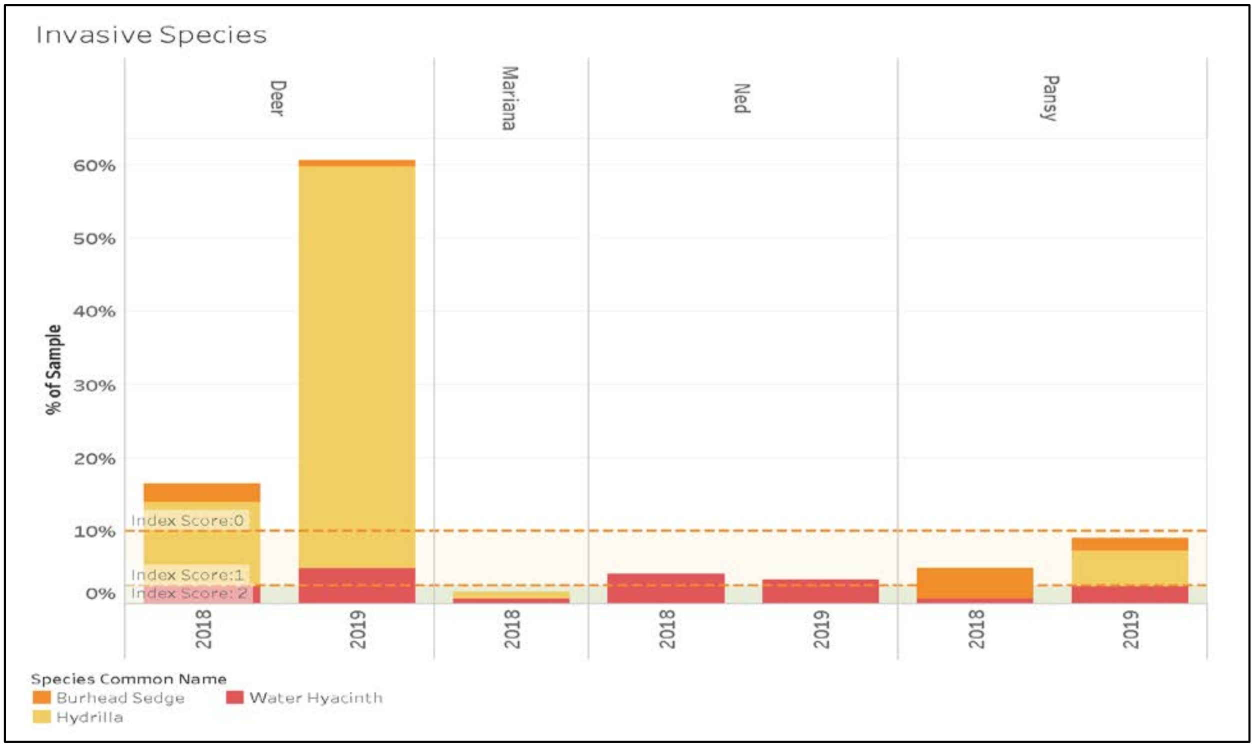


Figure 2-34. Outlying Lakes annual percentage of managed invasive species.

Species diversity is the final biological lake health indicator presented here. Species frequency data is used for the calculation of diversity index values. Species richness, evenness, and overall diversity are accounted for in the overall lake health index as a change from 2018 to 2019 (Figure 2-35).

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Deer, Ned, and Pansy exhibited an increase in species richness while Lakes Blue, Daisy, and Mariana underwent a decrease from 2018 to 2019.

Hill's Evenness #3 (E3): An increase in species evenness is preferred as it correlates to improvement in community resilience. Lakes Blue, Daisy, Mariana, Ned, and Pansy showed increasing values, with Lake Deer decreasing in evenness in 2019.

Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Lakes Blue, Mariana, Ned, and Pansy exhibited an increase in Shannon's diversity from 2018 to 2019. Lakes Daisy and Deer experienced a decrease during this time, however.

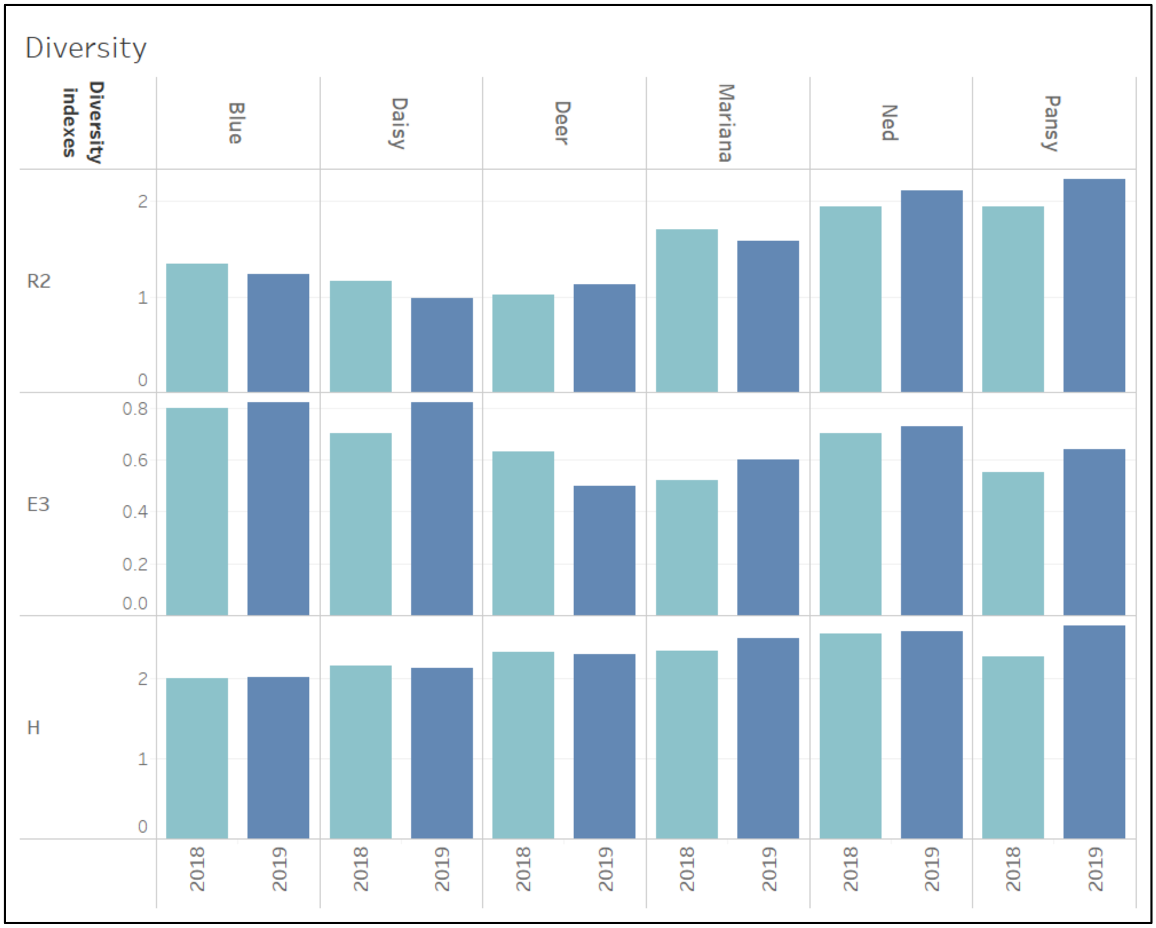


Figure 2-35. Outlying Lakes annual index values for species richness, evenness, and diversity.

2.6 Lake Health Scoring

Utilizing the data presented in this chapter, each waterbody has received scores for the various lake health criteria. In-depth explanations of these criteria can be found at the beginning of this section (pp. 34 – 35). Averaging of the individual indicator metrics provides the overall lake health index. The index ranges from 0 (poor) to 3 (exceptional) and allows for an objective comparison of area lakes based on water quality and ecological components. While this evaluation technique does not incorporate all factors that contribute to lake health, it provides a more comprehensive evaluation than observations of water quality or biology alone.

By its nature, the lake health index prioritizes water quality as the primary contributor to lake health. This follows with state and federal regulatory agencies' evaluation metrics. However, City staff sought to enhance the way we assess lake health. Targets such as the Numeric Nutrient Criteria (NNC) are valuable to identify the goalpost, but they don't necessarily demonstrate progress toward or away from that goal. For instance, there are lakes in the area that currently meet the NNC, but long-term trends indicate that their water quality is deteriorating. Alternatively, some waterbodies are currently impaired by regulatory standards, but are exhibiting improving water quality trends—providing evidence of the effectiveness of existing management strategies.

The importance of water quality notwithstanding, the biological criteria presented here are extremely valuable, but their usefulness requires a much more intuitive analysis. Biological responses to anthropogenic impacts are often inconsistent or reliant on complex mechanisms and influences. Only by compiling these vegetation community data over the long term, can we begin to understand the biological response drivers on a lake to lake basis. The FDEP utilizes a bioassessment protocol named the Lake Vegetation Index (LVI) which evaluates a lake's macrophyte community based on a sample of observed species. There are some fundamental differences in sampling approach, but the methods are fairly similar. The most valuable components of the LVI are likely the evaluation metrics which may be integrated into the current lake health index assessment process in the future.

To conclude, these lake health values are relative only to the waterbodies in this study area and are not absolute measurements of lake condition on a state-wide or national scale. Since lakes are evaluated annually, index values can change from year to year due to changes in environmental impacts and management strategies. Moreover, the lake health index is not intended to be used in any official regulatory capacity, but as a data-driven tool to identify waterbodies requiring greater management influence. With this information, the City hopes to maximize the effectiveness of its current lake management strategies and increase environmental stewardship from residents through knowledge and understanding. The following tables (Table 2-6 & 2-7) detail the lake health scores from 2018 and 2019. A comparison of these scores and an explanation of their implications is presented below.

2018	Waterbody	NNC Impairment	WQ Trend				PAC	% Inv	Diversity	Lake Health Score
			Chla	TN	TP	Secchi				
North Chain of Lakes	Lake Conine	0	2	2	2	3	2	0	3	1.8
	Lake Fannie	0	1	1	2	2	2	0	3	1.4
	Lake Haines	0	2	3	2	3	2	0	1	1.6
	Lake Hamilton	0	0	0	3	0	1	2	NA	0.9
	Lake Rochelle	0	3	2	3	3	3	1	3	2.3
	Lake Smart	0	2	1	2	2	1	2	1	1.4
	Little Lake Hamilton	0	1	1	2	1	2	2	NA	1.3
	Middle Lake Hamilton	0	1	2	3	2	1	2	NA	1.6
South Chain of Lakes	Lake Cannon	0	2	3	2	3	3	2	2	2.1
	Lake Eloise	0	2	2	2	3	1	2	1	1.6
	Lake Hartridge	0	0	0	2	0	3	2	1	1.0
	Lake Howard	1	3	3	2	3	3	2	2	2.4
	Lake Idylwild	1	2	1	3	2	3	2	1	1.9
	Lake Jessie	0	1	1	3	2	3	2	0	1.5
	Lake Lulu	0	3	2	3	3	3	2	1	2.1
	Lake May	0	3	3	3	3	3	1	0	2.0
	Lake Mirror	3	3	3	3	3	3	2	0	2.5
	Lake Roy	3	3	3	2	3	3	2	2	2.6
	Lake Shipp	0	3	3	3	3	3	2	1	2.3
	Spring Lake	3	3	3	3	3	3	1	2	2.6
	Lake Summit	3	3	3	3	3	3	2	1	2.6
	Lake Winterset	3	3	3	3	3	2	2	3	2.8
North Central Lakes	Lake Buckeye	3	3	3	3	3	3	0	0	2.3
	Lake Idyl	0	1	1	1	2	3	2	0	1.3
	Lake Martha	3	0	0	0	0	0	3	1	0.9
	Lake Maude	3	3	3	2	3	3	1	2	2.5
	Lake Silver	3	2	2	2	1	0	3	1	1.8
South Central Lakes	Lake Elbert	3	0	1	1	1	3	0	1	1.3
	Lake Link	3	2	3	2	2	3	1	2	2.3
	Lake Mariam	3	1	2	2	3	1	0	1	1.6
	Lake Otis	2	2	2	2	2	2	1	1	1.8
Outlying Lakes	Lake Blue	0	2	2	3	2	2	3	1	1.9
	Lake Daisy	3	3	2	2	2	1	3	1	2.1
	Lake Deer	0	2	2	2	2	3	0	1	1.5
	Lake Mariana	0	1	1	2	1	2	1	0	1.0
	Lake Ned	3	0	1	0	0	1	1	3	1.1
	Lake Pansy	3	0	1	1	1	2	0	2	1.3

Table 2-6. 2018 Lake Health Index

2019	Waterbody	NNC Impairment	WQ Trend				PAC	% Inv	Diversity	Lake Health Score
			Chla	TN	TP	Secchi				
North Chain of Lakes	Lake Conine	0	3	2	3	3	3	1	1	2.0
	Lake Fannie	3	2	2	2	3	2	1	2	2.1
	Lake Haines	1	2	3	2	3	2	0	3	2.0
	Lake Hamilton	0	0	0	3	0	1	2	2	1.0
	Lake Rochelle	0	3	3	3	3	3	0	1	2.0
	Lake Smart	0	2	2	3	2	3	1	2	1.9
	Little Lake Hamilton	0	1	1	2	1	2	3	1	1.4
	Middle Lake Hamilton	0	1	2	3	2	2	1	2	1.6
South Chain of Lakes	Lake Cannon	1	2	3	2	3	3	2	0	2.0
	Lake Eloise	0	2	2	2	3	2	1	2	1.8
	Lake Hartridge	1	0	0	1	0	3	1	2	1.0
	Lake Howard	1	3	3	2	3	2	3	3	2.5
	Lake Idylwild	1	2	1	2	3	3	1	2	1.9
	Lake Jessie	0	1	1	2	2	3	1	3	1.6
	Lake Lulu	0	3	2	3	3	3	2	2	2.3
	Lake May	0	3	3	3	3	3	1	3	2.4
	Lake Mirror	3	3	3	3	3	3	1	2	2.6
	Lake Roy	3	3	3	3	3	2	2	1	2.5
	Lake Shipp	0	3	3	3	3	3	1	1	2.1
	Spring Lake	3	3	3	3	3	3	1	3	2.8
	Lake Summit	3	3	3	2	3	3	2	2	2.6
	Lake Winterset	3	3	3	3	3	3	0	3	2.6
North Central Lakes	Lake Buckeye	3	3	3	3	3	3	0	2	2.5
	Lake Idyl	0	1	1	1	2	1	1	1	1.0
	Lake Martha	3	0	0	0	0	1	2	3	1.1
	Lake Maude	3	3	3	2	3	3	0	0	2.1
	Lake Silver	3	2	2	2	1	1	3	2	2.0
South Central Lakes	Lake Elbert	3	0	0	1	1	3	0	2	1.3
	Lake Link	3	2	3	2	2	NA	NA	NA	2.4
	Lake Mariam	3	1	2	2	2	2	0	2	1.8
	Lake Otis	2	2	2	2	2	2	0	3	1.9
Outlying Lakes	Lake Blue	0	2	2	3	2	1	3	2	1.9
	Lake Daisy	3	3	2	2	2	1	3	1	2.1
	Lake Deer	0	2	2	2	2	3	0	1	1.5
	Lake Mariana	0	1	1	2	0	2	3	2	1.4
	Lake Ned	3	0	2	0	0	1	1	3	1.3
	Lake Pansy	3	0	1	1	1	3	1	3	1.6

Table 2-7. 2019 Lake Health Index

North Chain of Lakes:

A comparison of lake health for the Northern Chain from 2018 to 2019 shows that all lakes exhibited improvement; with only Middle Lake Hamilton maintaining the same value. The average lake health index for this group increased from 1.5 to 1.75. Overall improvement was recorded in all criteria, but species diversity. This was primarily due to the inclusion of diversity values for Lakes Hamilton, Middle Hamilton, and Little Hamilton. Within the group, Lake Hamilton was identified as having the lowest index value both years—providing evidence for the need to focus management efforts on improving water quality.

South Chain of Lakes:

The general health of the Southern Chain showed overall improvement from 2018 to 2019. Average lake health index values increased slightly from 2.14 to 2.19. The majority of lakes exhibited maintenance or improvement in their lake health index. Lakes Cannon, Roy, Shipp, and Winterset underwent a slight decrease in their index values—primarily due to a decrease in invasive percentage or species diversity scores. Once again, Lake Hartridge possessed the lowest index value on account of its deteriorating water quality trends and a decrease in invasive and diversity scores.

North Central Lakes:

This lake group underwent a slight overall increase in lake health in 2019—going from an average index value of 1.72 to 1.75. The improvement can be attributed to an increase in percent invasive and diversity scores. All waterbodies, except for Lake Idyl underwent an increase in overall lake health. Incidentally, Lake Idyl scored the lowest in this lake group due to being currently impaired and its less than stellar water quality trends. Lake Martha also scored low within this group due to its deteriorating water quality trends. Both of these lakes possess little to no submerged aquatic vegetation to buffer against increased nutrient loading. Identifying and mitigating the primary pollutant sources should be a top priority for these waterbodies.

South Central Lakes:

The South Central group saw a general improvement in lake health from 2018 to 2019. An increase in the average lake health index from 1.75 to 1.87 can be attributed to improvements in water quality trends as well as vegetation abundance, % invasive, and diversity scores. All lakes in this group either maintained or improved their lake health scores from the previous year. Lake Elbert remains the lowest scoring lake in this group due to its declining water quality trends and its invasive percentage. Since this lake is not currently impaired, it is one to keep an eye on to ensure it does not become so in the future.

Outlying Lakes:

Similar to the other lake groups, the Outlying Lakes underwent an overall improvement in lake health from 2018 to 2019 with average index values increasing from 1.48 to 1.62. This increase is due to slight improvements in TN trend and species diversity scores. Even with these improvements, Secchi depth trend scores decreased slightly. Half of the waterbodies in this group improved in their overall lake health score—specifically Lakes Mariana, Ned, and Pansy. Currently, Lakes Mariana and Ned scored lowest within the Outlying Lakes group. Lake Mariana scored lower as its water quality impairments and trends need improvement. Lake Ned needs improvement with its poor water quality trends and low plant abundance and invasive species scores.

Overall:

Aggregating the lake health scores of all study area lakes from 2018 and 2019 allows for a general comparison (Table 2-8). The overall lake health score increased from 1.8 to 1.91 over the last year. Nearly every criterion saw improvement. Secchi depth trends remained static from the previous evaluation while the percent of invasive species score decreased somewhat from 1.46 to 1.25.

This change in invasive percentage is indicative of an overall increase in nuisance plants in Winter Haven's waterbodies. Some of this increase can be attributed to a brief moratorium on herbicide application by the FWC at the beginning of 2019. Since then, invasive treatments have resumed, but with much more caution and forethought; additionally, alternative treatment methods have been utilized such as stocking of triploid grass carp.

As we continue to track overall health of Winter Haven's lakes, we will be evaluating the effectiveness of our management strategies—many of which are described in the following section. Following the report is a list of individual lake management strategies that detail what management strategies the City has implemented and plans for the future.

Year	NNC Impairment	WQ Trend				PAC	% Inv	Diversity	Lake Health Score
		Chla	TN	TP	Secchi				
2018	1.32	1.84	1.92	2.19	2.11	2.22	1.46	1.32	1.80
2019	1.49	1.92	2.00	2.16	2.11	2.33	1.25	1.94	1.91

Table 2-8. Aggregated lake health scores for all Winter Haven lakes for 2018 and 2019 report years.

3- Management Strategies

Summary

Successful lake management programs are not solely defined by the number and types of strategies and practices implemented. Managers must also be cognizant of the characteristics and challenges presented by the waterbodies and their surrounding watersheds and use this understanding to select the most effective practices for each scenario. The lakes in the Winter Haven management area are unique due to their density, location, and status as social, economic, and environmental resources to the surrounding community. One of the primary challenges of managing dozens of lakes located within a relatively urban environment involves balancing the diverse needs of the various lake user groups while also maintaining the health of the waterbodies being used. A robust vegetative community, for example, may be considered favorable for fishing and water quality, however too much can cause issues for recreational activities such as boating or skiing. Furthermore, a data-driven approach is necessary to ensure that any proposed management strategies are based on objective, factual information. These concepts are such an integral part of the City's Natural Resources Division strategy that they have been incorporated into its Mission, Vision, Purpose, and Values (MVPV) detailed below. The City's Lakes Advisory Committee was integral to the development of the Division's MVPV. This chapter presents information on the primary lake management strategies employed by the City as seen through the lens of the Division's MVPV.

Mission:

Maintain and improve local natural resources through management based on a sound understanding of social, economic, and ecological systems.

Vision:

To be the premier knowledge base for local natural resources, with an engaged public, supporting natural systems through a community ethic.

Purpose:

Balance the needs of diverse user groups to sustain natural resources the community can be proud of.

Values:

Courteous, Cognizant, Cooperative, Resourceful, Responsive, Accurate, Adaptive

3.1 Structural Management Practices

Stormwater Assessment and Improvement Project

Summary:

Winter Haven's stormwater system is a network of drainage pipes, ditches, and other conveyances that capture surface water runoff and move it to storage ponds or, more often, directly into lakes. The Stormwater Assessment and Improvement Project (SAIP) was drafted by the City, in conjunction with various agencies and organizations, employing a holistic approach to planning maintenance and improvements to the stormwater infrastructure. This project was 100% funded by a legislative appropriation administered by the Florida Department of Environmental Protection (FDEP) and involves a four-pronged approach that includes:

1. Refining the current geospatial database of stormwater infrastructure: The City utilizes ArcGIS—a geographic information system (GIS) program that allows users to create, analyze, and manipulate geospatial data—to store information on the network of stormwater pipes and outfalls. The engineering firm, Chastain Skillman, has been employed by the City to update the currently outdated and fragmented inventory map to one that is more cohesive. Additionally, this updated database will include a standardized procedure for entering new stormwater information.

2. Ground truthing existing and previously unidentified stormwater infrastructure: Chastain Skillman has worked closely with the City to evaluate the current condition of the various pipes, drains, and other conveyances. Factors such as pipe and drain size, material type (e.g. concrete, steel, etc…) and flow capacity. This evaluation allows the City to more efficiently prioritize management and repairs to the existing stormwater infrastructure.

3. Hydrologic modeling contracted through Chastain Skillman, which incorporates accurate topographic, surface water, and groundwater information to identify surface water flow to the lakes and estimate pollutant loading. Results from this model can be used to identify areas within the City that experience the greatest potential for flooding during storm events as well as drainage basins with high nutrient loading potential. Cooperation with the Southwest Florida Water Management District (SWFWMD) has allowed for the collection of Light Detection and Ranging (LiDAR) data used in the development of a highly detailed topographic map of the City. This collaboration with the District provides the City with services and data it could not have achieved alone with a limited budget.

4. Identification and prioritization of targets for improvement by incorporating all of the previously mentioned methods. This suite of information will allow City employees to pinpoint problem areas and make informed decisions when prioritizing improvements. Understanding where resources should be focused is paramount when time and funds are in limited supply. Moreover, the implementation of an asset management program will greatly enhance the speed and efficiency of repairs, maintenance, and improvements to Winter Haven's stormwater systems. Figure 3-1 displays the locations of high priority target areas within the City as identified by initial evaluation by the SAIP.

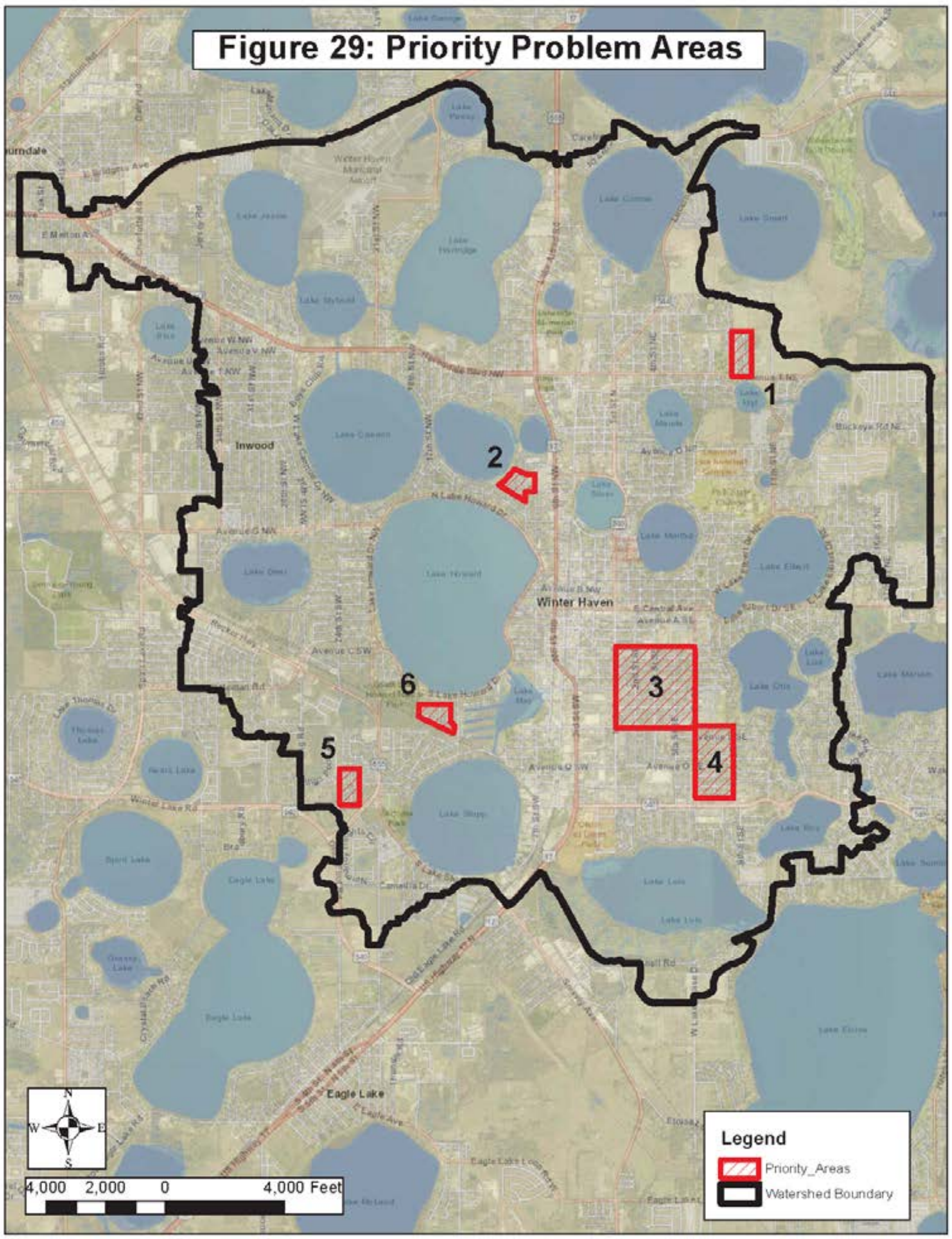


Figure 3-1. Priority sites indicated by increased flooding and pollutant load potential as determined by the Winter Haven SAIP.

