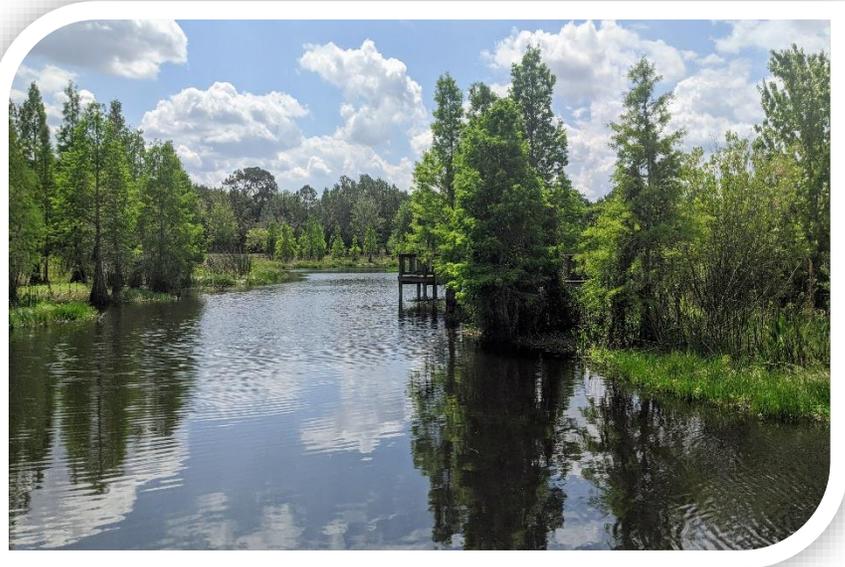


**WINTER HAVEN**  
*The Chain of Lakes City*

2020

# 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

**A**s the Chain of Lakes City, Winter Haven's economic, cultural, and ecologic identity is inextricably tied to the health of its more than 50 area 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. Starting in the 2018 report, Winter Haven Natural Resources staff developed an evaluation methodology based on water quality, hydrologic, and biological metrics to track comprehensive health of our lakes over time. This integrated, data-driven approach allows for objective prioritization and implementation of best management practices 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 utilized 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 2019 to 2020 can be found on pages 95 - 98. The average lake health score decreased slightly from 1.9 in 2019 to 1.85 in 2020. A review of the individual lake health index values showed that 41% of the lakes saw improving scores while 59% exhibited decreasing scores from 2019 to 2020. Further analysis showed that a decline in aquatic plant diversity, not water quality degradation, was the primary driver of the decrease in lake health scores.

**Water Quality:** Currently, 46% of lakes are meeting regulatory water quality targets with over 40% of the lakes exhibiting significant improving trends in chlorophyll-a, total nitrogen, total phosphorus, and water clarity. Many of the impaired lakes are slowly climbing back toward unimpaired status; with only a few exhibiting declining water quality trends.

**Hydrology:** Winter Haven received approximately 47 inches of rainfall in 2020—slightly below the 51.6 inch average. Despite this, most lake levels remained relatively high (pp. 40, 52, 64, 75, & 86). For many of these lakes, levels correlate directly with the water quality parameters. The consistently high lake levels are likely a contributing factor toward improving water quality.

**Aquatic Biology:** Comparing biological index scores from 2019 to 2020 showed that overall aquatic vegetation abundance remained static while the presence of invasive species decreased. This is indicative of successful management efforts for nuisance plants like hydrilla and water hyacinth. That said, species diversity values decreased on the whole. While some of the decreases in species richness and evenness could be attributed to invasive species death, there are many lakes with declining diversity values

that did not undergo invasive plant management in 2020. This decline is not wholly understood at the moment and is something that will require continued study to fully grasp the causes and impacts.

The City employs various structural and non-structural best management practices aimed at improving lake health. Some noteworthy projects that underwent considerable progress include construction of the Lake Conine Wetland (p. 109), the Gray to Green initiative (p. 113), and repairs/updates to the City's alum systems (p. 105). The Lake Conine wetland has been designed to treat stormwater runoff from a 400 acre drainage basin and is scheduled to be completed by late 2021. The Gray to Green initiative is an educational program that provides local developers with the tools they need to prioritize and implement green infrastructure on their sites. This project will be wrapping up by mid-2021. Finally, the City hired contractors to inspect and begin repairs on our 3 aging alum systems which help to neutralize pollutants before they can impact the lakes. Repairs should be completed by mid-2021. Obviously, COVID-19 has reduced Natural Resource's ability to conduct many education and outreach initiatives. Pending relaxation of social distancing guidelines, there are plans to ramp these programs back up in 2021 with the kickoff of kayak lake tours and other educational events.

One of the major additions debuted as part of the 2019 report was an online version complete with interactive charts, graphics, and photos. Due to its successful reception, this format is making a return for the 2020 report. You can reach the interactive report via the following link: [www.tinyurl.com/wh-fl-lakesreport-app](http://www.tinyurl.com/wh-fl-lakesreport-app)

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

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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

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# 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 has 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

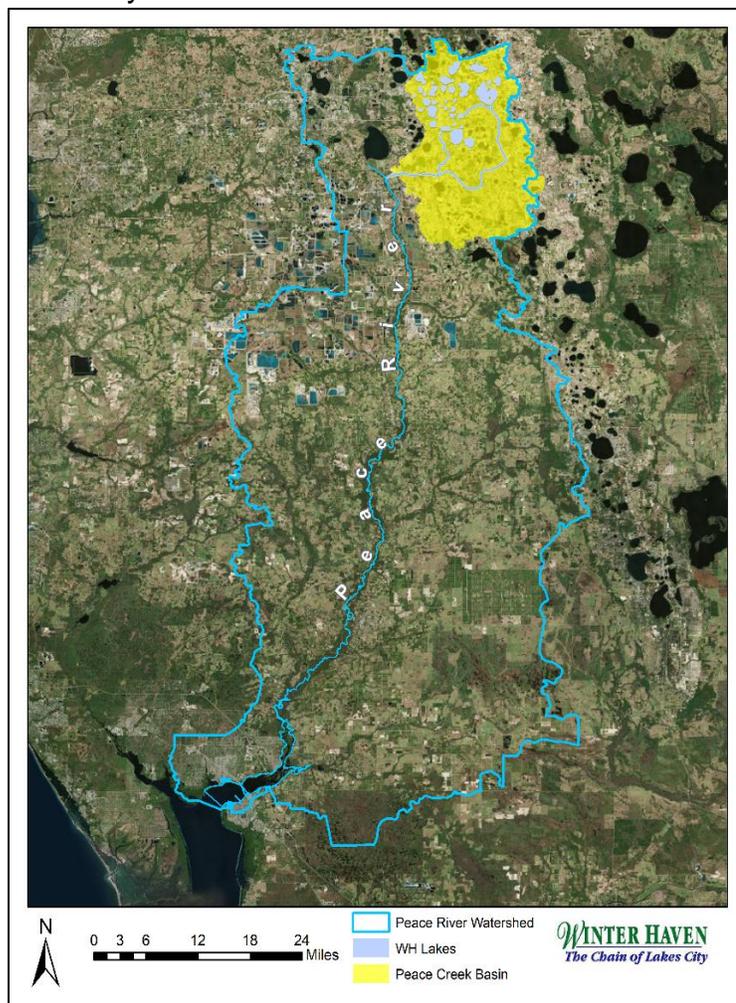


Figure 1-1. Map of Peace River & Peace Creek Watersheds

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 a 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 of 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.

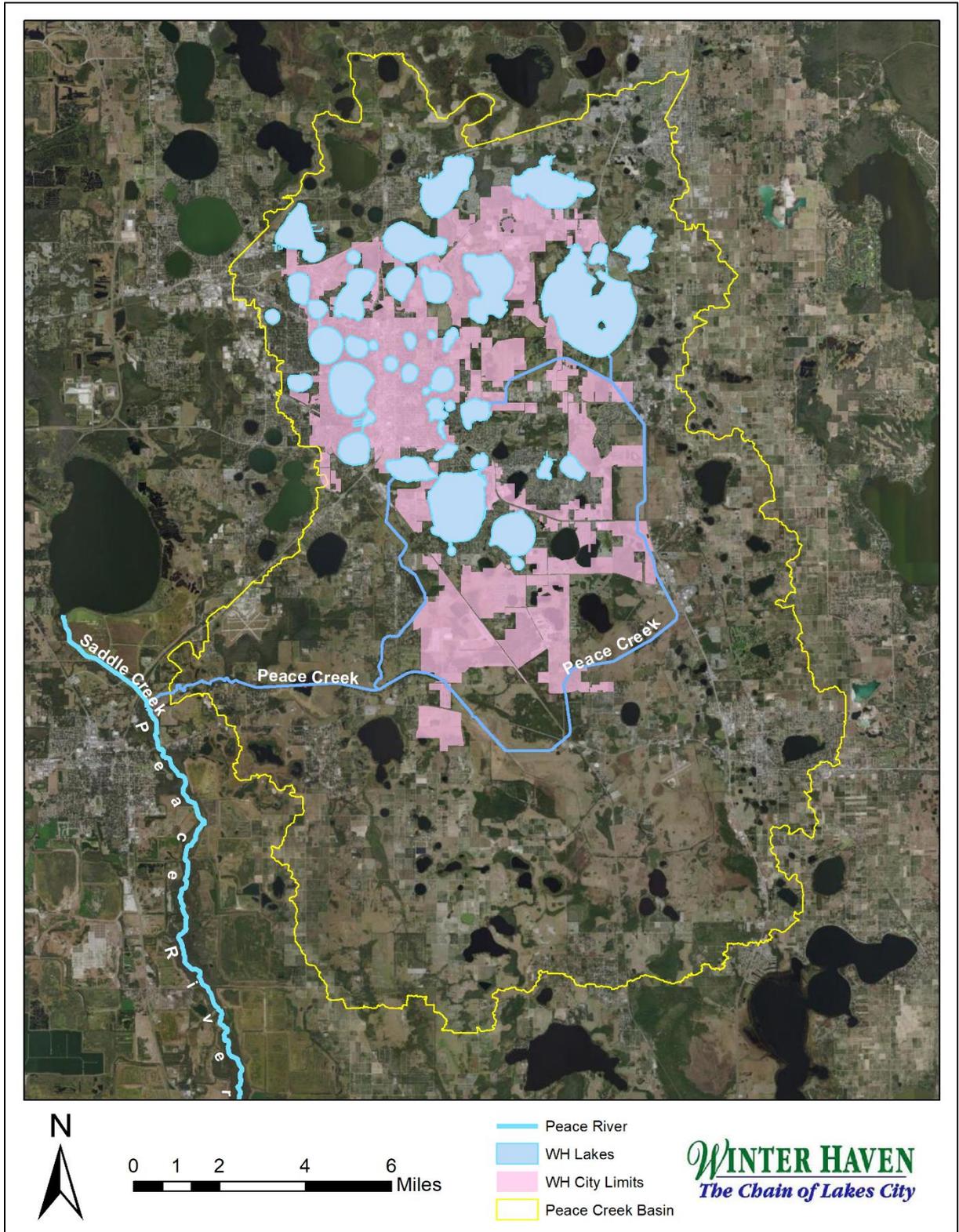


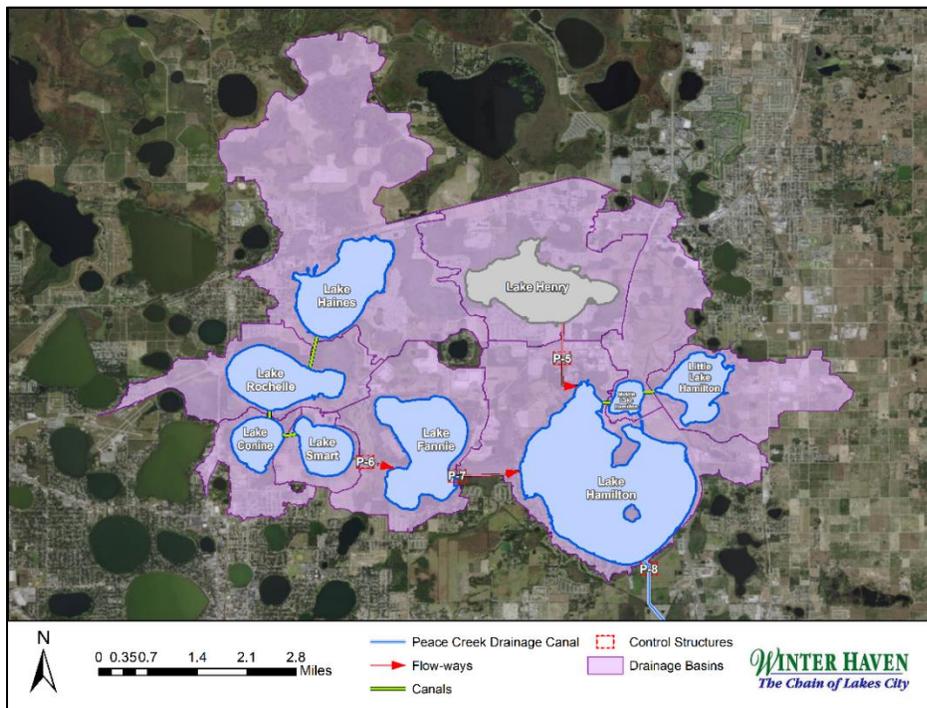
Figure 1-2. Map of the Peace Creek sub-basin, City of Winter Haven limits, contributing lakes and flow-ways.

*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 North Chain, which is located toward the outskirts of the Winter Haven area, 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 [15]. 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.



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 widely considered a recreational destination in Central Florida. This chain 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 [8]. 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; traveling south until it joins with the final stretch of the Peace Creek near the City of Bartow (Figure 1-4).

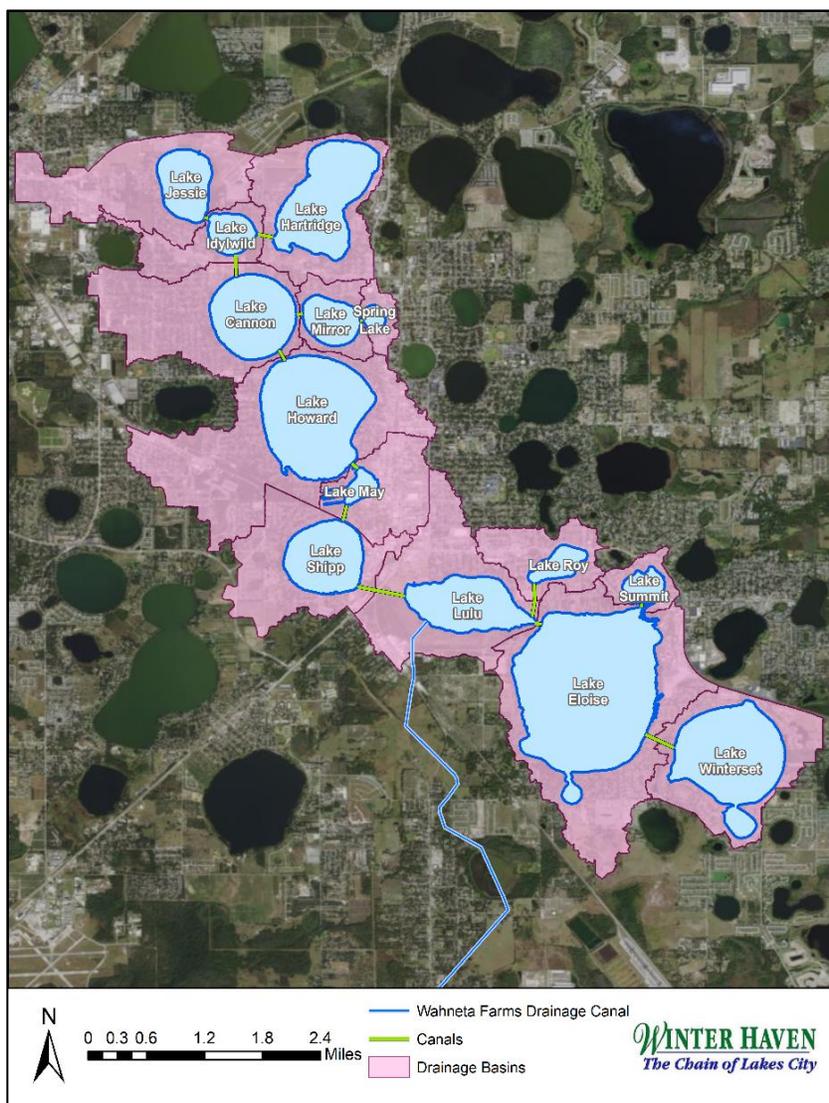


Figure 1-4. Map of South Chain of Lakes, Flow Pathways & Drainage Basins

### North Central Lakes

This series of lakes is squarely situated in the northern part of Winter Haven's central urban area. The following 5 lakes flow to the northeast before discharging to the North Chain of Lakes:

- *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.

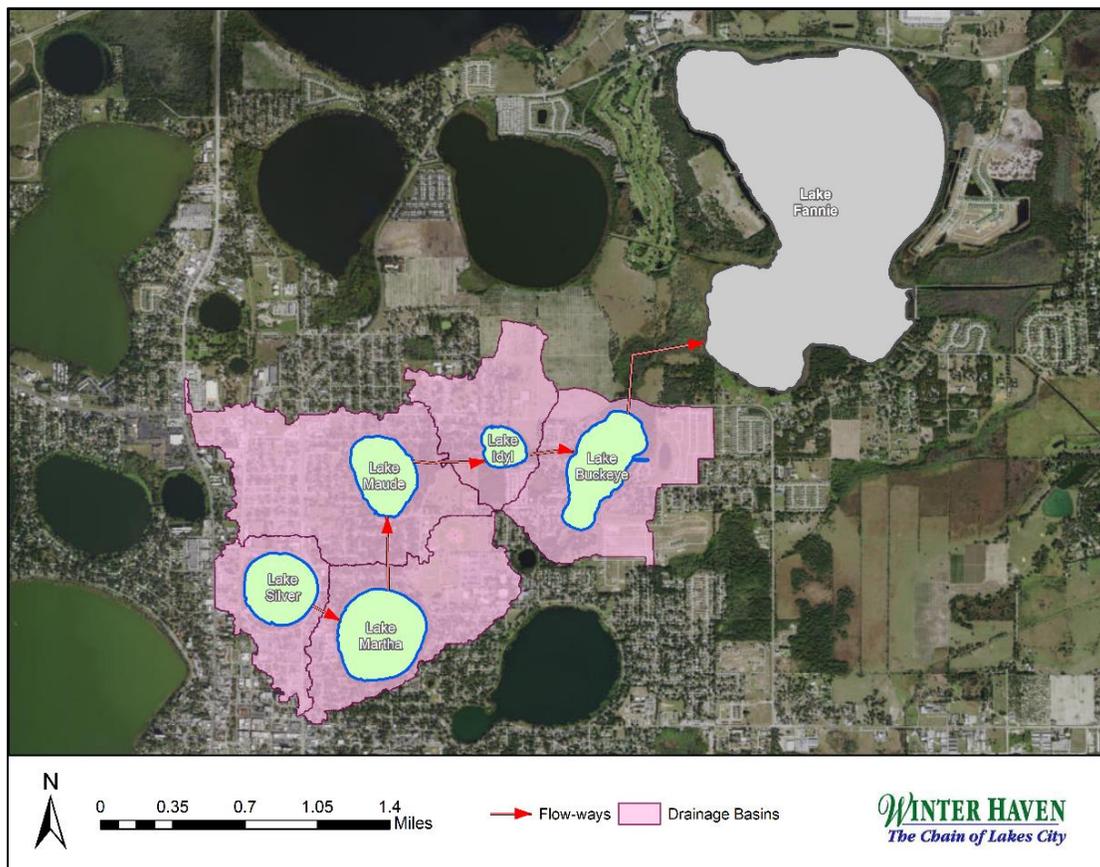


Figure 1-5. Map of North Central Lakes, Flow Pathways & Drainage Basins

### South Central Lakes

Similar to the North Central group, the South Central Lakes are categorized based on their location on the southern side of Winter Haven's urban center. 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). Within the non-navigable connections between these lakes, weirs control the maximum desired surface level for the purposes of flood prevention and water conservation.

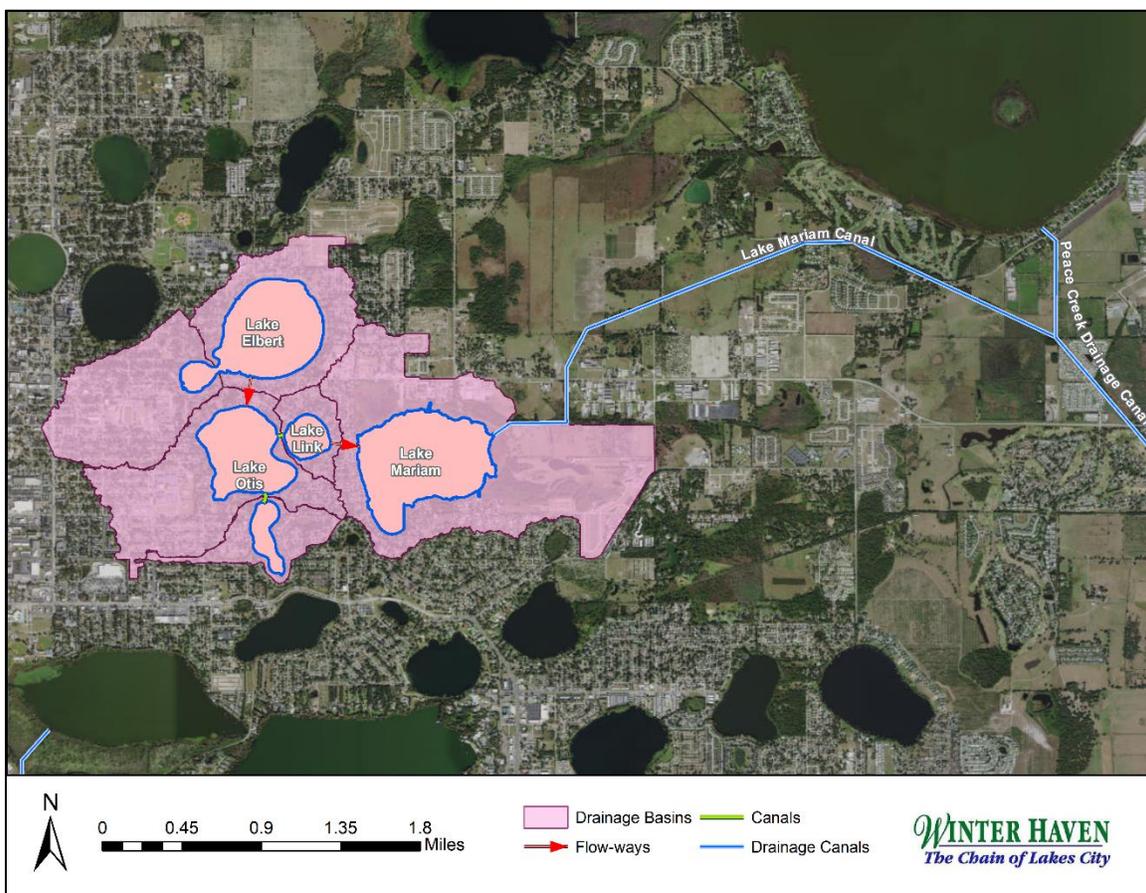


Figure 1-6. Map of South Central Lakes, Flow Pathways & Drainage Basins

*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 Peace Creek. However, since they are public lakes abutting City limits, they have been included in this analysis.

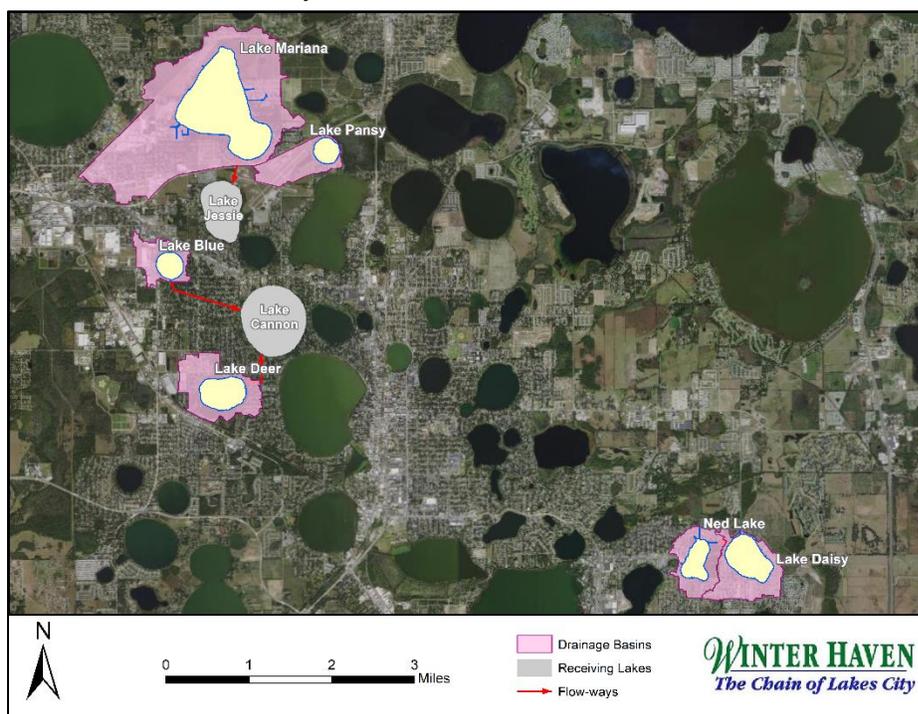


Figure 1-7. Map of Outlying Lakes, Flow Pathways & Drainage Basins

## 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 interactions amongst various components. While significant insights can be gained by studying the individual metrics, a more comprehensive approach is needed to identify systemic issues and prescribe effective solutions. For the purposes of managing the previously mentioned lakes, focus will be placed on understanding the interactions amongst water quality, hydrology, and ecology.

### Water Quality

At face value, the term "water quality" 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 evaluate a lake based on what they consider good or bad qualities. An attribute such as a lake's color or trophic state can have a different connotation to swimmers than it would to anglers or nature enthusiasts. Managing 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 (Chl-a):** *Measured as the concentration of the primary photosynthetic pigment of plants and algae in the water column, Chl-a 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 Impairment Evaluation*

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 (human) 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 reason for impairment of our waterbodies. On the geologic time scale (thousands of years), lakes go through a natural process called eutrophication or an 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 natural conditions, 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 targets that waterbodies must meet for their intended use classification, of which all of the Winter Haven lakes fall under Class III. Chlorophyll-a (Chl-a), a measure of algal abundance, is generally used as a response metric for a waterbody's trophic state. High Chl-a concentrations indicate an increased trophic state and vice versa. 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 Chl-a increase as illustrated by their correlative relationships (Figure 1-8). This figure shows that an increase in either TN or TP will generally lead to an increase in Chl-a. 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 water quality back to target concentrations.

In addition to the parameters mentioned above, other 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 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. Color is often imparted by the breakdown of tannins found in wetland plant matter. Therefore, lakes with large connecting wetlands typically have higher color concentrations. Total Alkalinity or water hardness, measured in milligrams per liter of Calcium Carbonate (mg/L CaCO<sub>3</sub>), 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 [17]. 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.

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) [7]. 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<sub>3</sub>) These categories are subject to individual thresholds for the annual geometric mean (AGM) concentrations of Chl-a, TN, & TP. Once a lake is categorized, annual Chl-a concentration is assessed. If the AGM Chl-a exceeds the NNC threshold, or if there is insufficient data to determine Chl-a impairment, the AGM TN & TP concentrations are subject to

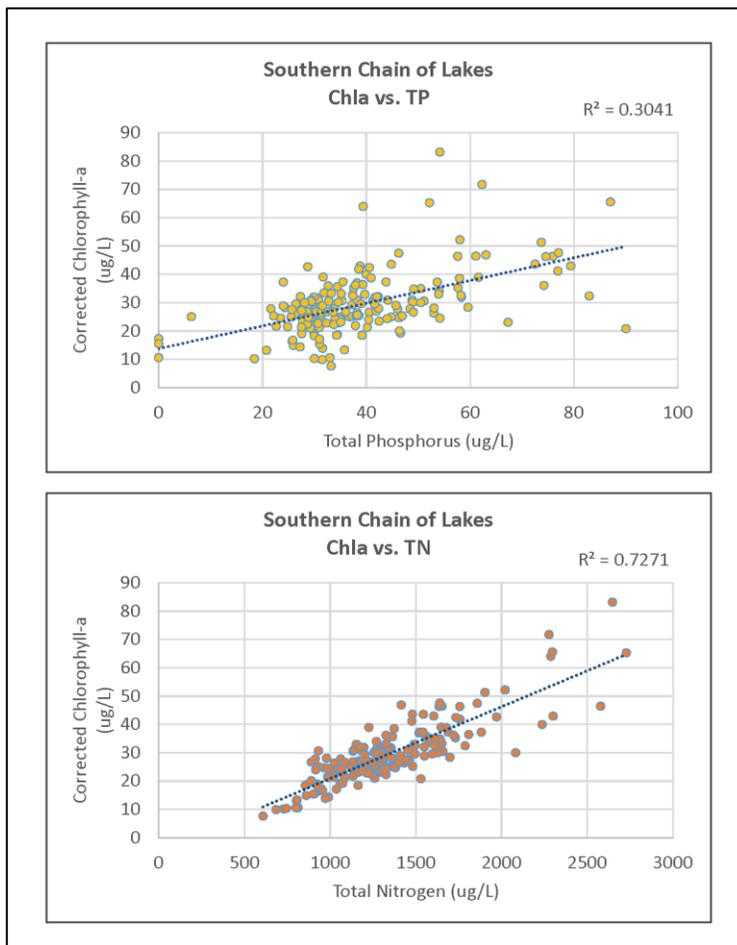


Figure 1-8. Linear Regression of Chlorophyll-a vs. Total Phosphorus & Total Nitrogen

the minimum impairment limit for that year. If there is no Chl-a 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 Chl-a, 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 Chl-a, TN, and/or TP.

*Regulatory Response*

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 [16]. Knowledge of the limiting nutrient can assist lake managers in determining what management practices to focus on to improve water quality.

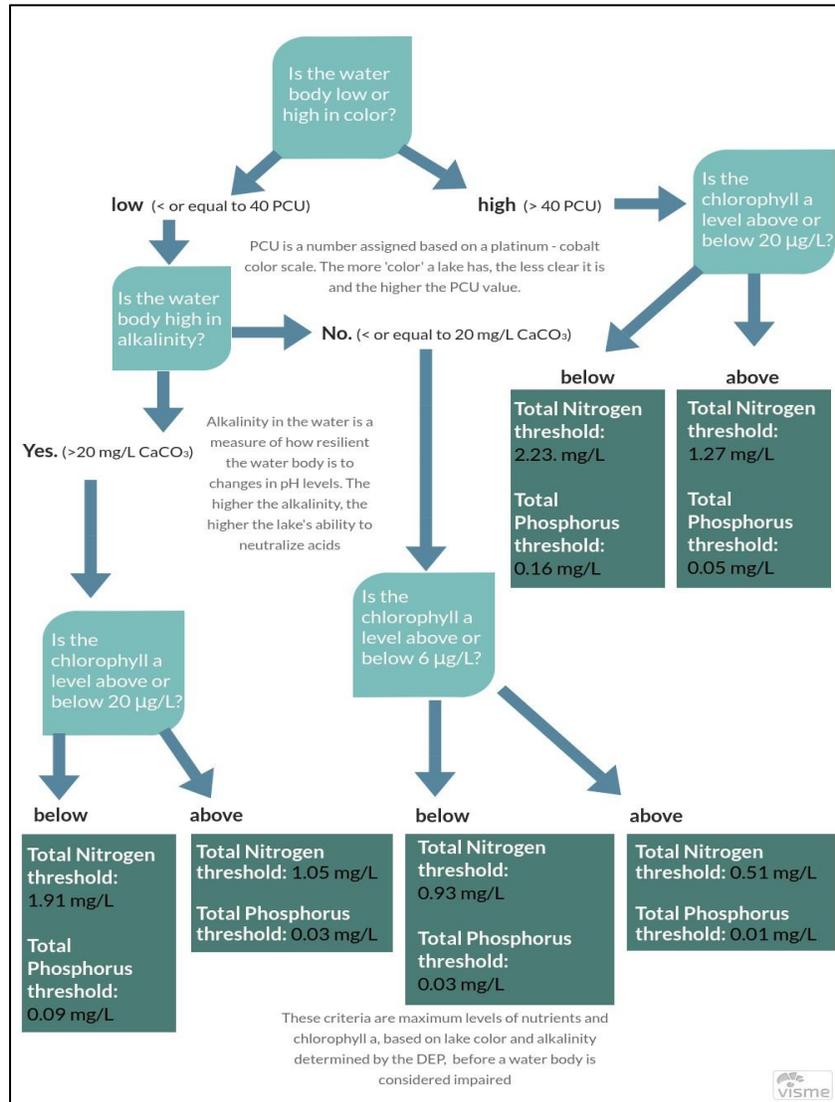


Figure 1-9. NNC Impairment Determination Flowchart

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 **Municipal Separate Storm Sewer Systems (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 annually. 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.

Similar 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 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) <sup>[21]</sup>:

#### **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 <sup>[6]</sup>. 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 before human development in the region [22] [23].

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 a lake's response to changes in water quality.

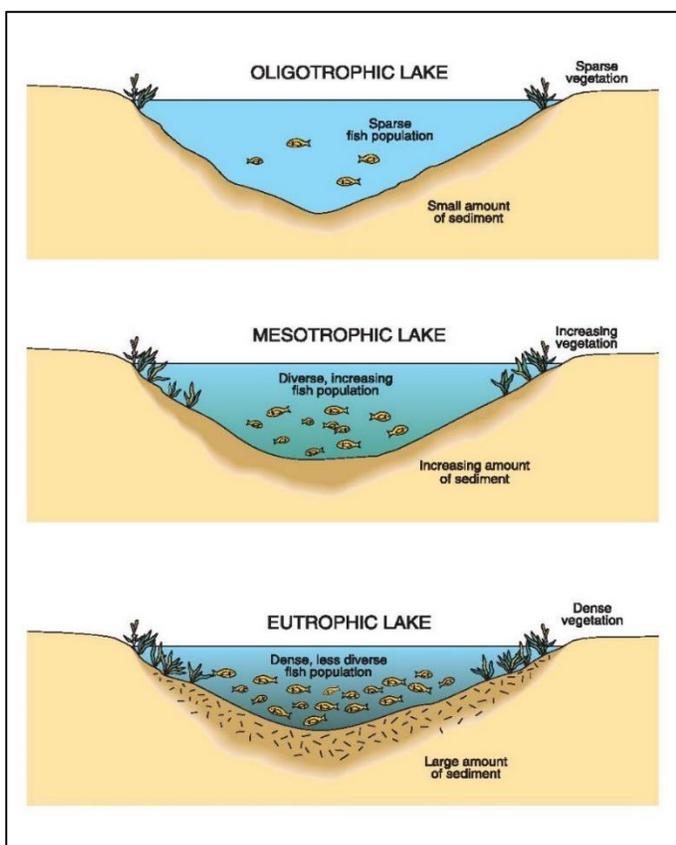


Figure 1-10. Diagram of Lake Trophic States [21].

## Hydrology

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 and genealogy—things 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 places these lakes on a hilltop that causes surface water to naturally migrate downstream toward the Peace River. The amount of rainfall received 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. An 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 that reduces runoff and increases 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, referred to as the water table, generally fluctuates readily based on rainfall, soil saturation, temperature, and humidity. The Upper Floridan Aquifer is confined under pressure. As a result, 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 [20], 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 stormwater in areas where fast recharge isn't feasible.

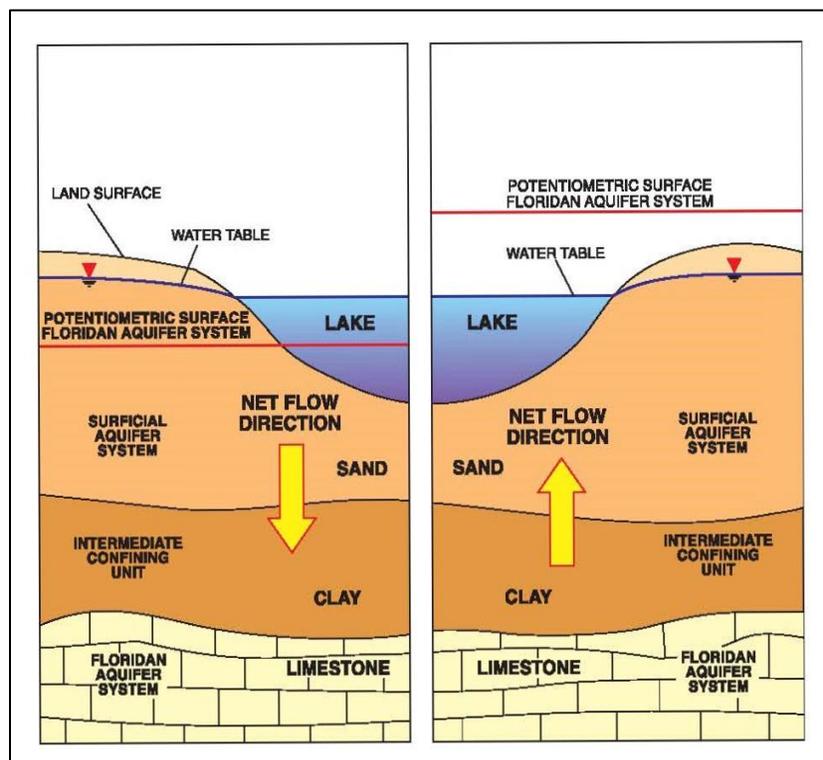


Figure 1-11. Diagram of Groundwater Interactions

### 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 soil data to determine how quickly water can percolate into the groundwater system.

**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 coarse 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 their status when ‘drained’/‘saturated’.

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.

