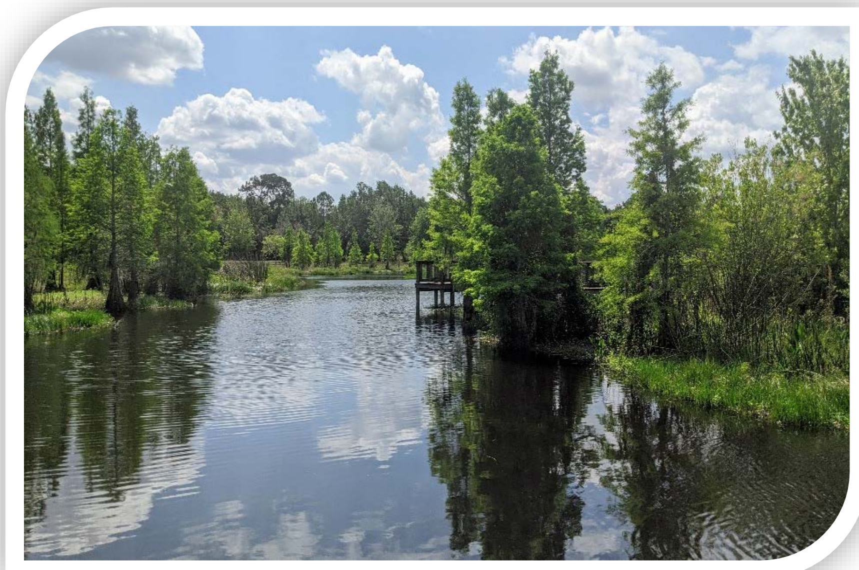
Winter Haven
The Chain of Lakes City

2021

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

As 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.

Effective lake management 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.

An overview of the primary lake health metrics and their annual changes can be found on pages 95 - 100. The average lake health score for all lakes increased from 1.85 in 2020 to 1.91 in 2021. A review of the individual lake health index values showed that 62% (or 23) of the lakes saw improving scores while 24% (or 9) of the lakes exhibited decreasing scores; the remaining 5 lakes exhibited no change in lake health score from the previous year. This indicates overall improvement in lake health for Winter Haven's waterbodies in 2021.

Water Quality: In 2021, 48% of lakes are meeting all regulatory water quality targets. Several of the previously impaired lakes are beginning to meet these target thresholds. Of the 19 lakes that are currently impaired, 58% are exhibiting statistically significant improving trends in at least one of the regulatory metrics (i.e. chlorophyll-a, total nitrogen, and total phosphorus).

Hydrology: Winter Haven received approximately 40 inches of rainfall in 2021 which is well below the 51.6 inch average. Despite this, lake levels as a whole still reached seasonal highs and many remained above average for most of the year. For nearly 60% of these lakes, an increase in level correlates directly with an improvement in at least one primary water quality parameter. As a result, maintaining higher water levels should result in overall lake health improvement for the majority of lakes in the area.

Aquatic Biology: Comparing biological index scores from 2018 to 2021 shows that overall aquatic vegetation abundance has remained relatively static. The presence of invasive species populations as well as vegetation diversity has fluctuated considerably from year to year. While 2021 saw an overall decline in invasive plant presence, some lakes did undergo a considerable increase in nuisance plant populations. This indicates that some lakes may require more frequent vegetation monitoring in order to minimize the impacts from invasive plant treatments. Fortunately, species diversity exhibited an increase from 2020 to 2021—indicating an improvement in the aquatic plant communities as a whole.

The City employs various structural and non-structural best management practices aimed at improving lake health. While the effects of COVID-19 has slowed down some of these efforts, it is important to highlight some noteworthy projects that City staff have made progress on in 2021. The Lake Conine Wetland Restoration project was completed in late 2020, laying the literal groundwork for recreational amenities to be placed on site (pp. 110-111). In 2021 the City's application for Legislative funding for this phase of the project ranked highest in the State—making the implementation of the recreational components highly likely in the future. The 319 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 (pp. 114-115). This project was completed in 2021 with future plans to implement a study of its practical application. Finally, Natural Resources staff have significantly ramped up its outreach and education programming in 2021 (pp. 125-126). These efforts include re-establishment of guided kayak tours for the public, lake education workshops targeted toward local community groups, and establishment of a part-time Natural Resources internship program. Staff are excited to provide these services in an effort to improve public understanding and engagement on issues related to our lakes.

One of the major additions debuted as part of the 2019 report was an online version complete with interactive charts, graphics, and photos. This version of the report will continue to be supported this year as well. You can reach the interactive report via the following link: www.tinyurl.com/wh-fl-lakesreport-app

Finally, special recognition must be made for the Lakes Advisory Committee who saw the addition of several new members in late 2020. This report would not have been possible without the guidance, advice, and support of local citizens with the passion to protect our natural resources. In addition, we'd like to thank you, our readers. We hope the information contained herein allows for a deeper, more meaningful understanding of the factors that affect the health of our lakes. Please don't hesitate to contact the City Natural Resources Division if you have questions, suggestions, or wish to support lake management efforts in the Winter Haven area.

Sincerely,

Devon Moore

City of Winter Haven
Natural Resources Division
Environmental Scientist

How to Navigate this Document

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

Contents

1- Introduction

1.1 Purpose

The lakes of the greater Winter Haven area are considered some of its most important natural assets. The utilization of these waterbodies by visitors and residents alike has cemented their role as economic and social resources. Our lakes also impart environmental benefits such as fish and wildlife habitat, water storage, aquifer recharge, 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*

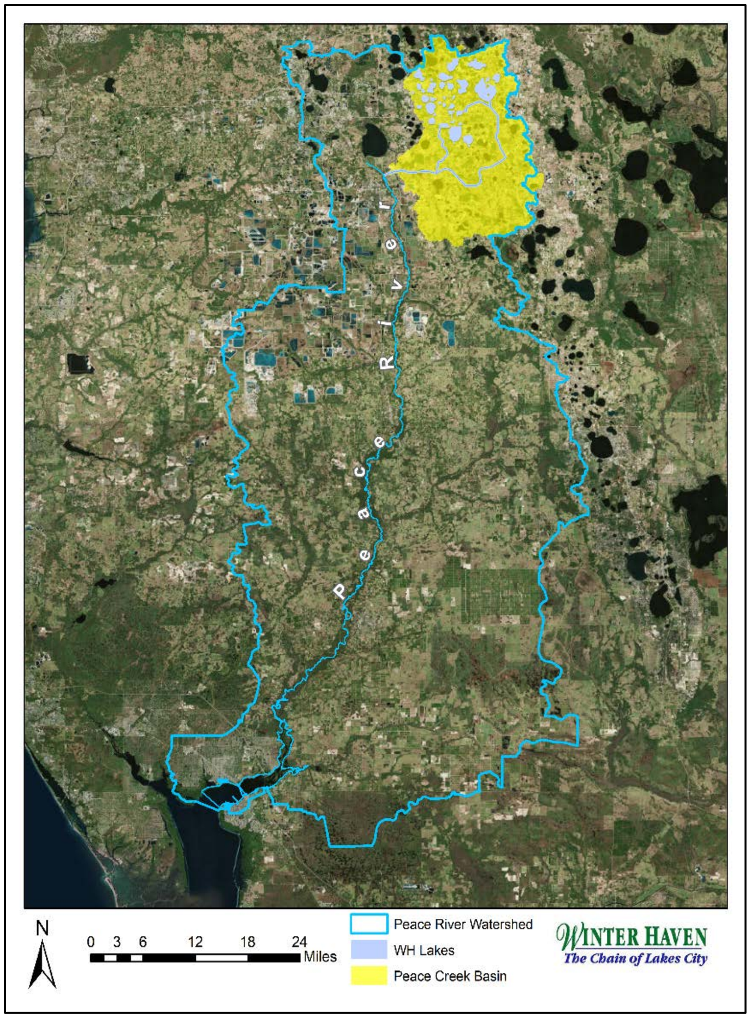


Figure 1-1. Map of Peace River & Peace Creek Watersheds

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.

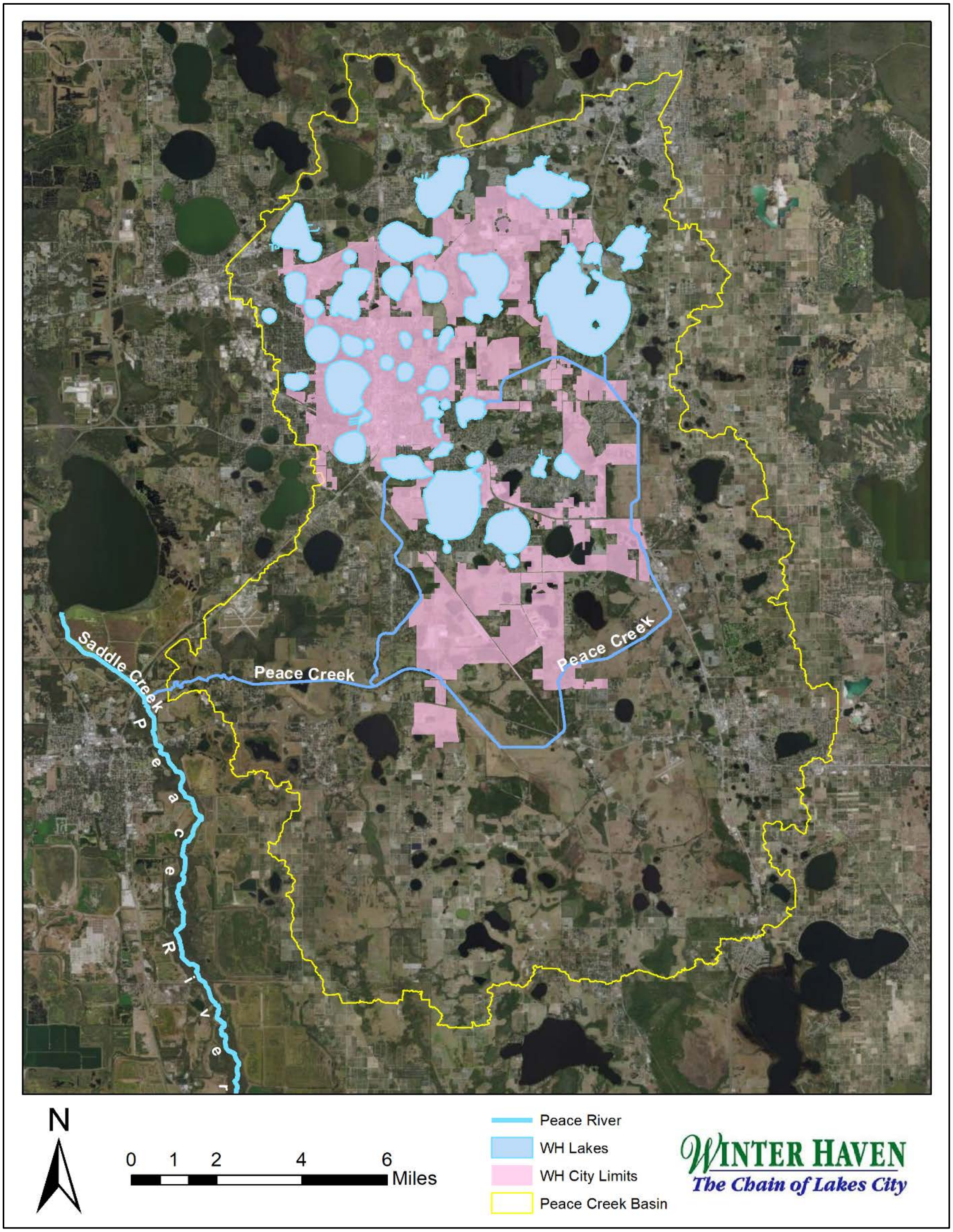


Figure 1-2. Map of the Peace Creek sub-basin, City of Winter Haven limits, contributing lakes and flow-ways.

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. In addition to these 8 waterbodies, Lake Henry discharges to Hamilton via the P-5 structure. However, because Lake Henry lacks public access and a means of water quality data collection, it has been excluded from this study.

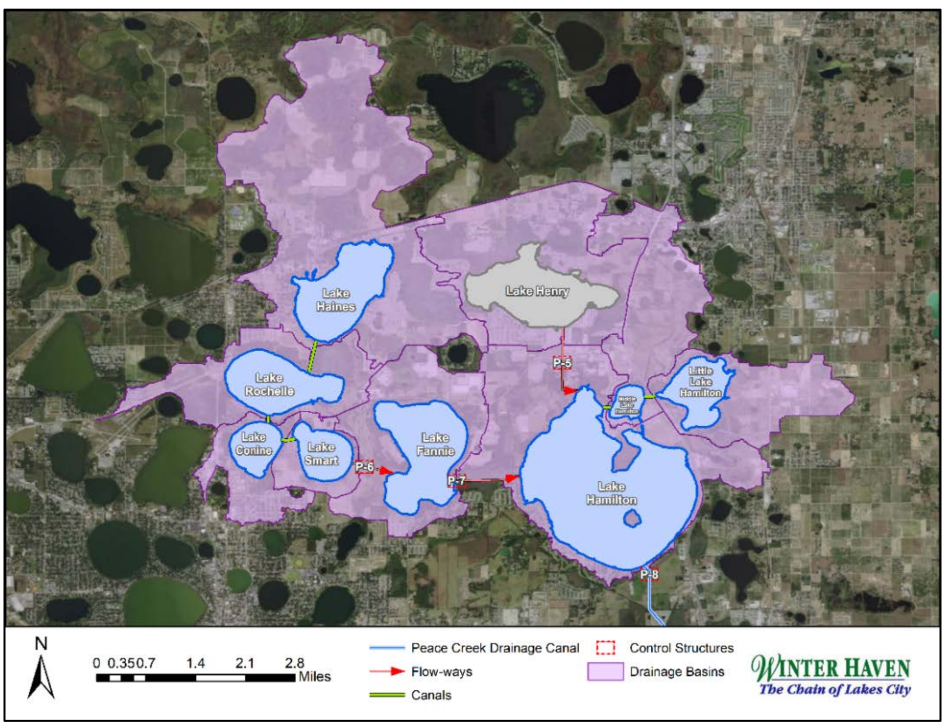


Figure 1-3. Map of North Chain of Lakes, Flow Pathways & Drainage Basins

Southern Chain of Lakes

Spanning the majority of the City of Winter Haven boundary, the Southern Chain of Lakes is 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).

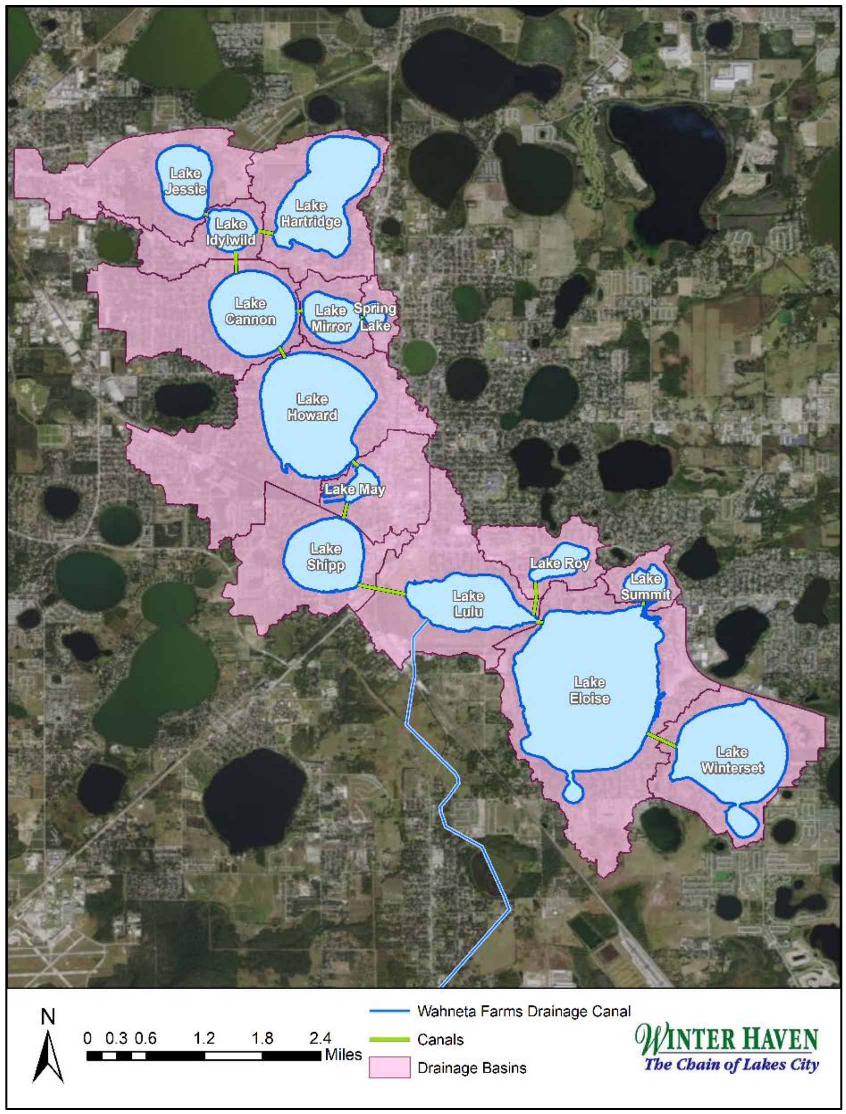


Figure 1-4. Map of South Chain of Lakes, Flow Pathways & Drainage Basins

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.

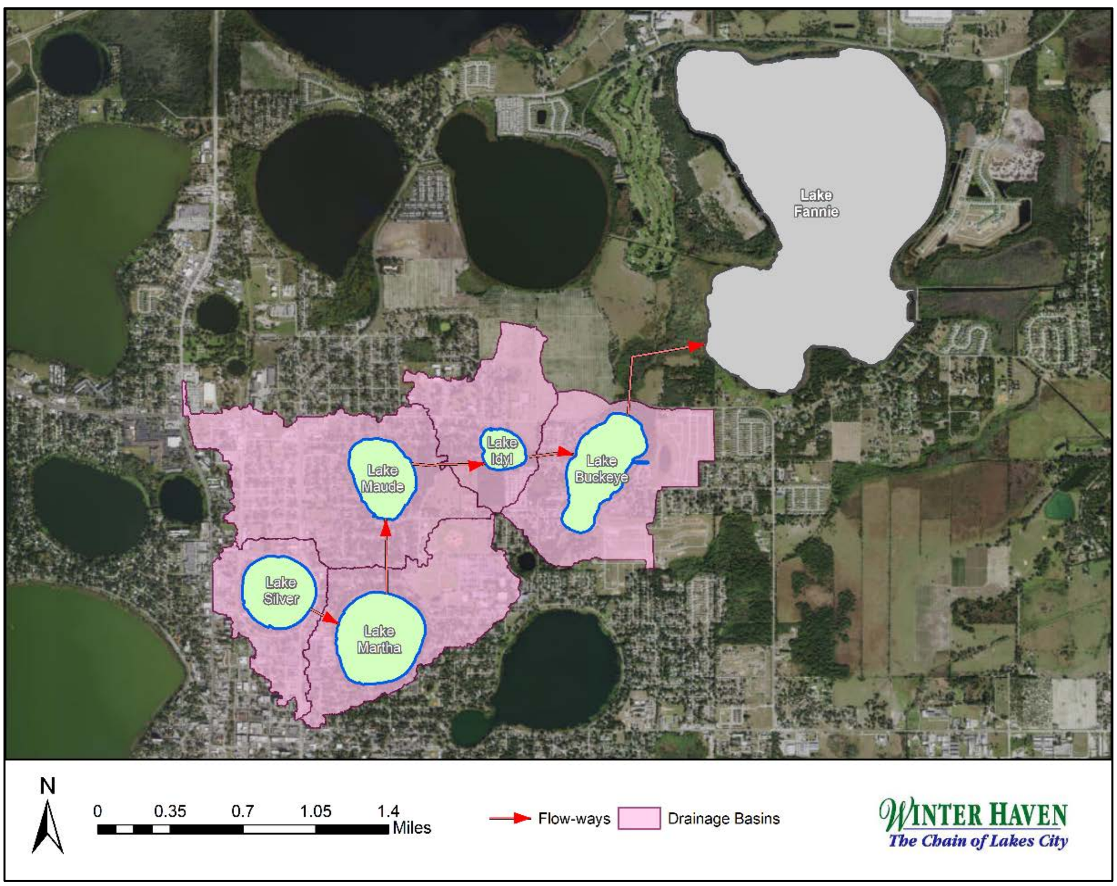


Figure 1-5. Map of North Central Lakes, Flow Pathways & Drainage Basins

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.

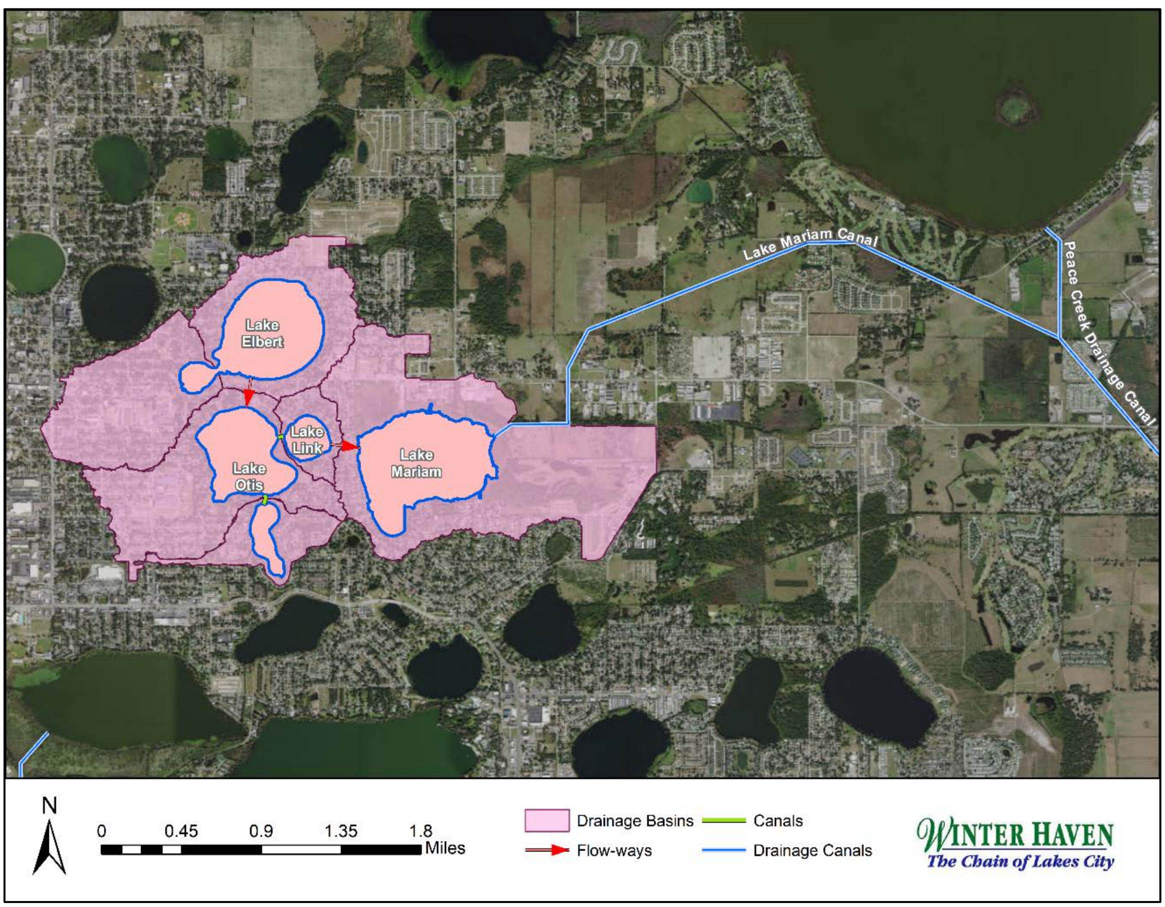


Figure 1-6. Map of South Central Lakes, Flow Pathways & Drainage Basins

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.

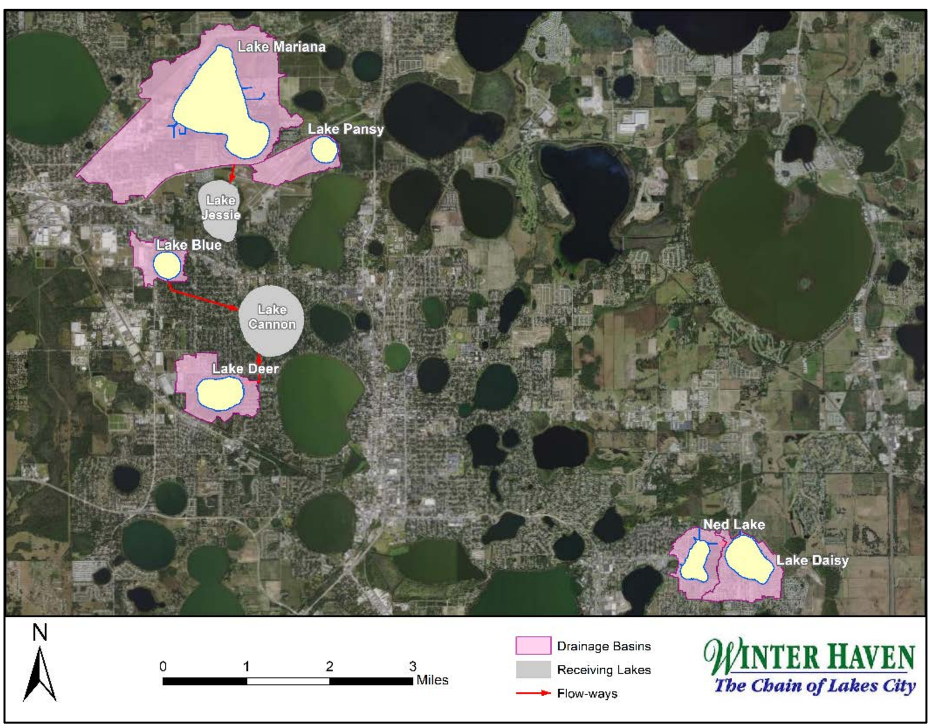


Figure 1-7. Map of Outlying Lakes, Flow Pathways & Drainage Basins

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 $CaCO_3$), indicates a waterbody's ability to neutralize acids and buffer against changes in pH. Generally, lakes with more alkalinity can support more productivity which is why this metric is used to classify lakes [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.

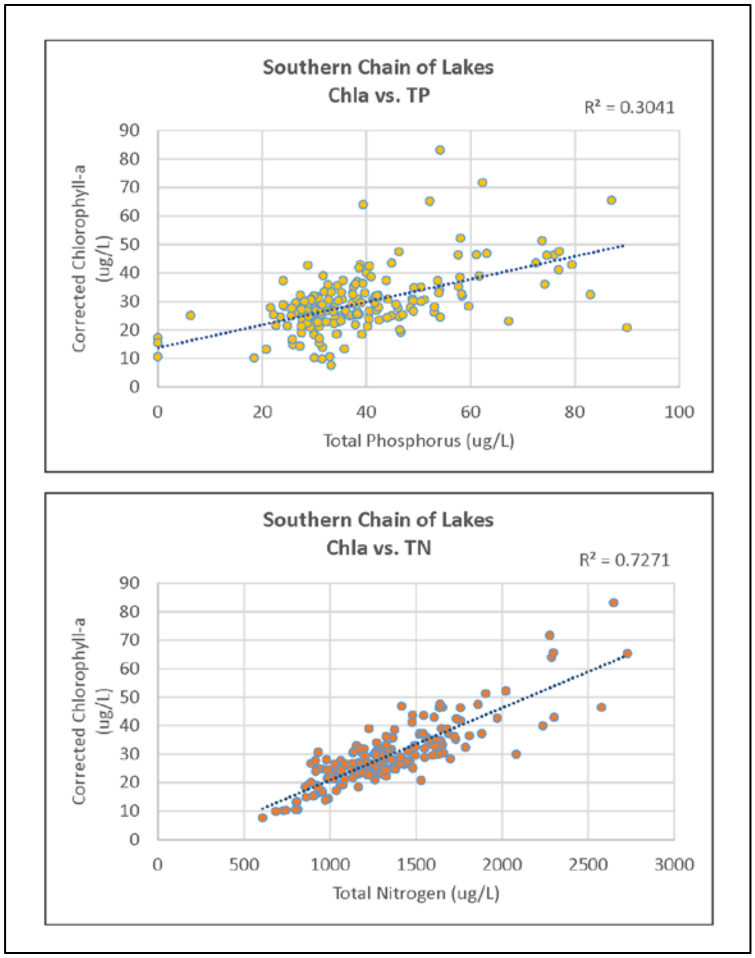


Figure 1-8. Linear Regression of Chlorophyll-a vs. Total Phosphorus & Total Nitrogen

In order to simplify the NNC impairment determination process, a flow chart was developed by City staff as a step-by-step guide (Figure 1-9) [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 $CaCO_3$) 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 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.

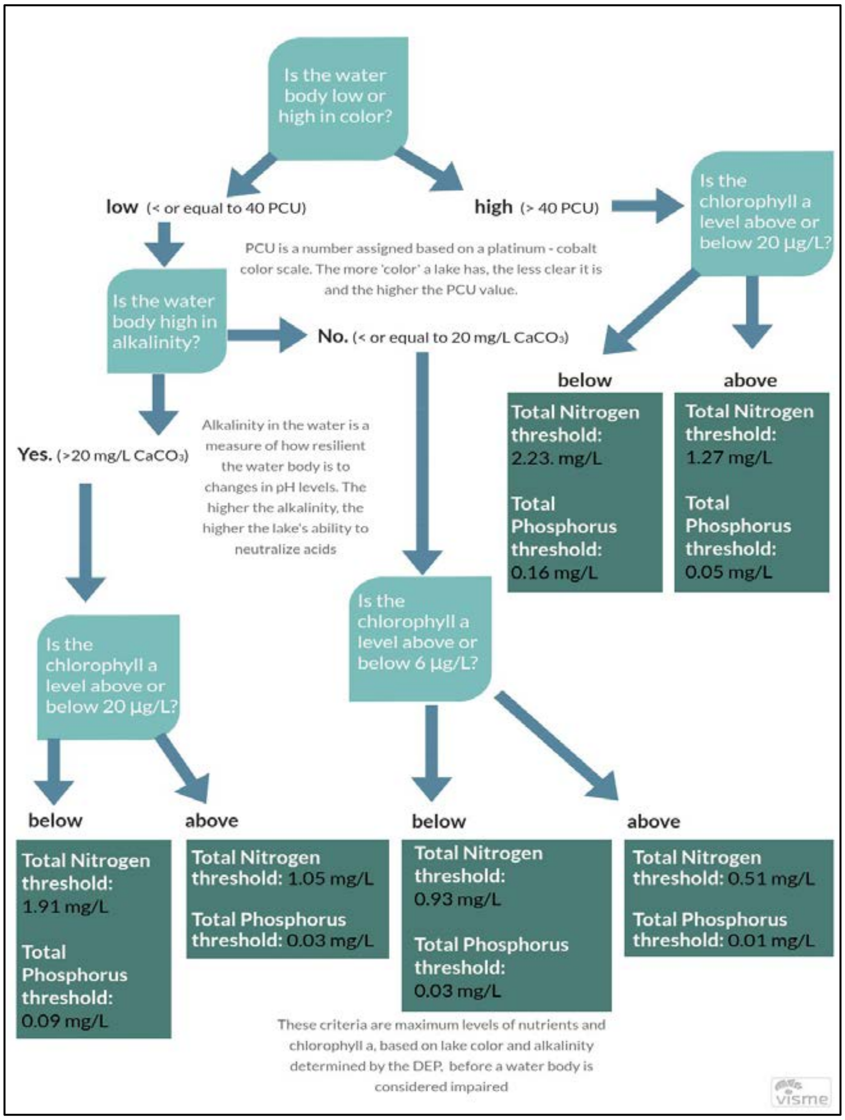


Figure 1-9. NNC Impairment Determination Flowchart

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 **M**unicipal **S**eparate **S**torm **S**ewer **S**ystems (MS4s). Non-point sources refer to the introduction of pollutants through surface runoff, atmospheric deposition, groundwater, sediments, and any other sources that don't possess a discreet entry point. Calculating the current loading rate for each stormwater outfall is accomplished by incorporating estimated annual runoff volumes, size of the contributing drainage areas, land uses, and their respective average loading rates for each pollutant per storm event—referred to as event mean concentrations (EMCs).

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

The FDEP evaluates nutrient impairment of State waterbodies via a cyclical assessment schedule. Impairment determination incorporates the most recent 7.5 years of quality-controlled data. Due to the large number of waterbodies in the State and FDEP staffing limitations, statewide annual re-evaluations of impairment aren't feasible. Using the FDEP methodology, the City of Winter Haven has begun evaluating NNC exceedances of local lakes 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) [21]:

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 [6]. 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.

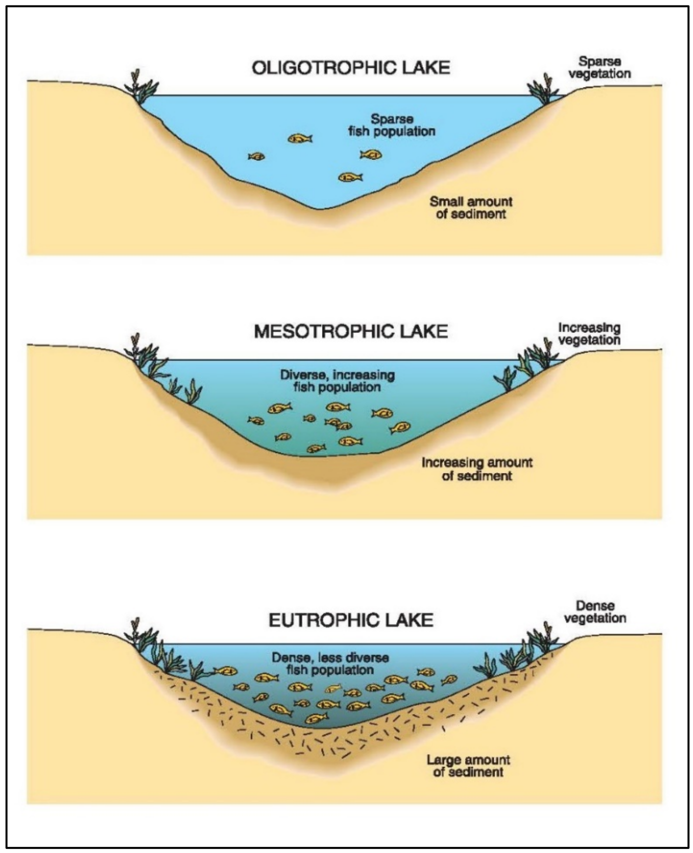


Figure 1-10. Diagram of Lake Trophic States [21].

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.