Public Benefit:

Using this data to drive decisions related to stormwater maintenance and improvement allows the staff to make efficient decisions about projects with the highest return on investment.

Support of Mission, Purpose, and Vision:

Stormwater is a major component of the "social, economic, and ecological systems" identified in the Mission and having a "sound understanding" of this system positions staff to fulfill the Division's Purpose. Having this understanding also positions the City to be the "premier knowledge base for local resources" in support of the Vision which gives the community an advantage when working to address State and Federal mandates.

Strategic Goals:

- Pursue grant funding to design and implement stormwater improvements within these priority areas by end of FY 2020.

Completed Objectives:

- ✓ Identified high priority areas within the City where green infrastructure could be implemented to reduce flooding and improve water quality to receiving waterbodies.
- ✓ Implemented Cartegraph—an asset management software that will allow the City to track and streamline workflows and strategize asset improvement.

Alum Treatment

Summary:

Aluminum sulfate (Al_2SO_4), also known as alum, has been a popular treatment option for surface waters in order to reduce concentrations of phosphorus, total suspended solids (TSS), algae and nitrogen originating from stormwater inputs. Alum injection is a stormwater management solution that can be especially useful in locations where the area for large settling ponds does not exist or as an alternative to less stable chemical coagulants. On contact with water, alum forms a precipitate or gelatinous floc in the water column. Nutrients and sediments adsorb to the alum floc which eventually falls out of solution and can be collected in settling reservoirs or allowed to settle in the treated waterbody (Figure 3-2). This alum floc is stable in a pH range of 5.5 – 7.5 [17]. Since Winter Haven's lakes are generally alkaline with stable pH levels, they make good candidates for alum treatment as there is little risk of the precipitate re-dissolving into the water column. The efficiency of pollutant removal via alum treatment varies dependent upon dosage, injection method, and ambient pollutant concentration in the treated waterbody. Alum may also be broadcast across an entire lake surface in order to create a barrier over nutrient-rich sediments, thereby reducing the influx of pollutants such as phosphorus. This capping process is one solution for lakes that have received historic point-source discharge.

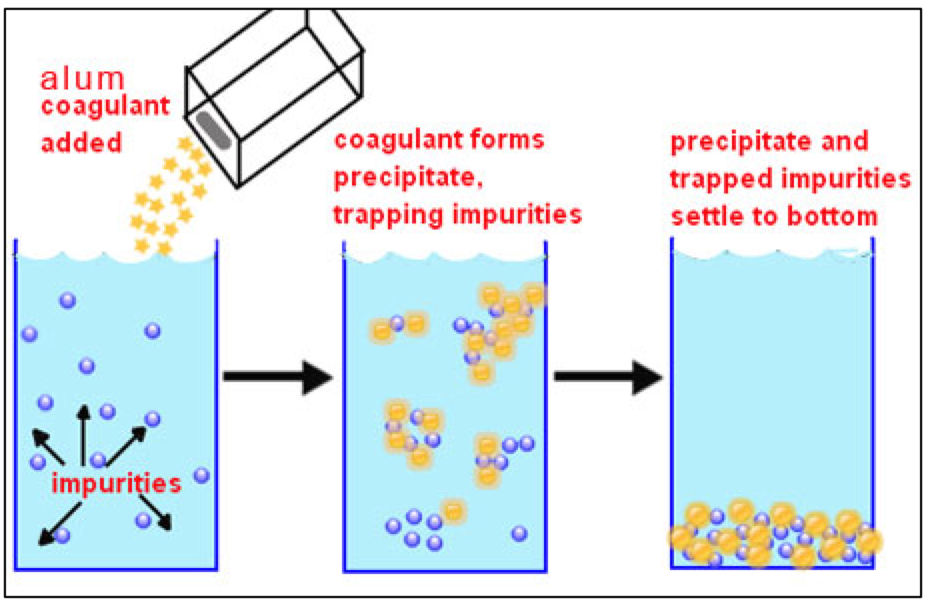


Figure 3-2. Diagram of alum floc adsorption properties. [16]

The City currently maintains three alum injection sites at points on Lakes Howard, Lulu, and May. Additionally, a broadcast alum treatment was contracted by the County in the mid-1990's to cap internal phosphorus loading from historic point-source discharges in Lake Conine [18]. The City's management goals for the three alum injection sites on the South Chain of Lakes involve updating the outdated equipment and developing an internal maintenance plan. Additionally, the City is interested in developing a study to determine current nutrient reduction efficiency of alum in these lake systems.

Public Benefit:

Alum's ability to make nutrients biologically unavailable is a viable option to reduce pollutant loads from stormwater. While alum does not intrinsically reduce ambient TN or TP concentrations in a waterbody, it actively works to prevent further decline in water quality.

Support of Mission, Purpose, and Vision:

Alum Injection is a management strategy that strives to "Maintain…local natural resources" as stated in the Mission. Alum injection will not solely cause improvements in lakes, but it does help to limit further impacts from being realized. By reducing stormwater impacts, lake systems become more predictable making it is easier to manage systems to "the needs of diverse user groups" as outlined in the Purpose. Alum injection is an interesting process and it provides an opportunity to talk with residents about it and other management tools and the effectiveness of different management strategies. This helped to create the "engaged public" identified in the Vision.

Strategic Goals:

- By end of 2020, contract specialists to perform the necessary repairs/maintenance of alum systems
- By end of 2021, develop a strategy to evaluate pollutant load reduction efficiency of systems

Completed Objectives:

- ✓ Inspected the City's alum injection facilities to identify repair & improvement needs
- ✓ Include improvements as part of FY 19-20 budget

Low Impact Development & Green Infrastructure

Low impact development (LID) and green infrastructure are terms referring to practices that incorporate natural processes in the development of stormwater systems. Traditional, or "gray", stormwater infrastructure relies on impervious materials, gutters, and pipes to transfer runoff from one area to another. Typically, these systems are implemented in urban areas to prevent flooding by directing stormwater to a nearby catchment or basin. In the Winter Haven area, gray infrastructure diverts runoff, as well as any pollutants, directly to lakes or stormwater ponds. In contrast, green infrastructure and LIDs utilize plants and soil characteristics to promote stormwater treatment and groundwater infiltration; resulting in cleaner and/or less runoff entering local waterbodies. Examples of green infrastructure and LIDs include raingardens, bioswales, pervious pavement, and exfiltration structures (French drains). Figure 3-3 displays one of several raingardens located within downtown Winter Haven.

Figure 3-3. Photo of a raingarden capturing runoff and road debris in downtown Winter Haven.

If designed properly and placed in appropriate areas, LIDs are able to capture sediments, heavy metals, and solid refuse during the first flush of a rainfall event, preventing it from entering the stormwater infrastructure. Employing well-drained soils to promote percolation, flooding along roadways can be reduced during 1-year to 10-year storm events. Planting of appropriate vegetation can also allow for nutrient uptake while also beautifying the urban landscape. In many cases, LIDs can be utilized in lieu of traditional stormwater ponds in city planning; often occupying smaller footprints than traditional stormwater ponds while mitigating similar volumes of stormwater. Green infrastructure can benefit developers by reducing the area devoted for stormwater mitigation and can often be more aesthetically pleasing.

Currently the City has constructed over 60 raingardens and exfiltration systems in and around Winter Haven's urban center. Lakes receiving stormwater benefits from these systems include: Lakes Elbert, Howard, Martha, Maude, May, Otis, Roy, and Silver. Nutrient removal capabilities are minimal on an individual basis, however LIDs can collectively have a greater impact in larger numbers as more stormwater is treated. Moreover, relatively low construction costs in addition to the aforementioned benefits make low impact projects an elegant solution for future stormwater treatment in the urban cityscape.

Public Benefit:

Low impact development and green infrastructure projects provide multiple benefits including stormwater pollutant load reduction, groundwater recharge, reduced ponding in roadways, and aesthetic improvements. These social, economic, and environmental benefits make LID implementation an efficient and effective management strategy for the City.

Support of Mission, Purpose, and Vision:

LID implementation directly supports the Mission by using “a sound understanding of social, economic, and ecological systems.” To “Maintain and Improve local natural resources”. Improving hydrology and water quality help to “balance the needs” identified in the Purpose. LID construction is a realization of the Vision, in that the City has received outside support because other agencies recognized the City is the “premier knowledge base for local natural resources”.

Strategic Goals:

- Pursue funding to design and construct additional LIDs
- Prioritize the maintenance/repair of existing LIDs in the downtown area in 2020
- Develop SOP to ensure existing and newly built LIDs are maintained into perpetuity
- Utilize modelling software to estimate existing pollutant load reduction for each BMP

Completed Objectives:

✓ Renegotiated contracts with funding partners to more realistically meet defined benefits

✓ Incorporated all LIDs and green infrastructure into the City’s asset management inventory

Stormwater Treatment Parks

Stormwater treatment parks, or nature parks, are engineered wetlands that perform similar functions as other forms of low impact development. The primary focus of nature parks is to reduce the impact of non-point source pollution on target waterbodies by treating surface runoff and stormwater effluent. Comprised of one or more reservoirs, designed with long retention times, and seeded with communities of natural wetland vegetation, nature parks receive redirected stormwater discharge and allow it to slowly pass through the reservoirs before releasing the treated water to an adjacent lake. The multiple aspects of this treatment process include: nutrient reduction via plant uptake, reductions to turbidity and suspended solids via sedimentation, capture of solid refuse, and an increase in water color through the introduction of dissolved tannins (organic matter). Secondary goals for these treatment parks are to create wetland habitat, increase biodiversity of wetland flora and fauna, introduce opportunities for public education, and provide recreational areas and green spaces. Maintenance of stormwater treatment parks involves ensuring all flow-ways are clear and free of dense vegetation or debris, treating invasive species, and occasionally removing excess sediment that builds up over time.

Figure 3-4. Map depicting the Winter Haven nature parks and their drainage basins. Also included is the proposed location of the Lake Conine Nature Park.

The City of Winter Haven maintains three nature parks adjacent to Lakes Howard, Hartridge, and Maude respectively. The South Lake Howard Nature Park is a roughly 16-acre park that treats a sizable 394-acre drainage area. The 9.4-acre Lake Hartridge Nature Park receives and treats runoff from a 56-acre basin. Lake Maude Nature Park, the smallest of the three at 6.4-acres, treats an approximately 18-acre contributing drainage basin. A fourth park which will be located on the southern shore of Lake Conine is currently in the process of selecting a construction contractor. This constructed wetland is designed to treat a drainage greater than 300 acres. A map of these nature parks and their drainage basins are displayed in Figure 3-4.

Public Benefit:

Stormwater treatment parks reduce stormwater pollutants from entering lakes. The uptake of nutrients via the aquatic plants, sediment settling in ponds, and capture of solid waste are the mechanisms that benefit lake health. In addition, each park benefits the community by providing a recreational space utilized by local residents.

Support of Mission, Purpose, and Vision:

Nature Parks are similar to LIDs in that they directly support the Mission by using "a sound understanding of social, economic, and ecological systems." To "maintain and improve local natural resources". Improving hydrology and water quality help to "balance the needs" identified in the Purpose. Their Construction is a realization of the Vision, in that the City has received outside support because other agencies recognized the City is the "premier knowledge base for local natural resources".

Strategic Goals:

- Continue to maintain beneficial communities of native vegetation in Lakes Howard, Hartridge, and Maude nature parks
- Begin construction of Lake Conine Treatment Wetland in early 2020

Completed Objectives:

- ✓ Completed contractor selection for construction of the Lake Conine Treatment Wetland

Floating Wetland Treatment

Summary:

Due to the nutrient absorption qualities of aquatic plants and wetland areas, they are often considered a natural treatment mechanism in lakes and ponds. During the normal plant life cycle, the nutrients that are sequestered in plant tissue can be released again as aquatic vegetation decomposes. Removing vegetation before it can undergo decomposition effectively reduces the nutrient load within a given waterbody. Recent research into temporary wetlands has yielded positive results with regards to ambient nutrient concentration reduction in lakes and ponds [UCF FTW Report]. Implementation of floating treatment wetlands (FTW) provides this benefit at generally lower installation and maintenance costs compared with a constructed shoreline wetland.

In late 2017, the City installed a FTW as a pilot project in a wet retention pond that discharges to Lake Martha at high surface levels (see Figure 3-5). The pond drains a sizable recreational ball park owned by Polk State College and maintained by City Parks and Grounds staff. This site was chosen because of its ongoing issues with nuisance plants like duckweed (*Lemnoideae spp.*) and snails that feed on aquatic vegetation—likely caused by nutrient-rich runoff from the ballfields. For several years, the snails have undergone a population explosion and subsequent die-off resulting in an unpleasant odor for the surrounding neighborhood. The City sought a means to lower nutrient concentrations in hopes of reducing the snails' food source and preventing their exponential growth. Partially funded through a Florida Lake Management Society grant, the goal of this project was to determine the effectiveness of FTWs as a nutrient reduction best management practice while also incorporating an educational citizen outreach component.

Figure 3-5. Photo of Floating Treatment Wetland installed at Polk State College recreational complex.

After a 12 month growing cycle, the pond experienced a marked reduction in TN from initial concentrations, albeit with little change in TP. More significantly, no reports of foul odors from the pond were received in 2018. In an effort to fulfill the educational component, the City hosted an aquatic plant giveaway for local lakeshore property owners. Attendees of the event received several plants harvested from the floating wetland to transplant on their property while also learning about the aesthetic and ecological benefits of aquatic plants and living shorelines. In total, over 120 individual plants were distributed. The City also replanted the FTW in order to continue studying the long-term effectiveness of nutrient reduction in the pond.

Public Benefit:

Through the City's efforts, it was determined that the floating wetland significantly reduced nitrogen concentrations in the study pond. The absence odor reports from nearby residents may indicate a shift in the pond's ecology as a result, however this claim is purely anecdotal until evidence can be brought forth. Finally, this project has contributed to citizen engagement by providing an educational opportunity in the plant giveaway event.

Support of Mission, Purpose, and Vision:

This pilot project is an implementation of the Mission as it is derived from an understanding of the "social, economic, and ecological systems" that govern the existing stormwater pond and the impacts that can be felt by the community and the adjacent lake. Currently this pond can reach conditions deemed undesirable by the local stakeholders, this project is designed to alleviate those conditions by restoring "natural resources the community can be proud of" as is part of the Division's Purpose. By engaging in this pilot project the City will deepen it's understanding of potential best management practices, further supporting its position as "the premier knowledge base for local natural resources" and creating an opportunity to engage the public in conversations about management strategy which works to achieve the Vision.

Strategic Goals:

- Harvest and restock FTW by end of 2020
- By end of 2020, develop education program promoting FTWs in private stormwater ponds; targeting private developers/HOAs

Completed Objectives:

- ✓ Continued to monitor water quality and ecology in the stormwater pond until end of 2019

3.2 Non-structural Management Practices

319 Gray to Green

Summary:

The use of low impact development (LID) and green infrastructure can provide benefits over traditional "pipe and pond" (gray) infrastructure by means of slowing, spreading, and soaking stormwater runoff; thereby promoting groundwater recharge and reducing pollutant loading from urban areas. The City of Winter Haven has become a forerunner in the process of prioritizing the design and implementation of green stormwater infrastructure. It was determined, however, that the adoption of the gray to green mindset by the local community would be necessary to protect our surface water and groundwater resources. By virtue of this, the City has initialized a plan to develop and implement a public education program targeting local engineers, developers, and City staff to provide the tools and information required for this shift in stormwater management focus.

In 2018, the City held public meetings with the local development community in an effort to create guidelines for the design and implementation of LIDs. Funding for this effort was sourced from a United States Environmental Protection Agency (EPA) 319 Education Grant administered by the Florida Department of Environmental Protection (FDEP) through "DEP AGREEMENT NO. NF015". Based on feedback from these meetings, the community identified several barriers for the utilization of green infrastructure. As a result, the City's Natural Resources Division developed a strategy to work with state permitting agencies and create a localized design methodology and manual based on Winter Haven's specific hydrologic conditions. To offset the cost of this endeavor, the City applied for and received a second 319 Education Grant through "DEP AGREEMENT NO. NF050".

The primary objectives for this upcoming phase of the 319 Gray to Green program, to be completed by July 2021, are summarized below:

1. Develop a localized stormwater permit design methodology and manual in cooperation with state permitting agencies.

2. Implement an education program to guide local developers, engineers, and designers on how to utilize the methodology and technical manual.

3. Draft a final report for the FDEP summarizing the results of this project.

Public Benefit:

Developing tools and methods that allow local developers to capitalize on the benefits of LIDs and green stormwater infrastructure supports hydrologic restoration and water quality improvement in Winter Haven's lakes. This forward-thinking, educational effort will ensure that the community as a whole is aware of environmental issues and engaged in practices that enhance our natural resources.

Support of Mission, Purpose, and Vision:

This is an effort driven by the "sound understanding of the social, economic, and ecological systems" identified in the Mission. Development has economic and social benefits to the area and can also have ecological benefits if planned properly, this approach strives to "Balance the need of diverse user groups" as identified in the Purpose. By providing tools and education to the development community and internal staff the hope is to further perpetuate the "community ethic" therefore realizing the Vision.

Strategic Goals:

- Begin implementing educational workshops by end of 2020
- By July 2021, submit a final report to FDEP detailing the results of this project

Completed Objectives:

- ✓ Hosted public meetings to obtain stakeholder feedback on the needs and limitations of the current stormwater permit regulations
- ✓ Applied for and obtained funding to continue creating opportunities for the implementation of Green Development practices
- ✓ Developed a LID design and implementation methodology and technical manual in early 2020

National Pollutant Discharge Elimination System

Summary:

As a directive of the United States Environmental Protection Agency (EPA), the National Pollutant Discharge Elimination System (NPDES) was created in 1972 under the Federal Clean Water Act. The NPDES is a permit system designed to regulate point source discharge into U.S. waters in an effort to improve water quality. The EPA works closely with the Florida Department of Environmental Protection (FDEP) to administer this program within the State of Florida.

Polk County is a primary permit holder in the region with numerous co-permittees under it; the City of Winter Haven is included as a co-permittee. The permit requires each co-permittee to list of all Municipal Separate Storm Sewer Systems (MS4s) maintained in their jurisdiction, document the functional maintenance of all infrastructure, track any public education initiatives that support pollutant load reduction, and monitor lake health to determine any measurable impacts.

Public Benefit:

The NPDES permit provides accountability and transparency to residents that every precaution is being taken by the organization to protect natural resources in all operations. The permit also requires the City to constantly improve their understanding of the potential local impacts and create plans for addressing those impacts.

Support of Mission, Purpose, and Vision:

By requiring the City to continually improve its understanding of the potential impacts it drives the Division to improve their "understanding of the social, economic, and ecological systems" directly supporting the Mission. "Sustaining natural resources" is a central focus of the Division's Purpose and the tracking associated with the permit has the same focus. The transparency created by the permit and the assurance to the residents that impactful activities are appropriately tracked supports the "engaged public" and "community ethic" outlined in the Vision.

Strategic Goals:

- Submit Cycle 4 Year 3 permit by end of March 2020
- Distribute Cycle 4 Year 4 permit data requests to City department heads by October 2020
- Collect requisite storm event data for the primary Lake May outfall by September 2020

Completed Objectives:

- ✓ Successfully submitted Cycle 4 Year 2 permit before the March due date

Street Sweeping

Summary:

One significant source of pollutant loading comes from sediment and debris accumulation in streets which drain to waterbodies via stormwater. Street sweeping is what is referred to as a non-structural best management practice (BMP) that helps to reduce pollutant loading by removing this debris before it can enter the stormwater infrastructure. In 2013, the City entered into a three-year contract with USA Services to sweep curbed streets in specified areas to mitigate this pollutant loading source. Areas swept include downtown and much of Winter Haven's residential areas. Department of Transportation (DOT) roads were prioritized for sweeping on a bi-weekly basis, owing to the larger concentration of nutrient runoff. The remaining residential areas were covered on a semi-annual basis. Many of the roads included in the sweeping plan fall within a major outfall basin. In 2016, the City renewed a service contract and issued an updated task order that improved upon these benefits by increasing residential sweeping to monthly and expanding sweeping coverage to priority basins (Figure 3-6). Since the contract renewal, City staff have played an active role in assessing the cost-effectiveness of the program and identifying any issues in service, producing monthly reports on the contractor's performance, to be in a good position to identify cost-savings and service improving changes in service that may need to be made when the contract period is complete in 2019. Based on this assessment, the City has decided to move sweeping duties in-house to improve quality of service and expand service area.

Public Benefit:

This non-structural BMP provides a physical removal of potential pollutant sources--sediments. It also limits debris from blocking the stormwater conveyance system which can lead to flooding. Removing this debris helps to extend street lifespans while also improving the cleanliness and overall aesthetic of City roadways. This is a true preventative maintenance approach that strives to reduce pollutant loading issues at the source which is exponentially more efficient and cost-effective than in-lake nutrient reduction practices.

Support of Mission, Purpose, and Vision:

Street sweeping is a preventative maintenance activity that is managed based on the understanding of the "social, economic, and ecological systems" identified in the Mission. Debris coming out of a stormwater pipe is one of the most visible forms of pollution and street sweeping helps to alleviate this issue in an effort to "sustain natural resources the community can be proud of" as identified in the Purpose. The location and efficiency of street sweeping activities are closely monitored to understand the effectiveness of the program making the City "the premier knowledge base", as outlined in the Vision, for understanding pollutant loading of local water bodies which is beneficial in addressing State and Federal mandates.

Strategic Goals:

- Develop proposal to create internal sweeper position and purchase sweeper equipment by end of 2019
- Utilize spatial data to adjust routes based seasonal high-debris areas (e.g. autumn leaf falls) by Fall 2020
- Improve communication of sweeper scheduling and predictability for residents using live-tracking software by Fall 2020
- Develop public education campaign to improve resident interactions and sweeping efficiency by Fall 2020

Completed Objectives:

- ✓ Evaluated contracted sweeper service and determined the quality of debris removal and cost of service would be improved by performing the sweeping duties in-house

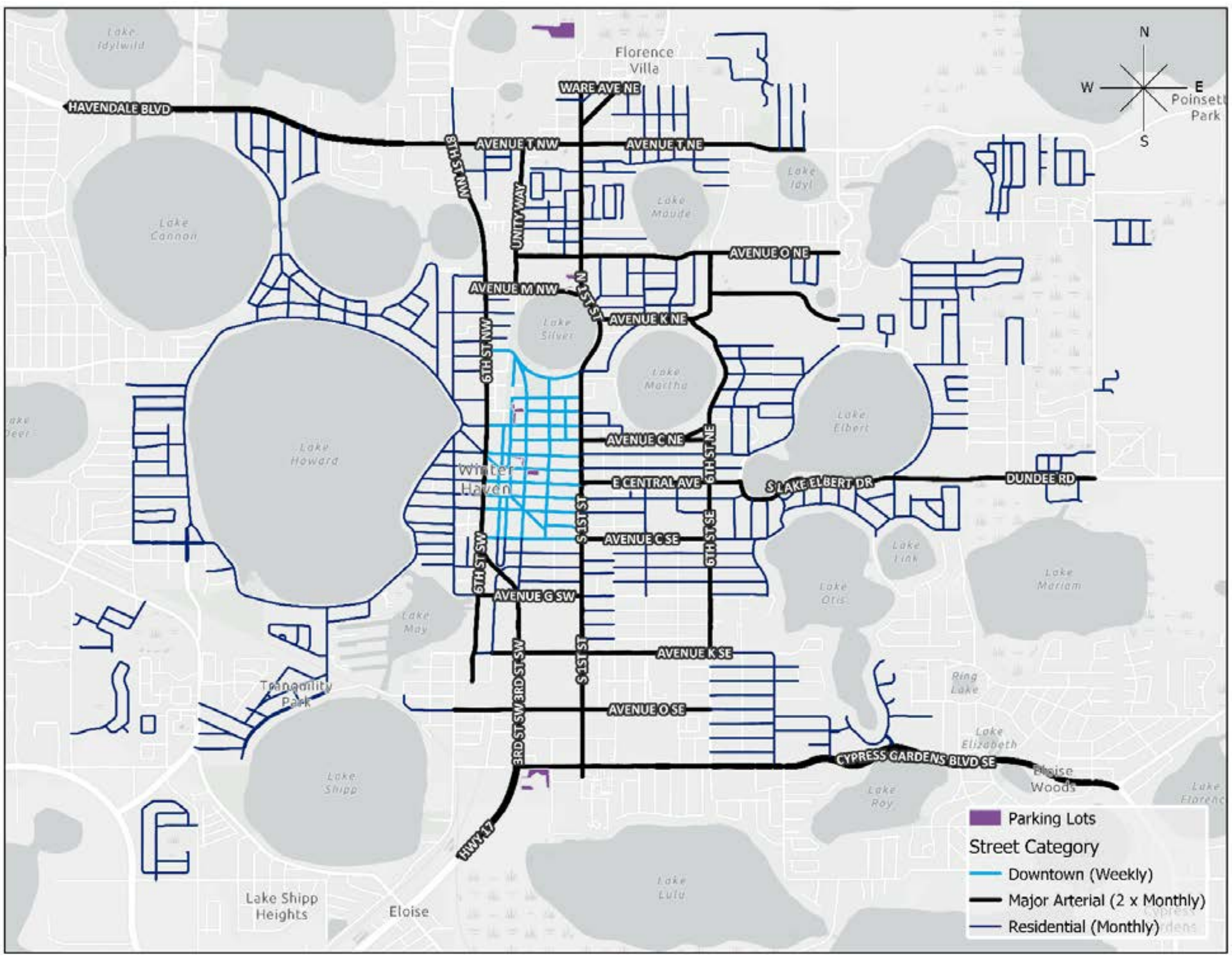


Figure 3-6. Map depicting roadways undergoing street sweeping. Legend indicates sweeping frequency of each street category.