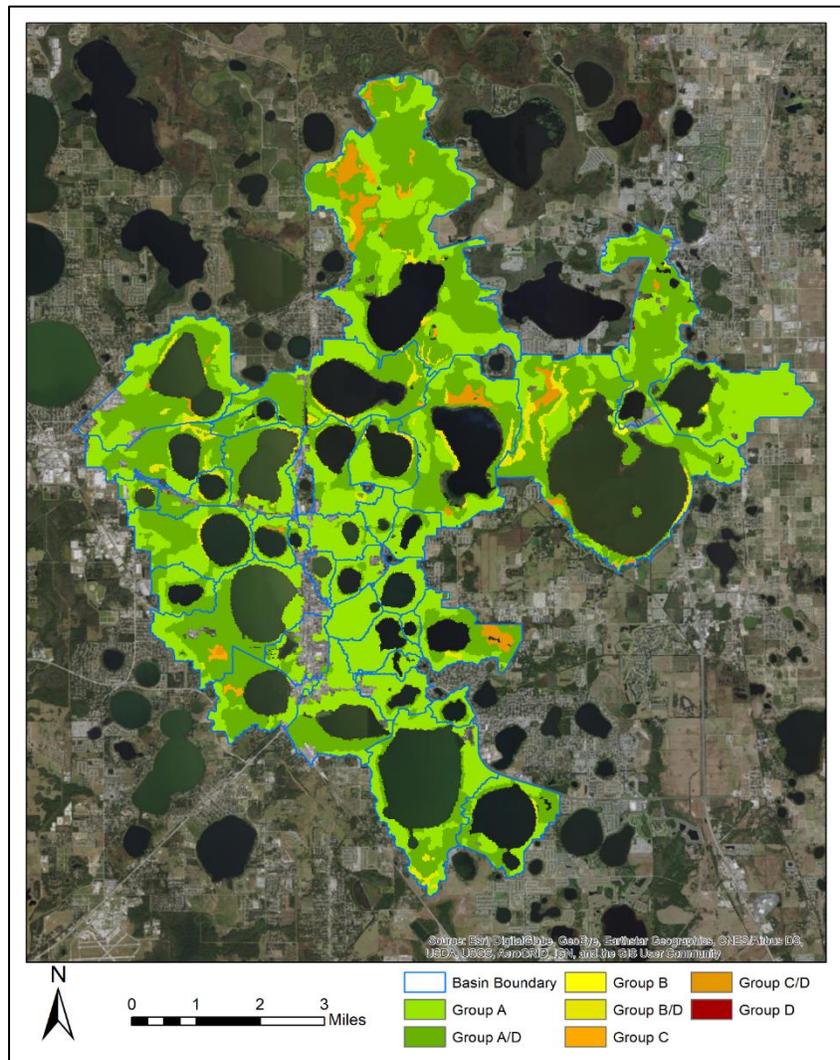
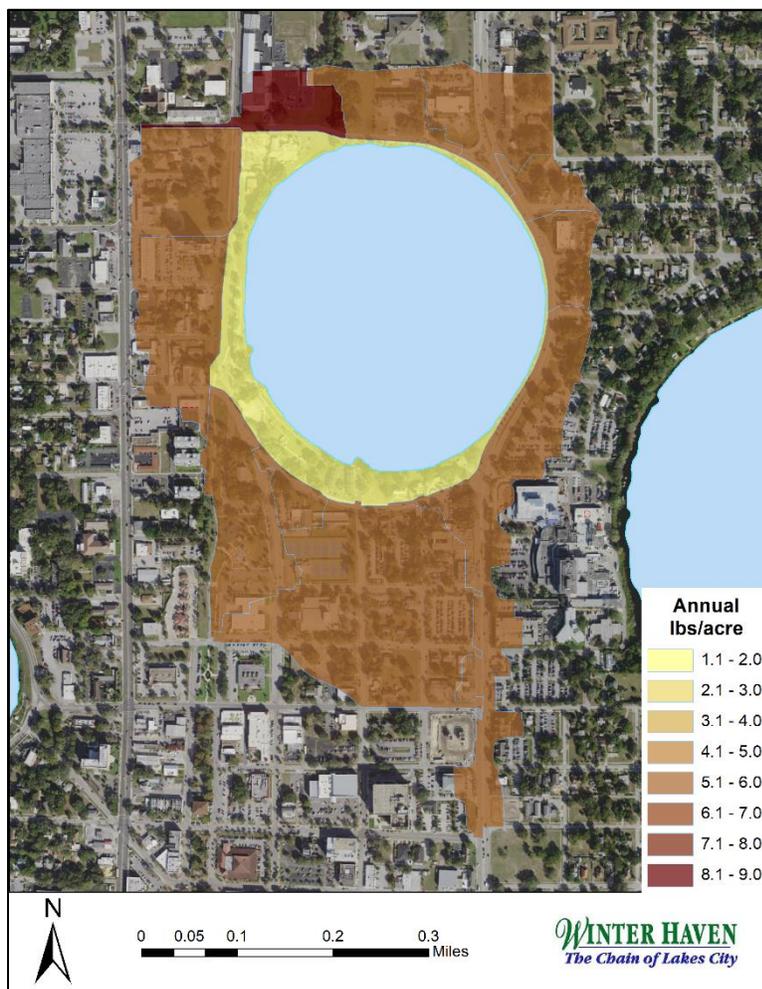


Figure 1-12. Hydrologic Soil Groups of the Winter Haven Lakes

*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 hydrologic modeling 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 several 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, soil type, impervious area, and land use to estimate the annual load of various pollutants such as TN, TP, suspended solids, and heavy metals [14]. 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 modeling 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, differences in land use can drastically impact pollutant loading even amongst a small urban area (Figure 1-13).

The calculated loading rates displayed here are raw values that exclude nutrient load reductions from stormwater best

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

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 rates and volumes <sup>[3]</sup>. 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 can pinpoint specific areas 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 often slow or nonexistent and so retrofitting green infrastructure projects like raingardens or infiltration pipes are some of the City's viable means to reduce pollutant loading.

As previously mentioned, groundwater can also be a contributor of pollutants if there are potential sources within a lake's drainage basin. Leaky Onsite Sewage Treatment & Disposal (OSTD), aka septic systems in the vicinity of a lake could be contributing to water quality issues. While the density of OSTDs within a basin doesn't provide concrete evidence of this, considering septic as a potential nutrient source can lead to exploratory studies as confirmation. This is just one component to consider when developing a water quality improvement plan.

### *Morphology*

One less frequently discussed component of hydrology is lake morphology or the size and shape of a waterbody. The depth and slope of a lake's benthos (bottom) can provide insights into how a waterbody may react to various environmental stimuli. For example, a deep, steeply sloping lake may be affected more strongly by aquifer fluctuations, will usually have a smaller zone where aquatic plants can grow, and will usually be less susceptible to sediment suspension through wind and wave action when compared to a more shallow and gradually sloping counterpart. As a result, morphology is useful to consider alongside other factors when developing a lake-specific management strategy.

## 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 can 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 presence of harmful invasive species.*

**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 producers of oxygen and a food source for organisms higher on the food chain. 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 several categories: submerged aquatic vegetation (SAV), emergent aquatic vegetation (EAV), floating leaf vegetation (FLV), 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, but 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. Floating leaf plants (FLV) are a subcategory of emergent vegetation that behave very similarly to EAV, but present a unique habitat type for fish and wildlife. Like other rooted plants, they are restricted to the shallower margins of lakes. However, their floating leaves provide cover from sunlight which restricts the growth of SAV below them. Often, floating leaf plants will form dense stands that can be an impediment to navigation in shallow waterbodies. Common species of FLV include fragrant water lily (*Nymphaea odorata*) and Spatterdock (*Nuphar advena*).

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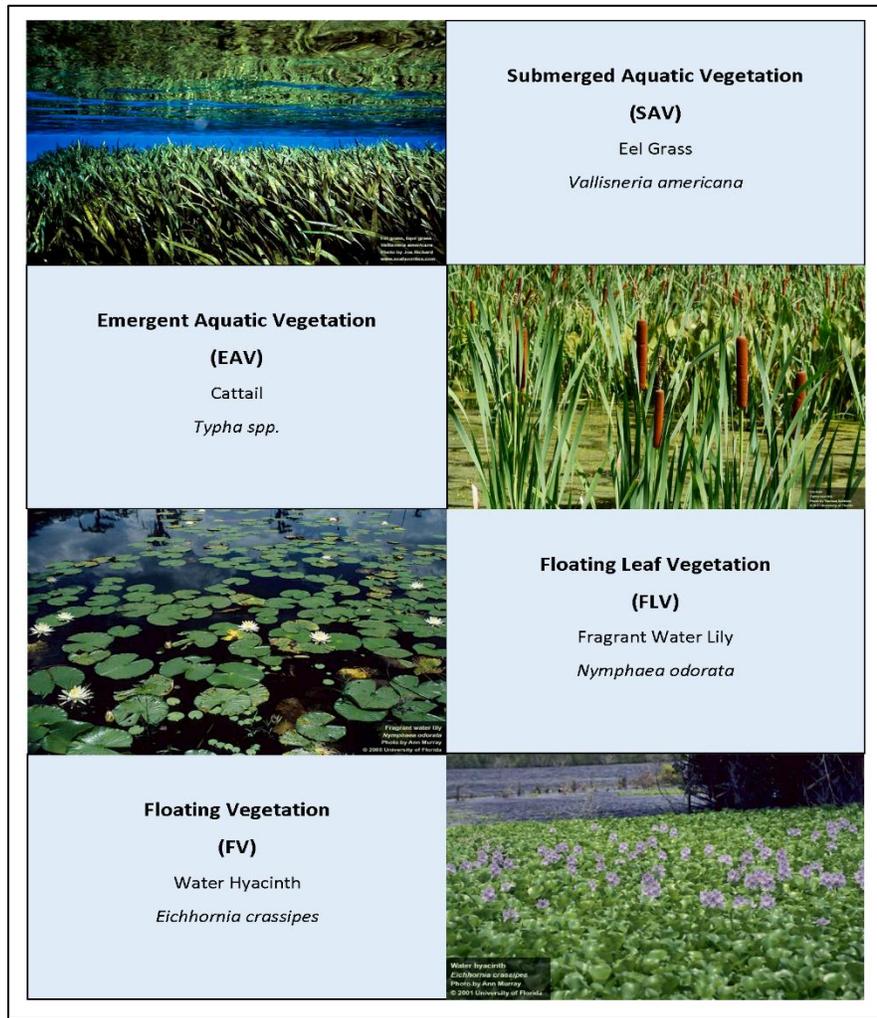


Figure 1-14. Examples of Aquatic Vegetation Categories

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. Because 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.*). A list of all species identified in Winter Haven lakes can be found in Table 4-8 in the appendix.

**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 [19]. 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 a 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.

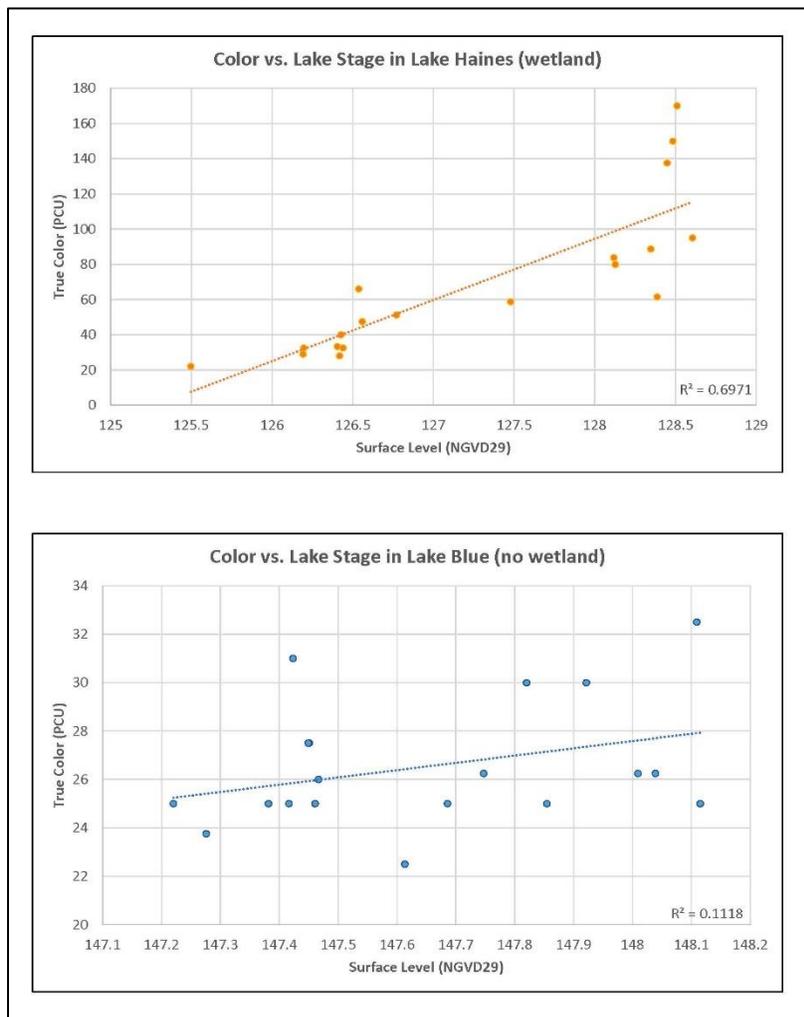


Figure 1-15. Correlation between Wetlands and True Color in Lake Haines & Lake Blue

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 <sup>[1]</sup>. Therefore, it can be inferred that greater PAC generally equates to lower potential suspended sediment concentrations. Unofficial sources state that a range of 15 – 30 PAC is generally considered a conservative target for beneficial wildlife habitat.

One additional benefit of SAV in lakes is their increased capacity to uptake nutrients directly from the water column compared to most emergent species <sup>[4]</sup>. 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, 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 <sup>[11]</sup>**

- **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 the 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 the 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.

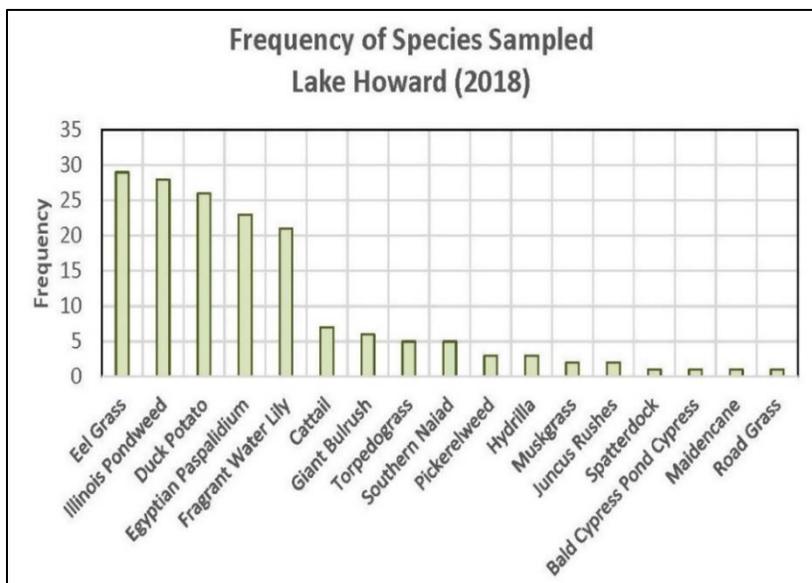


Figure 1-16. Species Frequency Chart of Aquatic Vegetation in Lake Howard

## 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 Partnership (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 ArcGIS, 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 point is given for each metric not determined to be impaired, while 0 is assigned to any currently impaired metrics. Points are totaled 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 ( $p\text{-value} \leq 0.05$ ) based on AGM values for each parameter (Chl-a, TN, TP, and Secchi depth) from 2000 to 2020. 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 for the given study year. 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 from 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 impacts.



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 following sections present an analysis of the various lake health metrics as well as a synopsis of management efforts to date.

*Water Quality*

A snapshot of the 2020 Annual Geometric Mean (AGM) Chl-a, TN, TP, and Secchi depth values for the NCOL is displayed in Figure 2-1. The current annual average is compared with each lake’s long-term mean and normal range (+/- 1 standard deviation) derived from the period between 2000 and 2020. With few exceptions, the NCOL exhibited better water quality in 2020 when compared with long-term values. Lake Hamilton’s 2020 Chl-a and TN concentrations far exceeded its long-term mean and were even above the historic normal range. Additionally, Lake Hamilton’s Secchi depth was also below average in 2020. Little Lake Hamilton’s 2020 TN concentration slightly exceeded its long-term average, while Lake Haines’ 2020 TP concentration reached the maximum extent of its normal range. The remaining waterbodies exhibited Chl-a and nutrient concentrations at or below and Secchi depths at or above their respective long-term averages.

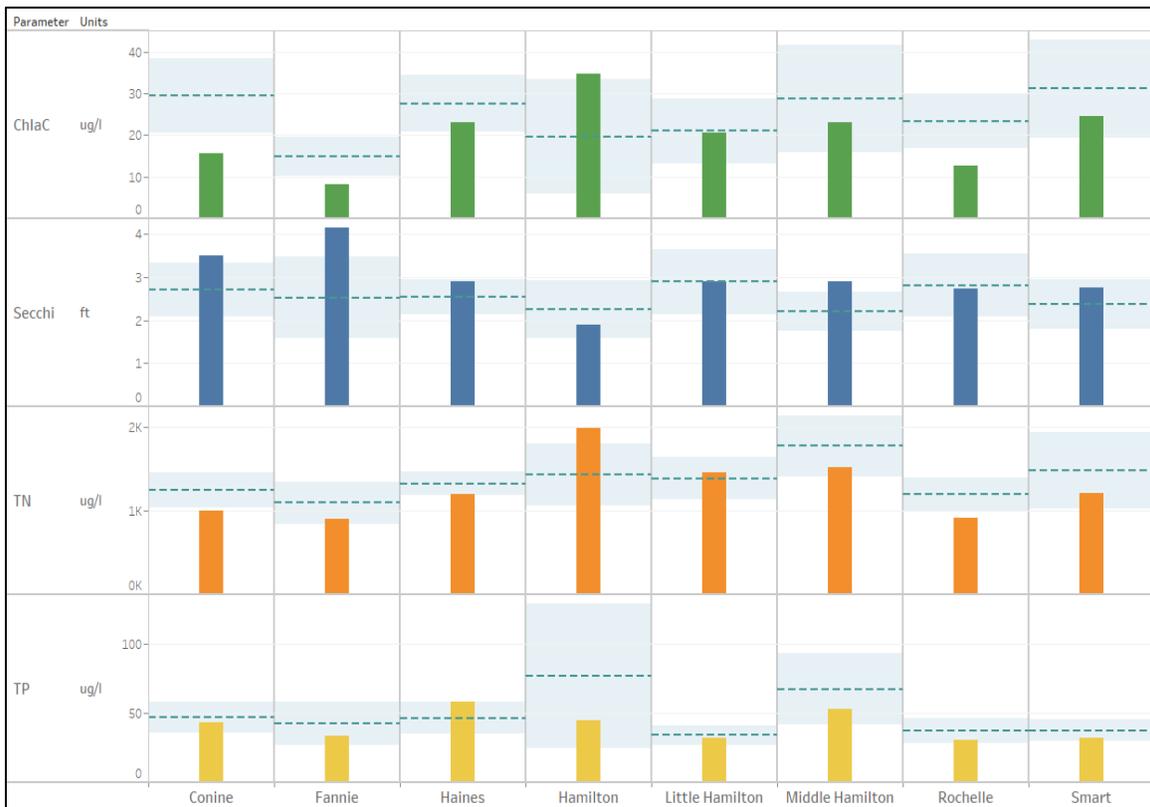


Figure 2-1. 2020 AGM Chla, TN, TP, & Secchi depth values for the North Chain of Lakes; dotted line represents long-term mean and the shaded area refers to the standard deviation range.

## NNC Impairment

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 (Chl-a), total nitrogen (TN), and total phosphorus (TP) concentrations between 2013 and 2020 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, Little Hamilton, Middle Hamilton, Rochelle, and Smart are impaired for Chl-a, TN, and TP exceedances. These equate to Impairment category scores of 0 in the Lake Health Index. Lake Haines remains impaired for Chl-a exceedances, but not for TN and TP due to a lack of multiple consecutive exceedances during the assessment period. This equates to an index score of 2 for Lake Haines. Lake Fannie had no Chl-a, TN, or TP exceedances during the assessment period. Similar to the previous year, Lake Fannie receives an index score of 3.

Currently, Lakes Conine, Haines, and Rochelle possess nutrient Total Maximum Daily Load (TMDL) directives due to their water quality impairments. The FDEP has plans to develop TMDLs for Lake Hamilton and Middle Lake Hamilton in 2021. Despite being impaired for nutrients, there are currently no plans to develop a TMDL for Lake Smart.

## Water Quality Trends

To determine whether each lake is experiencing overall water quality improvement or deterioration, an analysis of the long-term trends was performed. The monotonic (directional) trend test involves linear regressions of AGM Chl-a, TN, TP, and Secchi depth from 2000 to 2020 (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  $\leq 0.05$ ) were used to determine the trend relationship and validity respectively (see Table 4-4 in Appendix for regression statistics).

**Chlorophyll-a Trends:** Lake Hamilton is the only waterbody in this group exhibiting a significant increasing trend in Chl-a, while Lakes Conine and Rochelle showed significant decreasing trends from 2000 – 2020.

**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:** Lakes Conine, Fannie, Haines, and Rochelle displayed significant improving trends in water clarity. Only Lake Hamilton possesses a significant deteriorating trend in Secchi depth over this time frame.

The majority of waterbodies in the Northern Chain are experiencing some form of improvement in the four primary water quality parameters. However, greater focus will need to be placed on the Lake Hamilton chain. Determination of the nutrient sources for these lakes is critical to mitigating their water quality impacts. Development of TMDLs for these waterbodies is a good first step. However, the City plans to work closely with the FDEP and local stakeholders to address the water quality issues and develop future management goals for the Lake Hamilton group of waterbodies.

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. 2020 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 – 2020 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 (25<sup>th</sup> – 75<sup>th</sup> quartile). Annual rainfall for 2020 was 47.56 inches—just below 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 describes holding more water in these lakes year round, only discharging downstream prior to intense storm events (e.g. hurricanes).

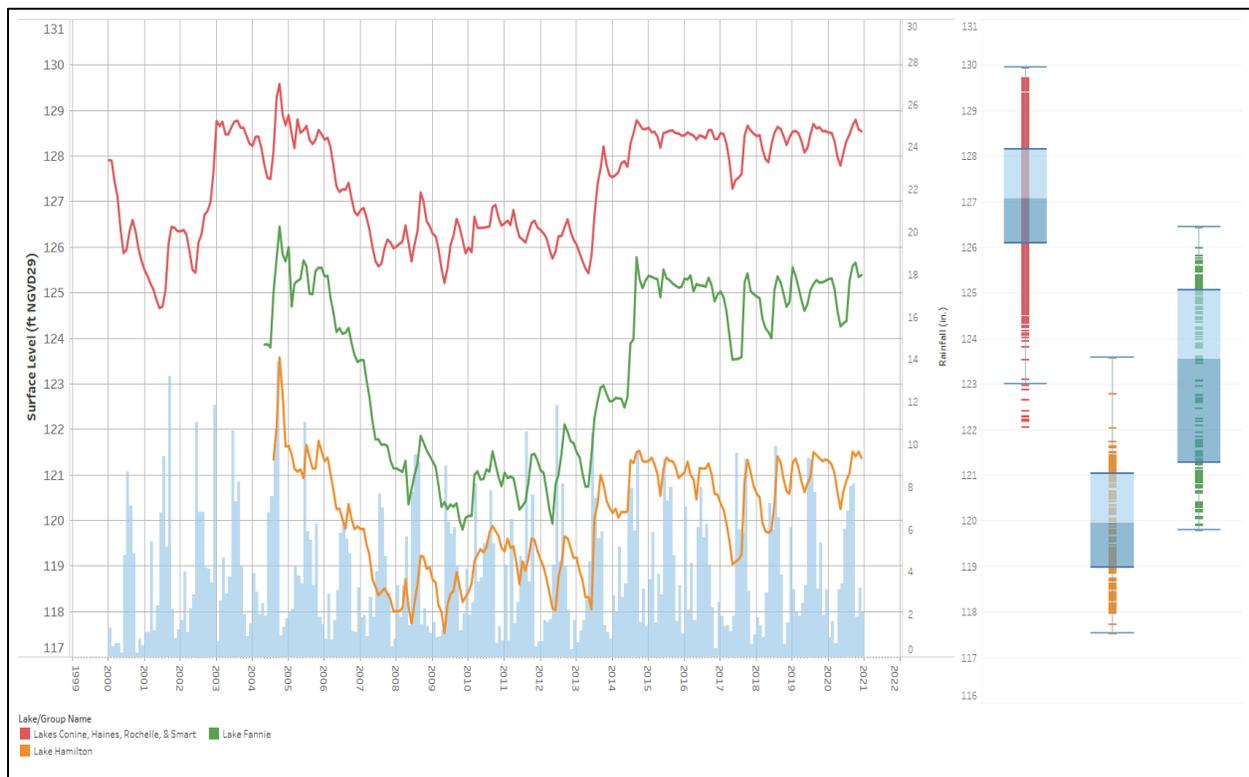


Figure 2-2. North Chain of Lakes hydrograph with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

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 [12]. This was analyzed in-depth in the 2018 Lakes Report and showed that 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).

One major hydrologic component to note is lake morphology and how it may impact water quality in the Northern Chain of Lakes. The majority of the waterbodies in this group

possess very large surface areas, but are also relatively shallow. This lake shape tends to allow for more sediment suspension due to wind and wave action. Morphological impacts provide greater evidence to support the relationships between water quality and surface level fluctuations. Sustained high surface levels over the last few years may have been a major contributor of improving water quality in the majority of the Northern Chain waterbodies.

Pollutant load modeling was conducted for drainage basins/sub-basins contributing to the North Chain of Lakes based on the most recent 2017 land use data. The purpose of this modeling is to identify areas of relatively high TN and TP loading where management efforts can be focused. The drainage basins for Lakes Haines, Little Hamilton, and Middle Hamilton were re-delineated to be more consistent with known stormwater inputs. As a result, the size of the basins and respective pollutant loads increased significantly compared with the values listed in the 2019 report.

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) with very little direct conveyance to the lakes. 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. One exception is the much higher TN loading in Little Lake Hamilton. A large area of industrial land use contributes much higher loading rates compared with the other lakes in the study area. The TP loading hotspots are aggregated near the southernmost lakes in this group due to the greater density of residential and commercial land uses (Figure 2-3). Most of the newer residential areas have implemented on-site stormwater catchment systems. However, the older neighborhoods to the southeast of Lake Conine drain directly to the waterbody. In order to address loads to Lake Conine, the City is in the process of constructing a treatment wetland that will capture and treat urban stormwater before discharging to the lake. Construction on the Lake Conine Wetland Restoration project began in 2020 and is scheduled to be completed by mid-2021. One other item to note on Lake Conine is historic point-source loading from the City's Wastewater Treatment facility as recently as 1992. Polk County enacted efforts to cap these nutrient rich sediment deposits with alum in the late 1990's. However, more information is needed to determine if these legacy sediments still contribute to the pollutant load.

An assessment of Onsite Sewage Treatment & Disposal (OSTD) systems data attributed 192 known septic systems in the NCOL drainage basins (Table 4-6; in appendix). Considering the total area of these basins and the spread of the systems, the overall density is not very high. The greatest aggregation of septic systems was in the Lake Hamilton basin, however. Considering the water quality trend data for Hamilton, future pollutant source analysis should include an evaluation of potential leachate from these OSTDs.

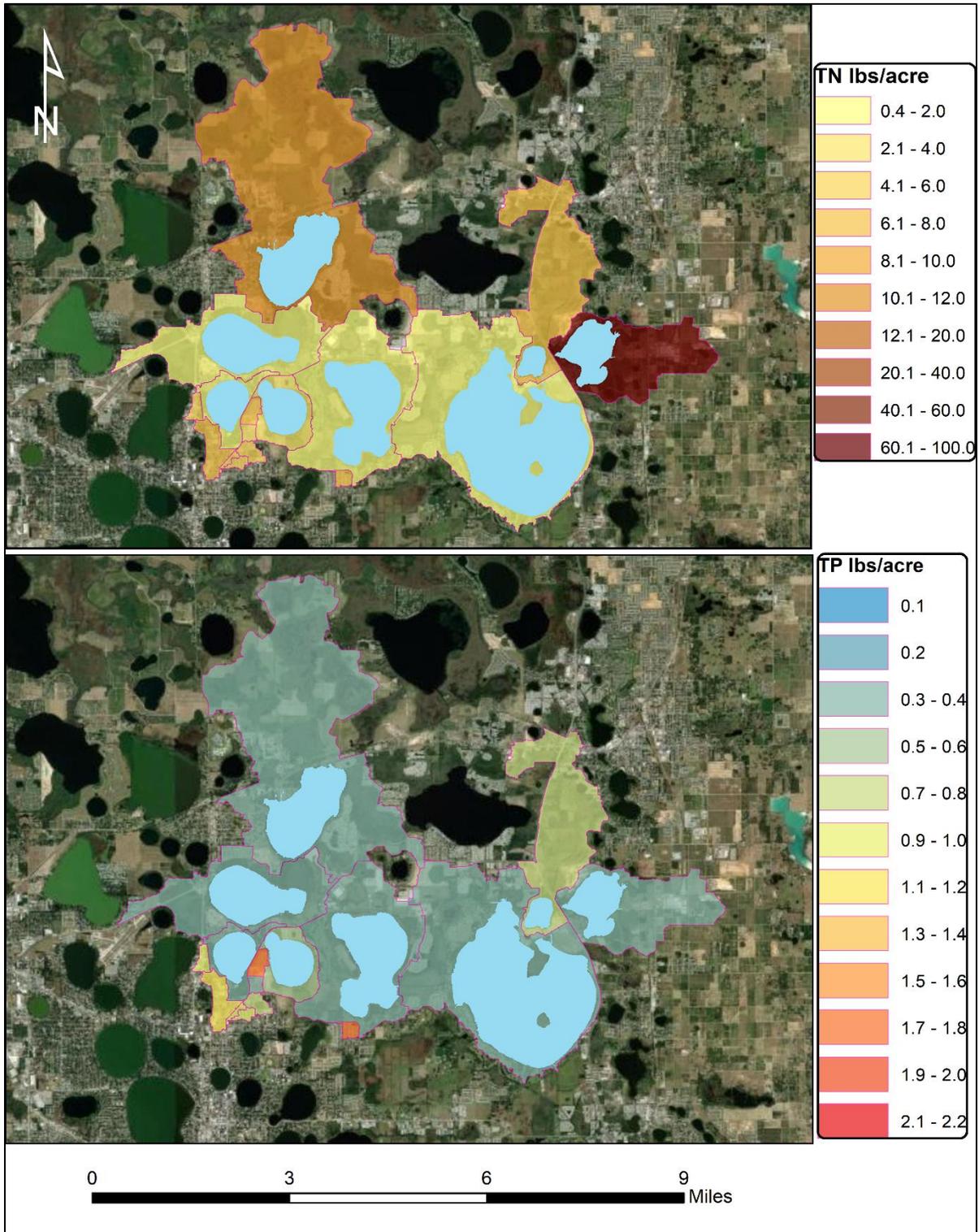


Figure 2-3. Areal TN & TP Loading for individual drainage basins in the North Chain of Lakes.

*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 and has since expanded to the 37 lakes presented in this report.

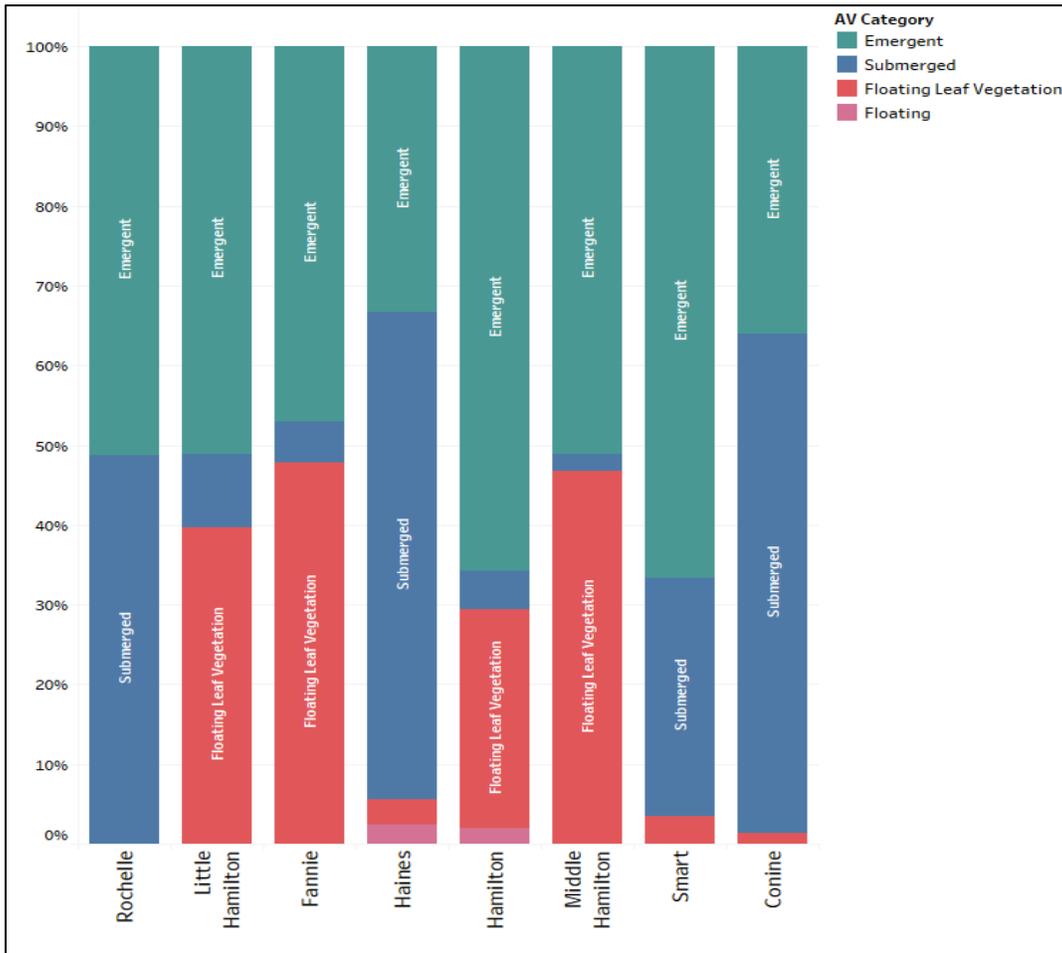


Figure 2-4. North Chain of Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

The various species of aquatic plants have been categorized into four groups—submerged aquatic vegetation (SAV), floating vegetation (FV), floating-leaf vegetation (FLV), and emergent aquatic vegetation (EAV). In 2020, Lakes Conline, Haines, and Rochelle have an almost equal mix of submerged and emergent plants. The remaining lake vegetation communities are comprised almost exclusively of EAV and FLV species (Figure 2-4). Lakes Haines and Hamilton possessed very minor populations of floating vegetation—primarily in the form of the invasive water hyacinth. Unsurprisingly, the lakes exhibiting declining water quality trends possessed very little SAV, since submerged plants are more efficient at sequestering nutrients like nitrogen and phosphorus.

### Vegetation Abundance

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, which was suggested by the Florida Fish and Wildlife Commission (FWC) as adequate for fish habitat, is also important for sediment stabilization and nutrient uptake.

In 2020, the majority of the NCOL underwent a decrease in overall vegetation coverage (Figure 2-5). Only Lakes Conine and Rochelle maintained PAC values above the ideal 30% threshold. Abundance in Lake Smart dropped by nearly half to a value just above the target 15% coverage. Lakes Fannie and Middle Hamilton decreased in vegetation abundance to below the 15% threshold. Despite PAC declines in Lakes Haines and Little Hamilton, their abundance values remained above 15%. Lake Hamilton’s coverage increased during this time, but not enough to exceed the 15% target.