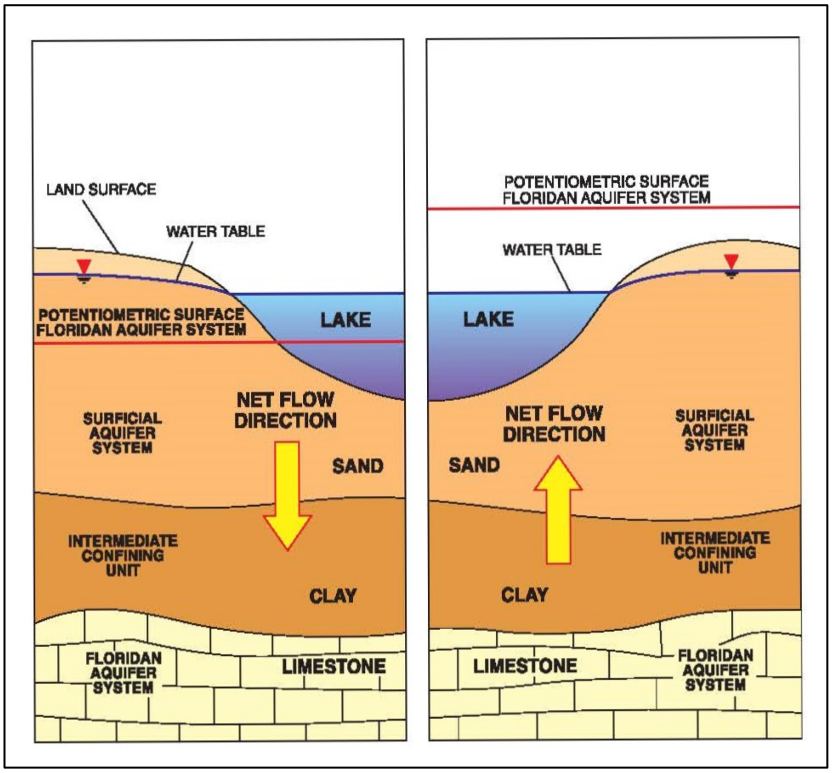


Figure 1-11. Diagram of Groundwater Interactions

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

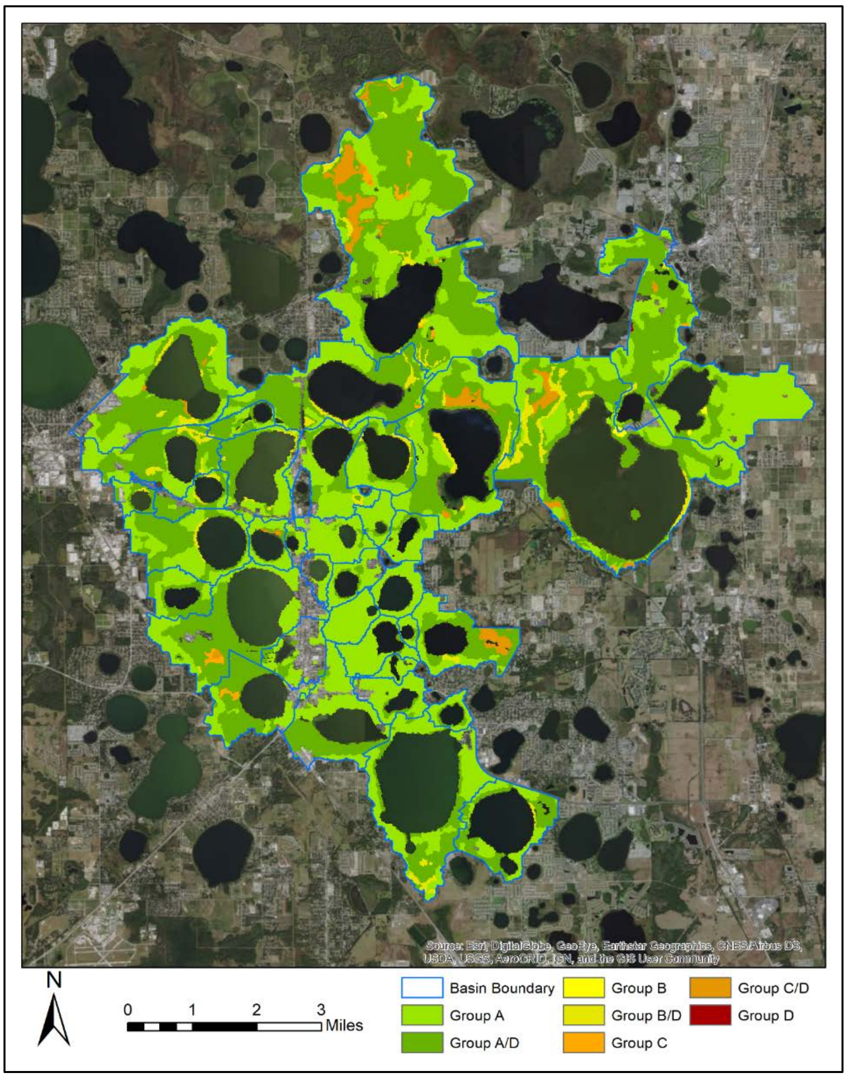


Figure 1-12. Hydrologic Soil Groups of the Winter Haven Lakes

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).

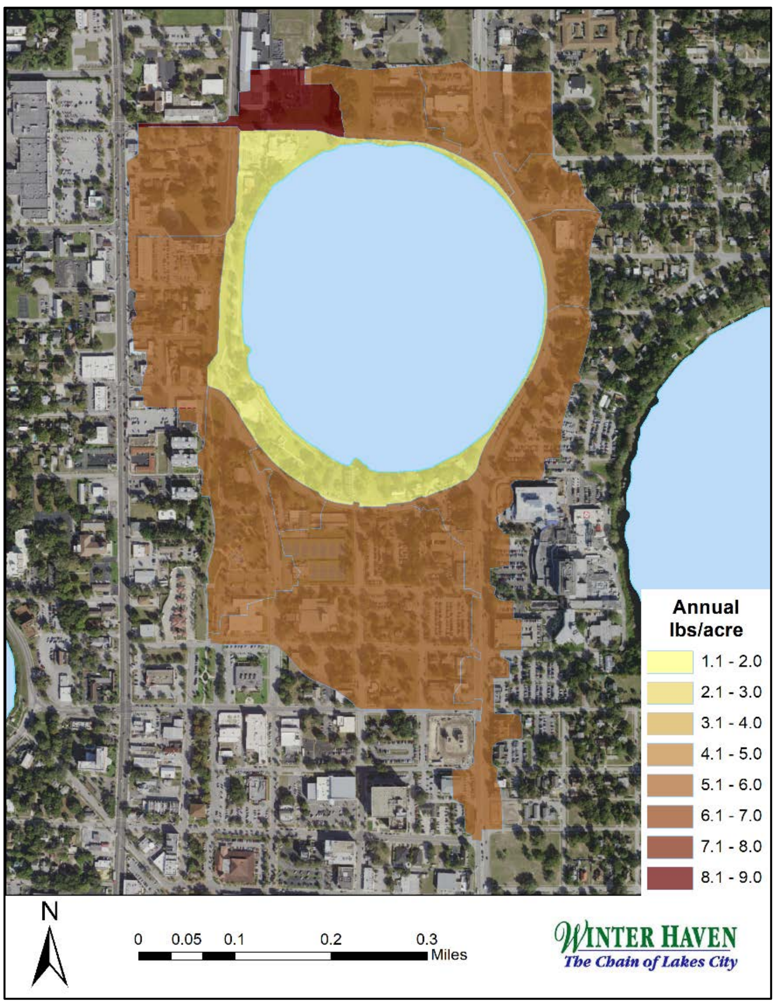


Figure 1-13. Annual Total Nitrogen Loads to Lake Silver in lbs/acre

The calculated loading rates displayed here are raw values that exclude nutrient load reductions from stormwater best management practices. There are numerous privately owned BMPs within each drainage basin, however the estimated load reduction they confer is not always documented. City land development code require a match of pre and post-development runoff rates and volumes [3]. 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). A full list of commonly occurring plant species in the area, with links to images, is provided in Table 4-8 (in the appendix).

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*). 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

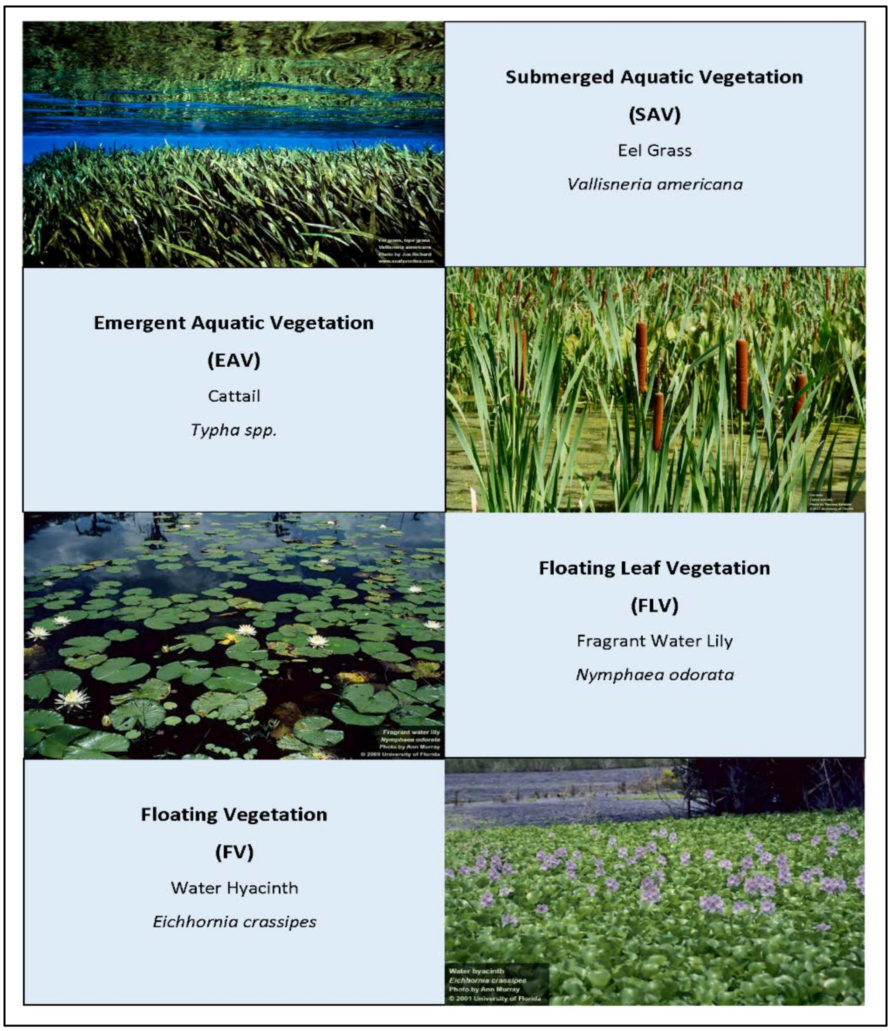


Figure 1-14. Examples of Aquatic Vegetation Categories

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.

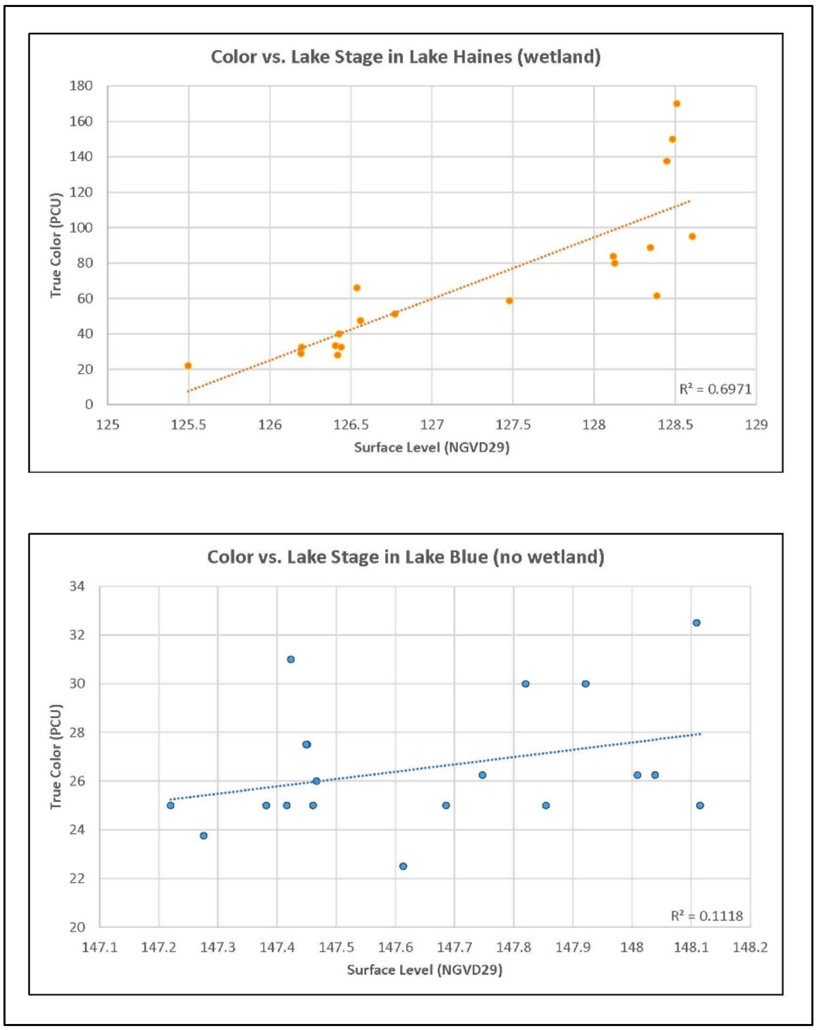


Figure 1-15. Correlation between Wetlands and True Color in Lake Haines & Lake Blue

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 [1]. 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 [4]. 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 [11]

- **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.

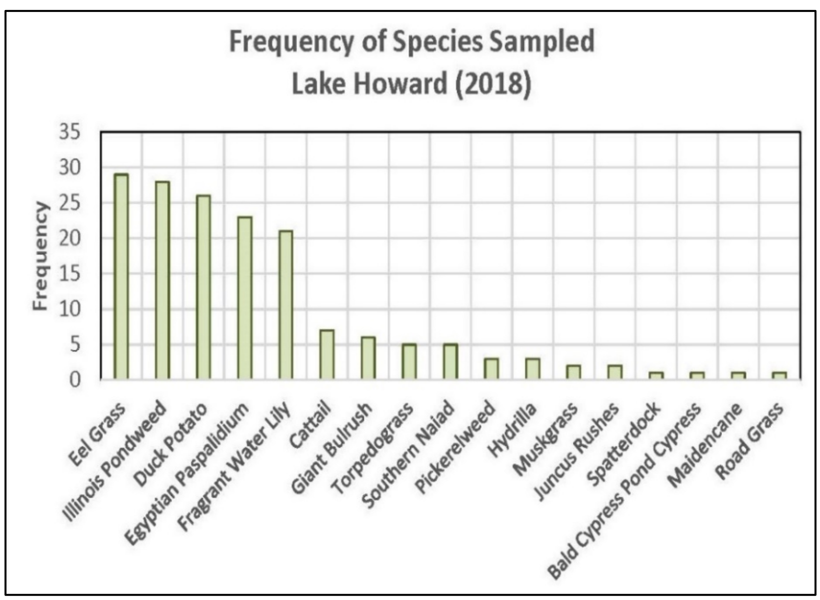


Figure 1-16. Species Frequency Chart of Aquatic Vegetation in Lake Howard

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-value ≤ 0.05) based on AGM values for each parameter (Chl-a, TN, TP, and Secchi depth) from 2000 to 2021. 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.

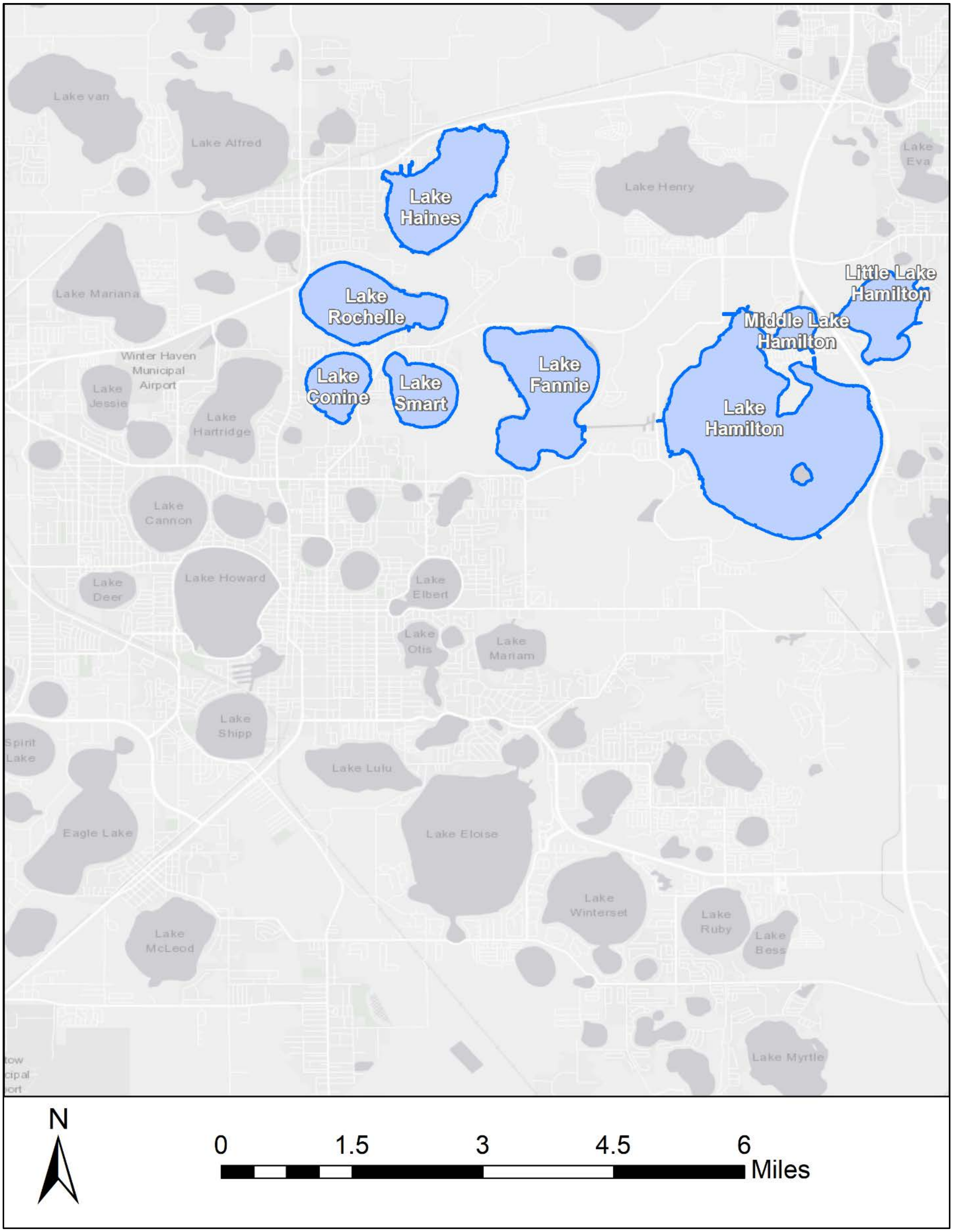
Vegetation Abundance: Abundance is scored based on percent area coverage (PAC) values as determined by SONAR mapping for the given study year. A score of 3 is given to lakes with PACs exceeding 30%; between 30% and 15% receives a score of 2; a 1 is assigned to lakes between 15% and 2.5%; a score of 0 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 the measurement of annual diversity index values in relation to that index's long-term mean. The long-term average of each index for each lake is calculated based on at least 3 years of species data. A score of 1 is given to each of the three indices (R2, E3, H) if their 2021 value meets or exceeds the respective long-term average; 0 scores are assigned if annual index values fall below the long-term average. For each waterbody, index scores are combined for a total possible score of 3.

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.

2.1 North Chain of Lakes



The Winter Haven North Chain of Lakes (NCOL) is made up of eight waterbodies: Lakes Conine, Fannie, Haines, Hamilton, Rochelle, Smart, Little Hamilton, and Middle Hamilton. While Lake Henry is also considered part of this Chain, it has been excluded from this study due to a lack of public access and means to collect water quality data. The 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 2021 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 2021. Similar to previous years, most of the NCOL waterbodies exhibited better water quality in 2021 when compared with long-term values. Lake Hamilton's 2021 Chl-a and TN concentrations far exceeded its long-term means. Additionally, Lake Hamilton's Secchi depth was also below average in 2021. The remaining lakes possessed 2021 Chl-a and TN concentrations at or below the long-term means; with above-average Secchi depths. However, while 2021 TP concentrations were either at or below long-term mean values for most in this group, Lakes Conine, Haines, Rochelle, and Smart had 2021 TP concentrations above their long-term averages.

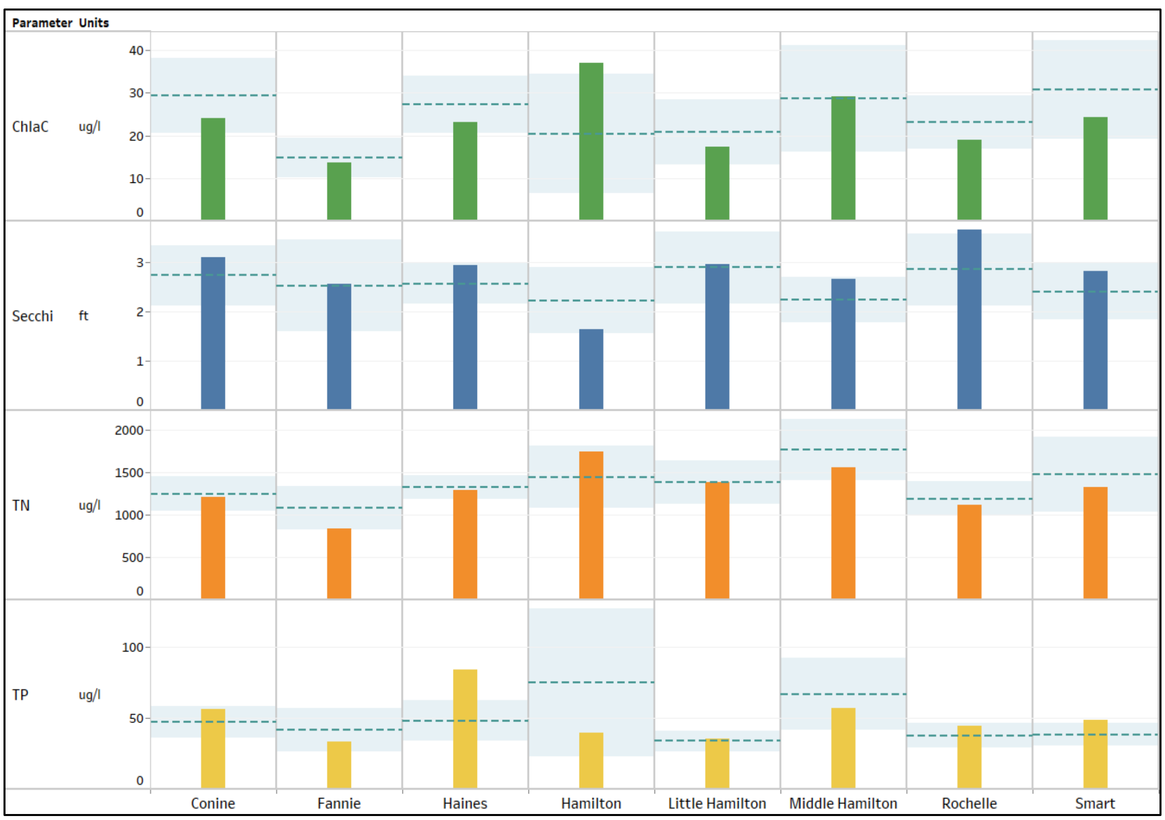


Figure 2-1. 2021 AGM Chla, TN, TP, & Secchi depth values for the North Chain of Lakes; dotted line represents long-term mean and the shaded area refers to the standard deviation range.

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, and Middle Hamilton were determined to be highly colored while Lakes Conine, Rochelle, Smart, Hamilton, 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 2014 and 2021 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, Middle Hamilton, and Smart were impaired for Chl-a, TN, and TP exceedances. These equate to Impairment category scores of 0 in the Lake Health Index. Lakes Hamilton and Little Hamilton were impaired for Chl-a and TN as of 2021 while Lake Haines was impaired for Chl-a and TP—leading to index scores of 1 for these waterbodies. Lakes Fannie and Rochelle exhibited no NNC exceedances, earning index scores of 3. Lake Rochelle has not exceeded NNC thresholds since 2014; if this trend continues, it may eventually be removed from the impaired waterbodies list.

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. Despite being impaired for nutrients, FDEP's reasoning for not including Lake Smart on the TMDL list is that Smart should receive water quality benefits for improvements made in upstream lakes (e.g. Lake Conine & Rochelle).

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 2021 (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 – 2021.

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 Hamilton, Rochelle, 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, Middle Hamilton, and Smart 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. 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	Not Significant	2
	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	Increasing	Not Significant	1
	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	Not Significant	2
	Secchi	Increasing (Improving)	Significant	3
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 (Improving)	Significant	3

Table 2-1. 2021 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 – 2021 indicate annual fluctuations that correspond with wet and dry season rainfall; with long-term ups and downs that correspond with extended periods of drought and excess rainfall (Figure 2-2). To the right of the hydrographs are box & whisker plots depicting each waterbody's median and normal range (25th – 75th quartile). Annual rainfall for 2021 was 40.13 inches—well below the average yearly total of 51.65 inches. Despite a slight downturn in 2021, lake levels have remained consistently above the median since 2014.

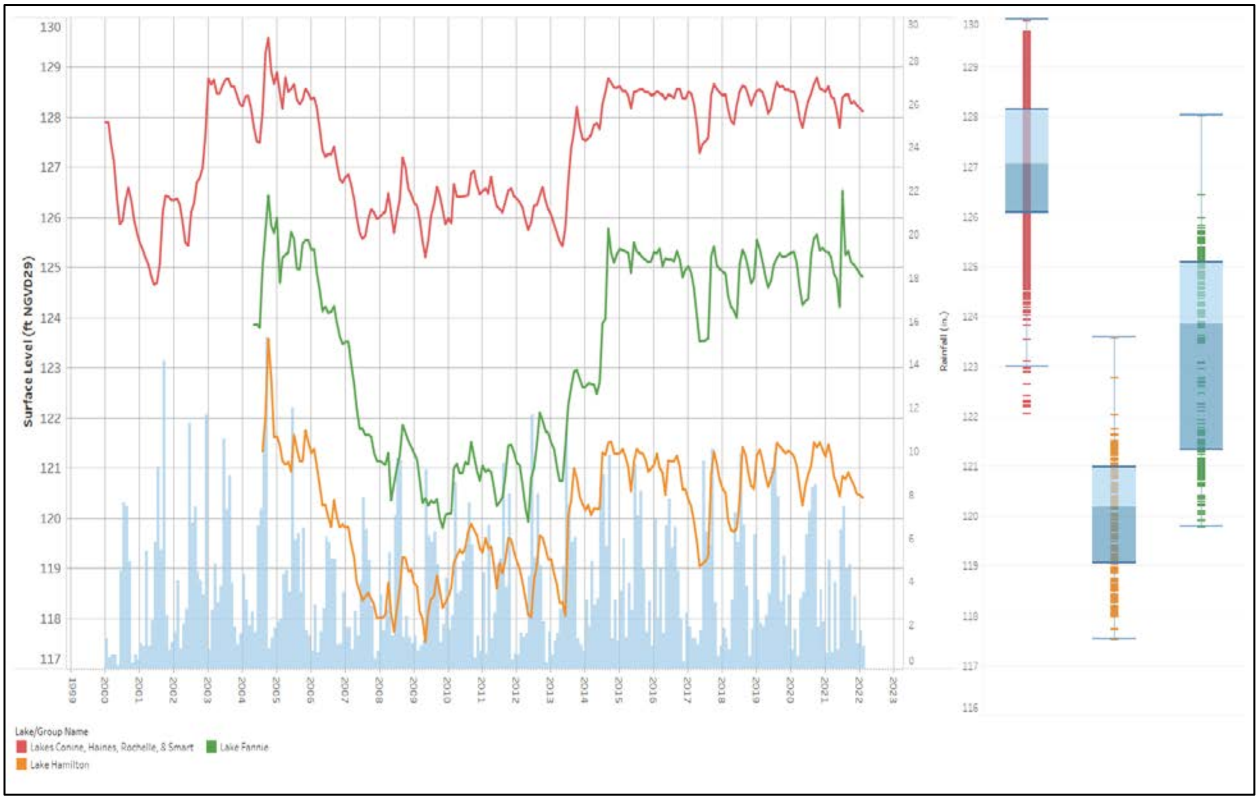


Figure 2-2. North Chain of Lakes hydrograph with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

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]. Linear regression analysis shows that most Northern Chain lakes exhibited significant relationships between surface level such that a rise in lake level resulted in reduced Chl-a and nutrient concentrations and increased Secchi depths from 2000 – 2021 (Table 4-5; in appendix). Only Lake Hamilton exhibited no correlation between SL and water quality. Based on these results, it can be concluded that maintaining higher lake levels would benefit water quality in this lake group. Fortunately, in 2017 the Southwest Florida Water Management District (SWFWMD) updated their control structure operations guidelines [1]. This strategy involves holding more water in these lakes year round, only discharging downstream prior to intense storm events (e.g.

hurricanes) in an effort to meet minimum flows and levels in the Peace River and to reduce flooding downtstream.

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 cover relatively larger areas, but are also quite 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.

Lakes closer to the City center are surrounded by older developments and stormwater infrastructure which flow directly to the lakes. 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 contribute less intense pollutant loads compared with higher density land uses. 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 recently completed construction of a treatment wetland that will capture and treat urban stormwater before discharging to the lake.

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 relatively low. 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.

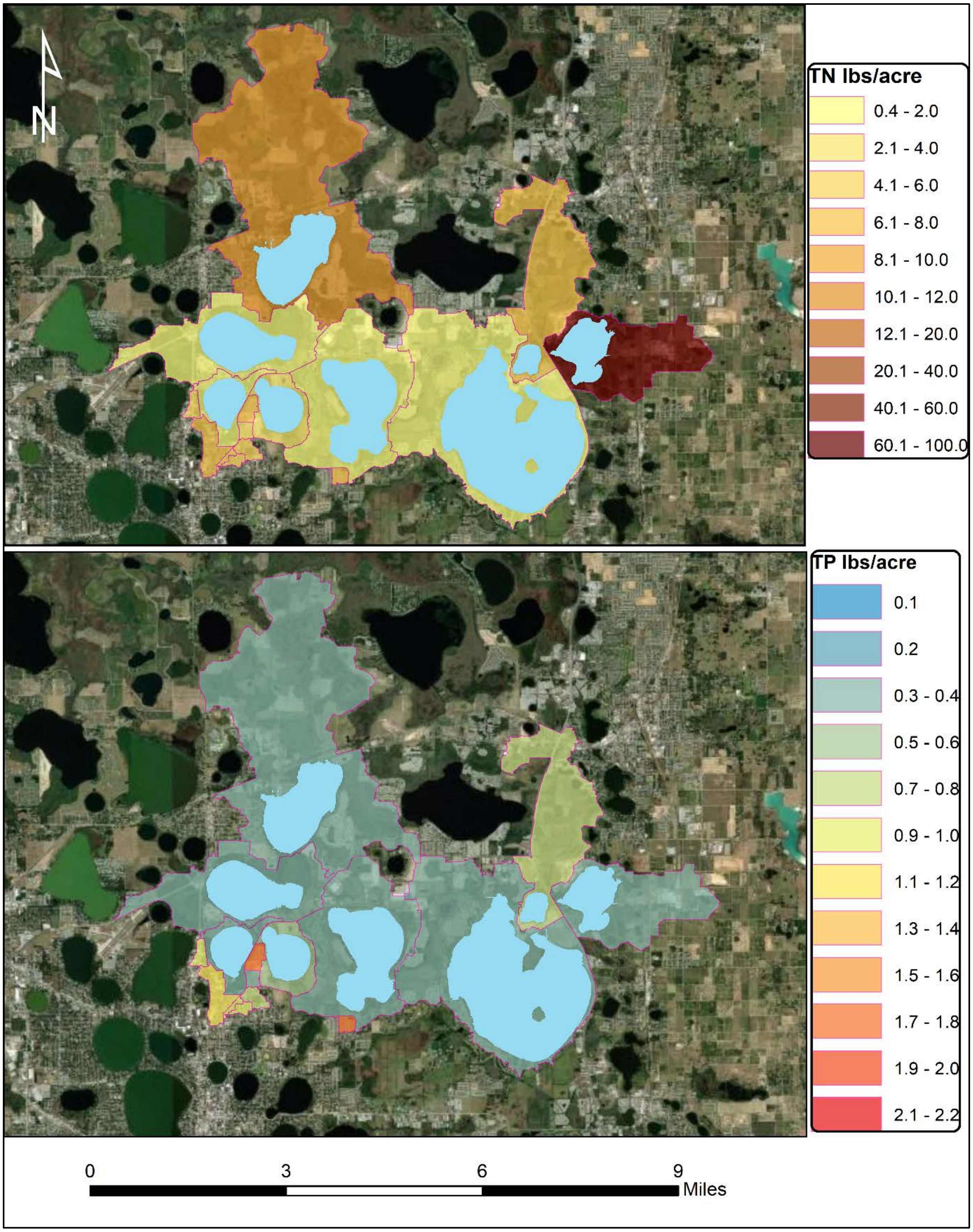


Figure 2-3. Areal TN & TP Loading for individual drainage basins in the North Chain of Lakes.

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.

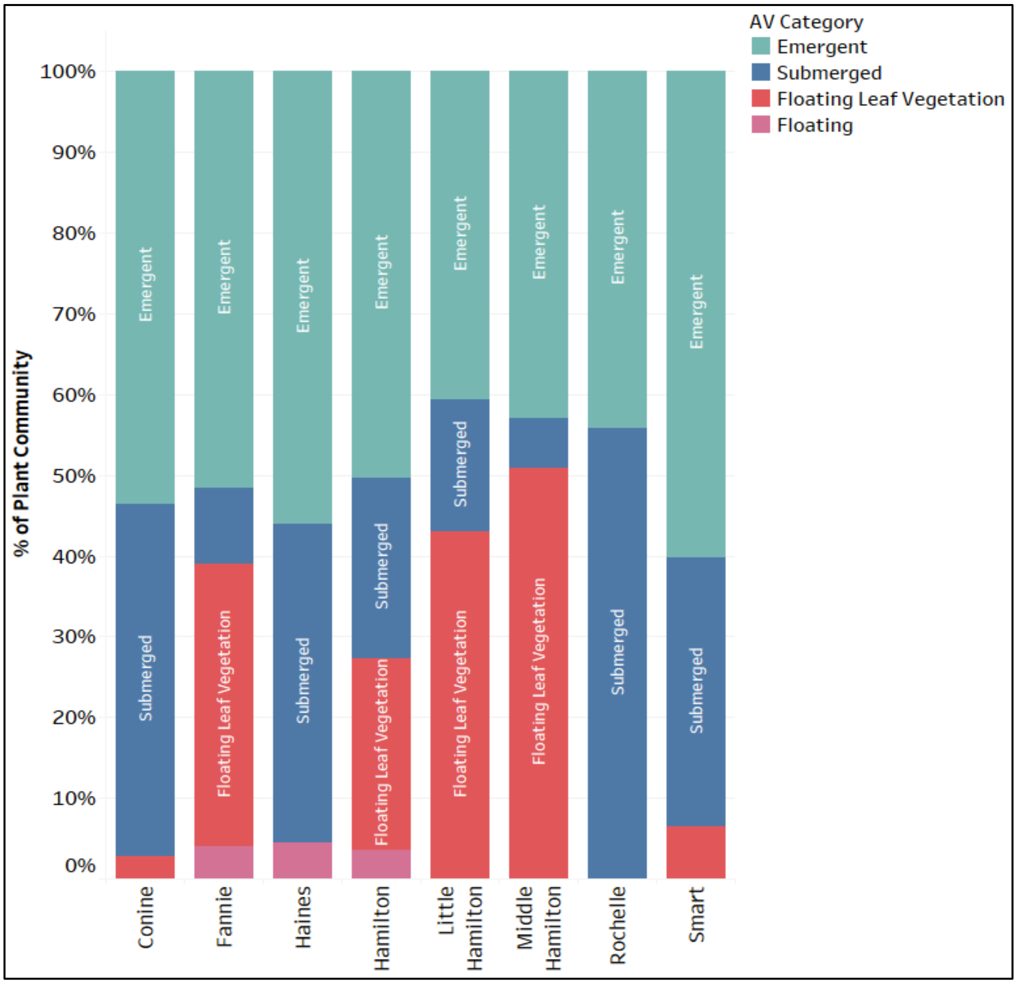


Figure 2-4. North Chain of Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

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 2021, Lakes Conine, Haines, Rochelle and Smart had an almost equal mix of submerged and emergent plants. The remaining lake vegetation communities possessed a very limited proportion of SAV species (Figure 2-4). Lakes Fannie, Haines, and Hamilton possessed very minor populations of floating vegetation—primarily in the form of the invasive water hyacinth. Lakes that historically possessed very little SAV, such as Lake Hamilton, are now exhibiting a larger proportion of submerged plants. This is beneficial as SAV can more efficiently uptake nutrients such as 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 2021, six of the eight NCOL underwent a decrease in overall vegetation coverage (Figure 2-5). Percent coverage in Lake Fannie increased to place it above the 15% target threshold and PAC in Lake Smart approached the ideal 30% target threshold. Despite the slight decrease in coverage, only Lake Rochelle maintained PAC above the ideal 30% threshold. Lake Conine's coverage dropped below the 30% ideal threshold and Lakes Haines and Little Hamilton exhibited declines in PAC below the 15% thresholds. Lakes

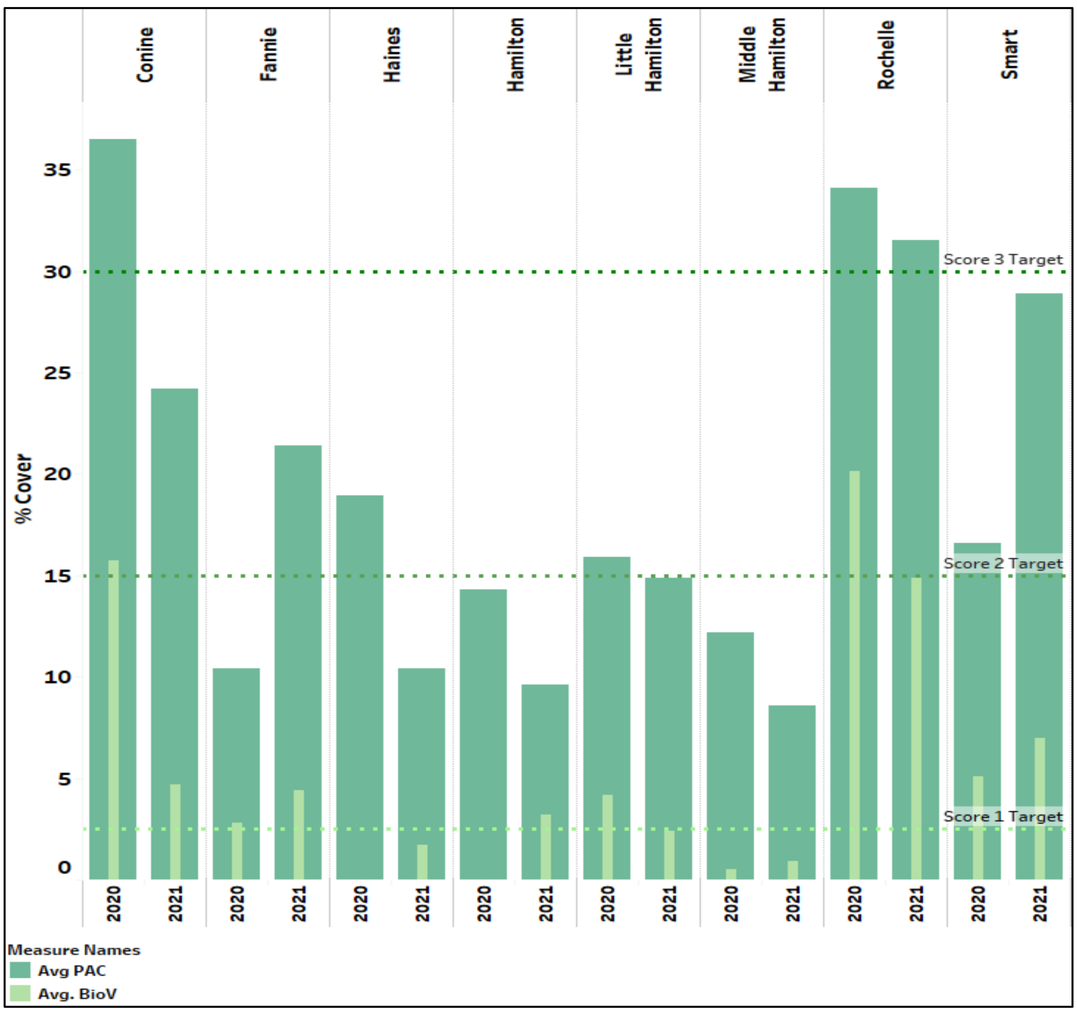


Figure 2-5. North Chain of Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

Hamilton and Middle Hamilton underwent slight PAC decreases, but with no change in index score.

Invasive Species Percentage

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*). Some lakes underwent a decrease in invasive species populations from 2020 to 2021 (Figure 2-6). Overall, the total percentage of invasive plants decreased from 36.9% in 2020 to 30.1% in 2021. This was mostly the result of a decrease in hydrilla. Invasive populations in Lakes Conine and Rochelle decreased below the 10% threshold while no invasives were identified in Lakes Haines and Hamilton in 2021—indicated by an absence of 2021 data on the chart. Middle Lake Hamilton saw in increase in invasive percentage resulting in an index score of 2 for 2021. Invasive populations increased in Lakes Fannie, Little Hamilton, and Smart, but not enough to alter

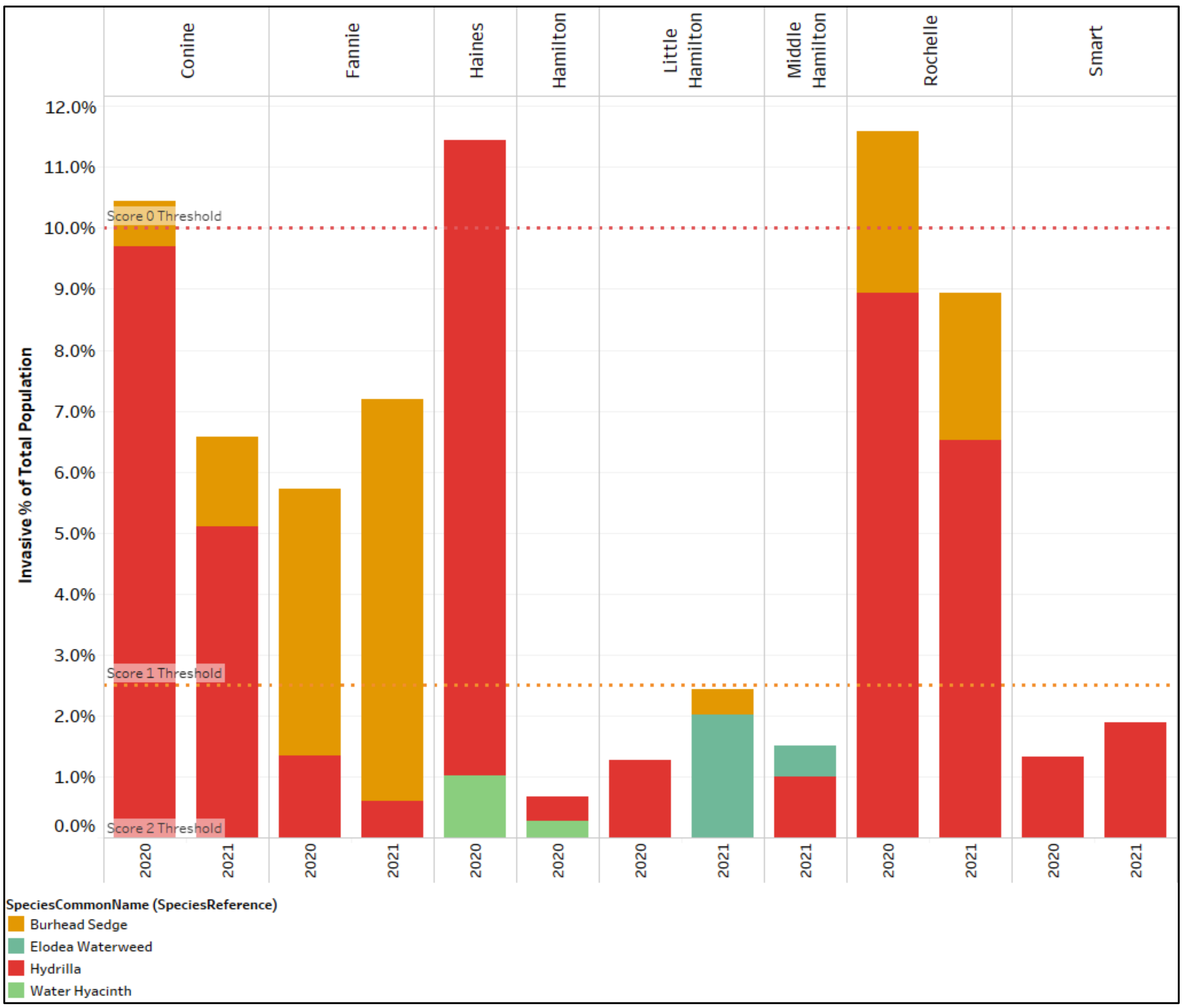


Figure 2-6. North Chain of Lakes annual percentage of invasive species.

their previous index scores. Overall invasive populations saw a decline in 2021 with no lakes exceeding the 10% invasive threshold—which is good news.

Species Diversity

Observing the relative changes in aquatic vegetation species diversity provides insights into the overall health of a waterbody. Each waterbody's annual values for the three most prominent diversity indices are displayed in relation to their respective long-term averages (Figure 2-7). It must be stressed that these index values are dependent on site-specific sampling effort. As such, these values are not meant to be compared between lakes—only as a comparison of changes to individual lakes over time. Index values at or exceeding the long-term average are given a point toward that lake's diversity index score (for a possible total of 3); index values that fall below this threshold are given no points.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Conine, Fannie, Smart, Little Hamilton, and Middle Hamilton met or exceeded the long-term average in 2021. Lake Rochelle fell below its average R2 value.

Hill's Evenness #3 (E3): Greater species evenness is preferred over one or two dominant species as it improves community resilience. Lakes Conine, Little Hamilton, and Middle Hamilton met or exceeded their long-term average. Lakes Fannie, Rochelle, and Smart fell below their averages

Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Lakes Conine, Fannie, Smart, Little Hamilton, and Middle Hamilton met or exceeded their average values in 2021. Lake Rochelle's 2021 H value fell below its average.

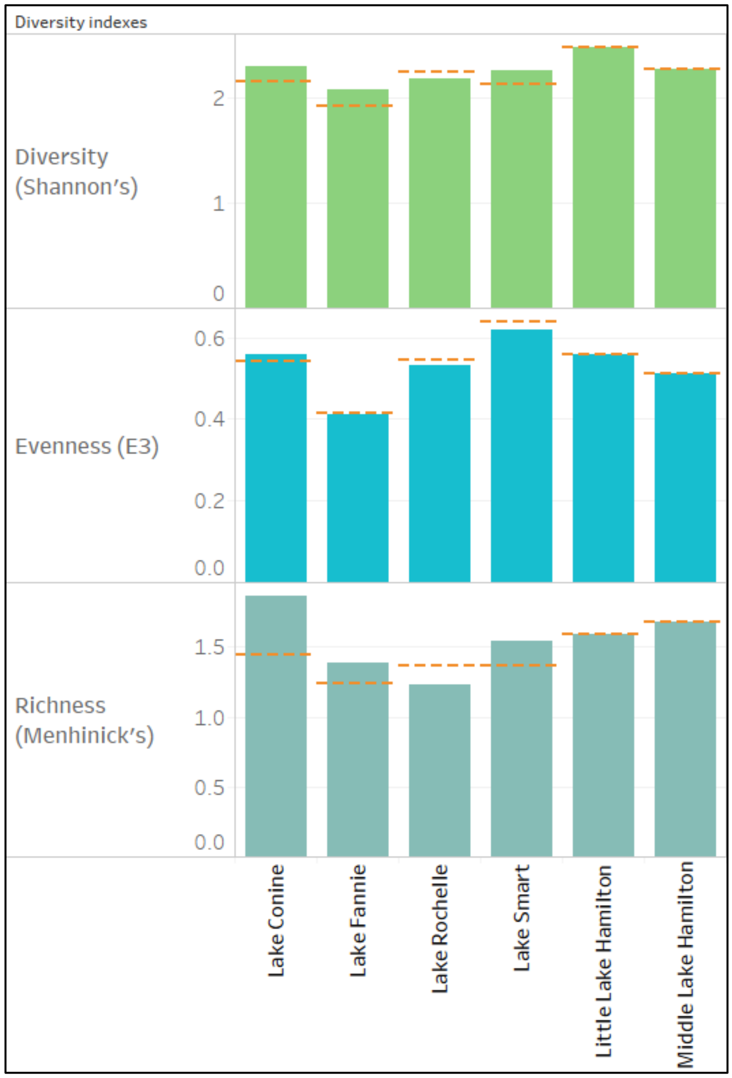


Figure 2-7. North Chain of Lakes annual index values for species richness, evenness, and diversity.

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.

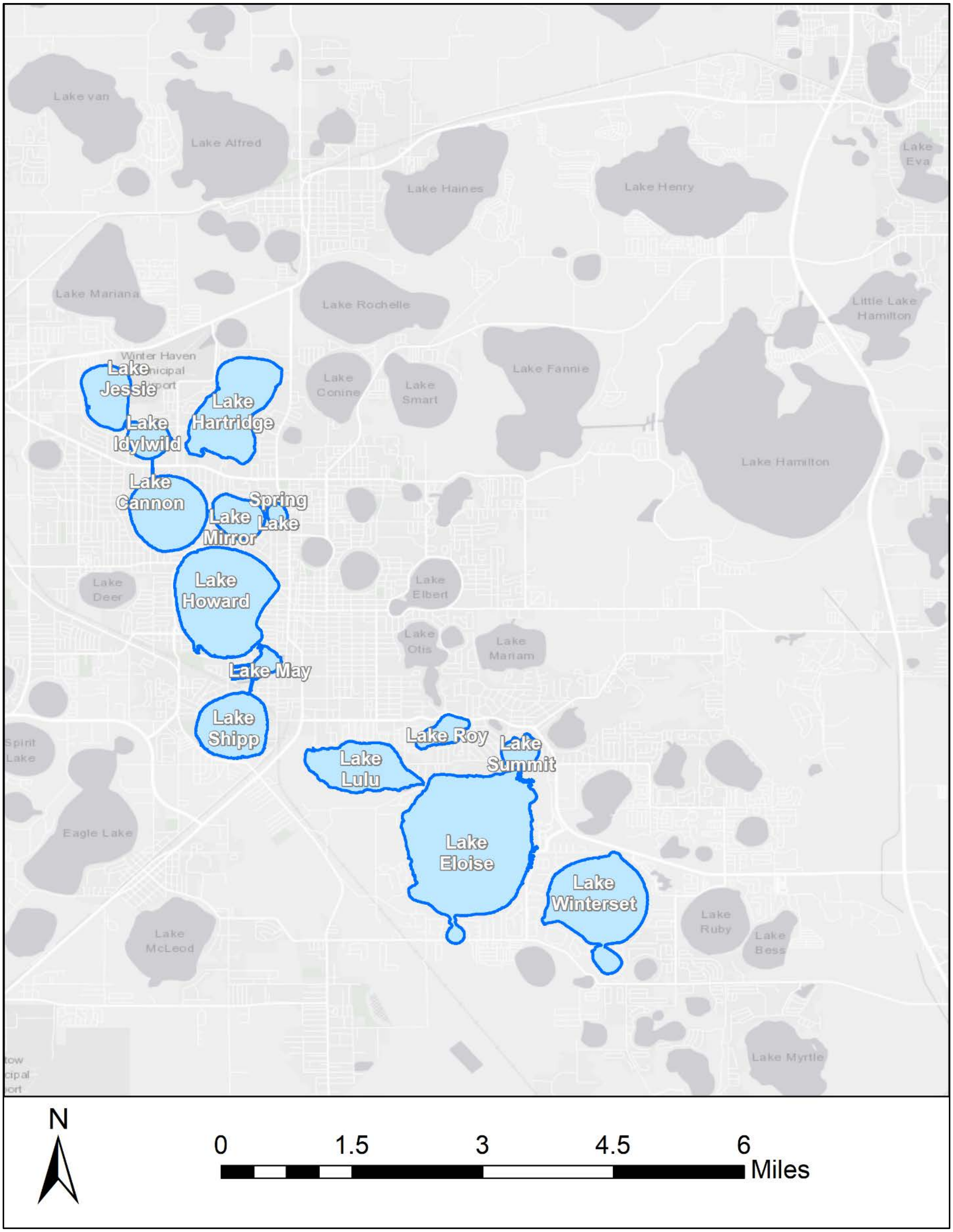
Management Conclusions

It is clear from the water quality data that while most of the NCOL are impaired—only Lakes Fannie and Rochelle have no NNC exceedances. However, the trend data shows that most of these lakes are experiencing improvement while Lake Hamilton is undergoing significant water quality deterioration. Ultimately, Lake Hamilton takes top priority with regards to future management actions. While the source of nutrients in Lake Hamilton's drainage basin remains difficult to decipher based on the pollutant load modeling, it has been speculated that a recurring bloom of nitrogen-fixing cyanobacteria has been taking place over the last few years. This is supported by the significant decline in TP concentrations in stark contrast to the wholesale deterioration of the other three water quality parameters—as the algae blooms produce nitrogen, they exhaust their supply of phosphorus from the water column. 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 feeding the algal blooms.

Based on the aquatic vegetation data, invasive species remain a continuous issue for this lake group. However, invasive populations have not exceeded the 10% threshold in any Northern Chain lakes since monitoring began. This could be a sign that invasive species are being more effectively managed. For most waterbodies in this group, the Fish and Wildlife Conservation Commission (FWC) implemented less herbicide treatments in 2021 than in previous years (Table 4-7; in appendix). 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. On this front, there has been outstanding cooperation between the City and Polk County on reporting and managing invasives in recent years.

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 2021 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 2021. Chl-a and TN concentrations exceed long-term averages in Lakes Eloise, Hartridge, and Roy, but were below-average for the remaining lakes. TP concentrations exceeded long-term averages in Lakes Eloise, Hartridge, Idylwild, Jessie, Lulu, Roy, and Summit. Secchi depths were at or above average for all in this group, excepting Lakes Eloise, Hartridge, and Roy.

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 2014 and 2021 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.

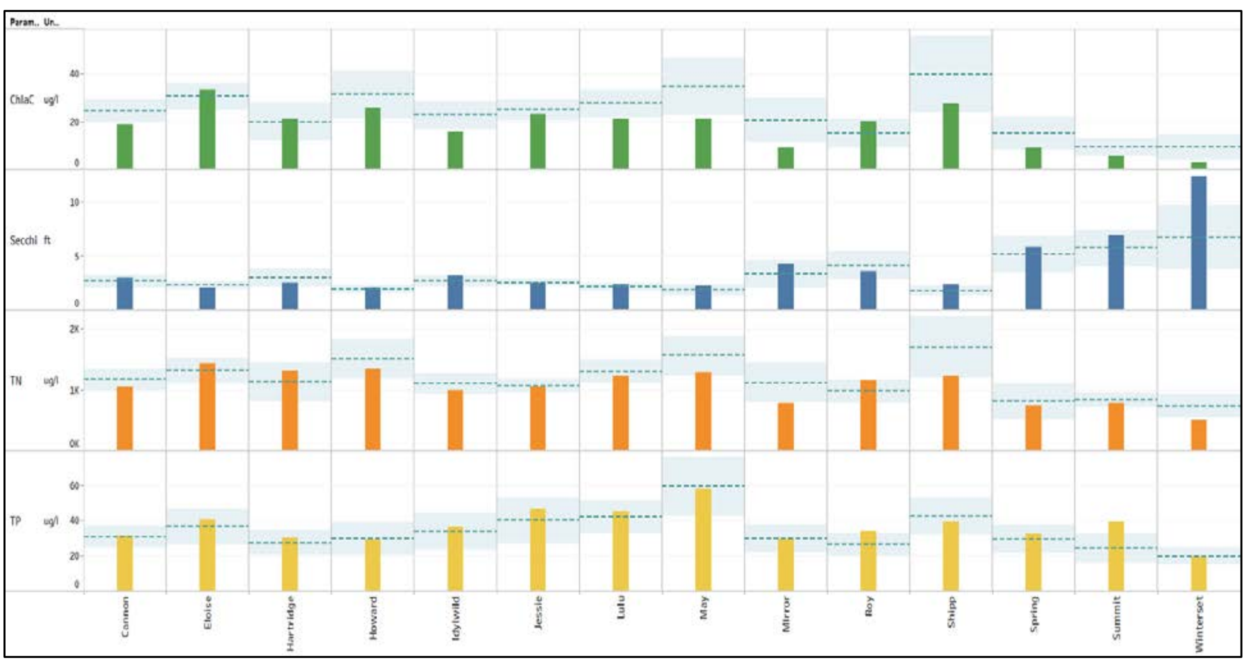


Figure 2-8. 2021 AGM Chla, TN, TP, & Secchi depth values for the South Chain of Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

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

Total Nitrogen: Lakes Eloise, Hartridge, Howard, Jessie, Lulu, May, and Shipp were determined to be impaired. Previously impaired lakes Cannon and Idylwild were removed from this list in 2021.

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 improvements.

Water Quality Trends

Determination of long-term monotonic (directional) trends in water quality was accomplished by plotting AGM Chl-a, TN, TP, and Secchi depth against time in years. The resulting regression analyses show direction (+/-), magnitude (R^2), and statistical significance (p-value ≤ 0.05) of each lake's water quality trends (Table 2-2). While the 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 - 2021. 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. 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, Shipp, Winterset, and Spring.

Water Clarity Trends: With regards to Secchi depth, all Southern Chain lakes except Hartridge and Jessie exhibited a significant 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 reduce nutrient loads via stormwater or other sources.

Waterbody	Parameter	Trend Direction	Significance	Index Score
Lake Cannon	Chla	Decreasing (Improving)	Significant	3
	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	Decreasing	Not Significant	2
	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	Not Significant	2
	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. 2021 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, all lakes in this group are held at roughly the same elevation. A hydrograph of the SCOL monthly SLs and rainfall from 2000 to 2021 shows short and long-term fluctuations in lake level in response to rainfall (Figure 2-9). Box and whisker plot shows overall variability for this lake group. The upper and lower reaches of the boxplot correspond with the respective 75th and 25th percentile surface elevations. SCOL surface levels have been consistently above the median (central boxplot line) since mid-2014—except for a brief period at the height of the 2017 dry season. Surface levels were depressed from 2006 until 2014 due to eight years of consistently below-average rainfall.

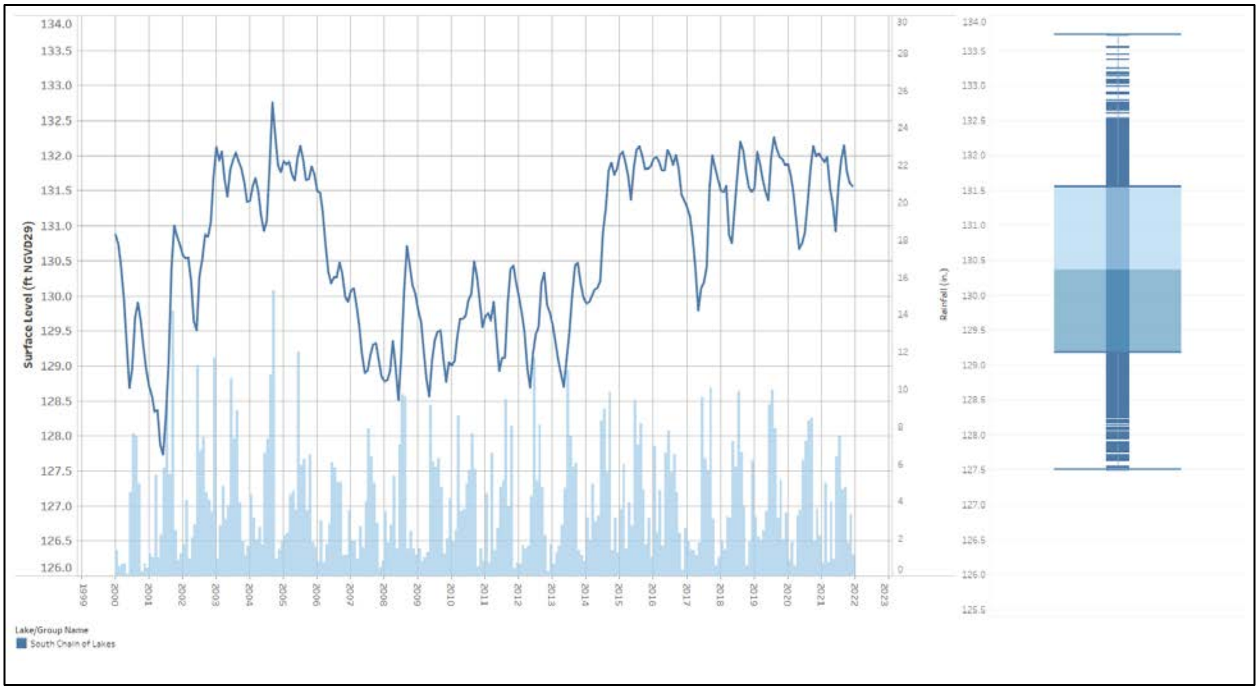


Figure 2-9. South Chain of Lakes hydrograph with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

Winter Haven's annual rainfall totaled approximately 40.13 inches in 2021—considerably below the average of 52 inches. Despite the low total rainfall, surface levels did not fall below the long-term median for this group (130.36 ft). By December of 2021, the SCOL were sitting at the 75th percentile surface level. This unexpected result may be due to buffering effects of elevated water table or Upper Floridan Aquifer levels. Regardless, surface elevation of the SCOL is at an optimal level for water quality and recreation.

The relationship between surface level and each primary water quality metric was assessed via a linear regression of data from 2000 to 2021 (Table 4-5; in appendix). It was determined that Lakes Cannon, Howard, Idylwild, Jessie, Lulu, May, Mirror, Roy, Shipp, Summit, and Winterset showed significant relationships between higher SL and improvement in one or more water quality metrics. It is likely that elevated surface levels result in increased flushing of nutrients at a minimum and other more impactful effects (e.g. increased wetland interaction) in select circumstances.

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]. Some, such as Lakes Winterset, Spring, and Summit are fairly deep and subject to greater groundwater influence—receiving increased flushing during hydrologically wet periods. While others are relatively shallow, like Lakes Eloise, Howard, and May, and may be prone to sediment suspension via wind/wave action during dryer periods. In addition, Lakes Jessie, Idylwild, and Lulu are bordered by more extensive wetland habitats able to filter excess nutrients when levels are higher. It is evident 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 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 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 at the outskirts of City limits. These basins primarily consist of low-medium density residential and open lands with moderate to high soil infiltration rates. Surrounding these lakes are newer developments that include built-in stormwater treatment facilities (e.g. retention ponds) which capture most stormwater flows instead of discharging directly to surface waters. 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.

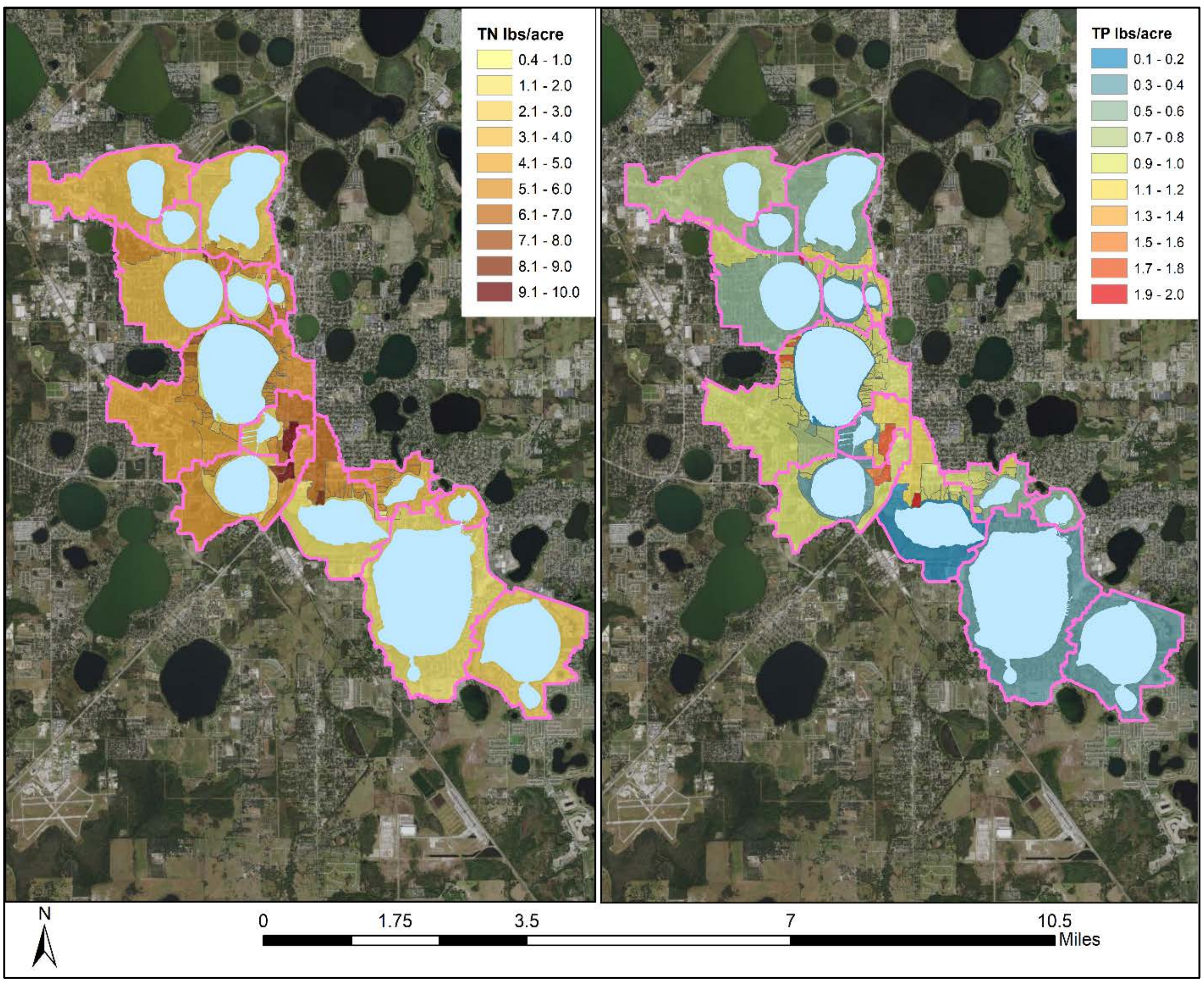


Figure 2-10. Areal TN & TP Loading for individual drainage basins in the South Chain of Lakes.

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 all 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. In addition to this, the more even mix of vegetation types is indicative of more diverse and healthy aquatic plant communities.

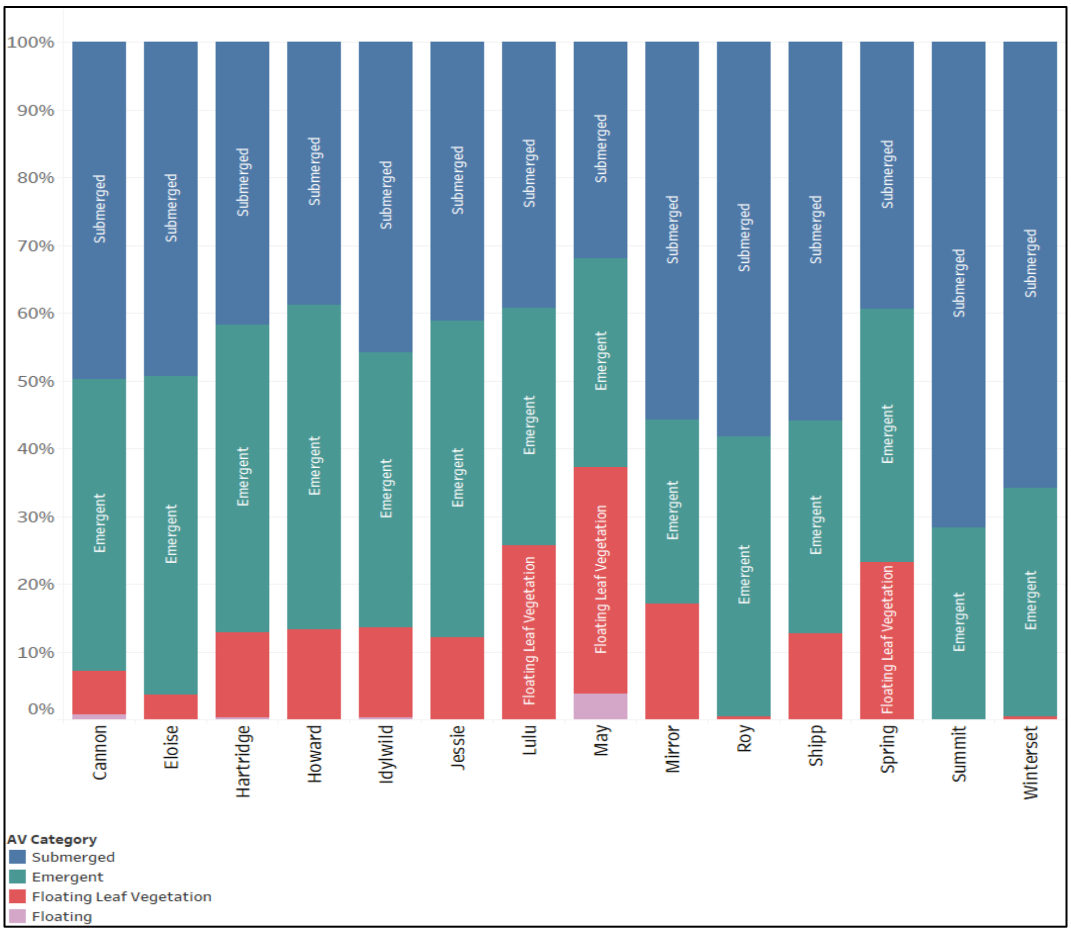


Figure 2-11. South Chain of Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

Vegetation Abundance

Measurements of percent area cover (PAC) and percent biovolume (% BV) indicate that the majority of the SCOL possessed excellent vegetation abundance in 2021 (Figure 2-12). Every Southern Chain waterbody exceeded the 15% PAC target, with all except Eloise at or above the 30% exceptional abundance threshold. 9 of the 14 lakes in this group underwent an increase in vegetation coverage from the previous year. While no lake health index scores changed due to these increases/decreases, Lake Eloise is extremely close to meeting the optimal 30% PAC target. It is likely that these abundance values are a contributing factor to the majority improvement in water quality for this lake group.

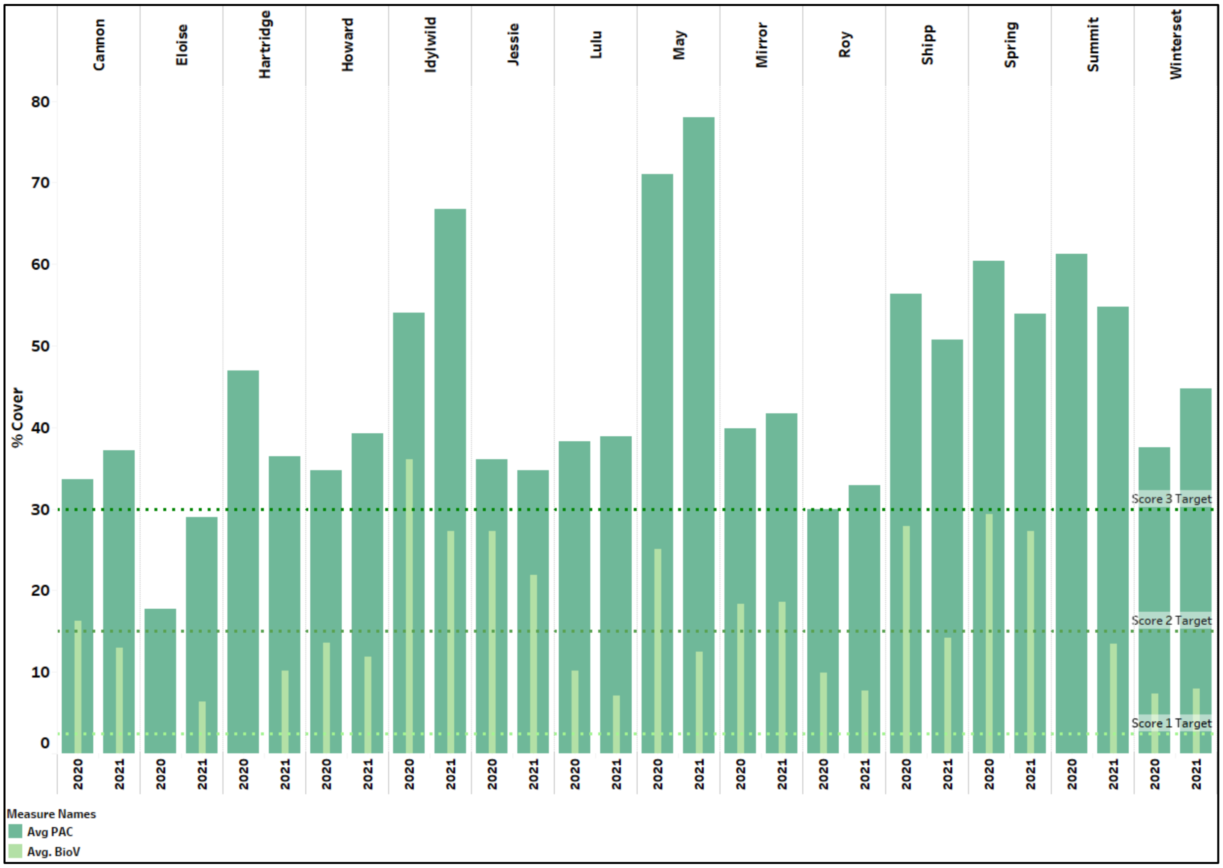


Figure 2-12. South Chain of Lakes annual aquatic vegetation percent area coverage and mean percent biovolume

Invasive Species Percentage

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*). The Southern Chain experienced a roughly 56% increase in invasive presence from 2020 to 2021. This is mainly the result of an increase in hydrilla. Invasive percentage did vary considerably from lake to lake (Figure 2-13). Also illustrated in this chart are the invasive percentage thresholds for the lake health index scoring.

Lakes Cannon, Idylwild, Lulu, May, Jessie, Roy, and Winterset experienced an increase in invasive percentages that led to a decline in their index score. Invasive percentages in Lakes May and Winterset exceeded the 10% extreme infestation threshold. Lakes Hartridge, Mirror, Shipp, Spring, and Summit exhibited invasive population declines resulting in improved index scores. No invasive species were detected during the 2021 survey of Lake Hartridge as well as both the 2020 and 2021 surveys of Lake Howard—which is why bars for these lakes/years were not depicted in the chart.

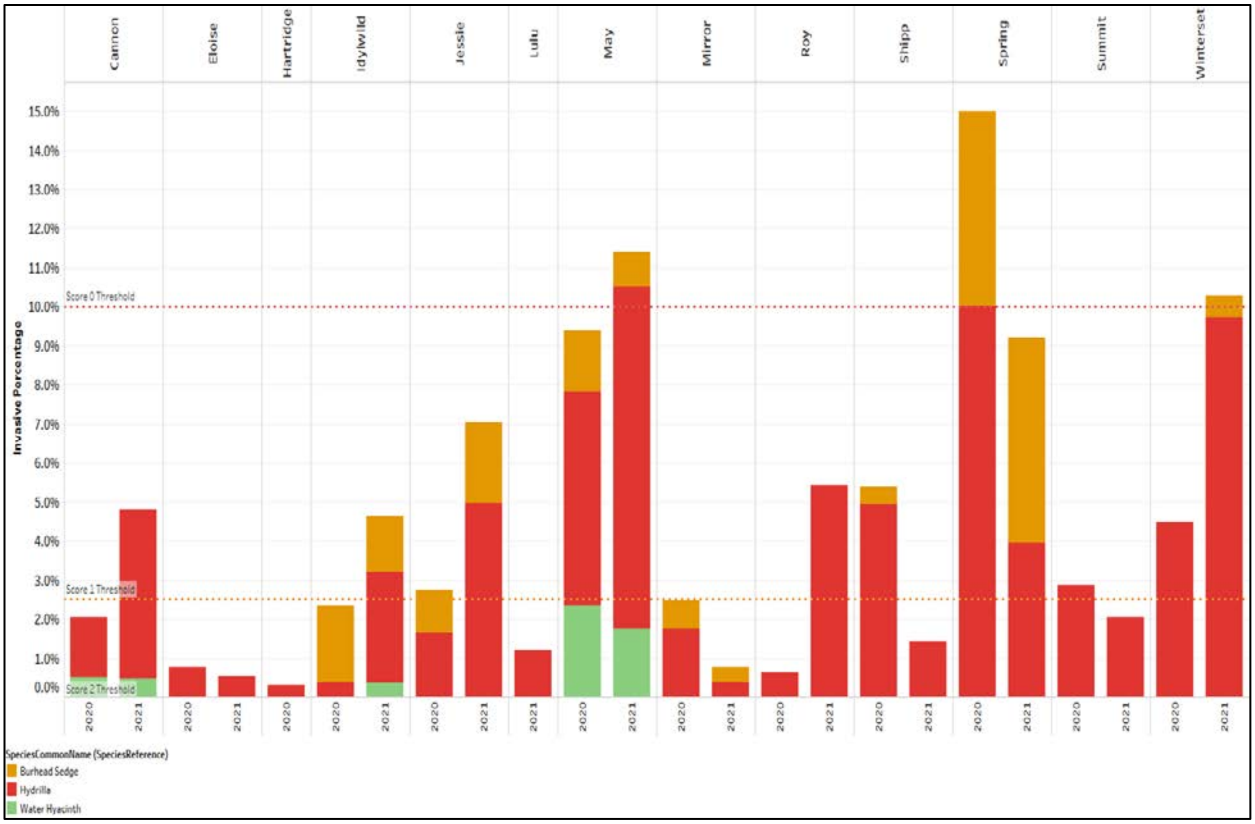


Figure 2-13. South Chain of Lakes annual percentage of managed invasive species.

Species Diversity

Species diversity index values for the South Chain of Lakes were calculated using available species data from 2017 to the present. Species richness, evenness, and uncertainty index values constitute the species diversity metrics for the lake health index (Figure 2-14). Individual index values for each lake were compared to the long-term averages for that lake. Individual index values meeting or exceeding the average are awarded a point—for a total possible species diversity value of 3 for each lake.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Hartridge, May, Spring, and Winterset had richness values meeting or exceeding their long-term averages in 2021. Species richness was below-average for Lakes Cannon, Eloise, Howard, Idylwild, Jessie, Lulu, Mirror, Roy, Shipp, and Summit in 2021.

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 Idylwild, Jessie, Lulu, May, Mirror, Roy, Shipp, and Summit possessed evenness values at or above average in 2021. Whereas, Lakes Cannon Eloise, Hartridge, Howard, Spring, and Winterset had below-average evenness in 2021.

Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Lakes Cannon, Hartridge, Howard, Idylwild, Lulu, May, Roy, Summit, and Winterset possessed at or above-average diversity in 2021. Lakes Eloise, Jessie, Mirror, Shipp, and Spring had diversity levels just below-average during this time.

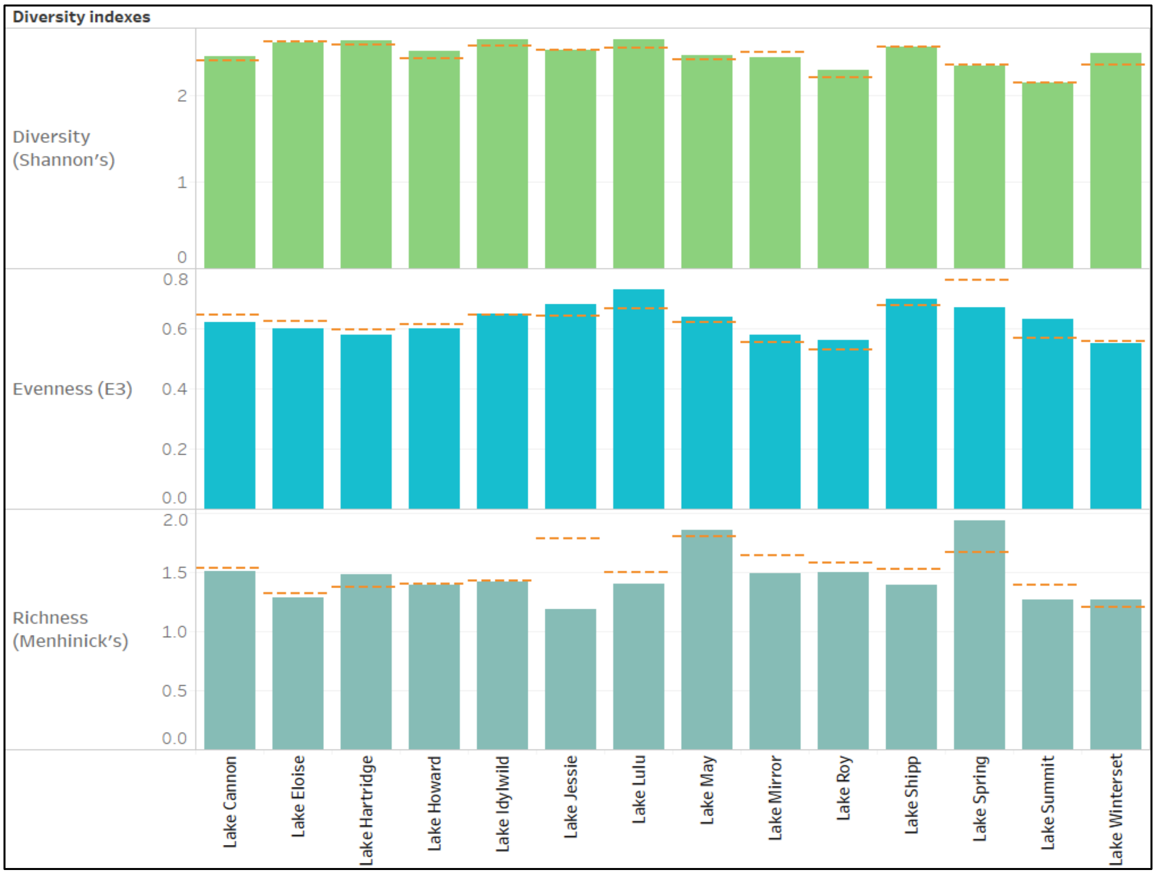


Figure 2-14. South Chain of Lakes annual index values for species richness, evenness, and diversity.

Based on the species diversity data, most of the SCOL possessed evenness and overall diversity values at or above-average during 2021. However, overall species richness was below-average for the majority in this lake group. It is to be expected that invasive treatment can have an impact on these diversity indices since the determination does not discriminate based on native and exotic species. That said, the formation of dense monocultures by invasive plants would have more detrimental effect on species diversity in the long term. Further analysis is necessary to evaluate any correlation between invasive treatments and changes in species diversity.

Management Conclusions

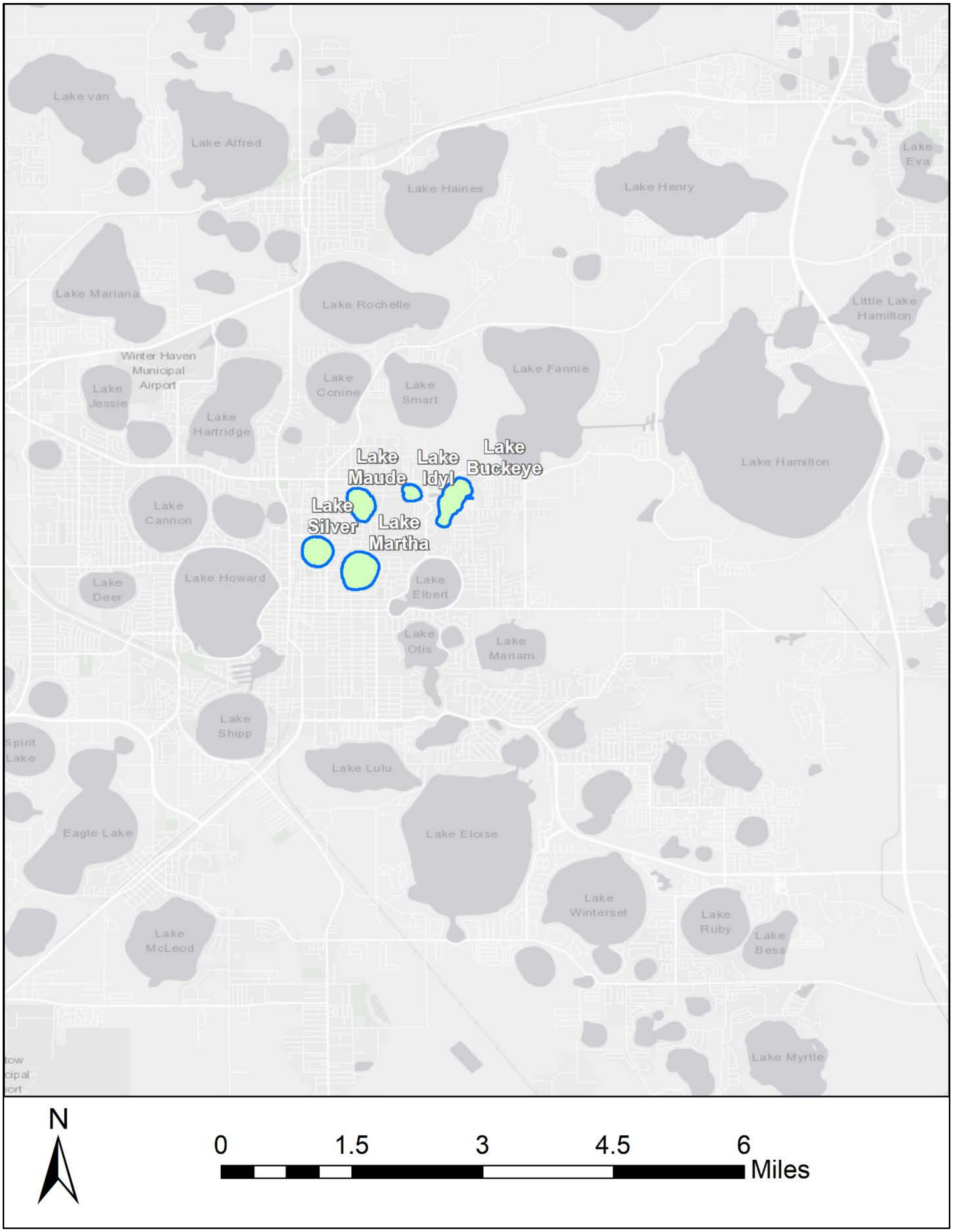
While many lakes of the Southern Chain possess TMDLs or are considered impaired by regulatory standards, one consolation is that the majority are exhibiting improvement in multiple water quality parameters. Interestingly, the waterbodies with the higher areal pollutant loadings are all ones undergoing 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 deteriorating water quality trends in Lake Hartridge will 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 mechanical 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 average annual acreage treated with herbicide for the lakes in this study area is about 198 acres per year. Due to the increase in invasive populations in 2021, the total acreage treated for the SCOL was 191. Lakes Jessie, Shipp, and Winterset were the only lakes in this group that had treatments exceeding 20 acres in 2021—none of which were whole-lake treatments (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.

The significant correlation between higher surface levels and improved water quality in this group supports management practices that focus on maintaining lake levels as high as possible. This will become especially pertinent during droughts or other periods when rainfall cannot support the hydrologic and water use needs of the region. The Winter Haven Utilities Department is prioritizing water storage and aquifer recharge projects in an effort to maintain these levels for the hydrologic benefit of the region.

With regards to pollutant loading, there are several potential management practices being considered for this lake group. The legacy pollutants stored as muck in Lakes May, Shipp, and Lulu could be addressed through sediment removal projects. Addressing potential loads from failing septic systems through septic to sewer conversions is another avenue that could be explored. However, both of these types of projects are exceedingly costly and may require outside funding to undertake. That said, the City is exploring opportunities to implement these types of BMPs for the lakes in this area.

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

2021 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. Alternatively, Chl-a and nutrient concentrations in Lakes Idyl and Martha are exceeding their long-term averages with Secchi depths well below average in 2021.

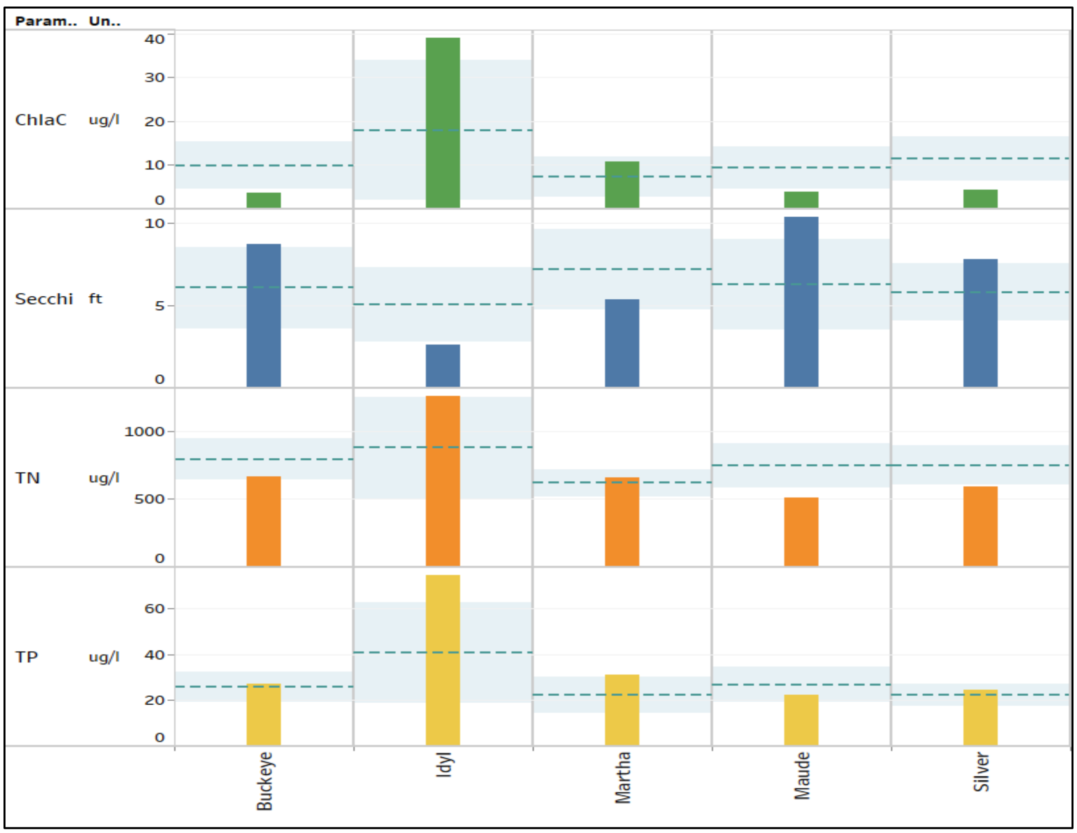


Figure 2-15. 2021 AGM Chla, TN, TP, & Secchi depth values for the North Central Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

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 2014 and 2021 (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-value ≤ 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. Lake Idyl is exhibiting and increasing trend in TP and Lake Martha is experiencing deteriorating trends in all water quality parameters. Considering that Lake Idyl is already impaired, the continual decline in water quality is concerning. Additionally, the significant decline of water quality in Lake Martha is a perfect example of the importance of trend analysis. This lake would likely have been overlooked until NNC thresholds are exceeded. 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 (Deteriorating)	Significant	0
	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. 2021 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 2021 despite the reception of only 40.13 inches of rainfall. This amount of precipitation is well below the long-term average of 52 inches.

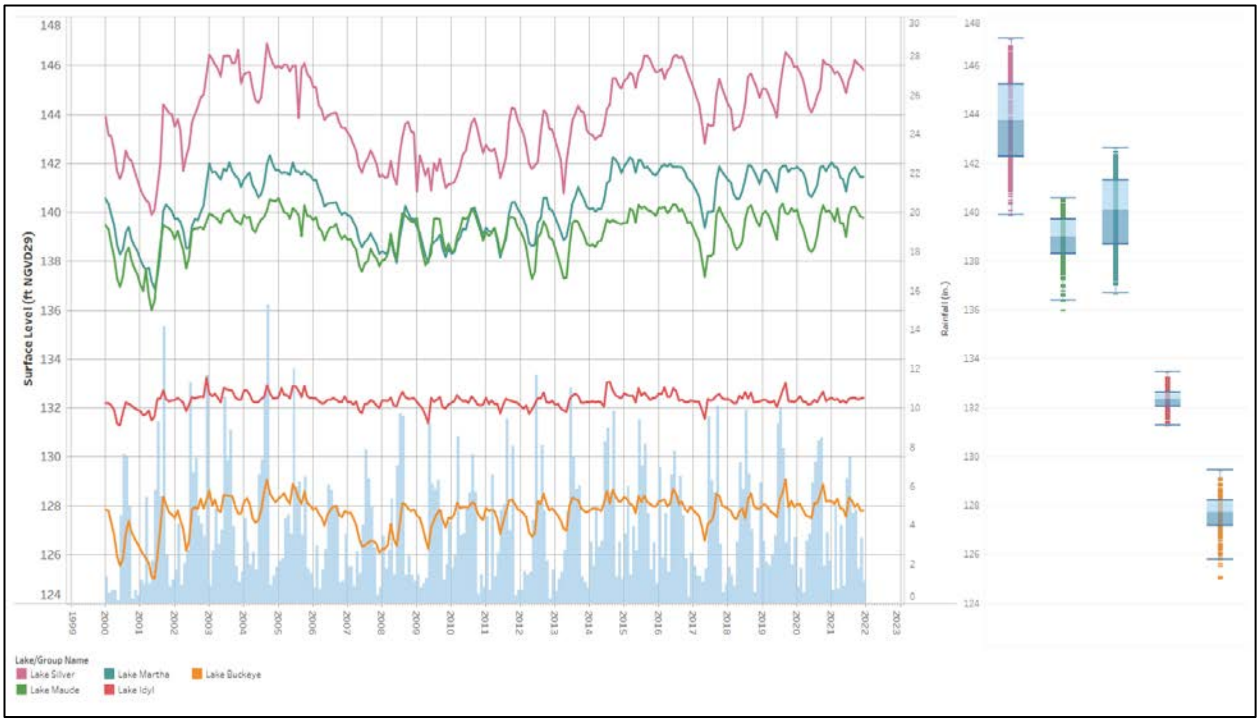


Figure 2-16. North Central Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Annual rainfall totals indicate hydrologic response to precipitation.

Incidentally, surface level fluctuations generally do not correlate strongly with water quality changes in this lake group as evidenced in the linear regression analysis based on surface level and water quality data from 2000 to 2021 (Table 4-5; in appendix). Only TN showed a significant correlation in Lake Maude wherein a rise in lake level results in a decline of nitrogen concentration. The general lack of correlation in this lake group is likely due to their less drastic seasonal or long-term water level fluctuations. 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. That said, alteration of managed levels for this group may not be feasible for the residents living near the flood elevation of these lakes.

While this lake group is morphologically diverse, most of the effects of the various lake shapes manifest as differences in groundwater influence and size of aquatic vegetation littoral zones. The deeper lakes like Silver and Martha would only support relatively narrow littoral zones, but these lakes lack any submerged vegetation. 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

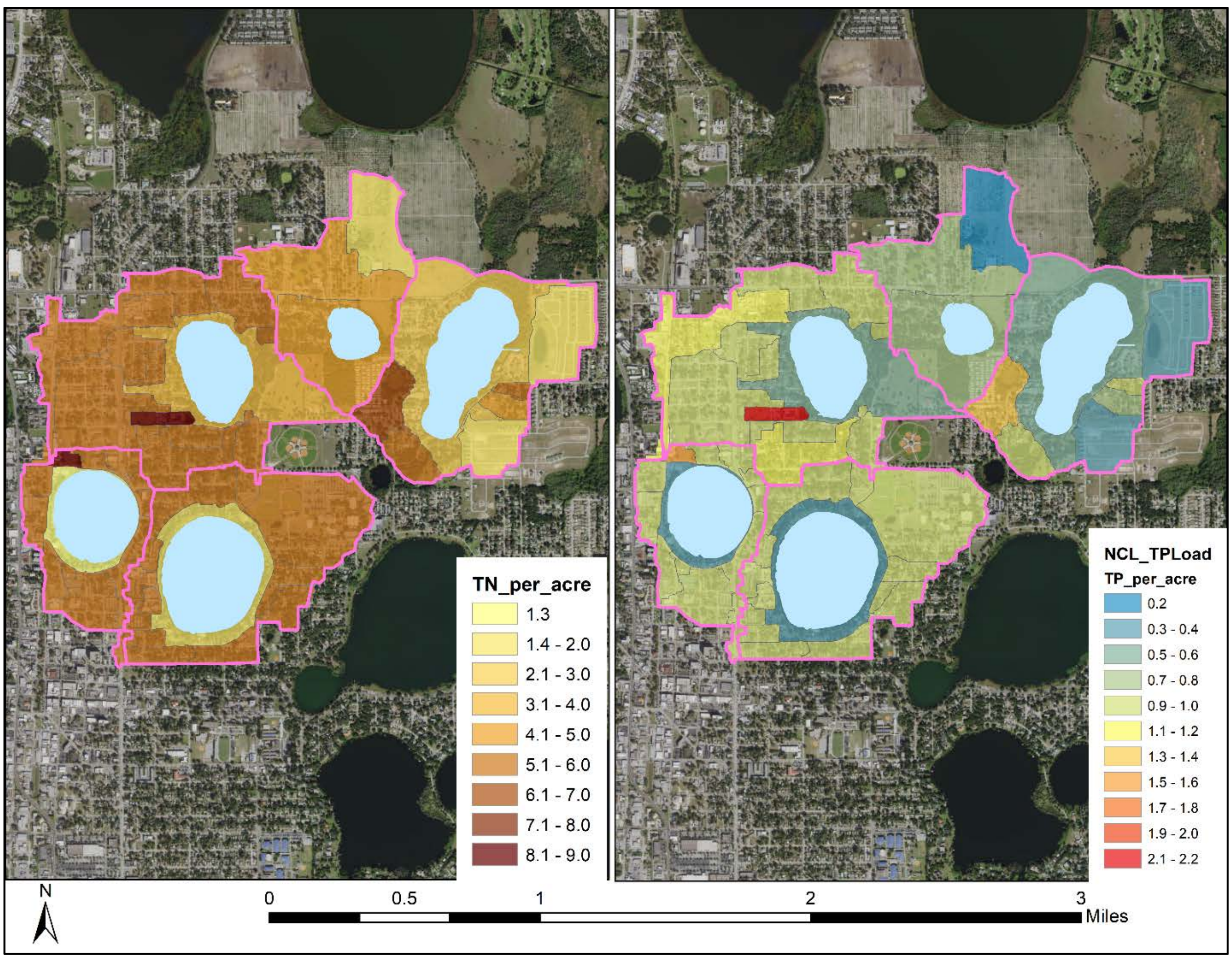


Figure 2-17. Areal TN & TP Loading for individual drainage basins in the North Central Lakes.

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 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 Idyl, Maude, and Silver 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 present. 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, 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.

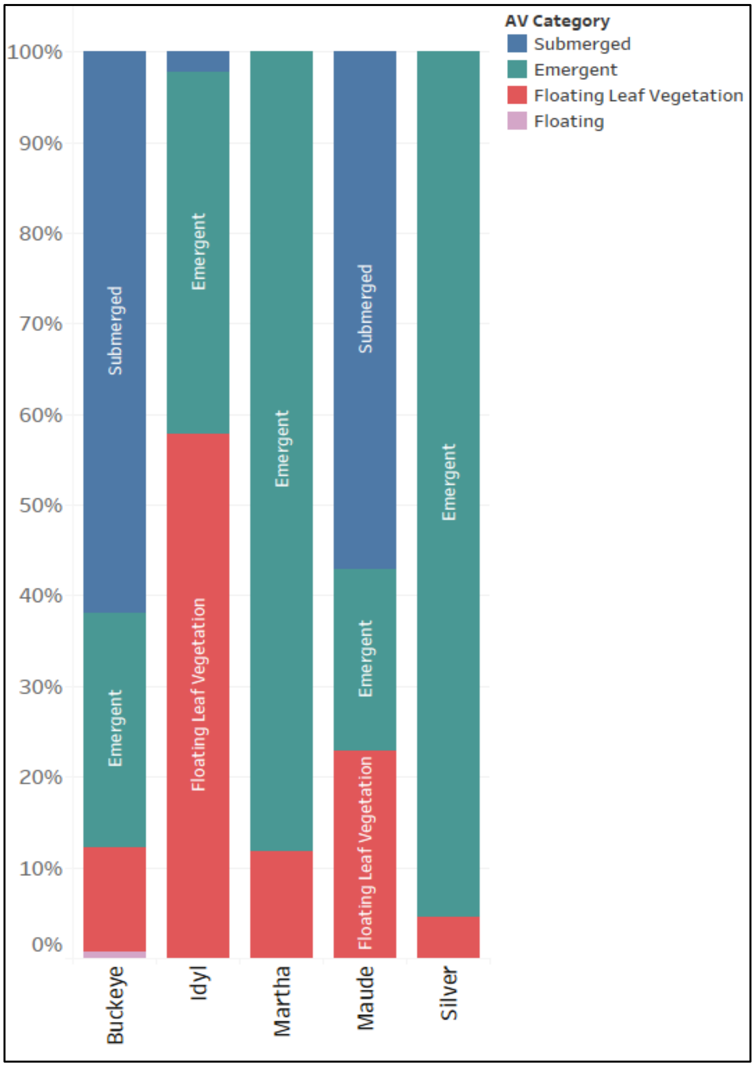


Figure 2-18. North Central Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

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 2021, Lakes Buckeye and Maude possessed PAC values well over 90% which likely contribute significantly to their excellent water quality (Figure 2-19). Lake Idyl continues to maintain PAC above the 30% abundance threshold. As usual, little aquatic vegetation was detected in Lakes Martha and Silver.

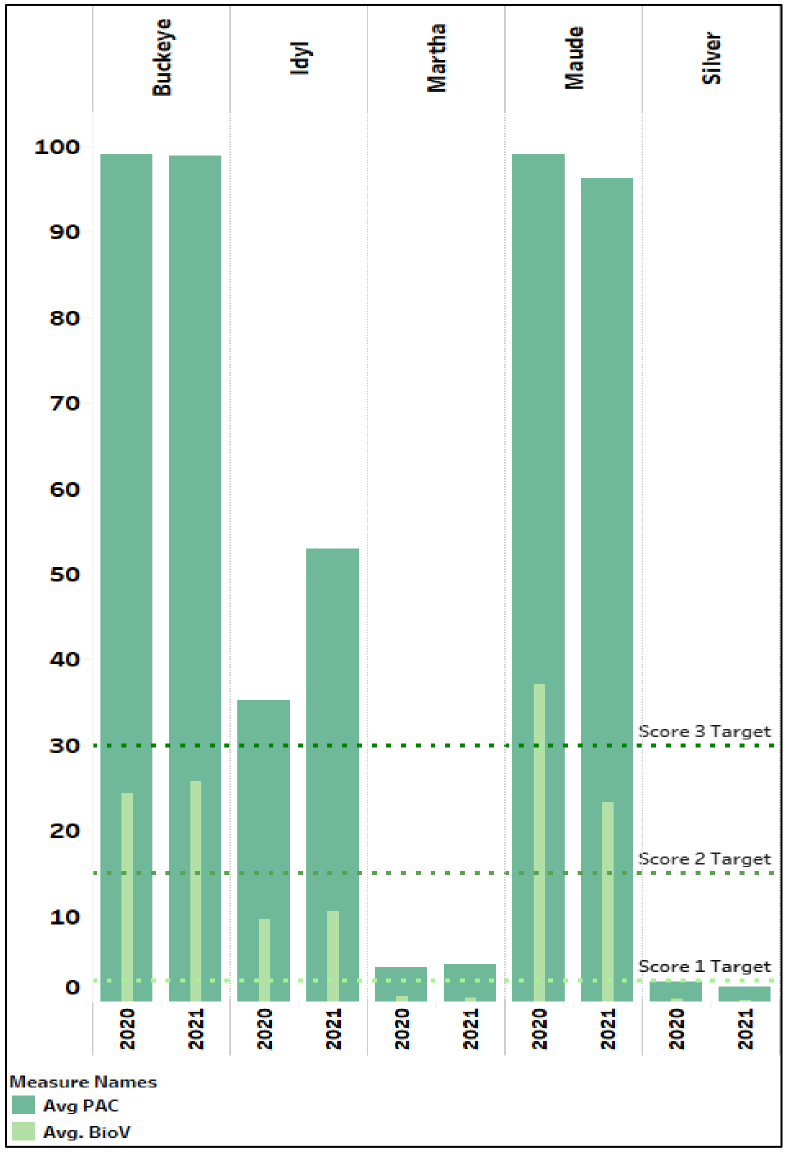


Figure 2-19. North Central Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

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*). Changes in the percentage of invasives from 2020 to 2021 has been recorded and analysed (Figure 2-20). Lake Buckeye underwent a decrease in invasive percentage due to treatment of hydrilla—improving its index score. Lakes Idyl and Martha saw an increase in presence of burhead sedge—lowering their index scores. No invasives were detected in Lakes Martha and Silver during both 2020 and 2021 surveys.

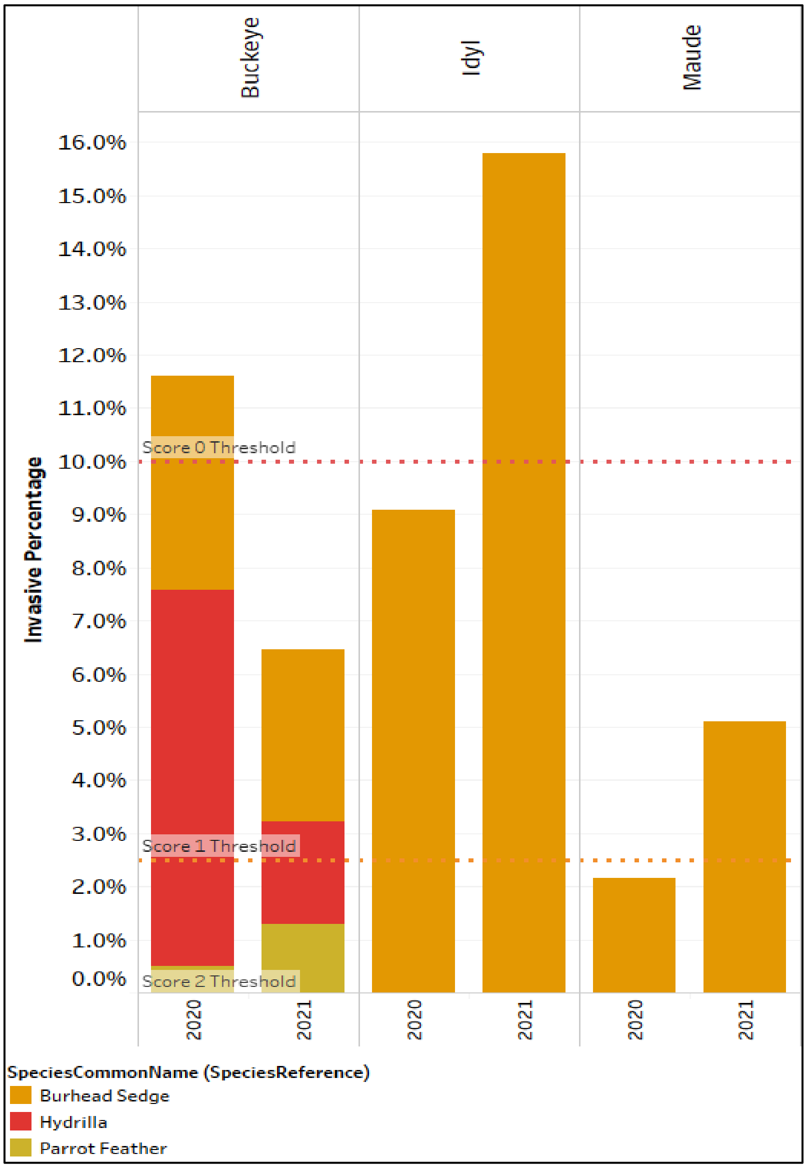


Figure 2-20. North Central Lakes annual percentage of managed invasive species.

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 comparing each lake's individual annual diversity index values with their respective long-term average (Figure 2-21). Annual index values that meet or exceed the average are awarded points while index values that fall below the average receive no points. A total possible score of 3 is awarded to a lake if all three diversity index annual values exceed the long-term average during that year.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Buckeye, Martha, Maude, and Silver possessed above-average richness values in 2021.

Hill's Evenness #3 (E3): Species evenness correlates to in community resilience. 2021 evenness values were above-average in Lakes Martha and Silver. Evenness was below-average in Lakes Buckeye, Idyl, and Maude.

Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. Only Lake Silver exhibited above-average diversity during 2021. Lakes Buckeye, Idyl, Martha, and Silver experienced below-average diversity.

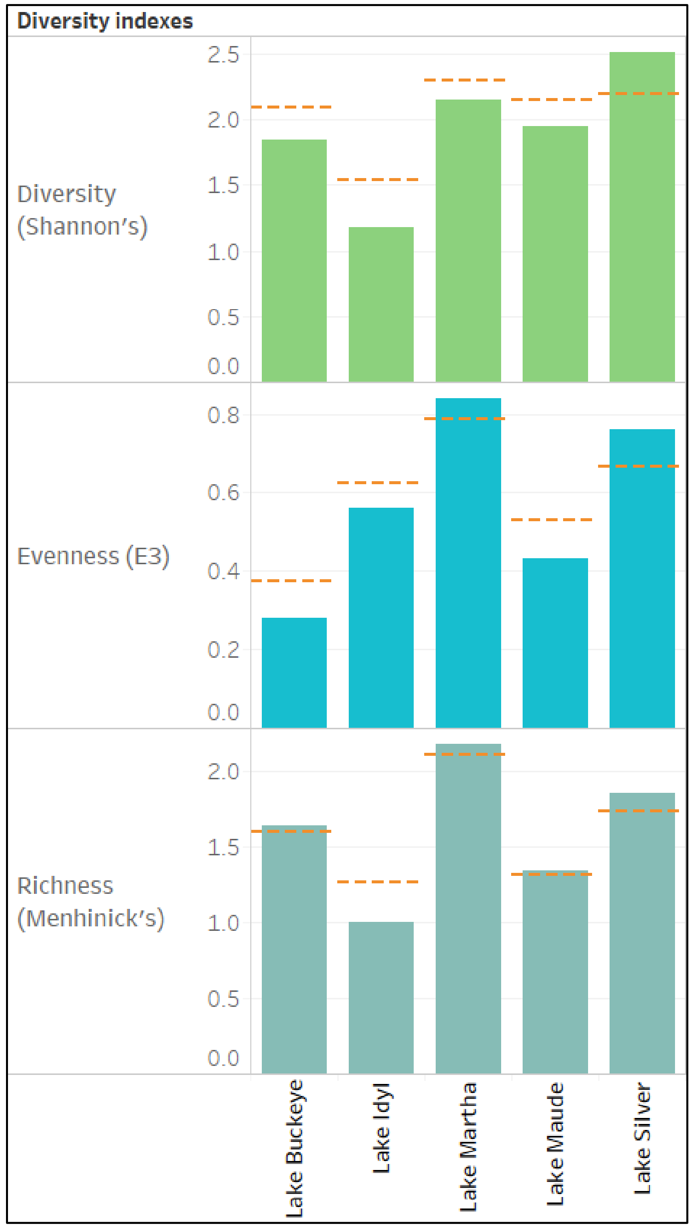


Figure 2-21. North Central Lakes annual index values for species richness, evenness, and diversity

The North Chain was somewhat lacking in aquatic vegetation diversity in 2021. Lakes Buckeye and Idyl are mostly dominated by one or two species so any minute changes in what species are detected can more dramatically affect their scores. Similar effects can also occur in Lakes Martha and Silver, but typically due to their lack of overall vegetation abundance. Lake Maude possessed lower diversity and evenness values in 2021. This could have been due to a dominance by American lotus—a native floating-leaf plant that undergoes cycles where populations can boom or bust. 2021 was a booming year for lotus, which likely competed with other native populations in the lake. Invasive plant management can also lead to changes in overall diversity since these indices do not discriminate between native and exotic species.

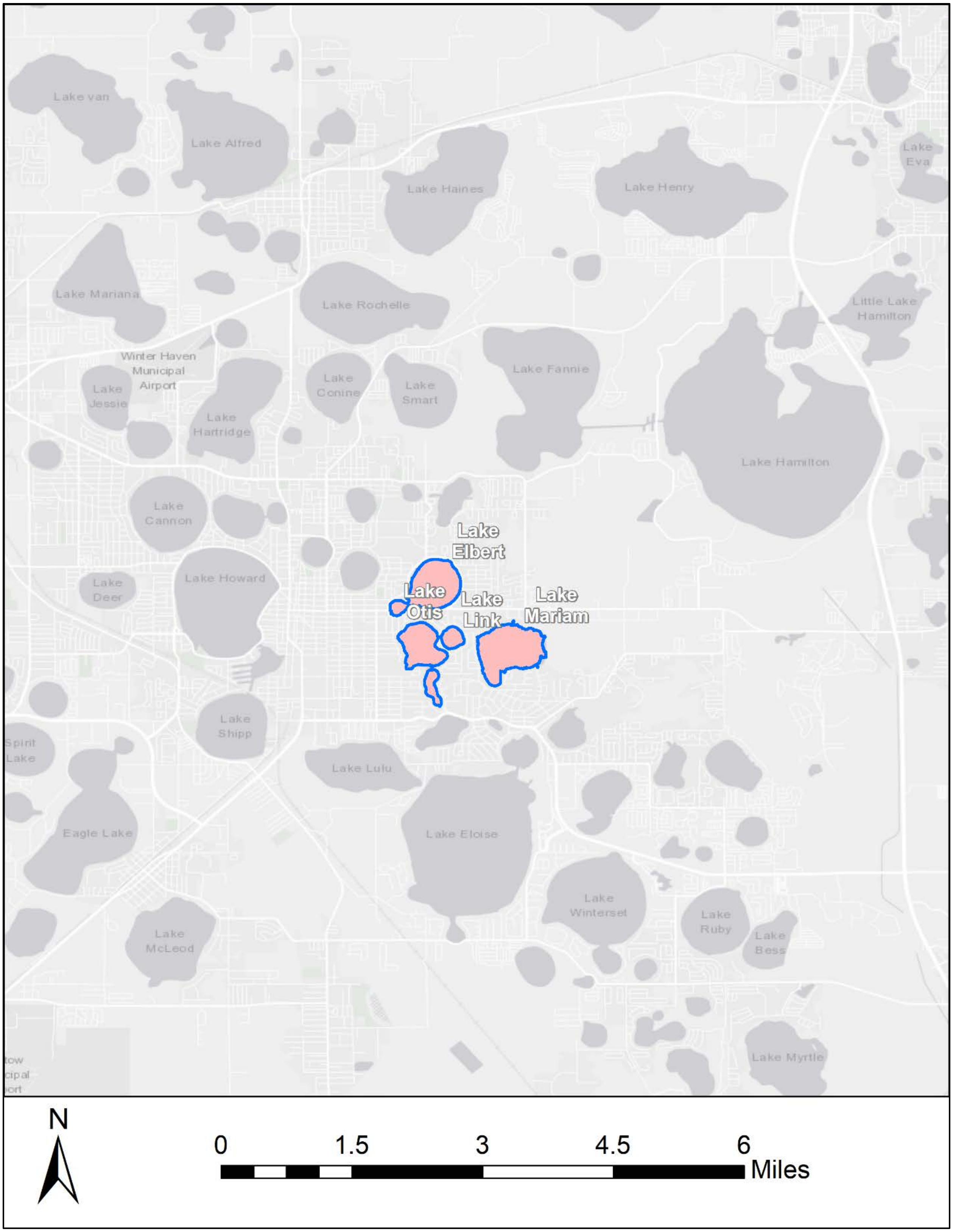
Management Conclusions

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. A diesel spill from the adjacent hospital that occurred in 2020 required significant environmental remediation. While the long-term impacts from this event are still unknown, this incident 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. City staff are working with Polk County to discuss harvesting native plants from other area lakes to seed Lake Martha.

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. Only Lake Buckeye underwent a small (<5 acre) herbicide treatment in 2021 (Figure 4-7; in appendix). That said, the increase in burhead sedge in Lakes Idyl and Maude will require future treatments to control. Fortunately, the NCL are in what is referred to as a maintenance stage with regards to invasive management. This typically only results in smaller scale treatments. Continual monitoring is critical for ensuring future success, however.

2.4 South Central Lakes



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 2021 AGM Chl-a, TN, TP, and Secchi depth values for the SCL with the long-term (2000 – 2021) mean and normal range (+/- 1 standard deviation) for each waterbody (Figure 2-22). All four lakes in this group exhibited poorer than average water quality in 2021. Chl-a concentrations were all slightly above-average. Total nitrogen was slightly above average in Lakes Link and Otis, but greatly above-average in Lake Elbert. Lake Mariam's 2021 TN concentration was slightly below-average, however. 2021 TP concentration were all well above-average. Finally, Secchi depths were all below-average—with Lake Elbert's falling below its normal range.

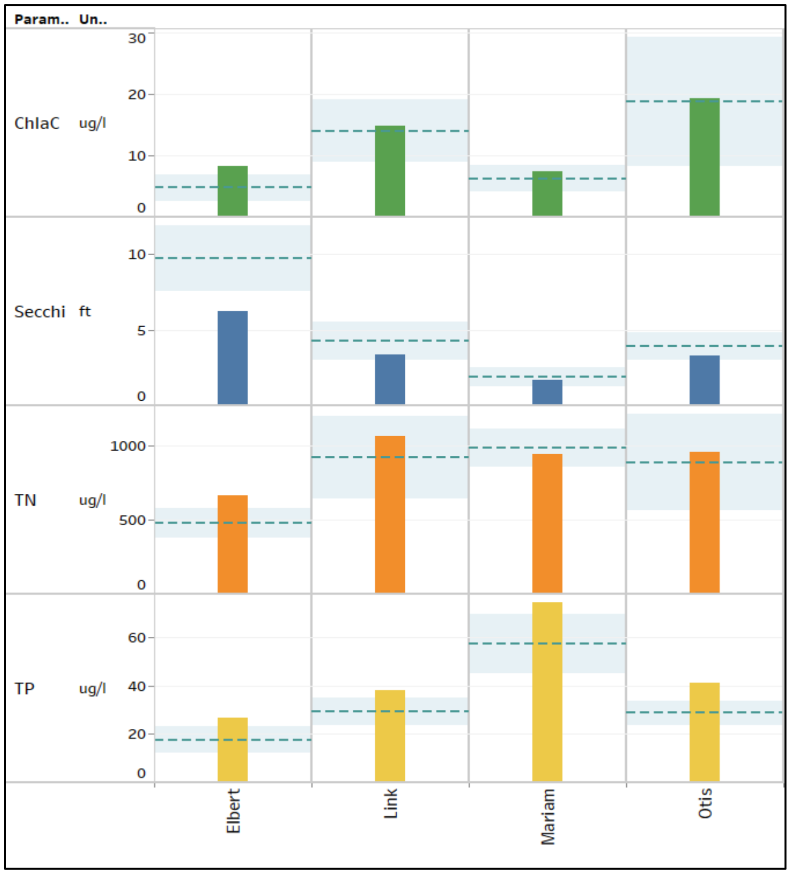


Figure 2-22. 2021 AGM Chla, TN, TP, & Secchi depth values for the South Central Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

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 low color, 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 2014 and 2021. 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. Nor do any 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 2021 (Table 2-4). Monotonic trend direction (increasing/decreasing) and statistical significance (p-value ≤ 0.05) were determined based on the resulting linear regression statistics (Table 4-4 in Appendix). The trend information, including the associated lake health index scoring, is presented in Table 2-4. The only significant water quality trends include deteriorating Chl-a, TN, TP, and Secchi depth trends in Lake Elbert and an improving TN trend in Lake Link.

Based on the trend data, it is clear that Lake Elbert's water quality is declining. It is unclear as to the reason for this deterioration of water quality, however there are some theories being considered as will be discussed in the following sections. There are currently water quality improvement practices being implemented in its drainage basin, but it appears that these have not been successful in curbing the downward trends. In the interim, additional management identifying the pollutant source(s) should be the primary objective. The improving TN trend in Lake Link is one positive note and its other parameters do appear to be improving as well—albeit not significantly. While trends in Lake Mariam and Otis are not significant, their declining parameters are important to keep close track of. If these slight deteriorating 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 (Deteriorating)	Significant	0
	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	Increasing	Not Significant	1
	Secchi	Decreasing	Not Significant	1

Table 2-4. 2021 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 2021 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. Due to below-average rainfall in 2021 (40.13 inches), it would have been expected for lake levels to decline. However, each of these lakes ended 2021 at levels close to the top of their normal ranges. It is likely that other hydrologic factors, such as water table and Upper Floridan aquifer levels remaining high, buffered more significant changes in lake surface level.

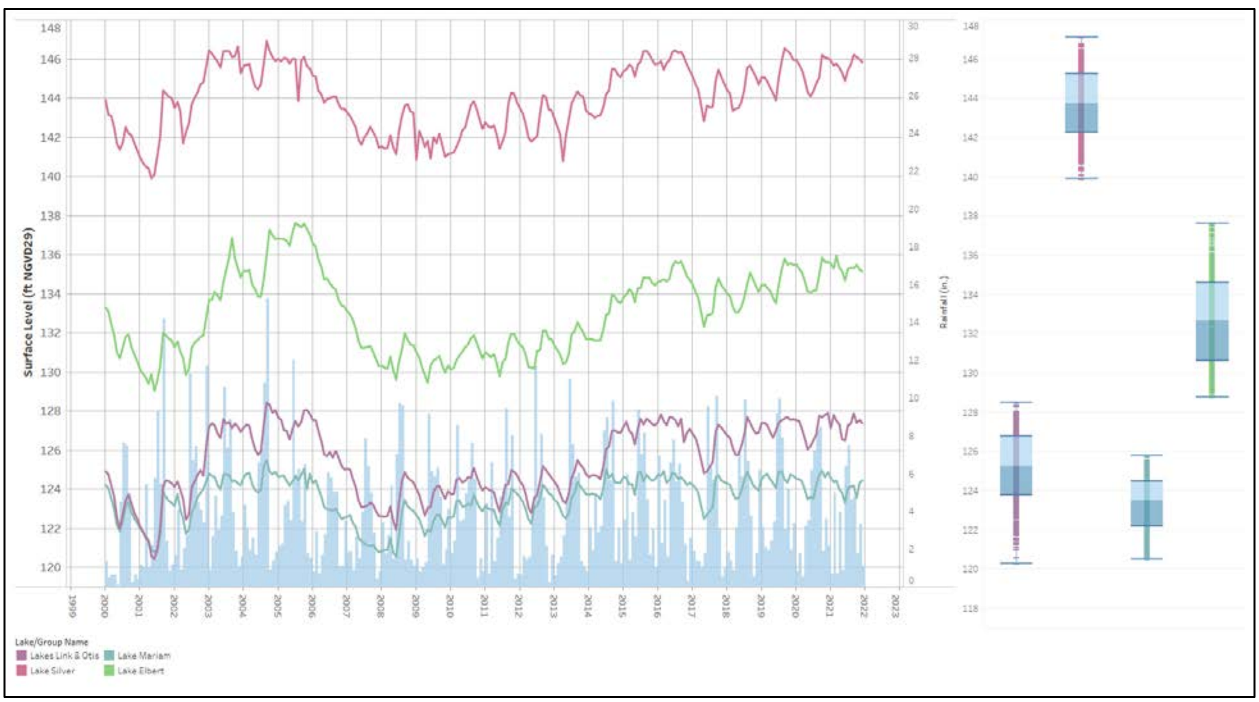


Figure 2-23. South Central Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Monthly rainfall totals indicate hydrologic response to precipitation.

Based on analysis of SL and water quality data between 2000 and 2021, linear regressions were performed to determine if changes in surface level significant correlate with changes in water quality (Table 4-5; in appendix). Lake Link exhibited significant correlations between SL and both TN and TP. Correlations were also significant between

SL and Chl-a, TN, and Secchi depth in Lake Otis. This means that as levels in these two lakes increase, water quality will generally improve. On the other hand, significant negative correlations were exhibited by Lake Elbert between SL and all of its water quality parameters—such that an increase in lake level results in a decline in water quality. While the positive correlations in Lakes Otis and Link may be the result of increased flushing during high water periods, the negative correlations in Lake Elbert may be evidence of the opposite. Since Lake Elbert cannot discharge downstream under current conditions, any stormwater entering the lake is essentially concentrating excess pollutants. This is the most likely situation as all other lakes in the area do not possess these types of relationships.

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

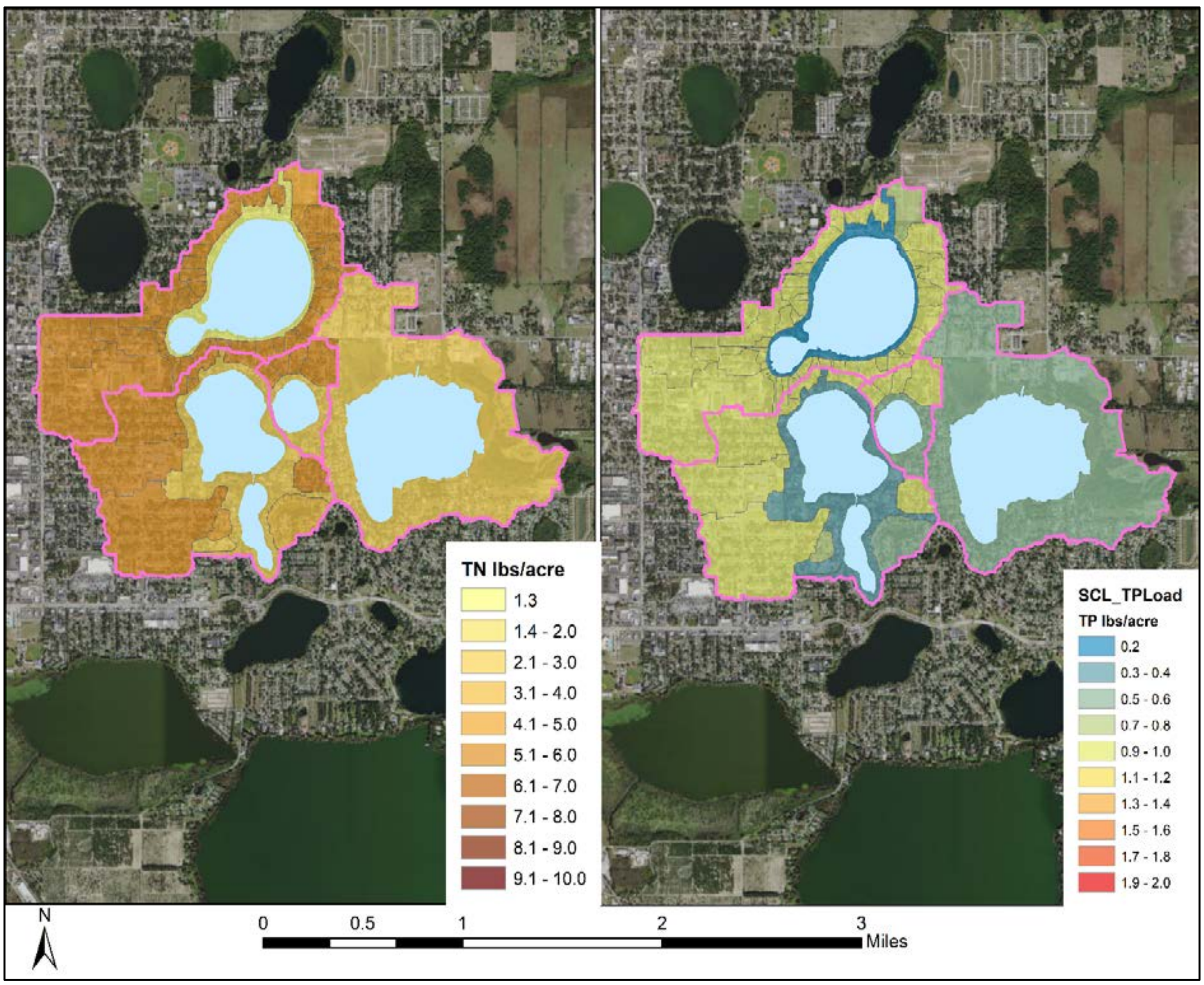


Figure 2-24. Areal TN & TP Loading for individual drainage basins in the South Central Lakes.

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.

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.

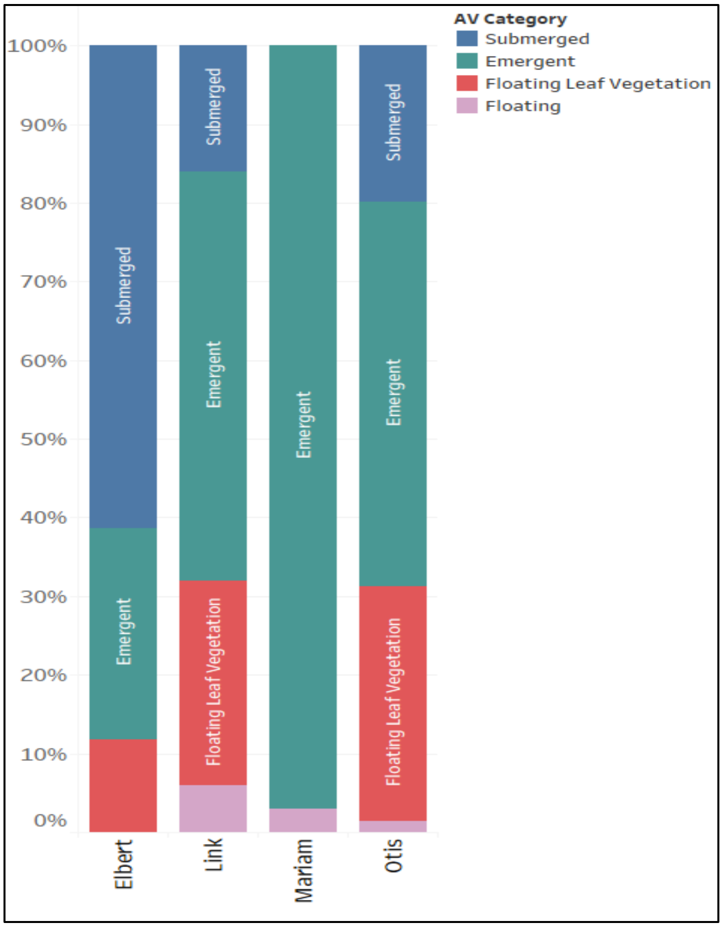


Figure 2-25. South Central Lakes categorical proportion of aquatic vegetation as emergent, submerged, floating-leaf, or floating.

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. Lake Link was unable to be surveyed from 2017 to 2018 as access from Otis was limited due to high water.

Analyzing the proportion of each vegetation type found in a given lake is useful to determine the general vegetation community at a glance. Ideally, waterbodies should possess a healthy mix of submerged aquatic vegetation (SAV), emergent aquatic vegetation (EAV), and floating-leaf vegetation (FLV). However, due to the unique characteristics and environmental stimuli found in each lake, an equal mix is not always indicative of a healthy waterbody. Lake Elbert appears to have an extremely robust SAV community dominating its total vegetation proportion (Figure 2-25). Lakes Link and Otis possess a majority of EAV and FLV species with relatively smaller SAV communities at roughly 25% of their total populations. Emergent vegetation is clearly the dominant type found in Lake Mariam, as there has been no SAV present in the last several surveys. 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. Nevertheless, staff would like to see a greater SAV presence in Lake Mariam in the future.

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 2021 PAC values in relation to set minimum targets (Figure 2-26).

Lake Elbert maintained a vegetation abundance score above the 30% ideal threshold in 2021. PAC declined in Lakes Link and Otis weakening their abundance scores to 2 and 1, respectively. Surprisingly, PAC increased considerably in Lake Mariam (beyond the 30% ideal target). This increase may have been due to a change in SONAR equipment improving the accuracy of the recorded data. That said, Lake Mariam still lacks any SAV, so this number could be inflated due to an abundance of emergent vegetation in the lake.

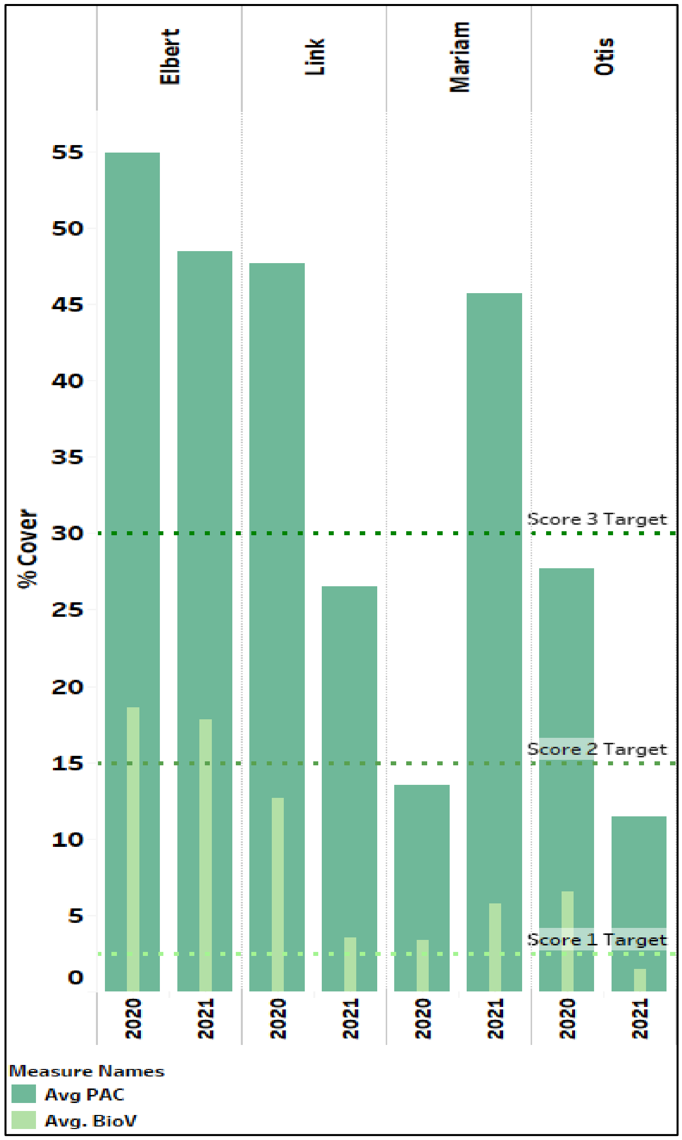


Figure 2-26. South Central Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

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

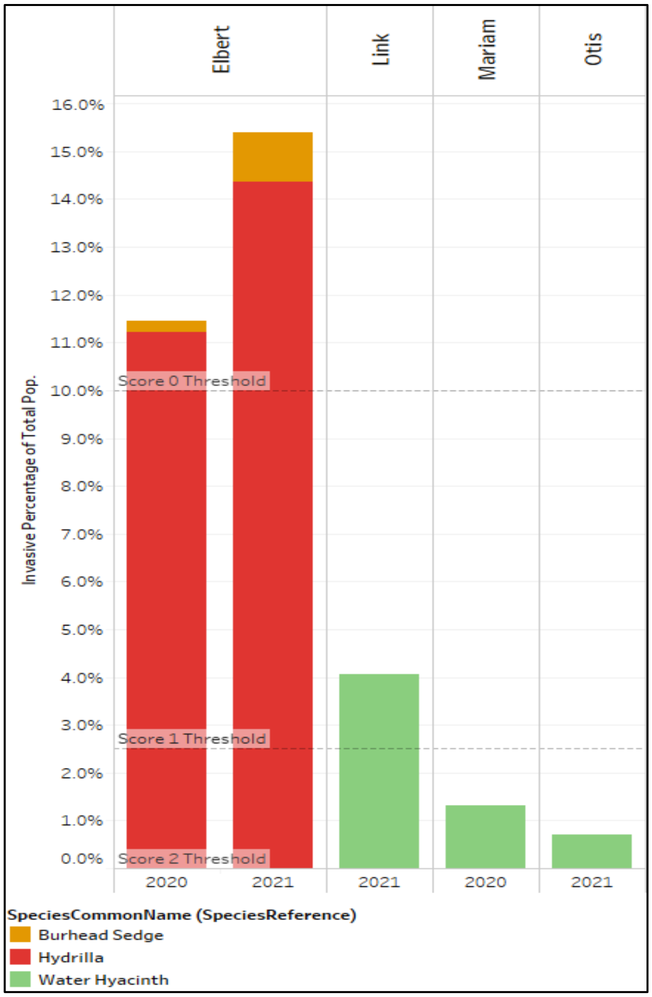


Figure 2-27. South Central Lakes annual percentage of managed invasive species.

invasives observed. The managed species found in this lake group include hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichhornia crassipes*), and burhead sedge (*Oxycaryum cubense*).

Invasive species presence saw some changes in each of these lakes from 2020 to 2021 (Figure 2-27). Lake Elbert saw an increase in both hydrilla and burhead sedge in 2021. As a result, Elbert's index score remains at 0. Due to some technical issues, 2020 data was unavailable for Lakes Link and Otis. In 2021, both lakes possessed some water hyacinth which resulted in a score of 1 for Lake Link and 2 for Lake Otis. Treatment of water hyacinth in Lake Mariam led to a reduction of invasives such that none were detected in 2021.

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. Scoring is based on 2021 index values in relation to their long-term average (Figure 2-28). If an individual 2021 index value meets or exceeds its long-term average, it is awarded a point—for a total possible score of 3 for each lake.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Lakes Elbert and Mariam experienced higher than average species richness in 2021. Lake Link and Otis had lower richness during this time.

Hill's Evenness #3 (E3): Higher species evenness is preferred as it correlates to improvement in community resilience. Lake Link, Mariam, and Otis achieved above-average evenness values in 2021, while Lake Elbert had below-average species 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 Lake Elbert possessed above-average diversity in 2021. Lakes Link, Mariam, and Otis all showed below-average overall diversity.

The diversity index values for Lake Elbert were all satisfactory in 2021 despite the increase in invasive percentage. This supports the concept that species diversity does not discriminate between native/exotic species. Lakes Link and Otis both had lower diversity and richness index scores which may be coincident with the decrease in both lakes' vegetation abundance in 2021. This result was odd considering the very minimal invasive herbicide treatments (< 2 acres) taking place in this lake group. Lastly, Lake Mariam saw above-average richness and evenness in 2021—which could be related to its increase in vegetation abundance.

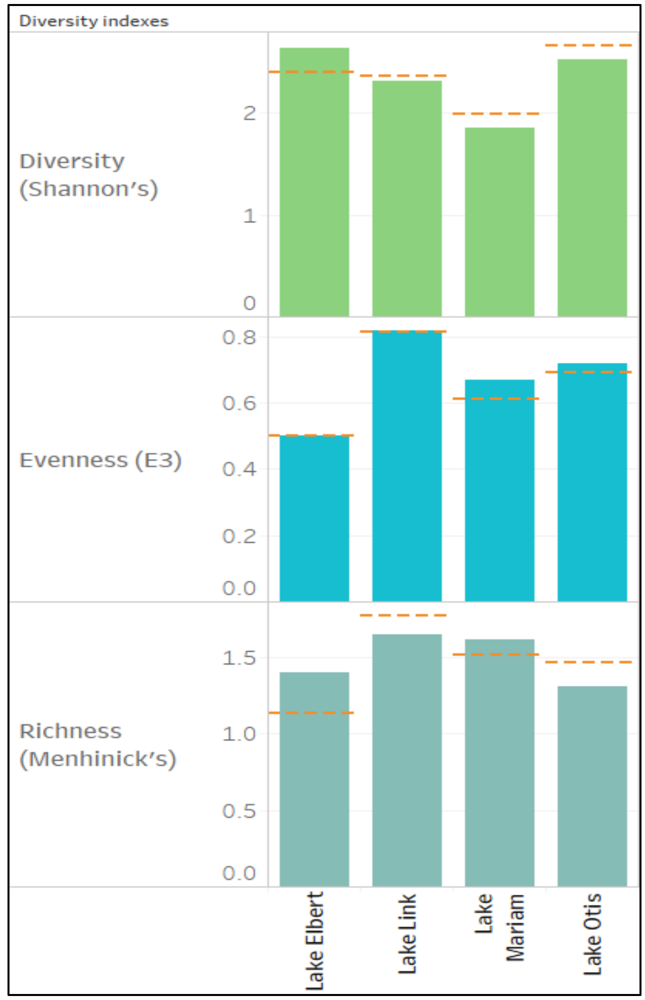


Figure 2-28. South Central Lakes annual index values for species richness, evenness, and diversity.

Management Conclusions

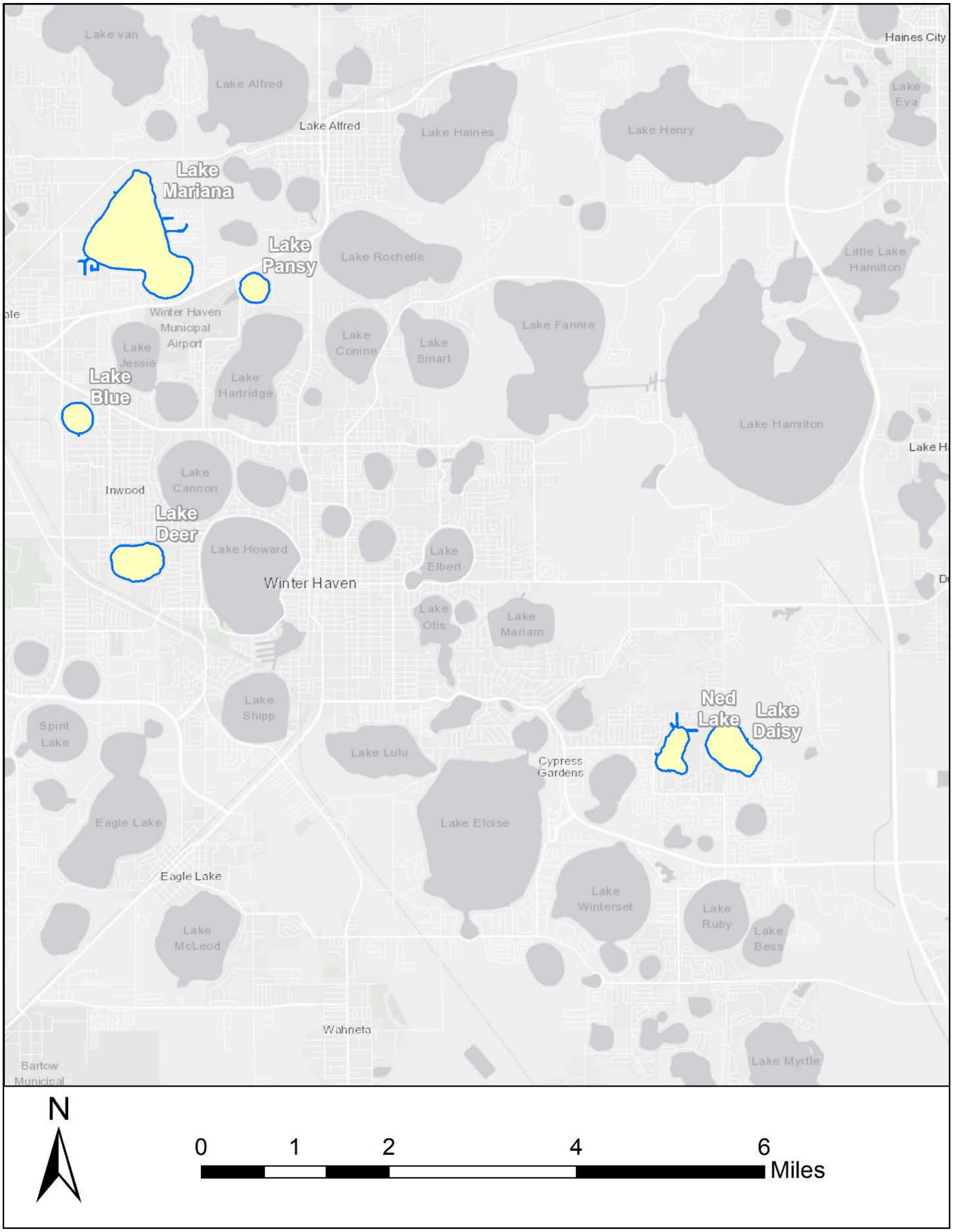
Lake Elbert continues to exhibit declining water quality trends in contrast to the other waterbodies in the South Central Lakes group. The source of this water quality deterioration remains unclear, though the relationships between surface level and each water quality parameter leads staff to believe that stormwater is a major factor. Several raingardens and other stormwater treatment projects are in the planning stages in this drainage basin.

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. A large-scale treatment has been planned for early 2022 which focuses on gradually reducing the hydrilla population in Elbert using a specialized herbicide. Part of this treatment will involve monthly water quality monitoring to better understand any potential water quality impacts from the decomposition of the invasive plant biomass. It is anticipated that the slower reduction in hydrilla will allow native species to replace the biomass and buffer against massive swings in nutrient availability. Results of this study should be available in the 2022 Lakes Report.

The decline of vegetation abundance in Lakes Link and Otis is a growing concern considering the unknown cause. 2021 invasive treatments only totaled 1.5 acres in Lake Otis—insufficient to significantly decrease the overall percent coverage in both of these lakes. Future management strategies may involve seeding submerged vegetation from other local lakes in order to supplement the minimal SAV presence in Lakes Otis and Link.

As was mentioned in the 2020 Lakes Report, the OSTD presence in the Lake Mariam and Otis basins may potentially contribute to nutrient loading. 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. Increasing trends in nutrient concentrations would warrant closer examination of these systems as a possible source. If so, septic-to-sewer conversion is an effective, albeit expensive avenue to remedy this issue.

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 limits. 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 to each other and may discharge east to the Peace Creek. The following is a presentation and analysis of the various lake health metrics for this group.

Water Quality

A snapshot of 2021 AGM Chl-a, TN, TP, and Secchi depth values shows the most recent water quality in relation to historic conditions; long-term averages are represented by the dotted lines and normal ranges as the light blue shaded areas (Figure 2-29). Lake Mariana's 2021 Chl-a concentration was significantly higher than average while Lake Blue's was significantly below average. 2021 Secchi depths were at the long-time average in Lakes Deer and Pansy; well below average in Lakes Blue, Mariana, and Ned; and well above average in Lake Daisy. TN concentrations were below average in Lakes Daisy, Deer, and Pansy while Lakes Blue, Mariana, and Ned had above average concentrations. Lastly, TP concentrations were below average in Lakes Blue, Daisy, and

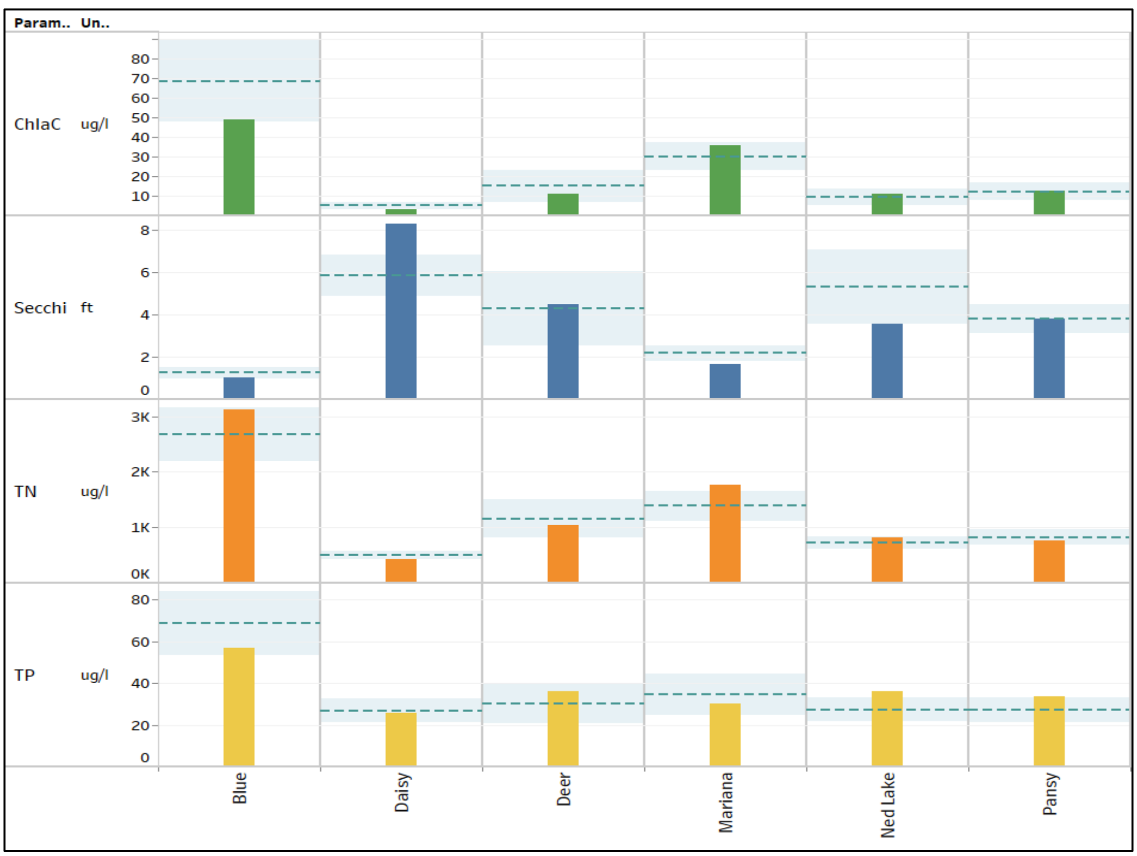


Figure 2-29. 2021 AGM Chla, TN, TP, & Secchi depth values for the Outlying Lakes; dotted lines represent long-term mean and the shaded areas refer to the standard deviation range.

Mariana, but above average in Lakes Deer, Ned, and Pansy. The snapshot shows that most waterbodies in this group did not exhibit significantly better or poorer water quality in 2021; with Lake Daisy as an exception due to its overall better 2021 water quality compared to long-term averages.

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 low color, high alkalinity waterbodies, Lake Pansy was determined to be highly colored, while Lake Daisy is a low color and 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 2014 to 2021 (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. Water quality in Lake Deer continues to remain below NNC thresholds since 2019. According to the City's annual evaluations, Lake Deer is not currently impaired. However, removal of Lake Deer from the official FDEP impaired waters list will require that this improved water quality continues for several more assessment cycles and continued monitoring.

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 2021 (Table 2-5). Linear regression lines were plotted in order to determine trend direction (+/-) and statistical significance (p-value ≤ 0.05) (Table 4-4 in appendix). By performing these regressions, the resulting statistics indicate whether lakes are improving or declining in each of the four previously mentioned water quality parameters.

Chlorophyll-a Trends: Of the OL group, Lake Daisy 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. While not currently impaired, Lakes Ned and Pansy are under increased scrutiny due to their deteriorating water quality trends. Solving water quality issues in these lakes should be of higher priority to prevent them from becoming impaired in the future.

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	3
	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. 2021 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 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 - 2021 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 Lake Pansy (Figure 2-30). Lake Pansy appears to have the greatest variability, but only during hydrologically dry periods. Lake Deer also appears to have been held at a higher surface elevation, exceeding 140 ft above sea level between 2000 and 2006. Since 2010, Deer's SL has rarely exceeded 138.75 despite hydrologically wetter periods from 2014 onward.

Analysis of surface level and water quality data from 2000 to 2021 shows a distinct lack of correlation between lake levels and the four primary water quality parameters in the

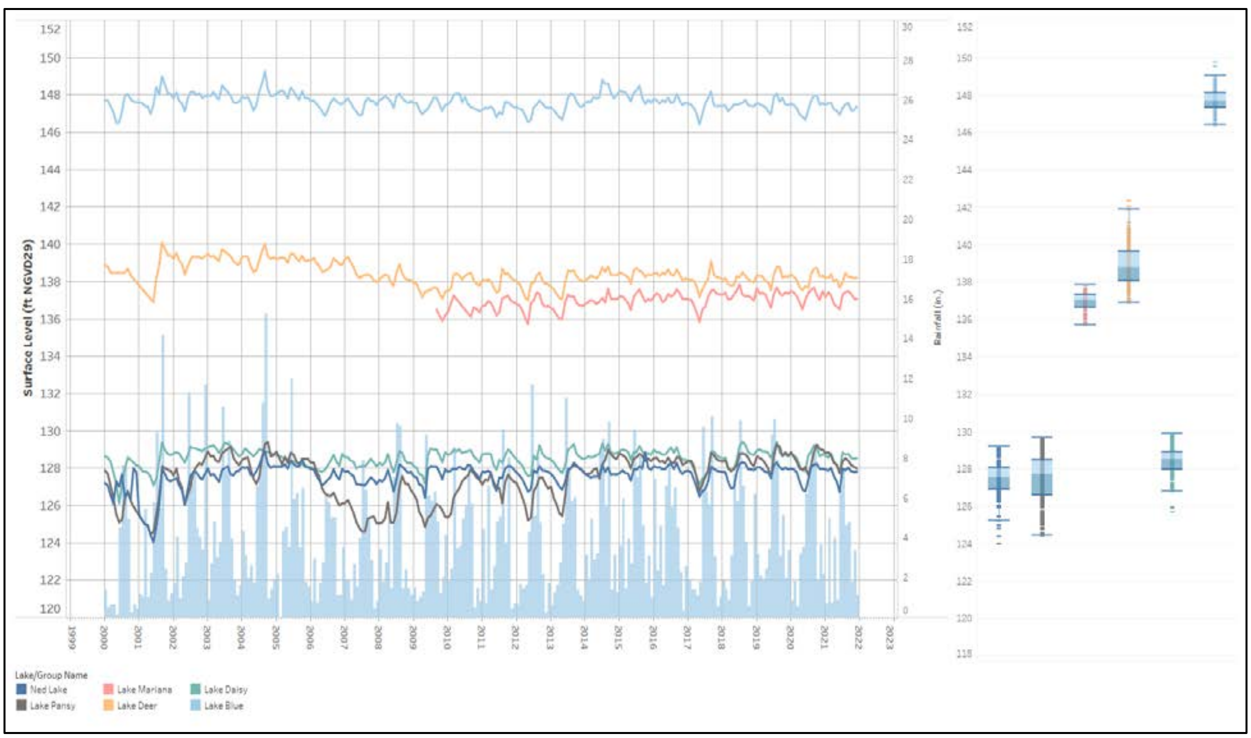


Figure 2-30. Outlying Lakes hydrographs with box & whisker plots detailing long-term surface level variability. Monthly rainfall totals indicate hydrologic response to precipitation.

Outlying Lakes (Table 4-5; in appendix). Only Lake Ned possesses a weak, albeit statistically significant, relationship between its surface level and Chl-a concentration. The direction of this correlation indicates the relationship is direct—meaning that a rise in SL results in an increase in Chl-a. However, lacking any relationships with nutrient concentrations or Secchi depth, it is unclear if this weak correlation is erroneous or simply anecdotal.

Pollutant load model analysis for this lake group indicates that stormwater nutrient loading for the Outlying lakes is below 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

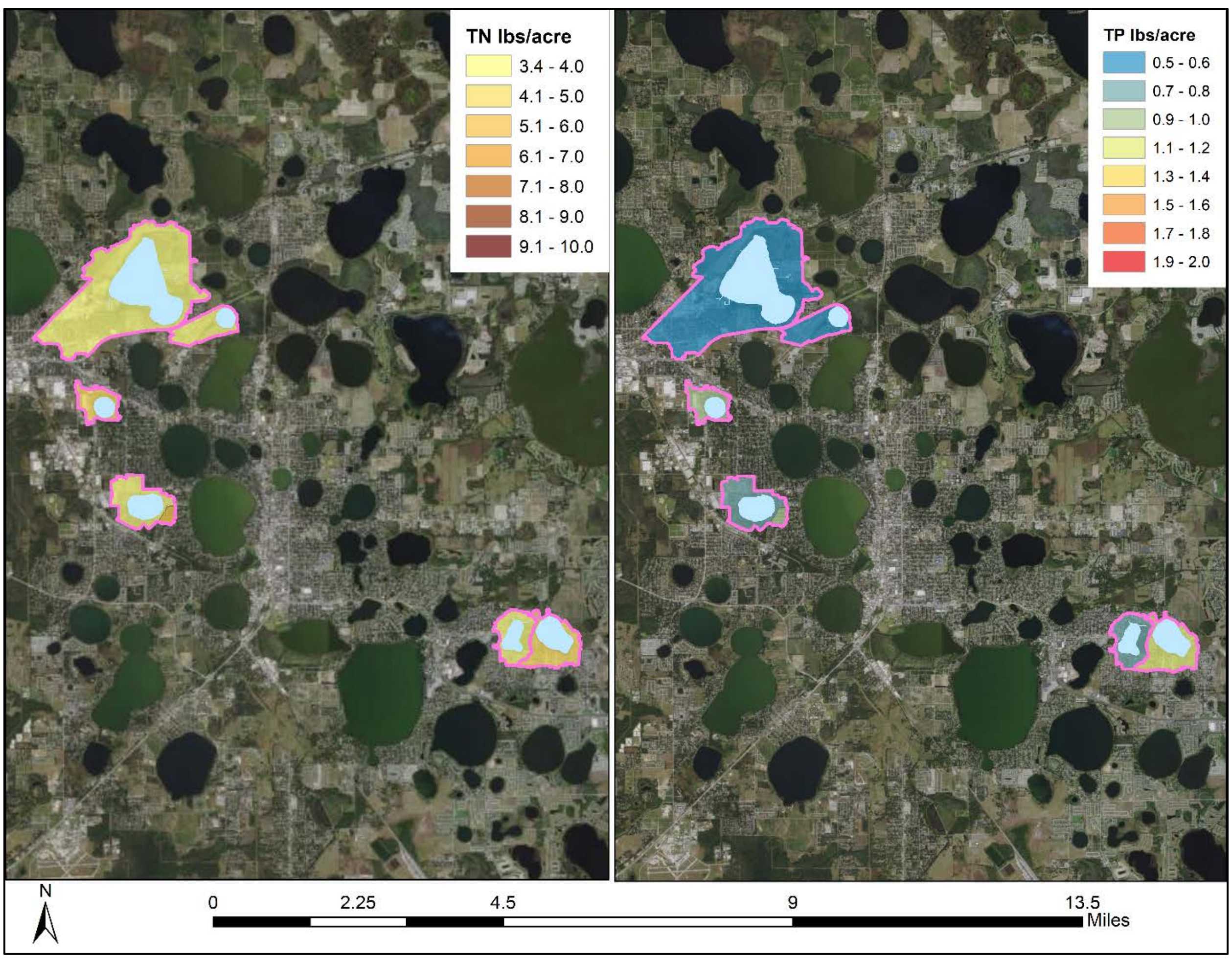


Figure 2-31. Areal TN & TP Loading for individual drainage basins in the Outlying Lakes.

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

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 in densities that might be of potential concern (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 if annual TN concentrations or long-term trends indicate otherwise.

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. Lake Mariana is especially susceptible to sediment suspension due to its much larger comparative surface area. Sediment suspension can also occur from boat traffic which may be a larger issue on more popular lakes for fishing or other recreational activities. Lakes without much rooted or submerged vegetation are more apt to experience increased water quality impacts from suspended sediments. Lake Ned comes to mind as a popular recreational lake in the community that may be suffering from this issue.

Ecology

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, 2020 vegetation abundance data for Lake Blue was absent.

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). In 2021, Lake Deer possessed a dominant proportion of SAV species. Emergent and floating leaf plants comprised the majority of vegetation populations in the other Outlying Lakes. Lake Blue possessed no plant types outside of the emergent category while SAV species comprised minimal proportions in Lakes Daisy and Ned. A good mix of vegetation types is important for a healthy aquatic plant community. SAV species are more efficient at producing oxygen and uptaking excess nutrient in the water column. Most lakes should also have a healthy emergent and floating leaf vegetation representatives to stabilize shoreline sediments, prevent erosion, and provide habitat. Prioritizing a more even proportion of vegetation types in this lake group should be a priority.

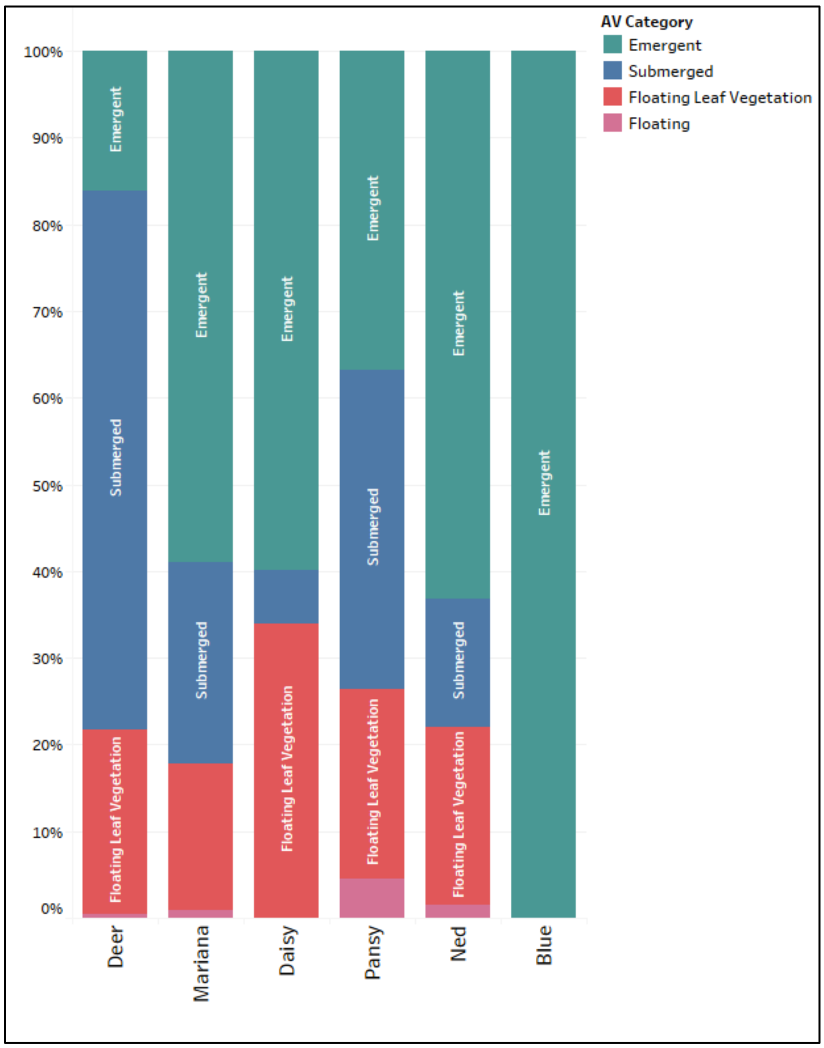


Figure 2-32. Outlying Lakes categorical proportion of aquatic vegetation as emergent, submerged, or floating.

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 aquatic vegetation detected via SONAR 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, data indicates that vegetation coverage did increase from 7% in 2019 to 18% in 2021—leading to an abundance score of 2. PAC increased substantially in Lakes Daisy, Deer, and Pansy in 2021. The abundance index scores improved to a 2 in Lake Daisy and a 3 in Lake Pansy. While increase vegetation coverage is typically beneficial, the increase in Lake Deer was likely due to an increase in hydrilla. Little PAC change was observed in Lakes Mariana and Lake Ned.

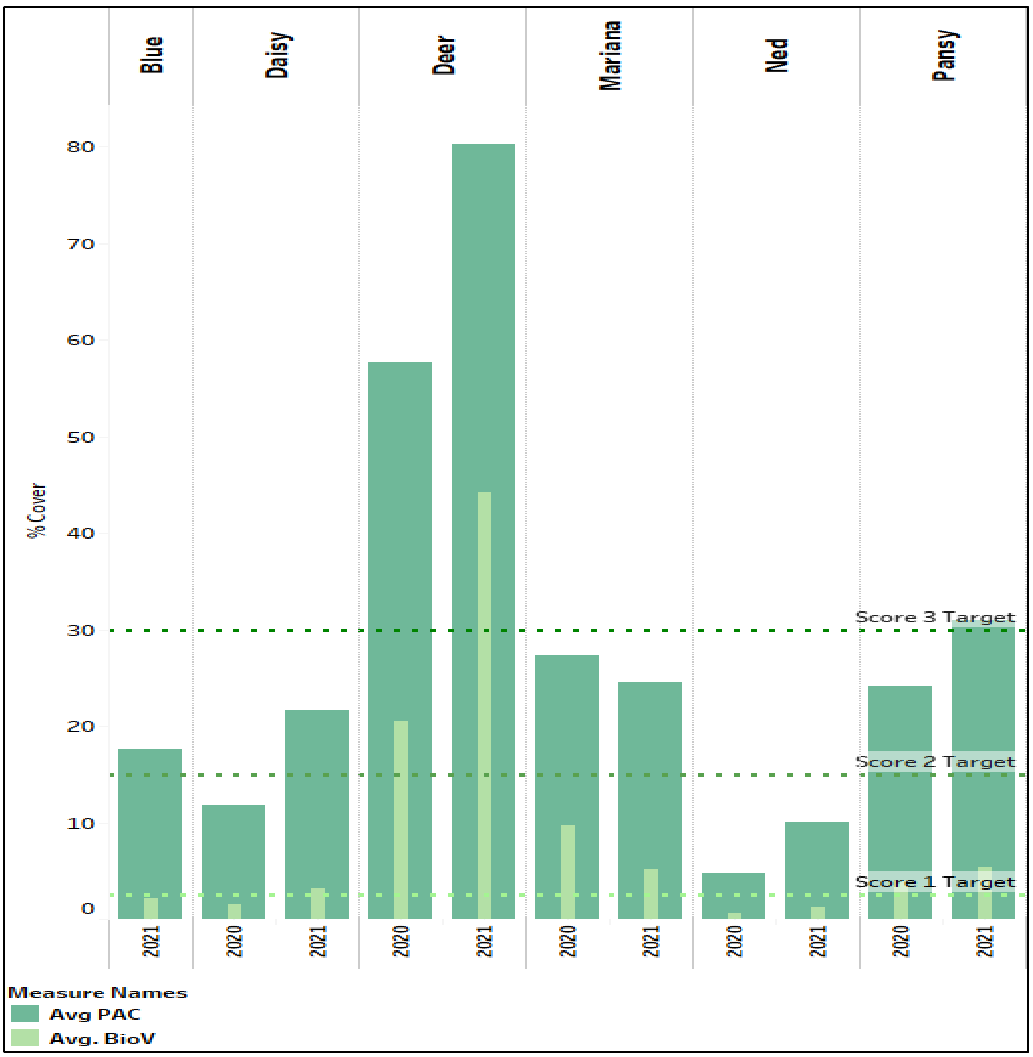


Figure 2-33. Outlying Lakes annual aquatic vegetation percent area coverage and mean percent biovolume.

Invasive Species Percentage

The percentage of invasive species found in the Outlying Lakes underwent considerable changes from 2020 to 2021 (Figure 2- 34). No managed invasive species have been detected in Lake Blue since vegetation monitoring began. The previously identified elodea in Lake Daisy was discovered to be a native species called baby's tears. However, a minor amount of burhead sedge was detected in 2021. Lake Deer underwent a substantial increase in hydrilla in 2021—resulting in a decline in invasive presence score. A small amount of water hyacinth was detected in Lake Mariana, causing its 2021 invasives score to decline as well. Lastly, Lake Pansy saw an increase in several invasive species populations—primarily hydrilla and water hyacinth. The invasive sacred lotus was not detected in 2021. Overall, this lake group underwent a significant increase in invasive species populations in 2021. Substantial management of these species will be required to return Lakes Deer and Pansy to a managed state.

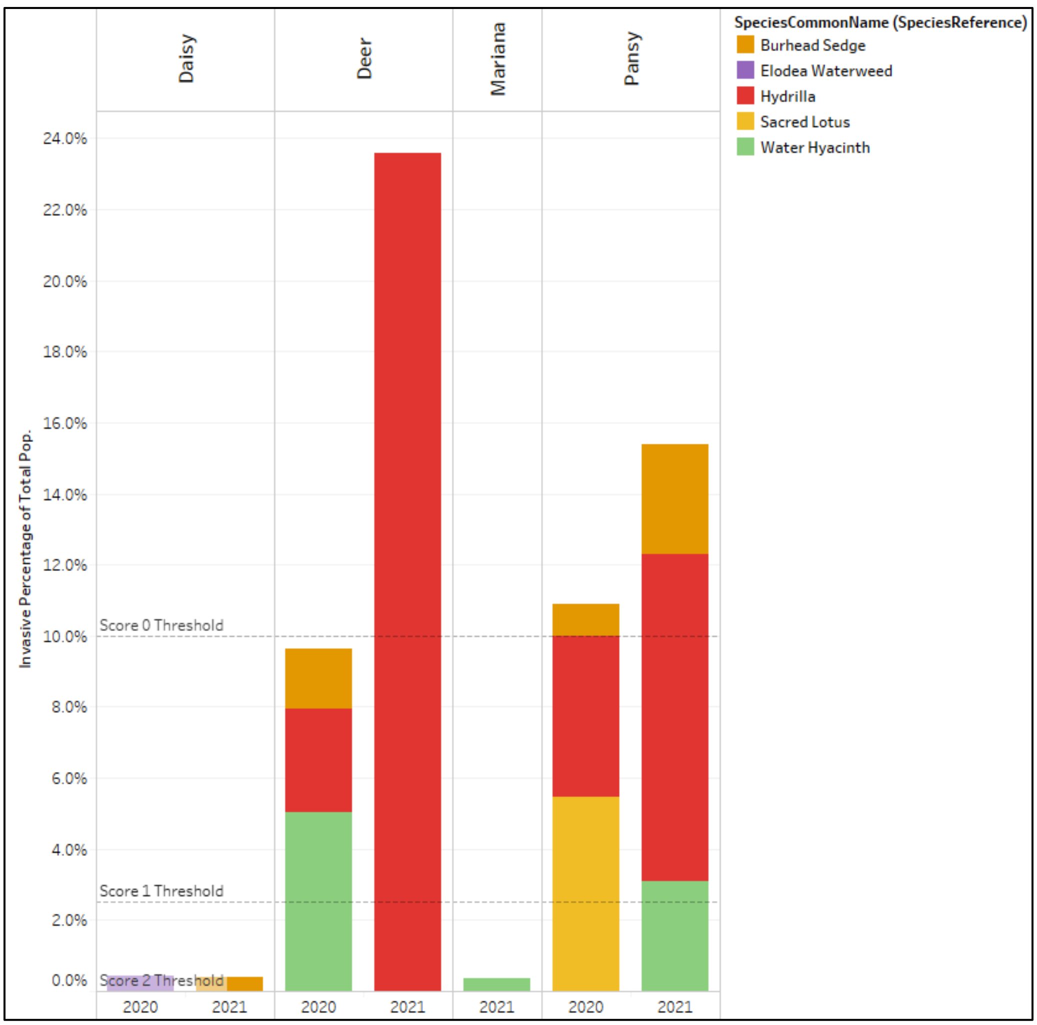


Figure 2-34. Outlying Lakes annual percentage of managed invasive species.

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 by comparison of 2021 values in relation to the long-term averages (Figure 2-35). Individual lake index values that meet or exceed the average are awarded a point, while those below the average are not. Based on performance of each of the three diversity indices, each lake could receive a total possible score of 3.

Menhenick's Richness (R2): Species richness denotes how many unique species are present in a population. Richness was at or above-average in Lakes Daisy and Mariana in 2021, but below-average in Lakes Blue, Deer, Ned, and Pansy.

Hill's Evenness #3 (E3): Changes in species evenness often correlate with community resilience. Lakes Ned and Pansy exhibited above-average evenness values in 2021, while Lakes Blue, Daisy, Deer, and Mariana had below-average evenness.

Shannon's Diversity (H): As a combination of species richness and evenness, Shannon's index indicates the overall species diversity for each site. 2021 diversity was above-average in Lakes Daisy, Mariana, Ned, and Pansy. Lakes Blue and Deer had below-average diversity during this period.

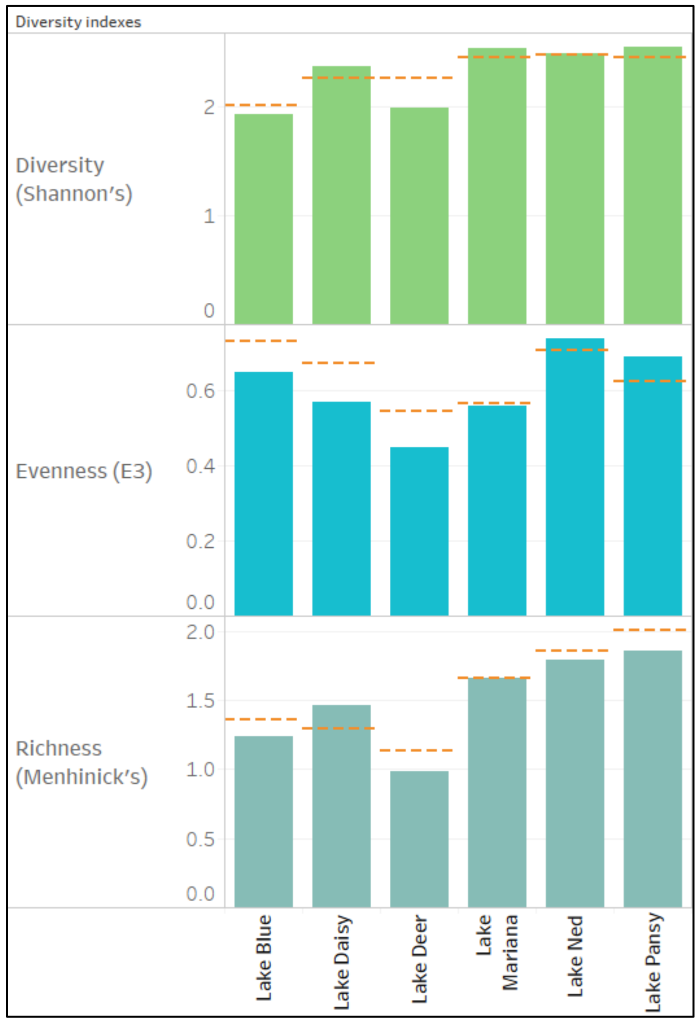


Figure 2-35. Outlying Lakes annual index values for species richness, evenness, and diversity.

Based on these data, Lakes Blue and Deer received scores of 0 for their below-average 2021 diversity index values. This was somewhat expected for Lake Deer due to the dominance of invasive hydrilla. However, these low index values were fairly confusing for Lake Blue which did not seem to undergo many vegetation changes from previous years. Further analysis is needed to better understand these communities. The remaining lakes in this group received diversity scores of 2. While not perfect, this shows that 2021 was generally a good year for the vegetation communities in the Outlying Lakes.

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 submerged vegetation abundance may be the primary goal for Lakes, Blue, Ned, and Daisy. The rapidity of the hydrilla expansion in Lake Deer requires 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. Perhaps more frequent monitoring is one strategy to keep invasives from gaining a foothold. Lakes Deer and Mariana received herbicide treatments in 2021 (Table 4-7; in appendix). However, both treatments were relatively minor which 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. The City may determine that additional carp should be stocked in Lake Deer to supplement herbicide treatments. As previously stated, continual monitoring of aquatic vegetation is critical for reducing the need for large-scale herbicide treatments.

Lack of aquatic vegetation coverage is one of the growing concerns for many lakes in the Winter Haven area. The Outlying Lakes are a group that could receive benefit through SAV seeding or planting efforts. SAV planting in Lakes Blue and Ned may prove challenging due to their lower water clarity. However, even seeding the lake margins with non-rooting submerged plants, like coontail, could improve water quality enough to allow other SAV species to take hold.

Managing the extremely high pollutant concentrations in Lake Blue is another high priority. Due to the relatively small size of its drainage basin, it has a comparatively lower volume of stormwater entering the lake. 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 bio-assessment 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 2-6 & 2-7) detail the lake health scores from 2020 and 2021. A comparison of these scores and an explanation of their implications is presented below.

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
	Ned Lake	3	0	2	0	0	1	3	0	1.1
	Lake Pansy	3	0	1	1	2	2	0	2	1.4

Table 2-6. 2020 Lake Health Index

2021	Waterbody	NNC Impairment	WQ Trend				PAC	% Inv	Diversity	Lake Health Score
			Chla	TN	TP	Secchi				
North Chain of Lakes	Lake Conine	0	3	2	2	3	2	1	3	2.0
	Lake Fannie	3	2	2	2	3	2	1	2	2.1
	Lake Haines	1	2	3	1	3	1	2	2	1.9
	Lake Hamilton	1	0	0	3	0	1	2	3	1.3
	Lake Rochelle	3	3	3	3	3	3	1	0	2.4
	Lake Smart	0	2	2	2	3	2	2	2	1.9
	Little Lake Hamilton	1	1	1	2	1	2	2	3	1.6
	Middle Lake Hamilton	0	1	2	3	3	1	2	3	1.9
South Chain of Lakes	Lake Cannon	2	3	3	2	3	3	1	1	2.3
	Lake Eloise	0	2	2	2	3	2	2	0	1.6
	Lake Hartridge	1	0	0	1	0	3	3	2	1.3
	Lake Howard	1	3	3	2	3	3	3	1	2.4
	Lake Idylwild	2	2	2	2	3	3	1	2	2.1
	Lake Jessie	0	2	1	2	2	3	1	1	1.5
	Lake Lulu	0	3	3	3	3	3	2	2	2.4
	Lake May	0	3	3	3	3	3	0	3	2.3
	Lake Mirror	3	3	3	3	3	3	2	1	2.6
	Lake Roy	3	3	3	2	3	3	1	2	2.5
	Lake Shipp	0	3	3	3	3	3	2	1	2.3
	Spring Lake	3	3	3	3	3	3	1	1	2.5
	Lake Summit	3	3	3	2	3	3	2	2	2.6
	Lake Winterset	3	3	3	3	3	3	0	2	2.5
North Central Lakes	Lake Buckeye	3	3	3	3	3	3	1	1	2.5
	Lake Idyl	0	1	1	0	1	3	0	0	0.8
	Lake Martha	3	0	0	0	0	1	3	2	1.1
	Lake Maude	3	3	3	3	3	3	1	1	2.5
	Lake Silver	3	2	2	2	1	0	3	3	2.0
South Central Lakes	Lake Elbert	3	0	0	0	0	3	0	2	1.0
	Lake Link	3	2	3	2	2	2	1	1	2.0
	Lake Mariam	3	1	2	1	2	3	3	2	2.1
	Lake Otis	3	2	2	1	1	1	2	1	1.6
Outlying Lakes	Lake Blue	0	2	2	3	2	2	3	0	1.8
	Lake Daisy	3	3	2	2	2	2	2	2	2.3
	Lake Deer	0	2	3	2	2	3	0	0	1.5
	Lake Mariana	0	1	1	2	0	2	2	2	1.3
	Ned Lake	3	0	2	0	0	1	3	2	1.4
	Lake Pansy	3	0	1	1	2	3	0	2	1.5

Table 2-7. 2021 Lake Health Index

North Chain of Lakes:

A comparison of lake health for the Northern Chain from 2020 to 2021 shows sweeping improvements in lake health scores in all, but one waterbody. Only Lake Smart experienced a slight decrease from 2.0 in 2020 to 1.9 in 2021—this change was primarily the result of a minor decline in species diversity scoring. Several lakes in this group exhibited improvements in both water quality (NNC impairment) as well as aquatic vegetation (abundance and invasive species presence). While many of the individual category scores varied during this period, the overall lake health score for the Northern Chain increased considerably from 1.7 in 2020 to 1.88 in 2021. This lake group has undergone gradual, but consistent improvement since the lake health assessment began in 2018 (Table 2-8).

South Chain of Lakes:

Lake Health scores for the Southern Chain also showed improvement in the majority of lakes from 2020 to 2021. Only Lakes Eloise, May, and Roy exhibited a slight decline in lake health score—exclusively due to minor decreases in species diversity and invasive presence evaluations. The remaining lakes either maintained lake health scores from the previous year or underwent some improvement. As a result, the overall lake health score for this group increased from 2.1 in 2020 to 2.2 in 2021 (Table 2-8). The majority of these improvements took place in the NNC impairment, vegetation abundance, and vegetation diversity categories. Since the lake health assessment began in 2018, the overall scores for this group have fluctuated between 2.14 and 2.20—with 2021 receiving the highest score so far.

North Central Lakes:

Mixed results were determined in a comparison of lake health scores in the North Central lake group from 2020 to 2021. Lakes Buckeye, Martha, and Silver underwent overall improvement, while Lakes Idyl and Maude saw some deterioration in lake health. The declines in lake health were almost exclusively from decreases in the invasive presence and species diversity categories. Unsurprisingly, these same categories were the ones that saw increases in the lakes exhibiting improvement. Since 2018, overall lake health scores for this group have fluctuated between 1.73 and 1.8 (Table 2-8). While the 2021 score (1.78) was slightly lower than in 2020 (1.8), these lakes have undergone improvement since monitoring began.

South Central Lakes:

The overall lake health scores for the South Central lake group underwent a decline from 2020 to 2021—from 1.82 to 1.69. Not only this, but since the lake health evaluations began in 2018, 1.69 has been this group's lowest annual score to date. While this may seem alarming, 2021's comparatively lower score is primarily due to declines in lake health scores in Lakes Otis and Link. Since the impairment and water quality trends have not changed much in the years since this assessment started, almost all of the lake health declines have been due to vegetation abundance, invasive presence, and species diversity declines. These category decreases are not insignificant. However, management of these issues is typically easier than those focused on water quality improvement.

Outlying Lakes:

Average lake health scores for the Outlying Lakes group underwent an increase from 1.54 in 2020 to 1.6 in 2021. Only Lake Deer underwent a decline in lake health score during this period—exclusively due to invasive species presence and species diversity category decreases. The remaining lakes in this group all experienced improvement—primarily in water quality trend and vegetation abundance categories. Since the lake health evaluations began in 2018, scores have ranged from 1.48 in 2018 to 1.63 in 2019 (Table 2-8). The Outlying Lakes group's 2021 score was near the top of this range. However, there is always room for improvement.

Overall:

Aggregating the lake health scores of all study area lakes from 2018 to 2021 allows for a general comparison of lake health since this style of evaluation commenced (Table 2-8). Overall, 2021 saw the highest aggregate score as well as the highest scores in the following categories: NNC impairment, Chl-a trends, TN trends, and vegetation abundance. It is worth noting that TP trend scores were at an all-time low in 2021.

The majority of lake health improvement has been exhibited in the water quality categories. Water quality has improved in several lakes such that many are starting to meet regulatory standards. Much management effort is still needed to maintain these trends and restore the existing impaired lakes. However, seeing these positive impacts manifesting helps to reassure staff that our management efforts are effective.

The lake health categories that have undergone the most flux have been invasive species presence and species diversity. This is to be expected since vegetation community dynamics can change drastically from year to year. Management of so many lakes requires constant monitoring and effective communication from various entities. City staff are taking a more active role in prioritizing invasive species treatment as well as promoting growth of healthy native species.

More information on the City's various management strategies is presented in the next section. Listed are strategic goals as a means to keep staff accountable for these projects.

Year	Lake Group	NNC Impairment	WQ Trend				PAC	% Inv	Diversity	Lake Health Score
			Chla	TN	TP	Secchi				
2018	North Chain of Lakes	0.00	1.50	1.50	2.38	2.00	1.75	1.13	2.20	1.51
	South Chain of Lakes	1.21	2.43	2.36	2.64	2.64	2.79	1.86	1.21	2.14
	North Central Lakes	2.40	1.80	1.80	1.60	1.80	1.80	1.80	0.80	1.73
	South Central Lakes	2.75	1.25	2.00	1.75	2.00	2.25	0.50	1.25	1.72
	Outlying Lakes	1.50	1.33	1.50	1.67	1.33	1.83	1.33	1.33	1.48
	Overall	**1.32**	**1.84**	**1.92**	**2.19**	**2.11**	**2.22**	**1.46**	**1.32**	**1.80**
2019	North Chain of Lakes	0.50	1.75	1.88	2.63	2.13	2.25	1.13	1.75	1.75
	South Chain of Lakes	1.36	2.43	2.36	2.43	2.71	2.79	1.36	2.07	2.19
	North Central Lakes	2.40	1.80	1.80	1.60	1.80	1.80	1.20	1.60	1.75
	South Central Lakes	2.75	1.25	1.75	1.75	1.75	2.33	0.00	2.33	1.82
	Outlying Lakes	1.50	1.33	1.67	1.67	1.17	1.83	1.83	2.00	1.63
	Overall	**1.49**	**1.89**	**2.00**	**2.16**	**2.11**	**2.33**	**1.25**	**1.94**	**1.90**
2020	North Chain of Lakes	0.63	1.75	1.88	2.63	2.13	1.88	1.25	1.50	1.70
	South Chain of Lakes	1.36	2.43	2.50	2.43	2.71	2.86	1.57	0.93	2.10
	North Central Lakes	2.40	1.80	1.80	1.80	1.60	2.20	1.80	1.00	1.80
	South Central Lakes	3.00	1.25	1.75	1.50	1.50	2.25	1.00	1.00	1.82
	Outlying Lakes	1.50	1.33	1.67	1.67	1.33	1.80	2.00	1.00	1.54
	Overall	**1.54**	**1.89**	**2.05**	**2.16**	**2.08**	**2.33**	**1.57**	**1.09**	**1.85**
2021	North Chain of Lakes	1.13	1.75	1.88	2.25	2.38	1.75	1.63	2.25	1.88
	South Chain of Lakes	1.50	2.57	2.50	2.36	2.71	2.93	1.50	1.50	2.20
	North Central Lakes	2.40	1.80	1.80	1.60	1.60	2.00	1.60	1.40	1.78
	South Central Lakes	3.00	1.25	1.75	1.00	1.25	2.25	1.50	1.50	1.69
	Outlying Lakes	1.50	1.33	1.83	1.67	1.33	2.17	1.67	1.33	1.60
	Overall	**1.70**	**1.95**	**2.08**	**1.97**	**2.11**	**2.35**	**1.49**	**1.62**	**1.91**

Table 2-8. Aggregated lake health scores for all Winter Haven lakes from 2018 to 2021 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 and this chapter presents information on the primary lake management strategies employed by the City as seen through the this lens.

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.

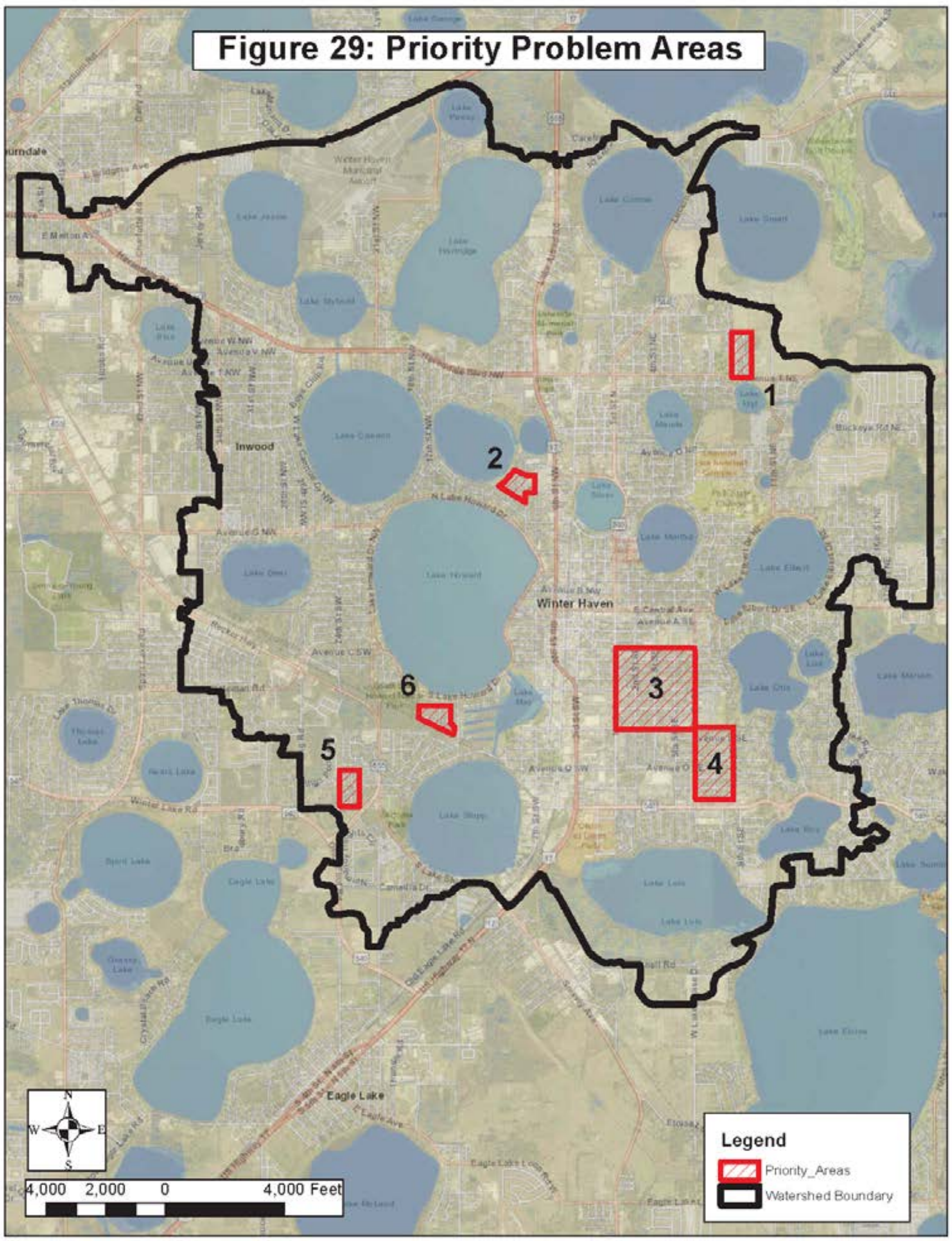


Figure 3-1. Priority sites indicated by increased flooding and pollutant load potential as determined by the Winter Haven SAIP.

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.
- Identify additional priority areas as part of stormwater needs planning by Summer 2022; required under House Bill 53.

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 cooperative funding agreement. The project timeline was extended and should be completed by end of 2022.

Alum Treatment

Summary:

Aluminum sulfate (Al_2SO_4), also known as alum, has been a popular treatment option for surface waters in order to reduce concentrations of phosphorus, total suspended solids (TSS), algae, and nitrogen originating from stormwater inputs. Alum injection is a stormwater management solution that can be especially useful in locations where the area for large settling ponds does not exist or as an alternative to less stable chemical coagulants. On contact with water, alum forms a precipitate or gelatinous floc in the water column. Nutrients and sediments adsorb to the alum floc which eventually falls out of solution and can be collected in settling reservoirs or allowed to settle in the treated waterbody (Figure 3-2). This alum floc is stable in a pH range of 5.5 – 7.5 [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.

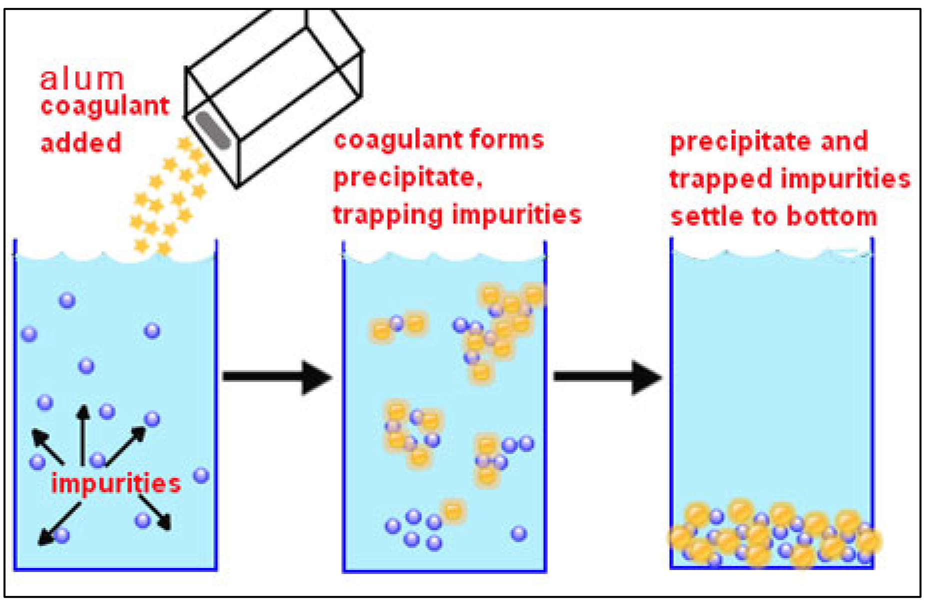


Figure 3-2. Diagram of alum floc adsorption properties. [2]

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:

- Repairs to be completed by end of 2022.
- Once systems are running, evaluate effectiveness through stormwater quality monitoring.

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).
- ✓ Inspection identified several repair needs on all systems. Repairs were expected to be completed by 2022, but are ongoing.

Low Impact Development & Green Infrastructure

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

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

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

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

Public Benefit:

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

Support of Mission, Purpose, and Vision:

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

Strategic Goals:

- Re-landscape raingardens near the Florida Citrus Building by end of 2022.
- Complete construction of additional raingardens along Ave O NE and South of Polk State College by end of 2022.
- 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.
- ✓ 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, Maude, and Lake Conine nature parks.
- Acquire funding to implement stormwater improvements on the newly acquired Lake Howard Nature Park property.
- Apply for funding to implement recreational elements for Lake Conine Nature Park.

Completed Objectives:

- ✓ Completed contractor selection for construction of the Lake Conine Treatment Wetland
- ✓ Completed construction of Lake Conine Nature Park in 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.

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

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

Public Benefit:

Through the City's efforts, it was determined that the floating wetland significantly reduced nitrogen concentrations in the study pond. The absence 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:

- Evaluate continued implementation at Polk State College stormwater pond.
    - Perform cost-benefit analysis to evaluate pollutant load reduction in relation to maintenance needs.

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:

- Seek funding to continue developing educational programming in future grant submission cycles.

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.
- ✓ Completed final report and submitted to the FDEP; grant requirements met and project was closed out.
- ✓ Applied for grant funding in 2021 in an effort to develop additional educational programming/real-world demonstrations for local developers; unfortunately, the application was not selected.

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 5 permit by end of March 2022
- Request all data be submitted to Natural Resources by October 2022

Completed Objectives:

- ✓ Successfully submitted previous year's 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.

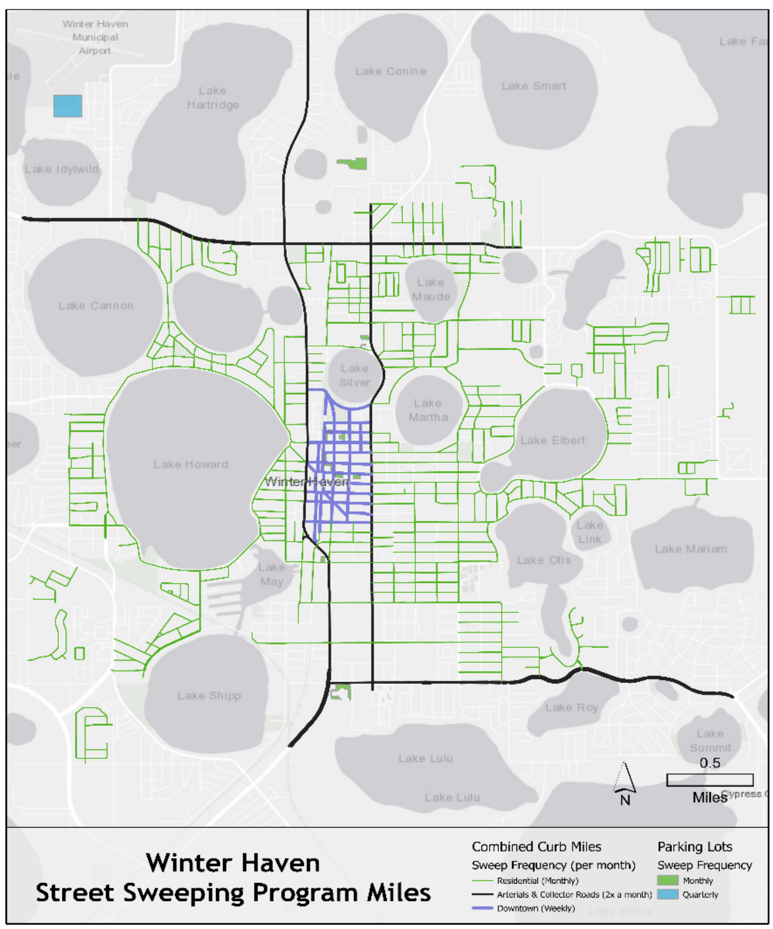


Figure 3-6. Map depicting roadways undergoing street sweeping. Legend indicates sweeping frequency of each street category.

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.
- ✓ Collected 1120.97 cubic yards of debris during the 2021 calendar year.

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.

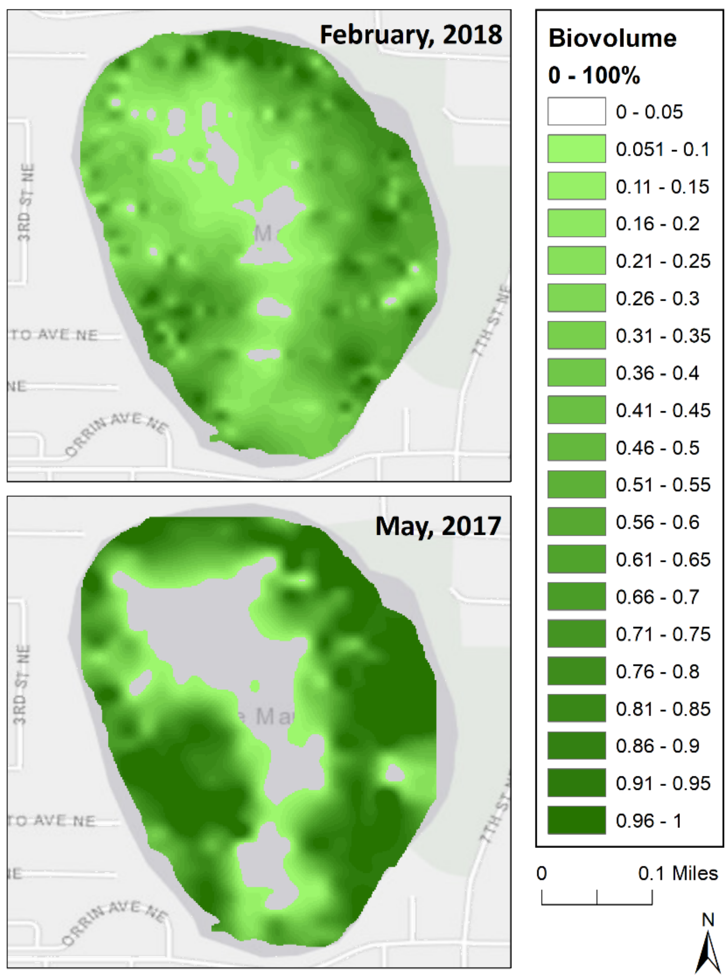


Figure 3-7. Biovolume heat map of Lake Maude. Color scale represents percent of water column occupied by plants.

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 2022, collect annual vegetation data for all study area lakes; continually refine survey methods to ensure accuracy and best practices.
- Draft strategy for using the LVI scoring protocol in conjunction with point-intercept data.
- Continue to represent Winter Haven’s interests in the Polk Regional Aquatic Vegetation Working Group.

Completed Objectives:

- ✓ Completed 2021 vegetation surveys for targeted waterbodies of interest in the study area
- ✓ Continuing to help grow and develop Polk Aquatic Vegetation Working Group
- ✓ Developed 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:

- Purchase additional surface level sensors for 7 area lakes by FY 22-23.

- 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.
- ✓ Budgeted for the purchase of 7 additional sensors to fill public lake data gaps.

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 usually 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^{th} grade. The children are introduced to concepts of lake hydrology and biology and also get to participate in fun activities such as kayaking (Figure 3-8). The Division actively encourages practical education for high-school and college-aged students who are interested in the natural sciences as well through an internship program that focuses on data collection and analysis. Recently, focus has been placed on developing an educational program for students, community groups, HOAs, and members of the general public. This has manifested as community Lake education seminars, re-

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

establishment of the City's guided kayak tour program, and educational events at grade schools.

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).
- Draft business case for implementation of a Natural Resources Volunteer program.
- Continue to support and develop Natural Resources internship program.

Completed Objectives:

- ✓ Developed a more education-oriented approach to City Summer Camp activities.
- ✓ Implemented guided kayak tours for the general public
- ✓ Implemented Lake Education Seminars hosted for community groups to learn more about their local lakes

4- Appendices

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4.2 Supplemental Data

Annual Geometric Mean Data

Chlorophyll-a

Lake Group	Waterbody	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
North Chain of Lakes	Lake Conine	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	24.0
	Lake Fannie	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	13.6
	Lake Haines	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	23.0
	Lake Hamilton	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	37.1
	Lake Rochelle	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	19.0
	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	24.3
	Little Lake Hamilton	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	17.3
	Middle Lake Hamilton	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	29.2
South Chain of Lakes	Lake Cannon	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	18.9
	Lake Eloise	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	33.2
	Lake Hartridge	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	21.1
	Lake Howard	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	25.5
	Lake Idylwild	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	15.8
	Lake Jessie	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	23.3
	Lake Lulu	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	21.3
	Lake May	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	21.3
	Lake Mirror	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	9.2
	Lake Roy	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	20.3
	Lake Shipp	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	27.7
	Lake Summit	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	5.9
	Lake Winterset	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	3.0
	Spring Lake	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	9.2
North Central Lakes	Lake Buckeye	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	3.6
	Lake Idyl		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	38.9
	Lake Martha	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	10.7
	Lake Maude	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	3.9
	Lake Silver	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	4.3
South Central Lakes	Lake Elbert	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	8.2
	Lake Link		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	14.9
	Lake Mariam	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	7.4
	Lake Otis		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	19.3
Outlying Lakes	Lake Blue	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	49.0
	Lake Daisy	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	3.0
	Lake Deer	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	10.8
	Lake Mariana	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	35.6
	Lake Ned	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	10.8
	Lake Pansy	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	12.7

Table 4-1. Annual geometric mean corrected chlorophyll-a concentrations from 2002 – 2021 for all study area lakes.

Total Nitrogen

Lake Group	Waterbody	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
North Chain of Lakes	Lake Conine	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	1211.1
	Lake Fannie	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	842.5
	Lake Haines	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	1289.4
	Lake Hamilton	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	1741.0
	Lake Rochelle	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	1114.2
	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	1320.7
	Little Lake Hamilton	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	1384.8
	Middle Lake Hamilton	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	1563.9
South Chain of Lakes	Lake Cannon	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	1046.3
	Lake Eloise	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	1436.5
	Lake Hartridge	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	1318.5
	Lake Howard	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	1336.7
	Lake Idylwild	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	998.2
	Lake Jessie	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	1043.5
	Lake Lulu	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	1228.9
	Lake May	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	1291.3
	Lake Mirror	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	784.3
	Lake Roy	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	1148.5
	Lake Shipp	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	1234.0
	Lake Summit	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	789.1
	Lake Winterset	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	499.6
	Spring Lake	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	742.7
North Central Lakes	Lake Buckeye	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	663.2
	Lake Idyl		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	1254.0
	Lake Martha	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	656.4
	Lake Maude	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	512.1
	Lake Silver	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	591.3
South Central Lakes	Lake Elbert	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	665.9
	Lake Link		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	1060.7
	Lake Mariam	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	945.7
	Lake Otis		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	953.5
Outlying Lakes	Lake Blue	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	3127.2
	Lake Daisy	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	425.2
	Lake Deer	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	1035.5
	Lake Mariana	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	1759.3
	Lake Ned	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	820.6
	Lake Pansy	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	761.4

Table 4-2. Annual geometric mean total nitrogen concentrations from 2002 – 2021 for all study area lakes.

Total Phosphorus

Lake Group	Waterbody	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
North Chain of Lakes	Lake Conine	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	56.5
	Lake Fannie	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	33.3
	Lake Haines	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	84.5
	Lake Hamilton	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	39.5
	Lake Rochelle	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	44.2
	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	48.5
	Little Lake Hamilton	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	35.3
	Middle Lake Hamilton	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	57.1
South Chain of Lakes	Lake Cannon	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	31.6
	Lake Eloise	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	40.5
	Lake Hartridge	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	30.1
	Lake Howard	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	29.4
	Lake Idylwild	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	36.7
	Lake Jessie	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	46.6
	Lake Lulu	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	45.0
	Lake May	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	57.8
	Lake Mirror	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	29.5
	Lake Roy	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	33.7
	Lake Shipp	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	39.2
	Lake Summit	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	39.3
	Lake Winterset	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	19.5
	Spring Lake	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	32.3
North Central Lakes	Lake Buckeye	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	27.1
	Lake Idyl		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	74.1
	Lake Martha	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	30.9
	Lake Maude	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	22.4
	Lake Silver	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	24.6
South Central Lakes	Lake Elbert	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	26.7
	Lake Link		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	38.4
	Lake Mariam	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	74.4
	Lake Otis		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	41.2
Outlying Lakes	Lake Blue	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	56.8
	Lake Daisy	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	25.7
	Lake Deer	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	36.3
	Lake Mariana	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	30.4
	Lake Ned	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	36.4
	Lake Pansy	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	33.6

Table 4-3. Annual geometric mean total phosphorus from 2002 – 2021 for all study area lakes.

Linear Regression Statistics

Water Quality Trends

Waterbody	Chl-a			Secchi			TN			TP		
	Dir.	R^2	p-value	Dir.	R^2	p-value	Dir.	R^2	p-value	Dir.	R^2	p-value
Lake Blue	-	0.0893	0.177	+	0.0306	0.436	-	0.0451	0.343	-	0.4858	0.000
Lake Buckeye	-	0.6175	0.000	+	0.7863	0.000	-	0.6692	0.000	-	0.3647	0.003
Lake Cannon	-	0.1904	0.042	+	0.3028	0.008	-	0.2553	0.016	-	0.0509	0.312
Lake Conine	-	0.3045	0.008	+	0.5370	0.000	-	0.1715	0.055	-	0.1187	0.116
Lake Daisy	-	0.3793	0.002	+	0.1662	0.060	-	0.1527	0.072	-	0.1056	0.140
Lake Deer	-	0.0902	0.174	+	0.1162	0.121	-	0.2307	0.024	-	0.1035	0.144
Lake Elbert	+	0.4196	0.000	-	0.3254	0.006	+	0.3991	0.002	+	0.1917	0.042
Lake Eloise	-	0.0516	0.309	+	0.3273	0.005	-	0.0927	0.168	-	0.1162	0.121
Lake Fannie	-	0.0352	0.403	+	0.2599	0.015	-	0.0435	0.352	-	0.1327	0.096
Lake Haines	-	0.1133	0.126	+	0.6864	0.000	-	0.4052	0.001	+	0.0013	0.873
Lake Hamilton	+	0.8216	0.000	-	0.4438	0.001	+	0.7914	0.000	-	0.4496	0.001
Lake Hartridge	+	0.6167	0.000	-	0.6587	0.000	+	0.6005	0.000	+	0.0117	0.633
Lake Howard	-	0.3102	0.007	+	0.4470	0.001	-	0.4341	0.001	-	0.0566	0.287
Lake Idyl	+	0.1293	0.119	-	0.0458	0.365	+	0.1811	0.061	+	0.2693	0.019
Lake Idylwild	-	0.1074	0.137	+	0.3492	0.004	-	0.0042	0.774	-	0.1052	0.141
Lake Jessie	-	0.0001	0.969	+	0.1274	0.103	+	0.0090	0.674	-	0.0464	0.336
Lake Link	-	0.0752	0.304	+	0.0441	0.435	-	0.2852	0.033	-	0.0217	0.586
Lake Lulu	-	0.3381	0.005	+	0.5615	0.000	-	0.2211	0.027	-	0.2847	0.011
Lake Mariam	+	0.0358	0.399	+	0.1269	0.104	-	0.0897	0.176	+	0.0150	0.588
Lake Mariana	+	0.1560	0.069	-	0.2903	0.010	+	0.1673	0.059	-	0.1773	0.051
Lake Martha	+	0.5726	0.000	-	0.4346	0.001	+	0.1908	0.042	+	0.3226	0.006
Lake Maude	-	0.3994	0.002	+	0.5300	0.000	-	0.5521	0.000	-	0.2266	0.025
Lake May	-	0.3923	0.002	+	0.6674	0.000	-	0.4927	0.000	-	0.4150	0.001
Lake Mirror	-	0.7068	0.000	+	0.5424	0.000	-	0.7132	0.000	-	0.2161	0.029
Lake Ned	+	0.5607	0.000	-	0.3504	0.004	-	0.0036	0.790	+	0.3450	0.004
Lake Otis	-	0.0446	0.432	-	0.0018	0.875	-	0.1577	0.128	+	0.0203	0.599
Lake Pansy	+	0.3336	0.005	+	0.0016	0.858	+	0.0220	0.510	+	0.1780	0.050
Lake Rochelle	-	0.4398	0.001	+	0.4923	0.000	-	0.2582	0.016	-	0.4428	0.001
Lake Roy	-	0.3306	0.005	+	0.4271	0.001	-	0.2433	0.020	-	0.0997	0.152
Lake Shipp	-	0.4525	0.001	+	0.8216	0.000	-	0.6029	0.000	-	0.3302	0.005
Lake Silver	-	0.0429	0.368	-	0.0237	0.505	-	0.0688	0.251	-	0.0017	0.858
Lake Smart	-	0.0311	0.499	+	0.2745	0.031	+	0.0335	0.482	-	0.1413	0.137
Lake Summit	-	0.5925	0.000	+	0.6675	0.000	-	0.4312	0.001	-	0.0004	0.925
Lake Winterset	-	0.7914	0.000	+	0.7317	0.000	-	0.7105	0.000	-	0.2252	0.026
Little Lake Hamilton	+	0.0534	0.313	-	0.0225	0.517	+	0.0787	0.218	-	0.0751	0.229
Middle Lake Hamilton	+	0.0087	0.680	+	0.1792	0.050	-	0.0722	0.227	-	0.3043	0.008
Spring Lake	-	0.3757	0.002	+	0.4410	0.001	-	0.4260	0.001	-	0.2441	0.019

Table 4-4. Trendline statistics for linear regressions of chl-a, TN, TP, and Secchi depth from 2000 - 2021. Stats include regression direction (+/-), R-squared value, and p-value.

Surface Level vs. Water Quality

Waterbody	Chl-a			Secchi			TN			TP		
	Dir.	R2	p-value	Dir.	R2	p-value	Dir.	R2	p-value	Dir.	R2	p-value
Lake Blue	-	0.006	0.740	+	0.002	0.830	-	0.081	0.200	+	0.010	0.660
Lake Buckeye	-	0.020	0.540	+	0.171	0.056	-	0.041	0.370	+	0.010	0.676
Lake Cannon	-	0.610	0.002	+	0.386	0.023	-	0.550	0.004	-	0.151	0.189
Lake Conine	-	0.350	0.004	+	0.533	0.000	-	0.314	0.007	-	0.102	0.146
Lake Daisy	-	0.053	0.315	+	0.054	0.310	-	0.009	0.684	+	0.011	0.653
Lake Deer	-	0.124	0.107	+	0.107	0.138	-	0.060	0.270	+	0.041	0.368
Lake Elbert	+	0.315	0.007	-	0.466	0.000	+	0.289	0.010	+	0.193	0.041
Lake Eloise	-	0.024	0.612	+	0.006	0.800	-	0.073	0.371	-	0.013	0.710
Lake Fannie	-	0.588	0.000	+	0.809	0.000	-	0.724	0.000	-	0.868	0.000
Lake Haines	-	0.003	0.794	+	0.263	0.015	-	0.244	0.020	+	0.233	0.023
Lake Hamilton	-	0.007	0.734	+	0.094	0.215	+	0.002	0.853	-	0.012	0.661
Lake Hartridge	-	0.039	0.517	-	0.044	0.491	-	0.040	0.512	-	0.346	0.035
Lake Howard	-	0.235	0.022	+	0.191	0.042	-	0.449	0.001	-	0.024	0.489
Lake Idyl	-	0.080	0.227	+	0.053	0.331	-	0.049	0.350	-	0.003	0.819
Lake Idylwild	-	0.681	0.001	+	0.855	0.000	-	0.915	0.000	-	0.097	0.301
Lake Jessie	-	0.379	0.025	+	0.353	0.032	-	0.553	0.004	-	0.015	0.695
Lake Link	-	0.172	0.110	+	0.097	0.240	-	0.524	0.002	-	0.415	0.007
Lake Lulu	-	0.138	0.212	+	0.413	0.018	-	0.453	0.012	-	0.074	0.370
Lake Mariam	+	0.001	0.906	+	0.016	0.575	-	0.114	0.124	-	0.044	0.352
Lake Mariana	-	0.034	0.548	-	0.002	0.873	-	0.137	0.213	-	0.004	0.833
Lake Martha	+	0.219	0.032	-	0.031	0.431	+	0.046	0.340	+	0.172	0.061
Lake Maude	-	0.091	0.172	+	0.157	0.068	-	0.248	0.018	-	0.112	0.128
Lake May	-	0.762	0.000	+	0.622	0.001	-	0.794	0.000	-	0.616	0.002
Lake Mirror	-	0.135	0.217	+	0.157	0.180	-	0.544	0.004	-	0.113	0.262
Lake Ned	+	0.202	0.036	+	0.013	0.615	-	0.171	0.056	+	0.040	0.374
Lake Otis	-	0.341	0.018	+	0.398	0.009	-	0.570	0.001	-	0.129	0.172
Lake Pansy	+	0.017	0.569	+	0.274	0.012	-	0.144	0.081	+	0.011	0.636
Lake Rochelle	-	0.334	0.005	+	0.328	0.005	-	0.232	0.023	-	0.096	0.161
Lake Roy	-	0.157	0.180	+	0.359	0.030	-	0.414	0.018	-	0.001	0.941
Lake Shipp	-	0.207	0.034	+	0.318	0.006	-	0.521	0.000	-	0.111	0.130
Lake Silver	+	0.067	0.256	-	0.046	0.350	-	0.000	0.955	+	0.000	0.977
Lake Smart	-	0.866	0.000	+	0.800	0.000	-	0.869	0.000	-	0.216	0.150
Lake Summit	-	0.361	0.030	+	0.331	0.040	-	0.378	0.025	+	0.015	0.692
Lake Winterset	-	0.255	0.078	+	0.272	0.068	-	0.440	0.014	-	0.001	0.943
Little Lake Hamilton	-	0.537	0.001	+	0.519	0.001	-	0.448	0.003	-	0.522	0.001
Middle Lake Hamilton	-	0.541	0.001	+	0.661	0.000	-	0.540	0.001	-	0.486	0.001
Spring Lake	+	0.118	0.251	-	0.176	0.153	+	0.110	0.268	+	0.233	0.095

Table 4-5. Trend statistics for linear regressions of lake surface levels against chl-a, TN, TP, and Secchi depth from 2000 - 2021. Stats include regression direction (+/-), R-squared value, and p-value.

Onsite Sewage Treatment & Disposal by Lake

Waterbody	OSTD Count	Density (OSTD/acre)
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	2021
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	4.8
Lake Cannon		93.8	65.7	5.5	0.8	13.6	137.0	66.9	5.3	8.0	10.6	1.5
Lake Conine	7.0	47.5	26.3	16.5	38.2	86.6	74.4	227.8	87.9	103.6	46.4	57.0
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	27.6
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	10.0
Lake Fannie	42.0	76.5	37.0	47.0	38.3	126.8	72.4	216.7	201.6	667.0	192.9	17.1
Lake Haines		417.8	81.3	53.5	87.8	111.5	23.4	69.8	160.0	286.4	74.7	225.7
Lake Hamilton	10.5	3.5	8.0	5.5	8.0	29.5	13.9	13.0	22.7	8.0	26.1	49.9
Lake Hartridge		5.3		2.5	8.6	9.8	0.3		1.0	4.7		4.0
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	56.0
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	0.5
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	2.0
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	11.8
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	1.5
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	10.5
Lake Roy	3.5	15.3	3.5	7.3	7.5	6.9	27.7	16.0	43.5	23.4	0.3	0.1
Lake Shipp	33.0	23.8	10.5	10.0	1.7	2.8	102.7	2.1	8.3	6.3	3.2	62.0
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	9.0
Lake Summit	1.8	15.0	12.0	4.5	20.2	2.2	47.7	8.6	0.5		22.4	
Lake Winterset		27.3	6.5	5.8	60.2	28.9	553.4	10.8		24.0	44.0	35.8

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

Table 4-8. List of aquatic plant species identified in Winter Haven Lakes.

4.3 List of Figures

4.4 List of Tables

5- Water Quality Management Plans

Summary

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

Lake Health Index (LHI)

An objective means of prioritizing management efforts for each waterbody through calculation of a numeric score. This score is calculated as an average of seven individual category scores. Individual category scores can range from 0 to 3, with a 3 representing ideal conditions for that category. As an average of the category scores, the aggregate LHI also ranges from 0 to 3. A description of the categories as well as how they are scored can be found on pages 34 and 35 in the Data Presentation and Analysis section of this report.

Status & Priority Level

The lake status is a brief narrative description of each waterbody's condition based on the impairment and water quality trend scores from the LHI. The priority level is a ranking system based on the status and LHI score of each waterbody. Priority level categories range from Low, Moderate, High, to Very High. The status and priority level info provides a means to rapidly and objectively prioritize management efforts for all lakes in the study area.

Lake Info

Provides basic physical and regulatory characteristics of each waterbody. The physical characteristics include lake surface area, volume, ratio of surface area to volume, average depth, and area of land that discharges to the lake. Also displayed is whether the waterbody currently possesses a Total Maximum Daily Load (TMDL) regulatory requirement as well as the nutrient (pollutant) of concern that is limiting water quality impacts. Much of this information can be found scattered throughout the Data Presentation and Analysis section of the report.

Water Quality Impacts/Challenges

A brief narrative describing the known issues or challenges that are potentially impacting the health of each waterbody. The issues are categorized (e.g. stormwater loading, invasive plant issues, or nearby septic systems) based on the means by which water quality may be impacted. Lake managers may utilize this info to narrow down the types of management strategies that may be effective to improve or maintain lake health.

Existing Best Management Practices

A list of existing management practices that City staff has previously implemented or is currently implementing to mitigate the known water quality impacts in the selected waterbody. This list provides a record of actions City staff have utilized, but does not necessarily indicate the efficacy of these actions. The list can be used to focus future management efforts.

Future Best Management Practices

A list of proposed management efforts based on the conclusions derived from the other information in the water quality management plan. This list may include structural practices such as construction of stormwater treatment areas or effluent treatment stations; non-structural practices such as implementation or expansion of street sweeping; or exploratory practices such as collection and analysis of various data or cost-benefit of implementing any structural/non-structural practices.

Waterbody

Lake Blue

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	2	2	3	2	2	3	0	1.75

Status	Priority Level
Currently impaired, but water quality trends show slight improvement.	High

Lake Info

Surface Area (acres)	54.3
Volume (cu.meter)	331368
SA:V Ratio	0.202047
Mean Depth (ft)	4.57
Drainage Basin Area (acres)	128
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Hydrology	While analysis has not determined that surface level correlates directly with water quality, it is likely that the shallow depth of this lake may allow for increased suspension of sediments.
Stormwater Pollutant Loading	Nutrient loading rates: 871.5 lbs/yr TN and 154.2 lbs/yr TP. This load primarily originates outside City limits.

Existing Best Management Practices

Aquatic Vegetation Management	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 Best Management Practices

1	Explore aquatic vegetation planting initiatives to improve submerged macrophyte abundance.
2	Develop plan to evaluate internal load from legacy sediments.
3	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.

Waterbody

Lake Buckeye

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	3	3	3	1	1	2.50

Status	Priority Level
Not currently impaired and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	72.4
Volume (cu.meter)	603451
SA:V Ratio	0.147931
Mean Depth (ft)	6.73
Drainage Basin Area (acres)	233.6
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment	Management involved treating 4.8 acres of invasive species in 2020. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is currently in a maintenance state.
Onsite Sewage Treatment & Disposal	There are 42 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates from 8 sub-basins: 867.1 lbs/yr TN and 154.8 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Street Sweeping	5.6 miles of residential and arterial roads are swept on a monthly basis in Lake Buckeye's drainage basin.

Future Best Management Practices

1	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.
2	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.

Waterbody

Lake Cannon

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
2	3	3	2	3	3	1	1	2.25

Status	Priority Level
Currently impaired, but water quality trends show improvement.	Moderate

Lake Info

Surface Area (acres)	338.2
Volume (cu.meter)	4545479
SA:V Ratio	0.0917396
Mean Depth (ft)	9.59
Drainage Basin Area (acres)	695.4
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

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.

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Invasive Species Treatment	Management involved treating 1.5 acres of invasive plants in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Onsite Sewage Treatment & Disposal	There are 338 known septic systems within this drainage basin--constituting a high density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates from 5 distinct sub-basins: 3863 lbs/yr TN and 637.8 lbs/yr TP. The City has implemented several BMPs in this basin to mitigate some of this load.

Future Best Management Practices

1	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.
2	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.
3	Explore implementation of Green Infrastructure in high nutrient loading areas within the drainage basin.

Waterbody

Lake Conine

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	3	2	2	3	2	1	3	2.00

Status	Priority Level
Currently Impaired, but water quality trends show improvement.	Moderate

Lake Info

Surface Area (acres)	235.4
Volume (cu.meter)	2723797
SA:V Ratio	0.10656
Mean Depth (ft)	9.03
Drainage Basin Area (acres)	559.1
Nutrient TMDL	Yes
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	Received an undetermined quantity of discharge from Wastewater Treatment Plant #2 as recently as 1992. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Hydrology	Analysis has determined that surface level correlates directly with water quality. It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Invasive Species Treatment	Management involved treating 57 acres of hydrilla using herbicides in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Stormwater Pollutant Loading	Nutrient loading rates from the 7 distinct drainage basins: 2836 lbs/yr TN and 474 lbs/yr TP. Stormwater runoff from the urban drainage basins to the south has historically been untreated.

Existing Best Management Practices

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.
Green Infrastructure	In 2021, the City completed 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.

Future Best Management Practices

1	Evaluate pollutant reduction efficiency of recently constructed Conine wetland by end of 2023.
2	Develop plan to evaluate internal load from legacy sediments
3	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.

Waterbody

Lake Daisy

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	2	2	2	2	2	2	2.25

Status	Priority Level
Not currently impaired and water quality trends show slight improvement.	Low

Lake Info

Surface Area (acres)	137.3
Volume (cu.meter)	1429257
SA:V Ratio	0.118447
Mean Depth (ft)	8.41
Drainage Basin Area (acres)	219.4
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Onsite Sewage Treatment & Disposal	There are 33 known septic systems within this drainage basin--constituting a low-moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates: 1717.7 lbs/yr TN and 382.2 lbs/yr TP. This load primarily originates outside City limits.

Existing Best Management Practices

Aquatic Vegetation Management	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 Best Management Practices

1	Explore aquatic vegetation planting initiatives to improve submerged macrophyte abundance.
2	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.

Waterbody

Lake Deer

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	2	3	2	2	3	0	0	1.50

Status	Priority Level
Currently impaired, but water quality trends show slight improvement.	High

Lake Info

Surface Area (acres)	116.9
Volume (cu.meter)	1036382
SA:V Ratio	0.139078
Mean Depth (ft)	7.6
Drainage Basin Area (acres)	260.5
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment	Management involved treating 27.6 acres of invasive species in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Onsite Sewage Treatment & Disposal	There are 41 known septic systems within this drainage basin--constituting a low-moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates from 2 sub-basins: 1451.1 lbs/yr TN and 261.2 lbs/yr TP. Much of this load originates outside City limits.

Existing Best Management Practices

Aquatic Vegetation Management	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 Best Management Practices

1	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.
2	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.
3	Explore construction of green infrastructure within the drainage basin.

Waterbody

Lake Elbert

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	0	0	0	0	3	0	2	1.00

Status	Priority Level
Not currently impaired, but water quality trends show substantial deterioration.	High

Lake Info

Surface Area (acres)	165.8
Volume (cu.meter)	2868995
SA:V Ratio	0.0712554
Mean Depth (ft)	11.28
Drainage Basin Area (acres)	439.8
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that increased surface level correlates with increased nutrient concetrations. It is likely that stormwater is a major contributor of pollutant loading.
Stormwater Pollutant Loading	Nutrient loading rates from 50 sub-basins: 2365.8 lbs/yr TN and 385.1 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Green Infrastructure	The City has constructed 2 raingardens that capture stormwater runoff along Lake Elbert's northern shoreline.
SAIP	Stormwater Assessment & Improvement Project: Identified priority area for green infrastructure to reduce flooding and improve water quality.
Street Sweeping	33.5 miles of downtown, residential, and arterial/collector roadways are swept in Lake Elbert's drainage basin on a monthly basis.

Future Best Management Practices

1	Pursue funding to manage stormwater from the parcels identified as part of the SAIP.
2	Explore construction of green infrastructure within the drainage basin.
3	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.

Waterbody

Lake Eloise

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	2	2	2	3	2	2	0	1.63

Status	Priority Level
Currently impaired, but water quality trends show slight improvement.	High

Lake Info

Surface Area (acres)	1181.3
Volume (cu.meter)	19173944
SA:V Ratio	0.0759647
Mean Depth (ft)	11.42
Drainage Basin Area (acres)	800.1
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	Received an undetermined quantity of discharge from the Cypress Gardens Wastewater Treatment Plant as recently as 1975. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Invasive Species Treatment	Management involved treating 10 acres of invasive plants in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Onsite Sewage Treatment & Disposal	There are 186 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates: 3875.24 lbs/yr TN and 665.4 lbs/yr TP. Much of this load originates outside of City limits.

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 Best Management Practices

1	Develop plan to evaluate internal load from legacy sediments.
2	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.
3	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.

Waterbody

Lake Fannie

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	2	2	2	3	2	1	2	2.13

Status	Priority Level
Not currently impaired and water quality trends show slight improvement.	Low

Lake Info

Surface Area (acres)	800.3
Volume (cu.meter)	7.18892e+06
SA:V Ratio	0.137263
Mean Depth (ft)	6.94
Drainage Basin Area (acres)	1368
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

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 to improve water quality while preventing flooding.

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality. It is likely that due to morphology, periods of lower surface level can lead to suspension of organic sediments and an increase in nutrient concentrations.
Invasive Species Treatment	Management involved treating 17 acres of hydrilla using herbicides in 2021. Large-scale invasive treatments can result in nutrient concentration increases.

Future Best Management Practices

1	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.
2	Development of One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes management of higher surface levels.

Waterbody

Lake Haines

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
1	2	3	1	3	1	2	2	1.88

Status	Priority Level
Currently impaired, but water quality trends show some improvement.	Moderate

Lake Info

Surface Area (acres)	687.5
Volume (cu.meter)	9104277
SA:V Ratio	0.0931087
Mean Depth (ft)	9.65
Drainage Basin Area (acres)	1630.4
Nutrient TMDL	Yes
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	Received an undetermined quantity of discharge from the Lake Alfred Wastewater Treatment Plant as recently as 1992. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Hydrology	Analysis has determined that surface level correlates directly with water quality. It is likely that due to morphology, periods of lower surface level can lead to suspension of organic sediments and an increase in nutrient concentrations.
Invasive Species Treatment	Management involved treating 225 acres of hydrilla and water hyacinth using herbicides in 2021. Large-scale invasive treatments can result in nutrient concentration increases.

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 Best Management Practices

1	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.
2	Develop plan to evaluate internal load from legacy sediments.

Waterbody

Lake Hamilton

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
1	0	0	3	0	1	2	3	1.25

Status	Priority Level
Currently impaired and water quality trends show significant deterioration.	Very High

Lake Info

Surface Area (acres)	2168.7
Volume (cu.meter)	16852885
SA:V Ratio	0.158668
Mean Depth (ft)	6.39
Drainage Basin Area (acres)	2008.8
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Internal Pollutant Loading	Due to the decline in phosphorus in conjunction with increasing chlorophyll-a and nitrogen, it is suspected that nitrogen-fixing cyanobacteria may be the cause of water quality deterioration.
Lack of Vegetation Coverage	PAC was only 10% in 2021. In addition to providing fish and wildlife habitat, healthy vegetation coverage also buffers against increases in nutrient concentrations and stabilizes lake sediments from suspension.
Onsite Sewage Treatment & Disposal	There are 62 known septic systems within this drainage basin--constituting a moderate-low density. More analysis is needed to determine if these are a potential pollutant source.

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 three years. 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 Best Management Practices

1	Work with local stakeholders to identify and mitigate sources of nutrient concentration increases. Also explore treatments for harmful algal blooms.
2	Explore aquatic vegetation planting initiatives to improve submerged macrophyte abundance.

Waterbody

Lake Hartridge

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
1	0	0	1	0	3	3	2	1.25

Status	Priority Level
Currently impaired and water quality trends show substantial deterioration.	Very High

Lake Info

Surface Area (acres)	446.4
Volume (cu.meter)	5504605
SA:V Ratio	0.099991
Mean Depth (ft)	9.01
Drainage Basin Area (acres)	476
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment	Management involved treating 4 acres of invasive plants in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is currently in a maintenance state.
Onsite Sewage Treatment & Disposal	There are 65 known septic systems within this drainage basin--constituting a moderate-low density. More analysis is needed to determine if these are a potential pollutant source.
Stormwater Pollutant Loading	Nutrient loading rates from 2 sub-basins: 2658.3 lbs/yr TN and 458.9 lbs/yr TP. Much of the stormwater load is treated by the nature park to the south.

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.
Green Infrastructure	The City has implemented Lake Hartridge Nature Park that treats stormwater from 73 acre southern drainage basin.
Street Sweeping	17.3 miles of residential and arterial roads are swept on a monthly basis in Lake Hartridge's southern drainage sub-basin.

Future Best Management Practices

1	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.
2	Continue to maintain the Lake Hartridge Nature Park to ensure its pollutant reduction efficiency.
3	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.

Waterbody

Lake Howard

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
1	3	3	2	3	3	3	1	2.38

Status	Priority Level
Currently impaired, but water quality trends show substantial improvement.	Moderate

Lake Info

Surface Area (acres)	631.6
Volume (cu.meter)	7209568
SA:V Ratio	0.108018
Mean Depth (ft)	8.71
Drainage Basin Area (acres)	1238.9
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	Received an undetermined quantity of discharge from the Jan Phyl Village Wastewater Treatment Plant as recently as 1977. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Hydrology	Analysis has determined that surface level correlates directly with water quality.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Stormwater Pollutant Loading	Nutrient loading rates from 53 sub-basins: 6321.3 lbs/yr TN and 1097.5 lbs/yr TP. Some of this load is treated by various stormwater BMPs throughout the basin.

Existing Best Management Practices

Alum Treatment	Injection points in three high-loading sub-basins in the eastern area. Alum treatment was designed to significantly reduce TP loads in those sub-basins; this system is currently in the process of repair.
Green Infrastructure	12 raingardens/infiltration systems treat stormwater to the east and South Lake Howard Nature Park was constructed to treat stormwater from a 700 acre basin to the west.
SAIP	Stormwater Assessment & Improvement Project: Identified priority area for green infrastructure in southern sub-basin to prevent flooding and improve water quality.
Street Sweeping	50.6 miles of downtown, residential, and arterial roads are swept on a monthly basis around the lake perimeter.

Future Best Management Practices

1	Complete alum system repair – by end of 2021. Evaluate pollutant reduction of systems.
2	Develop plan to evaluate internal load from legacy sediments.
3	Continue to maintain the Lake Howard Nature Park and other green infrastructure to ensure its pollutant reducti..
4	Design stormwater improvements at the newly purchased parcel adjacent to Lake Howard Nature Park.
5	Pursue funding to manage stormwater from the parcels identified as part of the SAIP.

Waterbody

Lake Idyl

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	1	1	0	1	3	0	0	0.75

Status	Priority Level
Currently impaired and water quality trends show some deterioration.	High

Lake Info

Surface Area (acres)	19
Volume (cu.meter)	133383
SA:V Ratio	0.175637
Mean Depth (ft)	6.07
Drainage Basin Area (acres)	179.5
Nutrient TMDL	No
Limiting Nutrient	Co-limited

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.
SAIP	Stormwater Assessment & Improvement Project: Identified priority area within the northern residential basin where green infrastructure could be implemented to reduce flooding and improve water quality.
Street Sweeping	4 miles of residential and arterial roads are swept in Lake Idyl's drainage basin on a monthly basis.

Water Quality Impacts/Challenges

Stormwater Pollutant Loading	Nutrient loading rates from 3 sub-basins: 934.9 lbs/yr TN and 154.5 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

Future Best Management Practices

1	Complete construction of green infrastructure within basin by end of 2021 (pending SWFWMD approval).
2	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.

Waterbody

Lake Idylwild

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
2	2	2	2	3	3	1	2	2.13

Status	Priority Level
Currently impaired, but water quality trends show slight improvement.	High

Lake Info

Surface Area (acres)	95.2
Volume (cu.meter)	1028780
SA:V Ratio	0.114098
Mean Depth (ft)	8.26
Drainage Basin Area (acres)	130.3
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

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.
Street Sweeping	Approximately 6 miles of arterial roadways are swept on a monthly basis in the small southern drainage basin.

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Onsite Sewage Treatment & Disposal	There are 33 known septic systems within this drainage basin--constituting a low density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates from 2 sub-basins: 669.1 lbs/yr TN and 121.6 lbs/yr TP. Some of this load is treated by various stormwater BMPs throughout the basin.

Future Best Management Practices

1	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.
2	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.

Waterbody

Lake Jessie

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	2	1	2	2	3	1	1	1.50

Status	Priority Level
Currently impaired with no water quality trends.	High

Lake Info

Surface Area (acres)	185
Volume (cu.meter)	2093316
SA:V Ratio	0.108968
Mean Depth (ft)	7.93
Drainage Basin Area (acres)	784.8
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

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.

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	from a Wastewater Treatment Plant; however data does not exist for the source. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Hydrology	Analysis has determined that surface level correlates directly with water quality.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Invasive Species Treatment	Management involved treating 56 acres of hydrilla in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Onsite Sewage Treatment & Disposal	There are 111 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates from a large drainage basin: 3871.2 lbs/yr TN and 652.3 lbs/yr TP. Most of this load is contributed from outside City limits.

Future Best Management Practices

1	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.
2	Develop plan to evaluate internal load from legacy sediments.
3	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.

Waterbody

Lake Link

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	2	3	2	2	2	1	1	2.00

Status	Priority Level
Not currently impaired and water quality trends show slight improvement.	Low

Lake Info

Surface Area (acres)	27.7
Volume (cu.meter)	317016
SA:V Ratio	0.107736
Mean Depth (ft)	8.84
Drainage Basin Area (acres)	66.5
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Invasive Species Treatment	While no invasive plants were treated in 2021, water hyacinth was observed. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is in a maintenance state.
Stormwater Pollutant Loading	Nutrient loading rates from 5 sub-basins: 197.2 lbs/yr TN and 31.7 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Street Sweeping	2.9 miles of residential and arterial roadways are swept in the Lake Link drainage basin on a monthly basis.

Future Best Management Practices

1	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.

Waterbody

Little Lake Hamilton

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
1	1	1	2	1	2	2	3	1.63

Status	Priority Level
Currently impaired with no water quality trends.	High

Lake Info

Surface Area (acres)	359.6
Volume (cu.meter)	3818505
SA:V Ratio	0.116115
Mean Depth (ft)	8.46
Drainage Basin Area (acres)	656.2
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality. This is likely due to increased flushing of nutrients during wetter periods. Maintaining a higher surface level should result in improved water quality.
Stormwater Pollutant Loading	Nutrient loading rates: 1471.7 lbs/yr TN and 198.04 lbs/yr TP. Despite being smaller, the land uses within this drainage basin contribute greater pollutant loads.

Existing Best Management Practices

Surface Level Management	The Southwest Florida Water Management District modified its existing surface level operation guidelines for the Northern Chain of Lakes in 2017. 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 Best Management Practices

1	Development of One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes management of higher surface levels.
2	Work with local stakeholders to identify and mitigate sources of nutrient concentration increases.

Waterbody

Lake Lulu

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	3	3	3	3	3	2	2	2.38

Status	Priority Level
Currently impaired, but water quality trends show substantial improvement.	Moderate

Lake Info

Surface Area (acres)	307.5
Volume (cu.meter)	2582361
SA:V Ratio	0.146822
Mean Depth (ft)	6.76
Drainage Basin Area (acres)	692.9
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Existing Best Management Practices

Alum Treatment	Injection points in three high-loading sub-basins in the eastern area. Alum treatment was designed to significantly reduce TP loads in those sub-basins; this system is currently in the process of repair.
Baffle Box	Polk County installed a baffle box to capture large quantities of solid waste and debris from storm systems draining Cypress Gardens Blvd.
SAIP	Stormwater Assessment & Improvement Project: Identified priority site for green infrastructure within the northernmost basin to reduce flooding and improve water quality.
Street Sweeping	11.6 miles of residential and arterial roads are swept on a monthly basis.

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	Received an undetermined quantity of discharge from City Wastewater and several citrus and fertilizer processing facilities as recently as 1977. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Hydrology	Analysis has determined that surface level correlates directly with some water quality parameters.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Invasive Species Treatment	Management involved treating 0.5 acres of water hyacinth in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is currently in a maintenance state.
Stormwater Pollutant Loading	Nutrient loading rates from 13 sub-basins: 2791.5 lbs/yr TN and 483 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

Future Best Management Practices

1	Complete alum system repair – by end of 2021. Evaluate pollutant reduction of systems.
2	Pursue funding to manage stormwater from the parcels identified as part of the SAIP.
3	Develop plan to evaluate internal load from legacy sediments.
4	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.

Waterbody

Lake Mariam

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	1	2	1	2	3	3	2	2.13

Status	Priority Level
Not currently impaired with no water quality trends	Low

Lake Info

Surface Area (acres)	203.7
Volume (cu.meter)	1012607
SA:V Ratio	0.248035
Mean Depth (ft)	4.65
Drainage Basin Area (acres)	418.4
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Onsite Sewage Treatment & Disposal	There are 132 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates: 1607.4 lbs/yr TN and 274.8 lbs/yr TP. The City has implemented BMPs to mitigate this load.

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.
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.

Future Best Management Practices

1	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.
2	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.

Waterbody

Lake Mariana

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	1	1	2	0	2	2	2	1.25

Status	Priority Level
Currently impaired with water quality trends showing slight deterioration.	High

Lake Info

Surface Area (acres)	515.6
Volume (cu.meter)	6449864
SA:V Ratio	0.0985656
Mean Depth (ft)	8.99
Drainage Basin Area (acres)	1417.6
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment	Management involved treating 2 acres of water hyacinth in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is in a maintenance state.
Onsite Sewage Treatment & Disposal	There are 158 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates: 6530.8 lbs/yr TN and 1160.6 lbs/yr TP. This load primarily originates outside City limits.

Existing Best Management Practices

Aquatic Vegetation Management	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 Best Management Practices

1	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.
2	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.

Waterbody

Lake Martha

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	0	0	0	0	1	3	2	1.13

Status	Priority Level
Not currently impaired, but water quality trends show substantial deterioration.	High

Lake Info

Surface Area (acres)	82.5
Volume (cu.meter)	1408454
SA:V Ratio	0.0722228
Mean Depth (ft)	10.21
Drainage Basin Area (acres)	224.4
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Diesel Spill	This waterbody received an indeterminate quantity of commercial-grade diesel fuel from the Winter Haven Hospital generator tanks in 2019. There were numerous ecological and water quality impacts from the spill as well as disturbance via the remediation effort.
Lack of Vegetation Coverage	PAC was only 4% in 2021. In addition to providing fish and wildlife habitat, healthy vegetation coverage also buffers against increases in nutrient concentrations and stabilizes lake sediments from suspension.
Stormwater Pollutant Loading	Nutrient loading rates from 14 sub-basins: 1217.1 lbs/yr TN and 199.1 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

Existing Best Management Practices

Floating 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.
Street Sweeping	7.15 miles of residential and arterial/collector roads are swept in Lake Martha's drainage basin on a monthly basis.

Future Best Management Practices

1	Complete construction of green infrastructure within basin by end of 2021 (pending SWFWMD approval).
2	Continue to monitor lake for any lasting impacts from diesel spill.
3	Explore aquatic vegetation planting initiatives to improve submerged macrophyte abundance.

Waterbody

Lake Maude

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	3	3	3	1	1	2.50

Status	Priority Level
Not currently impaired and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	51
Volume (cu.meter)	509872
SA:V Ratio	0.123331
Mean Depth (ft)	8.18
Drainage Basin Area (acres)	335.5
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Invasive Species Treatment	Underwent no invasive species treatment in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is currenlty in a maintenance state.
Stormwater Pollutant Loading	Nutrient loading rates from 14 sub-basins: 1900.5 lbs/yr TN and 320 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Green Infrastructure	Lake Maude Nature Park provides treatment through its natural wetland as well as constructed stormwater retention ponds.
Street Sweeping	15.7 miles of residential and arterial/collector roads are swept in Lake Maude's drainage basin on a monthly basis.

Future Best Management Practices

1	Continue to maintain the Lake Maude Nature Park and other green infrastructure to ensure their pollutant reduction efficiency.
2	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.
3	Complete construction of green infrastructure within basin by end of 2021 (pending SWFWMD approval).

Waterbody

Lake May

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	3	3	3	3	3	0	3	2.25

Status	Priority Level
Currently impaired, but water quality trends show substantial improvement.	Moderate

Lake Info

Surface Area (acres)	50.5
Volume (cu.meter)	241790
SA:V Ratio	0.257523
Mean Depth (ft)	5.28
Drainage Basin Area (acres)	301.8
Nutrient TMDL	Yes
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	Received an undetermined quantity of discharge from the Imhoff Wastewater Treatment plant as well as citrus and dairy processing facilities. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Hydrology	Analysis has determined that surface level correlates directly with water quality.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Invasive Species Treatment	Management involved treating 12 acres of hydrilla and water hyacinth in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Stormwater Pollutant Loading	Nutrient loading rates from 6 sub-basins: 1732.7 lbs/yr TN and 292.9 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

Existing Best Management Practices

Alum Treatment	Injection points in three high-loading sub-basins in the eastern area. Alum treatment was designed to significantly reduce TP loads in those sub-basins; this system is currently in the process of repair.
Aquatic Vegetation Management	The City monitors aquatic vegetation and shares this data with FWC and Polk County to assist with invasive treatment planning efforts.
Green Infrastructure	The 7th Street improvement project included swales to trap and infiltrate stormwater. Raingardens have also been constructed at the City's Utility Office.
Street Sweeping	27.3 miles of downtown, residential, and arterial roads are swept on a monthly basis.

Future Best Management Practices

1	Develop plan to evaluate internal load from legacy sediments (as part of muck removal project).
2	Complete alum system repair – by end of 2021. Evaluate pollutant reduction of systems.
3	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.

Waterbody

Middle Lake Hamilton

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	1	2	3	3	1	2	3	1.88

Status	Priority Level
Currently impaired, but water quality trends show some improvement.	Moderate

Lake Info

Surface Area (acres)	102.6
Volume (cu.meter)	525059
SA:V Ratio	0.240936
Mean Depth (ft)	5.01
Drainage Basin Area (acres)	18.3
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality. This is likely due to increased flushing of nutrients during wetter periods. Maintaining a higher surface level should result in improved water quality.
Stormwater Pollutant Loading	Nutrient loading rates: 11621.3 lbs/yr TN and 1072.03 lbs/yr TP. The pollutant load is higher in this lake due to the relative size of the lake compared to its very large drainage basin which extends to Haines City.

Existing Best Management Practices

Surface Level Management	The Southwest Florida Water Management District modified its existing surface level operation guidelines for the Northern Chain of Lakes in 2017. 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 Best Management Practices

1	Development of One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes management of higher surface levels.
2	Work with local stakeholders to identify and mitigate sources of nutrient concentration increases.

Waterbody

Lake Mirror

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	3	3	3	2	1	2.63

Status	Priority Level
Not currently impaired and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	130.1
Volume (cu.meter)	1737103
SA:V Ratio	0.0923453
Mean Depth (ft)	8.86
Drainage Basin Area (acres)	152.8
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment	No invasive treatment took place in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is in a maintenance state
Stormwater Pollutant Loading	Nutrient loading rates from 11 sub-basins: 749.6 lbs/yr TN and 120.9 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
SAIP	Stormwater Assessment & Improvement Project: Identified priority area within the southeastern basins where green infrastructure could be implemented to reduce flooding and improve water quality.
Street Sweeping	6.7 miles of downtown and residential roads are swept on a monthly basis in Lake Mirror's drainage basin.

Future Best Management Practices

1	Pursue funding to manage stormwater from the parcels identified as part of the SAIP.
2	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.

Waterbody

Ned Lake

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	0	1	1	2	3	0	2	1.50

Status	Priority Level
Not currently impaired, but water quality trends show substantial deterioration.	High

Lake Info

Surface Area (acres)	76.4
Volume (cu.meter)	678178
SA:V Ratio	0.138903
Mean Depth (ft)	7.17
Drainage Basin Area (acres)	180.6
Nutrient TMDL	No
Limiting Nutrient	Co-limited

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.

Water Quality Impacts/Challenges

Invasive Species Treatment	No invasive treatment took place in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is in a maintenance state.
Lack of Vegetation Coverage	PAC was 10% in 2021. In addition to providing fish and wildlife habitat, healthy vegetation coverage also buffers against increases in nutrient concentrations and stabilizes lake sediments from suspension.
Onsite Sewage Treatment & Disposal	There are 53 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates: 1002.9 lbs/yr TN and 202.7 lbs/yr TP. The City has yet to implement BMPs within this basin.

Future Best Management Practices

1	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.
2	Explore aquatic vegetation planting initiatives to improve submerged macrophyte abundance.

Waterbody

Lake Otis

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	2	2	1	1	1	2	1	1.63

Status	Priority Level
Not currently impaired and no water quality trends	Low

Lake Info

Surface Area (acres)	135
Volume (cu.meter)	2121504
SA:V Ratio	0.0784608
Mean Depth (ft)	10.63
Drainage Basin Area (acres)	451.8
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality.It is likely that increased flushing occurs at higher surface levels which reduces nutrient concentrations.
Invasive Species Treatment	invasive species with herbicide in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is in a maintenance state.
Lack of Vegetation Coverage	fish and wildlife habitat, healthy vegetation coverage also buffers against increases in nutrient concentrations and stabilizes lake sediments from suspension.
Onsite Sewage Treatment & Disposal	There are 66 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates from 11 sub-basins: 2291 lbs/yr TN and 372.6 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Green Infrastructure	A series of bioswales have been constructed by the City along 6th Street SE (within the southwestern drainage basin)
SAIP	Stormwater Assessment & Improvement Project: Identified priority area in western basins for green infrastructure to reduce flooding and improve water quality.
Street Sweeping	12.8 miles of residential and arterial/collector roadways are swept in the Lake Otis drainage basin on a monthly basis.

Future Best Management Practices

1	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.
2	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.
3	Pursue funding to manage stormwater from the parcels identified as part of the SAIP.

Waterbody

Lake Pansy

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	0	2	0	0	1	3	2	1.38

Status	Priority Level
Not currently impaired, but water quality trends show slight deterioration.	Moderate

Lake Info

Surface Area (acres)	49.4
Volume (cu.meter)	489708
SA:V Ratio	0.124381
Mean Depth (ft)	6.8
Drainage Basin Area (acres)	196
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Invasive Species Treatment	No invasive treatments took place in 2021, however a large percentage of invasives were discovered. Large-scale invasive treatments can result in nutrient concentration increases.
Stormwater Pollutant Loading	Nutrient loading rates: 880.7 lbs/yr TN and 111.2 lbs/yr TP. The City has yet to implement BMPs within this basin.

Existing Best Management Practices

Aquatic Vegetation Management	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 Best Management Practices

1	Explore construction of green infrastructure within the drainage basin.
2	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.

Waterbody

Lake Rochelle

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	3	3	3	1	0	2.38

Status	Priority Level
Not currently impaired, and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	559.9
Volume (cu.meter)	7475175
SA:V Ratio	0.0923532
Mean Depth (ft)	8.96
Drainage Basin Area (acres)	1109.7
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality. It is likely that inundation of surrounding wetlands and increased flushing results in lower nutrient concentrations. As a result, maintaining a higher surface level should improve water quality.
Invasive Species Treatment	Management involved treating 10.5 acres of hydrilla in 2021. Large-scale invasive treatments can result in nutrient concentration increases.

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 modified its existing surface level operation guidelines for the Northern Chain of Lakes in 2017. 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 Best Management Practices

1	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.
2	Development of One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes management of higher surface levels.

Waterbody

Lake Roy

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	2	3	3	1	2	2.50

Status	Priority Level
Not currently impaired and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	74.3
Volume (cu.meter)	1311358
SA:V Ratio	0.0698603
Mean Depth (ft)	10.76
Drainage Basin Area (acres)	281.8
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment	Underwent no invasive species treatment in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is currenlty in a maintenance state.
Onsite Sewage Treatment & Disposal	There are 125 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates from 13 sub-basins: 1448.3 lbs/yr TN and 241.5 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Green Infrastructure	along 6th Street in Lake Roy's westernmost sub-basin. These capture road runoff during storm events—preventing it from entering storm drains and subsequently the receiving waterbody.
SAIP	Stormwater Assessment & Improvement Project: Identified priority area within the westernmost basin where green infrastructure could be implemented to reduce flooding and improve water quality.
Street Sweeping	11.8 miles of residential and arterial roads are swept on a monthly basis in Lake Roy's drainage basin.

Future Best Management Practices

1	Pursue funding to manage stormwater from the parcels identified as part of the SAIP.
2	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.
3	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.

Waterbody

Lake Shipp

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	3	3	3	3	3	2	1	2.25

Status	Priority Level
Currently impaired, but water quality trends show substantial improvement.	Moderate

Lake Info

Surface Area (acres)	279.4
Volume (cu.meter)	2521861
SA:V Ratio	0.136606
Mean Depth (ft)	7.25
Drainage Basin Area (acres)	631.7
Nutrient TMDL	Yes
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Historic Point-Source Pollutants	Received an undetermined quantity of discharge from citrus and vegetable processing facilities. Discharges may constitute a considerable source of legacy nitrogen and phosphorus in the lake sediments.
Hydrology	Analysis has determined that surface level correlates directly with some water quality parameters. This is likely due to increased flushing. As a result, maintaining a higher surface level should improve water quality.
Invasive Species Treatment	Management involved treating 62 acres of hydrilla and burhead sedge in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Stormwater Pollutant Loading	Nutrient loading rates from 9 sub-basins: 3614.3 lbs/yr TN and 654.7 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Street Sweeping	12.4 miles of residential and arterial roads are swept on a monthly basis in Lake Shipp's drainage basin.

Future Best Management Practices

1	Develop plan to evaluate internal load from legacy sediments.
2	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.

Waterbody

Lake Silver

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	2	2	2	1	0	3	3	2.00

Status	Priority Level
Not currently impaired with no water quality trends	Low

Lake Info

Surface Area (acres)	54.3
Volume (cu.meter)	1282954
SA:V Ratio	0.0521857
Mean Depth (ft)	11.93
Drainage Basin Area (acres)	110.1
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Lack of Vegetation Coverage	PAC was only 2% in 2021. In addition to providing fish and wildlife habitat, healthy vegetation coverage also buffers against increases in nutrient concentrations and stabilizes lake sediments from suspension.
Stormwater Pollutant Loading	Nutrient loading rates from 12 sub-basins: 633.2 lbs/yr TN and 106.1 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

Existing Best Management Practices

Green Infrastructure	8 raingardens/exfiltration systems have been constructed in Lake Silver's drainage basin.
Street Sweeping	20.15 miles of downtown, residential, and arterial roads are swept in Lake Silver's drainage basin on a monthly basis.

Future Best Management Practices

1	Explore aquatic vegetation planting initiatives to improve submerged macrophyte abundance.
2	Complete refurbishment of downtown raingardens to ensure their pollutant reduction efficiency - by end of 2021.

Waterbody

Lake Smart

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
0	2	2	2	3	2	2	2	1.88

Status	Priority Level
Currently impaired, but water quality trends show slight improvement.	Moderate

Lake Info

Surface Area (acres)	281.2
Volume (cu.meter)	3581825
SA:V Ratio	0.0967997
Mean Depth (ft)	9.42
Drainage Basin Area (acres)	300.2
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Existing Best Management Practices

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
Surface Level Management	The Southwest Florida Water Management District modified its existing surface level operation guidelines for the Northern Chain of Lakes in 2017. 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.

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with water quality. This is likely due to increased flushing of nutrients during wetter periods. Maintaining a higher surface level should result in improved water quality.
Invasive Species Treatment	No invasive treatments took place in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Stormwater Pollutant Loading	Nutrient loading rates from the 2 distinct drainage basins: 1673.4 lbs/yr TN and 348.9 lbs/yr TP. Many of the developed areas in these basins currently mitigate much of this load.

Future Best Management Practices

1	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.
2	Development of One Water Master Plan prioritizes storage of more water in the Winter Haven area which promotes management of higher surface levels.

Waterbody

Spring Lake

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	3	3	3	0	2	2.50

Status	Priority Level
Not currently impaired and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	25.2
Volume (cu.meter)	378599
SA:V Ratio	0.0820699
Mean Depth (ft)	9.02
Drainage Basin Area (acres)	96.1
Nutrient TMDL	No
Limiting Nutrient	Co-limited

Water Quality Impacts/Challenges

Invasive Species Treatment	Management involved treating 9 acres of hydrilla in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Stormwater Pollutant Loading	Nutrient loading rates from 7 sub-basins: 520.7 lbs/yr TN and 90.8 lbs/yr TP. The City has implemented multiple BMPs to mitigate this load.

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.
Street Sweeping	7.4 miles of downtown, residential, and arterial roads are swept on a monthly basis in Spring Lake's drainage basin.

Future Best Management Practices

1	Explore implementation of additional stormwater BMPs within the drainage basin.
2	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.

Waterbody

Lake Summit

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	3	3	3	1	1	2.50

Status	Priority Level
Not currently impaired and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	67.4
Volume (cu.meter)	1110163
SA:V Ratio	0.0748577
Mean Depth (ft)	10.71
Drainage Basin Area (acres)	99.1
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Hydrology	Analysis has determined that surface level correlates directly with some water quality parameters. This is likely due to increased flushing. As a result, maintaining a higher surface level should improve water quality.
Invasive Species Treatment	No invasive treatments too place in 2021. Large-scale invasive treatments can result in nutrient concentration increases. This waterbody is currently in a maintenance state.
Onsite Sewage Treatment & Disposal	There are 52 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates: 513.3 lbs/yr TN and 82.7 lbs/yr TP. Much of this load originates outside of City limits.

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 Best Management Practices

1	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.
2	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.

Waterbody

Lake Winterset

Lake Health Index

NNC Impairment	Chla Trend	TN Trend	TP Trend	Secchi Trend	% Coverage	% Invasive	Species Diversity	Lake Health Score
3	3	3	2	3	3	2	2	2.63

Status	Priority Level
Not currently impaired and water quality trends show substantial improvement.	Low

Lake Info

Surface Area (acres)	555.5
Volume (cu.meter)	12499617
SA:V Ratio	0.0547962
Mean Depth (ft)	14.26
Drainage Basin Area (acres)	519.1
Nutrient TMDL	No
Limiting Nutrient	Phosphorus

Water Quality Impacts/Challenges

Invasive Species Treatment	Management involved treating 36 acres of hydrilla in 2021. Large-scale invasive treatments can result in nutrient concentration increases.
Onsite Sewage Treatment & Disposal	There are 71 known septic systems within this drainage basin--constituting a moderate density. The condition and pollutant load contribution of these systems are currently unknown.
Stormwater Pollutant Loading	Nutrient loading rates: 2258.8 lbs/yr TN and 407.6 lbs/yr TP. Much of this load originates outside of City limits.

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 Best Management Practices

1	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.
2	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.