Aquatic Vegetation Monitoring

Summary:

Aquatic vegetation monitoring (AVM) is a methodology employed by the Winter Haven Natural Resources Division to regularly assess plant abundance and diversity in City lakes. This protocol is based on a survey process developed by the Florida Fish and Wildlife Commission (FWC). Utilizing sound navigation and ranging (SONAR) technology, the Division is capable of measuring the distance from the surface to the lake bottom as well as to any vegetation in the water column. Percent area cover and biological volume make up the vegetation abundance metrics obtained through SONAR mapping. Figure 3-7 represents a biovolume heat map produced from SONAR mapping in Lake Maude. In addition, the Division performs point-intercept sampling; identifying the species present at regularly spaced points across a lake to provide a representative sample of plant diversity.

This information is then analyzed, allowing the City to incorporate vegetation data into the overall lake health evaluation. Information regarding invasive species is shared with Polk County and FWC for use in planning treatment. As this monitoring program continues, the City plans to collect multiple years of aquatic plant data to better understand the nuances of each lake's vegetative community. In addition, the Division works closely with the environmental departments of other agencies including the Cities of Lakeland and Haines City, FWC, and Polk County to coordinate monitoring strategies. The development of this Polk Regional Aquatic Vegetation Working Group has fostered beneficial relationships and support chain useful for representing the needs and interests of all parties in the region.

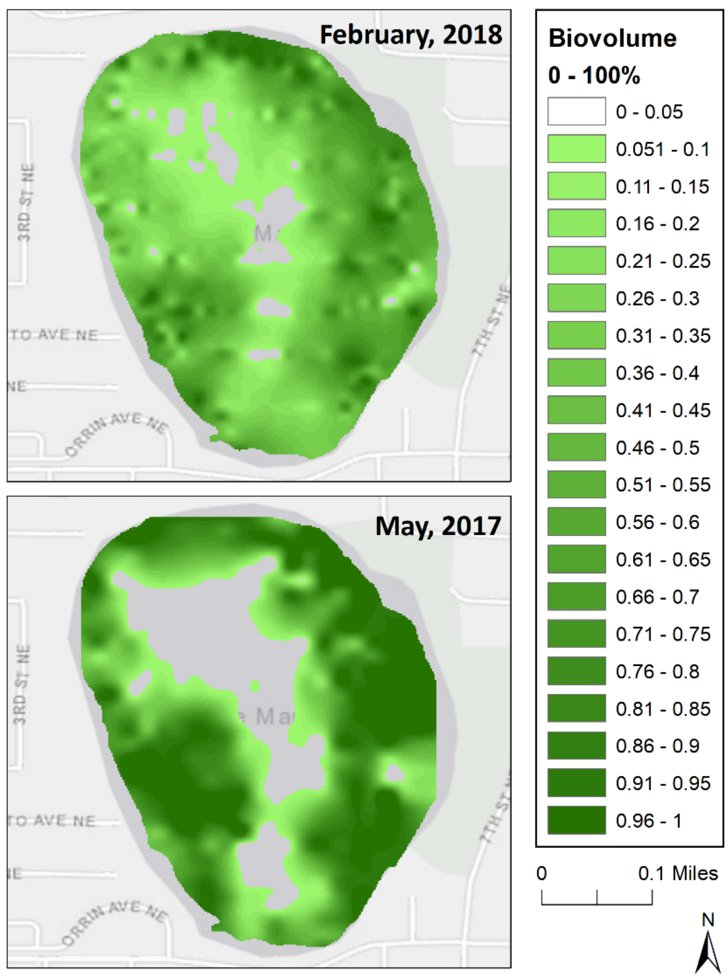


Figure 3-7. Biovolume heat map of Lake Maude. Color scale represents percent of water column occupied by plants.

Public Benefit:

Aquatic vegetation is a significant component of lake health. The early detection and rapid treatment response to invasive species ensures that waterbodies are clear and navigable for all user groups. More importantly, a thorough understanding of the ecological dynamics of aquatic plant life is crucial for lake management efforts. Major changes in vegetation communities can be indicative of negative ecological impacts. By closely monitoring these plant communities, the City can hopefully answer difficult questions and be prepared to respond with data-driven management strategies.

Support of Mission, Purpose, and Vision:

This effort supports the Mission by developing a “sound understanding of social, economic, and ecological systems” which enables the Division to serve its Purpose and “Balance the need of diverse user groups while sustaining natural resources”. This is also in fulfillment of the Vision by establishing the City as “the premier knowledge base for local natural resources” and ensuring the community is represented at the table for discussions about management of the resource.

Strategic Goals:

- By the end of 2020, collect annual vegetation data for all study area lakes; continually refine survey methods to ensure accuracy and best practices
- Continue to improve and develop better metrics for tracking health of aquatic vegetation communities (using Lake Vegetation Index as a potential standard)
- Continue to represent Winter Haven’s interests in the Polk Regional Aquatic Vegetation Working Group

Completed Objectives:

- ✓ Completed 2019 vegetation surveys for targeted waterbodies of interest in the study area; exception for Lake Link due to inaccessibility
- ✓ Continuing to help grow and develop Polk Aquatic Vegetation Working Group
- ✓ Developed new method to more accurately calculate total biological volume using sonar data

Hydrologic Monitoring

Summary:

Hydrologic monitoring is a practice that provides information on the quantities and movement of water in an area. Collection and analysis of rainfall, surface water, and groundwater data allows the City to build a better understanding of the relationships amongst these parameters as well as their impacts on water quality and drinking water supply. The Natural Resources Division and Utilities Department work together to obtain this data through a network of rainfall sensors, monitoring wells, and surface level gauges located throughout the City. Additional data, collected by the Southwest Florida Water Management District (SWFWMD) and the Lake Region Lakes Management District (LRLMD), is available to all interested in better understanding the local hydrology.

Hydrologic modelling was performed to identify areas with greater flooding potential as part of the Stormwater Assessment and Improvement Project. This modelling effort will also be useful in developing lake nutrient budgets as will be explained in the next section. Despite the wealth of information currently available, additional data is needed in order to build a more accurate model. As a result, the City has planned to expand its hydrologic monitoring network via installation of additional rainfall, groundwater, and surface level sensors.

Public Benefit:

Understanding the surface level impacts on lake health is crucial in the development of effective management strategies. Additionally, climate and groundwater monitoring have become increasingly important components in planning for municipal water supply needs for the future. These hydrologic elements directly impact residents' usage of local resources, therefore continued assessment is needed to ensure they are usable for years to come.

Support of Mission, Purpose, and Vision:

This activity directly supports the Mission by developing "a sound understanding of social, economic, and ecological systems". Due to the unique nature of the local system, water levels are critical not just for water quality, but also for navigation through the Chain of Lakes. Navigability is of the utmost importance to the "diverse user groups" in the Purpose, and by understanding how the local hydrology works the City is able to be the "premier knowledge base", mentioned in the Vision, that can drive decision making about management of the resource.

Strategic Goals:

- By end of 2020, upgrade all lake surface level sensors
- By end of 2020, conduct maintenance/repairs on all City weather stations

Completed Objectives:

- ✓ Established weather sensors at four locations throughout the City
- ✓ Developed hydrology section on the Winter Haven Natural Resources webpage with monthly updates
- ✓ Purchased network service to remotely monitor surface levels on 8 area lakes

Nutrient Budgeting

Summary:

A nutrient budget utilizes external pollutant load modelling data, internal load modelling data, as well as vegetation abundance and species composition data to estimate the amount of nutrients entering and leaving a lake system. External loading includes stormwater and surface runoff, atmospheric deposition of nitrogen and phosphorus, and groundwater seepage. Internal loading accounts for the nutrient cycling or flux from lake sediments and is calculated by evaluating the physical and chemical properties of these sediments. The biological component of a nutrient budget is determined by estimating nutrient amounts sequestered in the various species of aquatic vegetation in a waterbody.

The City is currently able to model for most forms of external loading through endeavors such as the Stormwater Assessment and Improvement Project. Internal loading requires an understanding of groundwater interactions as well as benthic sediment analysis—something the City is interested in pursuing. Estimating the nutrients bound in vegetative tissues involves evaluating the chemical properties of the most common aquatic plant species found in the study area lakes. This component requires laboratory analysis to determine typical nutrient ranges within each species by weight or volume. Linking this chemical information to the vegetation abundance data collected through the City's monitoring program should allow for the calculation of nutrients bound in a given lake's aquatic plant community.

This process of nutrient budgeting is useful as it provides lake managers more information that can be used to drive decisions. For example, identifying possible unknown sources of pollution such as septic leachate can be used to better allocate management resources.

Public Benefit:

The nutrient budgeting initiative stands to benefit residents by providing support for management practices that would improve water quality in Winter Haven's lakes. This supporting data may be used to apply for State or Federal funding to implement more intensive management strategies and assert the City's commitment to promoting healthy waterbodies.

Support of Mission, Purpose, and Vision:

This effort supports the Mission by developing a "sound understanding of social, economic, and ecological systems" which enables the Division to "balance the needs of diverse user groups to sustain natural resources". This is also in fulfillment of the Vision by establishing the City as "the premier knowledge base for local natural resources" and ensuring the community is represented at the table for discussions about management of the resource.

Strategic Goals:

- Incorporate nutrient source testing as part of the Division's FY 20-21 budget
- Identify a laboratory to conduct vegetation tissue analysis

Completed Objectives:

- ✓ Identified needs to develop a nutrient budgeting methodology

Education & Outreach

Summary:

Public education and outreach programs can be an extremely effective non-structural best management practice (BMP) recognized and employed by regulatory agencies both in Florida and nationwide. Teaching residents about the issues impacting the local environment can spark community engagement and lead to shifts in perception that can benefit people and nature alike. Discussing issues such as fertilizer use, water consumption, impacts of invasive species and herbicides, and harmful algal blooms creates relationships between the City and its residents; allowing their voices to be heard and responding with factual information.

The Winter Haven Natural Resources Division and Utilities Department actively pursue educational opportunities on a regular basis. Participation at events such as Project Eagle, the 7 Rivers Water Festival, and Water Wings and Wild Things allows the City to reach hundreds of children and adults in family-friendly venues with information on water, lakes, and wildlife. The City also hosts holiday events for the Fourth of July and Easter (Rock N' Freedom Fest & Hoppin' Hunt) where participants have the opportunity to kayak. These events allow City staff to increase awareness of our lakes as community resources. For roughly 30% of participants, this marks the first time they've participated in recreational activities on a lake, ever! Other outreach activities include Summer Camps where from June to July the Natural Resources Division hosts water education field trips for over 300 children ranging from kindergarten to 8th grade. The children are introduced to concepts of lake hydrology and biology and also get to participate in fun activities such as kayaking (Figure 3-8). The Division actively encourages practical education for high-school and college-aged students who are interested in the natural sciences as well through an internship program that focuses on data collection and analysis. Recently, focus has been placed on developing an educational program for grade-school students. The Division is currently working with the Cypress Junction Montessori School to implement a pilot program that incorporates hands-on learning in unique environments.

Figure 3-8. Photo depicting kayakers during the 2018 Summer Camp.

Public Benefit:

By providing opportunities to educate and receive feedback from residents, the City fosters public engagement on local environmental issues. An informed community is more likely to support practices and initiatives that benefit lake health. Educational initiatives aimed at children are especially important for building interest and understanding as well as promoting an environmental focus at a young age. Moreover, many residents are not aware of the resources available to them locally. By providing these introductory opportunities, the public can discover the amenities and benefits afforded by our lakes.

Support of Mission, Purpose, and Vision:

This initiative supports the City's Vision by fostering "an engaged public" through education and outreach opportunities. Over time, the hope is to see an increase in support of "natural systems through a community ethic" as residents improve their understanding of local environmental issues.

Strategic Goals:

- Continue to update and develop fun and engaging learning opportunities as part of the City's Summer Camp program
- Expand education program to general public, local schools, and private organizations (e.g. HOAs)
- Create volunteer program for City residents to participate in education/outreach events by end of 2021
- Expand public outreach efforts using social media – early 2020
- Continue to support and develop Natural Resources internship program

Completed Objectives:

- ✓ Developed a more education oriented approach to City Summer Camp activities
- ✓ Developed and implemented educational lesson plans for the Cypress Junction Montessori School

4- Appendix

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4.2 Supplemental Data

Annual Geometric Mean Data

Chlorophyll-a

Lake Group	Waterbody	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
North Chain of Lakes	Lake Conine	28.8	35.8	26.2	32.0	39.6	36.8	45.9	34.0	36.1	36.2	44.1	34.5	30.1	23.3	22.7	19.0	22.3	17.5	17.6
	Lake Fannie	10.6	11.9	13.0	21.3	13.4	14.7	14.3	16.9	22.6	22.0	25.6	19.1	17.1	13.7	10.5	11.3	11.5	12.0	11.6
	Lake Haines	18.6	34.3	26.1	31.7	34.9	44.8	28.3	29.8	25.8	23.7	21.3	35.2	28.7	18.7	16.8	26.0	23.8	34.4	23.7
	Lake Hamilton	0.0	3.9	1.5	2.0	13.6	7.7	6.8	16.0	28.9	26.5	22.8	29.0	29.2	22.5	21.3	24.9	45.8	40.5	32.8
	Lake Rochelle	26.7	31.3	25.8	31.2	29.3	20.9	28.8	27.4	33.1	27.6	19.7	26.6	26.0	24.5	18.2	13.0	17.4	17.2	13.3
	Lake Smart			27.5	28.7	27.5	25.7	40.1			56.9	50.5	46.9		19.0	23.7	21.3	39.8	19.5	22.4
	Little Lake Hamilton	16.0	20.6	13.2	9.1	19.4	13.6	20.4	35.4	26.8		22.6	39.2	26.4	28.3	11.6	17.3	27.5	22.2	15.8
	Middle Lake Hamilton	54.5	10.3	0.0	13.6	30.6	31.0	27.2	34.4	40.1	44.3	51.7	35.9	31.1	26.3	24.3	22.0	32.2	29.8	22.2
South Chain of Lakes	Lake Cannon	24.0	31.9	24.2	30.6	27.8	18.5	22.9	23.7	32.2	28.0	28.7	23.1	31.7	27.3	16.5	19.0	19.0	21.5	25.0
	Lake Eloise	32.9	28.1	32.1	30.6	43.7	34.1	25.5	30.5	27.1	31.0	39.0	25.6	36.0	33.5	32.0	37.0	22.8	25.9	21.4
	Lake Hartridge	10.6	10.6	10.2	10.3	7.7	13.3	14.9	14.4	22.9	22.8	28.5	27.5	31.0	30.5	28.1	26.7	25.9	24.6	22.3
	Lake Howard	37.3	25.1	28.8	42.9	31.0	37.4	64.0	41.9	33.3	24.7	30.0	29.6	26.9	25.0	25.4	27.6	24.7	21.7	20.0
	Lake Idylwild	30.2	17.3	21.9	24.7	20.1	25.0	21.3	29.3	37.3	33.2	23.3	21.0	26.8	22.5	16.8	13.9	24.8	21.3	18.3
	Lake Jessie	23.1	15.6	25.0	26.4	28.1	27.8	24.0	25.4	30.9	31.9	25.0	24.0	26.8	26.8	18.3	15.4	33.0	24.3	23.0
	Lake Lulu	32.0	26.6	28.0	26.7	39.0	38.6	35.0	34.8	30.9	29.6	25.2	22.3	23.1	17.2	21.2	25.4	25.7	30.2	22.3
	Lake May	32.4	35.1	32.0	46.4	36.1	47.6	65.6	51.3	46.3	32.6	35.3	37.3	33.0	24.4	18.5	29.1	30.6	23.5	21.7
	Lake Mirror	36.9	37.2	34.4	28.2	29.6	23.6	22.9	26.4	21.0	19.5	13.5	10.5	15.8	8.2	8.1	12.4	16.7	21.7	14.0
	Lake Roy	32.2	17.0	18.1	20.0	13.5	14.2	18.4	24.6	19.4	17.1	10.4	11.4	13.9	8.6	6.2	8.7	8.3	12.8	12.5
	Lake Shipp	65.3	42.7	42.5	43.6	46.9	71.7	83.2	30.0	47.5	38.8	36.4	36.2	32.5	22.7	27.2	26.6	29.6	28.9	27.4
	Lake Summit	14.9	16.7	9.0	13.2	11.7	10.3	9.8	15.1	13.8	10.6	8.1	6.4	5.5	5.0	6.3	6.2	7.3	6.7	5.4
	Lake Winterset	19.2	18.0	16.0	15.2	11.7	11.1	9.1	10.3	11.0	8.5	5.5	6.2	4.2	3.5	4.7	4.8	9.5	6.6	4.5
	Spring Lake	24.8	16.8	33.1	17.2	22.1	21.6	19.7	22.9	12.6	9.2	9.7	8.0	5.7	12.3	20.7	7.4	11.4	14.8	9.1
North Central Lakes	Lake Buckeye	13.6	17.6	18.3	14.3	24.2	12.1	13.6	10.6	10.2	7.4	6.0	7.1	4.9	7.1	5.3	5.4	4.9	6.5	9.5
	Lake Idyl	41.0		10.6	8.0	9.2	7.0	4.4	1.9	25.1	4.4	5.5	4.8		4.7	9.7	9.6	57.5	33.6	31.7
	Lake Martha	1.9	5.0	0.0	3.2	3.6	3.0	3.4	7.1	5.6	7.1	7.1	6.3	6.3	7.3	12.2	12.7	17.7	17.2	8.8
	Lake Maude	14.5	10.6	6.1	18.9	12.8	4.7	4.9	16.3	15.9	12.3	8.7	12.6	8.2	5.3	8.3	6.5	8.2	4.1	4.0
	Lake Silver	12.8	13.6	26.4		9.8	12.9	7.1	7.6	14.0	10.2	10.4	9.4	8.1	8.0	13.6	12.9	22.2	8.7	10.4
South Central Lakes	Lake Elbert	1.6	1.4	3.5	3.1	6.2	5.2	3.7	3.1	3.7	3.6	4.9	5.0	4.0	4.4	5.5	3.7	6.2	5.6	8.2
	Lake Link	29.6		10.4	13.6						5.2	10.0	15.5	15.3	14.5	13.8	11.1	13.9	17.3	14.2
	Lake Mariam	5.8	12.6	4.2	3.8	5.4	5.4	8.0	6.0	4.7	4.0	4.1	4.8	4.7	6.3	6.3	10.9	7.1	8.2	6.8
	Lake Otis	55.0		11.2	10.4						21.9	18.3	23.2	20.4	16.3	17.3	13.9	13.5	18.3	17.7
Outlying Lakes	Lake Blue	92.1	59.2	60.1	79.2	53.8	66.8	122.4	75.7	120.5	58.8	70.7	34.4	57.7	52.3	58.1	65.9	70.9	59.8	72.6
	Lake Daisy	5.7	8.2	6.7	3.6	4.8	9.0	8.5	5.7	5.7	4.8	3.7	4.9	4.8	4.4	3.8	3.4	4.5	4.5	3.9
	Lake Deer	25.8	11.3	3.7	7.6	16.4	17.3	21.6	31.6	27.9	18.8	11.5	28.4	22.2	10.3	12.4	8.1	11.3	4.9	8.7
	Lake Mariana	35.7	15.1	24.3	37.0	26.9	23.4	28.9	32.5	34.2	25.5	42.1	32.4	35.0	37.1	29.1	21.3	38.2	31.5	35.1
	Lake Ned	1.8	2.3	10.7	4.8	8.0	5.4	4.9	6.2	7.9	10.0	3.6	10.7	13.9	13.9	13.2	15.2	14.3	14.8	13.7
	Lake Pansy	4.8	11.6	6.4	8.8	10.9	11.7	15.9	12.1	11.2	11.4	8.7	15.4	23.3	16.5	16.4	15.6	15.3	13.0	13.7

Table 4-1. Annual geometric mean corrected chlorophyll-a concentrations from 2001 – 2019 for all study area lakes.

Total Nitrogen

Lake Group	Waterbody	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
North Chain of Lakes	Lake Conine	1214.9	1388.9	1251.1	1289.9	1460.6	1278.6	1464.4	1378.7	1475.8	1455.7	1647.9	1359.1	1364.1	1193.2	1140.2	1056.7	1054.4	970.0	859.7
	Lake Fannie	851.7	1239.8	1124.3	1003.1	997.5	863.4	913.5	1326.9	1401.4	1288.3	1727.9	1453.5	1389.2	1114.5	970.3	898.2	870.0	873.5	750.3
	Lake Haines	1328.7	1518.4	1357.6	1329.2	1464.2	1458.5	1263.5	1363.9	1398.7	1379.8	1292.2	1506.4	1497.0	1267.2	1258.0	1204.3	1069.2	1232.2	979.9
	Lake Hamilton	933.4	997.5	1053.1	1083.0	1113.9	1286.9	1194.5	1244.7	1511.3	1451.0	1426.4	1503.2	1715.9	1524.7	1432.8	1620.9	2329.0	2016.4	1672.6
	Lake Rochelle	1251.8	1289.0	1434.1	1274.2	1322.9	1084.7	1228.4	1249.6	1603.5	1346.9	1208.9	1306.6	1319.5	1426.7	1134.0	946.5	942.1	934.6	792.8
	Lake Smart			1622.9	1374.9	1221.8	1194.7	1654.9			2300.0	2490.1	2141.4		1173.0	1316.8	1122.0	1606.6	1093.4	989.2
	Little Lake Hamilton	1297.6	1476.6	1371.0	1052.0	1108.0	986.7	1365.8	1786.2	1559.7		1416.7	1891.5	1650.0	1701.6	1191.7	1274.2	1580.4	1433.1	1111.8
	Middle Lake Hamilton	2160.0	2284.1	1761.6	1388.0	1630.4	1426.8	1412.3	2260.0	2030.0	2408.9	2196.3	2183.4	2096.8	1711.7	1442.3	1379.1	1648.2	1582.0	1325.9
South Chain of Lakes	Lake Cannon	1248.9	1535.7	1479.5	1142.8	1061.8	856.1	1137.4	1046.9	1306.1	1206.3	1328.2	1162.7	1355.1	1289.6	931.8	1059.8	922.6	985.7	1143.9
	Lake Eloise	1615.6	1416.1	1276.9	1186.3	1480.1	1270.1	1166.6	1134.4	1167.2	1344.5	1648.2	1313.7	1559.7	1574.9	1336.2	1519.4	1012.7	1078.5	883.8
	Lake Hartridge	812.9	801.5	729.4	744.5	608.9	808.0	860.8	991.8	1246.7	1217.5	1415.4	1463.1	1638.1	1659.3	1355.7	1425.4	1251.6	1308.5	1204.6
	Lake Howard	1882.3	1364.6	1550.7	1605.2	1266.3	1521.1	2288.3	1758.0	1652.8	1381.3	1628.9	1597.2	1461.6	1378.6	1267.8	1439.4	1196.6	1134.1	1150.9
	Lake Idylwild	1256.7	949.0	1080.8	965.7	891.5	937.7	988.8	1203.7	1540.9	1328.4	1288.4	1260.8	1299.4	1243.2	955.9	973.4	1125.5	1022.2	969.6
	Lake Jessie	1302.7	909.3	1040.2	1027.3	980.0	914.4	916.8	1063.3	1140.5	1197.3	1208.6	1163.6	1134.2	1174.0	927.9	902.1	1153.5	1067.4	1117.5
	Lake Lulu	1177.0	1404.8	1308.6	1087.4	1226.5	1373.9	1587.7	1643.1	1454.7	1495.6	1482.5	1327.1	1164.7	1037.9	1084.7	1219.6	1204.9	1296.0	1047.5
	Lake May	1787.7	1616.6	1549.2	1635.4	1326.4	1640.6	2298.1	1904.8	1756.5	1609.6	1731.9	1688.7	1490.8	1322.8	1163.8	1409.7	1268.1	1190.9	1182.1
	Lake Mirror	1500.0	1748.6	1832.8	1169.5	1161.1	1091.6	1246.5	1234.8	1138.2	1077.6	991.4	900.0	1038.8	756.2	696.5	836.7	897.9	984.4	926.0
	Lake Roy	1441.9	1168.8	1011.4	890.9	812.8	814.9	1009.2	1277.0	1103.3	1142.8	964.3	977.3	1062.2	925.4	754.1	759.1	742.0	950.8	729.9
	Lake Shipp	2728.9	1970.7	1734.9	1544.2	1415.8	2277.6	2647.7	2082.6	1859.5	1681.1	1808.3	1722.2	1495.5	1228.1	1217.1	1249.6	1274.7	1307.9	1130.9
	Lake Summit	1149.8	1038.8	733.6	798.0	764.0	856.8	912.2	849.1	830.5	882.4	931.1	819.9	762.4	800.2	821.6	755.6	767.2	773.4	635.1
	Lake Winterset	1049.0	1174.3	995.6	851.0	688.9	686.6	713.8	669.4	760.4	589.7	713.0	739.0	674.7	618.6	654.0	625.2	712.5	609.9	506.2
	Spring Lake	1130.0	1230.2	1811.1	793.6	809.7	1052.9	867.8	741.2	707.8	613.3	665.3	580.0	510.6	680.5	721.0	593.7	666.1	712.8	643.3
North Central Lakes	Lake Buckeye	805.0	1045.4	1163.8	888.8	944.3	818.3	834.9	870.2	830.4	864.2	773.2	671.7	716.7	744.2	657.7	592.0	618.9	653.9	784.9
	Lake Idyl	1400.0		619.0	594.0	649.8	630.0	544.4	530.0	1000.0	557.8	546.8	529.6		619.3	825.2	850.2	1797.4	1446.9	1000.4
	Lake Martha	495.8	644.6	657.3	500.4	500.1	433.3	479.2	601.1	613.0	664.4	720.1	597.1	539.6	660.5	732.7	716.3	717.2	811.3	630.7
	Lake Maude	996.3	876.1	748.3	796.1	870.4	559.2	663.1	822.7	984.9	898.3	859.1	836.4	718.1	607.2	694.8	658.5	691.5	559.3	524.9
	Lake Silver	640.0	1090.0	900.0		689.4	718.6	713.0	603.7	763.1	1098.1	735.7	712.1	595.9	666.8	749.4	805.7	910.1	681.4	624.2
South Central Lakes	Lake Elbert	273.3	391.3	422.5	409.5	520.7	504.1	424.7	353.7	415.4	409.9	560.0	506.3	397.0	454.2	477.1	476.7	501.3	542.3	616.9
	Lake Link	1770.0		660.0	920.0						764.9	1036.5	1043.3	816.5	855.2	829.0	688.3	734.2	862.4	732.8
	Lake Mariam	913.9	1429.1	927.7	976.3	947.5	1036.9	1147.3	1070.5	1042.3	897.1	915.7	878.2	836.4	867.3	891.0	996.5	1078.0	1092.6	939.9
	Lake Otis	1980.0		690.0	600.0						970.0	1095.3	985.8	921.0	788.0	819.8	681.1	673.0	769.7	634.2
Outlying Lakes	Lake Blue	3548.9	2521.3	2664.8	2692.6	1836.2	2239.6	3561.0	2633.2	3691.4	2508.2	3155.2	2308.2	2633.9	2280.7	2203.4	2515.2	2587.2	2387.2	2332.2
	Lake Daisy	407.4	709.7	459.9	448.2	598.9	585.8	533.0	531.8	558.7	569.5	532.3	509.5	479.6	459.4	459.6	439.8	524.3	506.4	463.0
	Lake Deer	1912.9	1172.8	809.3	980.8	955.2	932.4	1235.3	1425.5	1511.5	1519.0	1129.2	1629.6	1515.7	1079.4	990.6	782.3	850.8	716.1	846.5
	Lake Mariana	1256.4	1016.1	1271.7	1456.3	1075.1	1030.1	1250.7	1476.0	1648.0	1421.1	1726.8	1456.3	1635.1	1789.2	1441.2	1190.6	1746.0	786.9	1415.4
	Lake Ned	794.3	712.2	634.5	598.7	659.4	632.4	627.3	609.6	661.6	767.8	656.7	808.9	766.2	691.3	639.9	678.0	708.5	691.2	657.5
	Lake Pansy	659.9	865.1	669.9	705.8	720.3	810.7	1025.4	920.9	855.6	835.3	813.2	1007.9	1233.7	885.8	796.2	788.9	835.8	726.1	753.4