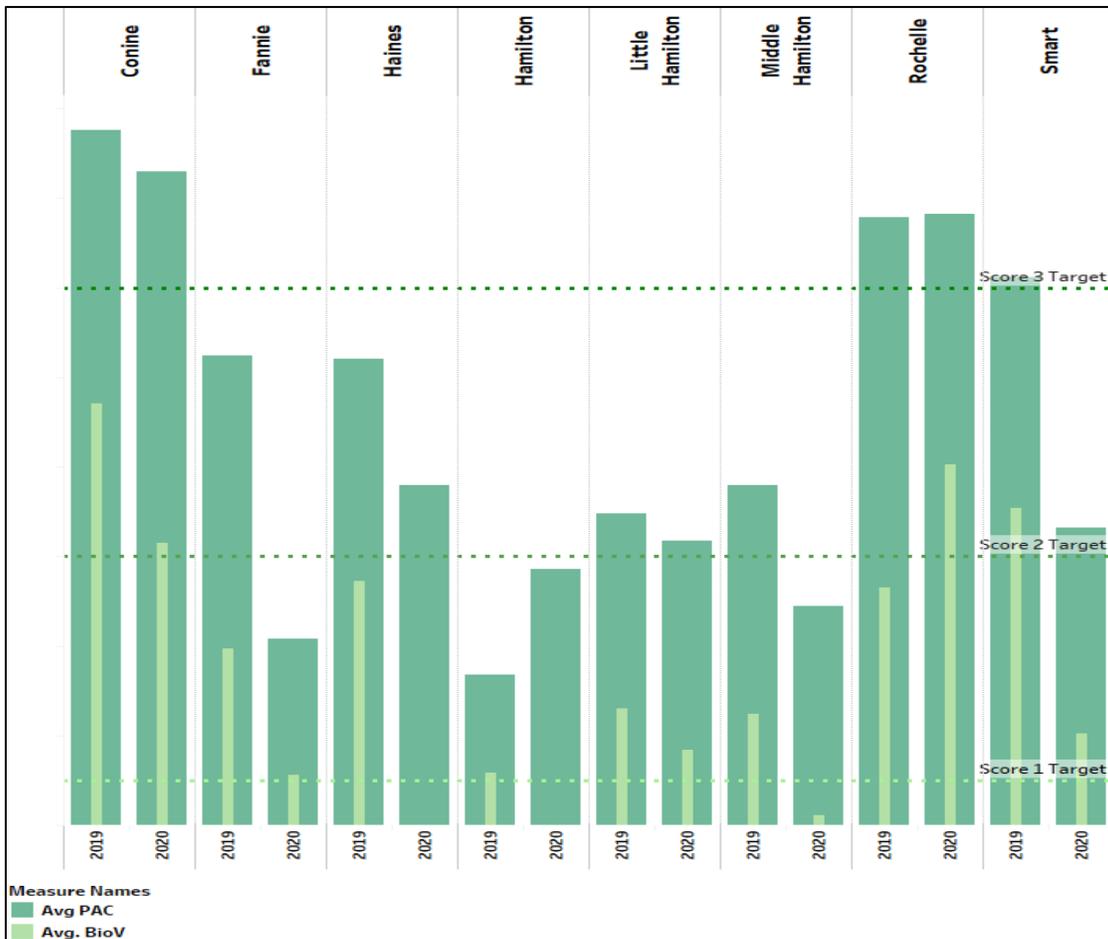


Figure 2-5. North Chain of Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

### Invasive Species Percentage

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. Ideally, the goal is to reduce the presence of invasive species. However maintaining populations below a target threshold is often the most feasible and cost-effective strategy. 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*). The majority of lakes in this group underwent a decrease in the presence of invasive species from 2019 to 2020 (Figure 2-6). However, most of these changes were not enough to alter the invasive scores from the previous year. Some of the notable changes include a significant decrease of hydrilla in Lake Smart which increased its score to a 2. Invasives were not discovered in Middle Lake Hamilton in 2020 which increased its score to a 3. An increase

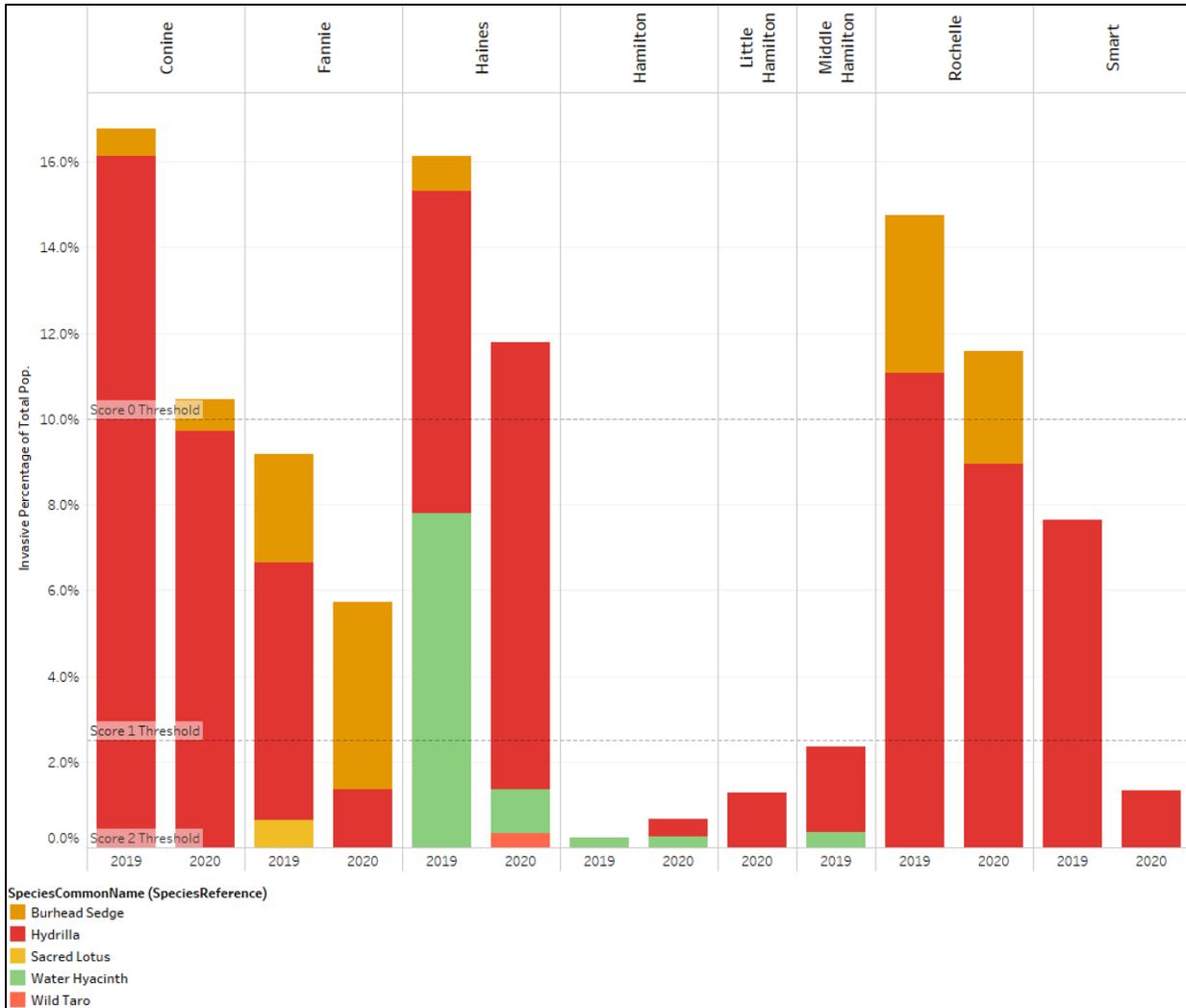


Figure 2-6. North Chain of Lakes annual percentage of invasive species.

of hydrilla in Little Lake Hamilton decreased its score to a 2. There was a considerable decline in water hyacinth in Lake Haines, but this did not result in a change in its score.

### Species Diversity

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 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 Fannie, Haines, Hamilton, Little Hamilton, Middle Hamilton, and Smart all showed an increase in species richness in 2020. Lakes Conine and Fannie decreased in richness during the same period.

**Hill’s Evenness #3 (E3):** Species evenness is preferred over one or two dominant species as it improves community resilience. Lakes Conine, Little Hamilton, Middle Hamilton, and Smart showed an increase in species evenness in 2020. Lakes Fannie, Haines, Hamilton, and Rochelle experienced a decrease in evenness.

**Shannon’s Diversity (H):** As a combination of species richness and evenness, Shannon’s index indicates the overall species diversity for each site. Only Lakes Little Hamilton and Smart

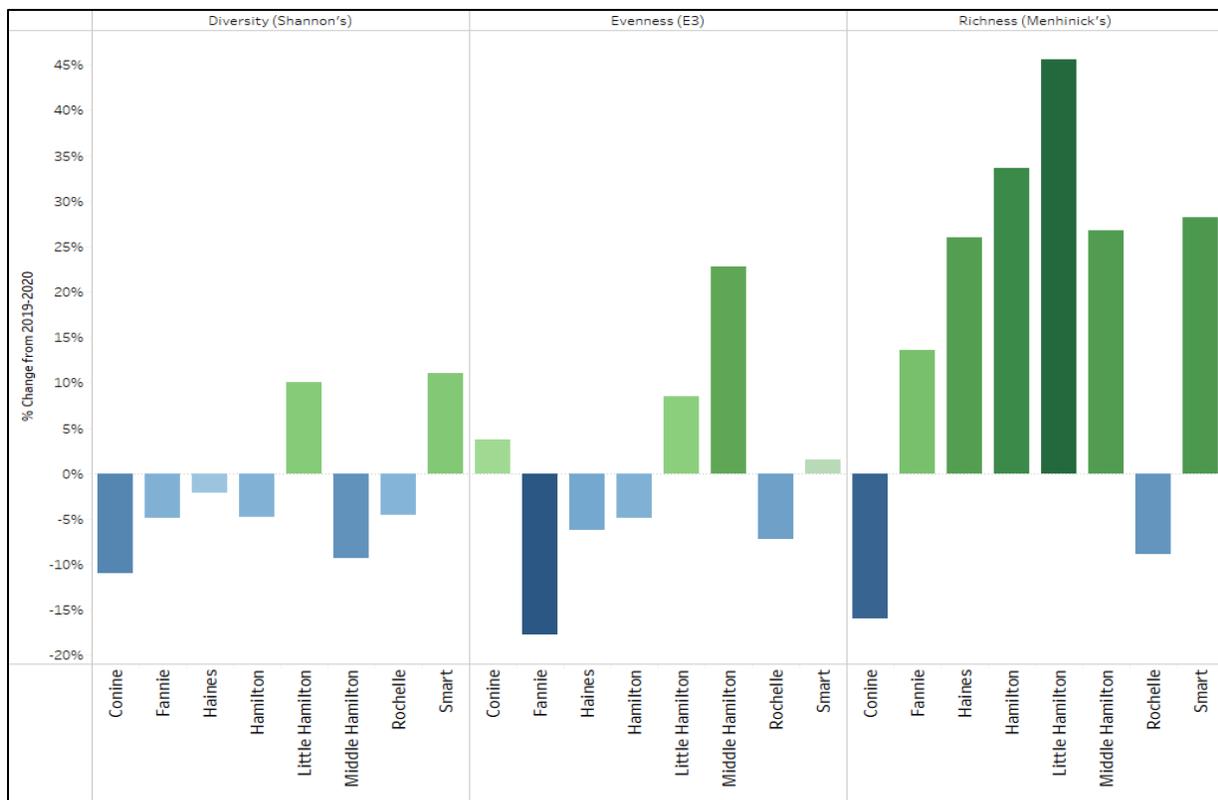


Figure 2-7. North Chain of Lakes annual index values for species richness, evenness, and diversity.

underwent an overall increase in diversity in 2020. Lakes Conine, Fannie, Haines, Hamilton, Middle Hamilton, and Rochelle decreased in diversity.

Species diversity may increase or decrease over time, but the index metrics don't discriminate based on native or invasive. Treatment of invasive species may result in a decrease in abundance and potential diversity, and can lead to the degradation of water quality as nutrients are released back into the water column. 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 exotic species squeeze out the diverse and beneficial natives. Striking this balance is one of the most difficult challenges for lake managers.

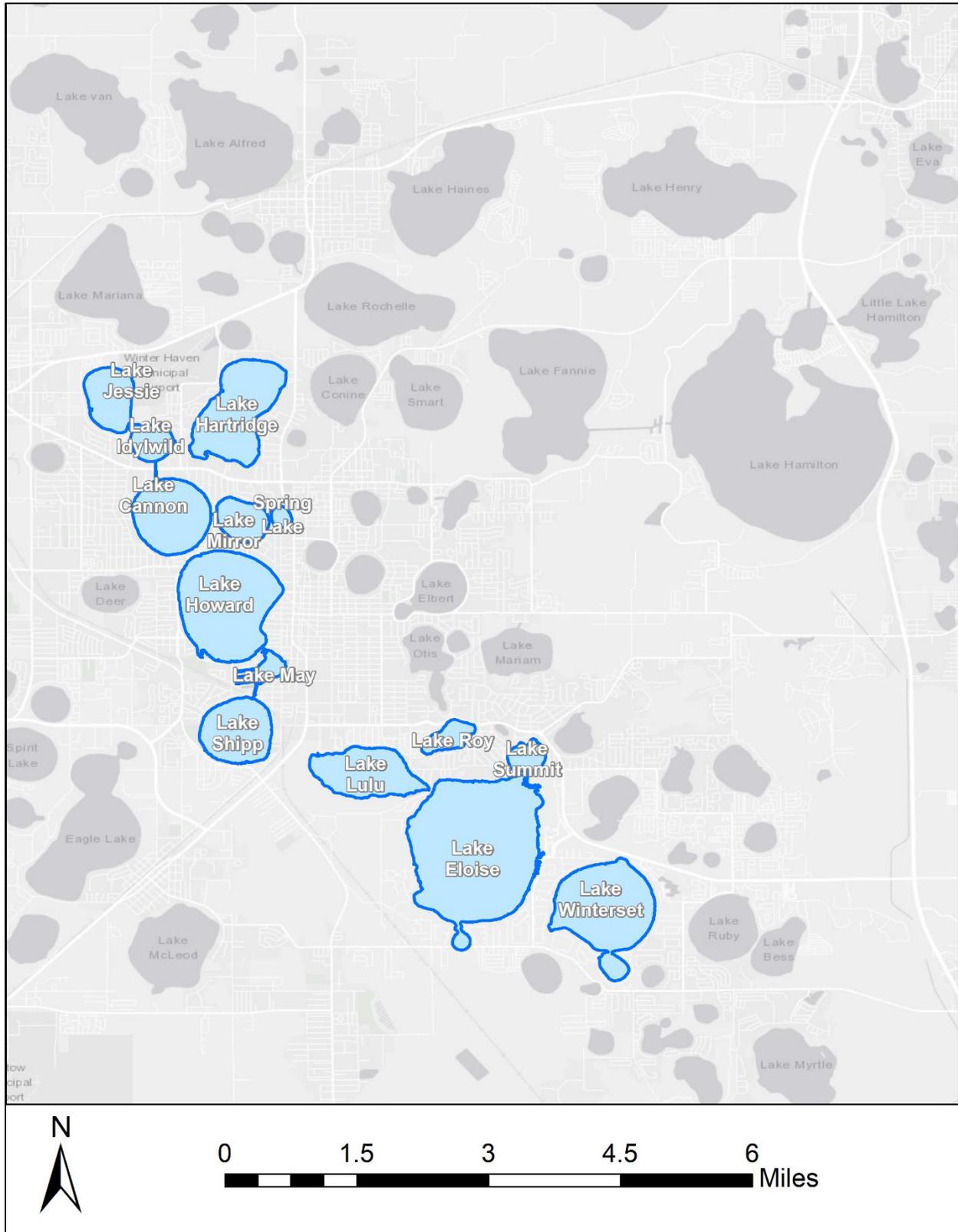
### **Management Conclusions**

It is clear from the water quality data that while most of the NCOL are impaired, many are undergoing some form of improvement based on the trends. That said, Lake Hamilton and Little Lake Hamilton require more focus and effort to address their deteriorating water quality. While the source of nutrients in Lake Hamilton's drainage basin remains difficult to decipher based on the pollutant load modeling, the re-delineation of Little Hamilton's basin provides some clarity as to its sources. The part of Little Hamilton's drainage basin that was previously excluded was a large area of industrial land use which appears to be contributing a substantial amount of nitrogen to this waterbody. Unfortunately, since the entirety of the Little Hamilton basin sits outside Winter Haven's boundary, this limits the City's recourse for mitigating this possible pollutant load. The City must work with Polk County, FDOT, Lake Alfred, Haines City and any other local stakeholders that discharge to this lake group in order to address these pollutant sources.

Based on the aquatic vegetation data, invasive species remain a continuous issue for this lake group. For most waterbodies in this group, the Fish and Wildlife Conservation Commission (FWC) implemented less herbicide treatments in 2020 than in previous years (Table 4-7; in appendix). The FWC is also attempting to utilize alternative treatment methods such as grass carp. One of the City's primary goals includes regular vegetation monitoring to facilitate rapid invasive management and minimize the implementation of large-scale herbicide treatments that can have negative consequences for water quality.

As the City collects more vegetation data, a better understanding of normal vegetation fluctuation will be possible. Biovolume percentage is not currently scored in the Lake Health Index. However, as more and more years of data are collected, evaluation of annual changes in biovolume may be incorporated into the study. The City may also incorporate concepts from the State's Lake Vegetation Index (LVI) program to evaluate how the proportion of various plant species in each lake impact the health of their aquatic communities.

## 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 following is a presentation and analysis of the various lake health metrics for this lake group.

### Water Quality

A snapshot of the 2020 Annual Geometric Mean (AGM) Chl-a, TN, TP, and Secchi depth values for the SCOL is displayed in Figure 2-8. The current annual average is compared with each lake’s long-term mean and normal range (+/- 1 standard deviation) derived from the period between 2000 and 2020. On the whole, water quality in the majority of the Southern Chain lakes was better than average in 2020. Chl-a and TN concentrations were at or below the long-term average in all except for Lake Hartridge. Aside from Lakes Jessie and Summit, TP concentrations were at or below long-term levels as well. Secchi depths were above average for most lakes, excepting Lake Hartridge.

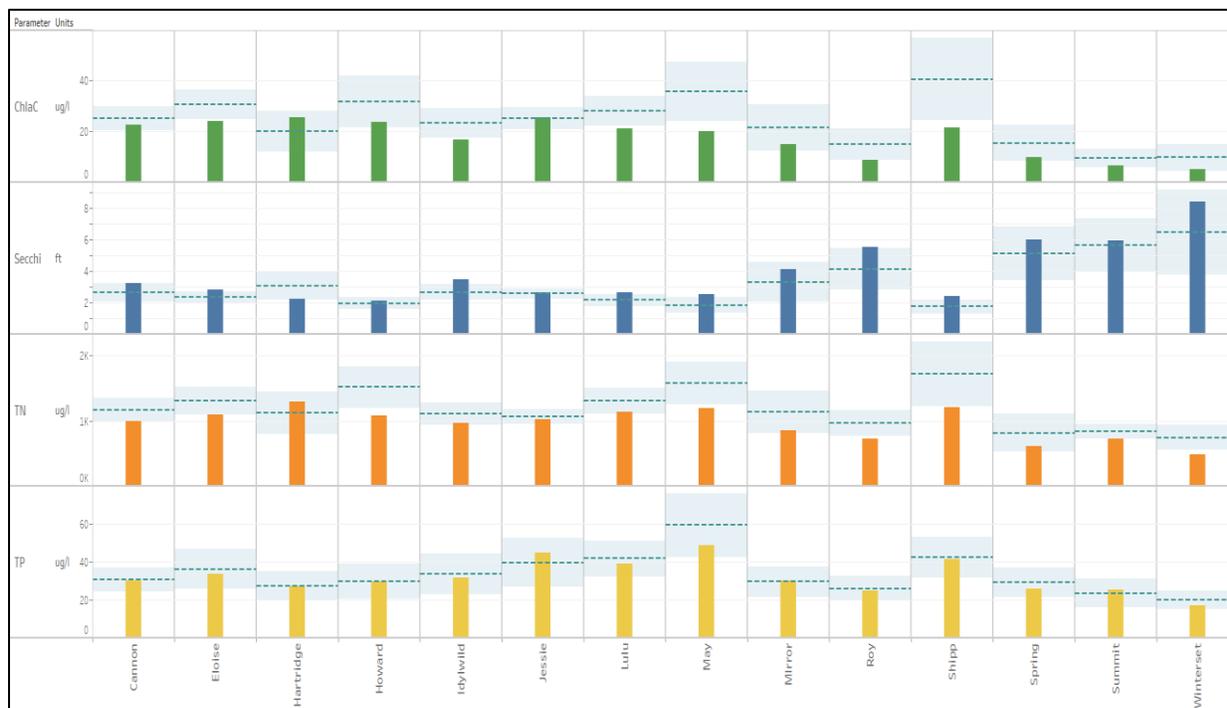


Figure 2-8. 2020 AGM Chl-a, TN, TP, & Secchi depth values for the South Chain of Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

### NNC Impairment

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) Chl-a, TN, and TP concentrations between 2013 and 2020 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.

**Chlorophyll-a:** Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, and Shipp were determined to be impaired.

**Total Nitrogen:** Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, May, and Shipp were determined to be impaired.

**Total Phosphorus:** Lakes Eloise, Jessie, Lulu, May, and Shipp were determined to be impaired.

Total Maximum Daily Loads (TMDLs) were originally developed in 2007 for Lakes Cannon, Hartridge, Howard, Idylwild, Jessie, Lulu, May, Mirror Shipp, and Spring based on historic impairments. In 2019, the Southern Chain of Lakes TMDLs were updated with two changes; Lake Eloise was added to the list while Lakes Mirror and Spring were excluded due to their water quality improvement.

### Water Quality Trends

In order to determine if long-term monotonic (directional) trends in water quality are occurring, AGM Chl-a, 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  $\leq 0.05$ ) of each lake's water quality trends (Table 2-2). While the 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 Chl-a trends from 2000 - 2020. Lake Hartridge is the only waterbody that exhibited a significant increase in Chl-a.

**Total Nitrogen Trends:** Lakes Cannon, Howard, Lulu, 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. The City's focus for the future will include identifying nutrient sources for Lakes Hartridge and Jessie as well as implementing best management practices to improve 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	Decreasing	Not Significant	2
	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 (Improving)	Significant	3
	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. 2020 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 2020 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 75<sup>th</sup> and 25<sup>th</sup> 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.

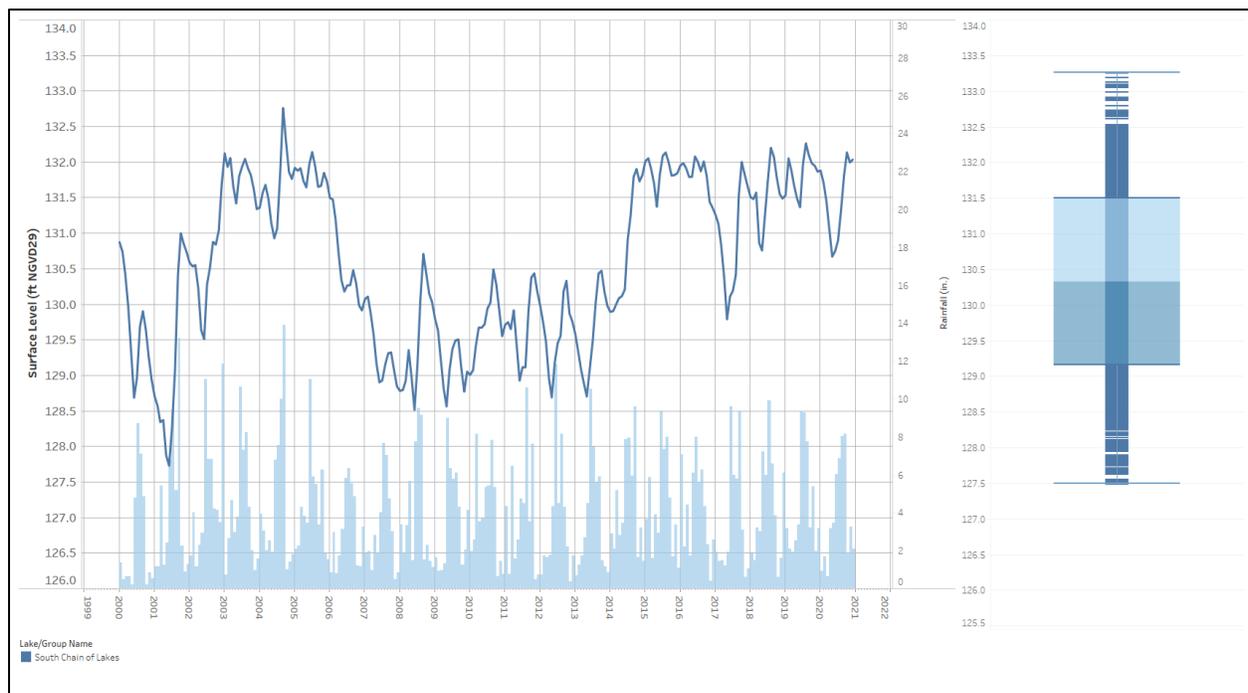


Figure 2-9. South Chain of Lakes hydrograph with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

Winter Haven’s annual rainfall totaled approximately 47 inches in 2020—somewhat below the annual average of 52 inches. Very little precipitation during the first half of the year led to a decline in surface levels toward the long-term average. However, multiple storm events during a short period of time led to the rapid rise in lake levels toward the end of the year. By December of 2020, the SCOL were sitting above the 75<sup>th</sup> percentile surface level.

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 Idylwild, Jessie, Lulu, May, Roy, and Shipp showed relationships between SL and one or more water quality metrics. Despite the nature of this lake group to hydrologically fluctuate as one entity, the impacts that changes in SL have on water quality vary from lake to lake—likely due to each waterbody’s unique morphological and

biological characteristics [23]. That said, it appears that one of the simplest management strategies with some of the greatest benefit to the SCOL involves maintaining maximum surface level as climate allows.

The morphology of the individual SCOL waterbodies varies considerably. Some, such as Lakes Winterset, Spring, and Summit are fairly deep and subject to greater groundwater influence. While others are relatively shallow and may be prone to sediment suspension via wind/wave action like Lakes May and Eloise. Morphology may be partly responsible for the relationships between SL and water quality in specific lakes.

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 with multiple groups contributing via stormwater infrastructure (e.g. FDOT, Polk County, and City of Winter Haven). Lakes Eloise, Hartridge, Jessie, Summit, and Winterset possess minimal stormwater infrastructure data which has limited staff's ability to

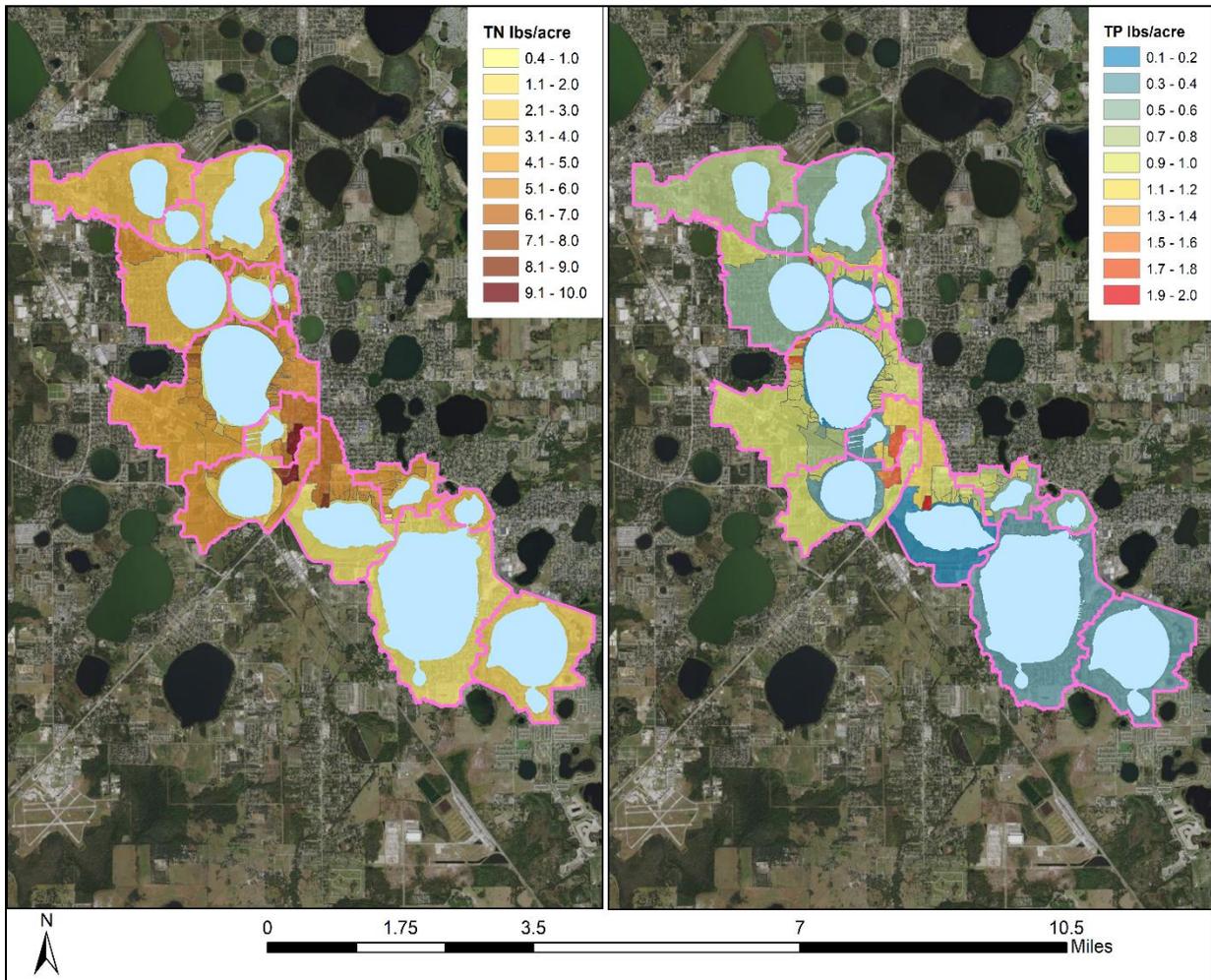


Figure 2-10. Areal TN & TP Loading for individual drainage basins in the South Chain of Lakes.

delineate individual sub-basins. Conversely, the waterbodies close to the City center possess multiple distinct stormwater systems (Figure 2-10).

The lowest areal TN and TP loads are located in the drainage basins of the peripheral lakes listed above. These basins primarily consist of low-medium density residential and open lands with moderate to high soil infiltration rates. These newer developments also include built-in stormwater treatment facilities (e.g. retention ponds) that capture most stormwater flows instead of discharging to a lake. 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. Other relatively high loading areas surround Lakes Howard, Cannon, Mirror, and Spring. While these are more residential areas, these neighborhoods were constructed prior to regulations mandating on-site stormwater mitigation. 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.

Lakes Eloise, Howard, Jessie, Lulu, May, and Shipp have all received historic point-source pollutant loading. These sources range from now defunct wastewater treatment facilities to agricultural and chemical processing plants. While these point-sources are no longer discharging to the lakes, their legacy sediments may still be contributing to water quality impacts. Further study is required to determine how these historic sources are affecting the lakes.

Analysis of OSTD system data for the area attributes 1111 known septic systems within the SCOL drainage basins (Table 4-6; in appendix). For most of these individual lake basins, the total number of OSTDs is relatively low. However, the densities within the Lake Cannon, Eloise, Jessie, and Roy basins are high enough that they could pose a current or future risk of groundwater pollutant loading. Water quality management strategies may involve exploratory analyses to determine if these septic systems are or will be contributing to water quality impacts as well as feasibility studies for septic-to-sewer conversion.

*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. Since 2018, vegetation data has been collected annually for all SCOL waterbodies.

Understanding the distribution of emergent (EAV), submerged (SAV), floating-leaf (FLV), 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 possess an exceptional proportion of submerged vegetation compared with other lakes in the area, with the majority of the Southern Chain possessing >30% SAV (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.

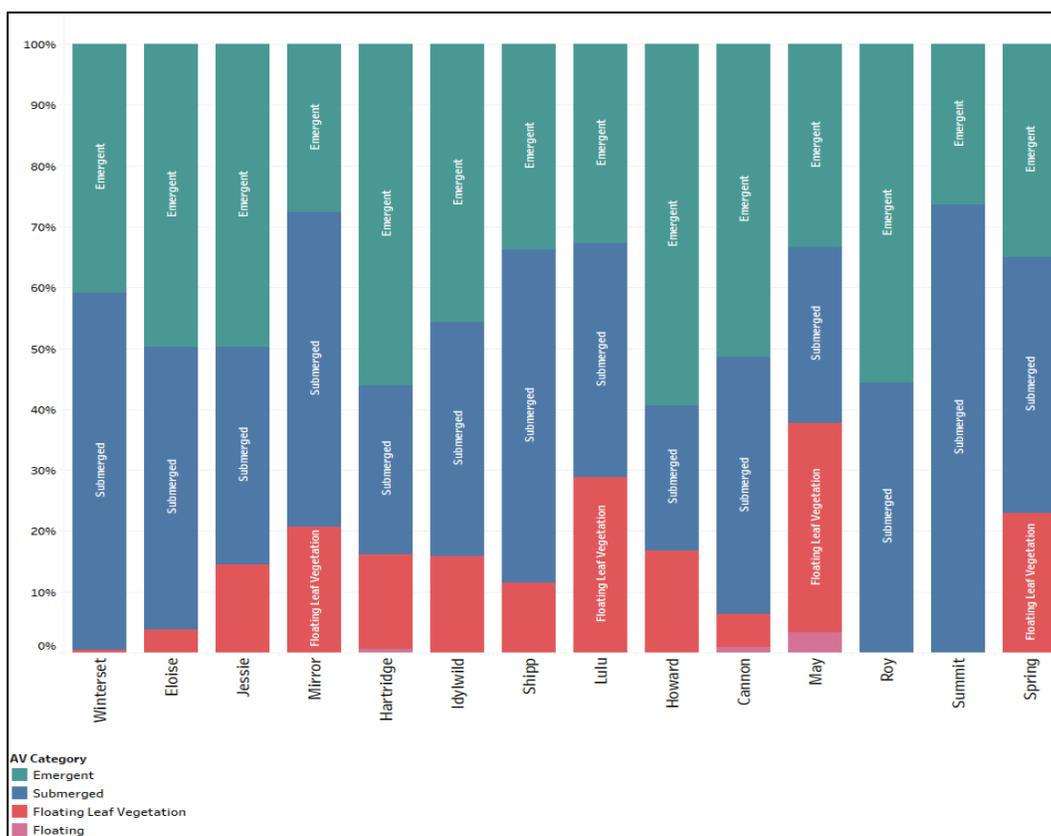


Figure 2-11. South Chain of Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

**Vegetation Abundance**

Measurements of percent area cover (PAC) and percent biovolume (% BV) indicate that the majority of the SCOL possessed excellent vegetation abundance in 2020 (Figure 2-12). Every Southern Chain waterbody exceeded the 15% PAC target, with all except

Eloise at or above the 30% exceptional abundance threshold. 10 of the 14 lakes in this group underwent an increase in vegetation coverage. Abundance increases in Lakes Howard and Roy led to increases in their lake health score for this category.

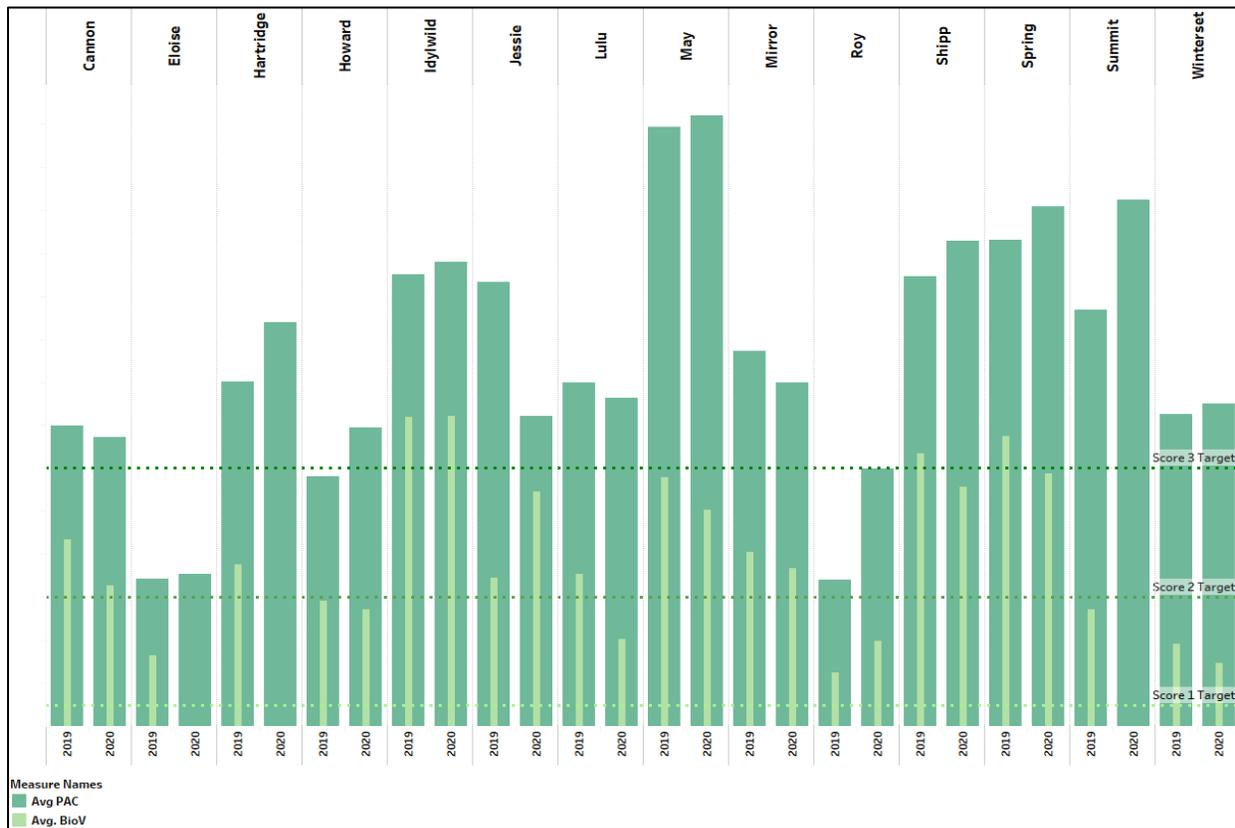


Figure 2-12. South Chain of Lakes annual aquatic vegetation percent area coverage and mean percent biovolume

### Invasive Species Percentage

Despite the overall increase to vegetation abundance, there were few major changes in the presence of invasive species in the SCOL from 2019 to 2020. The primary invasive species that are treated regularly in the Southern Chain include hydrilla (*Hydrilla verticillata*), burhead sedge (*Oxycaryum cubense*), and water hyacinths (*Eichhornia crassipes*). Only five of the Southern Chain lakes underwent an increase in invasive percentage from 2019 to 2020 (Figure 2-13). Also illustrated are the invasive percentage thresholds for the lake health index scoring; keep in mind that a score of 3 is only earned if no invasives were sampled during the survey.

There were no managed invasive species observed during 2020 surveys of Lakes Howard and Lulu. Lakes Cannon, Eloise, Hartridge, Idylwild, and Roy possessed invasive percentages below the 2.5% threshold needed for an index score of 2. Only Lake Spring exhibited an extreme abundance of invasive plants in 2020.

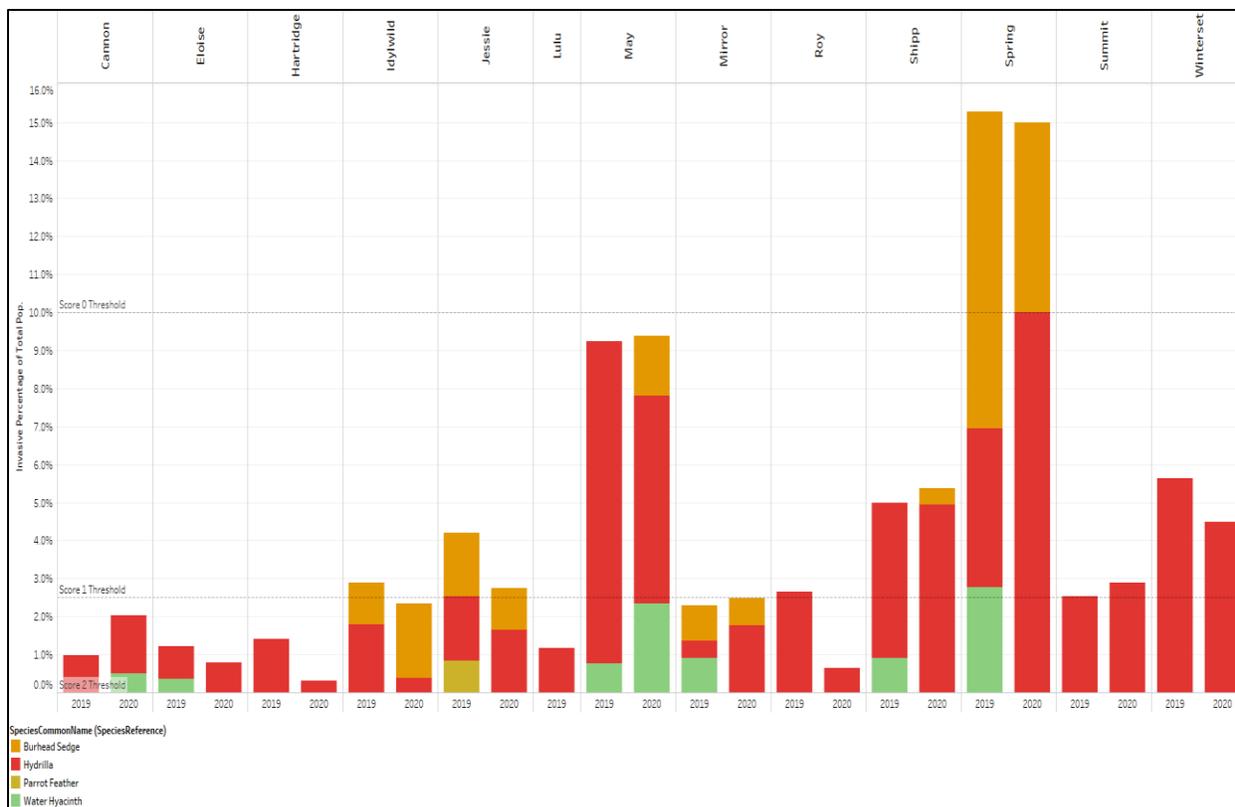


Figure 2-13. South Chain of Lakes annual percentage of managed invasive species.