Table 4-2. Annual geometric mean total nitrogen concentrations from 2001 – 2019 for all study area lakes.

Total Phosphorus

Lake Group	Waterbody	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
North Chain of Lakes	Lake Conine	48.6	59.2	53.9	48.1	63.2	56.6	66.5	50.9	47.7	52.7	61.5	47.2	47.1	37.4	36.9	37.6	39.1	30.4	33.4
	Lake Fannie	32.5	81.9	50.6	37.1	27.7	37.0	37.9	55.1	62.0	58.4	65.9	53.8	50.4	38.2	28.8	28.1	26.1	23.3	28.3
	Lake Haines	33.6	44.3	52.5	60.0	84.7	58.9	45.9	38.4	38.2	42.3	36.7	39.0	38.4	37.4	36.8	46.6	50.9	42.6	41.8
	Lake Hamilton	80.3	274.7	72.6	110.0	76.8	117.1	95.2	64.5	76.6	59.8	53.7	66.0	58.2	43.3	41.1	38.2	50.1	40.9	26.5
	Lake Rochelle	41.9	40.7	37.1	45.6	56.9	42.0	45.3	42.8	35.5	47.4	33.6	33.0	39.2	35.7	29.6	24.2	27.4	25.1	25.0
	Lake Smart			42.8	46.5	48.6	45.9	51.0			39.0	42.9	38.5		30.6	33.2	32.1	35.9	28.1	29.0
	Little Lake Hamilton	28.5	44.4	29.9	27.0	41.4	33.9	35.2	46.9	48.0		34.1	44.4	35.0	32.6	24.9	25.7	30.9	29.8	22.0
	Middle Lake Hamilton	167.0	83.5	60.5	53.0	67.4	66.5	61.4	66.0	78.0	76.6	69.5	78.2	62.8	56.8	49.0	48.2	60.7	53.5	33.6
South Chain of Lakes	Lake Cannon	27.1	13.4	37.3	36.3	46.0	39.2	34.8	30.4	27.3	33.8	31.0	29.9	30.6	29.0	25.7	30.0	27.6	24.9	26.7
	Lake Eloise	37.4	24.4	42.3	41.2	72.5	54.0	38.6	32.8	33.2	30.8	31.7	31.3	32.6	31.9	29.9	38.2	30.7	29.3	27.6
	Lake Hartridge	33.0	0.0	18.4	30.0	33.2	35.8	25.9	27.3	30.6	32.3	30.9	30.1	29.4	29.4	28.6	29.8	26.3	23.5	23.0
	Lake Howard	24.0	6.3	24.0	38.8	48.8	43.8	39.4	38.5	33.3	28.0	28.1	26.4	28.6	25.5	22.2	25.7	29.3	22.6	22.6
	Lake Idylwild	49.0	0.0	37.9	46.3	46.4	44.8	40.2	37.3	35.5	35.2	27.7	29.2	30.4	28.7	25.8	31.6	28.9	27.5	27.0
	Lake Jessie	67.3	0.0	36.7	53.0	53.1	48.4	40.5	46.9	38.2	41.7	35.1	35.1	36.0	32.4	30.0	31.0	39.7	34.0	34.4
	Lake Lulu	42.0	31.3	42.4	49.0	61.6	58.0	50.5	49.1	44.2	41.6	37.3	33.7	35.1	31.0	30.9	38.0	38.3	34.6	31.7
	Lake May	82.9	37.5	58.3	76.0	74.2	77.0	87.0	73.7	74.6	58.2	57.7	53.7	53.9	44.0	34.3	45.7	51.1	42.4	33.0
	Lake Mirror	31.0	14.4	39.2	46.0	45.2	38.5	31.2	29.1	25.5	27.9	24.7	31.0	28.2	23.4	20.9	25.2	24.3	24.3	22.2
	Lake Roy	31.5	11.2	26.9	28.9	37.5	35.5	28.0	25.8	24.4	26.2	20.4	23.3	26.3	28.6	22.2	22.6	19.7	23.2	19.9
	Lake Shipp	52.2	28.7	40.6	44.8	63.1	62.3	54.2	50.5	46.2	40.9	39.3	37.9	37.4	30.7	27.5	33.7	39.0	31.6	32.2
	Lake Summit	28.8	0.0	19.4	27.9	36.7	34.4	27.2	23.0	22.0	26.0	20.6	20.8	22.9	23.4	18.7	20.1	21.8	21.1	19.0
	Lake Winterset	23.0	11.7	18.3	25.5	30.4	28.8	21.9	19.4	16.0	16.9	16.4	19.1	18.5	19.5	15.9	16.9	17.7	17.6	16.2
	Spring Lake	33.0	25.1	49.2	36.5	43.3	44.0	30.8	27.2	23.2	22.8	19.9	21.0	26.1	29.1	29.3	22.9	24.8	25.6	23.3
North Central Lakes	Lake Buckeye	27.1	32.0	39.9	28.8	42.5	33.3	26.5	24.8	21.6	26.1	20.5	20.9	25.9	26.5	17.8	18.2	21.7	19.2	22.3
	Lake Idyl	62.0		20.0	31.0	34.7	23.0	17.9	16.7	41.3	25.1	21.4	20.0		26.5	41.6	58.8	96.8	61.0	46.2
	Lake Martha	9.9	0.0	15.2	20.9	27.3	21.6	16.9	19.3	17.2	23.7	20.3	23.5	27.1	25.2	22.1	24.5	32.7	34.0	24.0
	Lake Maude	35.2	20.1	21.8	19.5	42.1	25.5	22.3	38.3	35.4	38.2	32.3	29.5	27.1	25.4	22.6	20.4	20.8	16.7	22.6
	Lake Silver	30.0	23.0	14.0		32.2	27.9	21.4	18.8	20.4	27.6	22.2	19.5	21.0	23.9	21.7	21.3	25.5	17.5	21.2
South Central Lakes	Lake Elbert	10.6	13.5	7.1	15.6	28.4	27.0	18.8	16.3	15.2	15.2	20.7	18.4	18.5	21.7	16.4	17.3	16.2	15.5	18.4
	Lake Link	40.0		19.0	26.0						27.5	37.5	33.7	29.2	30.7	27.7	23.9	25.0	23.9	27.4
	Lake Mariam	51.0	56.1	61.4	53.6	66.7	61.1	75.0	74.8	63.2	58.5	45.7	42.3	43.6	35.9	42.0	44.1	75.4	66.8	62.8
	Lake Otis	35.0		21.0	27.0						33.0	30.5	34.8	28.5	27.8	25.6	26.3	25.4	26.4	23.3
Outlying Lakes	Lake Blue	80.3	54.0	86.2	95.2	74.2	83.2	91.2	71.2	89.3	60.6	62.4	55.4	65.7	53.1	54.1	55.8	61.0	49.4	51.9
	Lake Daisy	18.8	36.9	29.7	24.0	39.4	38.1	31.2	28.3	30.0	27.2	23.7	26.9	29.2	25.9	22.4	20.4	23.7	22.1	23.7
	Lake Deer	28.1	17.9	22.6	38.1	55.4	42.5	33.7	27.9	30.8	34.7	26.5	36.2	40.5	32.0	20.4	19.2	19.4	17.5	25.3
	Lake Mariana	46.6	24.2	39.5	68.7	51.7	41.6	31.1	34.8	28.6	32.1	31.1	33.0	32.7	31.4	26.2	27.9	30.9	31.9	28.1
	Lake Ned	22.0	23.8	26.5	21.0	24.5	31.1	24.9	20.9	24.0	27.3	22.2	32.1	43.3	29.0	27.9	31.3	31.6	26.4	27.1
	Lake Pansy	27.1	19.8	11.5	32.4	30.3	33.9	30.5	24.2	24.8	23.5	21.8	27.6	37.1	32.0	30.6	29.6	28.9	20.5	29.2

Table 4-3. Annual geometric mean total phosphorus from 2001 – 2019 for all study area lakes.

Linear Regression Statistics

Water Quality Trends

Waterbody	Chl-a			Secchi			TN			TP		
	Dir.	R^2	p-value	Dir.	R^2	p-value	Dir.	R^2	p-value	Dir.	R^2	p-value
Lake Blue	-	0.0509	0.339	+	0.0768	0.237	-	0.1016	0.171	-	0.5335	0.001
Lake Buckeye	-	0.5524	0.001	+	0.7493	0.001	-	0.6254	0.001	-	0.4070	0.002
Lake Cannon	-	0.1297	0.119	+	0.2593	0.022	-	0.2060	0.044	-	0.0696	0.261
Lake Conine	-	0.2260	0.034	+	0.5065	0.001	-	0.1333	0.113	-	0.2079	0.043
Lake Daisy	-	0.2807	0.016	+	0.0480	0.353	-	0.0704	0.258	-	0.0976	0.180
Lake Deer	-	0.0466	0.361	+	0.0902	0.198	-	0.1969	0.050	-	0.1505	0.091
Lake Elbert	+	0.3905	0.003	-	0.1697	0.071	+	0.2251	0.035	+	0.0925	0.192
Lake Eloise	-	0.0439	0.375	+	0.4001	0.003	-	0.1056	0.162	-	0.1663	0.074
Lake Fannie	-	0.0040	0.790	+	0.2168	0.039	-	0.0078	0.711	-	0.1048	0.164
Lake Haines	-	0.0748	0.243	+	0.6824	0.001	-	0.4141	0.002	-	0.1139	0.146
Lake Hamilton	+	0.8089	0.001	-	0.4302	0.002	+	0.7833	0.001	-	0.4477	0.001
Lake Hartridge	+	0.7105	0.001	-	0.6883	0.001	+	0.6463	0.001	+	0.0085	0.699
Lake Howard	-	0.2819	0.016	+	0.5002	0.001	-	0.3886	0.003	-	0.0739	0.246
Lake Idyl	+	0.0494	0.376	-	0.0011	0.897	+	0.0948	0.214	+	0.1558	0.105
Lake Idylwild	-	0.0333	0.441	+	0.2427	0.027	+	0.0033	0.809	-	0.1476	0.094
Lake Jessie	+	0.0004	0.932	+	0.1509	0.091	+	0.0257	0.500	-	0.1125	0.148
Lake Link	-	0.0642	0.382	+	0.0893	0.299	-	0.3644	0.022	-	0.1055	0.257
Lake Lulu	-	0.2504	0.025	+	0.5392	0.001	-	0.1907	0.054	-	0.3856	0.003
Lake Mariam	+	0.0278	0.482	+	0.1541	0.087	-	0.0641	0.282	-	0.0019	0.855
Lake Mariana	+	0.1919	0.053	-	0.2249	0.035	+	0.1005	0.173	-	0.1956	0.051
Lake Martha	+	0.6316	0.001	-	0.4381	0.001	+	0.2785	0.017	+	0.2994	0.013
Lake Maude	-	0.3038	0.012	+	0.4126	0.002	-	0.4398	0.001	-	0.1559	0.085
Lake May	-	0.2935	0.014	+	0.6389	0.001	-	0.4400	0.001	-	0.4719	0.001
Lake Mirror	-	0.6974	0.001	+	0.5494	0.001	-	0.7079	0.001	-	0.2939	0.013
Lake Ned	+	0.5956	0.001	-	0.2836	0.016	-	0.0755	0.241	+	0.2730	0.018
Lake Otis	-	0.0453	0.465	+	0.0026	0.862	-	0.1916	0.118	-	0.0358	0.517
Lake Pansy	+	0.4772	0.001	-	0.0001	0.967	+	0.0857	0.210	+	0.1108	0.152
Lake Rochelle	-	0.3672	0.005	+	0.5465	0.001	-	0.2050	0.045	-	0.6214	0.001
Lake Roy	-	0.4638	0.001	+	0.5237	0.001	-	0.3297	0.008	-	0.2225	0.036
Lake Shipp	-	0.4010	0.003	+	0.7789	0.001	-	0.5705	0.001	-	0.3926	0.003
Lake Silver	-	0.0069	0.735	-	0.0736	0.261	-	0.0335	0.453	-	0.0016	0.869
Lake Smart	-	0.0072	0.763	+	0.2232	0.075	+	0.0128	0.688	-	0.2921	0.038
Lake Summit	-	0.5714	0.001	+	0.7651	0.001	-	0.4247	0.002	-	0.0583	0.305
Lake Winterset	-	0.7852	0.001	+	0.7071	0.001	-	0.6577	0.001	-	0.2475	0.026
Little Lake Hamilton	+	0.0998	0.188	-	0.0331	0.456	+	0.0897	0.213	-	0.0991	0.189
Middle Lake Hamilton	+	0.0209	0.543	+	0.0854	0.211	-	0.0395	0.401	-	0.3091	0.011
Spring Lake	-	0.3359	0.007	+	0.4727	0.001	-	0.4597	0.001	-	0.3242	0.009

Table 4-4. Trendline statistics for linear regressions of chl-a, TN, TP, and Secchi depth from 2000 - 2019. Stats include regression direction (+/-), R-squared value, and p-value.

Surface Level vs. Water Quality

Table 4-5. Trend statistics for linear regressions of lake surface levels against chl-a, TN, TP, and Secchi depth from 2000 - 2018. Stats include regression direction (+/-), R-squared value, and p-value.

4.3 List of Figures

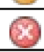
4.4 List of Tables

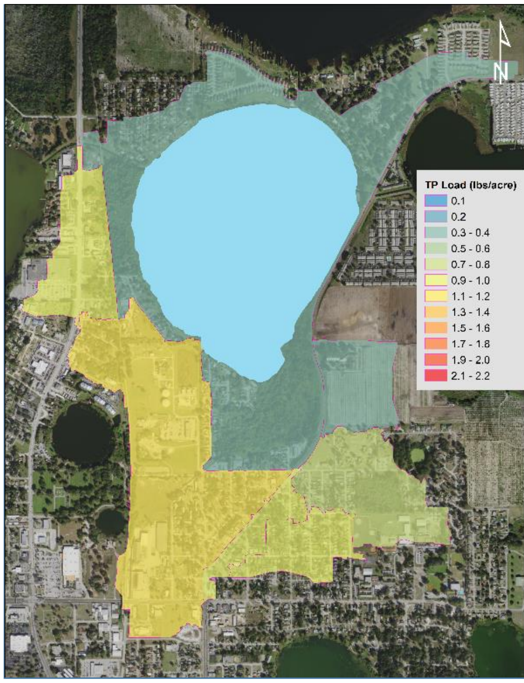
5- Water Quality Management Plans

Summary

The following pages include individual water quality management plans for the study area lakes. These plans illustrate the City's prioritization methodology by providing a simple breakdown of current status and priority level for each waterbody. Also listed are the primary lake health stressors as well as a breakdown of current and future management strategies the City may utilize to address them. While short and simple, these documents provide a much needed 'at-a-glance' overview distilled from information found in the report. The aim is to update these plans annually—providing a living document with which local, regional, and state decision-makers can use to drive management strategies and improve our lakes. Each plan includes a:

- Specialized map with a visual representation of some of the primary water quality impacts in that waterbody.
- Simplified breakdown of the lake health index for that waterbody; symbols are used to illustrate whether targets are being met (see legend below).
- Table of relevant waterbody statistics.
- List of primary challenges or stressors impacting water quality in that waterbody.
- List of existing and future management goals to improve water quality and overall lake health.
- Brief description of current water quality status and priority level for that waterbody

Lake Health Index Symbol Legend	
Symbol	**Meaning**
	Meeting/exceeding target
	At target threshold; needs improvement
	Not meeting target; needs significant improvement
	Significant improving trend
	Non-significant trend
	Significant deteriorating trend



Lake Conine

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	▲	–	▲	▲	✓	!	!	2.0

Status: *Currently impaired, but long-term trends show improvement.*
Priority: *Moderate*

Lake Stats	
Surface Area (acres)	235.4
Volume (m^3)	2,864,400
Avg. 2019 Surface Level (NGVD29)	129.2
Avg. Depth (feet)	9.03
Drainage Basin Area (acres)	559.1
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Conine receives stormwater runoff from **7** discreet drainage sub-basins (shown above). While management practices have been implemented in the developments north of the lake, the more dense urban areas south and west of Lake Conine receive little stormwater treatment. While the nutrient balance is split between nitrogen and phosphorus, the latter is often in low enough concentrations to be limiting. Therefore, the map above depicts annual Total Phosphorus (TP) loads from each drainage sub-basin (lbs/acre).

Historic Point-source Pollutant Loading:

Lake Conine received point-source discharges from the City of Winter Haven Wastewater Treatment Plant #2 as late as 1992. These discharges may be a considerable source of legacy nitrogen and phosphorus into the water column.

Invasive Species Treatment:

Since 1998, the Florida Fish and Wildlife Commission (FWC) has been battling the expansion of invasive species such as hydrilla in Lake Conine. Large-scale invasives treatment using herbicide cycles large amounts of nutrients back into the water column. As a result, the City considers early detection and rapid treatment response valuable to reduce the amount of herbicide used at one time. In 2019, hydrilla made up roughly **9%** of all species sampled.

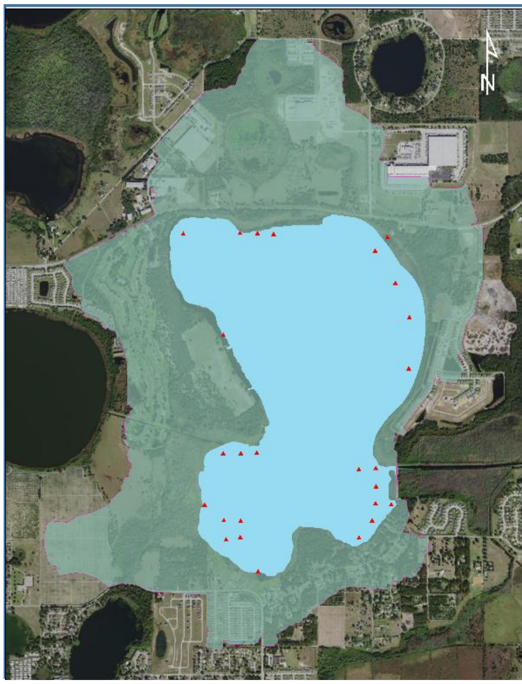
Best Management Practices

Existing Best Management Practices

- Green Infrastructure: Since the early 2000s, the City has set in motion the construction of a wetland along the south shore of Lake Conine. This wetland/nature park has been designed to treat much of the urban stormwater from the high-loading basins to the south.
- Aquatic Vegetation Management: Since 2016, the City has been monitoring vegetation communities in Lake Conine to rapidly detect the growth of invasives. Data is submitted to the FWC on a regular basis to reduce the amount of large-scale treatments to keep hydrilla and other species under control. In 2019, 200 triploid grass carp were stocked in the Northern Chain to supplement invasives treatment measures and reduce the amount of herbicide used.

Future Management Strategies

- Begin construction of the Lake Conine Treatment Wetland – by early 2020
- Develop plan to evaluate internal load from legacy sediments
- Continue to work with FWC staff to effectively keep invasive species in check. Seek out and promote alternative control strategies such as grass carp or mechanical harvest.



Lake Fannie

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	–	–	–	▲	✓	!	✓	2.1

Status: *Not currently impaired and no sign of long-term water quality deterioration.*

Priority: *Low*

Lake Stats	
Surface Area (acres)	800.3
Volume (m^3)	2,864,400
Avg. 2019 Surface Level (NGVD29)	125.1
Avg. Depth (feet)	6.94
Drainage Basin Area (acres)	1368.0
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment:

Since 1998, the Florida Fish and Wildlife Commission (FWC) has been battling the spread of hydrilla and other invasive species in Lake Fannie. In 2019, hydrilla was still the most abundant submerged aquatic species found in the lake despite a moderate decrease in invasive populations as a whole. Hydrilla made up roughly **7%** of all plants surveyed in 2019. Large-scale treatment of invasives using herbicide allows for nutrients to recycle back into the water column. The above map depicts Lake Fannie's drainage basin as well as the 2019 survey points where invasive species were detected (depicted as red points).

Surface Level Fluctuation:

Due to Lake Fannie's relatively shallow average depth, its highly organic sediments (muck) are easily suspended in the water column as a result of wind and boat wake action. Linear regression analysis has determined that surface level strongly correlates with each of the primary water quality metrics. During times of drought or excess water usage, Lake Fannie will likely see a significant decline in water quality.

Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Fannie to rapidly detect the growth of invasives since 2017. Data is submitted to the FWC on a regular basis to reduce the amount of large-scale treatments in order to keep hydrilla and other species under control. In 2019, FWC stocked **100** triploid grass carp in Lake Fannie to supplement its invasives management program and reduce the amount of herbicide used.

- Surface Level Management: The Southwest Florida Water Management District recently modified its existing surface level operation infrastructure and guidelines for the Northern Chain of Lakes. The implementation of remote operated infrastructure allows the District to more accurately maintain surface levels at or near the maximum level; only releasing water downstream when exceeding maximum guidance levels or prior to large storm events to prevent flooding.

Future Management Strategies

- Continue to work with FWC staff to effectively keep invasive species in check.
- One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Lake Fannie

Status: *Currently impaired, but showing some long-term water quality improvement.* ***Priority:*** *Moderate*

Lake Haines

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✓	–	▲	–	▲	✓	✗	✓	● 2.0

Lake Stats	
Surface Area (acres)	687.5
Volume (m^3)	9,104,277
Avg. 2019 Surface Level (NGVD29)	128.4
Avg. Depth (feet)	9.65
Drainage Basin Area (acres)	1630.4
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Invasive Species Treatment:

In the last two years, Lake Haines has seen a significant rise in invasive species like hydrilla and water hyacinth. In 2019, these two species were among the top 5 most abundant surveyed in the lake. Large-scale treatment of invasives using herbicide recycles nutrients the plants have absorbed back into the water column—leading to a decline in water quality. Due to this, there has been increased social and political pressure placed on the use of alternative treatment methods. The above map depicts Lake Haines' drainage basin as well as the points where invasive species were detected during the 2019 survey (shown as red points). Roughly **20%** of the species sampled were invasives such as hydrilla and water hyacinth.

Historic Point-source Pollutant Loading:

Lake Haines received point-source discharges from the Lake Alfred Wastewater Treatment Plant until 1992. These discharges may be a considerable source of legacy nitrogen and phosphorus into the water column. Since Lake Haines is co-limited by nitrogen and phosphorus, these legacy nutrients may be the primary contributor to its impairments.

Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Haines to rapidly detect the growth of invasives since 2017. Data is submitted to the Florida Fish and Wildlife Commission (FWC) on a regular basis to reduce the amount of large-scale treatments to keep hydrilla and other species under control. In 2019, FWC stocked **200** triploid grass carp in the Northern Chain to supplement its invasives management program and reduce the amount of herbicide used.

Future Management Strategies

- Continue to work with FWC staff to effectively keep invasive species in check; utilizing alternative treatment methods such as biological control and mechanical harvesting where appropriate.
- Develop plan to evaluate internal load from legacy sediments

Lake Hamilton

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	▼	▼	▲	▼	!	✓	✓	● 1.0

Status: *Currently impaired and showing significant water quality deterioration.*

Priority: *High*

Lake Stats	
Surface Area (acres)	2168.7
Volume (m^3)	16,852,885
Avg. 2019 Surface Level (NGVD29)	121.1
Avg. Depth (feet)	6.39
Drainage Basin Area (acres)	2008.8
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Hydrology:

Lake Hamilton is a unique case in that it has undergone a rapid decline in water quality within the last decade without any clear signs to the cause. There appears to be no significant relationship between surface level and water quality nor have there been any major changes to surrounding land uses in the last 20 years. That said, Lake Hamilton's morphology may play a role. As the largest lake with regards to surface area and one of the overall shallowest waterbodies in the study area, Lake Hamilton may undergo minimal flushing—leading to nutrient concentration in the waterbody. Further study is required to better understand hydrological functions in Lake Hamilton.

Lack of Aquatic Vegetation:

For its size and average depth, Lake Hamilton possesses very little aquatic vegetation. Due to the ability of macrophytes to buffer against changes in nutrient concentration by adsorbing excess nitrogen and phosphorus, a lack of emergent and/or submerged vegetation can lead to a rapid decline in water quality.

Onsite Sewage Treatment & Disposal (OSTD):

There are **62** known septic systems within Lake Hamilton's drainage basin; this constitutes a moderate-to-low density. That said, a lack of alternative pollutant sources may be indicative of OSTDs as a potential source. OSTDs are depicted as yellow points in the above map.

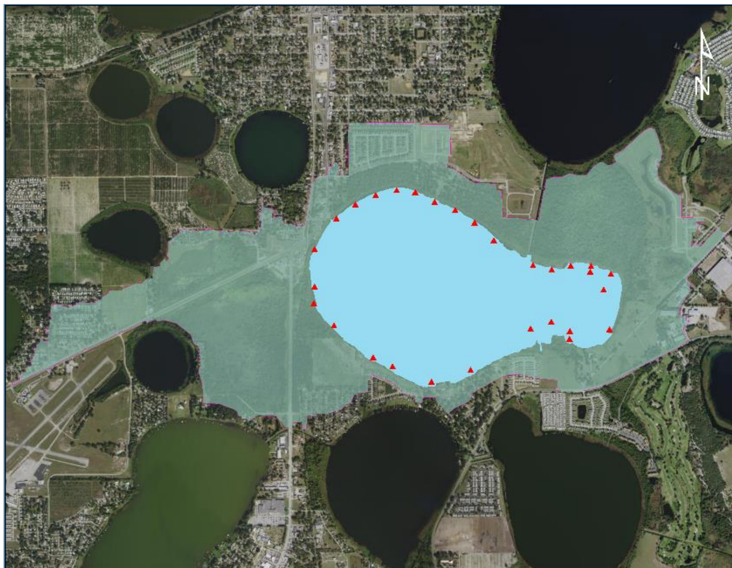
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has partnered with the Florida Fish and Wildlife Commission (FWC) to survey aquatic vegetation in the Hamilton Chain the last two years. Tracking the annual vegetation community changes in this lake has revealed its overall scarcity of macrophytes. In addition, early detection of invasive species is an ancillary goal of these surveys. Within the last 10 years, Lake Hamilton has undergone minimal herbicide treatment (<2% of total lake area per year) compared with the amount used in the early 2000s. This indicates that invasives are in a managed state.

Future Management Strategies

- Work with local stakeholders to identify sources of nutrient concentration increases in Lake Hamilton
  - Explore source analysis of septic systems in the drainage basin
  - Explore hydraulic (flow) analysis to determine if flushing is the issue
  - Conduct historical review of the area to determine if point-source discharges exist
- Look into potential aquatic vegetation planting initiatives to improve macrophyte abundance



Status: *Not currently impaired; showing improving water quality trends.* ***Priority:*** *Low*

Lake Rochelle

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	▲	▲	▲	✓	✗	!	2.0

Lake Stats	
Surface Area (acres)	559.9
Volume (m^3)	7,475,175
Avg. 2019 Surface Level (NGVD29)	128.5
Avg. Depth (feet)	8.96
Drainage Basin Area (acres)	1109.7
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment:

The Florida Fish and Wildlife Commission (FWC) has documented control efforts of hydrilla and other invasive species in Lake Rochelle since 1998. Treatment of large areas of invasives using herbicides allows for the re-release of nutrients back into the water column which can lead to deterioration of water quality. The above map shows Lake Rochelle's drainage basin as well as the points where invasive species were detected during the 2019 vegetation survey (depicted as red points). In 2019, hydrilla made up roughly **10%** of all plant species surveyed.

Surface Level Fluctuation:

Linear regression analysis has determined that changes in Lake Rochelle's surface level significantly affect chlorophyll-a concentration and water clarity. This is likely a result of changing connectivity with the wetlands surrounding large portions of the lake. As water level rises, so does nutrient absorption capabilities as well as an influx of color to the water column—leading to a decrease in algal productivity. Managing lake stage at a higher level should improve water quality in this lake.

Best Management Practices

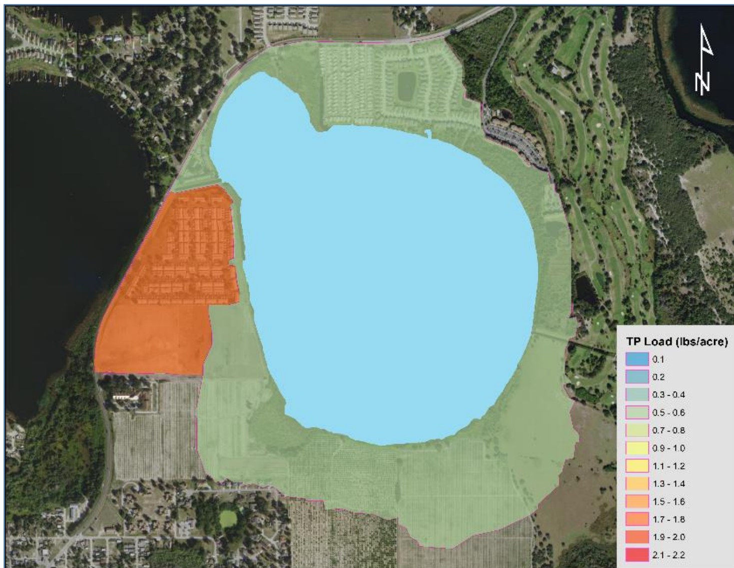
Existing Best Management Practices

- Aquatic Vegetation Management: The control of hydrilla in Lake Rochelle has been an ongoing battle since the late 1990s. Despite multiple treatments within the last 5 years, water quality has trended positively. However, greater social and political pressure has led to the utilization of alternative treatments. As of late 2019, **200** triploid grass carp were stocked in the Northern Chain to supplement existing treatments and reduce the need for herbicide.

- Surface Level Management: The Southwest Florida Water Management District recently modified its existing surface level operation infrastructure and guidelines for the Northern Chain of Lakes. The implementation of remote operated infrastructure allows the District to more accurately maintain surface levels at or near the maximum level; only releasing water downstream prior to large storm events to prevent flooding.

Future Management Strategies

- Continue to work with FWC staff to effectively keep invasive species in check; utilizing alternative treatment methods such as biological control and mechanical harvesting where appropriate.
- One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Lake Fannie



Status: *Currently impaired and showing little water quality improvement.* ***Priority:*** *High*

Lake Smart

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
										1.9

Lake Stats	
Surface Area (acres)	281.2
Volume (m^3)	3,581,825
Avg. 2019 Surface Level (NGVD29)	128.5
Avg. Depth (feet)	9.42
Drainage Basin Area (acres)	300.2
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Smart receives stormwater runoff from **2** distinct drainage sub-basins pictured in above map. Since phosphorus is the pollutant of concern the annual Total Phosphorus (TP) load is represented for each sub-basin in lbs/acre. The smaller basin with higher loading to the west possesses stormwater treatment best management practices (BMPs), as does the residential area to the north. The agricultural lands to the south of the lake have the potential to discharge high-nutrient runoff without any treatment.

Surface Level Fluctuation:

Linear regression analysis has determined that there is a significant correlation between surface level and all four primary water quality metrics for Lake Smart. This is likely due to increased flushing during periods of high water level as well as greater connectivity to the wetland area to the east of the lake.

Invasive Species Treatment:

The Florida Fish and Wildlife Commission (FWC) has a record of battling the spread of hydrilla in Lake Smart since 2000. Treatment of large areas of invasives using herbicides allows for the re-release of nutrients back into the water column which can lead to deterioration of water quality. In 2019, hydrilla increased to roughly **4%** of all plant species surveyed—indicating that management efforts will need to be focused in the coming year.

Best Management Practices

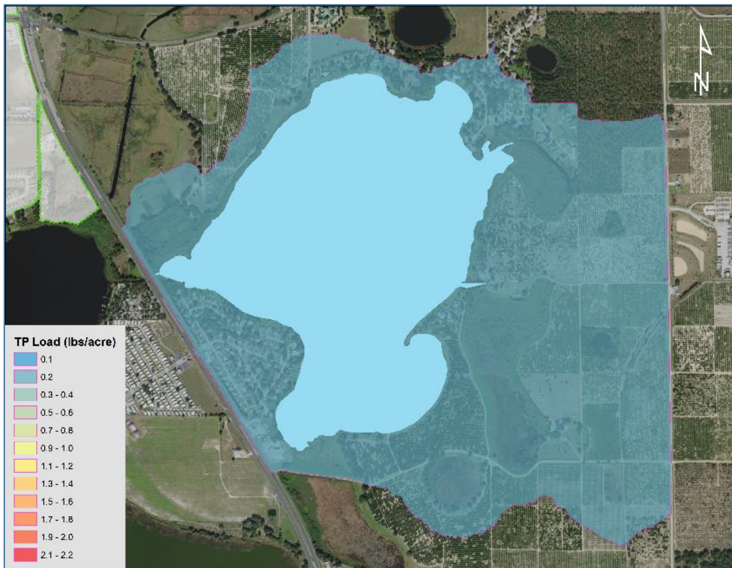
Existing Best Management Practices

- Surface Level Management: The Southwest Florida Water Management District recently modified its existing surface level operation infrastructure and guidelines for the Northern Chain of Lakes. The implementation of remote operated infrastructure allows the District to more accurately maintain surface levels at or near the maximum level; only releasing water downstream prior to large storm events to prevent flooding.

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Smart to rapidly detect the growth of invasives since 2017. Data is submitted to the Florida Fish and Wildlife Commission (FWC) on a regular basis to reduce the amount of large-scale treatments to keep hydrilla and other species under control. In 2019, FWC stocked **200** triploid grass carp in the Northern Chain to supplement its invasives management program and reduce the amount of herbicide used.

Future Management Strategies

- Continue to work with FWC staff to reduce the spread of invasive species
- One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Lake Smart



Status: *Currently impaired and no significant improving water quality trends.* ***Priority:*** *High*

Little Lake Hamilton

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	—	—	—	—	✓	✓	!	1.4

Lake Stats	
Surface Area (acres)	359.6
Volume (m^3)	3,818,505
Avg. 2019 Surface Level (NGVD29)	121.1
Avg. Depth (feet)	8.46
Drainage Basin Area (acres)	656.2
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Little Lake Hamilton does not possess multiple distinct drainage sub-basins. The above map depicts the annual Total Phosphorus (TP) load in lbs/acre. Little Hamilton's areal TP load is comparatively lower than other lakes in the study area. However, since this lake is completely outside Winter Haven's municipal limits, the City has little data on existing treatment implementation in the drainage basin. That said, there appears to be two wetland areas to the east that may provide treatment to runoff from the surrounding agricultural lands.

Surface Level Fluctuation:

Linear regression analysis has determined that there is a significant correlation between surface level and all four primary water quality metrics for Little Lake Hamilton. This is likely due to increased flushing during periods of high water level as well as greater connectivity to the wetland area to the east of the lake.

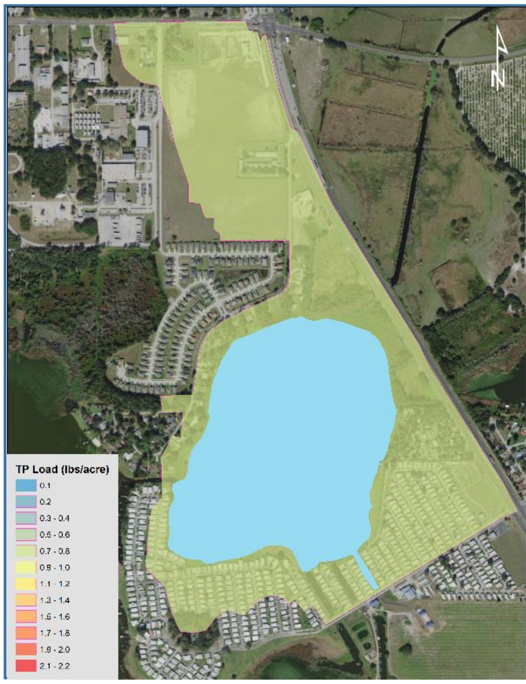
Best Management Practices

Existing Best Management Practices

- Surface Level Management: The Southwest Florida Water Management District recently modified its existing surface level operation infrastructure and guidelines for the Northern Chain of Lakes. The implementation of remote operated infrastructure allows the District to more accurately maintain surface levels at or near the maximum level; only releasing water downstream prior to large storm events to prevent flooding.

Future Management Strategies

- One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Little Lake Hamilton
- Work with local stakeholders to identify potential pollutant sources which may include historic point-source discharges or existing non-point sources.



Middle Lake Hamilton

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✖	✖	✖	—	—	▲	—	✔	!	✔	○ 1.6

Status: *Currently impaired and showing little water quality improvement.*
Priority: *High*

Lake Stats	
Surface Area (acres)	102.6
Volume (m^3)	525,059
Avg. 2019 Surface Level (NGVD29)	121.1
Avg. Depth (feet)	5.01
Drainage Basin Area (acres)	183.3
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Due to a lack of stormwater infrastructure in its watershed, Middle Lake Hamilton possesses no distinct drainage sub-basins. The above map depicts the annual Total Phosphorus (TP) load in lbs/acre which is moderately high due to the medium and high density residential land uses in the basin. Annual Total Nitrogen loads are proportional to TP loads.

Surface Level Fluctuation:

Linear regression analysis has determined that there is a significant correlation between surface level and all four primary water quality metrics for Middle Lake Hamilton. This is likely due to increased flushing during periods of high water level and a decrease in sediment suspension as lake depth increases.

Invasive Species Treatment:

Treatment of large areas of invasives using herbicides allows for the re-release of nutrients back into the water column which can lead to deterioration of water quality. While the Florida Fish and Wildlife Commission (FWC) does not show a record of treating invasive species in Middle Lake Hamilton specifically, an increase of invasive plants in recent years may require focused efforts to prevent their spread. In 2019, hydrilla and water hyacinths made up roughly **4%** of all species sampled.

Best Management Practices

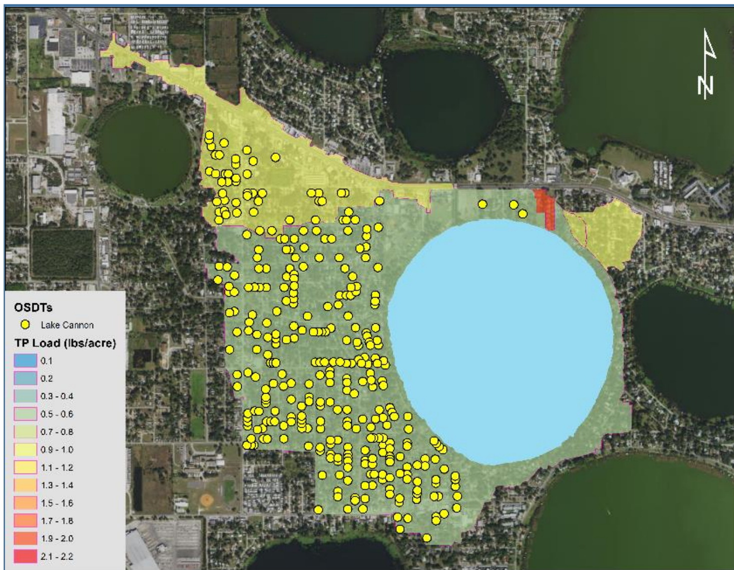
Existing Best Management Practices

- Surface Level Management: The Southwest Florida Water Management District recently modified its existing surface level operation infrastructure and guidelines for the Northern Chain of Lakes. The implementation of remote operated infrastructure allows the District to more accurately maintain surface levels at or near the maximum level; only releasing water downstream prior to large storm events to prevent flooding.

- Aquatic Vegetation Management: The City has partnered with the FWC to survey aquatic vegetation in the Hamilton Chain the last two years. This has allowed for the early identification of invasives before they spread throughout the waterbody.

Future Management Strategies

- One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Middle Lake Hamilton
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate.



Status: *Currently impaired, but showing some water quality improvement.* ***Priority:*** *Moderate*

Lake Cannon

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✓	—	▲	—	▲	✓	✓	✗	2.0

Lake Stats	
Surface Area (acres)	338.2
Volume (m^3)	4,545,479
Avg. 2019 Surface Level (NGVD29)	131.8
Avg. Depth (feet)	9.59
Drainage Basin Area (acres)	695.4
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Cannon receives stormwater runoff from **5** distinct drainage sub-basins (see above map). The four northern basins contribute the highest Total Phosphorus (TP) loads, however best management practices (BMPs) have been implemented to mitigate loads from these basins. The larger direct runoff basin contributes the lowest TP loading, however no City BMPs are in place here as the majority of this basin falls outside municipal limits.

Onsite Sewage Treatment & Disposal (OSTD):

OSTDs or septic systems can potentially contribute high non-point nutrient loading through leachate into groundwater. Septic systems (pictured as yellow points) are relatively dense in the western section of Lake Cannon's drainage basin—**338** known OSTDs are present.

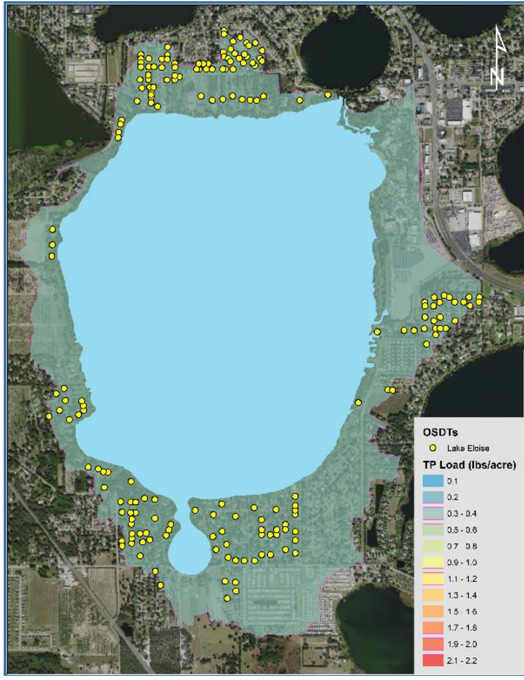
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **2.7** miles of residential and arterial roads are swept on a monthly basis in Lake Cannon's four northern sub-basins.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients



Lake Eloise

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	—	—	—	▲	✓	!	✓	1.8

Status: *Currently impaired and showing little water quality improvement.*

***Priority:** High*

Lake Stats	
Surface Area (acres)	1181.3
Volume (m^3)	19,173,944
Avg. 2019 Surface Level (NGVD29)	132.1
Avg. Depth (feet)	11.42
Drainage Basin Area (acres)	800.1
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Due to a lack of City or County stormwater infrastructure, Lake Eloise receives only direct runoff from its surrounding drainage basin. Since phosphorus is the limiting nutrient, the annual Total Phosphorus (TP) load is depicted in the map above. Relative to other lakes, TP loading is fairly low.

Historic Point-source Pollutant Loading:

Until 1975, Lake Eloise received regular discharges from the Cypress Gardens Wastewater Treatment Plant. This was a significant source of legacy nitrogen and phosphorus for this waterbody.

Onsite Sewage Treatment & Disposal:

There are **186** known OSTDs scattered throughout Lake Eloise's drainage basin. Eloise possesses a moderate density of septic systems which can contribute to nutrient loading through leachate in the groundwater (pictured as yellow points).

Invasive Species Treatment:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Eloise since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. That said, the last large-scale treatment in Eloise was conducted in 2008; subsequent management efforts have been spot treatments of less than 7% of the lake's total area per year. In 2019, hydrilla and water hyacinth made up roughly **4%** of all plants sampled in Lake Eloise.

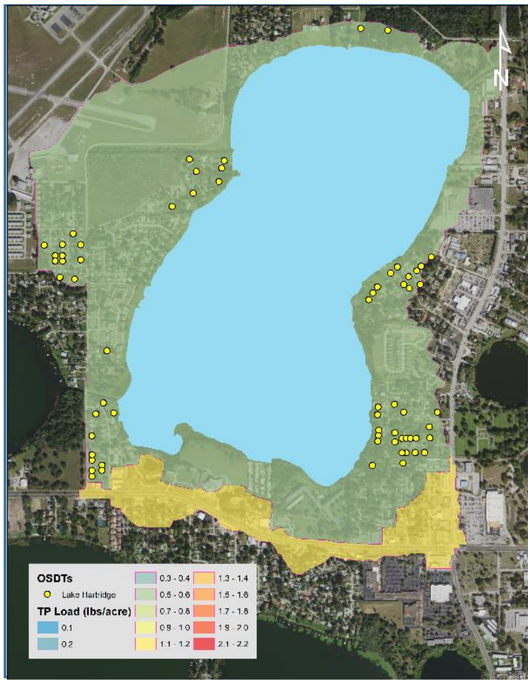
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Eloise to rapidly detect the growth of invasives since 2017. Data is submitted to the Florida Fish and Wildlife Commission (FWC) on a regular basis to reduce the amount of large-scale treatments to keep hydrilla and other species under control.

Future Management Strategies

- Develop plan to evaluate internal load from legacy sediments
- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate.



Lake Hartridge

Lake Health Index (Scales from 0 - 3)											
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✓	▼	▼	—	▼	✓	!	✓	1.0

Status: *Currently impaired and showing water quality degradation.*
Priority: *High*

Lake Stats	
Surface Area (acres)	446.4
Volume (m³)	5,504,605
Avg. 2019 Surface Level (NGVD29)	131.9
Avg. Depth (feet)	9.01
Drainage Basin Area (acres)	476.0
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Stormwater runoff enters Lake Hartridge via **2** primary drainage sub-basins: the larger direct runoff basin surrounding the lake and the smaller basin that collects runoff from Havendale Blvd. to the south. As the limiting nutrient is phosphorus, the above map depicts the annual Total Phosphorus (TP) loads to Lake Hartridge. It should be noted that while the load from the southern basin is higher, its stormwater receives treatment from street sweeping and a large treatment wetland prior to entering the lake.

Onsite Sewage Treatment and Disposal (OSTD):

There are **65** known OSTDs within Lake Hartridge's drainage basin. The density of septic systems (depicted as yellow points) in the basin is only moderate since they are not congregated in one area. However, septic systems can potentially leach excess nutrients to waterbodies through groundwater.

Invasive Species Treatment:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Hartridge since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. The last large-scale treatments occurred in 2008 and 2010, with only minor spot treatments since then. That said, the population of hydrilla has increased within the last year. In 2019, hydrilla made up roughly **3%** of all species surveyed and will need to be managed to prevent further spread.