## Species Diversity

Species diversity index values for the South Chain of Lakes were calculated using data from 2019 and 2020. 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 Lulu, May, Roy, and Winterset exhibited an increase in species richness from 2018 to 2019; Lakes Cannon, Eloise, Hartridge, Howard, Idylwild, Jessie, Mirror, Shipp, Spring, and Summit underwent a decrease in richness during this time period.

**Hill’s Evenness #3 (E3):** A change in species evenness is a comparison of relative abundance of each species surveyed and is related to community robustness. Lakes Cannon, Eloise, Hartridge, May, Shipp, and Summit showed an increase in species evenness in 2020. Lakes Howard, Idylwild, Jessie, Lulu, Mirror, Roy, Spring, and Winterset experienced a decrease in evenness.

**Shannon’s Diversity (H):** As a combination of species richness and evenness, Shannon’s index indicates the overall species diversity for each site. Only Lakes Cannon, May, and Roy underwent

an overall increase in diversity in 2020. Lakes Eloise, Hartridge, Howard, Idylwild, Jessie, Lulu, Mirror, Shipp, Spring, Summit, and Winterset experienced a decrease in this index value.

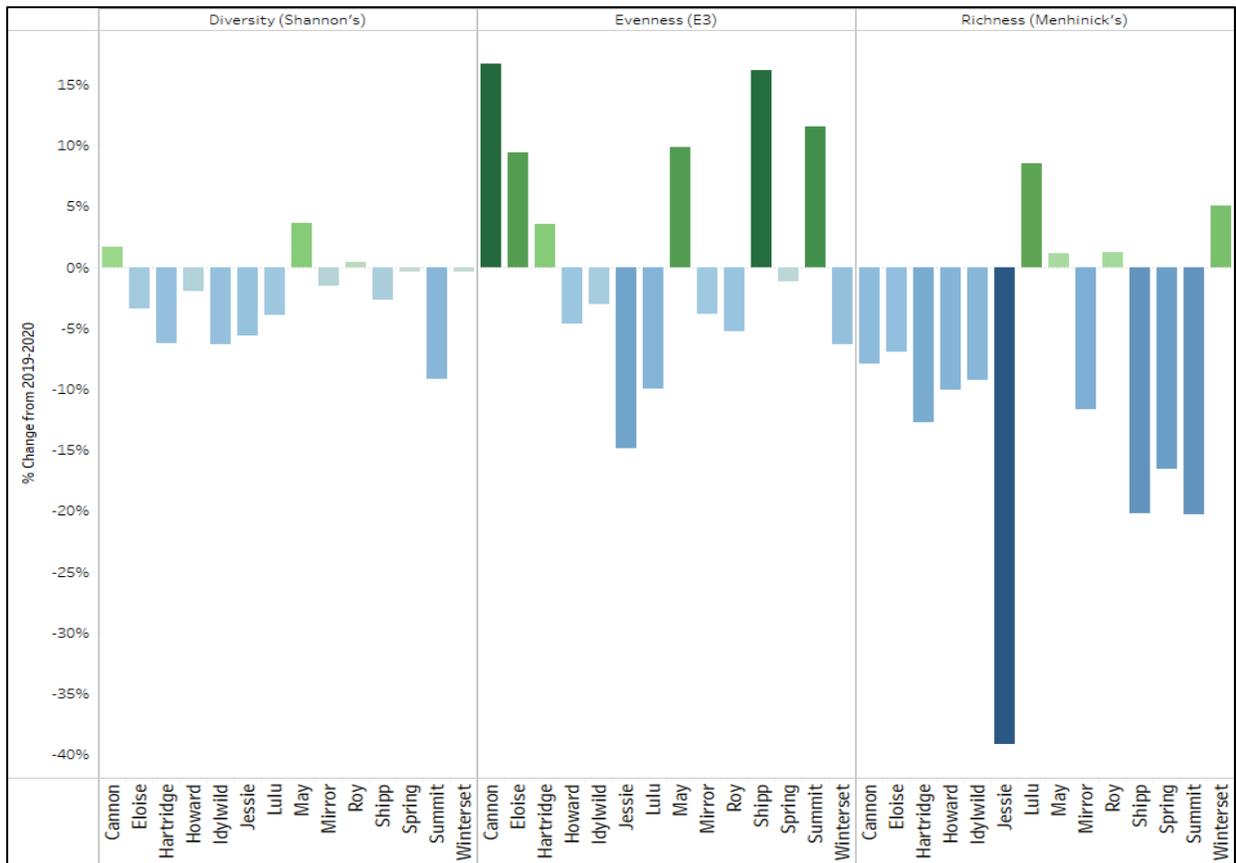


Figure 2-14. South Chain of Lakes annual index values for species richness, evenness, and diversity.

Based on the species diversity data, many of the SCOL waterbodies have undergone a decrease in species richness, evenness, and overall diversity since 2019. Some of the changes in evenness and overall diversity could be due to reduction of invasive species over the last year. As the City continues to collect additional years of data, we can gain a better understanding of each lake’s normal range of fluctuation in their aquatic plant communities.

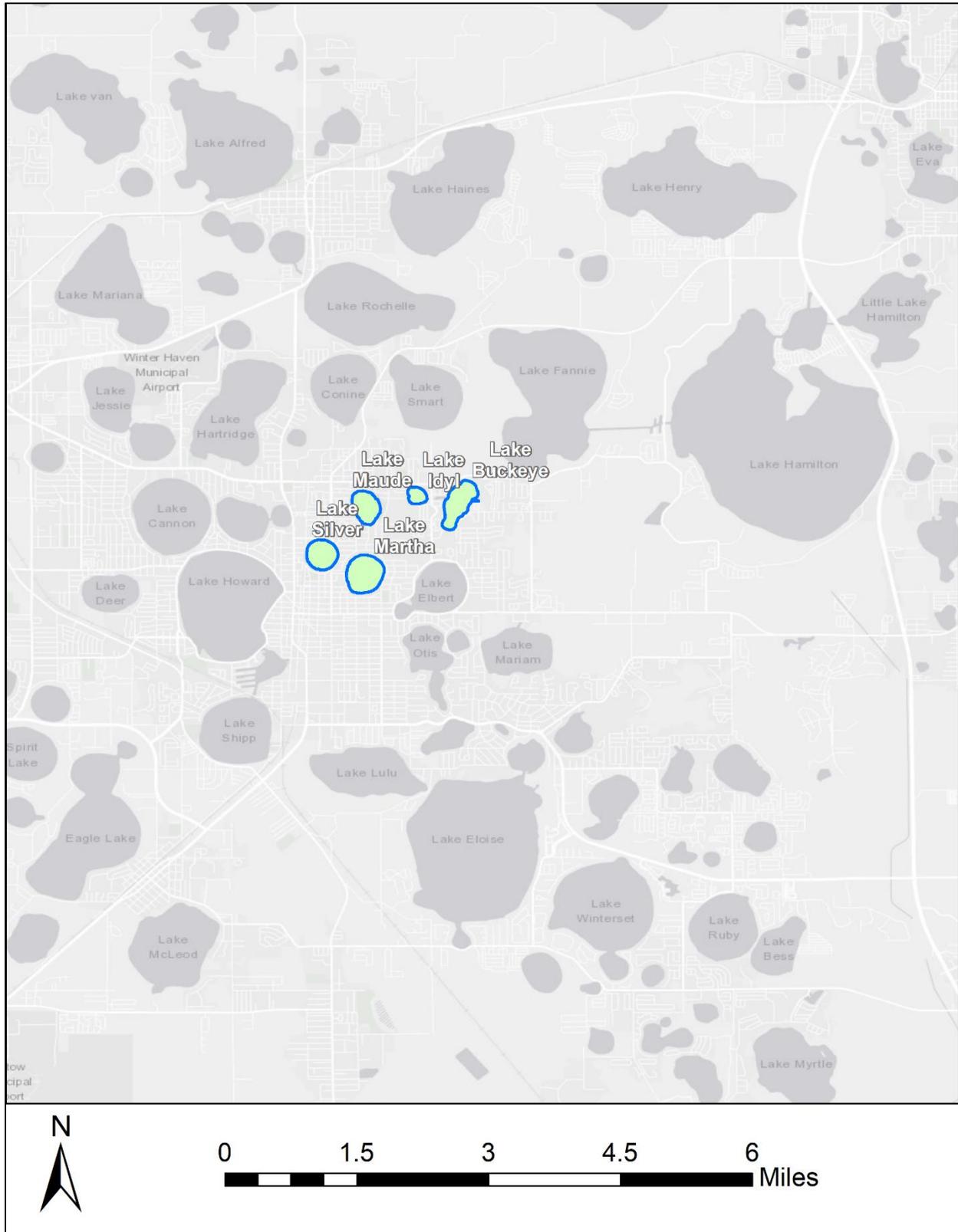
### Management Conclusions

With the majority of the Southern Chain possessing TMDLs or considered impaired by regulatory standards, one consolation is that the majority are exhibiting improvement in multiple water quality parameters. Interestingly, the waterbodies with the higher areal pollutant loadings are all ones undergoing sweeping water quality improvement. This may be evidence of the success of stormwater management practices such as street sweeping and green infrastructure. That said, correcting the water quality trends in Lakes Hartridge and Jessie require greater management effort. Nutrient source analysis may be an effective first step in determining where to focus these efforts.

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 reliable means to keep nuisance plants like hydrilla at bay. The median area treated with herbicide for the lakes in this study area is about 40 acres per year. Lakes Jessie and Winterset were the only lakes in this group that had treatments exceeding this value in 2020—neither of which exceeded 60 acres (Table 4-7; in appendix). Considering this, most of these lakes are considered in a maintenance stage in that management efforts are focused more on spot treating smaller areas and less on large-scale applications.

As the City collects more vegetation data, a better understanding of normal vegetation fluctuation will be possible. Biovolume percentage is not currently scored in the Lake Health Index. However, as more and more years of data is collected, evaluation of annual changes in biovolume may be incorporated into the study. The City may also incorporate concepts from the State's Lake Vegetation Index (LVI) program to evaluate how the proportion of various plant species in each lake impact the health of their aquatic communities.

## 2.3 North Central Lakes



The Winter Haven North Central Lakes (NCL) are a group of waterbodies connected by pipe and ditch conveyances and can contribute surface water to the North Chain of Lakes by discharging to Lake Fannie during high water periods. These five lakes include Lakes Buckeye, Idyl, Martha, Maude, and Silver. The following is a presentation and analysis of the various lake health metrics for this group.

*Water Quality*

2020 AGM Chl-a, 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 the data, Lakes Buckeye, Maude, and Silver are experiencing better than average water quality, while Lakes Idyl and Martha are experiencing poorer water quality (Figure 2-15). Lakes Buckeye and Maude both exhibit Chl-a and nutrient concentrations well below and Secchi depths well above their normal ranges. It is clear that water quality in these two lakes is the best it has been in quite some time.

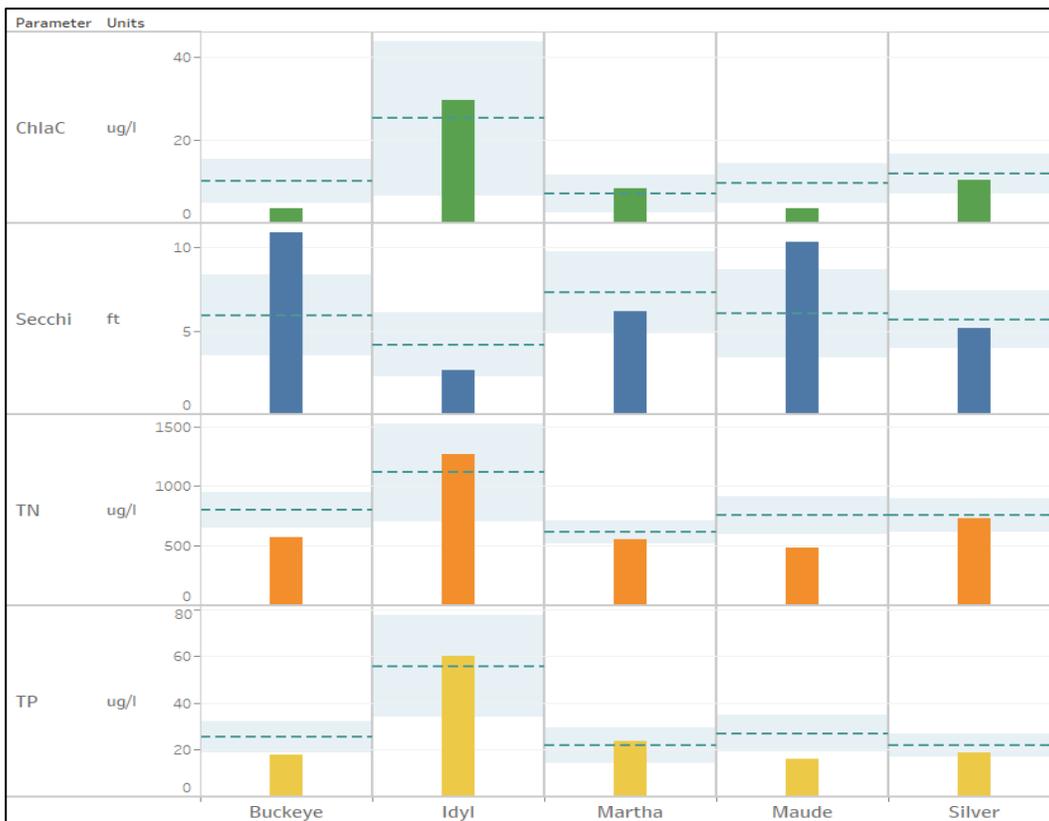


Figure 2-15. 2020 AGM Chl-a, TN, TP, & Secchi depth values for the North Central Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

**NNC Impairment**

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) Chl-a, TN, and TP concentrations between 2013 and 2020 (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 based on multiple consecutive exceedances of the NNC thresholds for Chl-a, TN, and TP.

None of the waterbodies in this group have had Total Maximum Daily Loads (TMDLs) developed. That said, it is likely that Lake Idyl will have a TMDL developed by FDEP in the future.

### Water Quality Trends

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 Chl-a, 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 ( $p\text{-value} \leq 0.05$ ) (Table 4-4 in appendix).

**Chlorophyll-a Trends:** Lakes Buckeye and Maude exhibited significant decreasing Chl-a trends while Chl-a in Lake Martha was increasing significantly.

**Total Nitrogen Trends:** Lakes Buckeye and Maude experienced significant decreasing trends in TN; while Lake Martha exhibited significantly increasing TN.

**Total Phosphorus Trends:** Lakes Buckeye and Martha exhibited significantly decreasing TP while Lake Martha showed a significant increase in TP.

**Clarity Trends:** Lakes Buckeye and Maude experienced significant increase in Secchi depth. Lake Martha's Secchi depth trend was decreasing.

Based on the trend data, it is clear that water quality is improving in both Lake Buckeye and Maude. While Lake Silver's Chl-a and nutrient concentrations appear to be moving in a downward direction, its Secchi depth is also decreasing. While these trends are not significant, the clarity aspect deserves some focus to determine why it is declining. Lake Idyl continues to exhibit deteriorating water quality, albeit the trends aren't significant. Considering this lake is already impaired, the continual decline in water quality is concerning. The significant decline in water quality in Lake Martha is a perfect example of the importance of trend analysis. This lake would likely have been overlooked if impairment was the only water quality metric considered. Now that an issue has been identified, management efforts can be focused to prevent future impairment of Lake Martha.

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

Table 2-3. 2020 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; overall depression of SLs was not observed during the 2006 – 2014 drought, nor have they been considerably higher since. Only Lakes Silver, Martha, and Maude exhibited longer-term fluctuation, albeit their SL range is still fairly narrow when compared with other lake groups. Nevertheless, each of these lakes reached a seasonal high in 2020 despite the reception of only 47 inches of rainfall. This amount of precipitation was technically below the long-term average of 52 inches. However, most of this rain was received toward the tail-end of the year.

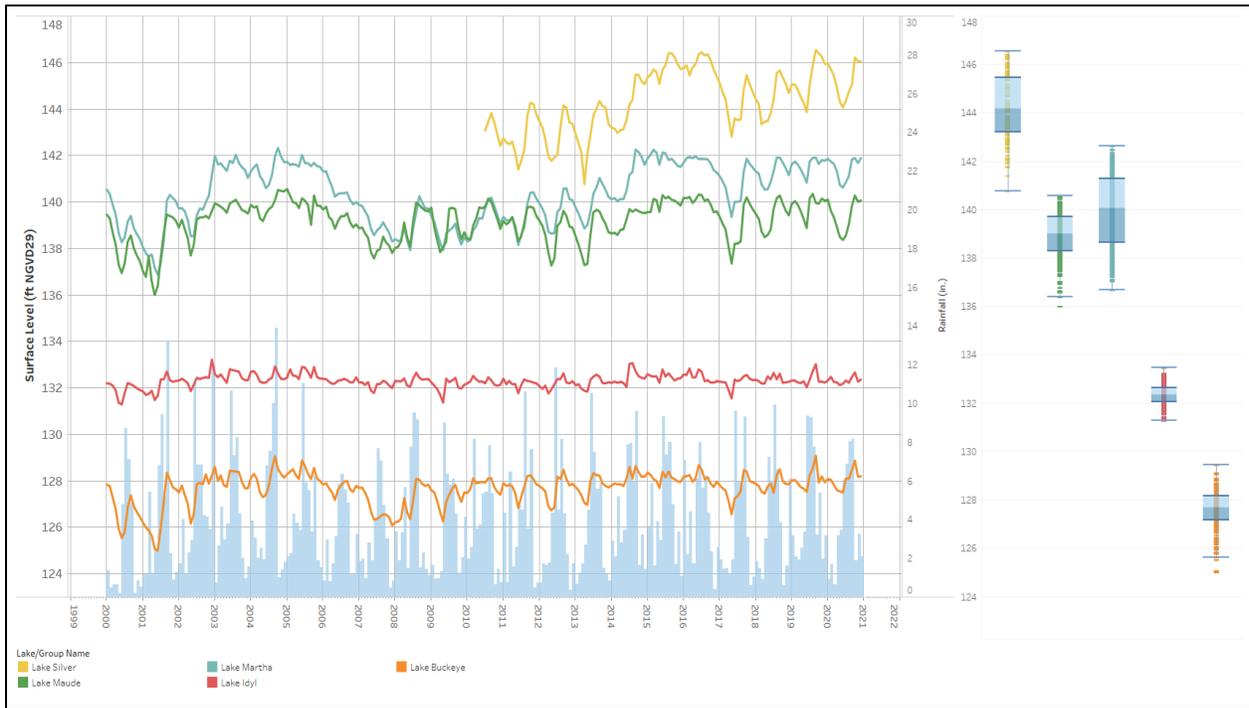


Figure 2-16. North Central Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

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 2018 lakes report—only Lake Martha exhibited a significant positive correlation between lake level and Chl-a (Table 4-5; in appendix). This is likely due to the lack of significant seasonal or long-term water level fluctuations in several of these lakes. 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.

While this lake group is morphologically diverse, most of the effects of the various lake shapes would only manifest as differences in groundwater influence and potential aquatic vegetation growing areas. The deeper lakes like Silver and Martha would only support relatively narrow littoral zones, but these lakes lack much vegetation abundance to begin with. However, Lakes Maude and Buckeye are shallow enough to support littoral zones covering the majority of the lakes' areas which has allowed for very dense beds of submerged vegetation. The surface areas of these lakes are small enough to limit the potential effects of wind and wave action on suspended sediments.

Pollutant loading rates vary considerably from lake to lake in this group. The surrounding soil types and land uses change considerably as you follow the flow pathway from Lake Silver to Buckeye. The commercial and residential land uses give way to more open lands and agricultural types as you move away from the City center. This change in land use equates to a similar transition from impervious percentage within each drainage basin. Additionally, the older downtown areas that convey stormwater directly to the lakes change to newer developments which bring greater on-site stormwater treatment with them. The higher areal loads are aggregated in these urban residential zones, with the

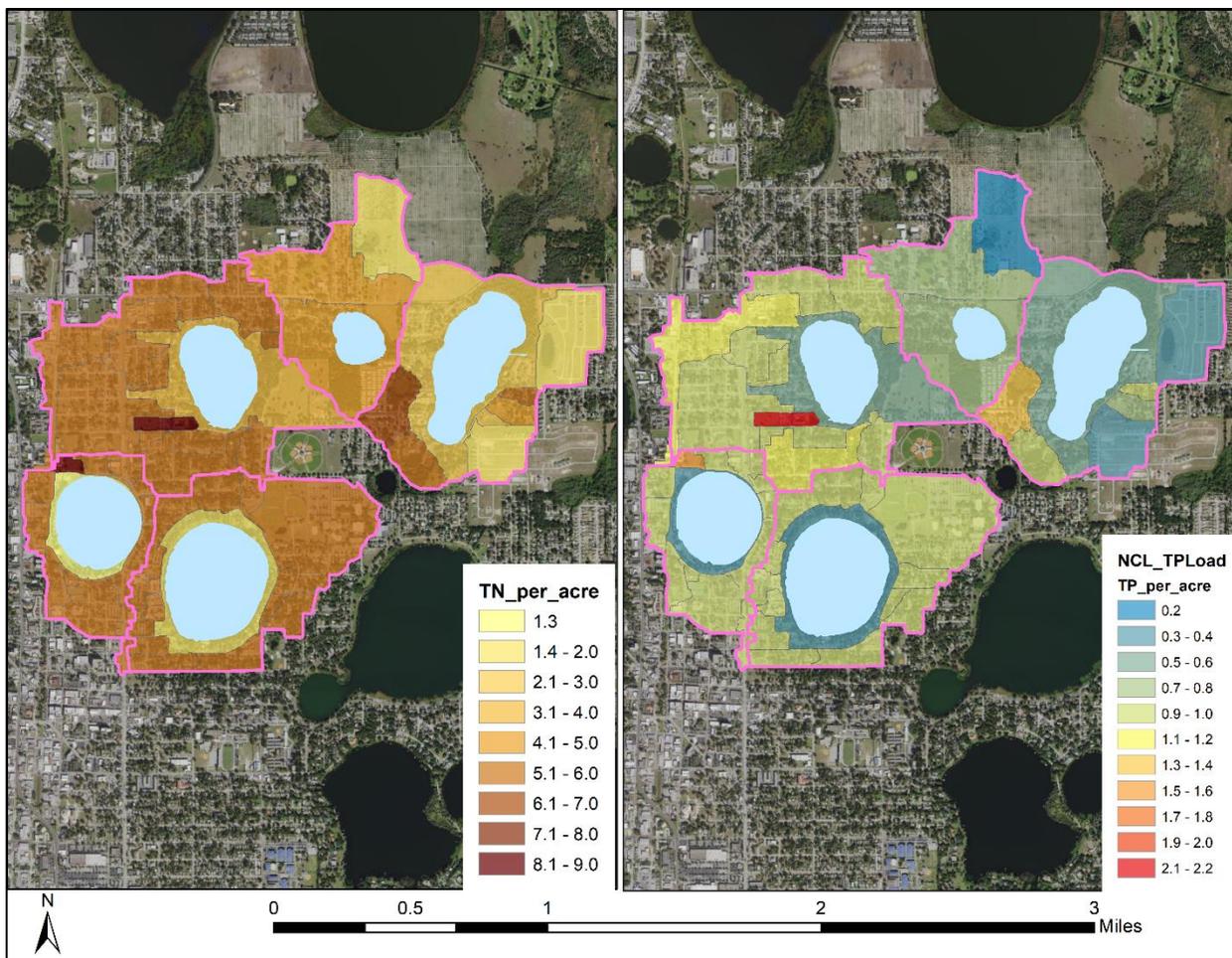


Figure 2-17. Areal TN & TP Loading for individual drainage basins in the North Central Lakes.

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 of hotspot areas around Lakes Maude and Idyl that could incorporate structural stormwater treatment practices such as raingardens. Aside from the City of Winter Haven, Polk County and FDOT are contributors of stormwater in many of these basins.

With regards to pollutant loading from other sources besides stormwater, the drainage basins in this group don't possess many Onsite Sewage Treatment and Disposal (OSTD) or septic systems. There are only 49 known septic units in the vicinity of these lakes—the majority of which are located within Lake Buckeye's basin (Table 4-6; in appendix). Despite this, the water quality trends don't indicate that these OSTDs are currently impacting water quality.

*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 vegetation abundance. 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, SAV, and Floating-leaf vegetation (FLV) is indicative of good species diversity and habitat for aquatic fauna. A lack of submerged types is not always cause for alarm, however, in most instances where this is the case,

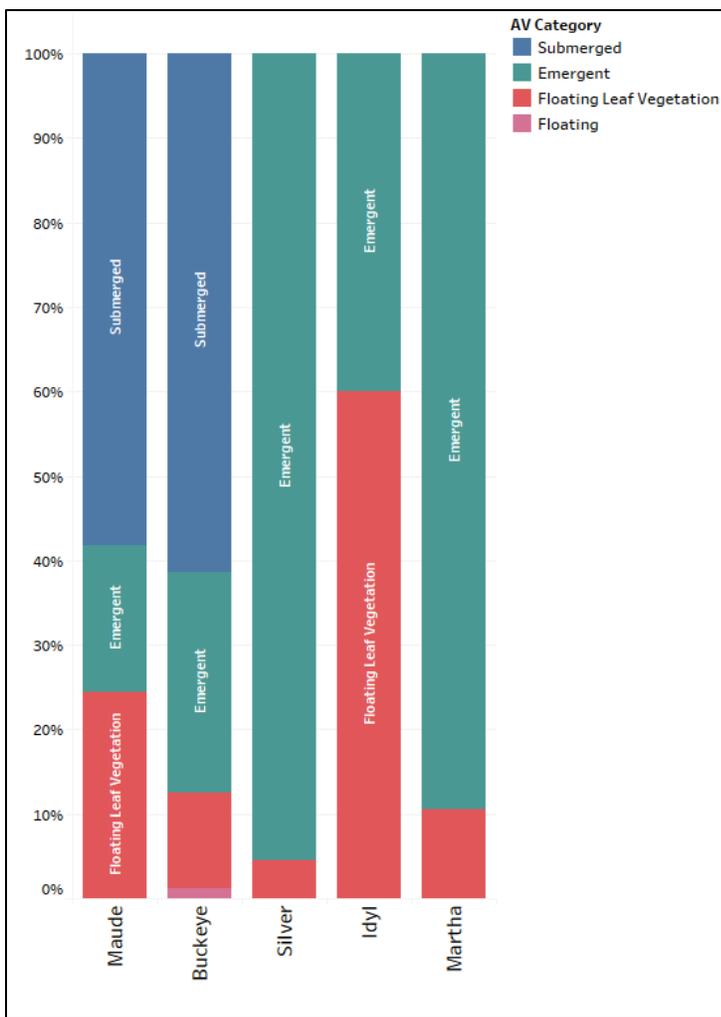


Figure 2-18. North Central Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

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 and FLV (Figure 2-18). There was a total lack of observed SAV species in Lakes Idyl, Martha, and Silver. It is not wholly understood why these lakes lack submerged plant communities, however, the City is searching to discover the underlying cause(s). For instance, in Lake Idyl, detritus and muck can be found throughout the waterbody. This type of sediment is 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, but no submerged species have been documented there in at least the last 5 years. The lack of SAV still remains a mystery.

### Vegetation Abundance

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 2020, Lakes Buckeye and Maude possessed PAC values well over 90% which likely contribute significantly to their excellent water quality (Figure 2-19). Lake Idyl underwent a significant increase in both %BV and PAC—placing it above the 30% abundance threshold. As usual, little to no SAV was detected in Lakes Martha and Silver. That said, the amount of emergent vegetation detected placed their PAC values above the 2.5% minimum expected threshold.

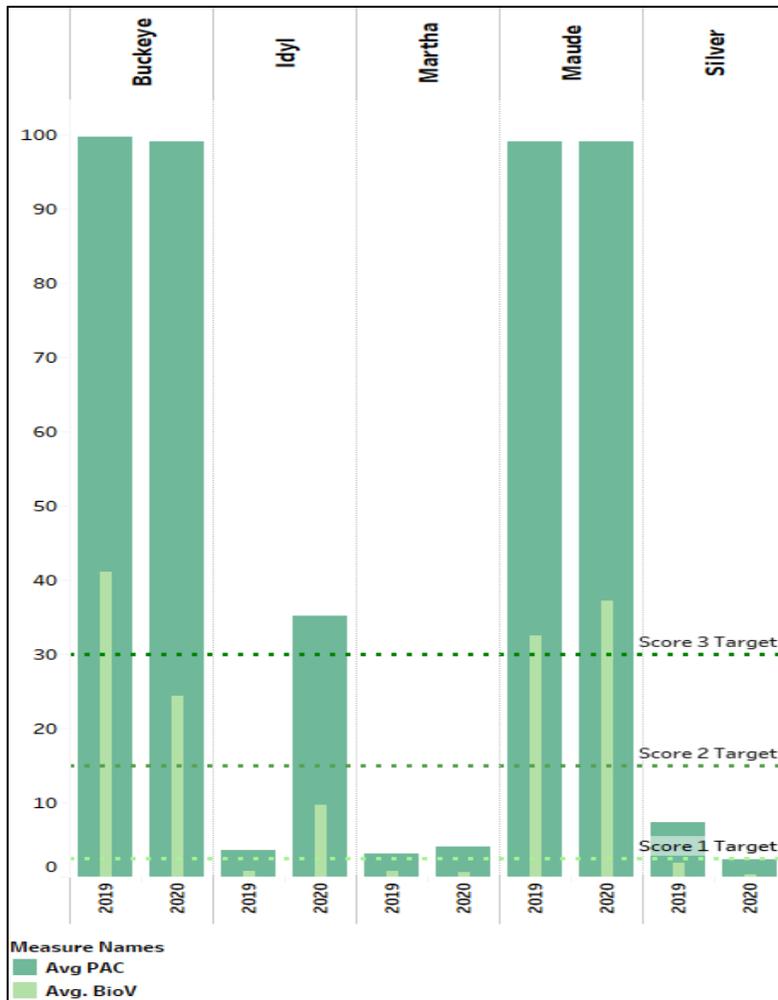


Figure 2-19. North Central Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

### Invasive Species Percentage

Monitoring efforts afford a look into the presence of invasive species in the Winter Haven area lakes. Tracking percentages of these managed invasives provides a means to measure treatment effectiveness with the goal of bringing each lake into a managed state. The primary invasive species identified in the North Central Lakes include burhead sedge (*Oxycaryum cubense*) and hydrilla (*Hydrilla verticillata*). According to the data, invasive species percentage declined in Lakes Idyl, Martha, and Maude from 2019 to 2020 (Figure 2-20). Lake Buckeye underwent an increase in invasive percentage during this time. There were no invasives detected as part of Lake Martha’s survey in 2020.

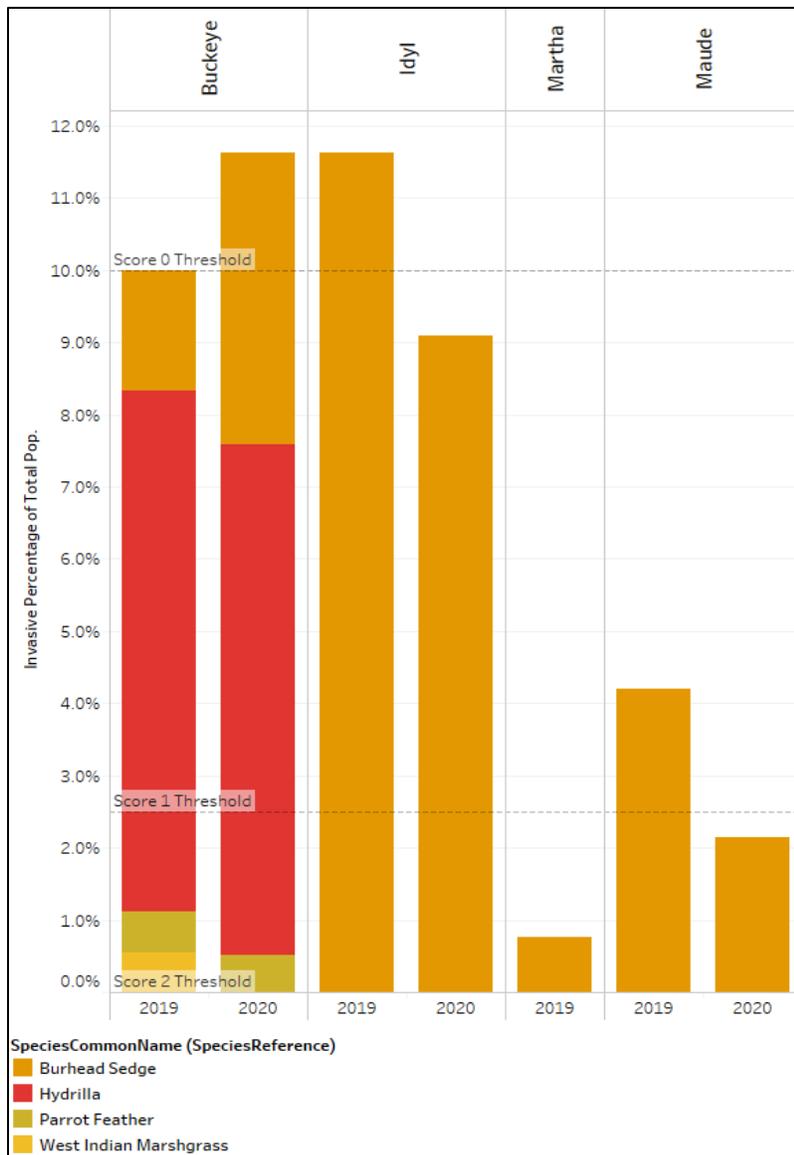


Figure 2-20. North Central Lakes annual percentage of managed invasive species.

### Species Diversity

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. Only Lake Idyl exhibited an increase in species richness from 2019 to 2020. Lakes Buckeye, Martha, Maude, and Silver underwent a decrease in richness.

**Hill’s Evenness #3 (E3):** Species evenness correlates to in community resilience. Lakes Martha and Maude showed an increase in species evenness in 2020. Lakes Buckeye, Idyl, and Silver underwent a decrease in 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 Idyl and Maude underwent an overall increase in diversity in 2020. Lakes Buckeye, Martha, and Silver experienced a decrease.

There was a general decline in overall species diversity in the North Central Lakes from 2019 to 2020. Lakes Buckeye and Silver specifically decreased in all three diversity metrics. Despite this, it is expected that these values will change over time. Once the City has collected a large enough dataset, can we begin to understand if a trend emerges. For

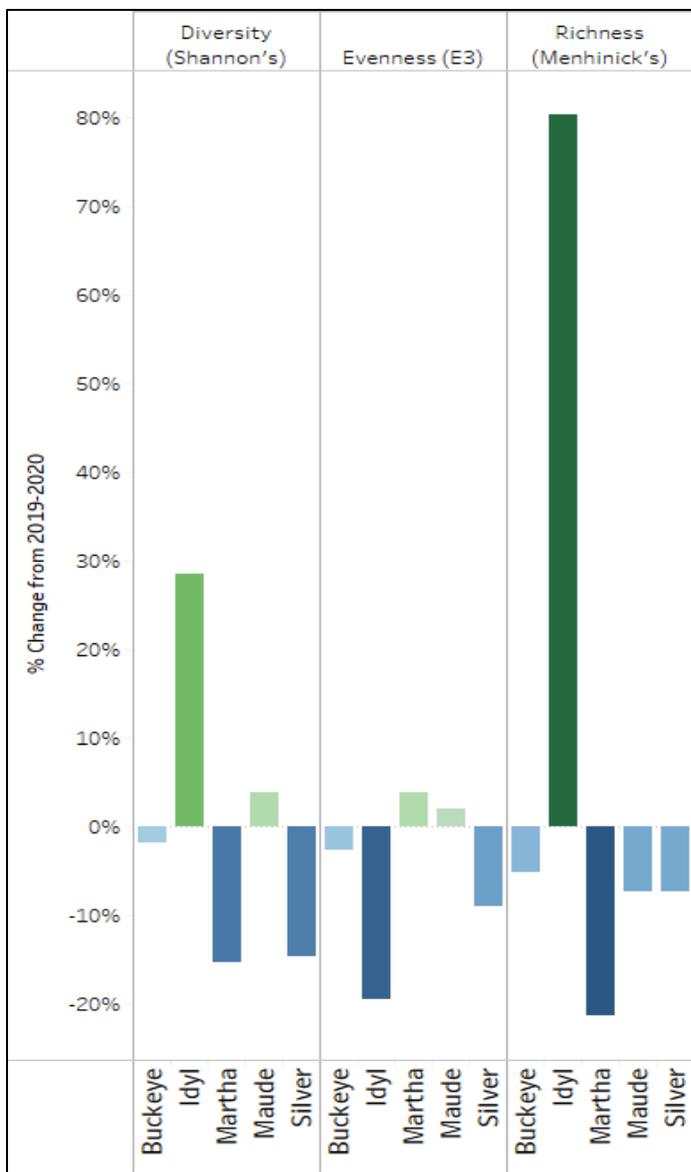


Figure 2-21. North Central Lakes annual index values for species richness, evenness, and diversity

now, tracking changes from year to year is the best quantitative method for tracking the health of the lakes' vegetation communities.

### Management Conclusions

It is evident based on the data presented that there is a great disparity in overall lake health amongst the North Central Lakes. Lake Buckeye and Lake Maude are both doing very well from a water quality and aquatic vegetation standpoint. Lake Idyl is impaired and management efforts are currently underway to reduce nutrient loads—utilizing BMPs such as street sweeping and the implementation of green infrastructure. Lake Silver is doing well from a water quality perspective, however, there is always room to improve the vegetation community there.