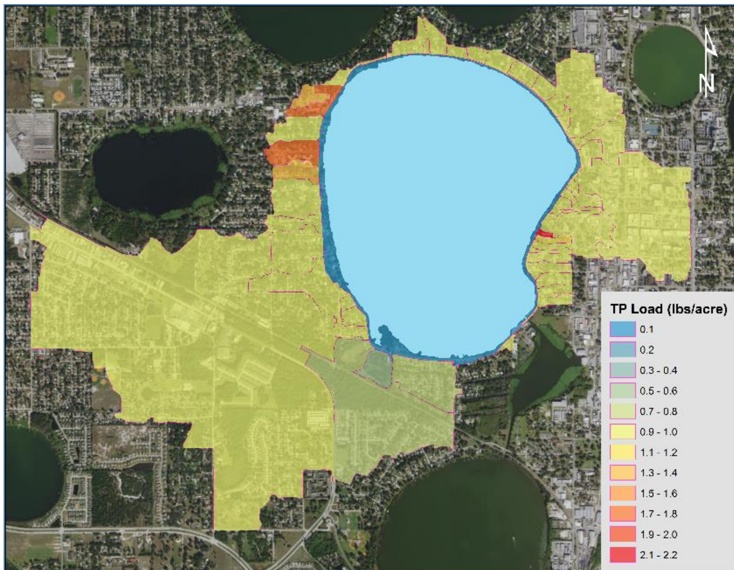
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **5.25** miles of residential and arterial roads are swept on a monthly basis in Lake Hartridge's southern drainage sub-basin.
- Green Infrastructure: The City has implemented Lake Hartridge Nature Park that treats stormwater from the entirety of the southern drainage sub-basin.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Hartridge to rapidly detect the growth of invasives since 2017. This has allowed for the early identification of invasives before they spread throughout the waterbody.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- Continue to maintain the Lake Hartridge Nature Park to ensure its pollutant reduction efficiency
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Currently impaired, but showing water quality improvement.* ***Priority:*** *Moderate*

Lake Howard

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✓	▲	▲	–	▲	✓	✓	✓	2.5

Lake Stats	
Surface Area (acres)	631.6
Volume (m^3)	7,209,568
Avg. 2019 Surface Level (NGVD29)	131.7
Avg. Depth (feet)	8.71
Drainage Basin Area (acres)	1238.9
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Howard receives urban stormwater runoff from **53** discreet drainage sub-basins. Private and public best management practices (BMPs) such as green infrastructure and street sweeping are in place to treat runoff from all sub-basins. Since phosphorus is the limiting nutrient, any water quality analyses or improvements should consider it the primary nutrient of concern. The map (above) identifies annual Total Phosphorus (TP) loads (lbs/acre) for each basin.

Historic Point-source Pollutant Loading:

Lake Howard received point-source discharges from the Jan-Phyl Village Wastewater Treatment Plant until 1977. These discharges may be a considerable source of legacy nitrogen and phosphorus into the water column.

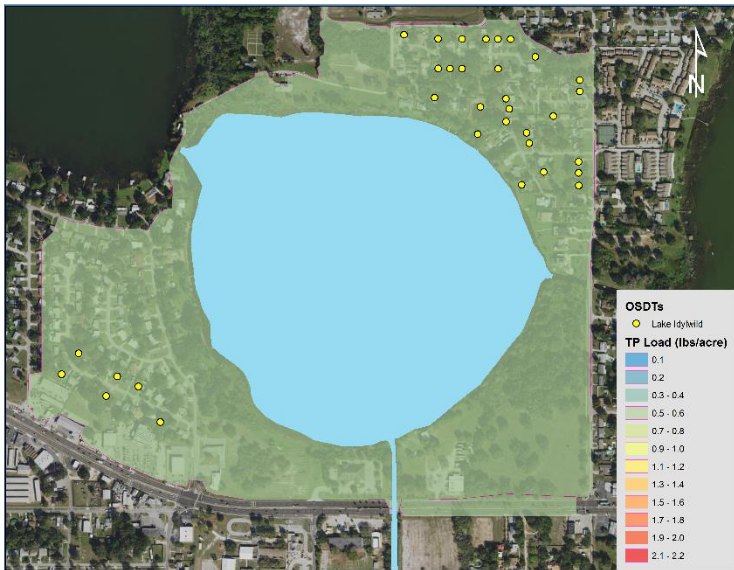
Best Management Practices

Existing Best Management Practices

- Alum Treatment: Injection points in three high-loading sub-basins in the eastern (downtown) area. At the time of construction, the alum treatment reduced up to 90% of TP loads in those sub-basins; however this system is in need of maintenance/repair.
- Street Sweeping: **23.2** miles of downtown, residential, and arterial roads are swept on a monthly basis around the lake perimeter.
- Green Infrastructure: The City has constructed **12** raingardens/infiltration systems within the eastern (downtown) section of Lake Howard's drainage basin. Additionally, South Lake Howard Nature Park was constructed to treat stormwater from the large southern drainage sub-basins.
- Stormwater Assessment & Improvement Project (SAIP): Identified priority area where stormwater could be diverted from a small southern sub-basin to Lake Howard Nature Park to prevent flooding and improve water quality.

Future Management Strategies

- Repair alum infrastructure and evaluate treatment effectiveness – by end of 2021
- Develop plan to expand/improve street sweeping service– by end of 2020
- Install trash/debris catchment system at Heritage Park – by early 2020
- Develop plan to evaluate internal load from legacy sediments
- Perform maintenance on existing raingardens – by end of 2020
- Budget for/pursue funding for SAIP priority site improvements in southern drainage basin – by 2021



Status: *Currently impaired and showing little water quality improvement.* ***Priority:*** *High*

Lake Idylwild

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✓	–	–	–	▲	✓	!	✓	1.9

Lake Stats	
Surface Area (acres)	95.2
Volume (m^3)	1,028,780
Avg. 2019 Surface Level (NGVD29)	131.8
Avg. Depth (feet)	8.26
Drainage Basin Area (acres)	130.3
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Idylwild receives stormwater runoff from **2** distinct drainage sub-basins. Shown in the map above, the Total Phosphorus (TP) load from these basins are low-to-moderate when compared with others in the study area. TP is depicted since phosphorus is the limiting nutrient in this waterbody. Street sweeping is conducted in the smaller basin to the south while drainage best management practices (BMPs) have been implemented in the larger direct runoff basin.

Onsite Sewage Treatment & Disposal (OSTD):

There are **33** known OSTDs within Lake Idylwild's drainage basin. The number of septic systems in basin is relatively low (depicted as yellow points). However, these can still potentially contribute nutrient loading through leachate to the groundwater.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Idylwild since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. While large-scale treatments in this lake ceased in 2008, management efforts within the last five years have treated approximately 10% – 30% of the lake's total surface area per year. Recent vegetation surveys have shown an expansion of invasive species, with exotics making up roughly **3.5%** of all plants sampled in 2019.

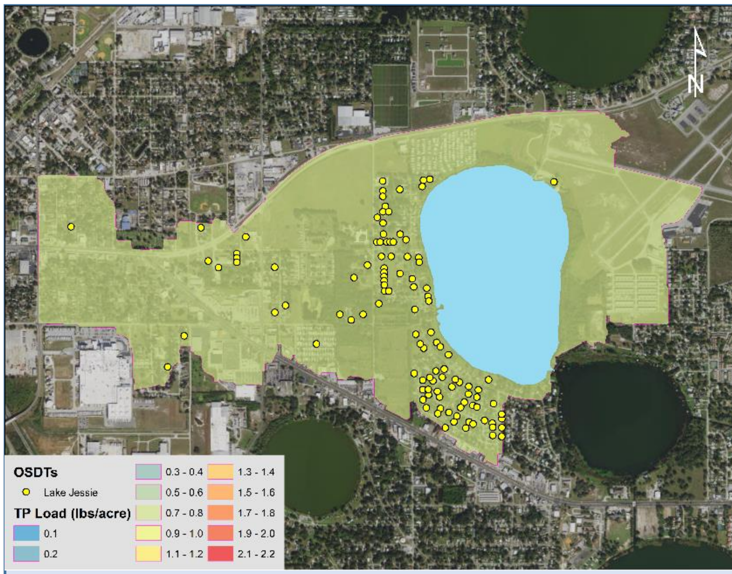
Best Management Practices

Existing Best Management Practices

- Street Sweeping: Approximately **1** mile of arterial roadways are swept on a monthly basis in the small southern drainage basin.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Idylwild to rapidly detect the growth of invasives since 2017. This has allowed for the early identification of invasives before they spread throughout the waterbody.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Currently impaired and water quality trends show no improvement.* ***Priority:*** *High*

Lake Jessie

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	–	–	–	–	✓	!	✓	1.6

Lake Stats	
Surface Area (acres)	185.0
Volume (m^3)	2,093,316
Avg. 2019 Surface Level (NGVD29)	131.9
Avg. Depth (feet)	7.93
Drainage Basin Area (acres)	784.8
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Jessie lacks multiple distinct stormwater sub-basins, but receives runoff from a fairly sizable drainage area. Since phosphorus is the limiting nutrient, Jessie's annual Total Phosphorus (TP) load has been plotted in the map above. The TP load is moderate compared to other lakes in the study area. It should be noted that City stormwater best management practices (BMPs) have been implemented at the airport site to the east, while private BMPs are in place to the west. Therefore, Lake Jessie's stormwater is not untreated.

Onsite Sewage Treatment & Disposal (OSTD):

There are **111** known OSTDs in Lake Jessie's basin. Septic systems (depicted as yellow points) are relatively dense in the western side of the basin. These systems can potentially contribute excess nutrient loads via groundwater leaching.

Historic Point-source Pollutant Loading:

Lake Jessie received some amount of historic wastewater discharge. The amount of contributed wastewater as well as the date that discharges ceased is undocumented, so there is no way to grasp how much legacy material is within Lake Jessie.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Jessie since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column.

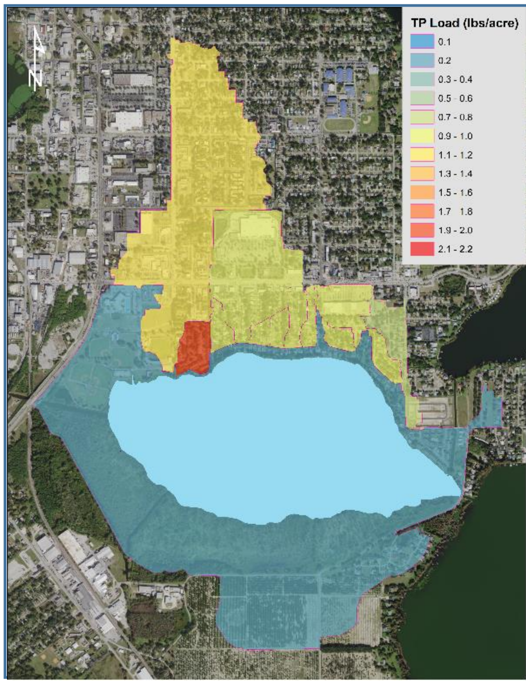
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Jessie to rapidly detect the growth of invasives since 2017. This has allowed for the early identification of invasives before they spread throughout the waterbody. As of 2019, invasive species only make up roughly **2%** of all aquatic plants sampled in the lake.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- Develop plan to evaluate internal load from legacy sediments
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Lake Lulu

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	▲	—	▲	▲	✓	✓	✓	● 2.3

Status: *Currently impaired, but showing mostly improving water quality trends.*
Priority: *Moderate*

Lake Stats	
Surface Area (acres)	307.5
Volume (m^3)	2,582,361
Avg. 2019 Surface Level (NGVD29)	131.7
Avg. Depth (feet)	6.76
Drainage Basin Area (acres)	692.9
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Lulu receives stormwater runoff from **13** distinct drainage sub-basins. The above map depicts the annual Total Phosphorus (TP) loads to Lake Lulu from each of these sub-basins since phosphorus is the limiting nutrient. TP loads from the urban basins are moderate to high compared to others in the study area. However, there are multiple public and private best management practices (BMPs) in place to mitigate these loads. Street sweeping and alum treatment are currently utilized as public BMPs within City limits.

Historic Point-source Pollutant Loading:

Lake Lulu has received historic point-source discharges from multiple sources. Wastewater was discharged to the lake from a municipal treatment facility until 1977. In addition, Lulu received discharges from several commercial, agricultural, and industrial facilities up until an undocumented period of time. These historic pollutant loads may still be contributing to water quality impacts to this day.

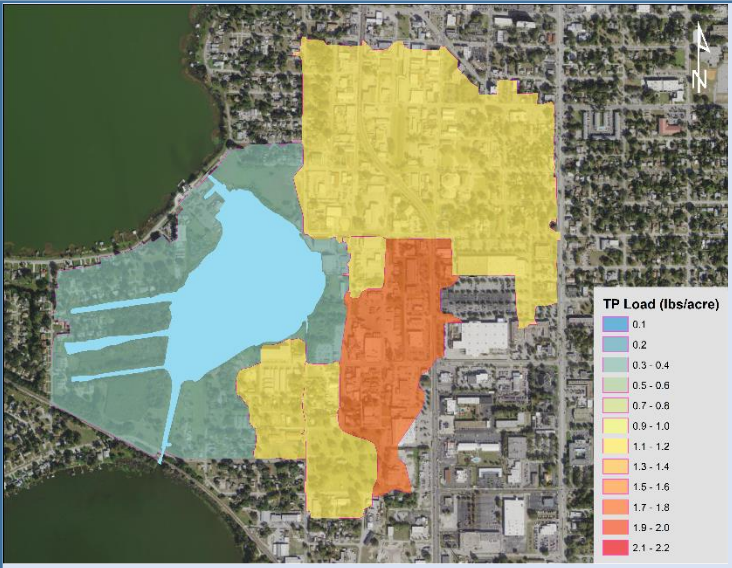
Best Management Practices

Existing Best Management Practices

- Alum Treatment: Injection points at several high-loading sub-basins in the along the northern shore. At the time of construction, alum treatment was designed to reduce up to 90% of TP loads in affected sub-basins; however this system is in need of maintenance/repair.
- Street Sweeping: **8.1** miles of residential and arterial roads are swept on a monthly basis; this only applies to areas within the City limits (NW basins).
- Baffle Box: Polk County installed a baffle box to capture large quantities of solid waste and debris from storm systems draining Cypress Gardens Blvd.
- Stormwater Assessment & Improvement Project (SAIP): Identified priority site within the northernmost basin where green infrastructure could be implemented to reduce flooding and improve water quality.

Future Management Strategies

- Repair alum infrastructure and evaluate treatment effectiveness – by end of 2021
- Develop plan to evaluate internal load from legacy sediments
- Budget for/pursue funding for SAIP priority site improvements in southern drainage basin – by 2021



Status: *Currently impaired, but showing overall water quality improvement.* ***Priority:*** *Moderate*

Lake May

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	▲	▲	▲	▲	✓	!	✓	● 2.4

Lake Stats	
Surface Area (acres)	50.5
Volume (m^3)	241,790
Avg. 2019 Surface Level (NGVD29)	131.9
Avg. Depth (feet)	5.28
Drainage Basin Area (acres)	301.8
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake May receives stormwater runoff from **6** urban drainage sub-basins with a high proportion of commercial land uses. As a result its pollutant loads are moderate-to-high compared to others in the study area. Lake May alternates between being co-limited and phosphorus limited, therefore the map above depicts annual Total Phosphorus (TP) loads of each sub-basin. Despite the higher TP loadings, there are multiple public and private best management practices (BMPs) in place to mitigate them. City BMPs include alum treatment, street sweeping, and green infrastructure.

Historic Point-source Pollutant Loading:

Lake May received historic point-source discharges from multiple entities. Until 1949, the Imhoff Wastewater Treatment facility discharged to the lake. May also received agricultural and food waste until an undocumented point in time. These sources may be contributing to internal nutrient loading which may currently be impacting water quality.

Invasive Species Treatment:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake May since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Large-scale hydrilla treatments ramped up around 2010, but have dropped back down to spot treatments. As of 2019, hydrilla and water hyacinths make up roughly 5% of all plants sampled in Lake May.

Best Management Practices

Existing Best Management Practices

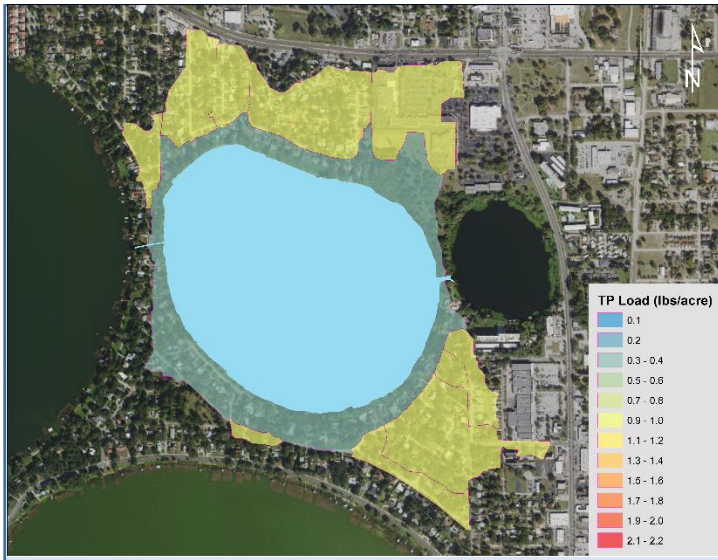
- Alum Treatment: Injection points in three of the eastern sub-basins treat much of the phosphorus load. At the time of construction, the alum treatment reduced up to 90% of TP loads in those sub-basins; however this system is in need of maintenance/repair.

- Street Sweeping: **10.8** miles of downtown, residential, and arterial roads are swept on a monthly basis in all but one sub-basin.

- Green Infrastructure: As part of a road improvement project for 7th Street SW, roadside swales were constructed to trap and infiltrate stormwater. Raingardens have also been constructed at the City's Utility Office.

Future Management Strategies

- Repair alum infrastructure and evaluate treatment effectiveness – by end of 2021
- Develop plan to expand street sweeping service to untreated basin – by end of 2020
- Develop plan to evaluate internal load from legacy sediments
  - Factor in long-term goals for muck removal project
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Not currently impaired; showing overall water quality improvement.* ***Priority:*** *Low*

Lake Mirror

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✔	✔	✔	▲	▲	▲	▲	✔	!	✔	2.6

Lake Stats	
Surface Area (acres)	130.1
Volume (m^3)	1,737,103
Avg. 2019 Surface Level (NGVD29)	131.6
Avg. Depth (feet)	8.86
Drainage Basin Area (acres)	152.8
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Mirror receives stormwater from **11** distinct drainage sub-basins. Medium-density residential land uses make up the majority of these basins and so they contribute moderate pollutant loading. Since phosphorus is the limiting nutrient in this waterbody, the map above depicts annual Total Phosphorus (TP) loads from each basin in lbs/acre. The residential land uses in this drainage basin make it difficult to implement structural best management practices (BMPs), however the City has implemented non-structural initiatives like street sweeping to mitigate pollutant loading.

Invasive Species Treatment:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake May since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Within the last 10 years, the treatment of hydrilla has been the primary focus. In 2019, however, water hyacinths and burhead sedge made up the majority of invasive species sampled; the percentage of all invasives found totaled approximately **3%** of the aquatic plants surveyed in Lake Mirror.

Best Management Practices

Existing Best Management Practices

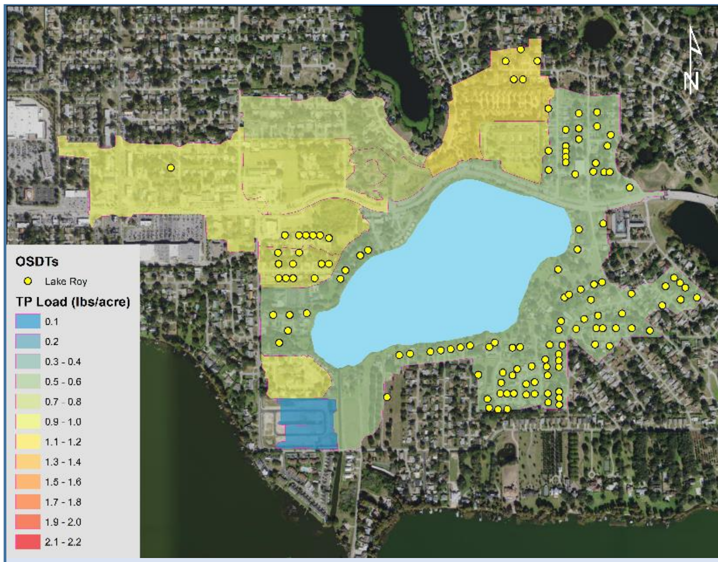
- Street Sweeping: **3.75** miles of downtown and residential roads are swept on a monthly basis in Lake Mirror's drainage basin.

- Stormwater Assessment & Improvement Project (SAIP): Identified priority area within the southeastern basins where green infrastructure could be implemented to reduce flooding and improve water quality.

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Mirror since 2017. This has allowed for the early detection of invasives to mitigate their spread and reduce the need for large-scale treatment.

Future Management Strategies

- Budget for/pursue funding for SAIP priority site improvements in southern drainage basin – by 2021
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Not currently impaired; showing overall water quality improvement.* ***Priority:*** *Low*

Lake Roy

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	▲	▲	▲	✓	✓	!	● 2.5

Lake Stats	
Surface Area (acres)	74.3
Volume (m^3)	1,311,358
Avg. 2019 Surface Level (NGVD29)	131.8
Avg. Depth (feet)	10.76
Drainage Basin Area (acres)	281.8
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Roy receives stormwater runoff from **13** distinct drainage sub-basins. Residential land uses surround the majority of the lake, however there is a larger proportion of commercial land uses to the northwest. Since phosphorus is the limiting nutrient in this waterbody, the above map depicts the annual Total Phosphorus (TP) load in lbs/acre for each sub-basin. Basins to the north and west contribute moderate TP loads. There are various private and public best management practices BMPs implemented within the watershed. The City has instituted street sweeping and green infrastructure in the areas within municipal boundaries.

Onsite Sewage Treatment & Disposal (OSTD):

There are **125** known OSTDs in Lake Roy's drainage basin (depicted as yellow points) which is at a moderate density. These systems can potentially contribute excess nutrient loads via groundwater leaching.

Invasive Species Management:

While current populations aren't at concerning levels, hydrilla has long been a frequent invader within Lake Roy. The Florida Fish and Wildlife Commission (FWC) has been documenting the treatment of hydrilla in this waterbody since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Within the last 10 years, there have been several larger herbicide applications in Lake Roy ranging from 30% to 50% of the entire lake's area. As of 2019, the percentage of hydrilla only made up 2% of all aquatic plants surveyed—down from 13.5% in 2018.

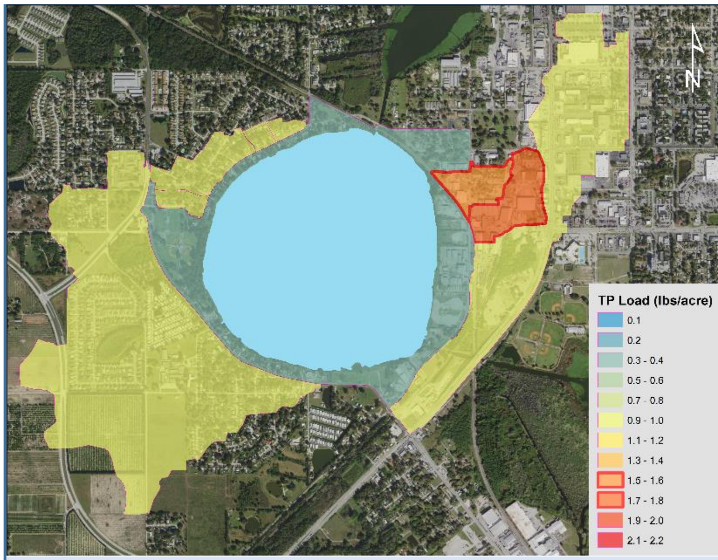
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **8.2** miles of residential and arterial roads are swept on a monthly basis in Lake Roy's drainage basin.
- Green Infrastructure: The City constructed a series of bioswales/raingardens along 6th Street in Lake Roy's westernmost sub-basin. These capture road runoff during storm events—preventing it from entering storm drains and subsequently the receiving waterbody.
- Stormwater Assessment & Improvement Project (SAIP): Identified priority area within the westernmost basin where green infrastructure could be implemented to reduce flooding and improve water quality.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Roy since 2017. This has allowed for the early detection of invasives to mitigate their spread and reduce the need for large-scale treatment.

Future Management Strategies

- Budget for/pursue funding for SAIP priority site improvements in southern drainage basin – by 2021
- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Currently impaired, but showing overall water quality improvement.* **Priority:** *Moderate*

Lake Shipp

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
⊗	⊗	⊗	▲	▲	▲	▲	✔	!	!	● 2.1

Lake Stats	
Surface Area (acres)	279.4
Volume (m^3)	2,521,861
Avg. 2019 Surface Level (NGVD29)	131.9
Avg. Depth (feet)	7.25
Drainage Basin Area (acres)	631.7
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Shipp receives stormwater from **9** distinct drainage sub-basins. A large proportion of the eastern basins are composed of commercial and industrial land uses which impart a relatively higher pollutant load. Since the limiting nutrient in Lake Shipp is phosphorus, the above map depicts annual Total Phosphorus (TP) loads of each sub-basin in lbs/acre. The City has implemented best management practices (BMPs) to address the majority of these loads. The basins outlined in red contribute the highest loading rates, but they do possess private BMPs to mitigate those loads.

Historic Point-source Pollutant Loading:

Records indicate that Lake Shipp received point-source discharges from at least two agricultural processing facilities. The point at which these discharges ended is not documented however. Regardless, these historic discharges may be contributing to internal nitrogen and phosphorus loading which can currently impact water quality.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Shipp since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Since 2010, only one large-scale treatment took place where over 30% of the total lake's surface area was treated. In 2019, hydrilla and water hyacinth made up roughly **7%** of all aquatic plants surveyed.

Best Management Practices

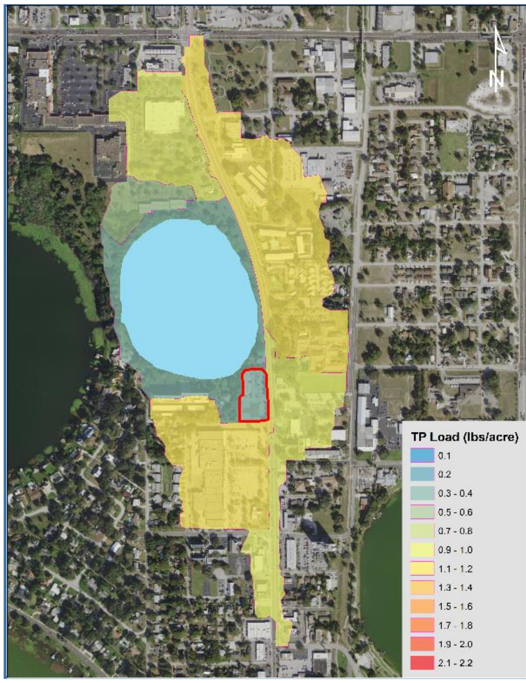
Existing Best Management Practices

- Street Sweeping: **9.1** miles of residential and arterial roads are swept on a monthly basis in Lake Shipp's drainage basin.