Lake Martha, while not currently impaired exhibits troubling water quality trends. Management efforts will need to be focused to address nutrient sources. Compounding the problem in 2020 was a diesel spill from the adjacent hospital that

required significant environmental remediation. This event certainly has not helped to alleviate the current issues in the lake. The lack of aquatic vegetation in Lake Martha is a matter of significance. A vegetation planting program is being considered to supplement lakes with minimal aquatic vegetation.

With the exception of Lake Buckeye, invasive species management has been fairly sporadic for this lake group. Lakes Silver and Martha don't possess much of an invasive species presence to begin with, but even Lake Buckeye and Idyl underwent very small, less than 10 acre treatments in 2020 (Figure 4-7; in appendix). The NCL are in what is referred to as a maintenance stage with regards to invasive management. Continual monitoring is critical for ensuring future success, however.



The Winter Haven South Central Lakes (SCL) comprise 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 following is a presentation and analysis of the various lake health metrics for this group.

**Water Quality**

A snapshot of the 2020 AGM Chl-a, TN, TP, and Secchi depth values for the SCL with the long-term (2000 – 2020) mean and normal range (+/- 1 standard deviation) for each waterbody (Figure 2-22). Lake Elbert is currently exhibiting poorer water quality with above-average Chl-a, TN, and TP concentrations as well as below average Secchi depth. Each of these parameters were at or exceeding the normal range (i.e. far poorer than normal conditions). For Lake Otis, 2020 Chl-a and TN concentrations were below the long-term averages, TP was slightly above average, and Secchi depth was slightly below average. Lake Mariam’s Chl-a and Secchi depth were very close to average levels; with TN well below average and TP well above average. Lake Link displayed better water quality than the long-term averages in all parameters.

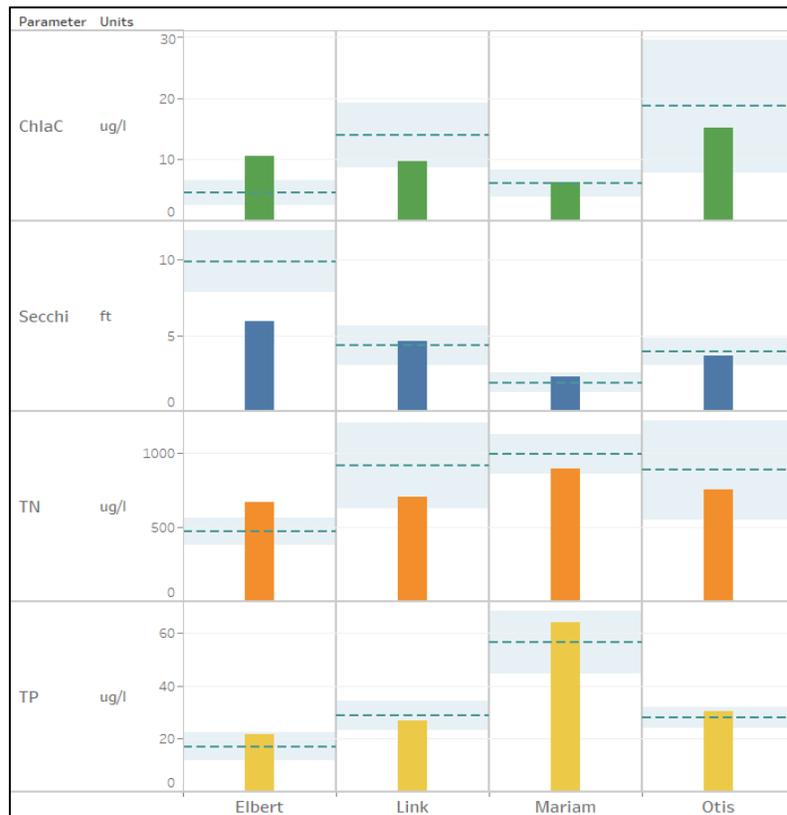


Figure 2-22. 2020 AGM Chl-a, TN, TP, & Secchi depth values for the South Central Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

**NNC Impairment**

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) Chl-a, TN, and TP concentrations between 2013 and 2020. The AGM concentrations during this time period are displayed in Tables 4-1 through 4-3 in the Appendix. Based on this methodology, none of the Lakes in this group meet the

impairment criteria. It should be noted that in 2019, Lake Otis was considered impaired for Chl-a due to consecutive NNC exceedances in 2012 and 2013. None of the South Central waterbodies possess Total Maximum Daily Loads (TMDLs). It is unlikely that TMDLs will be developed in the future unless the impairment status of any of these lakes changes.

### **Water Quality Trends**

Water quality trend evaluation was performed by plotting AGM Chl-a, TN, TP, and Secchi depth against time, in years, from 2000 to 2020 (Table 2-4). Monotonic trend direction (increasing/decreasing) and statistical significance ( $p\text{-value} \leq 0.05$ ) 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 deteriorating Chl-a, TN, and Secchi depth trends in Lake Elbert and an improving TN trend in Lake Link. Lake Otis's water quality appears to be moving in a positive direction, however these trends aren't significant. Lake Mariam's TN concentration and Secchi depth values also appear to be moving toward improvement, while its Chl-a and TP concentrations exhibit opposite movement.

Based on the trend data, it is clear that Lake Elbert's water quality is declining. This deterioration may be due, in part, to the recent roadway construction along SR-542. There are currently water quality improvement practices being implemented in its drainage basin. Hopefully, these trends slow and reverse in the near future now that the construction is completed. Otherwise, additional management strategies will need to be devised before Lake Elbert reaches impaired status. The somewhat positive trends in Lake Otis are reassuring considering this lake's previous impairment. Monitoring and management strategies will continue to be implemented in this waterbody to ensure further improvement. While trends in Lake Mariam are not significant, the concentrations of Chl-a and TP are parameters to keep close track of. If these increasing trends become significant, then more management effort will be needed to address the source(s) of pollution.

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 (Deteriorating)	Significant	0
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	Increasing	Not Significant	1
	TN	Decreasing	Not Significant	2
	TP	Increasing	Not Significant	1
	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. 2020 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 2020 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 underwent a moderate decline toward average levels due to a lack of rainfall during the first half of 2020. However, each of these lakes ended 2020 at levels close to the top of their normal ranges as a result of significant rainfall in the latter half of the year.

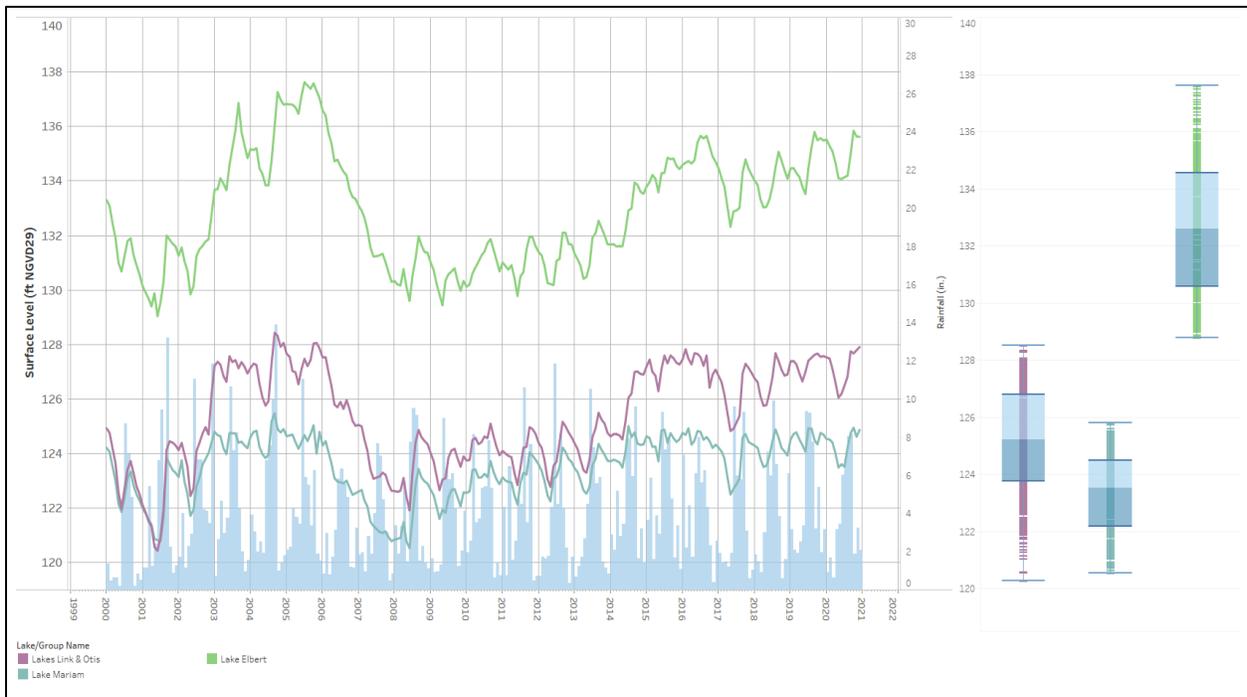


Figure 2-23. South Central Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Monthly rainfall totals indicate hydrologic response to precipitation.

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 narrower interquartile range in the boxplot.

Stormwater pollutant loads for this drainage basin originate mostly from institutional (i.e. educational facilities) and medium-density residential land uses. As a result, areal nutrient loads are within the 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 have management practices such as street sweeping implemented. In addition, the City has installed 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 of residential and open/agricultural lands. Aside from the City of Winter Haven, Polk County and FDOT also contribute stormwater to these basins.

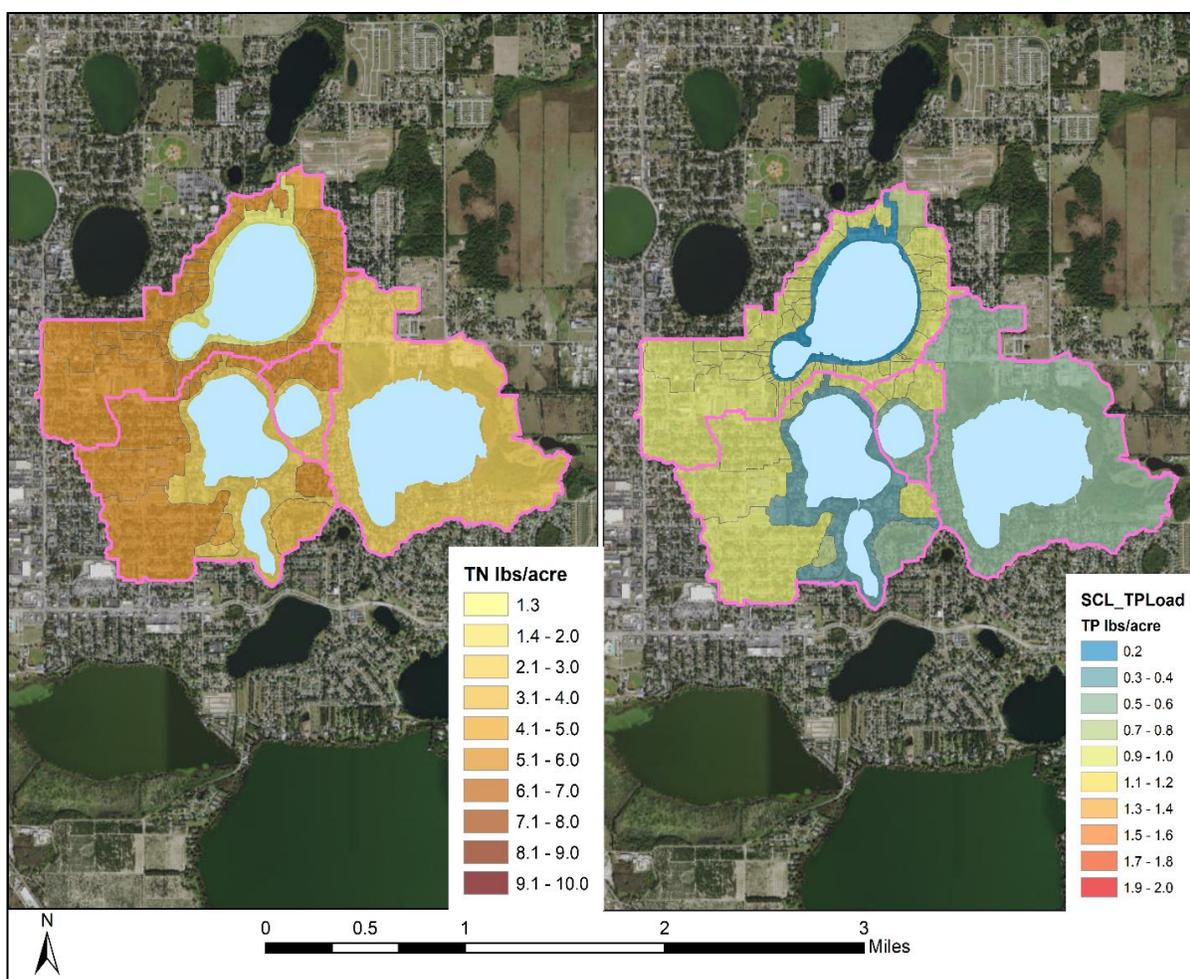


Figure 2-24. Areal TN & TP Loading for individual drainage basins in the South Central Lakes.

Other potential pollutant sources may originate from leaking Onsite Sewage Treatment & Disposal (OSTD) or septic systems. There are 215 known septic units in the SCL watershed—with the majority located in the Lake Mariam (132) and Lake Otis (66) drainage basins (Table 4-6; in appendix). Since OSTDs are generally a source of

nitrogen, an absence of increasing TN trends likely means that septic units are not a current source of pollutant loading in these waterbodies. That said, these systems do have potential to become sources in the future as they age and begin to fail. In the event that water quality begins to deteriorate in the future, management strategies should incorporate this information to evaluate potential nutrient leaching from OSTDs.

The morphology of the SCL waterbodies is quite diverse. Lake Elbert is much deeper and more bowl-shaped compared with the other lakes in this group. This equates to less sediment suspension potential and more groundwater interaction which may partly explain its much higher water clarity than the other South Central Lakes. Unsurprisingly, the higher clarity has allowed for a very robust littoral zone in Lake Elbert. Lake Mariam, on the other hand, is extremely shallow and pan-shaped. As a result, Lake Mariam has a very wide surrounding wetland made up of emergent vegetation. However, this also means that sediment suspension from wind/wave action is more pronounced. These factors may help to explain why Lake Mariam lacks any submerged aquatic plant species. Lake Link and the southern lobe of Lake Otis are very similar to Lake Elbert, while the northern portion of Lake Otis shares qualities with Lake Mariam. As a result, these areas share similar water quality and aquatic vegetation responses as their respective neighbors.

*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 a data collection error, no 2020 species data was recovered for Lakes Otis and Link; vegetation abundance data was able to be recorded, however.

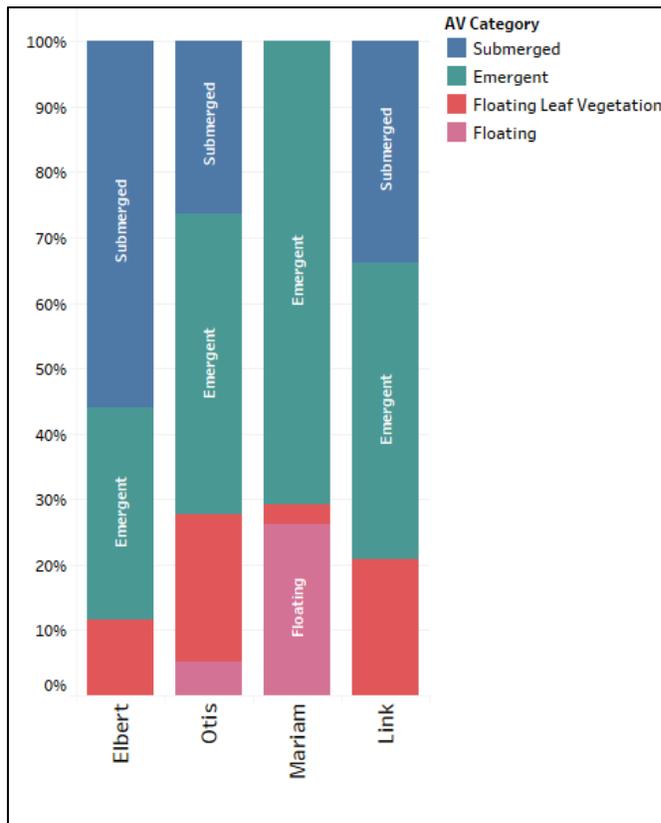


Figure 2-25. South Central Lakes categorical proportion of aquatic vegetation as emergent, submerged, floating-leaf, or floating

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 several surveys. A sizable proportion of floating vegetation (invasive water hyacinth) has historically been observed in Lake Mariam as well. Most of Lake Mariam is surrounded by fairly dense fringe wetland plants. These wetlands have resulted in higher true color imparted by the breakdown of organic tannins. This would also explain the lack of SAV as well as low Chl-a concentrations as sunlight cannot penetrate highly colored water.

**Vegetation Abundance**

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 2020 PAC values in relation to set minimum targets (Figure 2-26).

2020 PAC values remained well above the 30% ideal abundance target. Lake Mariam underwent a slight decrease in abundance in 2020—resulting in a decrease below the 15% target threshold. Lake Otis exhibited a slight increase during the same period, but still rests between the 15% and 30% thresholds. 2020 vegetation abundance in Lake Link sat well above the 30% ideal threshold.

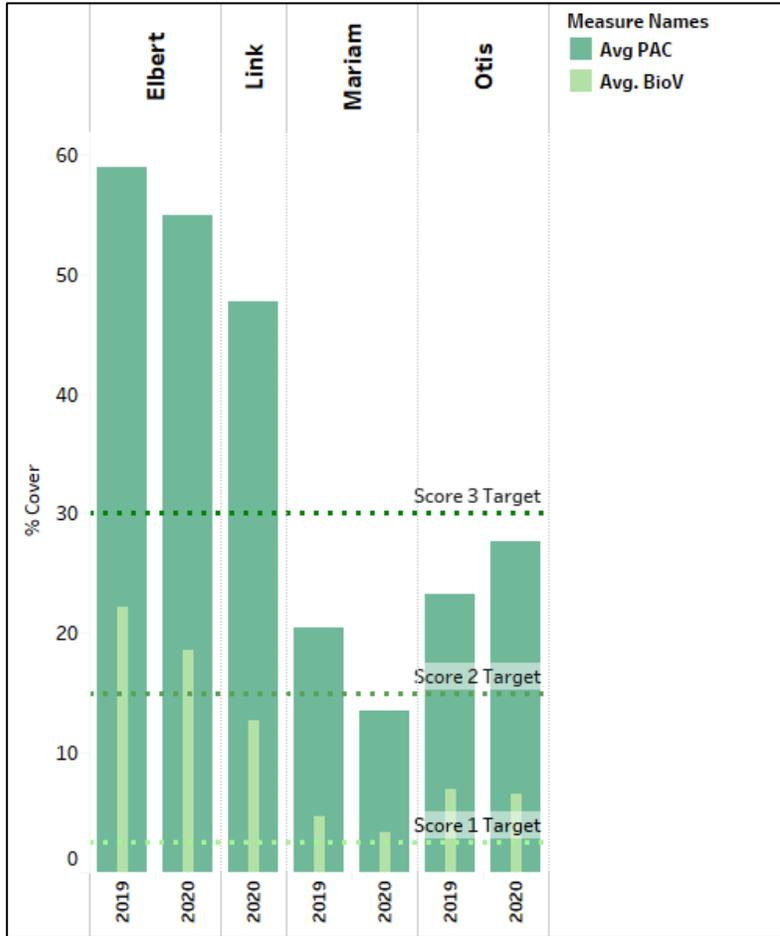


Figure 2-26. South Central Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

### Invasive Species Percentage

Ideally, a perfectly healthy biological community would be free from invasive species. In addition to causing ecological harm to native species, large-scale 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*).

Unfortunately, due to a lack of species data for Lakes Link and Otis and 2020, lake index scoring for invasives will not be included for these waterbodies. From 2019 to 2020, Lake Elbert underwent an increase in invasive species abundance while Lake Mariam saw a substantial decrease (Figure 2-27). The increase in Lake Elbert can be attributed to an uptick in hydrilla which resulted in a decrease in its invasive index score. The successful treatment of water hyacinth in Lake Mariam brought the invasive percentage below the 2.5% threshold for a category score of 2.

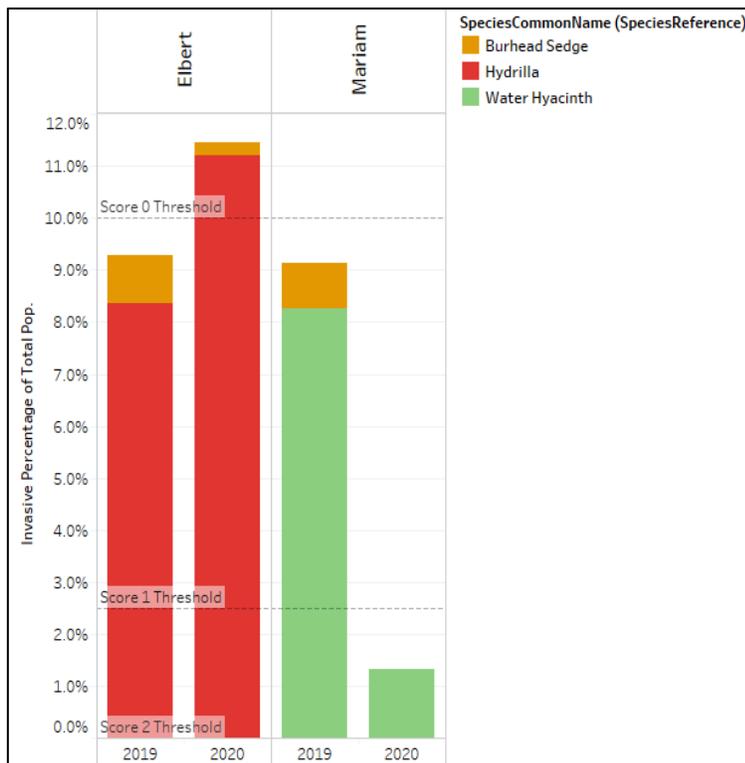


Figure 2-27. South Central Lakes annual percentage of managed invasive species.

### Species Diversity

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 2019 to 2020. Since no data was collected for Lakes Link and Otis, this metric will be excluded from the overall lake health index calculation.

**Menhenick’s Richness (R2):** Species richness denotes how many unique species are present in a population. Lake Elbert exhibited a decrease in richness while Lake Mariam saw an increase from the previous year

**Hill’s Evenness #3 (E3):** An increase in species evenness is preferred as it correlates to improvement in community resilience. Species evenness increased in Lake Elbert but slightly declined in Lake Mariam from 2019 to 2020.

**Shannon’s Diversity (H):** As a combination of species richness and evenness, Shannon’s index indicates the overall species diversity for each site. Both Lake Elbert and Mariam exhibited a decrease in Shannon’s diversity from 2019 to 2020.

Lake Elbert’s change in diversity metrics may be due to the displacement of more sparsely populated species by the expanding hydrilla. As this invasive species adopted a more prominent role in the lake’s vegetation community, it increased overall evenness at the expense of species richness and overall diversity. While we would expect the opposite effects to occur in Lake Mariam due to the reduction in water hyacinth, the lake lacked much aquatic vegetation to begin with. A seemingly minor change in relative abundances of various species can have a much more profound impact on species diversity. Further study of the long-term fluctuations in aquatic plant communities is needed to better understand these effects.

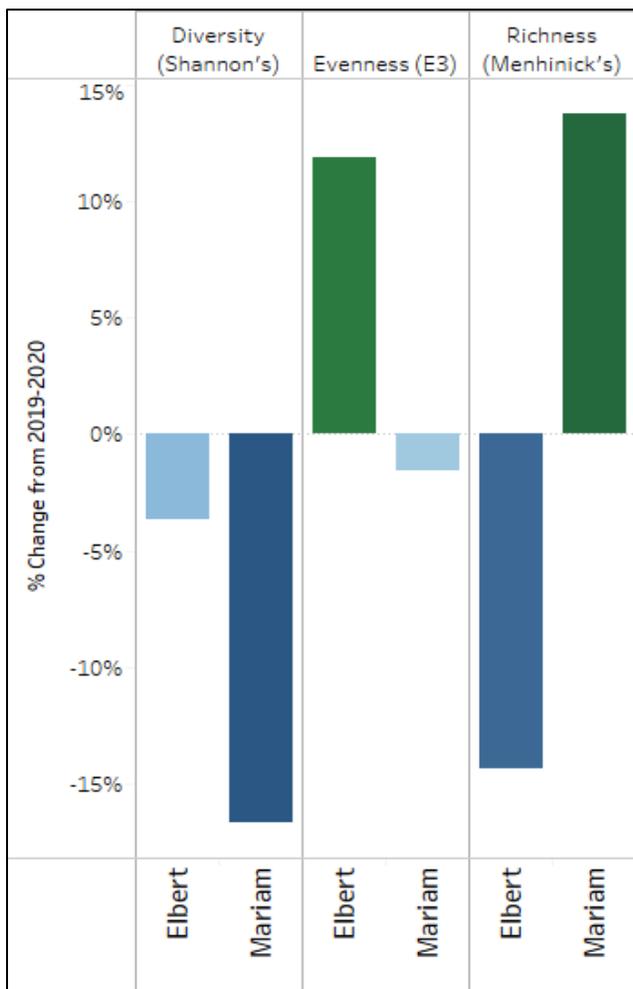


Figure 2-28. South Central Lakes annual index values for species richness, evenness, and diversity.

4-7; in appendix). That said, the City will continue to work closely with FWC and Polk County to improve invasive species treatment strategies and reduce the need for large-scale treatments in the future.

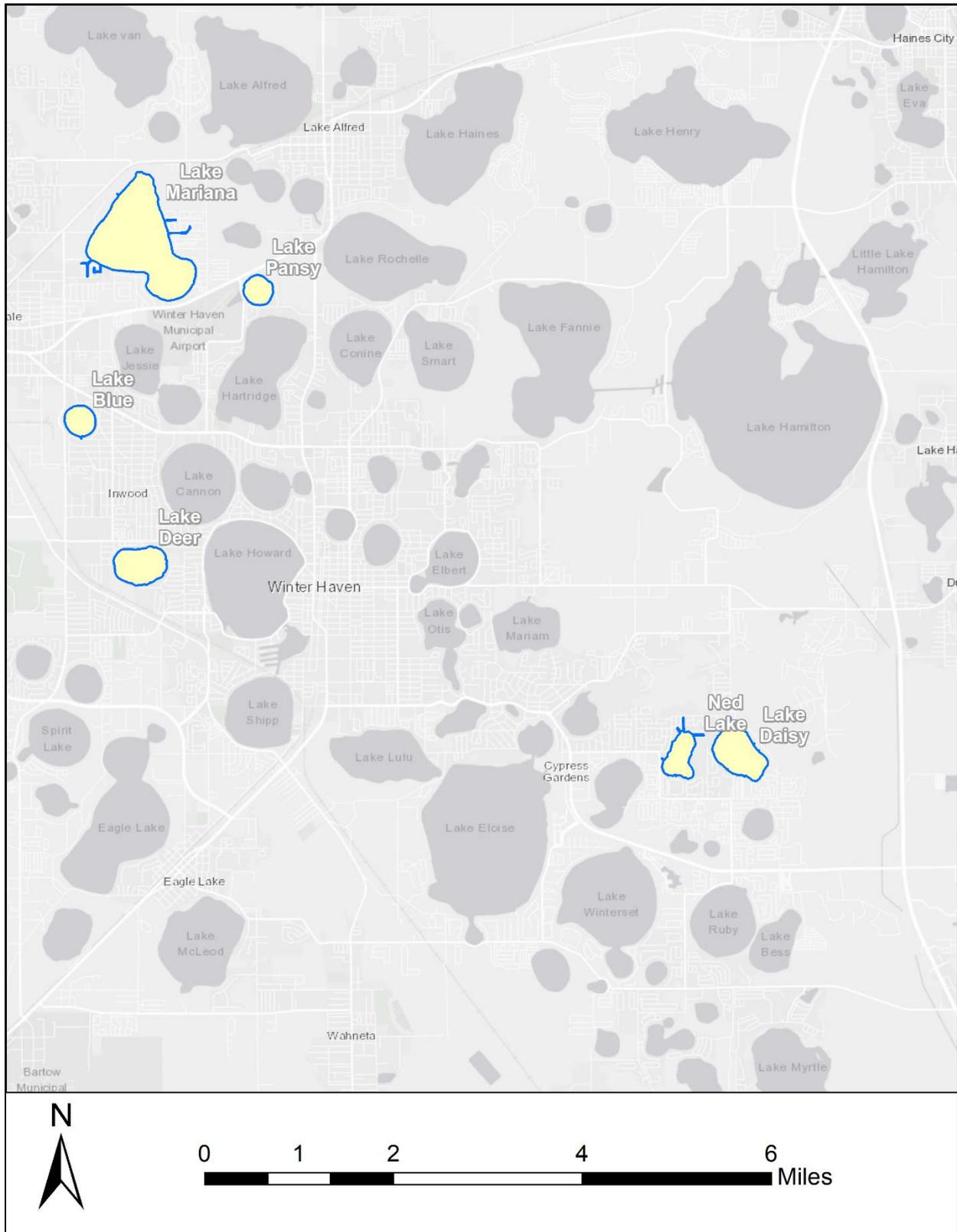
As previously mentioned, the OSTD presence in the Lake Mariam and Otis basins may potentially contribute to nutrient loading. Water quality trends aren't currently indicating the presence of significant impacts from these septic systems. However, OSTDs are known to eventually fail; leaching nutrients and other harmful constituents into surrounding waterbodies. Future management goals should involve evaluating the condition of these septic systems as well as pollutant source analysis to determine if they are currently contributing to water quality impacts.

### Management Conclusions

Except for Lake Elbert, water quality in the SCL group appears to be holding steady or improving. Managing stormwater in the Lake Elbert drainage basin is a major concern. The hope is that with the completion of the SR-542 project, water quality will begin to improve. Street sweeping and green infrastructure are already being utilized to reduce pollutant loads from stormwater. Additional raingardens within the Lake Elbert basin are also in the planning stages.

The robust aquatic vegetation community in Lake Elbert should help to buffer against further change, but this hinges upon adequate management of these populations. The increase in the hydrilla population presents a difficult problem—how to control invasives tactically to prevent further water quality degradation. In 2018, the FWC did stock Lake Elbert with 80 grass carp to assist in the control of hydrilla. Herbicide applications for this group were all very minor in 2020—with none exceeding 10 acres treated (Table

## 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 following is a presentation and analysis of the various lake health metrics for this group.

### Water Quality

A snapshot of 2020 AGM Chl-a, TN, TP, and Secchi depth values shows current water quality in relation to historic conditions (Figure 2-29). For the chlorophyll and nutrient parameters, they are considered better if lower than historic levels. Secchi depth is considered better if higher than the average. Lakes Blue, Daisy, Deer, and Pansy exhibited better Chl-a, TN, TP, and Secchi depth when compared to their long-term averages. While Lake Mariana’s Chl-a was lower than average, its TN and TP were at or higher than the long-term average and Secchi depth was slightly lower than average. Lake Ned’s water quality was worse than historic levels in each parameter.

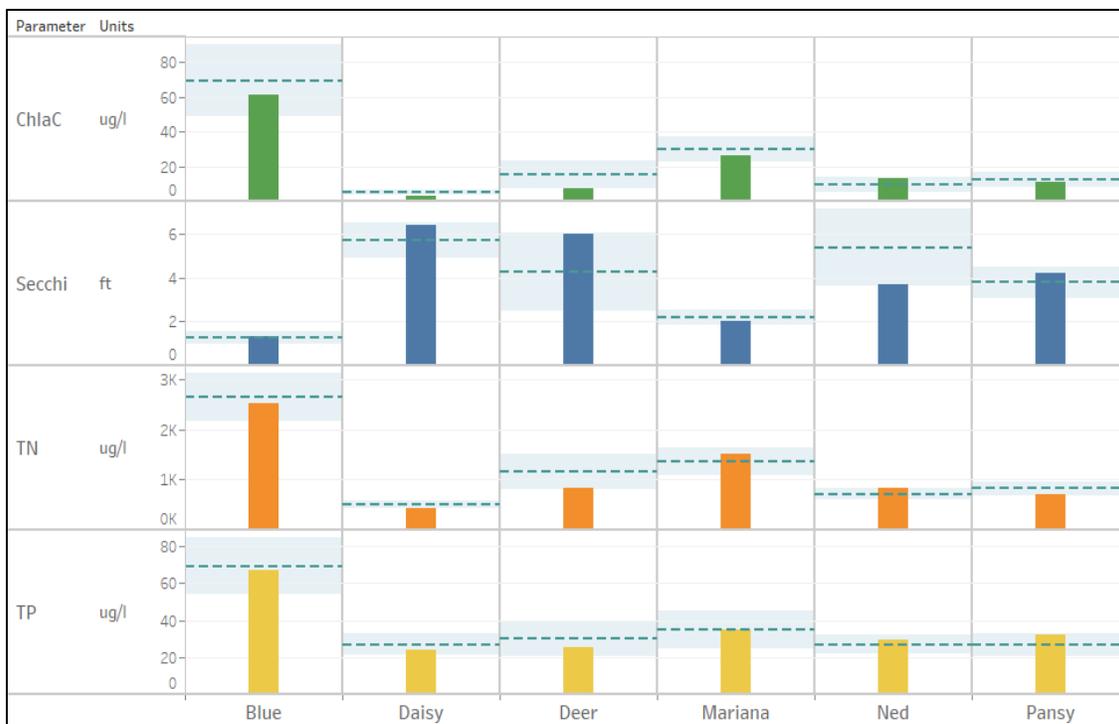


Figure 2-29. 2020 AGM Chl-a, TN, TP, & Secchi depth values for the Outlying Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

### NNC Impairment

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) Chl-a, TN, and TP concentrations during the assessment period from 2013 to 2020 (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 and Mariana were determined to be impaired for Chl-a, TN, and TP during this period. Lakes Daisy, Deer, Ned, and Pansy exhibit no impairments. It was noted during last year's analysis that Lake Deer would no longer be meeting impaired status pending the 2020 NNC concentrations. Since Chl-a, TN, and TP concentrations have not had multiple consecutive NNC exceedances in 7.5 years, it can no longer be considered impaired for these parameters.

### Water Quality Trends

Analysis of the long-term water quality trends was performed by plotting AGM Chl-a, TN, TP, and Secchi depth against time, in years, from 2000 to 2020 (Table 2-5). Linear regression lines were plotted in order to determine trend direction (+/-) and statistical significance ( $p\text{-value} \leq 0.05$ ) (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 exhibited a significant decreasing Chl-a trend, while Lakes Ned and Pansy showed significant increasing trends.

**Total Nitrogen Trends:** Lake Deer is the only waterbody in this group that exhibited a significant TN trend. In this case, TN was trending downward.

**Total Phosphorus Trends:** Lake Blue displayed a significant decreasing TP trend. Lake Ned exhibited a significant increasing TP trend.

**Clarity Trends:** Lakes Mariana and Ned both exhibited significant decreasing Secchi depth trends during this period.

Analysis of this information should inherently place greater management focus on the waterbodies that are currently impaired. Lakes Blue, Deer, and Mariana possess nutrient TMDLs and require the implementation of management practices to improve water quality. The highest priorities are Lakes Blue and Mariana which are currently impaired; and in the case of Lake Mariana, possess poorly trending water quality. Lake Deer is already on the path to improvement, but ensuring that these positive advances continue is equally important. Water quality trends in Lakes Ned and Pansy are cause for concern. Fixing the issues in these waterbodies before they become impaired is part of the purpose of this study.

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 (Improving)	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	Increasing	Not Significant	2

Table 2-5. 2020 Outlying Lakes WQ Trends for Chla, TN, TP, & Secchi Depth and their representative lake health index scores

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. Aside from Lakes Daisy and Ned, 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 or the Peace Creek; either by discharging during high water periods or through groundwater interaction. Monthly surface level (SL) and rainfall readings from 2000 - 2020 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 discharges via an overflow structure to a small private lake to the west as well as to the Peace Creek via a series of drainage ditches.

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 Lakes Ned and 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 Chl-a, 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 surrounded by residential areas, a significant change in surface level one

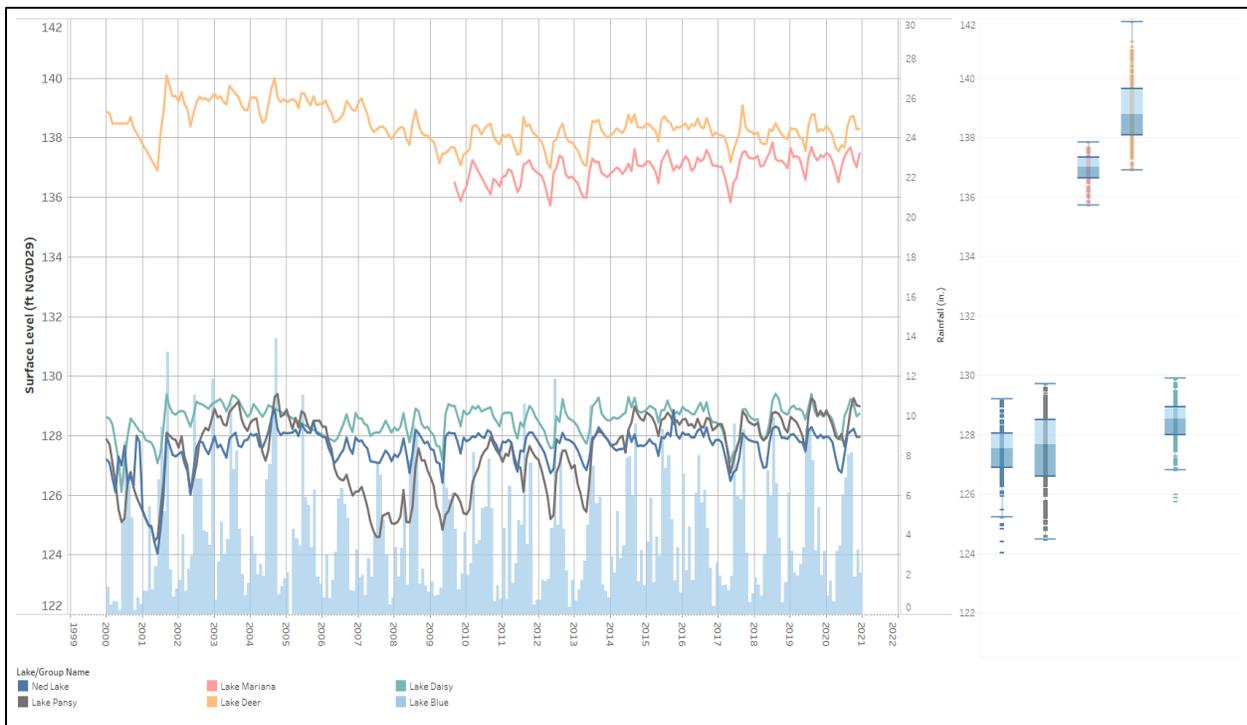


Figure 2-30. Outlying Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Monthly rainfall totals indicate hydrologic response to precipitation.