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Shipp since 2017. This has allowed for the early detection of invasives to mitigate their spread and reduce the need for large-scale treatment.

Future Management Strategies

- Explore expansion of street sweeping service to additional areas– by end of 2020
- Develop plan to evaluate internal load from legacy sediments
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Spring Lake

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	▲	▲	▲	✓	!	✓	● 2.8

Status: *Not currently impaired; showing overall water quality improvement.*

Priority: *Low*

Lake Stats	
Surface Area (acres)	25.2
Volume (m^3)	378,599
Avg. 2019 Surface Level (NGVD29)	131.5
Avg. Depth (feet)	9.02
Drainage Basin Area (acres)	96.1
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Spring Lake receives stormwater from **7** distinct drainage sub-basins. Commercial land uses make up the majority of area within these basins. As a result, raw pollutant loading is moderately high. Spring Lake is co-limited by nitrogen and phosphorus, however loading rates are proportional in the majority of sub-basins. Regardless, pollutant mitigation should factor in both nutrients. To be consistent with other basin maps, the above depicts annual Total Phosphorus (TP) loading from Spring Lake's basins in lbs/acre. The City has implemented best management practices such as street sweeping in the majority of Spring's basins. The commercial basin, outlined in red, has no documented stormwater mitigation; albeit the TP load is relatively low and the parcels within the basin are privately owned.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Shipp since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Over the last 10 years, management of invasive plants has been an ongoing battle, with hydrilla receiving the greatest share of treatment. While 2019 saw a decrease in hydrilla populations, burhead sedge and water hyacinth increased in number. The percentage of invasives in 2019 made up approximately **7%** of all plants surveyed.

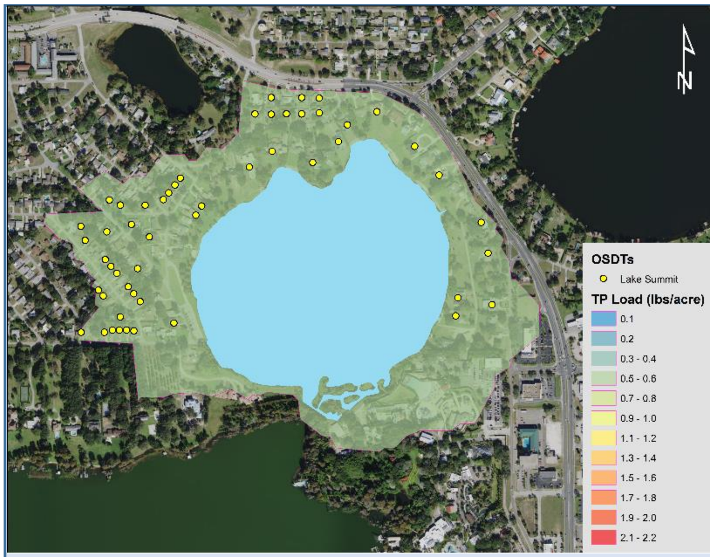
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **3.4** miles of downtown, residential, and arterial roads are swept on a monthly basis in Spring Lake's drainage basin.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Spring Lake since 2017. This has allowed for the early detection of invasives to mitigate their spread and reduce the need for large-scale treatment.

Future Management Strategies

- Determine if alleged untreated basin does possess regulated stormwater BMPs – by end of 2020
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Not currently impaired; showing improving water quality trends.* ***Priority:*** *Low*

Lake Summit

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	▲	−	▲	✓	✓	✓	2.6

Lake Stats	
Surface Area (acres)	67.4
Volume (m^3)	1,110,163
Avg. 2019 Surface Level (NGVD29)	132.0
Avg. Depth (feet)	10.71
Drainage Basin Area (acres)	99.1
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Located mostly outside of City limits, Lake Summit lacks much stormwater infrastructure. As a result, its drainage basin is relatively small and possesses no sub-basins. Since phosphorus is the limiting nutrient in this waterbody, the above map depicts annual Total Phosphorus (TP) loading in lbs/acre. Residential land uses comprise almost the entirety of the drainage basin which contribute to a moderately-low areal TP load compared to other lakes in the study area. Aside from Legoland's regulatory requirements for stormwater mitigation, there are no documented stormwater best management practices in this watershed.

Onsite Sewage Treatment & Disposal (OSTD):

The **52** septic systems (depicted as yellow points) are in Lake Summit's drainage basin are at a moderate density. These systems can potentially contribute excess nutrient loads via groundwater leaching.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Summit since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Throughout this time period, the level of invasives management has varied considerably. While hydrilla has been the primary focus of treatment efforts, it has remained in check since the City began its management efforts. In 2019, hydrilla made up only **2.4%** of all aquatic plants surveyed in Lake Summit.

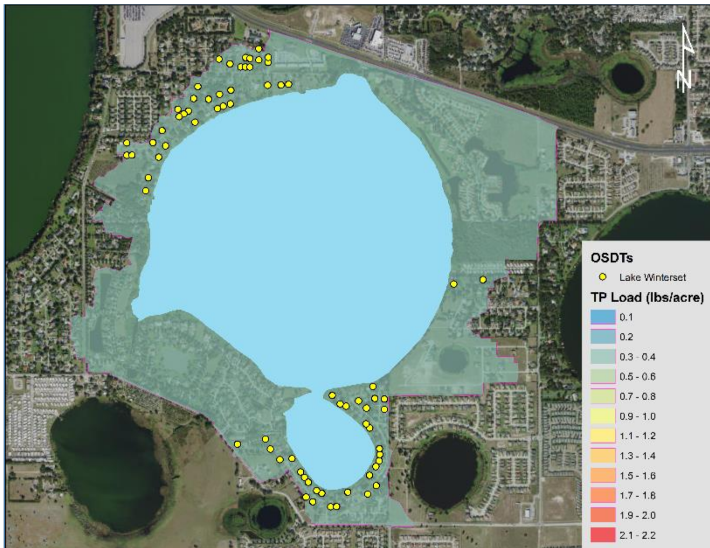
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Summit since 2017. This has allowed for the early detection of invasives to mitigate their spread and reduce the need for large-scale treatment.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Not currently impaired; showing overall water quality improvement.* **Priority:** *Low*

Lake Winterset

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	▲	▲	▲	✓	✗	✓	2.6

Lake Stats	
Surface Area (acres)	555.5
Volume (m^3)	12,499,617
Avg. 2019 Surface Level (NGVD29)	131.8
Avg. Depth (feet)	14.26
Drainage Basin Area (acres)	519.1
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Due to a lack of stormwater infrastructure, Lake Winterset receives runoff from a relatively small drainage basin. The majority of this area consists of residential developments which have implemented required stormwater mitigation best management practices (BMPs). Since phosphorus is the limiting nutrient in this waterbody, the above map depicts the annual Total Phosphorus (TP) load in lbs/acre. Lake Winterset's TP loading rate is comparatively low considering the entirety of the study area. The majority of this basin falls outside Winter Haven boundaries which limits the City's ability to implement stormwater mitigation BMPs.

Onsite Sewage Treatment & Disposal (OSTD):

The **71** septic systems (depicted as yellow points) are moderately dense in Lake Winterset's drainage basin. These systems can potentially contribute excess nutrient loads via groundwater leaching.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Winterset since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Throughout this time period, the overall treatment intensity has been low (<20% of the total lake area per year). However, Winterset did receive a whole-lake hydrilla treatment in 2016. This seems to have been only moderately effective as hydrilla made up roughly **10%** of the plant community in 2019.

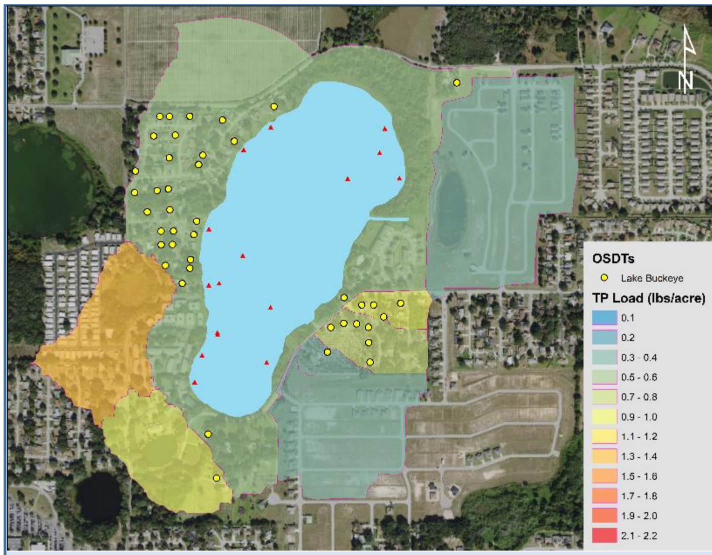
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Winterset since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Not currently impaired; showing overall water quality improvement.* ***Priority:*** *Low*

Lake Buckeye

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	▲	▲	▲	✓	✗	✓	2.5

Lake Stats	
Surface Area (acres)	72.4
Volume (m^3)	603,451
Avg. 2019 Surface Level (NGVD29)	128.1
Avg. Depth (feet)	6.73
Drainage Basin Area (acres)	233.6
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Buckeye receives stormwater runoff from **8** distinct drainage sub-basins. Residential land uses surround the majority of this waterbody, however it does receive runoff from agricultural land uses from the north. Since phosphorus is the limiting nutrient in this waterbody, the above map depicts the annual Total Phosphorus (TP) load in lbs/acre. Pollutant loading within these basins varies from low to moderately high. Most possess some form of stormwater best management practice (BMP) such as street sweeping or retention ponds.

Onsite Sewage Treatment & Disposal (OSTD):

There are **42** septic systems (depicted as yellow points) within Lake Buckeye's drainage basin. OSTDs can contribute excess nutrients via groundwater leaching and could be considered a potential loading source.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Buckeye since the early 2000s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. On the whole, invasives have been controlled via spot treatments, however there has been at least one whole-lake treatments, however there has been at least one whole-lake treatment in 2013. The primary species of concern is hydrilla which made up roughly **25%** of Lake Buckeye's plant community in 2019. The red points depicted in the above map show where invasive species were recorded during 2019's survey.

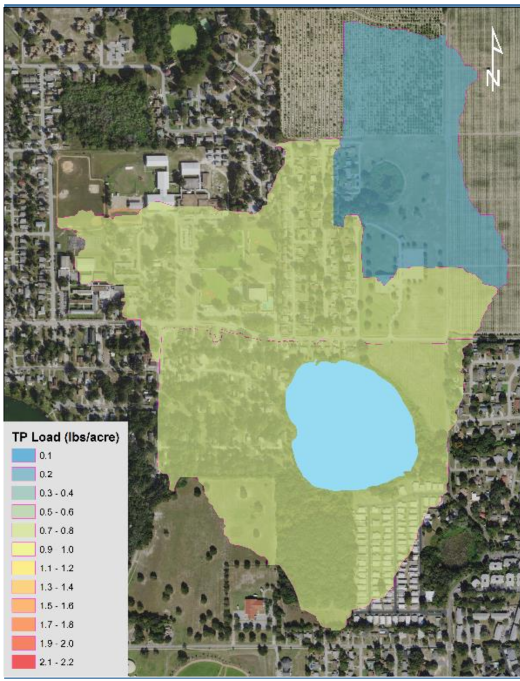
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Buckeye since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time. While hydrilla remains in high abundance, it has undergone a decrease since 2018.
- Street Sweeping: **3.3** miles of residential and arterial roads are swept on a monthly basis in Lake Buckeye's drainage basin.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Lake Idyl

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
⊗	⊗	⊗	▬	▬	▬	▬	!	!	!	● 1.0

Status: *Currently impaired and not showing any water quality improvement.*
Priority: *High*

Lake Stats	
Surface Area (acres)	19.0
Volume (m^3)	133,383
Avg. 2019 Surface Level (NGVD29)	132.4
Avg. Depth (feet)	6.07
Drainage Basin Area (acres)	179.5
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Idyl receives stormwater from **3** distinct drainage sub-basins. Land uses within these basins are primarily residential and some agricultural/open lands. While eutrophication in this lake may be limited by nitrogen and phosphorus, their relative loading rates are proportional. As such, the map above depicts annual Total Phosphorus (TP) loading in lbs/acre from each sub-basin. The two sub-basins with residential land uses contribute moderate TP loading rates; however these basins also possess stormwater mitigating best management practices (BMPs) such as street sweeping and retention ponds. Despite this, more could be done to reducing pollutant loads in an effort to improve water quality.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species spot treatment in Lake Idyl since 2015. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Water hyacinths and other emergent species have been the primary issues in this waterbody. Since Lake Idyl is relatively small, invasive species can quickly take over which makes early detection and rapid treatment response all the more critical. In 2019, Idyl saw an increase in burhead sedge which made up roughly **9%** of all species surveyed.

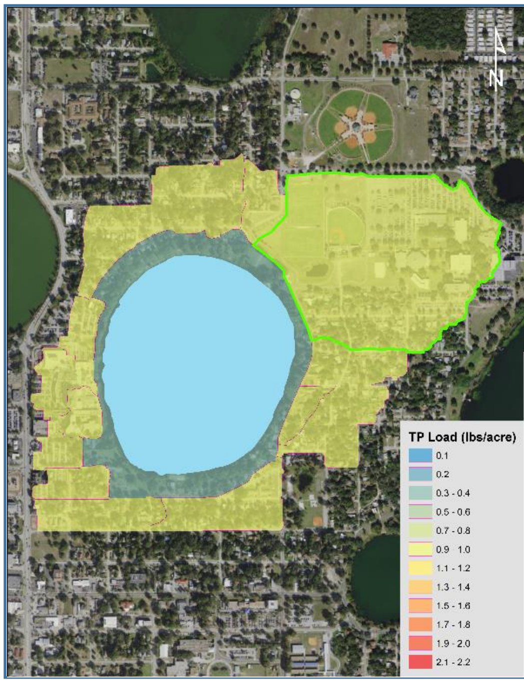
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **1.9** miles of residential and arterial roads are swept in Lake Idyl's drainage basin on a monthly basis.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Idyl since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time.
- Stormwater Assessment & Improvement Project (SAIP): Identified priority area within the northern residential basin where green infrastructure could be implemented to reduce flooding and improve water quality.

Future Management Strategies

- Budget for/pursue funding for SAIP priority site improvements in northern high-loading drainage basin – by 2021
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Lake Martha

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✔	✔	✔	▼	▼	▼	▼	!	✔	✔	○ 1.1

Status: *Not currently impaired, but showing rapid water quality degradation.*
Priority: *Moderate-High*

Lake Stats	
Surface Area (acres)	82.5
Volume (m^3)	1,408,454
Avg. 2019 Surface Level (NGVD29)	141.6
Avg. Depth (feet)	10.21
Drainage Basin Area (acres)	224.4
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Martha receives stormwater from **14** distinct drainage sub-basins. Residential and recreational land uses make up the majority of these basins and impart a moderate nutrient load. While water quality degradation may be limited by nitrogen and phosphorus, their relative loading rates are proportional. As such, the map above depicts annual Total Phosphorus (TP) loading in lbs/acre from each sub-basin. These loads are mitigated by various best management practices (BMPs), including street sweeping and stormwater ponds. All sub-basins possess some form of treatment.

Lack of Aquatic Vegetation:

For its morphology and sediment characteristics, Lake Martha possesses very little submerged aquatic vegetation abundance. Due to the ability of macrophytes to buffer against changes in nutrient concentration by adsorbing excess nitrogen and phosphorus, a lack of emergent and/or submerged vegetation can lead to a rapid decline in water quality; which appears to be taking place based on recent water quality trends.

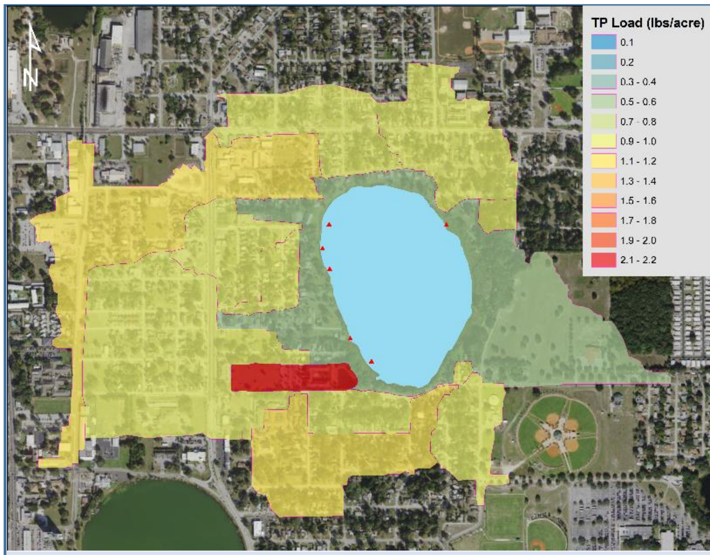
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **7.5** miles of residential and arterial/collector roads are swept in Lake Martha's drainage basin on a monthly basis.
- Floating Treatment Wetland: The City implemented an experimental floating wetland to mitigate some of the pollutant loads from the large eastern sub-basin outlined in green in the map. While floating wetland effectiveness is good in ponds and small lakes, their application in larger waterbodies has not been studied in-depth.

Future Management Strategies

- Explore aquatic vegetation planting and/or larger-scale floating wetland applications in Lake Martha



Status: *Not currently impaired; showing improving water quality trends.* ***Priority:*** *Low*

Lake Maude

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	▲	▬	▲	✓	✗	✗	● 2.1

Lake Stats	
Surface Area (acres)	51.0
Volume (m^3)	509,872
Avg. 2019 Surface Level (NGVD29)	139.9
Avg. Depth (feet)	8.18
Drainage Basin Area (acres)	333.5
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Maude receives stormwater from **14** distinct drainage sub-basins. Residential and recreational land uses make up the majority to the north, south, and east, however there is a higher proportion of commercial land uses to the west of the lake. While water quality degradation may be limited by nitrogen and phosphorus, their relative loading rates are proportional. As such, the map above depicts annual Total Phosphorus (TP) loading in lbs/acre from each sub-basin. The majority of sub-basins contribute moderate TP loads with one outlier in red. Despite the overall higher pollutant loads, all basins possess some form of mitigating best management practice (BMP) such as street sweeping or stormwater ponds.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has no documented invasive species treatments in Lake Maude to date. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. 2019 is the first year since the City began annual surveys in which managed invasives have been detected. The abundance of burhead sedge expanded in 2019 to make up over **10%** of all plants surveyed—depicted as red points on the map above.

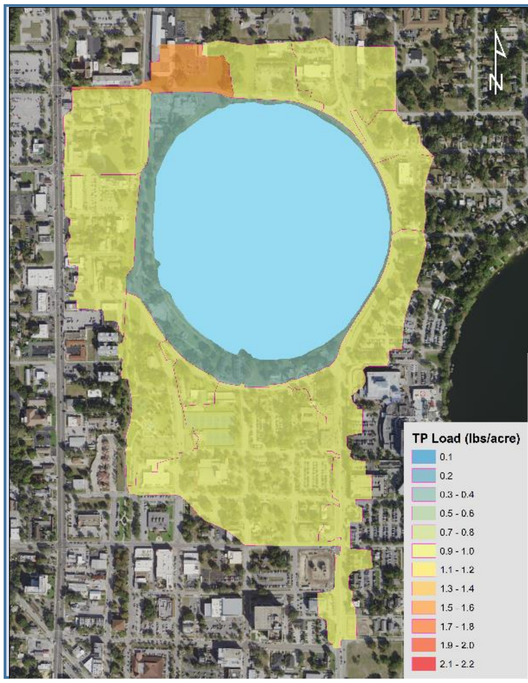
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **14.5** miles of residential and arterial/collector roads are swept in Lake Maude's drainage basin on a monthly basis.
- Green Infrastructure: Lake Maude Nature Park provides treatment through its natural wetland as well as constructed stormwater retention ponds.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Maude since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time.

Future Management Strategies

- Continue to budget for maintenance of Lake Maude Nature Park wetlands and stormwater basins each fiscal year
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Lake Silver

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✔	✔	✔	–	–	–	–	!	✔	✔	2.0

Status: *Not currently impaired, and not showing much change in water quality.*
Priority: *Low*

Lake Stats	
Surface Area (acres)	54.3
Volume (m^3)	1,282,954
Avg. 2019 Surface Level (NGVD29)	145.2
Avg. Depth (feet)	11.93
Drainage Basin Area (acres)	110.1
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Silver receives stormwater from **12** distinct urban drainage sub-basins. The primary land uses within this area are commercial, recreational and institutional which contribute moderate pollutant loading. The above map depicts annual Total Phosphorus (TP) load for each basin in lbs/acre. Despite water quality degradation in Silver being co-limited by nitrogen and phosphorus, their loading rates are proportional. Pollutant loading is mitigated by multiple private and public best management practices (BMPs) in the area. The City utilizes green infrastructure and/or street sweeping in each sub-basin.

Lack of Aquatic Vegetation:

For its morphology and sediment characteristics, Lake Silver possesses very little aquatic vegetation abundance. Due to the ability of macrophytes to buffer against changes in nutrient concentration by adsorbing excess nitrogen and phosphorus, a lack of emergent and/or submerged vegetation can lead to a rapid decline in water quality.

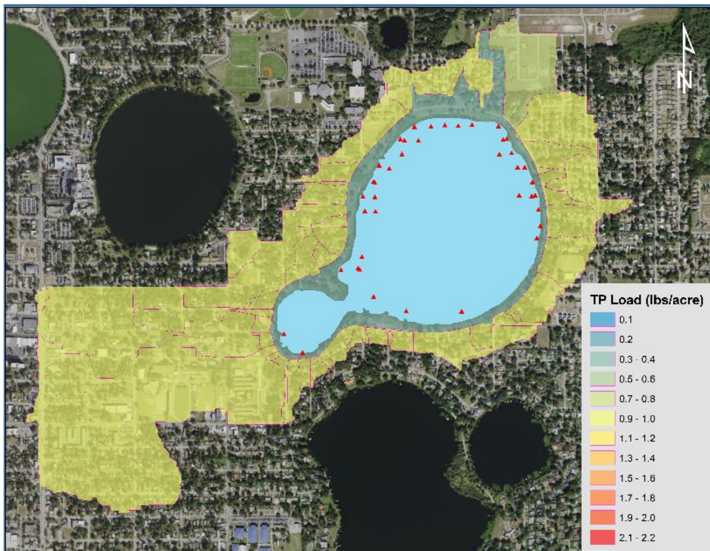
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **12.2** miles of downtown, residential, and arterial roads are swept in Lake Silver's drainage basin on a monthly basis.
- Green Infrastructure: **8** raingardens/exfiltration systems have been constructed in Lake Silver's drainage basin.

Future Management Strategies

- Explore aquatic vegetation planting and/or larger-scale floating wetland applications in Lake Martha
- Perform maintenance on existing raingardens to improve their effectiveness – by end of 2020



Status: *Not currently impaired, but showing some water quality degradation:* ***Priority:*** *Moderate-High*

Lake Elbert

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▼	▼	▬	▬	✓	✗	✓	● 1.3

Lake Stats	
Surface Area (acres)	165.8
Volume (m^3)	2,868,995
Avg. 2019 Surface Level (NGVD29)	134.7
Avg. Depth (feet)	11.28
Drainage Basin Area (acres)	439.8
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Elbert possesses a large stormwater drainage basin with **50** distinct sub-basins. Due to mostly residential land uses in the watershed, the pollutant loading rate is moderate compared with other basins in the study area. Since phosphorus is the nutrient limiting water quality degradation, the map above depicts annual Total Phosphorus (TP) loads for each sub-basin in lbs/acre. Stormwater mitigation best management practices (BMPs) including street sweeping, raingardens, and private retention ponds have been implemented so that all sub-basins possess some form of treatment.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Winterset since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Throughout this time period, the overall treatment intensity has been low (<20% of the total lake area per year). However, Winterset did receive a whole-lake hydrilla treatment in 2016. This seems to have been only moderately effective as hydrilla made up roughly **10%** of the plant community in 2019.

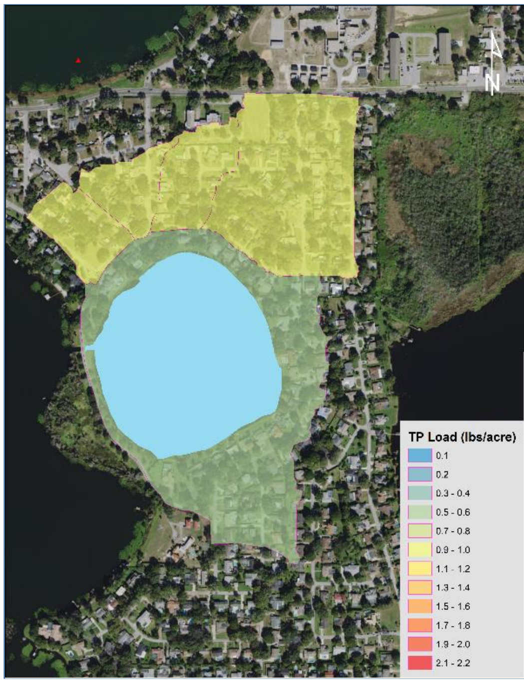
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **20.8** miles of downtown, residential, and arterial/collector roadways are swept in Lake Elbert's drainage basin on a monthly basis.
- Green Infrastructure: The City has constructed **2** raingardens that capture stormwater runoff along Lake Elbert's northern shoreline.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Elbert since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time.
- Stormwater Assessment & Improvement Project (SAIP): Identified priority area within the westernmost basin where green infrastructure could be implemented to reduce flooding and improve water quality.