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. Aside from the City of Winter Haven, Polk County, FDOT, and the City of Auburndale contribute stormwater to these basins.

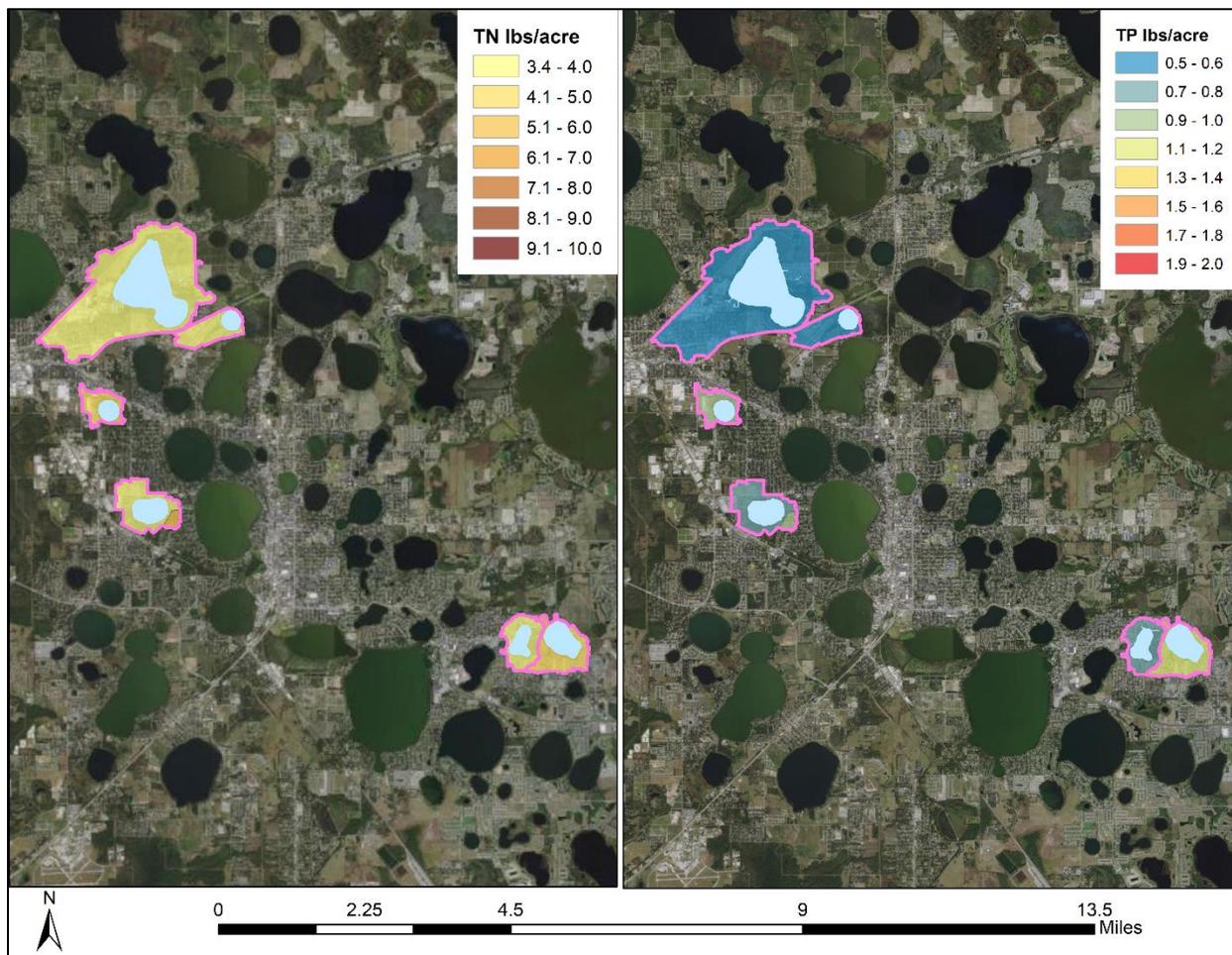


Figure 2-31. Areal TN & TP Loading for individual drainage basins in the Outlying Lakes.

It should be noted that some of the lakes in this group possess a moderate density of Onsite Sewage Treatment & Disposal (OSTD) or septic systems within their drainage basins. Only Lakes Daisy, Deer, and Ned possess septic systems with an average number of 44 per drainage basin (Table 4-6; in appendix). 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. The primary nutrient that is contributed via OSTDs is nitrogen. However, none of the lakes with septic units in their vicinity are undergoing increasing trends in TN. This is not indicative of widespread septic leaching. That said, future management goals for these basins may include nutrient source analysis as confirmation.

The morphology of the waterbodies in this group is very similar. All are relatively shallow which equates to little direct aquifer interaction and greater impacts from wind and wave action. This latter point has large implications depending on the abundance of rooted aquatic vegetation. It comes as no surprise that the impaired and poorly trending water quality lakes in this group are ones that lack robust submerged vegetation communities. Lake Mariana is especially susceptible to sediment suspension due to its much larger comparative surface area.

*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. It should be noted that due to a data recording error, the City does not possess 2020 vegetation abundance data for Lake Blue.

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), floating-leaf vegetation (FLV), and floating vegetation (FV). Lakes Deer, Mariana, and Pansy all possess a healthy mix of various aquatic vegetation types (Figure 2-32). Lake Deer underwent a massive decline in the abundance of SAV; from roughly 70% in 2019 to about 30% in 2020. This change is likely attributed to treatment of hydrilla which had previously undergone a population explosion. Lakes Blue, Daisy, and Ned have very little in the way of SAV which equates to these lakes’ inability to buffer against spikes in nutrient loading. Without the presence of submerged plants, the excess nutrients often contribute to harmful algal blooms. The complete lack of SAV in a shallow waterbody can also lead to increased sediment suspension via wave action. This may help to explain why Lake Ned’s water quality is trending poorly.

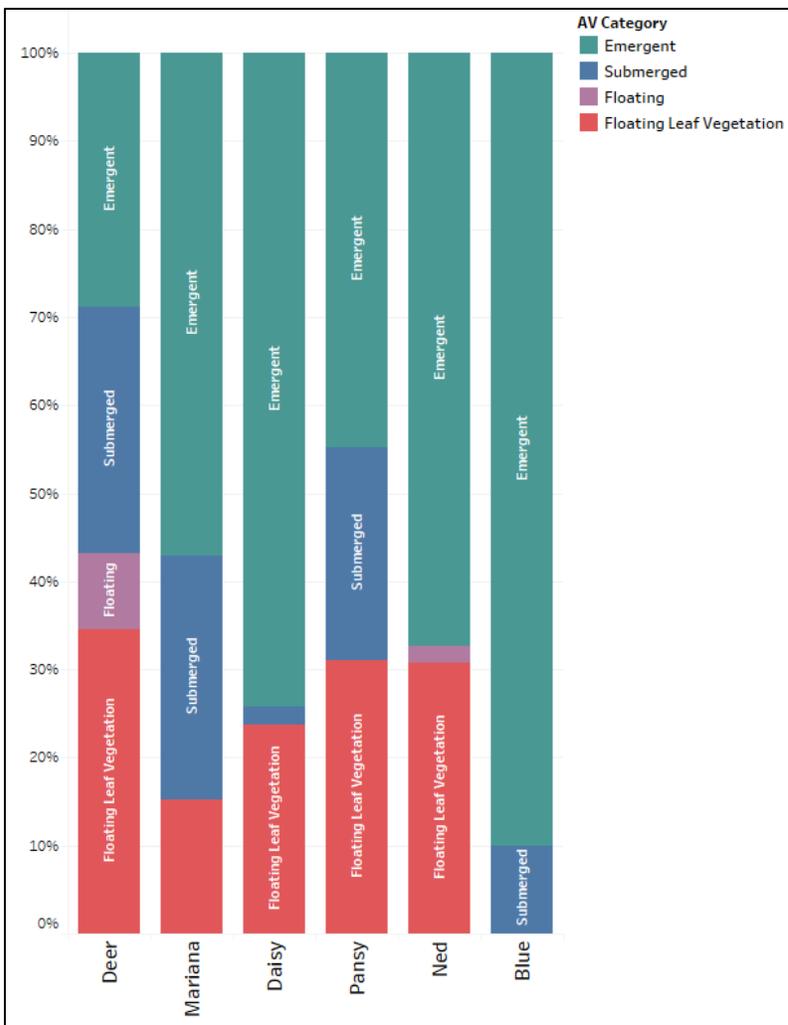


Figure 2-32. Outlying Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

### Vegetation Abundance

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. Due to a technological error, 2020 abundance data was not recovered in Lake Blue. However, based on observations from City staff, the total amount of aquatic vegetation has not changed much in Lake Blue since 2019. Lakes Daisy, Mariana, and Ned did not undergo a significant change in abundance from the previous year. The amount of rooted vegetation observed remained below the 15% target in both Daisy and Ned while Lake Mariana exhibited abundance above this threshold. Unfortunately, Lake Pansy’s vegetation abundance underwent a reduction below the 30% ideal target. Lake Deer’s total abundance decreased in 2020, but was not enough to drop it below the 30% threshold. Much of this reduction was due to treatment of invasive hydrilla.

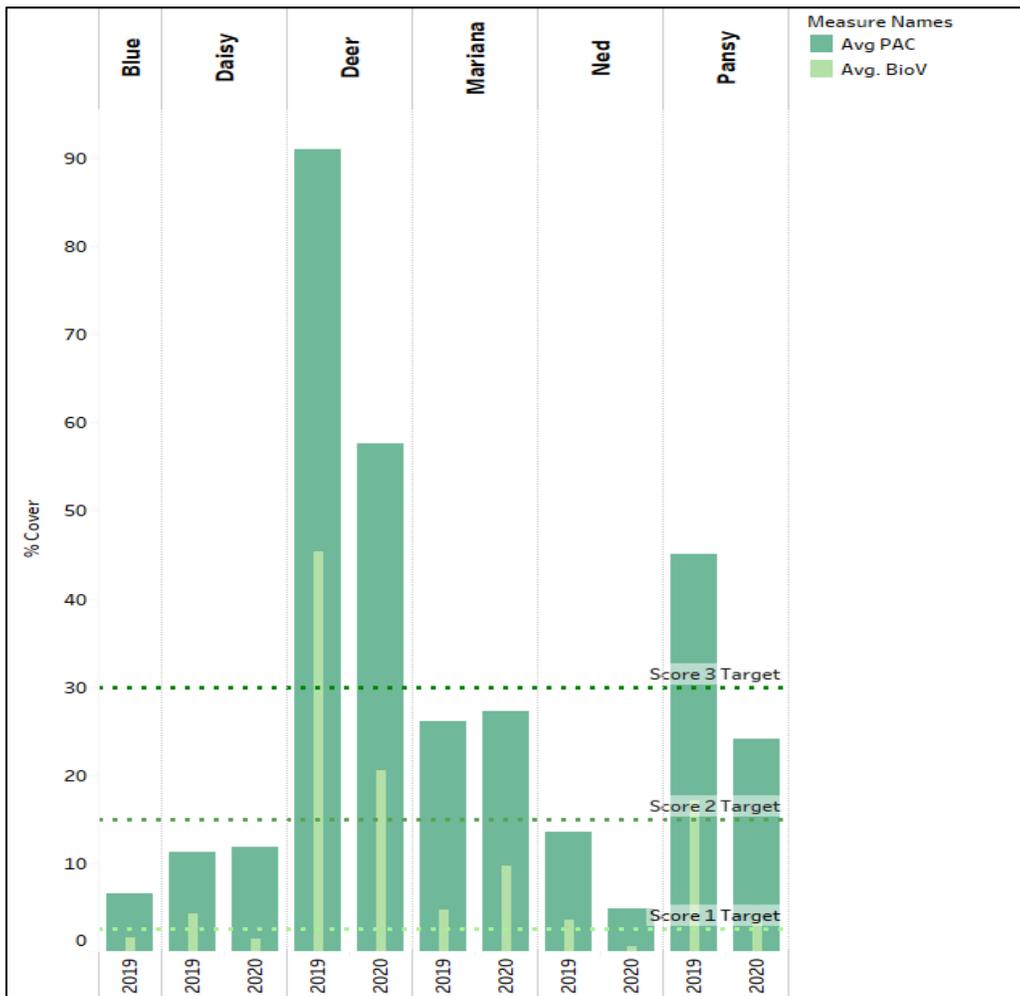


Figure 2-33. Outlying Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

### Invasive Species Percentage

The percentage of invasive species found in the Outlying Lakes underwent considerable changes from 2019 to 2020 (Figure 2- 34). In Lake Daisy, where there had been no previous observations of invasive species, a very minor presence of Elodea was recorded. This invasive is rarely seen in the Winter Haven lakes. Lake Deer underwent a significant decrease in Hydrilla which was the result of successful invasive treatment efforts in 2019. Similarly, the presence of Water Hyacinth in Lake Ned the previous year was reduced so that no observations of invasive species were recorded in 2020. Lake Pansy underwent a considerable increase in the invasive Sacred Lotus species since 2019. Unlike the American Lotus, the exotic variety originates in SE Asia and can be quite prolific once established. Future management efforts should focus on the gradual treatment of this invasive species. There were no managed invasive species observed in Lake Mariana in 2019 or 2020.

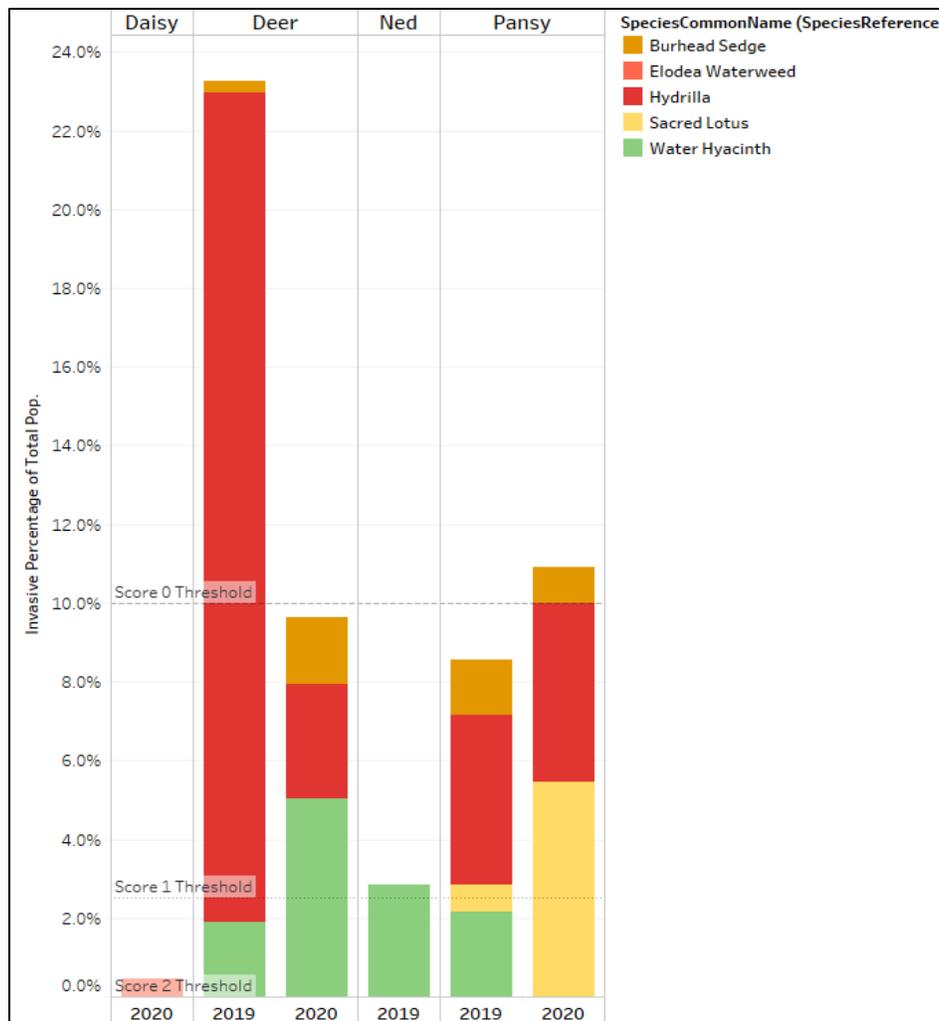


Figure 2-34. Outlying Lakes annual percentage of managed invasive species.

### Species Diversity

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 2019 to 2020 (Figure 2-35).

**Menhenick’s Richness (R2):** Species richness denotes how many unique species are present in a population. Lakes Daisy, Deer, and Pansy exhibited an increase in species richness while Lakes Blue, Mariana, and Ned underwent a decrease from 2019 to 2020.

**Hill’s Evenness #3 (E3):** Changes in species evenness often correlate with community resilience. Only Lake Deer exhibited an increase, with Lake Lake Pansy undergoing no change from the previous year. Lakes Blue, Daisy, Mariana, and Ned underwent a decrease in 2020.

**Shannon’s Diversity (H):** As a combination of species richness and evenness, Shannon’s index indicates the overall species diversity for each site. Lake Daisy was the only waterbody to exhibit an increase from 2019. Lakes Blue, Deer, Mariana, Ned, and Pansy underwent a decrease in diversity in 2020.

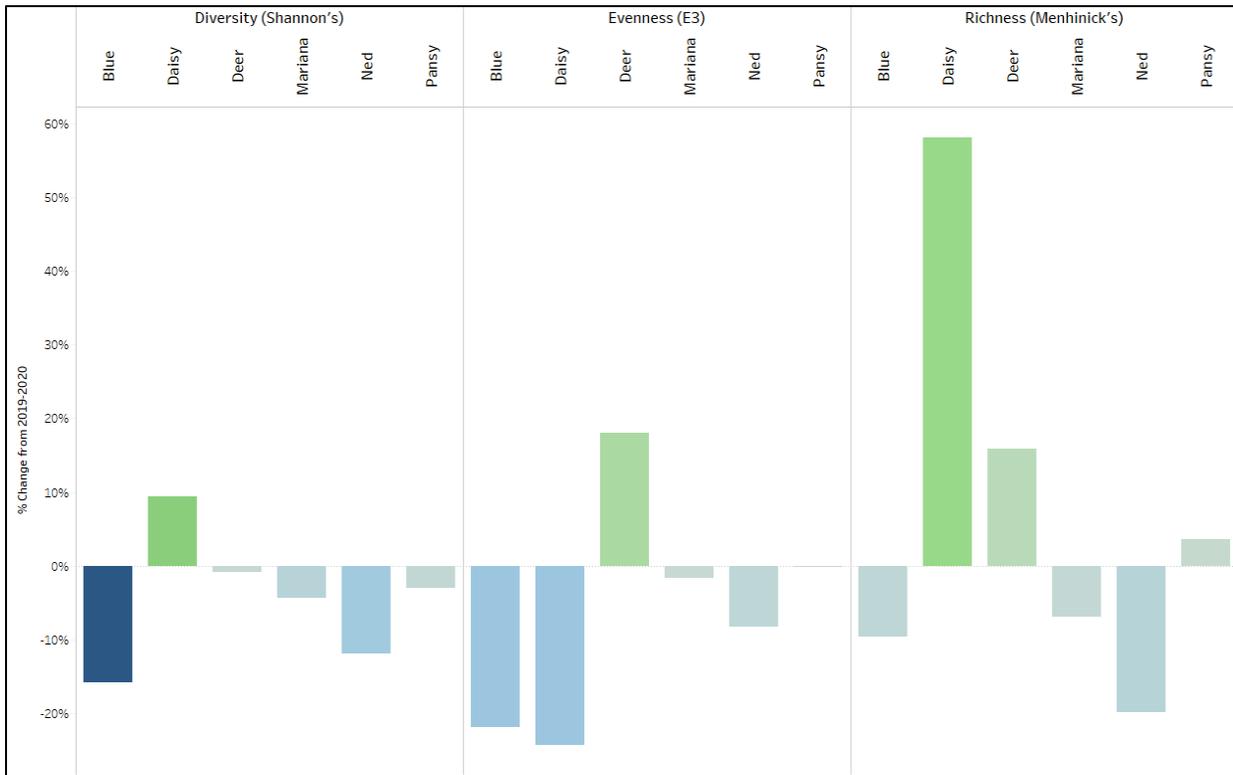


Figure 2-35. Outlying Lakes annual index values for species richness, evenness, and diversity.

Obviously, the general decline in species richness, evenness, and diversity of this lake group is not ideal. However, many of these changes can be attributed to the management of invasive species. While the goal is to observe increasing diversity index values over time, these metrics make up only a small component of overall lake health. As the City

collects multiple years of data, better comparisons can be made between annual diversity values and average conditions.

### **Management Conclusions**

The isolated nature of the lakes in this group requires a more specialized and individual approach to management. Unlike other groups, strategies implemented in one Outlying lake likely won't apply to the others. For example, the greatest challenge in Lake Deer is effectively managing invasive species, while addressing the lack of vegetation abundance may be the primary goal for Lakes Ned and Daisy. The massive hydrilla population explosion in Lake Deer in 2019 was surprising. The rapidity of this invasive expansion required a large-scale treatment using herbicide. Future management goals include working closely with FWC and Polk County to manage invasives before they reach abundances where large-scale herbicide treatments are necessary. Except for Lake Deer, none of these lakes underwent herbicide treatments of greater than 10 acres in 2020 (Table 4-7; in appendix). This has less of an impact on water quality by limiting the amount of nutrients re-released after the breakdown of treated vegetation. FWC has previously attempted the utilization of grass carp in these lakes as well. Lakes Deer and Pansy have had grass carp stocked in 2018 and 2019, respectively. As previously stated, continual monitoring of aquatic vegetation is critical for reducing the need for large-scale herbicide treatments.

One of the higher priorities in this lake group is managing the extremely high pollutant concentrations in Lake Blue. Due to the relatively small size of its drainage basin, it has a comparatively lower volume of stormwater inputs. That said, the surrounding land uses may have contributed significantly greater amounts of pollutants over time. One of the leading hypotheses is that Lake Blue possesses a large quantity of legacy pollutants in its sediments. Removal or inactivation of these may be a viable strategy moving forward. However, confirmation through sediment analysis would be a preferred first step.

On the topic of managing external pollutant loading, it should be noted that for most of these lakes, some or all of their drainage basins fall outside of the Winter Haven City limits. Cooperation with Polk County and any other local stakeholders is required to address stormwater loads in these areas. This includes determining if OSTD systems are contributing to pollutant loading via groundwater.

## 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 the sampling and scoring approach, but the objective is 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 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 2-36 & 2-37) detail the lake health scores from 2019 and 2020. A comparison of these scores and an explanation of their implications is presented below.

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 2-6. 2019 Lake Health Index

2020	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	0	1	1.9
	Lake Fannie	3	2	2	2	3	1	1	1	1.9
	Lake Haines	2	2	3	2	3	2	0	1	1.9
	Lake Hamilton	0	0	0	3	0	1	2	1	0.9
	Lake Rochelle	0	3	3	3	3	3	0	0	1.9
	Lake Smart	0	2	2	3	2	2	2	3	2.0
	Little Lake Hamilton	0	1	1	2	1	2	2	3	1.5
	Middle Lake Hamilton	0	1	2	3	2	1	3	2	1.8
South Chain of Lakes	Lake Cannon	1	2	3	2	3	3	2	2	2.3
	Lake Eloise	0	2	2	2	3	2	2	1	1.8
	Lake Hartridge	1	0	0	1	0	3	2	1	1.0
	Lake Howard	1	3	3	2	3	3	3	0	2.3
	Lake Idylwild	1	2	2	2	3	3	2	0	1.9
	Lake Jessie	0	1	1	2	2	3	1	0	1.3
	Lake Lulu	0	3	3	3	3	3	3	1	2.4
	Lake May	0	3	3	3	3	3	1	3	2.4
	Lake Mirror	3	3	3	3	3	3	1	0	2.4
	Lake Roy	3	3	3	3	3	2	2	2	2.6
	Lake Shipp	0	3	3	3	3	3	1	1	2.1
	Spring Lake	3	3	3	3	3	3	0	0	2.3
	Lake Summit	3	3	3	2	3	3	1	1	2.4
	Lake Winterset	3	3	3	3	3	3	1	1	2.5
North Central Lakes	Lake Buckeye	3	3	3	3	3	3	0	0	2.3
	Lake Idyl	0	1	1	1	1	3	1	2	1.3
	Lake Martha	3	0	0	0	0	1	3	1	1.0
	Lake Maude	3	3	3	3	3	3	2	2	2.8
	Lake Silver	3	2	2	2	1	1	3	0	1.8
South Central Lakes	Lake Elbert	3	0	0	1	0	3	0	1	1.0
	Lake Link	3	2	3	2	2	3	NA	NA	2.5
	Lake Mariam	3	1	2	1	2	1	2	1	1.6
	Lake Otis	3	2	2	2	2	2	NA	NA	2.2
Outlying Lakes	Lake Blue	0	2	2	3	2	NA	3	0	1.7
	Lake Daisy	3	3	2	2	2	1	2	2	2.1
	Lake Deer	0	2	2	2	2	3	1	2	1.8
	Lake Mariana	0	1	1	2	0	2	3	0	1.1
	Lake Ned	3	0	2	0	0	1	3	0	1.1
	Lake Pansy	3	0	1	1	2	2	0	2	1.4

Table 2-7. 2020 Lake Health Index

**North Chain of Lakes:**

A comparison of lake health for the Northern Chain from 2019 to 2020 shows that all lakes exhibited some decline in their lake health scores with the average lake health index for this group decreasing from 1.75 to 1.7. None of these score changes were a result of water quality decline, however. Scores in vegetation abundance and species diversity decreased, however the percent invasive score increased as a whole. It is likely that invasive plant management efforts in 2020 reduced overall vegetation abundance and diversity. The fact that these efforts did not result in significant degradation of water quality is a redeeming factor.

**South Chain of Lakes:**

Average lake health index values for the Southern Chain of Lakes decreased slightly from 2019 to 2020; going from 2.19 to 2.10. Similarly to the Northern Chain, this group only exhibited score changes in the biological criteria. Based on the average criteria values for this group, overall aquatic vegetation abundance and invasive species percentage scores increased slightly from the previous year. However, this group underwent a massive decrease in species diversity scores. Considering there was an overall increase in vegetation abundance, invasive management efforts likely did not have a major impact on the diversity scores. All that can be inferred is the distribution of aquatic communities underwent a natural shift over the last year.

**North Central Lakes:**

Average lake health scores for this group increased slightly from 2019 to 2020—going from an average index value of 1.75 to 1.8. The improvement can be attributed to increased total phosphorus trend, aquatic vegetation abundance, and invasive species percentage scores. That said, there was a slight decline in the Secchi depth trend as well as the species diversity scores. Overall, the largest change was a result of the decline in species diversity. Like the Southern Chain, this change may simply be due to natural changes in species distribution.

**South Central Lakes:**

The South Central group saw average lake health scores increased slightly from 2019 to 2020; from 1.81 to 1.82. Impairment and invasive species percentage scores increased from the previous year. However, there was also a decrease in the species diversity, total phosphorus trend, and Secchi depth trend scores. The biological score changes may not accurately reflect actual improvement or deterioration due to the lack of species data from Lakes Link and Otis. The water quality trend changes were the result of deterioration in Lakes Elbert and Mariam—something to consider for management strategy.

**Outlying Lakes:**

Average lake health scores for the Outlying Lakes underwent a minor decline from 2019 to 2020; going from 1.62 to 1.53. Despite increases in Secchi depth trend and invasive species percentage scores, average species diversity values for this group exhibited a significant reduction. Considering there was little change in the overall vegetation abundance values, the decline in diversity likely was not a result of invasive species management efforts. Like the other lake groups, the cause of this species diversity shift is difficult to identify.

**Overall:**

Aggregating the lake health scores of all study area lakes from 2018 to 2020 allows for a general comparison (Table 2-38). Overall, there was not much change in the water quality criteria. Impairment and TN trend scores underwent a slight increase from 2019, with Secchi depth trend scores exhibiting a minor decrease.

Biologically, there was improvement in the invasive species percentage scores from 2019 to 2020. Coupled with no appreciable change in vegetation abundance (PAC) during this time, it can be inferred that invasive plant management efforts were successful in reducing pest plants without significantly impacting the overall amount of aquatic plants. That said, each lake group underwent a significant decline in the diversity index scores during this period. It is difficult to determine the root cause of this ecological shift. The goal is to collect more species data to gain a better understanding of the long-term fluctuations in vegetation communities over time.

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 water quality management plans that detail what management strategies the City has implemented in each lake as well as future management goals.

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	1.89	2.00	2.16	2.11	2.33	1.25	1.94	1.90
2020	1.54	1.89	2.05	2.16	2.08	2.33	1.57	1.09	1.85

Table 2-8. Aggregated lake health scores for all Winter Haven lakes for 2018, 2, and 2020 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, might 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 detail information of the various pipes, drains, and outfalls. 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.

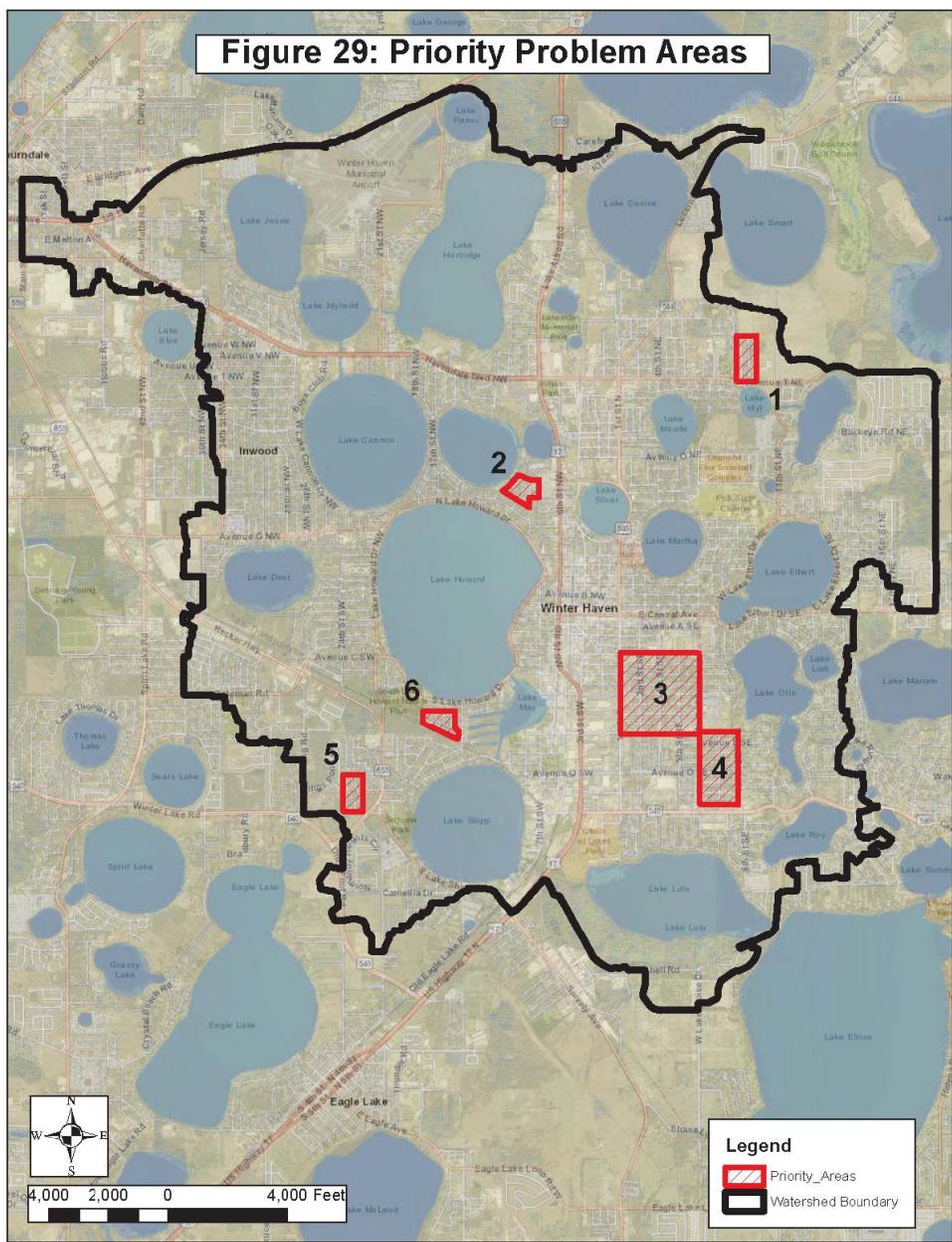


Figure 3-1. Priority sites indicated by increased flooding and pollutant load potential as determined by the Winter Haven SAIP.

**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 additional grant funding to design and implement stormwater improvements within these priority areas.
- Contract further study of the SAIP area to identify additional improvement sites by FY 2022.

**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.
- ✓ Stormwater improvements in Priority Area 1 have been designed as part of a raingarden implementation project; made possible through a SWFWMD cooperate funding agreement. This project is scheduled for completion by end of 2021.

## Alum Treatment

### Summary:

Aluminum sulfate ( $\text{Al}_2\text{SO}_4$ ), 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 [9]. 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.

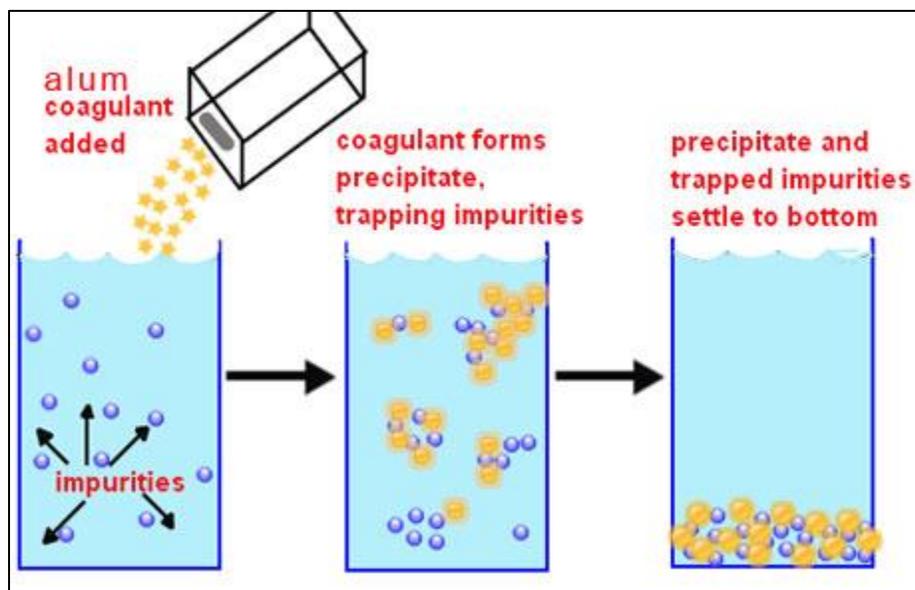


Figure 3-2. Diagram of alum floc adsorption properties. [2]

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 [5]. 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 the 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:**

- Complete repairs of alum facilities to return them to working order by end of 2021.
- Develop a strategy to evaluate effectiveness of alum treatment on lake water quality by 2022.

**Completed Objectives:**

- ✓ Inspected the City's alum injection facilities to identify repair & improvement needs.
- ✓ Include improvements as part of FY 19-20 budget.
- ✓ Contracted the inspection of alum facilities to determine any repair/improvement needs (FY2020).

## 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.

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 to stormwater mitigation and can often be more aesthetically pleasing.



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

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:**

- Conduct maintenance/landscaping improvements on additional downtown raingardens by end of 2021.
- Utilize modeling 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.
- ✓ Acquired funding via SWFWMD to construct LID improvements in multiple drainage basins; to be completed by end of 2021.
- ✓ Included raingardens and other LIDs into the Cartegraph (asset management software to track maintenance needs).
- ✓ Completed maintenance on some downtown raingardens in 2020.

## 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.

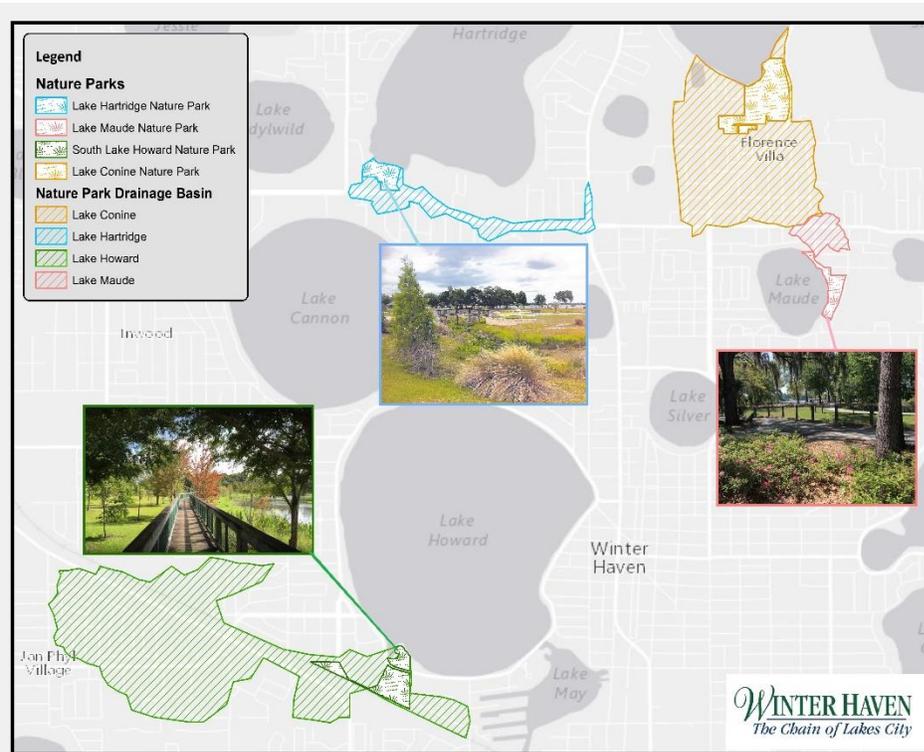


Figure 3-4. Map depicting the Winter Haven nature parks and their drainage basins. Also included is the proposed location of the Lake Conine Nature Park.

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 area 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 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 as 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.
- Acquire funding to implement stormwater improvements on the newly acquired Lake Howard Nature Park property by FY 2022.

**Completed Objectives:**

- ✓ Completed contractor selection for construction of the Lake Conine Treatment Wetland
- ✓ Construction of the Lake Conine Treatment Wetland began in early 2020—slated to be completed mid-2021.
- ✓ Purchased 8-acre parcel adjacent to South Lake Howard Nature Park. Stormwater and educational improvements intended to expand the existing nature park are planned for this site.

## 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.

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



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

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 of 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 its 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 replant FTW by end of 2021.
- Develop FTW educational components as part of the City's outreach programming in 2021.

**Completed Objectives:**

- ✓ Continued to monitor water quality and ecology in the stormwater pond until end of 2019.
- ✓ Continued to harvest and replant FTW in 2020.

## 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 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 to 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:**

- By July 2021, submit a final report to FDEP detailing the results of this project.
- Apply for grant funding to develop additional educational programming on the Gray to Green subject matter in FY 2022.

### **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.
- ✓ Implemented educational and technical workshops with City staff as well as local designers & engineers on the newly developed permit design methodology in 2021.

## 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 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 its 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 4 permit by end of March 2021
- Distribute Cycle 4 Year 5 permit data requests to City department heads by October 2021

### Completed Objectives:

- ✓ Successfully submitted Cycle 4 Year 4 permit by 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 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. Since 2016, the City began examining the effectiveness of the contracted sweeping service and whether these activities could be accomplished in-house. In 2020, the City created a new position within the Drainage division and purchased a sweeper. This has led to an increase in sweeping quality, efficiency, route control, and total area swept (Figure 3-6).

### 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.

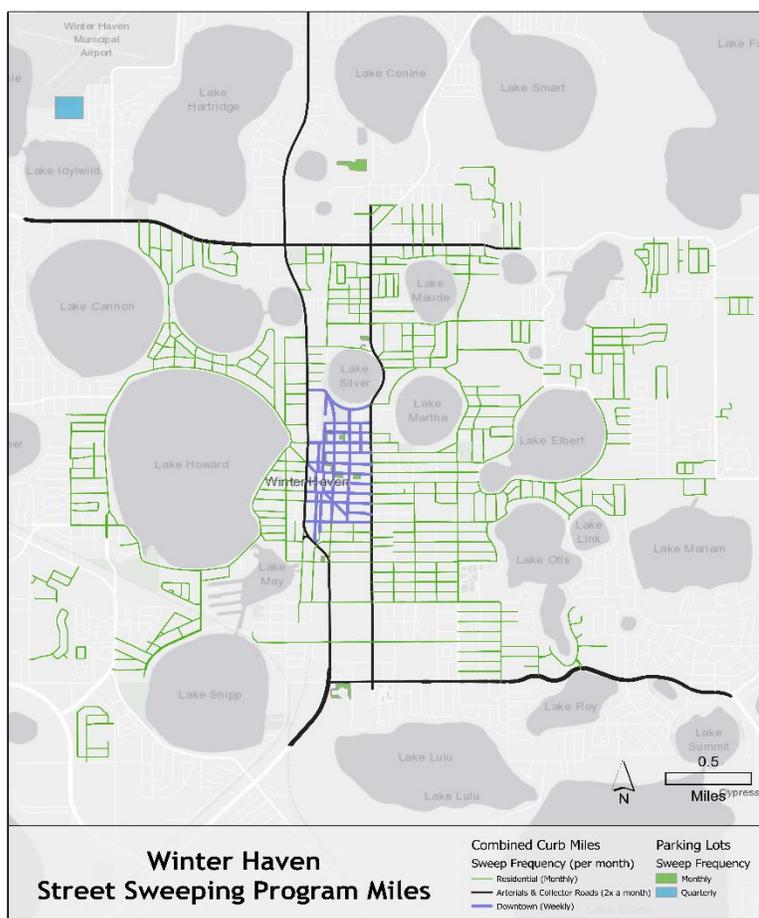


Figure 3-6. Map depicting roadways undergoing street sweeping. Legend indicates sweeping frequency of each street category.

**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 public education campaigns to improve resident interactions and sweeping efficiency.

**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
- ✓ Purchased sweeper and created sweeper position to conduct all City street sweeping in-house in 2020.
- ✓ Adjusted routes based on seasonal high-debris areas/periods using spatial data (e.g. autumn leaf falls).
- ✓ Incorporated live-tracking software to improve communication and predictability for residents.

## 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 a support chain useful for representing the needs and interests of all parties in the region.

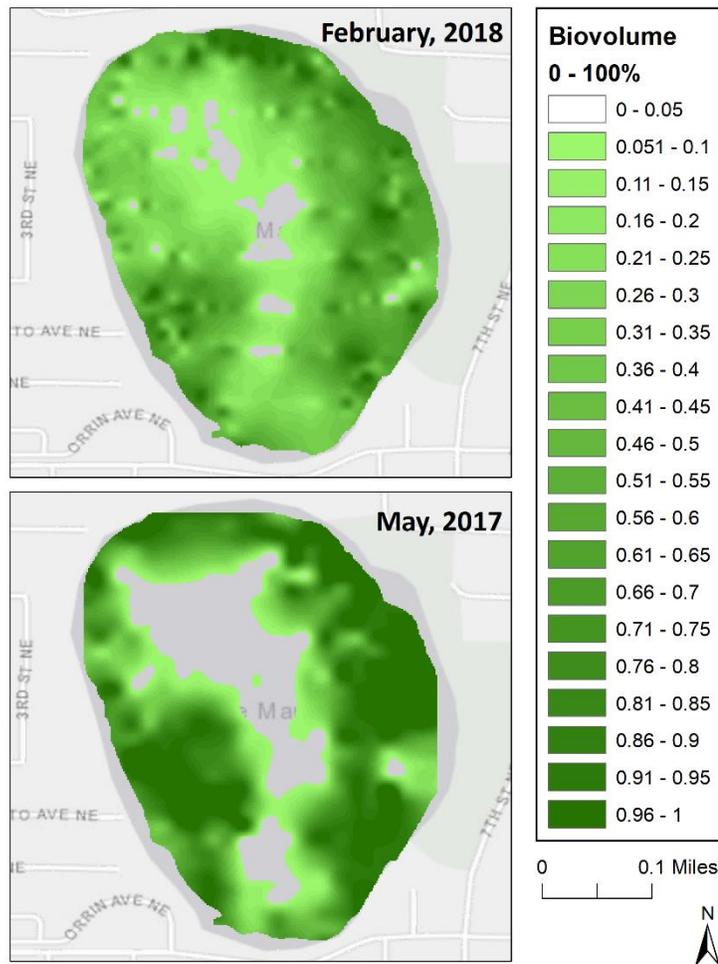


Figure 3-7. Biovolume heat map of Lake Maude. Color scale represents percent of water column occupied by plants.

**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 2021, 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 2020 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 modeling was performed to identify areas with greater flooding potential as part of the Stormwater Assessment and Improvement Project. This modeling 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 the 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:

- Budget for purchase of surface level sensors at additional Winter Haven area lakes as part of FY 2021.

- Work with Winter Haven Water Department to implement additional rainfall and groundwater sensors throughout the City.

**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
- ✓ Replaced defunct surface level sensors on 8 area lakes.

## Nutrient Budgeting

### Summary:

A nutrient budget utilizes external pollutant load modeling data, internal load modeling 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 future Natural Resources Division budgets.
- 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 (Winter Haven Water) 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 8<sup>th</sup> grade. The children are introduced to concepts of lake hydrology and biology and also get to



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

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.

**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 the general public, local schools, and private organizations (e.g. HOAs).
- Conduct research and create proposals for implementation of a Natural Resources Volunteer program.
- Continue to support and develop Natural Resources internship program.
- Implement a City kayak tour outreach program by 2021.

**Completed Objectives:**

- ✓ Developed a more education-oriented approach to City Summer Camp activities.

## 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	2020
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	15.7
	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	8.1
	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	23.1
	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	34.7
	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	12.6
	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	24.5
	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	20.6
	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	23.1
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	22.6
	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	23.8
	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	25.2
	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	23.7
	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	16.6
	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	25.2
	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	20.8
	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	19.9
	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	14.7
	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	8.7
	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	21.5
	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	6.4
	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	4.9
	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	9.9
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	3.4
	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	29.7
	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	8.2
	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	3.4
South Central Lakes	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	10.5
	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	10.6
	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	9.8
	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	6.3
Outlying Lakes	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	15.1
	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	61.1
	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	3.0
	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	7.2
	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	26.3
	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	13.5
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	10.7	

Table 4-1. Annual geometric mean corrected chlorophyll-a concentrations from 2001 – 2020 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	2020	
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	997.9	
	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	899.2	
	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	1192.9	
	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	1994.1	
	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	914.3	
	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	1217.0
	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	1455.5	
	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	1520.2	
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	995.0	
	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	1094.3	
	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	1297.6	
	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	1077.2	
	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	971.4	
	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	1021.3	
	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	1132.2	
	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	1188.7	
	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	856.2	
	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	720.5	
	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	1210.5	
	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	726.6	
	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	490.0	
	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	615.5	
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	571.5	
	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	1266.9	
	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	558.9	
	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	488.4	
South Central Lakes	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	726.7	
	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	669.2	
	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	701.6
	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	893.2	
Outlying Lakes	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	753.1	
	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	2528.3	
	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	435.3	
	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	821.9	
	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	1509.6	
	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	842.0	
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	703.4		

Table 4-2. Annual geometric mean total nitrogen concentrations from 2001 – 2020 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	2020
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	43.7
	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	33.7
	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	58.1
	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	44.6
	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	30.6
	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	31.9
	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	32.4
	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	53.4
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	30.0
	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	33.5
	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	27.4
	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	29.9
	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	31.7
	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	44.7
	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	38.9
	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	48.9
	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	30.1
	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	25.0
	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	41.2
	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	25.3
	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	17.2
	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	25.7
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	18.2
	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	59.9
	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	23.9
	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	16.2
	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	19.1
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	21.7
	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	26.9
	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	64.1
	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	30.6
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	67.0
	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	23.9
	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	25.1
	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	34.6
	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	29.7
	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	31.9

Table 4-3. Annual geometric mean total phosphorus from 2001 – 2020 for all study area lakes.

Linear Regression Statistics

Water Quality Trends

Waterbody	Chl-a			Secchi			TN			TP		
	Dir.	R <sup>2</sup>	p-value	Dir.	R <sup>2</sup>	p-value	Dir.	R <sup>2</sup>	p-value	Dir.	R <sup>2</sup>	p-value
Lake Blue	-	0.0594	0.287	+	0.0733	0.235	-	0.1008	0.161	-	0.4772	0.001
Lake Buckeye	-	0.5901	0.000	+	0.7812	0.000	-	0.6682	0.000	-	0.4451	0.001
Lake Cannon	-	0.1412	0.093	+	0.2971	0.011	-	0.2415	0.024	-	0.0647	0.266
Lake Conine	-	0.2962	0.011	+	0.5484	0.000	-	0.1835	0.053	-	0.2006	0.042
Lake Daisy	-	0.3344	0.006	+	0.0718	0.240	-	0.1091	0.144	-	0.1100	0.142
Lake Deer	-	0.0777	0.221	+	0.1261	0.114	-	0.2353	0.026	-	0.1617	0.071
Lake Elbert	+	0.4626	0.001	-	0.2559	0.019	+	0.3210	0.007	+	0.1233	0.119
Lake Eloise	-	0.0821	0.208	+	0.4578	0.001	-	0.1441	0.090	-	0.1608	0.072
Lake Fannie	-	0.0139	0.439	+	0.2951	0.011	-	0.0211	0.529	-	0.1190	0.126
Lake Haines	-	0.0948	0.175	+	0.6819	0.000	-	0.4393	0.001	-	0.0502	0.329
Lake Hamilton	+	0.8128	0.000	-	0.4224	0.001	+	0.8089	0.000	-	0.4457	0.001
Lake Hartridge	+	0.6889	0.000	-	0.6881	0.000	+	0.6195	0.000	+	0.0073	0.713
Lake Howard	-	0.3043	0.010	+	0.4770	0.001	-	0.4423	0.001	-	0.0633	0.271
Lake Idyl	+	0.0770	0.250	-	0.0181	0.583	+	0.1406	0.114	+	0.1986	0.056
Lake Idylwild	-	0.0665	0.259	+	0.3119	0.008	+	0.0002	0.947	-	0.1385	0.097
Lake Jessie	+	0.0005	0.922	+	0.1506	0.082	+	0.0137	0.613	-	0.0770	0.223
Lake Link	-	0.0953	0.263	+	0.0897	0.278	-	0.3900	0.013	-	0.1134	0.220
Lake Lulu	-	0.2999	0.010	+	0.5788	0.000	-	0.2232	0.031	-	0.3617	0.004
Lake Mariam	+	0.0255	0.489	+	0.1700	0.063	-	0.0864	0.196	-	0.0002	0.957
Lake Mariana	+	0.1313	0.106	-	0.2297	0.028	+	0.1136	0.135	-	0.1724	0.061
Lake Martha	+	0.5738	0.000	-	0.4228	0.001	+	0.1906	0.048	+	0.2804	0.014
Lake Maude	-	0.3588	0.004	+	0.4779	0.001	-	0.5053	0.000	-	0.2158	0.034
Lake May	-	0.3508	0.005	+	0.6765	0.000	-	0.4803	0.000	-	0.4674	0.001
Lake Mirror	-	0.6829	0.000	+	0.5405	0.000	-	0.7043	0.000	-	0.2478	0.022
Lake Ned	+	0.6059	0.000	-	0.3174	0.008	-	0.0219	0.522	+	0.2762	0.014
Lake Otis	-	0.0531	0.409	+	0.0004	0.941	-	0.1977	0.097	-	0.0130	0.686
Lake Pansy	+	0.3732	0.003	-	0.0017	0.859	+	0.0384	0.395	+	0.1390	0.096
Lake Rochelle	-	0.4376	0.001	+	0.4595	0.001	-	0.2648	0.017	-	0.6194	0.000
Lake Roy	-	0.4920	0.000	+	0.5496	0.000	-	0.3826	0.003	-	0.2036	0.040
Lake Shipp	-	0.4431	0.001	+	0.8047	0.000	-	0.5912	0.000	-	0.3503	0.005
Lake Silver	-	0.0103	0.670	-	0.0774	0.235	-	0.0357	0.425	-	0.0082	0.703
Lake Smart	-	0.0181	0.619	+	0.2473	0.050	+	0.0264	0.548	-	0.3199	0.022
Lake Summit	-	0.5788	0.000	+	0.6800	0.000	-	0.4513	0.001	-	0.0414	0.376
Lake Winterset	-	0.7790	0.000	+	0.6914	0.000	-	0.6895	0.000	-	0.2542	0.020
Little Lake Hamilton	+	0.0836	0.216	-	0.0283	0.479	+	0.0906	0.197	-	0.0959	0.184
Middle Lake Hamilton	+	0.0094	0.676	+	0.1453	0.088	-	0.0583	0.292	-	0.3128	0.008
Spring Lake	-	0.3543	0.004	+	0.4606	0.001	-	0.4621	0.001	-	0.3185	0.008

Table 4-4. Trendline statistics for linear regressions of chl-a, TN, TP, and Secchi depth from 2000 - 2020. Stats include regression direction (+/-), R-squared value, and p-value.

**Surface Level vs. Water Quality**

Waterbody	Chl-a			Secchi			TN			TP		
	Dir.	R <sup>2</sup>	p-value	Dir.	R <sup>2</sup>	p-value	Dir.	R <sup>2</sup>	p-value	Dir.	R <sup>2</sup>	p-value
Lake Blue	-	0.0147	0.620	+	0.0026	0.837	-	0.0990	0.189	+	0.0018	0.865
Lake Buckeye	-	0.0019	0.859	+	0.1075	0.171	-	0.0124	0.650	+	0.0337	0.452
Lake Cannon	-	0.1207	0.145	+	0.0848	0.227	-	0.0980	0.192	+	0.0318	0.465
Lake Conine	-	0.2834	0.019	+	0.4872	0.001	-	0.2560	0.027	-	0.0979	0.192
Lake Deer	-	0.1939	0.059	+	0.1578	0.092	-	0.1047	0.177	+	0.0416	0.402
Lake Elbert	+	0.2348	0.036	-	0.3835	0.005	+	0.1656	0.084	+	0.1245	0.138
Lake Eloise	+	0.0752	0.256	-	0.0003	0.940	-	0.0143	0.626	+	0.1033	0.180
Lake Fannie	-	0.5485	0.002	+	0.8750	0.000	-	0.6806	0.000	-	0.8710	0.000
Lake Haines	+	0.0014	0.877	+	0.1819	0.069	-	0.1665	0.083	+	0.2307	0.037
Lake Hamilton	-	0.0603	0.378	+	0.1533	0.149	-	0.0065	0.775	+	0.0019	0.878
Lake Hartridge	-	0.0027	0.832	+	0.0094	0.693	-	0.0086	0.706	-	0.0942	0.201
Lake Howard	-	0.1440	0.109	+	0.1542	0.096	-	0.3714	0.006	-	0.0045	0.786
Lake Idyl	-	0.1500	0.125	+	0.1226	0.168	-	0.0874	0.249	-	0.0164	0.624
Lake Idylwild	-	0.3580	0.007	+	0.4141	0.003	-	0.4738	0.001	-	0.0159	0.607
Lake Jessie	-	0.0677	0.282	+	0.2710	0.022	-	0.2410	0.033	-	0.0574	0.323
Lake Link	-	0.1825	0.145	+	0.1430	0.203	-	0.5894	0.002	-	0.7446	0.000
Lake Lulu	-	0.0183	0.581	+	0.1255	0.137	-	0.3219	0.011	-	0.0043	0.790
Lake Mariam	-	0.0000	0.989	+	0.0238	0.528	-	0.0893	0.214	-	0.1129	0.160
Lake Mariana	-	0.0369	0.595	+	0.0133	0.751	-	0.2439	0.147	-	0.0253	0.661
Lake Martha	+	0.2143	0.046	-	0.0087	0.704	+	0.0569	0.325	+	0.1501	0.101
Lake Maude	-	0.0365	0.433	+	0.0739	0.260	-	0.1769	0.073	-	0.0794	0.242
Lake May	-	0.2408	0.033	+	0.3782	0.012	-	0.4728	0.001	-	0.2089	0.049
Lake Mirror	-	0.0041	0.794	+	0.0293	0.484	-	0.4728	0.001	+	0.0303	0.476
Lake Otis	-	0.3867	0.023	+	0.5717	0.003	-	0.6137	0.002	-	0.5517	0.004
Lake Pansy	+	0.0187	0.577	+	0.2804	0.020	-	0.1048	0.176	+	0.0000	0.981
Lake Rochelle	-	0.2489	0.030	+	0.2903	0.017	-	0.1488	0.103	-	0.0687	0.279
Lake Roy	-	0.2418	0.032	+	0.2997	0.015	-	0.0335	0.453	-	0.0020	0.854
Lake Shipp	-	0.1407	0.113	+	0.2139	0.046	-	0.4980	0.001	-	0.0796	0.242
Lake Silver	+	0.1394	0.322	-	0.2510	0.169	-	0.0000	0.999	-	0.0218	0.705
Lake Smart	-	0.8451	0.001	+	0.7772	0.004	-	0.8549	0.001	-	0.6511	0.015
Lake Summit	-	0.0854	0.225	+	0.1110	0.163	-	0.3344	0.009	-	0.0086	0.706
Lake Winterset	-	0.0133	0.638	+	0.0206	0.557	-	0.0244	0.523	+	0.0033	0.815
Little Lake Hamilton	-	0.5169	0.004	+	0.5472	0.002	-	0.4536	0.008	-	0.5257	0.003
Middle Lake Hamilton	-	0.5008	0.003	+	0.6534	0.000	-	0.4942	0.003	-	0.4926	0.004
Spring Lake	+	0.0638	0.297	-	0.0376	0.426	+	0.0302	0.477	+	0.1757	0.074

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.

**Onsite Sewage Treatment & Disposal by Lake**

<b>Waterbody</b>	<b>OSTD Count</b>	<b>Density (OSTD/acre)</b>
Lake Blue	0	0.00
Lake Buckeye	42	0.18
Lake Cannon	338	0.49
Lake Conine	40	0.07
Lake Daisy	33	0.15
Lake Deer	48	0.18
Lake Elbert	2	0.00
Lake Eloise	186	0.23
Lake Fannie	33	0.02
Lake Haines	15	0.01
Lake Hamilton	62	0.03
Lake Hartridge	65	0.14
Lake Howard	30	0.02
Lake Idyl	6	0.03
Lake Idylwild	33	0.25
Lake Jessie	111	0.14
Lake Link	15	0.23
Lake Lulu	42	0.06
Lake Mariam	132	0.32
Lake Mariana	0	0.00
Lake Martha	1	0.00
Lake Maude	0	0.00
Lake May	1	0.00
Lake Mirror	0	0.00
Lake Otis	66	0.15
Lake Pansy	0	0.00
Lake Rochelle	38	0.03
Lake Roy	125	0.44
Lake Shipp	57	0.09
Lake Silver	0	0.00
Lake Smart	0	0.00
Lake Summit	52	0.52
Lake Winterset	71	0.14
Little Lake Hamilton	0	0.00
Middle Lake Hamilton	4	0.02
Ned Lake	53	0.29
Spring Lake	0	0.00

Table 4-6. Count and density of known OSTD systems within each lake drainage basin.

**Invasive Plant Management Treatment Area**

Waterbody	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Lake Blue		1.8	1.3	1.3				1.0			
Lake Buckeye		3.3	18.8	71.0	3.9	23.5	12.6	2.0	2.9	1.3	6.2
Lake Cannon		93.8	65.7	5.5	0.8	13.6	137.0	66.9	5.3	8.0	10.6
Lake Conine	7.0	47.5	26.3	16.5	38.2	86.6	74.4	227.8	87.9	103.6	46.4
Lake Daisy		1.0	0.5	1.0	0.5	1.5	1.0				1.0
Lake Deer	2.5	0.4	0.5		0.0	1.0	1.6	0.2	125.6	123.0	44.0
Lake Elbert	4.3	173.0	10.5	173.0	4.0	1.5	50.4	172.0	42.3		1.0
Lake Eloise		38.5	17.5	25.5	9.5	27.4	31.4	61.6	99.6	31.7	22.6
Lake Fannie	42.0	76.5	37.0	47.0	38.3	126.8	72.4	216.7	201.6	667.0	192.9
Lake Haines		417.8	81.3	53.5	87.8	111.5	23.4	69.8	160.0	286.4	74.7
Lake Hamilton	10.5	3.5	8.0	5.5	8.0	29.5	13.9	13.0	22.7	8.0	26.1
Lake Hartridge		5.3		2.5	8.6	9.8	0.3		1.0	4.7	
Lake Howard	14.5	27.3	1.8	29.3	11.5	0.8	2.0	1.5	1.5		1.3
Lake Idyl						5.4	8.3	3.5	1.0		1.0
Lake Idylwild	1.5	4.0	0.5	2.0	0.0	20.6	18.6	26.9	0.2	25.4	0.5
Lake Jessie		44.8	62.8	7.0	39.7	32.3	99.0	54.1	46.5	53.8	54.3
Lake Link		11.0		0.5	11.0	11.9	10.5	6.0	6.0	0.5	1.0
Lake Lulu	9.0	29.3	319.0	152.0	9.4	155.8	8.0	8.0	16.9	38.2	8.0
Lake Mariam					2.0	5.0	4.0	3.0	4.0	11.0	1.0
Lake Mariana	2.5			8.3	5.5	6.2	2.6	1.5		2.0	7.0
Lake Martha	5.0	18.3									
Lake Maude		9.3	0.5		0.1	1.0	0.5				0.1
Lake May	21.3	51.5	93.8	3.5	30.1	54.7	11.7	4.4	8.0	16.2	15.3
Lake Mirror		28.0	0.5	16.1	36.9	56.4	70.5	12.3	15.5		18.4
Lake Ned	29.0	28.5	159.8		0.5	1.0	0.5				2.1
Lake Otis		37.3		6.5	6.0	43.6	40.5	48.1	6.4	8.0	5.0
Lake Pansy	7.3	9.5			2.6	3.0	3.3	2.7	6.7	6.0	3.1
Lake Rochelle	15.3	119.3	580.5	32.5	68.0	109.3	152.6	572.3	250.7	315.3	139.6
Lake Roy	3.5	15.3	3.5	7.3	7.5	6.9	27.7	16.0	43.5	23.4	0.3
Lake Sears	0.3	1.3	0.3		1.0	1.0	0.1	2.0	1.0		
Lake Shipp	33.0	23.8	10.5	10.0	1.7	2.8	102.7	2.1	8.3	6.3	3.2
Lake Silver	2.0	6.0									
Lake Smart	5.3	1.3	3.5	1.3	6.2	18.3	13.2	278.2		78.5	
Lake Spring		21.0	14.0	60.5		34.9	16.6	13.5	21.3	7.2	11.3
Lake Summit	1.8	15.0	12.0	4.5	20.2	2.2	47.7	8.6	0.5		22.4
Lake Thomas		100.3			0.9	62.8	0.1	0.6	67.5		1.5
Lake Winterset		27.3	6.5	5.8	60.2	28.9	553.4	10.8		24.0	44.0

Table 4-7. Annual invasive plant herbicide treatment area (in acres) for each Winter Haven study area waterbody.

Common Name	Scientific Name	Common Name	Scientific Name
Alligator Weed	<a href="#">Alternanthera philoxeroides</a>	Sacred Lotus	<a href="#">Nelumbo nucifera</a>
American Lotus	<a href="#">Nelumbo lutea</a>	Sawgrass	<a href="#">Cladium jamaicense</a>
Bald Cypress Pond Cypress	<a href="#">Taxodium spp.</a>	Soft Rush	<a href="#">Juncus effusus</a>
Banana Lily	<a href="#">Nymphoides aquatica</a>	Southern naiad	<a href="#">Najas guadalupensis</a>
Bladderwort	<a href="#">Utricularia spp.</a>	Spatterdock	<a href="#">Nuphar advena</a>
Brazilian Pepper	<a href="#">Schinus terebinthifolius</a>	Stonewort Nitella	<a href="#">Nitella spp.</a>
Bulrushes	<a href="#">Scirpus spp.</a>	Swamp Bay	<a href="#">Persea palustris</a>
Burhead Sedge	<a href="#">Oxycaryum cubense</a>	Sweetbay Magnolia	<a href="#">Magnolia virginiana</a>
Buttonbush	<a href="#">Cephalanthus occidentalis</a>	Torpedograss	<a href="#">Panicum repens</a>
Carolina Willow	<a href="#">Salix caroliniana</a>	Water Hyacinth	<a href="#">Eichhornia crassipes</a>
Cattail	<a href="#">Typha spp.</a>	Water Lettuce	<a href="#">Pistia stratiotes</a>
Climbing Hempweed	<a href="#">Mikania scandens</a>	Water Pennywort	<a href="#">Hydrocotyle spp.</a>
Coontail	<a href="#">Ceratophyllum demersum</a>	Water Spangles	<a href="#">Salvinia minima</a>
Duck Potato	<a href="#">Sagittaria lancifolia</a>	Wild Taro	<a href="#">Colocasia esculenta</a>
Duckweed	<a href="#">Lemna spp.</a>		
Eel Grass	<a href="#">Vallisneria americana</a>		
Egyptian Paspalidium	<a href="#">Paspalidium geminatum</a>		
Elodea Waterweed	<a href="#">Egeria densa</a>		
Filamentous Algae	<a href="#">Lyngbya species</a>		
Fire Flag	<a href="#">Thalia geniculata</a>		
Fragrant Water Lily	<a href="#">Nymphaea odorata</a>		
Hairy Maiden Fern	<a href="#">Thelypteris hispidula</a>		
Hydrilla	<a href="#">Hydrilla verticillata</a>		
Illinois Pondweed	<a href="#">Potamogeton illinoensis</a>		
Knotted Spikerush	<a href="#">Eleocharis interstincta</a>		
Knotweed	<a href="#">Polygonum spp.</a>		
Maidencane	<a href="#">Panicum hemitomon</a>		
Melaleuca	<a href="#">Melaleuca quinquenervia</a>		
Muskgrass	<a href="#">Chara spp.</a>		
Papyrus	<a href="#">Cyperus papyrus</a>		
Para grass	<a href="#">Urochloa mutica</a>		
Parrot Feather	<a href="#">Myriophyllum aquaticum</a>		
Pickerelweed	<a href="#">Pontederia cordata</a>		
Primrose Willow	<a href="#">Ludwigia spp.</a>		
Red Maple	<a href="#">Acer rubrum</a>		
Redtop Panicum	<a href="#">Panicum rigidulum</a>		
Road Grass	<a href="#">Eleocharis baldwinii</a>		
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## 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	
✘	✘	✘	▲	▬	▲	▲	✔	✘	⚠	1.9

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	235.4
Volume (m <sup>3</sup> )	2,723,797
Avg. Depth (feet)	9.03
Drainage Basin Area (acres)	559.1
Limiting Nutrient	Co-Limited
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Conine receives stormwater runoff from **7** drainage sub-basins which contribute a total of **2836 lbs of TN** and **474 lbs of TP** per year. Due to the age of the area, stormwater from the urban drainage basins to the south has historically been untreated.

### 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:

Management of hydrilla has historically been a concern for the North Chain of Lakes. In addition to posing an ecological threat, large-scale treatment of invasive species can have water quality impacts by releasing excess nutrients into the water column. In 2020, hydrilla made up **9.7%** of the total population of sampled aquatic vegetation. This was a decrease from **16%** the previous year. Additionally, the total area of hydrilla treated in 2020 was **45 acres**—down from **51** acres the previous year.

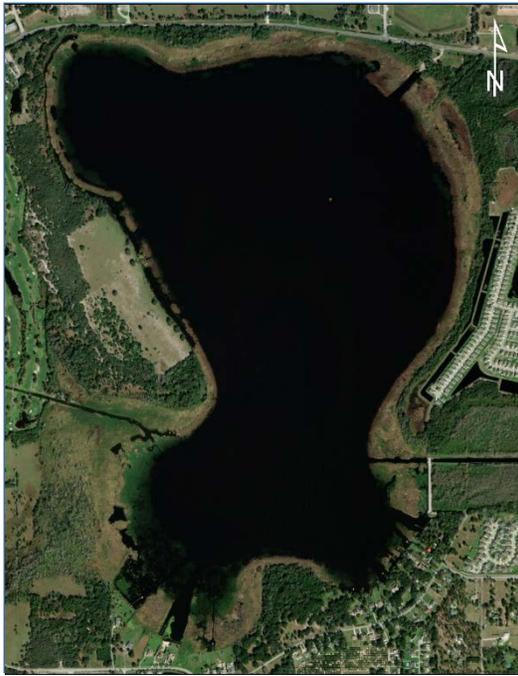
## Best Management Practices

### Existing Best Management Practices

- **Green Infrastructure:** In 2020, the City began construction of a treatment wetland on 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. This data is shared with FWC and Polk County to assist with treatment development. In 2019, FWC stocked **200** triploid grass carp in the Northern Chain to supplement invasives treatment measures and reduce the amount of herbicide used.

### Future Management Strategies

- Complete construction of Lake Conine Wetland Treatment project and begin water quality monitoring onsite by end of 2021.
- Develop plan to evaluate internal load from legacy sediments
- Continue to work with FWC to monitor invasive species and provide input on effective vegetation management practices. Reach managed status of invasive vegetation to reduce the need for large-scale treatment.



# 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	
✓	✓	✓	—	—	—	▲	●	●	●	● 1.9

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	800.3
Volume (m <sup>3</sup> )	2,723,797
Avg. Depth (feet)	6.94
Drainage Basin Area (acres)	1368.0
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Invasive Species Treatment:

Management of hydrilla has historically been a concern for the North Chain of Lakes. In addition to posing an ecological threat, large-scale treatment of invasive species can have water quality impacts by releasing excess nutrients into the water column. In 2020, hydrilla made up **1.3%** of the total population of sampled aquatic vegetation. This was a decrease from **6%** the previous year. Additionally, the total area of hydrilla treated in 2020 was **192 acres**—down from **667 acres** the previous year.

### 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 and Polk County to assist with treatment development. 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. Reach managed status of invasive vegetation to reduce need for large-scale treatment.
- Development of One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Lake Fannie



# 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	
✗	✗	✓	—	▲	—	▲	✓	✗	●	1.8

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	687.5
Volume (m <sup>3</sup> )	9,104,277
Avg. Depth (feet)	9.65
Drainage Basin Area (acres)	1630.4
Limiting Nutrient	Co-limited
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Invasive Species Treatment:

Management of hydrilla and water hyacinth have historically been a concern for the Lake Haines. In addition to posing an ecological threat, large-scale treatment of invasive species can have water quality impacts by releasing excess nutrients into the water column. In 2020, hydrilla made up **10.4%** and hyacinth made up **1%** of the total population of sampled aquatic vegetation. The overall percentage of invasives decreased since 2019. Invasive treatment for all species totaled **89** acres in 2020, slightly higher than the **75** acres in 2019.

### 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.

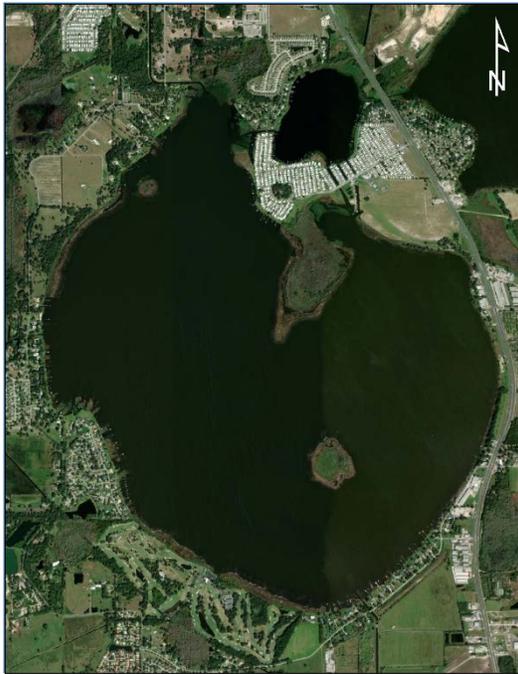
## Best Management Practices

### 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 shared with FWC and Polk County on a regular basis to assist with treatment development. 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. Reach managed status of invasive vegetation to reduce the need for large-scale treatment.
- 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	
⊗	⊗	⊗	▼	▼	▲	▼	☹	✔	☹	0.9

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	2168.7
Volume (m <sup>3</sup> )	16,852,885
Avg. Depth (feet)	6.39
Drainage Basin Area (acres)	2008.8
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Water Quality Stressor Identification:

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.

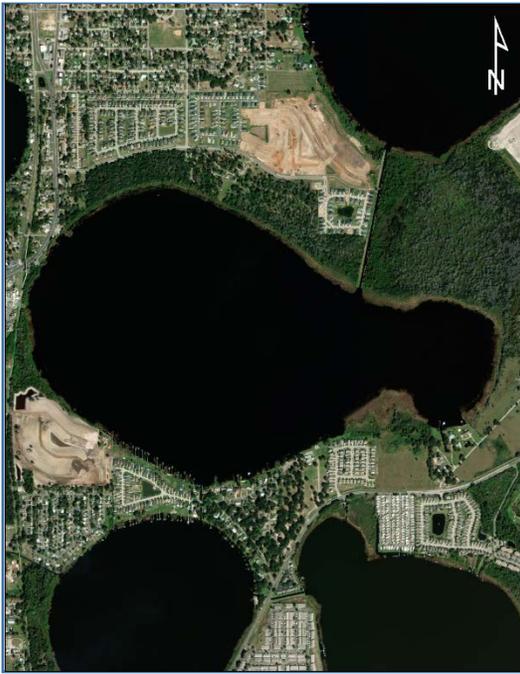
## Best Management Practices

### 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
  - Identify any potential pollutant sources in the drainage basin
- Explore aquatic vegetation planting initiatives to improve submerged macrophyte abundance.



# 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	
✘	✘	✘	▲	▲	▲	▲	●	✘	✘	● 1.9

**Status:** *Currently impaired; showing improving water quality trends.*

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	559.9
Volume (m <sup>3</sup> )	7,475,175
Avg. Depth (feet)	8.96
Drainage Basin Area (acres)	1109.7
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Invasive Species Treatment:

Management of hydrilla has historically been a concern for the North Chain of Lakes. In addition to posing an ecological threat, large-scale treatment of invasive species can have water quality impacts by releasing excess nutrients into the water column. In 2020, hydrilla made up **8.9%** of the total population of sampled aquatic vegetation. This was a decrease from **11.1%** the previous year. Additionally, the total area of hydrilla treated in 2020 was **139 acres**—down from **157 acres** the previous year.

### 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 City has been monitoring vegetation communities in Lake Rochelle to rapidly detect the growth of invasives since 2017. Data is shared with FWC and Polk County on a regular basis to assist with treatment development. 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. Reach managed status of invasive vegetation to reduce the need for large-scale treatment.
- One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Lake Rochelle



# 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	
✘	✘	✘	—	—	▲	—	✔	✔	✔	2.0

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	281.2
Volume (m <sup>3</sup> )	3,581,825
Avg. Depth (feet)	9.42
Drainage Basin Area (acres)	300.2
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Smart receives stormwater runoff from **2** drainage sub-basins which contribute a total of **1673.4 lbs of TN** and **348.9 lbs of TP** per year. That said, developed areas in these basins are newer and rely on stormwater ponds to mitigate much of the pollutant loading.

### 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:

Management of hydrilla has historically been a concern for the North Chain of Lakes. In addition to posing an ecological threat, large-scale treatment of invasive species can have water quality impacts by releasing excess nutrients into the water column. In 2020, hydrilla made up **1.3%** of the total population of sampled aquatic vegetation. This was a decrease from **7.6%** the previous year. Additionally, no herbicide treatments were implemented in 2020—down from **39.3** acres treated the previous 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 shared with the Florida Fish and Wildlife Commission (FWC) and Polk County to develop treatment plans. In 2019, FWC stocked **200** triploid grass carp in the Northern Chain to supplement its invasives management program

### 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. Reach managed status of invasive vegetation to reduce the need for large-scale treatment.
- One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes higher surface levels in Lake Smart



# 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	
✘	✘	✘	—	—	—	—	✔	✔	✔	1.5

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	359.6
Volume (m <sup>3</sup> )	3,818,505
Avg. Depth (feet)	8.46
Drainage Basin Area (acres)	656.2
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

While Little Lake Hamilton lacks much direct stormwater drainage, it possesses a fairly sizable basin that contributes **1472.7 lbs of TN** and **198.04 lbs of TP** per year. Some of the land uses within this basin include higher density residential, agricultural, and industrial which provide greater nutrient loads per acre than other less intensive land uses.

### 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.

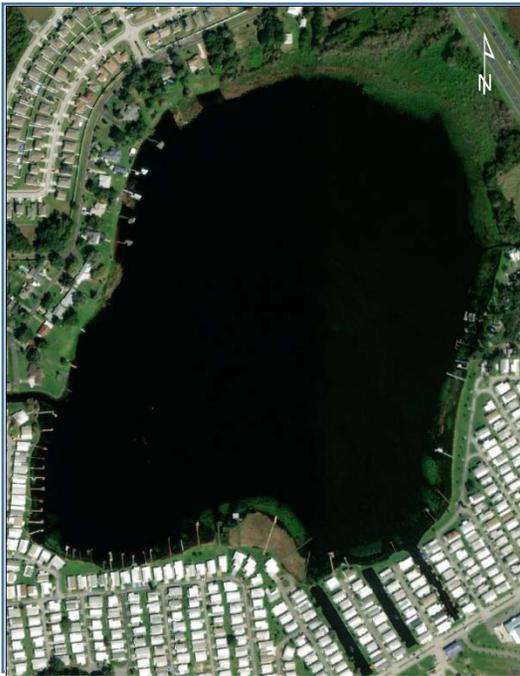
## Best Management Practices

### 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	
✘	✘	✘	—	—	▲	—	🟡	🟢	🟢	🟡 1.8

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	102.6
Volume (m <sup>3</sup> )	525,059
Avg. Depth (feet)	5.01
Drainage Basin Area (acres)	183.3
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Middle Lake Hamilton possesses a sizable drainage basin that extends north toward Haines City. This basin, which includes agricultural and high density residential land uses contributes **11621.3 lbs of TN** and **1072.03 lbs of TP** per year.

### 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.

## 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 Middle Lake Hamilton
- Due to the majority of this Lake's drainage basin being outside of Winter Haven limits, the City must coordinate with local stakeholders to address nutrient loading from stormwater.



# 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	
✘	✘	✔	—	▲	—	▲	✔	✔	✔	2.3

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	338.2
Volume (m <sup>3</sup> )	4,545,479
Avg. Depth (feet)	9.59
Drainage Basin Area (acres)	695.4
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Cannon receives stormwater runoff from **5** distinct drainage sub-basins which contribute a total of **3863 lbs of TN** and **637.8 lbs of TP** annually. The City has implemented some stormwater BMPs within its limits, so the actual loads are somewhat less than this.

### 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.

### Invasive Species Treatment:

Large scale treatment of invasive plants can cycle nutrients back into the water column. Prioritizing rapid response and small-scale treatments is preferred to reduce these impacts. Invasive plant species made up on **2%** of the total sampled population and only **9.6** acres were treated using herbicides in 2020. Lake Cannon is considered in a maintenance state according to FWC. Due to the density of surrounding private residences, mechanical removal of invasive plants is not feasible for Lake Cannon.

## Best Management Practices

### Existing Best Management Practices

- Street Sweeping: **9.58** miles of residential and arterial roads are swept on a monthly basis in the drainage basins within City limits. This was an increase over the **2.7** miles swept in 2019.

### Future Management Strategies

- Explore source analysis of septic systems in the drainage basin to determine if OSTD leaching is a major contributor to excess nutrients. If so, coordinate with Polk County to explore septic-to-sewer conversion.
- Continue to monitor aquatic plants and share data with FWC and Polk County; assisting with planning invasive treatment programs.
- Explore implementation of Green Infrastructure in high nutrient loading areas within Lake Cannon's drainage basin.



# 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 <sup>3</sup> )	19,173,944
Avg. Depth (feet)	11.42
Drainage Basin Area (acres)	800.1
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## 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. **3875.24 lbs of TN** and **665.4 lbs of TP** are contributed from this basin annually. Much of this runoff originates outside of City limits.

### 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.

### Invasive Species Treatment:

Large-scale treatment of invasive plants can release nutrients back into the water column which can have water quality impacts. In 2020, only **0.8%** of the plants sampled were invasive with FWC only treating **22** acres. Lake Eloise is currently in a maintained state with regards to invasive vegetation.

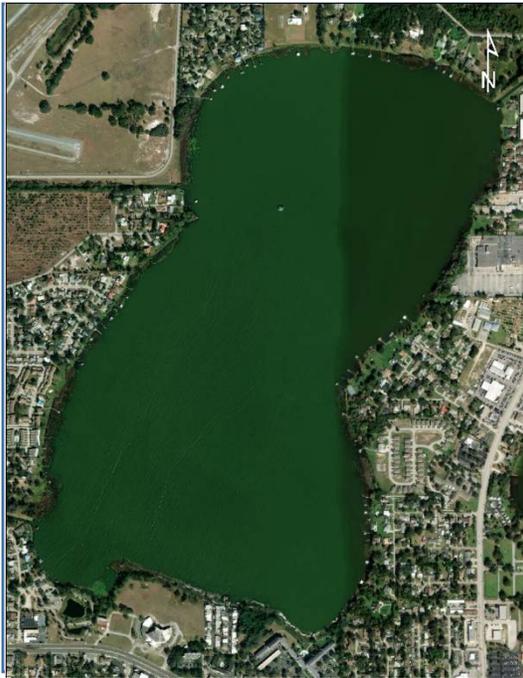
## Best Management Practices

### Existing Best Management Practices

- The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 optimize invasive species control measures. Future work may explore the use of mechanical harvesting, however a lack of adjacent public lands to dispose of the discarded material is an added challenge to feasibility.



# 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 (m <sup>3</sup> )	5,504,605
Avg. Depth (feet)	9.01
Drainage Basin Area (acres)	476.0
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Stormwater runoff enters Lake Hartridge via **2** primary drainage sub-basins; contributing a total of **2658.3 lbs of TN** and **458.9 lbs of TP** annually.

### 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:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Invasive plants made up only **0.3%** of the total vegetation community and only **4.7** acres were treated using herbicide in 2020. Lake Hartridge is currently in a maintenance state with regards to invasive species management.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **17.3** miles of residential and arterial roads are swept on a monthly basis in Lake Hartridge's southern drainage sub-basin. This is up from **5** miles in 2019.
- **Green Infrastructure:** The City has implemented Lake Hartridge Nature Park that treats stormwater from **73** acre southern drainage basin.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✗	✗	✓	▲	▲	▬	▲	✓	✓	✗	● 2.3

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	631.6
Volume (m <sup>3</sup> )	7,209,568
Avg. Depth (feet)	8.71
Drainage Basin Area (acres)	1238.9
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Howard receives urban stormwater runoff from **53** discreet drainage sub-basins. These basins contribute **6321.3 lbs of TN** and **1097.5 lbs of TP** annually. That said, there are multiple stormwater BMPs implemented in these basins to reduce nutrient loading, so these values are much less in actuality.

### 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.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. There have been no managed invasive species detected during vegetation surveys the last two years. However, FWC did treat **1** acre of burhead sedge in 2020. With that, Lake Howard is in a maintained state with regards to invasive species management.

## 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; this system is currently in the process of repair.
- Street Sweeping: **50.6** miles of downtown, residential, and arterial roads are swept on a monthly basis around the lake perimeter. This is up from **23** miles in 2019.
- 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 over **700** acre southern drainage sub-basins. A trash catchment system was installed at the Heritage Park outfall. The City purchased a parcel to treat stormwater from the large southern 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

- Complete alum system repair – by end of 2021
- Develop plan to evaluate internal load from legacy sediments
- Continue to perform maintenance on all existing raingardens in 2021
- Design stormwater improvements at the newly purchased parcel adjacent to Lake Howard Nature Park.
- Pursue funding to manage stormwater from the property identified as part of the SAIP.



# 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

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	95.2
Volume (m <sup>3</sup> )	1,028,780
Avg. Depth (feet)	8.26
Drainage Basin Area (acres)	130.3
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Idylwild receives stormwater runoff from **2** distinct drainage sub-basins which contribute a total of **669.1 lbs of TN** and **121.6 lbs of TP** annually. That said, there are existing BMPs implemented in these basins to treat some of this stormwater.

### 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. However, these can still potentially contribute nutrient loading through leachate to the groundwater.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. As of 2020, **1.9%** of the vegetation community was determined to be invasive species—mostly burhead sedge and hydrilla. However, FWC only treated **0.5** acres of invasives with herbicide in 2020. Lake Idylwild is considered in an invasive species maintenance state.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** Approximately **6** miles of arterial roadways are swept on a monthly basis in the small southern drainage basin.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✘	✘	✘	—	—	—	—	✔	☹	✘	1.3

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	185.0
Volume (m <sup>3</sup> )	2,093,316
Avg. Depth (feet)	7.93
Drainage Basin Area (acres)	784.8
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Jessie receives stormwater from a fairly sizable drainage basin. This basin contributes **3871.2 lbs of TN** and **652.3 lbs of TP** annually.

### 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 estimate how much legacy material is within Lake Jessie.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrient back into the water column. As of 2020, **2.7%** of the vegetation community was determined to be invasive species—mostly burhead sedge and hydrilla. FWC treated **54** acres of hydrilla with herbicide in 2020. That said, Lake Jessie is considered in an invasive species maintenance state.

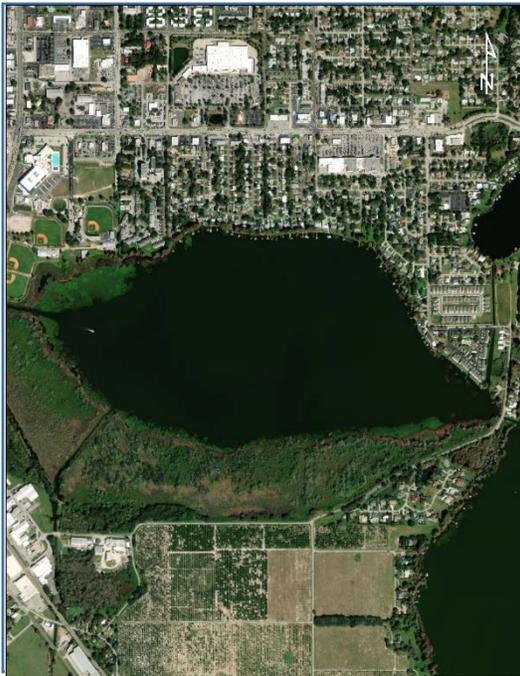
## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✘	✘	✘	▲	▲	▲	▲	✔	✔	⚠	2.4

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	307.5
Volume (m <sup>3</sup> )	2,582,361
Avg. Depth (feet)	6.76
Drainage Basin Area (acres)	692.9
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Lulu receives stormwater runoff from **13** distinct drainage sub-basins which contribute a total of **2791.5 lbs of TN** and **483 lbs of TP** annually. The City has implemented multiple stormwater BMPs in these basins.

### 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.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Staff did not locate any invasive species during the 2020 vegetation survey. That said, FWC treated **8** acres of floating water hyacinth in 2020; which likely occurred prior to the vegetation survey performed by City staff. With that, Lake Lulu is considered in an invasive species maintenance state.

## 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; this system is in the process of being repaired.
- Street Sweeping: **11.6** miles of residential and arterial roads are swept on a monthly basis
- 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

- Complete repair of alum infrastructure 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.
- The City will continue to work with the FWC to optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	50.5
Volume (m <sup>3</sup> )	241,790
Avg. Depth (feet)	5.28
Drainage Basin Area (acres)	301.8
Limiting Nutrient	Co-limited
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake May receives stormwater runoff from **6** urban drainage which contribute a total of **1732.7 lbs of TN** and **292.9 lbs of TP** annually. The City has implemented multiple stormwater BMPs to treat some of this pollutant load, however.

### 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:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Burhead sedge, hydrilla, and water hyacinth made up **9.4%** of the species surveyed in 2020. FWC treated only **15** acres using herbicide in the same year. Lake May is considered in a maintenance state with regards to invasive species.

## 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; this system is in the process of being repaired.
- Street Sweeping: **27.3** miles of downtown, residential, and arterial roads are swept on a monthly basis. This is up from **10.8** miles in 2019.
- Green Infrastructure: As part of a road improvement project for 7<sup>th</sup> Street SW, roadside swales were constructed to trap and infiltrate stormwater. Raingardens have also been constructed at the City's Utility Office.
- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

- Complete alum system repairs by end of 2021.
- 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 optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✓	✓	✓	▲	▲	▲	▲	✓	⚠	✗	2.4

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	130.1
Volume (m <sup>3</sup> )	1,737,103
Avg. Depth (feet)	8.86
Drainage Basin Area (acres)	152.8
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Mirror receives stormwater from **11** distinct drainage sub-basins which contribute a total of **749.6 lbs of TN** and **120.9 lbs of TP** annually. The City has implemented stormwater BMPs to treat some of this pollutant load.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Burhead sedge, hydrilla, and water hyacinth made up **2.5%** of the species surveyed in 2020. FWC treated only **17.4** acres using herbicide in the same year. Lake Mirror is considered in a maintenance state with regards to invasive species.

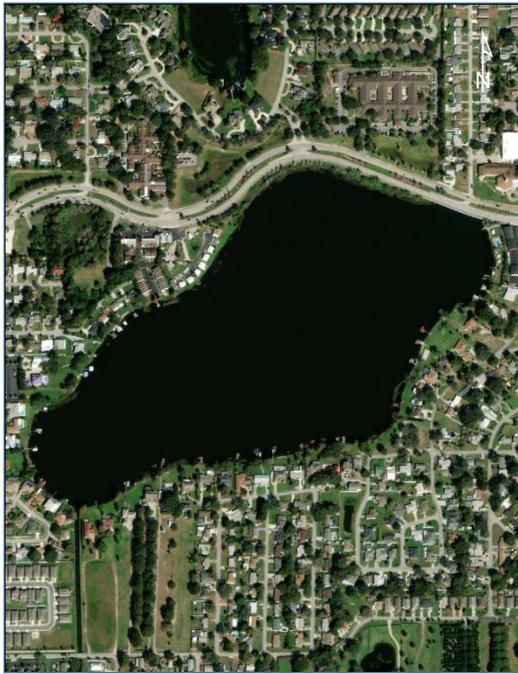
## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **6.7** miles of downtown and residential roads are swept on a monthly basis in Lake Mirror's drainage basin. This is up from **3.8** in 2019.
- **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 monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

- Budget for/pursue funding for SAIP priority site improvements in southern drainage basin.
- The City will continue to work with the FWC to optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✓	✓	✓	▲	▲	▲	▲	✓	✓	✓	2.6

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	74.3
Volume (m <sup>3</sup> )	1,311,358
Avg. Depth (feet)	10.76
Drainage Basin Area (acres)	281.8
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Roy receives stormwater runoff from **13** distinct drainage sub-basins which contribute a total of **1448.3 lbs of TN** and **241.5 lbs of TP** annually. The City has implemented multiple stormwater BMPs to treat some of this pollutant load.

### Onsite Sewage Treatment & Disposal (OSTD):

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

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Hydrilla made up only **0.6%** of the species surveyed while FWC performed no herbicide treatments in Lake Roy in 2020. Lake Roy is considered in a maintenance state with regards to invasive species.

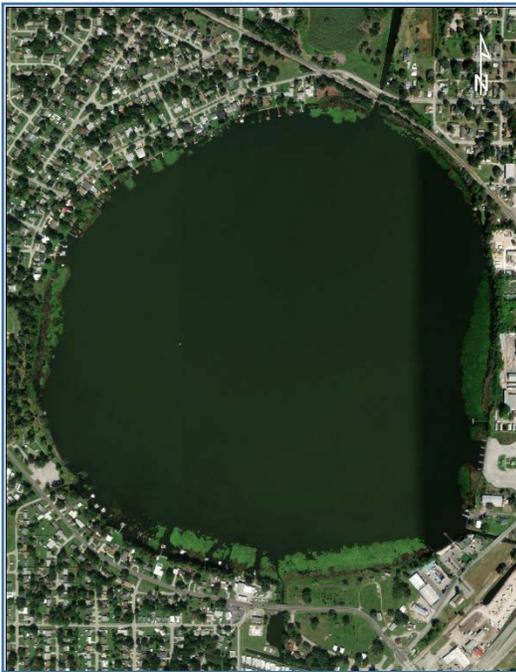
## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **11.8** miles of residential and arterial roads are swept on a monthly basis in Lake Roy's drainage basin. This is up from **8.2** miles in 2019.
- **Green Infrastructure:** The City constructed a series of bioswales/raingardens along 6<sup>th</sup> 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 monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

- Budget for/pursue funding for SAIP priority site improvements in southern 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 optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	279.4
Volume (m <sup>3</sup> )	2,521,861
Avg. Depth (feet)	7.25
Drainage Basin Area (acres)	631.7
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Shipp receives stormwater from **9** distinct drainage sub-basins which contribute a total of **3614.3 lbs of TN** and **654.7 lbs of TP** annually. The City has implemented stormwater BMPs to treat some of this pollutant load.

### 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 Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Burhead sedge and hydrilla made up **5.3%** of the species surveyed while FWC treated only **2** acres of invasives using herbicides in 2020. Lake Shipp is considered in a maintenance state with regards to invasive species.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **12.4** miles of residential and arterial roads are swept on a monthly basis in Lake Shipp's drainage basin. This is an increase from **9.1** miles swept in 2019.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

- Develop plan to evaluate internal load from legacy sediments
- The City will continue to work with the FWC to optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✓	✓	✓	▲	▲	▲	▲	✓	✗	✗	2.3

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	25.2
Volume (m <sup>3</sup> )	378,599
Avg. Depth (feet)	9.02
Drainage Basin Area (acres)	96.1
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Spring Lake receives stormwater from **7** distinct drainage sub-basins which contribute a total of **520.7 lbs of TN** and **90.8 lbs of TP** annually. The City has implemented stormwater BMPs to treat some of these pollutant loads.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Burhead sedge and hydrilla made up **15%** of the species surveyed in 2020. To keep up with this, FWC treated **11.3** acres of invasives with herbicide. That said, Spring Lake is considered in a maintained state with regards to invasive plant management.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **7.4** miles of downtown, residential, and arterial roads are swept on a monthly basis in Spring Lake's drainage basin. This was an increase from **3.4** miles in 2019.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

- Explore implementing additional stormwater BMPs within the drainage basin.
- The City will continue to work with the FWC to optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✓	✓	✓	▲	▲	▬	▲	✓	⚠	⚠	2.4

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	67.4
Volume (m <sup>3</sup> )	1,110,163
Avg. Depth (feet)	10.71
Drainage Basin Area (acres)	99.1
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Located mostly outside of City limits, the City has not delineated any distinct drainage sub-basins. That said, the surrounding areas contribute **513.3 lbs of TN** and **82.7 lbs of TP** annually. Due to the majority of this basin being outside Winter Haven limits, the City has not implemented major nutrient reduction BMPs.

### Onsite Sewage Treatment & Disposal (OSTD):

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

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Hydrilla made up **2.9%** of the species surveyed while FWC treated **21** acres of invasives using herbicides in 2020. Lake Summit is considered in a maintenance state with regards to invasive species.

## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 and Polk County to optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✓	✓	✓	▲	▲	▲	▲	✓	☹	☹	2.5

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	555.5
Volume (m <sup>3</sup> )	12,499,617
Avg. Depth (feet)	14.26
Drainage Basin Area (acres)	519.1
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

The City has not delineated any distinct drainage sub-basins for Lake Winterset. That said, the surrounding areas contribute **2258.8 lbs of TN** and **407.6 lbs of TP** annually. Due to the majority of this basin being outside Winter Haven limits, the City has not implemented major nutrient reduction BMPs.

### Onsite Sewage Treatment & Disposal (OSTD):

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

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Hydrilla made up **4.5%** of the species surveyed while FWC treated **44** acres of invasives using herbicides in 2020. Lake Winterset is considered in a maintenance state with regards to invasive species.

## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 and Polk County to optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✓	✓	✓	▲	▲	▲	▲	✓	✗	✗	2.3

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	72.4
Volume (m <sup>3</sup> )	603,451
Avg. Depth (feet)	6.73
Drainage Basin Area (acres)	233.6
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Buckeye receives stormwater runoff from **8** distinct drainage sub-basins which contribute a total of **867.1 lbs of TN** and **154.8 lbs of TP** annually. The City has implemented stormwater BMPs to treat some of this pollutant load.

### Onsite Sewage Treatment & Disposal (OSTD):

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

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Invasives such as hydrilla, burhead sedge and parrot feather made up **11.6%** of the species surveyed in 2020. FWC treated **6.2** acres of invasives using herbicides in the same year. Lake Buckeye has not had a major herbicide treatment (> 20 acres) since 2015 and appears to be in a maintenance stage.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **5.6** miles of residential and arterial roads are swept on a monthly basis in Lake Buckeye's drainage basin. This is an increase from **3.3** miles in 2019.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 and Polk County to optimize invasive species control measures. Future work may explore the use of mechanical harvesting and grass carp.



# 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	
✘	✘	✘	—	—	—	—	✓	⚠	✓	1.3

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	19.0
Volume (m <sup>3</sup> )	133,383
Avg. Depth (feet)	6.07
Drainage Basin Area (acres)	179.5
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Idyl receives stormwater from **3** distinct drainage sub-basins which contribute a total of **934.9 lbs of TN** and **154.5 lbs** of TP annually. The City has implemented stormwater BMPs to treat some of this pollutant load.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Burhead sedge made up **9.1%** of the species surveyed in 2020. FWC treated only **1** acre of invasives using herbicides in the same year. Lake Idyl's past herbicide treatments have all been fairly minor; as such this lake is considered in a maintenance state.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **4** miles of residential and arterial roads are swept in Lake Idyl's drainage basin on a monthly basis. This is an increase from **1.9** miles in 2019.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.
- **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

- The City is currently in the process of designing green infrastructure within the SAIP priority basin via a SWFWMD grant. Upon approval of the design, this treatment area will be constructed by the end of 2021.
- The City will continue to work with the FWC and Polk County to optimize invasive species control measures. Future work may explore the use of mechanical harvesting.



# 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	
✓	✓	✓	▼	▼	▼	▼	🟡	✓	🟡	🔴 1.0

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

**Priority:** *Moderate-High*

Lake Stats	
Surface Area (acres)	82.5
Volume (m <sup>3</sup> )	1,408,454
Avg. Depth (feet)	10.21
Drainage Basin Area (acres)	224.4
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Martha receives stormwater from **14** distinct drainage sub-basins which contribute a total of **1217.1 lbs of TN** and **199.1 lbs of TP** annually. The City has implemented multiple stormwater BMPs to treat some of this pollutant load.

### 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 absorbing 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.

### Diesel Spill:

In mid-2020, Lake Martha received an unknown quantity of diesel from the Winter Haven Hospital generator tanks. Due to the severity of the spill, a large-scale clean-up and remediation effort was undertaken via contractors hired by Hospital management. While these remediation efforts have largely been successful, it is unclear if any long-term impacts will arise from this event.

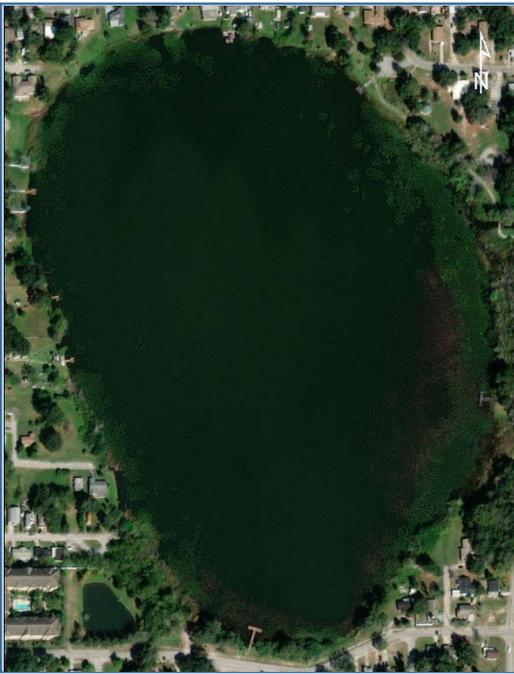
## Best Management Practices

### Existing Best Management Practices

- Street Sweeping: **7.15** 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 Polk State College recreation complex. 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.
- The City will continue to monitor lake water quality and biology for any lasting impacts from the diesel spill.
- Green infrastructure designs have been developed for part of the Lake Martha drainage basin. Pending SWFWMD approval, construction of these BMPs will be completed by the end of 2021.



# 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	
✓	✓	✓	▲	▲	▲	▲	✓	✓	✓	2.8

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	51.0
Volume (m <sup>3</sup> )	509,872
Avg. Depth (feet)	8.18
Drainage Basin Area (acres)	335.5
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Maude receives stormwater from **14** distinct drainage sub-basins which contribute a total of **1900.5 lbs of TN** and **320 lbs of TP** annually. The City has implemented multiple stormwater BMPs to reduce these pollutant loads.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Burhead sedge made up **2.2%** of the species surveyed in 2020. While FWC did not perform any herbicide treatments in the same year. Lake Maude has consistently been in a maintenance state regarding invasive species since 2012.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **15.7** miles of residential and arterial/collector roads are swept in Lake Maude's drainage basin on a monthly basis. This is an increase from **14** miles swept in 2019.
- **Green Infrastructure:** Lake Maude Nature Park provides treatment through its natural wetland as well as constructed stormwater retention ponds.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 and Polk County to optimize invasive species control measures. Future work may explore the use of mechanical harvesting and grass carp.
- Green infrastructure designs have been developed for part of Lake Maude's drainage basin. Pending SWFWMD approval, construction of these BMPs will be completed by the end of 2021.



# 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	
✓	✓	✓	—	—	—	—	☹️	✓	✗	🟡 1.8

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	54.3
Volume (m <sup>3</sup> )	1,282,954
Avg. Depth (feet)	11.93
Drainage Basin Area (acres)	110.1
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Silver receives stormwater from **12** distinct urban drainage sub-basins which contribute a total of **633.2 lbs of TN** and **106.1 lbs of TP** annually. The City has implemented multiple stormwater BMPs to treat a portion of this pollutant load.

### 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:** **20.15** miles of downtown, residential, and arterial roads are swept in Lake Silver's drainage basin on a monthly basis. This is an increase from **12.2** miles swept in 2019.
- **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 remaining existing raingardens to improve their effectiveness – by end of 2021.



# 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	
✓	✓	✓	▼	▼	▬	▼	✓	✗	⚠	1.0

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

**Priority:** *Moderate-High*

Lake Stats	
Surface Area (acres)	165.8
Volume (m <sup>3</sup> )	2,868,995
Avg. Depth (feet)	11.28
Drainage Basin Area (acres)	439.8
Limiting Nutrient	Phosphorus
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Elbert possesses a large stormwater drainage basin with **50** distinct sub-basins which contribute a total of **2365.8 lbs of TN** and **385.1 lbs of TP** annually. The City has implemented several stormwater BMPs to treat some of this pollutant load.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Hydrilla and burhead sedge made up **11.4%** of the species surveyed in 2020. FWC only treated **1** acre of burhead sedge using herbicide in the same year and had stocked **80** grass carp in 2018. Invasive vegetation treatment efforts have deviated quite a bit over the last decade with the latest large-scale treatment taking place in 2017.

## Best Management Practices

### Existing Best Management Practices

- **Street Sweeping:** **33.5** miles of downtown, residential, and arterial/collector roadways are swept in Lake Elbert's drainage basin on a monthly basis. This is an increase from **20.8** miles swept in 2019.
- **Green Infrastructure:** The City has constructed **2** raingardens that capture stormwater runoff along Lake Elbert's northern shoreline.
- **Aquatic Vegetation Management:** The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.
- **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.
- The City is exploring redevelopment of boat ramp area which would include construction of multiple raingardens.
- The City will continue to work with the FWC and Polk County to optimize invasive species control measures. Future work may explore additional stocking of grass carp



# 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	2.5

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	27.7
Volume (m <sup>3</sup> )	317,016
Avg. Depth (feet)	8.84
Drainage Basin Area (acres)	66.5
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## 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—some of which are outside City limits. These basins contribute a total of **197.2 lbs of TN** and **31.7 lbs of TP** annually. The City has implemented some stormwater BMPs to treat pollutant loading within Winter Haven jurisdictional portions of this basin.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Unfortunately, due to a data capture error, species data is unavailable for this lake. However, FWC treated **0.5 acres** of burhead sedge during 2020. Based on historic treatment data, Lake Link is considered in a maintenance state with regards to invasive species management.

## Best Management Practices

### Existing Best Management Practices

- Street Sweeping: **2.9** miles of residential and arterial roadways are swept in the Lake Link drainage basin on a monthly basis.
- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

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



# 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	
✓	✓	✓	—	—	—	—	🟡	✓	🟡	🟡 1.6

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	203.7
Volume (m <sup>3</sup> )	1,012,607
Avg. Depth (feet)	4.65
Drainage Basin Area (acres)	418.4
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Mariam receives stormwater from a single large drainage basin that straddles City and County jurisdictional boundaries. This basin contributes a total of **1607.4 lbs of TN** and **274.8 lbs of TP** annually. The City has implemented stormwater BMPs within its portion of the drainage basin to treat some of this pollutant load.

### Onsite Sewage Treatment & Disposal (OSTD):

There are **132** known septic systems in Lake Mariam's drainage basin. 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 Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. As of 2020, water hyacinth made up **1.3%** of the species sampled of which FWC treated **11** acres using herbicide. Based on historic treatment data, Lake Mariam is considered in a maintenance state with regards to invasive species management.

## Best Management Practices

### Existing Best Management Practices

- Street Sweeping: **1.9** 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 monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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 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	
								NA	NA	2.2

**Status:** *Currently impaired for chlorophyll and not showing improving water quality trends.*

**Priority:** *Moderate-High*

Lake Stats	
Surface Area (acres)	135.0
Volume (m <sup>3</sup> )	2,121,504
Avg. Depth (feet)	10.63
Drainage Basin Area (acres)	451.8
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Otis receives stormwater from **11** distinct drainage sub-basins which contribute a total of **2291 lbs of TN** and **372.6 lbs of TP** annually. The City has implemented several stormwater BMPs to treat some of the pollutant load in this basin.

### Onsite Sewage Treatment & Disposal (OSTD):

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

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Unfortunately, due to a data capture error, species data is unavailable for this lake. However, FWC treated **5** acres of water hyacinth and burhead sedge during 2020. Lake Otis's last large-scale herbicide treatment took place in 2017. In 2018, **30** grass carp were stocked to help keep hydrilla populations low.

## Best Management Practices

### Existing Best Management Practices

- Street Sweeping: **12.8** miles of residential and arterial/collector roadways are swept in the Lake Otis drainage basin on a monthly basis. This is an increase from **8.7** miles swept in 2019.
- Green Infrastructure: A series of bioswales have been constructed by the City along 6<sup>th</sup> Street SE (within the southwestern drainage basin)
- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.
- 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.
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate.



# 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	
✗	✗	✗	—	—	▲	—	NA	✔	✗	1.7

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	54.3
Volume (m <sup>3</sup> )	331,368
Avg. Depth (feet)	4.57
Drainage Basin Area (acres)	128.0
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Located completely outside Winter Haven limits, Lake Blue receives stormwater from a single drainage basin. Due to industrial and commercial land uses this basin contributes **871.5 lbs of TN** and **154.2 lbs of TP** annually. Since this basin is outside of Winter Haven jurisdiction, the City has not implemented any direct stormwater-related BMPs to mitigate these pollutant loads.

### 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 limited. That said, there is a moderate fringe of emergent vegetation surrounding much of this lake.

### Lake Morphology:

Since Lake Blue is uniformly shallow, sediment suspension via wind/wave action can potentially lead to increased internal nutrient loading. Any legacy pollutant sources could undergo consistent mixing and redistribution within this waterbody.

## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County. While invasive species management may not be the primary concern, tracking the introduction of exotics is critical for preventing their spread.

### 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



# 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

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

**Priority:** *Low*

Lake Stats	
Surface Area (acres)	137.3
Volume (m <sup>3</sup> )	1,429,257
Avg. Depth (feet)	8.41
Drainage Basin Area (acres)	219.4
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## 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. This basin contributes **1717.7 lbs of TN** and **382.2 lbs of TP** annually. Since the only portion of Lake Daisy's basin within Winter Haven limits is primarily undeveloped land, the City has not implemented any direct stormwater treatment BMPs yet.

### 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. While submerged invasive species aren't a large concern, FWC has occasionally treated very small areas (1 acre or less) of invasive floating plants.

### Onsite Sewage Treatment & Disposal (OSTD):

Lake Daisy has **33** confirmed septic systems in its drainage basin—a moderate density compared with other lakes in the study area. OSTDs can contribute excess nutrients via groundwater leachate.

## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

- Examine 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 plan specifically targeting stormwater runoff and/or septic effluent in Lake Daisy's basin.
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate.



# 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	
✘	✘	✘	—	—	—	—	✓	⚠	✓	1.8

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	116.9
Volume (m <sup>3</sup> )	1,036,382
Avg. Depth (feet)	7.60
Drainage Basin Area (acres)	260.5
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lake Deer receives stormwater runoff from **2** distinct drainage sub-basins which contribute **1451.1 lbs of TN** and **261.2 lbs of TP** annually. Due to the small area of this basin within Winter Haven limits, the City has not yet implemented any direct stormwater BMPs to treat these pollutant loads.

### Onsite Sewage Treatment & Disposal (OSTD):

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

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Hydrilla, burhead sedge, and water hyacinth made up **8.6%** of the surveyed population in 2020. FWC conducted herbicide treatments over **44** acres and significantly reduced both populations of hydrilla and hyacinth during this period. In 2018, FWC stocked **90** grass carp to assist with hydrilla management and reduce the amount of herbicide used.

## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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
- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.



# 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	
✘	✘	✘	—	—	—	▽	✓	✓	✘	1.1

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

**Priority:** *High*

Lake Stats	
Surface Area (acres)	515.6
Volume (m <sup>3</sup> )	6,449,864
Avg. Depth (feet)	8.99
Drainage Basin Area (acres)	1417.6
Limiting Nutrient	Phosphorus
Nutrient TMDL	Yes

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Due to the majority of Lake Mariana's drainage basin being outside of Winter Haven limits, the City has delineated only a single large basin. This basin contributes **6530.8 lbs of TN** and **1160.6 lbs of TP** annually. Also due to the aforementioned basin boundary, the City has not implemented any direct stormwater BMPs to treat these pollutant loads.

### Onsite Sewage Treatment & Disposal (OSTD):

There are **158** septic systems within Lake Mariana's drainage basin. 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 Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. The City has not located any managed invasive species during its last two annual vegetation surveys. However, FWC has implemented small-scale herbicide treatments to manage hydrilla and water hyacinth since 2010. Lake Mariana is considered in an invasive species maintenance state.

## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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	
✓	✓	✓	▼	▬	▼	▼	🟡	✓	✗	🟡 1.1

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

**Priority:** *Moderate-High*

Lake Stats	
Surface Area (acres)	76.4
Volume (m <sup>3</sup> )	678,178
Avg. Depth (feet)	7.17
Drainage Basin Area (acres)	180.6
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## 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. This single basin contributes **1002.9 lbs of TN** and **202.7 lbs of TP** annually. The City has not implemented any direct stormwater treatment BMPs within this basin.

### Onsite Sewage Treatment & Disposal (OSTD):

The **53** septic systems 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 Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Water hyacinth has previously been found in Lake Ned, however the City did not locate any during the 2020 vegetation survey. FWC has conducted minor floating plant herbicide treatments since 2014 and treated **2** acres in 2020.

### Lack of Submerged Aquatic Vegetation:

City vegetation surveys have failed to find any significant SAV communities in Lake Ned in the last 3 years. Based on FWC management records, hydrilla was prolific until a large-scale herbicide treatment in 2012 and the stocking of **38** grass carp in 2011. It is unclear if there was a robust native SAV population at this time, but the current lack of any limits the lake's ability to buffer against nutrient influx.

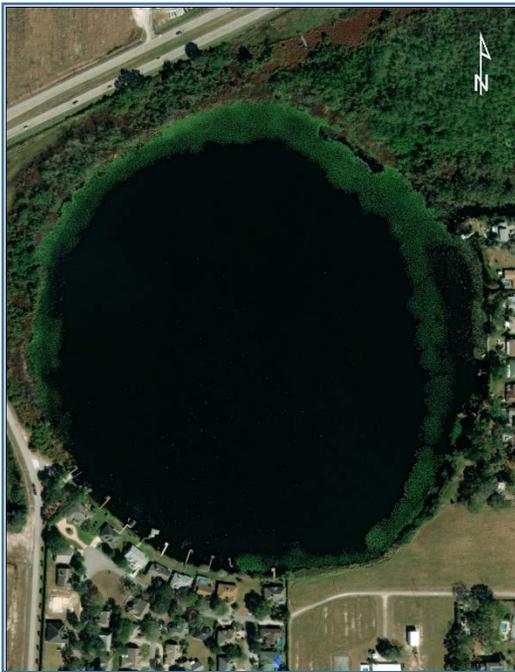
## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### 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
- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.



# 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	
✓	✓	✓	⚠	⚠	⚠	⚠	✓	✗	✓	1.4

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

**Priority:** *Moderate*

Lake Stats	
Surface Area (acres)	49.4
Volume (m <sup>3</sup> )	489,708
Avg. Depth (feet)	6.80
Drainage Basin Area (acres)	196.0
Limiting Nutrient	Co-limited
Nutrient TMDL	No

## Water Quality Impacts/Challenges

### Stormwater Pollutant Loading:

Lacking much contributing stormwater infrastructure, Lake Pansy receives stormwater runoff from a relatively small drainage basin which contributes **880.7 lbs of TN** and **111.2 lbs of TP** annually. The City has not yet implemented any direct stormwater BMPs to treat this pollutant load.

### Invasive Species Treatment:

Large-scale treatment of invasives using herbicide can cycle nutrients back into the water column. Burhead sedge, hydrilla, and sacred lotus made up **10.9%** of the species sampled in 2020. That said, FWC has only performed small-scale (<10 acre) herbicide treatments in Lake Pansy since 2010—even stocking **20** grass carp in the lake in 2019. This has resulted in an invasive species maintenance state for this lake.

## Best Management Practices

### Existing Best Management Practices

- Aquatic Vegetation Management: The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.

### Future Management Strategies

- Explore possible stormwater BMPs within Lake Pansy's drainage basin.
- The City will continue to work with the FWC to manage for invasive species; utilizing alternative treatment methods where appropriate.