Future Management Strategies

- Budget for/pursue funding for SAIP priority site improvements in southwestern drainage basin – by 2021
- Develop plan to perform cleanout/maintenance of raingardens – by end of 2020
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Lake Link

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✔	✔	✔	–	▲	–	–	NA	NA	NA	● 2.4

Status: *Not currently impaired; showing minor water quality improvement.*

Priority: *Low*

Lake Stats	
Surface Area (acres)	27.7
Volume (m^3)	317,016
Avg. 2019 Surface Level (NGVD29)	127.3
Avg. Depth (feet)	8.84
Drainage Basin Area (acres)	66.5
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

As one of the smallest lakes in the study area, Lake Link has a similarly sized stormwater drainage basin with only **5** distinct sub-basins. Surrounded exclusively by medium-density residential land uses, the pollutant loading to Lake Link is middle of the road compared with other lakes. With water quality degradation being proportionally limited by both nitrogen and phosphorus, the above map depicts annual Total Phosphorus (TP) loads from each sub-basin in lbs/acre. Pollutant loads from the four northern basins are mitigated through street sweeping, however most of the southern basin is outside City limits and not within the sweeper service area.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Link since 2008, with several large-scale treatments during this period. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Hydrilla has consistently been the primary target of treatment as it can quickly overwhelm this small waterbody, leaving it unnavigable. Due to the City's inability to access Lake Link due to extremely high water levels, a vegetation survey was not performed in 2019. However, the hydrilla population still remains a subject of concern to maintain lake health.

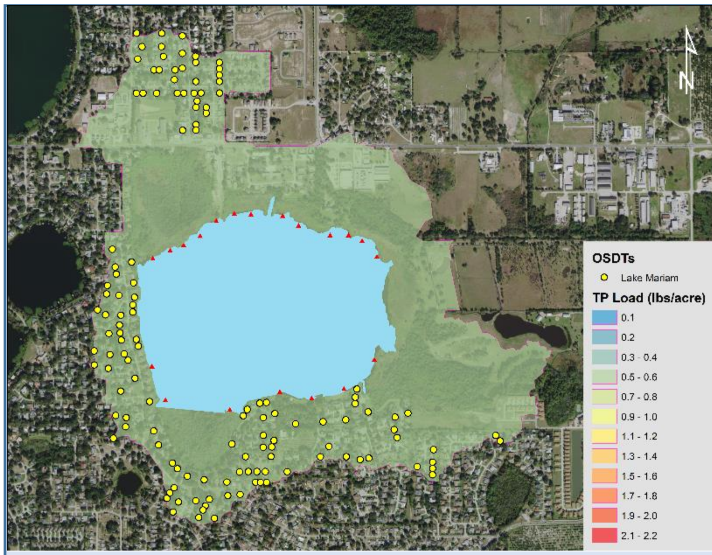
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **2.07** miles of residential and arterial roadways are swept in the Lake Link drainage basin on a monthly basis.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Link since 2017, but was unable to perform a survey in 2019. Lake Link's small size means that early detection and rapid response is critical to minimize treatment intensity.

Future Management Strategies

- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Not currently impaired and not showing any change in water quality trends.* ***Priority:*** *Low*

Lake Mariam

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✔	✔	✔	–	–	–	–	✔	✘	✔	1.9

Lake Stats	
Surface Area (acres)	203.7
Volume (m^3)	1,012,607
Avg. 2019 Surface Level (NGVD29)	124.6
Avg. Depth (feet)	4.65
Drainage Basin Area (acres)	418.4
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Due to a lack of stormwater infrastructure, Lake Mariam receives only direct stormwater runoff from its undivided drainage basin. Land uses within this basin vary from residential and commercial to the north, south, and west to agricultural and open lands to the east. The pollutant load from this basin is moderate and the City has implemented street sweeping as a best management practice within municipal limits (in the northern part of the basin). Nitrogen and phosphorus both limit the capacity for eutrophication, however their loading rates are proportional. In keeping with other lakes in this study area, the map above depicts the annual Total Phosphorus (TP) load to Lake Mariam in lbs/acre.

Onsite Sewage Treatment & Disposal (OSTD):

There are **132** known septic systems in Lake Mariam's drainage basin (depicted as yellow points in the above map). These OSTDs are relatively dense in the southern and western parts of the basin and may contribute to pollutant loading via groundwater leaching.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Mariam since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. While large-scale treatments have not taken place in this lake, both hydrilla and water hyacinth have been primary targets of spot treatments. Hydrilla has effectively been eliminated within the last 10 years, but hyacinths made up approximately 12% of the total plant population according to the 2019 survey (Invasive plant detections are depicted as red points in the above map).

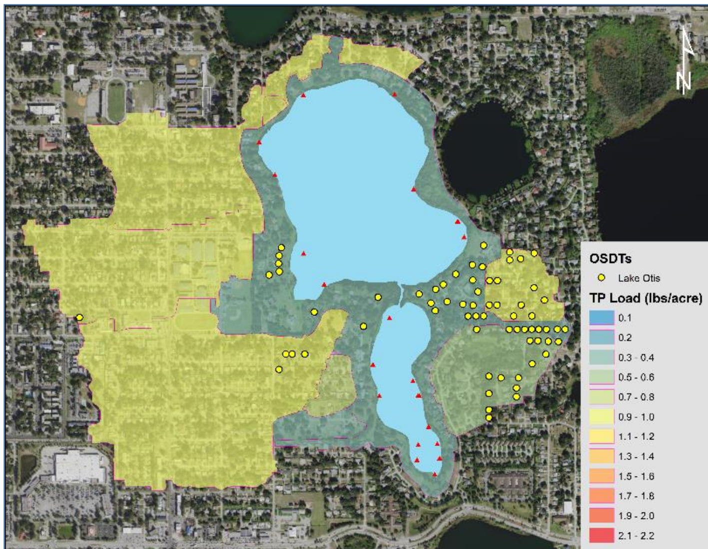
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **2.5** miles of arterial and residential roadways are swept within the northern part of Lake Mariam's drainage basin on a monthly basis.
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Mariam since 2017. Recent surveys indicate a resurgence of water hyacinths and a need for more targeted treatment.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Currently impaired for chlorophyll and not showing improving water quality trends.* ***Priority:*** *Moderate-Hiah*

Lake Otis

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✓	✓	–	–	–	–	✓	✗	✓	● 1.9

Lake Stats	
Surface Area (acres)	135.0
Volume (m^3)	2,121,504
Avg. 2019 Surface Level (NGVD29)	127.3
Avg. Depth (feet)	10.63
Drainage Basin Area (acres)	451.8
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Otis receives stormwater from **11** distinct drainage sub-basins. Much of the surrounding watershed is residential with the High School to the west contributing a decent proportion of institutional land use. The medium density residential and institutional areas to the west provide moderate pollutant loading while the lower density residential areas directly surrounding the lake contribute slightly lower nutrient loads. Nitrogen and phosphorus loading is proportional in this watershed, therefore the above map depicts the annual Total Phosphorus (TP) loads for each sub-basin in lbs/acre. The City has implemented best management practices to mitigate loading in each sub-basin.

Onsite Sewage Treatment & Disposal (OSTD):

The **66** septic systems (depicted as yellow points) are moderately dense in Lake Otis's drainage basin. These systems can potentially contribute excess nutrient loads via groundwater leaching.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Otis since 2008 with large scale treatments focused on hydrilla. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. 2019 saw a substantial decrease in hydrilla, however water hyacinth abundance exploded with their population making up roughly **12%** of the total surveyed vegetation community (shown as red points in the above map).

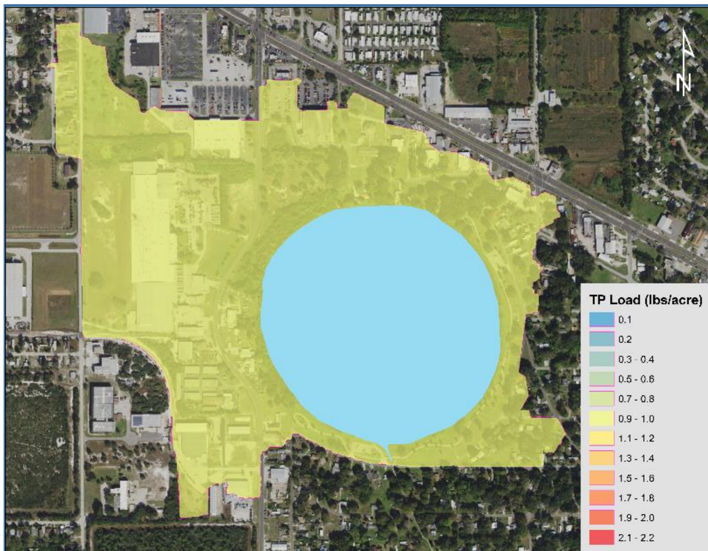
Best Management Practices

Existing Best Management Practices

- Street Sweeping: **8.7** miles of residential and arterial/collector roadways are swept in the Lake Otis drainage basin on a monthly basis.
- Green Infrastructure: A series of bioswales have been constructed by the City along 6th Street SE (within the southwestern drainage basin)
- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Otis since 2017. These surveys have allowed for the early detection and rapid treatment of invasives.
- Stormwater Assessment & Improvement Project (SAIP): Identified priority area within the westernmost basins where green infrastructure could be implemented to reduce flooding and improve water quality.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- Budget for/pursue funding for SAIP priority site improvements in western drainage basins – by 2021
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Currently impaired, but showing minor water quality improvement.* ***Priority:*** *Moderate-High*

Lake Blue

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
										1.9

Lake Stats	
Surface Area (acres)	54.3
Volume (m^3)	331,368
Avg. 2019 Surface Level (NGVD29)	147.5
Avg. Depth (feet)	4.57
Drainage Basin Area (acres)	128.0
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Located completely outside Winter Haven limits, Lake Blue has little stormwater infrastructure and receives direct runoff from the surrounding lands only. Industrial and commercial land uses are present to the west of the lake, while medium-density residential land use can be found to the southeast. Likely as a result of long-term untreated stormwater runoff from this basin, Lake Blue has poor water quality. Since phosphorus as the limiting nutrient, the above map depicts the annual Total Phosphorus (TP) load to Lake Blue in lbs/acre. There are no City implemented best management practices in place to mitigate stormwater loading.

Lack of Aquatic Vegetation:

Despite Lake Blue's morphology and benthic substrate, the water quality cannot support a robust littoral zone. Specifically, the clarity is too low for submerged plants to receive enough light beyond a depth of one or two feet. As a result, the ability for this lake to buffer against nutrient inflows is almost nonexistent. There is a moderate wetland fringe around this lake, however.

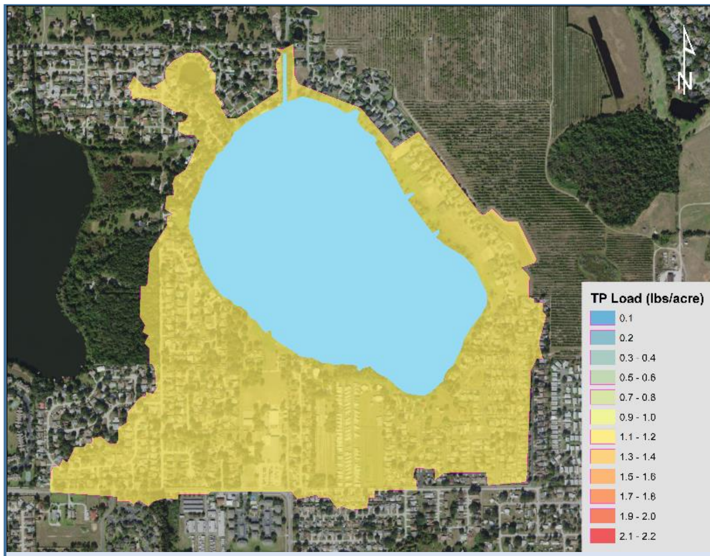
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring aquatic vegetation communities in Lake Blue since 2017. This is primarily to prevent the spread of invasive species, but it has shown that eel grass and other native species can and do grow in this waterbody.

Future Management Strategies

- Work with Polk County to develop a specialized management plan
    - Explore aquatic vegetation planting and/or larger-scale floating wetland applications
    - Conduct sediment analysis to determine if legacy nutrients are contributing to poor water quality
- The City will continue to work with the FWC to prevent the spread of invasive species if/when they are introduced to Lake Blue



Status: *Not currently impaired; showing minor water quality improvement.* ***Priority:*** *Low*

Lake Daisy

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▲	–	–	–	!	✓	!	2.1

Lake Stats	
Surface Area (acres)	137.3
Volume (m^3)	1,429,257
Avg. 2019 Surface Level (NGVD29)	128.9
Avg. Depth (feet)	8.41
Drainage Basin Area (acres)	219.4
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Daisy is bordered by City limits to the northeast, whereas the rest of its singular drainage basin is within unincorporated Polk County. Lacking significant stormwater infrastructure, Lake Daisy only receives direct runoff from the surrounding residential land uses. Nitrogen and phosphorus loading rates are proportional in this watershed, therefore the annual Total Phosphorus (TP) load was used to represent pollutant loading to Lake Daisy in lbs/acre (shown in the above map). Due to the large presence of medium-density residential lands in the basin, Lake Daisy receives moderately high pollutant loading. There are no documented best management practices in place to mitigate stormwater at this time.

Lack of Aquatic Vegetation:

Lake Daisy's morphology and water quality appears to be adequate to support a robust littoral zone, but there is very little submerged aquatic plant abundance. A lack of aquatic vegetation limits a waterbody's ability to buffer against the introduction of excess nutrients—eventually leading to a rapid decline in water quality. The FWC has not documented any herbicide application in this lake.

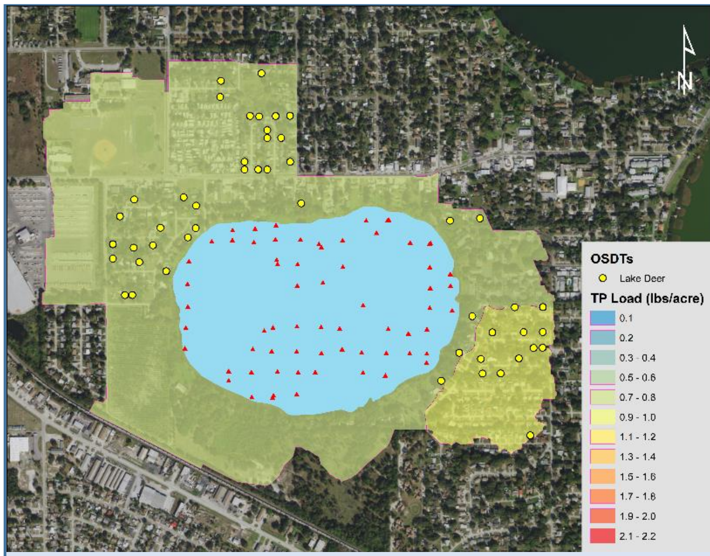
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Daisy since 2017. It is this monitoring effort that has allowed staff to determine that something is inhibiting the growth of aquatic plants in an adequate environment.

Future Management Strategies

- Conduct research into potential causes for this lack of vegetation such as biological control or other physical factors such as sediment type
- Work with Polk County to develop a management plant specifically targeting stormwater runoff in Lake Daisy's drainage basin
- The City will continue to work with the FWC to manage for invasive species should they become an issue in this waterbody



Status: *Currently impaired and not showing any improving water quality trends.* ***Priority:*** *High*

Lake Deer

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	–	–	–	–	✓	✗	!	1.5

Lake Stats	
Surface Area (acres)	116.9
Volume (m^3)	1,036,382
Avg. 2019 Surface Level (NGVD29)	138.3
Avg. Depth (feet)	7.60
Drainage Basin Area (acres)	260.5
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Deer receives stormwater runoff from **2** distinct drainage sub-basins. The larger basin contributes runoff from various land uses including residential, commercial, and open lands while the smaller basin to the east is exclusively residential. These basins produce moderate pollutant loading. The above map depicts annual Total Phosphorus (TP) loads from each basin in lbs/acre; TP was chosen as phosphorus is the primary nutrient limiting eutrophication in Lake Deer.

Onsite Sewage Treatment & Disposal (OSTD):

Lake Deer has **41** confirmed septic systems in its drainage basin (depicted as yellow points in the above map)—a moderate density compared with other lakes in the study area. OSTDs can contribute excess nutrients via groundwater leachate.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Deer since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Throughout this time period, hydrilla and water hyacinths have been the target of herbicide spot treatments. However, 2019 saw a massive hydrilla population explosion where this species made up **>55%** of all plants surveyed (depicted as red points in above map). This resulted in several large-scale treatments in 2019.

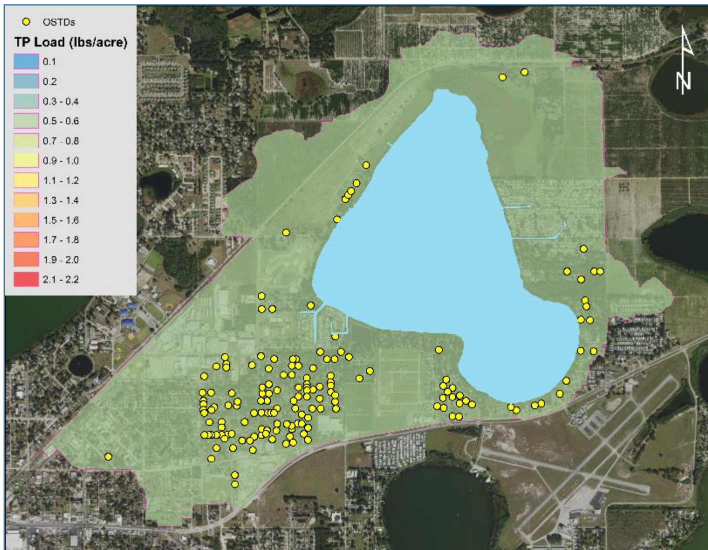
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Deer since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time. This hydrilla proliferation shows that even with regular monitoring, invasive species can rapidly expand.

Future Management Strategies

- Work with Polk County to develop a management plan specifically targeting stormwater runoff in Lake Deer's drainage basin
- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Status: *Currently impaired and showing some water quality degradation.* ***Priority:*** *High*

Lake Mariana

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✗	✗	✗	–	–	–	▼	✓	✓	✓	● 1.4

Lake Stats	
Surface Area (acres)	515.6
Volume (m^3)	6,449,864
Avg. 2019 Surface Level (NGVD29)	137.3
Avg. Depth (feet)	8.99
Drainage Basin Area (acres)	1417.6
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Due to a lack of documented stormwater infrastructure in the area, Lake Mariana's drainage basin has been delineated as one large direct runoff watershed. Land uses within this basin vary from residential, commercial, industrial, and agricultural/open lands. On the whole, the pollutant loading rate to Mariana is moderate compared to other lakes in the study area. The above map depicts the annual Total Phosphorus (TP) load to Lake Mariana in lbs/acre.

Onsite Sewage Treatment & Disposal (OSTD):

There are **158** septic systems within Lake Mariana's drainage basin (depicted as yellow points). These OSTDs are in higher density in the southwest part of the basin. Septic systems have the potential to leach excess nutrients to waterbodies via groundwater.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Mariana since the late 1990s. Large-scale treatment of invasive species can re-release excess nutrients back into the water column. The majority of herbicide applications on this lake have been minor spot treatments to combat the spread of hydrilla and water hyacinths. As of 2019, invasive species made up **<2%** of all plants surveyed—indicating the success of management efforts.

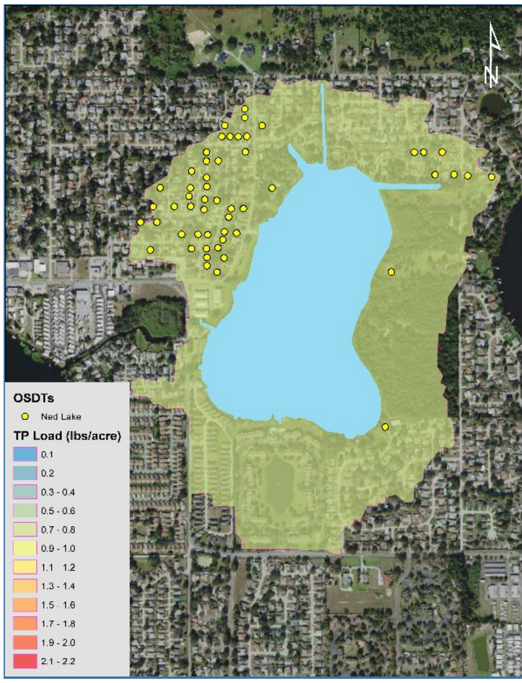
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Mariana since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate



Lake Ned

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▼	▬	▼	▼	!	!	✓	1.3

Status: *Not currently impaired, but showing significant water quality degradation.*

Priority: *Moderate-High*

Lake Stats	
Surface Area (acres)	76.4
Volume (m^3)	678,178
Avg. 2019 Surface Level (NGVD29)	128.0
Avg. Depth (feet)	7.17
Drainage Basin Area (acres)	180.6
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lake Ned is located completely outside of City limits and possess no known stormwater infrastructure draining directly to the lake. As a result, Lake Ned possesses a singular direct runoff drainage basin surround primarily by residential land uses; with some minor commercial land uses to the west. The pollutant load to Lake Ned is moderate as evidenced in the above map depicting the annual Total Phosphorus (TP) load in lbs/acre. Since Lake Ned is outside municipal limits, there are no City stormwater best management practices in place.

Onsite Sewage Treatment & Disposal (OSTD):

The **53** septic systems (depicted as yellow points) are moderately dense in the northwestern part of Lake Ned's drainage basin. These systems can potentially contribute excess nutrient loads via groundwater leaching.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Ned since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Large-scale hydrilla treatments were documented in 2012 with practically no treatment occurring since then. Since the City initiated vegetation monitoring in 2017, the vegetation abundance in Lake Ned has been very low. This lack of aquatic plants can impact this lake's ability to buffer against inflows of excess nutrients via stormwater—which appears to be taking place based on long-term water quality trends.

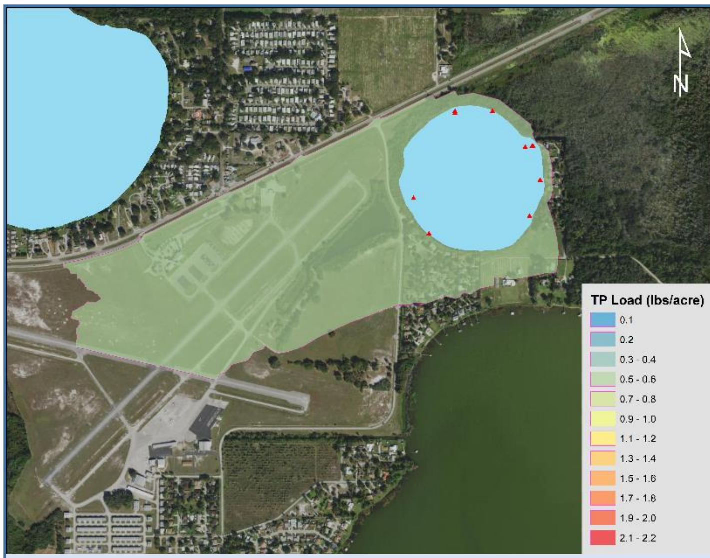
Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Ned since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time; however at this point, the City is more interested in promoting the return of submerged aquatic plants.

Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if human waste is a major contributor to excess nutrients
- Conduct research into potential causes for this lack of vegetation either due to water quality issues or past vegetation management efforts
    - Explore vegetation planting as a possible best management practice
- The City will continue to monitor aquatic vegetation communities to promote healthy plant populations



Status: *Not currently impaired, but showing minor water quality degradation.* ***Priority:*** *Moderate*

Lake Pansy

Lake Health Index (Scales from 0 - 3)										
NNC Impairment			WQ Trends				Aquatic Vegetation			Overall Score
Chla	TN	TP	Chla	TN	TP	Secchi	Abundance	Invasives	Diversity	
✓	✓	✓	▼	–	–	–	✓	!	✓	● 1.6

Lake Stats	
Surface Area (acres)	49.4
Volume (m^3)	489,708
Avg. 2019 Surface Level (NGVD29)	128.6
Avg. Depth (feet)	6.80
Drainage Basin Area (acres)	196.0
Limiting Nutrient	Co-Limited

Water Quality Impacts/Challenges

Stormwater Pollutant Loading:

Lacking much contributing stormwater infrastructure, Lake Pansy receives stormwater runoff from a relatively small drainage basin. To the west is the Winter Haven airport which has best management practices on site to treat stormwater prior to discharging to the lake, while the residential area to the south possess little-to-no treatment. On the whole, the pollutant load to Lake Pansy is relatively low. The above map depicts the annual Total Phosphorus (TP) load to the lake in lbs/acre. While both nitrogen and phosphorus contribute to water quality degradation, TP was selected for display since loading rates are proportional to nitrogen.

Invasive Species Management:

The Florida Fish and Wildlife Commission (FWC) has documented invasive species treatment in Lake Pansy since the late 1990s. Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. Hydrilla, water hyacinth, and burhead sedge have been the primary species targeted with herbicides, with large-scale hydrilla treatments occurring in 2005 and 2011. Since 2011, only spot treatments have been conducted. 2019 saw an increase in the abundance of these invasives with their populations making up nearly **10%** of all species surveyed (depicted as red points in the above map).

Best Management Practices

Existing Best Management Practices

- Aquatic Vegetation Management: The City has been monitoring vegetation communities in Lake Pansy since 2017. The goal is to detect the spread of invasives early to reduce the amount of treatment needed at one time.

Future Management Strategies

- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate