

Winter Haven Lakes Report

Presented by the Lakes Advisory Committee

2024



CITY OF WINTER HAVEN
Public Works Department
Natural Resources Division

City of Winter Haven Natural Resources

Mission:

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

Vision:

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

Purpose:

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

Values:

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

Executive Summary

The City of Winter Haven possesses one of the highest densities of natural lakes in the state of Florida. Thirty-seven of these lakes have been identified as providing cultural, ecologic, and economic benefits for the Chain of Lakes City. Proper management of these resources 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. The Winter Haven Natural Resources Division (NRD) is committed to evaluating the water quality, hydrologic, and biological factors on an annual basis. In 2018, City staff developed a scientific methodology to objectively prioritize management efforts for the 37 public lakes under our jurisdiction; it was then that the Annual Lakes Report was initially drafted. The purpose of this report is fourfold: to educate the public about the factors that affect lake health, describe the evaluation methodology developed by the City, present the most recent data and analysis, and highlight the management strategies employed by the City to maintain and improve lake health. Moreover, the report ensures accountability of the NRD's management efforts by tying them to the City's adopted strategic goals. The information contained within this report is shared not only with our residents, but with myriad federal, state, and local agencies with whom the City partners.

Each year, the City NRD gathers and analyzes a tremendous amount of data on the lakes, presenting it to the public via this document and an interactive online format found using the following link: www.tinyurl.com/wh-fl-lakesreport-app. The content contained within this document is divided into three primary sections. For those interested in learning about the aforementioned factors that influence lake health, the Introduction (starting on page 10), provides detailed, but easy-to-understand definitions and descriptions of the hydrology, water chemistry, and ecology of Winter Haven's lakes. The Management Strategies section (starting on page 35), details the projects and initiatives the City currently employs to maintain and improve the health of these lakes; including critical milestones and references to how these efforts tie back to City-wide strategic goals. Finally, the Data Presentation & Analysis section (starting on page 62) delves into the data and presents the insights and conclusions that allow the City to make its management decisions.

The following State of the Lakes statement is designed for individuals wanting a brief overview of the most current data regarding the study area lakes:

Water Quality: In 2024, 54% of the 37 study area lakes met State regulatory water quality targets. This marks a substantial improvement from 2018 when only 37% of area lakes were meeting these targets. Of the 17 lakes that are currently still impaired, over 50% are exhibiting statistically significant improving trends in at least one of the regulatory metrics (i.e. chlorophyll-a, total nitrogen, and/or total phosphorus). Furthermore, only three of these impaired waterbodies are currently exhibiting actively deteriorating water quality

trends. These three lakes remain the City's top priority regarding the planning of management actions.

Hydrology: Winter Haven received 46.5 inches of rainfall in 2024. This annual total is actually below the regional average of roughly 52 inches. During the dry season (January – June), lake surface levels declined considerably. However, an extremely active tropical storm season resulted in surface levels increasing beyond where they were at during the start of 2024—some even reaching record highs. For nearly 60% of these lakes, an increase in level correlates directly with an improvement in at least one primary water quality parameter. It should also be noted that lake levels have remained relatively high since our last major drought from 2008 to 2013. Due to the relationships between surface level and water quality, these consistently high lake levels are one of the likely contributors to the water quality improvements observed since monitoring began.

Aquatic Biology: Aquatic vegetation monitoring remains a critical management strategy in order to maintain robust, healthy, and native ecological communities. Comparing biological criteria scores from 2018 to 2024 indicates that ecological health of these lakes has improved considerably. The annual average aquatic vegetation coverage percent for the study area is at a record high. Additionally, the average percentage of invasive exotic plant species within these vegetation communities is at an all-time low. This indicates that management efforts have been successful at reducing invasive plant abundance while promoting the growth of native, beneficial species.

The City employs various management practices aimed at improving lake health. The important milestones for these activities are detailed extensively in the Management Strategies section of the report. However, there are some notable projects and initiatives to highlight:

Hydrologic monitoring is critical for understanding how changes in precipitation can impact surface level, water quality, and ecologic functions in our lakes (page 38). City staff continue to deploy automated surface level sensors in area lakes to improve the quality and quantity of lake level data. Additionally, the NRD is working closely with the Winter Haven Water Department to purchase and install several weather stations and aquifer level sensors throughout the City. These should significantly improve the City's ability to track and model hydrologic changes throughout the study area instead of just downtown.

Implementation of green stormwater infrastructure helps to capture and treat urban runoff and increase groundwater recharge (page 40). Construction of several raingardens in the downtown area was completed in 2024. An expansion to the South Lake Howard Nature Park is currently in the construction phase and is scheduled to be completed before the end of the 2025-2026 fiscal year. This expansion is expected to significantly increase the treatment capacity and wildlife habitat of the park.

Natural Resources staff made efforts to expand outreach and education programming in 2024 (page 50). The NRD hosted or participated in 37 individual outreach events,

engaging with a record-setting 1800 residents and visitors. The City hosted its inaugural Kid's Fishing Derby at South Lake Howard Nature Park—with over 100 attendees. Additionally, the NRD devoted a combined 108 hours of staff time working with youth during the summer camps in 2024 and has increased the number of guided kayak tour offerings on our lakes. Lastly, the Division began organizing independent lakeshore clean-up events, inviting residents to join staff in beautifying the City's shorelines. Most of these activities are slated to be recurring events hosted by the City.

This report is a considerable endeavor—one that would not be possible without the guidance, advice, and support of local citizens with the passion to protect our natural resources. The City recognizes the efforts of the Lakes Advisory Committee whose leadership resulted in the initial directive to create this report and whose members devote valuable time to review. Additionally, we'd like to thank you, the reader. 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,

City of Winter Haven
Natural Resources Division

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ANNUAL LAKES REPORT

How to navigate this document

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- What is the purpose of the report?
- What lakes are being studied?
- How are the lakes being evaluated?

#2 | Management Strategies

- What management practices does the City utilize?
- What are the benefits of these efforts?
- What are the goals and success criteria?

#3 | Data Presentation & Analysis

- What is the health of a specific lake or lakes?
- What specific management efforts are used for each lake?
- How do the lakes compare?

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- Where can I find supporting info that was referenced in the report?
- How do I locate a specific figure or table in the report?

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#1 | Introduction



1.1 Purpose

The lakes of the greater Winter Haven area are considered some of its most important natural assets. The use of these waterbodies by visitors and residents alike has cemented their role as economic and cultural 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.

Much of the information in this report has been gathered by the Natural Resources Division's ongoing monitoring efforts. It presents a comprehensive outlook on the characteristics that comprise lake health and provides a detailed list of management strategies aimed at improving water quality. In using this holistic assessment approach, the City can prioritize waterbodies based on measurable conditions and implement specific management practices geared toward each lake's characteristics and issues. Using methods and techniques that are technically sound but presented in a manner that is accessible ensures that the information contained within this report can be understood and applied by the scientific community as well as the general public.

The work the City does to monitor and maintain the health of its lakes is also incredibly beneficial outside City limits. Winter Haven's lakes form part of the headwaters for the Peace River. The Peace River flows toward the Gulf of Mexico, eventually emptying into Charlotte Harbor—an economically and ecologically vital estuary along Florida's southwest coast. Since our lakes flow into such a major waterway, the health of both are intrinsically tied with far-reaching consequences for many people, businesses, and ecosystems.

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

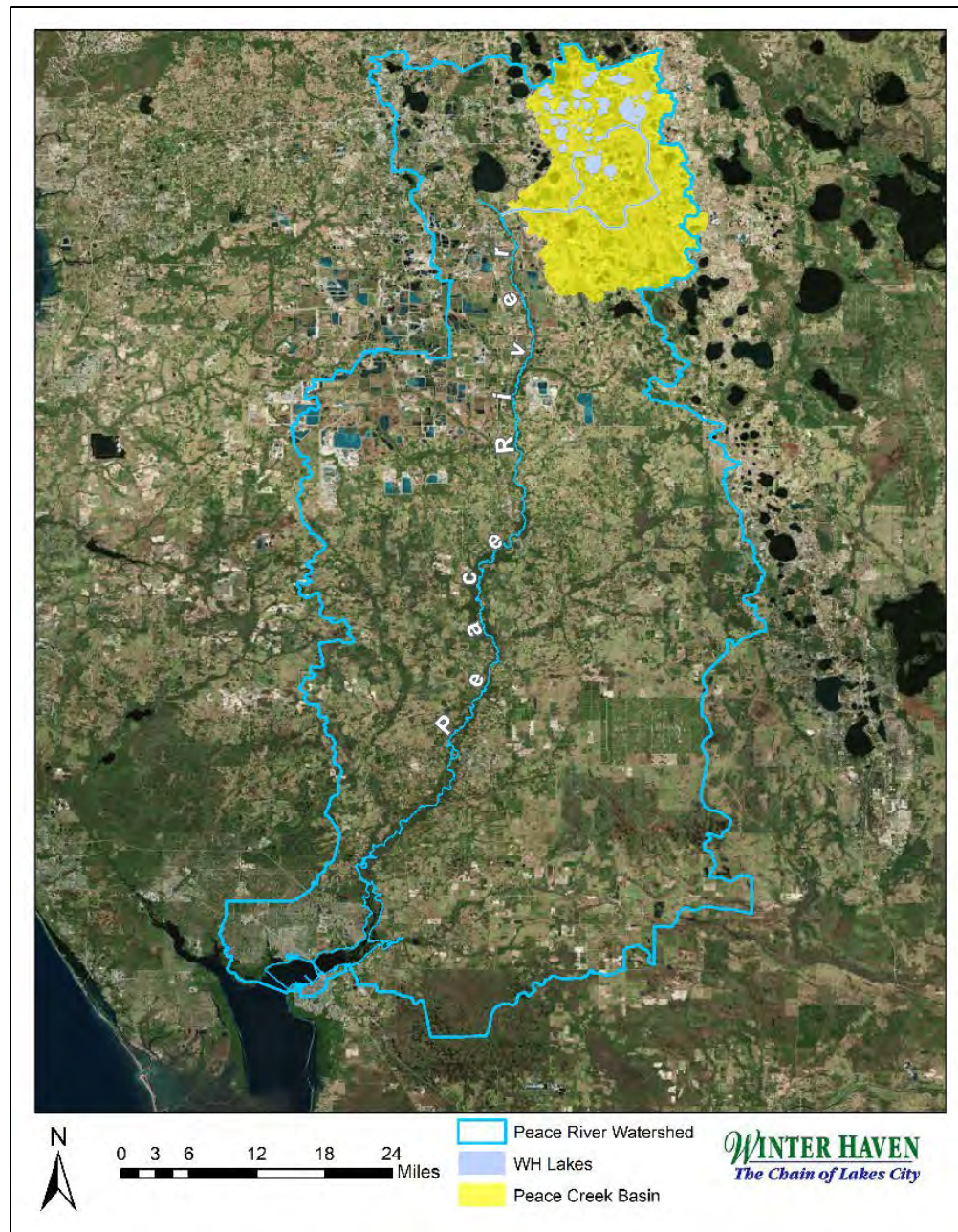


Figure 1-1. Map of Peace River & Peace Creek Watersheds

The lakes of the Winter Haven area are located at the top of the Peace River watershed, in what is known as the Peace Creek sub-basin. As excess water discharges to the Peace Creek, they become 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).

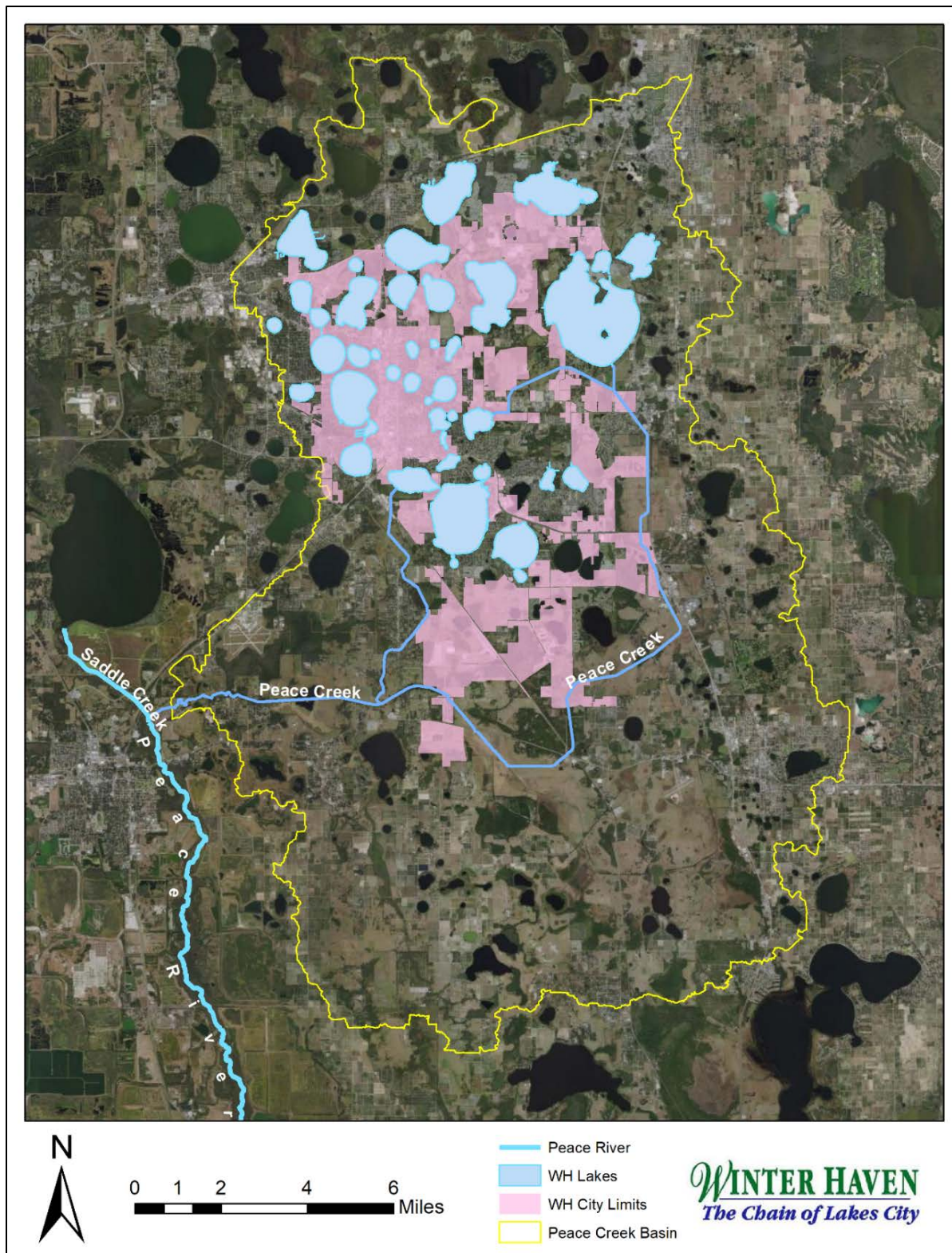


Figure 1-2. Map of the Peace Creek sub-basin, City of Winter Haven limits, contributing lakes and flow-ways.

Winter Haven Lakes

This report focuses on the 37 primary lakes that the Winter Haven Natural Resources Division monitors for lake health. These lakes were selected for monitoring based on several criteria:

- The lake must have some form of public access (e.g. public park, boat ramp, or navigable canal from another publicly accessible lake).
- The lake must be located within or adjacent to Winter Haven city limits, or it must discharge directly to a public lake within city limits.
- The lake must discharge, either directly or indirectly, to the Peace Creek.
- The lake must have a sufficient period of record water quality and hydrologic data set (approximately 20 years) in order to evaluate.

The lakes included in this report were previously categorized into five groups: *North Chain of Lakes*, *North Central Lakes*, *South Chain of Lakes*, *South Central Lakes*, and *Outlying Lakes*, based on their geographic location and where they discharge water to. This was done in order to summarize the water quality, hydrologic, and ecological data by group. Recent iterations of this report evaluate each lake individually, meaning the lake groupings are no longer necessary. The following are the 37 lakes listed in alphabetical order:

Blue	Idyl	Pansy
Buckeye	Idylwild	Rochelle
Cannon	Jessie	Roy
Conine	Link	Shipp
Daisy	Lulu	Silver
Deer	Mariam	Smart
Elbert	Mariana	Spring
Eloise	Martha	Summit
Fannie	Maude	Winterset
Haines	May	Little Hamilton
Hamilton	Mirror	Middle Hamilton
Hartridge	Ned	
Howard	Otis	

The series of waterways connected by navigable canals is colloquially referred to as the Winter Haven Chain of Lakes (highlighted in **bold** in the list above). Many of these canals were constructed in the early 1900’s, in part as a means to transport citrus through the region [Cavitt, 2015; Gernert, 2016]. With the advent of the automobile, the canals never got to serve this purpose—instead their primary role became recreational transportation. Winter Haven’s Chain of Lakes are a major component of the City’s culture and economy. The Lakes are used year-round for recreation and lake-centric tourism benefits many local businesses. Similarly, residents and visitors enjoy the lakes for everything from water skiing to seaplane training. Whether it’s fishing, boating, water skiing, kayaking, or flying

a seaplane, Winter Haven has built its day-to-day life around our lakes, which means caring for them is a critical responsibility.

The Winter Haven Chain of Lakes can be differentiated into a 'North Chain' and 'South Chain'; managed at different levels and separated by a lock system between lakes Conine and Hartridge. The lock system is controlled by the Lakes Region Lakes Management District (LRLMD), a special taxing district originally established to maintain the canals and local boat ramps. The LRLMD also controls surface levels for the 14 Southern Chain of Lakes via a passive control structure at Lake Lulu. The Southwest Florida Water Management District (SWFWMD) manages the surface level of the nine Northern Chain of Lakes via a series of active water control structures. For the purposes of water conservation and flood control, the SWFWMD sets the maximum desired levels at each of these structures—discharging water to the Peace Creek Canal when surface levels exceed the upper limits ^[SWFWMD, 2019]. In this system, water flows from west to east toward the terminal discharge point at Lake Hamilton.

The remaining (interior) lakes have non-navigable flow ways (i.e. pipes and ditches) that allow them to flow either directly to the Peace Creek or indirectly via one of the lake chains. The movement of water through many of these connections is determined by water control structures put in place primarily to maintain 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 at an adjustable level. Whereas passive structures include weirs or pipes set at the lake's maximum desired water level. Passive structures only allow for the overflow of water above that set level. The SWFWMD and LRLMD maintain the majority of structures in the Winter Haven area, however, a couple of passive structures are managed by Polk County (Table 1-1). The canals and connections for these lakes are shown in Figure 1-3.

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

Table 1-1. Control structure elevations (in feet above sea level), contributing waterbodies, and managing agencies of study area lakes.

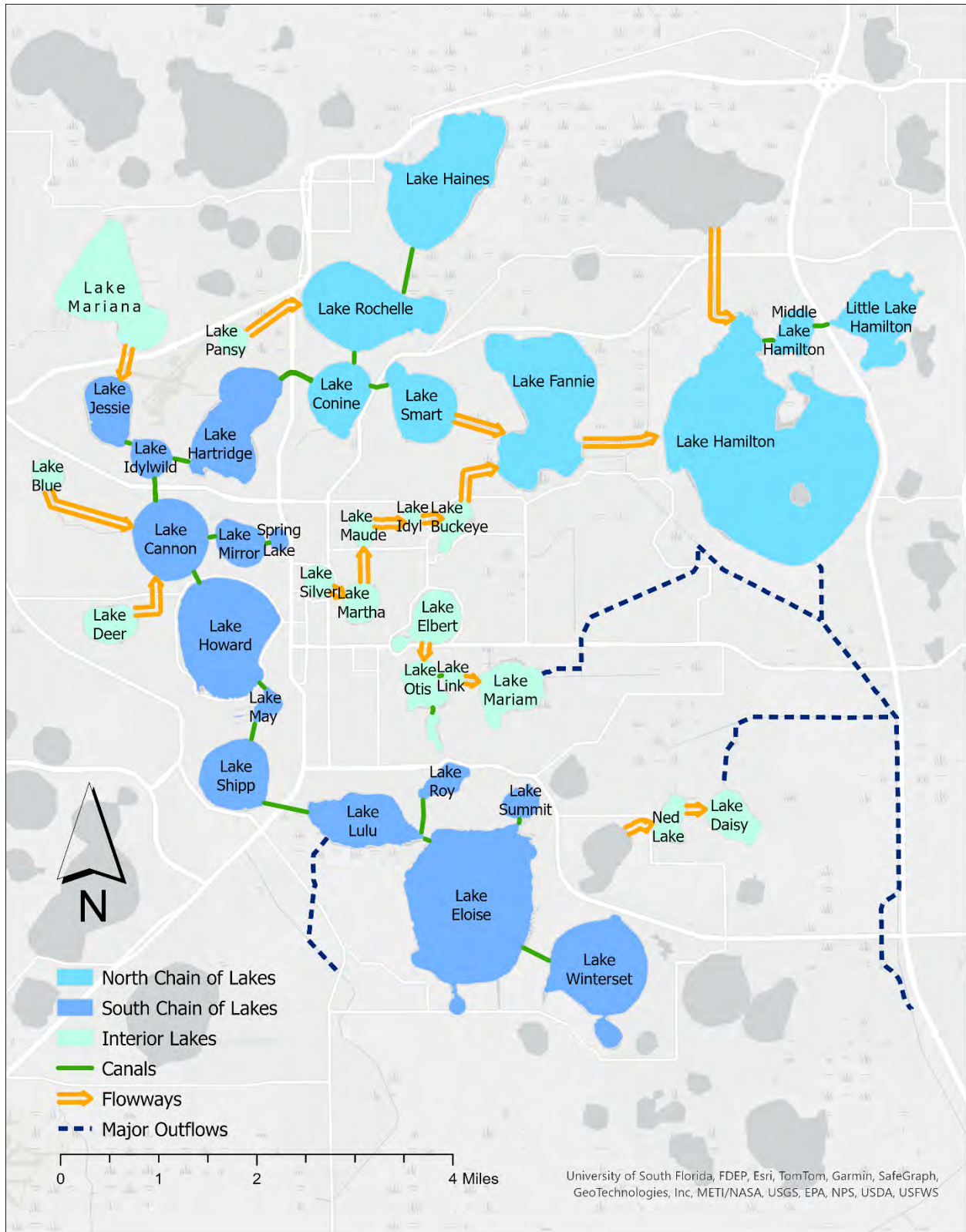


Figure 1-3. Map of Winter Haven Lakes, navigable canals, non-navigable flow-ways, and major outflows.

1.3 Background on the Metrics

Just as a person's physical health relies on multiple factors, so are the facets of lake health built upon complex interactions amongst various components. The focus of this report will be placed on understanding the interactions between and among water quality, hydrology, and ecology.

Water Quality

The term "water quality" refers to a selection of physical and chemical characteristics, parameters, or attributes pertaining to water. Some parameters more obvious to the casual observer include water clarity or color. However, there are myriad less-obvious parameters with examples ranging from the amount of dissolved oxygen to the concentration of metals or other elements in the water column.

An extensive synopsis of every water quality metric studied would be extraneous. For the sake of simplicity, this report focuses on the water quality metrics that are most relevant from a regulatory standpoint—or parameters that are indicative of a lake's ability to meet environmental, human health, or water supply standards. Throughout the remainder of this report, the following core water quality metrics will be used in the City's analysis in the context of overall lake health.

Primary Water Quality Metrics

Chlorophyll-a (Chl-a): *Measured as the concentration of the photosynthetic pigment found in plant and algal cells, Chl-a is used to estimate algal abundance in the water column. While algae is important ecologically, it can become problematic at higher concentrations. Therefore, the goal is to maintain Chl-a concentrations at or below a target threshold and/or lower them over time.*

Nutrients: *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 plant and algal growth. Therefore, a higher concentration of nutrients leads to higher Chl-a levels. As a result, the goal is to maintain TN and TP concentrations at or below specified target thresholds and/or lower them over time.*

Water Clarity: *Measured as Secchi depth, or the maximum depth in the water column that light can penetrate. Clarity can be used to represent the amount of both suspended and dissolved matter in the water column. Clarity is often inversely proportional to Chl-a concentrations. Therefore, the goal is to maintain clarity at or above levels consistent with natural lakes in Florida and/or increase clarity levels over time.*

Trophic State & Water Quality

Mentioned above, trophic state is a concept describing a waterbody's level of primary productivity; 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 1-4) [USGS, 1998]:

Trophic States

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

Generally, oligotrophic lakes are clearer, less build-up of organic sediments, and possess less abundance of plants and fish. These types of lakes are rare in Florida, but ubiquitous in the northern US. Eutrophic lakes, on the other hand, are less clear due to increased amounts of organic matter and 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 are on the extreme high end—often associated with toxic algal blooms, fish kills, and overabundance of nuisance plants.

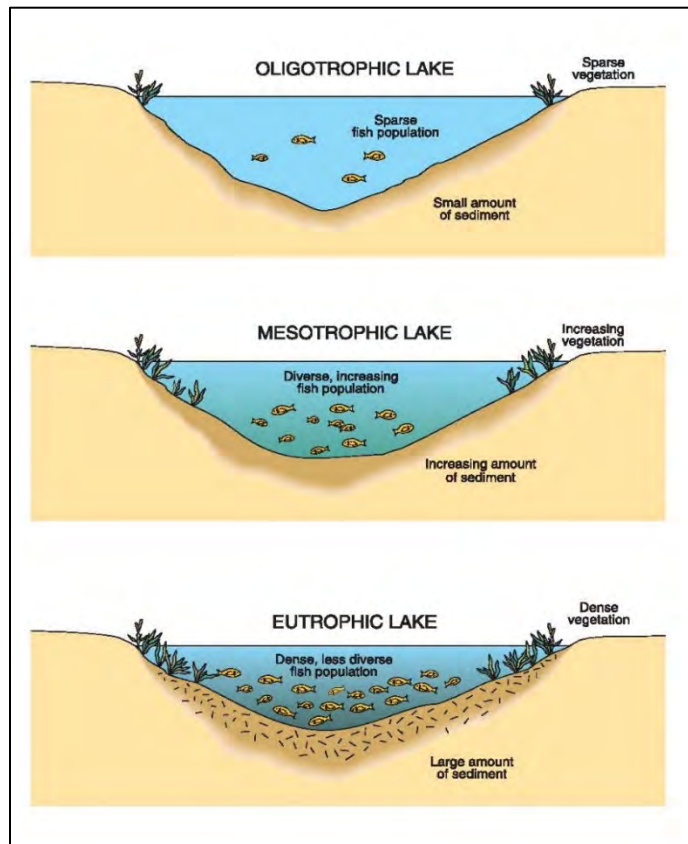


Figure 1-4. Diagram of Lake Trophic States [USGS, 1998].

Eutrophication is the process by which waterbodies increase in trophic state, usually due to human-originated (anthropogenic) factors, like pollution from runoff. That said, trophic state also naturally increases slowly over the geologic timescale. Chlorophyll-a (Chl-a), a measure of algal abundance, is generally used as an indicator for a waterbody's trophic state. Nitrogen and phosphorus, two of the main elements required for plant growth, are the primary drivers of Chl-a increases in the water. Figure 1-5 shows that an increase in total nitrogen (TN) and/or total phosphorus (TP) will generally lead to an increase in Chl-a. Trophic state index (TSI) is a standard metric incorporating chlorophyll and nutrient values into one measure. While it was used as a regulatory water quality metric for a time, TSI was determined to be too simplistic and didn't capture the complex interactions between nutrients and algal concentrations [FDEP, 2013]. For example, due to Florida's naturally high-phosphorus soils, meeting a standard TSI threshold was impossible for many Florida lakes. Instead, Chl-a, TN, and TP are evaluated separately as regulatory water quality metrics. This way localized differences in the lakes can be better accounted for.

Nutrient Cycles

Nitrogen (N) and Phosphorus (P) have been established as the primary drivers of eutrophication, 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. 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. Inorganic 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 (mineral) and organic forms. Plants and algae uptake mineral 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 beds. Bacteria in the sediments convert the organic P to inorganic P which can return to the water column depending on the current phosphorus gradient in the water. 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 P. Unlike the nitrogen cycle, phosphorus does not undergo a transformation to an atmospheric form; meaning the only effective means to reduce P in aquatic environments is through the physical removal of plants, animals, or sediments (muck removal). Due to the large costs associated with removal, it's often more economically feasible to develop methods to lock phosphorus in an unavailable form or prevent it from entering aquatic environments altogether.

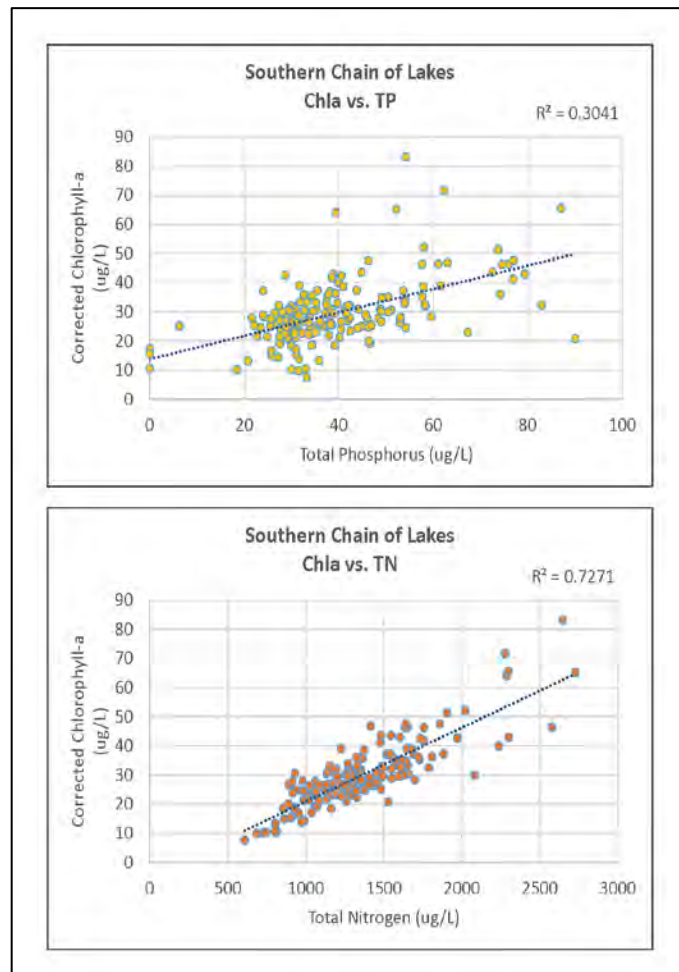


Figure 1-5. Linear Regression of Chlorophyll-a vs. Total Phosphorus & Total Nitrogen

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 or the presence of naturally phosphate-rich sediments can exacerbate eutrophication. These legacy nutrients require special consideration as even a significant reduction of stormwater input may not have much effect on water quality if the majority of nutrient loading originates from the underlying sediments.

Paleolimnology, or the study of historic lake conditions, can provide insights into the trophic state of lakes before human activity. By testing the layers of sediment that have accumulated on the lake floor, inferences regarding historic nutrient 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 [Whitmore et al., 1996; Whitmore & Brenner, 2002]. That said, anthropogenic pollution has led to an increase in trophic status and poorer water quality over time.

Regulatory Impairment Evaluation

A major effort by State and Federal environmental agencies in recent decades was the development of an objective set of standards to measure anthropogenic impacts to waterbodies. 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 and historical water chemistry characteristics. All of the Winter Haven lakes fall under Class III and are therefore subject to NNC impairment thresholds that support recreation and healthy ecosystems. As a result, whether or not a lake is impaired is one of the primary metrics that we use to evaluate lake health.

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*

Impairment: *Threshold concentrations of Chl-a, TN, and TP, set forth by the Numeric Nutrient Criteria, are used to determine whether a lake is meeting its intended use classification. Figure 1-6 is a flow chart that explains the impairment determination process.*

As stated, impairment determination also looks at historic water chemistry values. Lakes are initially categorized based on the long-term geometric mean (average) true color and total alkalinity. Color, or the measure of dissolved organic material in the water column, is measured in platinum cobalt units (PCU). High color concentrations can block sunlight, limiting Chl-a concentrations. The presence or absence of wetland vegetation can alter a

lake's natural color concentration. Alkalinity, measured as the amount of calcium carbonate (mg/L CaCO_3) in the water, buffers against changes in pH that can affect flux of nutrients in the water column. Generally, lakes with more alkalinity can support more productivity which is why this metric is used to classify lakes. 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.

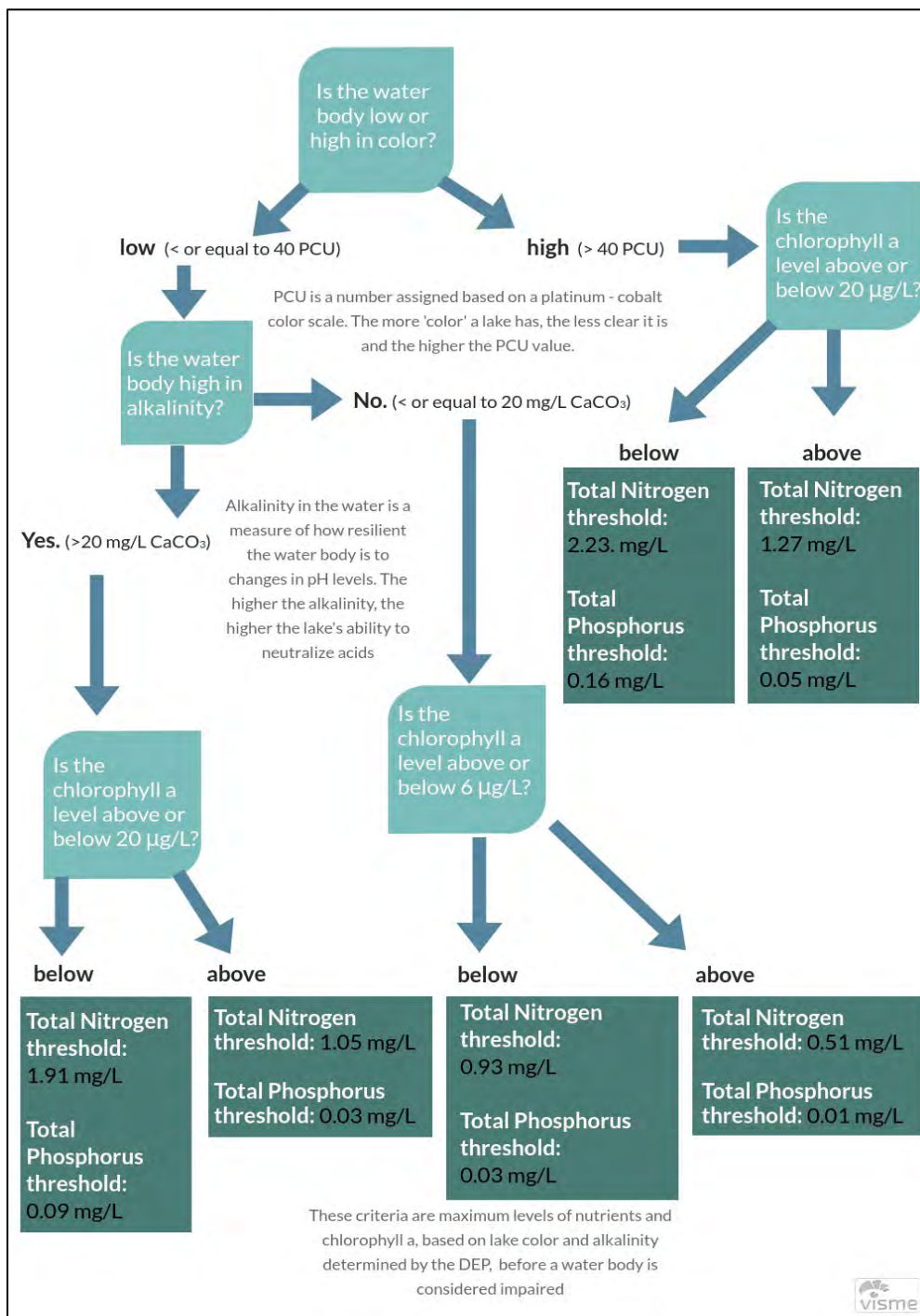


Figure 1-6. NNC Impairment Determination Flowchart

Impairment Response

After a waterbody is determined to have 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 pollutants 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. Research shows that the majority of Florida lakes are phosphorus limited or co-limited (by both nitrogen and phosphorus) [Lakewatch 102, 2000]. Knowledge of the limiting nutrient can assist lake managers in determining what management practices to focus on to improve water quality.

In order to establish appropriate nutrient reduction goals that will lead to water quality improvement, the FDEP must estimate the current pollutant loading rate from potential sources (e.g. lbs/year of TP). Point sources refer to discharge from wastewater treatment plants and **Municipal Separate Storm Sewer Systems (MS4s)**. Nonpoint sources refer to the introduction of pollutants through surface runoff, atmospheric deposition, groundwater, sediments, and any other sources that don't possess a discrete entry point. Modeling pollutant loading rates is explained more in the next section.

Once a waterbody has a TMDL established, the FDEP works with local stakeholders to develop a management plan. Plans include the targeted water quality goals, a timeline for achievement, and a confirmation process for best management practices. This ensures that the managing entities (like the City) are able to meet the intended goals using methods that are scientifically sound, technically and financially feasible, and in a timely manner.

Tracking water quality trends is critical to lake management. For impaired waterbodies, it helps lake managers know whether their strategies are being effective. Whereas, for waterbodies that are meeting the water quality targets, it can warn of potential future issues that managers can work proactively to correct. It is for these reasons that the City considers water quality trends a critical lake health metric.

Water Quality Trends: *The long-term changes in Chl-a, TN, TP, and Clarity. Trend analysis uses statistical analysis to determine direction (up or down), magnitude (how much are levels changing), and significance (validity of the trend).*

Hydrology

Hydrology is the study of the pathways that water takes through our environment. Water's journey is long as it travels the Earth through different pathways. 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 (rainfall) and groundwater flows.*

Groundwater Level: *The elevation of groundwater surface measured in feet above sea level. There are two major types of groundwater in peninsular Florida. The surficial aquifer or water table and the confined aquifer.*

Drainage Characteristics: *How water enters and leaves a given waterbody from its surrounding drainage basin. Includes precipitation, land use, soil types and surface runoff potential (imperviousness), this information can even be used to model the rate of pollutant loading.*

Precipitation

It is important to start off with the primary driver of Winter Haven's hydrology—precipitation (i.e. rainfall). Due to Winter Haven's elevation on Florida's central ridge system, its lakes sit at the top of a watershed. This means that all water naturally flows downstream away from the lakes. With no rivers imparting flow to the area, rainfall remains the only water input for the region. As a result, the amount of rainfall received is responsible for fluctuations in lake levels and for maintaining the capacity of groundwater reservoirs.

Precipitation enters lakes either directly or via surface runoff from the surrounding land (i.e. stormwater). The total area that contributes stormwater runoff to a waterbody is referred to as its drainage basin. In a natural system the effective drainage basin of a lake is relatively small. The lack of impervious surfaces (e.g. roads and buildings) and stormwater infrastructure (i.e. pipes and ditches) cause much of that surface flow to seep into the ground before it reaches the lake. Land development increases both impervious surface area and the drainage basin size, causing issues such as more extreme surface level fluctuations as well as increased pollutant loading in lakes. However, these impacts can be mitigated by creating open spaces for water seep into the ground. Stormwater that infiltrates into the ground is then referred to as groundwater.

Groundwater

There are two primary tiers of groundwater in Florida: the upper layer known as the surficial aquifer, and the deeper Floridan aquifer that is 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 1-7). In locations or during periods of time where the aquifer levels are high, water may flow to the surface via the bottom of lakes. Naturally, the opposite occurs when the water table and potentiometric surface are low.

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 bed can provide insights into how it reacts to changes in groundwater. For example, a deeper lake may have a more direct connection with the aquifer and would more quickly gain or lose water due to potentiometric changes.

The Upper Floridan Aquifer is the sole municipal water source for the City of Winter Haven. Winter Haven has been previously listed as one of the fastest growing areas in the US [US Census Bureau, 2018]. Due to this population increase, the potential hydrologic impacts of water use must be considered for both the ecological outlook of our lakes and the future of our drinking water supply. The primary hydrologic strategies for this area include promoting rapid recharge of the Floridan aquifer and the long-term storage, treatment, and slow infiltration of stormwater in areas where fast recharge isn't feasible.

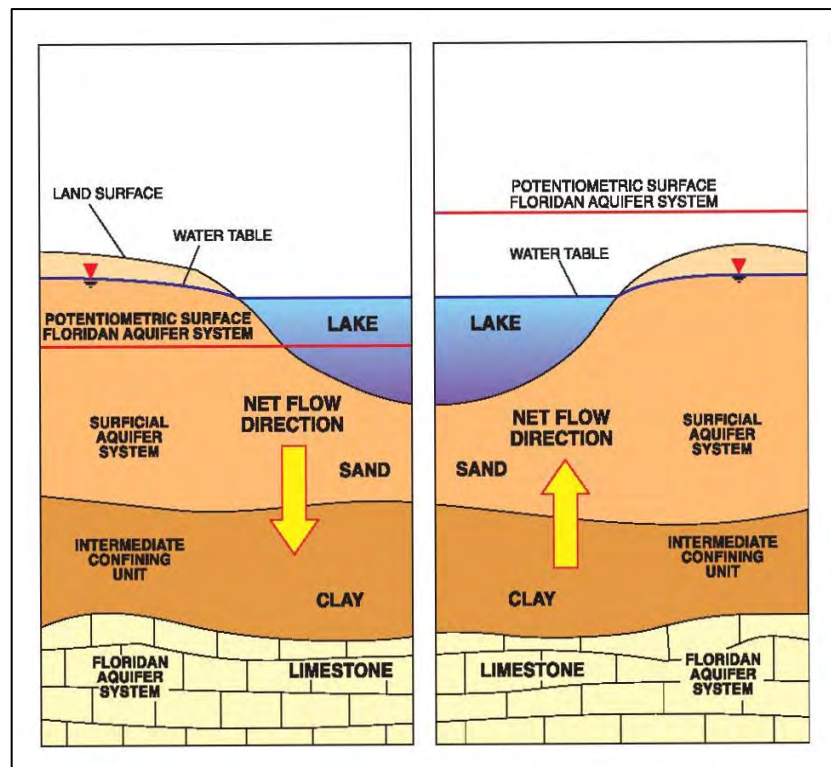


Figure 1-7. Diagram of Groundwater Interactions.

Soil Characteristics

The types of soils found in lake drainage basins can significantly impact the infiltration rate of stormwater. The United States Department of Agriculture (USDA) has classified soils into several hydrologic groups based on sediment types (e.g. sand, clay, loam) and their respective water infiltration rates. This information has informed site development planning and engineering across the country since the early 1900s. Environmental scientists can also utilize soil data to determine how quickly water can percolate into the groundwater system.

USDA Hydrologic Soil Groups

Group A: Soils consisting mostly of excessively drained sands or gravel with a high infiltration rate when thoroughly wet.

Group B: Soils consisting of moderately well-drained coarse or fine texture sediments with a moderate infiltration rate when thoroughly wet.

Group C: Soils consisting of fine textures having a layer that impedes the downward movement of water with a slow infiltration rate when thoroughly wet.

Group D: Soils consisting chiefly of clays or clay layers near the surface or over nearly impervious material with a very slow infiltration rate.

Dual Groups: (A/D, B/D, C/D) Mixed soils with no dominant type where the designation applies to their status when 'drained'/'saturated'.

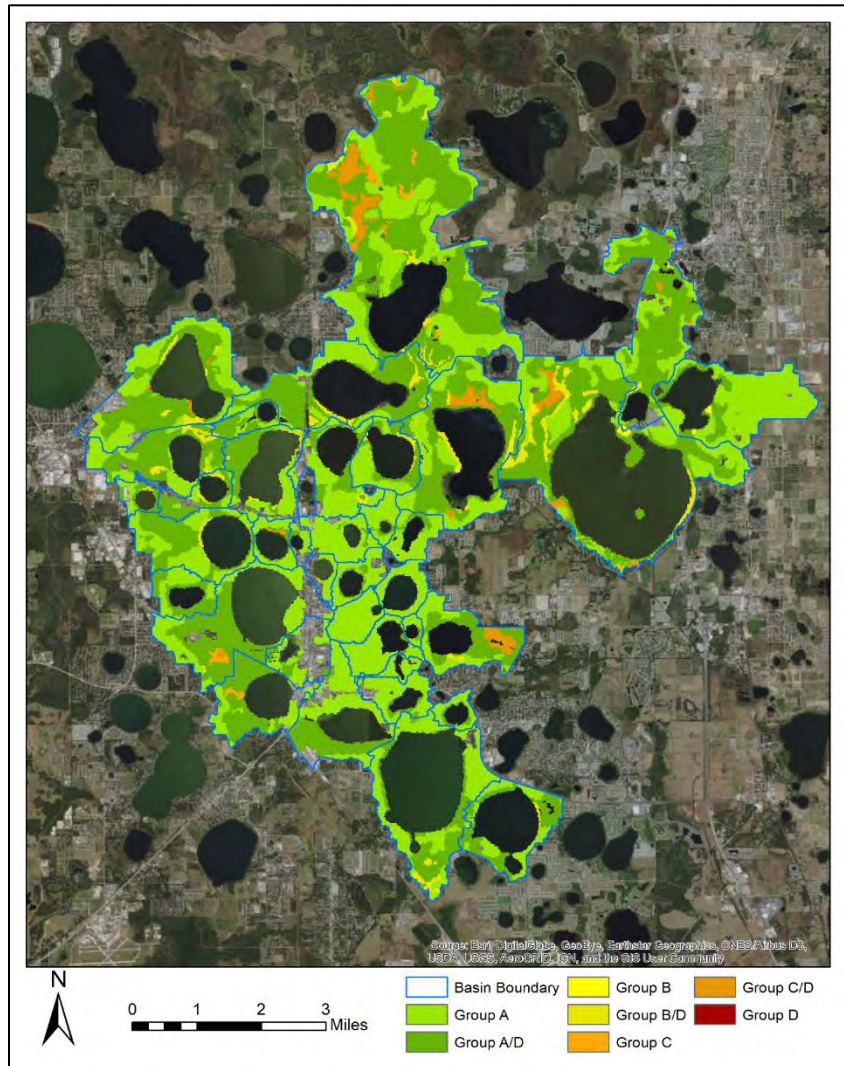


Figure 1-8. Hydrologic Soil Groups of the Winter Haven Lakes.

The proportion of each soil group making up a given lake drainage basin can indicate the infiltration potential within that basin. This information can also be used to determine adequate locations for management practices 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 poorly-drained soil types increases

further from the downtown area (Figure 1-8). It can be inferred that stormwater infiltration BMPs will be more effective in the City center with surface water storage/treatment practices being relegated to the less well-drained lower elevations at the periphery of the downtown area.

Drainage/Pollutant Modeling

Pulling together the previously mentioned drainage characteristics can yield insights into the amount of stormwater and pollutants entering a lake. This process is referred to as stormwater modeling. Modeling stormwater flows is the basis for the TMDL targets mentioned in the water quality section, but the process can also be useful in pinpointing pollution sources in a drainage basin and helping lake managers prioritize drainage projects.

There are various methods and tools that lake managers use to model stormwater and pollutant loads. 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 [Schueler, 1987]. Tied to each land use are average impervious percentages to

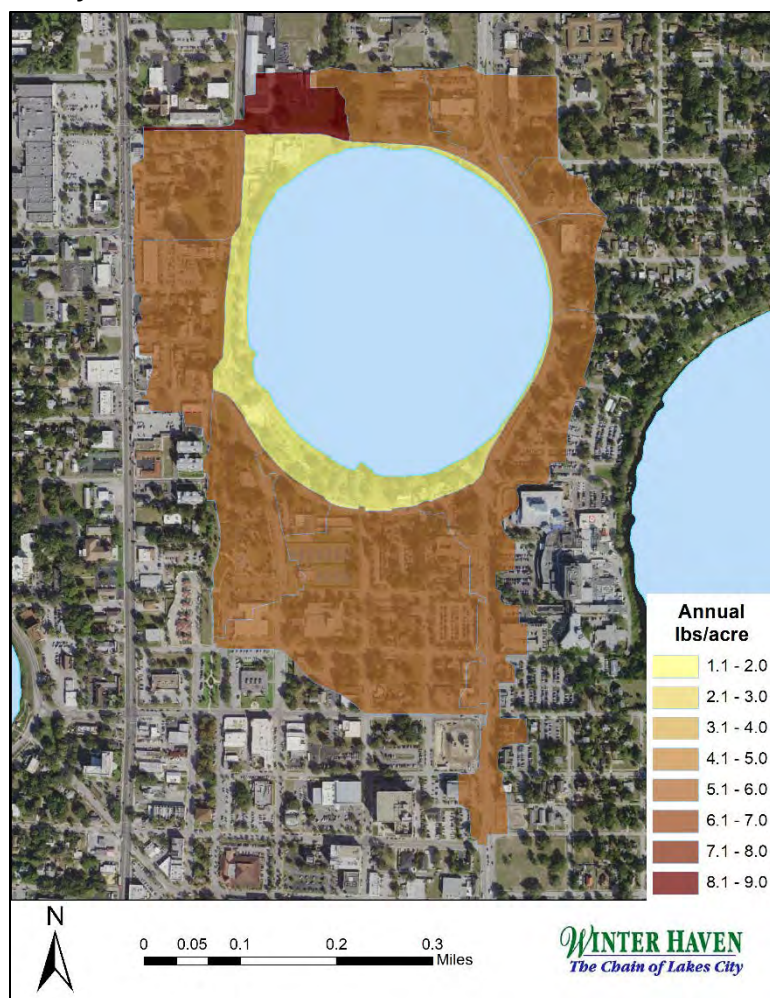


Figure 1-9. Annual Total Nitrogen Loads to Lake Silver in lbs/acre.

determine runoff rates as well as event mean concentrations (EMCs) which denote average loading rates for each pollutant for a given storm event size. The result of this modeling work is the ability to estimate annual pollutant loads from a delineated drainage basin. In Figure 1-9, differences in land use types and impervious percentages result in drastically different TP loading rates.

The calculated loading rates displayed here are raw values that exclude nutrient load reductions from stormwater best management practices (BMPs). There are numerous privately owned BMPs within each drainage basin, however the estimated load reduction they confer is not always documented. The City's Unified Land Development Code

requires a match of pre and post-development runoff rates and volumes [City Code § 21-161]. By design, these BMPs capture the majority of runoff. However, many parcels that were developed before 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 urban center where aging stormwater infrastructure and high density of impervious surfaces funnel untreated stormwater directly to lakes. The City actively installs stormwater management practices that capture, filter, or infiltrate runoff in downtown areas lacking existing infrastructure. Additionally, City officials review development projects and recommend these types of practices on private properties.

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, near 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.

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; that is, maintenance of a healthy, well-balanced population of fish and 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. 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 for 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 1-10). 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, lake morphology, and surface level can significantly impact available real estate where SAV can grow. Common examples of SAV in our lakes include eelgrass (*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 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 oxygen and nutrients to their root systems—meaning that most species are relegated to the shallow margins of lakes. Duck potato (*Sagittaria lancifolia*) and cattail (*Typha spp.*) are a couple examples.

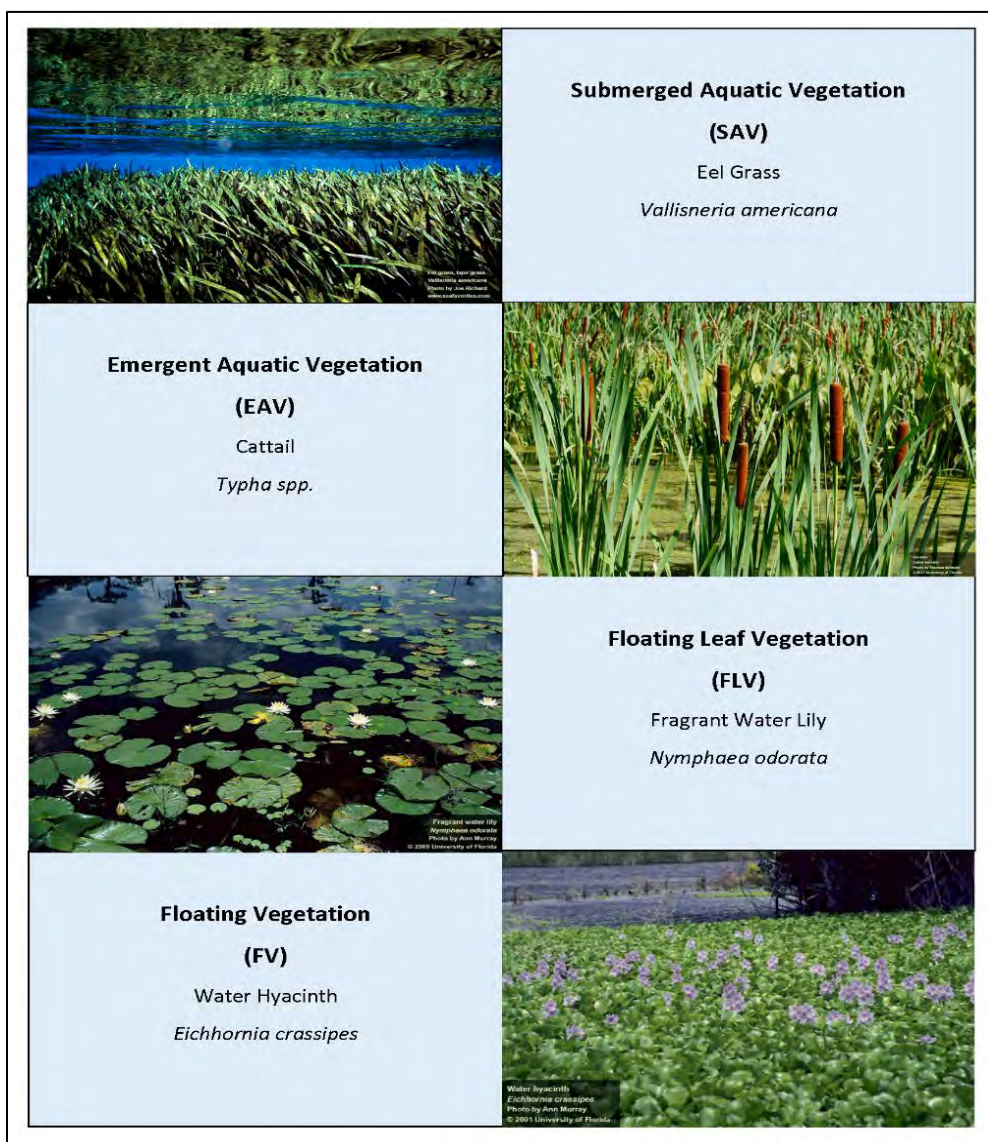


Figure 1-10. Examples of Aquatic Vegetation Categories.

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. The base of these plants is rooted into the substrate, but their floating leaves extend to the water's surface without the need for strong stems to support them. Often, floating leaf plants will form dense stands that can shade out submerged species below them and become 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 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 or nuisance plant species in Florida are floating plants. Examples of FV species are water hyacinths (*Eichhornia crassipes*) and duckweeds (*Lemnoideae spp.*).

Vegetation Abundance

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 on which many species of wildlife rely. Wetlands can act as a pollutant sink and a source of beneficial chemical components [USEPA, 2015]. 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 1-11 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 dense surrounding wetlands, elicits a much stronger relationship between surface

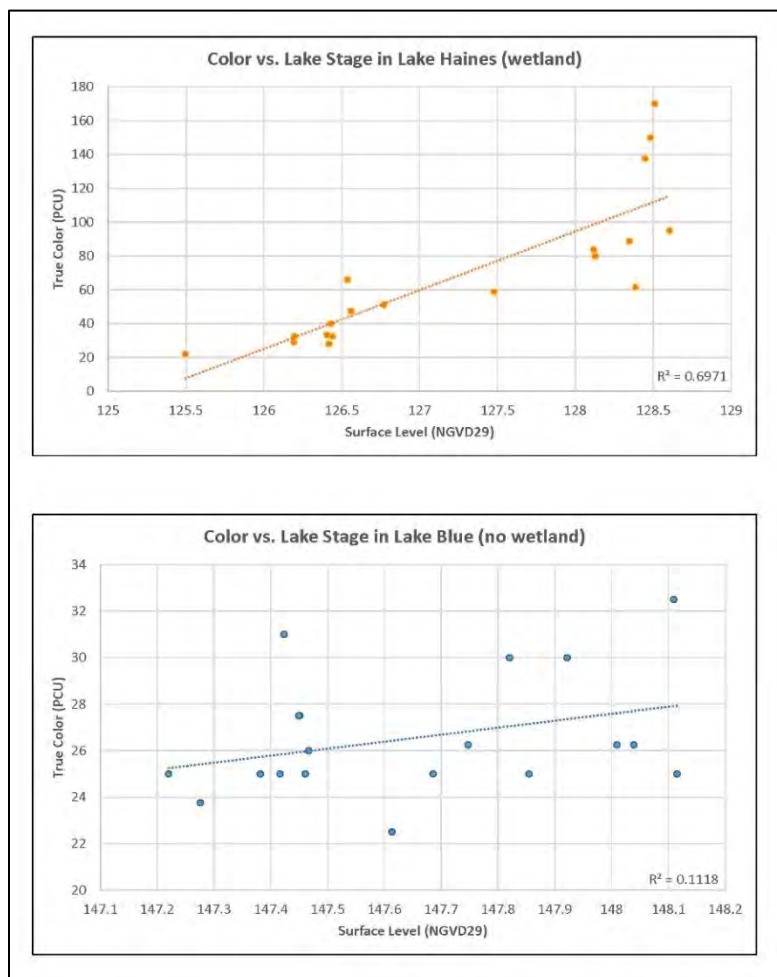


Figure 1-11. Correlation between Wetlands and True Color in Lake Haines & Lake Blue.

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.

The area within a lake that can support the growth of rooted aquatic vegetation is referred to as the littoral zone. Taking into consideration the growth habits of SAV, EAV, and FLV, 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. A strong network of rooted plants contributes to the stabilization of the benthic sediments in lakes [Barko & James, 1998]. Therefore, it can be inferred that a greater area of rooted vegetation generally equates to lower potential suspended sediment concentrations.

One additional benefit of SAV in lakes is their increased capacity to uptake nutrients directly from the water column compared to other growth patterns [Denny, 1980]. 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. In addition to measuring the areal coverage of aquatic plants, SONAR mapping can determine the volume of the water column taken up by plant matter. Both measures are used to evaluate the vegetation abundance in Winter Haven's lakes.

Percent Area Coverage (PAC): The percentage of a lake area taken up by rooted aquatic vegetation. Lake managers suggest maintaining PAC of at least 15% for most Florida lakes.

Biological Volume (BV): The volume of aquatic plant mass measured as a percentage of the total lake volume. Generally, a higher BV equates to better water quality.

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.

Using frequency data, we can identify a waterbody's dominant species, proportion of each plant category, and gauge the relative distribution or evenness of the species present (Figure 1-12). The resulting scores, referred to as diversity index values can be used to evaluate the health of vegetation communities. Ecologically, a diverse and evenly distributed population is a healthy 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, the following indices were chosen to compare the changes in vegetation communities over time and not for comparing the diversity of one lake to another: [Ludwig & Reynolds, 1988]

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 level of uncertainty of sampling the same species multiple times in a row; as such, this value increases as a population becomes more diverse.

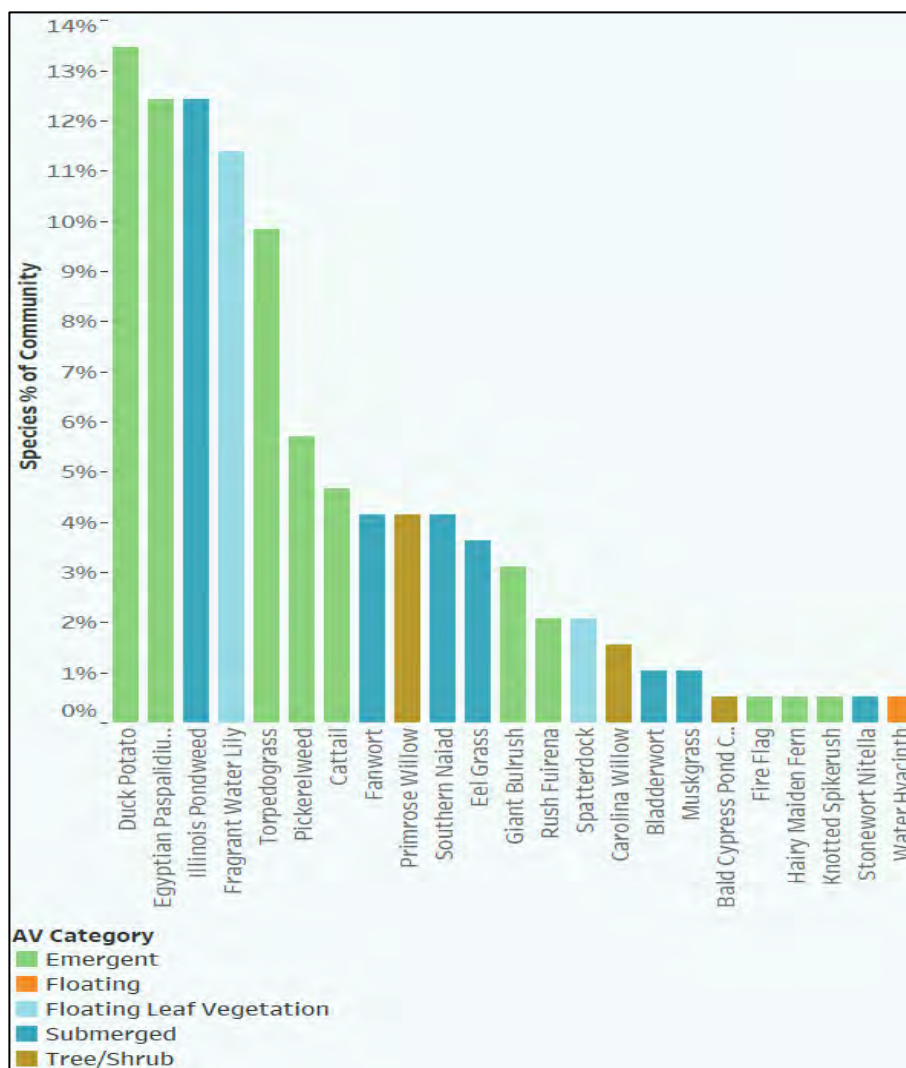


Figure 1-12. Species Frequency Chart of Aquatic Vegetation in Lake Howard (2023).

In the realm of vegetation management, knowing where a given species is located is equally as important as understanding the community 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.

Invasive Species Presence: Measured as the percentage of the total aquatic vegetation community comprised by ecologically or economically significant invasive species. Ideally, invasive presence is maintained at or as close to zero as possible.

The City of Winter Haven manages invasive aquatic plants along City-owned shorelines and provides support to the organizations that manage the lakes. 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.

#2 | Management Strategies



Summary

One of the primary challenges of managing dozens of lakes spanning both urban and rural areas involves balancing the diverse needs of the various lake user groups while addressing the unique challenges associated with each lake or watershed. A single management practice or approach will not be effective in all scenarios. One of the first steps in developing a management strategy is to gain an understanding of which practices are available and applicable in addressing a given issue.

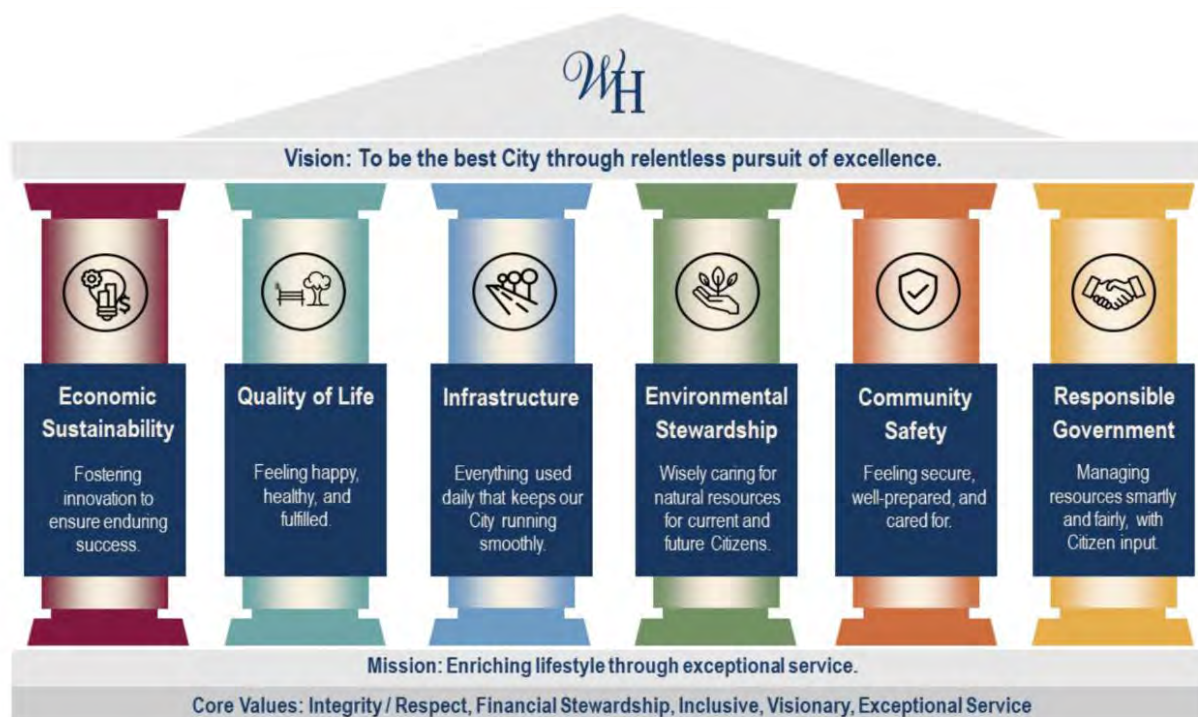
To that end, management practices are often categorized based on what aspects of lake health they seek to maintain or improve. Practices that improve water quality should seek to reduce algae or pollutant concentrations. Hydrologic strategies should incorporate groundwater recharge or surface water storage components to maintain or restore natural hydrologic processes. Strategies aimed at ecological improvement should help to improve fish and wildlife habitat either through the creation of new habitat or by the restoration of disturbed areas. Further, the primary purpose of some practices is to increase awareness of environmental issues and to promote public engagement and stewardship of our natural resources. This last category is important since widespread adoption of pro-environment practices by citizens can be more effective than individual projects implemented by a government agency. In many cases, a single practice is able to address multiple lake health aspects.



The City's Natural Resources team is constantly reviewing the effectiveness of practices the organization currently utilizes while also researching new and innovative solutions applicable to our lakes. The following section details many of the City's management strategies with a brief description of the practice itself and an explanation for which aspect(s) of lake health it addresses. Furthermore, this section of the report details strategic goals for each management strategy that helps demonstrate how staff plan to implement these practices in the future.

Additionally, it is critical for the management strategies to be consistent with the mission, goals, and values of the organization implementing them. In 2024, the City of Winter

Haven Commission adopted its FY 25-29 Strategic Plan which established a comprehensive framework to guide all City policies, operations, and decision-making over the next five years (https://issuu.com/cofwh/docs/city_of_winter_haven_fy25-fy29_strategic_plan_-_v1). The plan describes six pillars that comprise the City's vision for a sustainable, vibrant, and inclusive future: economic sustainability, quality of life, infrastructure, environmental stewardship, community safety, and responsible government. Within each pillar are several broad goals with detailed strategies for successfully implementing those goals. Each of the lake management efforts listed in this section should align with one or more of these goals and/or strategies. This ensures that all of Winter Haven's lake management actions work within the framework approved by the government and its citizens.



Environmental Monitoring



Summary:

Environmental monitoring encompasses the Natural Resources Division's data collection programs as they relate to the lakes and their health. These include water quality sampling, surface level and groundwater level tracking, and aquatic vegetation surveying. The information gathered through these monitoring efforts helps guide the City's management decisions. Since so much of this data appears in the annual Lakes Report, these monitoring efforts not only address the water quality, hydrology, and ecology aspects of lake health, but public engagement as well. Therefore, this particular management strategy lies at the heart of the Division's purpose, mission, and vision. The individual monitoring efforts are described more below:

Aquatic Vegetation Monitoring

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 amount of vegetation in the water column. Percent area cover and biological volume make up the vegetation abundance metrics obtained through SONAR mapping (Figure 2-1). 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

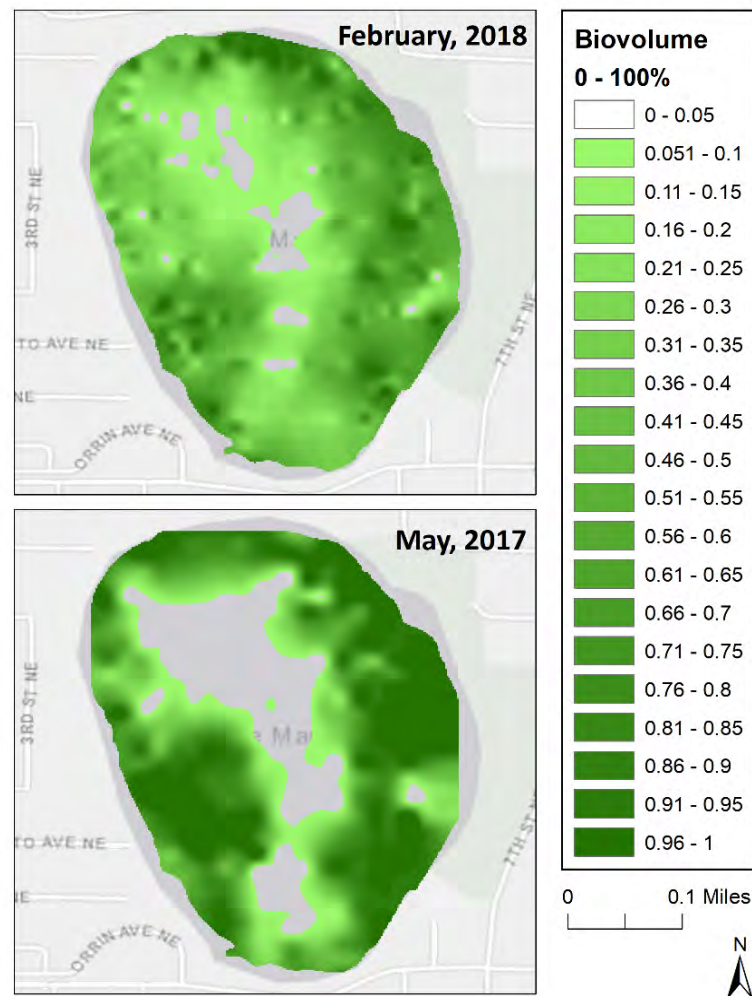


Figure 2-1. Biovolume heat map of Lake Maude. Color scale represents percent of water column occupied by plants.

information is also shared with partner agencies, such as Polk County and the Florida Fish and Wildlife Commission (FWC) to assist with invasive plant management efforts.

Hydrologic Monitoring

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 lake health and municipal water supply. The Natural Resources Division and Utilities Department work together to obtain this data through a network of weather stations, monitoring wells, and surface level gauges located throughout the City. Surface level, rainfall, groundwater, and streamflow data collected by Polk County, the Southwest Florida Water Management District (SWFWMD) and the Lake Region Lakes Management District (LRLMD), is also incorporated into the City's analysis. This data is also used in hydrologic models that can help identify areas of potential flooding and/or higher pollutant loading due to differences in soils and land use.

Water Quality Monitoring

Water quality monitoring involves collecting and analyzing the chemical properties of surface and groundwater. This includes physical properties like dissolved oxygen, pH, and temperature; as well as concentrations of pollutants of concern like chlorophyll-a, nutrients, and other heavy metals. The City relies heavily on outside parties like the Florida Department of Environmental Protection, Polk County, and the volunteer-based Lakewatch program to gather water quality samples—mostly due to funding and staffing constraints. Utilizing these publicly-available data, the City is able to devote more time and effort to statistical analysis; allowing for impairment determination and water quality trend tracking. That said, the City does conduct some water quality sampling such as when evaluating the effectiveness of municipal stormwater or water quality projects or tracking the presence of forever chemicals (e.g. PFAS) in our lakes.

Support of City Pillars:

Environmental Stewardship

Goal 4.3: Continue to monitor lakes and implement proactive strategies for lake management.
Data collected through monitoring efforts drive management strategies to improve lake health. Both the data and these strategies are published in the annual Lakes Report.

Strategic Goals:

- Continue aquatic vegetation, hydrologic, and water quality monitoring efforts for analysis in the annual lakes report and to guide management efforts.
- Stay up to date on new and innovative research, methods, and technologies; such as aerial and satellite imaging, AI-based analysis tools, plant tissue nutrient content analysis, and automated hydrologic monitoring equipment.
- Maintain close working partnerships with state and local environmental agencies.

Green Stormwater Infrastructure



Summary:

Green stormwater infrastructure (GSI) is a term referring to stormwater management practices that incorporate natural processes to capture and filter runoff. Traditional, or “gray”, stormwater infrastructure relies on impervious materials, gutters, and pipes to transfer runoff from one area to another. The primary purpose of gray infrastructure is to prevent flooding by diverting runoff, as well as any pollutants, directly to lakes or stormwater ponds. In contrast, green infrastructure works to slow runoff rates, promote natural hydrologic processes like evaporation and groundwater infiltration, and filter pollutants using the nutrient sequestration capacity of plants.

Infiltration GSI

The purpose of these types of GSI practices is to capture sediments, heavy metals, and other solid debris during the first flush of a rainfall event, preventing it from entering waterbodies at the “end of the pipe”. Taking advantage of well-drained soils to promote infiltration, 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. Under the right soil conditions, these types of GSI can be utilized in lieu of conventional stormwater practices; often occupying smaller footprints than traditional stormwater ponds while providing improved pollutant capture. The common types of infiltration GSI practices include raingardens (Figure 2-2), vegetated swales, and exfiltration pipes (i.e. French drains). Practices such as raingardens can also be a relatively low-cost option for residents to reduce minor flooding and improve aesthetics on private property as well. Currently, the City has constructed over 60 raingardens, bioswales, and exfiltration systems in and around Winter Haven’s urban center. Waterbodies receiving stormwater benefits from these systems include: Lakes Elbert, Howard, Martha, Maude, May, Otis, Roy, and Silver.



Figure 2-2. Photo of a raingarden capturing runoff and road debris in downtown Winter Haven.

Storage GSI

In areas lacking highly porous soils, infiltration GSI practices become much less effective. Instead, there are types of GSI practices that are designed to store stormwater and slow down runoff rates. One type of storage practice includes constructed wetlands which function similarly to traditional stormwater retention ponds. However, these practices have added benefits such as increased evaporation and plant water uptake (transpiration), nutrient sequestration by the wetland plants, and habitat for fish and wildlife. Additionally, these areas can be used as recreational green spaces by the public. The City has constructed four of these constructed wetland parks ranging from the 6 acre Lake Maude Nature Park to the 40 acre Lake Conine Nature Park. These parks capture and filter runoff from drainage basins totaling over 760 acres while also providing enhanced features like walking trails, picnic pavilions, and playgrounds (Figure 2-3). The natural resources division maintains these parks through regular invasive plant management efforts and occasional sediment removal. Other forms of storage GSI practices include rainwater catchment systems and green roofs. Rain barrels are an excellent example of a storage practice that is low cost and easily implemented by residents and homeowners.



Figure 2-3. Map depicting the Winter Haven nature parks and their drainage basins.

Support of City Pillars:

Quality of Life

Goal 2.3: Champion arts, beautification, and address blight to be an attractive and enriching community. *Many of the green infrastructure practices implemented on public properties and rights-of-way include landscaping design choices that enhance the aesthetics of the City's green spaces.*

Goal 2.4: Ensure that as the City grows, opportunities for access to recreation grow along with the population, especially geographically. *Constructed wetland parks include passive recreational amenities such as walking trails, exercise equipment, picnic areas, and playgrounds that further the recreational opportunities available in various locations throughout Winter Haven.*

Infrastructure

Goal 3.4: Pursue emerging opportunities to embrace new technology, infrastructure, and enterprise opportunities. *Green stormwater infrastructure is considered an innovative stormwater design strategy for managing urban runoff. City staff are consistently identifying areas where GSI can be implemented to address nonexistent or underperforming gray infrastructure.*

Environmental Stewardship

Goal 4.3: Continue to monitor lakes and implement proactive strategies for lake management. *One of the primary benefits of GSI is the reduction in stormwater runoff and pollutant loading to the lakes.*

Goal 4.4 Integrate the elements of the One Water philosophy to ensure a balance between water supply and nature. *Many GSI practices promote groundwater infiltration where applicable; leading to an increase in aquifer recharge and more sustainability of the City's water supply.*

Strategic Goals:

- Continue to maintain the functionality of the more than 75 green stormwater best management practices; including regular sediment removal and landscape maintenance of raingardens & exfiltration systems, sediment removal and vegetation management of the nature park ponds.
- Complete expansion of South Lake Howard Nature Park, to include additional stormwater treatment and recreational amenities (by FY2027).
- Complete Lake Elbert trail project, to include vegetated swales and raingardens to capture runoff from a previously untreated drainage basin (by FY2026).
- Explore opportunities to implement additional GSI practices where needed; specifically in areas lacking existing infrastructure and those experiencing roadway flooding and relatively high pollutant loading rates.

Low-Impact Development & Gray to Green



Summary:

Conventional development philosophy has been to move stormwater runoff off of roads and properties as quickly as possible; sending pollutants downstream to the lakes with little to no treatment. This type of stormwater management is often referred to as gray infrastructure in reference to the use of pipes, drains, and concrete flumes. In recent decades, there has been an increase in awareness and adoption of low-impact development (LID); stormwater practices that seek to slow, spread, and soak runoff into the landscape close to where it originates. These features usually try to mimic natural hydrologic processes like groundwater infiltration and evapotranspiration, often incorporating vegetation into their designs (e.g. raingardens, grassed swales, etc.). This led to these best management practices being defined as green stormwater infrastructure (GSI). Taken together, LID+GSI provides water quality and hydrologic benefits for local lakes.

Since the 1990s, Winter Haven has become a forerunner in the implementation of GSI in the state of Florida by implementing numerous raingardens and infiltration basins throughout the City. However, to be effective, it was determined that the adoption of GSI practices on City properties and rights of way alone would not be sufficient. Therefore, in 2016, the City initiated a public education program targeting local engineers and developers, providing tools and incentives to shift mindsets away from gray infrastructure and toward GSI. This program was referred to as Gray to Green.

The Gray to Green initiative began by exploring the perceived benefits and barriers to widespread LID+GSI adoption within the development community. Based on feedback from roundtable discussions with local development professionals, the City worked with subject matter experts to produce a Gray to Green Development Guide. This document was designed to be an educational introduction to the philosophy of LID+GSI; illustrating the benefits and demonstrating which practices would be effective in the Winter Haven area. Expanding on the development guide, the City followed up with the creation of the Gray to Green Permit Design Methodology—a step-by-step guide for engineers on how to properly design GSI practices and how to get infiltration credit through the permitting process. Both phases of the Gray to Green program were made possible through 319 Stormwater Education grants via the Florida Department of Environmental Protection.

City staff continue to prioritize developer adoption of LID+GSI through the development review process. Natural Resources staff not only promote the Gray to Green philosophy to developers, but we actively review and recommend specific practices based on individual site conditions. Advocating for these GSI practices early in the development review process is critical in order to reduce redesign costs by developers. At its heart, the Gray to Green program is an education strategy designed to increase engagement with practices and technologies that benefit the environment.

Support of City Pillars:

Economic Sustainability

Goal 1.4: Ensure the strategic approach to growth management that includes robust public engagement. *The Gray to Green program seeks to engage the development community in sustainable development practices that are considered a smart form of growth.*

Quality of Life

Goal 2.3: Champion arts, beautification, and address blight to be an attractive and enriching community. *The principles of low-impact development include preserving open space and utilizing green infrastructure to capture and store stormwater runoff on site. These concepts implemented in new development promote aesthetic benefits and beautification over traditional pipe and pond systems.*

Infrastructure

Goal 3.4: Pursue emerging opportunities to embrace new technology, infrastructure, and enterprise opportunities. *The Gray to Green program champions the innovative principles of low-impact development and promotes LID+GSI practices on private properties through new and redevelopment.*

Environmental Stewardship

Goal 4.2: Leverage partnerships and implement best practices to ensure a clean environment for all citizens. *The Gray to Green Development Guide and Permit Design Manual are tools to assist in collaborations with private developers to implement innovative best management practices.*

Goal 4.3 Continue to monitor lakes and implement proactive strategies for lake management. *One of the primary benefits of GSI is the reduction in stormwater runoff and pollutant loading to the lakes.*

Goal 4.4 Integrate the elements of the One Water philosophy to ensure a balance between water supply and nature. *Many GSI practices promote groundwater infiltration where applicable, which leads to an increase in aquifer recharge and more sustainability of the City's water supply.*

Strategic Goals:

- Continue promotion of the Gray to Green Development Guide and Permit Design Manual to construction, engineering, and landscape architecture firms seeking to engage in commercial and residential development within the City of Winter Haven.
- Conduct and support research into developer perceptions on municipal stormwater policies that can promote LID+GSI practices by private commercial and residential developers (by FY2027).
- Pursuant to Strategic Plan goals 4.3.5 and 4.4.1: work with the Winter Haven Planning Department to update the City's land development code and comprehensive plan such that LID+GSI is promoted and incentivized.



National Pollutant Discharge Elimination System Reporting

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 the City of Winter Haven as a co-permittee under it. 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. Natural Resources staff compile relevant information from each City department and submit an annual NPDES report to the FDEP each spring. The benefit of this program to the City is the quantifiable standard it provides for actions like stormwater infrastructure inspections and repairs, best management practices implemented, and outreach programs conducted that can be referenced to track annual performance.

Support of City Pillars:

Infrastructure

Sub-goal 3.3.4: Maintain relationships with local, regional, state, and federal regulatory agencies directly related to integrated water resource management. *The NPDES reporting process requires that the City report its stormwater management efforts to the Federal, State, and County agencies. This enhances accountability by ensuring that Winter Haven maintains the strict standards outlined in the NPDES reporting guidelines. It also provides an opportunity to coordinate with other co-permittees under the Polk County permit.*

Environmental Stewardship

Goal 4.3: Continue to monitor lakes and implement proactive strategies for lake management. *The NPDES report requires annual evaluation of lake water quality and other factors important to lake health; ensuring that the City is cognizant of potential infrastructure and management needs.*

Strategic Goals:

- Submit report for Cycle 4 Year 8 report by March 2025.
- Begin compiling data for Cycle 4 Year 9 report due in 2026.
- Attend coordination meetings with NPDES report co-permittees and FDEP/EPA agency officials.



Nutrient Pollutant Inactivation/Treatment

Summary:

Nutrient inactivation is an umbrella term for a suite of non-structural best management practices that utilize chemical compounds that limit the bioavailability of pollutants like nitrogen and phosphorus in a lake's water column or sediments. These options are useful in situations where other stormwater control strategies would not be as effective; for example, areas lacking space for structural practices like raingardens. There are numerous products available that differ in their active ingredients, modes of action, and methods of application. Some target phosphorus in the water column, whereas others help to keep nutrients from escaping from the sediments on the lake bed. Understanding where each is effective and applicable is important for lake managers.

Aluminum sulfate (Al_2SO_4), also known as alum, has been a popular treatment option to reduce phosphorus and total suspended solids concentrations in surface waters for several decades. Alum works as a coagulant, causing nutrients and sediments to adsorb to the product's particles and bind together into a gelatinous flocculent (Figure 2-4). This alum floc is stable in a pH range of 5.5 – 7.5 [Harper, 2007] making it effective in Winter Haven's lakes which are typically a neutral pH of 7. Alum can be broadcast over the entirety of a lake's surface to strip phosphorus from the water column, or injected at stormwater outfalls to treat pollutants from a discrete entry point. The City currently maintains three alum injection sites at points on Lakes Howard, Lulu, and May. Additionally, a broadcast alum treatment was conducted by Polk County in the mid-1990's to cap internal phosphorus loading from historic point-source discharges in Lake Conine [ERD, 2018].

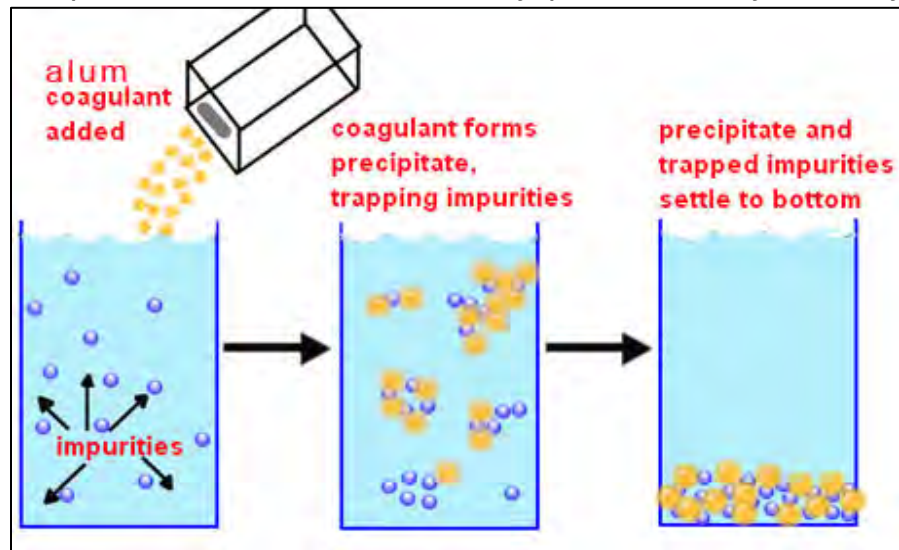


Figure 2-4 Diagram of alum floc adsorption properties. [Bionics, 2013]

Other phosphorus-binding materials include lanthanum-based products like Phoslock® and EutroSORB®. These function very similarly to alum, but instead of using aluminum sulfate, bioavailable phosphorous in sediment binds to a lanthanum-embedded bentonite clay material. These have shown relatively high capacity to reduce total phosphorus concentrations in lakes and reduce phosphorus flux from lake bed sediments [Copetti et al., 2016]. These products are relatively new, so lake managers are exploring different applications such as stormwater

effluent filtration or broadcast applications over large areas. The City of Winter Haven has conducted a pilot study using EutroSORB® on a small private lake, with great success. This has resulted in plans to employ this product to reduce phosphorus levels in Lake Idyl as well. While these products have been shown to be effective in different applications, they are relatively expensive compared to alum or other options.

An even more recent product that aims to inactivate phosphate from the water column is made from silica (i.e. sand particles). Products like Algae Armor are demonstrated to remove up to 80% of the phosphate dissolved in the water column [Xanthopoulou et al., 2021]. Despite being the least expensive category of phosphorus-reducing products on the market, it only targets dissolved phosphate in the water column, with minimal application to deactivate sediment-bound phosphorus. The City is currently exploring a pilot study to examine the effectiveness of this product and where it can most feasibly be utilized.

Support of City Pillars:

Environmental Stewardship

Goal 4.3: Continue to monitor lakes and implement proactive strategies for lake management. *Phosphorus is considered a pollutant of concerns for the majority of lakes in the Winter Haven area. Addressing phosphorus loading from stormwater runoff and flux from lake sediments helps to curtail eutrophication, thereby reducing the presence of harmful algal blooms and growth of nuisance vegetation in the lakes.*

Sub-goal 4.4.3: Explore and implement best management practices and innovative approaches to water resource infrastructure that further protect the natural environment. *Identifying and testing innovative products and approaches to phosphorus inactivation keeps staff knowledgeable about the latest scientific advancements and provides opportunities for the City to be a leader in lake management research application.*

Strategic Goals:

- Continue to maintain the City's 3 alum injection systems at Lakes Howard, Lulu, and May.
- Acquire grant funding to implement a EutroSORB® treatment for Lake Idyl.
- Conduct pilot study exploring the effectiveness of Algae Armor® in the Lake Conine Nature Park ponds and determine if silica-based products are a viable solution for lake phosphate removal (in FY2025).

One Water



Summary:

One Water is an organizational planning effort which was borne out of the 2010 Sustainable Water Resource Plan and seeks to preserve the quality of life afforded by Winter Haven's water resources. The impetus for this effort is the identified threat of hydrologic decline that is driven by several factors: population growth, limited fresh water supply, climate change, aging infrastructure, funding needs, and increased regulatory pressure [Black & Veatch, 2021]. The goals of the plan are to ensure the future of the region's potable water supply and natural water resources. This is accomplished by improving utility planning, water conservation, wastewater treatment processes, reuse water infrastructure, watershed optimization, land use planning, and many other practices.

One of the signature recommendations evaluated and accepted as part of the One Water Master Plan is the Sapphire Necklace—a conceptual design of Winter Haven ringed by approximately 5000 acres of restored wetlands and nature parks (Figure 2-5). These sites would provide water storage, groundwater infiltration, wildlife habitat, and the backdrop for recreational amenities such as an expanded trail network—all of which benefit Winter Haven's lakes and the residents that utilize them while addressing water quality, hydrologic, ecologic, and public engagement needs of the community.

For more information visit:

OneWaterWH.com



Support of City Pillars:

Infrastructure

Sub-goal 3.3.1: Adopt, implement, and maintain the One Water Master Plan to ensure sufficient capacity for potable, reuse, and wastewater needs. *Completing and implementing the One Water Master Plan is, in itself, one of the City's primary strategic goals. Natural Resources' role in this effort is to provide technical guidance on hydrologic analysis and monitoring.*

Environmental Stewardship

Sub-goal 4.4.2: Continue to explore acquisition and/or activation opportunities of priority parcels that significantly benefit sustainable water resource initiatives. *The Natural Resources Division has assisted with identifying and acquiring potential wetland restoration sites that further the water storage and treatment capacity of the Winter Haven area.*

Strategic Goals:

- Budget for and complete the water storage features at the newly acquired parcel on Dundee Rd.
- Work with Polk County Environmental Lands to complete purchase of wetland parcel on US17.

- Currently working with Polk County to acquire a wetland parcel at the corner of US17 & Hwy 92

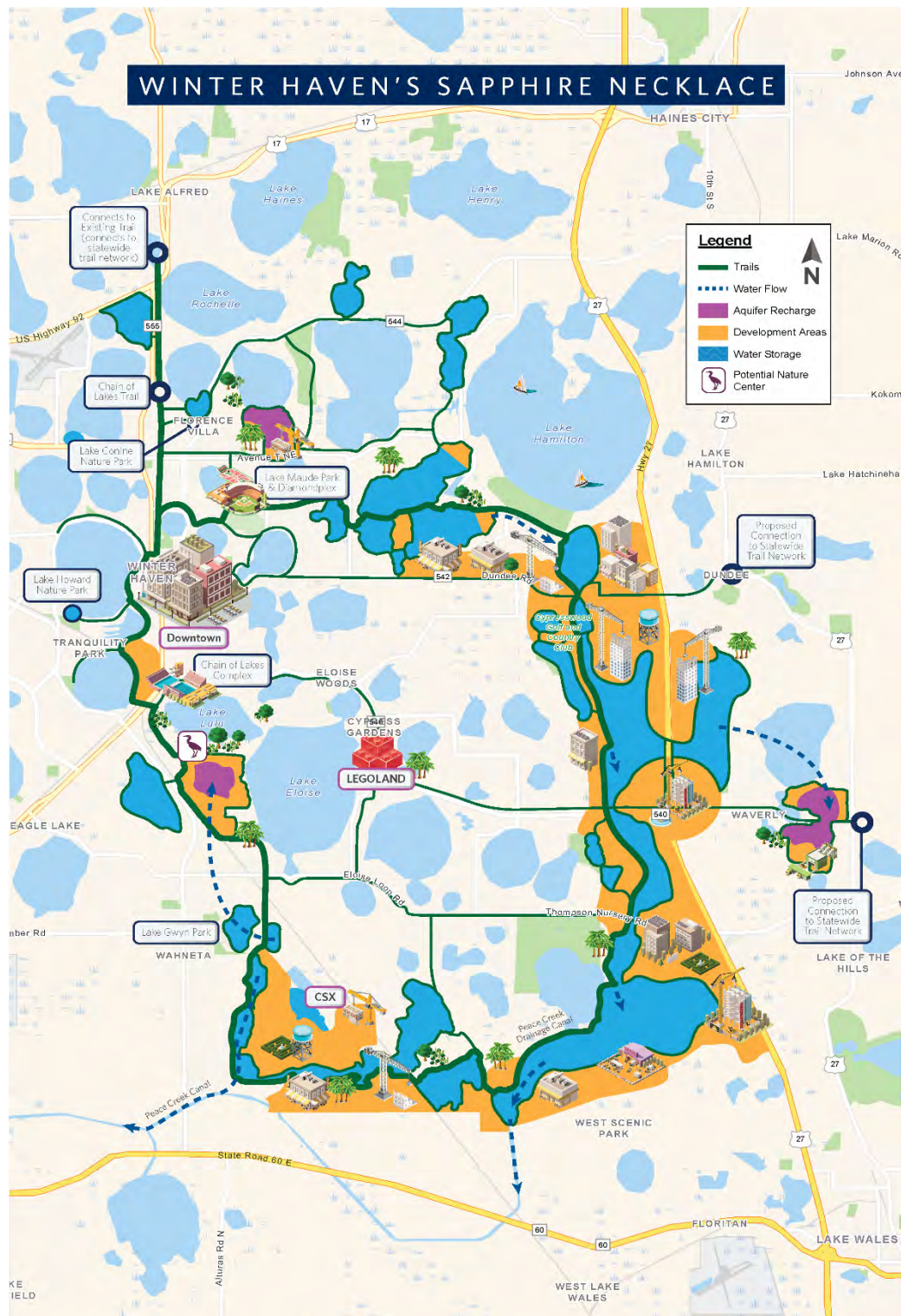


Figure 2-5. Rendering of the Sapphire Necklace concept that includes water storage, aquifer recharge, and nature park areas.

Public Outreach & Education



Summary:

Outreach encompasses most of the Division's efforts that spread information to the public, with the aim of increasing knowledge and engagement to solve common issues like litter, residential runoff, and overuse of potable water. Some believe that the role of government agencies is to solve issues through command and control policies like regulations. However, studies have shown that many environmental issues cannot be solved through regulatory compliance alone—mostly due to limits on staff and funding to implement, oversee, and enforce these regulations [Paddock, 2004]. Instead, increasing residents' understanding of local environmental issues is shown to result in voluntary public participation and stewardship actions. Therefore, informal education efforts are a vital public service that help to protect natural resources by motivating community participation. The Natural Resources Division has implemented numerous outreach programs that fall into distinct categories:

Public Events

Staff participation in public events like the 7 Rivers Water Festival, Arbor Day, and Community Fest are opportunities to hear from individual residents and respond with personalized information and guidance in a relaxed setting (Figure 2-6). The events often provide the widest reach, allowing for interactions with several dozen to several hundred participants per event. Whether the events are sponsored by the City or another agency (e.g. Water Wings & Wild Things at Circle B Bar Reserve), the Natural Resources team is excited to participate and interact with attendees.

Recreation

Residents who can physically interact with natural resources may be more likely to take action to protect them. Kayaking is an excellent outreach opportunity to introduce residents to our water



Figure 2-6. Photo of 2025 Community Fest booth with activity teaching about the impacts from litter.



Figure 2-7. Image of 2022 guided kayak tour on Lakes Conine and Hartridge.

resources and the plants and animals that reside in them (Figure 2-7). Time spent on the water provides unique experiences and settings that help to convey concepts like water quality, hydrology, ecology, and what actions residents can make to improve them. These tours are typically hosted on local lakes several times per year and attendees are provided with a pre and post tour survey to gauge knowledge retention and satisfaction.

Workshops/Seminars

These include adult educational programs that target neighborhood, community groups and homeowners' associations (HOAs). The goal is to provide knowledge so that these groups can solve issues specific to their area. Workshop topics include sustainable landscaping, residential stormwater management, and living with wildlife. While the total number of participants is smaller than the public events, these seminars provide a unique forum for community members to share their specific issues and gain insights into how they can be solved through cooperation. The City has conducted in-person lake watershed seminars, virtual raingarden workshops, and community tree planting discussions; with plans to expand the capacity to implement more each year.

Volunteer Missions

Volunteer events provide unique opportunities for especially dedicated residents to make a difference in their community. The City has traditionally partnered with other organizations, like Keep Winter Haven Clean and Beautiful to host litter pick-up events such as Project Eagle. Recently, the Natural Resources Division has begun sponsoring other types of activities like lakeshore clean-ups and adopt-a-raingarden programs. These forms of outreach are still relatively new, but the City's strategic plan includes goals associated with developing and expanding a City-wide volunteer network.

Youth Education

The primary objective of youth outreach is the creation of positive experiences that instill an appreciation for water, wildlife, and outdoor recreational activities. Children that are able to build stronger connections with nature are increasingly likely to engage in stewardship or other activities that protect natural resources later in life [Andrejewski, 2011]. Outreach also supports STEM education by reinforcing concepts learned in school while

providing guidance to students interested in pursuing careers in environmental sciences. Natural Resources staff have worked with numerous local schools and youth organizations, developing lesson plans and teaching both in the classroom and on field trips. Additionally, the City hosts a youth summer camp annually where attendees get to learn about nature, the water cycle, and local wildlife at South Lake Howard Nature Park.

Support of City Pillars:

Quality of Life

Sub-goal 2.3.2: Establish a community adoption program for rights of way, parks, and public spaces. *While the volunteer missions so far have only included individual events, there are plans to incorporate public lakeshores, raingardens, and parks into the planned public space adoption program.*

Sub-goal 2.4.5: Provide creative opportunities for adult sports and recreation. *The City's kayaking tours on public lakes constitute a unique recreational opportunity in addition to the educational benefits they provide.*

Environmental Stewardship

Sub-goal 4.3.2: Develop and facilitate an education/outreach program tied to awareness and protection of local lakes. *The majority of the outreach programs mentioned in this section aim to improve lake health by developing public stewardship of these resources.*

Strategic Goals:

- The City conducted 37 outreach events in 2024 with a total of almost 1,800 individual engagements. A comparison of records over the last five years marks this as a record for the most public education and engagement during a calendar year.
- Continue to participate in public outreach events and develop new and unique offerings and educational opportunities at Natural Resources' booths.
- Conduct at least 3 adult educational workshops/seminars in 2025; focusing on Florida Friendly Landscaping, sustainable stormwater management, and lakeshore/pond vegetation management.
- Increase the frequency of guided kayak tours on local lakes (at least 9) in 2025.
- Coordinate with UF/IFAS to enhance the educational lesson plans incorporated during kayak tours.
- Budget for kayak, trailer, and equipment upkeep and replacement at regular intervals to ensure quality experiences for participants.
- Continue to develop relationships with local schools and youth organizations to expand youth education opportunities.
- Organize and conduct at least two litter clean-up events in 2025.

Sediment Management



Summary:

As a result of natural deposition, biological cycles, and pollution, sediment (aka muck) accumulates in Florida's waterbodies over time. Sediment deposited from historic point-sources, often referred to as legacy sediments, can be a significant contributor of nitrogen and phosphorus. Internal pollutant loading, also known as nutrient flux, can be exacerbated by low lake surface levels as well as wind and wave action. This internal loading can even exceed pollutant reductions from external sources such as stormwater—leading to declines in water quality despite the implementation of numerous best management practices [PBS&J, 2010]. As a result, the City of Winter Haven conducted sediment analysis in several muck-heavy waterbodies. Sediment cores were collected from Lakes Lulu, May, and Shipp from 2005 to 2009, coupled with bathymetric evaluation to determine water and muck volumes as well as seepage monitoring and chemical analysis of surface water and sediments to estimate internal nutrient loading.

The volume of muck in Lakes Lulu, May, and Shipp was estimated to be 1.3M yd³, 1.0M yd³, and 487K yd³, respectively. To put these volumes in perspective, if equally distributed over the lake's surface area, the depth of muck in Lakes Lulu, May, and Shipp would be 2.25 ft, 2.75 ft, and 6 ft, respectively. The estimated annual nitrogen and phosphorus loading from these sediments is provided in Table 2-1 [PBS&J, 2010]. Based on these estimates, internal influx accounts for between 27%-44% of total nitrogen loading and between 5%-14% of total phosphorus loading in these lakes.

While nutrient inactivation treatments can help to reduce internal loads of phosphorus, nitrogen flux and sediment suspension through wind and wave action limit their effectiveness. Therefore, sediment removal via dredging remains one of the most effective means of mitigating legacy nutrient loading. However, this practice is often prohibitively expensive—exceeding multi-million dollar figures for even small areas of muck removal. Nonetheless, the City has explored outside funding opportunities and other means to reduce these costs. Recently, staff are seeking legislative funding to develop a pilot project that would remove a considerable volume of sediment from Lake May. A significant cost-cutting aspect of this project is the utilization of a City-owned parcel on the southwest shore of Lake May to temporarily store and dewater the removed muck. The expected outcome includes improvements to water quality, navigability, and fish habitat in the lake.

Lake	TN Influx (kg)	TP Influx (kg)	TN Areal Loading (kg/ac)	TP Areal Loading (kg/ac)
May	641	14.3	12.7	0.28
Shipp	2814	80.5	10.2	0.29
Lulu	1668	91.7	5.43	0.3

Table 2-1. Annual TN & TP mass loading & areal loading values for Lakes May, Shipp, and Lulu determined through the sediment analysis performed by ERD.

Support of Mission, Vision, and Purpose:**Environmental Stewardship**

Sub-goal 4.3.4: Inventory and develop strategies to address legacy stormwater systems and discharges that negatively impact local waterbodies. *Much of the sedimentation that occurs in local lakes is considered to be comprised of legacy pollutants from historic point-source discharges (i.e. wastewater, stormwater, etc.). Sediment removal is a viable strategy that has been identified and efforts are underway to acquire funding to implement it as a management practice.*

Strategic Goals:

- Continue to seek grant and/or legislative funding for sediment removal projects in Winter Haven lakes.

Stormwater Assessment and Improvement Program



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 involved contracted work through the consulting firm Chastain-Skillman. The SAIP is a four-pronged approach that includes:

1. Cataloging and refining a database of stormwater infrastructure using geographic information systems (GIS).
2. Ground-truthing existing and previously unidentified stormwater infrastructure with information such as pipe and drain size, material type (e.g. concrete, steel, etc.), and flow capacity.
3. Hydrologic modeling, which incorporates accurate topographic, surface water, and groundwater information as well as land use and impervious surface data to identify areas where storm flooding and pollutant loading are highest.
4. Identification and prioritization of targets for improvement by incorporating all of the previously mentioned methods. This suite of information allows the Public Works Department make objective, data-driven decisions about where to address stormwater issues.

The City has incorporated asset management software into this plan, which has greatly enhanced the speed and efficiency of repairs, maintenance, and improvements to Winter Haven's stormwater systems. Figure 2-8 displays the locations of high-priority target areas within the City as identified by initial evaluation by the SAIP. Once improvements are implemented in the top priority areas, future analysis of this stormwater model will allow the City to explore additional areas in need of stormwater infrastructure practices.

Traditionally, stormwater improvement needs are identified by City staff that observe conditions directly in the field or when residents submit complaints. As a result, this process has been reactive. The primary benefit of utilizing up-to-date data and modelling, is that the City can now take a more proactive approach to addressing drainage issues. However, this effort requires consistent inspections and cataloging of information to function properly—underscoring the need for proper data management.

Support of City Pillars:

Infrastructure

Sub-goal 3.4.1: Incorporate advanced transportation and infrastructure systems that leverage technology for enhanced effectiveness and efficiency in the delivery of municipal services. *The SAIP utilizes innovative technologies, like ArcGIS and Cartegraph asset management software to increase the efficiency and effectiveness of stormwater infrastructure improvement.*

Environmental Stewardship

Sub-goal 4.3.4: Inventory and develop strategies to address legacy stormwater systems and discharges that negatively impact local waterbodies. *One of the most critical components of the SAIP is the inventorying of existing stormwater infrastructure to determine where repairs and improvements are needed. Implementing these improvements often comes with significant water quality and hydrologic improvements for lakes and their drainage basins.*

Strategic Goals:

- Utilize concept plans for Priority Area 1 from SAIP to implement stormwater improvements for Lake Idyl. These improvements were incorporated into a Pollutant Reduction Plan submitted to FDEP in 2024.
- Acquire funding for implementation of Priority Area 1 stormwater improvements; FDEP 319 Stormwater Grant application submitted in 2024.
- Explore implementation of stormwater improvements in the other priority areas identified in the SAIP.

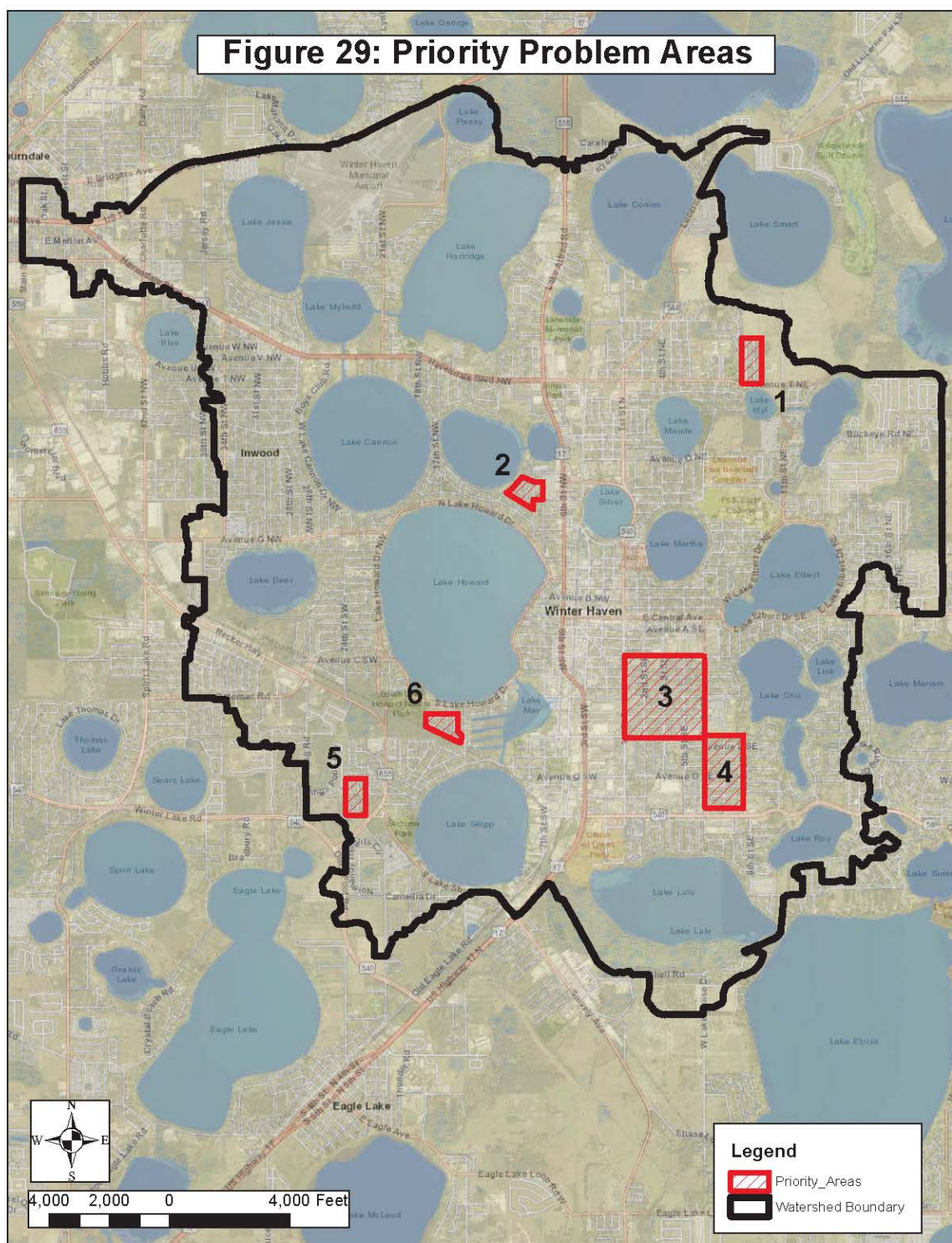


Figure 2-8. Priority sites indicated by increased flooding and pollutant load potential as determined by the Winter Haven SAIP.

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 debris before it can enter the stormwater infrastructure and the lakes. In 2013, the City contracted third-party support to sweep curbed streets in specified areas to mitigate this pollutant loading source. However, in 2016, the City began exploring a transition to in-house sweeping services in order to improve the quality and efficiency of road debris removal. In 2020, a new position was created within the Drainage division and a street sweeper was purchased; leading to an increase in sweeping quality, efficiency, route control, and total area swept.

The areas where sweeping is conducted include commercial and residential roadways in the core downtown corridor. Department of Transportation (DOT) roads have also been prioritized for regular sweeping. The sweeper routes and frequency are presented in Figure 2-9. In 2023, the City swept over 2000 centerline miles, equating to over 2000 lbs of nitrogen and over 4000 lbs of phosphorus prevented from entering into local lakes.

Support of City Pillars:

Environmental Stewardship

Sub-goal 4.2.2: Develop and implement a litter and dumping mitigation plan. *Street sweeping efforts help to remove a considerable amount of litter from entering the City's stormwater system.*

Sub-goal 4.4.3: Explore and implement best management practices and innovative approaches to water resource infrastructure that further protect the natural environment. *The debris and sediment captured through street sweeping is a preventative measure that helps to improve lake water quality.*

Strategic Goals:

- Continue to conduct in-house sweeping services as a best management practice to reduce pollutant loading to the lakes.
- Fill the street sweeper employee position vacated since early 2024; due to this position being vacant, minimal street sweeping was conducted during this calendar year.
- Explore the addition of new sweeper routes and/or increasing the frequency of sweeping in high-volume areas.

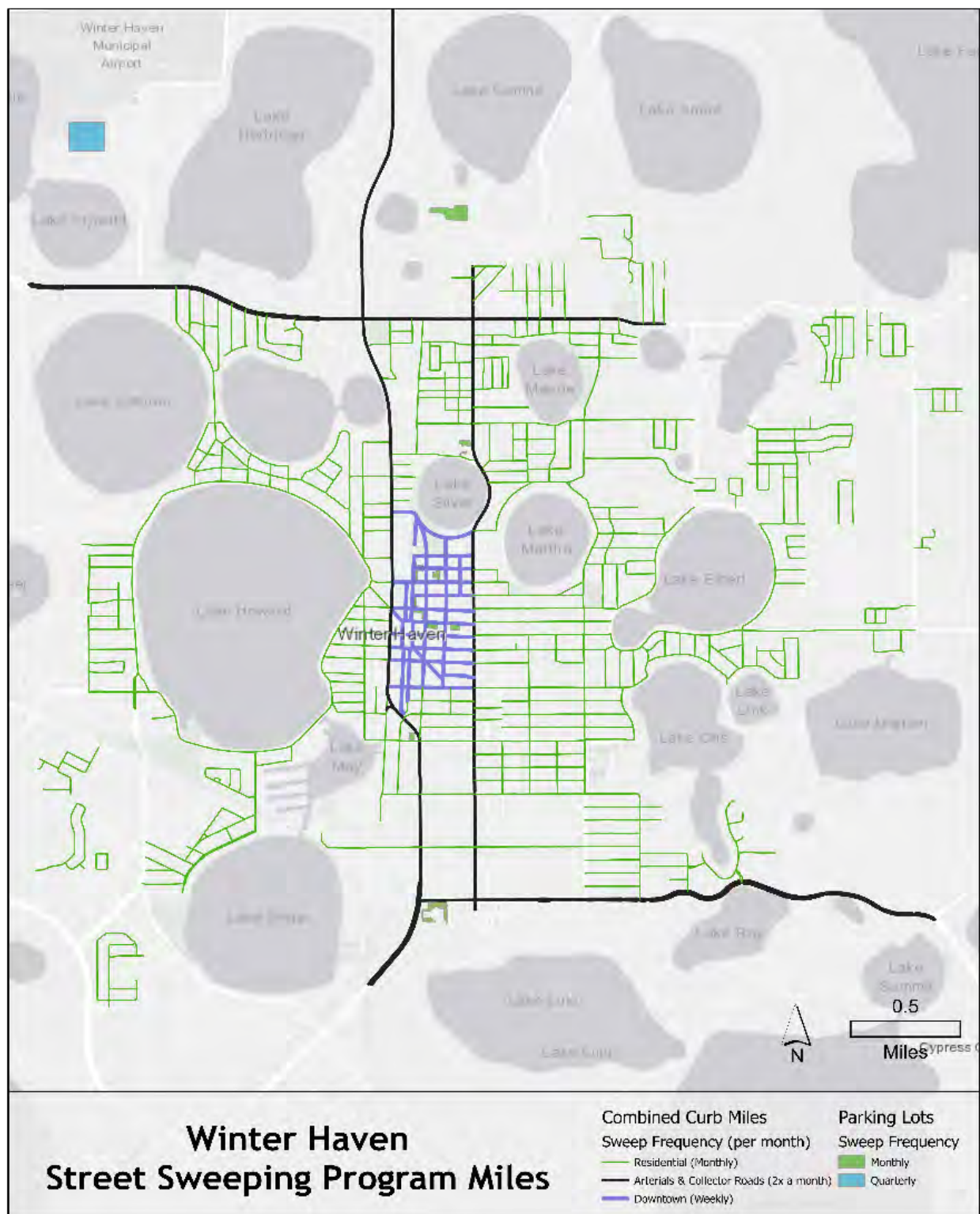


Figure 2-9. Map depicting roadways undergoing street sweeping. Legend indicates sweeping frequency of each street category.

Vegetation & Habitat Management



Summary:

Fostering adequate fish and wildlife habitat is one of the core objectives for managing healthy lakes. In the absence of more structural features like coral and rock outcroppings not typically found in Florida's fresh waterbodies, the majority of habitat is comprised of aquatic vegetation. Proper management of this habitat involves actions that promote the proper abundance and diversity of plants. Some circumstances may require removal of nuisance plants and floating mats of vegetation (i.e. tussocks), which can cause both ecological and economic issues. Areas underneath tussocks are deprived of oxygen creating dead zones. Also, as tussocks drift around lakes, they can become navigational hazards by blocking canals and stormwater outflows.



Figure 2-10. Photos of Lake Martha diesel spill remediation planting (top) and Lake Idyl tussock removal (bottom).

Another practice involves the reduction and removal of invasive plant species (Figure 2-10). Native plants have trouble competing with the extraordinary growth rates and lack of natural predators of exotic species, thus reducing diversity and wildlife habitat. Many invasive plants, like hydrilla and water hyacinth can clog up waterways, making navigation and recreational activities more difficult. Controlling terrestrial invasives, like Brazilian Peppertree, is also important for maintaining healthy ecosystems on City-owned properties. Controlling the introduction and spread of invasive plants is critical to preserving the health of our lakes and other natural resources. That said, early detection and rapid response planning is especially important to minimize the negative impacts of invasive removal efforts and herbicides.

Some circumstances require the re-introduction of native plants in areas that have become denuded. Planting efforts can help to restore

fish and wildlife habitat in areas that have been heavily impacted by invasive species or other environmental factors (Figure 2-10). Finally, the City also looks for opportunities to expand critically important fish and wildlife habitat through the purchase and management of public properties. Many of the City's nature parks were purchased wetland parcels that have been improved to provide multiple recreational amenities and ecosystem services.

Support of City Pillars:

Environmental Stewardship

Sub-goal 4.4.2: Continue to explore acquisition and/or activation opportunities of priority parcels that significantly benefit sustainable water resource initiatives. *The City has acquired several parcels in the last few decades that have been designated for use as recreational and wildlife habitat areas—including each of the 4 nature parks and sites identified as part of the One Water 'Sapphire Necklace' concept. These properties serve multiple purposes, one of which involves protection of critical fish and wildlife habitat.*

Sub-goal 4.4.3: Explore and implement best management practices and innovative approaches to water resource infrastructure and further protect the natural environment. *Invasive and nuisance plant removal, if conducted properly and under the right conditions, constitute best management practices that help to maintain the ecological integrity of the lakes and terrestrial ecosystems. Planting of native vegetation is another form of ecological best management practice.*

Sub-goal 4.5.1: Develop and maintain a complete inventory of all City-owned parcels and assess opportunities for enhanced access to lakes and natural upland areas. *The City has inventoried and conducts regular inspections and improvements to its multiple nature parks and natural parcels. Vegetation management is a large component of maintaining this collection of natural public properties.*

Strategic Goals:

- Coordinated with FWC to conduct planting of native submerged aquatic plants in Lake Martha in 2024; explore other opportunities to introduce native vegetation in local lakes that may be in need.
- Continue to monitor lakes for drainage, navigation, and habitat issues; coordinate with the Lakes Region Lakes Management District to remove tussocks from lakes that pose a critical navigational and or flooding risk to local residents.
- Explore partnership with Polk County Environmental Lands Division to purchase wetland property within Winter Haven city limits; budget funds to restore habitat and/or improve with recreational amenities.
- Continue to budget for internal aquatic plant management efforts (i.e. equipment, herbicides, licensing); ensure City staff maintain applicator licenses and permits.

#3 | Data Presentation & Analysis



Overview

The purpose of this section is the compilation of lake data and the assessment of lake health with a focus on the metrics and criteria described in the introduction. The objective nature of this evaluation methodology allows for the identification of issues affecting each lake individually as well as the comparison of lakes with each other. This prescriptive approach allows staff to not only recommend management actions to correct lake-specific issues, but also prioritize these actions so that funding and effort go to the lakes with the greatest need.

This section has been organized so that hydrologic information common to all study area lakes (i.e. rainfall, aquifer level, etc.) is presented at the beginning in order to reduce redundancy. Next, lake-specific information is presented separately for each waterbody. The lakes are ordered alphabetically by name to make locating them easier. Finally, this section concludes with a comparison of all lakes in the study area where prioritization rankings and management considerations for the Winter Haven area as a whole are presented.

Lake Health Evaluation Methodology

The primary feature in this section is the Lake Health Index—an evaluation methodology that provides an objective annual score for each lake based on five water quality and three biological criteria. ***The eight individual criteria are scored based on a scale of 0 to 3. The higher the score, the better the lake is doing in that particular criterion.***

Lake Health Index								
Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
3	3	3	2	3	2	2	3	2.6

The mean (average) of individual criterion values is calculated to derive the Lake Health Index value for each lake during the current report year. **This overall Lake Health Index value also ranges from 0 to 3** and can be used to track changes in lake health over time as well as rank the area lakes to prioritize management action. The following are descriptions of the individual lake health criteria:



Water Quality Criteria

- *Water Quality Impairments*
- *Chlorophyll-a Trends*
- *Total Nitrogen Trends*
- *Total Phosphorus Trends*
- *Clarity Trends*

Biological Criteria

- *Vegetation Abundance*
- *Invasive Species Percentage*
- *Species Diversity*

Water Quality Impairments: This criterion indicates a lake's level of impairment in the three primary water quality parameters—chlorophyll-a (Chl-a), total nitrogen (TN), and total phosphorus (TP)—based on exceedance of the Numeric Nutrient Criteria thresholds. A point is awarded for each parameter not exhibiting impairment. For example, a lake with no impairments receives a score of **3**, but a lake impaired for Chl-a and TN would receive a score of **1**.

Water Quality Trends: The water quality trend criteria explores long-term changes in the four primary water quality parameters (i.e. Chl-a, TN, TP, and Clarity) which is critical for identifying potential water quality issues before impairment sets in while also highlighting successes in the management of currently impaired lakes. Improving trends for Chl-a, TN, and TP correspond with decreasing concentrations, whereas an improving water clarity trend would correspond with an overall increase in Secchi depths; and vice versa for deteriorating trends.

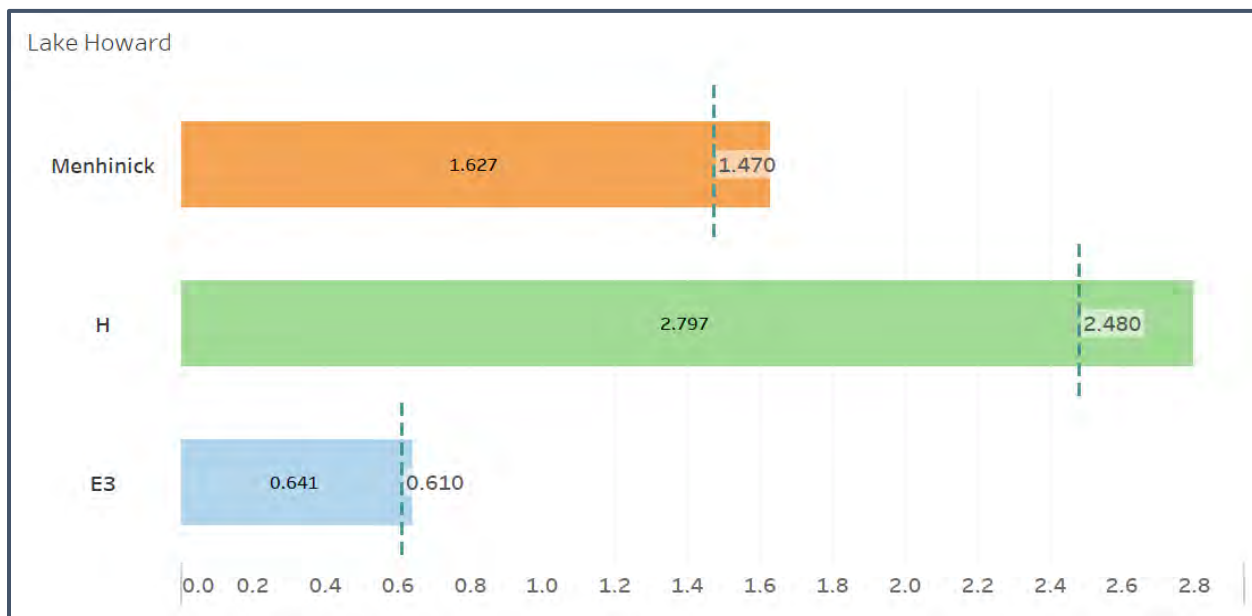
A linear regression statistical analysis is used to evaluate 20-year trend direction and significance for each parameter. The Pearson Correlation Coefficient (R Coefficient) ranges from -1 to +1, indicating whether the trend is decreasing or increasing, respectively. The closer this coefficient is to either -1 or +1, the stronger the trend. Subsequently, statistical significance is evaluated to determine if the trend results are valid or due to random chance. Significance is measured using a 95% confidence level, or a probability value (p-value) of less than 0.05. 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**.

Parameter	R Coefficient	p-value	Trend	Index Score
Chla	-0.313	0.168	No Trend	2
TN	-0.030	0.898	No Trend	2
TP	-0.584	0.005	Decreasing	3
Secchi	-0.417	0.060	No Trend	1

Vegetation Abundance: The abundance of aquatic vegetation is a critical ecological factor that impacts fish and wildlife habitat as well as a lake's ability to buffer against changes in water quality. The evaluation of abundance is based on the percent area coverage (PAC) or the total area of the lake bed occupied by vegetation as determined by SONAR mapping. A score of **3** is given to lakes with PAC exceeding 30%; a score of **2** is given for PAC between 30% and 15%; a score of **1** is assigned to PAC between 15% and 2.5%; and a score of **0** is given to lakes with less than 2.5% PAC.

Invasive Species Percentage: The presence of invasive aquatic plants can have negative impacts on lake ecology and navigation. Evaluation of this criterion is based on the proportion of each lake's managed invasive plant species in relation to all species present during the annual survey. A score of **3** is assigned if a lake has no managed invasive species present; a **2** is given if the invasive percentage is less than 2.5% of the total population; invasive presence between 2.5% and 10% is given a score of **1**; while **0** scores are given if invasive species make up greater than 10% of a lake's total population.

Species Diversity: The diversity of aquatic vegetation often parallels the ecological health of a waterbody. Species diversity is based on the species frequency data for a given report year using three distinct diversity index calculations. These include the Menhinick species richness index which is based on the number of unique species recorded; Hill's evenness index (E3) which measures how evenly species are distributed; and Shannon's overall diversity index (H) which evaluates the probability of sampling the same species multiple times in a row. Using three different indices provides a more robust assessment of diversity that a single index cannot sufficiently approximate. The annual diversity index values are compared to the long-term median values for that lake to determine the lake health score. A point is awarded for each diversity index that meets or exceeds its respective long-term median value; for a total possible score of **3**. In the example below, the diversity criterion score for Lake Howard would be 3 because all of the diversity index values exceeded their long-term medians (shown as dotted vertical lines).



Winter Haven Regional Hydrology

Winter Haven's regional hydrology is completely driven by precipitation. An abundance or lack of rainfall can significantly impact water resources such as lake levels, stream flows to the Peace Creek, and groundwater supply. Changes in lake surface elevation influence not only recreation, such as usability of boat ramps and navigation through canals, but can also have drastic effects on water quality and wetland ecology. Rainfall on the Winter Haven Ridge recharges the Floridan Aquifer—the underground source of the State's drinking water supply. Just as important as rainfall, the amount of water in the Upper Floridan Aquifer (UFA) also affects the levels and overall health of the lakes.

On average, the City of Winter Haven receives 51.62 inches of rainfall annually. This is typically distributed throughout the year in distinct wet and dry seasons. The wet season is concentrated from June through September evidenced by the higher average monthly rainfall around 7-8 inches, shown as the orange dotted lines (Figure 3-1). Whereas the dry season, which ranges from October to May, usually receives much less monthly rainfall—between 2-4 inches. The light blue shaded areas on the graph represent the normal range, or one standard deviation above and below the median rainfall during a given month.

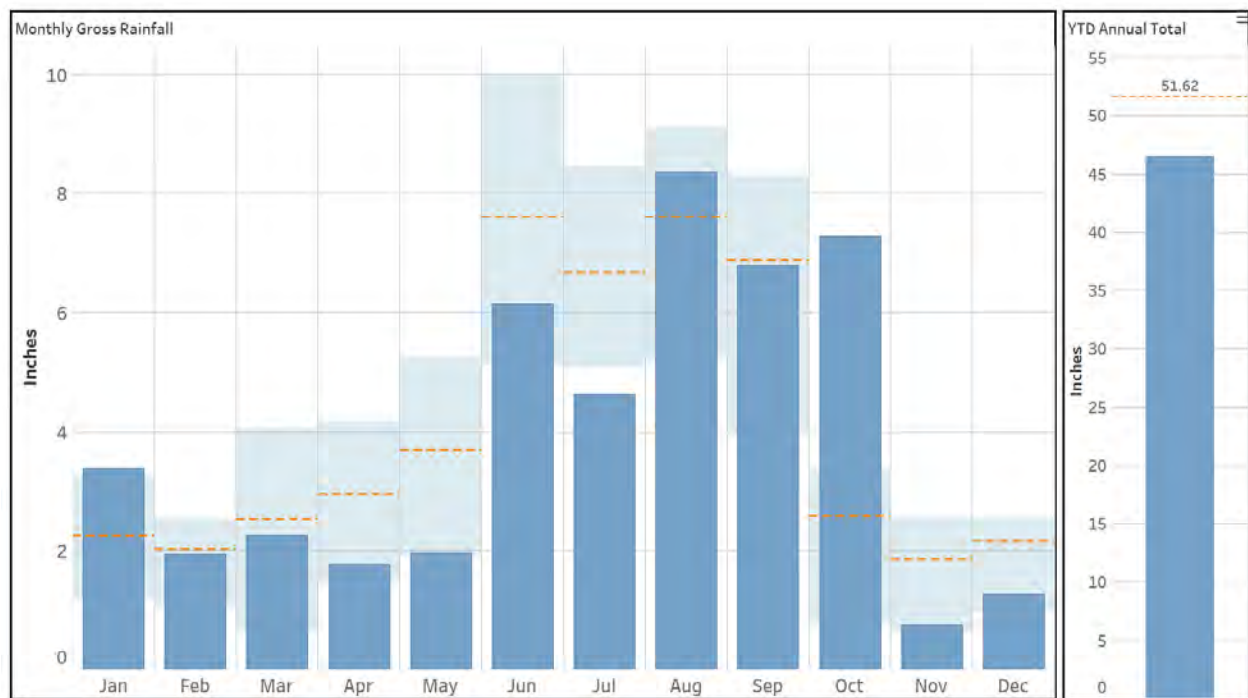


Figure 3-1. 2024 monthly and annual rainfall totals in relation to the long-term average.

In 2024, the City of Winter Haven received 46.55 inches of rainfall which was almost 5 inches below the annual average. Monthly rainfall totals were only above-average in January, August, and October; with the latter receiving near-record rainfall due to hurricane activity. February, March, and September received rainfall near to the average for those months. However, April, May, June, July, November, and December received rainfall totals near or below their normal range. Over 48% of the rainfall received in 2024

fell during the three month window from August to October. Despite the lower-than-average annual total rainfall received, the lakes and aquifer were able to bounce back to well above-average levels by the end of the wet season—due to the tremendous volume of water injected into the region.

This marks the second consecutive year with below-average rainfall. However, this is not abnormal as similar totals were received between 2017-2018 and 2020-2021. The last prolonged drought the area experienced occurred between 2006 and 2014 with eight consecutive years of below-average rainfall (Figure 3-2). It is too early to determine if the region is headed toward another extended period of low annual rainfall and subsequent drought. That said, water conservation efforts are still necessary and relevant as even a short period of below-average rainfall can manifest through declines in lake and aquifer levels. These impacts are discussed further in this section and in the individual lake reports.

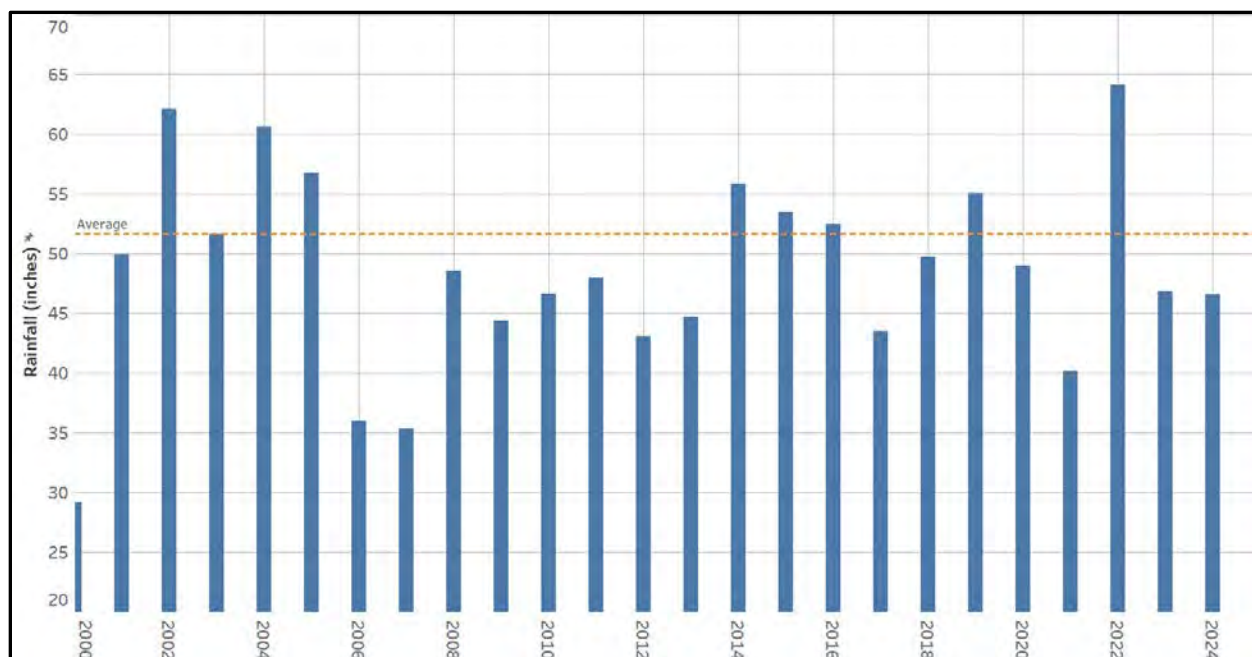


Figure 3-2. Annual rainfall totals for the Winter Haven area from 2000 to 2024.

Figure 3-3 depicts the upper surface elevation of the UFA and monthly rainfall totals from 2000 until 2024. The dotted line represents the long-term average UFA level, while the shaded area represents the normal range of one standard deviation above and below the median level. For reference, the ground elevation of the monitoring station is approximately 170 feet above sea level; making the long-term average more than 50 feet below the ground surface in downtown Winter Haven.

The Upper Floridan Aquifer undergoes both seasonal and long-term fluctuations corresponding with annual rainfall patterns and climatic cycles. This is evidenced by the drastically lower UFA levels in the early 2000s, followed by a short period of above-average levels from 2003 to 2006. The prolonged drought from 2006 to 2014 resulted in consistently lower UFA levels that barely peaked above the long-term average. The UFA

has remained relatively stable since then—consistently exceeding the long-term average and even the upper normal range most years while occasionally dipping below the normal range during the dry season.

The lack of rainfall at the beginning of 2024 resulted in a sharp UFA decline to 113 feet above sea level in June. Despite below-average monthly rain totals in June and July, beginning of the wet season led to a slight increase in the UFA level. By August, the UFA was back to the long-term average; eventually rising well above the normal range in October, due precipitation received through tropical storms. The UFA level ended 2024 slightly above the long-term average—a good place to begin the 2025 dry season. Winter Haven’s local lakes also exhibited similar fluctuations.

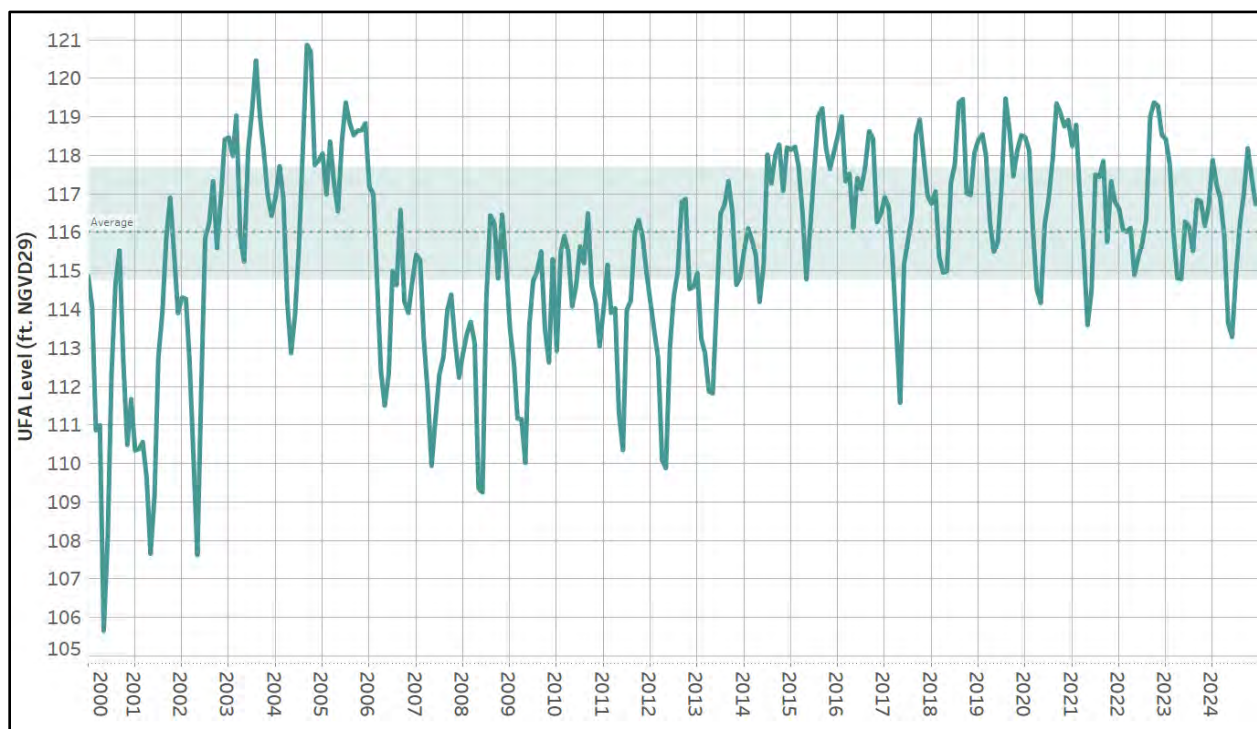


Figure 3-3. Monthly Upper Floridan Aquifer levels from 2000 to 2024. UFA levels graphed in relation to long-term mean and normal range.

Lake-Specific Data Analysis

The following pages comprise water quality, hydrologic, and biological data collected, analyzed, and presented for each individual lake in the study area. As previously stated, the lakes are presented in alphabetical order. Additionally, a Lake Management Summary is included at the end of this section that summarizes the lake health scores for all area lakes and presents specific management considerations for Winter Haven's lakes as a whole. To help you navigate to specific lake sections, please reference the following table which includes page numbers and direct links (in the digital version); click the lake name to go directly to that lake's starting page.

Lake Name	Starting Page #	Lake Name	Starting Page #
Blue	69	Mariana	184
Buckeye	75	Martha	190
Cannon	81	Maude	196
Conine	87	May	202
Daisy	93	Mirror	208
Deer	99	Ned	214
Elbert	105	Otis	220
Eloise	111	Pansy	226
Fannie	117	Rochelle	232
Haines	123	Roy	238
Hamilton	129	Shipp	244
Hartridge	135	Silver	250
Howard	141	Smart	256
Idyl	148	Spring	262
Idylwild	154	Summit	268
Jessie	160	Winterset	274
Link	166	Little Hamilton	280
Lulu	172	Middle Hamilton	286
Mariam	178	Lake Management Summary	292

Lake Blue

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Blue	0	2	2	3	1	3	3	2	2.0

Features & Statistics:

Surface area	54.3 acres
Mean depth	4.57 feet
Maximum depth	9.8 feet
Volume	268.6 acre-feet
Drainage basin area	128 acres
Annual TN Load	871.5 lbs
Annual TP Load	154.2 lbs
Limiting nutrient	Phosphorus

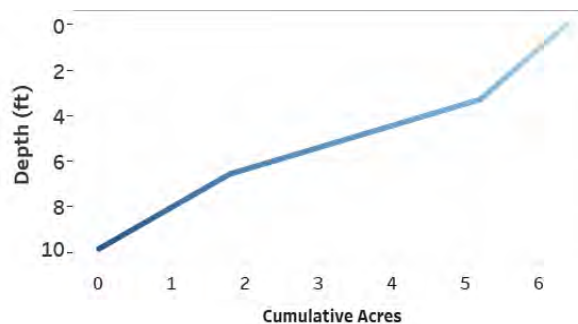


Figure 3-4. Hypsograph of Lake Blue depicting the depth profile and morphology of the lake bed.

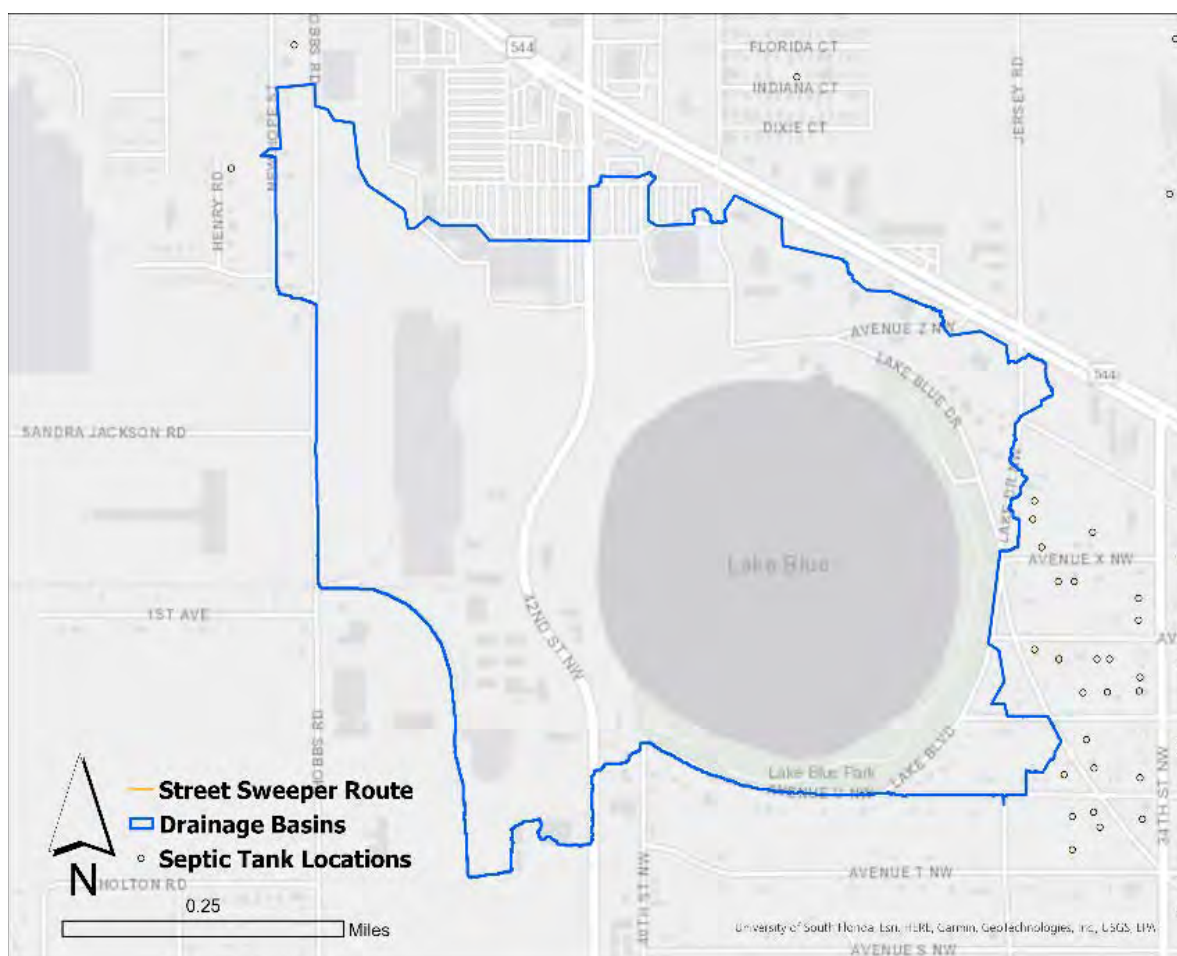


Figure 3-5. Map of Lake Blue's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

The morphology of Lake Blue indicates that it is a relatively small and shallow waterbody (Figure 3-4). Due to its shallowness, Lake Blue may undergo somewhat increased sediment suspension due to wind and recreational boating activities. With little stormwater infrastructure surrounding it, Lake Blue's drainage basin is also relatively small; at just over twice the area of the lake itself (Figure 3-5). Despite the relatively low volume of stormwater entering the lake, a high proportion of industrial land uses in the drainage basin have resulted in some of the highest per-acre rates of nitrogen and phosphorus loading in the area. This has likely contributed to Lake Blue exhibiting some of the poorest water quality in the region. Fortunately, there are few septic systems within close proximity of this waterbody, so surface runoff remains one of the primary pollutant sources to manage. It should be noted that Lake Blue and its drainage basin fall completely outside the municipal limits of Winter Haven.

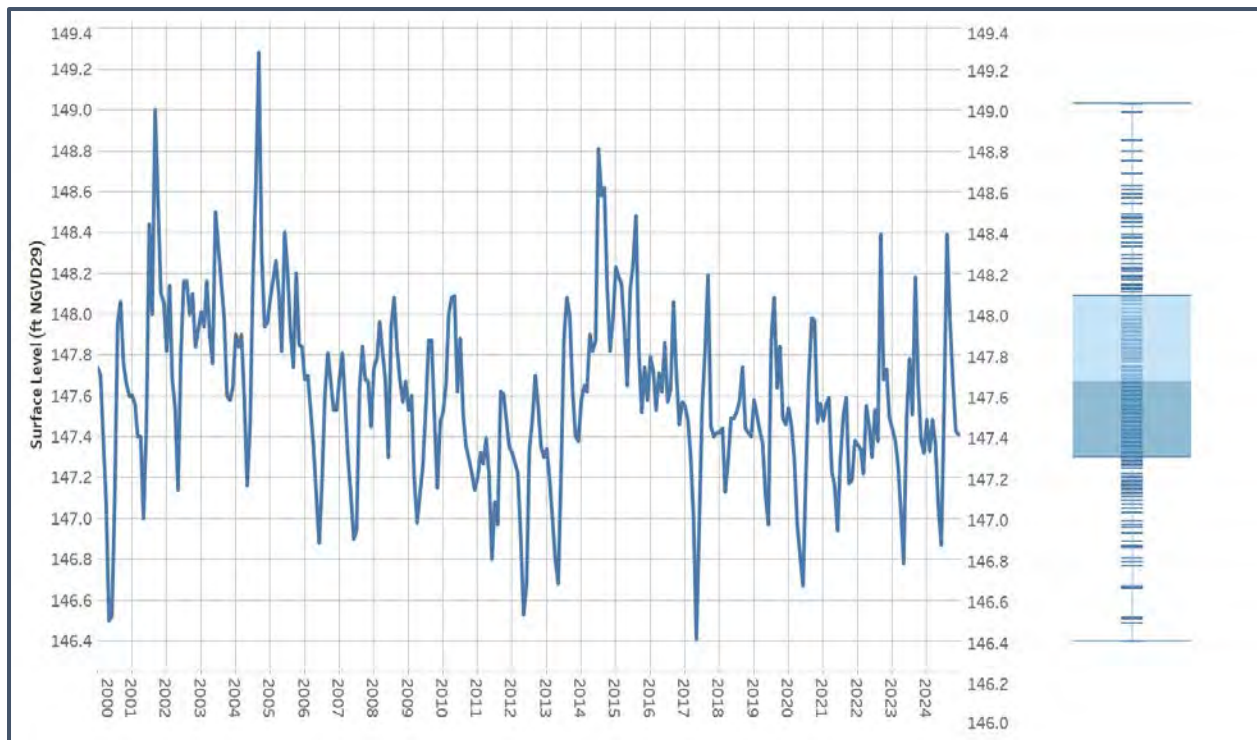


Figure 3-6. Hydrograph of Lake Blue depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details the total range, median, and normal range of surface level during the period of record.

Lake Blue sits at the very top of the Winter Haven watershed; overflowing via a pipe/ditch system to Lake Cannon only during high-water periods. Throughout the period of record, the surface level of Lake Blue has fluctuated between 146.4 and 149.8 feet above sea level. The normal range of seasonal fluctuations is between 147.3 to 148.1 feet; with more extreme peaks and troughs occurring during particularly wet and dry years, respectively (Figure 3-6). During 2024, Lake Blue reached a wet season peak of 148.4 ft and a dry season low of 146.83 ft, but ended the year at 147.4 ft which is right at the lower end of the normal range. Changes in Lake Blue's surface level are not correlated with Chl-a, TN, TP, or clarity (see appendix).

Water Quality Impairment:

For purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Blue is categorized as a clear, alkaline waterbody. The lake is considered impaired for Chl-a, TN, and TP due to exceedances of the impairment thresholds during the assessment

period (Figure 3-7). This equates to an impairment criterion score of 0. In 2018, the FDEP established a total maximum daily load (TMDL) for Lake Blue. The TMDL stipulates a 66% reduction in TN and a 67% reduction in TP to meet NNC guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.313	0.168	No Trend	0	2
TN	Y	-0.030	0.898	No Trend		2
TP	Y	-0.584	0.005	Decreasing		3
Secchi	NA	-0.417	0.060	No Trend		1

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of annual Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Total phosphorus exhibited a statistically significant improving trend; Chl-a and TN exhibited non-significant improving trends; and Secchi depth exhibited a non-significant declining trend. Despite its impairments and high nutrient pollutant loads, Lake Blue is exhibiting marginal improvement in water quality. That said, it has a long way to go in order to start meeting the impairment thresholds. For example, the chlorophyll-a concentrations, which were roughly 50 ug/l, would need to be at or below 20 ug/l to meet the target.



Figure 3-7. Lake Blue AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Blue on 2/9/2024. The percent coverage during this survey was 78% and the total BV was 11.9% (Figure 3-8). Similar to last year's survey, the high coverage value may have been an error in the SONAR's ability to distinguish between decaying organic matter and living vegetation as shown by the light green areas in the center of the lake. That said, there has been a marked increase in vegetation abundance in recent years. The result is the Lake Blue receives a score of 3 for this criterion.

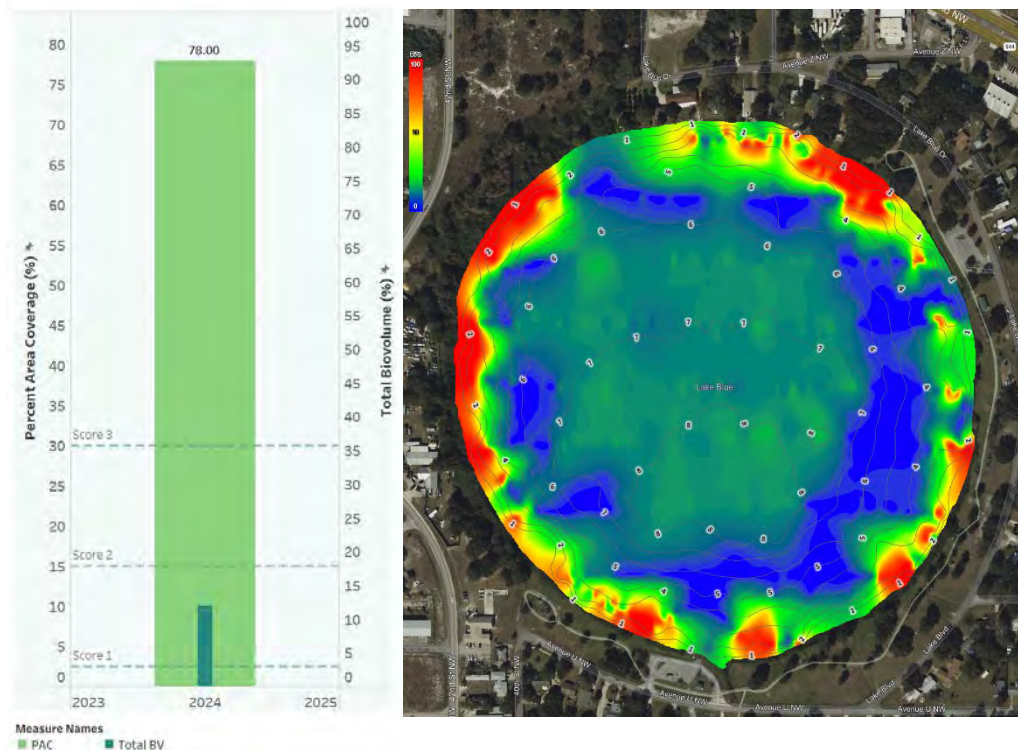


Figure 3-8. Graph depicting 2024 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

Based on data from the 2024 vegetation survey, Lake Blue's vegetation community was primarily made up of emergent vegetation (Figure 3-9). The most abundant species was pickerelweed—a native emergent. However, this lake experienced a surge in submerged aquatic vegetation abundance, with eelgrass making up over 15% of surveyed species. Normally, the water clarity in this lake is too poor for SAV to grow. Therefore, the increase in eelgrass demonstrates how even gradual water quality improvement can result in biological responses. While exotic plants, like primrose willow, were present these often do not require management action to control. Therefore, Lake Blue possessed no appreciable presence of managed invasive species—earning a score of 3 for this criterion.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). During 2024, Lake Blue's richness and diversity indices exceeded their long-term medians. Evenness was slightly below the median resulting in a criterion score of 2 (Figure 3-10). These results are consistent with previous years. The vegetation community in

Lake Blue has not shifted considerably since monitoring began. The lack of invasive species management has not shifted the species dynamics like in other lakes.

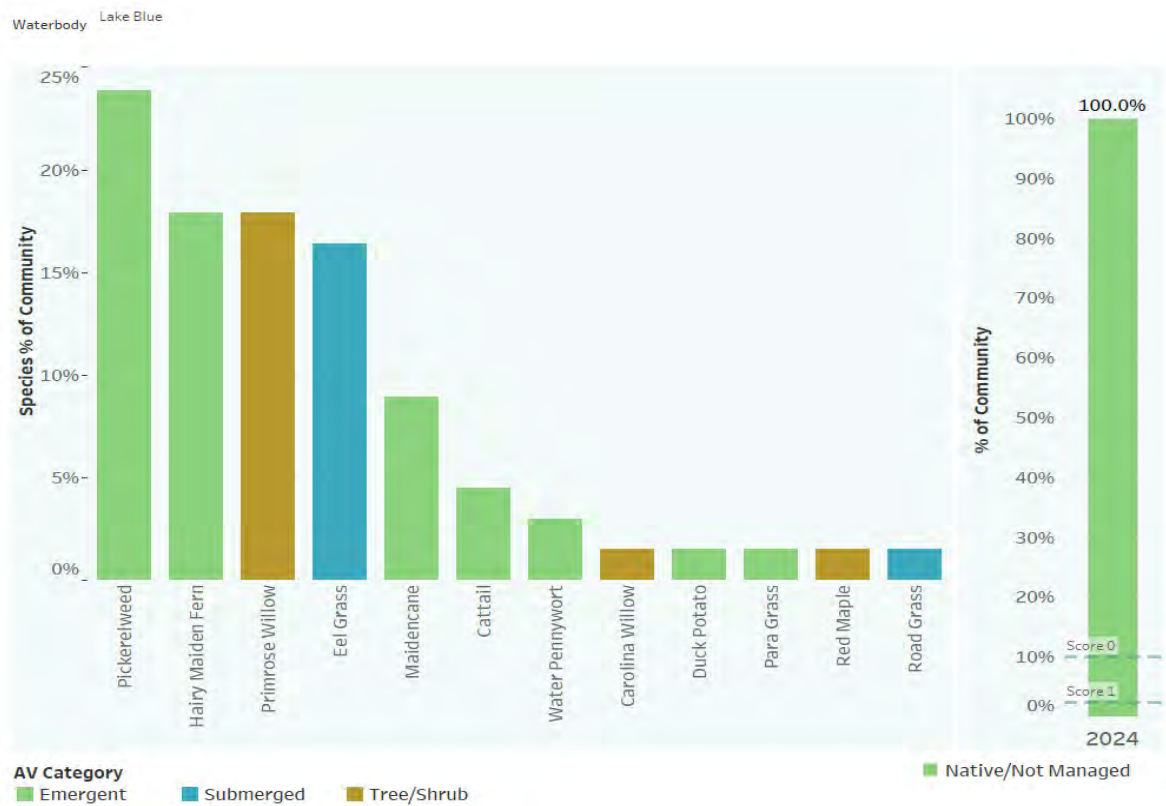


Figure 3-9. Chart depicting species frequency and invasive species percentage of Lake Blue during 2024.

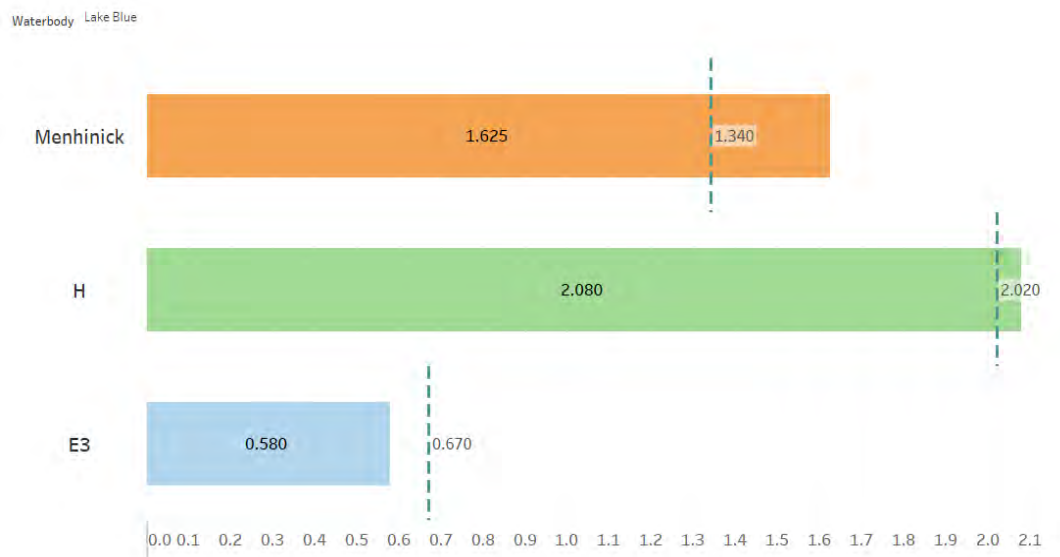


Figure 3-10. Chart depicting 2024 diversity index values for Lake Blue.

Lake Health Tracking:

A comparison of Lake Blue's health index scores from 2018 to 2024 shows relative stability in lake health (Figure 3-11). During this period, there has been a slight shift in the water clarity trend score and an overall improvement in vegetation abundance, with diversity contributing to the majority of the score variation. Though the trends show some general movement toward better water quality, Lake Blue is still far from meeting the impairment thresholds.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	3	2	2	3	3	2.1
2019	0	2	2	3	2	1	3	3	2.0
2020	0	2	2	3	2	NA	3	0	1.7
2021	0	2	2	3	2	2	3	1	1.9
2022	0	2	2	3	2	3	3	3	2.3
2023	0	2	2	3	1	3	3	0	1.8
2024	0	2	2	3	1	3	3	2	2.0

Figure 3-11. Chart depicting a comparison of Lake Blue's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Blue currently exhibits poor water quality with impairments in each of the NNC metrics. With high intensity industrial and commercial land uses dominating the drainage basin, the stormwater pollutant load is likely the primary driver of these water quality issues.
- Despite the 2023 PAC values, Lake Blue distinctly lacks vegetation beyond the shoreline. The low clarity likely prevents the growth of vegetation in water deeper than a few feet, resulting a very narrow littoral zone. Fish and wildlife habitat is limited by the lack of submerged vegetation.
- The morphology of Lake Blue likely exacerbates its water quality issues. At an average depth of 4.6 feet, wind and wave action have greater potential to suspend sediments from the lake bed—leading to poor water clarity.

Lake Management Strategy:

- The City currently conducts annual aquatic vegetation monitoring and shares this information with partnering agencies for use in management efforts. Staff will continue to support Polk County and FWC in these efforts.
- City staff may work with Polk County and other agencies to explore the potential for aquatic vegetation planting. However, the poor water clarity may hinder the planting of submerged vegetation.
- Polk County has implemented an algal neutralization device in the lake to help filter the water column and increase clarity. So far, this has not yielded major changes in chlorophyll-a concentrations or improvements to water clarity. It is likely that any improvements from this effort will be observed over a longer time period. Further water quality monitoring will provide additional insights.

Lake Buckeye

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Buckeye	3	2	2	2	2	3	1	3	2.3

Features & Statistics:

Surface area	72.4 acres
Mean depth	9 feet
Maximum depth	26.8 feet
Volume	683.2 acre-feet
Drainage basin area	233.6 acres
Annual TN Load	867.1 lbs
Annual TP Load	154.8 lbs
Limiting nutrient	Phosphorus

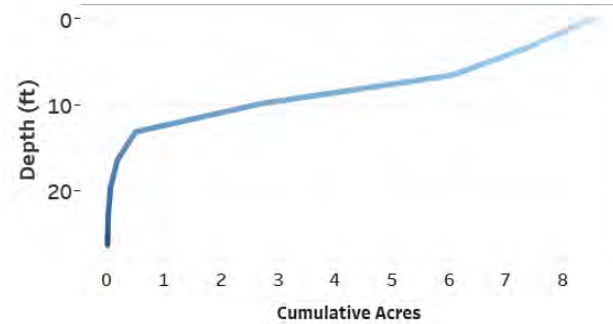


Figure 3-12. Hypsograph of Lake Buckeye depicting the depth profile and morphology of the lake bed.

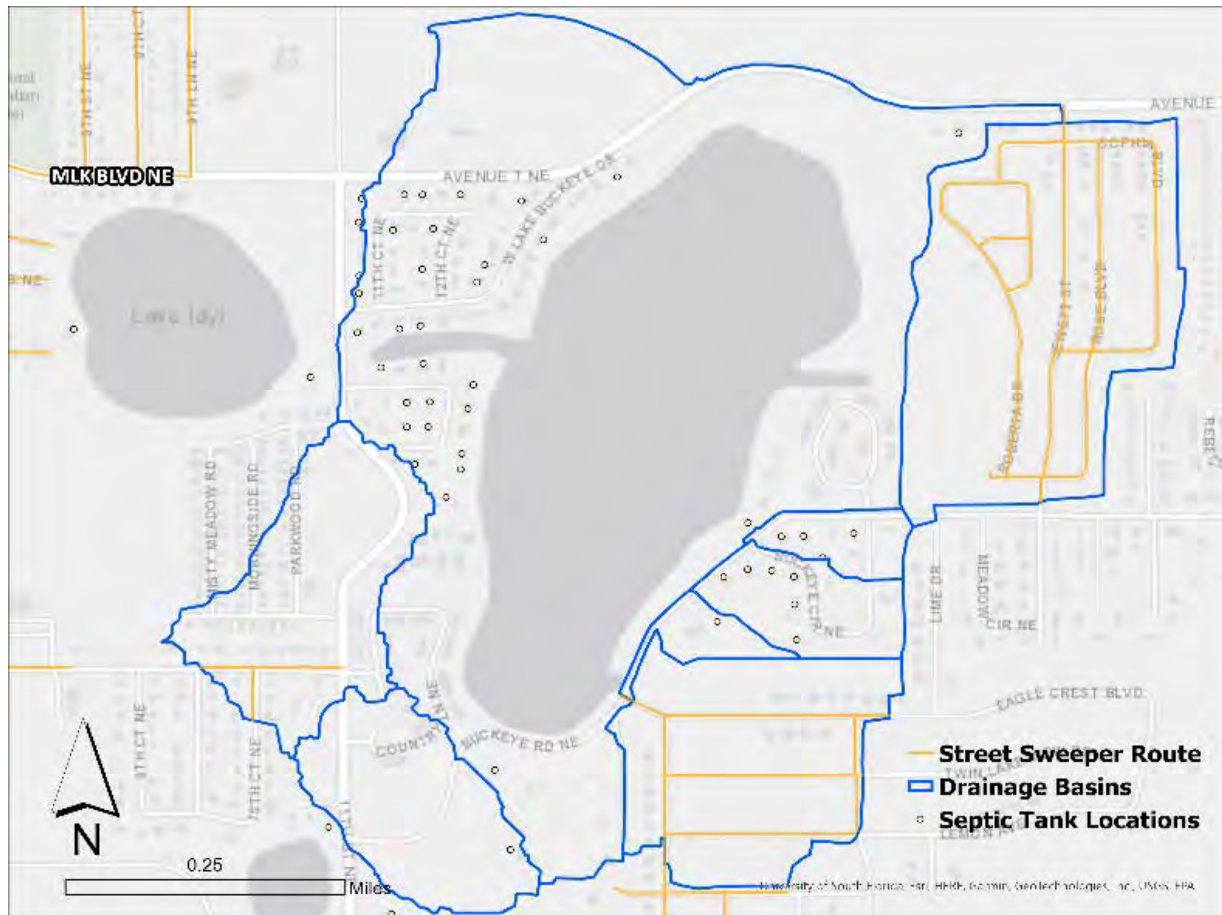


Figure 3-13. Map of Lake Buckeye's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Buckeye is a relatively small waterbody at just over 70 acres. It's mean depth of 9 feet is just slightly more than the overall average for all lakes in the study area; but it has some significantly deeper areas of over 26 feet (Figure 3-12). Compared to the total lake area, Buckeye's drainage basin is over three times as large which is slightly above average (Figure 3-13). Land use within the Buckeye drainage basin is primarily residential, contributing relatively low amounts of nitrogen and phosphorus per acre compared with other lakes in the area. There are approximately 40 septic systems within close proximity of the lake—potentially contributing nitrogen via groundwater seepage. However, as a phosphorus-limited waterbody, this is unlikely to have significant water quality impacts.

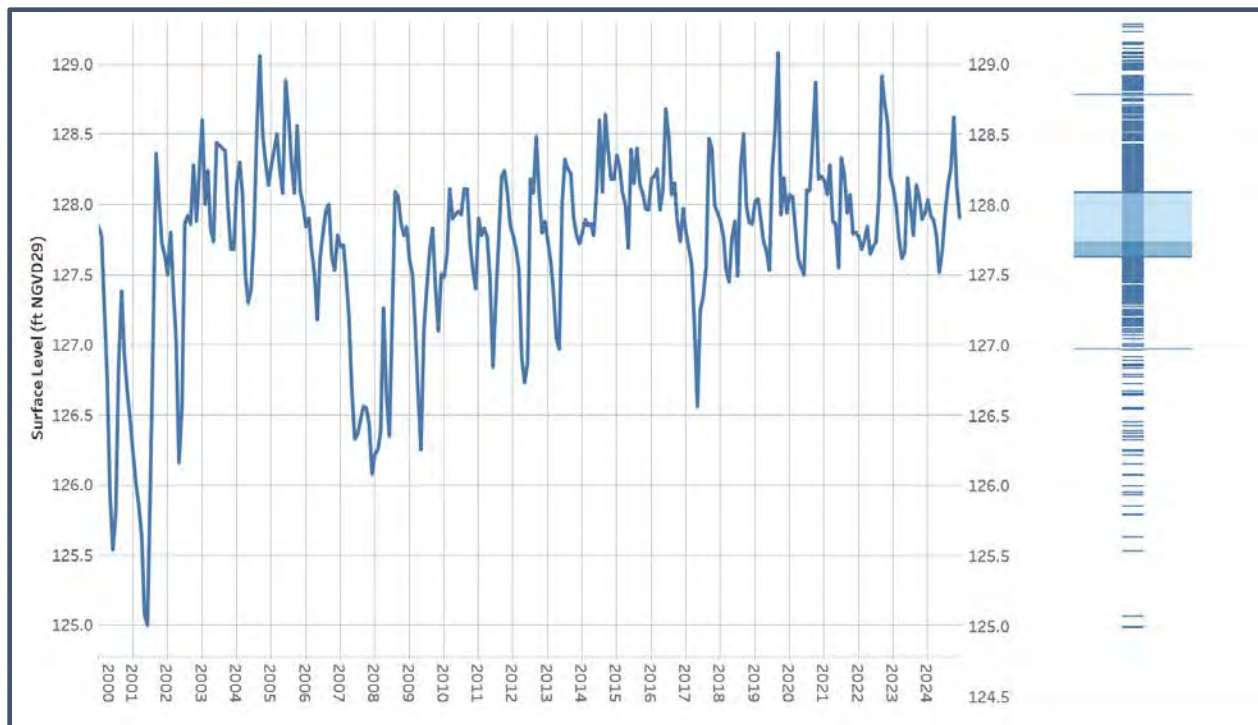


Figure 3-14. Hydrograph of Lake Buckeye depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Compared with other lakes in the area, Lake Buckeye sits at a lower elevation within the watershed; receiving a constant overflow from Lake Idyl and discharging downstream to Lake Fannie. Over its period of record, Lake Buckeye's surface level has fluctuated between 125 and 129.8 feet above sea level. The normal level range fluctuates less than half a foot, between 127.6 and 128 feet (Figure 3-14). During 2024, Lake Buckeye reached a dry season low of 127.5 ft at the start of the wet season in June and a wet season peak of 128.6 ft after the hurricanes in October. The surface level ended the year slightly above average at 127.9 ft. Changes in Lake Buckeye's surface level is not correlated with Chl-a, TN, TP, or clarity (see appendix).

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Buckeye is categorized as a clear, alkaline waterbody. Since 2000, there has only been one year in which Buckeye exceeded NNC thresholds in Chl-a and TP—2005 (Figure 3-15). However, Buckeye's Chl-a concentration did exceed the NNC impairment threshold in 2024 and TN also

exhibited higher-than-normal concentrations in 2023 and 2024. Impairment for Chl-a could be a future possibility if the NNC threshold is exceeded again in 2025. The City will be closely monitoring the water quality in this lake moving forward.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.199	0.388	No Trend	3	2
TN	N	-0.221	0.336	No Trend		2
TP	N	-0.209	0.364	No Trend		2
Secchi	NA	0.346	0.125	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. All four water quality parameters exhibited non-significant improving trends in 2024. In previous years, Lake Buckeye has shown significant improving trends. However, higher concentrations of Chl-a, TN, and TP coupled with lower Secchi depths indicate a recent shift toward poorer water quality. Again, this is a lake that will require close monitoring to ensure that water quality does not continue to decline.



Figure 3-15. Lake Buckeye AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Buckeye on 4/18/2024. The PAC during this survey was 55.2% and the total BV was 5.2%—equating to an abundance criterion score of 3 (Figure 3-16). Compared with the previous year, this constituted a significant increase in vegetation abundance. It is likely that invasive plant expansion and subsequent management

efforts by state and county agencies resulted in the previous decline vegetation abundance. However, this recent resurgence demonstrates how these impacts are often short-lived.

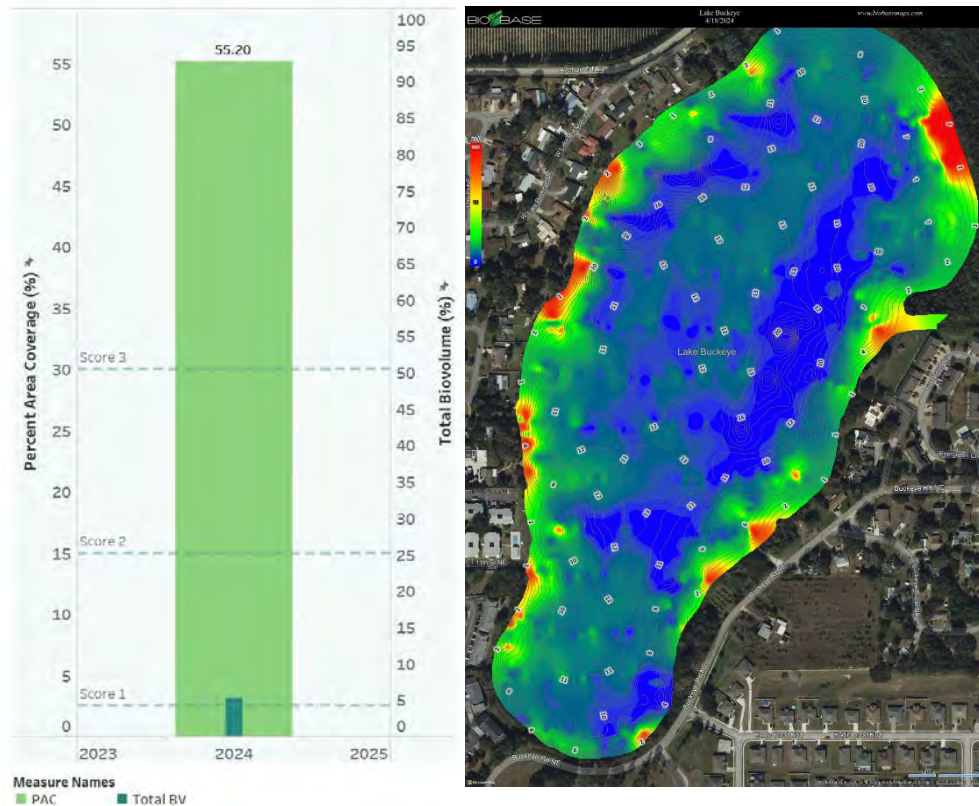


Figure 3-16. Graph depicting 2023 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

Invasive Species Management:

In previous years, coontail was the most dominant species present in Lake Buckeye by a very large margin. However, a surge in hydrilla and subsequent invasive herbicide treatment in 2021 caused a sharp decline in water clarity—decreasing the abundance of submerged species with it. By 2023, coontail was no longer the dominant plant species in the lake, being replaced by the emergent spatterdock lily. Based on the 2024 survey, coontail has exhibited a resurgence in abundance, followed by a relatively even mix of emergent and floating leaf plants. Invasive plants like hydrilla, burhead sedge, and parrot feather were present in low numbers, but collectively at over 6% of the population—resulting in an invasive abundance score of 1 (Figure 3-17).

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). During 2024, Lake Buckeye's richness, evenness, and diversity indices exceeded their long-term medians, resulting in a criterion score of 3 (Figure 3-18). Species richness was at the long-term median—indicating no net increase or decrease in the number of unique species present; while evenness and overall diversity were well above the average. This is primarily due to the resurgence in submerged species leading to a more even distribution of aquatic vegetation throughout the lake.

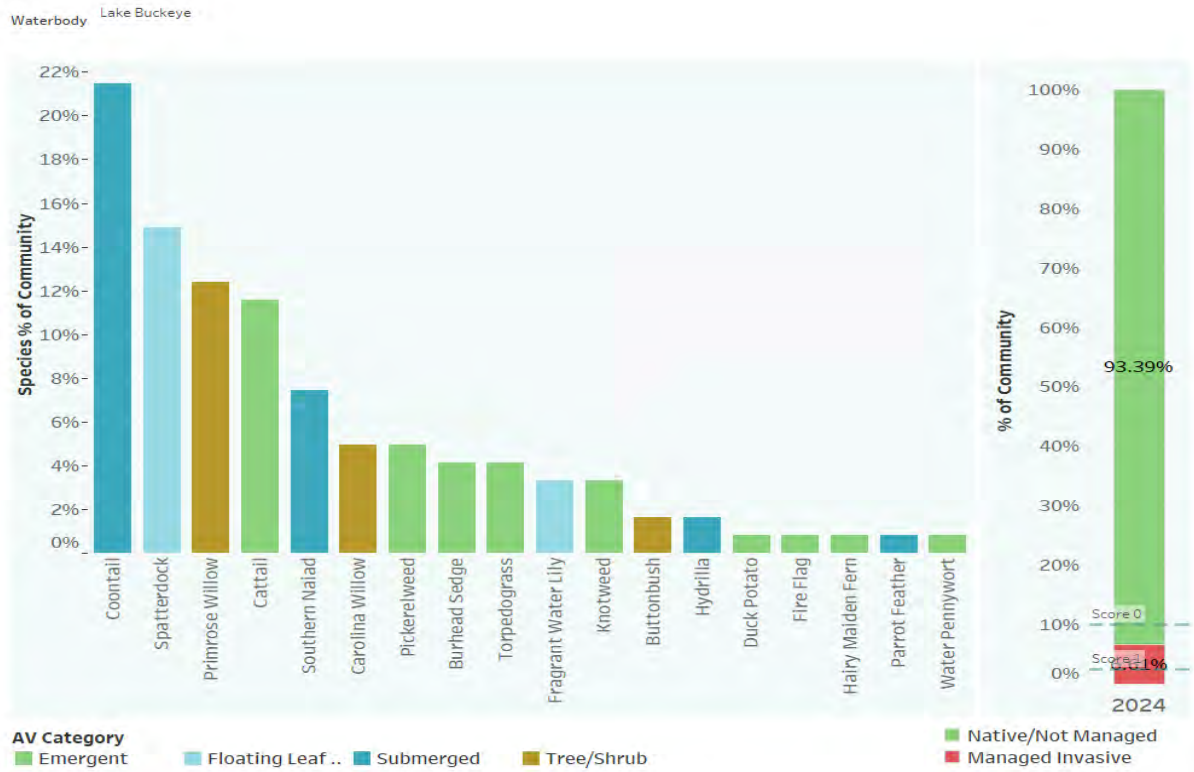


Figure 3-17. Chart depicting species frequency and invasive species percentage of Lake Buckeye during 2024.

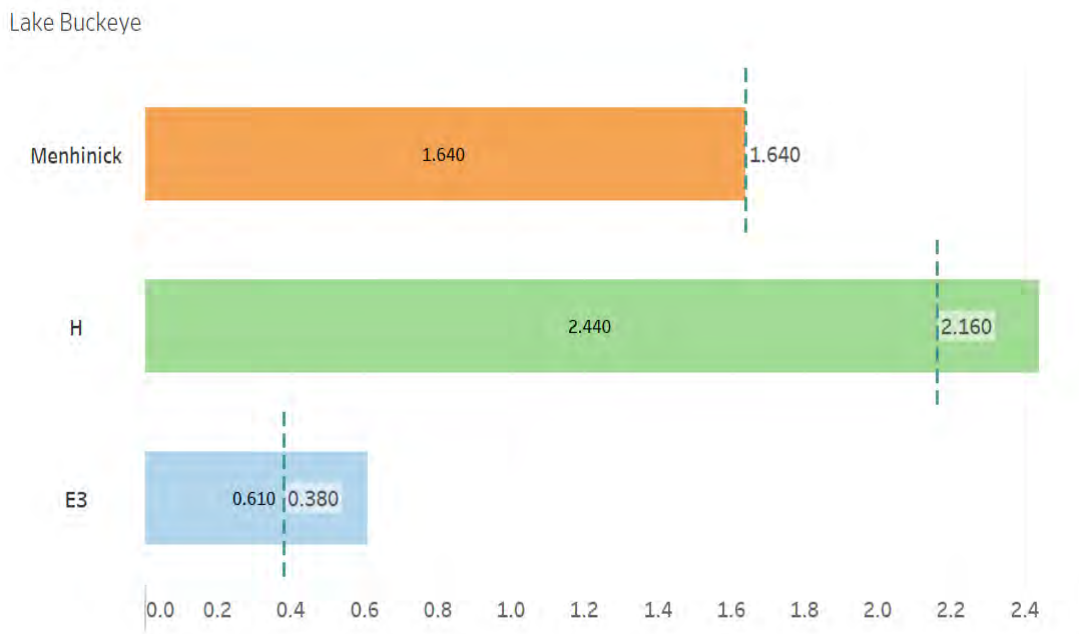


Figure 3-18. Chart depicting 2024 diversity indices for Lake Buckeye. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Buckeye's health index scores from 2018 to 2024 shows relative consistency. However, shifts in the water quality trend scores in 2024 lowered its overall lake health index value to its lowest point since monitoring began (Figure 3-19). These shifts in water quality metrics were likely due in part to invasive species treatments and the subsequent impacts from the increase in decaying plant matter in the lake. The restoration of vegetation abundance should help to buffer against future shifts in water quality. However, continual monitoring to facilitate the early detection and rapid response of invasive management efforts should help to prevent impacts on a large scale in the future.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	0	1	2.4
2019	3	3	3	3	3	3	0	3	2.6
2020	3	3	3	3	3	3	0	2	2.5
2021	3	3	3	3	3	3	1	1	2.5
2022	3	3	3	3	3	3	1	0	2.4
2023	3	3	3	2	3	2	2	3	2.6
2024	3	2	2	2	2	3	1	3	2.3

Figure 3-19. Chart depicting a comparison of Lake Buckeye's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Buckeye currently exhibits good water quality. However, stormwater pollutant loading is a potential concern if water quality trends ever change for the worse.
- The presence of OSTDs (septic) systems in the drainage basin may not currently be an issue assuming they are functioning properly. However, as these systems age, they may begin to leach nutrients into the water table—leading to water quality declines.
- The management of invasive species like hydrilla and burhead sedge are a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody. Large-scale invasive treatments can sometimes result in the sharp declines in vegetation abundance as seen in 2023.

Lake Management Strategies:

- Stormwater management within this basin includes street sweeping up to 5.6 miles monthly. Resident education is also important to address non-point pollutants from stormwater runoff such as fertilizer and pesticides.
- City staff may explore source analysis to determine if OSTD leachate is a potential contributor to nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large scale herbicide treatments and potential water quality issues that follow.

Lake Cannon

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Cannon	2	2	2	2	2	3	1	2	2.0

Features & Statistics:

Surface area	338.2 acres
Mean depth	10.9 feet
Maximum depth	20 feet
Volume	3479.2 acre-feet
Drainage basin area	695.4 acres
Annual TN Load	3863.1 lbs
Annual TP Load	637.8 lbs
Limiting nutrient	Co-limited (N & P)

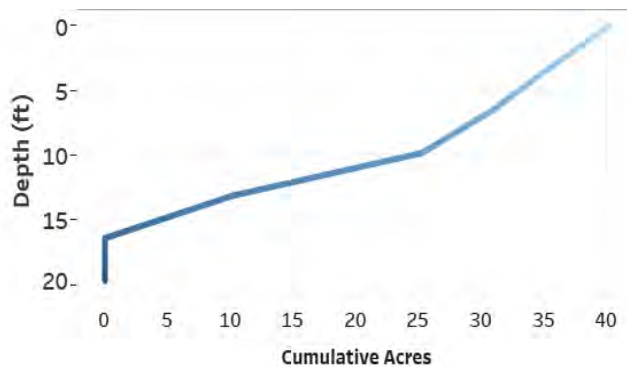


Figure 3-20. Hypsograph of Lake Cannon depicting the depth profile and morphology of the lake bed.

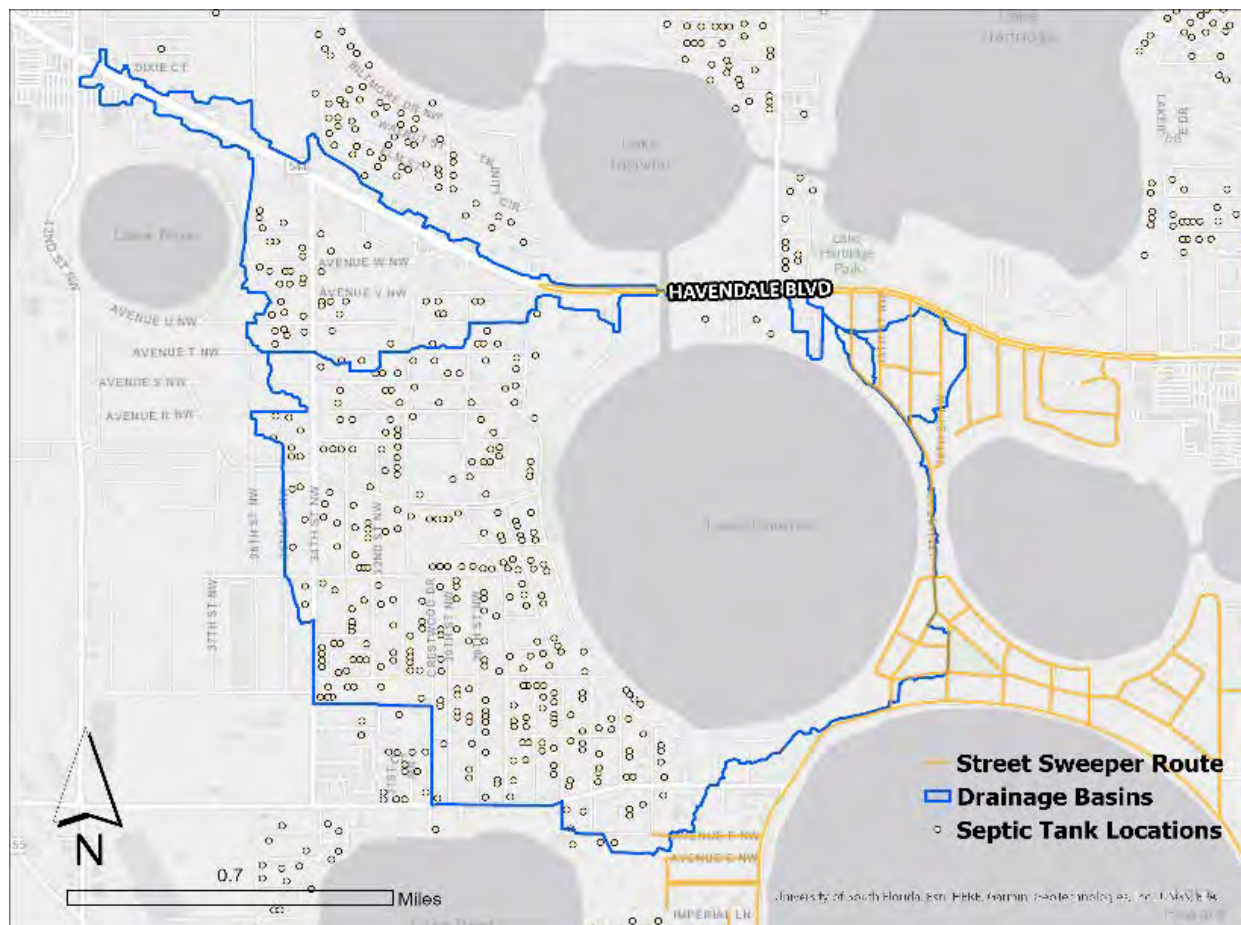


Figure 3-21. Map of Lake Cannon's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Cannon is a moderately sized waterbody at over 300 acres. It exhibits somewhat above average depth compared with other lakes in the area with a mean depth of 11 feet and a maximum depth of 20 feet; a cone-shaped depression typical of most sinkhole lakes on the Central Florida ridge (Figure 3-20). Lake Cannon's drainage basin is roughly twice the size of its lake area and is comprised primarily of medium density residential land uses (Figure 3-21). The per-acre nitrogen and phosphorus loads contributed by this basin rank 17th compared to the 37 other lakes in the study area. There are 338 known septic systems within the drainage basin on the west side of the lake. These have the potential to contribute elevated nitrogen loads via groundwater seepage.

As part of the South Chain of Lakes, Cannon is connected to Lakes Howard, Idylwild, and Mirror via navigable canals. Excess water from the South Chain of Lakes discharges to the Wahneta Farms drainage canal via a passive overflow structure at the south shore of Lake Lulu; eventually connecting with the Peace Creek near Bartow. Due to its canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-22). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Cannon's surface level directly correlate with water clarity and indirectly correlate with Chl-a and TN (see appendix). This carries management implications as a higher surface level should result in water quality improvements.

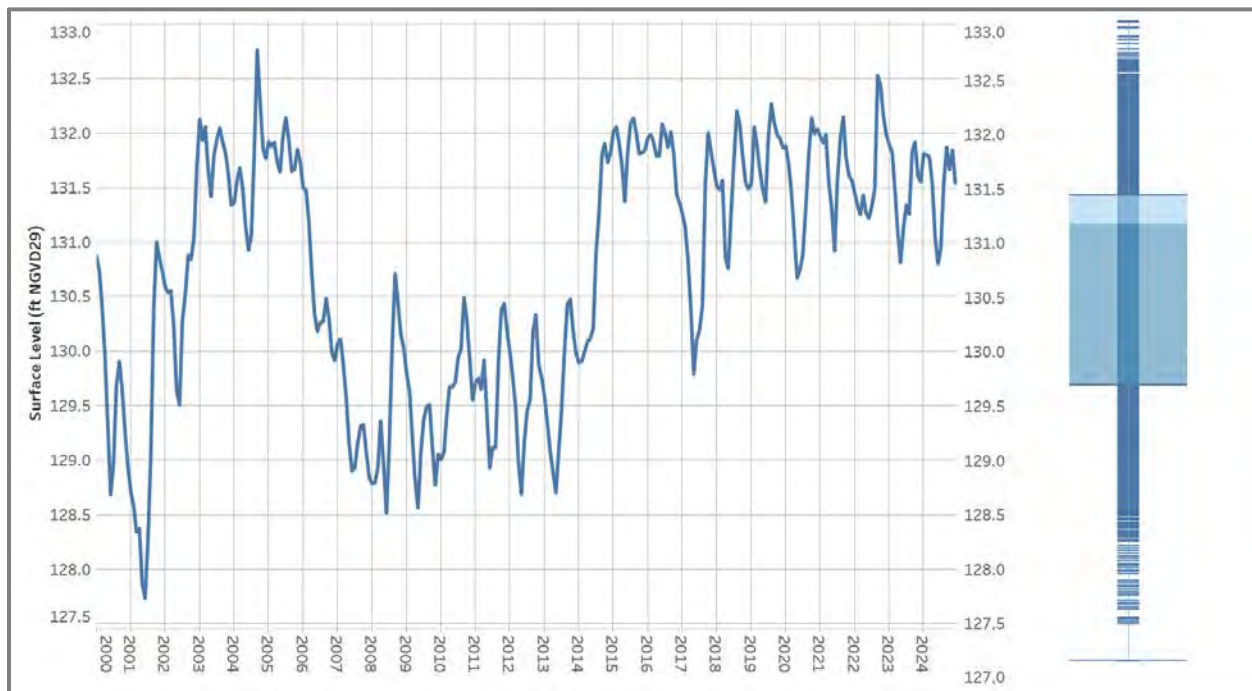


Figure 3-22. Hydrograph of the South Chain of Lakes depicting monthly surface level readings from 2000 to 2024. A box & whisker plot details the total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Cannon is categorized as a clear, alkaline waterbody. Based on exceedances in 2018, 2019, and 2020, it is considered impaired for Chl-a (Figure 3-23). In 2019, the FDEP established a total maximum daily load (TMDL) for Lake Cannon which stipulates a 20% reduction in TN concentration to meet the Chl-a guidelines. The annual average Chl-a and TP concentrations exceeded the NNC thresholds in 2024. Both chlorophyll-a and TP concentrations have fluctuated above and below the impairment threshold over the last four years which is relatively common for lakes with pollutant concentrations right at the impairment threshold.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.231	0.313	No Trend	2	2
TN	N	-0.160	0.489	No Trend		2
TP	N	-0.208	0.366	No Trend		2
Secchi	NA	0.063	0.786	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Each of the four parameters exhibited non-significant improving trends—downward for Chl-a, TN, and TP; and upward for Secchi depth. The spikes in average TP concentration in 2022 and 2024 have shifted the TP trend from statistically significant, exhibited in previous years, to non-significant. Continued monitoring is required to determine if these trend shifts are signs of long-term degradation.

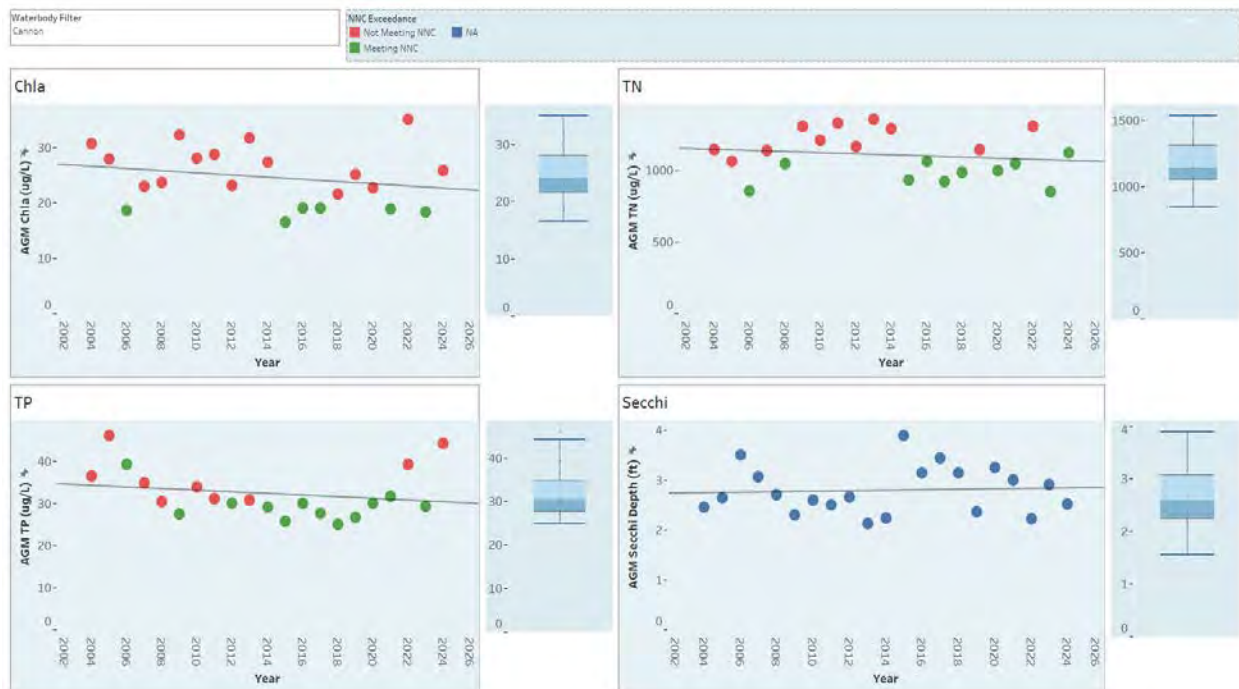


Figure 3-23. Lake Cannon AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

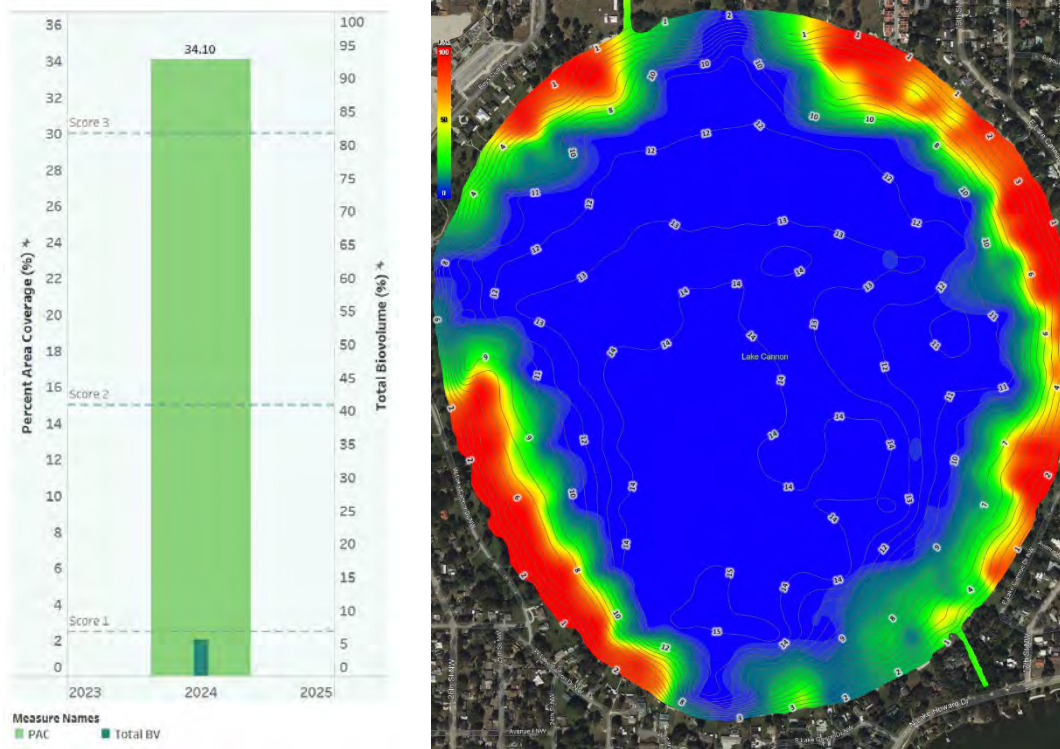


Figure 3-24. Graph depicting 2024 PAC/BV and biovolume heatmap; biovolume values range from green (lowest) to red (highest).

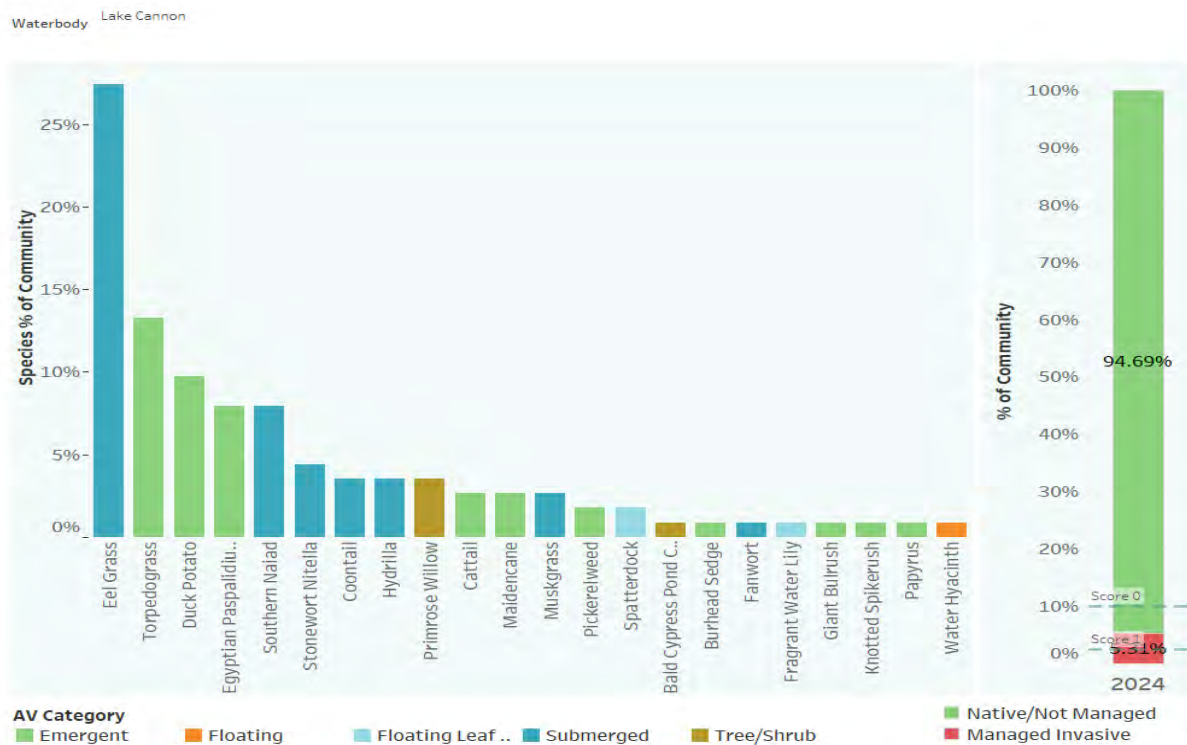


Figure 3-25. Chart depicting species frequency and invasive species percentage of Lake Cannon during 2024.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted on Lake Cannon on 5/31/2024. The PAC during this survey was 34.1% and the total BV was 5.5% (Figure 3-24). Due to the slope of Lake Cannon's bed, the littoral zone is limited to around 10-12 feet in depth. Both the PAC and BV values exhibited a slight increase from 2023 to 2024. Over the years, Lake Cannon has not exhibited much variability in the amount of vegetation—maintaining an abundance score of 3 since monitoring began.

Invasive Species Management:

Based on data from the 2024 survey, Lake Cannon's vegetation community was comprised of a good mix of submerged and emergent species. The most abundant species by far was the submerged native, eel grass (Figure 3-25). The invasive hydrilla, burhead sedge, and water hyacinth made up 5.3% of the community in 2024. This was a slight decrease from nearly 7% in 2023. As a result, Lake Cannon scored a 1 in the invasive species presence criterion. Hydrilla, which is the dominant invasive present, required additional management effort to keep under control.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). In 2024, all three of Lake Cannon's species richness and overall diversity indices exceeded their respective medians while the evenness index fell below its long-term median (Figure 3-26). This equates to a diversity score of 2. This decline in species evenness may be due to the management of invasive plants—allowing for a greater dominance of eel grass in 2024. Indeed, while the plant community was somewhat more evenly distributed in 2023, there was a significant decrease in hydrilla abundance in the most recent survey.

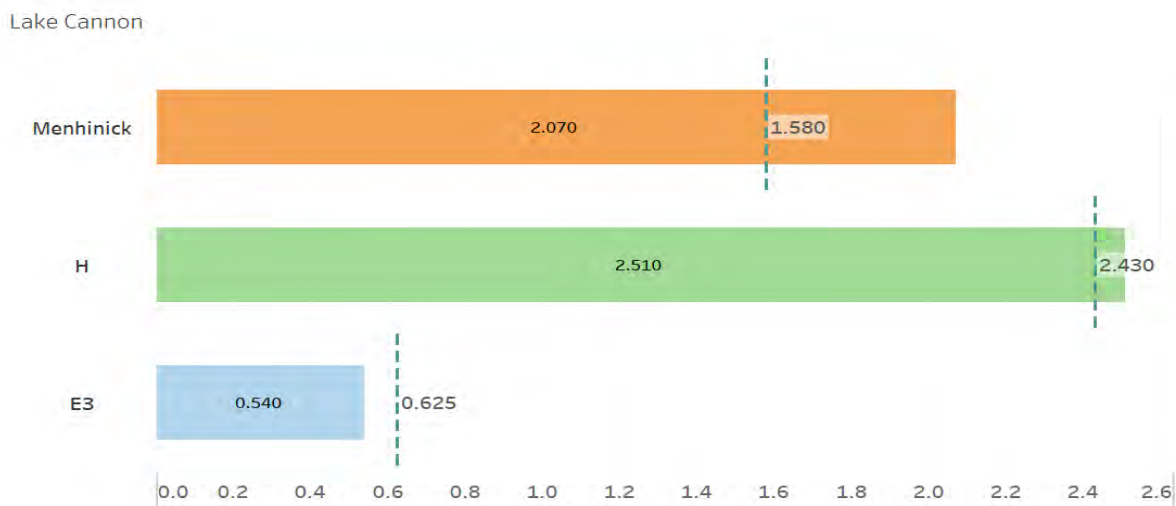


Figure 3-26. Chart depicting 2024 diversity index values for Lake Cannon. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Cannon's health index scores over time shows a gradual increase from 2018 to 2023, then an abrupt decrease to its lowest point in 2024 (Figure 3-27). In the years since lake health monitoring began, the impairment criterion has shown steady improvement. The trend criteria appears to have decreased from significant improving scores to non-significant trends we

see in 2024. These shifts in the trends demonstrate how additional management efforts are needed to maintain the improving direction of water quality. Vegetation abundance has remained high, with some fluctuation in the invasive and diversity criteria.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	3	2	3	3	2	NA	2.1
2019	1	2	3	2	3	3	2	1	2.1
2020	1	2	3	2	3	3	1	2	2.1
2021	2	3	3	2	3	3	1	1	2.3
2022	2	2	2	2	3	3	2	3	2.4
2023	2	2	2	3	2	3	1	3	2.3
2024	2	2	2	2	2	3	1	2	2.0

Figure 3-27. Chart depicting a comparison of Lake Cannon's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Cannon's chlorophyll-a concentrations still exceed the impairment threshold. Stormwater is a primary concern as a leading contributor of nutrient pollutant loading as is the effluent from Lake Blue.
- The presence of OSTDs (septic) systems in the drainage basin may not currently be an issue assuming they are functioning properly. However, as these systems age, they may begin to leach nutrients into the water table—leading to water quality declines.
- The management of invasive species like hydrilla is a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody. The subsequent treatment can result in impacts to native vegetation and water quality.
- Several water quality metrics are significantly correlated with Lake Cannon's surface level; likely due to increased flushing during wetter periods. The means that drought conditions could result in water quality declines.

Lake Management Strategy:

- Street sweeping is currently conducted on City roads in the eastern part of the drainage basin (Figure 3-21). In total, nearly 10 miles of roadways are swept monthly.
- City staff may explore source analysis to determine if OSTD leachate is a potential contributor to nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Conine

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Conine	3	3	3	2	3	2	1	3	2.5

Features & Statistics:

Surface area	235.4 acres
Mean depth	9 feet
Maximum depth	18 feet
Volume	2105.1 acre-feet
Drainage basin area	559.1 acres
Annual TN Load	2836.2 lbs
Annual TP Load	474.4 lbs
Limiting nutrient	Co-limited (N & P)

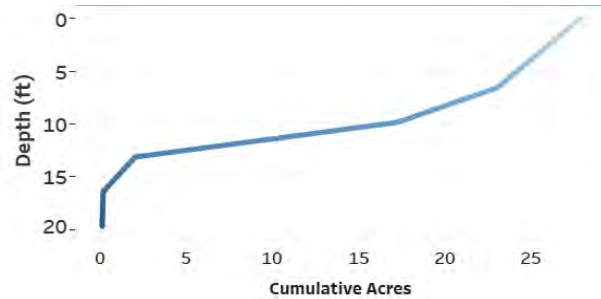


Figure 3-28. Hypsograph of Lake Conine depicting the depth profile and bed morphology.

Hydrology:

With a surface area of 235 acres, Lake Conine ranks 15th of area lakes in size. Its morphology is fairly conical, with an average depth of 9 feet and maximum depth of roughly 18 feet (Figure 3-28). Lake Conine receives surface runoff from an area approximately twice the size of the lake; contributing a moderate amount of nitrogen and phosphorus (Figure 3-29). Based on per-acre loading rates, Lake Conine's pollutant load ranks 19th out of area lakes. There are 39 known septic systems within this basin—potentially contributing a minor amount of nitrogen via groundwater leaching.

As part of the Northern Chain, Lake Conine is connected via navigable canals to Lakes Rochelle and Smart, as well as a lock system to Lake Hartridge,

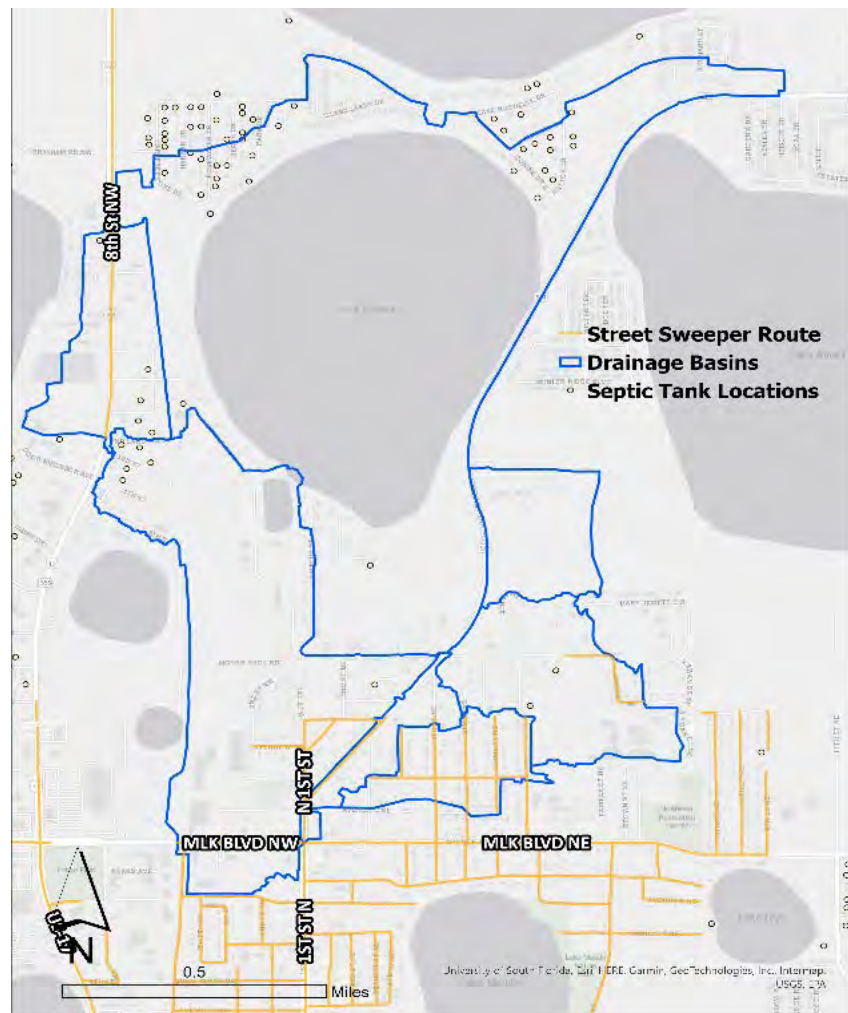


Figure 3-29. Map of Lake Conine's drainage basin, City street sweeper routes, and nearby septic systems.

Excess water from the North Chain eventually drains via the SWFWMD-managed P-8 control structure to the south of Lake Hamilton and enters the Peace Creek.

Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-30). During 2024, Lake Conine reached a dry season low of 127.8 feet in June and a wet season peak of 130.3 feet in October. The October peak was a record high for this chain of lakes; exceeding the previous record experienced during the triple hurricane season of 2004. The surface level ended the year above the high end of the normal range, at 128.5 feet. Changes in Lake Conine's surface level are directly correlated with water clarity and indirectly correlated with Chla and TN (see appendix). This carries management implications as maintaining a higher surface level should result in improved water quality.

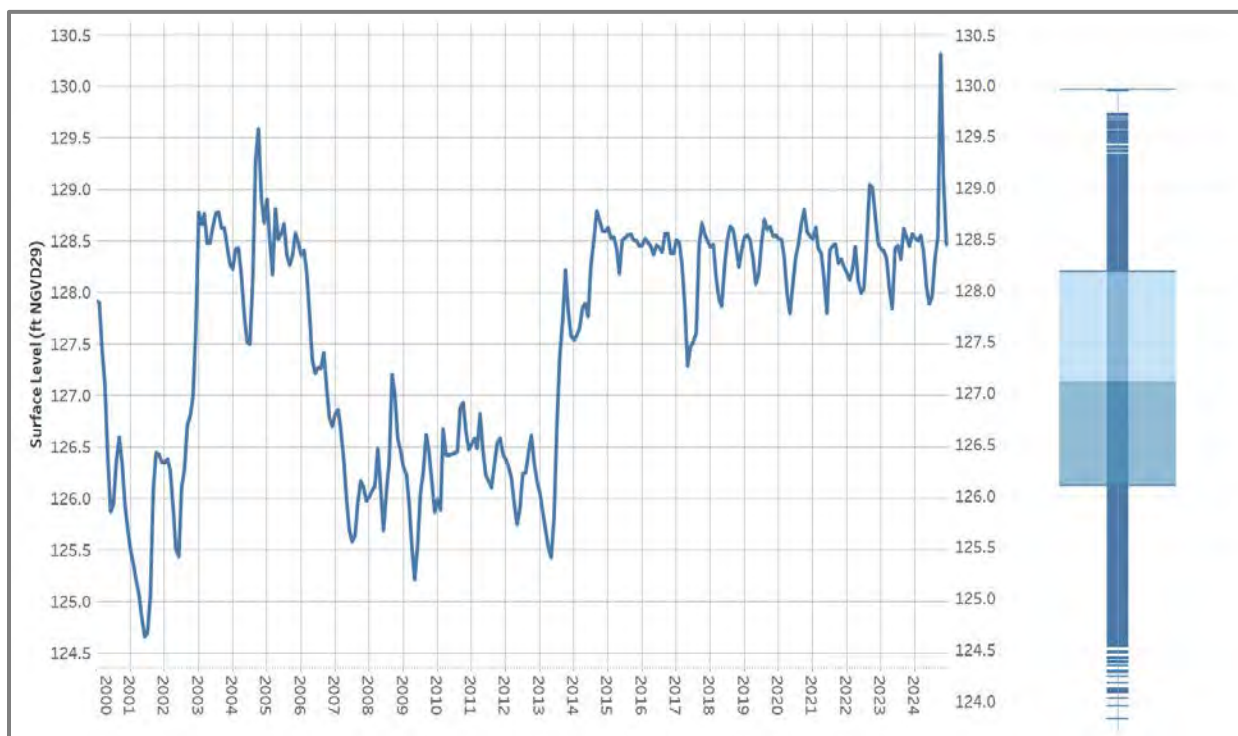


Figure 3-30. Hydrograph of Lake Conine depicting monthly surface level readings from 2000 to 2024. A box & whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Conine is categorized as a clear, alkaline waterbody. Based on a lack of multiple consecutive exceedances in the last 7.5 years, Lake Cannon is no longer exhibiting impaired status (Figure 3-31). This marks the second consecutive year that the lake has maintained Chl-a, TN, and TP at levels deemed not-impaired by the NNC. Continued improvement in water quality demonstrates how management actions have helped to restore the lake to previous conditions. Due to its previous impairments, the FDEP established a total maximum daily load for Lake Conine in 2018; stipulating a 36% reduction in TN and a 57% reduction in TP in order to meet NNC guidelines.

The City will continue to work towards meeting these guidelines through its management activities.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.818	0.000	Decreasing	3	3
TN	N	-0.669	0.001	Decreasing		3
TP	N	-0.293	0.198	No Trend		2
Secchi	NA	0.751	0.000	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Lake Conine exhibits significant improving trends in Chl-a and Secchi depth and non-significant improving trends in TN and TP. This equates to water quality trend criteria scores listed in the table below. Individual AGM values and trend statistics can be found in the appendix.

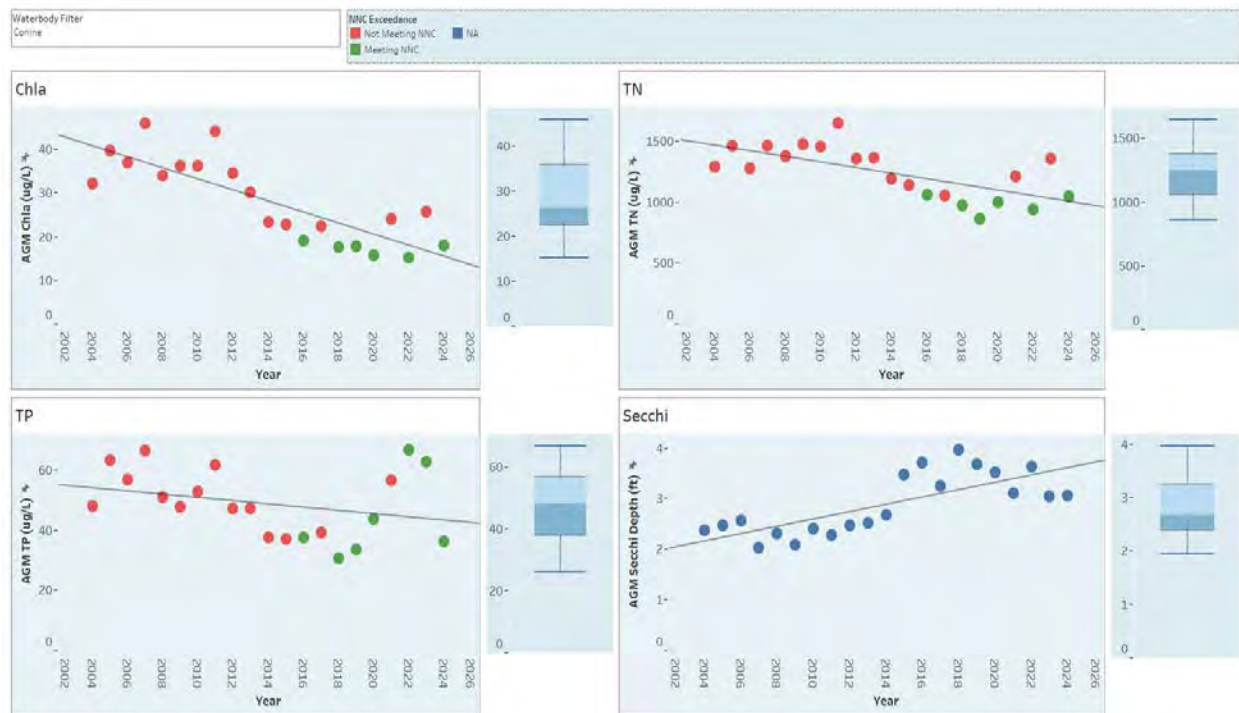


Figure 3-31. Lake Conine AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Conine on 8/1/2024. The PAC during this survey was 28.1% and the total BV was 4.64% (Figure 3-32). Lake Conine saw a dramatic drop in abundance in 2021 has continued to exhibit similar vegetation abundance since. This was likely due to treatment of invasive species like hydrilla. The PAC did experience an increase from 2023 to 2024, albeit with a slight decrease in biological volume. However, both values are marginally higher than what was reported in 2021 and 2022. The PAC value in 2024 earns Lake Conine a vegetation abundance score of 2.

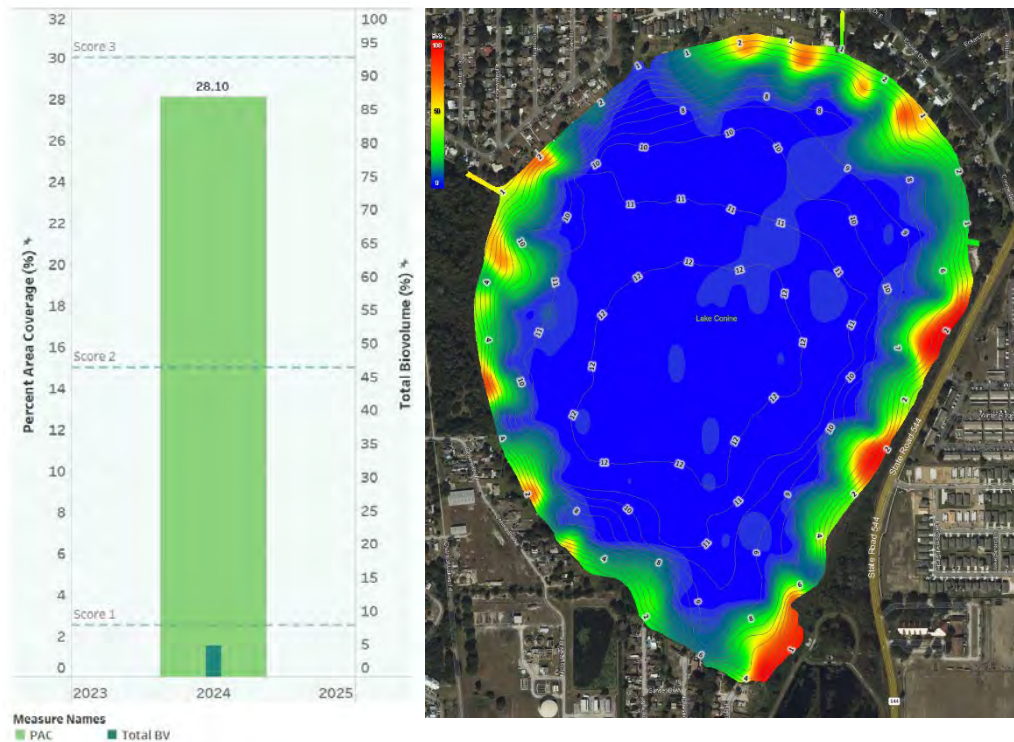


Figure 3-32. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Conine; biovolume values range from green (lowest) to red (highest).

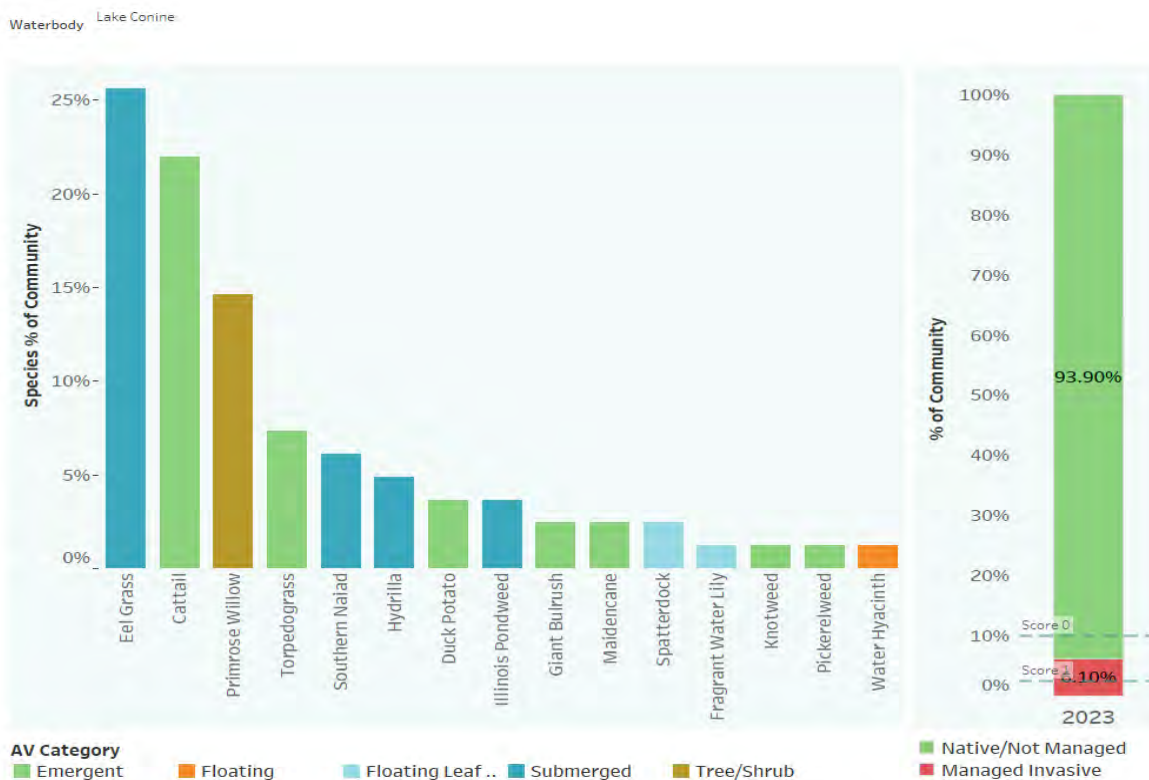


Figure 3-33. Chart depicting species frequency and invasive species percentage of Lake Conine during 2024.

Invasive Species Management:

During the 2024 survey, there was a relatively even mix of submerged and emergent plant types present. The most abundant species was the native eelgrass at 26% (Figure 3-33). The population percentage for hydrilla and water hyacinth totaled 3.95% which relates to an invasive presence criterion score of 1. Hydrilla has historically been the primary invasive species present in Lake Conine. Fortunately, the 2024 invasive percentage was nearly half of what it was in 2023 with no loss in vegetation abundance—indicating that native species are filling in the gaps left by invasive treatment efforts.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Lake Conine's diversity indices exceeded their long-term median values (Figure 3-34). Conine exhibited surprisingly little change in diversity index values from 2023 to 2024. Species richness and overall diversity were slightly lower, while evenness was slightly higher in 2024. This indicates that the vegetation community in the lake is relatively stable.

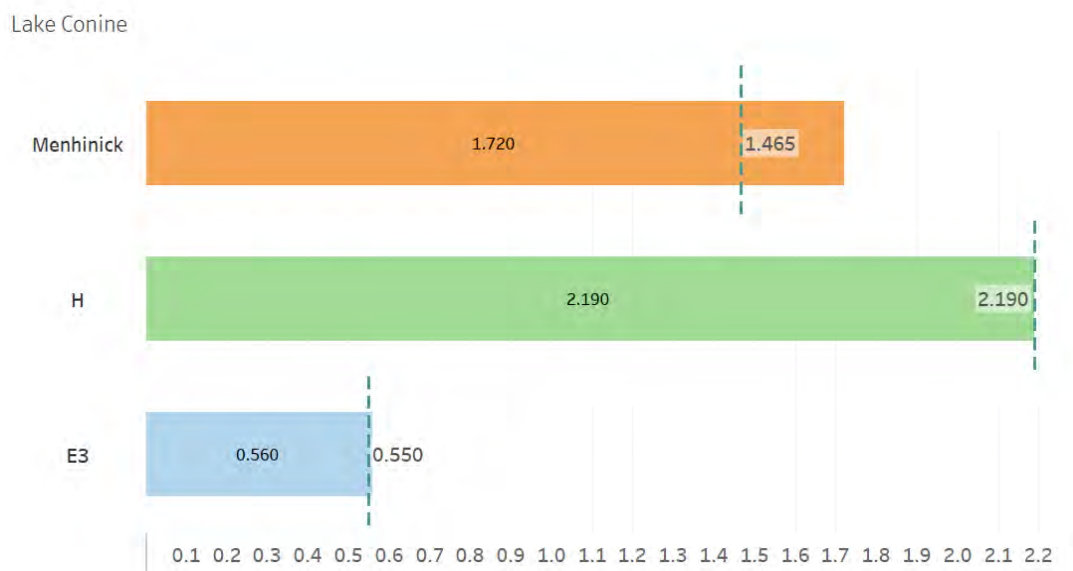


Figure 3-34. Chart depicting 2024 diversity indices for Lake Conine. Dashed line represent median values.

Lake Health Tracking:

A comparison of Lake Conine's health index scores from 2018 to 2024 shows general improvement. The recent shift in the impairment scores in 2023 and 2024 were the primary drivers of these lake health changes (Figure 3-35). Additionally, the trend criteria scores improved somewhat since 2018, indicating that the water quality impairment score should continue to improve in the future. One of the primary areas for improvement will be addressing invasive species presence which has shown some positive movement since 2022. Overall, Lake Conine is doing much better than it was when monitoring began. The stability in lake health scores over the last two years is a good sign that management efforts have made consistent improvements during this time.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	2	3	2	0	2	1.6
2019	0	3	2	3	3	3	0	2	2.0
2020	0	3	2	3	3	3	0	0	1.8
2021	0	3	2	2	3	2	0	3	1.9
2022	0	3	2	2	3	2	1	1	1.8
2023	3	3	3	2	3	2	1	3	2.5
2024	3	3	3	2	3	2	1	3	2.5

Figure 3-35. Chart depicting a comparison of Lake Buckeye's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- In addition to stormwater influx to Lake Conine, the wastewater treatment plant near this lake was a historic contributor of point-source pollutants. These legacy nutrients in the lake bed are a potential source of nitrogen and phosphorus.
- The management of invasive species like hydrilla and burhead sedge are a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody.
- Several water quality metrics are significantly correlated with Lake Conine's surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City is addressing stormwater pollutant loading through the recent construction of the Lake Conine Nature Park—a form of green stormwater infrastructure utilizing constructed wetlands designed to treat runoff from the largest southern sub-basins contributing to Lake Conine.
- Street sweeping is conducted on City roadways in the southern portion of the drainage basin—roughly 0.75 miles monthly.
- City staff continue to monitor aquatic vegetation and share the information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- Previous efforts by Polk County have used alum to “cap” historic legacy sediments in Lake Conine. Future efforts may evaluate the longevity of this project and the potential for future nutrient flux from the lake bed. However, water quality trends indicate that efforts to date have been successful.

Lake Daisy

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Daisy	3	3	3	3	3	3	2	2	2.8

Features & Statistics:

Surface area	137.3 acres
Mean depth	8.5 feet
Maximum depth	13 feet
Volume	1179.7 acre-feet
Drainage basin area	356 acres
Annual TN Load	1717.7 lbs
Annual TP Load	382.25 lbs
Limiting nutrient	Co-limited (N & P)

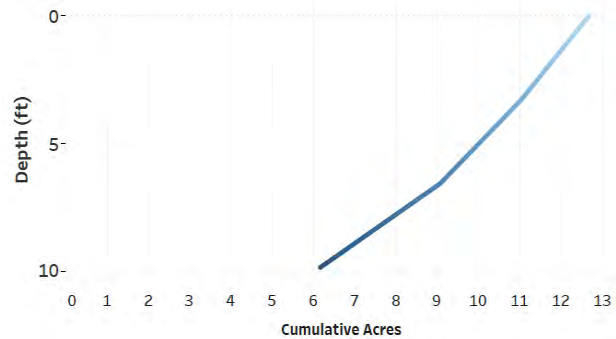


Figure 3-36. Hypsograph of Lake Daisy depicting the depth profile and morphology of the lake bed.

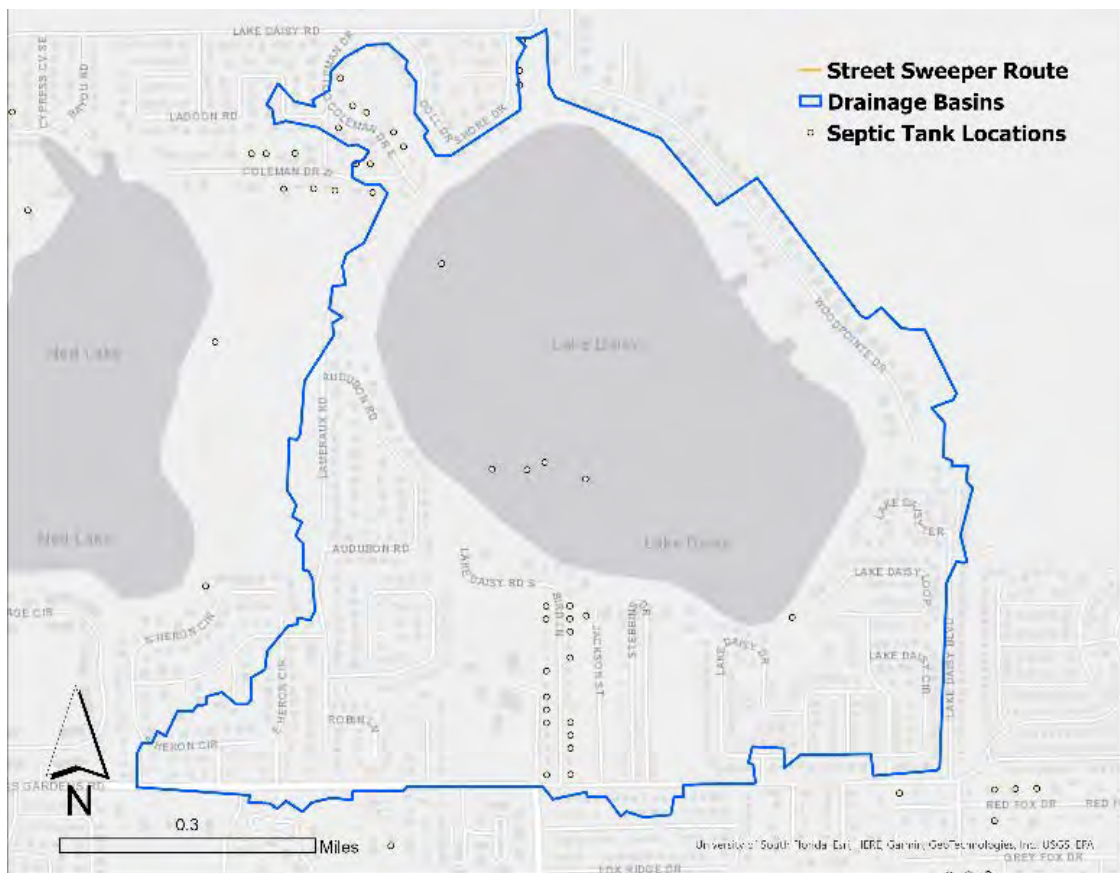


Figure 3-37. Map of Lake Daisy's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Daisy is a small and shallow waterbody at just 137 acres, an average depth of 8.5 feet, and a maximum depth of 13 feet (Figure 3-36). Due to its small size and relative shallowness, it has a higher than normal propensity for sediment suspension due to wind and wave action. Lake Daisy's drainage basin is also relatively small and made up mostly of residential land uses (Figure 3-37). Despite receiving relatively low nitrogen and phosphorus loads by volume, its per-acre nitrogen and phosphorus loads are some of the highest in the study area; mostly due to the abundance of high-density residential land use within the basin. There are approximately 30 septic systems within the drainage basin, but this density is low and not likely to be a major contributor to pollutant loads. Since the vast majority of the drainage basin falls outside of Winter Haven limits, the City does not conduct street sweeping services within the basin.

Over its period of record, Lake Daisy's surface level has fluctuated between 125.75 and 129.9 feet above sea level. The normal range is much narrower; between 127.9 and 128.9 feet (Figure 3-38). During 2024, Lake Daisy reached a dry season low of 127.7 feet in June and a wet season peak of 129.7 feet in October. The surface level ended the year slightly below the median at 128.4 feet. It should be noted that Lake Daisy's surface level reached a high not observed in the last 20 years due to increased rainfall during the active hurricane season. This excess water quickly dissipated afterwards. Changes in Lake Daisy's surface level are not correlated with Chl-a, TN, TP, or clarity (see appendix).

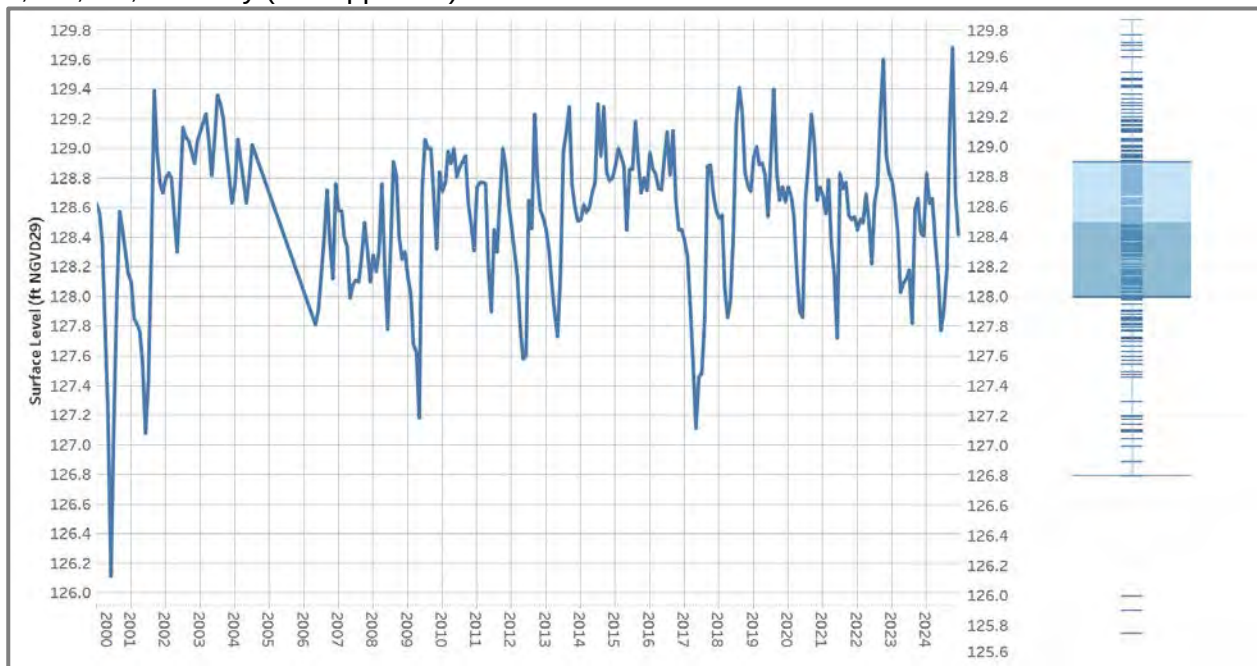


Figure 3-38. Hydrograph of Lake Daisy depicting monthly surface level readings from 2000 to 2024. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Daisy is categorized as a clear, low-alkalinity waterbody. Lake Daisy has not exhibited exceedances of any of its NNC parameters within the 7.5 year assessment period (Figure 3-39). The most recent exceedance occurred for TP in 2009. The lack of impairments earns Lake Daisy a score of 3.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the trend analysis, all four of the primary water quality parameters exhibit significant improving trends. This equates to trend criteria scores of 3 for each of these parameters. Individual AGM values and trend statistics can be found in the appendix.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.662	0.001	Decreasing	3	3
TN	N	-0.749	0.000	Decreasing		3
TP	N	-0.759	0.000	Decreasing		3
Secchi	NA	0.517	0.016	Increasing		3



Figure 3-39. Lake Daisy AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Daisy on 9/17/2024. The PAC during this survey was 32.3% and the total BV was 4.2% (Figure 3-40). Lake Daisy has traditionally lacked submerged vegetation. In 2022 there was a significant increase in the presence of native SAV. However, the introduction of hydrilla in late 2022 required immediate treatment which ultimately reduced the overall abundance. Fortunately, 2024 saw another substantial increase in abundance; the highest on record. The result is an abundance criterion score of 3.

Invasive Species Management:

Based on data from the 2024 survey, Lake Daisy exhibited a more even mix of emergent and submerged species (Figure 3-41). Previously wholly dominated by emergent species, Daisy saw

a considerable increase in coontail, which made up over 12% of the community. A small amount of hydrilla was detected in 2024, totaling less than 1% of the population and resulting in an invasives criterion score of 2. This substantial increase in vegetation abundance coupled with a decline in invasives demonstrates a significant improvement in biological health.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, Lake Daisy's species richness and overall diversity indices exceeded their long-term median values (Figure 3-42). Species evenness fell slightly below the median value—resulting in a diversity criterion score of 2. The evenness decrease from the previous year was very slight; well within normal fluctuations based on annual or seasonal variation. Species richness was recorded as the highest on record and overall diversity is also at one of the highest points in monitoring history for this lake. Overall, the biological community of Lake Daisy appears to be stabilizing in a state much better than when monitoring began.

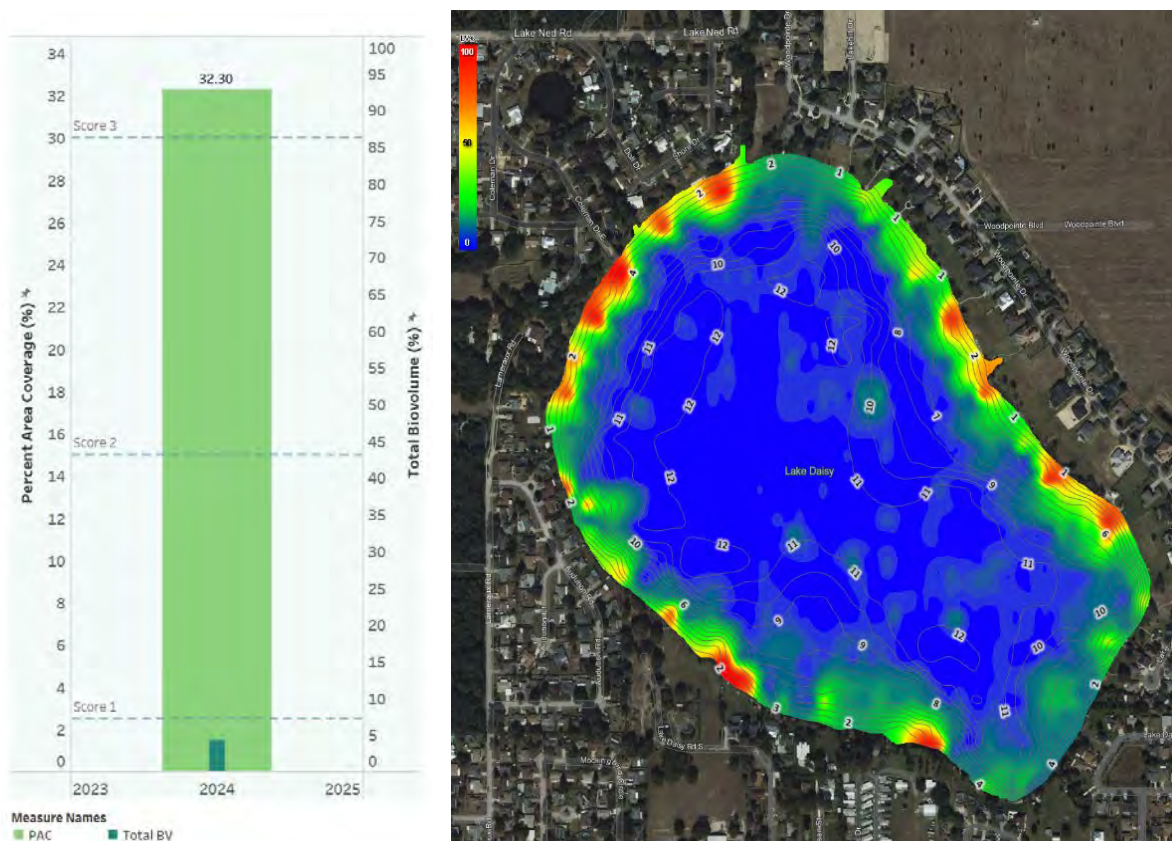


Figure 3-40. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Daisy; biovolume values range from green (lowest) to red (highest).

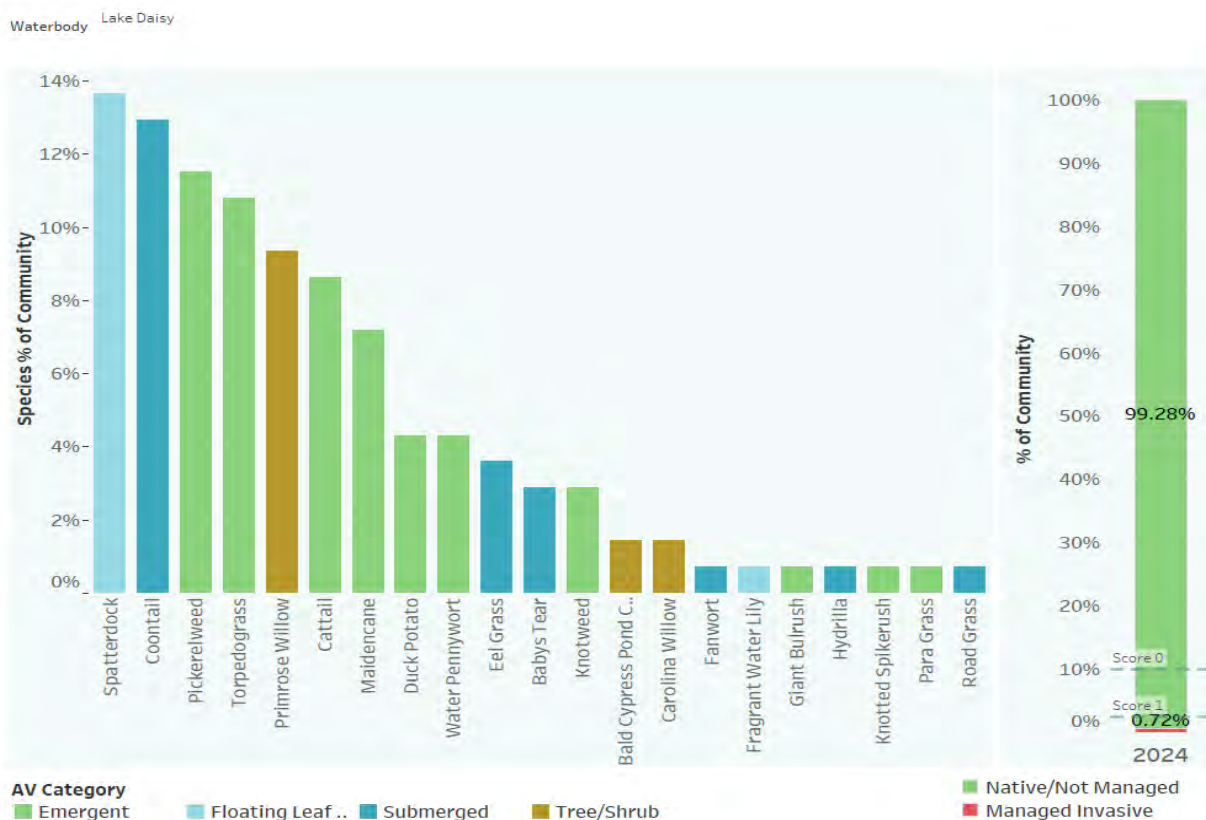


Figure 3-41. Chart depicting species frequency and invasive species percentage of Lake Daisy during 2024.

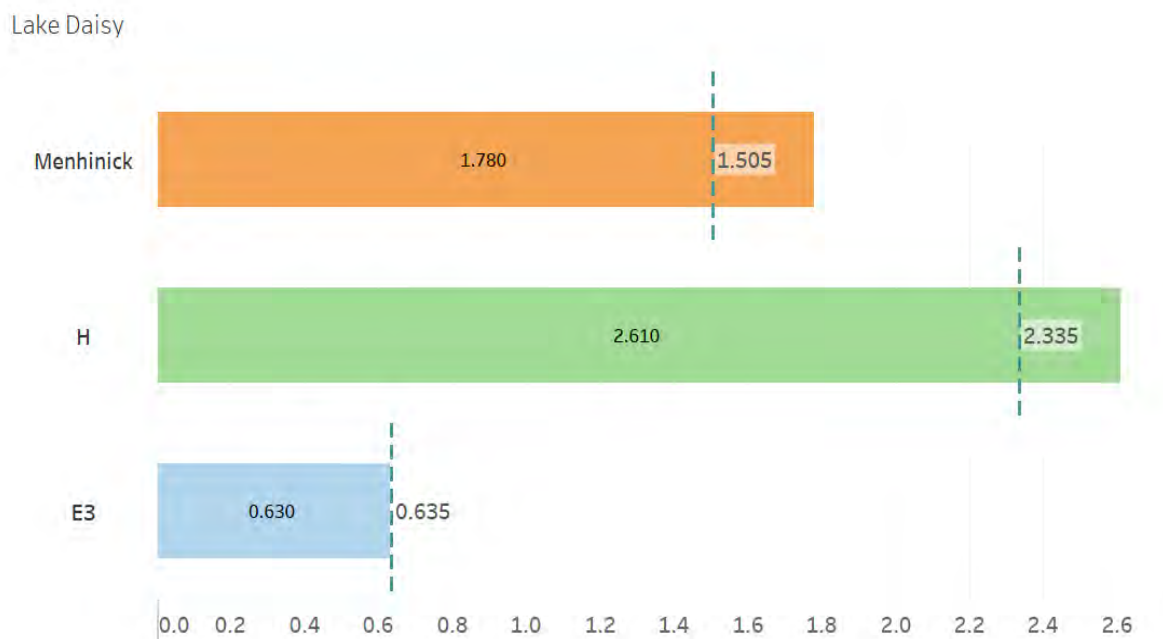


Figure 3-42. Chart depicting 2024 diversity indices for Lake Daisy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Daisy's health index scores from 2018 to 2024 shows a substantial increase during the last three years (Figure 3-43). The majority of this increase has come from statistically significant changes in three of the four trend criteria as well as an increase in the vegetation criterion scores. The LHI in 2024 ties with 2022 as the highest on record for this lake. Invasive species management and preserving biological diversity are the only areas for improvement at this time and should be the primary focus of any future management effort.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	2	2	2	1	3	1	2.1
2019	3	3	2	2	2	1	3	1	2.1
2020	3	3	2	2	2	1	2	2	2.1
2021	3	3	2	2	2	2	2	2	2.3
2022	3	3	3	3	3	3	2	2	2.8
2023	3	3	3	3	3	2	1	3	2.6
2024	3	3	3	3	3	3	2	2	2.8

Figure 3-43. Chart depicting a comparison of Lake Daisy's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Daisy currently exhibits acceptable water quality. Lacking stormwater infrastructure, the primary sources of pollutant loading would be from nonpoint sources like direct sheetflow from residential lots.
- While the presence of invasive species is currently low, there is potential for these plants to take over large areas of a waterbody in a single season. This requires regular monitoring to detect new infestations early before they require large-scale management.
- While the OSTD systems within the drainage basin are in low densities, these could be a potential avenue for pollutant loading via groundwater if they begin to fail. Continually monitoring water quality for nitrogen influx is recommended.

Lake Management Strategy:

- With the majority of the drainage basin comprised of residential housing, future management of stormwater will likely consist of public education and outreach. Education aims to increase residents' knowledge of best stormwater practices and ways they can collectively reduce their pollutant load.
- If water quality becomes a future issue, City staff may explore source analysis to determine if OSTD leachate is a potential contributor to nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species remains the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Deer

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Deer	3	3	3	3	3	3	1	1	2.5

Features & Statistics:

Surface area	119 acres
Mean depth	7.3 feet
Maximum depth	17.5 feet
Volume	877.8 acre-feet
Drainage basin area	377 acres
Annual TN Load	1451.1 lbs
Annual TP Load	261.2 lbs
Limiting nutrient	Co-limited (N & P)

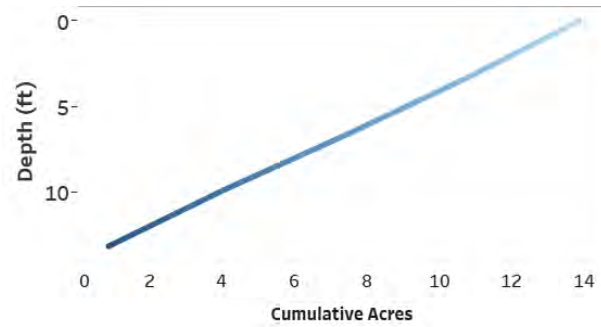


Figure 3-44. Hypsograph of Lake Deer depicting the depth profile and morphology of the lake bed.

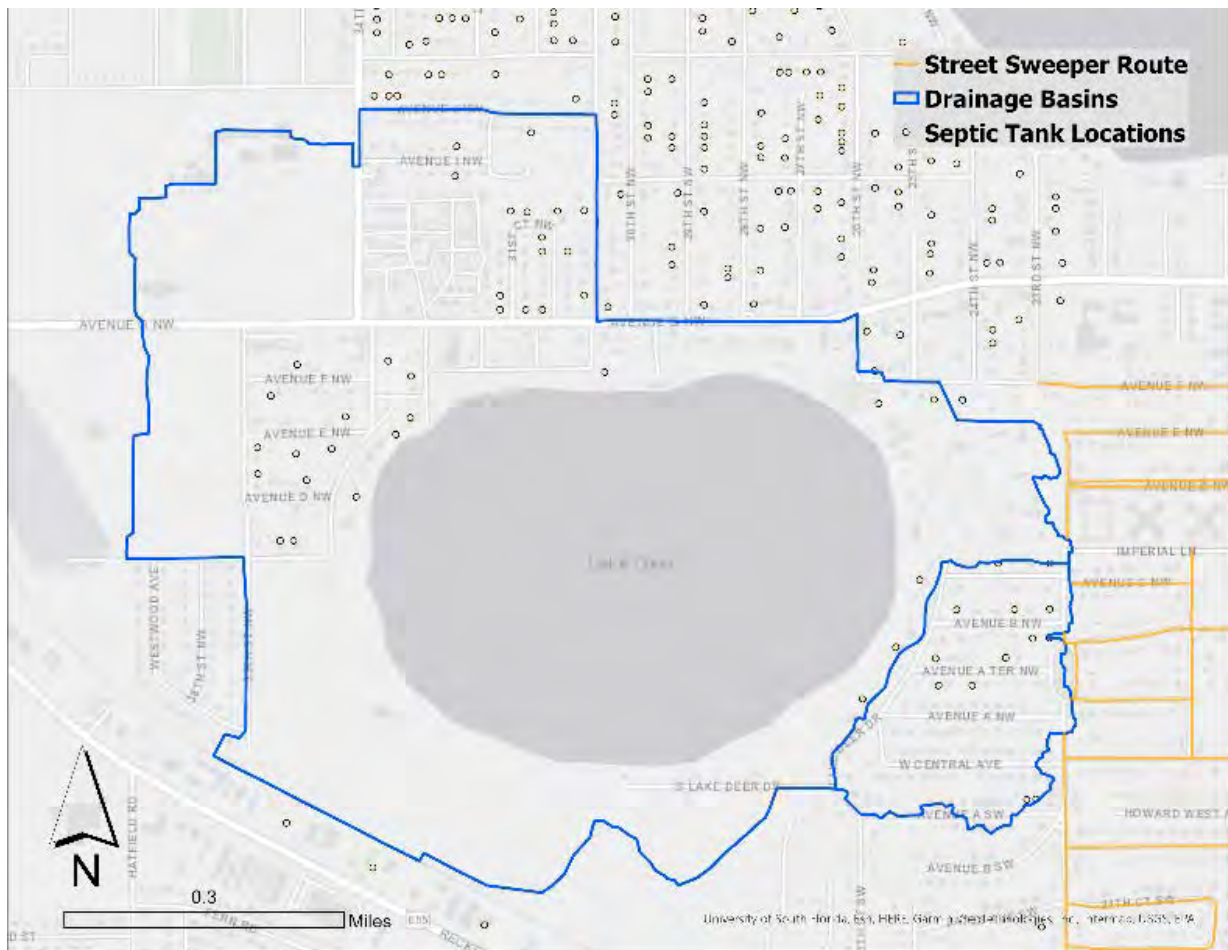


Figure 3-45. Map of Lake Deer's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Deer is a smaller waterbody at 119 acres, with an average depth of 7.3 feet, and a maximum depth of 17.5 feet (Figure 3-44). Despite it having a shallower average depth than the regional mean, Lake Deer possesses some very deep areas. As a result of its morphology, it has a fairly wide littoral zone which supports a very robust area of submerged aquatic vegetation. Lake Deer receives stormwater runoff from a drainage basin nearly three times the size of the waterbody (Figure 3-45). The primary land use within this basin is residential which contributes almost 1,500 lbs of nitrogen and 260 lbs of phosphorus to the lake annually. By area, these pollutant loads rank 9th highest out of the 37 lakes in the study area. There are 41 septic systems located within this basin—a relatively low density. However, factoring in other septic systems in close proximity to the basin reveals a higher density of OSTDs that could impact water quality. The areas of the drainage basin within City limits possess few public roadways. As a result, the City provides no street sweeping services within the basin.

Lake Deer's surface level sits fourth highest within the Winter Haven watershed. Over its period of record, Lake Deer's surface level has fluctuated between 136.9 and 141.9 feet above sea level. That said, Deer's surface level has not exceeded 140.1 feet since before the year 2000 (Figure 3-46). The normal range fluctuates between 136.9 and 139.6 feet. However, since around 2008, Deer's level has remained at the low end of this range. This is likely the result of an alteration to the lake's water control structure driving a shift in the overall hydrological regime. In 2024, Deer reached a dry season low of 137.3 ft in June and a wet season peak of 138.8 ft in September. Changes in Lake Deer's surface level are not correlated with any of the primary water quality metrics (see appendix).

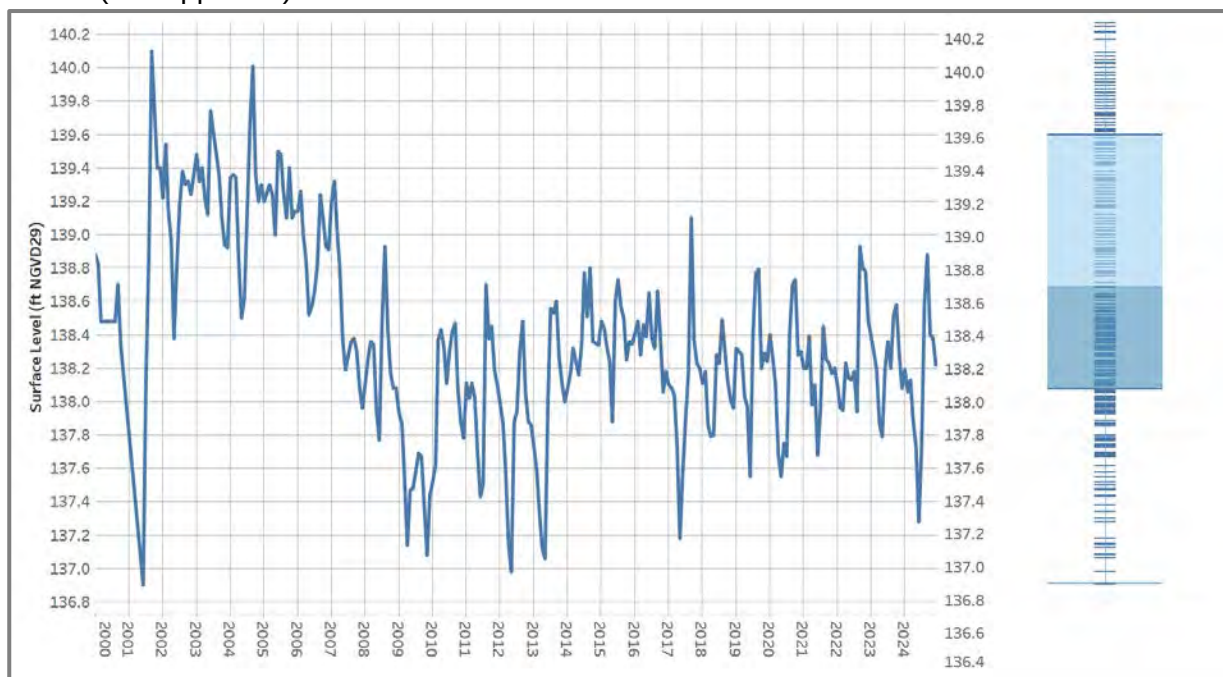


Figure 3-46. Hydrograph of Lake Deer depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface levels during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Deer is categorized as a clear, alkaline waterbody. Lake Deer has not exhibited exceedances of NNC

thresholds since 2013 (Figure 3-47). Since there have been no exceedances in the 7.5 year assessment period, Lake Deer is currently considered not impaired—earning an impairment criterion score of 3. Due to its previous impairments, the FDEP established a TMDL for Lake Deer in 2015 stipulating a 12% reduction in TN in order to meet the NNC guidelines. Lake Deer is currently meeting these guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.608	0.003	Decreasing	3	3
TN	N	-0.480	0.028	Decreasing		3
TP	N	-0.588	0.005	Decreasing		3
Secchi	NA	0.546	0.010	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. All four of the primary water quality metrics exhibited significant improving trends during this period. Despite the overall improvement in water quality, Lake Deer is still on FDEP's study list and will be for quite some time to ensure that water quality continues to be maintained below impairment thresholds.

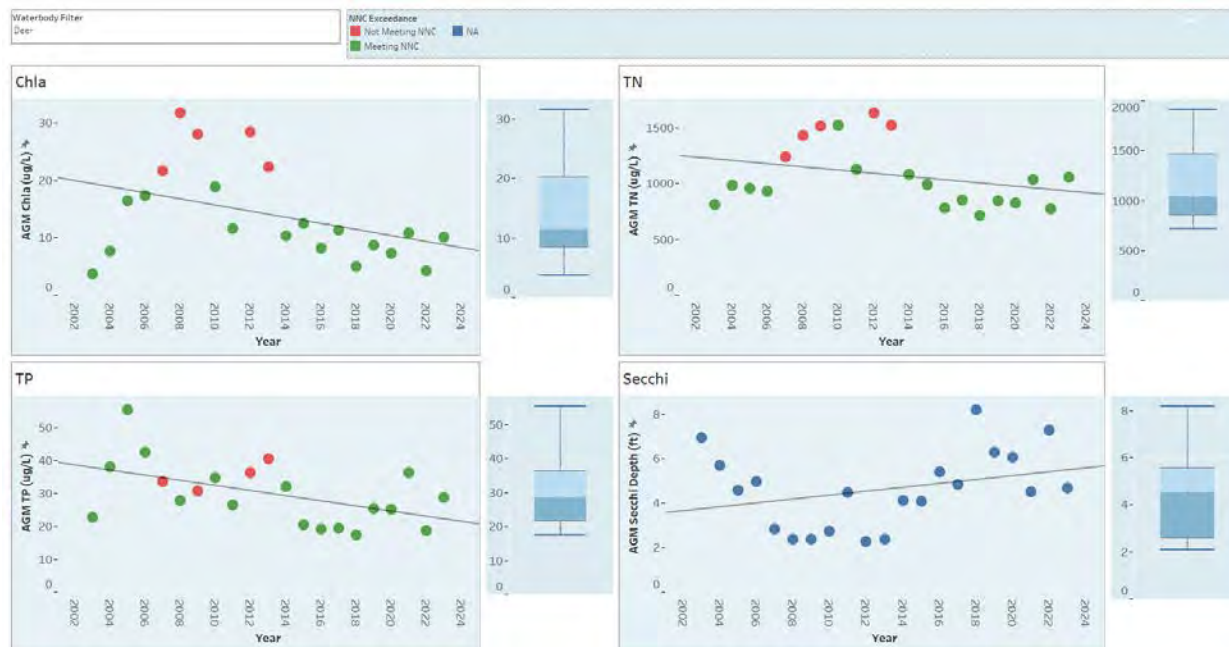


Figure 3-47. Lake Deer AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Deer on 2/2/2024. The PAC during this survey was 90.6% and the total BV was 26% (Figure 3-48). Lake Deer has historically maintained very high abundances of aquatic vegetation due to its shallow morphology and wide littoral zone. The water quality improvements observed are likely due, in part, to the nutrient sequestration capacity of this vegetation. The amount of vegetation coverage observed in 2024 was the second highest on record and equates to a vegetation abundance score of 3.

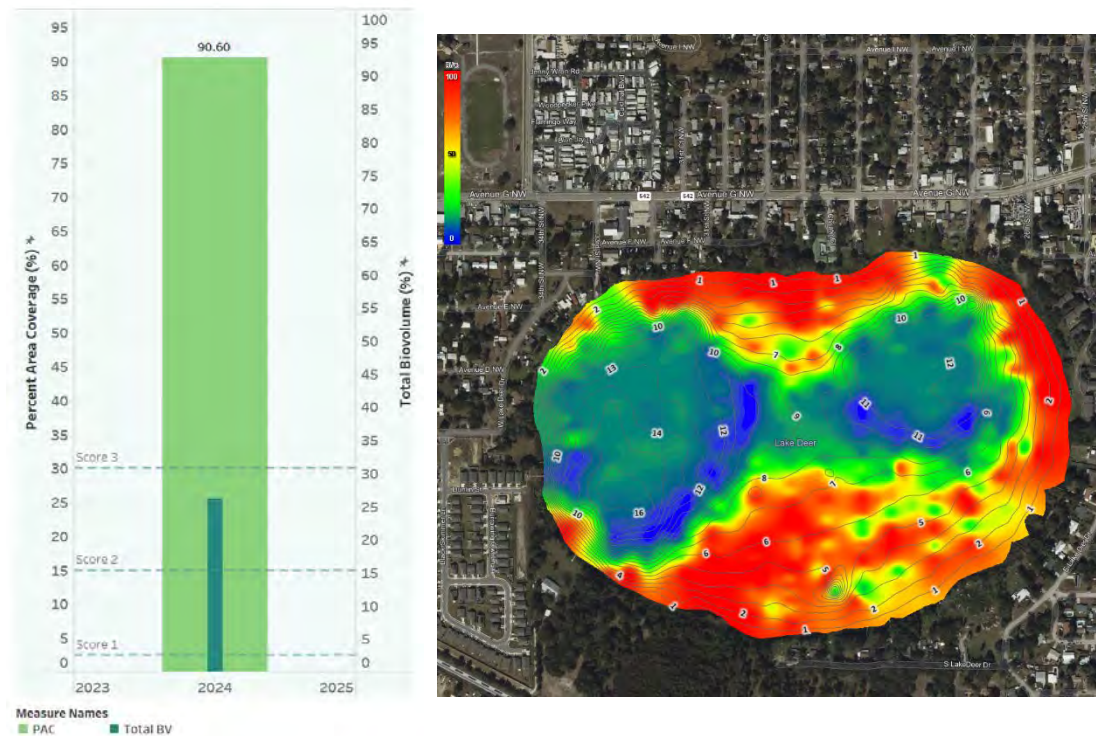


Figure 3-48. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Deer; biovolume values range from green (lowest) to red (highest).

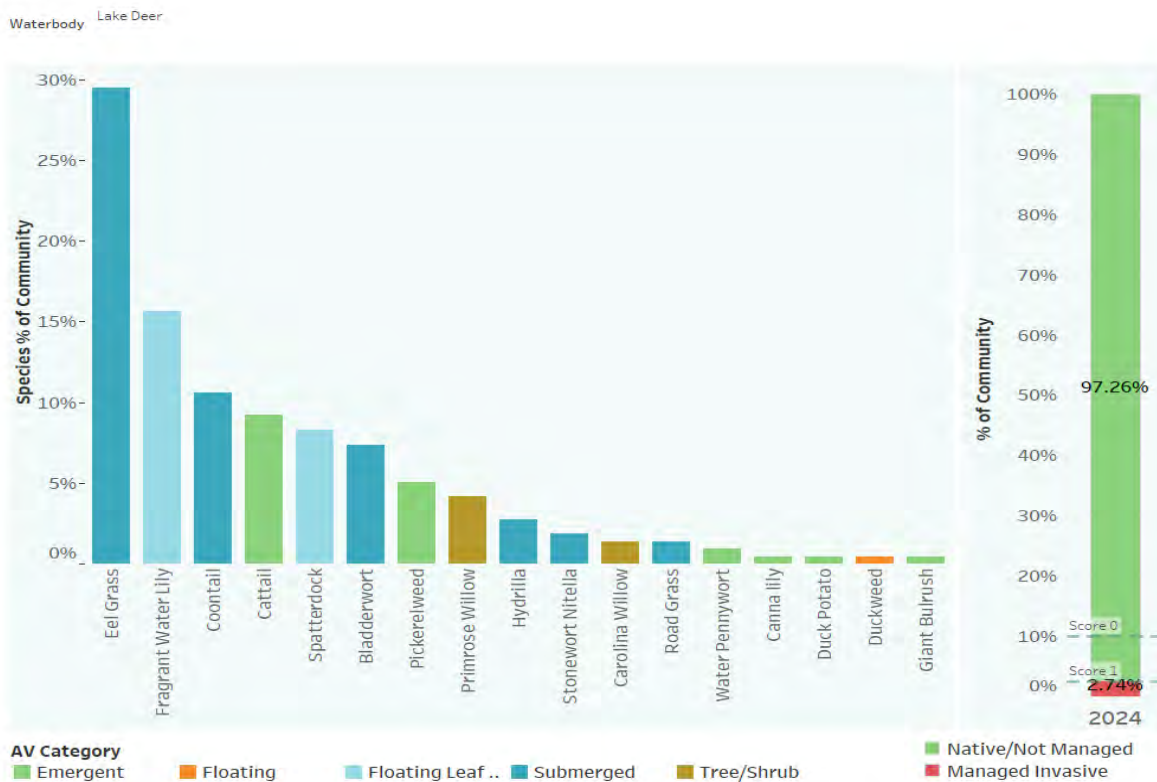


Figure 3-49. Chart depicting species frequency and invasive species percentage of Lake Deer during 2024.

Invasive Species Management:

Based on data from the 2024 survey, submerged plants make up a large percentage of the total vegetation community at over 50% (Figure 3-49). The native eel grass was the dominant species during this survey at nearly 30% of the community. Unlike previous years, Lake Blue exhibited a much lower proportion of invasive species. Hydrilla was the only invasive present and in only small numbers—at just 2.75%. This earns Lake Deer an invasive abundance score of 1 and demonstrates how invasive management practices have been effective in recent years.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, only the species richness index met or exceeded its long-term media value (Figure 3-50). Unfortunately, the decrease in invasive presence lowered both the species evenness and overall diversity metrics. This earns Lake Deer a score of 1 in the diversity criterion. A decrease in the species diversity values is a worthy tradeoff for control of invasive species, however. Continued management employing early detection and rapid treatment should allow natives to fill the niches vacated by the invasive plants.

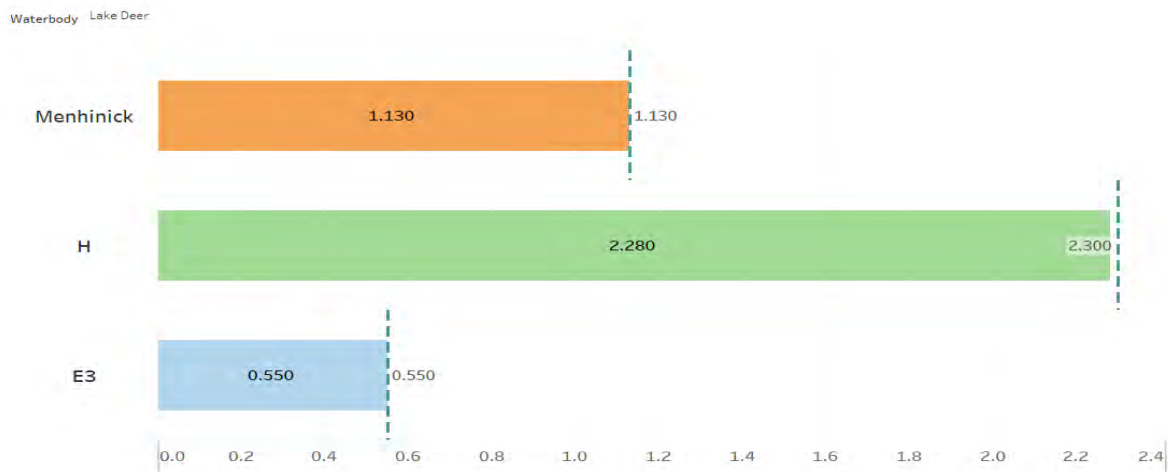


Figure 3-50. Chart depicting 2024 diversity indices for Lake Deer. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Deer's health index scores from 2018 to 2024 shows a substantial increase since 2021. Most of this improvement has been due to meeting impairment thresholds along with generally stable long-term water quality trends (Figure 3-51). Vegetation abundance remains high, but the main issue plaguing Lake Deer now is management of invasive species.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	2	2	3	1	2	1.8
2019	0	2	2	2	2	3	0	2	1.6
2020	0	2	2	2	2	3	0	2	1.6
2021	0	2	3	2	2	3	0	0	1.5
2022	3	2	3	2	3	3	0	1	2.1
2023	3	2	2	3	2	3	0	2	2.1
2024	3	3	3	3	3	3	1	1	2.5

Figure 3-51. Chart depicting a comparison of Lake Deer's Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- While Lake Deer's water quality is improving, managing the stormwater pollutant loads from its drainage basin is still a priority.
- The presence of OSTDs (septic) systems in the drainage basin may be a potential source of pollutants. As these systems age, they may begin to leach nutrients into the water table—leading to water quality issues.
- The management of invasive species is especially important for Lake Deer. Hydrilla has been a constant issue since monitoring began since it can quickly undo management efforts in a single season.

Lake Management Strategy:

- While the City has little stormwater infrastructure contributing to Lake Deer, efforts can still be made to improve these pollutant loads through implementation of green infrastructure where possible.
- City staff may explore source analysis of septic systems in the vicinity of Lake Deer to determine if they are contributing pollutant loads via groundwater. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Elbert

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Elbert	3	0	0	1	0	2	3	1	1.3

Features & Statistics:

Surface area	177 acres
Mean depth	14 feet
Maximum depth	26 feet
Volume	2325.9 acre-feet
Drainage basin area	605 acres
Annual TN Load	2365.8 lbs
Annual TP Load	385.1 lbs
Limiting nutrient	Co-limited (N & P)

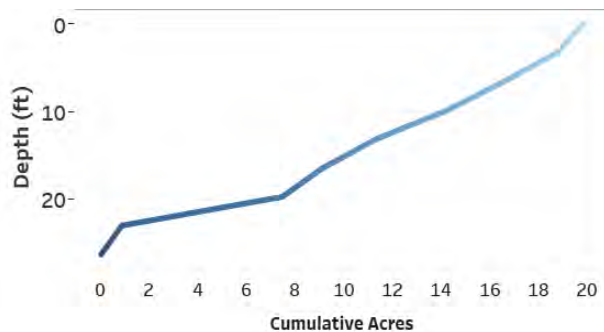


Figure 3-52. Hypsograph of Lake Elbert depicting the depth profile and morphology of the lake bed.

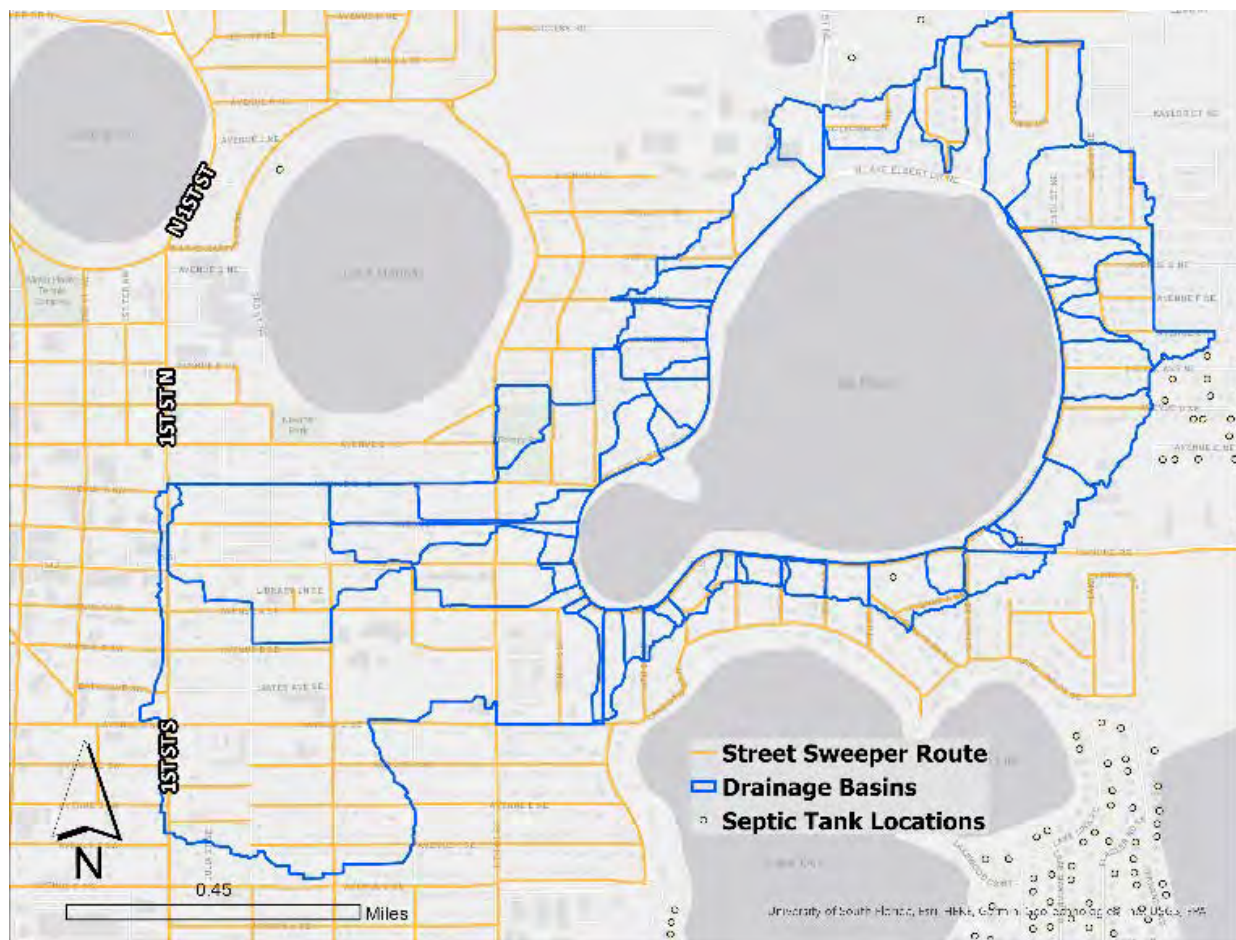


Figure 3-53. Map of Lake Elbert's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Elbert is a moderate sized waterbody with a surface area of nearly 200 acres. Elbert is deeper than most lakes in the area with an average depth of 14 feet; the regional mean depth is only 8.5 feet (Figure 3-52). Despite its more bowl-shaped morphology, Lake Elbert possesses a wide littoral zone that is capable of supporting a dense submerged aquatic plant community. Stormwater is conveyed to this waterbody from a 439 acre urbanized drainage basin made up of 50 individual sub-basins (Figure 3-53). By far the largest proportion of land use in this basin is comprised of medium-density residential which contributes up to 2,365 lbs of TN and 385 lbs of TP to the lake annually. Compared with the other lakes in the region, the TN and TP loads per acre rank 12th and 15th, respectively. There are very few known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within the vicinity of Lake Elbert. Completely within City limits, Winter Haven conducts monthly street sweeping services of up to 33.5 miles within this basin.

Over its period of record, Lake Elbert's surface level has fluctuated between 128.8 and 137.6 feet above sea level (Figure 3-54). A water level pump station is only activated during extremely high levels—such as after Hurricane Ian in 2022. As a result, Lake Elbert's level is able to fluctuate more or less naturally. The normal level range is much narrower—between 131.9 and 134.7 feet. During 2024, Elbert's level declined to a June low of 133.1 feet, but reached a wet-season high of 134.7 feet in November. These level fluctuations were within the lake's normal range. Based on 2019 regression analyses, changes in Lake Elbert's level are significantly correlated with Chl-a, TN, TP, and clarity such that an increase in surface level should result in water quality improvements.

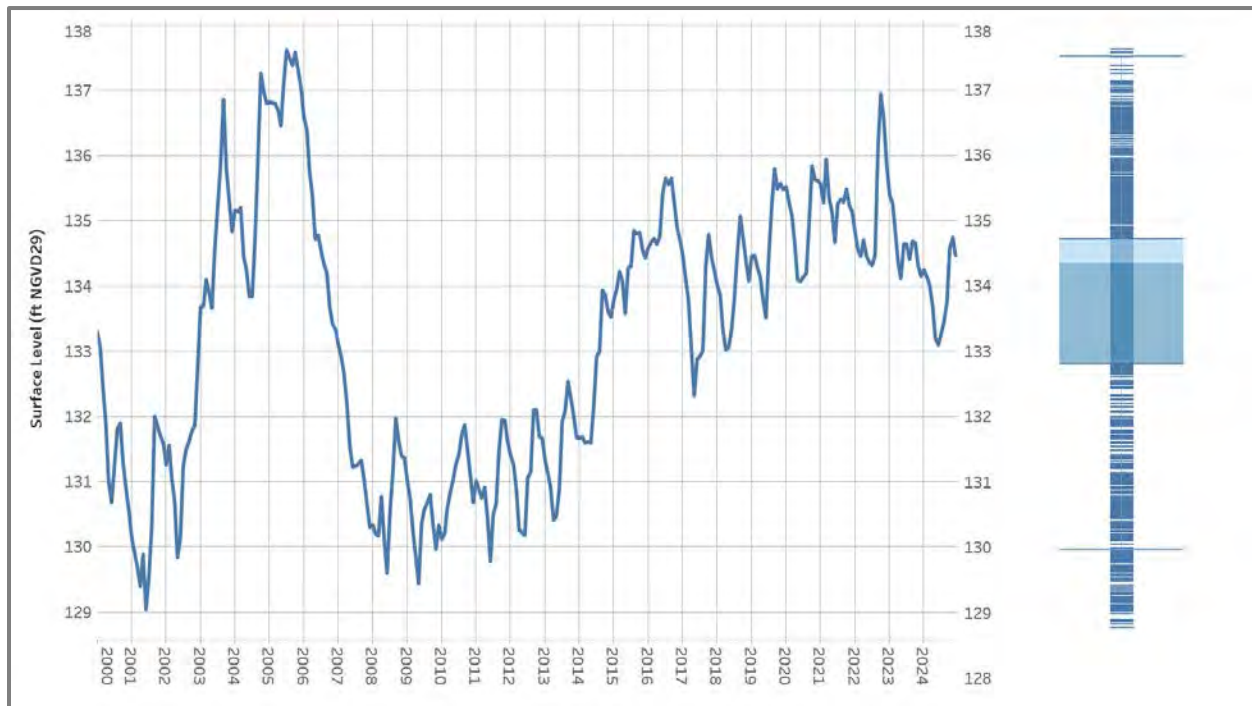


Figure 3-54. Hydrograph of Lake Elbert depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Elbert is categorized as a clear, alkaline waterbody. Since 2000, Lake Elbert has not exhibited any

exceedances of NNC thresholds (Figure 3-54). By virtue of this, Lake Elbert is not considered impaired by any of the primary water quality metrics—earning an impairment criterion score of 3.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	0.767	0.000	Increasing	3	0
TN	N	0.703	0.000	Increasing		0
TP	N	0.024	0.919	No Trend		1
Secchi	NA	-0.722	0.000	Decreasing		0

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Chl-a, TN, and Secchi depth exhibit significant declining trends—earning scores of 0 for their respective trend criteria. That said, TP exhibits a non-significant increasing trend that has been recently shifting toward a decreasing direction in recent years. These statistics earn TP a trend score of 1.

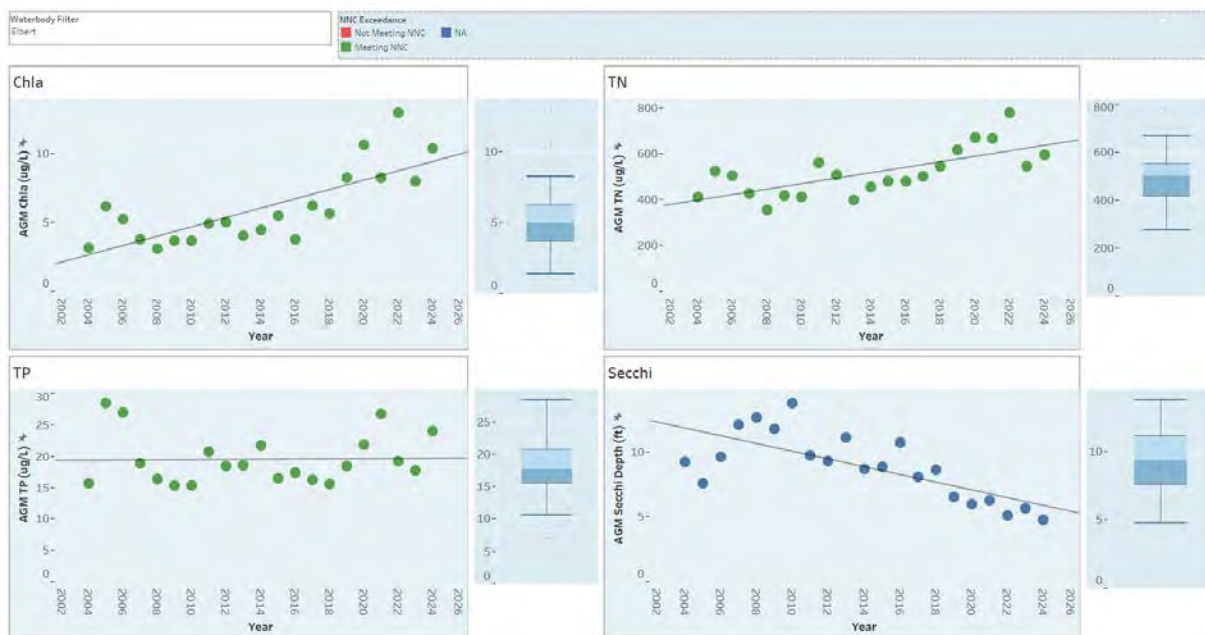


Figure 3-55. Lake Elbert AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Elbert on 7/19/2024. The PAC during this survey was 18.2% and the total BV was 1.3%; slightly lower than the previous year (Figure 3-56). A comparison of abundance from previous years shows a continuous decline in the amount of submerged vegetation present in the lake. This is likely due to the continued management of hydrilla, but it may also be an indication of the water clarity decline having an impact on the vegetation community. As a result of the below thirty percent PAC value, Elbert receives an abundance criterion score of 2.

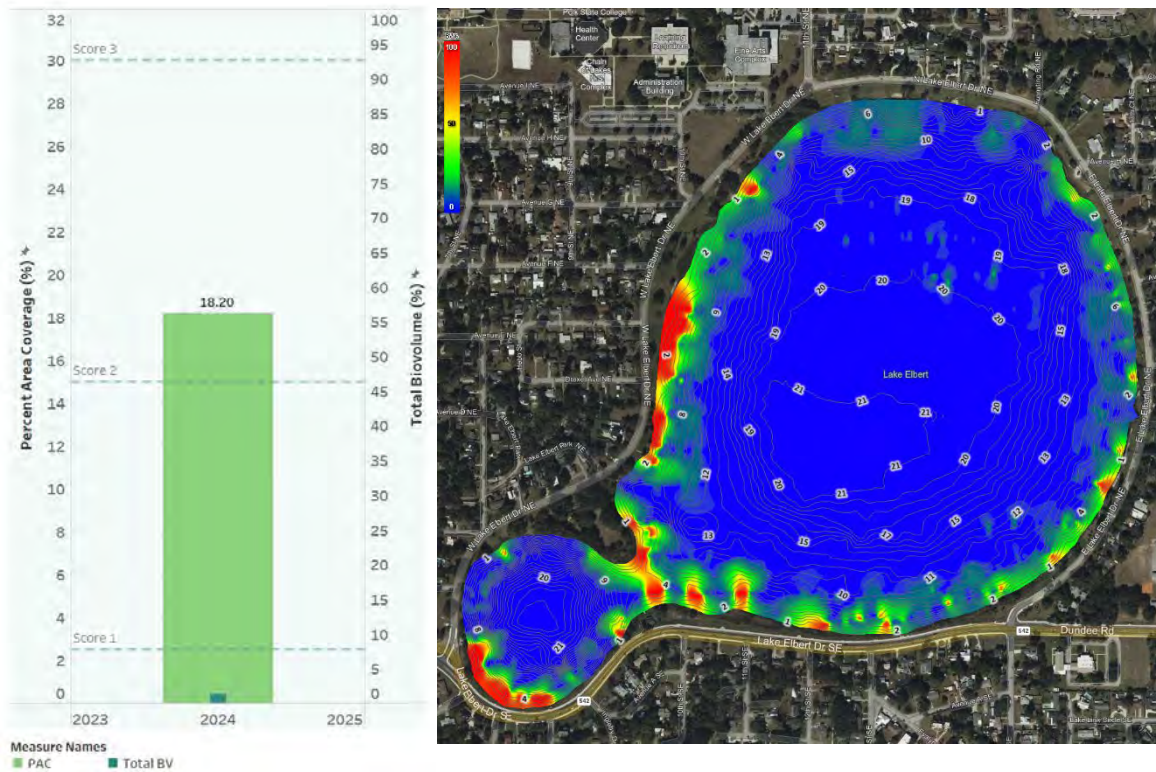


Figure 3-57. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Elbert; biovolume values range from green (lowest) to red (highest).

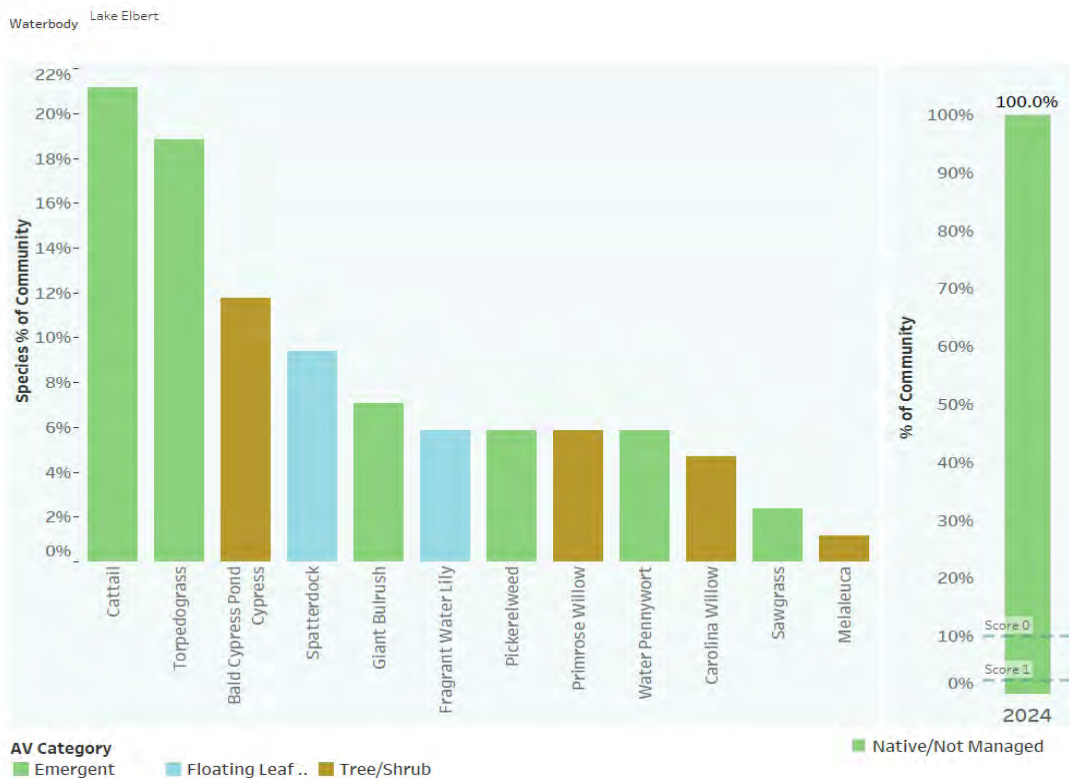


Figure 3-56. Chart depicting species frequency and invasive species percentage of Lake Elbert during 2024.

Invasive Species Management:

Based on 2024 data, emergent species were the only plants present during the survey (Figure 3-57). This is surprising since Lake Elbert has historically been a submerged plant-dominated lake. Lake Elbert has historically had issues managing invasives and the dominance often shifts between hydrilla and eelgrass on an annual basis. There is a positive aspect to the absence of SAV in 2024—there were no invasive species detected, leading to an invasive presence score of 3. Again, the loss of submerged plants may be the result of continued invasive plant management efforts coupled with a sharp decline in water clarity in recent years.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, only the evenness index exceeded its long-term median value—resulting in a diversity score of 1 (Figure 3-58). It comes as little surprise that the species richness and overall diversity index values fell below the average due to the loss of submerged plants (native and invasive alike). Future management efforts should seek to restore native submerged plants in order to better balance the ecological community.

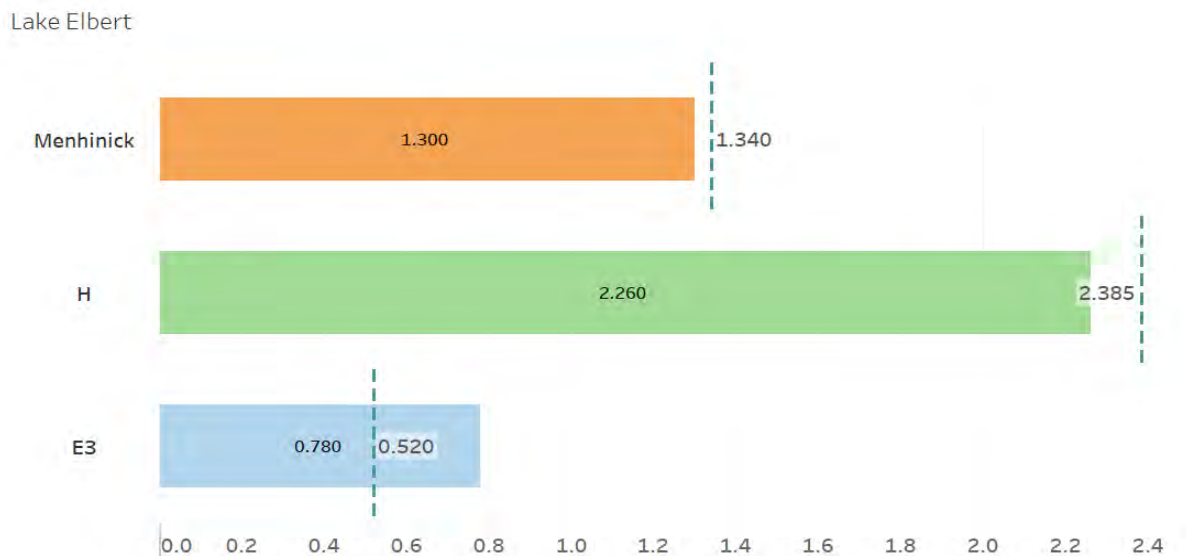


Figure 3-58. Chart depicting 2024 diversity indices for Lake Elbert. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Elbert's health index scores from 2018 to 2024 shows consistently low values, below 1.5 (Figure 3-59). The trend scores have been the primary contributor to the low lake health scores. However, the abundance of invasive species has been a consistent issue as well. The lake health score of 2023 marks the best Lake Elbert has been on record—mostly due to the improvements in the biological criteria. In 2024, invasive presence score improved, but this came with a drop in vegetation abundance and diversity scores which resulted in a slightly lower LHI score during this year.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	1	1	1	3	1	0	1.3
2019	3	0	0	1	1	3	0	2	1.3
2020	3	0	0	1	0	3	0	1	1.0
2021	3	0	0	0	0	3	0	3	1.1
2022	3	0	0	0	0	3	0	2	1.0
2023	3	0	0	1	0	2	2	3	1.4
2024	3	0	0	1	0	2	3	1	1.3

Figure 3-59. Chart depicting a comparison of Lake Elbert's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- The prevalence of older residential neighborhoods within Lake Elbert's drainage basin means that stormwater pollutant loading goes largely unmitigated. Managing this stormwater is a high priority.
- The management of invasive species like hydrilla is a constant concern. Recent efforts to reduce invasive presence have only been able to slow the spread. Large-scale herbicide applications are not advised due to the fragility of Lake Elbert's water quality.
- Lake Elbert's water quality metrics are significantly correlated with its surface level. This means that drought conditions could result in further declines in water quality.

Lake Management Strategy:

- In addition to conducting street sweeping (annual removal of 378 lbs of TN and 205 lbs of TP), the City has plans to address stormwater pollutant loading through construction of green infrastructure (swales and raingardens) as part of a planned trail improvement project. These structural management practices are estimated to remove an additional 125 lbs of TN and 19 lbs of TP annually.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Additionally, staff will advocate for alternative invasive management strategies to limit large-scale herbicide use to reduce further water quality declines.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- With the majority of land use in the drainage basin being residential, public education should be prioritized to increase residents' knowledge of best stormwater practices and ways they can collectively reduce their pollutant load.
- The loss in submerged vegetation may require supplemental planting efforts to restore the SAV habitat. City staff will explore potential funding avenues through FWC.

Lake Eloise

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Eloise	0	3	2	3	2	2	2	1	1.9

Features & Statistics:

Surface area	1185 acres
Mean depth	13 feet
Maximum depth	20 feet
Volume	15,544 acre-feet
Drainage basin area	1981.4 acres
Annual TN Load	3875.2 lbs
Annual TP Load	665.4 lbs
Limiting nutrient	Phosphorus

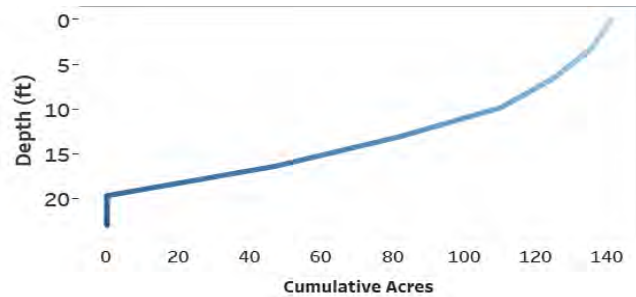


Figure 3-60. Hypsograph of Lake Eloise depicting the depth profile and morphology of the lake bed.

Hydrology:

At over 1,100 acres, Lake Eloise is the largest waterbody on Winter Haven's Chain of Lakes. Its mean depth is somewhat deeper than the regional average of 8.4 feet; and it has deeper areas around 20 feet (Figure 3-60). Due to its large size and relatively small littoral zone, wind and wave action is likely to contribute to increased sediment suspension in this lake.

Stormwater is conveyed to this waterbody from a 1,981 acre drainage basin—of which the lake makes up the majority (Figure 3-61). The terrestrial areas of the basin are comprised mostly of residential land uses, with some agricultural in small quantities. These land uses contribute up to 3,875 lbs of TN and 665 lbs of TP to the lake annually. There are 186 septic systems within this basin—mostly congregated in the north and



Figure 3-61. Map of Lake Eloise's drainage basin and nearby septic systems.

south areas of the basin. There exist few City-owned roadways with stormwater infrastructure that drain to the lake. As a result, the City does not conduct street sweeping services in this basin.

Lake Eloise is part of the South Chain of Lakes with navigable connections to Lakes Lulu, Summit, and Winterset. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-62). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Eloise's surface level do not correlate with water quality.

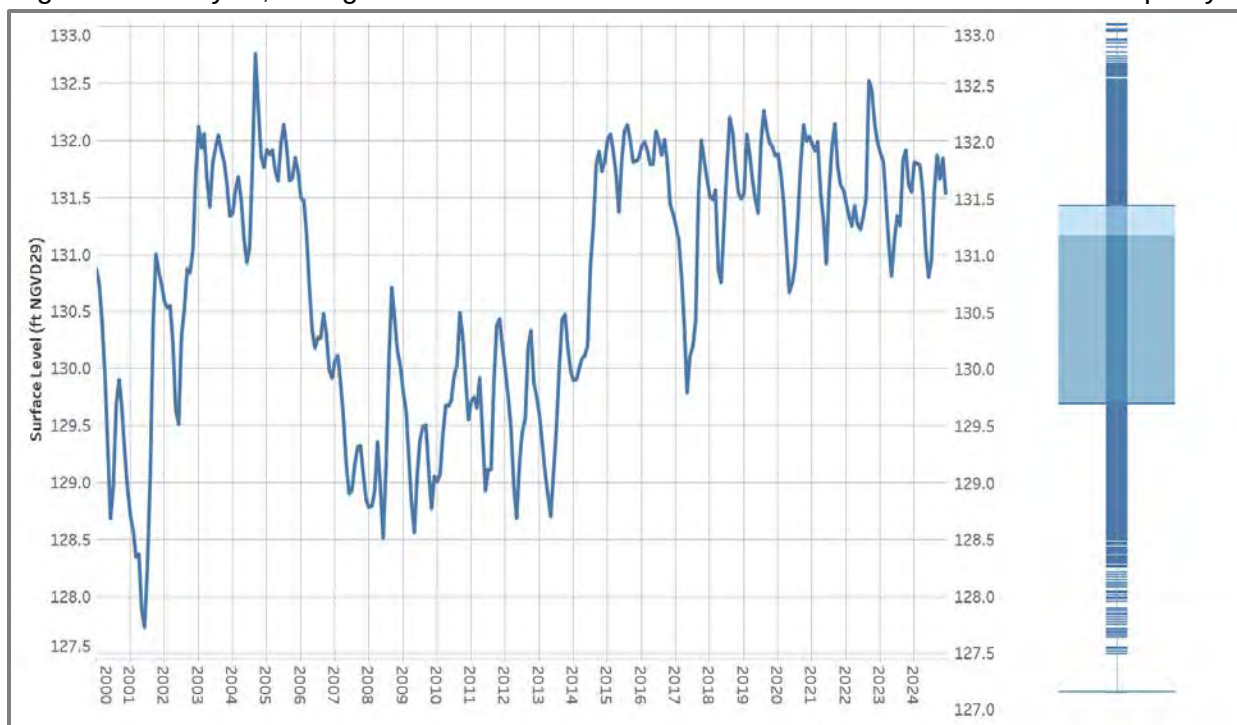


Figure 3-62. Hydrograph of the South Chain of Lakes depicting monthly surface level readings from 2000 to 2024. A box & whisker plot details the total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Eloise is categorized as a clear, alkaline waterbody. Based on NNC exceedances most years during the assessment period, Lake Eloise is considered impaired for Chl-a, TN, and TP—earning it an impairment criterion score of 0 (Figure 3-63). In 2019, the FDEP established a total maximum daily load (TMDL) for Lake Eloise stipulating a 39% reduction in TN in order to meet NNC guidelines.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the trend data, Chl-a and TP exhibited significant improving trends. Total nitrogen and Secchi depth exhibit non-significant improving

trends. The downgrade from significant to non-significant Secchi depth trend in 2024 marks a slight shift in the clarity trend and is something to monitor further for any future changes in water quality.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.470	0.031	Decreasing	0	3
TN	Y	-0.287	0.208	No Trend		2
TP	Y	-0.513	0.017	Decreasing		3
Secchi	NA	0.339	0.132	No Trend		2



Figure 3-63. Lake Eloise AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative abundance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Eloise on 11/25/2024. The PAC during this survey was 18.2% and the total BV was 2.6% (Figure 3-64). A comparison of abundance metrics from previous years shows a surge in coverage to 36% in 2020 and then a general fluctuation within the 15%-20% range. The coverage in 2024 was slightly greater than that in 2023.

Invasive Species Management:

Based on 2024 species data, the native eelgrass was the most dominant species at 20% of the community (Figure 3-65). The remaining plants were comprised of a good mix of submerged and emergent species. The only managed invasive species was hydrilla at less than 1%—earning Lake Eloise an invasive presence score of 2. Hydrilla has historically been a very minor issue and is considered controlled in Lake Eloise.

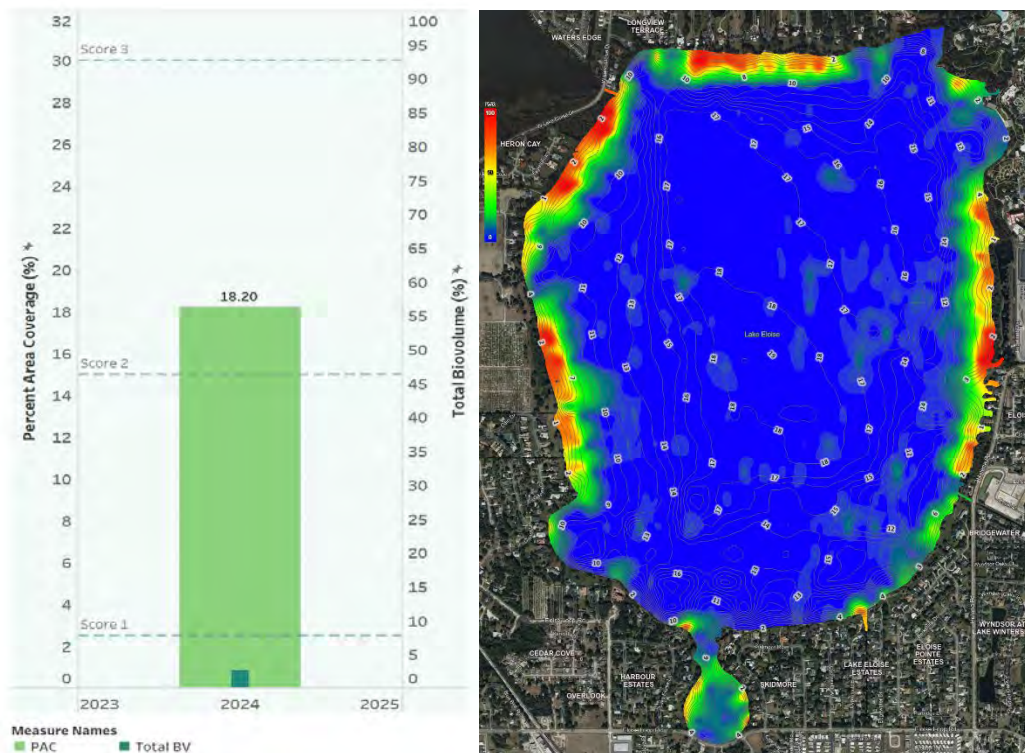


Figure 3-64. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Eloise; biovolume values range from green (lowest) to red (highest).

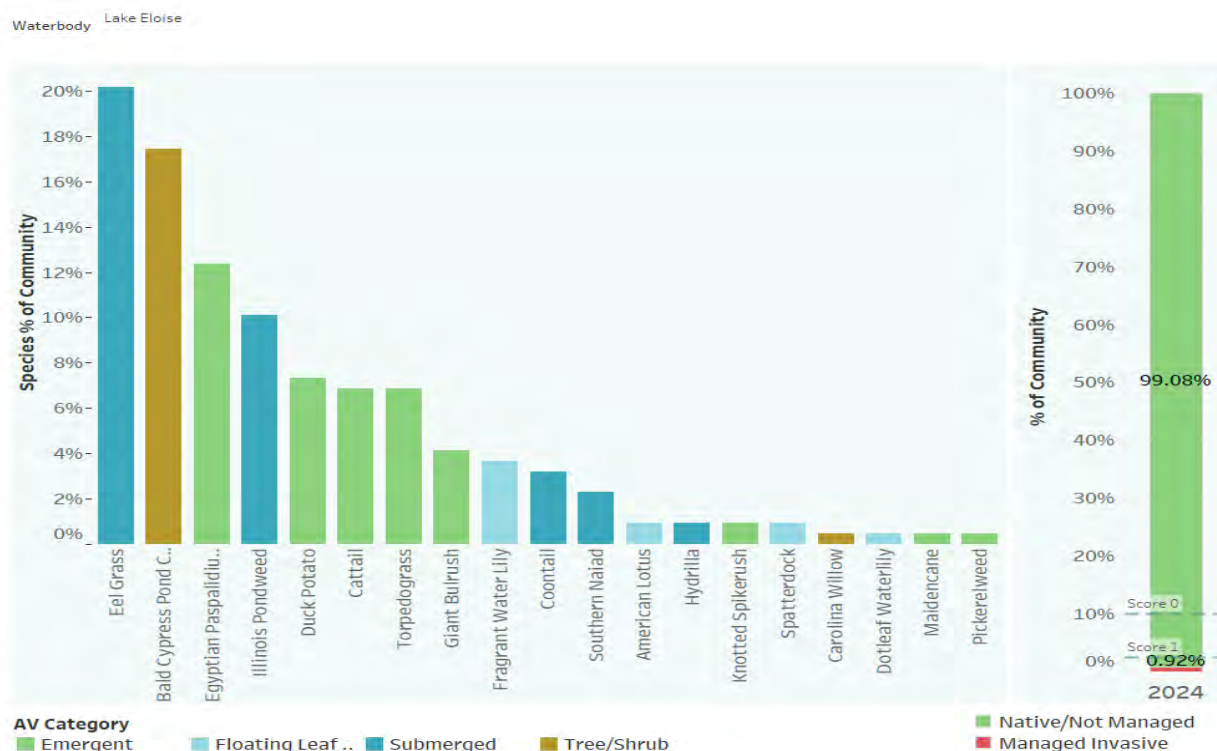


Figure 3-65. Chart depicting species frequency and invasive species percentage of Lake Eloise during 2024.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, richness was the only index that met or exceeded its median value—earning Lake Eloise a diversity criterion score of 1 (Figure 3-66). This is the second straight year that species evenness and overall diversity were below the lake’s median. However, these changes are likely natural fluctuations in community dynamics. It should be noted that Lake Eloise’s species diversity is not greatly impacted by active management efforts due to a lack of invasive species presence. The vegetation community in this lake largely self-regulates.

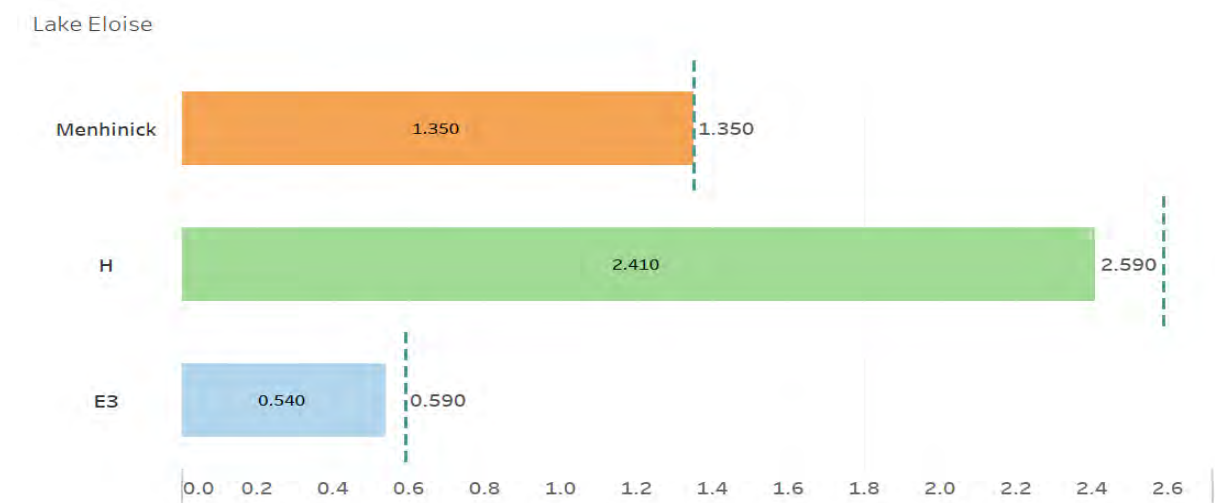


Figure 3-66. Chart depicting 2024 diversity indices for Lake Eloise. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Eloise’s health index scores from 2018 to 2024 shows relative consistency (Figure 2-67). Since the City began documenting lake health, most of the changes to Lake Eloise’s scores have come from the biological criteria. As stated previously, invasive species have not been a large component of the vegetation community and the vegetation community typically fluctuates naturally with minor management input. While the lake has remained impaired, the trends are showing gradual improvement in all water quality metrics.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	2	2	3	1	2	2	1.8
2019	0	2	2	2	3	2	2	2	1.9
2020	0	2	2	2	3	3	2	1	1.9
2021	0	2	2	2	3	2	2	2	1.9
2022	0	2	2	2	3	2	2	1	1.8
2023	0	3	2	3	3	2	2	1	2.0
2024	0	3	2	3	2	2	2	1	1.9

Figure 3-67. Chart depicting a comparison of Lake Eloise’s Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- In addition to the stormwater pollutant loads, Lake Eloise has had historic point source loading from the Cypress Gardens Wastewater Treatment Plant as late as 1975. There is potential for these legacy nutrients to be embedded in the lake sediments.
- While invasive species like hydrilla are generally in check, it can only take a single season for even a small population to take over large areas of a waterbody.
- The presence of OSTDs (septic) systems in the drainage basin could have potential impacts if they are leaching into the water table. Though with the lake being phosphorus-limited, the nitrogen leaching from septic systems are less of a concern.

Lake Management Strategy:

- With the majority of the drainage basin comprised of residential housing, public education and outreach is a viable strategy for mitigating stormwater pollutant loading. Staff have worked with individual communities and homeowner's associations within the basin to suggest the use of green infrastructure in their private stormwater systems.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- The City may explore source analysis to determine if septic systems in the drainage basin may be contributing nutrient loads to Lake Eloise. Further management may involve septic-to-sewer conversions in areas where the City provides sewer service.

Lake Fannie

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Fannie	3	3	3	2	2	2	0	3	2.3

Features & Statistics:

Surface area	800.3 acres
Mean depth	7.6 feet
Maximum depth	10.75 feet
Volume	5828.2 acre-feet
Drainage basin area	2208.8 acres
Annual TN Load	4133.2 lbs
Annual TP Load	717.7 lbs
Limiting nutrient	Co-limited (N & P)

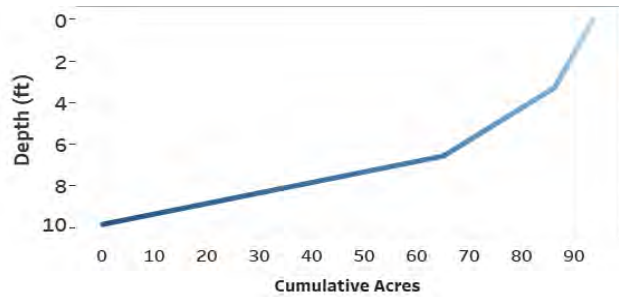


Figure 3-68. Hypsograph of Lake Fannie depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Fannie is a large, but shallow waterbody at 800 acres, with an average depth of 7.6 feet, and a maximum depth of only 10.75 feet (Figure 3-68). This makes it highly susceptible to sediment suspension via wind and wave action. Stormwater is conveyed to this waterbody from a 5,800 acre, mostly rural drainage basin (Figure 3-69). Though, the previously agricultural land uses are shifting more toward residential. These land uses contribute 4,133 lbs of TN and 717 lbs of TP to the lake annually. By area, however, these loads rank 35th compared to the other lakes in the region. There are 33 septic systems within this drainage basin. However, due to their low density, this isn't a major concern from a pollutant loading standpoint. There is also very little stormwater infrastructure present within the drainage basin—likely contributing to its relatively low pollutant loads.



Figure 3-69. Map of Lake Fannie's drainage basin, City street sweeping services, and nearby septic systems.

Hydrology:

Lake Fannie is located within the North Chain of Lakes, but sits at a different elevation compared to its neighbors—Lake Smart, to the west; and Lake Hamilton to the east. Over its period of record, Lake Fannie's surface level has fluctuated between 119.8 and 128 feet above sea level. The normal range is between 121.4 and 125.1 feet (Figure 3-70). Though, since 2014, the amount of annual fluctuation has stabilized toward the high end of the normal range. During 2024, Lake Fannie reached a dry season low of 124.4 feet in June and a wet season peak of 125.4 feet in November. At the end of 2024, the surface level was 125.05 feet; right at the high range of levels. With District managed control structures on its upstream and downstream flow pathways, Lake Fannie's level is managed quite closely. Often levels are maintained at or near recommended highs until water must be released ahead of intense storms. According to 2019 regression analyses, changes in Lake Fannie's surface level significantly correlate with Chl-a, TN, TP, and clarity such that higher levels should result in improved water quality.

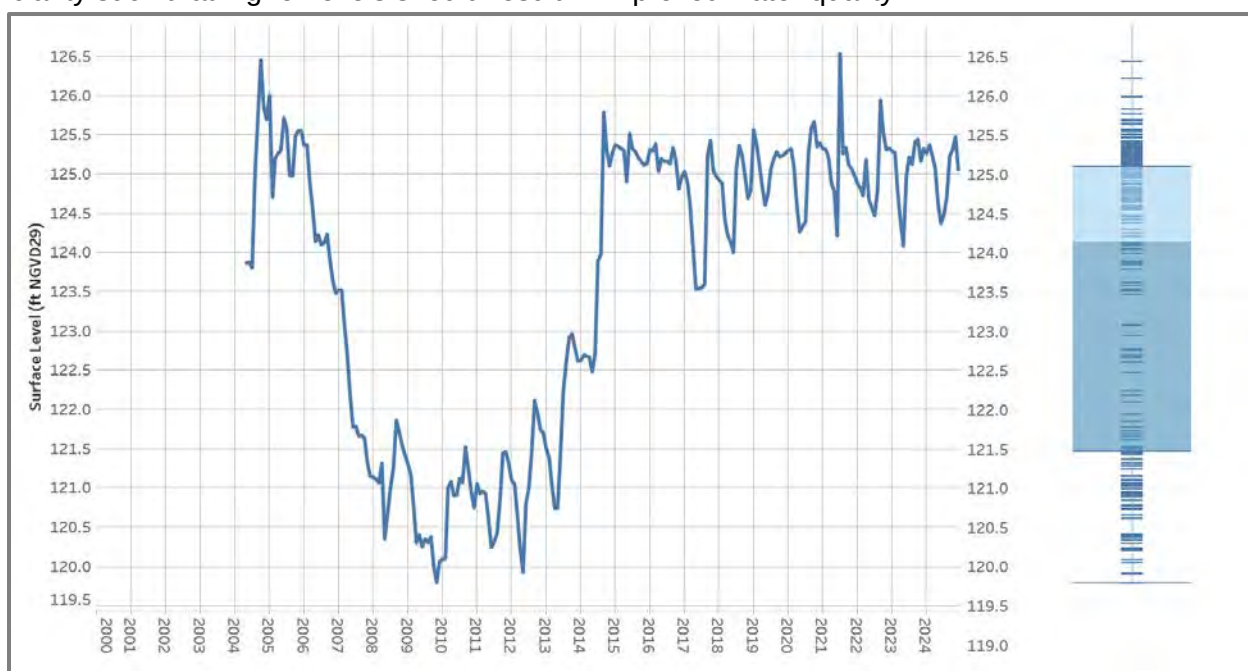


Figure 3-70. Hydrograph of Lake Fannie depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Fannie is categorized as a high color waterbody. Due to a lack of NNC exceedances in Chl-a, TN, and TP during the assessment period, Lake Fannie is considered unimpaired (Figure 3-71). The last exceedances recorded were in 2011; as a result, Lake Fannie has received an impairment criterion score of 3 since 2019.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.644	0.002	Decreasing	3	3
TN	N	-0.465	0.034	Decreasing		3
TP	N	-0.301	0.186	No Trend		2
Secchi	NA	0.416	0.061	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the water quality data, Chl-a and TN exhibited significant improving trends—earning a trend criterion score of 3. The non-significant trends for TP and Secchi depth receive trend criteria scores of 2. This was a departure from the previous year when Chl-a and Secchi depth were the significant improving trends. That said, trends can change due to abnormal values experienced from year to year. Overall, Lake Fannie appears to be mostly trending in an improving direction.

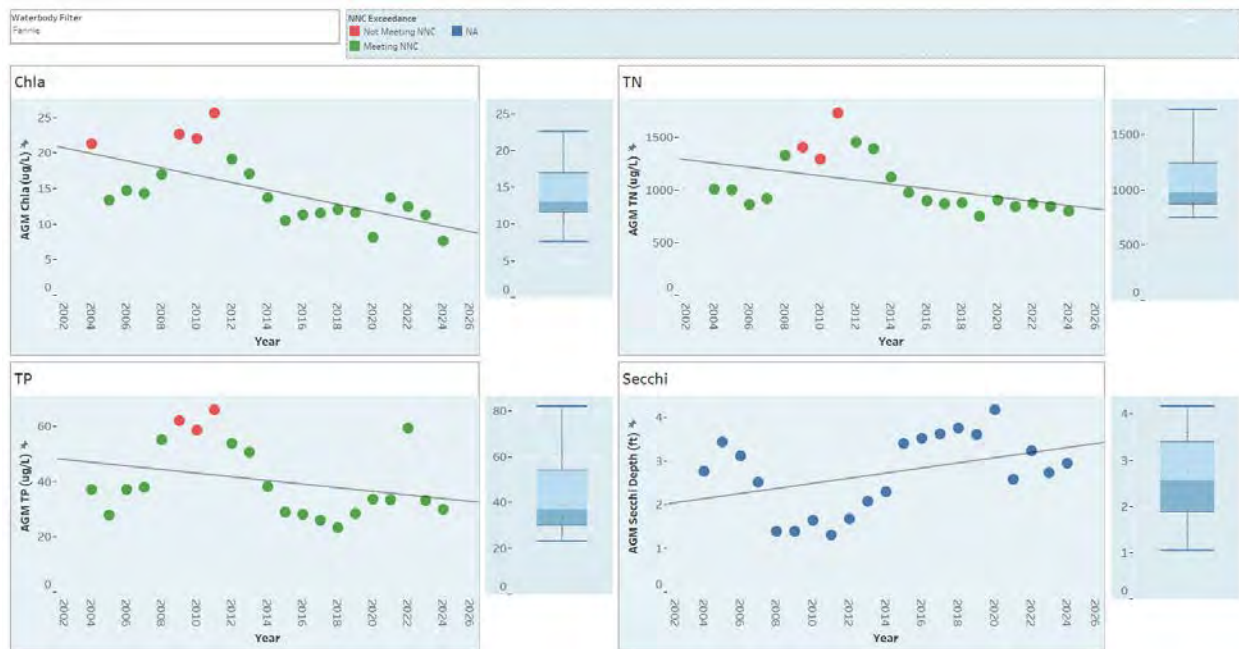


Figure 3-71. Lake Fannie AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Fannie on 10/31/2024. The PAC during this survey was 23.1% and the total BV was recorded at 4.2% (Figure 3-72). This was a slight increase in coverage from the previous year, but still earns a criterion rank of 2. This gradual increase in vegetation abundance is a good thing for a lake that generally lacks SAV due to the highly colored water.

Invasive Species Management:

Based on the data, the most dominant plant types in 2024 were emergent species, with SAV making up about 16% of the total community (Figure 3-73). Over the last five years, submerged species have increased in abundance; likely a result of gradually improving water clarity. Invasive species like burhead sedge and water hyacinth made up nearly 12% of the population. This places the invasive presence criterion score at 0. That said, this was a slight decrease in invasive presence from the previous year. It is a good sign when an increase in total vegetation abundance coincides with a decline in invasive abundance—meaning that native plants are filling the niches left open through management of non-native plants.

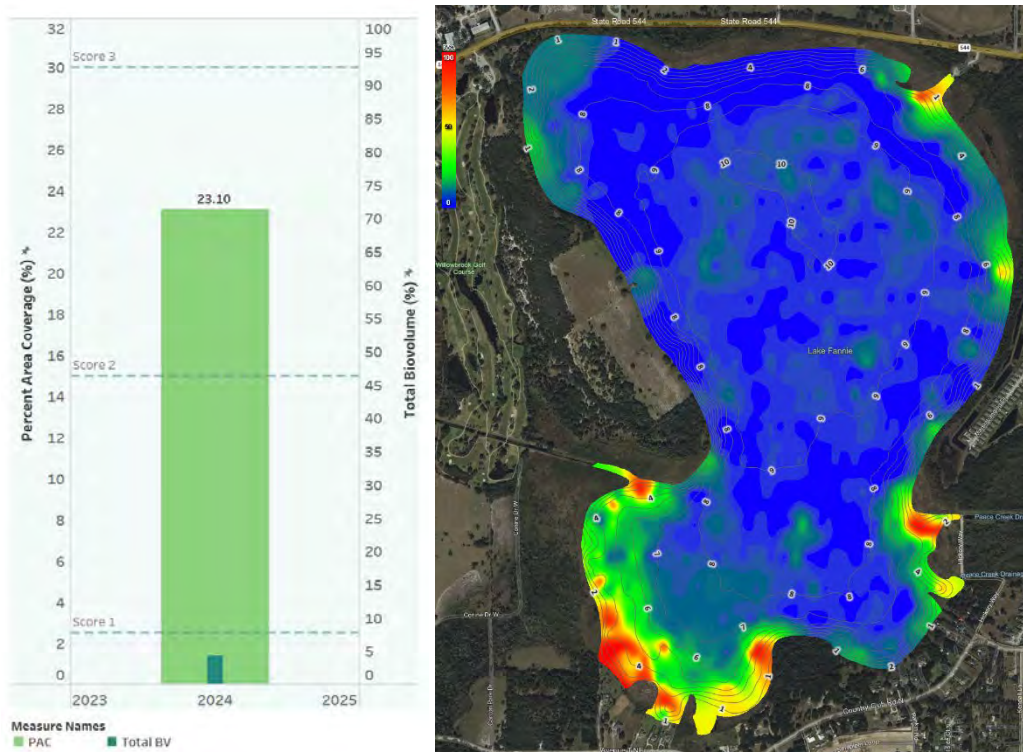


Figure 3-72. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Fannie; biovolume values range from green (lowest) to red (highest).

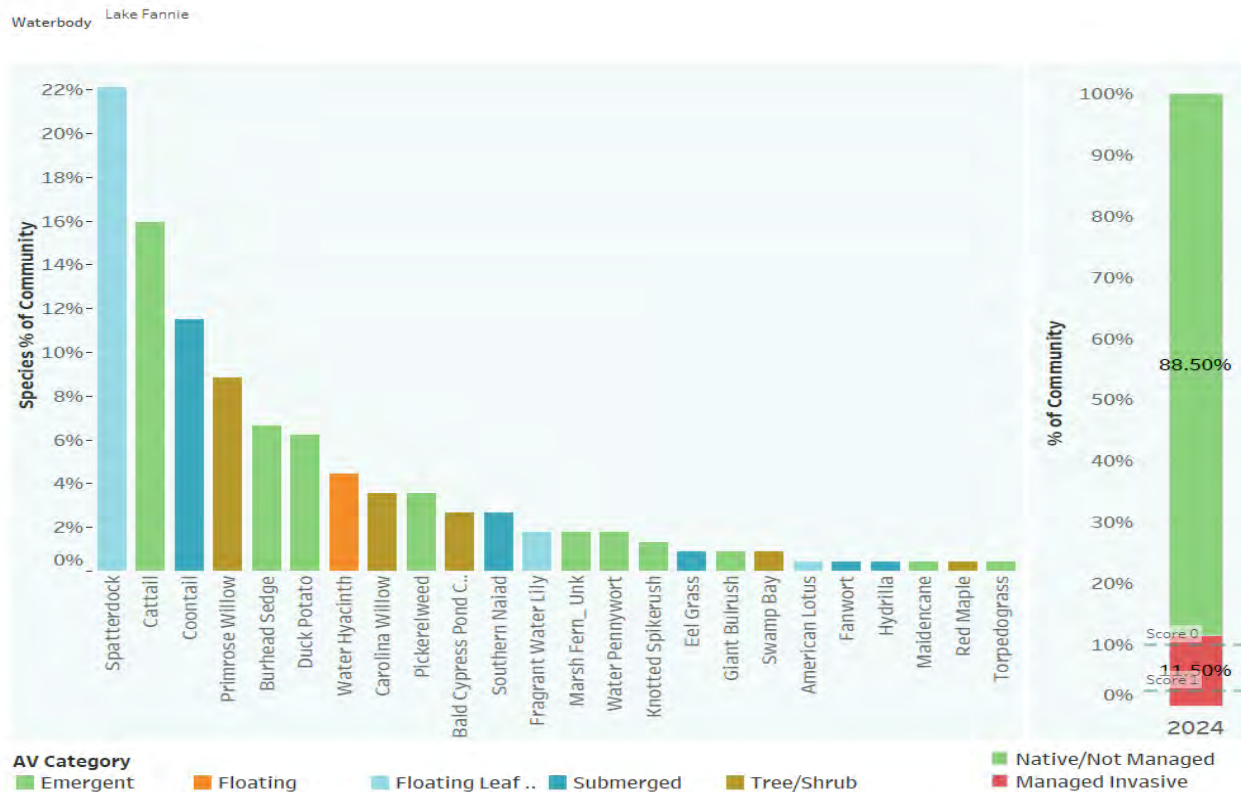


Figure 3-73. Chart depicting species frequency and invasive species percentage of Lake Fannie during 2024.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Lake Fannie's diversity indices exceeded their respective long-term medians—resulting in a diversity criterion score of 3 (Figure 3-74). This is likely due to the increased prevalence of less abundant species now that the large stands of burhead sedge and hydrilla have been treated. It should be noted that this is a second year running in which all three diversity indices exceeded their median values. Continued management of invasives should hopefully allow other native species to fill the newly opened ecological niches and improve the overall community in the long term.

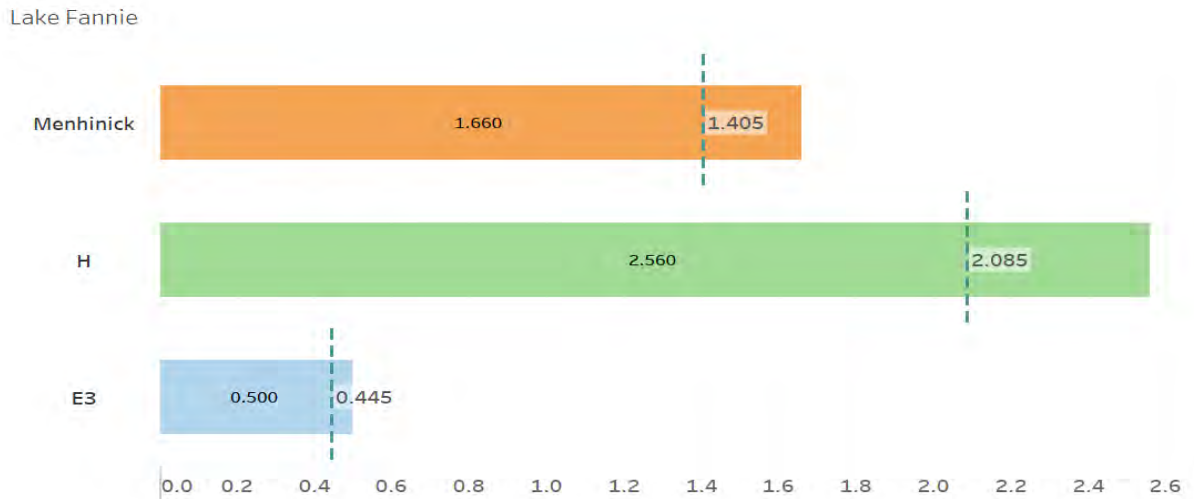


Figure 3-74. Chart depicting 2024 diversity indices for Lake Fannie. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Fannie's health index scores from 2018 to 2024 shows a significant improvement since monitoring began (Figure 3-75). The large jump in 2019 was due to water quality meeting NNC guidelines, while subsequent improvements are mostly due to positive shifts in the trend directions and significance. Despite invasive presence consistently underperforming, the recent downward trend in non-native abundance should eventually lead to improvements in that score. Species diversity has been consistently better since 2020—another positive improvement in lake health. Overall, Lake Fannie is doing substantially better than it was seven years ago.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	2	2	2	0	2	1.3
2019	3	2	2	2	3	2	0	1	1.9
2020	3	2	2	2	3	1	0	1	1.8
2021	3	2	2	2	3	2	0	2	2.0
2022	3	2	2	2	3	2	0	3	2.1
2023	3	3	2	2	3	2	0	3	2.3
2024	3	3	3	2	2	2	0	3	2.3

Figure 3-75. Chart depicting a comparison of Lake Fannie's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- While the majority of the drainage basin is undeveloped, new housing in the area carries potential for added stormwater pollutant loading. Fortunately, the majority of these newer developments are required to include stormwater treatment in their site plans.
- The management of invasive species like hydrilla and burhead sedge is a constant concern. Management that foregoes large-scale herbicide treatments is advised in order to prevent water quality decline.
- Lake Fannie's water quality metrics are significantly correlated with its surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in further water quality decline.

Lake Management Strategy:

- As the Lake Fannie drainage basin continues to develop into residential land uses, public education efforts aimed at improving residents' knowledge of proper stormwater management practices can help to ensure water quality continues to trend in a positive direction.
- Street sweeping services run within the small portion of the drainage basin that lies within City limits.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to correlation between surface level and water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Haines

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Haines	0	3	3	1	2	1	3	2	1.9

Features & Statistics:

Surface area	687.5 acres
Mean depth	9.6 feet
Maximum depth	15.5 feet
Volume	7380.9 acre-feet
Drainage basin area	2317.8 acres
Annual TN Load	5701 lbs
Annual TP Load	1055.9 lbs
Limiting nutrient	Co-limited (N & P)

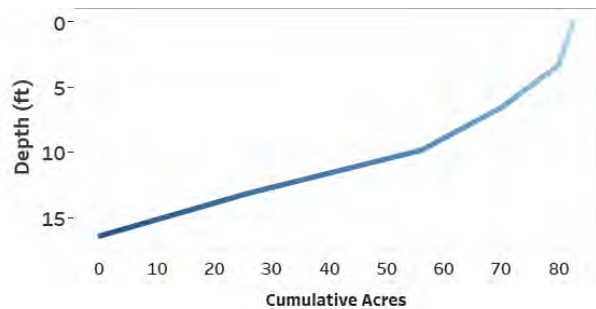


Figure 3-76. Hypsograph of Lake Haines depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Haines is one of the larger waterbodies in the region at nearly 700 acres in area. With a mean depth of 9.6 feet, Haines is somewhat deeper than other lakes in the North Chain, but is only slightly above the regional average depth of 8.5 feet (Figure 3-76). Like many other large and relatively shallow waterbodies, Lake Haines is more susceptible to sediment suspension via wind and wave action. Stormwater is conveyed to this waterbody from a massive and mostly rural drainage basin with a total area of 2,317 acres (Figure 3-77). The majority of the basin is comprised of wetland and agricultural land uses. This basin contributes 5,701 lbs of TN and 1,055 lbs of TP to the lake annually. However, on a per acre basis, these loads rank relatively low compared with other drainage basins in the area. There are 14 septic systems within the basin which is not at a density to cause potential harm via leaching to the water table.

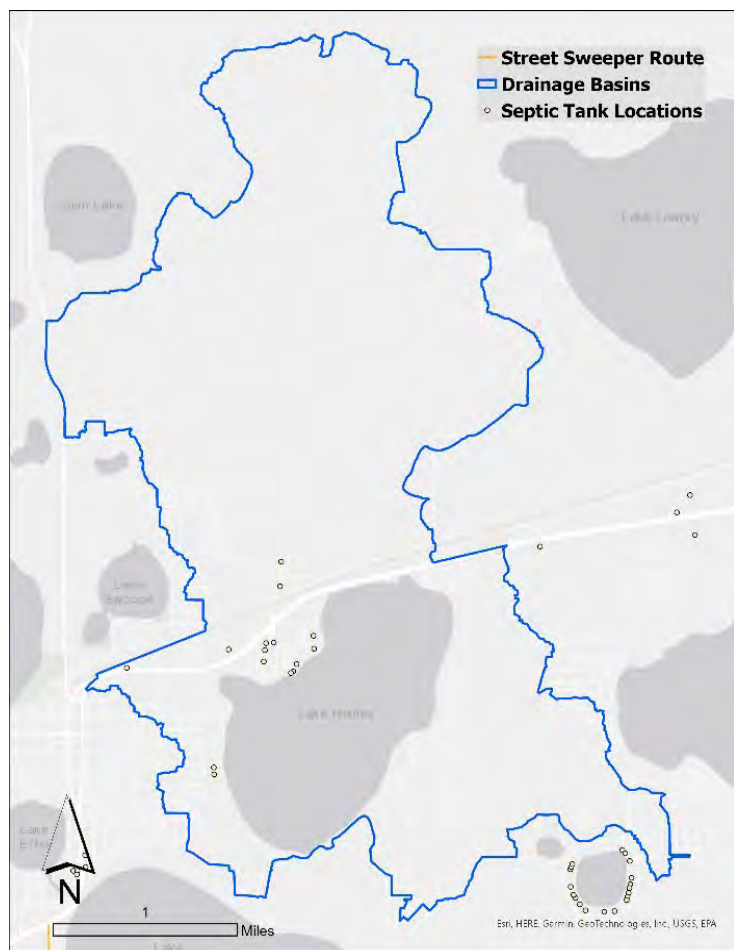


Figure 3-77. Map of Lake Haines' drainage basin and nearby septic systems.

As part of the Northern Chain, Lake Haines is connected via navigable canal to Lake Rochelle. Excess water from the North Chain eventually drains via the SWFWMD-managed P-8 control structure at the south of Lake Hamilton and enters the Peace Creek. Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-78). During 2024, the North Chain reached a dry season low of 127.8 feet in June and a wet season peak of 130.3 feet in October. The October peak was a record high for this chain of lakes; exceeding the previous record experienced during the triple hurricane season of 2004. The surface level ended the year above the high end of the normal range, at 128.5 feet. Changes in Lake Haines' surface level are directly correlated with water clarity and indirectly correlated with TN (see appendix). It is likely that the abundance of wetlands surrounding Lake Haines contributes to these relationships as higher surface levels would increase wetland inundation and the benefits they provide. This carries management implications as maintaining a higher surface level should result in improvements in these metrics.

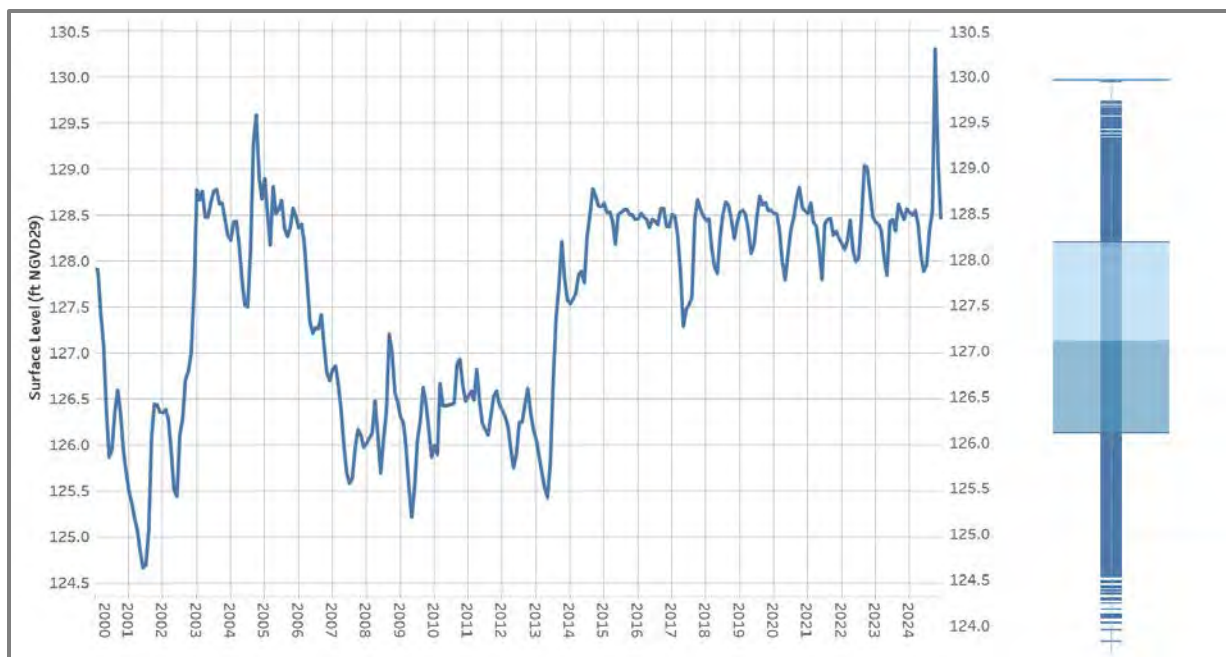


Figure 3-78. Hydrograph of Lake Haines depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairments based on the Numeric Nutrient Criteria (NNC), Lake Haines is categorized as a high-color waterbody. Based on multiple NNC exceedances during the assessment period, Lake Haines is considered impaired for Chl-a, TN, and TP—equating to an impairment score of 0 (Figure 2-79). While TN was not previously impaired since 2015, consecutive exceedances of the NNC threshold the last two years resulted in it becoming impaired in 2024. In 2018, the FDEP established a total maximum daily load (TMDL) for Lake Haines stipulating a 33% reduction in TN to achieve NNC guidelines.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the water quality data, Lake Haines exhibits

significant improving trends in Chl-a and TN—earning trend criteria scores of 3. Non-significant trends for TP and Secchi depth were observed, but TP was moving in an upward direction due to high concentrations in recent years.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.583	0.006	Decreasing	0	3
TN	Y	-0.450	0.041	Decreasing		3
TP	Y	0.322	0.154	No Trend		1
Secchi	NA	0.314	0.166	No Trend		2



Figure 3-79. Lake Haines' AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Haines on 11/8/2024. The PAC during this survey was 12.1% and the total BV was 4.1% (Figure 3-80). This marks a considerable decrease in coverage from the previous year, but it is still higher than it was in 2021 and 2022. These abrupt changes in coverage are likely due to efforts in controlling invasive weeds like hydrilla. The result of the 2024 coverage value is that Lake Haines receives a vegetation abundance score of 1.

Invasive Species Management:

Based on 2024 species data, emergent vegetation remains the most dominant vegetation type in Lake Haines. Fortunately, no invasive plants were detected in 2024 (Figure 3-81). In previous years, invasive plants like hydrilla were abundant. Despite the decrease in overall abundance, the return of SAV and elimination of managed invasives demonstrates marked restoration in the aquatic plant community. That said, continued monitoring is critical to detect the future return of invasive plants and to plan for management action before populations can expand to extremes.

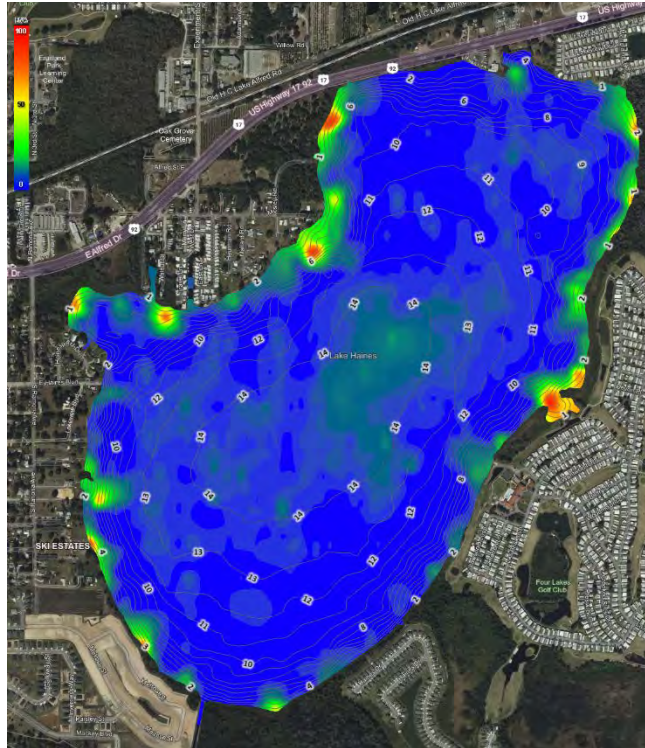
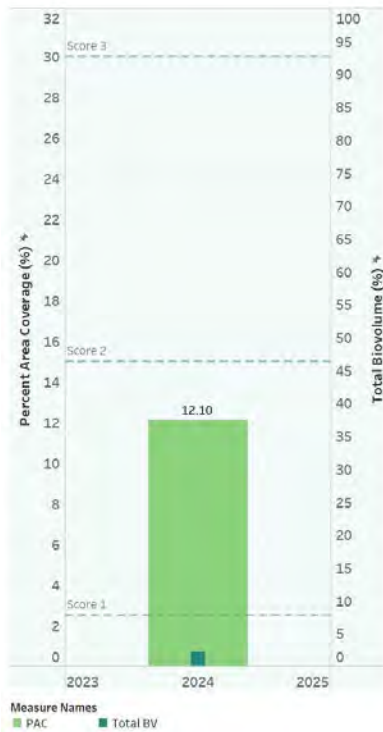


Figure 3-80. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Haines; biovolume values range from green (lowest) to red (highest).

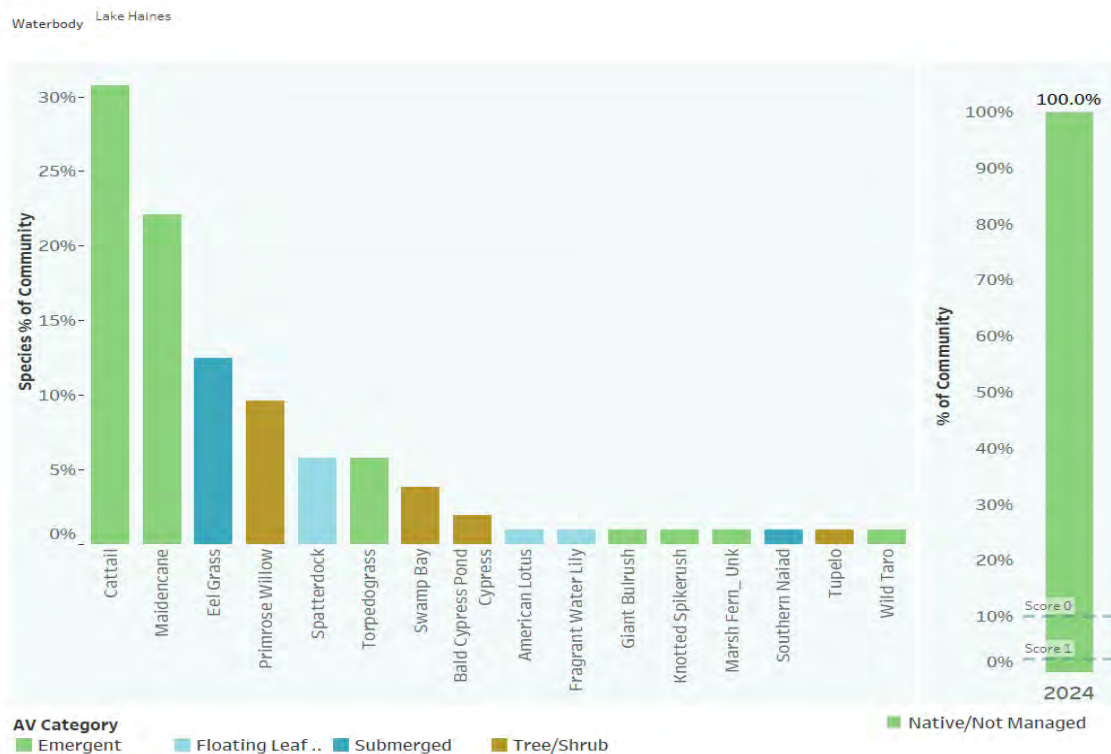


Figure 3-81. Chart depicting species frequency and invasive species percentage of Lake Haines during 2024.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, the species richness and overall diversity indices exceeded their respective median values (Figure 3-82). This equates to a diversity score of 2. The return of submerged species led to increases in the total number of species detected, but with the dominance of a few plant species, it is no surprise that evenness was below the long-term median. It is fortunate that invasive management efforts had a positive impact on the diversity in Lake Haines.

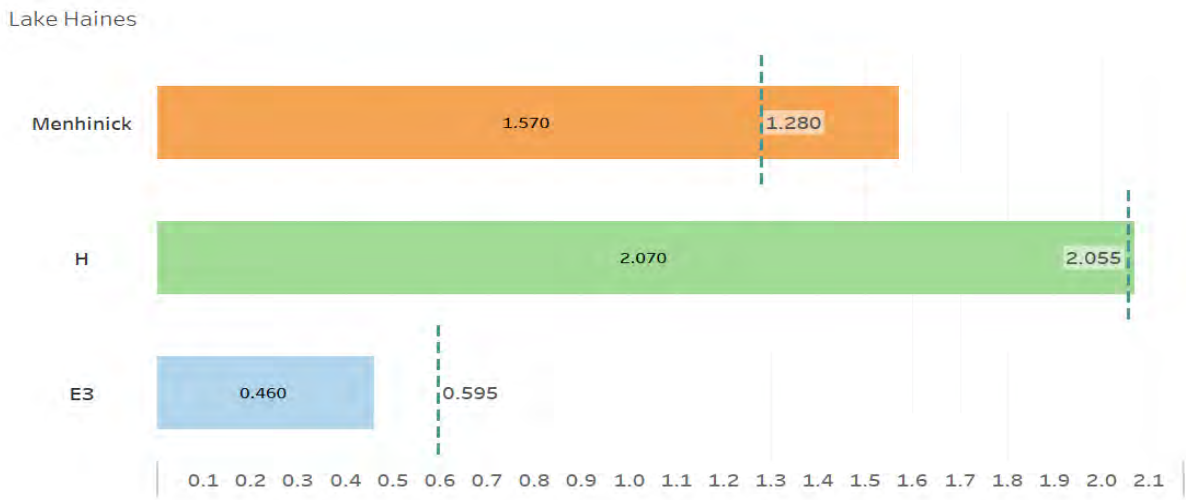


Figure 3-82. Chart depicting 2024 diversity indices for Lake Haines. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Haines' health index scores from 2018 to 2024 shows some variability over time (Figure 3-83). Despite meeting impairment targets in previous years, recent shifts in water quality have resulted in full impairment. Water quality trends are also variable, with improvement in Chl-a, but recent declines in TP and clarity. Vegetation abundance and diversity have fluctuated wildly, most likely due to repeated invasive treatment efforts. The one criterion demonstrating sole improvement has been invasive presence which has reached its highest score in 2024. Now that invasive plants have been reduced to undetectable levels, it will be important to monitor this lake closely to prevent rapid expansions when these plants inevitably return.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	3	2	3	2	0	1	1.6
2019	1	2	3	2	3	2	0	2	1.9
2020	2	2	3	2	3	3	0	2	2.1
2021	1	2	3	1	3	1	1	2	1.8
2022	1	2	3	1	3	1	1	1	1.6
2023	1	3	3	1	3	3	1	0	1.9
2024	0	3	3	1	2	1	3	2	1.9

Figure 3-83. Chart depicting a comparison of Lake Haines' Lake Health Index scores from 2018 to 2023.

Lake Health Impacts/Challenges:

- Due to the low density of urban development in the drainage basin, the per acre stormwater pollutant loading is relatively low. That said Lake Haines may possess some legacy nutrients from historic point-source loading via the Lake Alfred Wastewater Treatment Facility.
- The correlation between surface level and water quality is likely due in part to Lake Haines' morphology. As a large, shallow waterbody, it is more susceptible to sediment suspension from wind and wave action. This is exacerbated when lake levels are lower. The presence of large swathes of wetlands surrounding this lake also provide additional benefits when the lake level is higher.
- The management of invasive species like hydrilla is a constant concern. Even though it was not detected, these plants are never truly eradicated; it is expected they will return. Large-scale herbicide treatments may also impact both native vegetation and water quality.

Lake Management Strategy:

- Due to correlations between surface level and water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Additionally, staff will advocate for invasive management actions that limit the large-scale use of herbicides. Grass carp have been utilized in the Northern Chain to supplement herbicide treatments and to reduce the amount of chemicals needed to manage invasives in these lakes.
- Staff can support Polk County and the City of Lake Alfred in efforts to mitigate pollutant loading either through source analysis or guidance on the use of green infrastructure within the drainage basin.

Lake Hamilton

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Hamilton	0	0	0	3	0	2	1	3	1.1

Features & Statistics:

Surface area	2168.7 acres
Mean depth	6.39 feet
Maximum depth	17 feet
Volume	13,662.9 acre-feet
Drainage basin area	4177.6 acres
Annual TN Load	6701.7 lbs
Annual TP Load	1167.8 lbs
Limiting nutrient	Phosphorus

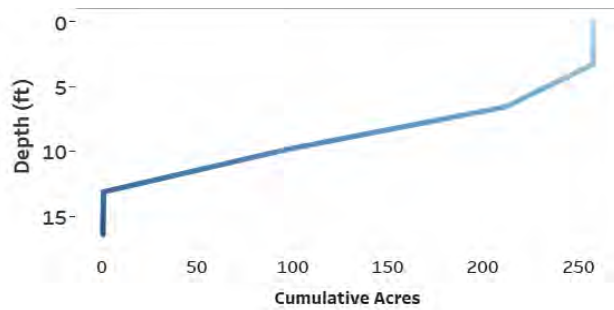


Figure 3-84. Hypsograph of Lake Hamilton depicting the depth profile and morphology of the lake bed.

Hydrology:

At 2,168 acres, Lake Hamilton is the largest lake within the study area. That said, it is one of the shallower waterbodies, with an average depth of just over 6 feet and a maximum depth of 17 feet (Figure 3-84). This makes it extremely susceptible to sediment suspension in windy conditions. Stormwater is conveyed to this waterbody from a 4,177 acre drainage basin comprised primarily of residential and wetland land uses which contributes 6,701 lbs of TN and 1,167 lbs of TP to the lake annually. On a per acre basis, these loading rates are some of the lowest in the study area. There are approximately 62 septic systems within this drainage basin—a relatively low density for its size. Lacking City roads and stormwater infrastructure conveying runoff to the lake, Winter Haven does not conduct any street sweeping services within this basin nor are there many stormwater improvements to be made.

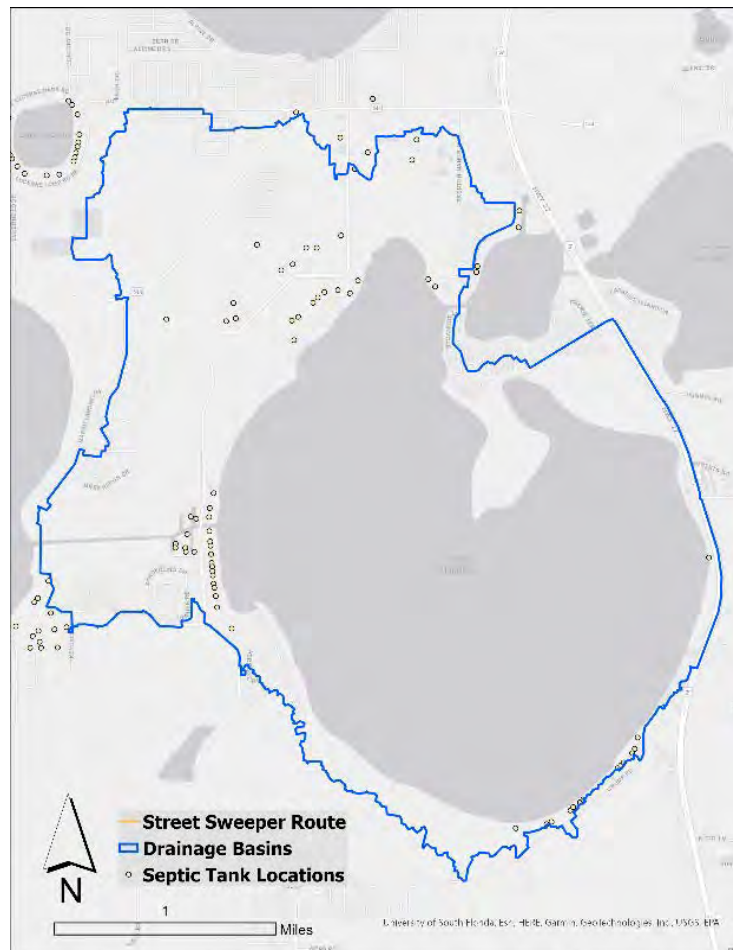


Figure 3-85. Map of Lake Hamilton's drainage basin and nearby septic systems.

Lake Hamilton is part of the North Chain of Lakes and receives excess water from Lake Fannie and Lake Henry—discharging its own excess water to the Peace Creek. Hamilton actually sits at the lowest level of all lakes within the study area. Over its period of record, Lake Hamilton's surface level has fluctuated between 117.5 and 123.6 feet above sea level. The normal range of fluctuation is between 119 and 121 feet (Figure 3-86). In 2017, the SWFWMD enacted new water level management protocols with the intent to restore seasonal level fluctuations within the lake's normal range. This is accomplished by releasing water downstream during the rainy season and storing water during the dry season. During 2024, Lake Hamilton reached a low of 120.26 feet in July and a wet season peak of 121.86 feet in October. The peak actually marks the highest the lake has reached since the record-breaking rainfall received during the hurricane season of 2004. Changes in Lake Hamilton's surface level are not correlated with Chl-a, TN, TP, or clarity (see appendix).

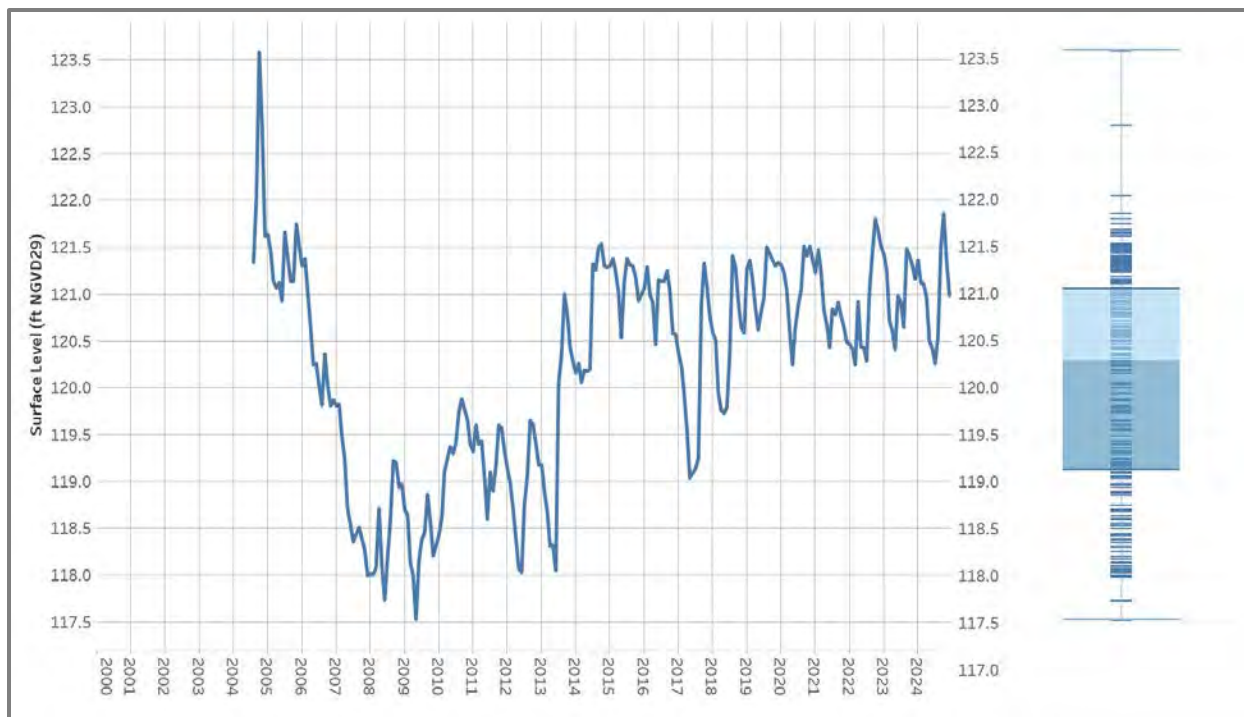


Figure 3-86. Hydrograph of Lake Hamilton depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Hamilton is categorized as a clear, alkaline waterbody. Based on multiple consecutive NNC exceedances during the assessment period, Lake Hamilton is considered impaired for Chl-a, TN, and TP (Figure 3-87). This equates to an impairment criterion score of 0. While the FDEP began developing a total maximum daily load (TMDL) for Lake Hamilton in 2020, the City and Polk County have introduced a pollutant reduction plan to address the water quality issues. This plan has been accepted by the FDEP.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Chl-a, TN, and Secchi depth each exhibit significant deteriorating trends—earning trend criteria scores of 0. Surprisingly, TP exhibits a

significant improving trend, for a criterion score of 3. These trends are indicative of a cycle of nitrogen-fixing cyanobacteria blooms occurring in Lake Hamilton—increasing Chl-a and TN concentrations while decreasing TP and clarity. Further study is needed to assess other potential drivers of these trends.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	0.839	0.000	Increasing	0	0
TN	Y	0.817	0.000	Increasing		0
TP	Y	-0.800	0.000	Decreasing		3
Secchi	NA	-0.609	0.003	Decreasing		0

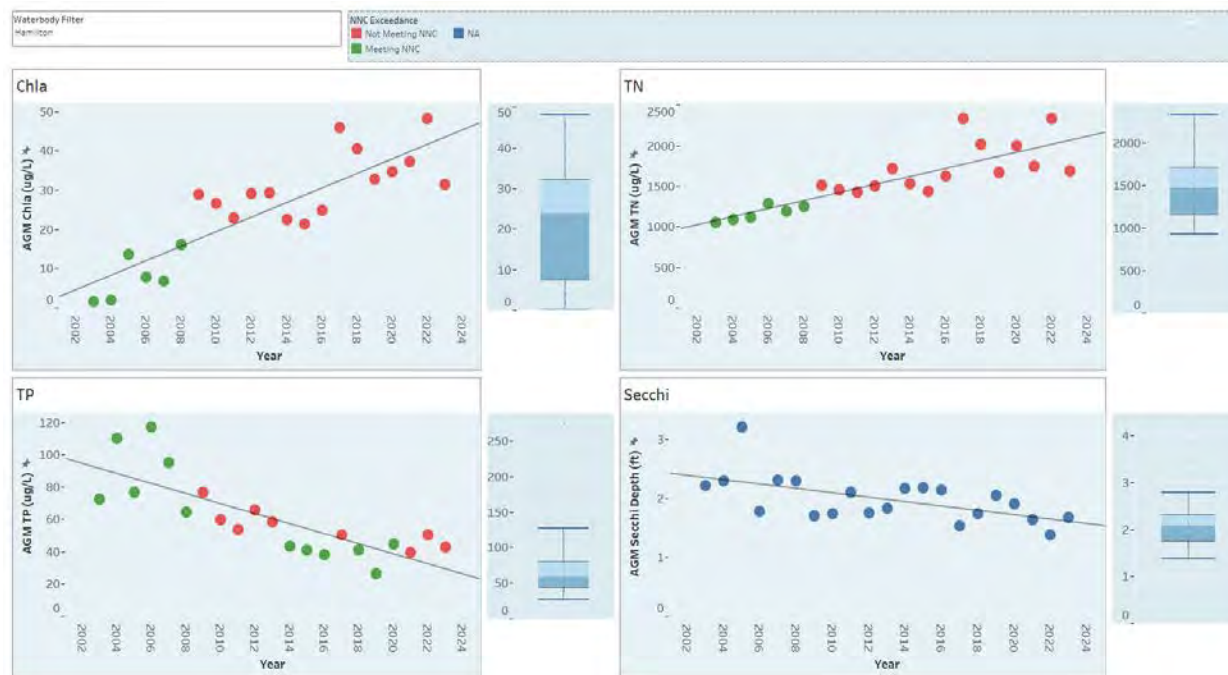


Figure 3-87. Lake Hamilton AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

Due to delays, an aquatic vegetation survey was conducted for Lake Hamilton on 1/10/2025. The PAC during this survey was 15.8% and the total BV was recorded at 2.1%; a slight increase from the previous year equating to a score of 2 (Figure 3-88). A comparison of data from previous years shows a slight, but consistent increase in coverage from 7.7% in 2018 to the current percentage. Based on Lake Hamilton's morphology and water clarity, this amount of coverage is expected.

Invasive Species Management:

Based on 2024 species data, the dominant plant type in the lake was emergent, with giant bulrush and cattail comprising over 30% of the community (Figure 3-89). Submerged plants made up less than 15% of the community. Invasive floating invasive plants (water hyacinth & water lettuce) comprised 5.7% of the community. This invasive percentage changed very little from the previous survey.

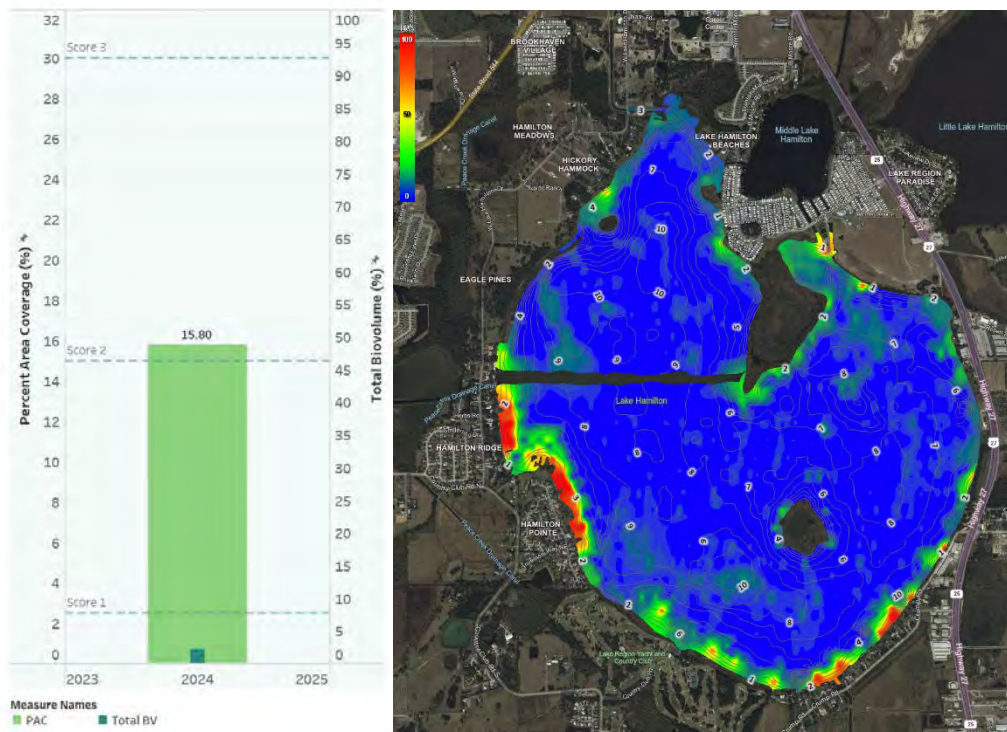


Figure 3-88. Graph depicting 2024 PAC/BV and biovolume of Lake Hamilton; biovolume values range from green (lowest) to red (highest).

Waterbody Lake Hamilton

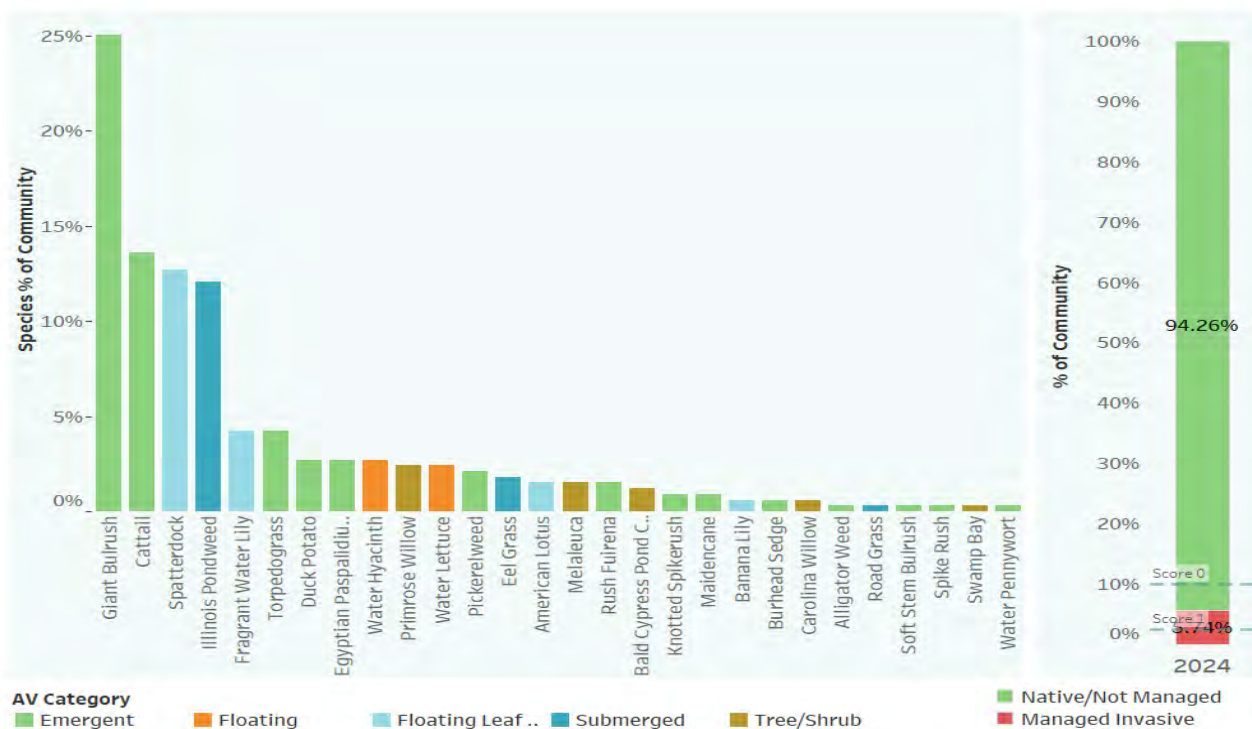


Figure 3-89. Chart depicting species frequency and invasive species percentage of Lake Hamilton during 2024.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Lake Hamilton's diversity indices exceeded their respective median values (Figure 3-90). This marks the second consecutive year exhibiting above-average species diversity. Maintaining this level of diversity may be accomplished through continued monitoring and management of invasive species in order to protect the native plants present.

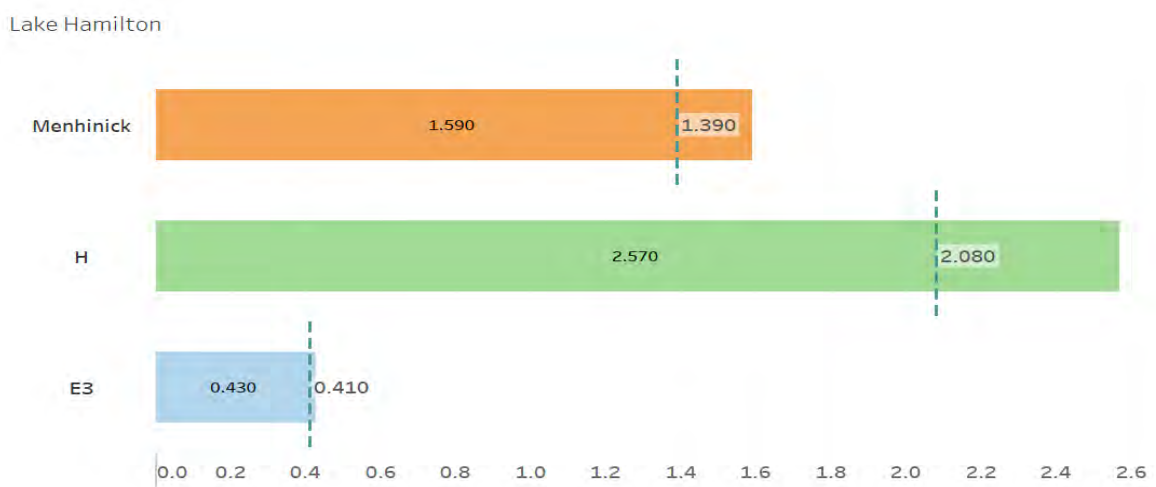


Figure 3-90. Chart depicting 2024 diversity indices for Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Hamilton's health index scores from 2018 to 2024 demonstrates why this waterbody is a high management priority (Figure 3-91). Besides an instance of TP meeting NNC guidelines for a year in 2021, the water quality scores have been consistently impaired and trending in a poor direction. Regarding the biological criteria, vegetation abundance has remained the same until 2024 where it saw a slight increase. Unfortunately, the reintroduction of non-native species dropped the invasive score down this year. Diversity has remained unchanged since 2021. Continued vegetation management is required to improve the invasive presence score with the goal of maintaining higher vegetation abundance and diversity scores as well.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	0	0	3	0	1	2	0	0.8
2019	0	0	0	3	0	1	2	2	1.0
2020	0	0	0	3	0	1	1	1	0.8
2021	1	0	0	3	0	1	1	3	1.1
2022	0	0	0	3	0	1	3	3	1.3
2023	0	0	0	3	0	1	3	3	1.3
2024	0	0	0	3	0	2	1	3	1.1

Figure 3-91. Chart depicting a comparison of Lake Hamilton's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Hamilton's water quality is continuing to decline. The likely existence of nitrogen-fixing cyanobacteria (i.e. blue-green algae) is evidenced by the increases in chlorophyll-a and total nitrogen concentrations, coupled with a decrease in total phosphorus. It is unclear if this is due to stormwater, OSTDs, or other sources.
- Lake Hamilton continues to lack an abundance of aquatic vegetation. An increase in coverage could improve nutrient sequestration in the future.

Lake Management Strategy:

- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection will help to prevent a resurgence of invasive species.
- As part of the pollutant load reduction plan submitted by the County, there are several projects underway and planned that are intended to reduce the pollutant load to Lake Hamilton. These include:
 - o Stormwater treatment BMPs at Lake Eva, Lake Conine (i.e. Lake Conine Nature Park), and a proposed treatment wetland on the west side of Lake Hamilton;
 - o Street sweeping in the Haines City area to reduce stormwater pollutant loads;
 - o Seepage study and septic-to-sewer conversion project proposed for the City of Lake Hamilton;
 - o Installation of bioactive media in stormwater features along US Hwy 27 should help to reduce nitrogen and phosphorus pollutant loading from runoff.

Lake Hartridge

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Hartridge	1	0	0	3	0	3	3	3	1.6

Features & Statistics:

Surface area	446.4 acres
Mean depth	9 feet
Maximum depth	22 feet
Volume	4462.7 acre-feet
Drainage basin area	920 acres
Annual TN Load	2658.3 lbs
Annual TP Load	458.9 lbs
Limiting nutrient	Phosphorus

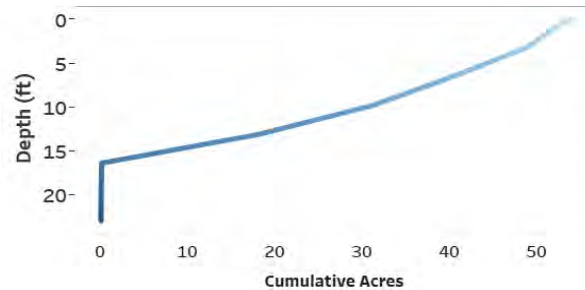


Figure 3-92. Hypsograph of Lake Hartridge depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Hartridge is a moderate-to-large waterbody at 446 acres, an average depth of 9 feet, and a maximum depth of over 20 feet (Figure 3-92). Hartridge's average depth is slightly deeper than the regional mean of 8.5 feet—meaning that sediment suspension is not necessarily a major issue. Stormwater is conveyed to this waterbody from a 920 acre drainage basin made up of a mix of residential, commercial, transportation, and industrial land uses (Figure 3-93). Based on stormwater modelling, Lake Hartridge receives 2,658 lbs of TN and 459 lbs of TP from this basin annually. There are 65 septic systems in the vicinity of the lake that may constitute a source of pollutant loading through groundwater. The City conducts monthly street sweeping services for over 17 miles along Havendale

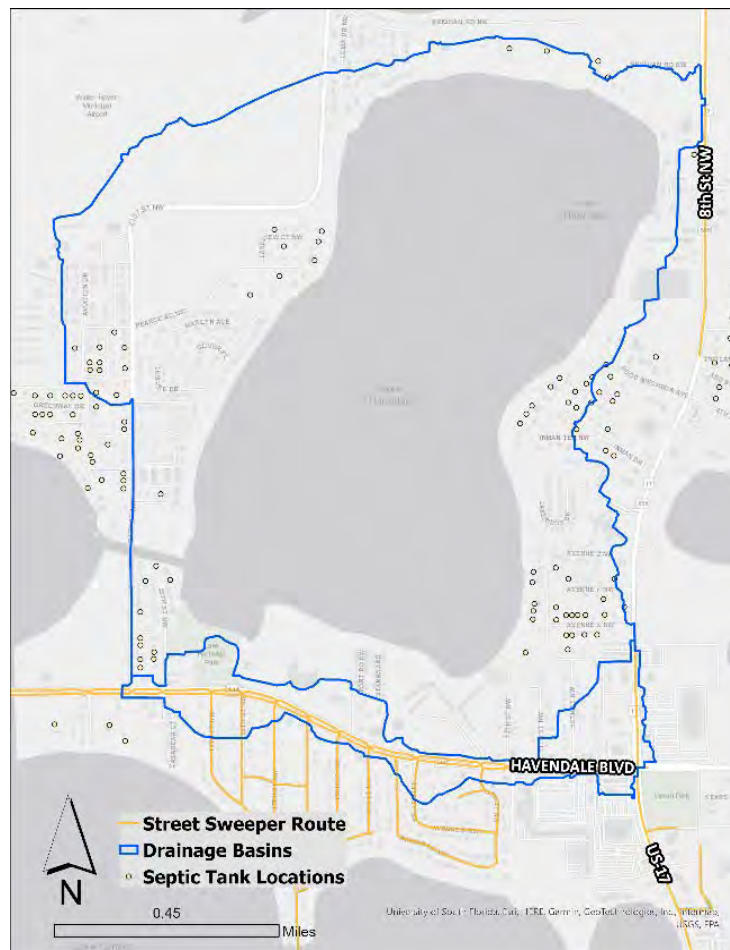


Figure 3-93. Map of Lake Hartridge's drainage basin, City street sweeper routes, and nearby septic systems.

Bldv and US Hwy 17. Lake Hartridge is the northernmost waterbody in the South Chain with navigable connections to Lake Idylwild to the west and Lake Conine (via lock) to the northeast. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-94). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Hartridge's surface level correlates indirectly with TP—indicating that higher levels should result in lower TP concentrations (see appendix).

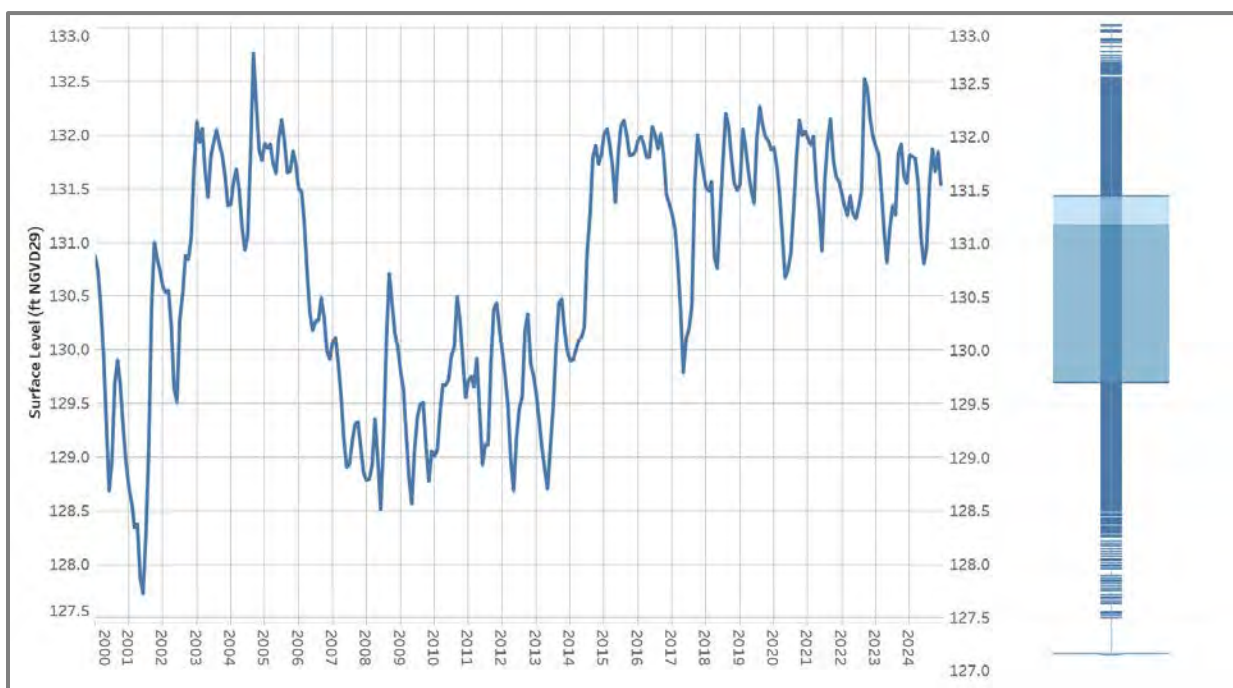


Figure 3-94. Hydrograph of the South Chain of Lakes depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Hartridge is categorized as a clear, alkaline waterbody. Based on numerous consecutive NNC threshold exceedances during the assessment period, Lake Hartridge is considered impaired for Chl-a and TN (Figure 3-95). Phosphorus concentrations have exceeded the NNC threshold in 2021 and now 2024, but impairment requires two consecutive exceedance years to be considered impaired. Lake Hartridge earns an impairment criterion score of 1.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this period, Chl-a, TN, and Secchi depth exhibit significant deteriorating trends—equating to trend criteria scores of 0. TP exhibits a non-significant improving trend, for a criterion score of 2. This recent shift in the trend direction may point to the

presence of nitrogen-fixing bacteria in Lake Hartridge. It should be noted that looking specifically at more recent data (i.e. 2012 – 2024), the trends are much more static or even moving in improving directions. Future reports may explore these more short-term trends in-depth to provide additional context and nuance to this analysis.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	0.551	0.010	Increasing	1	0
TN	Y	0.532	0.013	Increasing		0
TP	N	-0.466	0.033	Decreasing		3
Secchi	NA	-0.750	0.000	Decreasing		0

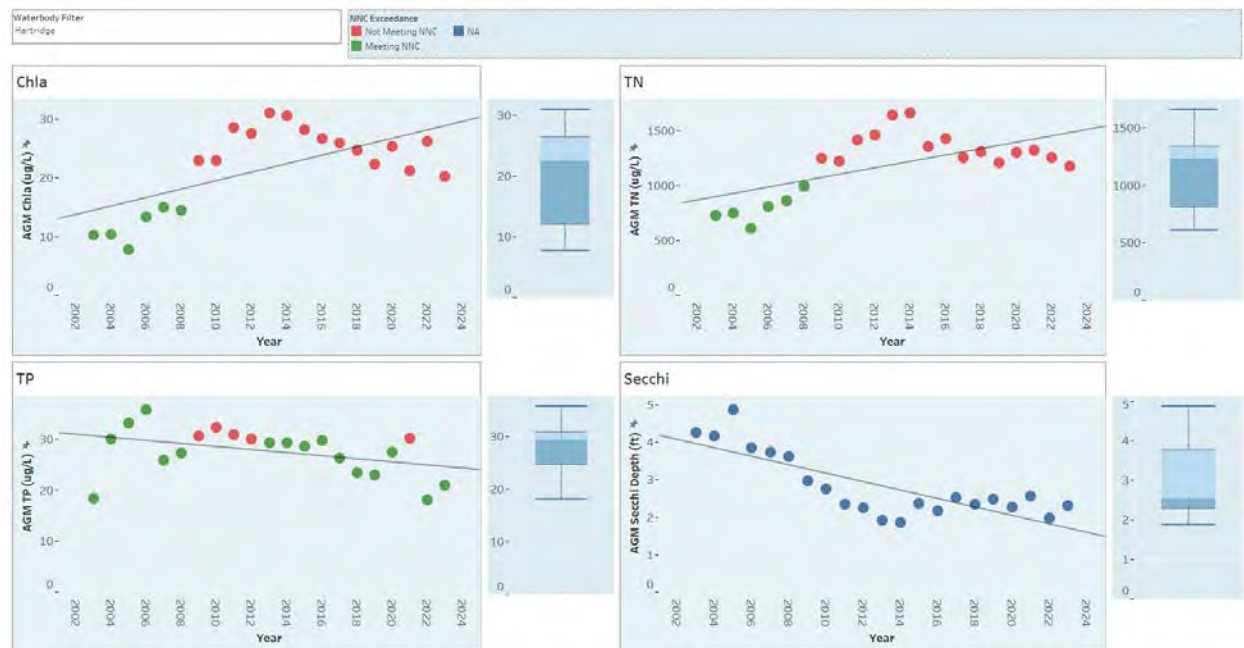


Figure 3-95. Lake Hartridge AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Hartridge on 10/17/2024. The PAC during this survey was 43.1% and the total BV was 8.4% (Figure 3-96). A comparison to previous years shows that vegetation abundance has remained relatively consistent since monitoring began; with PAC values above 35%. Lake Hartridge's gently sloping morphology likely allows for a wide littoral zone that aquatic plants can occupy. This abundance equates to a lake health criterion score of 3.

Invasive Species Management:

Based on the 2024 data, the native Illinois pondweed continues to be the dominant species present, followed by a healthy mix of native emergent and floating leaf plants (Figure 3-97). There were no invasive species detected in 2024; resulting in a score of 3. A comparison to previous years shows that invasives are generally controlled, with total community percentages consistently falling below 2% each year since 2018. Overall, this lake has a great aquatic plant community of which management efforts should strive to maintain.

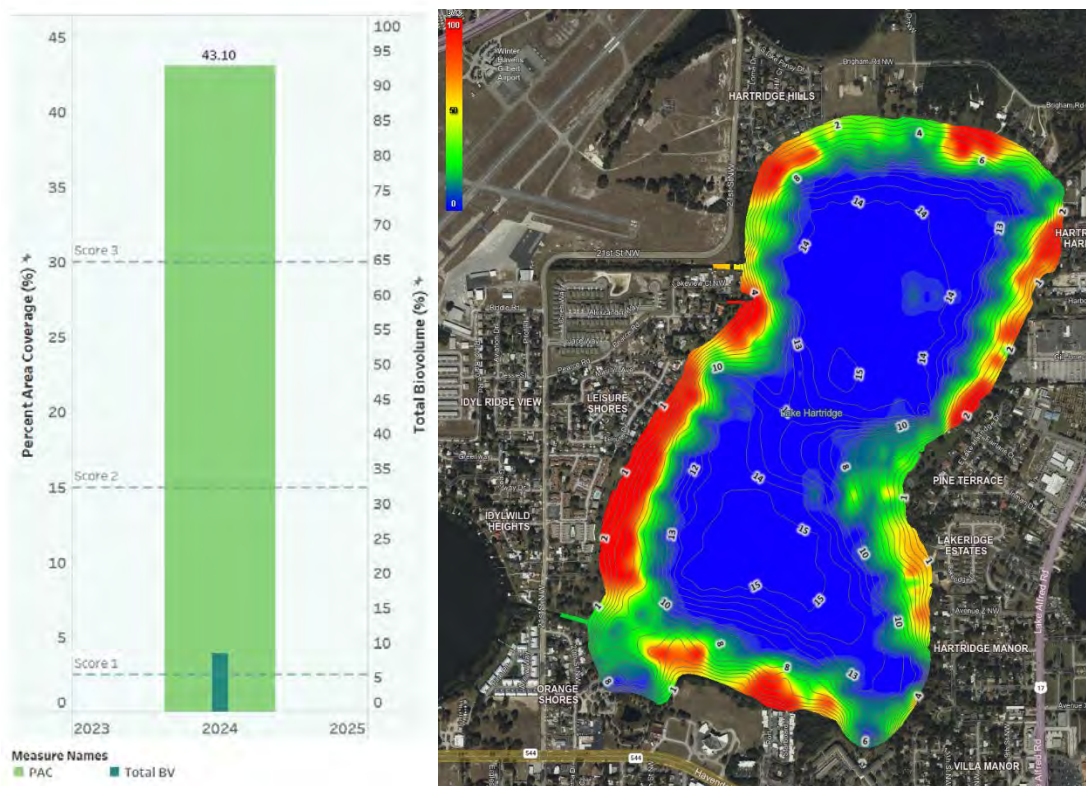


Figure 3-96. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Hartridge; biovolume values range from green (lowest) to red (highest).

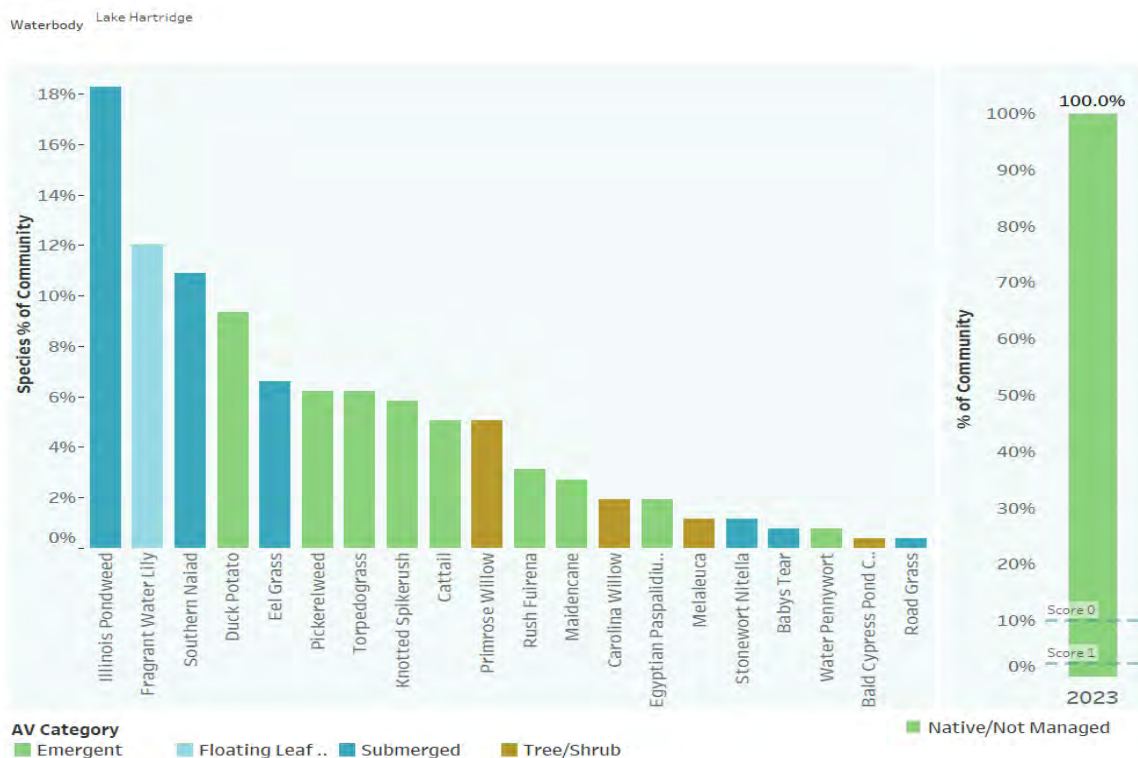


Figure 3-97. Chart depicting species frequency and invasive species percentage of Lake Hartridge during 2024.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Lake Hartridge's diversity indices exceeded their long-term median values (Figure 3-98). The richness index saw an increase from the previous year despite not having a reintroduction of invasive species. A community of 22 unique species, none of which are management invasives is a sign of a healthy aquatic ecosystem.

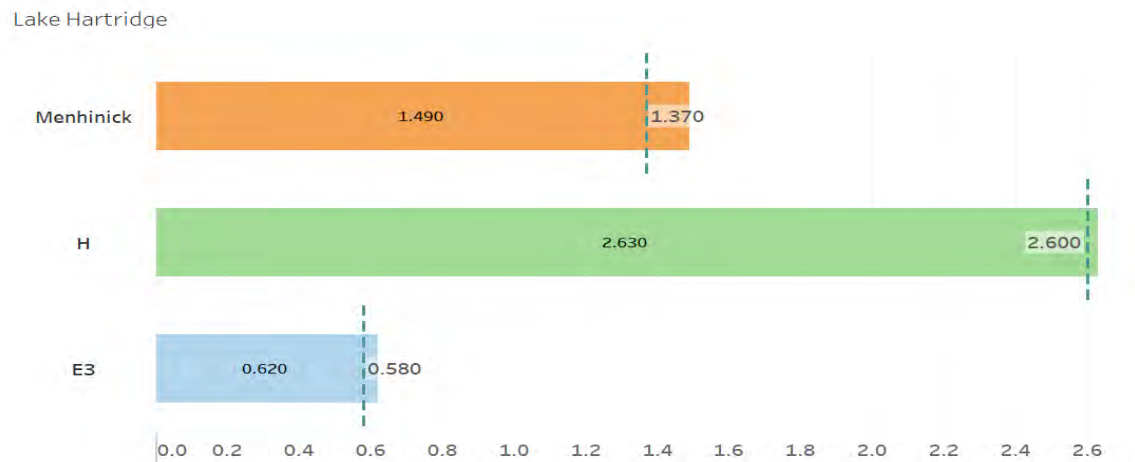


Figure 3-98. Chart depicting 2024 diversity indices for Lake Hartridge. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Hartridge's health index scores from 2018 to 2024 shows only minor changes (Figure 3-99). The impairment criterion score improved in 2019 due to TP no longer exceeding the NNC thresholds. However, with the exception of TP in the most recent assessment, the trend scores have consistently been pointing to deteriorating water quality. Vegetation abundance has remained high, with invasive and diversity scores exhibiting the most variability. This is likely due, in part, to invasive plant management efforts and the changes in the vegetation community that follow. Lake Hartridge's consistently low score places it high on the City's priority list for management action. However, it should be noted that 2024 marks this lake's highest LHI score since monitoring began.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	0	0	2	0	3	3	2	1.3
2019	1	0	0	1	0	3	2	2	1.1
2020	1	0	0	1	0	3	2	3	1.3
2021	1	0	0	1	0	3	3	3	1.4
2022	1	0	0	1	0	3	2	2	1.1
2023	1	0	0	2	0	3	3	2	1.4
2024	1	0	0	3	0	3	3	3	1.6

Figure 3-99. Chart depicting a comparison of Lake Hartridge's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Stormwater runoff, specifically from Hartridge's highly urbanized southern drainage basins remains one of the primary avenues for pollutant loading to the lake.

- In addition to stormwater, pollutant loading from OSTDs may be a potential contributor to Lake Hartridge's poor water quality. As these septic systems age, they may begin to leach nutrients into the water table—leading to additional water quality issues.
- The management of invasive species like hydrilla is a consistent concern. It can only take a single season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- The City currently conducts street sweeping services in the southern drainage sub-basin that collects water from Havendale Blvd. This is estimated to remove 192 lbs of TN and 104 lbs of TP annually.
- Additionally, a wetland treatment park was constructed in the early 2000s to capture and treat a substantial amount of runoff from this basin. Future studies are required to determine the actual pollutant removal efficiency.
- The City may explore source analysis to determine if OSTD leachate is a contributor of pollutants to the lake. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.

Lake Howard

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Howard	1	3	3	3	2	2	2	3	2.4

Features & Statistics:

Surface area	631.6 acres
Mean depth	8.71 feet
Maximum depth	16 feet
Volume	5844.9 acre-feet
Drainage basin area	1869 acres
Annual TN Load	6321.3 lbs
Annual TP Load	1097.5 lbs
Limiting nutrient	Phosphorus

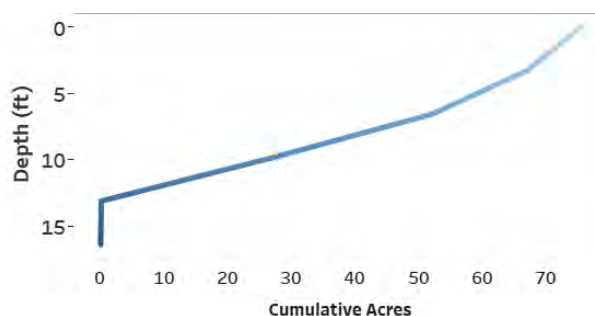


Figure 3-100. Hypsograph of Lake Howard depicting the depth profile and morphology of the lake bed.

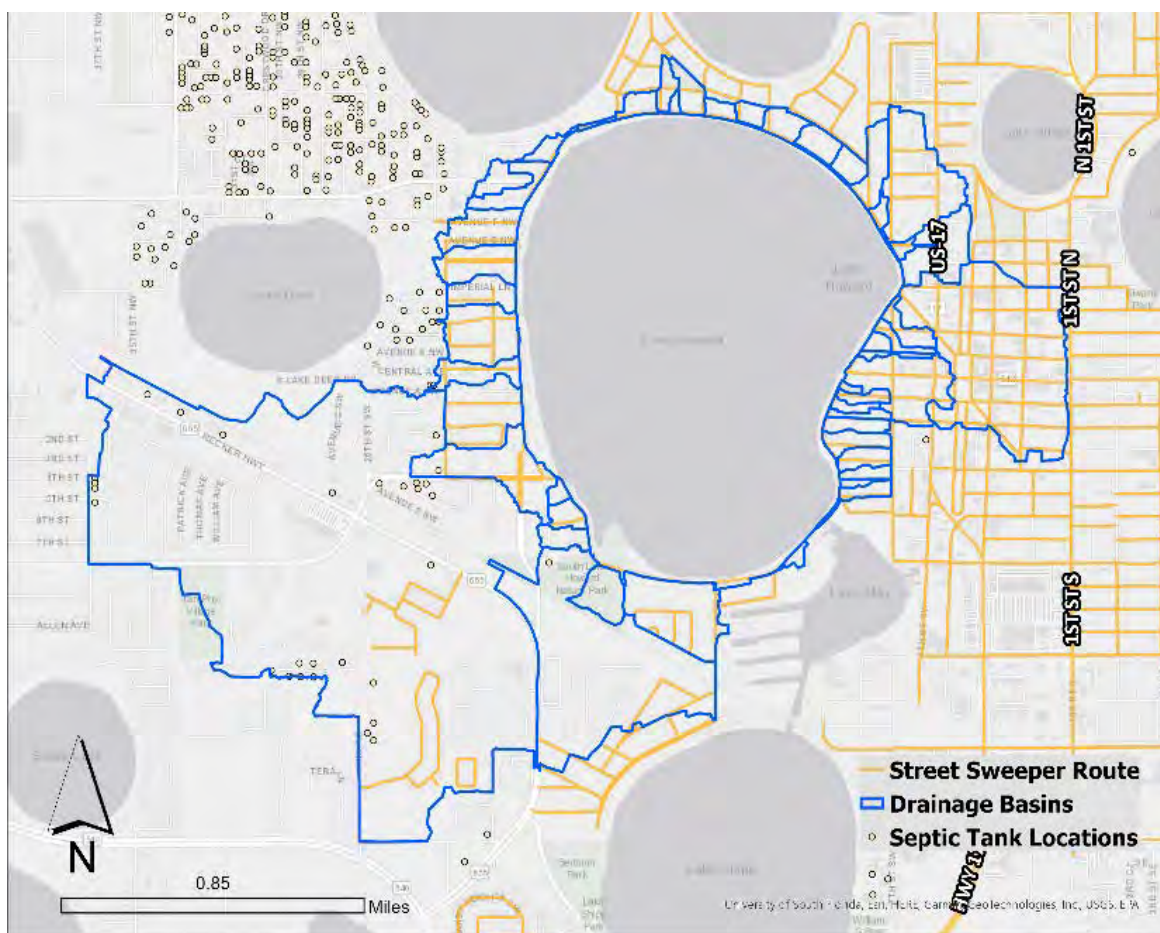


Figure 3-101. Map of Lake Howard's drainage basin, City street sweeping routes, and nearby septic systems.

Hydrology:

Lake Howard is one of the larger lakes in the South Chain at 632 acres. Its average depth of 8.7 feet is just slightly above the regional mean depth for the lakes in the study area; and its shallowly sloping bowl-shaped morphology provides ample littoral zone for aquatic vegetation to grow (Figure 3-100). Stormwater is conveyed to this waterbody from a large and complex drainage basin that is comprised of 53 separate sub-basins (Figure 3-101). Residential land uses make up the majority of this basin, contributing 6,321 lbs of TN and 1,097 lbs of TP to the lake annually. On a per acre basis, these loading rates rank 20th out of the 37 lakes in the study area. There are fewer than 30 septic systems present within the drainage basin. This is likely too low of a density to contribute meaningful pollutant loads via septic leaching into the groundwater. Much of the stormwater from downtown streets and surrounding neighborhoods is not captured in traditional stormwater treatment ponds. Therefore, the City conducts monthly street sweeping services for more than 50 miles per month.

Lake Howard is located centrally in the Southern Chain with navigable connections to Lakes May and Cannon. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-102). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Howard's surface level correlate with Chl-a, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

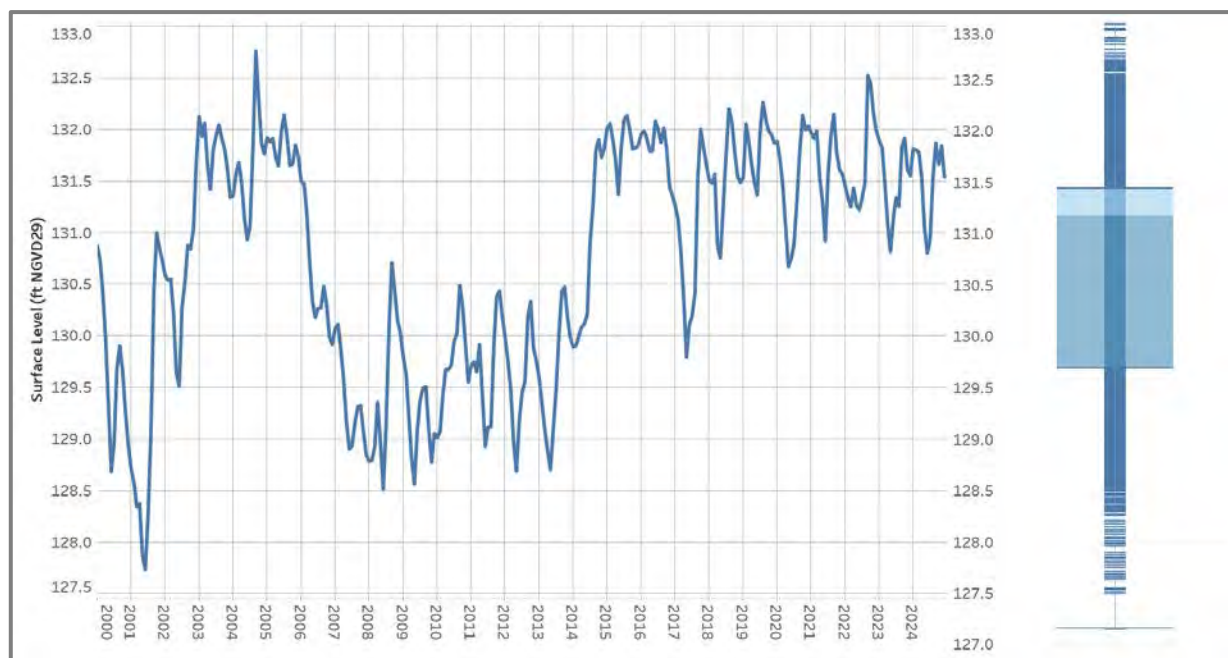


Figure 3-102. Hydrograph of Lake Howard depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Howard is categorized as a clear, alkaline waterbody. Due to numerous consecutive NNC exceedances during the assessment period, Lake Howard is considered impaired for Chl-a and TN (Figure 3-103). There have been no NNC exceedances for TP since 2009. In 2019, the FDEP established a total maximum daily load for Lake Howard, stipulating a 39% reduction in TN to meet NNC guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.634	0.002	Decreasing	1	3
TN	Y	-0.618	0.003	Decreasing		3
TP	N	-0.687	0.001	Decreasing		3
Secchi	NA	0.392	0.079	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the data, Chl-a, TN, TP, and Secchi depth all exhibit significant improving trends—earning trend criteria scores of 3. Despite its impairments, Lake Howard is on track to meet water quality targets if these trends continue.

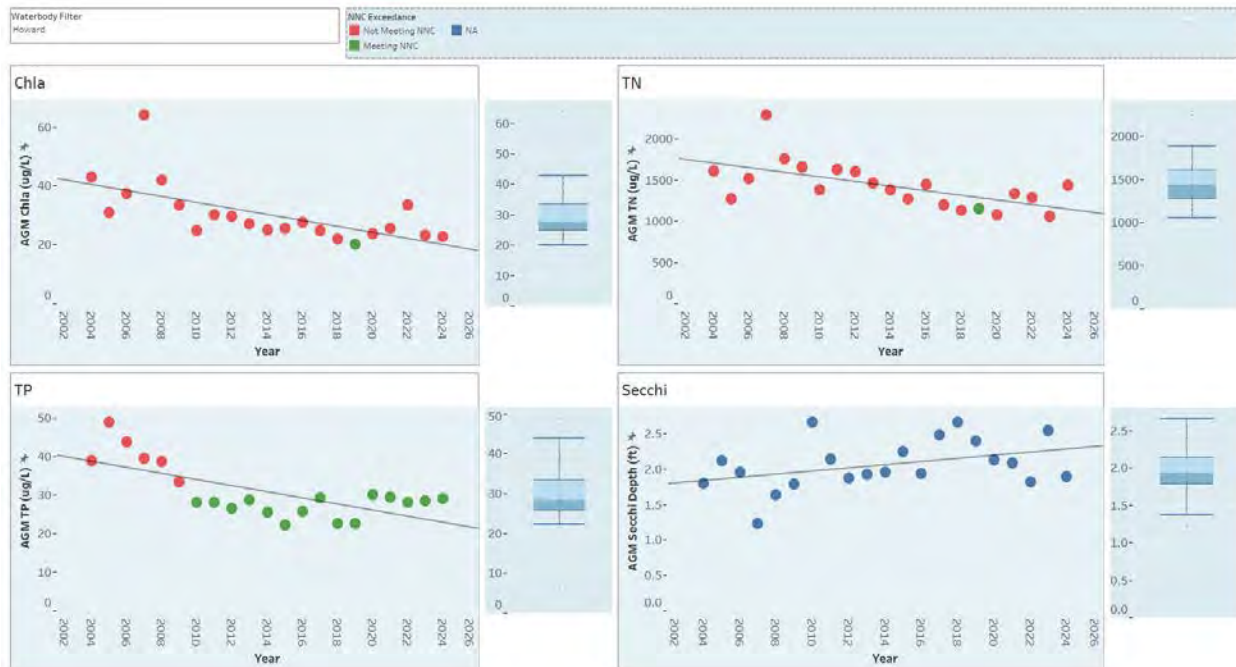


Figure 3-103. Lake Howard AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Howard on 5/3/2024. The PAC during this survey was 26.4% and the total BV was 3.8% (Figure 3-104). A review of abundance values from previous years shows that Lake Howard's coverage has fluctuated between 27% and 39%; this year's PAC values being the lowest on record. Lacking much of an invasive species presence, the majority of this variance in abundance can be attributed to natural fluctuations. The result of

the 2024 values equates to an abundance criterion score of 2. The highest density of aquatic vegetation appears to be concentrated along the southwest shoreline.

Invasive Species Management:

Based on data from the 2024 survey, Lake Howard has a healthy mix of native submerged, emergent, and floating leaf plant types (Figure 3-105). Lake Howard has historically not had issues with invasive plants, but in the last two years small populations of the floating plant water hyacinth have been detected. The small quantities of these invasives made up less than 1% of the community; even so, this equates to an invasive presence score of 2.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). In 2024, all three of these indices exceeded their long-term median values (Figure 3-106). With over 25 unique plant species present, it comes as no surprise that Lake Howard is one of the most diverse waterbodies in the area. However, the evenness index value in 2024 was the highest on record—indicating a more equal distribution of the species present.

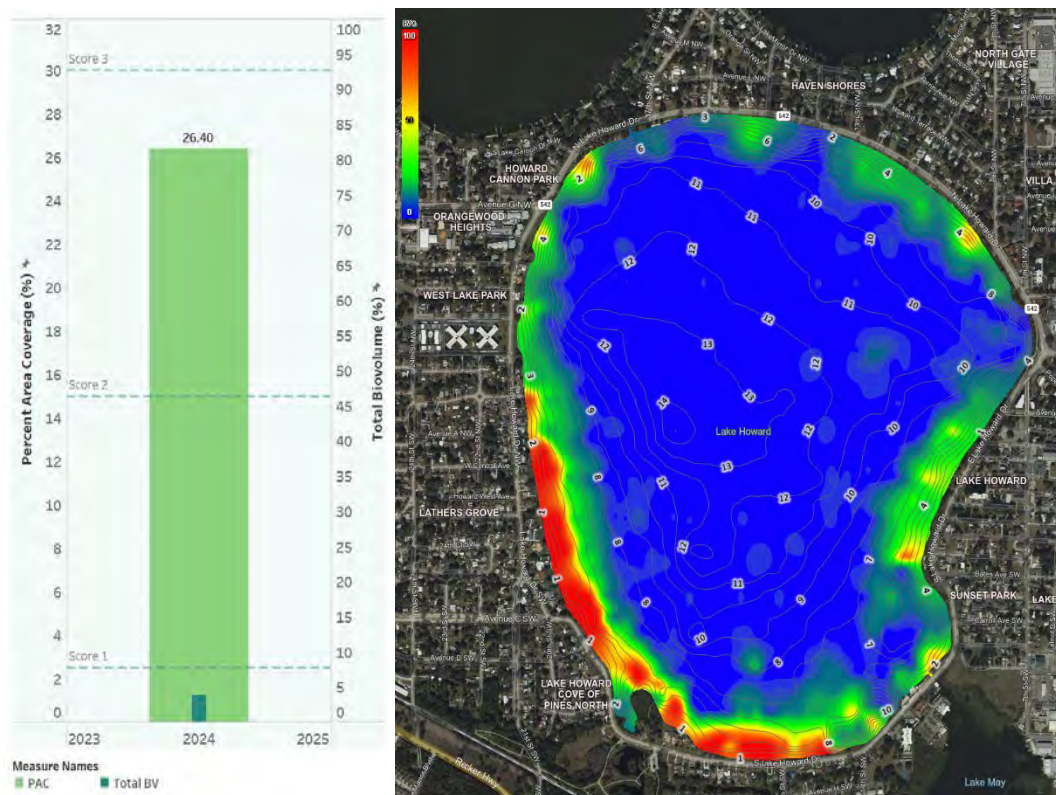


Figure 3-104. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Howard; biovolume values range from green (lowest) to red (highest).

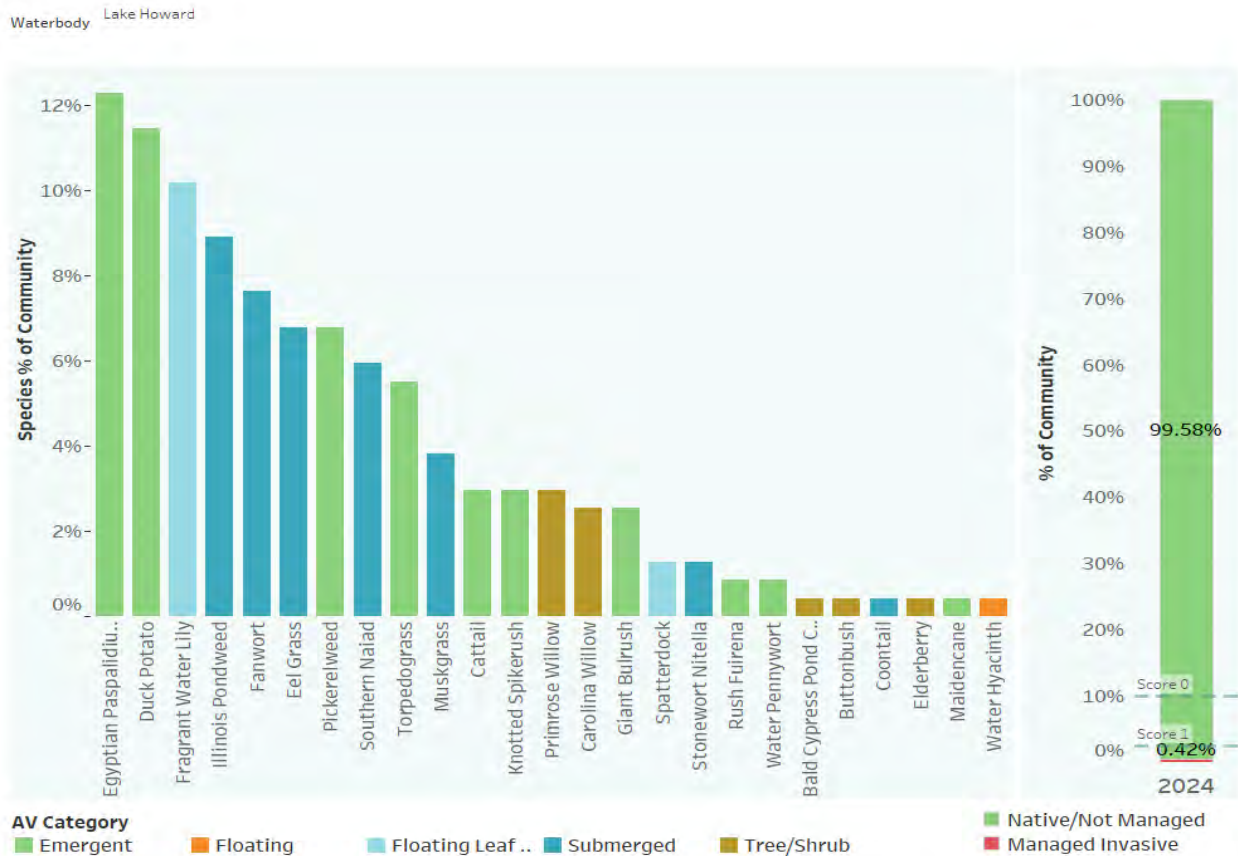


Figure 3-105. Chart depicting species frequency and invasive species percentage of Lake Howard during 2024.

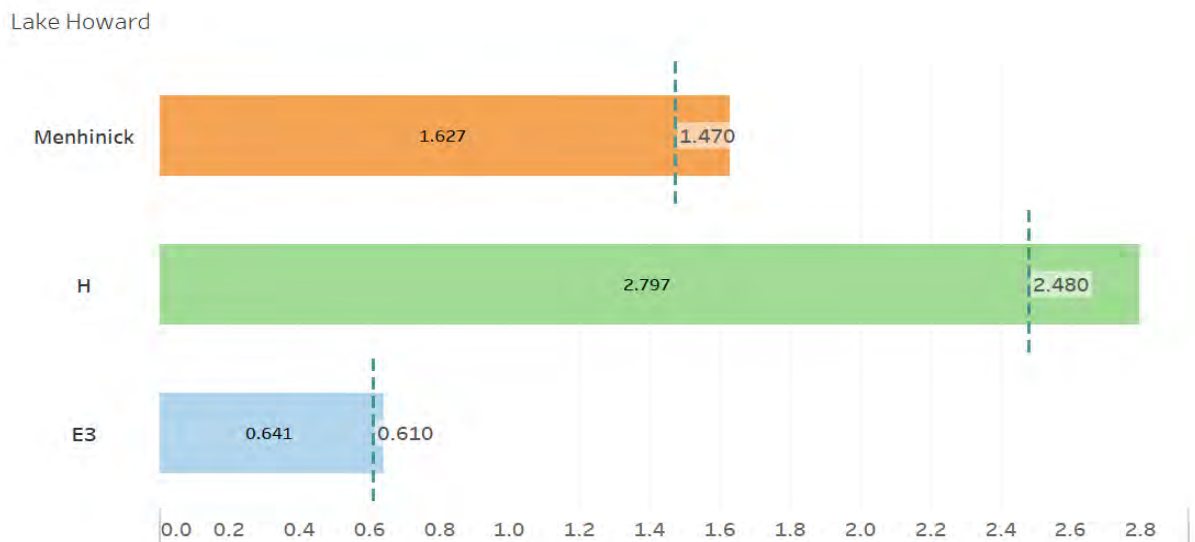


Figure 3-106. Chart depicting 2024 diversity indices for Lake Howard. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Howard's health index scores from 2018 to 2024 shows consistently good values and few changes (Figure 3-107). While it is impaired, Lake Howard's water quality is trending in a positive direction. Invasive percentage has remained minimal which indicates that the lake health changes are the result of natural fluctuations in the vegetation community. That said, minimal presence of invasive plants in the last two years highlights how non-native management is needed to prevent further spread and potential negative impacts.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	1	3	3	2	3	3	2	NA	2.4
2019	1	3	3	2	3	2	3	3	2.5
2020	1	3	3	2	3	3	3	1	2.4
2021	1	3	3	2	3	3	3	1	2.4
2022	1	3	3	2	3	2	3	2	2.4
2023	1	3	3	3	3	2	2	2	2.4
2024	1	3	3	3	2	2	2	3	2.4

Figure 3-107. Chart depicting a comparison of Lake Howard's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- In addition to stormwater inputs to the lake, the now decommissioned Jan Phyl Village Wastewater Treatment Plant was contributing point-source discharges as late as 1977. These discharges could be a source of legacy nutrients.
- Several water quality metrics are significantly correlated with Lake Howard's surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- While not currently an issue, the management of invasive species like water hyacinth is a potential concern. It can only take a single season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- Treating stormwater from the surrounding drainage basin is one of the primary strategies for improving water quality. The City mitigates stormwater through various methods:
 - o Street Sweeping over 50 miles per month in the downtown area.
 - o Construction of a stormwater treatment/nature park on the south side of Lake Howard in the early 2000s.
 - o Construction of an alum injection system in the mid-2000s estimated to reduce Lake Howard's TN loads by 4% and TP loads by 15% annually.
 - o The Stormwater Assessment and Improvement Project: identified priority areas for green infrastructure in southern drainage sub-basins to prevent flooding and improve water quality.
 - o Construction and maintenance of other green infrastructure; including over 12 raingardens that capture the first flush of stormwater in the downtown area.

- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC in order to coordinate invasive treatment efforts.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- A trash catchment system was installed at Heritage Park in 2020 to capture floating litter and debris from Lake Howard's largest drainage sub-basin.

Lake Idyl

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Idyl	0	0	0	0	0	3	0	2	0.6

Features & Statistics:

Surface area	19 acres
Mean depth	6.1 feet
Maximum depth	10 feet
Volume	108.1 acre-feet
Drainage basin area	231 acres
Annual TN Load	934.9 lbs
Annual TP Load	154.5 lbs
Limiting nutrient	Co-limited (N & P)

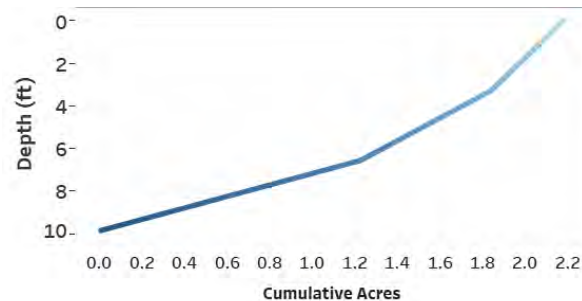


Figure 3-108. Hypsograph of Lake Idyl depicting the depth profile and morphology of the lake bed.

Hydrology:

One of Winter Haven's smallest waterbodies, Lake Idyl is 18 acres, has an average depth of 6.7 feet, and a maximum depth of just under 10 feet (Figure 3-108). With a depth much shallower than the regional average, sediment suspension is an issue for Lake Idyl. Stormwater is conveyed to this waterbody from a 231 acre drainage basin comprised of three separate sub-basins (Figure 3-109). Mostly comprised of residential land uses, the basin contributes 935 lbs of TN and 154 lbs of TP to the lake annually. On a per acre basis, these pollutant loads rank 12th compared with other lakes in the region. There are six septic systems present in the drainage basin. This low density is likely not a major contributor of pollutants via groundwater leaching. Due to stormwater inputs, the City conducts street sweeping services on the majority of roadways in the basin.

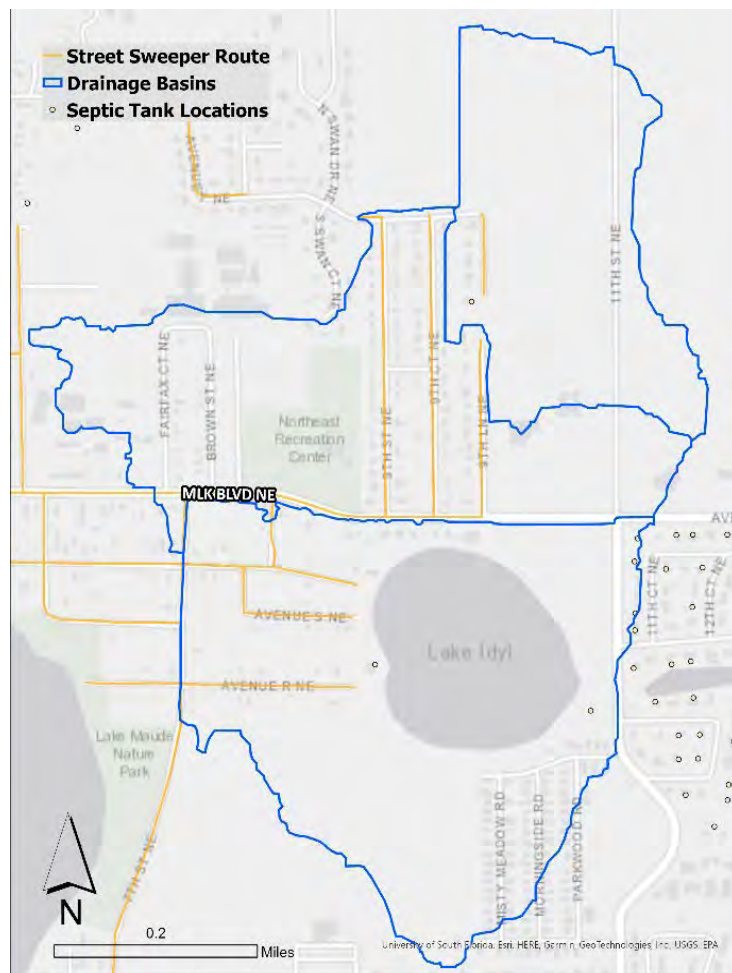


Figure 3-109. Map of Lake Idyl's drainage basin, City street sweeper routes, and nearby septic systems.

Lake Idyl receives excess flow from Lake Maude and discharges its overflow to Lake Buckeye. Its average surface elevation is at about the midway point within the Peace Creek watershed. Over its period of record, Lake Idyl's surface level has fluctuated between 131.3 and 133.9 feet above sea level. The normal level range fluctuates much more narrowly between 132.3 and 132.5 feet (Figure 3-110). During 2024, Lake Idyl reached a dry season low of 132.2 feet in May and a wet season peak of 132.8 feet after the hurricanes in October. Idyl ended the year with a surface level of 132.15—well below its normal range. Changes in Lake Idyl's surface level are not significantly correlated with any of the primary water quality metrics; likely because it exhibits such minimal fluctuation (see appendix).

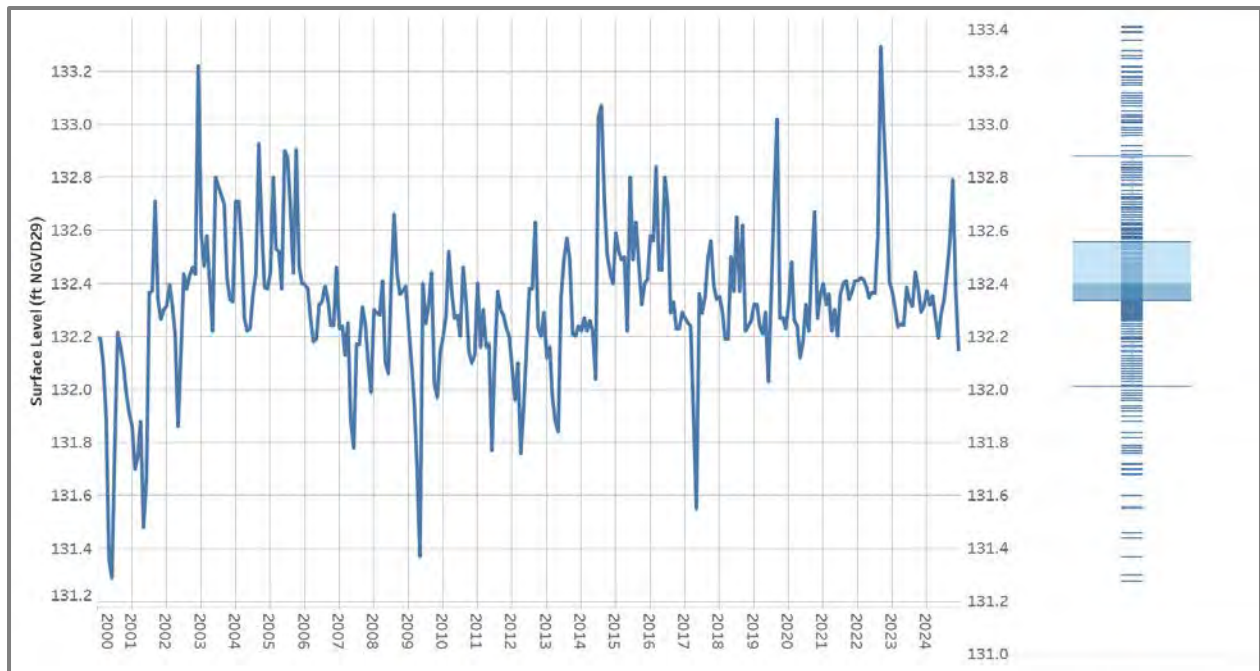


Figure 3-110. Hydrograph of Lake Idyl depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Idyl is categorized as a clear, alkaline waterbody. Due to multiple consecutive NNC exceedances during the assessment period, Lake Idyl is considered impaired for Chl-a, TN, and TP (Figure 3-111). This equates to an impairment criterion score of 0. From 2022 to 2024, Lake Idyl's TN and TP concentrations were below impairment thresholds. The Chl-a concentration was below the impairment threshold in 2022 and 2023, but exceeded it in 2024. Due to these impairments, the FDEP approved the City's draft alternative restoration plan for Lake Idyl in lieu of a total maximum daily load (TMDL).

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	0.574	0.008	Increasing	0	0
TN	Y	0.678	0.001	Increasing		0
TP	Y	0.755	0.000	Increasing		0
Secchi	NA	-0.635	0.003	Decreasing		0

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the data, all four parameters exhibit significant deteriorating trends. These trends underscore the need to address the water quality issues in this lake. It is believed that stormwater pollutant loading has been the primary driver of water quality decline, but impacts from sediment suspension and invasive plant treatments likely contribute to sustained poor water quality in recent years.

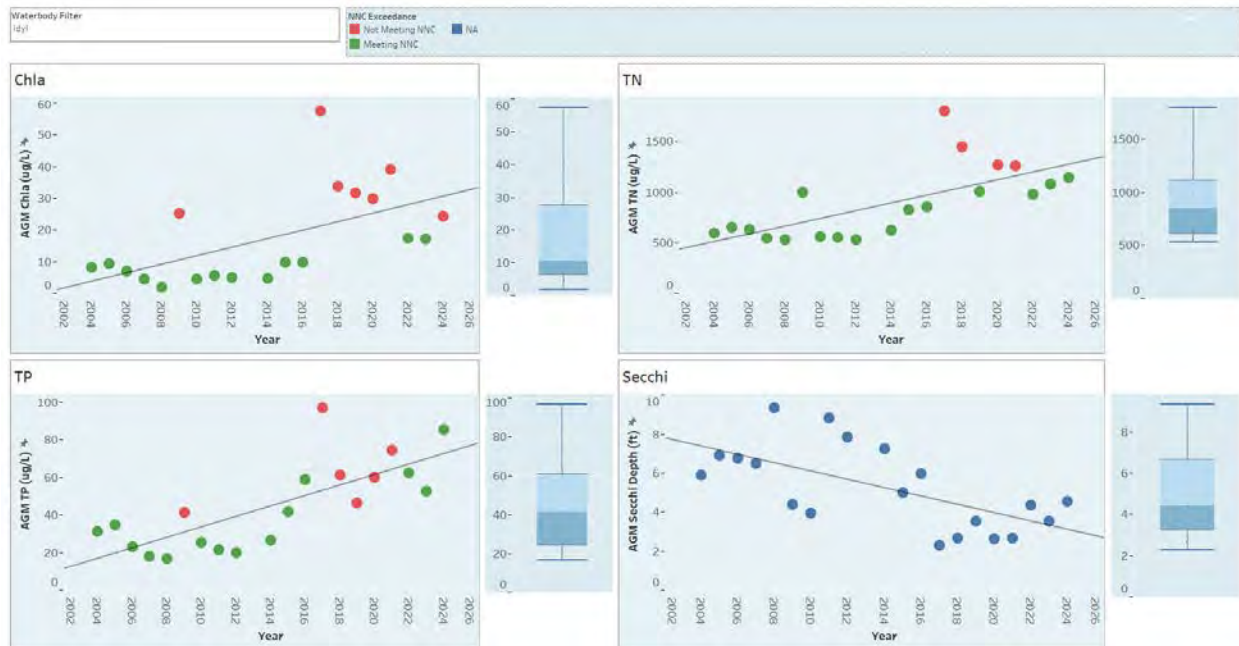


Figure 3-111. Lake Idyl AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Idyl on 2/9/2024. The PAC during this survey was 87.6% and the total BV was 9.6% (Figure 3-112). A comparison of abundance values from previous years shows that Lake Idyl typically exhibits high vegetation coverage in excess of 35%. Much of the lake is covered by spatterdock; a floating leaf plant that is usually found in shallow waters with mucky substrate. This amount of coverage equates to an abundance score of 3.

Invasive Species Management:

Based on the 2024 data, 35% of the plant community was comprised of spatterdock, followed by a mix of floating and submerged species (Figure 3-113). Managed invasive species made up 26% of the community; comprised of burhead sedge and floating water hyacinth. A comparison of data over the last six years shows that this is the highest abundance of invasives for this lake on record. The current percentage earns Lake Idyl an invasive criterion score of 0.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, Lake Idyl's overall diversity and evenness indices exceeded its long-term median values (Figure 3-114). This equates to a diversity criterion score of 2. Lake Idyl has traditionally had low species diversity, likely due to the

dominance of spatterdock and primrose willow. It is also likely that the mucky substrate hinders the growth of most native submerged species. However, the recent presence of submerged plants is a good sign of ecological improvement.

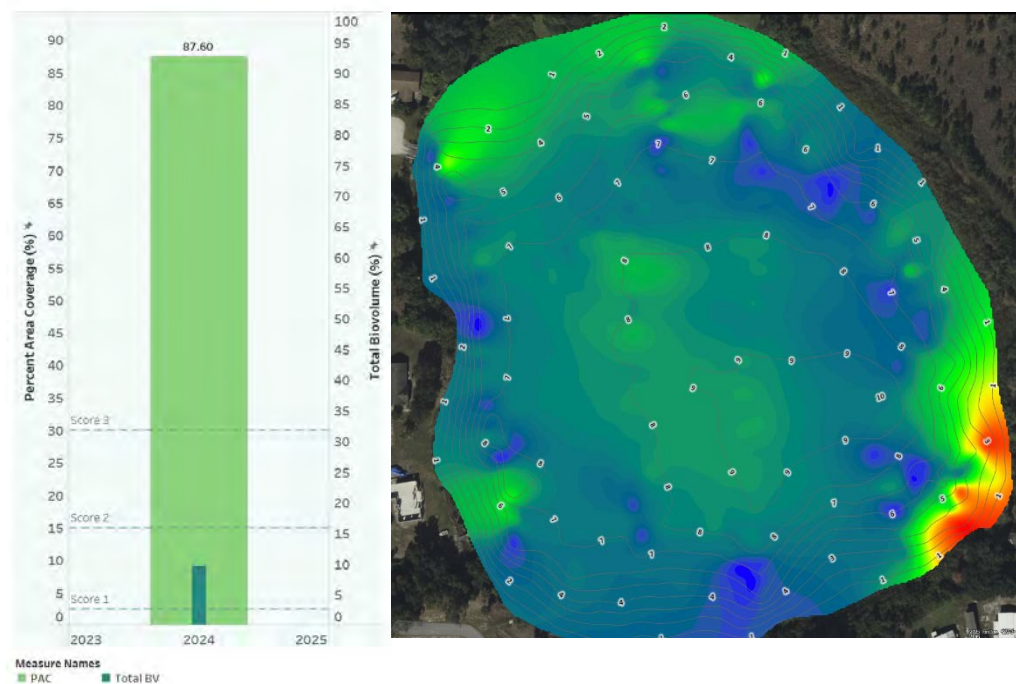


Figure 3-112. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Idyl; biovolume values range from green (lowest) to red (highest).

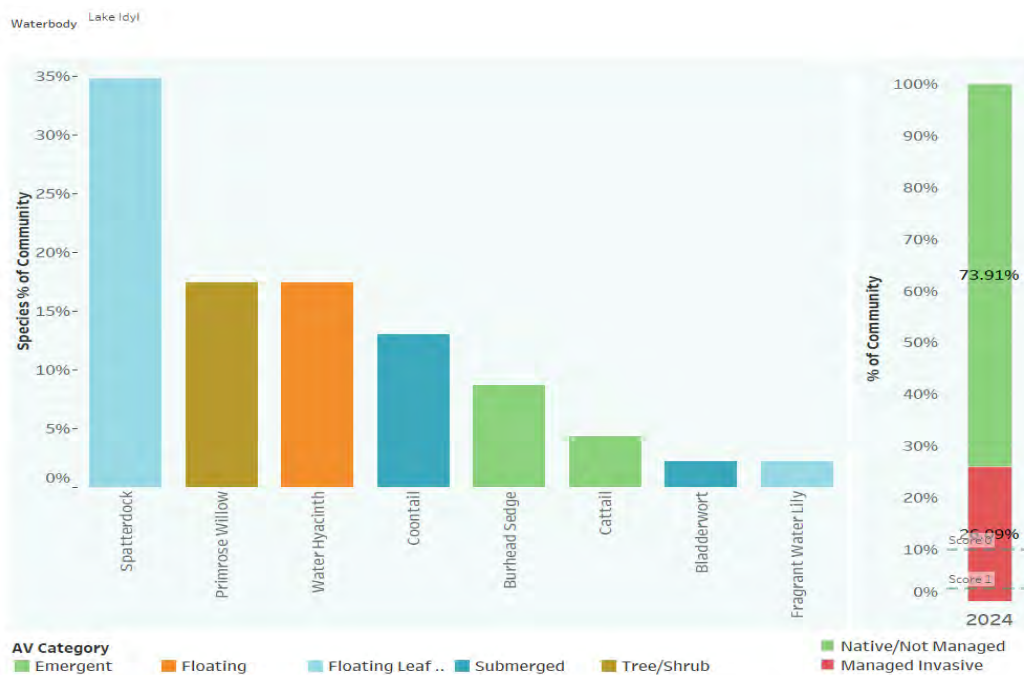


Figure 3-113. Chart depicting species frequency and invasive species percentage of Lake Idyl during 2024.

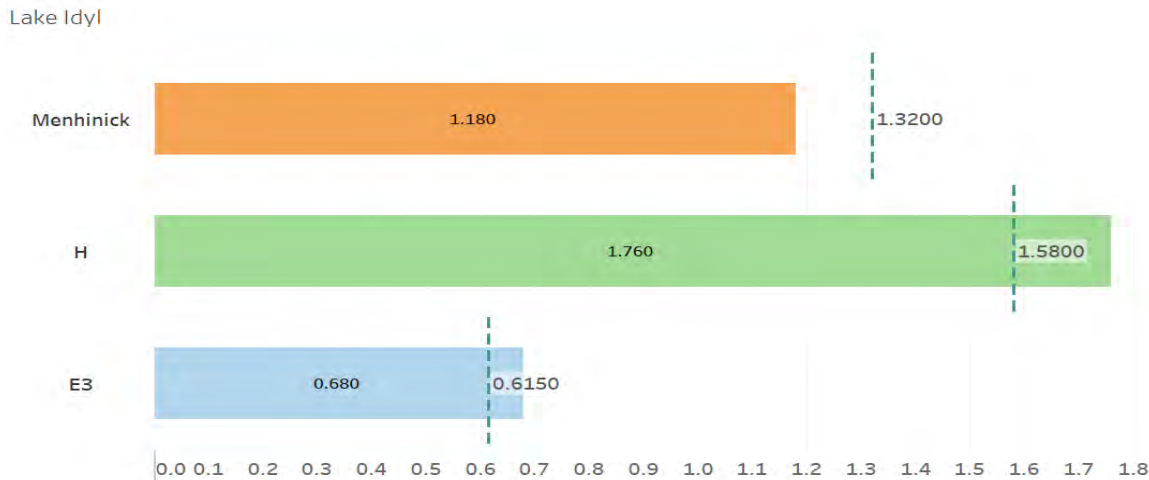


Figure 3-114. Chart depicting 2024 diversity indices for Lake Idyl. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Idyl's health index scores from 2018 to 2024 illustrates consistently low scores (Figure 3-115). Since monitoring began, Lake Idyl has remained impaired and exhibited a decline all of its water quality trends. The presence of managed invasive species has also been a consistent issue. Species diversity varies considerably—likely due to changes in the vegetation community as a result of increased invasive species presence and subsequent management efforts. On the whole, Lake Idyl is considered a high-priority lake on which to focus future management efforts on.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	1	2	3	1	1	1.3
2019	0	1	1	1	2	1	0	1	0.9
2020	0	1	1	1	1	3	0	2	1.1
2021	0	1	1	0	1	3	0	0	0.8
2022	0	1	1	0	1	3	1	2	1.1
2023	0	0	0	0	0	3	0	1	0.5
2024	0	0	0	0	0	3	0	2	0.6

Figure 3-115. Chart depicting a comparison of Lake Idyl's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading is one of the primary factors believed to be driving the decline in water quality.
- The management of invasive species and floating tussocks is a constant concern as these plants can quickly take over large areas of a lake and/or the shoreline in a single growing season.
- The dominance of spatterdock can often result in a higher occurrence of tussocks. These tussocks can present navigation, drainage, and habitat problems.

Lake Management Strategy:

- In addition to street sweeping (annual removal of 45 lbs of TN and 25 lbs of TP), the City has submitted a water quality improvement plan to FDEP in 2024. This plan includes:

- o A raingarden at the Recreation & Cultural Center is estimated to remove 17.6 lbs of TN and 0.76 lbs of TP annually.
 - o Stormwater improvements in the drainage basin which are estimated to remove 386 lbs of TN and 60 lbs of TP annually.
 - o Sediment inactivation treatment designed to neutralize 1,113 lbs of bioavailable phosphorus from the lake's sediment and water column.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Idylwild

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Idylwild	2	3	2	3	3	3	1	3	2.5

Features & Statistics:

Surface area	95.2 acres
Mean depth	8.3 feet
Maximum depth	14 feet
Volume	834 acre-feet
Drainage basin area	225.4 acres
Annual TN Load	669.14 lbs
Annual TP Load	121.61 lbs
Limiting nutrient	Co-limited (N & P)

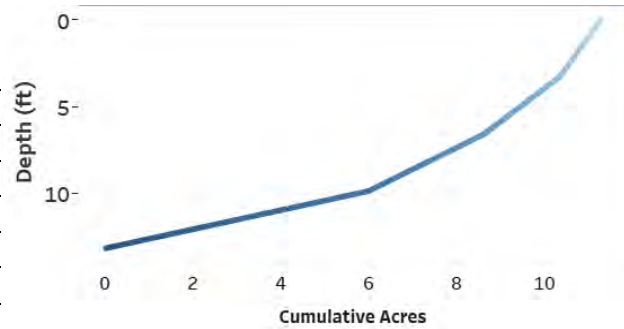


Figure 3-116. Hypsograph of Lake Idylwild depicting the depth profile and morphology of the lake bed.

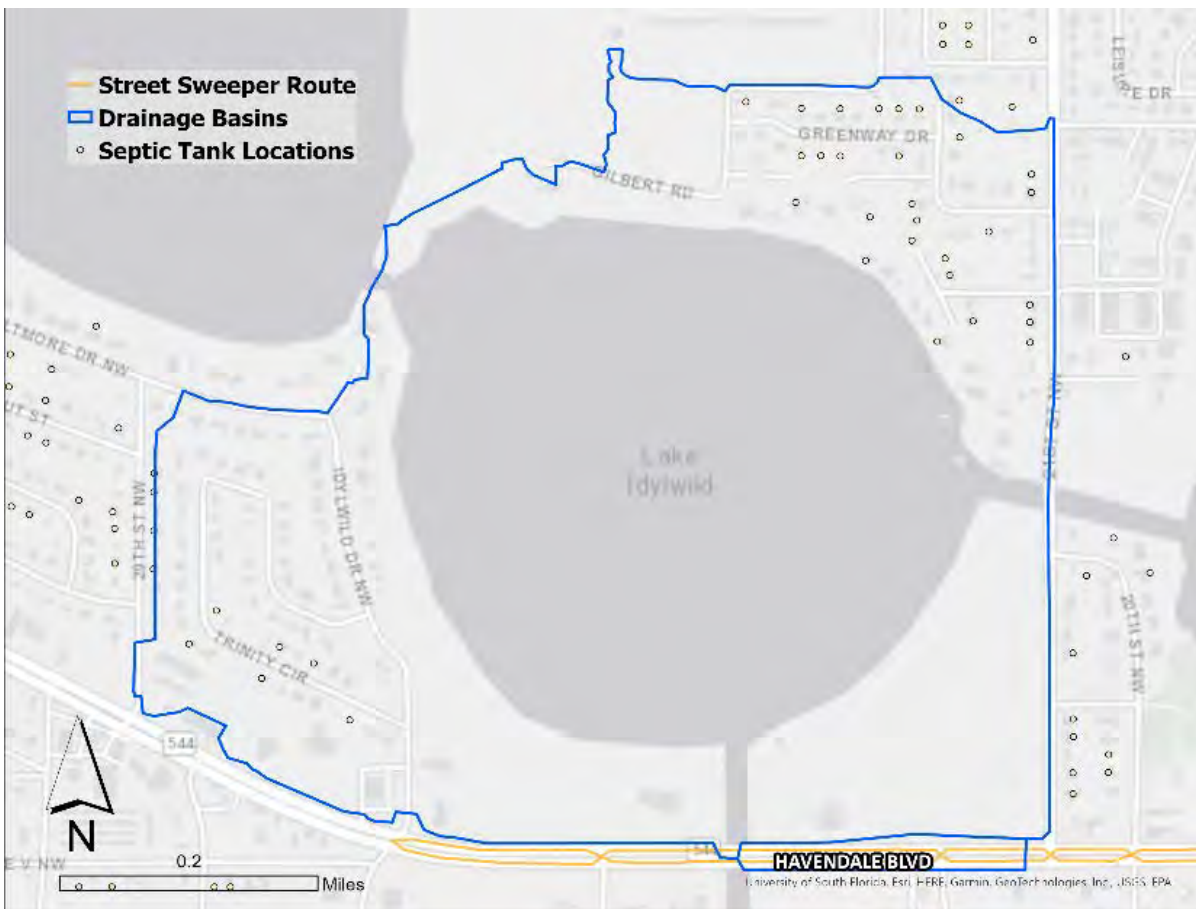


Figure 3-117. Map of Lake Idylwild's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Idylwild is one of the City's smaller lakes at 95 acres. Its depth is right around the regional mean, with an average depth of 8.3 feet and maximum depth approaching 15 feet (Figure 3-116). Stormwater is conveyed to this waterbody from a 225 acre drainage basin made up primarily of residential land uses; though there is a small transportation-heavy sub-basin that includes Havendale Blvd (Figure 3-117). These land uses contribute 669 lbs of TN and 121 lbs of TP to Lake Idylwild annually. On a per acre basis, these pollutant loading rates rank 23rd out of the 37 area lakes. There are 33 known septic systems in this drainage basin; a relatively low density, but septic systems can pose a potential pollutant loading issue. To manage stormwater from the main arterial roads to the south of the lake, the City conducts street sweeping services of up to 6 miles twice per month.

Lake Idylwild is part of the South Chain of Lakes with navigable connections to Lake Cannon, Hartridge, and Jessie. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-118). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Idylwild's surface level correlate with Chl-a, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should correlate with improved water quality.

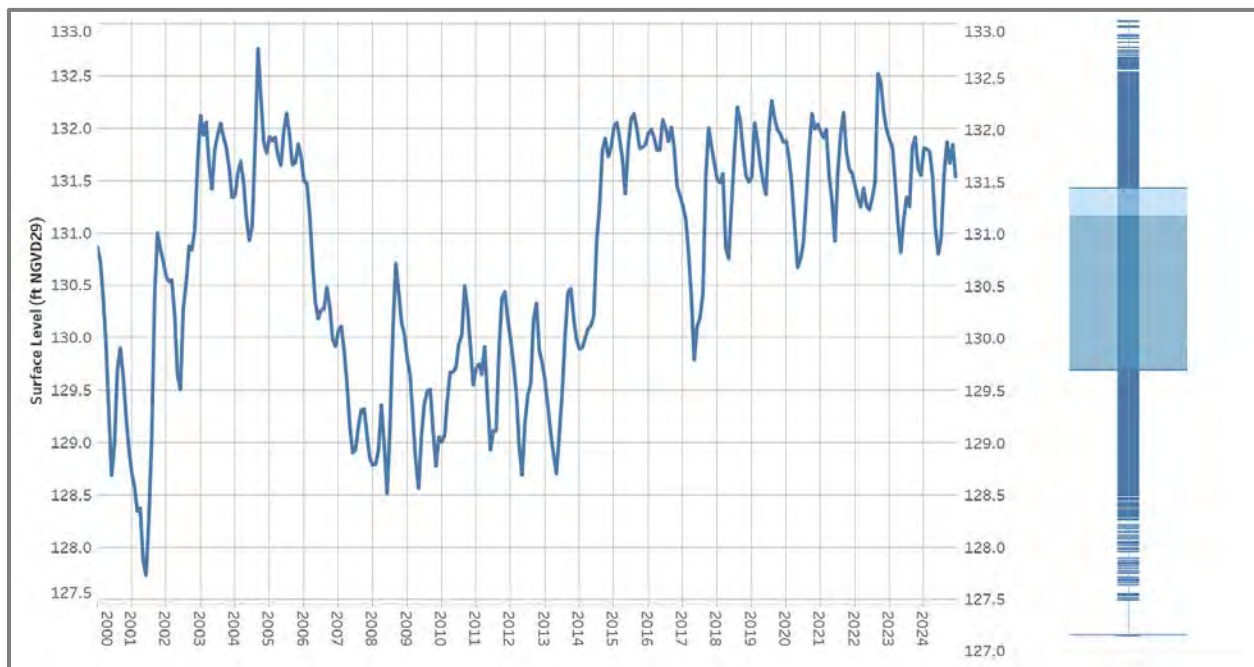


Figure 3-118. Hydrograph of Lake Idylwild depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Idylwild is categorized as a clear, alkaline waterbody. Due to consecutive NNC exceedances in 2017 and 2018, Lake Idylwild is considered impaired for Chl-a (Figure 3-119). This equates to an impairment criterion score of 2. Concentrations of Chl-a also exceeded the NNC threshold in 2022 and 2024. In 2019, the FDEP established a total maximum daily load for Lake Idylwild, stipulating a 31% reduction in TN to meeting NNC guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.489	0.025	Decreasing	2	3
TN	N	-0.190	0.409	No Trend		2
TP	N	-0.557	0.009	Decreasing		3
Secchi	NA	0.441	0.046	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the data, Chl-a, TP, and Secchi depth exhibit significant improving trends; which equate to trend criterion scores of 3. While also improving, the TN trend is not statistically significant; which results in a trend score of 2. With the Chl-a concentrations continuing to trend in a downward direction, there should be a point in the near future where Chl-a becomes unimpaired, thereby increasing its water quality scores. Considering Lake Idylwild's previous impairments, these trends highlight how much the lake has improved in the last two decades.



Figure 3-119. Lake Idylwild AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Idylwild on 4/25/2024. The PAC during this survey was 87% and the total BV was 26.8% (Figure 3-120). The 2024 coverage value was the highest on record and equates to a vegetation abundance criterion score of 3. A comparison of abundance data since 2018 shows that Lake Idylwild consistently maintains high vegetation coverage and biovolume via its large littoral zone in proportion to the entire lake surface area—demonstrated by the vegetation heatmap. This likely contributes to the water quality improvements observed in recent years.

Invasive Species Management:

Based on the 2024 survey data, native species dominated the vegetation community. Lake Idylwild exhibits a fairly even mix of emergent, submerged, and floating-leaf vegetation (Figure 3-121). Fragrant water lily and eel grass made up nearly 30% of the community, followed by 19 other unique species. Managed invasive species present were hydrilla and burhead sedge making up 3.2% of the vegetation community; resulting in an invasive criterion score of 1. That said, this was a more than 50% reduction in invasives from the previous year. Based on data from 2018 to 2023, the invasive percentage has consistently been between 1.75% and 7%. This indicates that invasive populations are in a relatively controlled state.

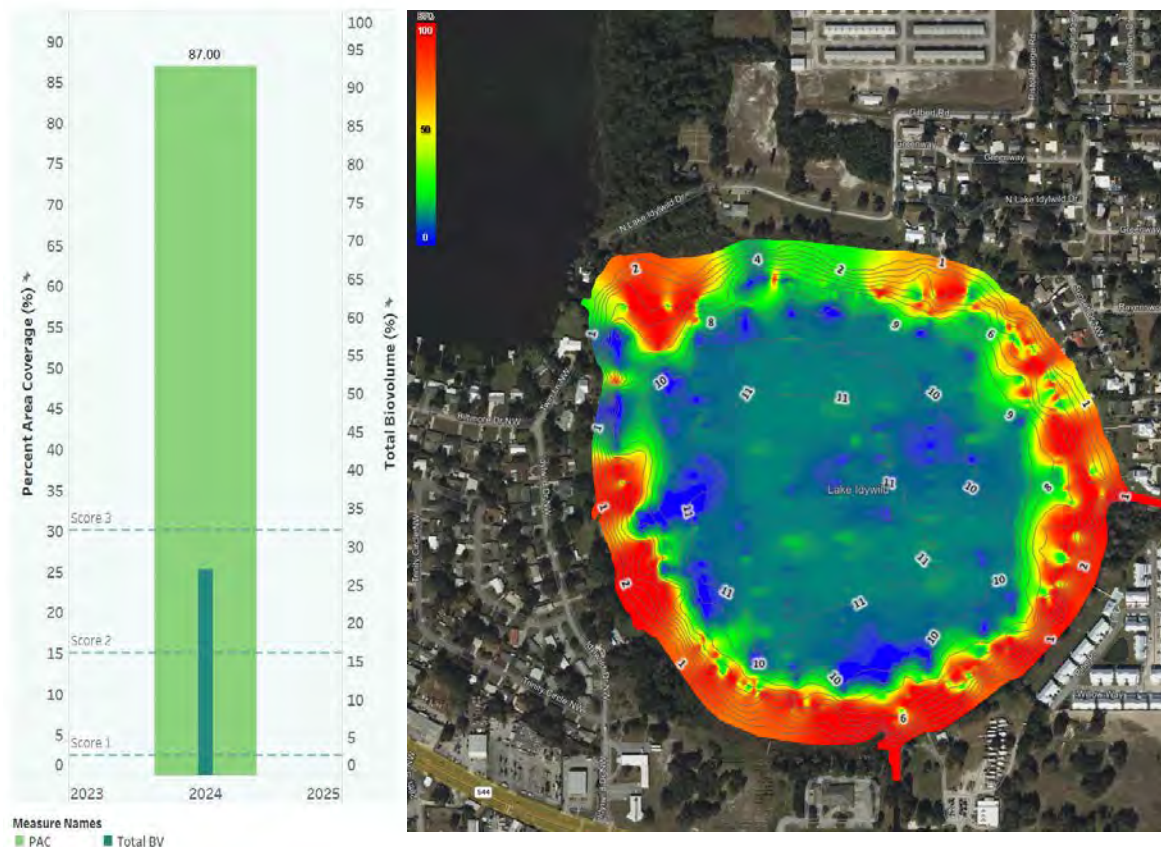


Figure 3-120. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Idylwild; biovolume values range from green (lowest) to red (highest).

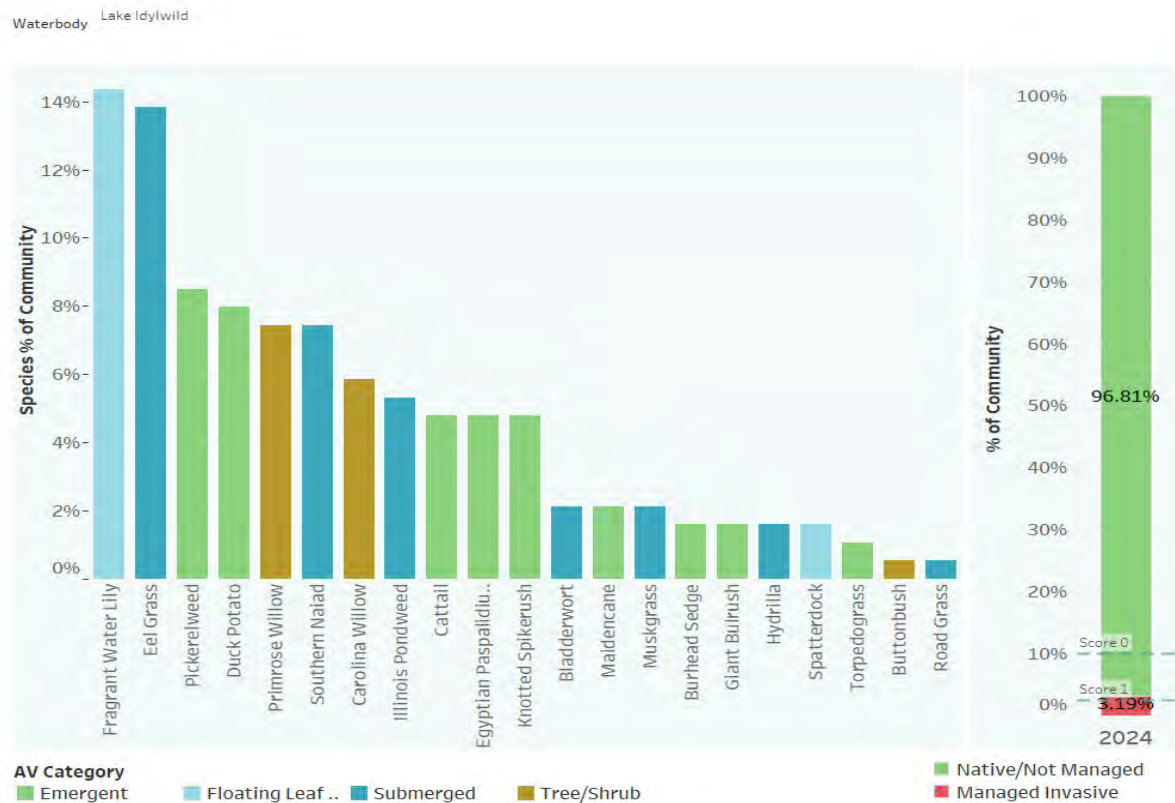


Figure 3-121. Chart depicting species frequency and invasive species percentage of Lake Idylwild during 2024.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Lake Idylwild's diversity indices exceeded their respective median values (Figure 3-122). This equates to a diversity criterion score of 3. In general, the shifts in the vegetation community are the result of natural processes since invasive species management is minimal. Continued monitoring should be prioritized to prevent the spread of invasive species in the future.

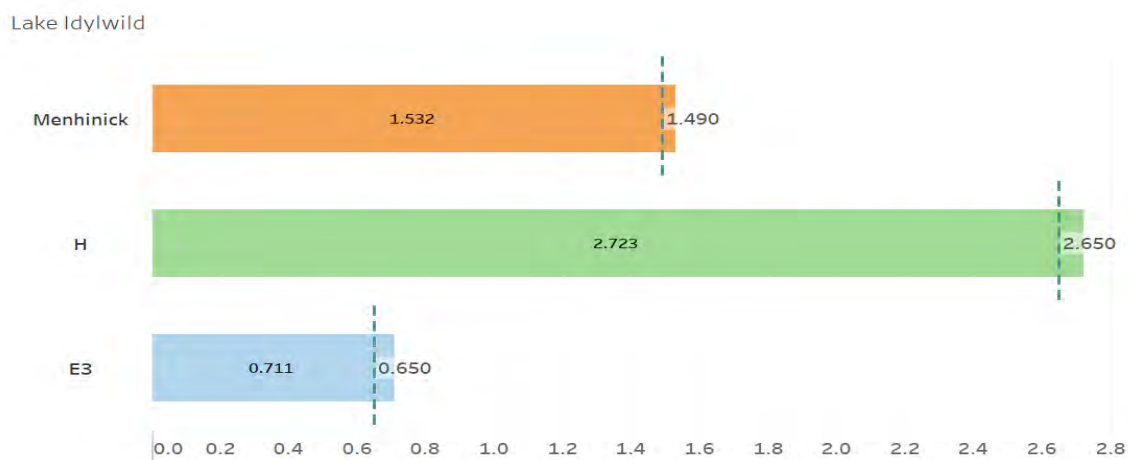


Figure 3-122. Chart depicting 2024 diversity indices for Lake Idylwild. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Idylwild's health index scores from 2018 to 2024 shows general improvement (Figure 3-123). The majority of this has come from water quality improvements. TN began meeting the NNC guidelines in 2020—resulting in impairment score increases. The trend scores in all parameters have also improved since monitoring began. Lake Idylwild consistently maintains excellent vegetation abundance. The continual cycle of invasive species resurgence and treatment creates the annual fluctuations in the invasive and diversity scores. Ultimately, Lake Idylwild's lake health scores have been somewhat higher than average—placing it lower on the priority ranking.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	1	2	1	3	2	3	2	1	1.9
2019	1	2	1	2	3	3	1	3	2.0
2020	1	2	2	2	3	3	1	0	1.8
2021	2	2	2	2	3	3	1	2	2.1
2022	2	2	2	2	3	3	1	2	2.1
2023	2	3	2	3	3	3	1	3	2.5
2024	2	3	2	3	3	3	1	3	2.5

Figure 3-123. Chart depicting a comparison of Lake Idylwild's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- While water quality is improving, managing stormwater runoff is important for the continued control of nitrogen and phosphorus loading to Lake Idylwild.
- Several water quality metrics are significantly correlated with Lake Idylwild's surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species like hydrilla is a constant concern. It can only take a single season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.
- The City currently conducts street sweeping in the basin to combat stormwater pollutant loads. Residential education campaigns can be implemented to promote green stormwater infrastructure and reduce pollutant loads from urban stormwater runoff.

Lake Jessie

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Jessie	0	2	1	2	1	3	0	1	1.3

Features & Statistics:

Surface area	185 acres
Mean depth	7.9 feet
Maximum depth	10 feet
Volume	1697.1 acre-feet
Drainage basin area	973.4 acres
Annual TN Load	3871.2 lbs
Annual TP Load	652.3 lbs
Limiting nutrient	Co-limited (N & P)

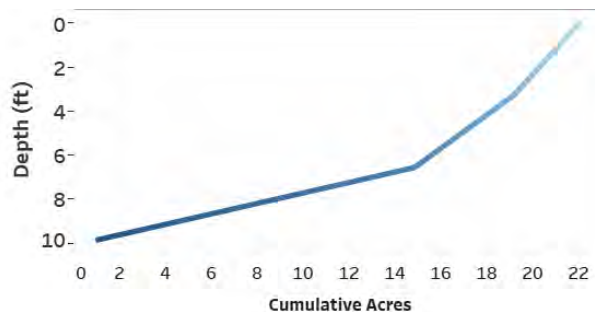


Figure 3-124. Hypsograph of Lake Jessie depicting the depth profile and morphology of the lake bed.

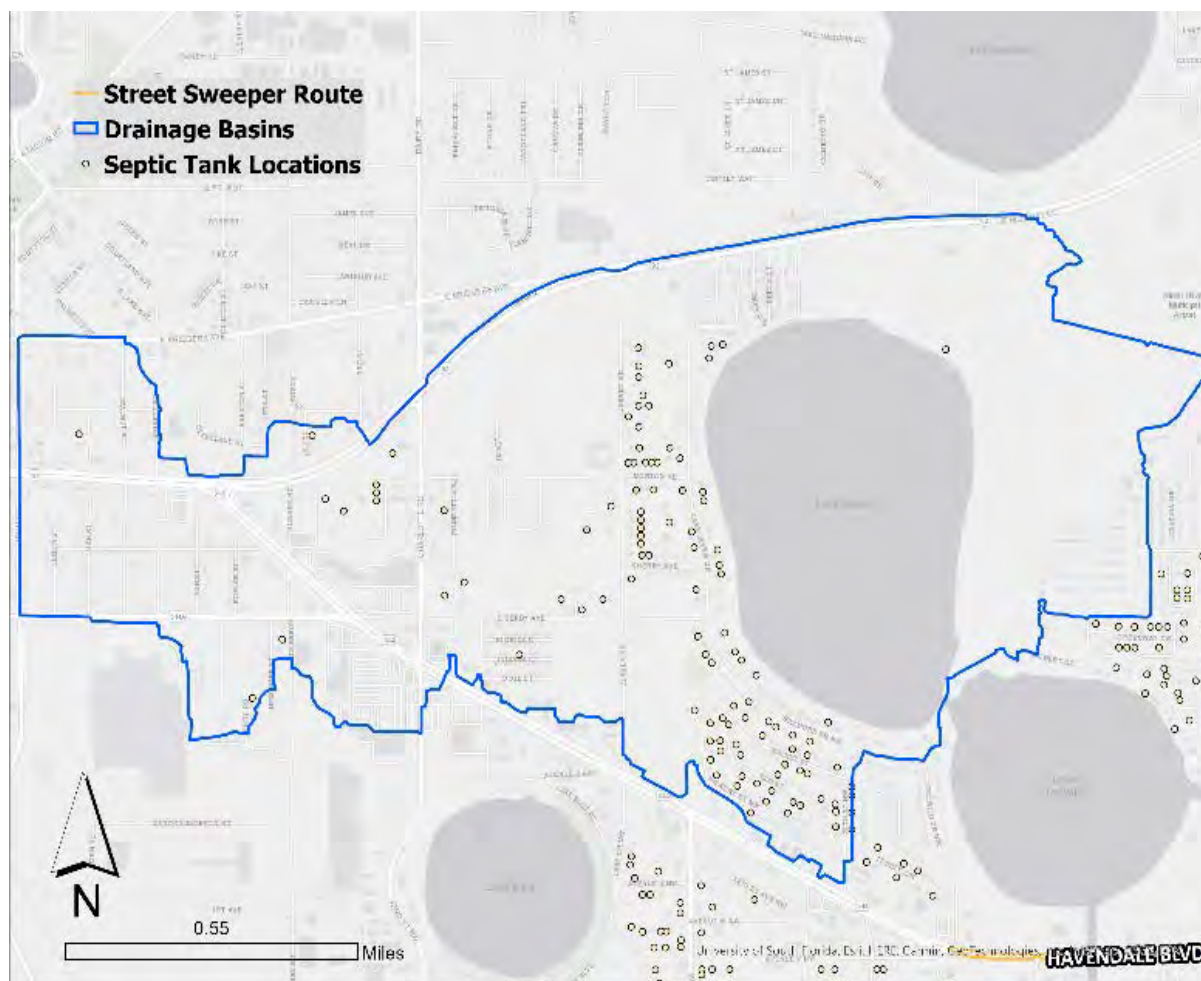


Figure 3-125. Map of Lake Jessie's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Jessie is a moderately sized, but shallow waterbody at 185 acres, an average depth of 8 feet, and a maximum depth of around 10 feet (Figure 3-124). The shallow depth provides ample viable space for aquatic vegetation to grow, but also makes sediment suspension from wind action more likely. Stormwater is conveyed to this waterbody from a 1600 acre drainage basin comprised of a mix of residential, commercial, and agricultural land uses (Figure 3-125). Based on pollutant load modelling, these land uses contribute 3,871 lbs of TN and 652 lbs of TP to Lake Jessie annually. Due to the size of the drainage basin in relation to the lake, these pollutant loads rank 11th out of 37 on a per acre basis. There are 111 septic systems present within the unincorporated Polk County side of the drainage basin. This constitutes a relatively high density and a potential nutrient source via septic leaching into groundwater. Lacking City-owned roadways or stormwater infrastructure on the east side of the lake, the City does not conduct any street sweeping services within this basin.

Lake Jessie is part of the South Chain of Lakes with a navigable connection to Lake Idylwild to the southeast. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-126). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Jessie's surface level correlate with Chl-a, TN, and clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

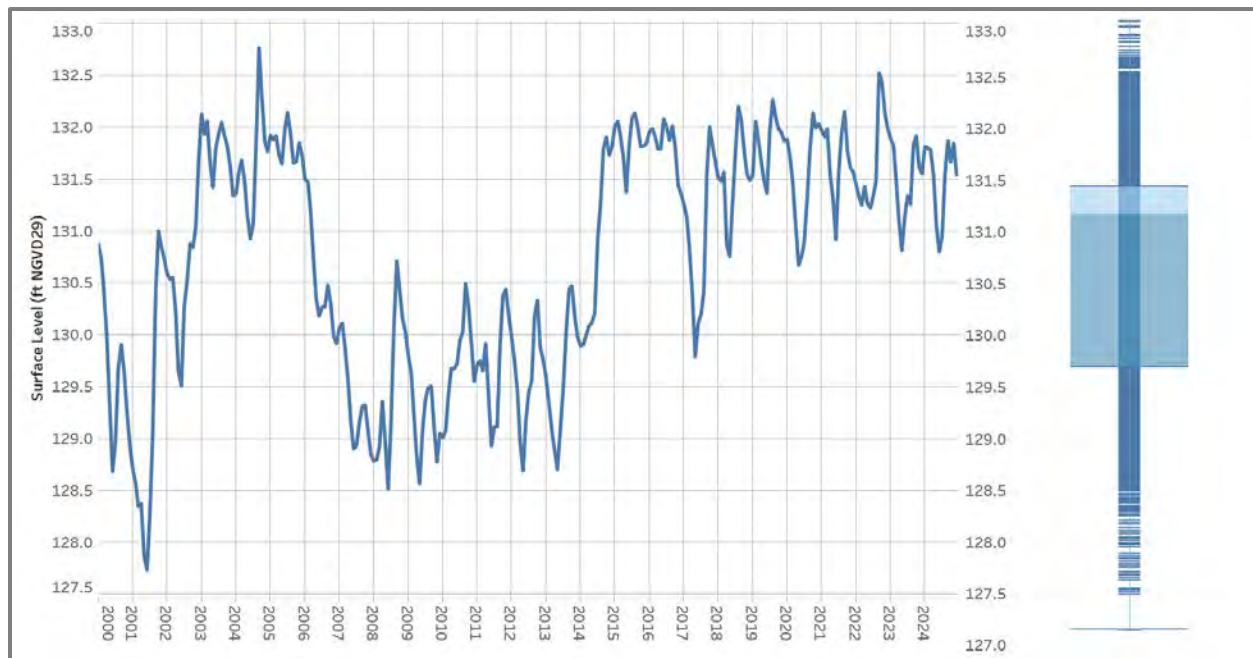


Figure 3-126. Hydrograph of Lake Jessie depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface levels during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Jessie is categorized as a clear, alkaline waterbody. Due to multiple consecutive NNC exceedances during the assessment period, Lake Jessie is considered impaired for Chl-a, TN, and TP. This results in an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load for Lake Jessie, stipulating a 12% reduction in TN to meet NNC guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.223	0.331	No Trend	0	2
TN	Y	0.054	0.816	No Trend		1
TP	Y	-0.351	0.119	No Trend		2
Secchi	NA	-0.040	0.862	No Trend		1

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. None of these parameters exhibited statistically significant trends. Whereas, Chl-a and TN earn a trend criteria score of 1 for their non-significant deteriorating trends and Secchi depth receives a criteria score of 2 for improving trend (Figure 3-127). Individual AGM values and trend statistics can be found in the appendix.



Figure 3-127. Lake Jessie AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Jessie on 2/20/2024. The PAC during this survey was 86.3% and the total BV was 14.2%; exhibiting little change from the previous year (Figure 3-128). A comparison of abundance data from 2018 to 2024 indicates that Lake Jessie consistently maintains coverage above 30%. This is unsurprising due to the gradual slope of the

lake bed allowing for a wide littoral zone. The result is a vegetation abundance criterion score of 3.

Invasive Species Management:

Based on data from the 2024 survey, Lake Jessie is clearly dominated by eelgrass, making up 21% of species (Figure 3-129). The remaining plants are comprised of a mix of emergent, submerged, and floating leaf. Unfortunately, the proportion of invasive species increased from 6% in 2023 to 11% in 2024. The invasives present include hydrilla and burhead sedge. This has resulted in an invasive criterion score of 0 and indicates the need for management action to prevent further spread.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 survey, the species evenness and overall diversity indices met or exceeded their long-term median values (Figure 3-130). The number of unique species (i.e. 23) is high compared with the other study lakes. However, a couple of less abundant species were not detected in 2024, resulting in a relatively lower richness index value for Lake Jessie. Due to this, the 2024 diversity criterion score for Lake Jessie is 2.

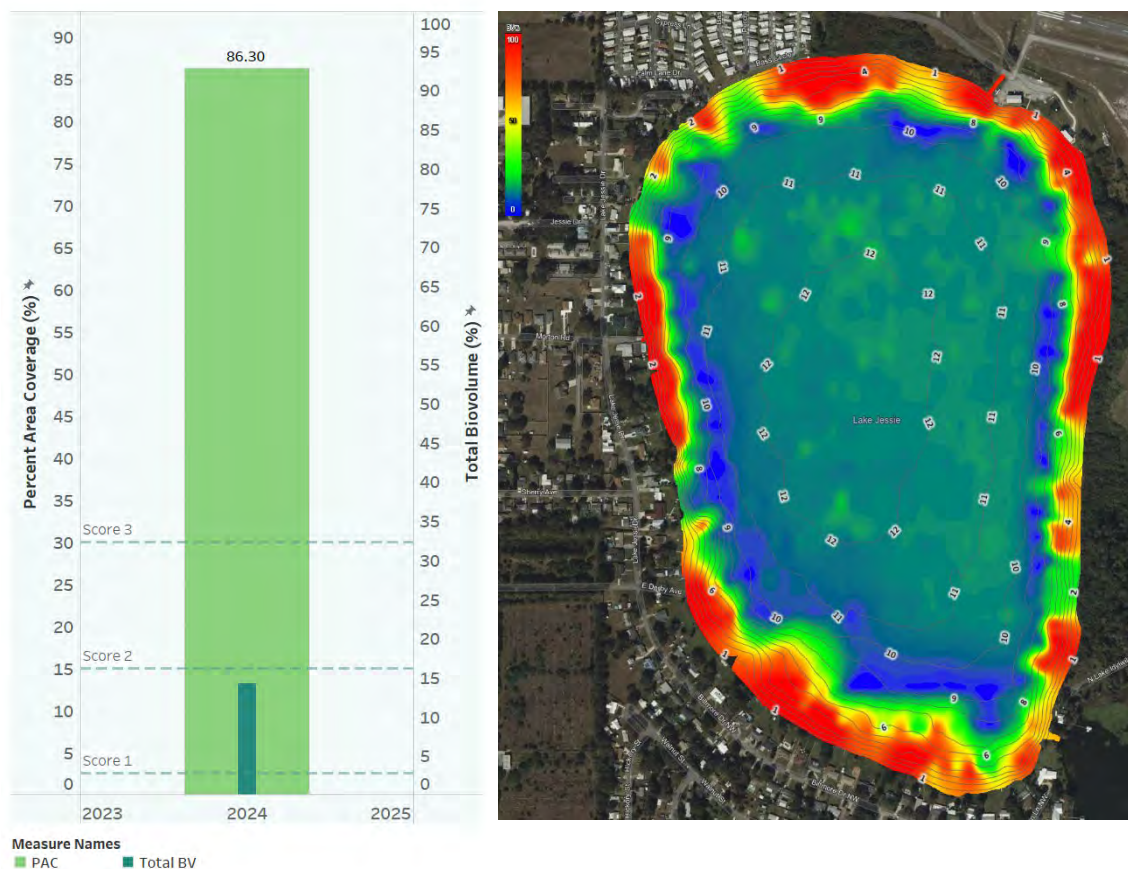


Figure 3-128. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Jessie; biovolume values range from green (lowest) to red (highest).

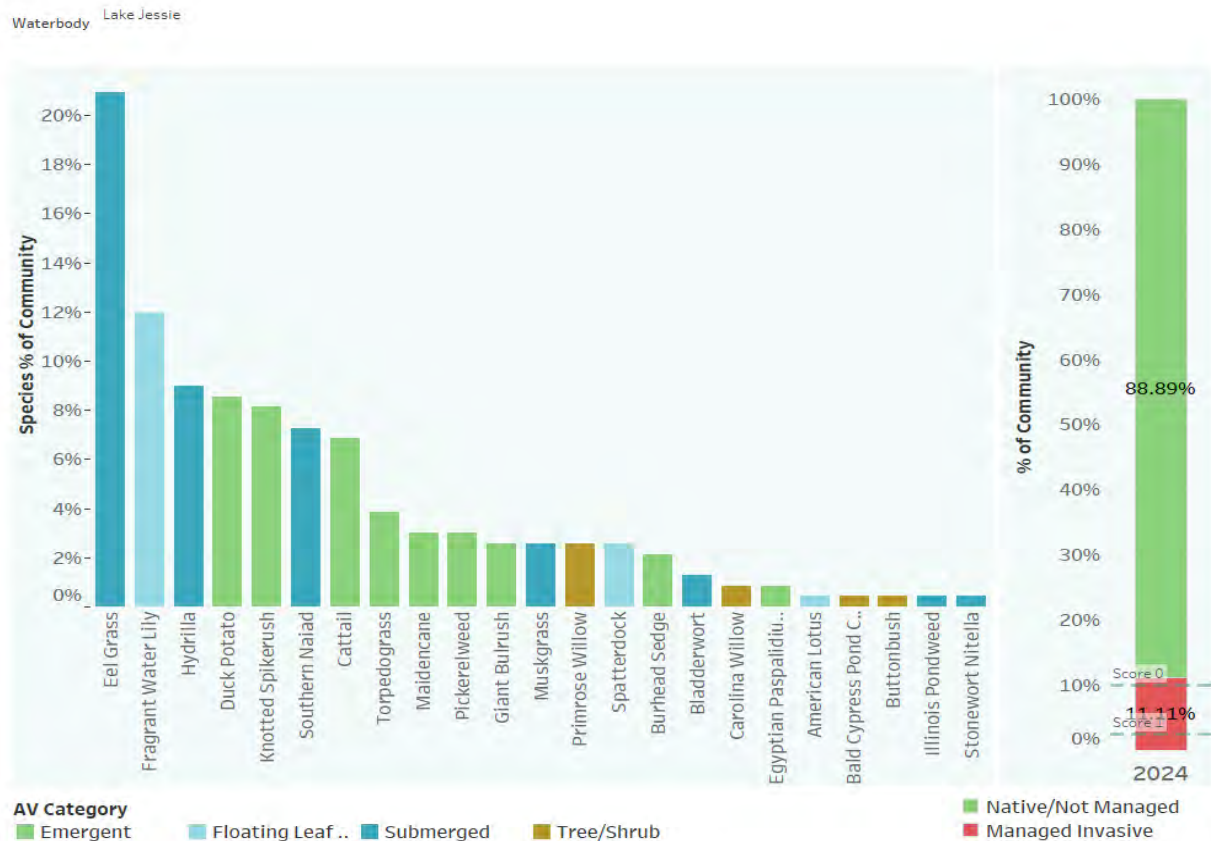


Figure 3-129. Chart depicting species frequency and invasive species percentage of Lake Jessie during 2024.

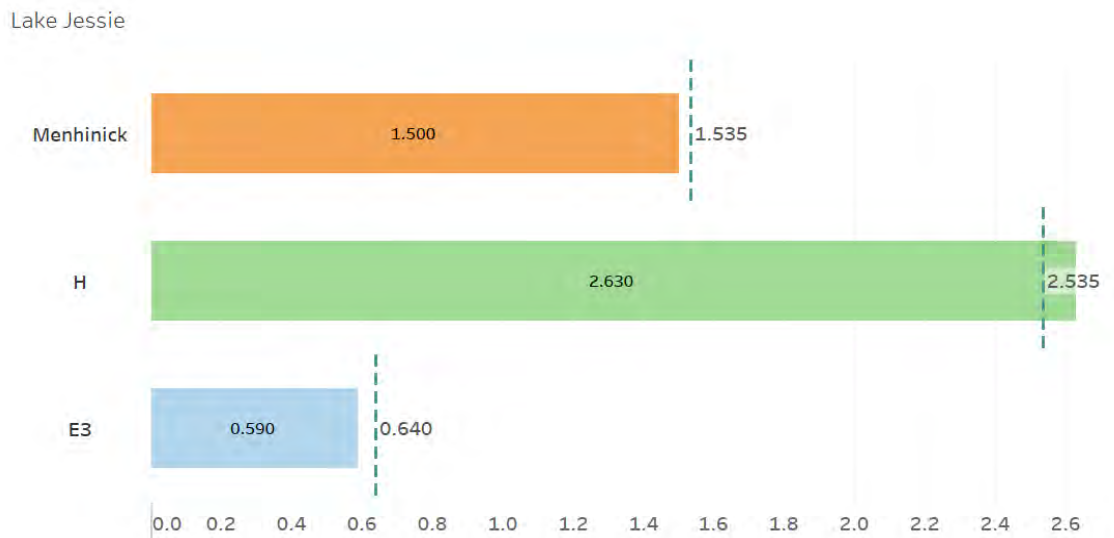


Figure 3-130. Chart depicting 2024 diversity indices for Lake Jessie. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Jessie's health index scores from 2018 to 2024 some variability (Figure 3-131). While impairment criterion scores have not changed in this five year span, trend scores have fluctuated somewhat. Most notable are the improvement to the Chl-a trend statistics. The

majority of the score variance has come from invasive species presence and species diversity. This is likely a reflection of changes in the vegetation community, due in part to the invasive species management efforts. Lake Jessie's water quality and invasive management issues place it higher on the City's priority list for management action.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	3	2	3	2	1	1.6
2019	0	1	1	2	2	3	1	3	1.6
2020	0	1	1	2	2	3	1	0	1.3
2021	0	2	1	2	2	3	0	1	1.4
2022	0	1	1	2	2	3	1	1	1.4
2023	0	2	1	3	2	3	1	2	1.8
2024	0	2	1	2	1	3	0	1	1.3

Figure 3-131. Chart depicting a comparison of Lake Jessie's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- In addition to stormwater pollutant loading, there are reports of historic wastewater treatment plant discharges for this waterbody. The volume and time frame for these discharges is unconfirmed, however. Regardless, these historic point-source pollutants could be impacting water quality now.
- The density of OSTDs within this basin could be a source for nutrient pollutant loading if they are leaching into the nearby water table.
- Several water quality metrics are significantly correlated with Lake Jessie's surface level, likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species is a constant concern for this waterbody. While invasive presence is low this year, it can take a single growing season for many of these species to take over large areas of the lake.

Lake Management Strategy:

- City staff may explore source analysis of both the historic point source and OSTD pollutant loading. Future management actions may involve sediment removal/inactivation and/or septic-to-sewer conversion.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Reducing the recent hydrilla infestation is necessary to get Lake Jessie back into a maintenance routine comprised of smaller-scale treatments that will have less water quality and habitat impacts.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Link

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Link	3	1	2	1	2	2	3	1	1.9

Features & Statistics:

Surface area	27.7 acres
Mean depth	8.84 feet
Maximum depth	22 feet
Volume	257 acre-feet
Drainage basin area	63.1 acres
Annual TN Load	197.2 lbs
Annual TP Load	31.7 lbs
Limiting nutrient	Phosphorus

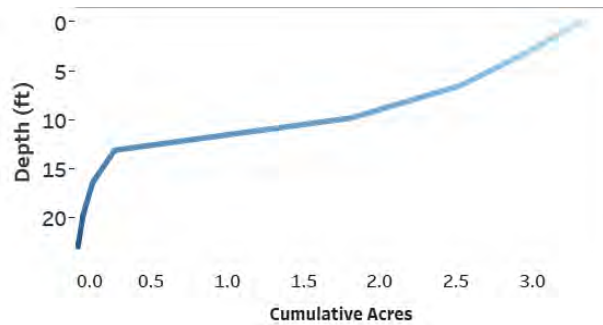


Figure 3-132. Hypsograph of Lake Link depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Link is a small but deep waterbody at 28 acres, an average depth of 8.8 feet, and a maximum depth of 22 feet (Figure 3-132). This is representative of a classic sinkhole lake, but the steep slopes of the lake bed limits the available habitat for aquatic plant growth. Stormwater is conveyed to this waterbody from a 63-acre drainage basin comprised of four separate sub-basins (Figure 3-133). Made up almost entirely of residential land uses, the drainage basin contributes 197 lbs of TN and 32 lbs of TP to Lake Link annually. On a per acre basis, these loading rates rank 25th out of the 37 area lakes. There are 15 septic systems present within Link's drainage basin. This constitutes a low density and likely doesn't contribute much pollutant loading. To combat stormwater loading, the City conducts street sweeping services of 2.9 miles per month along the north side of the drainage basin.

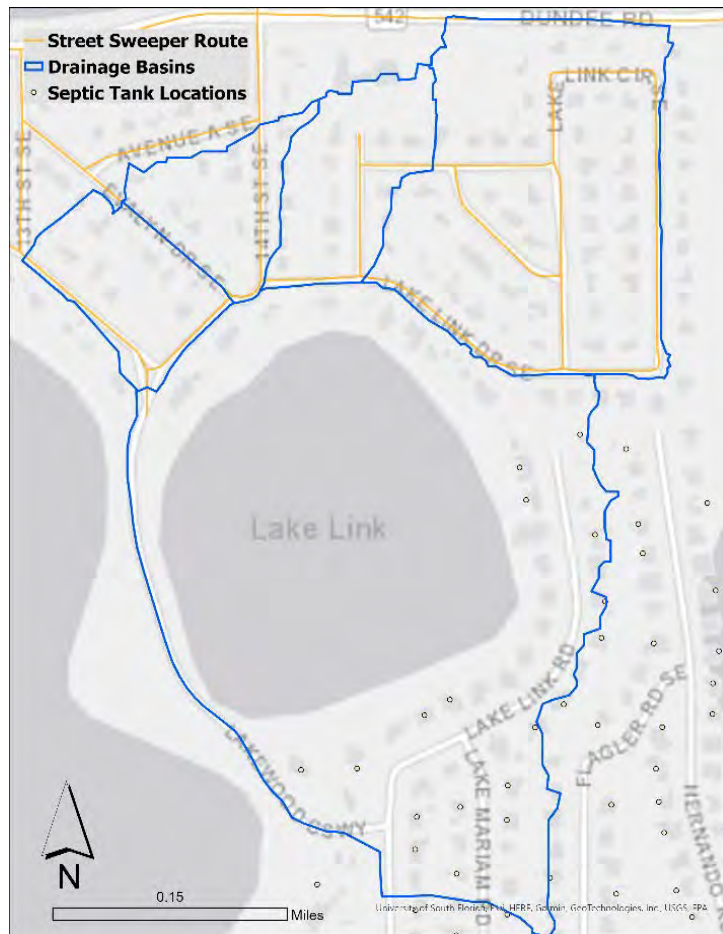


Figure 3-133. Map of Lake Link's drainage basin, City street sweeper routes, and nearby septic systems.

Lake Link is connected to Lake Otis via a navigable canal and overflows via underground pipe to Lake Mariam. The surface elevation of these two lakes sits near the bottom of the Peace Creek watershed. Over its period of record, the shared surface level of Lakes Link and Otis has fluctuated between 120.3 and 128.8 feet above sea level. The wide range of fluctuation is possible because of the steep-sloped morphology of these lakes. The normal range of fluctuation is much narrower—between 124.9 and 127.2 feet (Figure 3-134). During 2024, Lake Link reached its peak of 126.4 feet in June and plummeted to a low of 125 feet in November; ending the year near the low end of the normal range at 125.2 feet. This is strange due to the tremendous amount of rainfall received during the 2024 hurricane season. It is likely that the Lake Region Lakes Management District opened the control structure to lower the lake level prior to the storms. According to linear regression analysis, changes in Lake Link's surface level are inversely correlated with TN and TP concentrations (see appendix). This carries management implications as an increase in level should result in improved water quality.

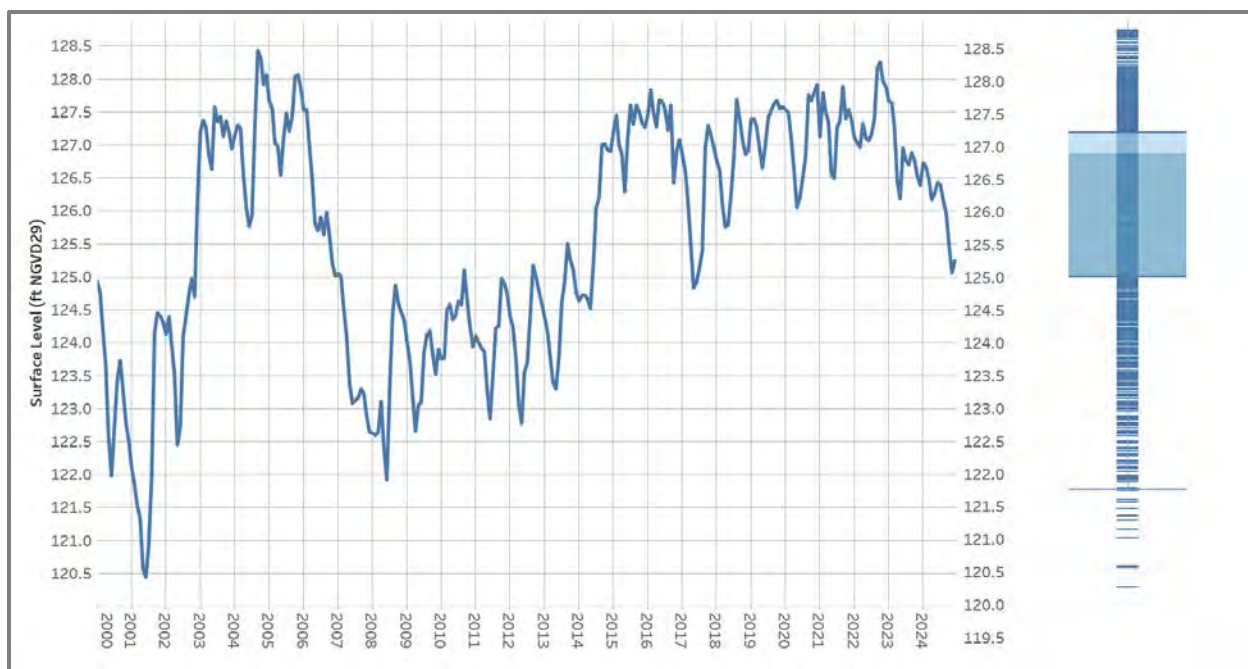


Figure 3-134. Hydrograph of Lake Link depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria, Lake Link is categorized as a clear, alkaline waterbody. Based on the water quality data, Lake Link has not exhibited NNC exceedances in any of the primary water quality parameters during the assessment period (Figure 3-135). This equates to an impairment criterion score of 3.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	0.418	0.107	No Trend	3	1
TN	N	-0.104	0.703	No Trend		2
TP	N	0.071	0.794	No Trend		1
Secchi	NA	-0.483	0.058	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. None of the parameters exhibited statistically significant trends. However, TN and Secchi depth are moving in a generally improving direction while Chl-a and TP are moving in a deteriorating direction. These trends aren't worrisome considering Lake Link's water quality is currently meeting intended use standards.

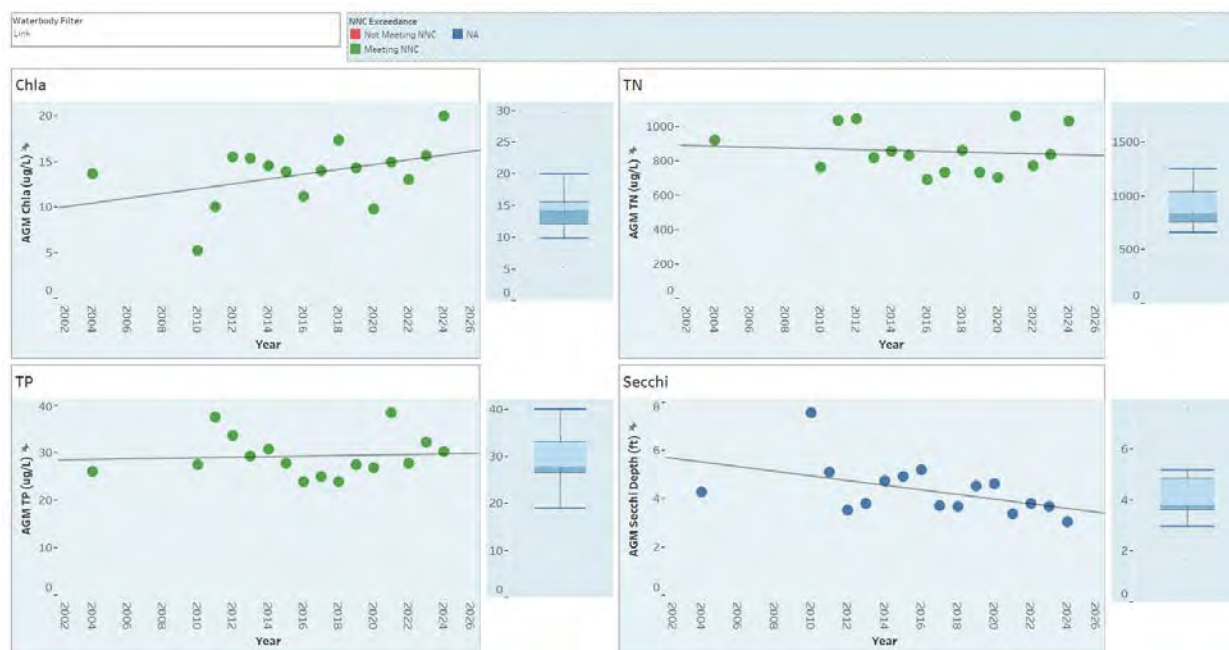


Figure 3-135. Lake Link AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Link on 9/6/2024. The PAC during this survey was 25.8% and the total BV was 3.6% (Figure 3-136). This was a slight decrease in coverage from the previous year and equates to an abundance criterion score of 2. Over the period of record, Lake Link has had generally high abundance values. Management of invasive species like hydrilla is the primary driver behind changes in coverage and biovolume.

Invasive Species Management:

Based on the 2024 survey, Lake Link possessed a fairly even mix of emergent, floating-leaf and submerged species. While SAV was previously much more prominent, invasive management efforts have reduced their numbers somewhat (Figure 3-137). Fortunately, no managed invasives were detected in 2024—highlighting an effective hydrilla treatment in the previous year. This equates to an invasive criterion score of 3, but continued monitoring is necessary for early detection and rapid response to any future outbreaks.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Due to the reduction in the invasive species previously present, Lake Link's species richness and overall diversity indices were lower than the median (Figure 3-138). The evenness index value indicates a more equal spread of unique species in 2024, however. These index values equate to a diversity criterion score of 1.

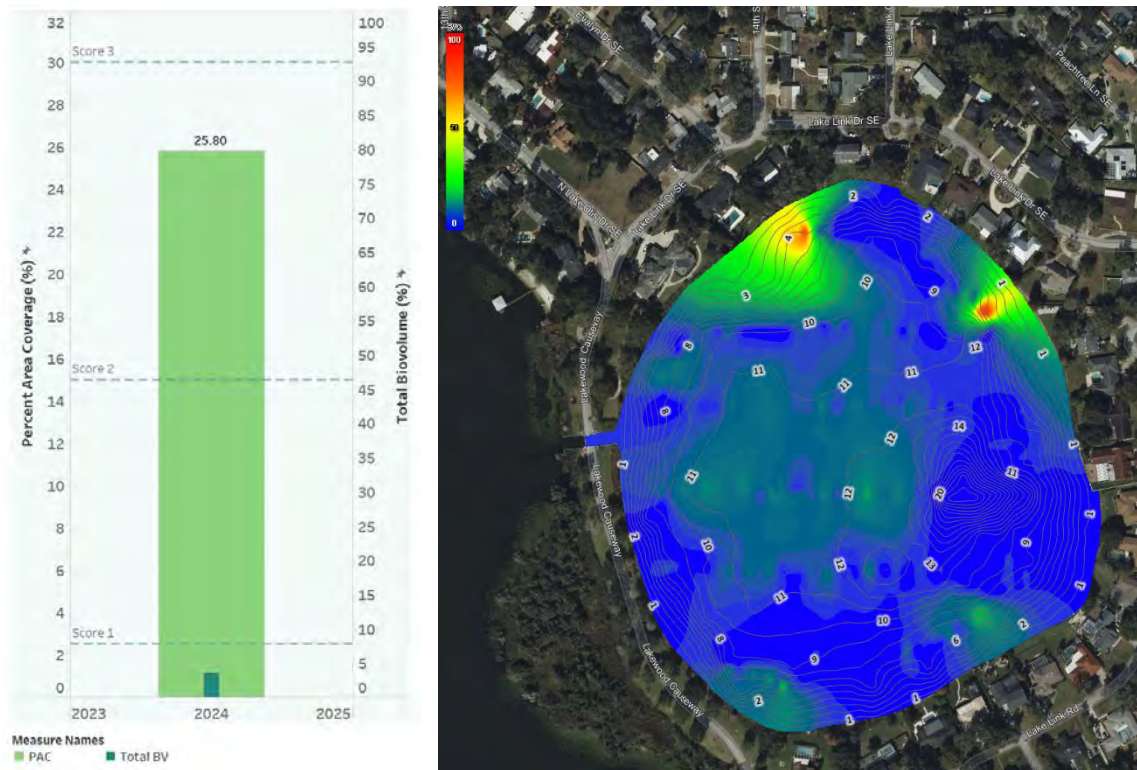


Figure 3-136. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Link; biovolume values range from green (lowest) to red (highest).

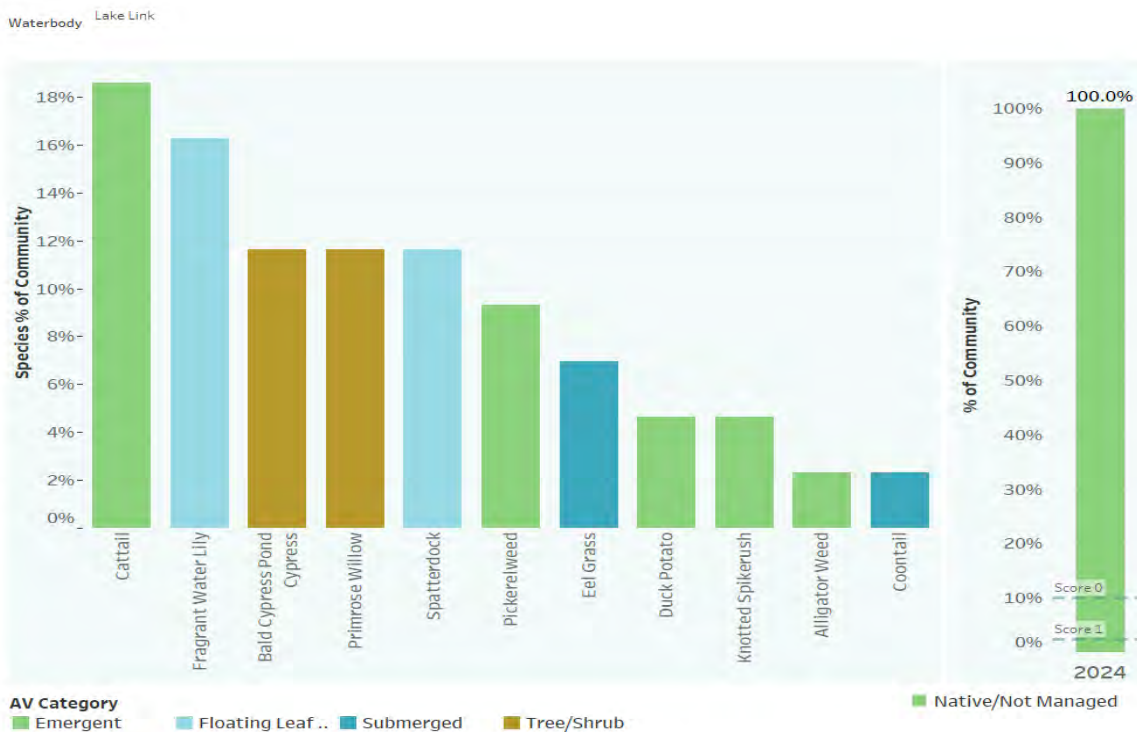


Figure 3-137. Chart depicting species frequency and invasive species percentage of Lake Link during 2024.

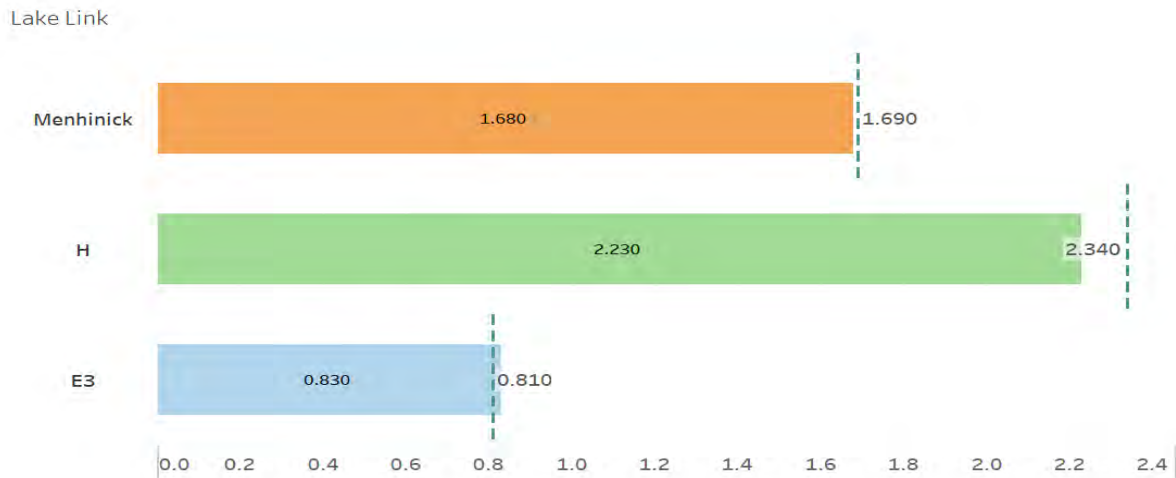


Figure 3-138. Chart depicting 2024 diversity indices for Lake Link. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Link's health index scores from 2018 to 2024 shows some decline over time (Figure 3-139). While this is a decrease in overall lake health, it should be noted that the 2019 and 2020 scores were artificially higher due to a lack of biological data to balance the water quality scores. Based on the 2018 score, it appears that invasive species management has been a constant issue. The treatment of invasive species has likely caused the declines in abundance and diversity. It remains to be seen if these effects will continue into subsequent years. While there have been downward shifts in the trend scores, these are concerning since the lake doesn't exhibit impairments and the increasing trajectories of Chl-a and TP aren't statistically significant. However, management action should be considered if these trends become more pronounced in the future.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	2	3	2	2	3	0	2	2.1
2019	3	2	3	2	2	NA	NA	NA	2.4
2020	3	2	3	2	2	3	NA	NA	2.5
2021	3	2	3	2	2	2	1	1	2.0
2022	3	2	3	2	2	2	1	1	2.0
2023	3	1	2	1	1	3	2	1	1.8
2024	3	1	2	1	2	2	3	1	1.9

Figure 3-139. Chart depicting a comparison of Lake Link's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Link currently exhibits healthy water quality. However, pollutant loading via stormwater is a potential concern if water quality trends begin deteriorating.
- The management of invasive species like hydrilla has been a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- Several water quality metrics are significantly correlated with Lake Link's surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City currently conducts street sweeping in the northern drainage sub-basins. Since much of the zoning in this basin is residential, public outreach and education are ideal management strategies. Education aims to increase residents' knowledge of best stormwater practices and ways they can collectively reduce their pollutant load.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Lulu

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Lulu	0	3	3	3	3	3	1	3	2.4

Features & Statistics:

Surface area	307.5 acres
Mean depth	6.8 feet
Maximum depth	10 feet
Volume	2093.6 acre-feet
Drainage basin area	1006.5 acres
Annual TN Load	2791.5 lbs
Annual TP Load	483 lbs
Limiting nutrient	Phosphorus

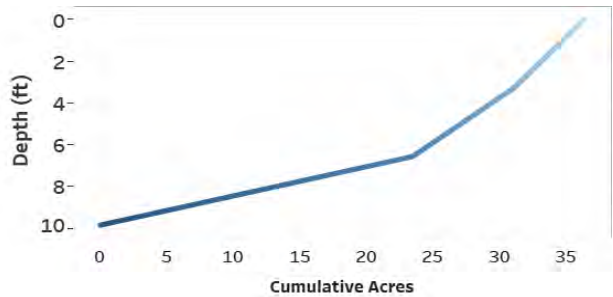


Figure 3-140. Hypsograph of Lake Lulu depicting the depth profile and morphology of the lake bed.

Hydrology:

One of the larger waterbodies on the South Chain, Lake Lulu has a total area of 307 acres. While large, Lulu is one of the shallower lakes with a mean depth of 6.8 feet and a maximum depth of 10 feet (Figure 3-140). The shallowness of the lake makes it much more susceptible to sediment suspension via wind and wave action. Stormwater is conveyed to this waterbody from a 1,006 acre drainage basin comprised of 13 individual sub-basins (Figure 3-141). The primary land uses in this drainage area are commercial, wetlands and residential which contribute 2,791 lbs of TN and 483 lbs of TP to Lake Lulu annually. Though these loads rank on the low side compared with the other 36 lakes in the study area. There are 46 septic systems located within the County portion of the basin. This constitutes a moderate density which can have potential impacts on water quality. To combat stormwater pollutant loading, the City conducts 11.6 miles of street sweeping monthly for residential roads and twice monthly for larger roadways.



Figure 3-141. Map of Lake Lulu's drainage basin, City street sweeper routes, and nearby septic systems.

Lake Lulu is centrally located on the South Chain with navigable connections to Lakes Eloise and Shipp. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-142). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Lulu's surface level correlate with TN and clarity (see appendix). This carries management implications as an increase in levels should result in improved water quality.

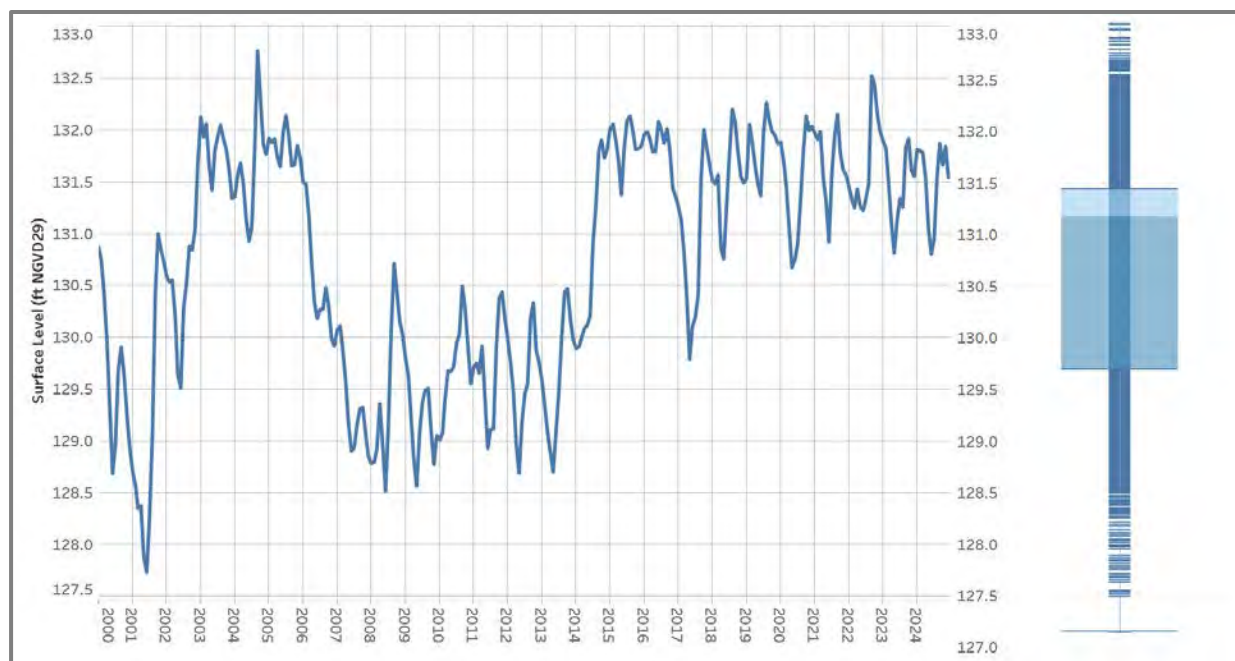


Figure 3-142. Hydrograph of Lake Lulu depicting monthly surface level readings from 2000 to 2024. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Lulu is categorized as a clear, alkaline waterbody. Due to consistent NNC exceedances during the assessment period, Lake Lulu is considered impaired for Chl-a, TN, and TP (Figure 3-143). This equates to an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load for Lake Lulu stipulating a 35% reduction in TN in order to meet NNC guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.659	0.001	Decreasing	0	3
TN	Y	-0.532	0.013	Decreasing		3
TP	Y	-0.686	0.001	Decreasing		3
Secchi	NA	0.545	0.011	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on these data, all four of these parameters exhibit significant improving trends. While on the right track, it will still take some time for water quality values to consistently meet NNC guidelines for Lake Lulu to be considered unimpaired.



Figure 3-143. Lake Lulu AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Lulu on 7/2/2024. The PAC during this survey was 46.2% and the total BV was 1%; though such a low BV value may be due to a processing error (Figure 3-144). This equates to a vegetation abundance criterion score of 3. Lake Lulu has traditionally supported high vegetation abundance due to its shallow depth and gradually sloping lake bed.

Invasive Species Management:

Based on data from the 2024 survey, Lake Lulu maintains a healthy mix of submerged, emergent, and floating leaf plants. The most dominant species present is the native fragrant water lily around 12% (Figure 3-145). Hydrilla was the only managed invasive species detected during the survey at 2.6%; earning an invasive criterion score of 1. Throughout the period of record, the invasive presence in Lake Lulu has traditionally fluctuated between zero and four percent—requiring continual maintenance to keep invasives from expanding.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Lake Lulu's diversity indices met or exceeded their respective median values; equating to a diversity criterion score of 3 (Figure 3-145). The overall vegetation community has been relatively diverse through the period of record, with over 22 unique species detected. A portion of this diversity may be due to the

undeveloped shoreline to the south of the lake. A lack of disturbance on this shoreline may provide an opportunity for smaller or less robust species to survive.

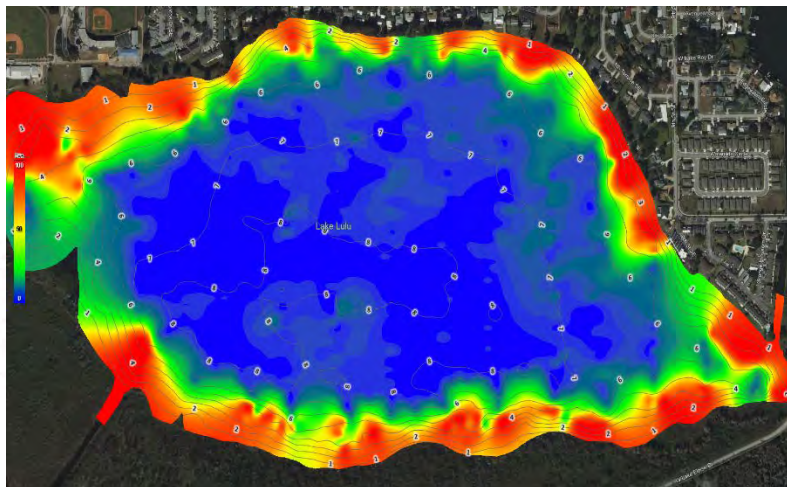
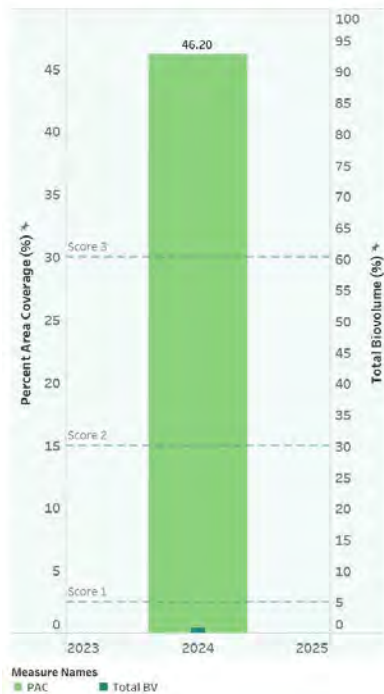


Figure 3-144. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Lulu; biovolume values range from green (lowest) to red (highest).

Waterbody Lake Lulu

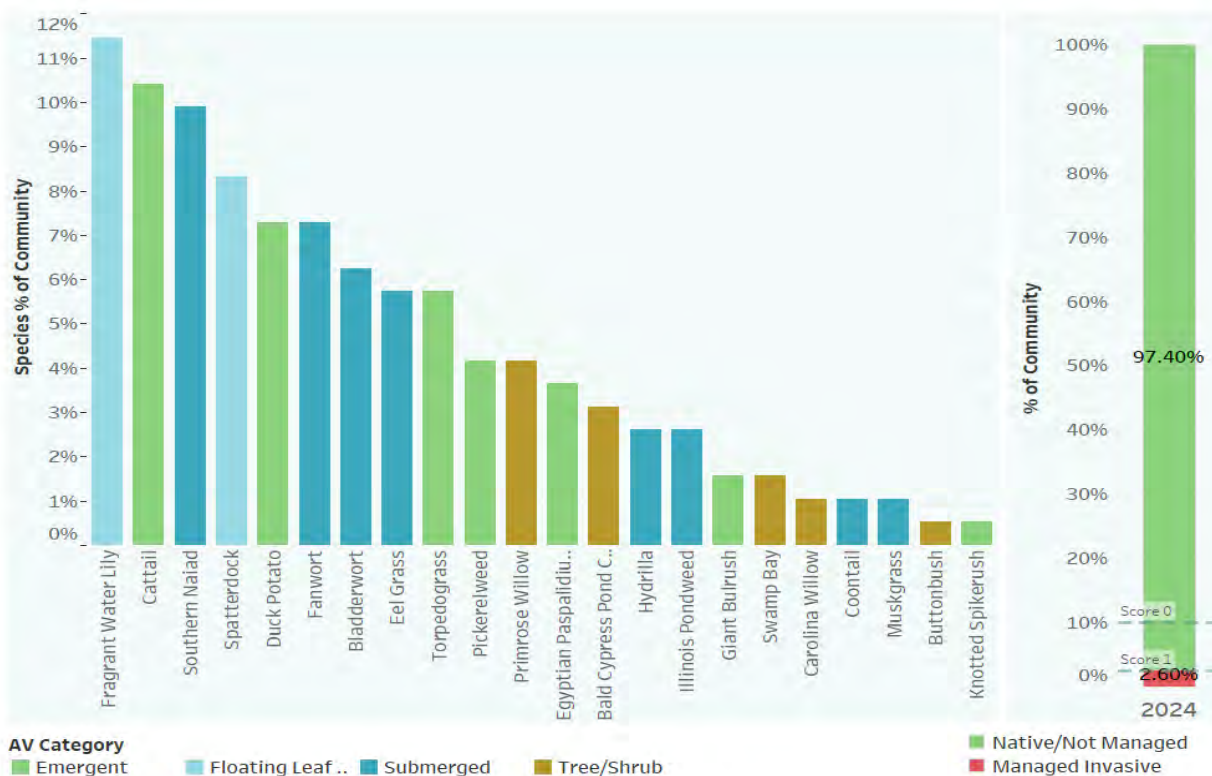


Figure 3-145. Chart depicting species frequency and invasive species percentage of Lake Lulu during 2024.

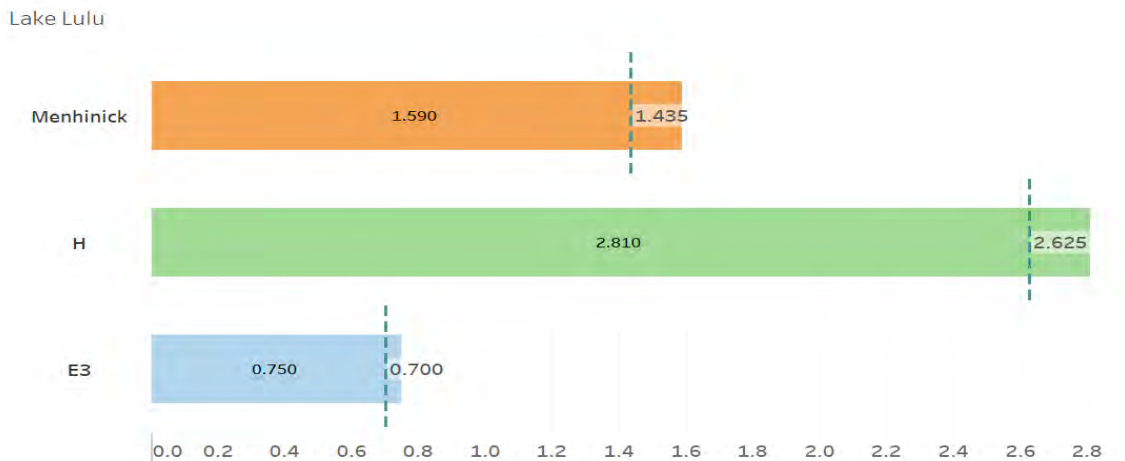


Figure 3-146. Chart depicting 2024 diversity indices for Lake Lulu. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Lulu's health index scores from 2018 to 2024 shows some improvement, increasing from 2.1 to 2.4 (Figure 3-147). Regarding the water quality metrics, impairment hasn't changed. However, TN concentrations began to exhibit significant improving trends starting in 2020. From a biological perspective, Lake Lulu has consistently maintained high vegetation abundance. However, the invasive presence and diversity metrics have been the largest source of score fluctuation. This is mostly due to cycles of invasive expansion and subsequent management efforts. Overall, Lake Lulu is lower on the priority list, but also a lake on which to keep a close eye to ensure that it continues to improve.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	2	3	3	3	1	1	2.0
2019	0	3	2	3	3	3	2	1	2.1
2020	0	3	3	3	3	3	3	1	2.4
2021	0	3	3	3	3	3	2	3	2.5
2022	0	3	3	3	3	3	1	3	2.4
2023	0	3	3	3	3	3	1	3	2.4
2024	0	3	3	3	3	3	1	3	2.4

Figure 3-147. Chart depicting a comparison of Lake Lulu's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- In addition to stormwater and potential septic pollutant loads, Lake Lulu received historic point-source discharges from a now defunct City wastewater treatment plant as well as several citrus fertilizer processing facilities. These historic pollutant loads may contribute to internal nutrient loading from the legacy sediments.
- The management of invasive species remains a consistent concern. Species like hydrilla can take over large areas of a waterbody in a single growing season.

- Several water quality metrics are significantly correlated with Lake Link's surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- City staff may explore source analysis of both the historic point-source and septic pollutant loading. Future management actions may involve sediment removal/inactivation, septic-to-sewer conversion, and stormwater infrastructure improvements.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- In addition to street sweeping, the City combats stormwater loading through an alum injection system designed to reduce TN loads by 8% and TP loads by 21% annually.

Lake Mariam

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Mariam	3	0	2	1	1	3	1	1	1.5

Features & Statistics:

Surface area	203.7 acres
Mean depth	4.65 feet
Maximum depth	6.5 feet
Volume	820.9 acre-feet
Drainage basin area	622.1 acres
Annual TN Load	1609.45 lbs
Annual TP Load	274.8 lbs
Limiting nutrient	Co-limited (N & P)

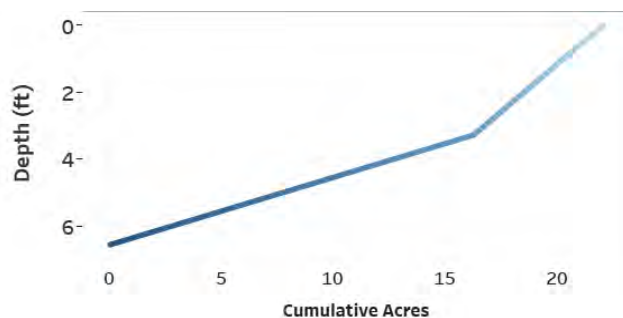


Figure 3-148. Hypsograph of Lake Mariam depicting the depth profile and morphology of the lake bed.

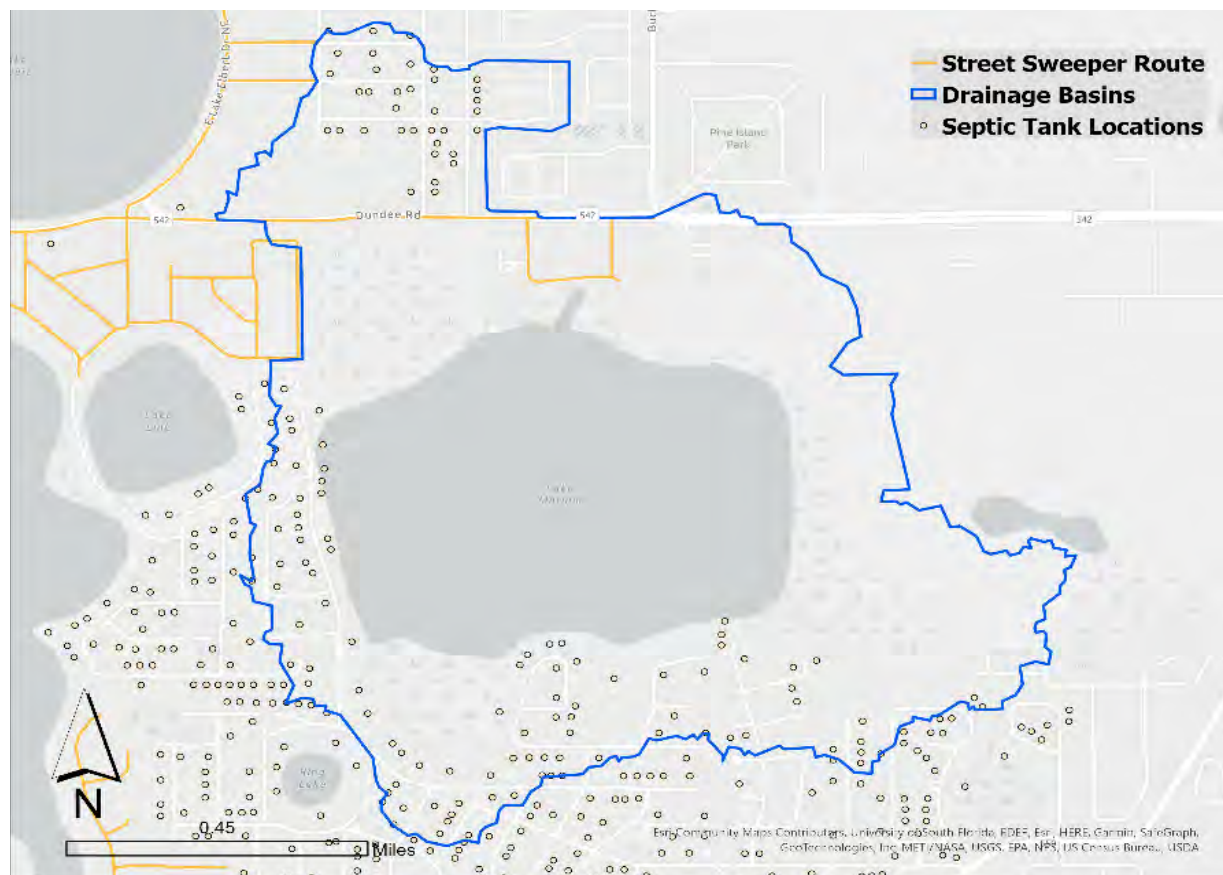


Figure 3-149. Map of Lake Mariam's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Mariam is a moderately sized, but very shallow waterbody at 203 acres, an average depth of 4.6 feet, and a maximum depth of around 7 feet (Figure 3-148). The shallow nature of this waterbody likely contributes to higher sediment suspension and while it should support a large amount of vegetation, the higher turbidity likely prevents many species from receiving sunlight through the water column. Stormwater is conveyed to this waterbody from a 622 acre drainage basin comprised of wetlands, residential and commercial land uses (Figure 3-149). This basin contributes 1,609 lbs of TN and 275 lbs of TP to Lake Mariam annually; but on a per acre basis, these pollutant loads rank 32nd out of 37 lakes. There are 132 septic systems located within this drainage area which is fairly dense and may be a potential contributor of nutrient loading via groundwater leaching. To combat stormwater loading, the City conducts 1.9 miles of street sweeping twice monthly on Dundee Rd.

Lake Mariam receives excess water from Lake Link and discharges overflow to the Peace Creek via a network of ditches. Its surface elevation sits second lowest within the Peace Creek watershed. Over the period of record, Lake Mariam's surface level has fluctuated between 120.5 and 125.8 feet above sea level. The normal range for this waterbody is between 122.2 and 124.5 feet (Figure 3-150). During 2024, Lake Mariam's level dropped 122.6 feet in June and rose to a wet season high of 124.1 feet in November. Changes in Lake Mariam's surface level are not correlated with its water quality metrics.

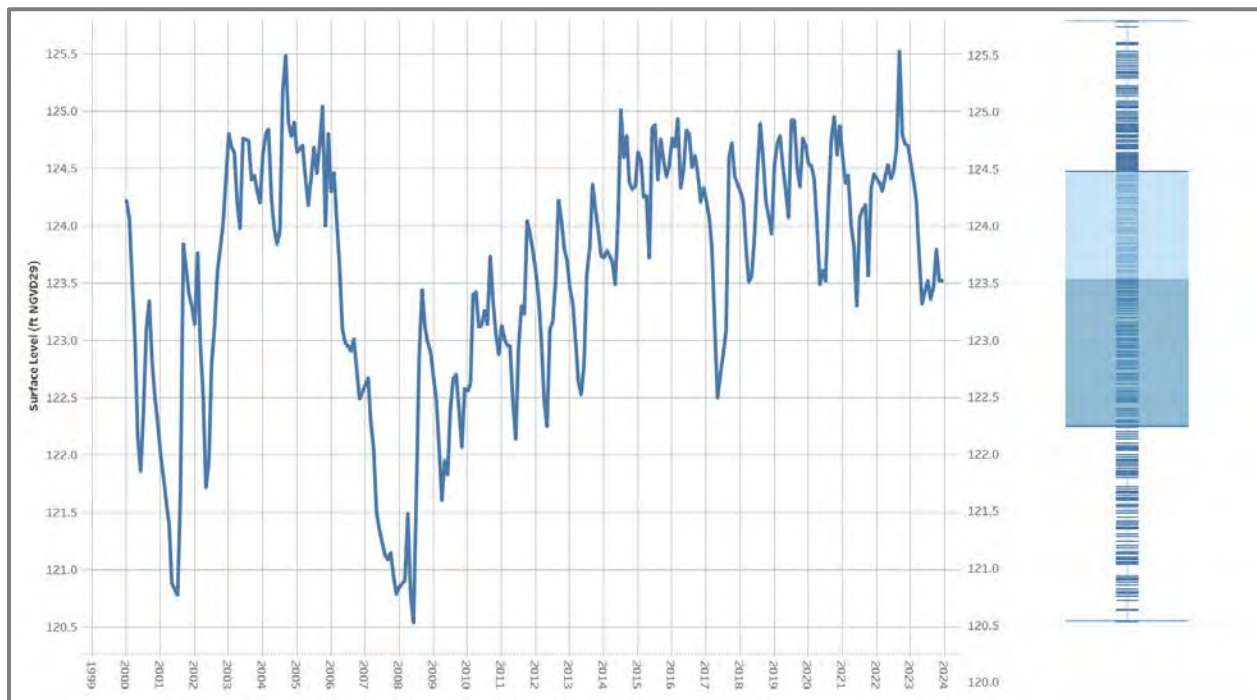


Figure 3-150. Hydrograph of Lake Mariam depicting monthly surface level readings from 2000 to 2023. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Mariam is categorized as a high-color waterbody; likely due to its large connected wetland that contributes tannins to the water column. Based on the water quality data, Lake Mariam exhibited no NNC exceedances during the assessment period (Figure 3-151). This equates to an impairment criterion score of 3.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on these data, Chl-a exhibits a significant deteriorating trend, earning a score of 0. The remaining parameters exhibit non-significant trends; TP and Secchi in deteriorating directions and TN with an improving direction. The Chl-a trend remains the only concern as it could be highlighting potential impairment in the future. That said, the Chl-a concentrations are currently well below the impairment threshold.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	0.466	0.033	Increasing	3	0
TN	N	-0.194	0.399	No Trend		2
TP	N	0.271	0.234	No Trend		1
Secchi	NA	-0.074	0.749	No Trend		1



Figure 3-151. Lake Mariam AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mariam on 5/14/2024. The PAC during this survey was 85.8% and the total BV was 4.8% (Figure 3-152). However, these abundance values almost certainly contain errors during the SONAR mapping as there is little to no submerged vegetation growing in the center of the lake. That said, there is a considerable amount of emergent vegetation present along the periphery due to the extensive wetland areas surrounding this lake. Therefore, Lake Mariam receives an abundance score of 3. It should be noted that the turbidity and high color present in Lake Mariam likely side effects from the lake's shallow morphology and dense surrounding wetlands that contribute organic matter. Therefore, the lack of SAV is not a major concern.

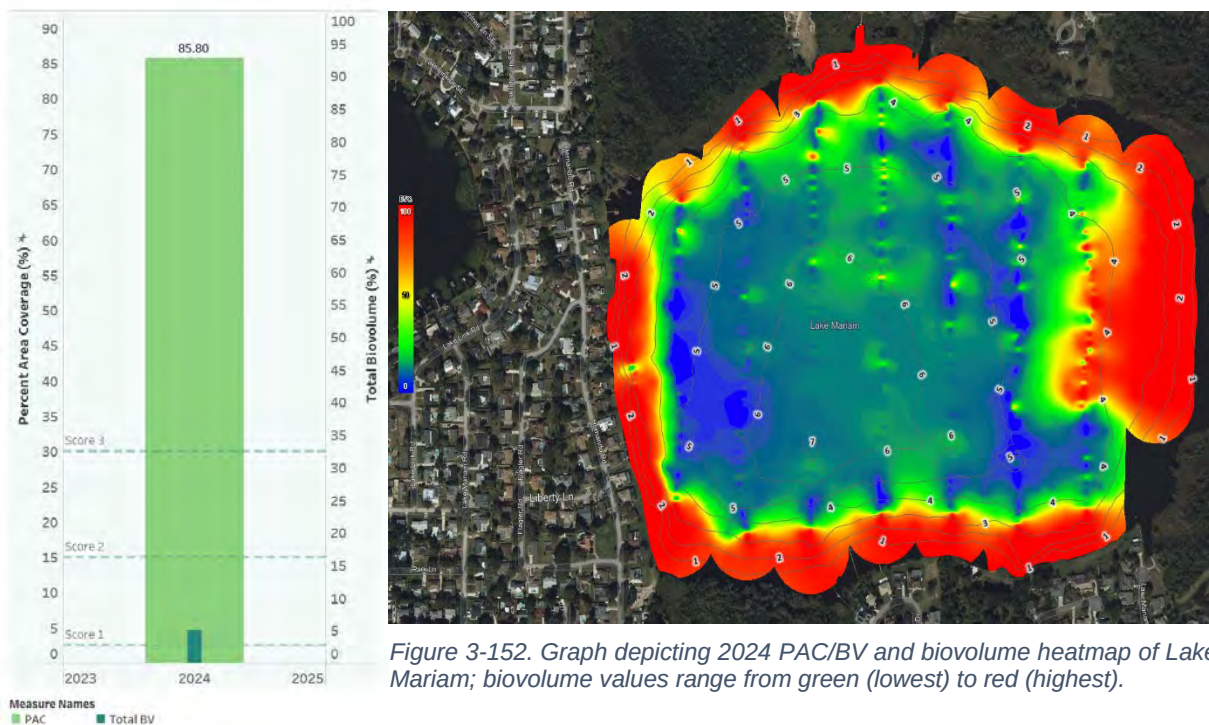


Figure 3-152. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Mariam; biovolume values range from green (lowest) to red (highest).

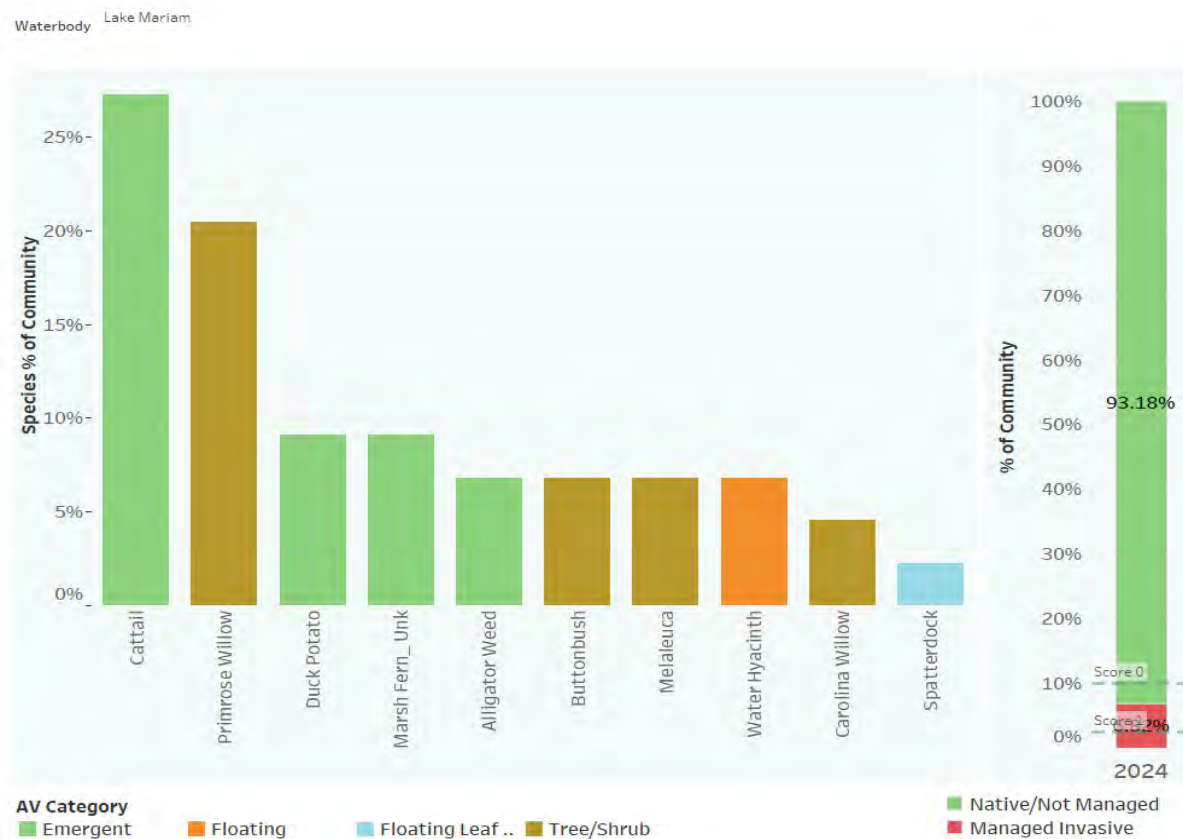


Figure 3-153. Chart depicting species frequency and invasive species percentage of Lake Mariam during 2024.

Invasive Species Management:

Based on Lake Mariam's high color concentration, it is dominated by emergent species like cattail and primrose willow with almost no submerged plants present in the lake (Figure 3-153). Invasive presence in Mariam has undergone a boom and bust cycle in recent years. A large percentage of the community (11.3%) was comprised of burhead sedge and water hyacinth in 2023, but these numbers have dropped down to just 6.8% in 2024 due to management efforts. Continued treatment will be necessary to keep these non-natives under control.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, just Lake Mariam's evenness index exceeded its long-term median (Figure 3-154). Relative to other waterbodies, Lake Mariam has low species richness since it can mostly only support emergent plant types. The decrease in richness and overall diversity was likely due to shifts in the community, driven by the invasive treatments.

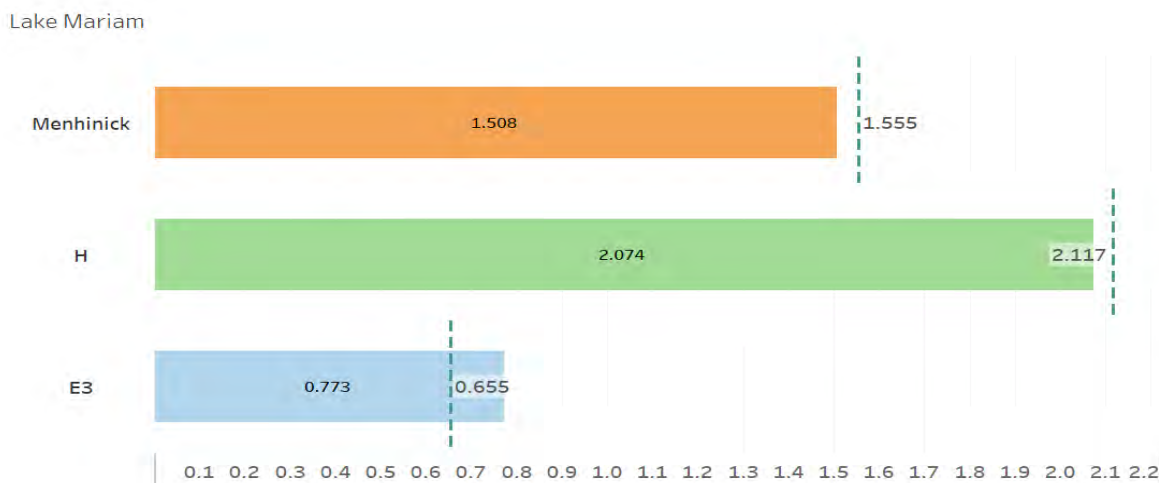


Figure 3-154. Chart depicting 2024 diversity indices for Lake Mariam. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mariam's health index scores from 2018 to 2024 show some variation (Figure 3-155). While the impairment score has remained stable over the last six years, the water quality trend scores have gotten progressively worse. Vegetation abundance has increased, but this may be due to some errors with the SONAR detecting detritus in the center of the lake. The invasive presence has decreased considerably since monitoring began while diversity has gotten better in the last few years. Overall, Lake Mariam is in the middle of the priority rankings. It may not currently be impaired, but it is important to continue monitoring the water quality trends as well as the presence of invasive species.

Lake Health Impacts/Challenges:

- In addition to the moderate level of stormwater runoff from the drainage basin, the presence of so many septic systems may be a contributing factor for nutrient pollutant loading. As these systems age, they may begin to leach nutrients into the water table—leading to water quality declines.

- The management of invasive species is a consistent concern for this waterbody. It can only take a single growing season for even a small population to take over large areas of a waterbody.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	1	2	2	3	1	0	1	1.6
2019	3	1	2	2	2	2	0	2	1.8
2020	3	1	2	1	2	1	1	1	1.5
2021	3	1	2	1	2	3	3	2	2.1
2022	3	1	2	1	2	3	2	2	2.0
2023	3	0	2	1	2	3	0	3	1.8
2024	3	0	2	1	1	3	1	1	1.5

Figure 3-155. Chart depicting a comparison of Lake Mariam's Lake Health Index scores from 2018 to 2024

Lake Management Strategy:

- City staff may explore source analysis to determine if OSTD leachate is a potential contributor of nutrient pollutant loading. Further management action may involve working with Polk County in septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Mariana

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Mariana	0	1	1	3	0	2	3	0	1.3

Features & Statistics:

Surface area	515.6 acres
Mean depth	8.99 feet
Maximum depth	20 feet
Volume	5228.9 acre-feet
Drainage basin area	1935.7 acres
Annual TN Load	6530.8 lbs
Annual TP Load	1160.6 lbs
Limiting nutrient	Phosphorus

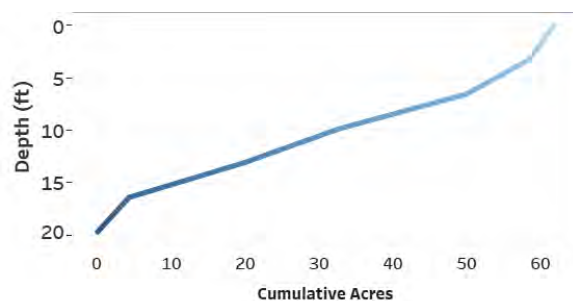


Figure 3-156. Hypsograph of Lake Mariana depicting the depth profile and morphology of the lake bed.

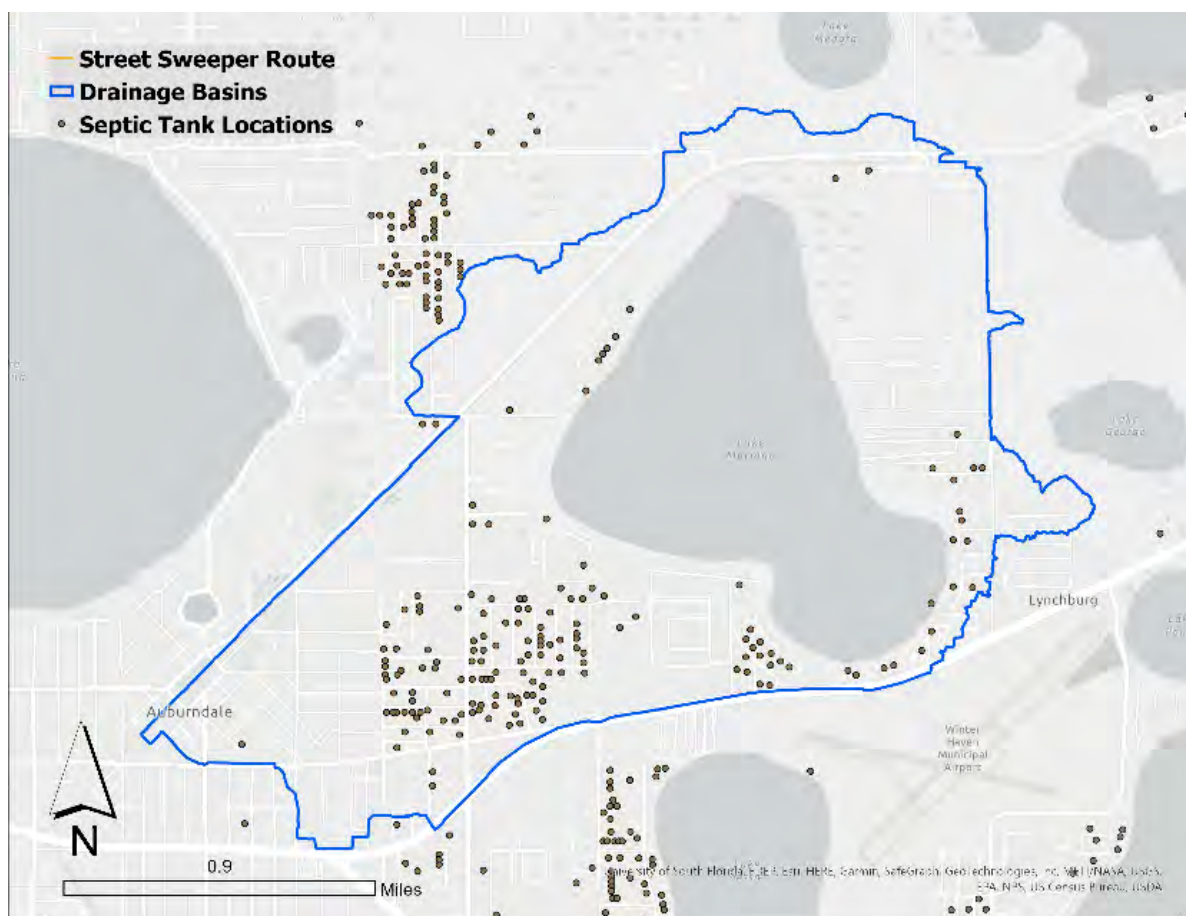


Figure 3-157. Map of Lake Mariana's drainage basin and nearby septic systems.

At over 515 acres in surface area, Lake Mariam is one of the larger lakes in the study area. It has an average depth of 9 feet and a maximum depth of over 20 feet (Figure 3-156). Stormwater is conveyed to this waterbody from a 1,935 acre drainage basin which includes residential, commercial, industrial, and agricultural land uses (Figure 3-157). The drainage basin contributes 6,530 lbs of TN and 1,160 lbs of TP annually; these pollutant loads rank around 20th out of 37 on a per acre basis. There are 158 known Onsite Sewage Treatment and Disposal (OSTD/septic) systems within this basin. This constitutes a high density and could be a potential contributor to nutrient loading via groundwater leaching.

Lake Mariana is located mostly outside Winter Haven limits to the northwest of the city center. The lake discharges excess water via a ditch to Lake Jessie with a range of surface elevations that sit higher in the Peace Creek watershed. Over its period of record, Lake Mariana's surface level has fluctuated between 135.7 and 137.8 feet above sea level. The normal range for this lake is 136.6 and 137.3 feet (Figure 3-158). During 2024, Lake Mariana reached a dry season low of 136.3 feet in April and a wet season high of 137.5 feet in October. The surface level did bounce back and ended the year in the lower portion of the normal range at 136.7 feet. Changes in this lake's level are not correlated with the primary water quality metrics.

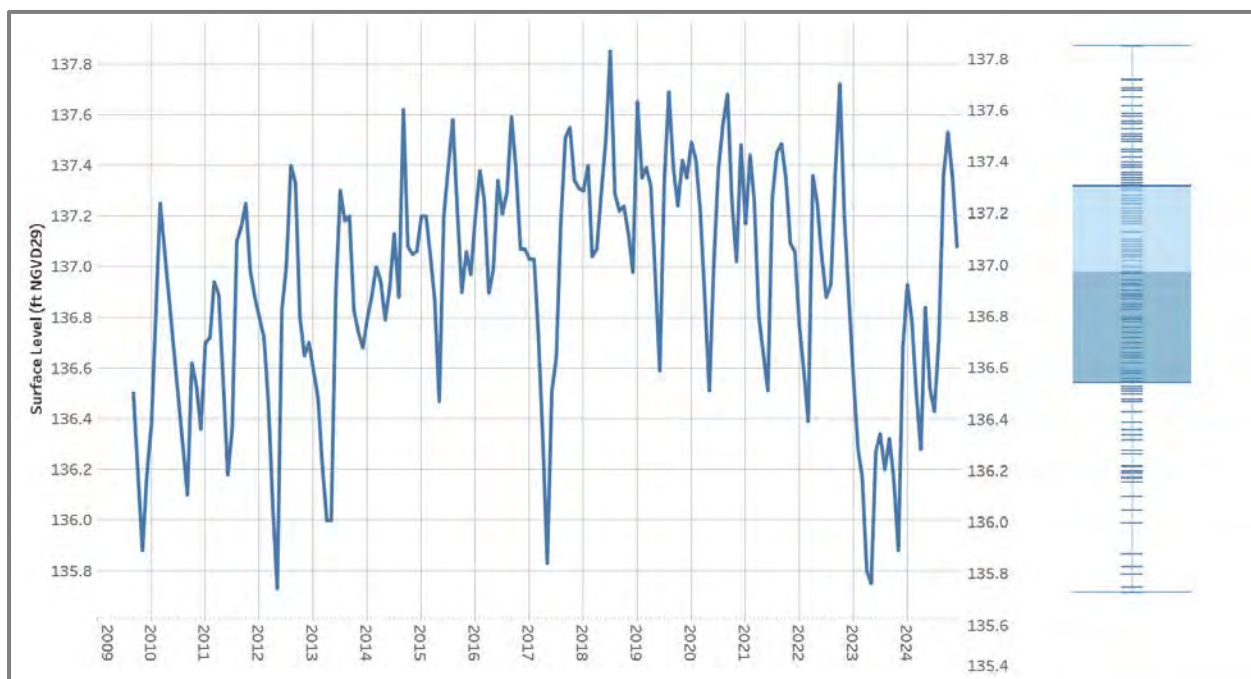


Figure 3-158. Hydrograph of Lake Mariana depicting monthly surface level readings from 2010 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairments:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Mariana is categorized as a clear, alkaline waterbody. Due to numerous, consecutive NNC exceedances during the assessment period, Lake Mariana is considered impaired for Chl-a, TN, and TP (Figure 3-159). This equates to an impairment criterion score of 0. In 2018, the FDEP established a total maximum daily load for this lake, stipulating a 44% reduction in TN loading in order to meet NNC guidelines. It should be noted that while Chl-a and TN concentrations have fluctuated widely over the period of record, TP concentrations have remained relatively static over the last 15 years.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	0.223	0.330	No Trend	0	1
TN	Y	0.183	0.426	No Trend		1
TP	Y	-0.535	0.013	Decreasing		3
Secchi	NA	-0.491	0.024	Decreasing		0

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. According to the data, only Secchi depth exhibited a significant deteriorating trend. Chl-a and TN shifted in their trend statistics such that their deteriorating trends in 2022 are now non-significant—indicating some improvement. The TP concentrations, on the other hand, are trending significantly in a downward direction.



Figure 3-159. Lake Mariana AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mariana on 11/15/2024. The PAC during this survey was 27.7% and the total BV was 4.05% (Figure 3-160). The 2024 coverage value decreased slightly from the previous year and equates to an abundance criterion score of 2. Throughout the monitoring period, Lake Mariana has maintained vegetation coverage between 22% and 31%. Due to its morphology, Lake Mariana has ample habitat space for submerged aquatic vegetation, but low clarity prevents growth in deeper areas of the lake. According to the BV heatmap, the denser vegetation areas are concentration along the eastern and northwestern shorelines.

Invasive Species Management:

Based on data from the 2024 survey, Lake Mariana is dominated by emergent plants including cattail and maidencane (Figure 3-161). This is a striking departure from previous years where

Illinois pondweed was the dominant species present. In fact, the total lack of pondweed in 2024 is somewhat concerning. There has not been a presence of invasive species in Mariana since 2022; therefore, no invasive treatments should have taken place that would potentially impact the pondweed population. The City, County, and FWC are currently examining the lake to determine what could be the cause of the pondweed decline. The lack of invasive species in 2024 earns Mariana an invasive presence score of 3.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, none of Lake Mariana's diversity indices met or exceeded their long-term median values (Figure 3-162). This equates to a diversity criterion score of 0. These diversity numbers can be mostly explained by the absence of pondweed reducing the total number of unique species present. The lack of pondweed changed the community dynamics and relative proportions of the remaining plant species. This clearly demonstrates how a loss in just a single species can have substantial impacts on the entire vegetation community and ecosystem as a whole.

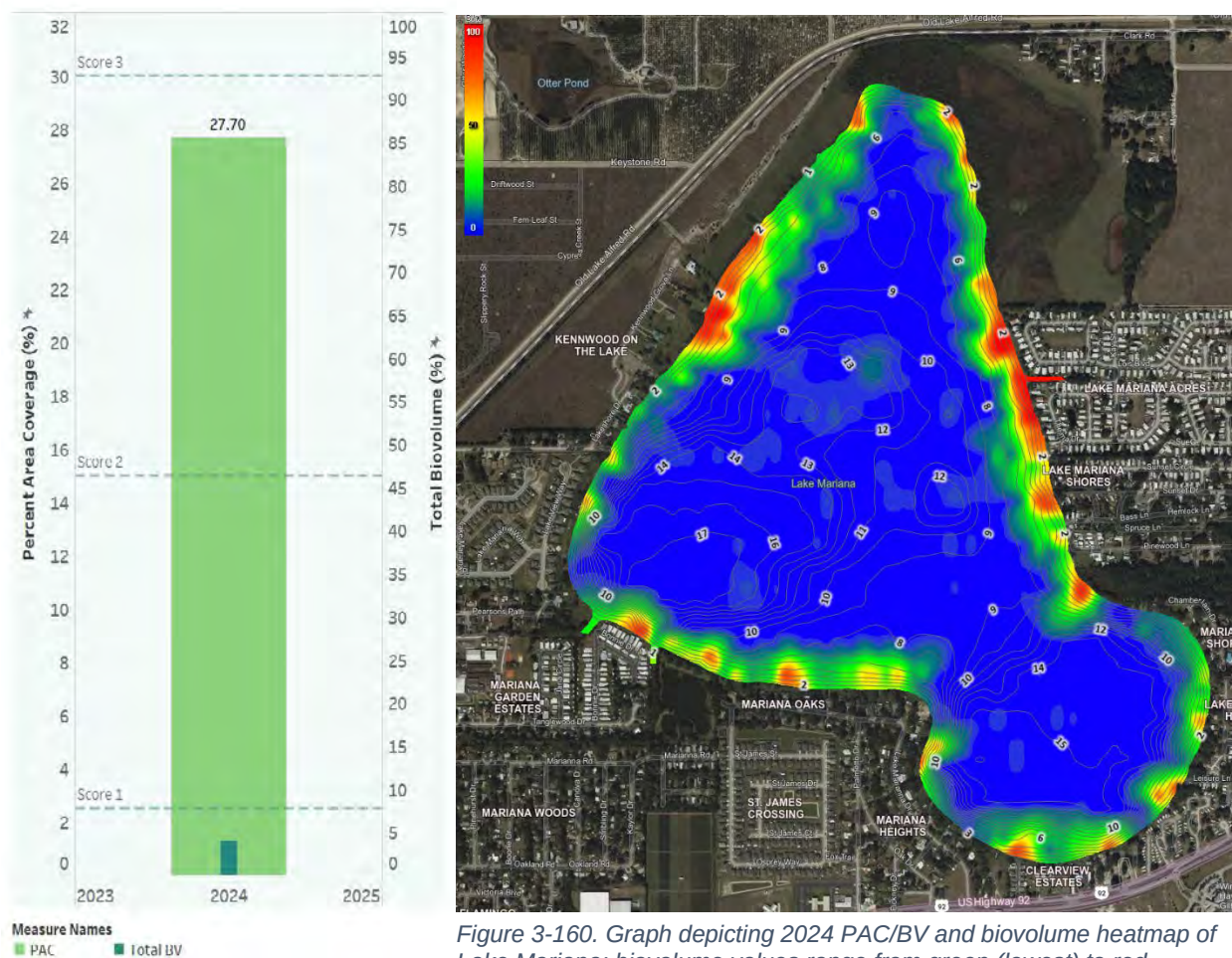


Figure 3-160. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Mariana; biovolume values range from green (lowest) to red (highest).

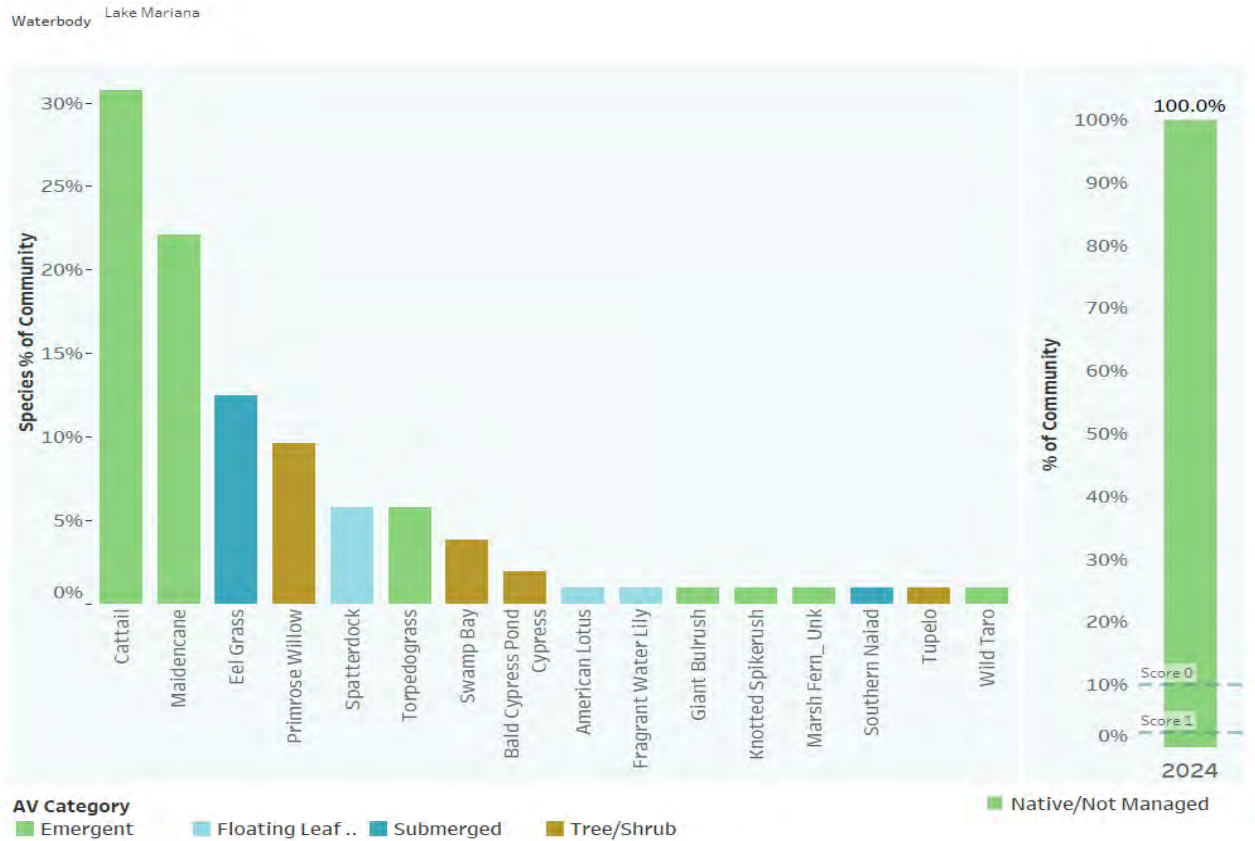


Figure 3-161. Chart depicting species frequency and invasive species percentage of Lake Mariana during 2024.

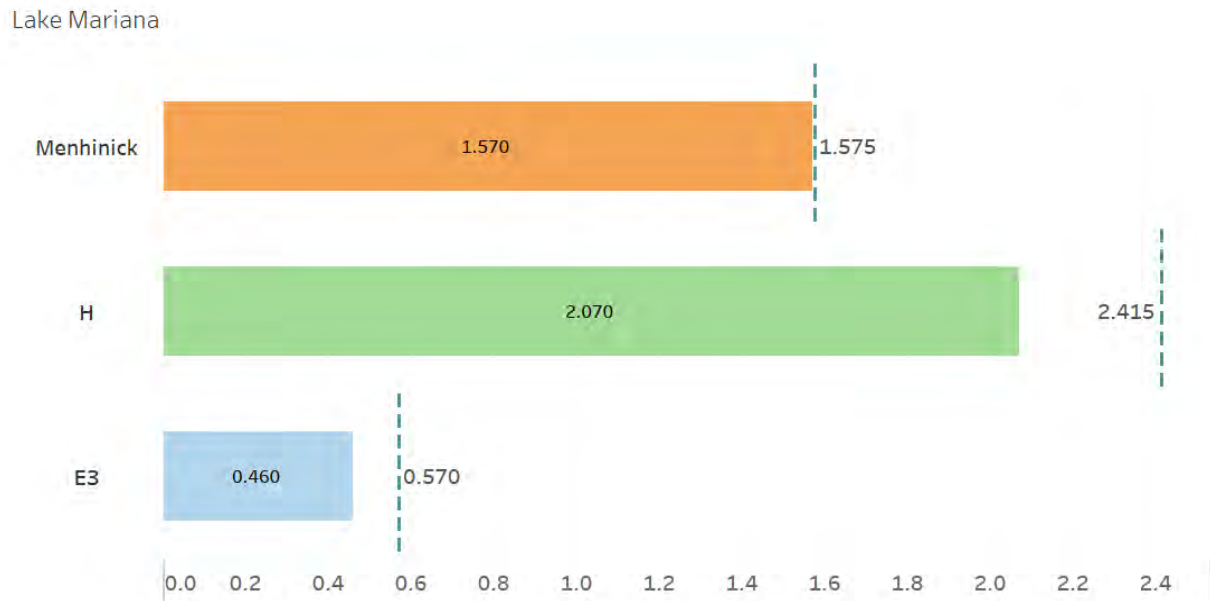


Figure 3-162. Chart depicting 2024 diversity indices for Lake Mariana. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mariana's health index scores from 2018 to 2024 shows little change (Figure 3-163). The impairment scores have remained static over this span. A dip in the Chl-a and TN trend scores in 2022 was corrected the following year. There hasn't been much change in the vegetation abundance and invasive scores either. Most of the annual fluctuation has occurred with the diversity scores. With that, Lake Mariana is still considered a relatively high priority due to its water quality impairments and poor water clarity trend.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	2	1	2	2	1	1.3
2019	0	1	1	2	0	2	3	2	1.4
2020	0	1	1	2	0	2	3	1	1.3
2021	0	1	1	2	0	2	2	2	1.3
2022	0	0	0	3	0	2	3	1	1.1
2023	0	1	1	3	0	3	3	2	1.6
2024	0	1	1	3	0	2	3	0	1.3

Figure 3-163. Chart depicting a comparison of Lake Mariana's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- The presence of such a high density of OSTDs in the drainage basin is currently one of the larger concerns regarding water quality. That said, stormwater runoff presents another form of pollutant loading to the lake.
- While invasive species aren't currently an issue, management of these is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- One major potential challenge in managing Lake Mariana is the coordination and collaboration between the various municipalities responsible for it. Unfortunately, many of the OSTDs in the basin aren't within the Winter Haven limits. Management efforts will require strong direction to implement basin-wide improvements.

Lake Management Strategy:

- The City plans to provide what support it can to manage the water quality issues in this basin. This may involve exploring source analysis of the nutrients in the water to identify the cause of water quality deterioration. Staff will also advocate for septic-to-sewer conversions where appropriate.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow. The City is also exploring the lack of pondweed in the lake in 2024.

Lake Martha

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Martha	3	0	1	1	0	1	3	0	1.1

Features & Statistics:

Surface area	82.5 acres
Mean depth	10.21 feet
Maximum depth	19 feet
Volume	1141.8 acre-feet
Drainage basin area	307.5 acres
Annual TN Load	1217.1 lbs
Annual TP Load	199.1 lbs
Limiting nutrient	Phosphorus

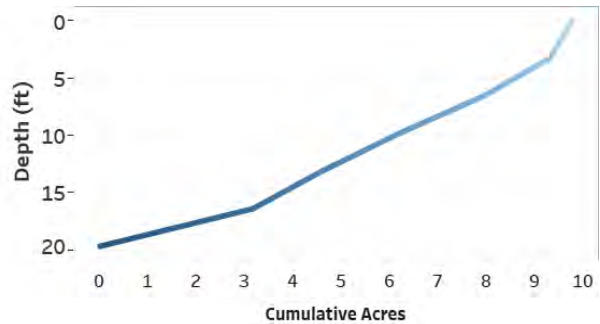


Figure 3-164. Hypsograph of Lake Martha depicting the depth profile and morphology of the lake bed.

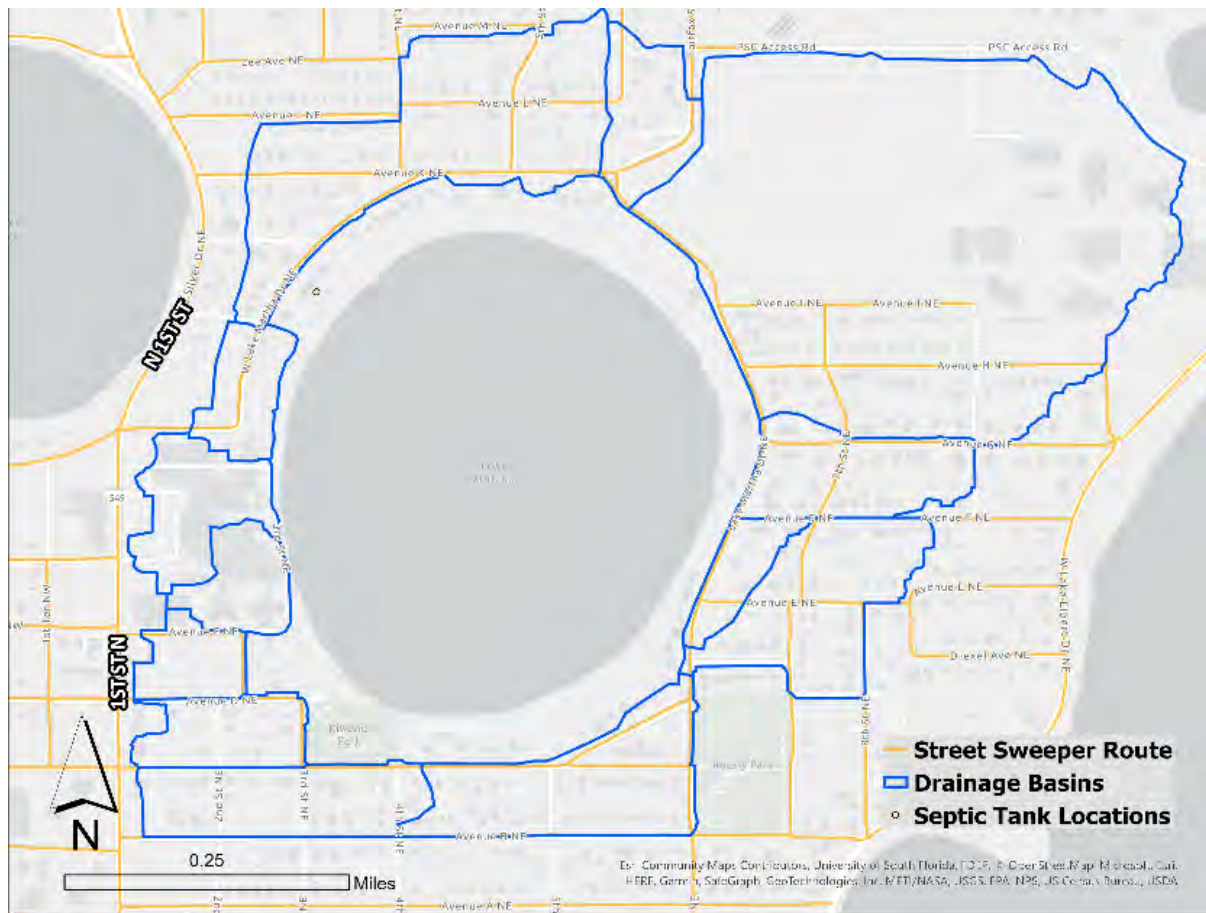


Figure 3-165. Map of Lake Martha's drainage basin, city street sweeper routes, and nearby septic systems.

Hydrology:

Lake Martha is a smaller, but deeper waterbody at 82 acres, an average depth of 10.2 feet, and a maximum depth of about 19 feet (Figure 3-164). This lake morphology is indicative of a classic sinkhole lake. Despite Martha's average depth being almost two feet deeper than the regional mean lake depth, the slope of its lake bed should still support a healthy abundance of aquatic vegetation. Stormwater is conveyed to this waterbody from a 307 acre drainage basin comprised of 14 individual sub-basins (Figure 3-165). Located in a mostly residential area, the primary land uses in this basin are medium density residential and institutional (e.g. schools). This basin contributes 1,217 lbs of TN and 199 lbs of TP to the lake annually; which ranks 13th out of 37 lakes on a loading per acre basis. The City combats the local stormwater pollutant loading by conducting 7.15 miles of street sweeping in this basin per month.

In the heart of downtown Winter Haven, Lake Martha receives overflow from Lake Silver and discharges excess water to Lake Maude. Martha's surface elevation sits near the top of the Peace Creek watershed. Over its period of record, Lake Martha's surface level has fluctuated between 136.7 and 142.6 feet above sea level. The normal range is much narrower—between 139.7 and 141.2 feet (Figure 3-166). During 2024, Lake Martha's surface level dropped to a low of 140.6 feet in June and rose to a wet season high of 141.8 feet in November. The surface level ended the year above the normal range at 141.6 feet. Based on linear regression analysis, Chl-a rises as Lake Martha's surface level increases; which is opposite to what would be expected. This correlation is most likely coincidental.

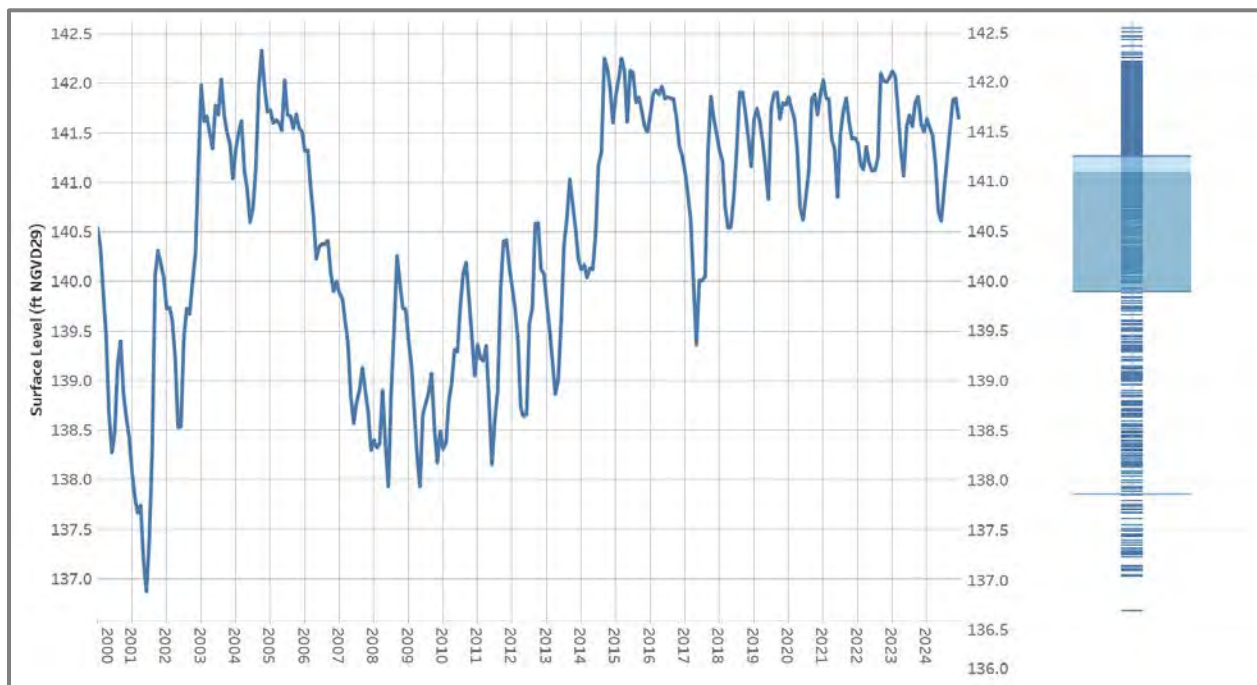


Figure 3-166. Hydrograph of Lake Martha depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Martha is categorized as a clear, alkaline waterbody. Throughout recent monitoring, Lake Martha has not exhibited any NNC exceedances in Chl-a, TN, or TP (Figure 3-167). This equates to an impairment score of 3. It should be noted that these parameters have remained relatively low

since 2019. If these low concentrations continue, it could shift Lake Martha's trends into a positive direction.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	0.601	0.004	Increasing	3	0
TN	N	0.286	0.208	No Trend		1
TP	N	0.133	0.566	No Trend		1
Secchi	NA	-0.723	0.000	Decreasing		0

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. According to the data, Chl-a and Secchi depth exhibited significant deteriorating trends. These equate to trend criteria scores of 0. The TN and TP trends, while in a deteriorating direction, were not significant—earning scores of 1. This is a slight change from previous years and indicates that some water quality metrics are exhibiting improvement. As stated previously, continued low Chl-a, TN, and TP concentrations may end up shifting all of these trends toward more favorable directions.

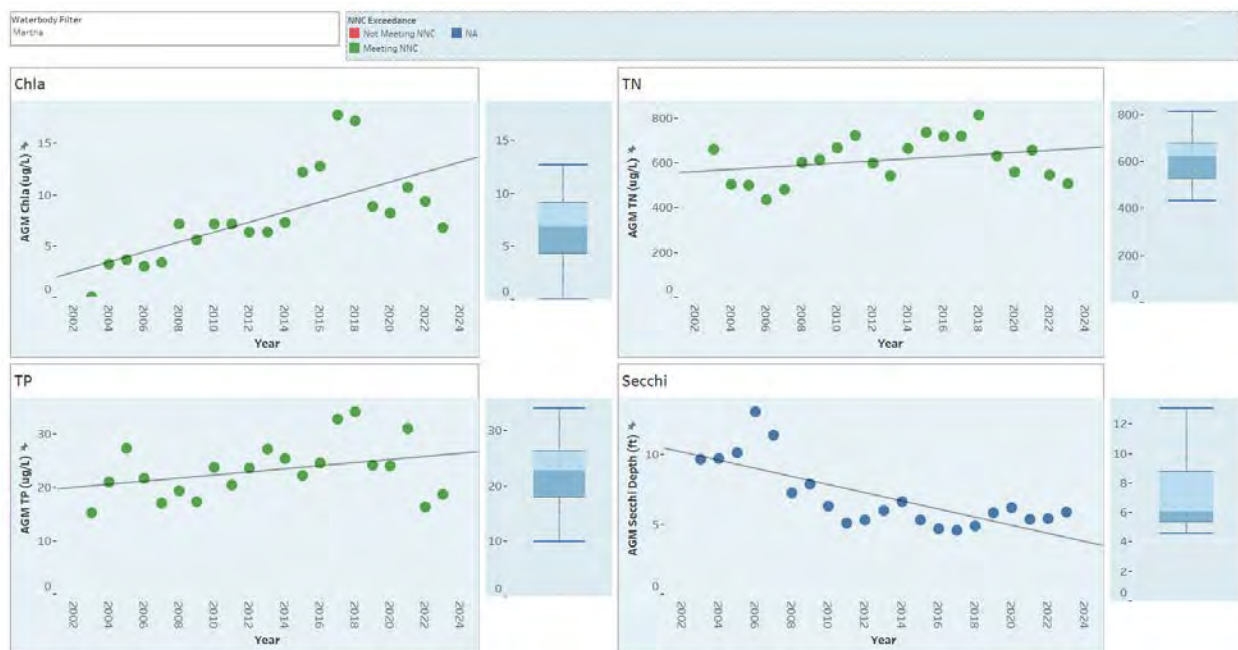


Figure 3-167. Lake Martha AGM Chl-a, TN, TP, and Secchi depth values from 2003 to 2023. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Martha on 8/6/2024. The PAC during this survey was 4.8% and the total BV was 0.43% (Figure 3-168). This equates to an abundance score of 1. A review of Lake Martha's abundance values from 2018 to 2024 shows a consistent lack of vegetation coverage and biovolume. While the lake bed steeply slopes into deeper water, its relatively high water clarity should support much more vegetation than is currently present. The reason for this lack of aquatic plants still remains unclear. The City attempted to plant some native SAV species near the Martha boat ramp in 2024, but these plantings did not survive. It is likely that grass carp stocked in 2011 are eating any plants introduced to the lake.

Invasive Species Management:

Based on data from the 2024 survey, it is clear that emergent species dominate the vegetation community. At over 30% of the community, the exotic torpedo grass is the most abundant species by far (Figure 3-169). While there are several exotic species present, they don't pose much of a management concern. The result is an invasive presence criterion score of 3. The lack of submerged vegetation is much more concerning since this lake should support it. The leading theory is that triploid grass carp were stocked in the 2010s in an effort to biologically control hydrilla in the lake. The density of carp was likely higher than needed and this population has since denuded the lake of SAV.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Martha's diversity indices failed to meet or exceed their long-term median values (Figure 3-170). Reviewing the species frequencies from the previous year, many plant species were in higher proportions in 2023 than 2024. The species present were also much more evenly distributed in 2023 compared to 2024. Overall, there was a slightly decrease in diversity in the most recent report year. Since there are no managed invasive species present, these changes have occurred due to natural fluctuations in the community.

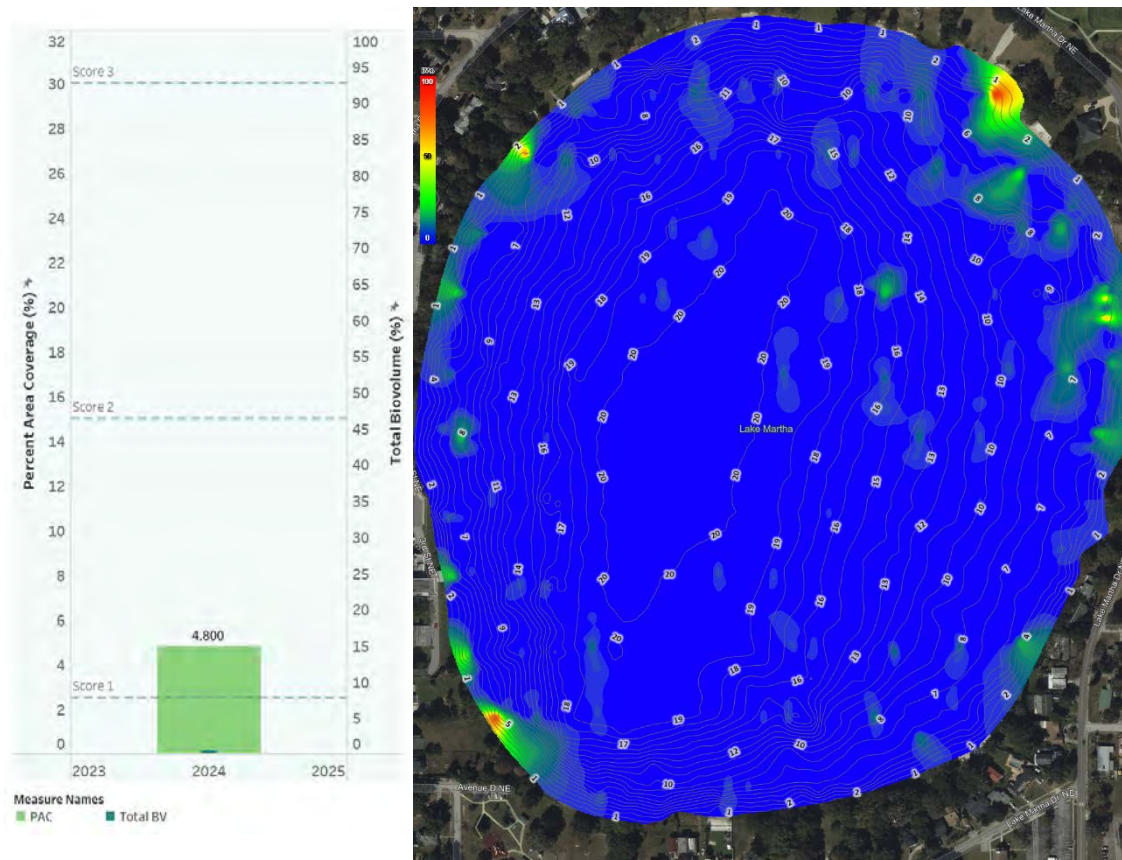


Figure 3-168. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Martha; biovolume values range from green (lowest) to red (highest).

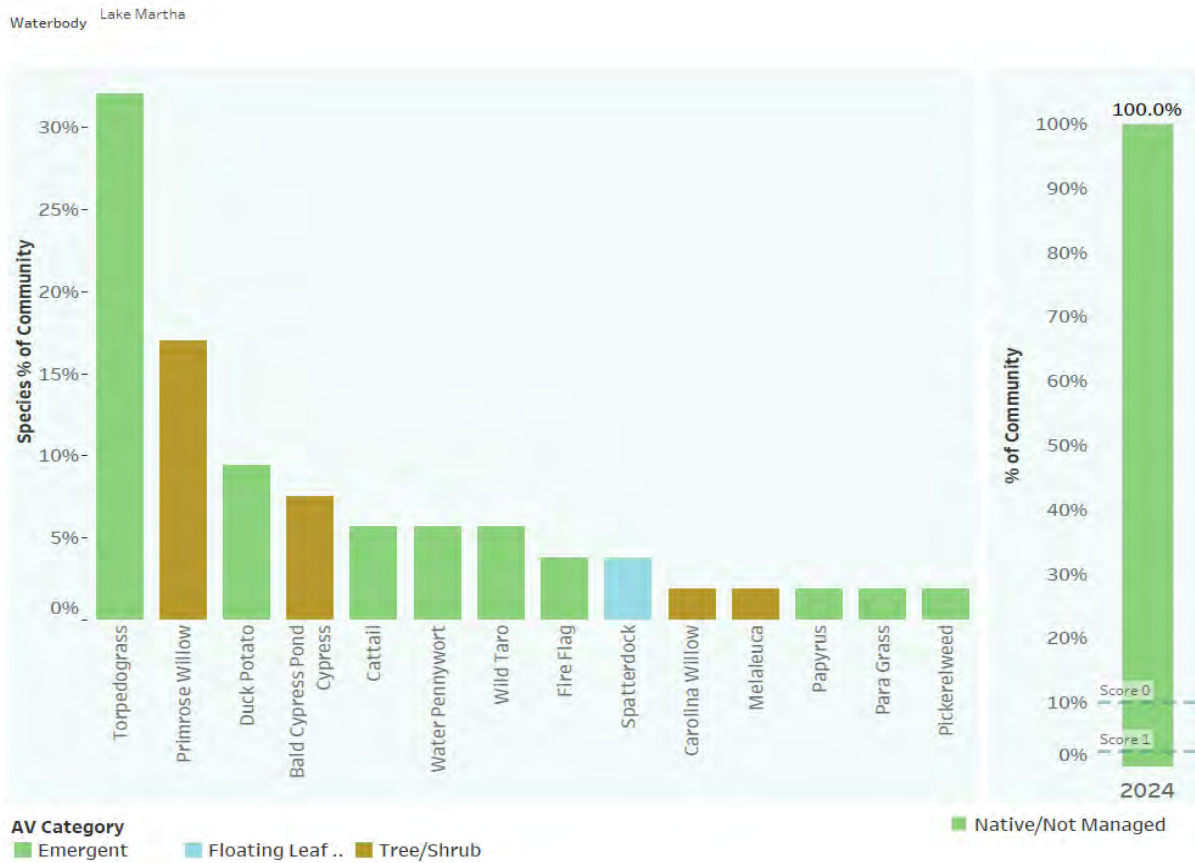


Figure 3-169. Chart depicting species frequency and invasive species percentage of Lake Martha during 2024.

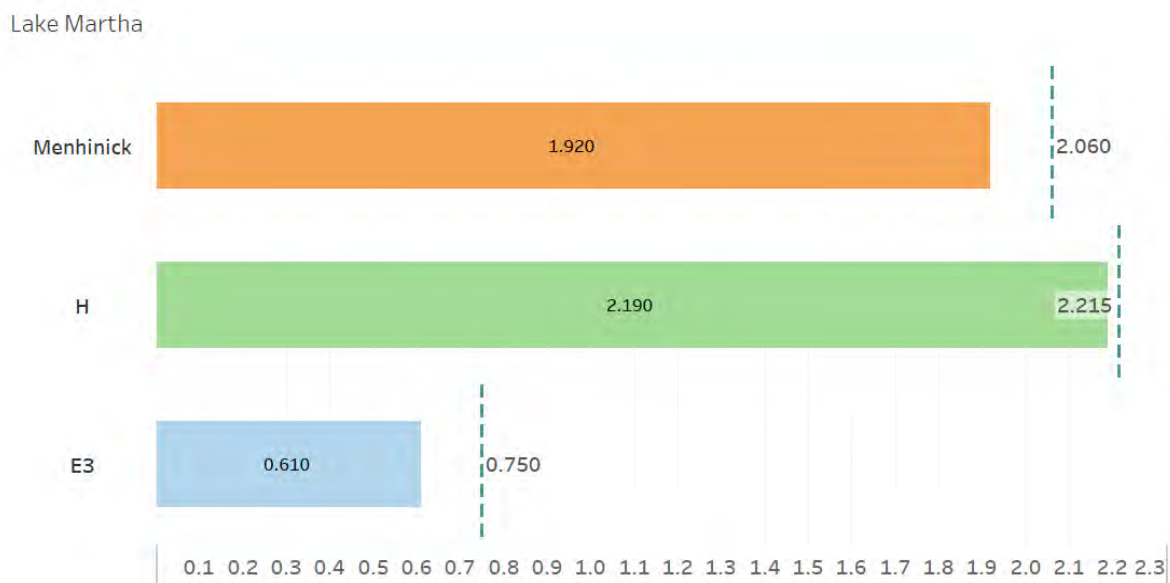


Figure 3-170. Chart depicting 2024 diversity indices for Lake Martha. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Martha's health index scores from 2018 to 2024 shows marginal improvement (Figure 3-171). Since the City began documenting lake health, Lake Martha has exhibited no changes in impairment but has undergone some positive changes in the trend scores. Also notable is how the vegetation abundance has increased since the first year of monitoring. Diversity largely changes through natural selection in the vegetation community and the invasive presence has consistently remained low. Overall, improving Lake Martha's water quality before it becomes impaired places it higher on the priority ranking.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	0	0	0	0	3	0	0.8
2019	3	0	0	0	0	1	2	3	1.1
2020	3	0	0	0	0	1	3	1	1.0
2021	3	0	0	0	0	1	3	2	1.1
2022	3	0	1	0	0	1	3	2	1.3
2023	3	0	1	1	0	1	3	2	1.4
2024	3	0	1	1	0	1	3	0	1.1

Figure 3-171. Chart depicting a comparison of Lake Martha's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Despite Lake Martha not being impaired, its water quality trends are concerning. Stormwater pollutant loading from the surrounding drainage basin is one of the City's primary management concerns for combating these water quality issues.
- A healthy, robust vegetation community is considered to provide a buffer against changes in water quality from increased nutrient loading. The lack of submerged vegetation and overall abundance is a concern. However, efforts to increase vegetation abundance through planting are curtailed by the presence of grass carp in the waterbody.
- In 2019, Lake Martha experienced a diesel fuel spill. While likely not a contributor to increased Chl-a or nutrient concentrations, this event led to a significant ecological disturbance. Fortunately, remediation efforts were successful at removing petroleum from the lake.

Lake Management Strategy:

- Implementing stormwater infrastructure improvements to address the water quality trends is an ongoing goal.
- With the majority of the drainage basin comprised of residential housing, public education and outreach is a valid management strategy. These efforts aim to increase residents' knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- City staff have explored habitat restoration via vegetation planting initiatives. However, the presence of grass carp poses a significant roadblock to successful implementation. Staff will continue to monitor vegetation and work with the FWC to track the presence of grass carp until such a time that planting becomes a viable solution.

Lake Maude

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Maude	3	3	3	2	2	3	2	3	2.6

Features & Statistics:

Surface area	51 acres
Mean depth	8.18 feet
Maximum depth	14 feet
Volume	413.4 acre-feet
Drainage basin area	385.75 acres
Annual TN Load	1900.5 lbs
Annual TP Load	320.03 lbs
Limiting nutrient	Co-limited (N & P)

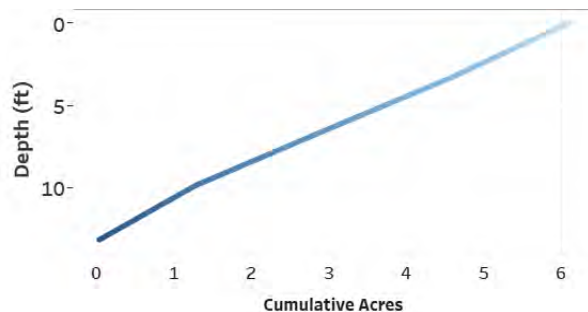


Figure 3-172. Hypsograph of Lake Maude depicting the depth profile and morphology of the lake bed.

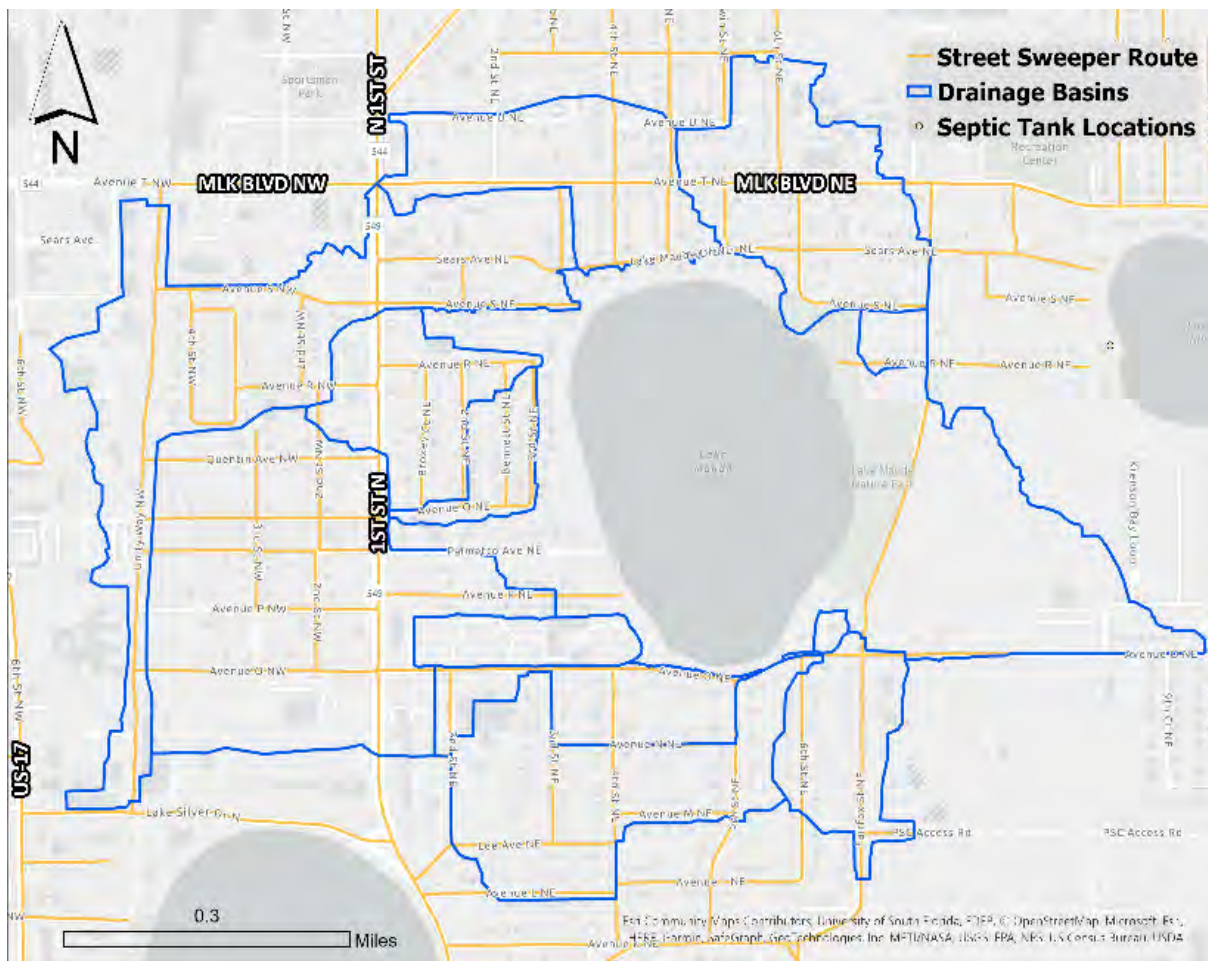


Figure 3-173. Map of Lake Maude's drainage basin and City street sweeper routes.

Hydrology:

Lake Maude is a smaller waterbody at 51 acres, an average depth of 8.2 feet, and a maximum depth of 14 feet in deeper areas (Figure 3-172). The shallowness of the lake provides ample habitat for aquatic vegetation to grow. Stormwater is conveyed to this waterbody from a 385 acre drainage basin, comprised of 14 individual sub-basins (Figure 3-173). The primary land uses within this basin include residential, recreational, and commercial which contribute 1,900 lbs of TN and 320 lbs of TP to the lake annually. These pollutant loads rank very high on a per acre basis. To combat stormwater pollutant loading, the City conducts 15.7 miles of street sweeping in this basin on a monthly frequency.

Lake Maude is near Winter Haven's downtown; it receives excess water from Lake Martha and discharges overflow to Lake Idyl. The mean surface elevation for the lake sits relatively high in the entire Peace Creek watershed. Over its period of record, Lake Maude's surface level has fluctuated between 136 and 140.9 feet above sea level. The normal range is much narrower—between 138.9 and 139.5 feet (Figure 3-174). During 2024, Lake Maude dropped to a dry season low of 138.5 feet in June then rose to a wet season peak of 140.2 feet in September. The surface level ended the year well above the high range at 139.9 feet. Changes in Lake Maude's surface level are weakly correlated with TN (see appendix). This carries some management considerations as maintaining higher surface levels should result in a decrease in TN concentrations.

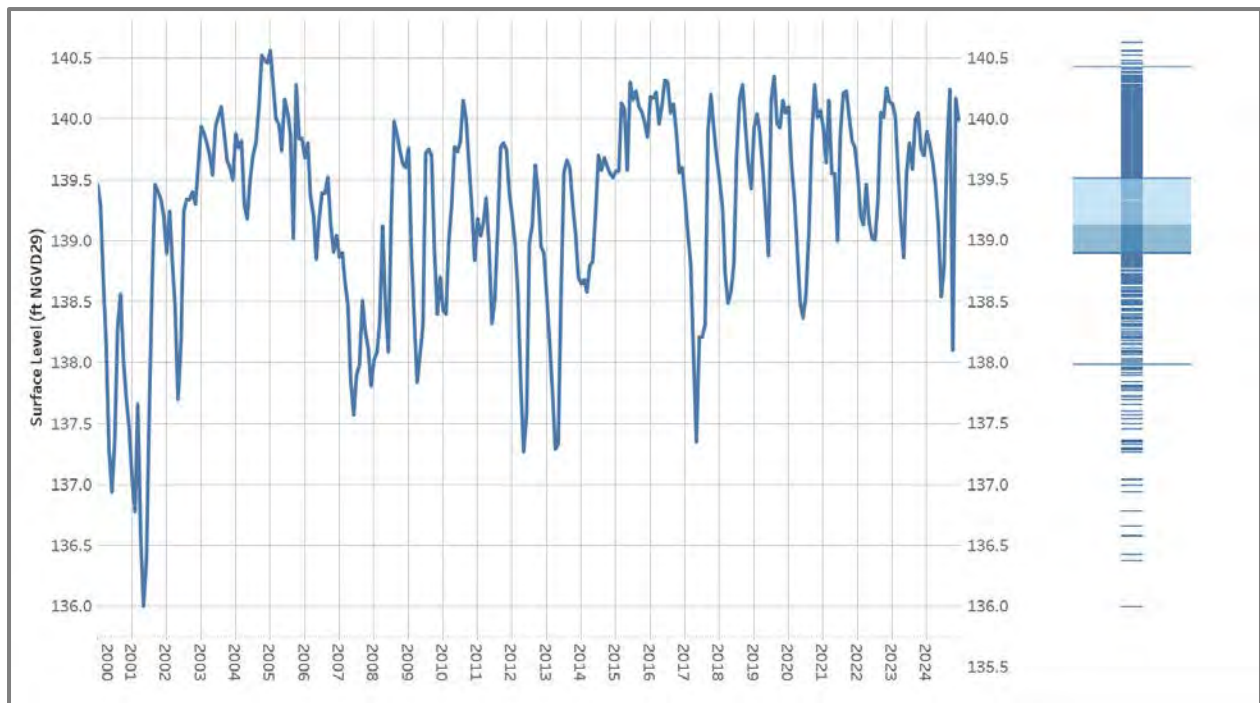


Figure 3-174. Hydrograph of Lake Maude depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Maude is categorized as a clear, alkaline waterbody. Lake Maude has not exhibited any NNC exceedances during the assessment period (Figure 3-175). This equates to an impairment criterion score of 3. While the 2023 water quality parameters were poorer than usual, in 2024 these returned to more normal and preferable levels.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the data, Chl-a and TN exhibited significant improving trends—earning trend criteria score of 3. Lake Maude's TP and Secchi depth trends, while not statistically significant, are also improving. This equates to a trend criterion score of 2. While Secchi depth was previously trending upward, the recent change to the statistical significance indicates that some recent activities have negatively impacted water clarity. This is something to monitor, but is not an inherently concerning shift.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.568	0.007	Decreasing	3	3
TN	N	-0.491	0.024	Decreasing		3
TP	N	-0.181	0.431	No Trend		2
Secchi	NA	0.390	0.081	No Trend		2

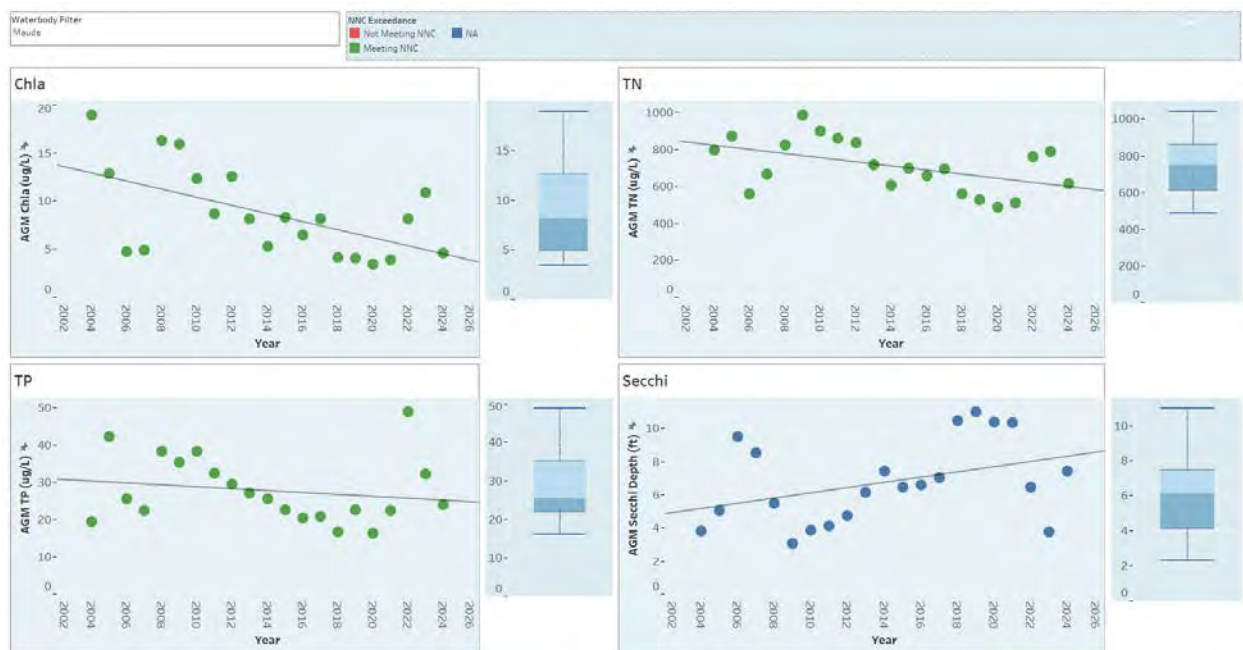


Figure 3-175. Lake Maude AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Maude on 1/19/2024. The PAC during this survey was 43.4% and the total BV was 4.5% (Figure 3-176). This equates to a vegetation abundance criterion score of 3. This was actually a considerable decline in overall abundance from the previous year. This recent decline in coverage and BV may be a response to invasive hydrilla treatments reducing the overall abundance in the lake.

Invasive Species Management:

Based on the data from the 2024 survey, Lake Maude experienced a shift in the vegetation community, with the floating-leaf spatterdock taking the most dominant place (Figure 3-177). The remaining vegetation types include an even mix of submerged and emergent plants. Regarding managed invasive species, hydrilla and burhead sedge made up 2.4% of the total population. This equates to an invasive presence criterion score of 2 and constitutes a slight decrease from the previous year. While currently in a managed state, the presence of invasives requires constant management to keep it under control.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Lake Maude's diversity indices exceeded their long-term median values (Figure 3-178). This equates to a diversity criterion score of 3. The increases in diversity were likely caused by efforts to control hydrilla and burhead sedge in the lake. By reducing the abundance of these invasive species, other native plants were able to fill in the niches left behind and create a more diverse and evenly distributed vegetation community.

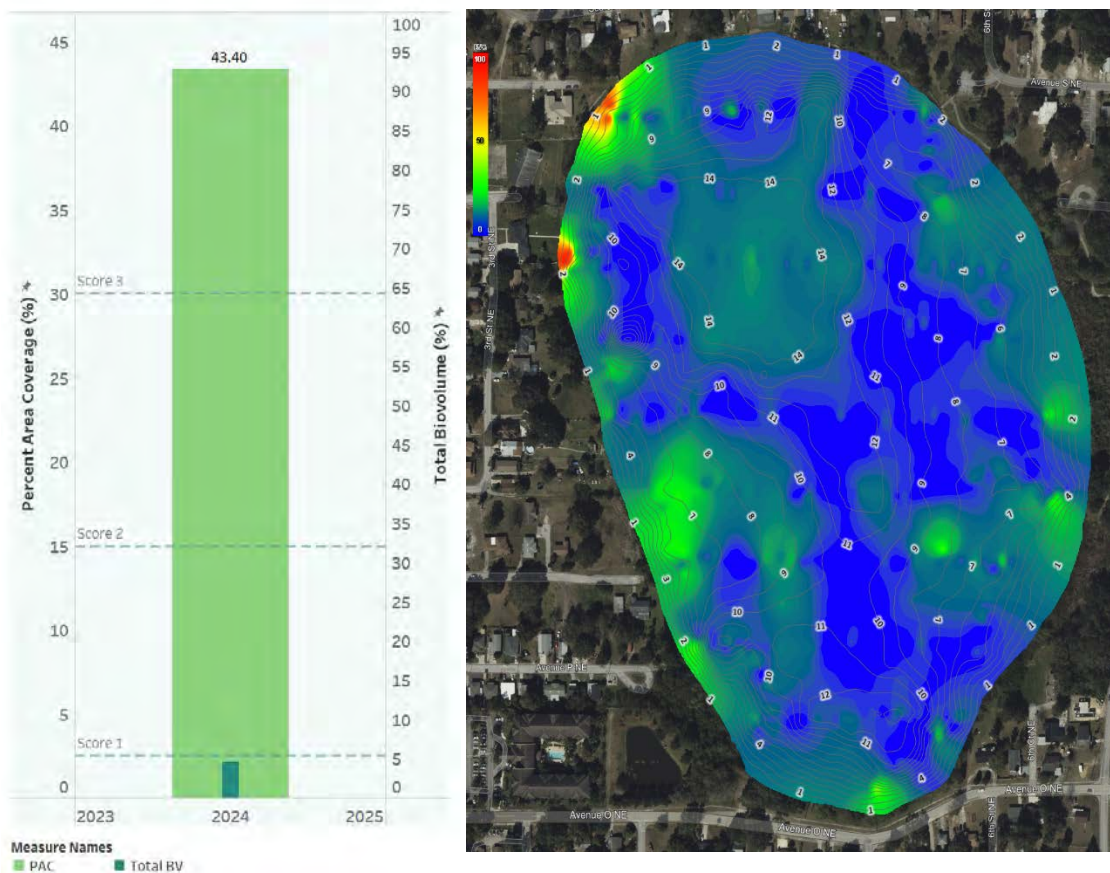


Figure 3-176. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Maude. Biovolume values range from green (lowest) to red (highest).

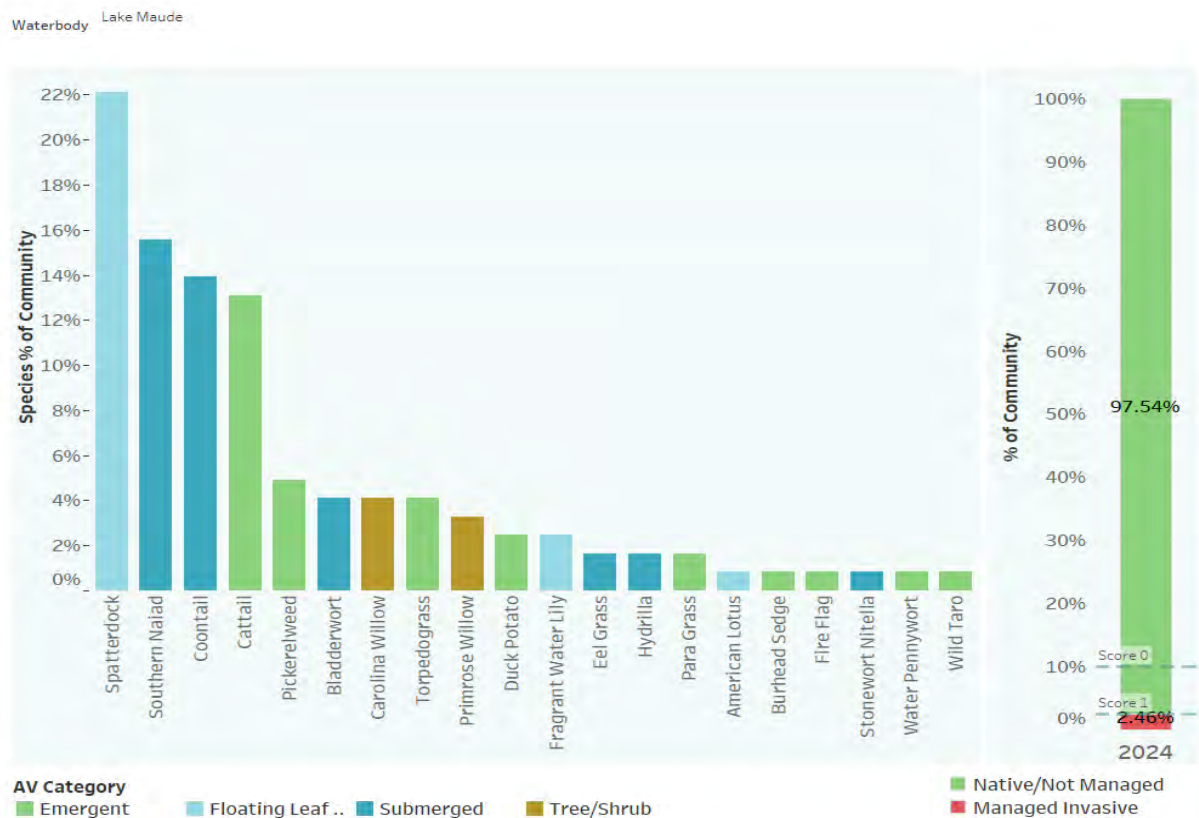


Figure 3-177. Chart depicting species frequency and invasive species percentage of Lake Maude during 2024.

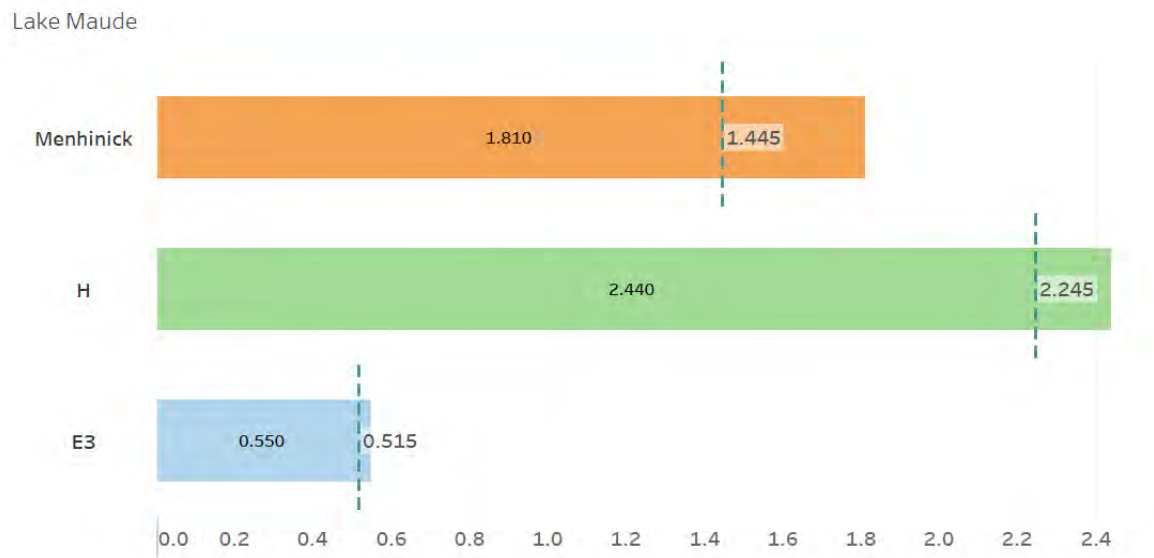


Figure 3-178. Chart depicting 2024 diversity indices for Lake Maude. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Maude's health index scores from 2018 to 2024 shows relative stability with index scores ranging from 2.4 to 2.8 (Figure 3-179). Throughout the monitoring period, water quality impairment, trends, and vegetation abundance have remained largely positive. There have been some minor changes in the statistical significance of the TP and Secchi depth trends, however. Where the majority of the score changes derive are from the invasive species presence and species diversity scores. This is to be expected as invasive plant populations expand and are treated. Overall, Lake Maude falls lower on the priority ranking due to its excellent water quality and robust vegetation community.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	2	3	3	1	3	2.6
2019	3	3	3	2	3	3	1	1	2.4
2020	3	3	3	3	3	3	2	1	2.6
2021	3	3	3	3	3	3	1	0	2.4
2022	3	3	3	2	3	3	2	3	2.8
2023	3	3	3	2	2	3	1	2	2.4
2024	3	3	3	2	2	3	2	3	2.6

Figure 3-179. Chart depicting comparison of Lake Maude's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Maude currently exhibits excellent water quality. However, stormwater pollutant loading is a potential concern if water quality trends begin to deteriorate.
- The management of invasive species like burhead sedge and hydrilla is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- The City already mitigates quite a bit of stormwater pollutant loading through extensive street sweeping as well as the construction and maintenance of the Lake Maude Stormwater Treatment Park—a form of green stormwater infrastructure.
- With so much residential housing in the basin, public education and outreach is another viable strategy. Education aims to increase residents' knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake May

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake May	0	3	3	3	3	3	1	2	2.3

Features & Statistics:

Surface area	50.5 acres
Mean depth	5.28 feet
Maximum depth	10 feet
Volume	196 acre-feet
Drainage basin area	353.6 acres
Annual TN Load	1732.7 lbs
Annual TP Load	292.9 lbs
Limiting nutrient	Co-limited (N & P)

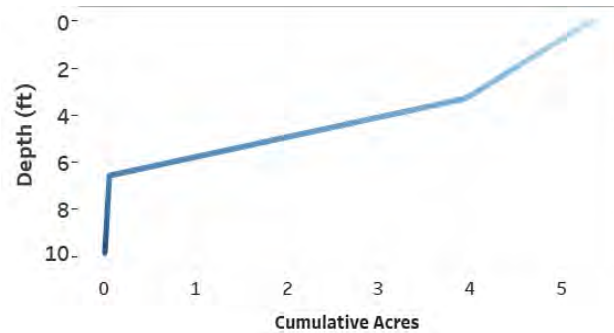


Figure 3-180. Hypsograph of Lake May depicting the depth profile and morphology of the lake bed.

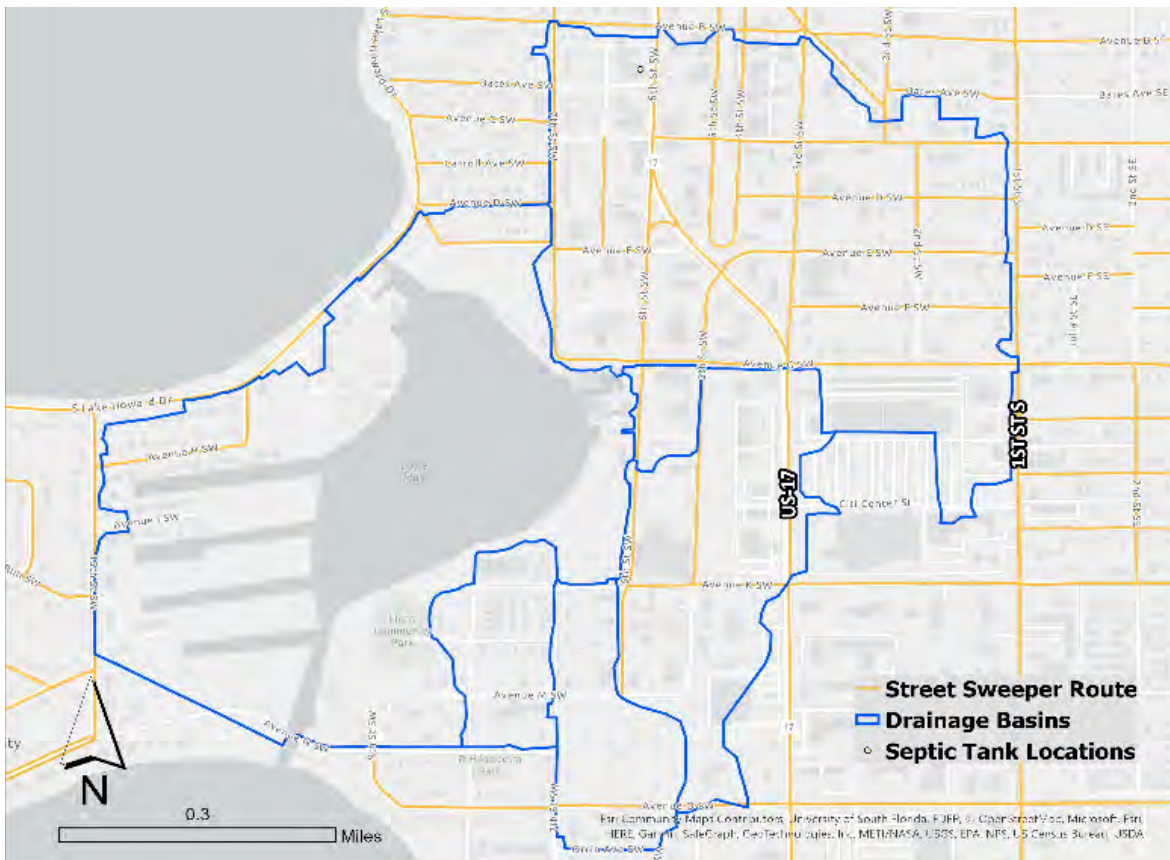


Figure 3-181. Map of Lake May's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake May is a small and shallow waterbody with a surface area of 50 acres, an average depth of 5.3 feet, and a maximum depth of around 10 feet (Figure 3-180). Lake May's shallowness coupled with its high boat traffic means that it likely has low water clarity and poorer water quality due in part to the increase suspended solids. That said, the shallowness of the lake supports an abundance of aquatic vegetation. Stormwater is conveyed to this waterbody from a 353 acre urbanized drainage basin comprised of six individual sub-basins (Figure 3-181). The basin is comprised of commercial, industrial, and residential land uses that contribute 1,733 lbs of TN and 293 lbs of TP to the lake annually. On a per acre basis, these pollutant loads rank Lake May 4th out of 37 lakes. To mitigate stormwater nutrient loads, the City conducts 27.3 miles of street sweeping services within the drainage area on a monthly basis and an alum injection system to treat runoff from Lake May's primary drainage sub-basin.

Lake May is centrally located on the South Chain with navigable canals leading to Lake Howard and Lake Shipp. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-182). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake May's surface level correlate with Chl-a, TN, TP, and clarity (see appendix). This carries management implications as an increase in levels should result in improved water quality across the board.

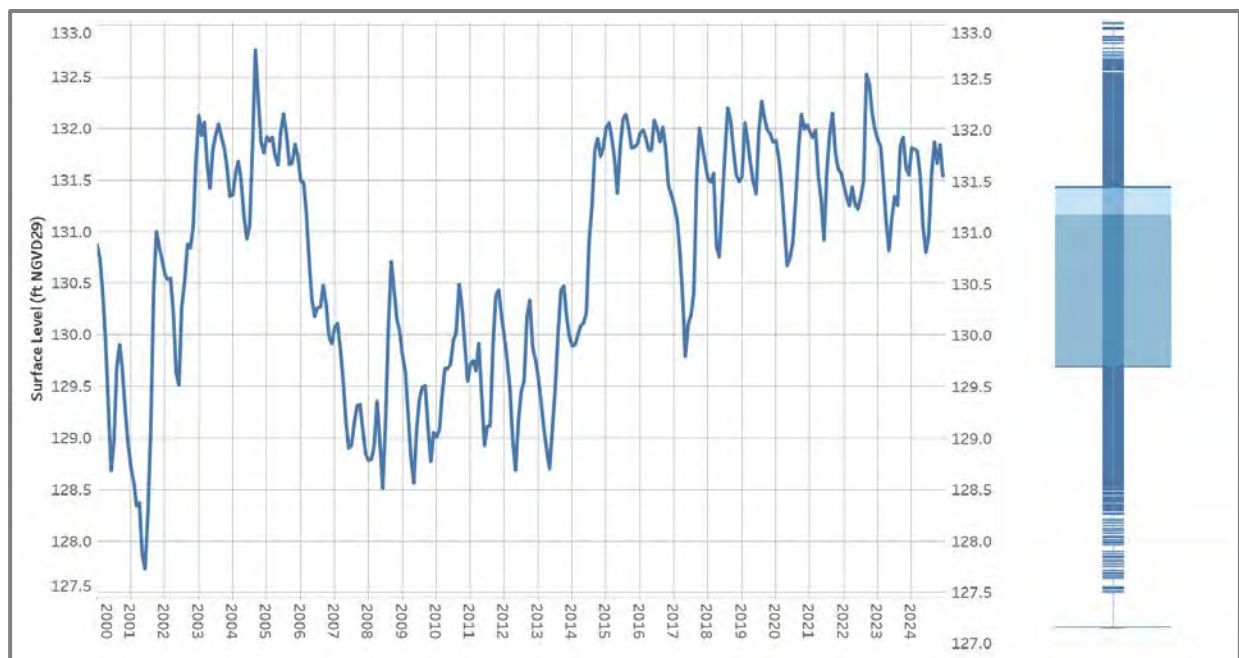


Figure 3-182. Hydrograph of Lake May depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake May is categorized as a clear, alkaline waterbody. Due to numerous consecutive NNC exceedances during the assessment period, Lake May is considered impaired for Chl-a, TN, and TP (Figure 3-183). This equates to an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load for Lake May, stipulating a 44% TN and 57% TP reduction to meet NNC guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.701	0.000	Decreasing	0	3
TN	Y	-0.727	0.000	Decreasing		3
TP	Y	-0.740	0.000	Decreasing		3
Secchi	NA	0.603	0.004	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Based on the data, each of Lake May's water quality parameters exhibited significant improving trends. The result is trend criteria scores of 3 for each of these parameters. Over time, with continued improving trends, Lake May should begin to meet the NNC impairment guidelines and exhibit much better water quality than when monitoring began.

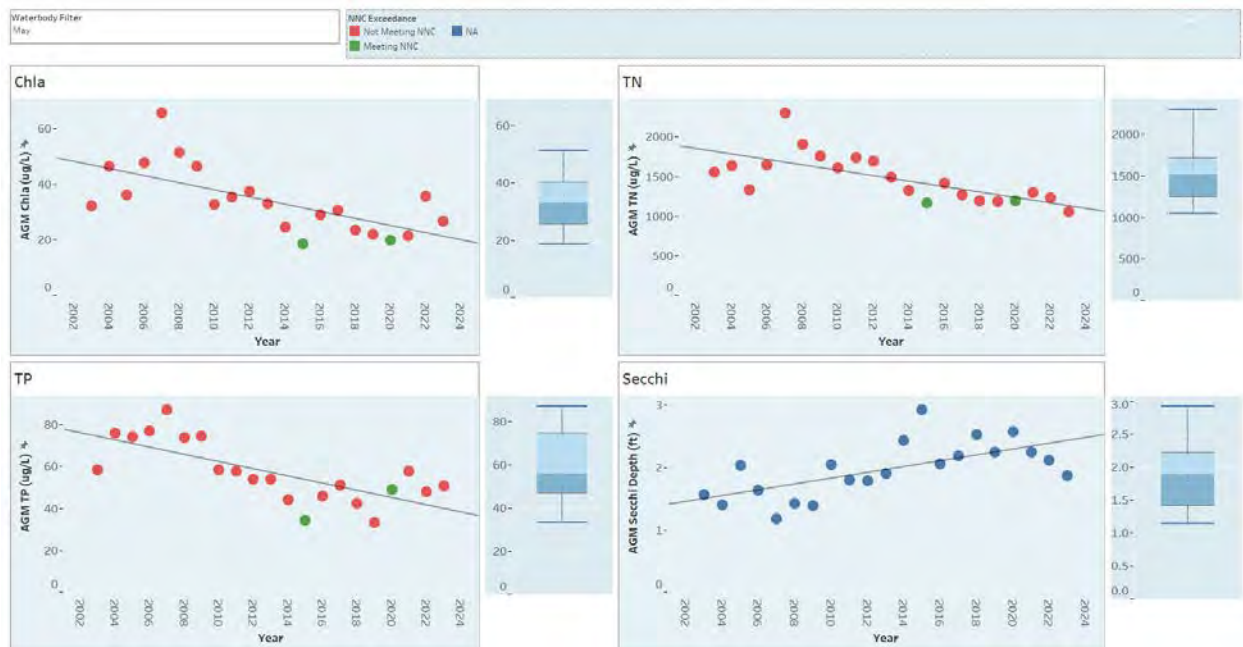


Figure 3-183. Lake May AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake May on 6/13/2024. The PAC during this survey was 97.1% and the total BV was 29.3% (Figure 3-184). This equates to an abundance criterion score of 3. Lake May has traditionally maintained a high vegetation abundance. Its

shallow depth and gradually sloping lake bed lend itself well to a wide littoral zone. This has occasionally raised navigation concerns in the past as over 50% of the surface is occupied by aquatic plants. Striking a balance between ecology and recreation is one of the City's management goals for this waterbody, but for now the navigational lanes remain open and usable.

Invasive Species Management:

Based on the 2024 survey, the floating-leaf plant spatterdock was the most dominant species in the lake (Figure 3-185). This was followed by a healthy mix of submerged and emergent species. With the amount of boat traffic and commercial land uses surrounding this lake, invasive species have been a constant concern. In 2024, burhead sedge, hydrilla, and water hyacinth made up 5.2% of the plant community; resulting in an invasive presence score of 1. Fortunately, this percentage decreased considerably from the previous years—constituting the lowest presence of invasive species since monitoring began. Continued management is still necessary to get these exotic plants into a controlled state.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, Lake May's species richness and overall diversity indices exceeded their long-term median values (Figure 3-186). This equates to a diversity criterion score of 2. While the evenness index was slightly below average, it was not by much. The invasive plant control efforts likely shifted the species dynamics such that the myriad plants present were slightly less equally distributed.

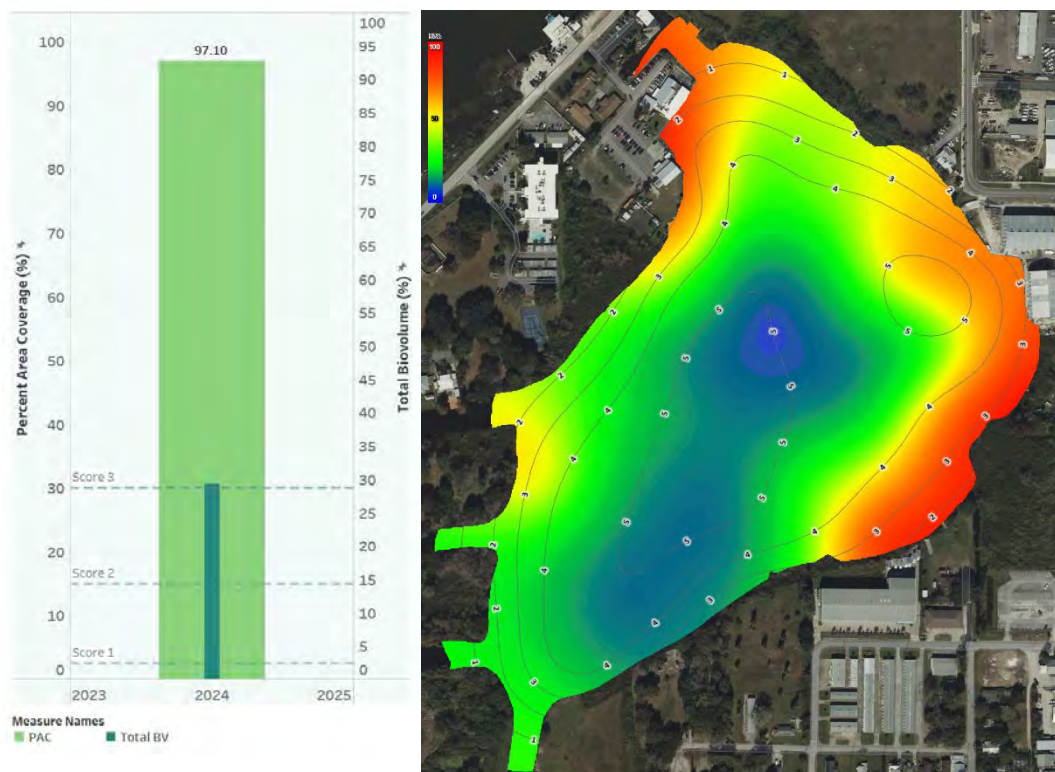


Figure 3-184. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake May; biovolume values range from green (lowest) to red (highest).

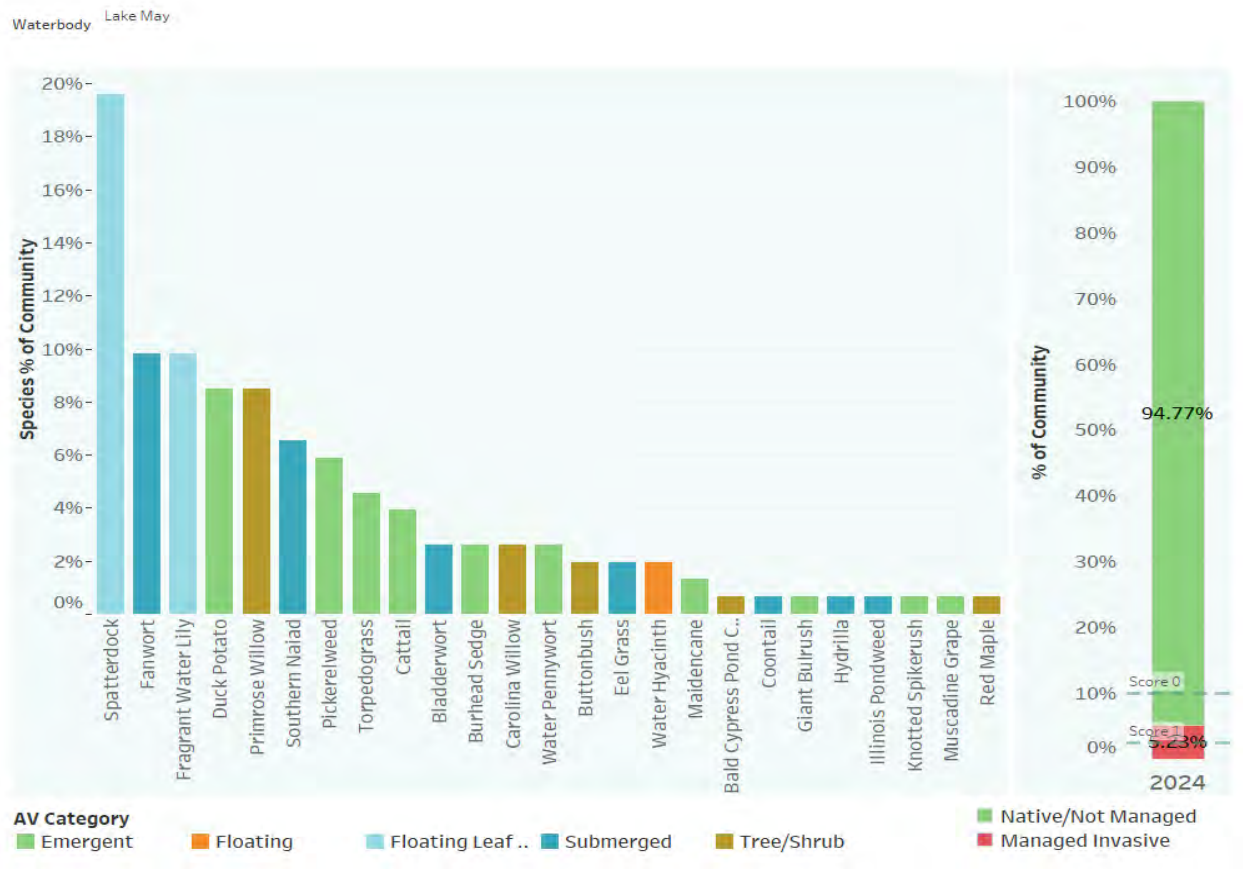


Figure 3-185. Chart depicting species frequency and invasive species percentage of Lake May during 2024.

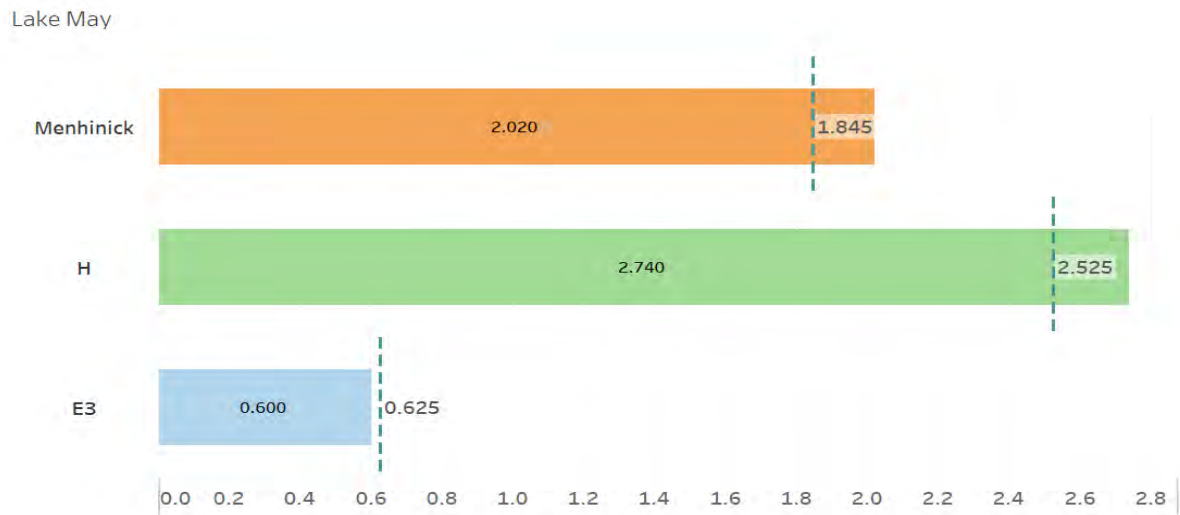


Figure 3-186. Chart depicting 2024 diversity indices for Lake May. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake May’s health index scores from 2018 to 2024 shows relative stability—with lake health ranging from 2.0 to 2.3 (Figure 3-186). In the seven-year span that Lake May has been monitored, the only changes in score have been in the invasive presence and diversity

criteria. Based on these scores, it appears that the changes in diversity have mostly been the result of invasive species management efforts. Overall, Lake May ranks in the middle of the pack with regards to management priority. While it is impaired, its water quality and vegetation abundance indicate that its overall health is improving.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	3	3	3	3	1	0	2.0
2019	0	3	3	3	3	3	0	1	2.0
2020	0	3	3	3	3	3	0	3	2.3
2021	0	3	3	3	3	3	0	2	2.1
2022	0	3	3	3	3	3	0	2	2.1
2023	0	3	3	3	3	3	0	3	2.3
2024	0	3	3	3	3	3	1	2	2.3

Figure 3-187. Chart depicting a comparison of Lake May's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- In addition to stormwater pollutant loading, Lake May received historic point-source discharges from the Imhoff Wastewater Treatment Plan as well as those from citrus and dairy processing facilities. The sediments in Lake May could house a considerable amount of these legacy nutrients and be a constant source of internal loading.
- Several water quality metrics are significantly correlated with Lake May's surface level; likely due to increased flushing during wetter periods. The means that drought conditions could result in water quality declines.
- Management of invasive species is a consistent concern. Lake May's invasive populations, while lower, still need control efforts to reach a maintained state. The large scale use of herbicides can result in water quality declines.
- In addition to invasives, tussock formation from the floating-leaf spatterdock can impact recreational navigation.

Lake Management Strategy:

- To mitigate stormwater pollutant loading, the City has implemented street sweeping, an alum injection system designed to reduce TN loads by 10% and TP loads by 45%, and general stormwater infrastructure improvements as part of the 7th Street Complete Streets Project.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC for invasive species management planning.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Mirror

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Mirror	1	3	3	2	2	3	2	3	2.4

Features & Statistics:

Surface area	130.1 acres
Mean depth	8.86 feet
Maximum depth	15.5 feet
Volume	1408.3 acre-feet
Drainage basin area	277.9 acres
Annual TN Load	749.6 lbs
Annual TP Load	120.9 lbs
Limiting nutrient	Co-limited (N & P)

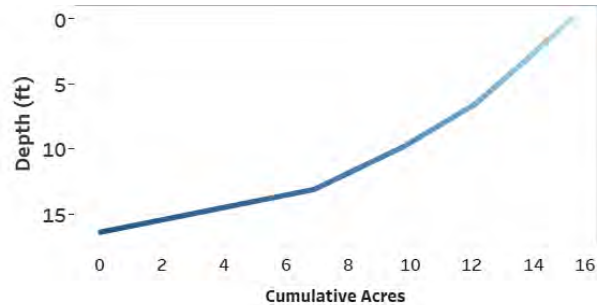


Figure 3-188. Hypsograph of Lake Mirror depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Mirror is a moderately sized waterbody with a surface area of 130 acres. Mirror's mean depth is slightly deeper than the regional average with deeper areas over 15 feet (Figure 3-188). Lake Mirror's bowl-shaped morphology provides adequate habitat for a robust aquatic vegetation community. Stormwater is conveyed to this waterbody from a 278 acre drainage basin comprised of 11 individual sub-basins (Figure 3-189). Residential land uses make up the vast majority of the drainage basin, contributing 750 lbs of TN and 121 lbs of TP to the lake annually—which is relatively low on a per acre basis. To mitigate stormwater loading, the City conducts 6.7 miles of street sweeping in this basin on a monthly basis.

Lake Mirror is located on the South Chain with navigable canals connecting to Lake Cannon and Spring. Due to these canal connections, surface levels fluctuate consistently across the South Chain

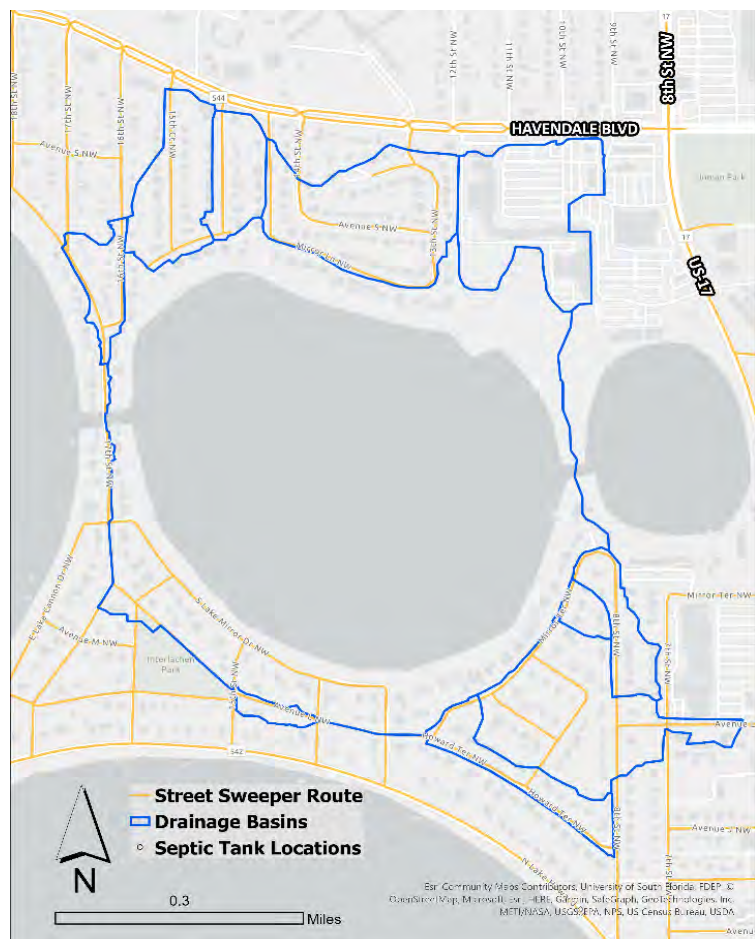


Figure 3-189. Map of Lake Mirror's drainage basin and City street sweeper routes.

of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-190). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Mirror's surface level correlate with TN (see appendix). This carries some management implications as maintaining higher levels should result in a decrease in TN concentrations.

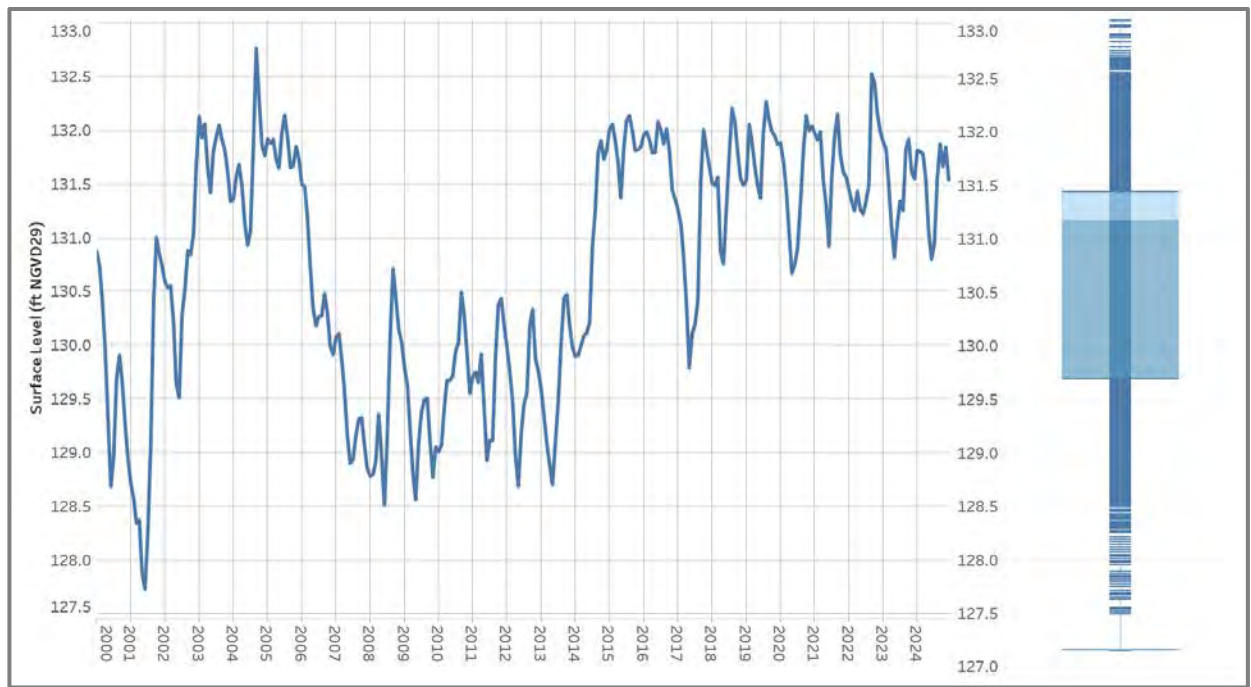


Figure 3-190. Hydrograph of Lake Mirror depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Mirror is categorized as a clear, alkaline waterbody. While previously un-impaired, recent NNC exceedances for Chl-a and TP during 2023 and 2024 have resulted in impairments in those parameters (Figure 3-191). This equates to an impairment score of 1. These recent concentrations are uncharacteristically high for a lake that has been meeting requirements since 2010. The FDEP established a total maximum daily load for Lake Mirror in 2007.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.456	0.038	Decreasing	1	3
TN	N	-0.668	0.001	Decreasing		3
TP	Y	-0.337	0.136	No Trend		2
Secchi	NA	0.312	0.168	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Lake Mirror exhibited significant improving trends in Chl-a and TN, and non-significant improving trends in TP and Secchi depth. Despite the recent impairment classification, it is a good sign that Mirror's chlorophyll and nitrogen levels are still trending downward.



Figure 3-191. Lake Mirror AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Mirror on 1/25/2024. The PAC during this survey was 62.1% and the total BV was 8.6% (Figure 3-192). Not only does this equate to a vegetation abundance criterion score of 3, but these are the highest coverage and biovolume numbers on record. Throughout the period of record, Lake Mirror has maintained exceptional vegetation abundance; which has likely contributed to its water quality improvements and should hopefully help to buffer against continued increases in Chl-a and TN.

Invasive Species Management:

Based on the 2024 survey, Lake Mirror is dominated by submerged vegetation. Eelgrass, Illinois pondweed, and southern naiad comprised over 46% of the community (Figure 3-193). A high number of remaining plants include a mix of emergent, floating-leaf and submerged species—indicative of high diversity. The invasive burhead sedge was the only managed exotic species present—making up just 1.9% of the community. This is a reduction from previous years and equates to an invasive criterion score of 2. Hydrilla, which made up almost 5% of the community in 2022, was absent during 2024—highlighting how invasive treatment efforts have been successful. The reduction in invasives coupled with an increase in overall plant abundance also exemplifies successful invasive plant management. That said, continued monitoring and maintenance is necessary to prevent future infestations.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, all three of Mirror's diversity indices met or exceeded their long-term median values (Figure 3-194). This equates to a diversity criterion score of 3 and is a large shift from the previous year where two of the indices were below average. From 2023 to 2024, the number of unique species detected increased from 17 to 24. In addition to an increase in species richness, the distribution of these species was much more equitable. Both of these improvements then led to an increase in the overall diversity index.

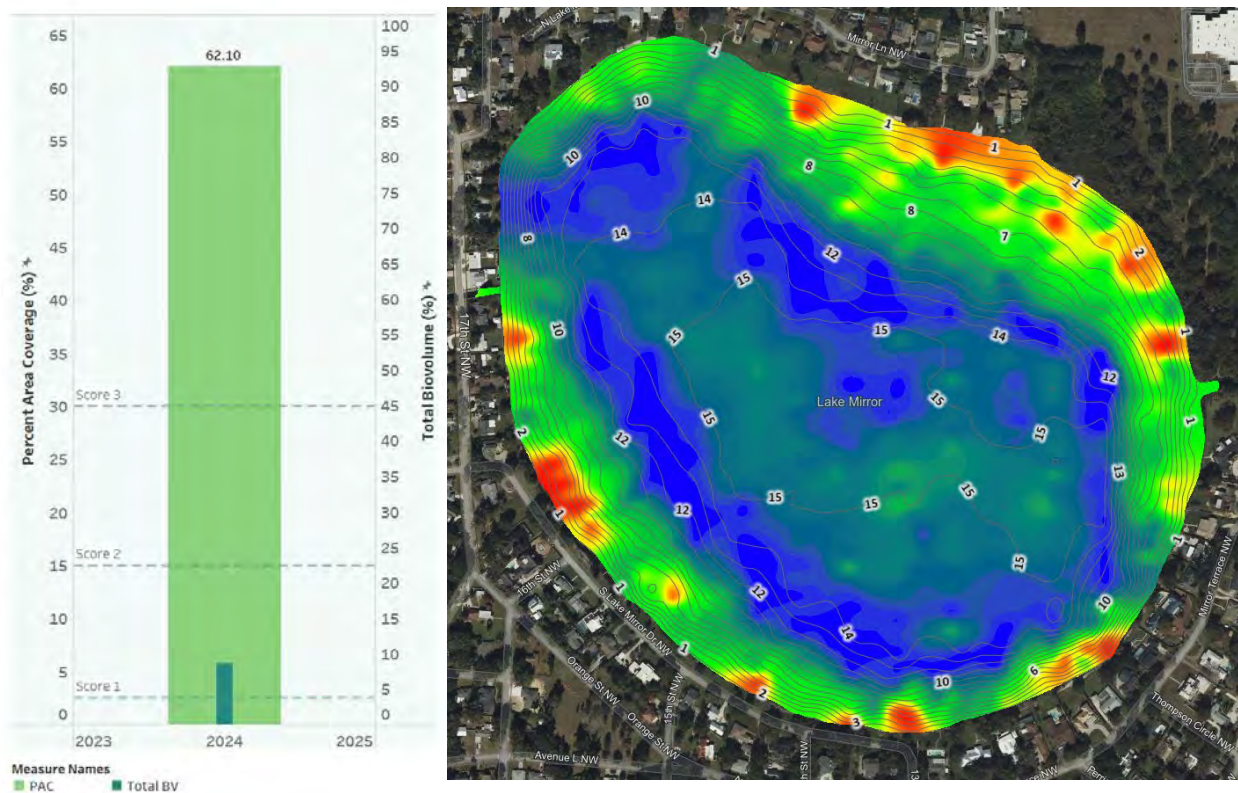


Figure 3-192. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Mirror; biovolume values range from green (lowest) to red (highest).

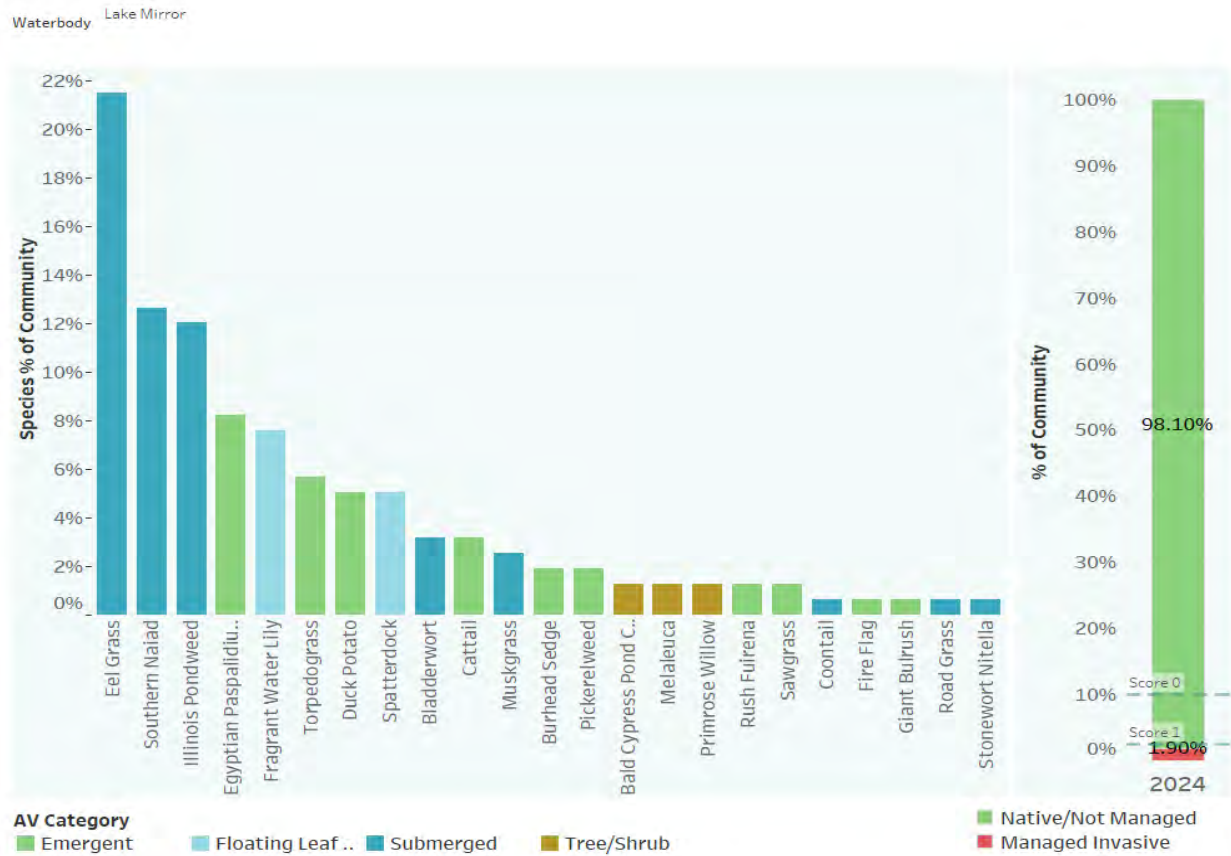


Figure 3-193. Chart depicting species frequency and invasive species presence of Lake Mirror during 2024.

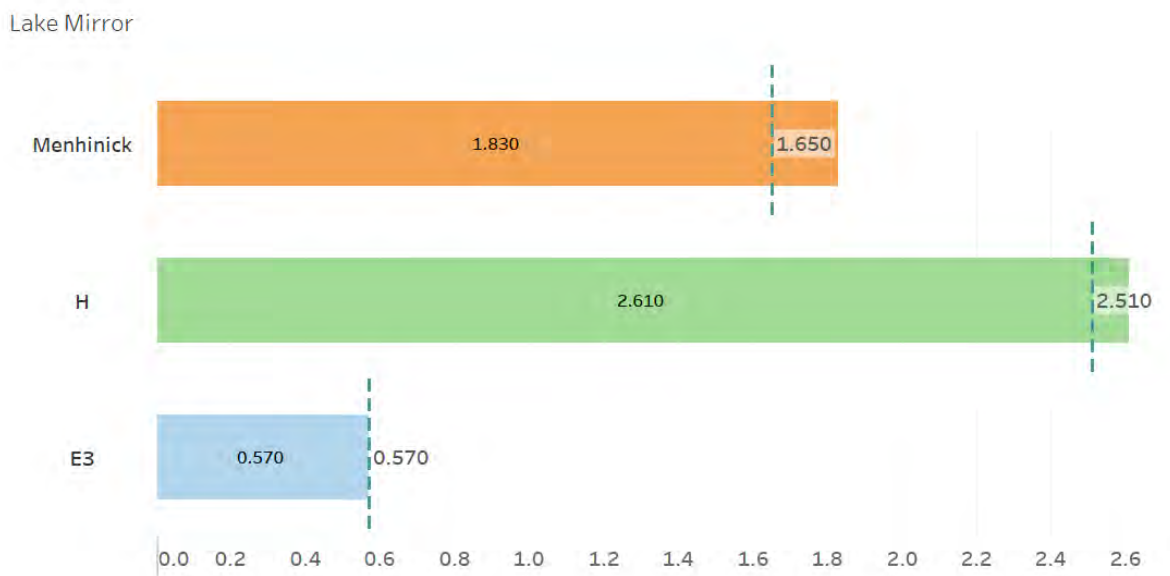


Figure 3-194. Chart depicting 2024 diversity indices for Lake Mirror. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Mirror's health index scores from 2018 to 2024 shows relatively good lake health with slight alterations (Figure 3-195). Unfortunately, the latest LHI score is the lowest on record due to the recent impairments in Chl-a and TN and shift in the TP and Secchi depth trends. Invasive presence and diversity have vascillated over time, mostly due to invasive management efforts and the resulting impacts on the vegetaiton community. Lake Mirror was previously lower on the priority list, but recent shifts in water quality require closer inspection to determine the underlying causes and to develop management strategies to address them.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	2	0	2.5
2019	3	3	3	3	3	3	1	2	2.6
2020	3	3	3	3	3	3	1	1	2.5
2021	3	3	3	3	3	3	2	1	2.6
2022	3	3	3	3	3	3	1	3	2.8
2023	3	3	3	3	3	3	1	1	2.5
2024	1	3	3	2	2	3	2	3	2.4

Figure 3-195. Chart depicting a comparison of Lake Mirror's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading is one of the primary concerns with regards to water quality decline. While the per acre pollutant loads are relatively low, there are very few structural stormwater practices present in the basin that help to reduce these loads
- The management of invasive species like hydrilla is a consistent concern. As observed in Lake May during 2022, it can only take a single growing season for even a small population to take over large areas of a waterbody.

Lake Management Strategy:

- With the majority of the drainage basin comprised of residential housing, public education and outreach is a valid stormwater management strategy. Education aims to increase residents' knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- The Stormwater Assessment and Improvement Project has identified a priority area in the southeastern part of Lake Mirror's drainage basin. Implementation of green infrastructure can reduce flooding in addition to stormwater pollutant loads where treatment has historically been lacking. Staff can explore funding opportunities to implement green infrastructure in these areas.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Ned

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Ned	3	0	0	1	0	3	2	1	1.3

Features & Statistics:

Surface area	76.4 acres
Mean depth	7.2 feet
Maximum depth	16 feet
Volume	549.8 acre-feet
Drainage basin area	256.9 acres
Annual TN Load	1002.9 lbs
Annual TP Load	202.7 lbs
Limiting nutrient	Phosphorus

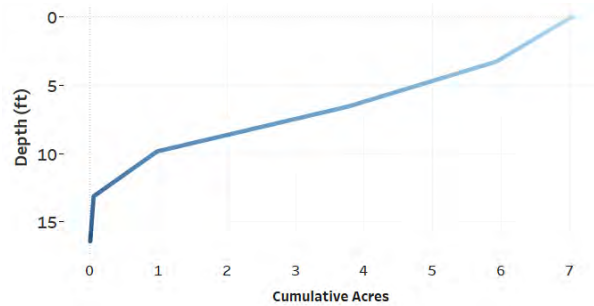


Figure 3-196. Hypsograph of Lake Ned depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Ned is a relatively small waterbody at 76 acres, an average depth of 7.2 feet, and a maximum depth approaching 16 feet (Figure 3-196). This is one of Winter Haven's shallower lakes which not only makes the lake more susceptible to sediment suspension, but should also support a dense aquatic vegetation community. Stormwater is conveyed to this waterbody from a 257 acre drainage basin made up mostly of residential and agricultural land uses (Figure 3-197). Based on stormwater pollutant load modelling, this drainage area contributes 1,003 lbs of TN and 203 lbs of TP to the lake annually. On a per acre basis the TN and TP loads rank 14th and 6th highest, respectively, out of the 37 area lakes. There are 53 known septic systems within the basin. These could be a contributor of pollutant loads via groundwater leaching.

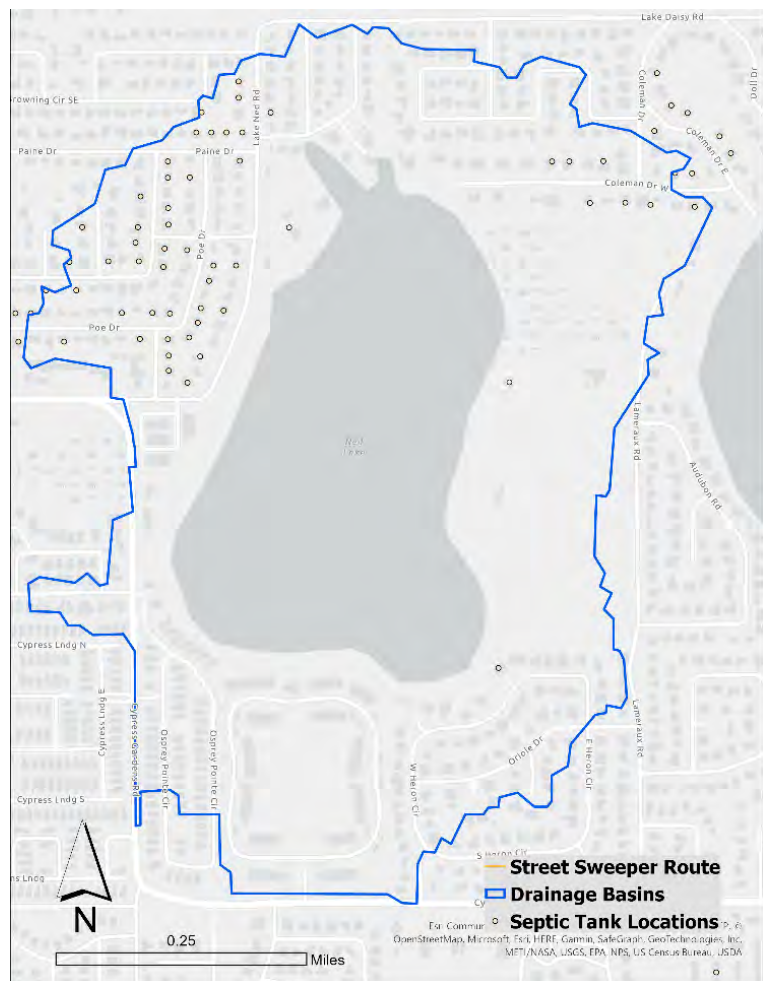


Figure 3-197. Map of Lake Ned's drainage basin and nearby septic systems.

Lake Ned is located almost entirely outside City limits to the southeast of downtown Winter Haven. Its average surface elevation sits relatively low in the Peace Creek watershed when compared to the other study area lakes. Over its period of record, Lake Ned's surface level has fluctuated between 124 and 129.2 feet above sea level. The normal range fluctuates between 126.9 and 128 feet (Figure 3-198). During 2024, Lake Ned's surface level dropped to 126.9 feet in June and then climbed to a wet season high of 128.2 feet in October after the hurricanes. The surface level ended the year just below the high end of the normal range at 127.9 feet. Changes in Lake Ned's surface level are not correlated with its primary water quality metrics.

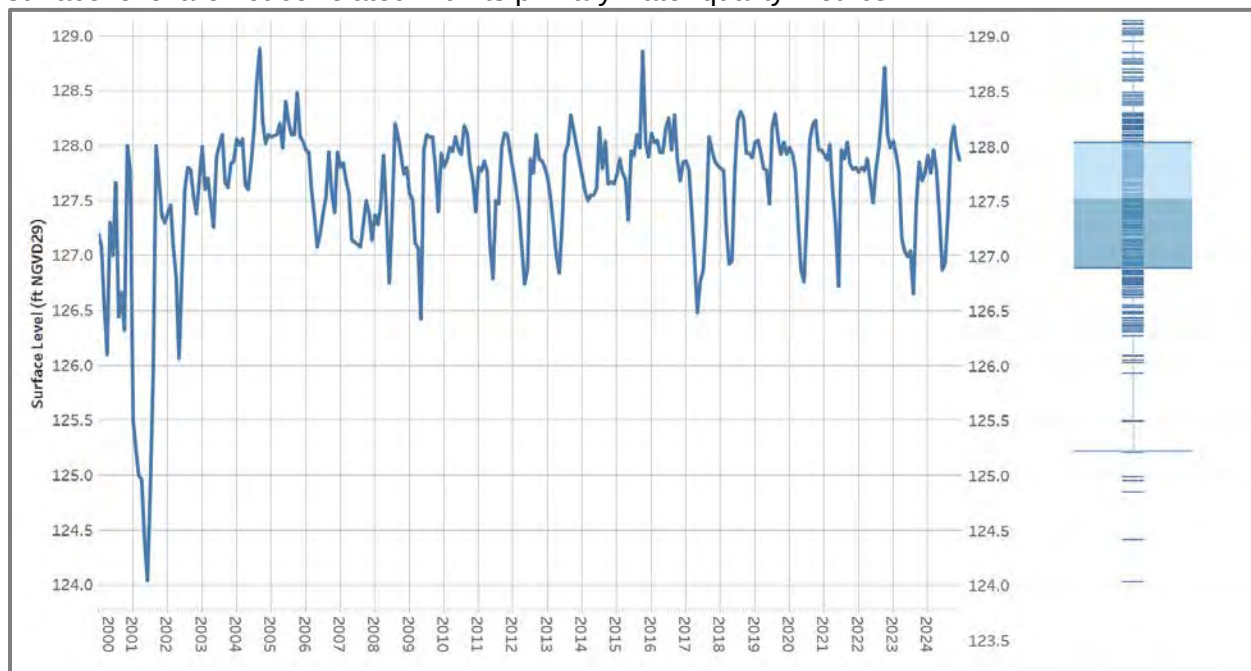


Figure 3-198. Hydrograph of Lake Ned depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Ned is categorized as a clear, alkaline waterbody. Due to a lack of exceedances in any of the NNC parameters during the assessment period, Lake Ned is considered un-impaired (Figure 3-199). This equates to an impairment criterion score of 3. Recently, concentrations of Chl-a, TN, and TP have been higher than normal; with Secchi depths at or below median levels—indicating water quality declines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	0.779	0.000	Increasing	3	0
TN	N	0.750	0.000	Increasing		0
TP	N	0.394	0.077	No Trend		1
Secchi	NA	-0.856	0.000	Decreasing		0

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Chl-a, TN, and Secchi depth all exhibited

significant deteriorating trends. This equates to trend criteria scores of 0. While a deteriorating TP trend was present in 2023, this has shifted to a non-significant deteriorating trend in 2024. It is evident that Lake Ned's water quality is trending in a negative trajectory. Management efforts will be critical in order to prevent water quality impairment in the future.



Figure 3-199. Lake Ned AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Ned on 5/24/2024. The PAC during this period was 42.4% and the total BV was 9% (Figure 3-200). By exceeding the 30% coverage threshold, Ned receives a vegetation abundance criterion score of 3. Since monitoring began, Lake Ned has consistently had low vegetation abundance scores below 10%. However, in recent years, these coverage and biovolume values have increased significantly; indicating improvement in the vegetation community. The 2024 abundance values are the highest on record for Lake Ned and will hopefully provide much needed fish and wildlife habitat as well as water quality improvements.

Invasive Species Management:

Based on the 2024 survey data, the vegetation community in Lake Ned has completely shifted away from an emergent dominated lake to one supporting an abundance of submerged species (Figure 3-201). Eelgrass became the most dominant species in the lake, making up over 20% of the community. Behind it, a mix of other submerged, emergent, and floating-leaf plants made up the remainder of the ecosystem. The only managed invasive species detected during 2024 was hydrilla which made up just 1.1% of the community. This equates to an invasive presence score of 2. Lake Ned has not traditionally had a major issue with invasive plants; never exceeding 6% of the total community since monitoring began. Management efforts to treat hydrilla will eventually be necessary to prevent it from spreading and taking over the lake.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, Lake Ned's species richness index was the only one of the three that met or exceeded its long-term median value (Figure 3-202). This equates to a diversity criterion score of 1. In 2024, the richness index increased from previous years due to detection of multiple new plant species. The tremendous increase in eelgrass and other SAV varieties, while good, did slightly decrease the evenness and overall diversity indices mostly due to the dominance of a few plants over other less represented species. Since invasive species management has not occurred in or around Lake Ned in several years, it can be assumed that these shifts in the vegetation community have occurred naturally.

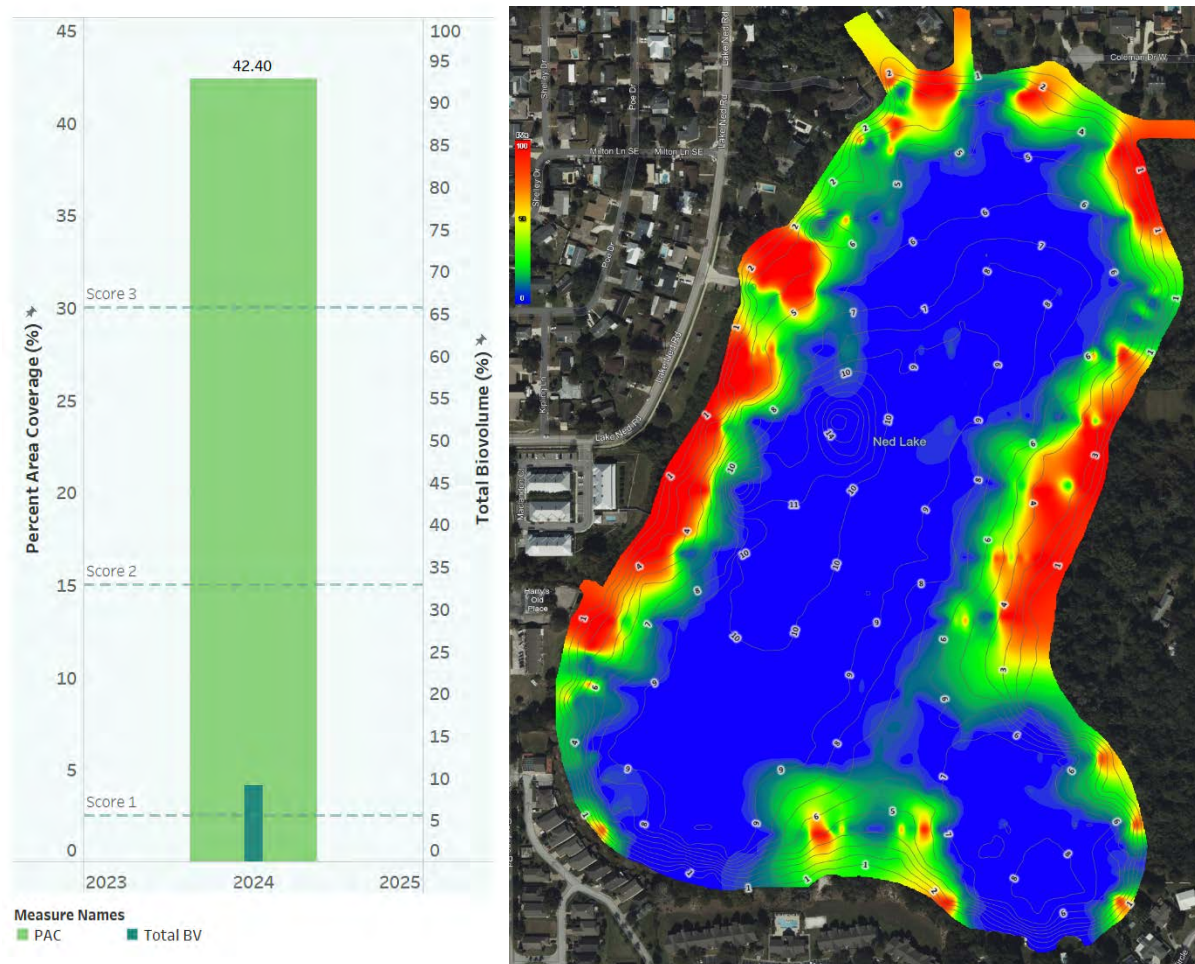


Figure 3-200. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Ned; biovolume values range from green (lowest) to red (highest).

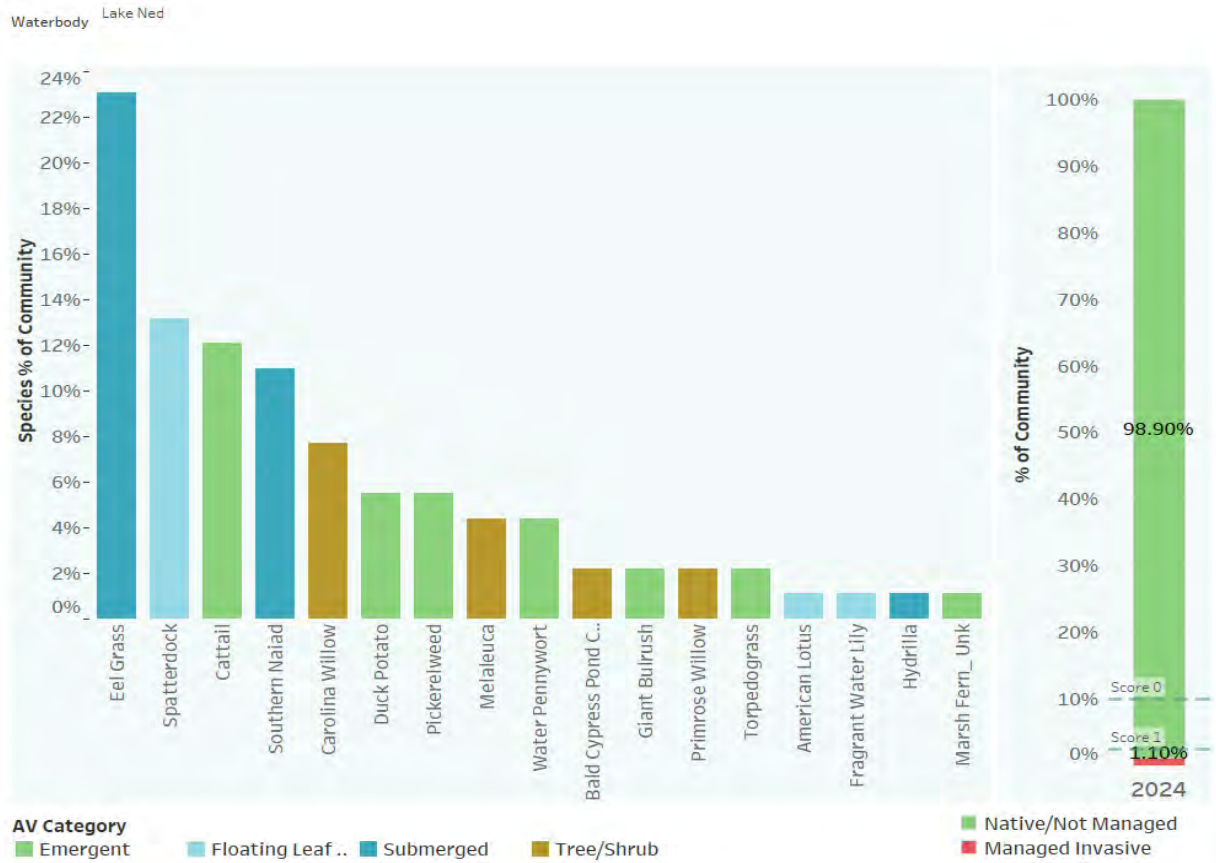


Figure 3-201. Chart depicting species frequency and invasive species percentage of Lake Ned during 2024.

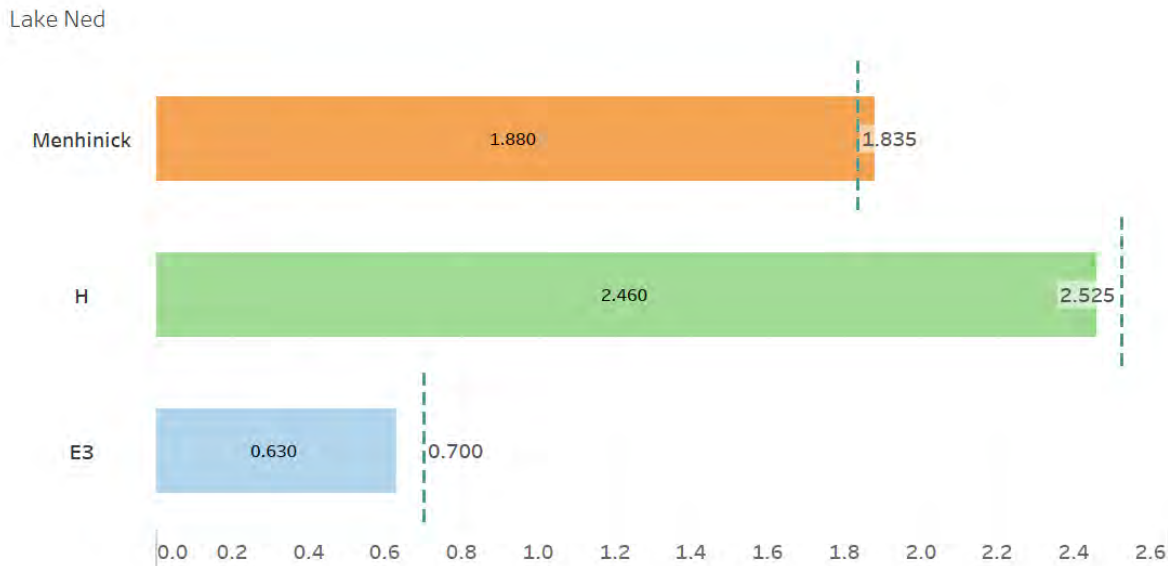


Figure 3-202. Chart depicting 2024 diversity indices for Lake Ned. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Ned's health index scores from 2018 to 2024 shows relatively stability, but consistently low scores (Figure 3-203). Water quality is relatively good in Lake Ned with no change to its impairment score. However, there was a shift in the TN trend toward deterioration. The majority of the score fluctuation has occurred from the biological criteria. As stated, vegetation abundance is recovering. Invasive presence has been relatively low throughout the monitoring timeline, but the diversity score has fluctuated widely. Overall, Lake Ned is in the middle of the priority list. Efforts should focus on improving water quality trends before the lake becomes impaired.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	1	0	0	1	1	3	1.1
2019	3	0	2	0	0	1	1	3	1.3
2020	3	0	2	0	0	1	3	0	1.1
2021	3	0	2	0	0	1	3	1	1.3
2022	3	0	1	0	0	2	2	3	1.4
2023	3	0	0	0	0	2	3	2	1.3
2024	3	0	0	1	0	3	2	1	1.3

Figure 3-203. Chart depicting a comparison of Lake Ned's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- While stormwater pollutant loading remains a potential concern, the presence of so many OSTDs within the basin may be a contributor of nutrients via groundwater leaching and may be why the TN trend has shifted to the negative.
- The management of the vegetation community includes ensuring adequate abundance and invasive species control. Early detection and rapid response is crucial to keep these invasive plants from becoming a larger problem that would necessitate larger-scale control (which comes with potentially negative impacts). Fortunately, the abundance of SAV has increased tremendously in recent years.

Lake Management Strategy:

- City staff can provide support to Polk County in exploring source analysis to determine if the OSTDs are contributing to increased pollutant loads in Lake Ned. Further management efforts may explore septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large scale herbicide treatments and the potential water quality issues that follow.

Lake Otis

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Otis	3	2	2	1	1	3	3	3	2.3

Features & Statistics:

Surface area	135 acres
Mean depth	10.63 feet
Maximum depth	32 feet
Volume	1719.9 acre-feet
Drainage basin area	586.9 acres
Annual TN Load	2291 lbs
Annual TP Load	372.6 lbs
Limiting nutrient	Co-limited (N & P)

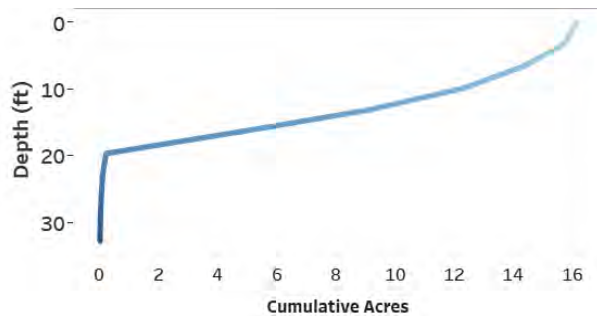


Figure 3-204. Hypsograph of Lake Otis depicting the depth profile and morphology of the lake bed.

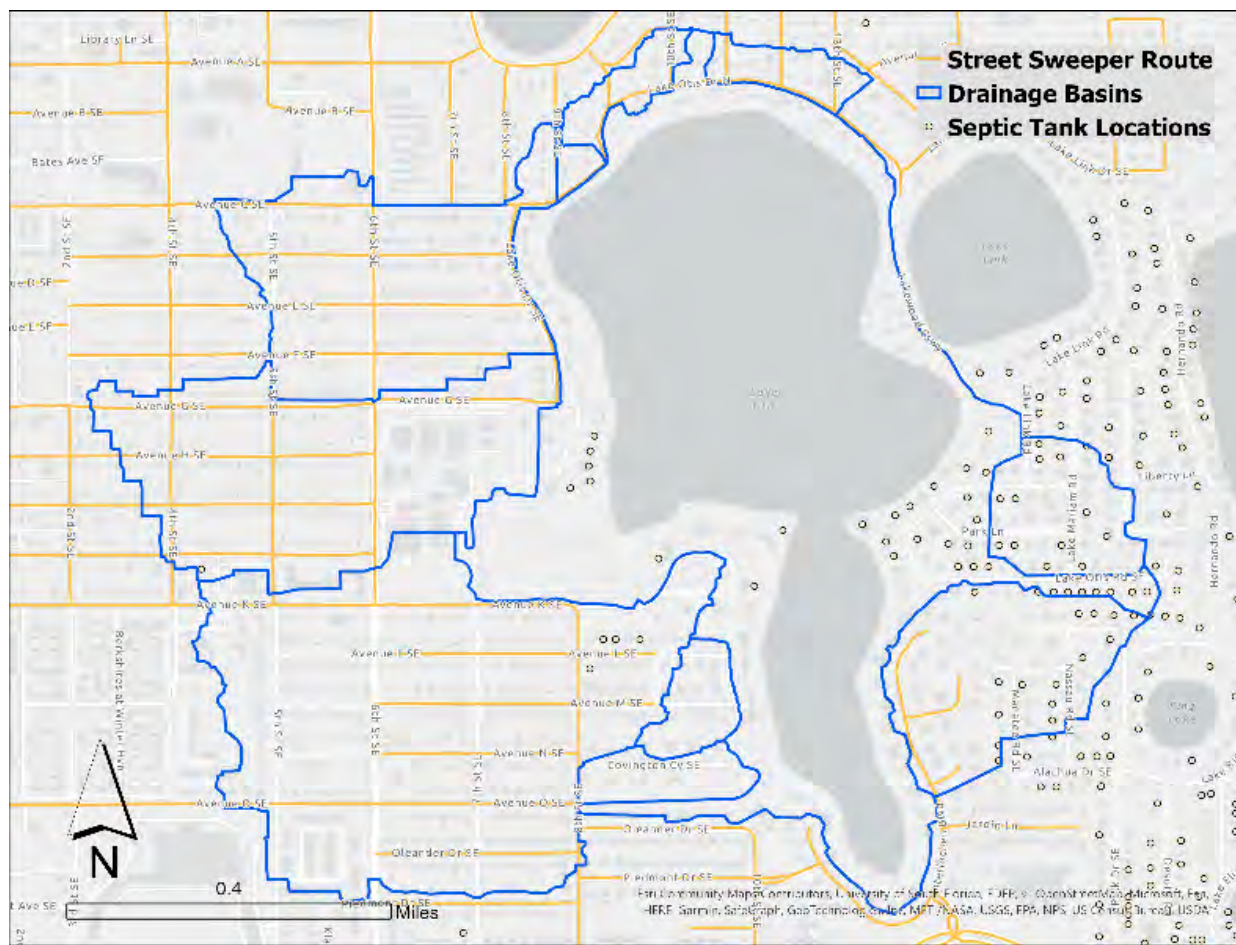


Figure 3-205. Map of Lake Otis' drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Otis is a moderately sized waterbody comprised of a main lake basin and Little Lake Otis to the south. It has a surface area of 135 acres, an average depth of 10.6 feet, and a maximum depth of over 30 feet in deeper areas (Figure 3-204). The average depth of Lake Otis is generally deeper than the regional mean depth, with the deepest sections in Little Lake Otis. The main lake is shallower and should have enough of a littoral zone to support a robust aquatic plant community. Stormwater is conveyed to this waterbody from a 587 acre drainage basin comprised of 11 individual sub-basins (Figure 3-205). By far, the most dominant land uses in this basin are residential which contribute 2,291 lbs of TN and 372 lbs of TP to the lake annually. On a per acre basis, these pollutant loads rank moderately high compared with the other 36 lakes in the study area. There are 66 septic systems located within the drainage basin. These constitute a moderate density and may contribute to pollutant loading via groundwater leaching. To mitigate stormwater loads, the City conducts 12.8 miles of street sweeping within the basin.

Lake Otis and its neighbor, Lake Link, are connected via a navigable canal—indicating that they are held at the same surface level. Excess water discharges from Lake Link to Lake Mariam to the east. The surface elevation of these two lakes sits near the bottom of the Peace Creek watershed. Over its period of record, the shared surface level of Lakes Link and Otis has fluctuated between 120.3 and 128.8 feet above sea level. The wide range of fluctuation is possible because of the steep-sloped morphology of these lakes. The normal range of fluctuation is much narrower—between 124.9 and 127.2 feet (Figure 3-206). During 2024, Lake Otis reached its peak of 126.4 feet in June and plummeted to a low of 125 feet in November; ending the year near the low end of the normal range at 125.2 feet. This is strange due to the tremendous amount of rainfall received during the 2024 hurricane season. It is likely that the Lake Region Lakes Management District opened the control structure to lower the lake level prior to the storms. According to linear regression analysis, changes in Lake Otis' surface level are correlated with Chl-a, TN, and Secchi depth (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

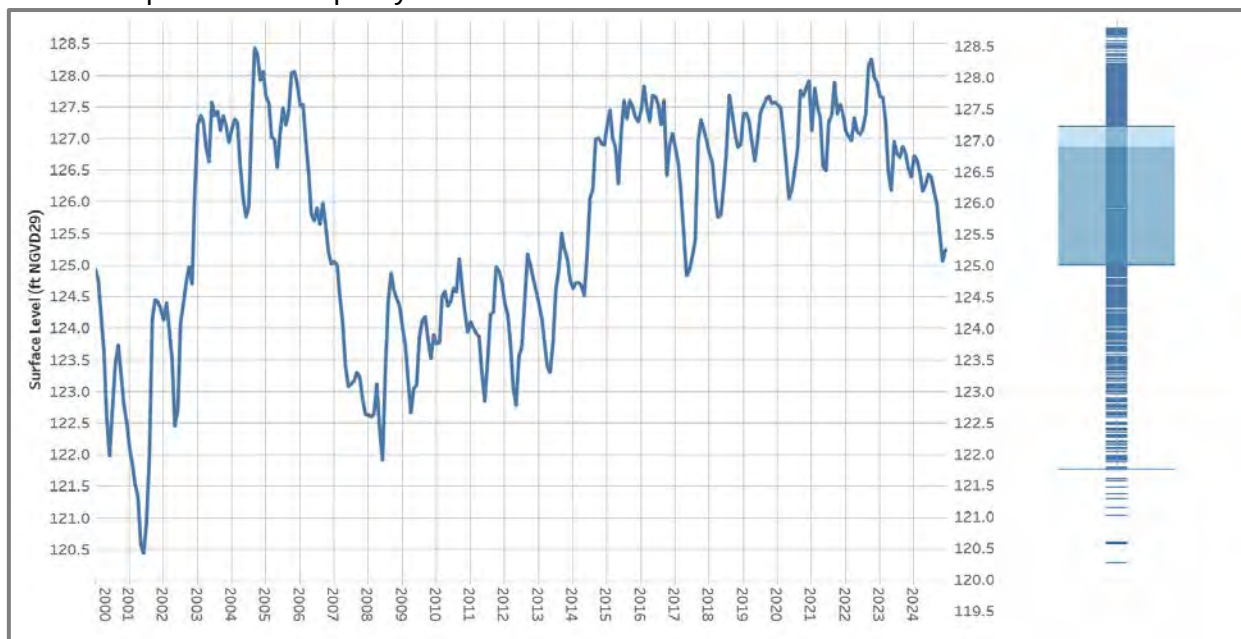


Figure 3-206. Hydrograph of Lake Otis depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

For the purposes of determining water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Otis is categorized as a clear, alkaline waterbody. Due to a lack of NNC exceedances during the assessment period, Lake Otis is considered un-impaired (Figure 3-207). This equates to an impairment criterion score of 3. Lake Otis did exhibit Chl-a impairment as late as 2019, but has since improved to the point of being delisted.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.124	0.646	No Trend	3	2
TN	N	-0.182	0.499	No Trend		2
TP	N	0.026	0.924	No Trend		1
Secchi	NA	-0.103	0.703	No Trend		1

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Lake Otis exhibits no statistically significant trends. However, TP and Secchi depth trends are in a deteriorating direction, while the Chl-a and TN trends are in an improving direction. Deteriorating trend directions earn scores of 1 while improving directions earn scores of 2.



Figure 3-207. Lake Otis AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Otis on 8/23/2024. The PAC during this survey was 30.9% and the total BV was 3.18% (Figure 3-208). Exceeding the 30% PAC threshold results in an abundance criteria of 3. A comparison of abundance records from 2018 to the present shows that Lake Otis' coverage is typically between 15% and 30%. The coverage value for 2024 is the second highest on record, indicating a general increasing trend in abundance.

Invasive Species Management:

Based on the 2024 survey data, Lake Otis maintains a healthy mix of vegetation types. The most dominant species was fragrant water lily at 14% of the population (Figure 3-209). There were no managed invasive species present in Lake Otis in 2024. This equates to an invasive criterion score of 3. Prior to 2018, hydrilla was the primary invasive species to be controlled. Grass carp were stocked in 2019 and appear to be having a positive impact on the control of the hydrilla while also allowing other native submerged species to grow.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on 2024 species data, all three of Lake Otis's diversity indices exceeded their respective median values; equating to a diversity criterion score of 3 (Figure 3-210). This is a positive change considering the elimination of invasive species did not negatively impact species richness, the distribution of the plant community, nor the overall diversity in the lake.

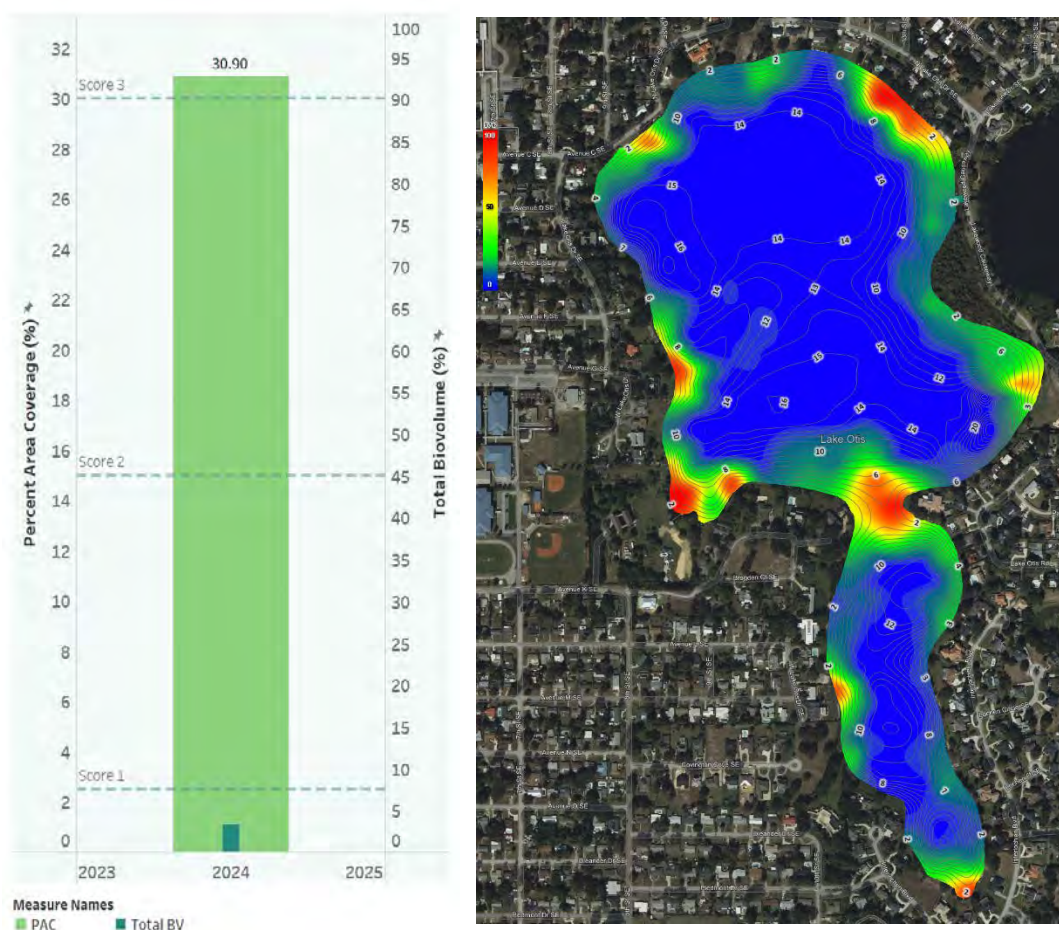


Figure 3-208. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Otis; biovolume values range from green (lowest) to red (highest).

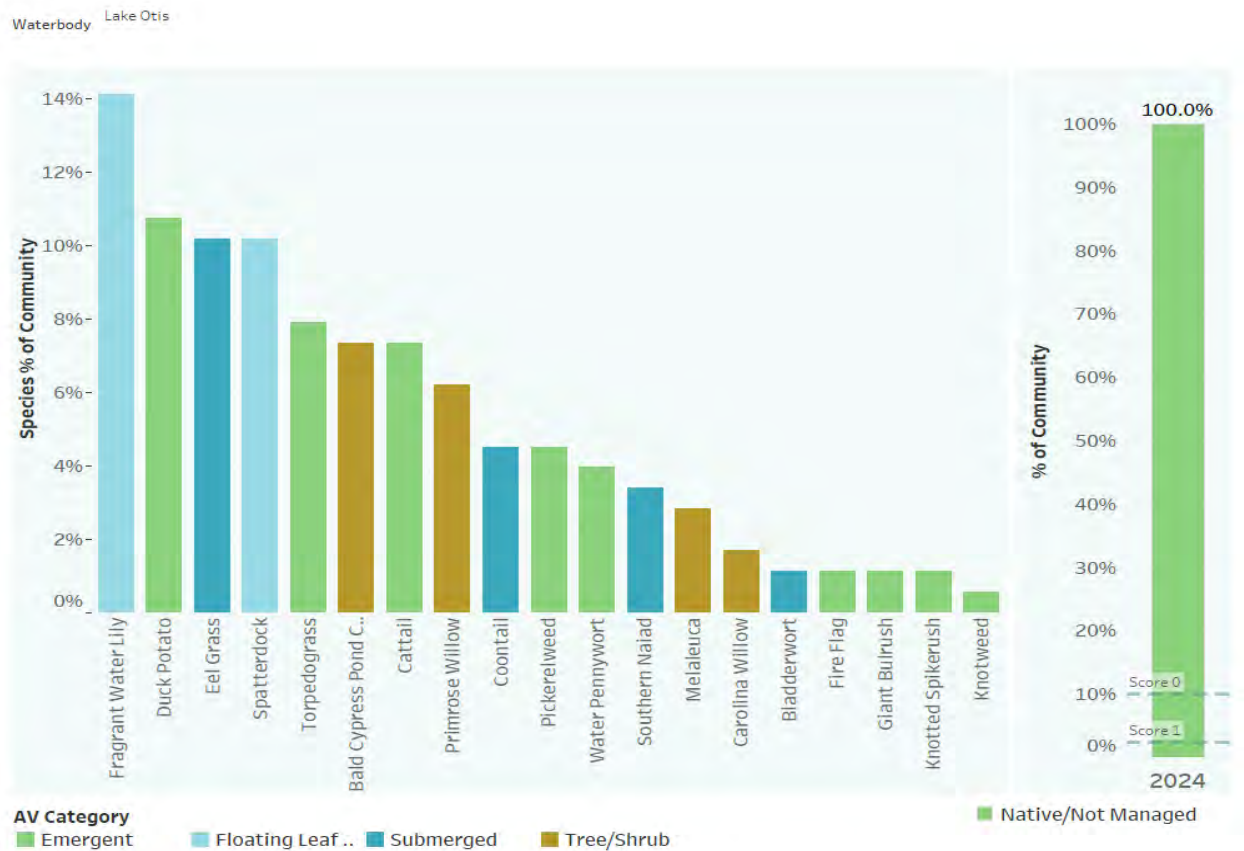


Figure 3-209. Chart depicting species frequency and invasive species percentage of Lake Otis during 2024.

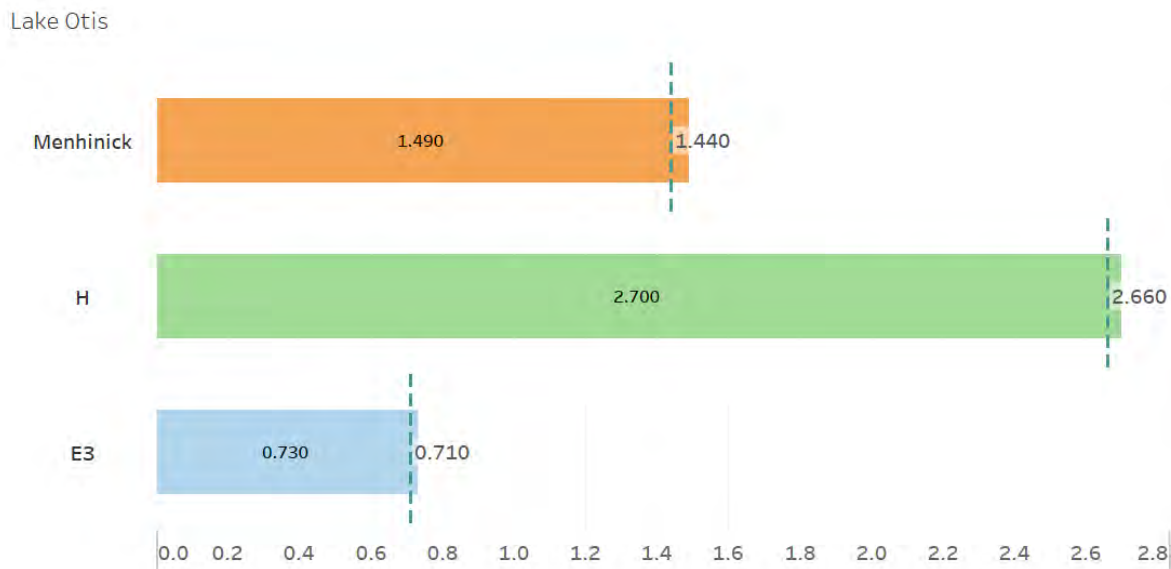


Figure 3-210. Chart depicting 2024 diversity indices for Lake Otis. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Otis' health index scores from 2018 to 2024 shows values ranging from 1.6 to 2.3 (Figure 3-211). During this time the impairment criterion has seen improvement as Chl-a began meeting NNC guidelines. The water quality trends have remained relatively static, with TP and Clarity shifting directions slightly from year to year. Vegetation abundance and species diversity have exhibited the most improvement in recent years. Overall, Lake Otis ranks lower on the priority list as it is currently meeting water quality standards and the trends do not indicate deterioration.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	2	2	2	2	2	2	1	2	1.9
2019	2	2	2	2	2	2	0	2	1.8
2020	3	2	2	2	2	2	NA	NA	2.2
2021	3	2	2	1	1	1	2	1	1.6
2022	3	2	2	1	2	2	2	2	2.0
2023	3	1	2	1	1	3	1	2	1.8
2024	3	2	2	1	1	3	3	3	2.3

Figure 3-211. Chart depicting a comparison of Lake Otis' Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading from the western portion of the basin is a concern. Additionally, the presence of septic systems on the eastern side of the basin could potentially leach pollutants to the lake via groundwater.
- The management of invasive species like hydrilla is a consistent concern. There are also potential impacts from all types of invasive management strategies. Finding the right balance is important.
- Several water quality metrics are significantly correlated with Lake Otis' surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City's current stormwater management strategy includes street sweeping and the implementation of green infrastructure (swales) along 6th St SE. The Stormwater Assessment and Improvement Plan has also identified several potential areas in the basin where stormwater improvements can be made. Staff will explore funding opportunities to implement these.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC.
- The City may explore source analysis to determine if the septic systems in the basin are a contributor of pollutant loading. Further management may involve septic-to-sewer conversions.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Pansy

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Pansy	3	1	2	1	1	2	3	2	1.9

Features & Statistics:

Surface area	49.4 acres
Mean depth	6.8 feet
Maximum depth	14 feet
Volume	397 acre-feet
Drainage basin area	243.8 acres
Annual TN Load	880.7 lbs
Annual TP Load	111.2 lbs
Limiting nutrient	Phosphorus

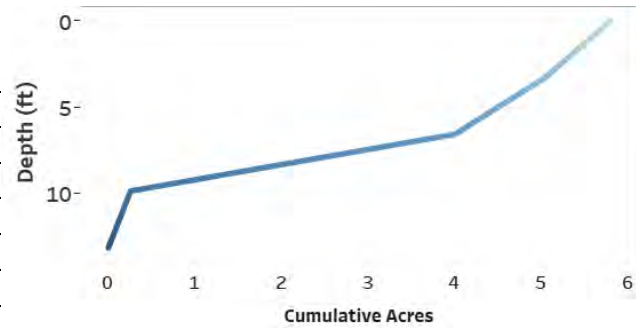


Figure 3-212. Hypsograph of Lake Pansy depicting the depth profile and morphology of the lake bed.

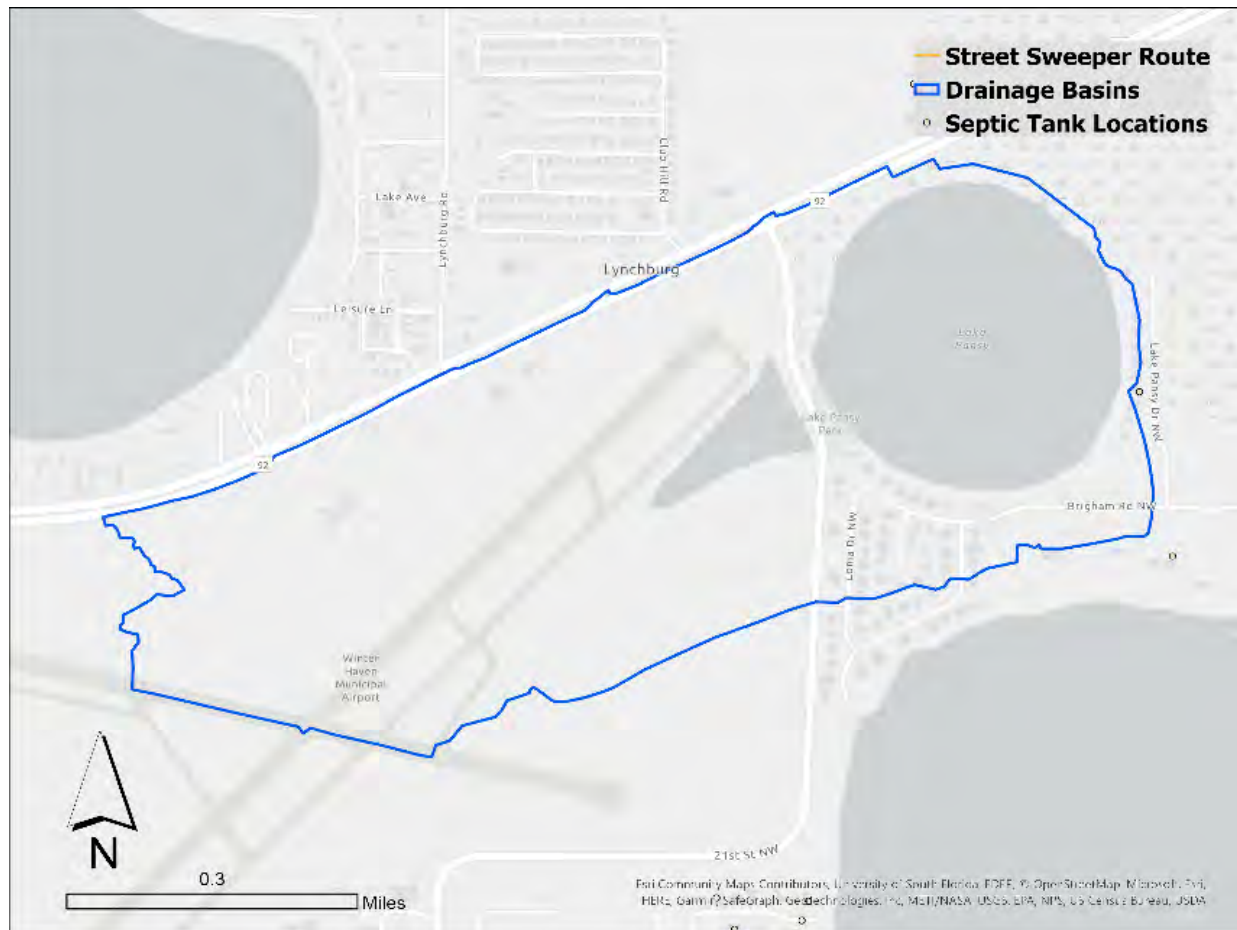


Figure 3-213. Map of Lake Pansy's drainage basin and nearby septic systems.

Hydrology:

Lake Pansy is a relatively small and shallow waterbody at just 49 acres, an average depth of 7 feet, and a maximum depth of 14 feet (Figure 3-212). Such a shallow waterbody should support a robust littoral zone for aquatic vegetation. However, in the absence of vegetation coverage, this shallowness increases susceptibility to sediment suspension via wind and wave action. Stormwater is conveyed to this waterbody from a nearly 400 acre drainage basin that extends to the Winter Haven Gilbert airfield (Figure 3-213). The land uses directly surrounding the lake are residential and wetlands while those from the airport section are institutional. Based on stormwater pollutant load modelling, this drainage area contributes 880 lbs of TN and 111 lbs of TP to the lake annually—relatively low pollutant loading rates when compared with the other drainage basins in the study area.

Lake Pansy is considered an isolated waterbody located to the northwest of downtown Winter Haven. It is believed that excess water can discharge from Lake Pansy to Lake Rochelle via the wetland to the east. Pansy's surface elevation sits at a slightly higher level than the North Chain of Lakes. Over its period of record, Lake Pansy's surface level has fluctuated between 124.5 and 129.7 feet above sea level. The normal range of fluctuation is much narrower—between 126.6 and 128.5 feet (Figure 3-214). During 2024, Lake Pansy dropped to a dry season low of 127.5 feet in June, then rose to end the year at a record peak of 129.68 feet by December. According to linear regression analysis, changes in Lake Pansy's surface level correlates directly with water clarity (see appendix). This indicates that higher surface levels result in increased flushing and water clarity.

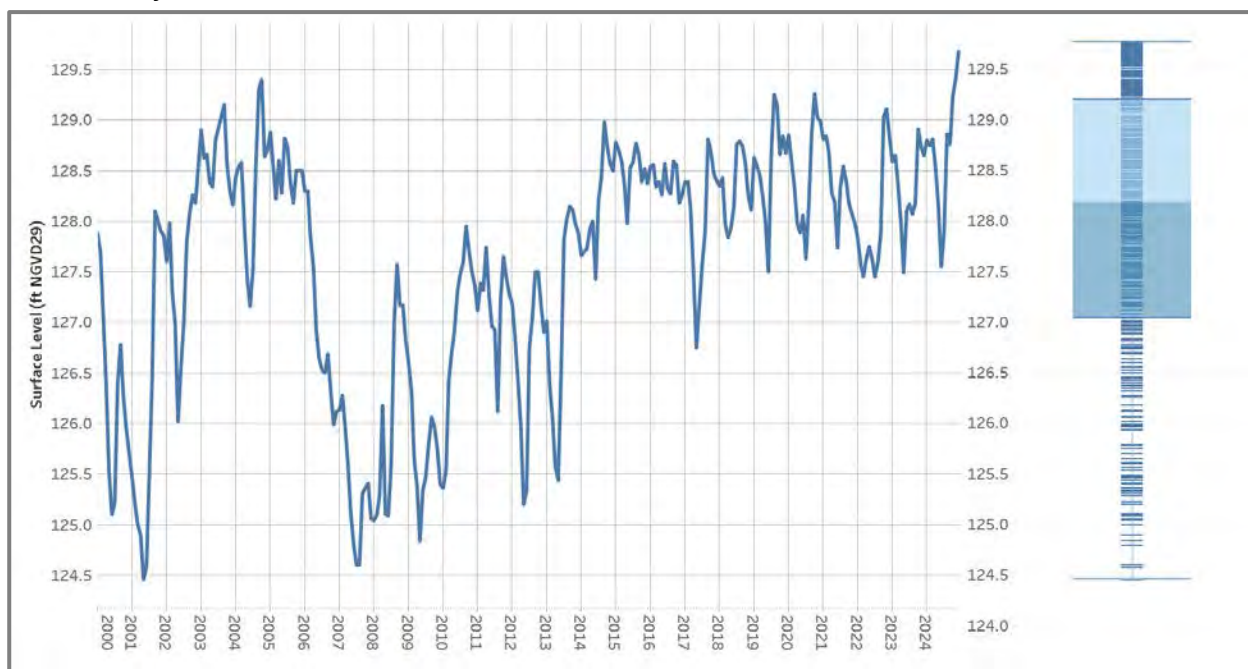


Figure 3-214. Hydrograph of Lake Pansy depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Pansy is categorized as a highly colored waterbody. Aside from a single NNC exceedance of Chl-a during 2023, Lake Pansy's water quality has met the NNC guidelines (Figure 3-215). Pansy's status is currently un-impaired which earns it an impairment criterion score of 3.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	0.300	0.199	No Trend	3	1
TN	N	-0.203	0.390	No Trend		2
TP	N	0.043	0.857	No Trend		1
Secchi	NA	-0.118	0.621	No Trend		1

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this time frame, none of the NNC parameters exhibited a statistically significant trend. The trends for Chl-a, TP, and Secchi depth moved in a deteriorating direction, earning a trend criterion score of 1; whereas the TN trend moved in an improving direction, for a criterion score of 2. Considering the lack of impairments, these trends are not concerning as they don't indicate declining water quality.



Figure 3-215. Lake Pansy AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Pansy on 8/15/2024. The PAC during this survey was 20.7% and the total BV was 4.1% (Figure 3-216). Since the PAC exceeded the 15% threshold, this equates to an abundance criterion score of 2. Comparing Lake Pansy's abundance values from 2018 to 2023 indicates that its coverage often fluctuates between 15% and 45%. This may be the result of consistent invasive species treatments. There was practically no change in vegetation coverage from 2023 to 2024.

Invasive Species Management:

Based on the 2024 survey, Lake Pansy possesses a fairly diverse and vegetation community made up of many types of flora (Figure 3-217). The native fragrant water lily was the most dominant species followed by several other emergent and submerged species. SAV became a

much more integral part of the ecosystem with eelgrass, coontail, southern naiad, and bladderwort making up nearly 20% of the community. There were no managed invasive species detected in 2024; equating to an invasive criterion score of 3. In previous years, hydrilla and water hyacinth have been problematic, but their absence indicates that control efforts have been effective.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, Lake Pansy's species evenness and overall diversity indices met or exceeded their long-term median values (Figure 3-218). This equates to a diversity criterion score of 2. Since species richness met the median in 2023, it is likely that the lack of invasive species detected have resulted in this change. Comparing the species frequency charts from previous years, the distribution of aquatic plants is much more equitable in 2024—also resulting in an increase in the overall diversity value.

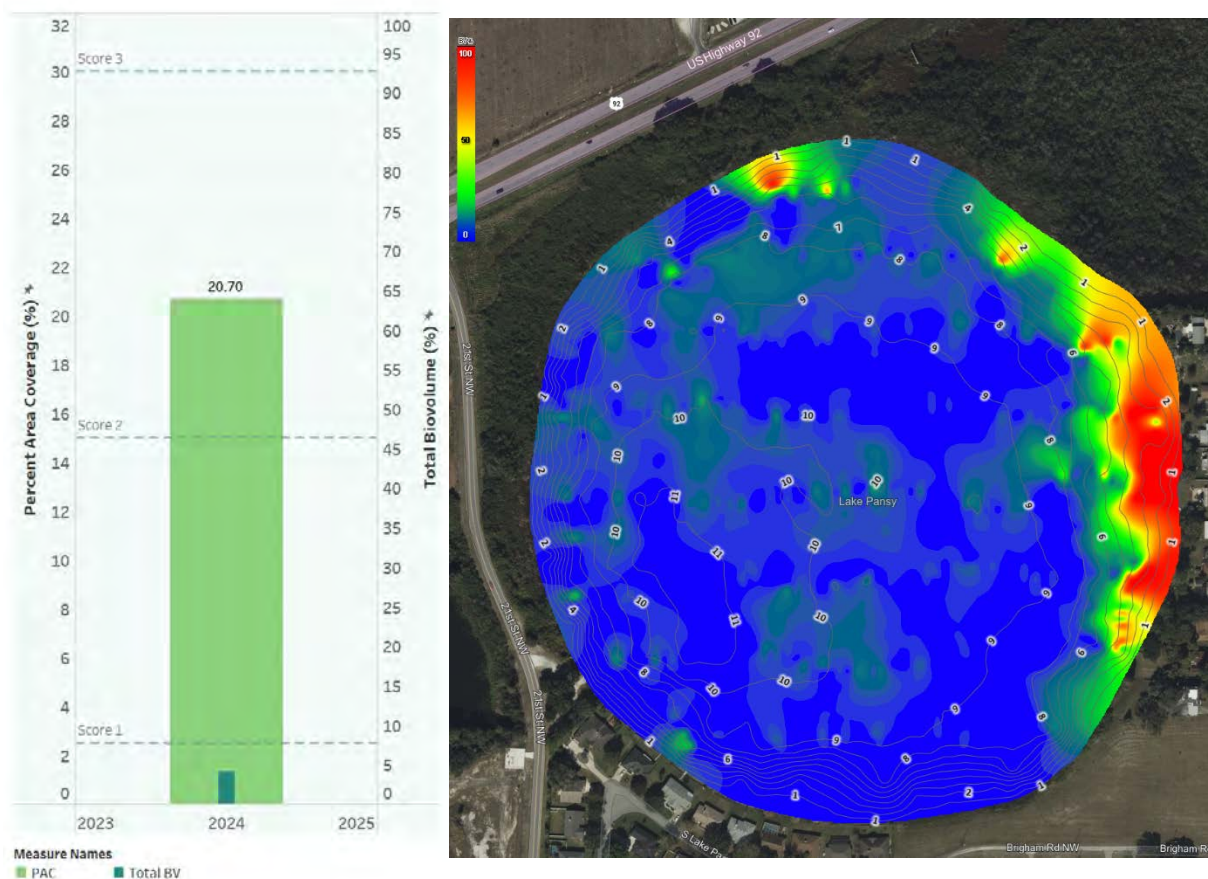


Figure 3-216. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Pansy; biovolume values range from green (lowest) to red (highest).

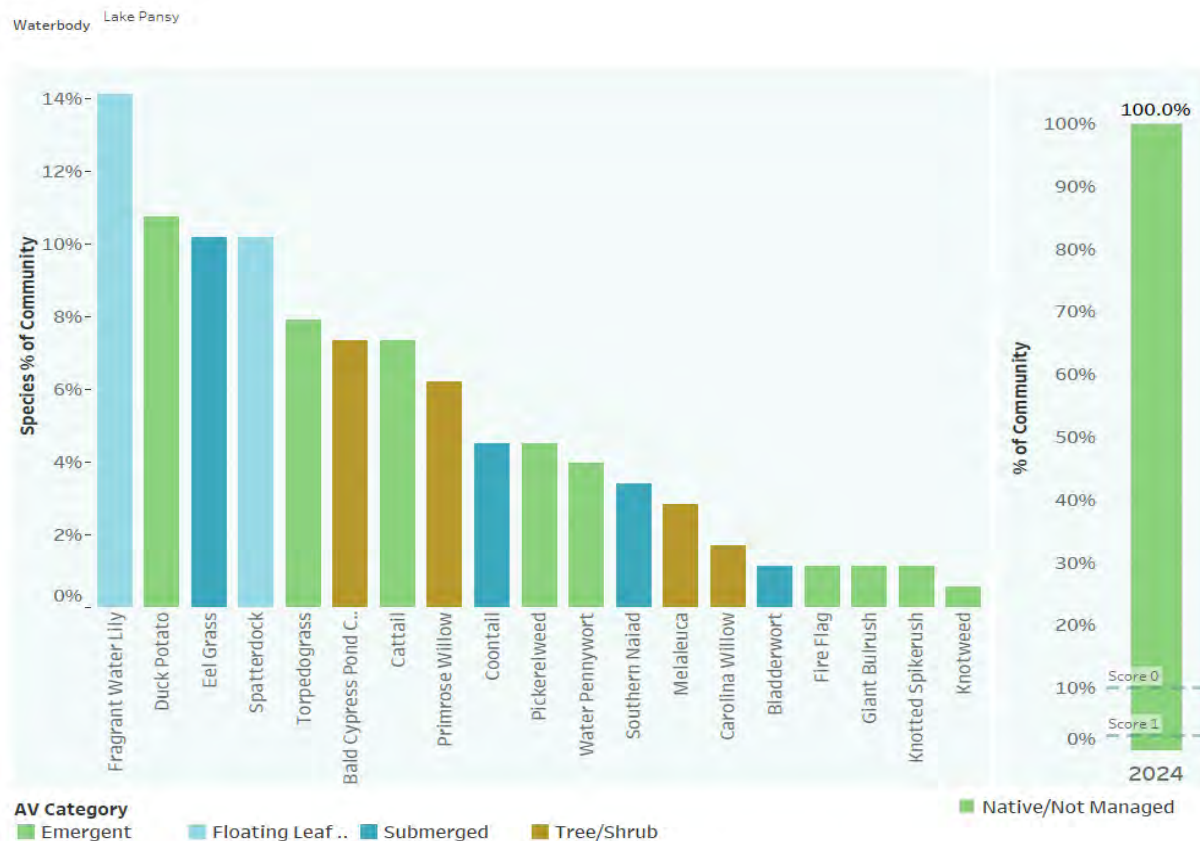


Figure 3-217. Chart depicting species frequency and invasive species percentage of Lake Pansy during 2024.

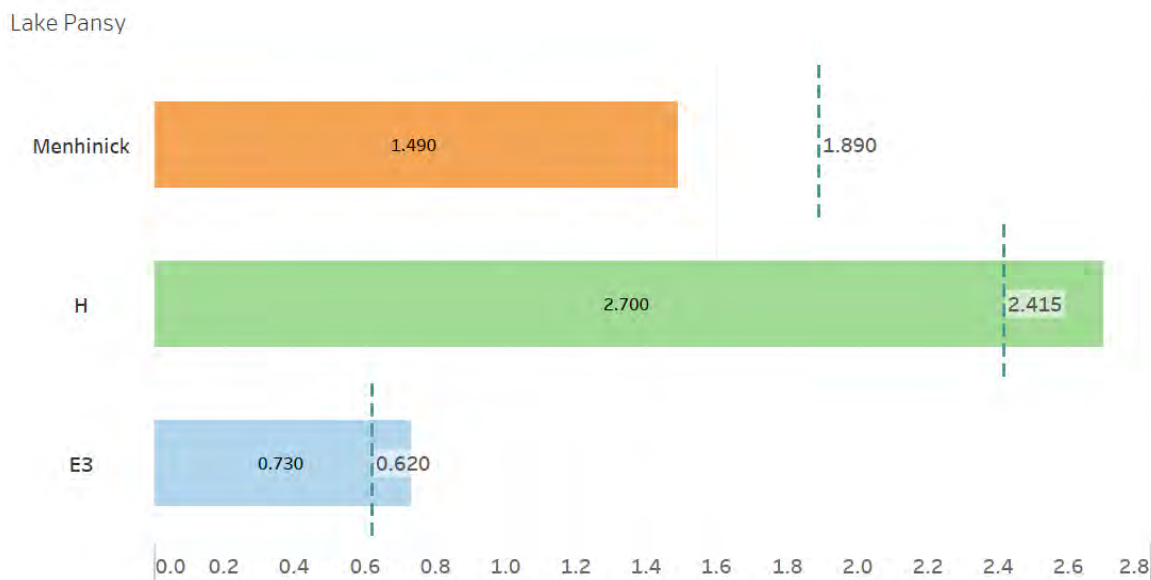


Figure 3-218. Chart depicting 2024 diversity indices for Lake Pansy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Pansy's health index scores from 2018 to 2024 demonstrates general consistency (Figure 3-219). There has been no change in the impairment scores during this time frame. However, trend scores have mostly improved, with the most recent shift in the Chl-a trend being an important positive change in lake health. While Pansy's abundance and diversity scores have vascillated, the major takeaway from recent years is a dramatic improvement in the invasive presence scores. Overall, Lake Pansy sits in the middle of the priority ranking. While it is not currently impaired, its water quality trends are not ideal and the invasive treatments it undergoes could impact water quality and vegetation diversity in the future.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	0	1	1	1	2	0	1	1.1
2019	3	0	1	1	1	3	0	3	1.5
2020	3	0	1	1	2	2	0	3	1.5
2021	3	0	1	1	2	3	0	2	1.5
2022	3	0	1	1	2	2	1	0	1.3
2023	3	0	2	1	1	2	2	1	1.5
2024	3	1	2	1	1	2	3	2	1.9

Figure 3-219. Chart depicting a comparison of Lake Pansy's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading is one of the primary concerns for water quality management. While the City does not possess much stormwater infrastructure in the area, there is room for measures to reduce pollutant loading in the drainage basin.
- The management of invasive species is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- Lake Pansy's water clarity is correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City can explore expanding street sweeping services to 21st Street to reduce potential stormwater pollutant loading.
- The residential communities around the lake provide opportunities for public outreach and education. This aims to increase residents' knowledge of best stormwater practices and ways they can individually reduce their pollutant load.
- City staff will continue to monitor aquatic vegetation and share the information with Polk County and the FWC. Staff will also take a more active role in advocating for the most effective, but least impactful invasive management strategies to ensure proper balance of the vegetation community.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Rochelle

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Rochelle	3	3	3	2	3	3	1	2	2.5

Features & Statistics:

Surface area	559.9 acres
Mean depth	8.96 feet
Maximum depth	20 feet
Volume	6060.2 acre-feet
Drainage basin area	1667.7 acres
Annual TN Load	3002.6 lbs
Annual TP Load	522.2 lbs
Limiting nutrient	Phosphorus

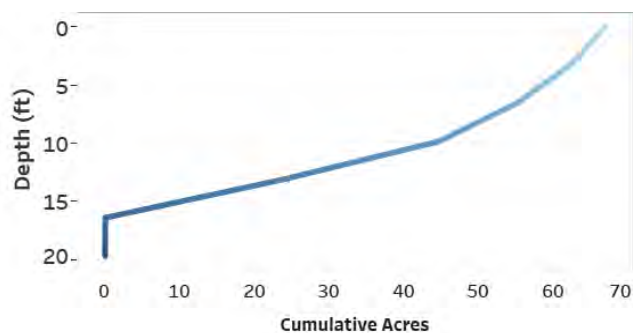


Figure 3-220. Hypsograph of Lake Rochelle depicting the depth profile and morphology of the lake bed.



Figure 3-221. Map of Lake Rochelle's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Rochelle is one of Winter Haven's larger waterbodies with a surface area of 560 acres. Rochelle is slightly deeper than the regional average with a mean depth of nearly 9 feet and a maximum depth of 20 feet (Figure 3-220). Despite the depth, the slope of the lake bed is relatively gradual—allowing for a large littoral zone to support a robust vegetation community. Stormwater is conveyed to this waterbody from a 1,670 acre, relatively rural drainage basin (Figure 3-221). Wetland, residential, agricultural, and commercial land uses comprise the drainage basin, contributing 3,002 lbs of TN and 522 lbs of TP to the lake annually. On a per acre basis, these are some of the lowest pollutant loading rates in the study area. There are over 40 septic systems within the basin. These constitute a relatively low density based on the number of systems per acre. To mitigate stormwater pollutant loading, the City conducts 4.4 miles of street sweeping twice monthly along US Highway 17.

As part of the North Chain of Lakes, Lake Rochelle is connected to Lakes Conine and Haines via navigable canals. Excess water from the North Chain eventually drains via the SWFWMD-managed P-8 control structure at the south of Lake Hamilton and enters the Peace Creek. Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-222). During 2024, the North Chain reached a dry season low of 127.8 feet in June and a wet season peak of 130.3 feet in October. The October peak was a record high for this chain of lakes; exceeding the previous record experienced during the triple hurricane season of 2004. The surface level ended the year above the high end of the normal range, at 128.5 feet. Changes in Lake Rochelle's surface level are directly correlated with water clarity and indirectly correlated with Chl-a and TN (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

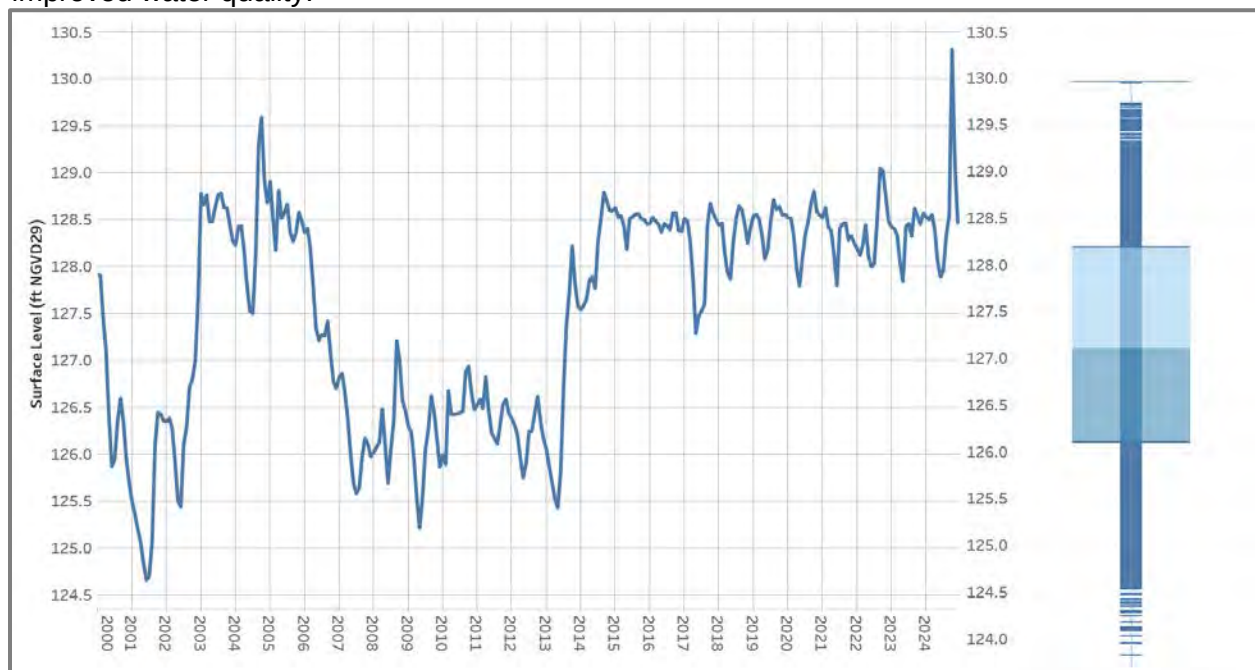


Figure 3-222. Hydrograph of Lake Rochelle depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria, Lake Rochelle is categorized as a clear, alkaline waterbody. While Lake Rochelle was previously impaired, a lack of NNC exceedances during the assessment period has resulted in its currently un-impaired status (Figure 3-224). This equates to an impairment criterion score of 3. In 2018, the FDEP established a total maximum daily load stipulating a 32% TN reduction to meet NNC guidelines. While Lake Rochelle has been meeting all NNC thresholds since 2015, the TP concentrations in the last three years have been relatively high.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.841	0.000	Decreasing	3	3
TN	N	-0.637	0.002	Decreasing		3
TP	N	-0.222	0.334	No Trend		2
Secchi	NA	0.452	0.040	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During the most recent analysis, Ch-l-a, TN, and Secchi depth exhibited significant improving trends—equating to trend criteria scores of 3. TP exhibited a non-significant improving trend; for a trend score of 2.

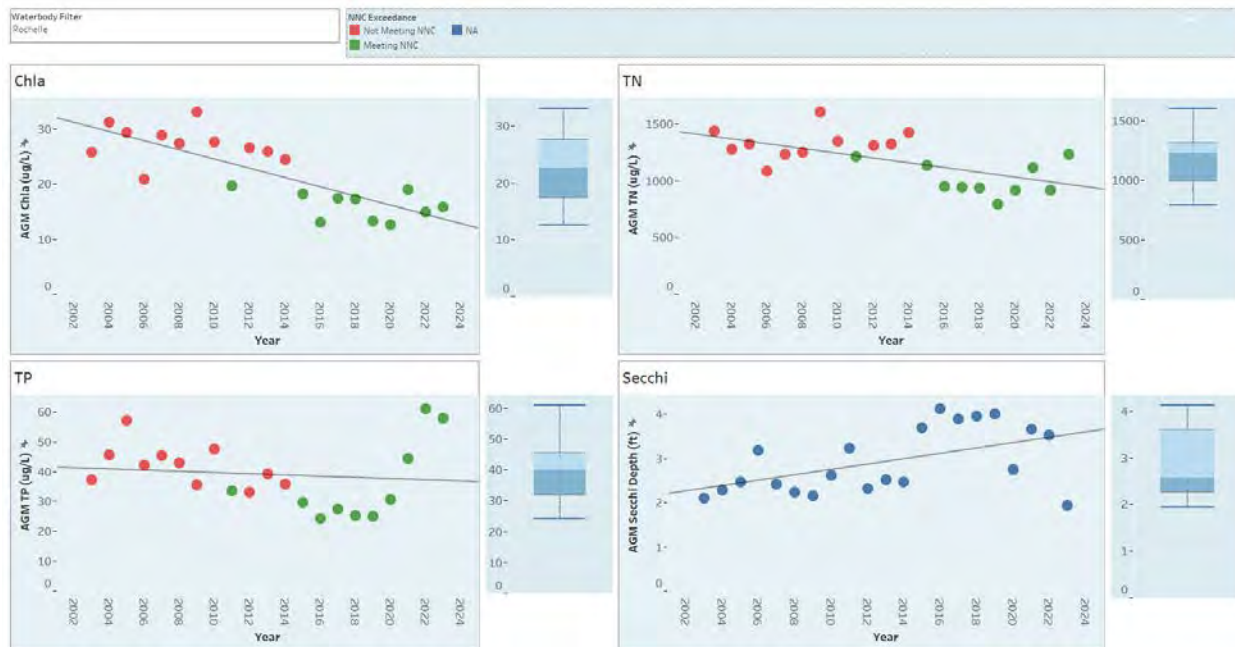


Figure 3-223. Lake Rochelle AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Rochelle on 2/27/2024. The PAC during this survey was 45.9% and the total BV was 5.1% (Figure 3-224). This equates to an abundance criterion score of 3. Lake Rochelle has consistently maintained vegetation coverage above 30% until it dipped below this threshold in 2023. Fortunately, coverage rose considerably to a new

record PAC value in 2024. Looking to the species data for explanation, it appears that an increase in invasive plants may be partially responsible for this.

Invasive Species Management:

Based on data from the 2024 survey, Lake Rochelle boasts a healthy mix of both submerged and emergent vegetation—with eelgrass dominating the community at 22% (Figure 3-225). Hydrilla, burhead sedge, and water hyacinth comprised the managed invasive species present at over 7% of the community; equating to an invasive presence criterion score of 1. The invasive presence has been a constant issue since 2019 but has exhibited a gradual decline until 2024 where it rose somewhat from the 3% recorded in 2023. Continued management is necessary to keep these plants under control.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, only Lake Rochelle's richness and evenness indices met their long-term median values (Figure 3-226). This equates to a diversity criterion score of 2. Overall, Lake Rochelle exhibits moderate diversity compared with other waterbodies in the area. Despite not meeting its median value, the overall diversity index was just slightly low and not a major concern.

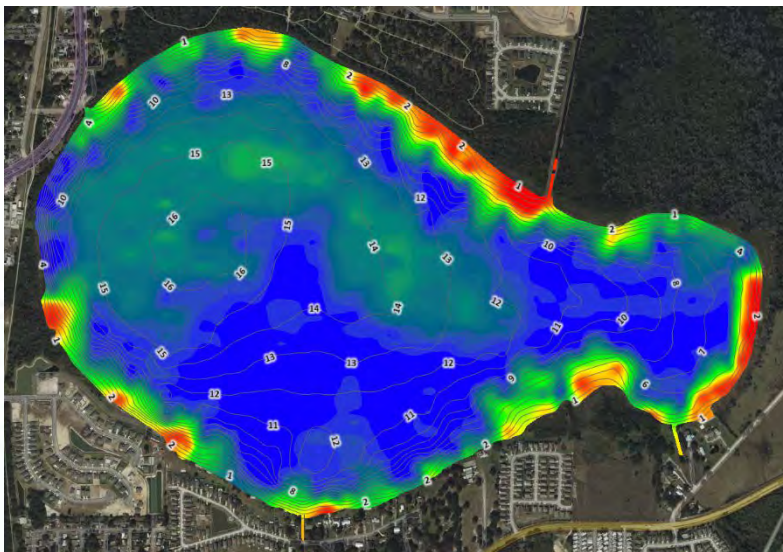
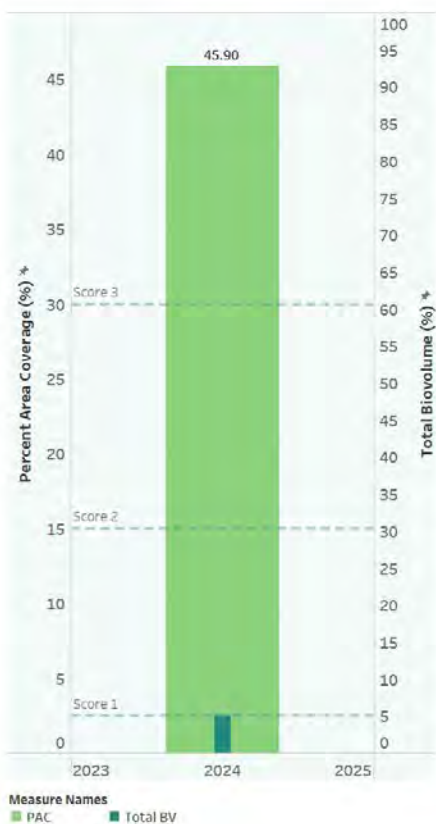


Figure 3-224. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Rochelle; biovolume values range from green (lowest) to red (highest).

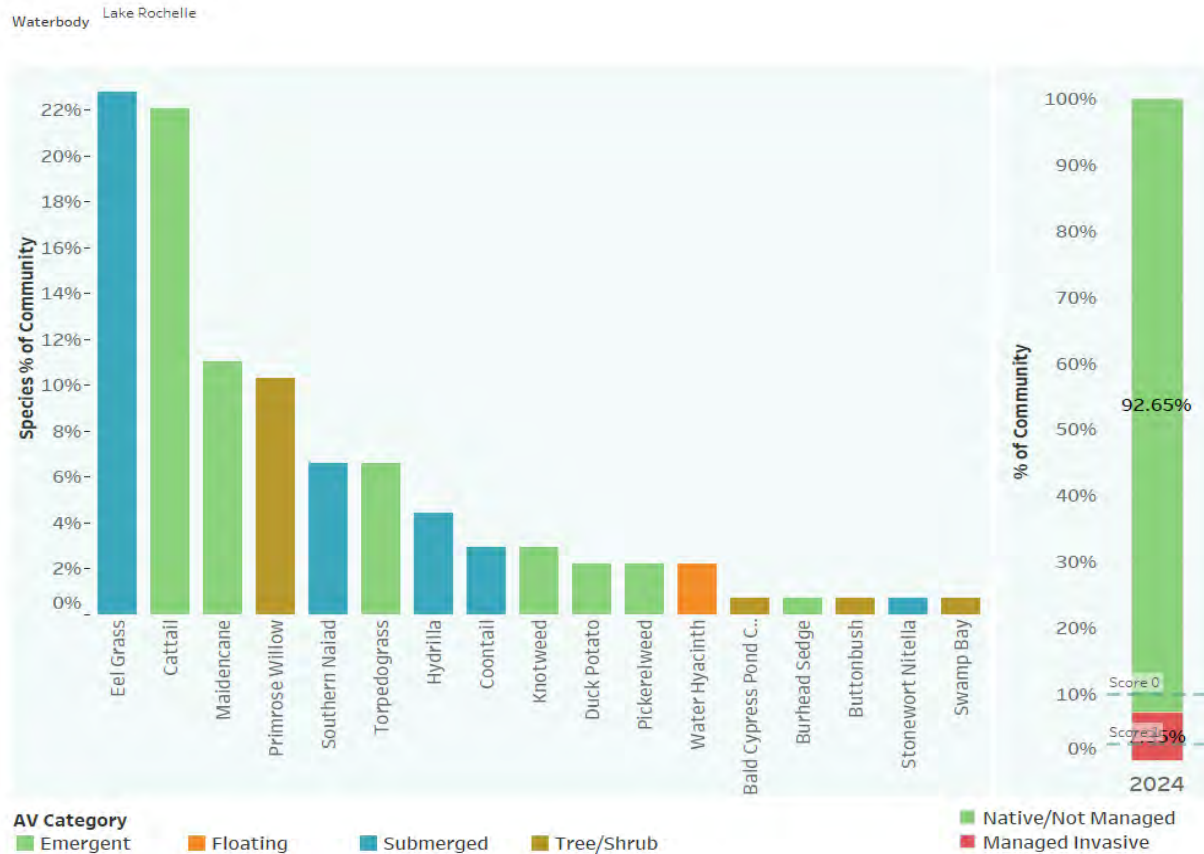


Figure 3-225. Chart depicting species frequency and invasive species percentage of Lake Rochelle during 2024.

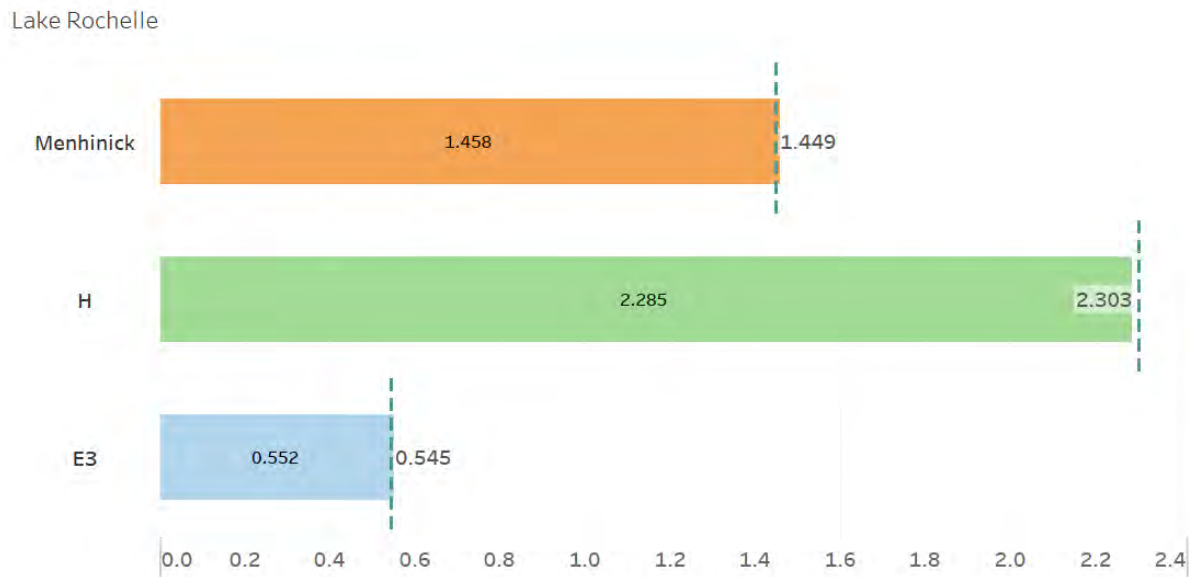


Figure 3-226. Chart depicting 2024 diversity indices for Lake Rochelle. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Rochelle's health index scores from 2018 to 2024 shows relative stability (Figure 3-227). Over this span, Rochelle's water quality has improved considerably; both exhibiting improving trends and meeting NNC guidelines after 2020. Its vegetation abundance scores have remained high. Much of the lake health score variability has been the result of shifts in the invasive species and diversity criteria over the years. Overall, Lake Rochelle ranks lower on the priority list since its water quality is now meeting standards and continues to exhibit improvement. The main area for management action is controlling invasive plants.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	2	3	3	3	1	3	2.3
2019	0	3	3	3	3	3	0	3	2.3
2020	0	3	3	3	3	3	0	1	2.0
2021	3	3	3	3	3	3	0	0	2.3
2022	3	3	3	3	3	3	0	2	2.5
2023	3	3	3	2	3	2	1	1	2.3
2024	3	3	3	2	3	3	1	2	2.5

Figure 3-227. Chart depicting a comparison of Lake Rochelle's Lake Health Index scores from 2018 to 2024.

Lake Health Impact/Challenges:

- Lake Rochelle currently exhibits good water quality and improving trends. However, stormwater pollutant loading is a potential concern and one of the primary factors to look to if water quality begins trending in an unfavorable direction.
- Several of Lake Rochelle's water quality parameters are correlated with surface level, likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species like hydrilla is one of the primary concerns. Large-scale herbicide treatments can lead to water quality declines; which is a possibility as hydrilla is still not in a controlled state.

Lake Management Strategy:

- In order to mitigate stormwater pollutant loading, the City conducts street sweeping along one of the few public roads in the basin. The addition of new housing in the area provides opportunities for public education and outreach. This aims to increase residents' knowledge of best stormwater practices and ways they can individually reduce their pollutant loads.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Recent invasive species management efforts have included herbicide treatment and minimal stocking of triploid grass carp. This measured, but integrated approach appears to be gradually improving the invasive presence in Lake Rochelle, but more effort is required to keep these species under control.

Lake Roy

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Roy	3	3	2	3	2	3	3	1	2.5

Features & Statistics:

Surface area	74.3 acres
Mean depth	10.76 feet
Maximum depth	26 feet
Volume	1063.1 acre-feet
Drainage basin area	353.7 acres
Annual TN Load	1448.3 lbs
Annual TP Load	241.53 lbs
Limiting nutrient	Phosphorus

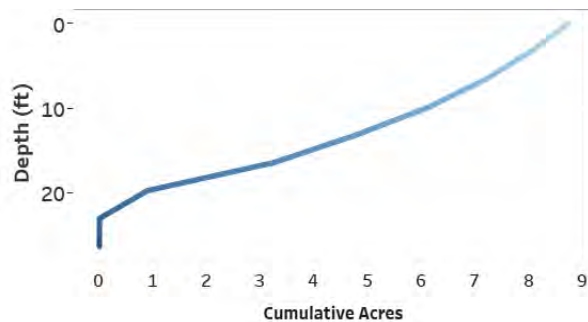


Figure 3-228. Hypsograph of Lake Roy depicting the depth profile and morphology of the lake bed.

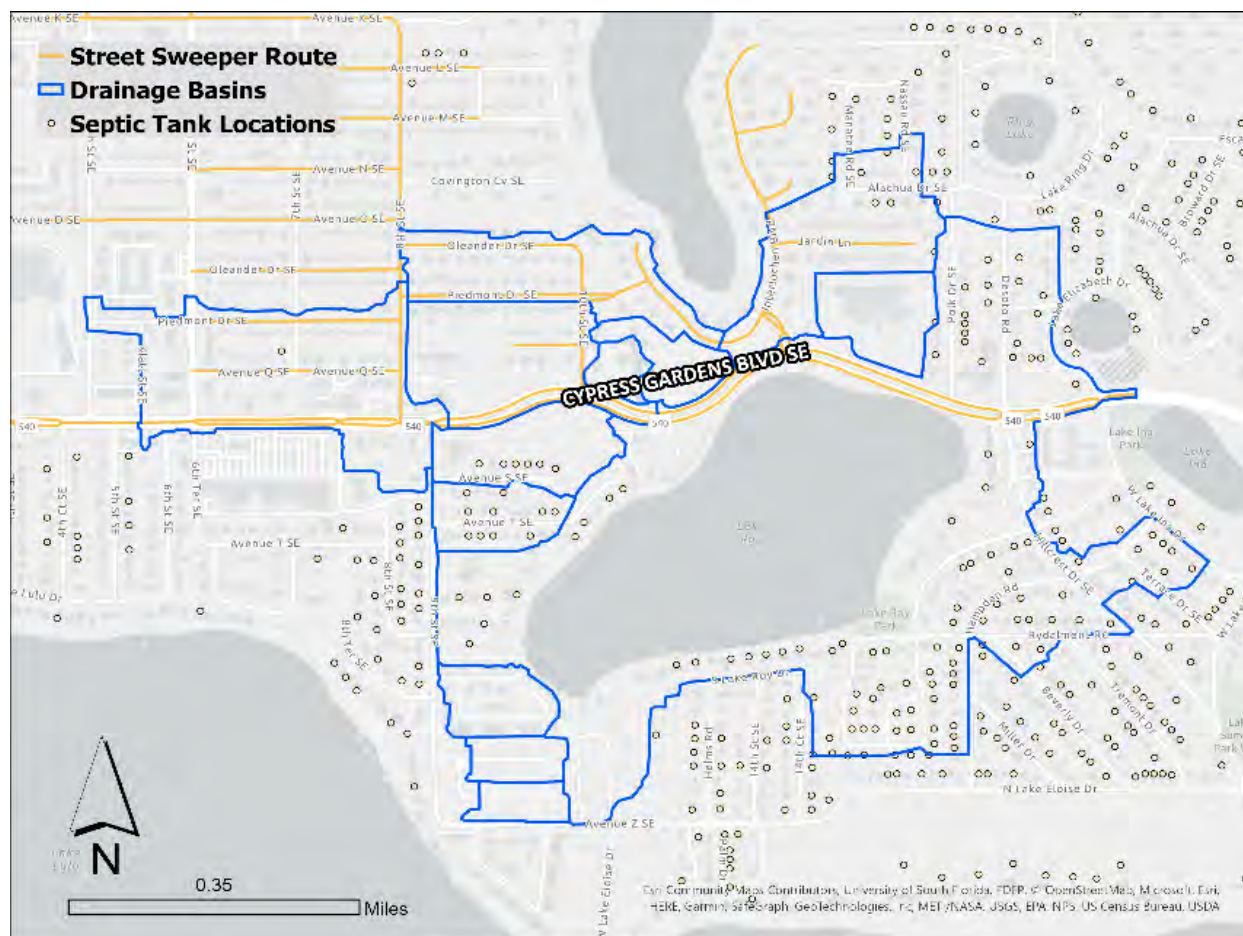


Figure 3-229. Map of Lake Roy's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Roy is a smaller, but deeper waterbody at 74 acres, an average depth of roughly 11 feet, and a maximum depth of over 25 feet (Figure 3-228). While Roy is deeper than many other lakes in the region, it possesses a gradual sloping lake bed which can support a large littoral zone and a robust aquatic plant community. Stormwater is conveyed to this waterbody from a 354 acre drainage basin comprised of 13 individual sub-basins (Figure 3-229). The basin is comprised mostly of residential land uses, but does include some commercial and transportation uses. This basin contributes 1,448 lbs of TN and 241 lbs of TP to the lake annually; the nitrogen load, in particular, is relatively high within the region on a per acre basis. There are 125 septic systems located within the basin—constituting a high density and greater potential for pollutant loading via groundwater leaching. To combat stormwater pollutant loading within the Winter Haven portion of the drainage area, the City conducts 11.8 miles of street sweeping on a monthly basis.

Lake Roy is located on the South Chain of Lakes, connecting to Lake Lulu via navigable canal. Due to the canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-230). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Roy's surface level correlates with TN and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

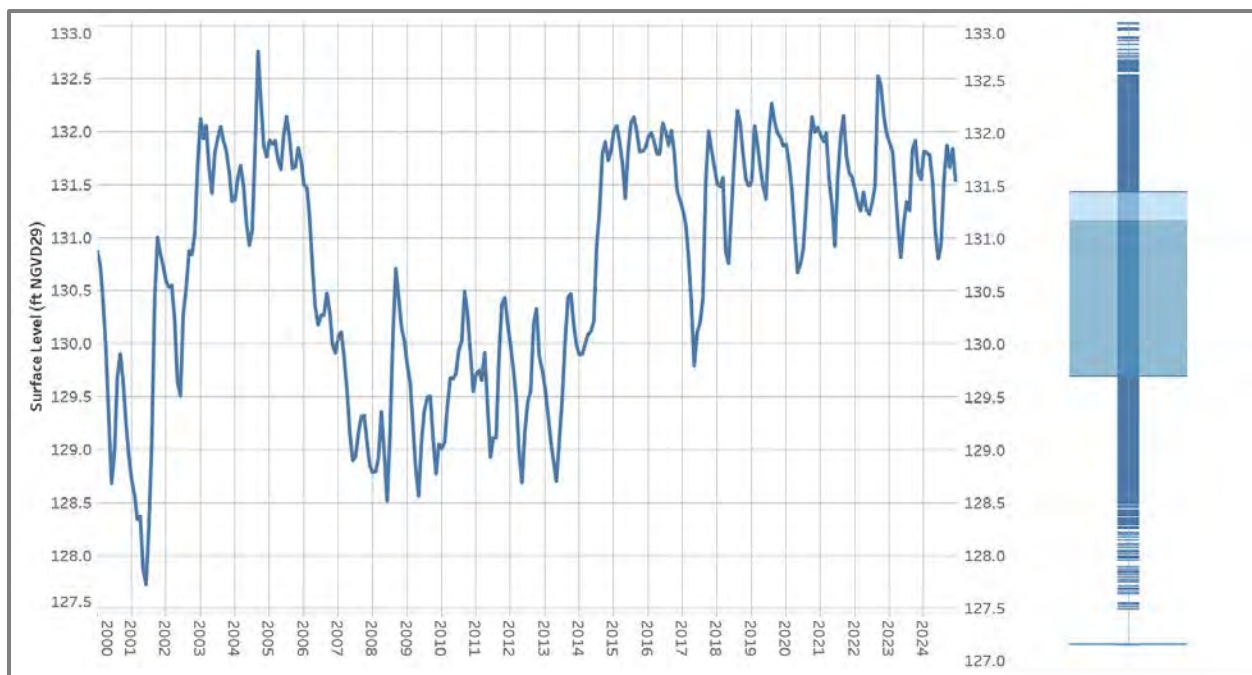


Figure 3-230. Hydrograph of Lake Roy depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Roy is categorized as a clear, alkaline waterbody. Aside from an outlier year during 2021, Lake Roy has not exhibited any NNC exceedances during the assessment period (Figure 3-231). As a result, Roy is considered un-impaired and earns an impairment criterion score of 3. Despite the high Chl-a and nutrient concentrations in 2021, Lake Roy has exhibited low Chl-a, TN, and TP concentrations in recent years.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.511	0.018	Decreasing	3	3
TN	N	-0.309	0.173	No Trend		2
TP	N	-0.569	0.007	Decreasing		3
Secchi	NA	0.303	0.182	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this period, Chl-a and TP exhibited significant improving trends. This equates to a trend criteria score of 3 for these parameters. Secchi depth and TN exhibited non-significant improving trends; for criterion scores of 2.



Figure 3-231. Lake Roy AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots showing relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Roy on 3/29/2024. The PAC during this survey was 43% and the total BV was 7.6% (Figure 3-232). PAC over the 30% threshold equates to an abundance criterion score of 3. In 2018, Lake Roy had a PAC of over 50%. However, in 2019, this abundance value dropped to 17%. This was likely due to large-scale invasive species

treatments between these two surveys. Fortunately, the abundance has recovered significantly, remaining above 30% since 2021.

Invasive Species Management:

Based on data from the 2024 survey, Lake Roy is very clearly dominated by submerged plants with native eelgrass and Illinois pondweed making up over 40% of the community (Figure 3-233). The remaining plants include a mix of other SAV and emergent species. There were no managed invasives detected in 2024; equating to an invasive presence criterion score of 3. Lake Roy has typically possessed at least a minor presence of invasive hydrilla in the past, but this population has gradually decreased in recent years. This indicates general success in managing and controlling invasives.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). Based on the 2024 species data, Lake Roy's overall diversity index exceeded its long-term median value with both the species richness and evenness being slightly below-average (Figure 3-234). This equates to a diversity criterion score of 1. The decrease in species richness from 2023 was likely due to the removal of hydrilla, whereas the slightly lower evenness value can be explained by an even greater dominance of eelgrass and pondweed compared with previous years. Neither of these occurrences are negative, but the diversity indices do not distinguish between native or exotic species. Overall, Lake Roy's vegetation community is healthy.

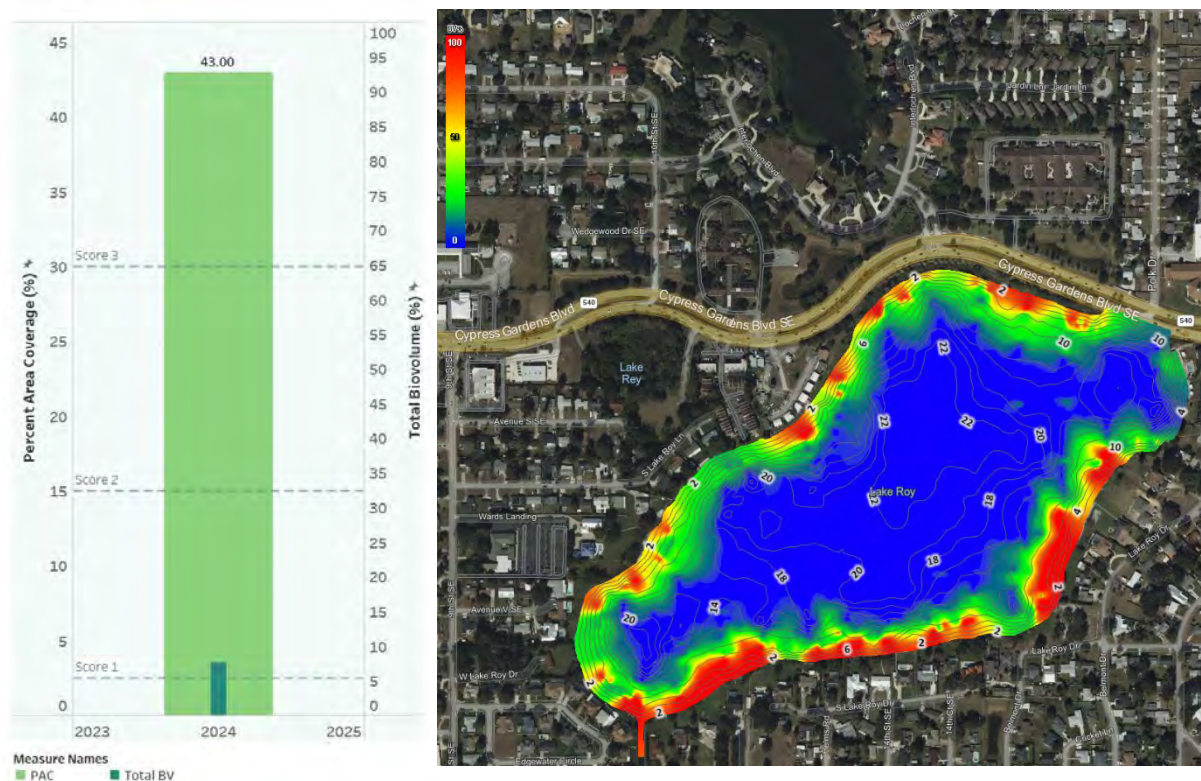


Figure 3-232. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Roy; biovolume values range from green (lowest) and red (highest).

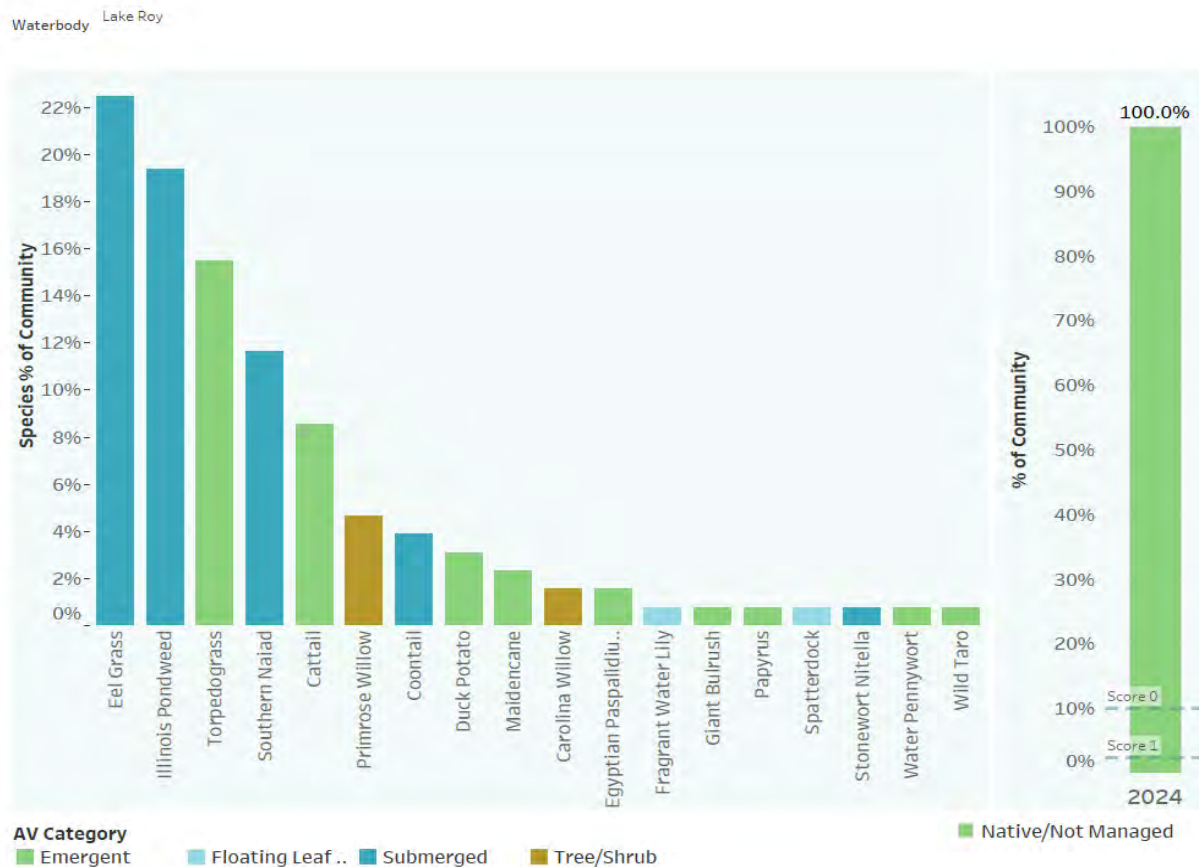


Figure 3-233. Chart depicting species frequency and invasive species percentage of Lake Roy during 2024.

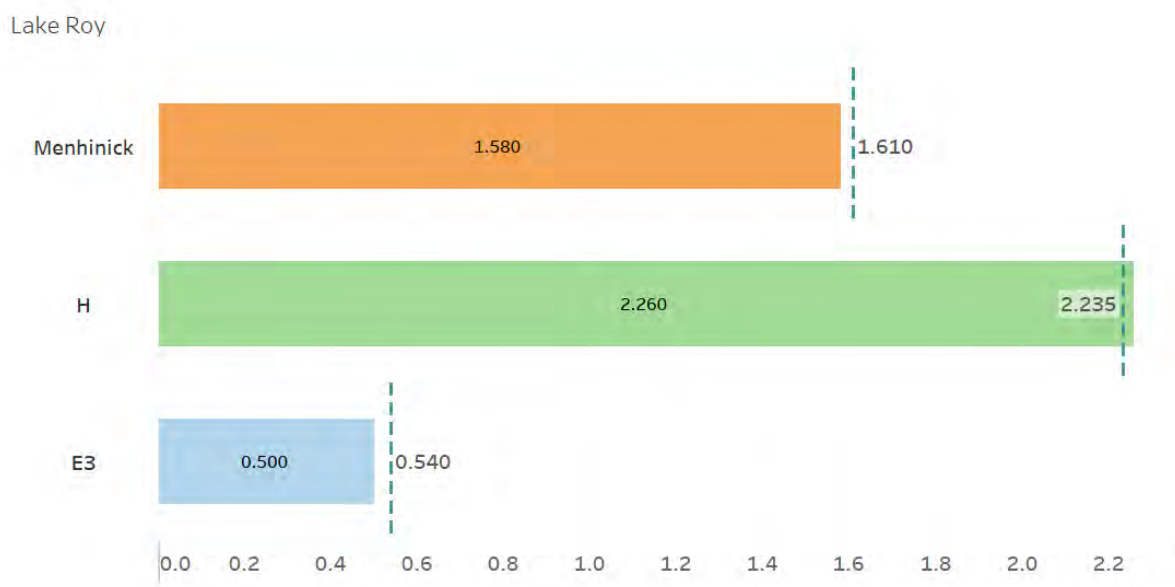


Figure 3-234. Chart depicting 2024 diversity indices for Lake Roy. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Roy's health index scores from 2018 to 2024 shows consistently high lake health (Figure 3-235). Over this span, the water quality criteria scores have changed very little. Lake Roy has excellent water quality and continues to exhibit generally improving trends. Vegetation abundance exhibited a decline in 2019 and 2020, but has since recovered. Invasive presence and its impact on species diversity continues to fluctuate and is the primary source of lake health changes at this point. Overall, Lake Roy is ranked low on the priority list due to these higher lake health scores.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	2	3	3	0	2	2.4
2019	3	3	3	3	3	2	1	2	2.5
2020	3	3	3	3	3	2	2	3	2.8
2021	3	3	3	2	3	3	1	2	2.5
2022	3	3	3	2	3	3	2	3	2.8
2023	3	3	2	3	2	3	2	2	2.5
2024	3	3	2	3	2	3	3	1	2.5

Figure 3-235. Chart depicting a comparison of Lake Roy's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Roy currently exhibits excellent water quality with no signs of deterioration. However, if this changes, the City would look to stormwater and the septic presence as potential primary drivers of water quality decline.
- The management of invasive species like hydrilla has been a concern in the past. While current populations appear to be controlled, it can take just a single growing season for these to take over large areas of a waterbody.
- Several of Lake Roy's water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- The City currently conducts street sweeping and has implemented treatment swales in the northern portion of the drainage basin. Future stormwater mitigation efforts may be construction of green infrastructure in one of the northern sub-basins identified by the Stormwater Assessment and Improvement Plan.
- If water quality begins to decline, the City may explore source analysis to determine if septic systems may be leaching pollutants into the water table. Further management may be septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response helps to prevent large-scale herbicide treatments and potential water quality impacts that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Shipp

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Shipp	0	3	3	3	3	3	1	2	2.3

Features & Statistics:

Surface area	279.4 acres
Mean depth	7.25 feet
Maximum depth	14 feet
Volume	2044.5 acre-feet
Drainage basin area	910.6 acres
Annual TN Load	3614.3 lbs
Annual TP Load	654.7 lbs
Limiting nutrient	Phosphorus

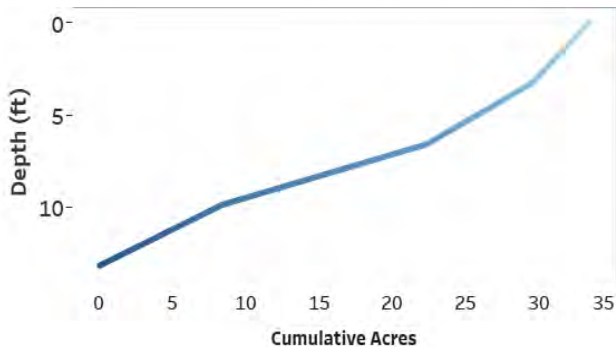


Figure 3-236. Hypsograph of Lake Shipp depicting the depth profile and morphology of the lake bed.

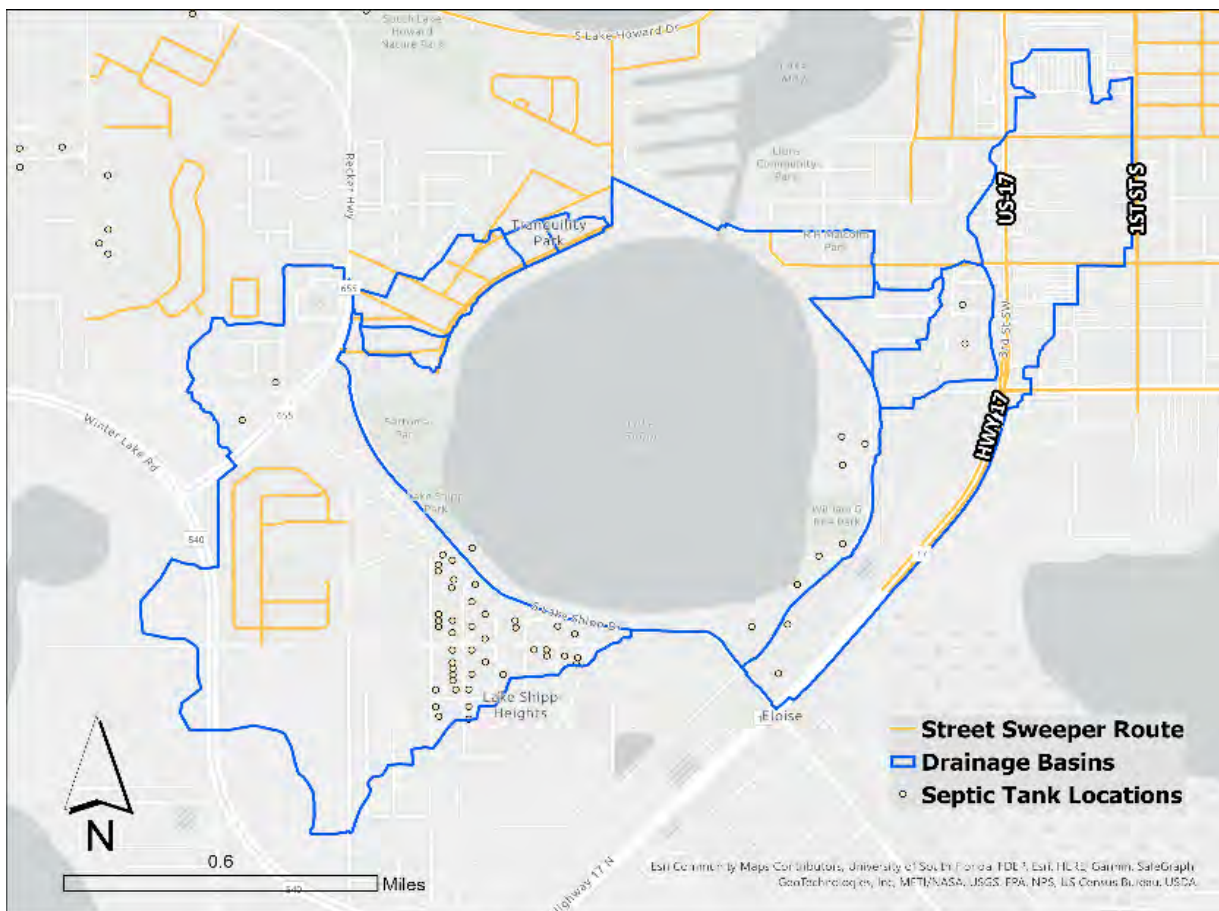


Figure 3-237. Map of Lake Shipp's drainage basin, City street sweeper routes, and nearby septic systems.

Hydrology:

Lake Shipp is a moderately-sized waterbody with a surface area of 280 acres. An average depth of 7.2 feet and a maximum depth of over 13 feet make Shipp a relatively shallow lake compared with other waterbodies in the region (Figure 3-236). The shallowness of the lake should allow it to support a wide littoral zone and robust aquatic vegetation community. Stormwater is conveyed to this waterbody from a 910 acre drainage basin comprised of 9 individual sub-basins (Figure 3-237). Ranked by area, the primary land uses in this basin are medium-density residential, commercial, high-density residential, industrial, and agricultural/open land. Based on stormwater pollutant load modeling, this drainage area contributes 3,614 lbs of TN and 655 lbs of TP to the lake annually; on a per acre basis, these loads are fairly high compared with other lakes in the study area. There are over 50 septic systems within the basin—constituting a moderate density with some potential for pollutant loading through groundwater leaching. To combat stormwater pollutant loading, the City conducts 12.4 miles of street sweeping in the basin on a monthly basis.

Lake Shipp is located centrally within the South Chain of Lakes with navigable connections to Lakes Lulu and May. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-238). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Shipp's surface level correlates with TN and water clarity (see appendix). This carries management implications as maintaining higher levels should result in improved water quality.

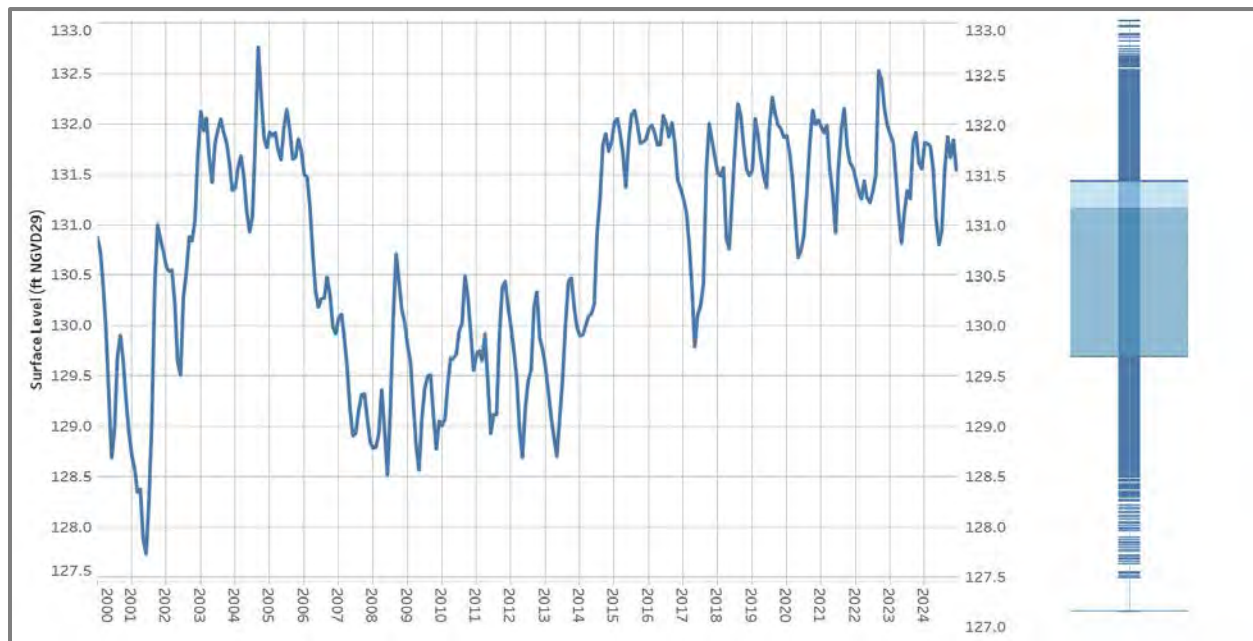


Figure 3-238. Hydrograph of Lake Shipp depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Shipp is categorized as a clear, alkaline waterbody. Due to consistent NNC exceedances during the assessment period, Lake Shipp is considered impaired for Chl-a, TN, and TP (Figure 3-239). This equates to an impairment criterion score of 0. In 2019, the FDEP established a total maximum daily load stipulating a 53% reduction in TN in order for Lake Shipp to meet NNC guidelines.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.621	0.003	Decreasing	0	3
TN	Y	-0.653	0.001	Decreasing		3
TP	Y	-0.585	0.005	Decreasing		3
Secchi	NA	0.741	0.000	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Each of Lake Shipp's water quality parameters exhibited significant improving trends during this period. This equates to trend criteria scores of 3 for Chl-a, TN, TP, and Secchi depth. It should be noted that despite the long-term trends, Chl-a, TP, and TN concentrations appear to have generally increased over the last four years.



Figure 3-239. Lake Shipp AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Shipp on 10/6/2024. The PAC during this survey was 52.5% and the total BV was 14.4% (Figure 3-240). A PAC exceeding the 30% threshold equates to an abundance criterion score of 3. Since monitoring began, Lake Shipp has consistently exhibited PAC around in the 50% range. The robustness of this lake's littoral zone can be attributed to its gradual sloping bed and the abundance of vegetation likely contributes to

the improving water quality trends. The southern portion of Lake Shipp is much more gradually sloping than the north—supporting a much wider littoral zone.

Invasive Species Management:

Based on the 2024 survey data, Lake Shipp has a healthy mix of vegetation types. It is currently dominated by submerged species like eelgrass and southern naiad (Figure 3-241). Managed invasive species made up 5.3% of the community; comprised of burhead sedge and hydrilla. This was a moderate increase from the 1.7% invasive percentage from 2023 and equates to an invasive presence criterion score of 1. Hydrilla has previously been the major management concern for Lake Shipp. Its recent expansion requires additional management action to prevent further expansion.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2024 species data, Lake Shipp's richness and overall diversity indices met or exceeded their respective median values (Figure 3-241). This equates to a diversity criterion score of 2. Species evenness was only a small amount below the average value—indicating that the distribution of species was only slightly less equitable in 2024. Despite the lower evenness score, Lake Shipp does boast relatively high overall diversity which has held somewhat constant despite regular minor invasive treatment efforts.

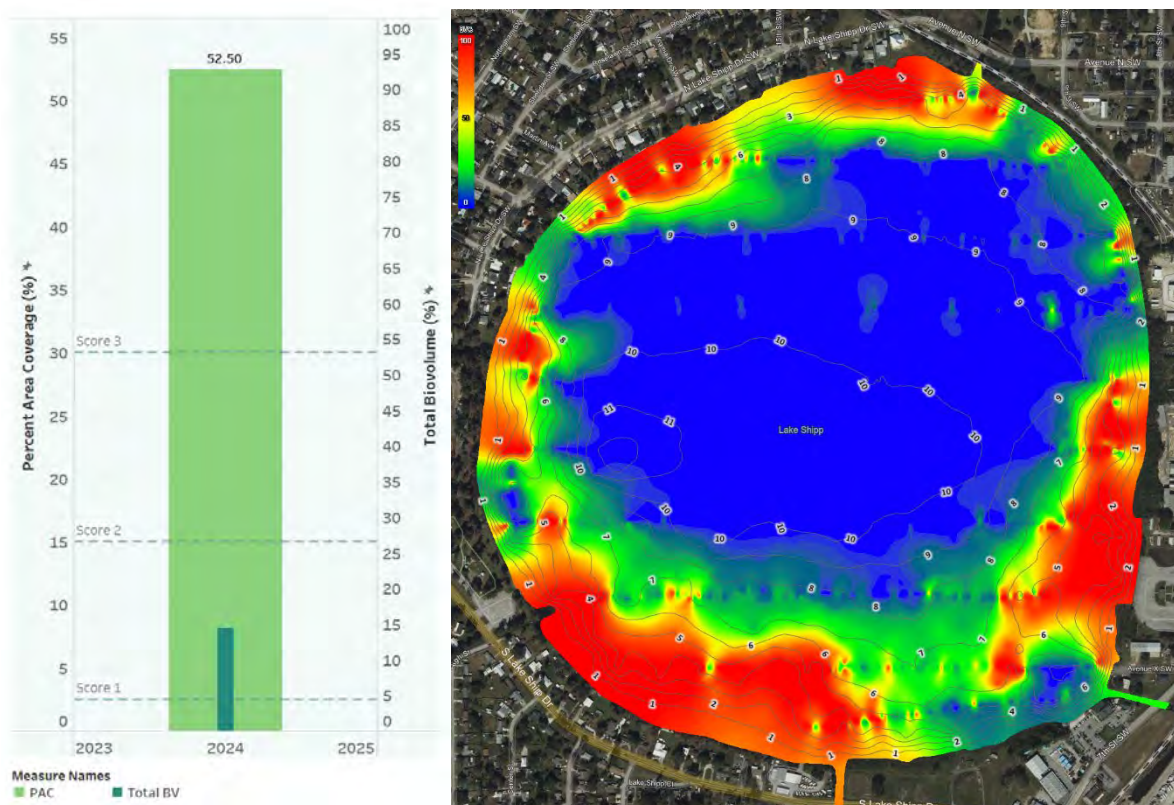


Figure 3-240. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Shipp; biovolume values range from green (lowest) to red (highest).

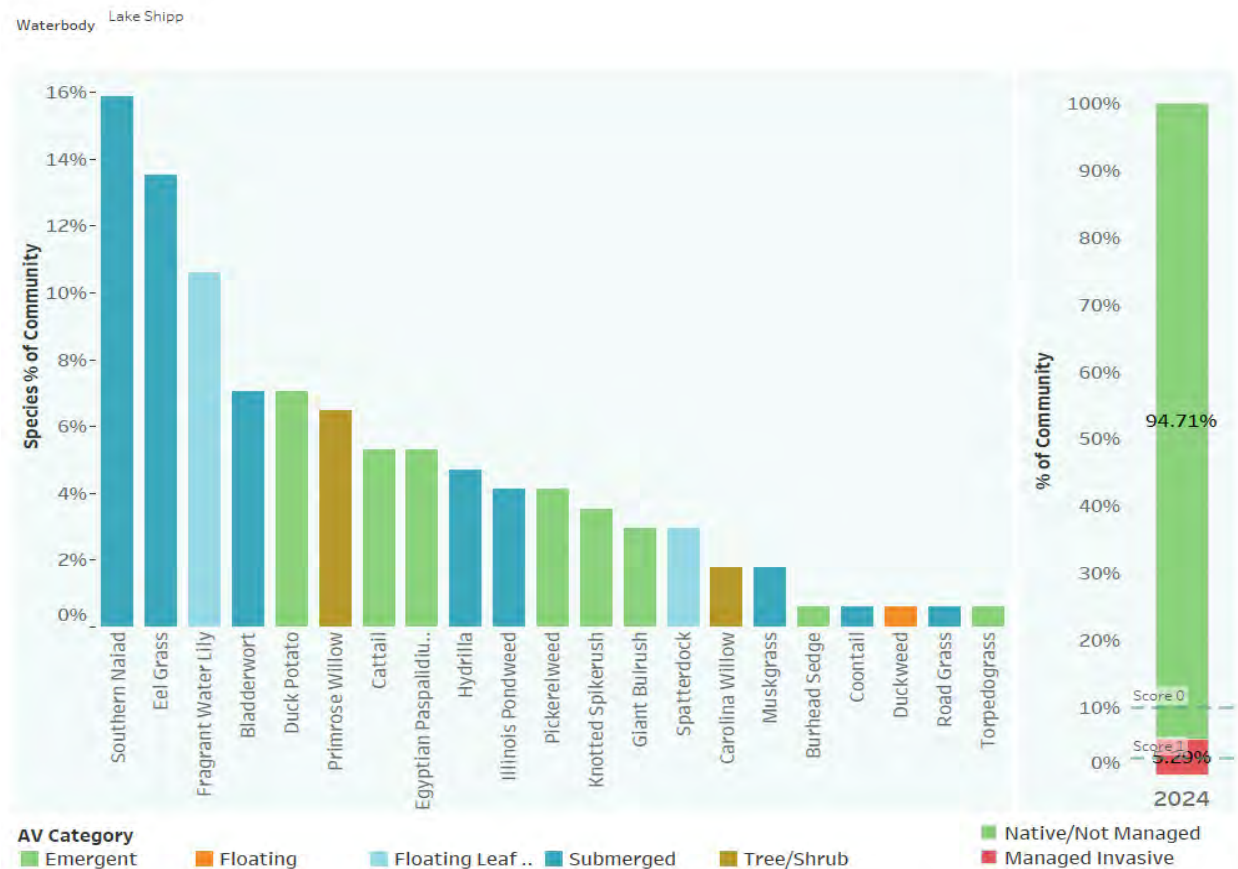


Figure 3-241. Chart depicting species frequency and invasive species percentage of Lake Shipp during 2024.

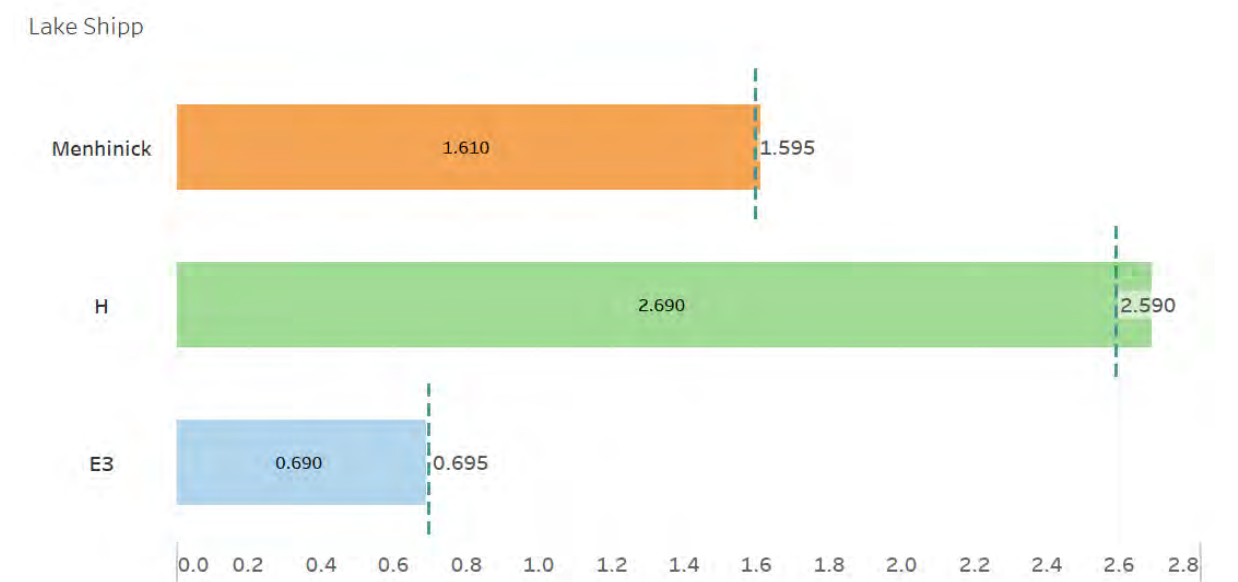


Figure 3-242. Chart depicting 2024 diversity indices for Lake Shipp. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Shipp's health index scores from 2018 to 2024 shows relative consistency (Figure 3-243). Throughout this span, the water quality criteria have remained the same. While Lake Shipp remains impaired, its water quality has been consistently improving. The only fluctuation has been in the invasive presence and diversity criteria—shifting due to expansion and treatment of exotic plant species. Overall, Lake Shipp ranks moderately low on the priority list. While it is impaired, the trend and biological scores indicate that management efforts have been having a positive impact.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	3	3	3	3	3	1	1	2.1
2019	0	3	3	3	3	3	1	1	2.1
2020	0	3	3	3	3	3	1	1	2.1
2021	0	3	3	3	3	3	2	1	2.3
2022	0	3	3	3	3	3	2	2	2.4
2023	0	3	3	3	3	3	2	2	2.4
2024	0	3	3	3	3	3	1	2	2.3

Figure 3-243. Chart depicting a comparison of Lake Shipp's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- In addition to considerable stormwater pollutant loading, Lake Shipp historically received point-source inputs from multiple agricultural processing facilities. These legacy sediments may contribute to internal nutrient loading. Furthermore, the moderate density of septic systems may potentially contribute to additional loading.
- The management of invasive species like hydrilla has been a concern in the past. While current populations appear to be controlled, it can take just a single growing season for these to take over large areas of a waterbody.
- Several of Lake Shipp's water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- To mitigate stormwater loading, the City has implemented street sweeping in the basin and has plans to construct green infrastructure along the northwest portion of the drainage basin as part of a Complete Streets improvement project.
- The City may explore sediment removal and/or septic system source analysis to determine if these alternative loading pathways are a significant contributor of nutrients.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Now that hydrilla is in a controlled state, maintaining that control is a high priority to prevent future large scale herbicide treatments.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Silver

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Silver	3	2	2	3	1	2	3	1	2.1

Features & Statistics:

Surface area	54.3 acres
Mean depth	11.9 feet
Maximum depth	32 feet
Volume	1040.1 acre-feet
Drainage basin area	164.2 acres
Annual TN Load	633.2 lbs
Annual TP Load	106.1 lbs
Limiting nutrient	Phosphorus

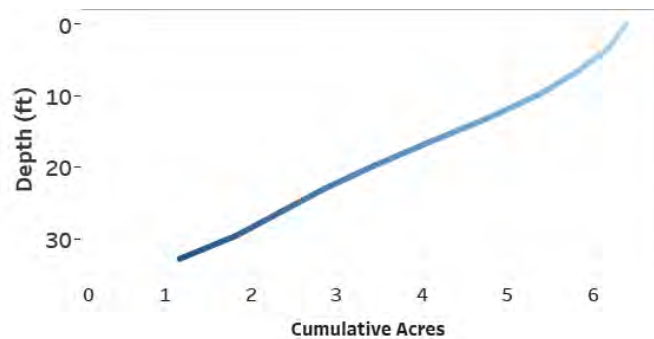


Figure 3-244. Hypsograph of Lake Silver depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Silver is a small, but deep waterbody with a surface area of 55 acres, an average depth of 12 feet, and a maximum depth of over 32 feet (Figure 3-244). Silver's depth likely results in increased interactions with the aquifer. Despite its depth, there are still areas near the shore where aquatic vegetation can grow. Stormwater is conveyed to this waterbody from an urbanized 164 acre drainage basin, comprised of 12 individual sub-basins (Figure 3-244). By far, the most dominant land use in this basin is commercial, followed by institutional, medium-density residential, recreational, and industrial. Based on stormwater pollutant load modeling, this drainage area contributes 633 lbs of TN and 106 lbs of TP to the lake annually; on a per acre basis, these loads rank relatively high compared with other drainage basins in the study area. To combat stormwater pollutant loading, the City conducts 20.15 miles of street sweeping—nearly all roads in this basin are swept monthly.

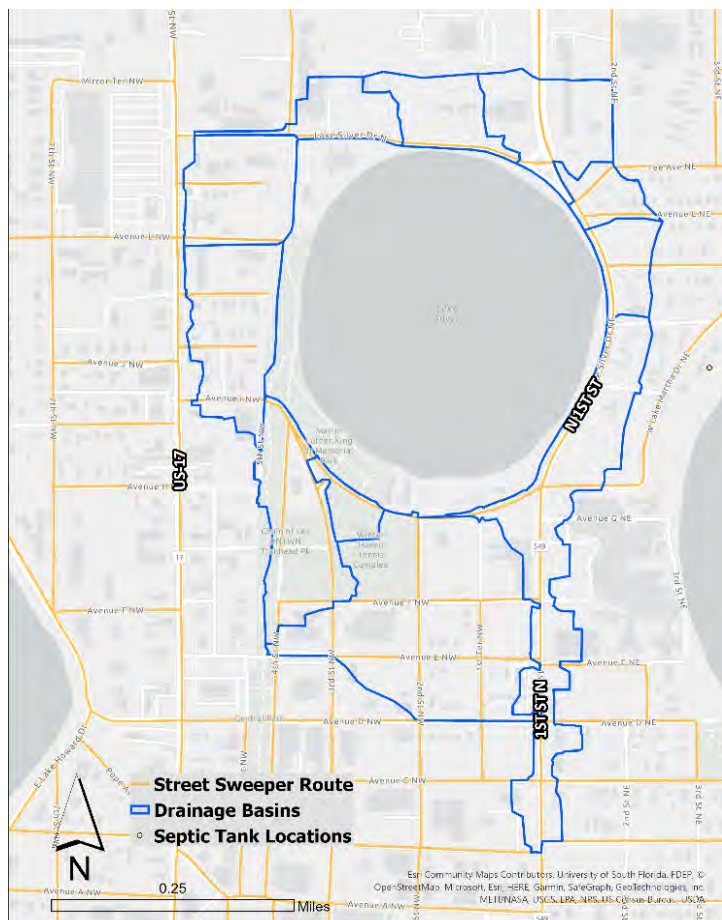


Figure 3-245. Map of Lake Silver's drainage basin, City street sweeper routes, and nearby septic systems.

Lake Silver is located in the center of downtown Winter Haven. Sitting at one of the highest elevations in the Peace Creek watershed, it discharges excess water downstream to Lake Martha via pipe. Over its period of record, Lake Silver's surface level has fluctuated between 139.9 and 147.1 feet above sea level. The normal level range fluctuates between 142.3 and 145.3 feet (Figure 3-246). During 2024, Lake Silver dropped to a dry season low of 144 feet in June, then rose to a peak of 146.5 feet in October; ending the year at an above-average level of 145.8 feet. Changes in Lake Silver's surface level are not significantly correlated with any of its water quality metrics (see appendix).

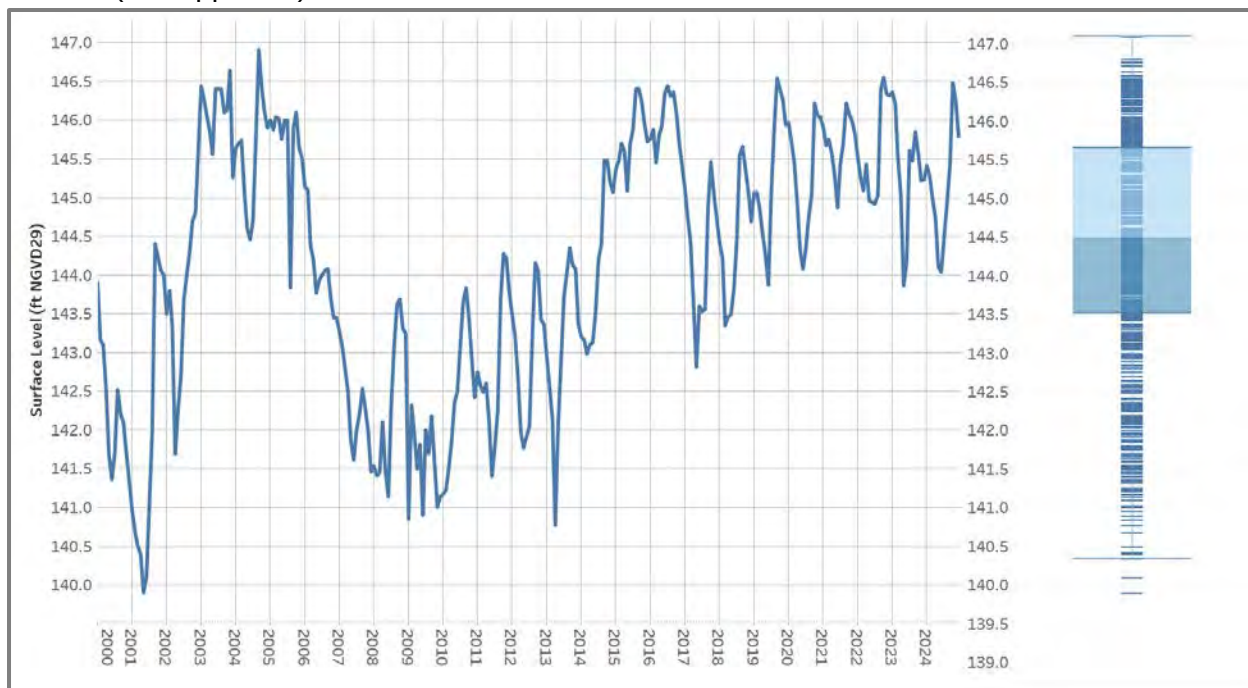


Figure 3-246. Hydrograph of Lake Silver depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria, Lake Silver is categorized as a clear, alkaline waterbody. Aside from an exceedance of the Chl-a threshold in 2017, Lake Silver has not exhibited any other NNC exceedances during the assessment period (Figure 3-247). Consequently, Lake Silver is not considered impaired and earns an impairment criterion score of 3. It should be noted that Silver's 2024 Chl-a and TP concentrations were well below the normal range—indicating better water quality than normal.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.224	0.342	No Trend	3	2
TN	N	-0.276	0.239	No Trend		2
TP	N	-0.523	0.018	Decreasing		3
Secchi	NA	-0.015	0.952	No Trend		1

Water Quality Trends

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this period, Chl-a, TN, and Secchi depth

exhibited non-significant trends. The trends for Chl-a and TN were in an improving direction equating to a trend score of 2; whereas Secchi depth was in a negative direction for a score of 1. Exhibiting a significant improving trend, TP earned a trend score of 3. Overall, Lake Silver's trends do not indicate that water quality is deteriorating at all.

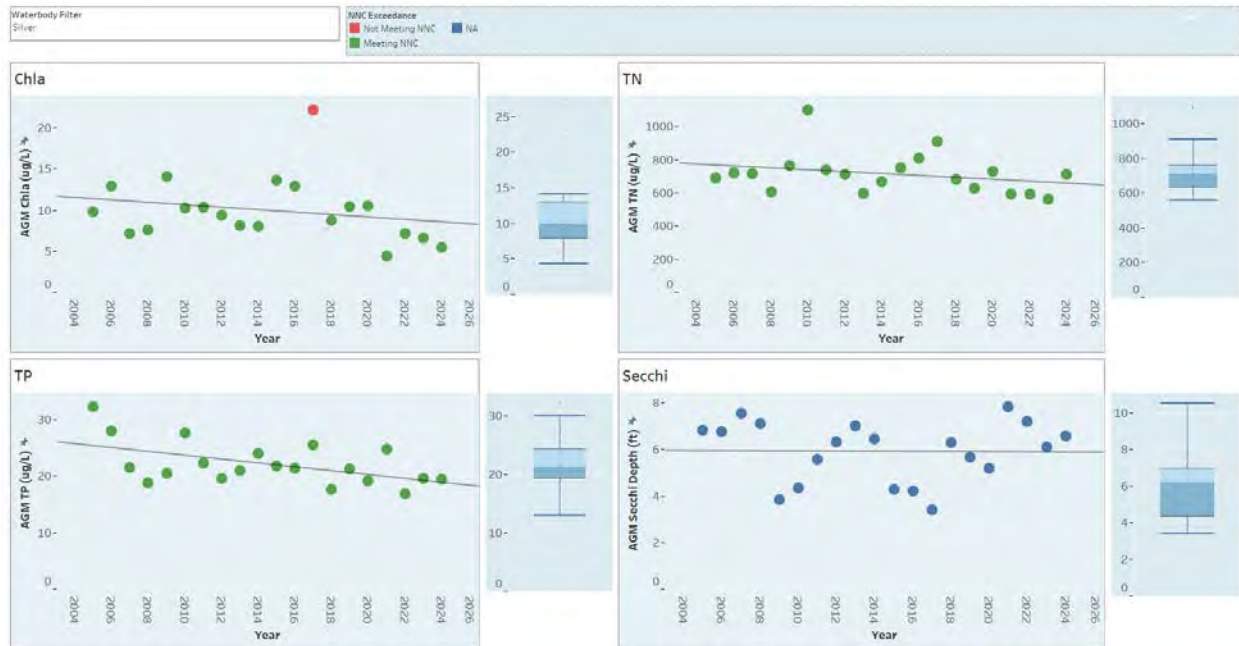


Figure 3-247. Lake Silver AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Silver on 8/6/2024. The PAC during this survey was 18.8% and the total BV was 1.3% (Figure 3-248). This level of coverage is the highest on record and earns Silver a vegetation abundance criterion score of 2. Since monitoring began, Lake Silver has displayed very low vegetation abundance, often lacking much submerged presence. However, there was a noticeable increase in the native SAV species eelgrass which should provide additional water quality and fish habitat enhancements.

Invasive Species Management:

Based on data from the 2024 survey, Lake Silver's vegetation community has undergone a dramatic, but positive shift. The native SAV species, eelgrass, became the most dominant plant detected during the survey, followed by the typical emergent species (Figure 3-249). The newfound presence of SAV is a positive change that should result in improved water quality and possibly better fish and wildlife habitat. As usual, Lake Silver lacked any managed invasive species during the survey; earning an invasive presence score of 3.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2024 species data, Lake Silver's species richness index was the only diversity value that exceeded its long-term median; equating to a diversity score of 1 (Figure 3-250). The shift in species distribution with the increase in eelgrass likely led to the slightly lower evenness and overall diversity scores. However, since there has not been any invasive management efforts in Silver, these changes are mostly natural fluctuations.

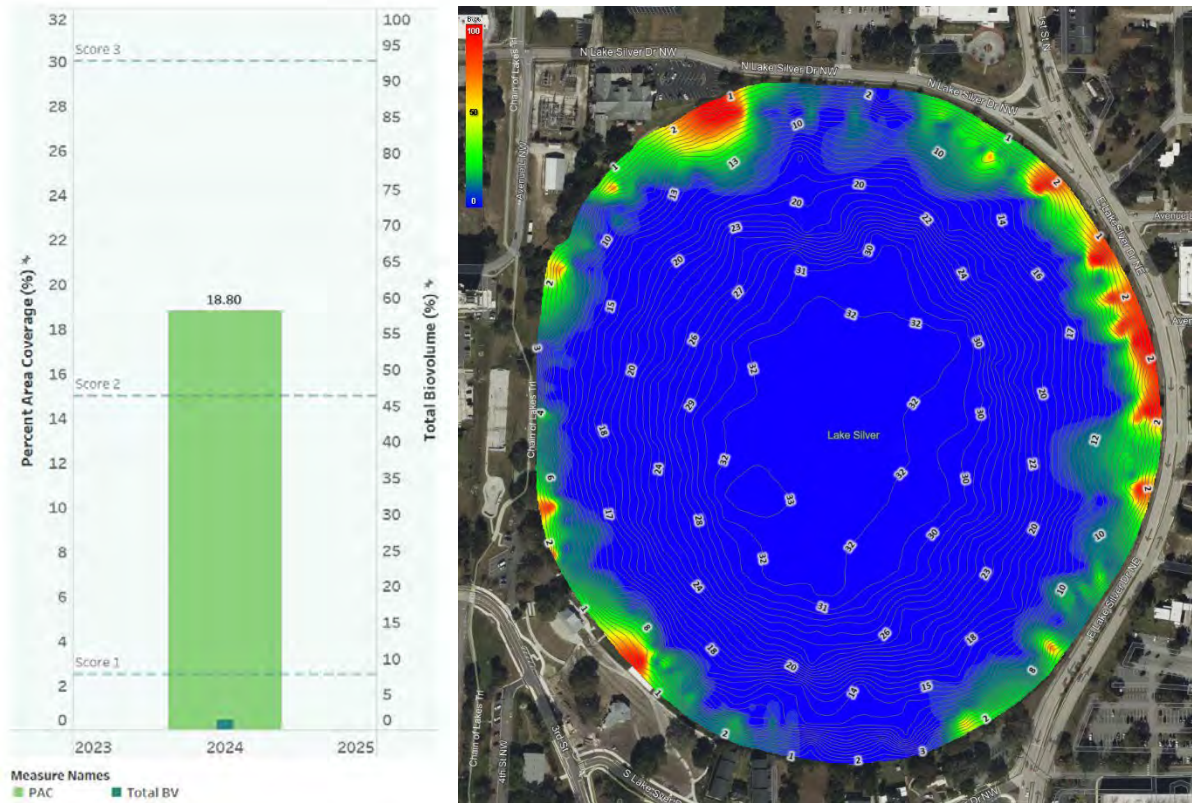


Figure 3-248. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Silver; biovolume values range from green (lowest) to red (highest).

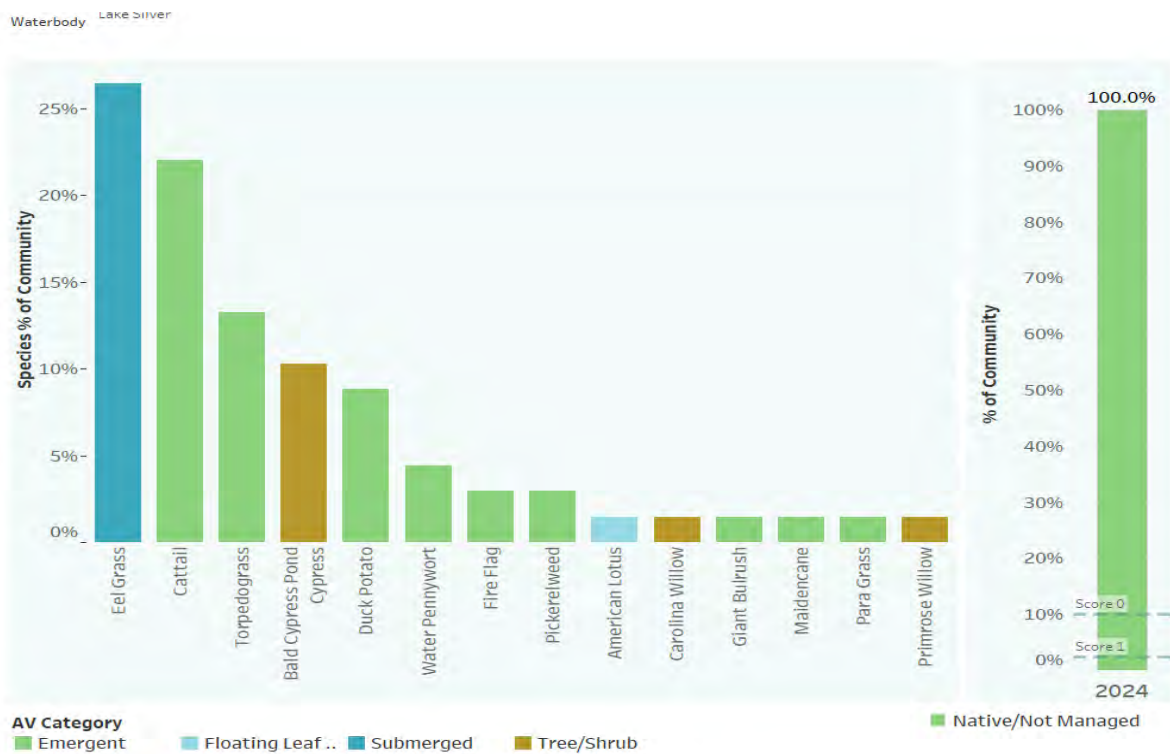


Figure 3-249. Chart depicting species frequency and invasive species percentage of Lake Silver during 2024.

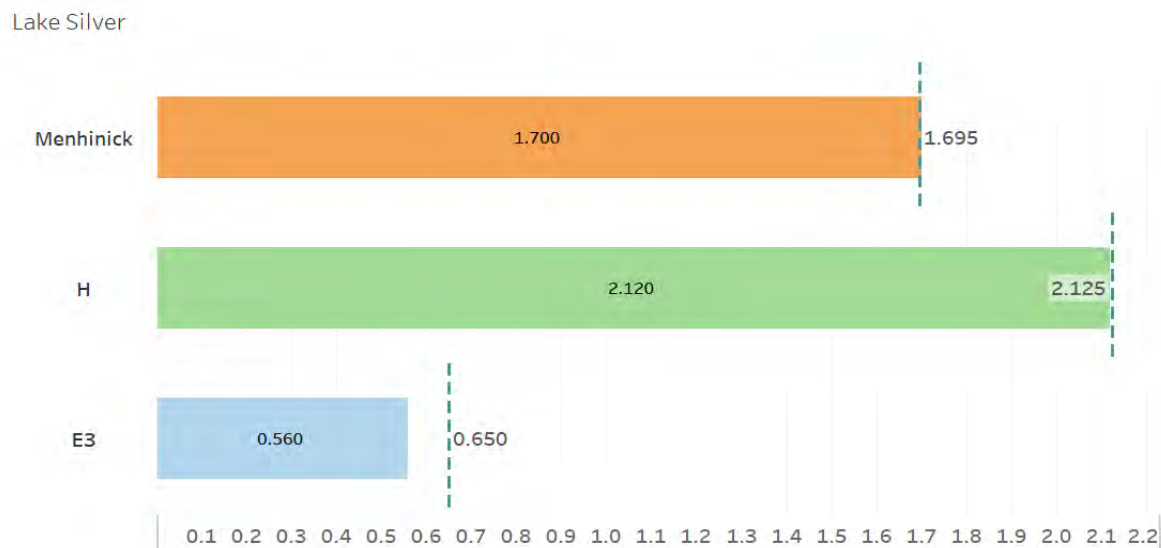


Figure 3-250. Chart depicting 2024 diversity indices for Lake Silver. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Silver's health index scores from 2018 to 2024 shows some variability, with values ranging from 1.6 to 2.1 (Figure 3-251). Over this span, the impairment, trends, and invasive presence criteria were unchanged. The primary form of score variance came from vegetation abundance and diversity—with wide swings from year to year. The consistent lack of vegetation coverage was one of the primary criteria that brought its score down. Overall, Lake Silver ranks lower on the priority list. Its water quality is good, trends don't indicate deterioration, and it does not have issues with invasive plants. The recent shift in the vegetation community is a good sign that one of the primarily lacking areas is undergoing improvement.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	2	2	2	1	0	3	1	1.8
2019	3	2	2	2	1	1	3	3	2.1
2020	3	2	2	2	1	0	3	0	1.6
2021	3	2	2	2	1	0	3	3	2.0
2022	3	2	2	2	1	0	3	0	1.6
2023	3	2	2	2	2	1	3	2	2.1
2024	3	2	2	3	1	2	3	1	2.1

Figure 3-251. Chart depicting a comparison of Lake Silver's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Silver currently exhibits good water quality. However, stormwater pollutant loading is still a potential concern if trends begin to indicate a decline.
- While Lake Silver has no invasive species present, its lack of vegetation abundance has previously hindered its ability to buffer against changes in water quality in addition to negative impacts on fish and wildlife habitat.

Lake Management Strategy:

- To mitigate stormwater loading, the City conducts over 20 miles of street sweeping within the drainage basin. Raingardens and other green infrastructure have been constructed along streets in the drainage basin south of the lake. There are opportunities to construct additional green infrastructure within the drainage basin, however.
- While the lake now has a growing population of submerged aquatic vegetation, there is only one species of SAV present. Ideally, Lake Silver should have 3 or 4 SAV species in order to prevent decimation from pests, disease, or human disturbance. The City should continue to explore the possibility of planting other varieties of SAV to bolster the vegetation community. This would also help to improve the species diversity scores in the future.

Lake Smart

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Smart	0	2	2	2	2	3	1	3	1.9

Features & Statistics:

Surface area	281.2 acres
Mean depth	9.42 feet
Maximum depth	16 feet
Volume	2903.8 acre-feet
Drainage basin area	642.6 acres
Annual TN Load	1673.4 lbs
Annual TP Load	348.9 lbs
Limiting nutrient	Phosphorus

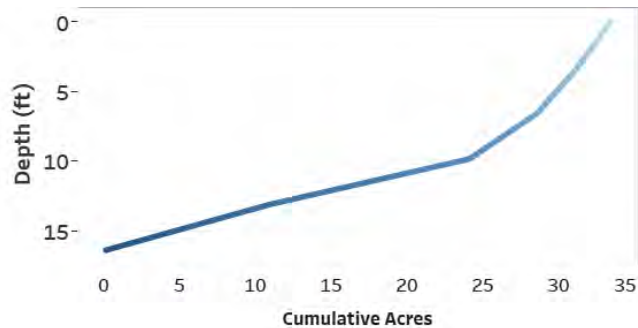


Figure 3-252. Hypsograph of Lake Smart depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Smart is moderately sized at 282 acres, but is actually one of the smaller lakes on the North Chain. Lake Smart is relatively deep with an average depth of 9.4 feet and a maximum depth of over 15 feet (Figure 3-252). Despite this depth, the lake supports a moderate littoral zone that should support a robust vegetation community. Stormwater is conveyed to this waterbody from a 643 acre drainage basin made up of residential, agricultural, and wetland land uses (Figure 3-253). Based on stormwater pollutant modelling, this drainage area contributes 1,673 lbs of TN and 349 lbs of TP to the lake annually; on a per acre basis, these loading rates are relatively average compared to other lakes in the study area. Due to a lack of drainage infrastructure discharging stormwater from City roadways, Winter Haven does not currently conduct street sweeping services in Lake Smart's drainage basin.



Figure 3-253. Map of Lake Smart's drainage basin and nearby septic systems.

As part of the North Chain of Lakes, Smart is connected to Lake Conine to the west via navigable canal and Lake Fannie to the east via a non-navigable canal. Excess water from the North Chain eventually drains via the SWFWMD-managed P-8 control structure at the south of Lake Hamilton and enters the Peace Creek. Over the period of record, surface levels in this section of the North Chain (Lakes Conine, Haines, Rochelle, and Smart) have fluctuated between 122 and 129.5 feet above sea level. The normal range fluctuates much less between 126.1 and 128.2 feet (Figure 3-254). During 2024, the North Chain reached a dry season low of 127.8 feet in June and a wet season peak of 130.3 feet in October. The October peak was a record high for this chain of lakes; exceeding the previous record experienced during the triple hurricane season of 2004. The surface level ended the year above the high end of the normal range, at 128.5 feet. Changes in Lake Smart's surface level are directly correlated with water clarity and indirectly correlated with Chl-a and TN (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

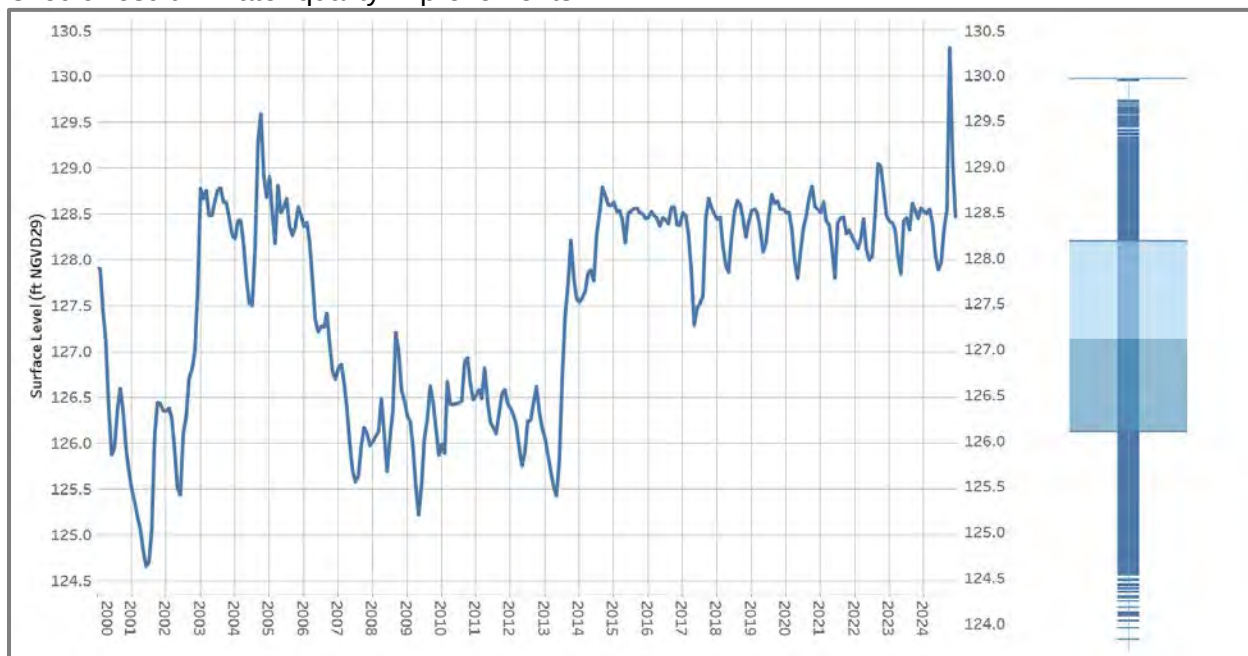


Figure 3-254. Hydrograph of Lake Smart depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Smart is categorized as a clear, alkaline waterbody. Due to numerous NNC exceedances during the assessment period, Lake Smart is considered impaired for Chl-a, TN, and TP (Figure 3-255). This equates to an impairment criterion score of 0. In 2024, an alternative restoration plan, submitted by Polk County, was accepted by the FDEP. This plan includes several projects aimed at improving water quality in the lake.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.457	0.056	No Trend	0	2
TN	Y	-0.312	0.207	No Trend		2
TP	Y	-0.450	0.061	No Trend		2
Secchi	NA	0.303	0.222	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. All four of these parameters exhibited non-significant improving trends during this period. The result is that each parameters receives a trend criterion score of 2. It should be noted that the 2024 concentrations of Chl-a and TP met the NNC impairment thresholds—indicating recently better water quality than in the past.

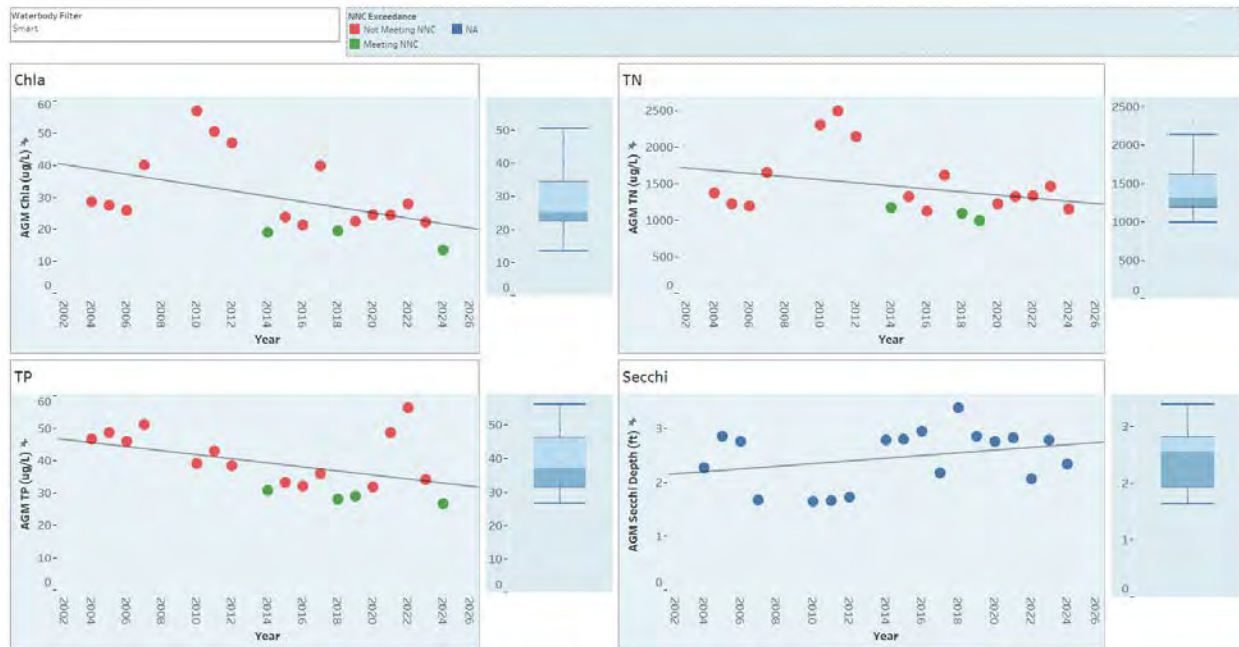


Figure 3-255. Lake Smart AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Smart on 3/15/2024. The PAC during this survey was 56.1% and the total BV was 7.7% (Figure 3-256). A PAC value above 30% equates to an abundance criterion score of 3. An increase in vegetation abundance provides more wildlife habitat and increased water quality improvement potential. This coverage value is the second highest on record.

Invasive Species Management:

Based on data from the 2024 survey, Lake Smart supports a healthy mix of vegetation types, with elgrass and cattail being the most dominant (Figure 3-257). The invasive hydrilla made up 6.7% of the community—resulting in an invasive presence criterion score of 1. Hydrilla has historically been the primary invasive concern for Lake Smart. Its population peaked at 12.9% in 2019 but has remained below 10% since. Management efforts have effectively kept it in a controlled state.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2024 species data, all three of Lake Smart's diversity indices met or exceeded their respective median values (Figure 3-258). This equates to a diversity score of 3. This marks the second consecutive year where all diversity measures have been above-average in Lake Smart.

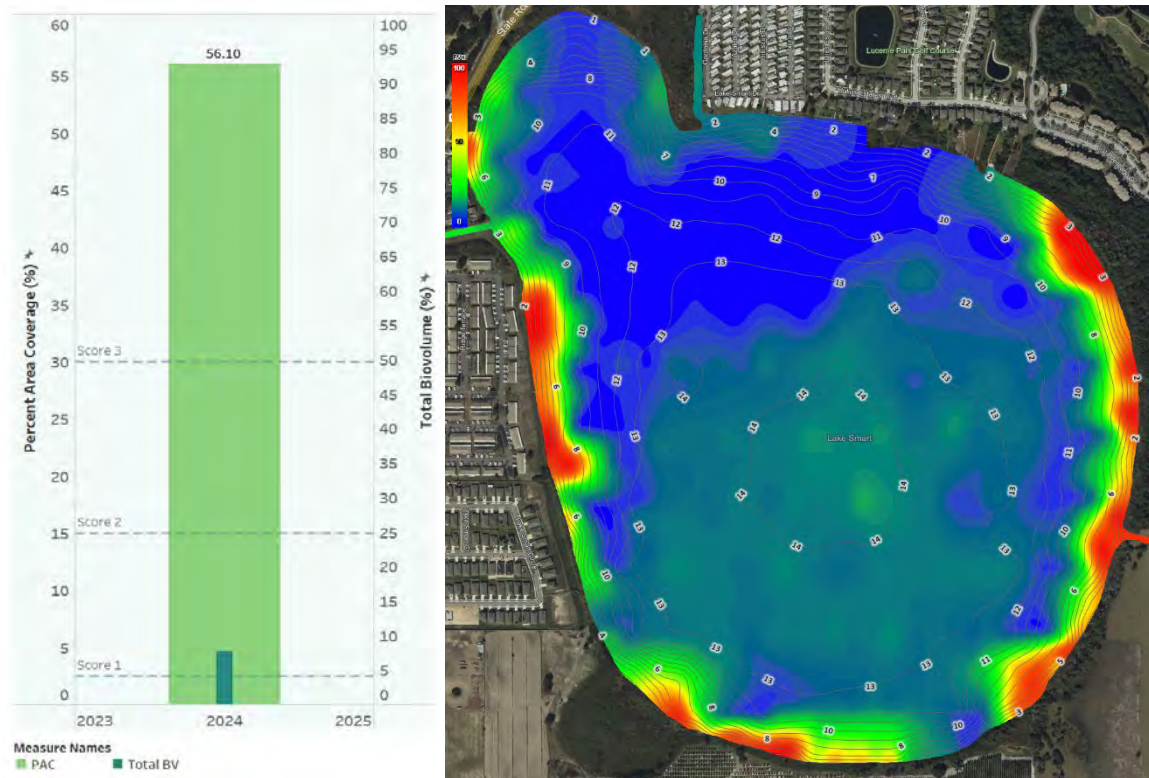


Figure 3-256. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Smart; biovolume values range from green (lowest) to red (highest).

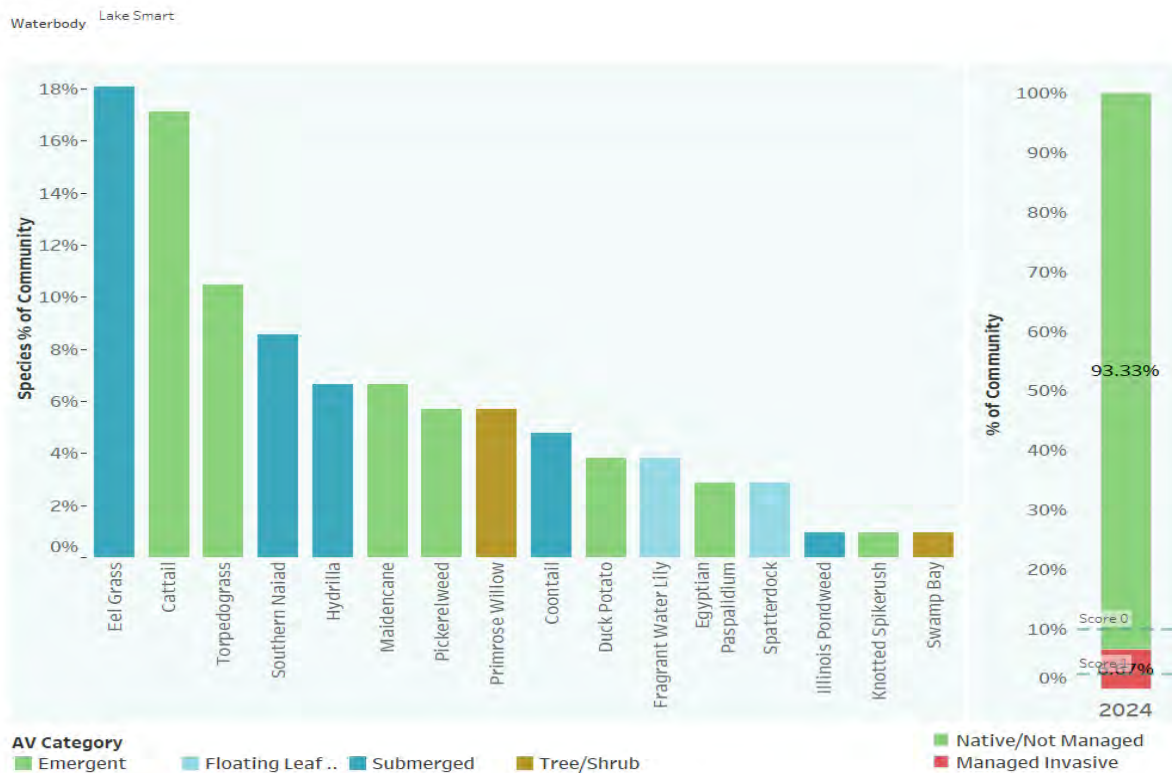


Figure 3-257. Chart depicting species frequency and invasive species percentage of Lake Smart during 2024.

Lake Smart

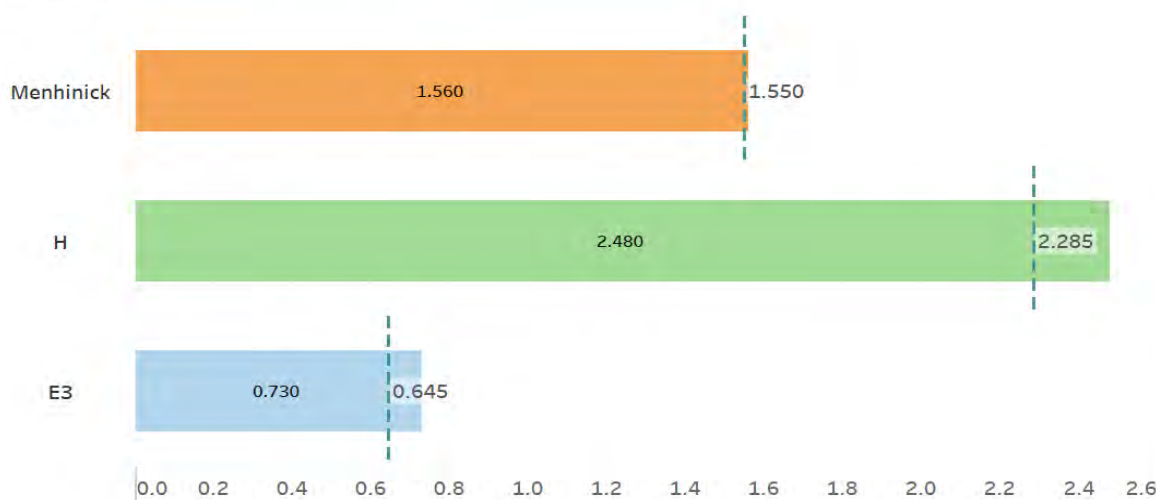


Figure 3-258. Chart depicting 2024 diversity indices for Lake Smart. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Smart's health index scores from 2018 to 2024 shows some improvement—with values ranging from 1.3 to 2.0 (Figure 3-259). The impairment criterion score has not shifted during this period. However, the trend scores have varied somewhat with both the TP and Clarity trends shifting from significant to non-significant improving. Lake Smart's initial vegetation abundance was low, but has since improved; as have its diversity scores. Invasive presence is the primary criterion exhibiting decline. Overall, Lake Smart ranks moderate-to-high on the ranking list. Management action is required to definitively improve water quality and control invasive plants.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	2	1	2	2	1	2	0	1.3
2019	0	2	2	3	2	3	0	1	1.6
2020	0	2	2	3	2	2	2	3	2.0
2021	0	2	2	2	3	2	1	2	1.8
2022	0	2	2	2	3	3	1	2	1.9
2023	0	2	2	2	2	2	1	3	1.8
2024	0	2	2	2	2	3	1	3	1.9

Figure 3-259. Chart depicting a comparison of Lake Smart's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- While stormwater loading may be a potential contributor to water quality impairment, much of Lake Smart's basin lacks direct stormwater inflows to the waterbody. The large presence of agriculture on the south side of the basin may be an area for runoff mitigation, but much of this land is currently being converted to residential land uses.
- The management of invasive species like hydrilla is a consistent concern. The hydrilla population, while low, can rapidly take over large areas of the lake without constant management.

- Several of Lake Smart's water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- Polk County submitted a pollutant reduction plan for Lake Smart in 2023 which was accepted by the FDEP in 2024. The plan involves sediment inactivation to help reduce phosphorus flux into the water column by the highly organic material in the lake bed.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Spring

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Spring	3	3	2	2	2	3	0	3	2.3

Features & Statistics:

Surface area	25.2 acres
Mean depth	9.02 feet
Maximum depth	23 feet
Volume	306.9 acre-feet
Drainage basin area	120.2 acres
Annual TN Load	520.7 lbs
Annual TP Load	90.8 lbs
Limiting nutrient	Co-limited (N & P)

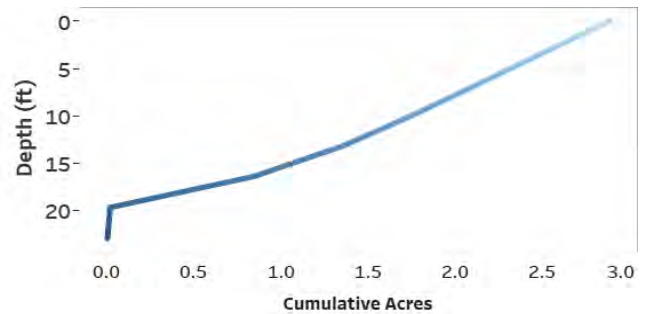


Figure 3-260. Hypsograph of Lake Spring depicting the depth profile and morphology of the lake bed.

Hydrology:

Lake Spring is the smallest lake on the South Chain at just 25 acres. While small, it is one of the South Chain's deeper lakes with an average depth of 9 feet and maximum depth of over 20 feet (Figure 3-260). Spring's morphology is indicative of a traditional sinkhole-formed lake. Despite its depth, Lake Spring's gradually sloping lake bed supports a wide littoral zone and robust vegetation community. Stormwater is conveyed to this waterbody from a 120 acre drainage basin, comprised of 7 individual sub-basins (Figure 3-261). The most dominant land use within this basin is commercial, followed by residential and institutional. Based on stormwater pollutant load modeling, this drainage area contributes 520 lbs of TN and 91 lbs of TP to the lake annually. These pollutant loads rank 6th highest (out of 37) on a per acre basis; mostly due to the high density of commercial land uses in the basin. To combat stormwater loading, the City conducts 7.4 miles of street sweeping in this basin on a monthly basis.

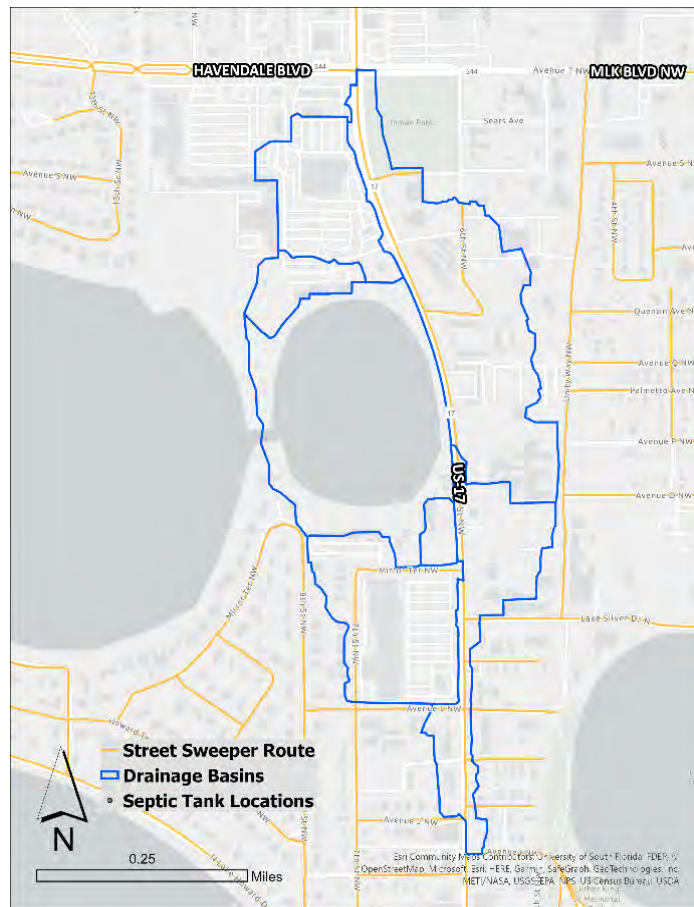


Figure 3-261. Map of Lake Spring's drainage basin and City street sweeper routes.

Lake Spring is located on the South Chain with a navigable connection to Lake Mirror to the west. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-262). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, Lake Spring's surface level is not correlated with its water quality parameters (see appendix).

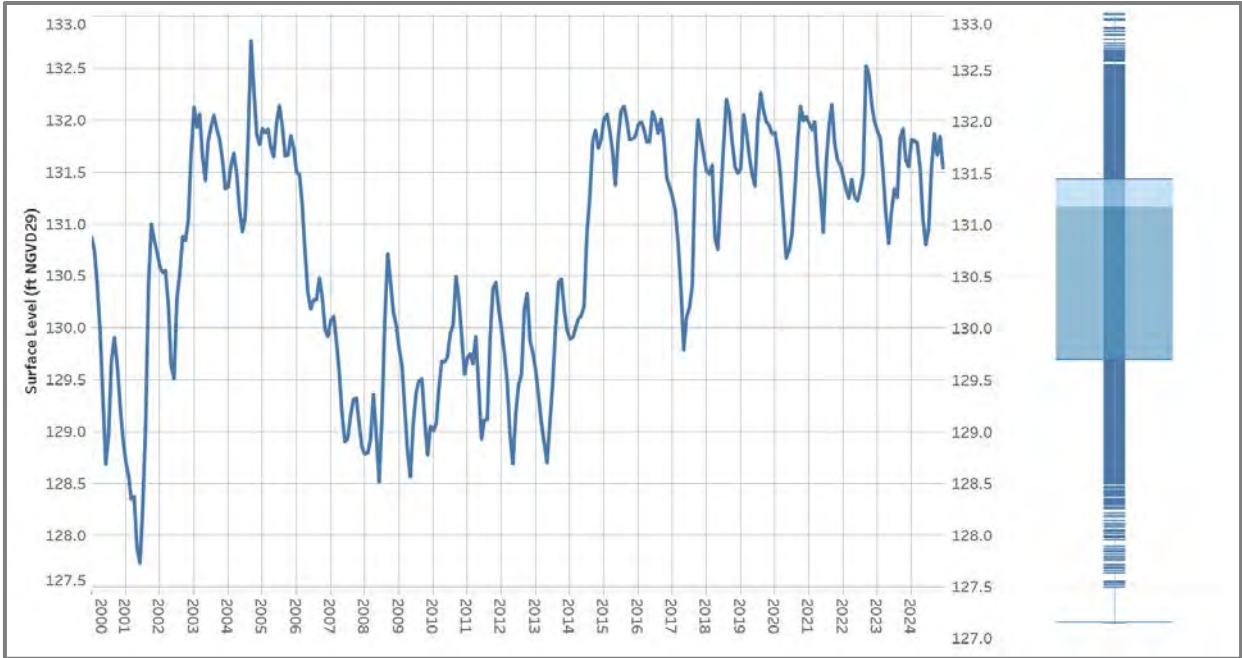


Figure 3-262. Hydrograph of Lake Spring depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Spring is categorized as a clear, alkaline waterbody. Despite an exceedance of Chl-a in 2015, Lake Spring has exhibited no other NNC exceedances during the assessment period (Figure 3-263). Due to this, Spring is considered un-impaired and earns an impairment criterion score of 3. It should be noted that the Chl-a, TN, and TP concentrations were higher than average during 2024; it is unclear what caused this recent spike in NNC parameters.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.434	0.049	Decreasing	3	3
TN	Y	-0.380	0.089	No Trend		2
TP	Y	-0.151	0.513	No Trend		2
Secchi	NA	0.344	0.127	No Trend		2

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Chl-a exhibited a significant improving trend during this period; equating to a trend criteria score of 3. The trends for TN, TP, and Secchi depth, while in an improving direction, were not statistically significant; earning trend scores of 2. This is a recent shift from the previous year when all four parameters exhibited significantly improving trends—likely due to the elevated Chl-a, TN, and TP concentrations in 2024.

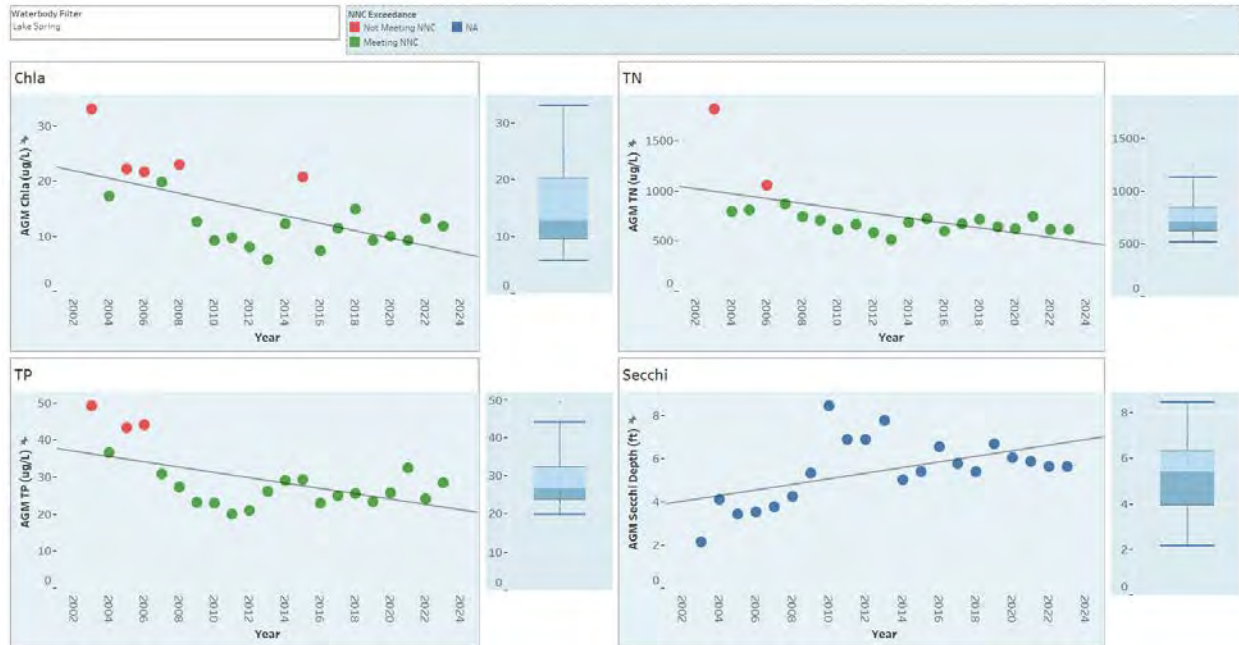


Figure 3-263. Lake Spring AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Spring on 1/25/2024. The PAC during this survey was 80.4% and the total BV was 12.5% (Figure 3-264). A PAC over the 30% threshold equates to a vegetation abundance criterion score of 3. Over the last six years, Lake Spring has maintained high vegetation abundance with coverage consistently above 50%. The PAC during 2024 was the highest on record and is surprising considering this increase occurred despite a reduction in invasive species abundance.

Invasive Species Management:

Based on data from the 2024 survey, Lake Spring possesses a mix of vegetation types. The submerged plant, eelgrass, was the most dominant at over 18% (Figure 3-264). Invasive species, represented by hydrilla and burhead sedge, made up 13.5% of the community. Despite this percentage equating to an invasive criterion score of 0, it was actually a substantial reduction in invasive presence from the previous year. Historically, hydrilla has been an issue in Lake Spring. Due to the small size of the lake, even a minor expansion in invasive abundance constitutes a large proportion of the lake's total area. For a species like hydrilla that can grow roughly a foot per day under the right conditions, it does not take long for it to exceed a managed state. Future management efforts may require more frequent vegetation monitoring in order to facilitate early detection and rapid invasive response.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2024 species data, all three of Lake Spring's diversity indices exceeded their long-term median values, for a diversity criterion score of 3 (Figure 3-266). While species richness did not deviate from the previous year, the evenness and overall diversity indices experienced an increase. This is likely due to the reduction in hydrilla which led to a more even distribution of all plant species. Indeed, the next eight species with a community frequency below eelgrass' were in relatively equal proportions. This demonstrates how control of invasives can have a positive impact on the ecological community, making it more diverse and equitable.

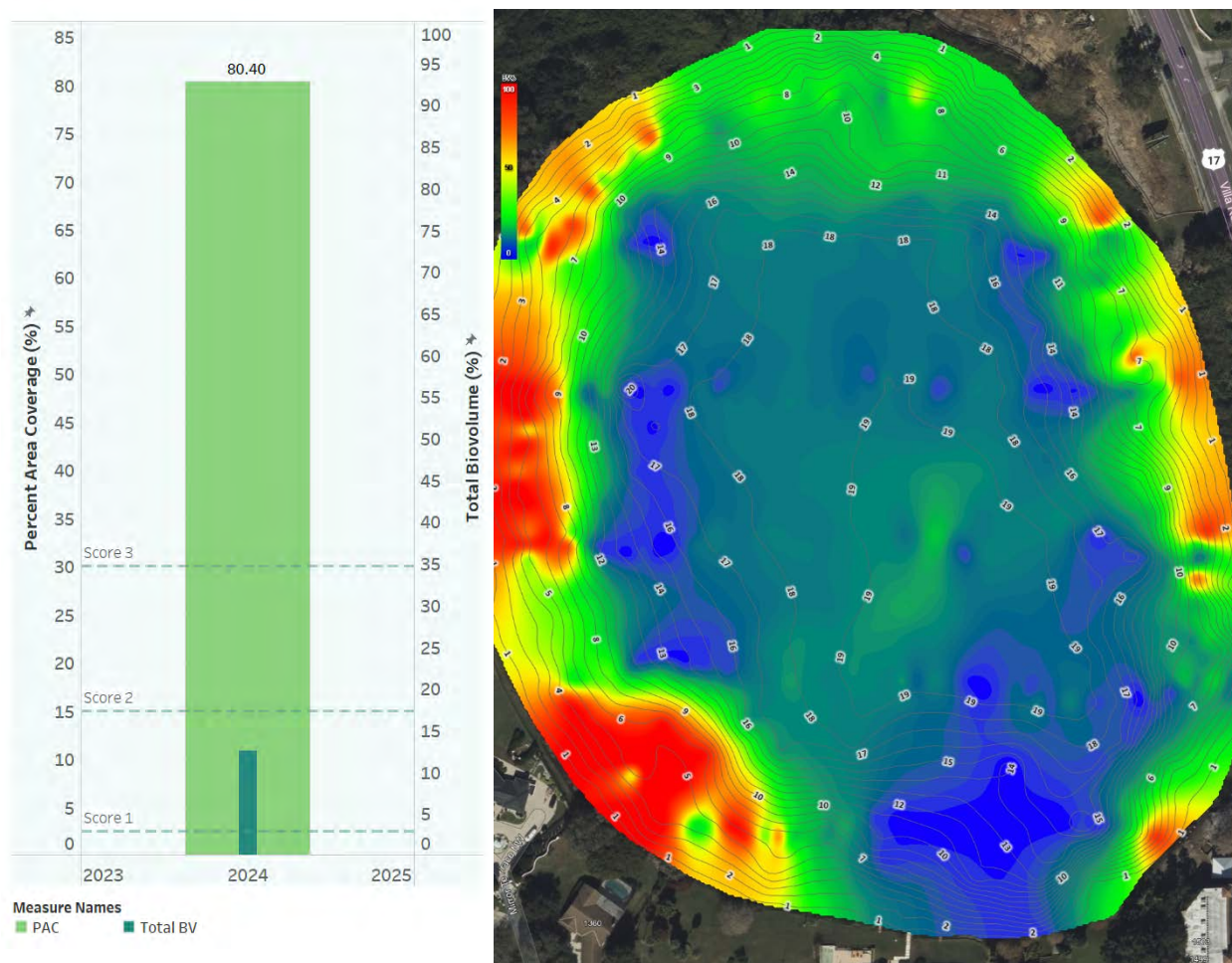


Figure 3-264. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Spring: biovolume values range from green (lowest) to red (highest).

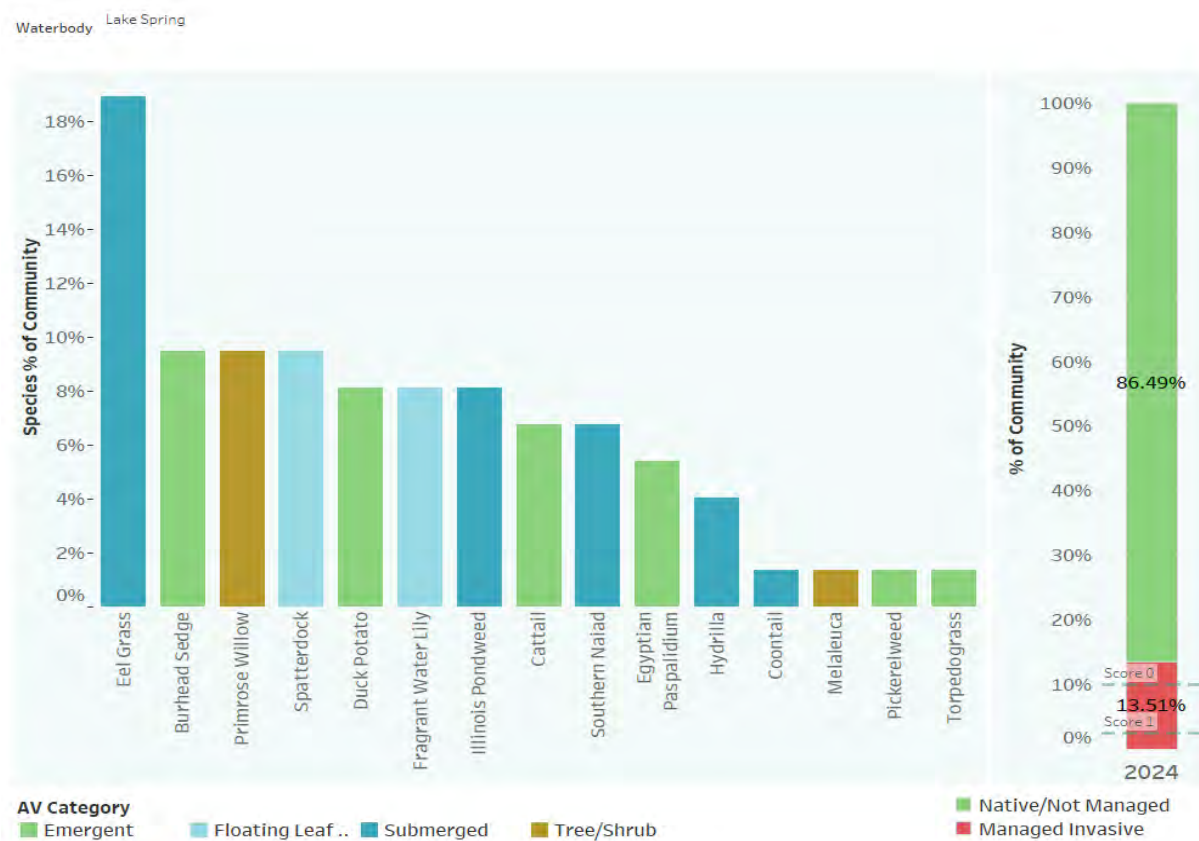


Figure 3-265. Chart depicting species frequency and invasive species percentage of Lake Spring during 2024.

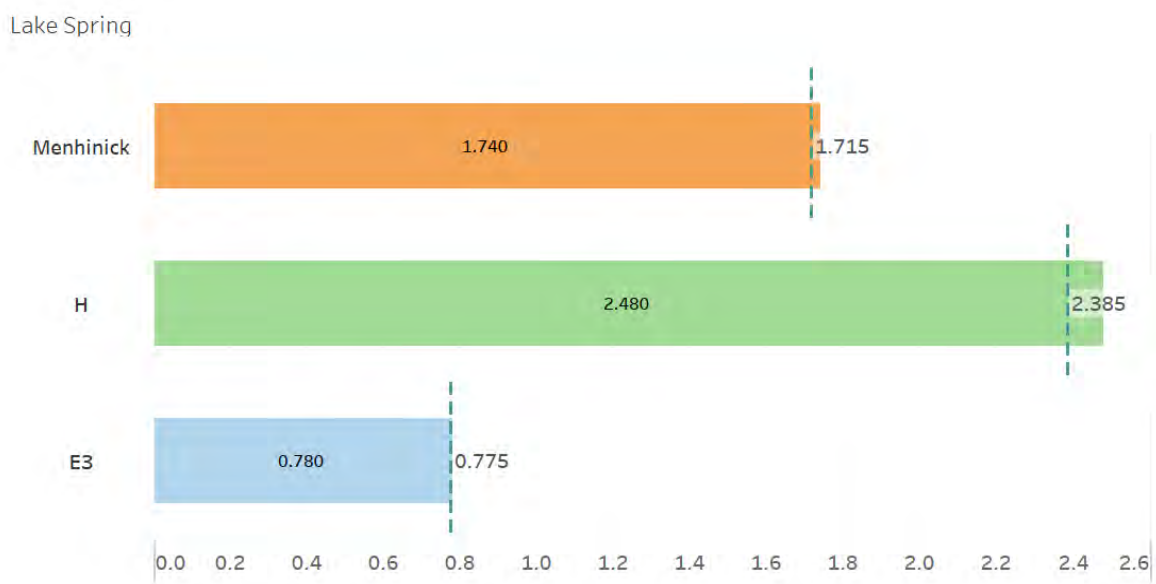


Figure 3-266. Chart depicting 2024 diversity indices for Lake Spring. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Spring's health index scores from 2018 to 2024 shows consistently good values ranging from 2.3 to 2.6 (Figure 3-267). During this span, there have been no changes in the impairment or vegetation abundance criteria scores. While the TN, TP, and Clarity trends underwent a downgrade due to a loss in significance, this does not necessarily indicate a decline in water quality—just that the water quality is stabilizing. The primary source of lake health change has been through the surge and subsequent treatment of invasive plants; which impacts species diversity in turn. Overall, Lake Spring ranks low on the priority list due to it exhibiting good water quality, generally good trends, and excellent vegetation abundance.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	0	1	2.4
2019	3	3	3	3	3	3	0	2	2.5
2020	3	3	3	3	3	3	0	2	2.5
2021	3	3	3	3	3	3	0	1	2.4
2022	3	3	3	3	3	3	1	2	2.6
2023	3	3	3	3	3	3	0	1	2.4
2024	3	3	2	2	2	3	0	3	2.3

Figure 3-267. Chart depicting a comparison of Lake Spring's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Spring currently exhibits excellent water quality. However, stormwater pollutant loading is the leading vector for water quality issues if trends shift toward a deteriorating direction in the future.
- The management of invasive species is currently the primary management concern for Lake Spring. While hydrilla and burhead sedge abundance was lower in 2024, their proportions are still above the ideal range. These invasives can also quickly rebound and expand in the future; requiring additional management effort to control.

Lake Management Strategy:

- The City currently conducts over seven miles of street sweeping along the major roadways in the drainage basin to mitigate stormwater loading. Future stormwater management may aim to implement green infrastructure, if applicable locations can be identified.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.

Lake Summit

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Summit	3	3	2	1	3	3	2	1	2.3

Features & Statistics:

Surface area	67.4 acres
Mean depth	10.71 feet
Maximum depth	29 feet
Volume	900 acre-feet
Drainage basin area	166.5 acres
Annual TN Load	513.3 lbs
Annual TP Load	82.7 lbs
Limiting nutrient	Co-limited (N & P)

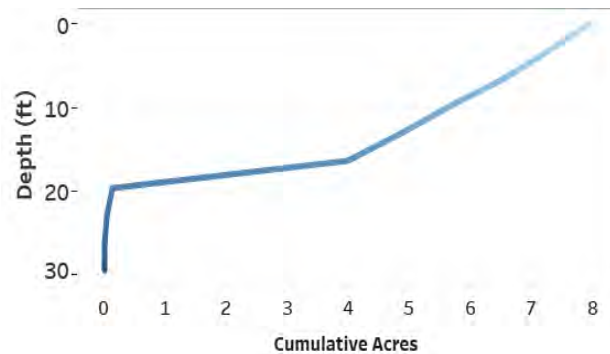


Figure 3-268. Hypsograph of Lake Summit depicting the depth profile and morphology of the lake bed.



Figure 3-269. Map of Lake Summit's drainage basin and nearby septic systems.

Hydrology:

Lake Summit is a small, but deep waterbody at 67 acres, an average depth of 10.7 feet, and a maximum depth of almost 30 feet (Figure 3-268). Summit's average depth is almost two feet deeper than the regional mean. Coupled with the small size of the lake, the lake bed has a steeper slope. While this would normally significantly limit the littoral zone, Lake Summit has very high water clarity which allows its aquatic plants to grow in deeper water than many other lakes in the study area. Stormwater is conveyed to this waterbody from a 166 acre drainage basin (Figure 3-269). The basin is dominated by residential land uses, contributing 513 lbs of TN and 83 lbs of TP to the lake annually. On a per acre basis, these pollutant loading rates are fairly low compared with other drainage basins in the study area. There are 52 septic systems present in the basin. This constitutes a moderate density that may contribute some pollutant loading through groundwater leaching. Due to the drainage basin being mostly outside of Winter Haven limits, the City does not conduct any street sweeping that benefits this lake.

As part of the South Chain, Lake Summit is connected to Lake Eloise via navigable canal. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-270). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear regression analysis, changes in Lake Summit's surface level are correlated with Chl-a, TN, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

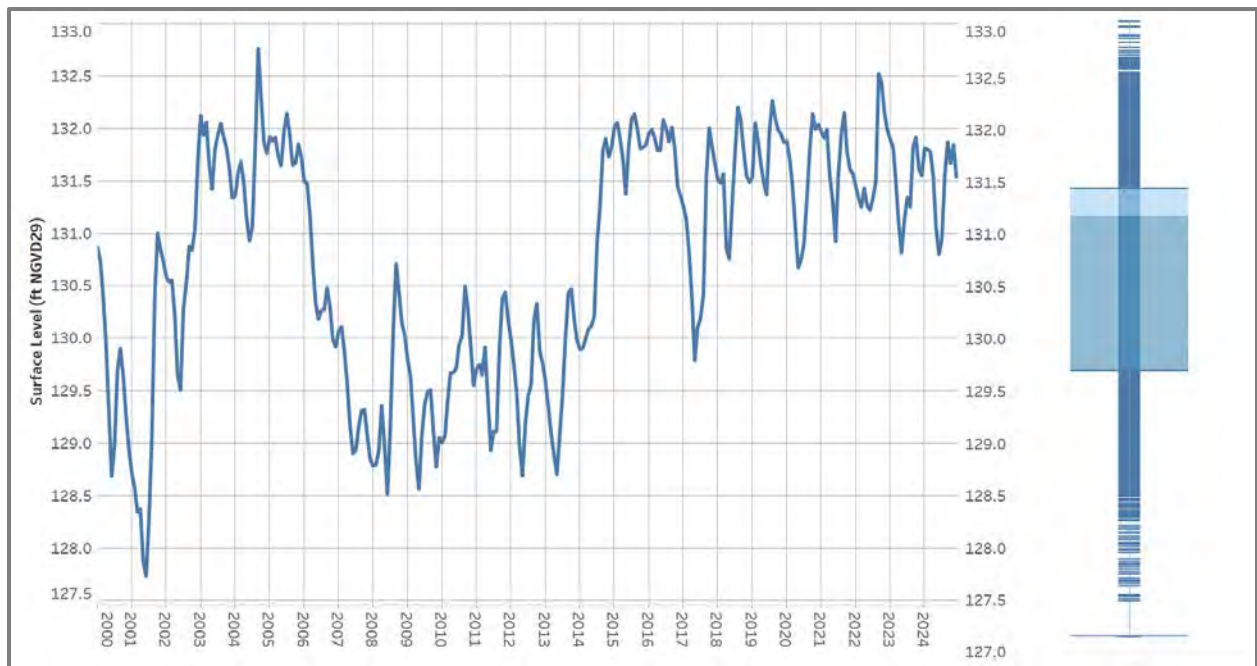


Figure 3-270. Hydrograph of Lake Summit depicting monthly surface level readings from 2000 to 2024. A box and whisker plot detail total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Summit is categorized as a clear, alkaline waterbody. Lake Summit has not exhibited any NNC exceedances during the assessment period (Figure 3-271). This equates to an impairment criterion score of 3. Lake Summit has consistently maintained excellent water quality throughout its period of record. It should be noted that the 2024 AGM TP concentration was the highest on record. This spike warrants some closer inspection to determine the cause.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.817	0.000	Decreasing	3	3
TN	N	-0.512	0.018	No Trend		2
TP	N	0.051	0.827	No Trend		1
Secchi	NA	0.721	0.000	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this period, Chl-a and Secchi depth exhibited significant improving trends; earning trend a criteria score of 3 for these parameters. TN exhibited non-significant improving trend and TP a non-significant deteriorating trend; for trend criterion scores of 2 and 1, respectively. The recent shifts in TN and TP trends aren't necessarily concerning; they just indicate that the previously improving water quality is beginning to stabilize.

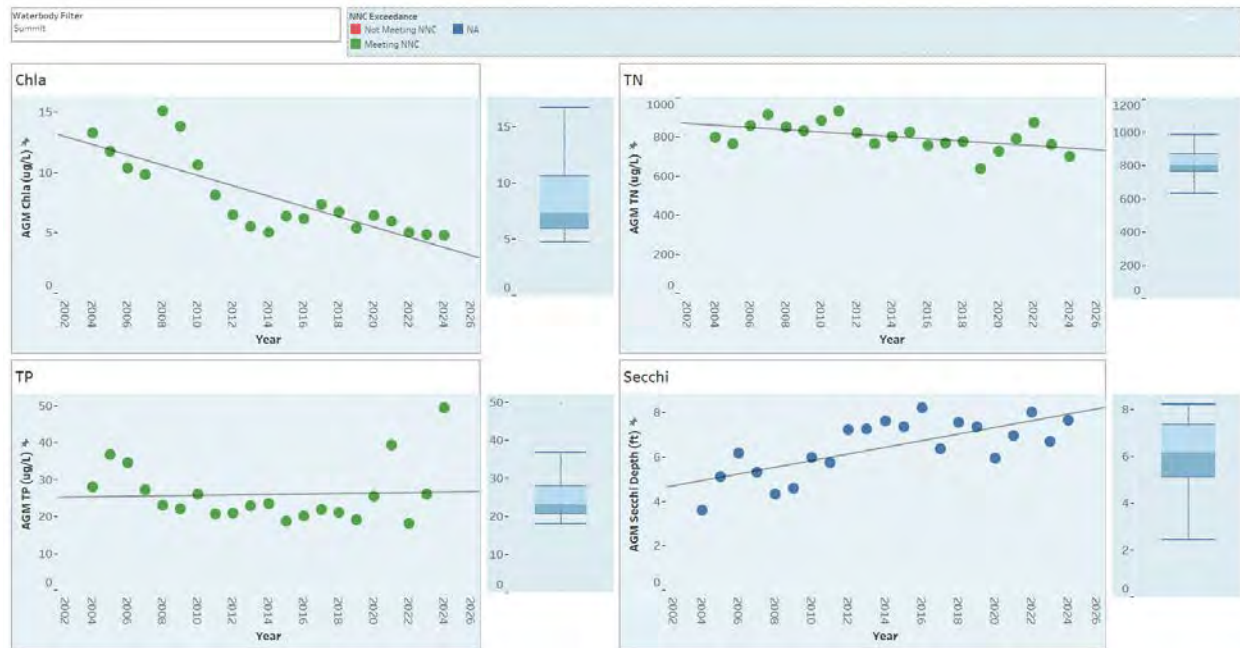


Figure 3-271. Lake Summit AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Summit on 3/7/2024. The PAC during this survey was 55.7% and the total BV was 9.6% (Figure 3-272). A PAC above the 30% threshold equates to a vegetation abundance criterion score of 3. Since 2018, Lake Summit has maintained

consistently high abundance, with coverage between 48% and 63%. The excellent water clarity is likely the main factor for this robust vegetation community and vice versa—creating a positive feedback loop of great water quality and biological abundance.

Invasive Species Management:

Based on the 2024 data, Lake Summit is dominated by submerged aquatic vegetation as evidenced by the top three species, making up over 50% of the community, are SAV varieties (Figure 3-273). Water hyacinth was the only invasive species detected in 2024. At only 1.1% of the community, this earns the lake an invasive species criterion score of 2. Hydrilla has historically been the primary invasive species requiring management in Lake Summit. Therefore, this reduction constitutes a significant improvement in the vegetation community.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2024 species data, only Lake Summit's evenness index met or exceeded its median value (Figure 3-274). This equates to a diversity criterion score of 1. All three diversity indices underwent a decline from the previous year. The total number of unique species decreased from 15 to 12, and the distribution of these species was slightly less equitable in 2024. The invasive management efforts in 2023 and 2024 were the likely causes for these shifts in diversity.

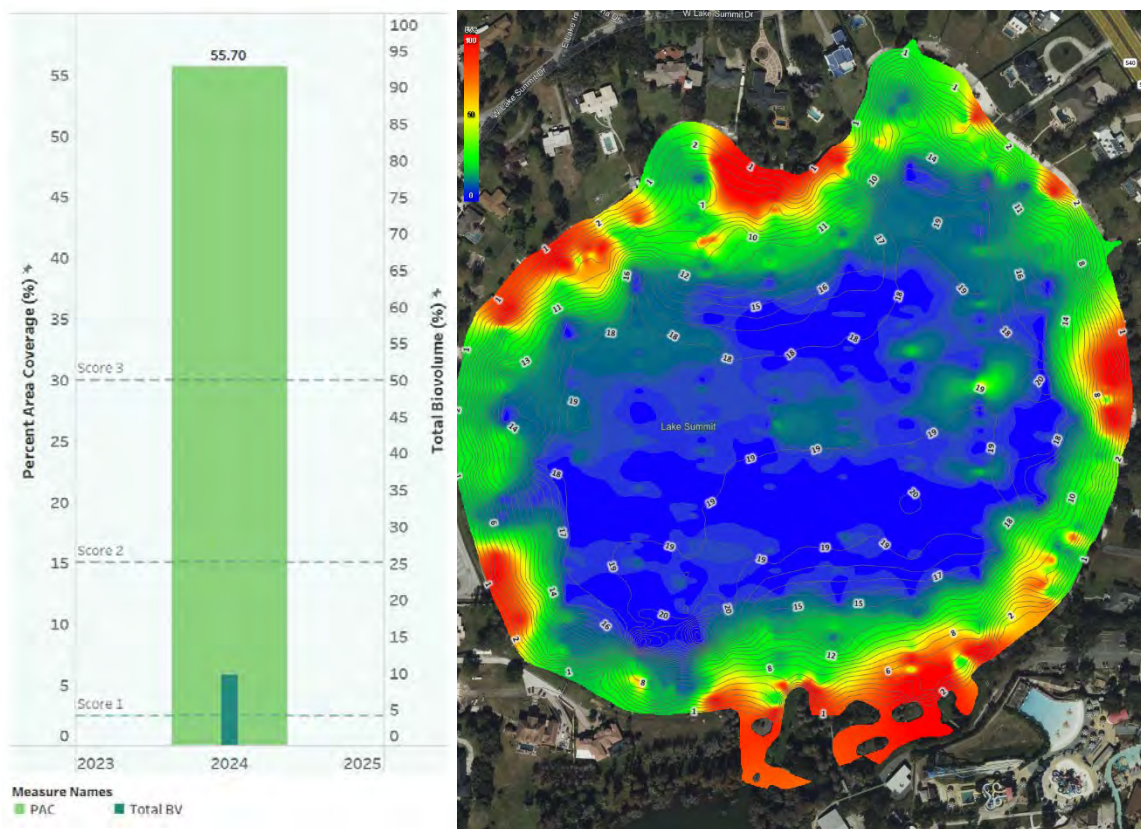


Figure 3-272. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Summit; biovolume values range from green (lowest) to red (highest).

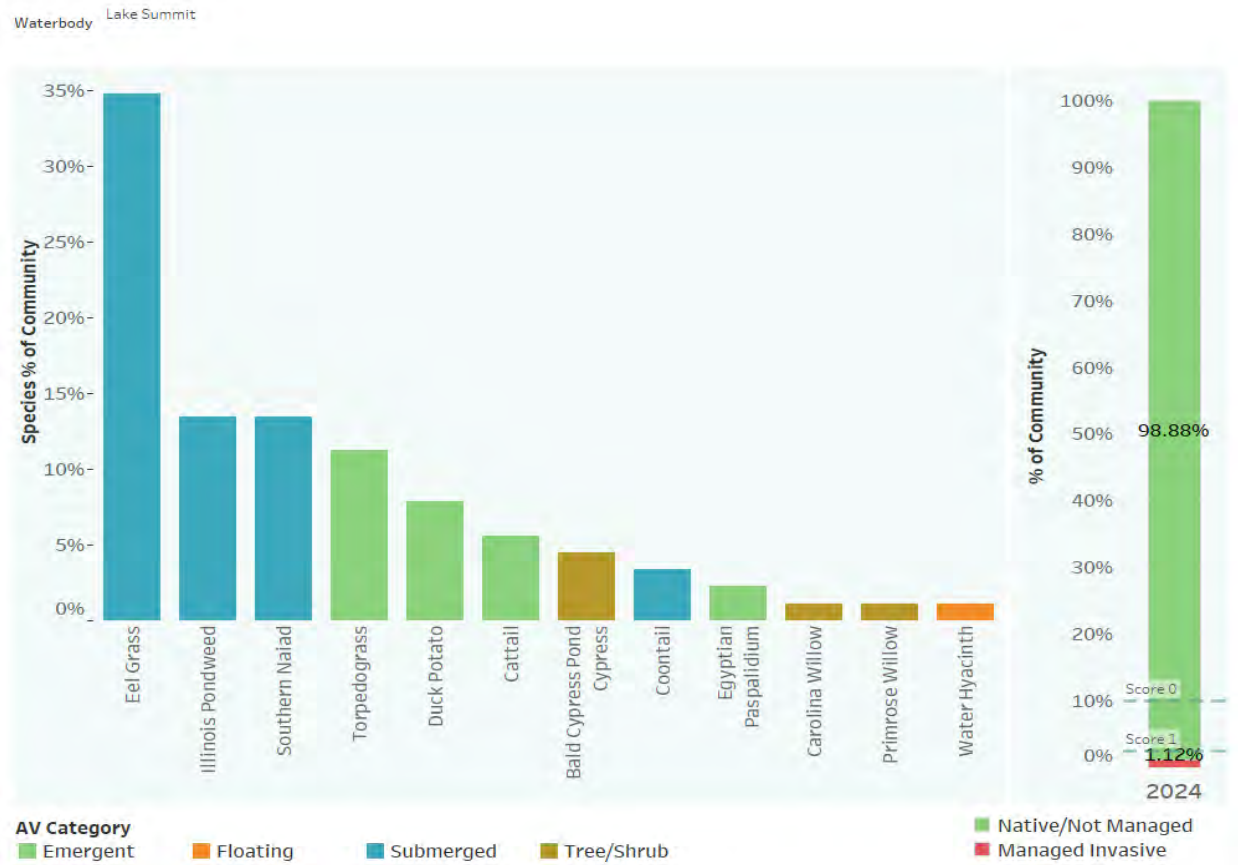


Figure 3-273. Chart depicting species frequency and invasive species percentage of Lake Summit during 2024.



Figure 3-274. Chart depicting 2024 diversity indices for Lake Summit. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Summit's health index scores from 2018 to 2024 shows consistently good values ranging from 2.3 to 2.6 (Figure 3-275). The impairment and vegetation abundance criteria have been consistently good. There have been some recent declining shifts in the trend scores, but the majority of lake health fluctuation has been due to invasive species presence and diversity criterion scores. These criteria likely change in response to natural factors as well as invasive species treatment efforts. Overall, Lake Summit ranks low on the City's management priority list due to its excellent water quality and improving trends.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	3	1	1	2.5
2019	3	3	3	2	3	3	1	2	2.5
2020	3	3	3	2	3	3	1	1	2.4
2021	3	3	3	2	3	3	1	1	2.4
2022	3	3	3	2	3	3	1	3	2.6
2023	3	3	2	2	3	3	1	3	2.5
2024	3	3	2	1	3	3	2	1	2.3

Figure 3-275. Chart depicting a comparison of Lake Summit's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Summit currently exhibits excellent water quality. However, stormwater and septic system pollutant sources remain a potential concern if trends ever begin to deteriorate.
- The management of invasive species like hydrilla is a consistent concern. It can only take a single growing season for even a small population to take over large areas of a waterbody.
- Several of Lake Summit's water quality parameters are correlated with surface level, likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.

Lake Management Strategy:

- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best strategy to prevent large-scale herbicide treatments and potential water quality issues that follow.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.

Lake Winterset

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Lake Winterset	3	3	3	3	3	3	1	2	2.6

Features & Statistics:

Surface area	555.5 acres
Mean depth	14.26 feet
Maximum depth	32 feet
Volume	10,133.6 acre-feet
Drainage basin area	1074.5 acres
Annual TN Load	2258.8 lbs
Annual TP Load	407.59 lbs
Limiting nutrient	Phosphorus

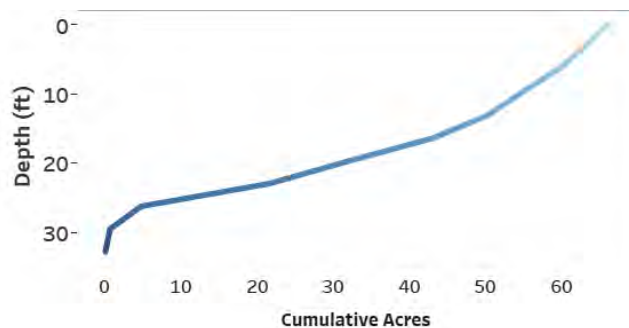


Figure 3-276. Hypsograph of Lake Winterset depicting the depth profile and morphology of the lake bed.

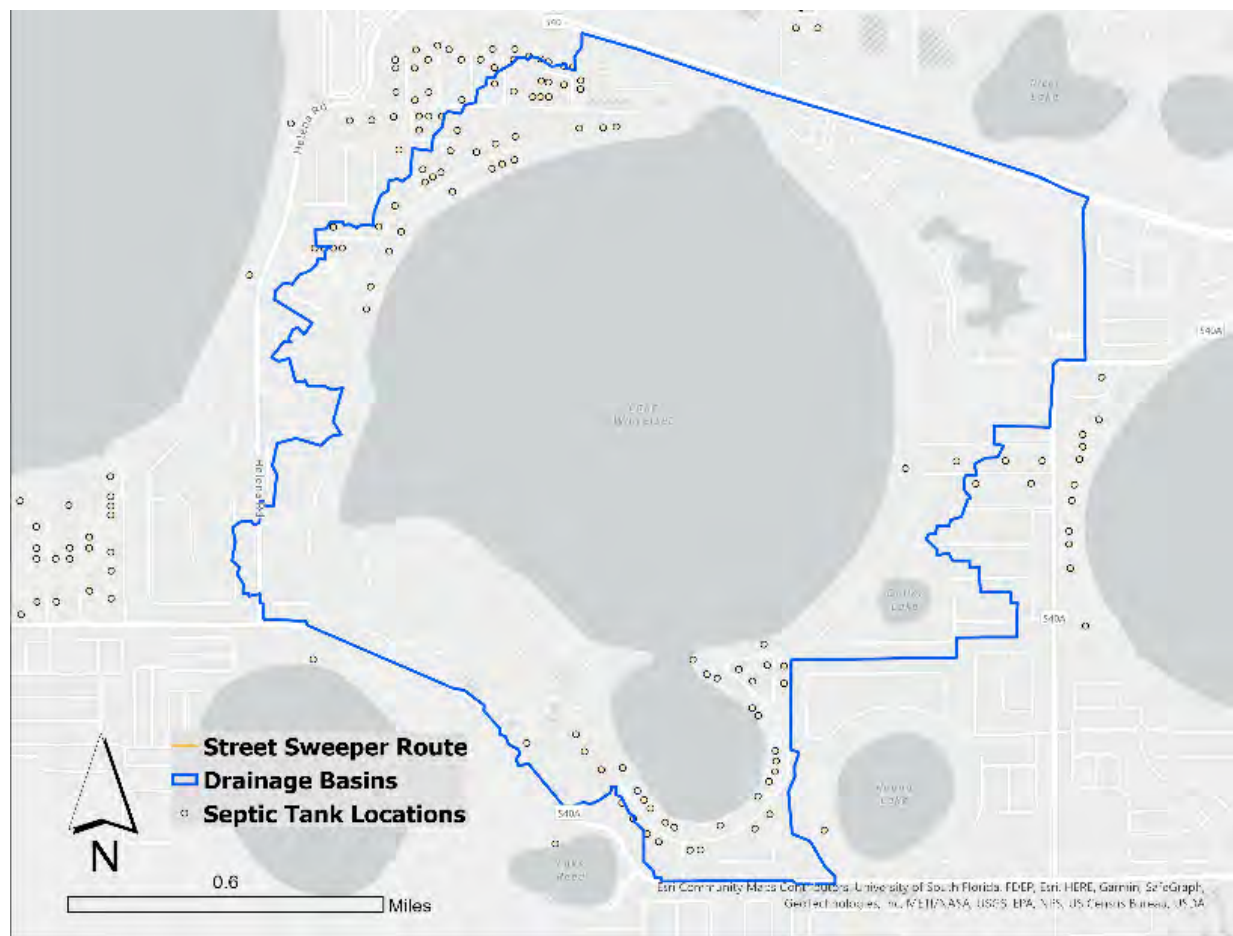


Figure 3-277. Map of Lake Winterset's drainage basin and nearby septic systems.

Hydrology:

Lake Winterset is one of the largest lakes on the South Chain at 555 acres. It is also one of the deepest lakes in the study area, with an average depth of over 14 feet, and a maximum depth of 32 feet (Figure 3-276). Similar to Lake Summit, Winterset has a steeper sloping lake bed which would normally severely limit its littoral zone. However, like Summit, Lake Winterset's water clarity is high enough to allow aquatic vegetation to grow in deeper water. Stormwater is conveyed to this waterbody from a 1,074 acre drainage basin. The primary land uses in this basin are residential, commercial, wetlands, and agricultural. Based on stormwater pollutant load modelling, this drainage area contributes 2,259 lbs of TN and 408 lbs of TP to the lake annually. Since the relative size of the drainage basin is small, the per acre pollutant loading rates are actually some of the lowest in the study area. There are 71 septic systems located within the basin. These constitute a moderate density with pollutant load potential via groundwater leaching. Located mostly outside Winter Haven limits, the City does not conduct any street sweeping services within Lake Winterset's drainage basin.

Lake Winterset is at the very southern end of the South Chain with a navigable connection to Lake Eloise. Due to these canal connections, surface levels fluctuate consistently across the South Chain of Lakes. Throughout the period of record, the South Chain's surface level has fluctuated between 127.5 and 133.7 feet above sea level. The normal range is much narrower—between 129.7 and 131.4 feet (Figure 3-278). That said, wetter and drier periods often result in more extreme peaks and troughs, respectively. During 2024, the South Chain reached a dry season low of 130.8 ft in June and a wet season peak of 131.8 ft in September. The level of the South Chain by the end of the year was slightly above the top of the normal range at 131.5 ft. The South Chain's level remained at or above the high end of the normal range throughout most of the year—consistent with annual level fluctuations over the last 10 years. According to linear

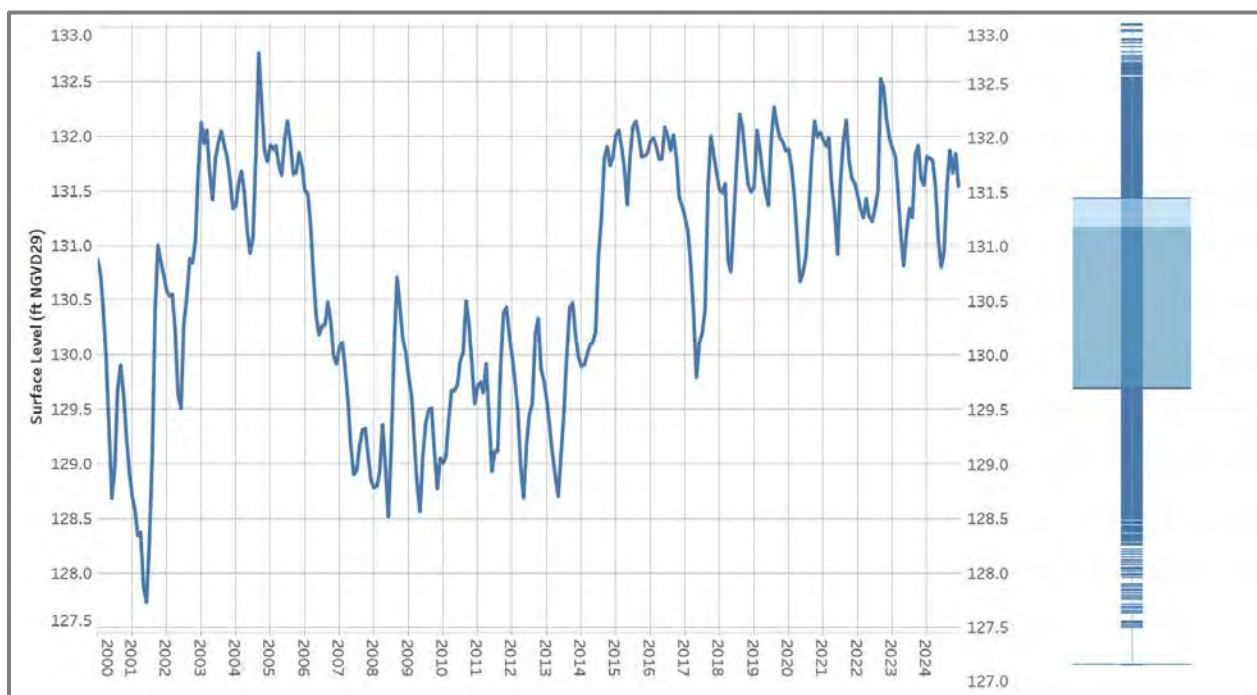


Figure 3-278. Hydrograph of Lake Winterset depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

regression analysis, changes in Lake Winterset's surface level are correlated with TN concentrations—likely due to slight increases in flushing during rainy periods (see appendix).

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Lake Winterset is categorized as a clear, alkaline waterbody. Due to the presence of no NNC exceedances of Chl-a, TN, or TP during the assessment period, Lake Winterset is considered unimpaired (Figure 3-279).

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	N	-0.815	0.000	Decreasing	3	3
TN	N	-0.778	0.000	Decreasing		3
TP	N	-0.686	0.001	Decreasing		3
Secchi	NA	0.767	0.000	Increasing		3

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this period, all four of these parameters exhibited statistically significant improving trends. This equates to trend criteria scores of 3 for each of these. Lake Winterset likely has the best water quality in Winter Haven and will continue to be as long as the trends consistently maintain these improving directions.



Figure 3-279. Lake Winterset AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Lake Winterset on 3/19/2024. The PAC during this survey was 42.3% and the total BV was 4.3% (Figure 3-280). A PAC value over the 30% threshold equates to a vegetation abundance criterion score of 3. Since 2018, Lake Winterset's vegetation coverage percentage has remained high. This robust vegetation community is likely

the result of and a contributor to Winterset's excellent water clarity and improving water quality trends.

Invasive Species Management:

Based on data from the 2024 survey, Lake Winterset is dominated by submerged species. Eelgrass and southern naiad made up over 30% of the vegetation community (Figure 3-281). Invasives like hydrilla and burhead sedge constituted 6.4% of the population. This equates to an invasive percentage score of 1. This invasive percentage was a slight decrease from the previous year and continues a trend of invasive population reduction since 2022. Continued monitoring and management efforts will be required to bring these invasive percentages down below a 2.5% threshold constituting a maintained status.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity. According to the 2024 species data, Lake Winterset's species richness and overall diversity indices exceeded their long-term median values (Figure 3-282). This equates to a diversity criterion score of 2. Both species richness and overall diversity increased in 2024. While the species evenness decreased slightly in 2024, this change was likely due to natural shifts in the vegetation community.

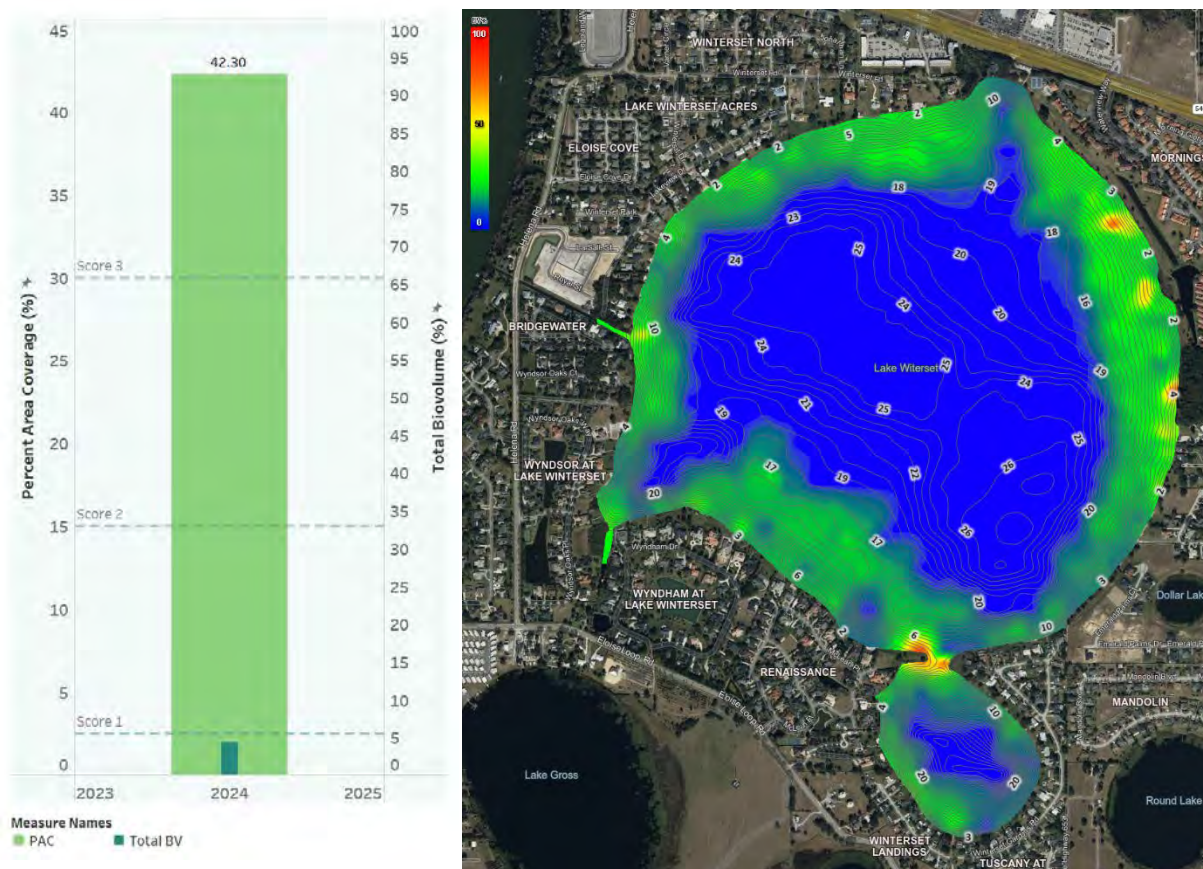


Figure 3-280. Graph depicting 2024 PAC/BV and biovolume heatmap of Lake Winterset; biovolume values range from green (lowest) to red (highest).

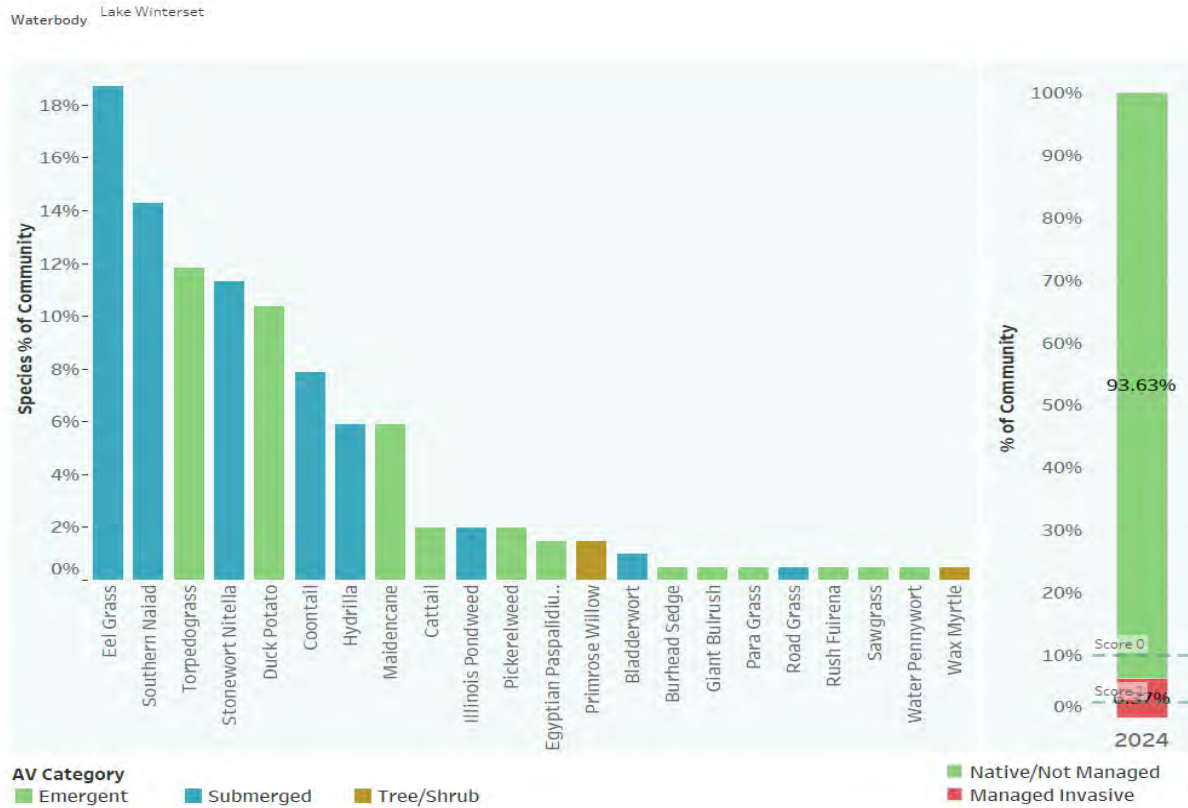


Figure 3-281. Chart depicting species frequency and invasive species presence of Lake Winterset during 2024.

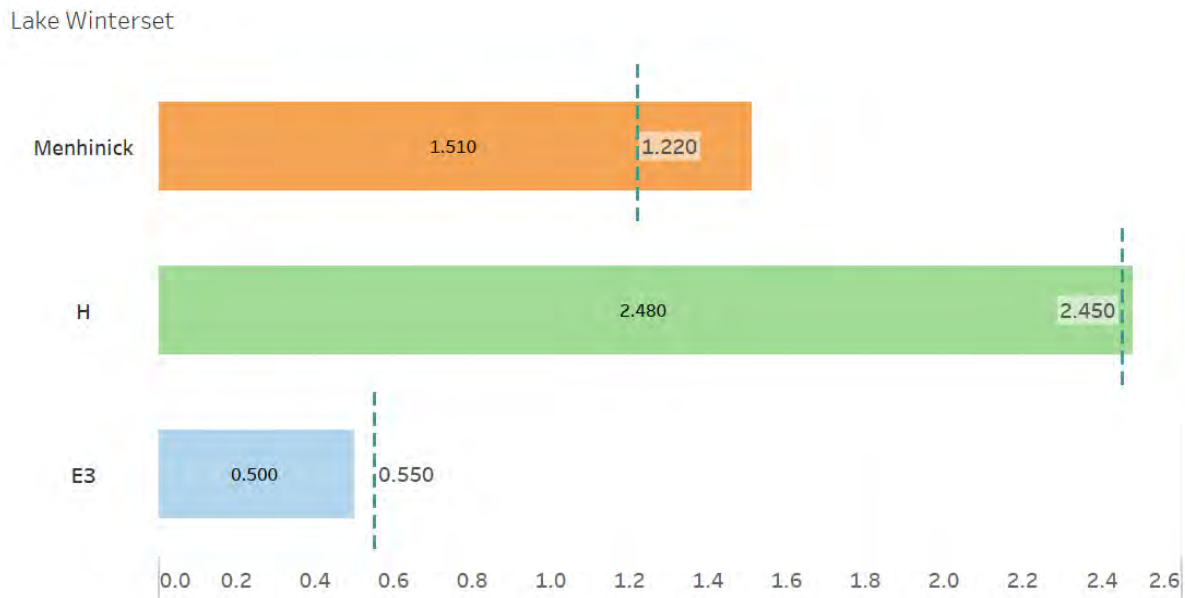


Figure 3-282. Chart depicting 2024 diversity indices for Lake Winterset. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Lake Winterset's health index scores from 2018 to 2024 shows consistently high values ranging from 2.4 to 2.8 (Figure 3-283). The primary changes in score have been the result of invasive species presence and diversity criteria fluctuations. Management efforts to control invasive species, while necessary, likely impact species diversity in some way. Overall, Lake Winterset ranks low on the City's management priority list due to its excellent water quality and improving trends.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	3	3	3	3	3	2	1	1	2.4
2019	3	3	3	3	3	3	1	3	2.8
2020	3	3	3	3	3	3	1	3	2.8
2021	3	3	3	3	3	3	0	3	2.6
2022	3	3	3	3	3	3	0	1	2.4
2023	3	3	3	3	3	3	1	2	2.6
2024	3	3	3	3	3	3	1	2	2.6

Figure 3-283. Chart depicting a comparison of Lake Winterset's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Lake Winterset currently exhibits excellent water quality. However, stormwater and septic system loading are potential concerns if trends ever shift toward deterioration.
- The management of invasive species like hydrilla is a consistent concern. Based on the species data, the hydrilla population appears to be expanding in Lake Winterset. This may prompt the FWC to conduct more impactful treatment efforts in order to control it; which may result in some temporary declines in water quality.

Lake Management Strategy:

- If water quality becomes a future issue, City staff may explore source analysis to determine if septic leachate is a potential contributor of nutrient pollutant loading. Further management may involve septic-to-sewer conversions.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Bringing the hydrilla population down to a managed state should reduce the future need for large scale herbicide treatments and the potential water quality issues that follow.
- With the majority of the drainage basin comprised of residential housing, future management of stormwater may consist of public education and outreach. This aims to increase residents' knowledge of best stormwater practices and ways they can individually reduce their nutrient load.

Little Lake Hamilton

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Little Lake Hamilton	0	2	1	2	1	3	3	1	1.6

Features & Statistics:

Surface area	359.6 acres
Mean depth	8.46 feet
Maximum depth	22 feet
Volume	3095.7 acre-feet
Drainage basin area	1015.9 acres
Annual TN Load	1472.7 lbs
Annual TP Load	198 lbs
Limiting nutrient	Phosphorus

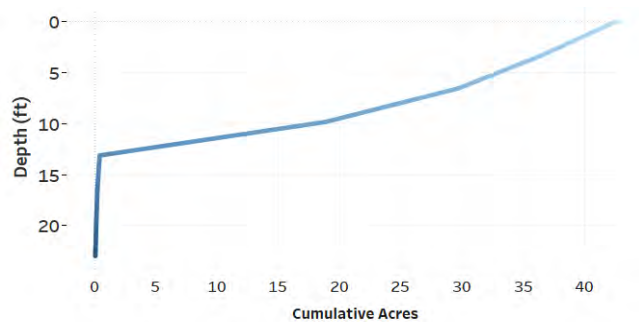


Figure 3-284. Hypsograph of Little Lake Hamilton depicting the depth profile and morphology of the lake bed.

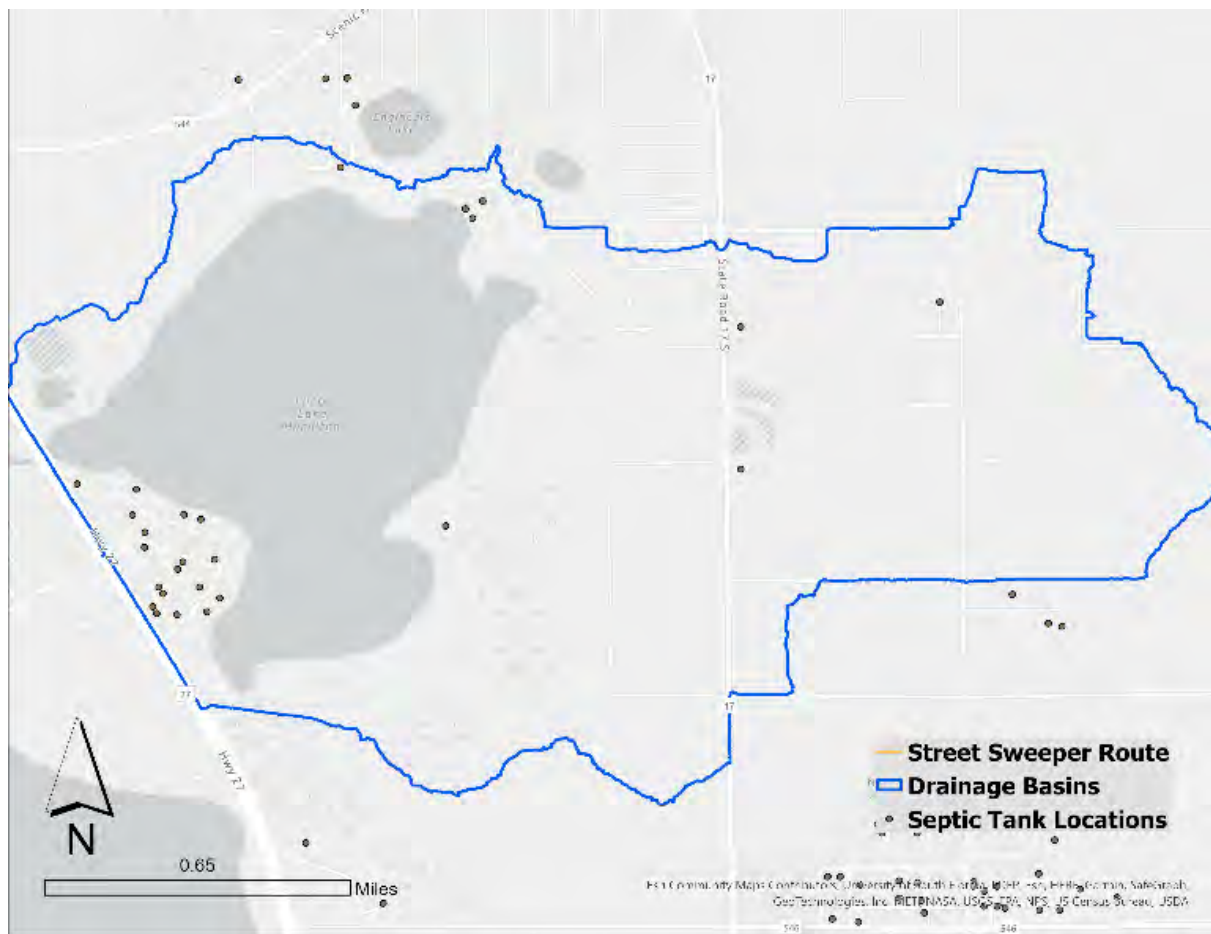


Figure 3-285. Map of Little Lake Hamilton's drainage basin and nearby septic systems.

Hydrology:

A moderately sized waterbody, Little Lake Hamilton has a surface area of 351 acres, an average depth of 8.5 feet, and a maximum depth of over 20 feet in a few deeper areas (Figure 3-284). With an average surface area and depth, Little Hamilton is able to support a moderate littoral zone and aquatic plant community. Stormwater is conveyed to this waterbody from a 1,016 acre drainage basin made up of agricultural, residential, and wetland land uses (Figure 3-285). Based on stormwater pollutant load modelling, this drainage area contributes 1,472 lbs of TN and 198 lbs of TP to the lake annually—some of the lowest pollutant loading rates in the region by area. There are 26 septic systems present in the basin—constituting a low density. Since Little Hamilton is completely outside Winter Haven limits, the City does not conduct any street sweeping services in the basin.

Little Lake Hamilton is part of the North Chain with navigable connections to Lake Hamilton and Middle Lake Hamilton via canals. The North Chain discharges to the Peace Creek via the P-8 water control structure on the south side of Lake Hamilton. The three Hamilton lakes' surface levels all sit at the lowest elevation of all the waterbodies in the study area. Over its period of record, the Hamilton surface level has fluctuated between 117.5 and 123.6 feet above sea level. The normal range of fluctuation is between 119 and 121 feet (Figure 3-286). In 2017, the SWFWMD enacted new water level management protocols with the intent to restore seasonal level fluctuations within the lake's normal range. This is accomplished by releasing water downstream during the rainy season and storing water during the dry season. During 2024, these lakes reached a low of 120.26 feet in July and a wet season peak of 121.86 feet in October. The peak actually marks the highest the lake has reached since the record-breaking rainfall received during the hurricane season of 2004. According to linear regression analysis, changes in Little Hamilton's surface level are strongly correlated with Chl-a, TN, TP, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

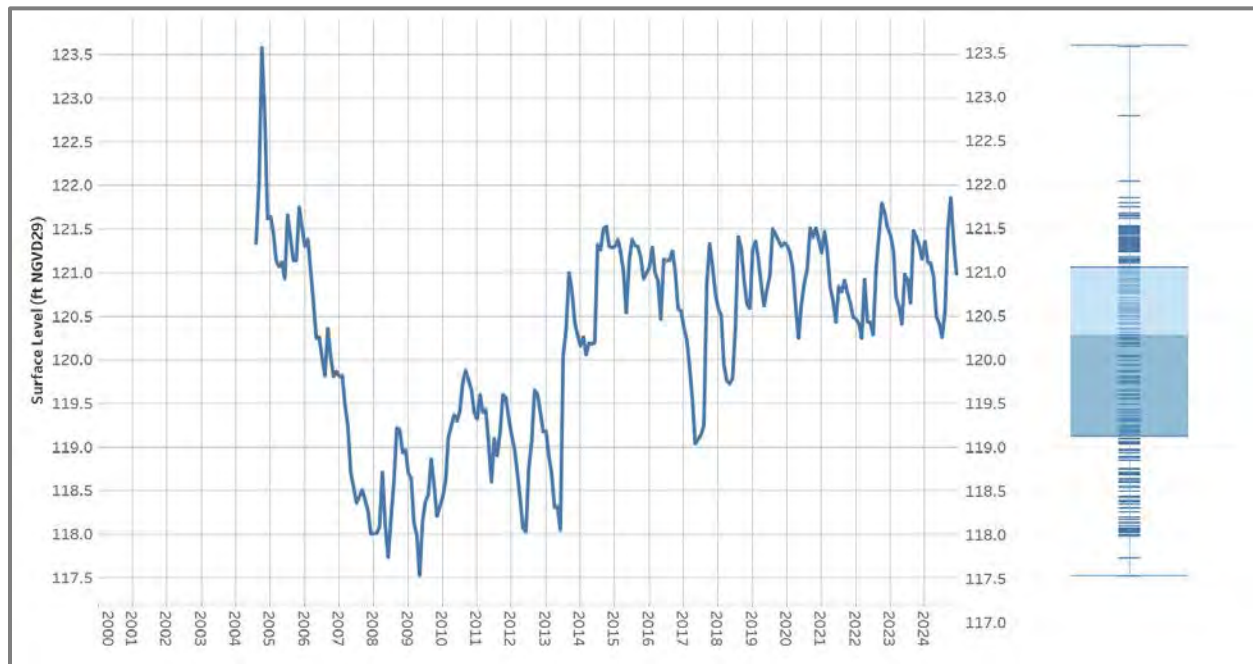


Figure 3-286. Hydrograph of Little Lake Hamilton depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Little Lake Hamilton is categorized as a clear, alkaline waterbody. Since impairment can be determined by more than one exceedance in any three year span during the assessment period, Little Hamilton is considered impaired for Chl-a, TN, and TP based on exceedances in the last two years (Figure 3-287). This equates to an impairment criterion score of 0. In 2021, the FDEP adopted a Polk County proposed pollutant reduction plan for the Lake Hamilton Chain. This plan stipulates that existing or planned pollutant reduction strategies have been accepted in lieu of a total maximum daily load.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	-0.058	0.808	No Trend	0	2
TN	Y	0.112	0.640	No Trend		1
TP	Y	-0.410	0.072	No Trend		2
Secchi	NA	-0.333	0.151	No Trend		1

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this period, Chl-a and TP depth exhibited non-significant improving trends while TN and Secchi depth exhibited non-significant deteriorating trends; equating to trend criterion scores of 2 and 1, respectively. The trend direction for Chl-a actually shifted from deteriorating to improving from 2023 to 2024—a positive change. That said, with the water quality being impaired, the ideal situation would be to have all significant improving trends to reverse these impairments.

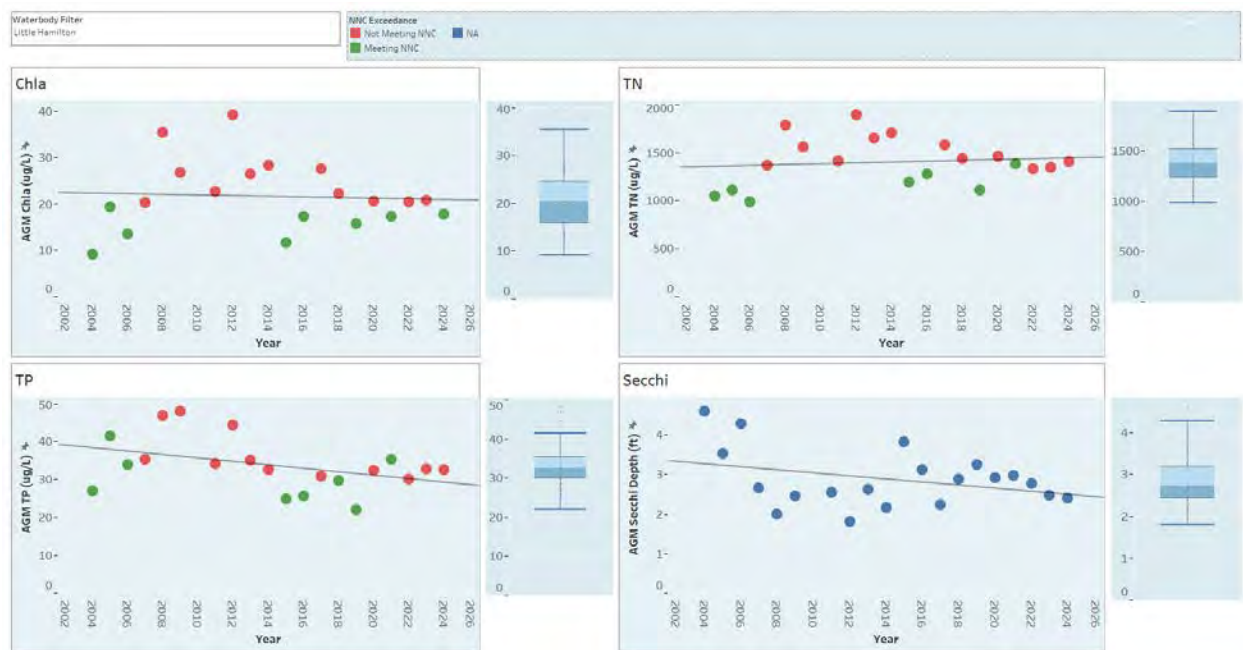


Figure 3-287. Little Lake Hamilton AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Little Lake Hamilton on 10/13/2024. The PAC during this survey was 35% and the total BV was 4%; a significant increase in abundance from the previous year (Figure 3-288). A PAC above 30% equates to an abundance criterion score of 3. Since 2018, Little Hamilton has exhibited moderate vegetation abundance with values less than 20%. However, the increase in 2024 demonstrates some improvement in the vegetation community.

Invasive Species Management:

Based on the 2024 survey data, Little Lake Hamilton is dominated by emergent and floating-leaf plants. Cattail, spatterdock, and fragrant water lily made up nearly 50% of the community (Figure 3-289). Fortunately, there were no managed invasive species detected during the last three annual surveys. This absence equates to an invasive criterion score of 3. In previous years, hydrilla, burhead sedge, and elodea were invasives to be managed. This continued lack of invasive plants indicates successful management of exotics and a relatively healthy aquatic plant community.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to the 2024 species data, only Little Hamilton's evenness index met or exceeded its long-term median value (Figure 3-290). This equates to a diversity criterion score of 1. The total number of unique species dropped from 20 to 16 in the last year. This negatively impacted the species richness and overall diversity indices. Due to the lack of invasive species presence, it is likely that this shift in the vegetation community was due to natural fluctuations

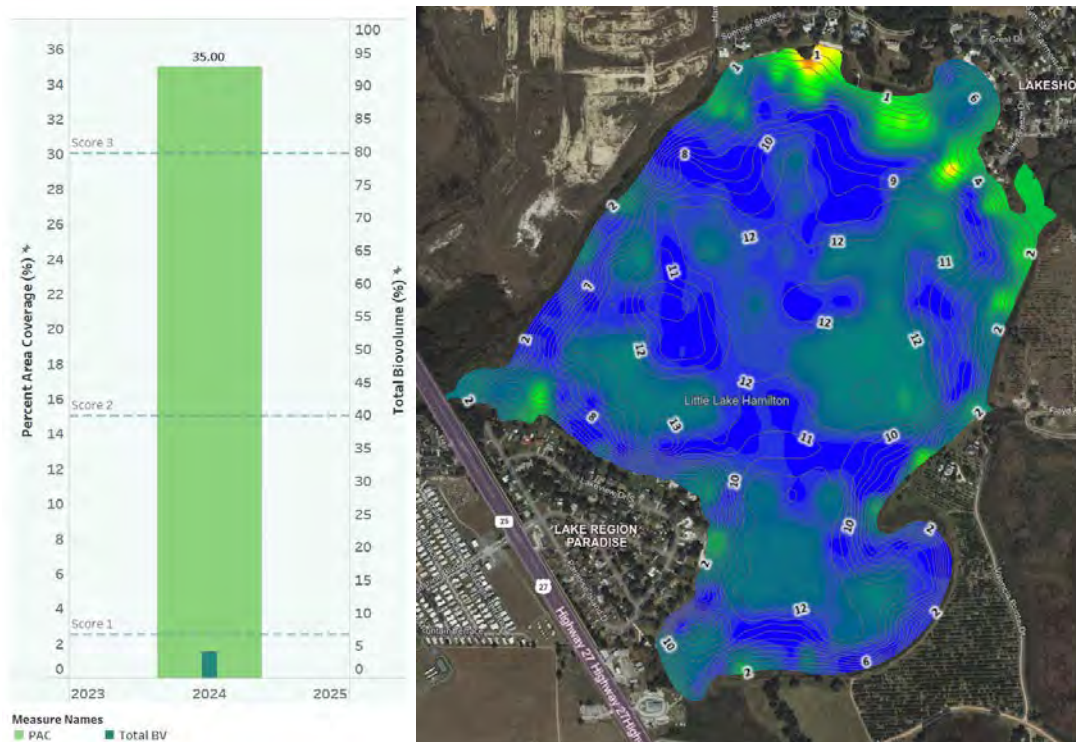


Figure 3-288. Graph depicting 2024 PAC/BV and biovolume heatmap of Little Lake Hamilton; biovolume values range from green (lowest) to red (highest).

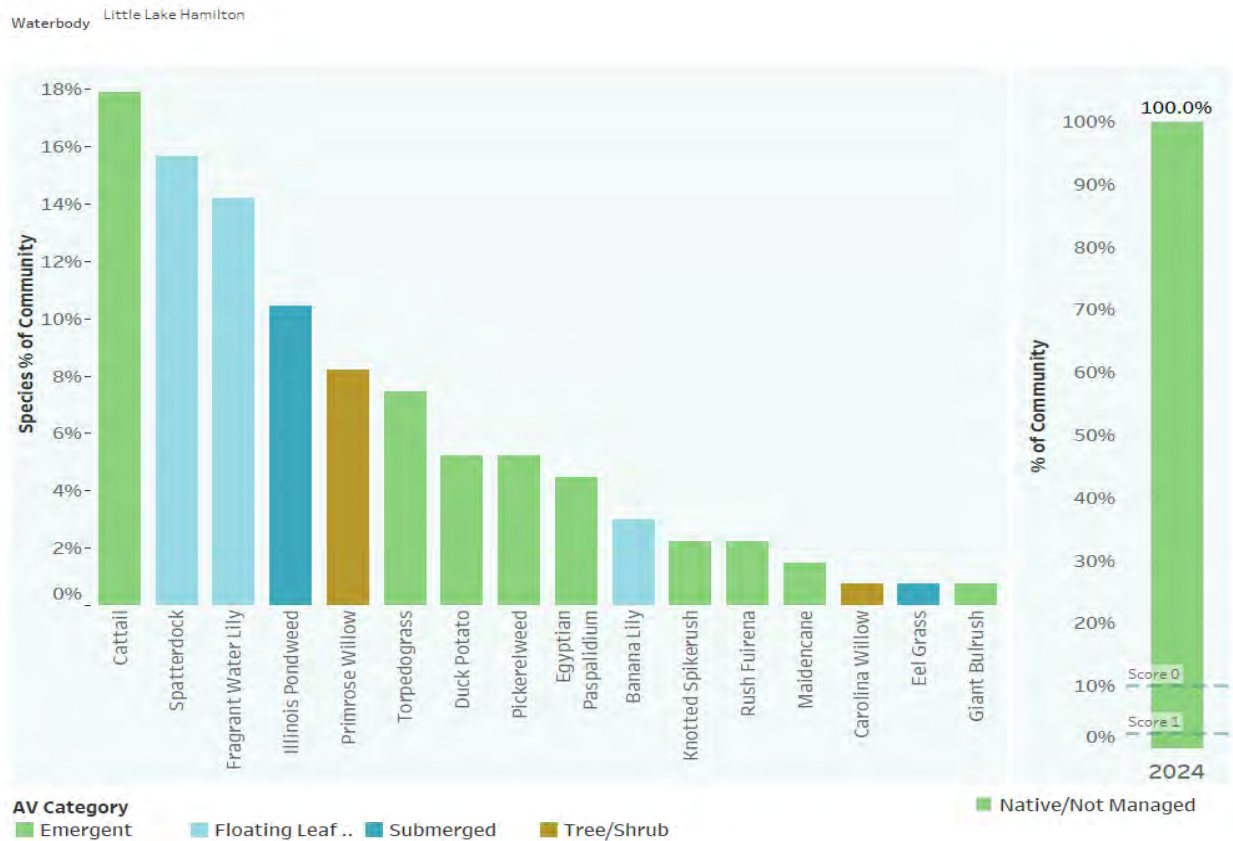


Figure 3-289. Chart depicting species frequency and invasive species percentage of Little Lake Hamilton during 2024.

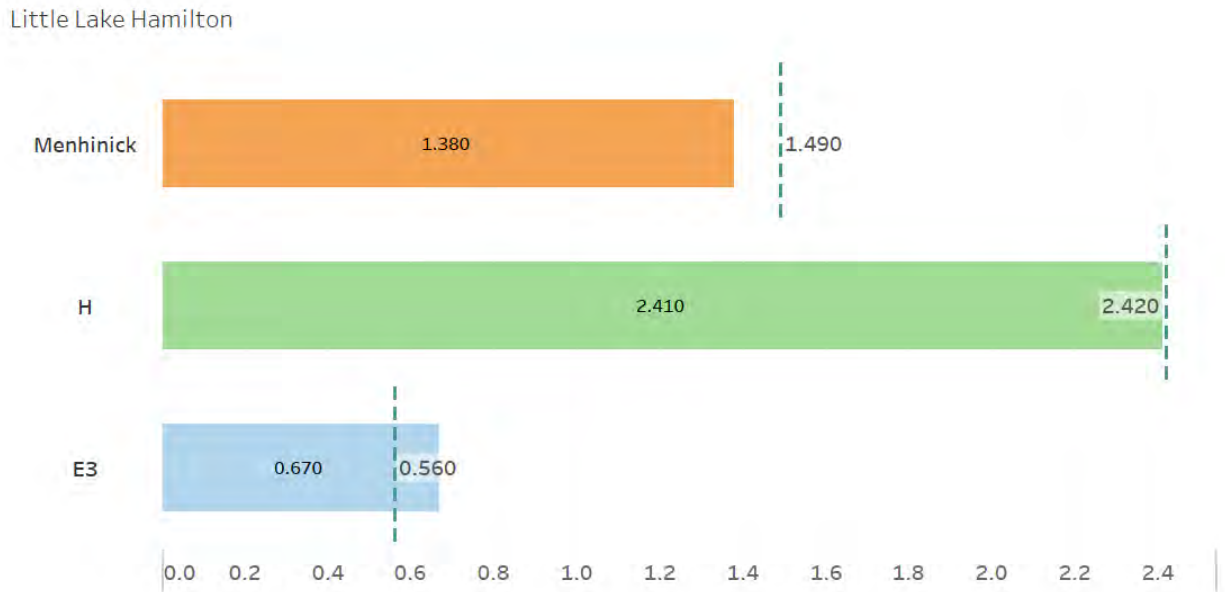


Figure 3-290. Chart depicting 2024 diversity indices for Little Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Little Lake Hamilton's health index scores from 2018 to 2024 shows slight improvement—with values ranging from 1.3 to 1.6 (Figure 3-291). During this time frame, there has been very little change in the water quality criteria scores. Vegetation abundance increased in 2024, while invasive species presence has been effectively null since 2022. Species diversity has presented the greatest fluctuation in scores over the course of monitoring. Overall Little Lake Hamilton ranks high on the priority list due to its water quality impairments and little indication that water quality will begin to trend upwards.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	1	2	1	2	2	1	1.3
2019	0	1	1	2	1	2	3	0	1.3
2020	0	1	1	2	1	2	2	3	1.5
2021	1	1	1	2	1	1	1	3	1.4
2022	0	1	1	2	1	2	3	3	1.6
2023	0	1	1	2	1	2	3	2	1.5
2024	0	2	1	2	1	3	3	1	1.6

Figure 3-291. Chart depicting a comparison of Little Lake Hamilton's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Stormwater and septic system pollutant loading remain the primary factors likely impacting water quality. Since Little Lake Hamilton's drainage basin falls outside of Winter Haven's jurisdiction, the City is limited in its capacity to manage these potential pollution sources.
- Several of Little Lake Hamilton's water quality parameters are correlated with surface level; likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species is a consistent concern. While invasive species were not detected in the last three years, it can take a single growing season for a previously undetected population to take over large areas of a waterbody.

Lake Management Strategy:

- The City plans to provide support to Polk County and other municipalities in the vicinity of Little Lake Hamilton as water quality management plans are developed and implemented.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.

Middle Lake Hamilton

Lake Health Index									
Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
Middle Lake Hamilton	0	1	2	3	3	3	0	3	1.9

Features & Statistics:

Surface area	102.6 acres
Mean depth	5.01 feet
Maximum depth	7 feet
Volume	425.7 acre-feet
Drainage basin area	1539.9 acres
Annual TN Load	11,621.3 lbs
Annual TP Load	1072 lbs
Limiting nutrient	Co-limited (N & P)

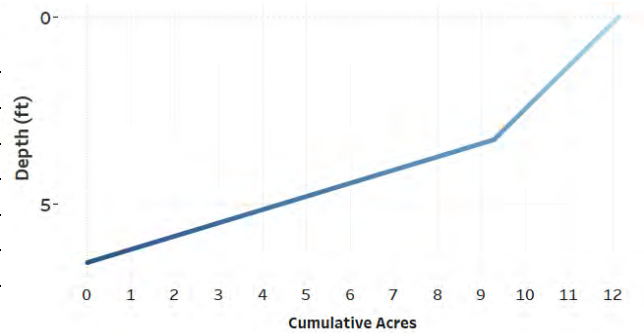


Figure 3-292. Hypsograph of Middle Lake Hamilton depicting the depth profile and morphology of the lake bed.

Hydrology:

Middle Lake Hamilton is the smallest lake part of the North Chain at just 103 acres. It also is one of the shallowest lakes in the study area with an average depth of 5 feet and a maximum depth of just 7 feet (Figure 3-292). This shallow depth makes the lake susceptible to sediment suspension via wind and wave action, and the high level of tannins in the water prevent much submerged vegetation from growing. Stormwater is conveyed to this waterbody from a comparatively enormous 1540 acre drainage basin that extends far to the north (Figure 3-293). The basin is comprised of residential, commercial, agricultural, and wetland land uses which contribute 11,621 lbs of TN and 1,072 lbs of TP to the lake annually. Despite these massive pollutant loads, on a per acre basis, these only rank 8th highest out of the 37 lakes in the area. There are a little over 30 septic systems in the basin. However, the majority of these are very far from the actual waterbody and don't

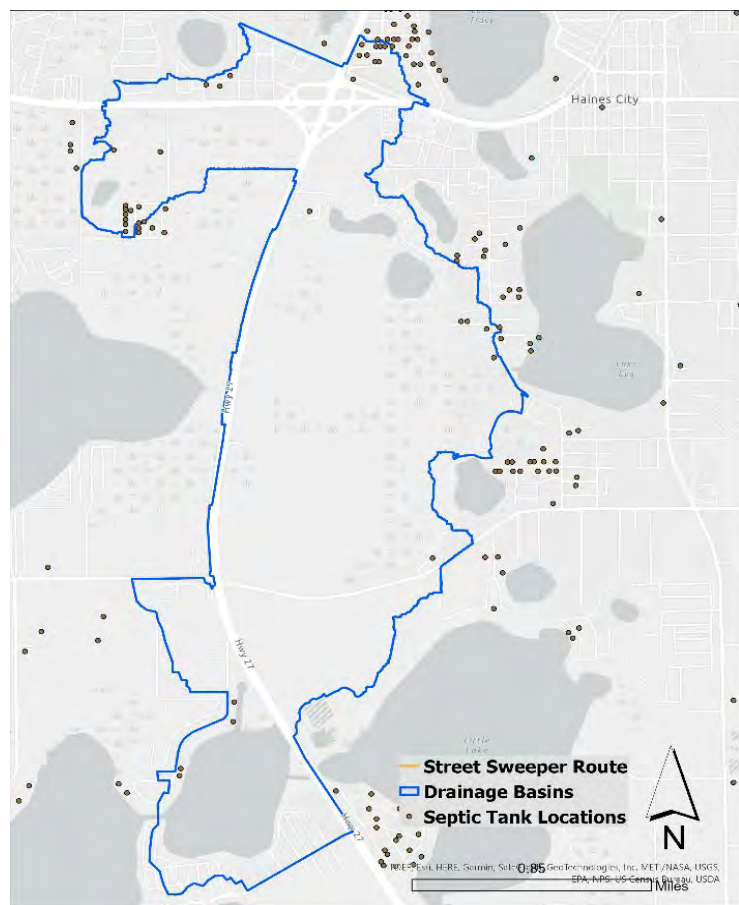


Figure 3-293. Map of Middle Lake Hamilton's drainage basin and nearby septic systems.

constitute a high enough density to be a major pollutant concern. With the majority of the basin outside of Winter Haven limits, the City does not conduct any street sweeping services in the vicinity.

Middle Lake Hamilton is part of the North Chain with navigable connections to Lake Hamilton and Little Lake Hamilton via canals. The North Chain discharges to the Peace Creek via the P-8 water control structure on the south side of Lake Hamilton. The three Hamilton lakes' surface levels all sit at the lowest elevation of all the waterbodies in the study area. Over its period of record, the Hamilton surface level has fluctuated between 117.5 and 123.6 feet above sea level. The normal range of fluctuation is between 119 and 121 feet (Figure 3-294). In 2017, the SWFWMD enacted new water level management protocols with the intent to restore seasonal level fluctuations within the lake's normal range. This is accomplished by releasing water downstream during the rainy season and storing water during the dry season. During 2024, these lakes reached a low of 120.26 feet in July and a wet season peak of 121.86 feet in October. The peak actually marks the highest the lake has reached since the record-breaking rainfall received during the hurricane season of 2004. According to linear regression analysis, changes in Middle Hamilton's surface level are strongly correlated with Chl-a, TN, TP, and water clarity (see appendix). This carries management implications as maintaining higher levels should result in water quality improvements.

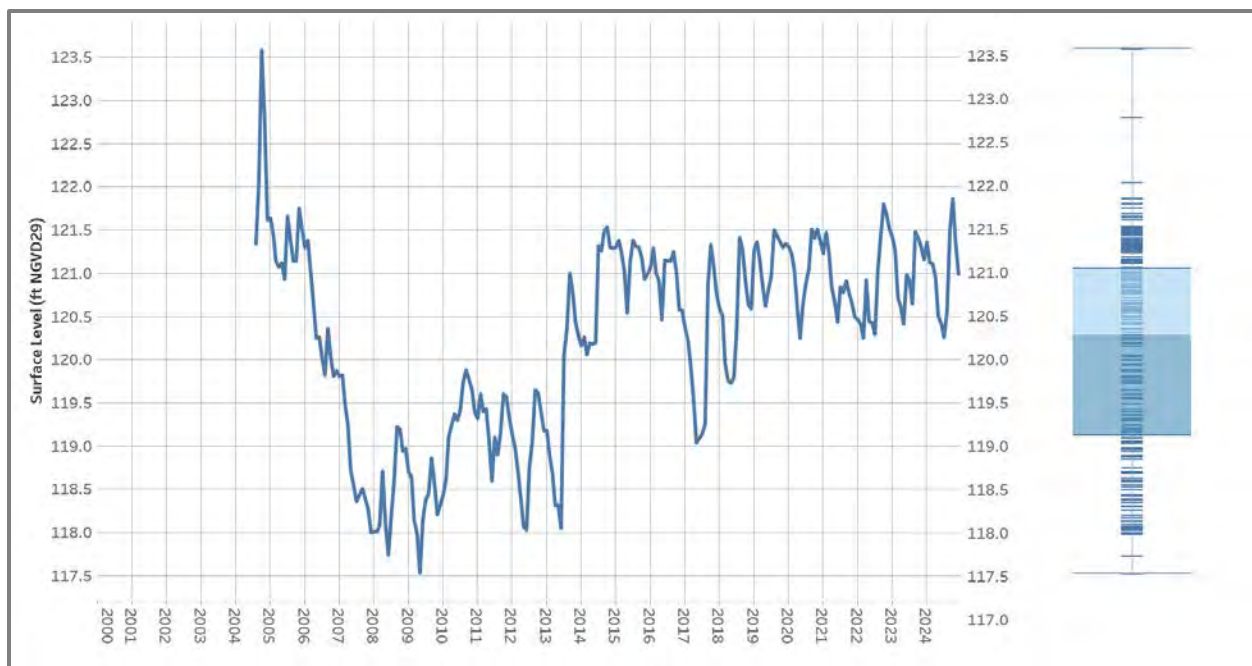


Figure 3-294. Hydrograph of Middle Lake Hamilton depicting monthly surface level readings from 2000 to 2024. A box and whisker plot details total range, median, and normal range of surface level during the period of record.

Water Quality Impairment:

To determine water quality impairment based on the Numeric Nutrient Criteria (NNC), Middle Lake Hamilton is categorized as a clear, alkaline waterbody. Due to numerous NNC exceedances during the assessment period, Middle Hamilton is considered impaired for Chl-a, TN, and TP (Figure 3-295). Like Lakes Hamilton and Little Hamilton, the FDEP has adopted a Polk County-developed pollutant reduction plan in lieu of a total maximum daily load. It should be noted that the 2024 AGM Chl-a concentration actually met the NNC threshold—indicating marginal improvement in water quality.

Water Quality Trends:

Long-term trend evaluation was conducted using linear regression analysis of AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. During this period, TP and Secchi depth exhibited significant improving trends; for trend criteria score of 3. TN exhibited a non-significant improving trend and Chl-a exhibited a non-significant deteriorating trend; for trend criterion scores of 2 and 1, respectively. Despite its impairments, these water quality trends indicate marginal improvement in water quality over the last 20 years.

Parameter	Impaired	R Coefficient	p-value	Trend	Impairment Score	Trend Score
Chla	Y	0.350	0.120	No Trend	0	1
TN	Y	-0.363	0.106	No Trend		2
TP	Y	-0.536	0.012	Decreasing		3
Secchi	NA	0.455	0.038	Increasing		3

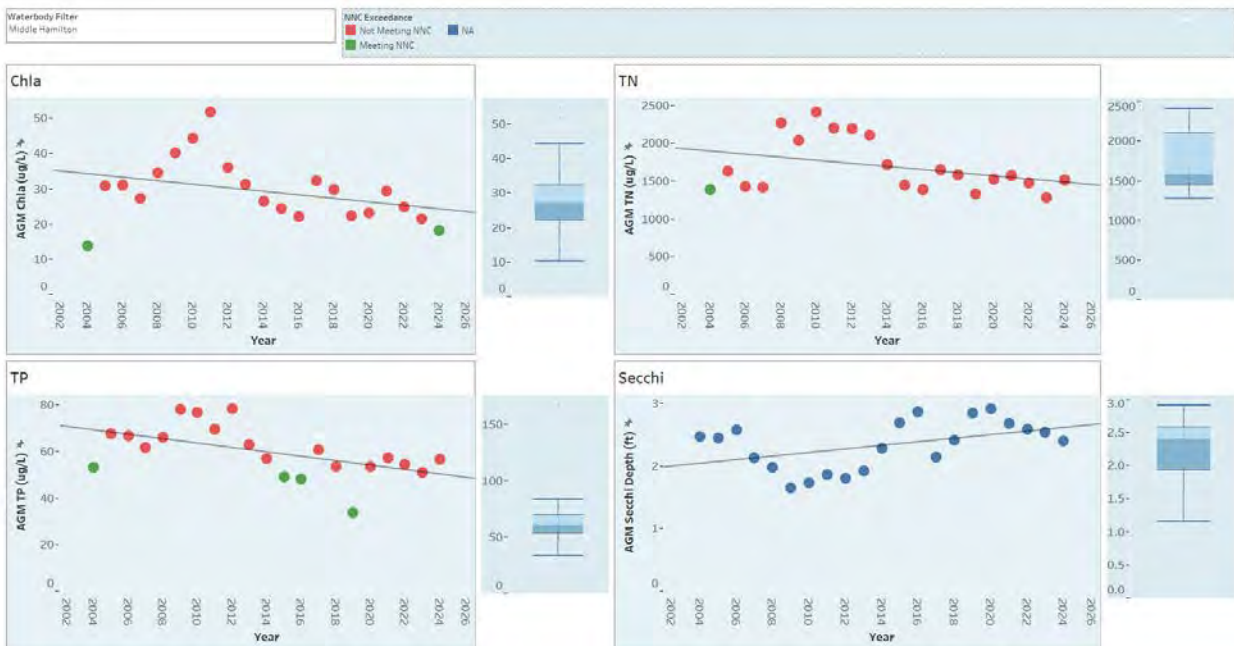


Figure 3-295. Middle Lake Hamilton AGM Chl-a, TN, TP, and Secchi depth values from 2004 to 2024. Data points colored in red depict NNC exceedances. Also detailed are trend lines and box & whisker plots that show relative variance.

Aquatic Vegetation Abundance:

An aquatic vegetation survey was conducted for Middle Lake Hamilton on 6/7/2024. The PAC during this survey was 52.9% and the total BV was 7% (Figure 3-296). A PAC above 30% equates to an abundance criterion score of 3. Middle Hamilton's vegetation abundance has previously been low. Values have ranged from 8.6% in 2021 to above 50% the last two years. These record highs are indicative of an expanding vegetation community—most likely due to invasive species.

Invasive Species Management:

Based on data from the 2024 survey, Middle Hamilton's vegetation community has shifted considerably in the last year (Figure 3-297). The most dominant plant present was the floating-leaf spatterdock at just under 20%. This was followed by a mix of emergent, submerged, and

floating plants. Invasive species like hydrilla, water hyacinth, and burhead sedge made up 22% of the community. While a slight decrease from the previous year, this equates to an invasive criterion score of 0. Considering that hydrilla and hyacinth were the first and third most dominant species in 2023, the invasive control efforts were successful at reducing their relative proportions. However, Middle Hamilton is far from being in a controlled state. Additional treatments will be required in the future.

Species Diversity:

This evaluation examines three diversity indices: species richness (Menhinick), species evenness (E3), and overall diversity (H). According to 2024 species data, all three of Middle Hamilton's diversity indices exceeded their respective median values, earning a diversity criterion score of 3 (Figure 3-298). The actual number of unique species didn't change from the previous year, but the relative proportions of each were much more evenly distributed; increasing not just the evenness index, but the richness and overall diversity indices as well. Species diversity does not discriminate between natives and invasives, so these increases aren't necessarily a good outcome for the ecological health of the lake.

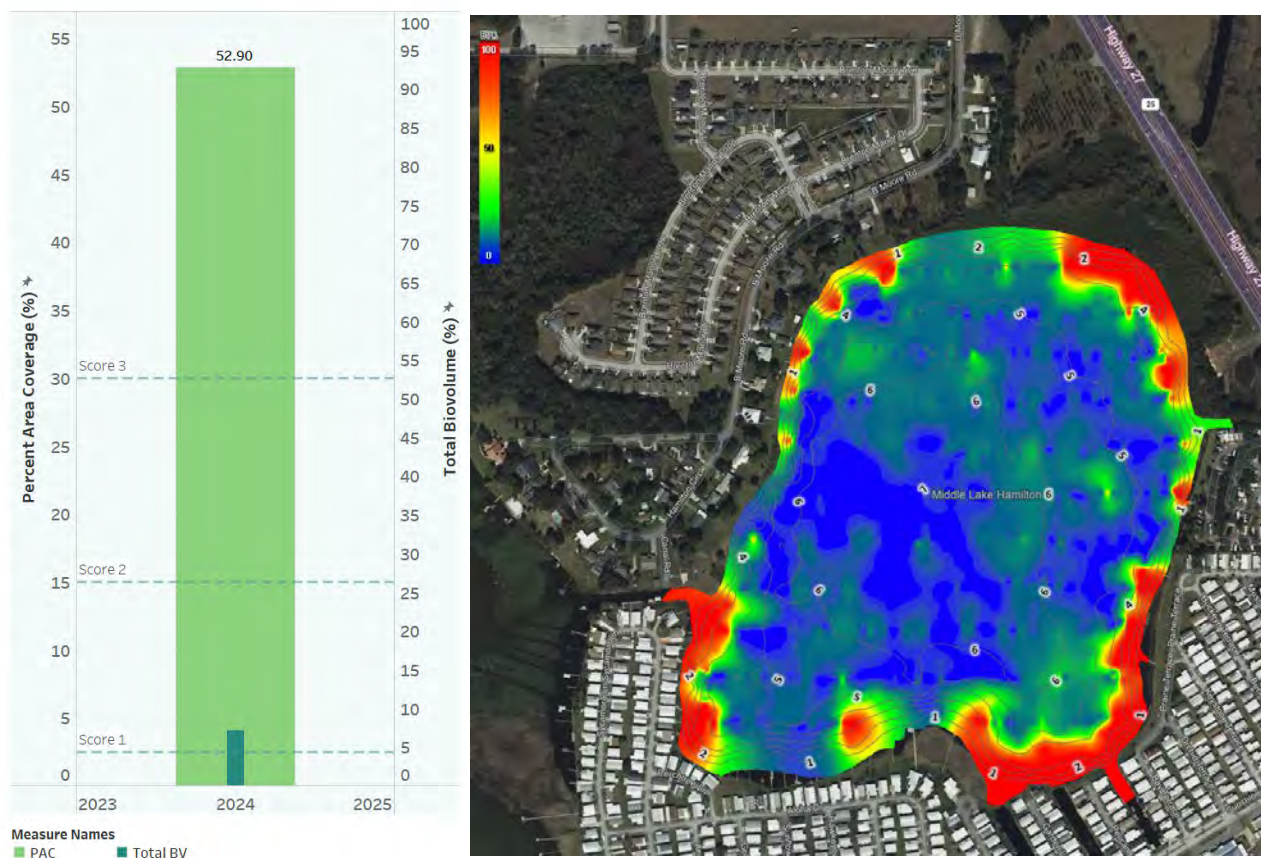


Figure 3-296. Graph depicting 2024 PAC/BV and biovolume heatmap of Middle Lake Hamilton; biovolume values range from green (lowest) to red (highest).

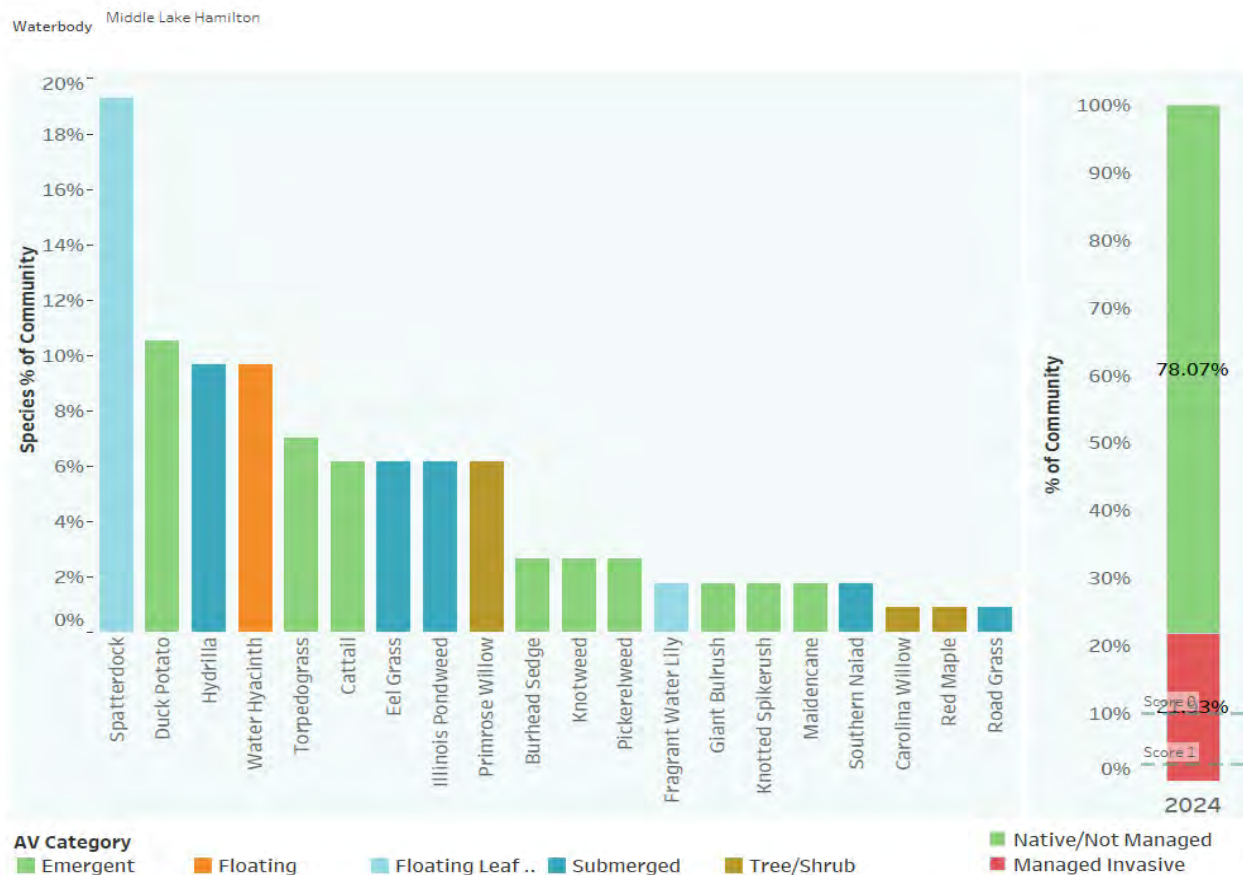


Figure 3-297. Chart depicting species frequency and invasive species percentage of Middle Lake Hamilton during 2024.



Figure 3-298. Chart depicting 2022 diversity indices for Middle Lake Hamilton. Dashed lines represent median values.

Lake Health Tracking:

A comparison of Middle Lake Hamilton's health index scores shows gradual improvement from values of 1.3 in 2018 to 1.9 in the last three years (Figure 3-299). While impairment has not changed during this span, the water clarity trend score has increased to a significant improving trend. Aquatic vegetation abundance has improved, but at the cost of the increase in invasive species. Surprisingly, the species diversity criterion has remained high since 2021. Overall, Middle Lake Hamilton ranks moderately high due to its water quality impairments coupled with invasive management issues.

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health
2018	0	1	2	3	2	1	1	0	1.3
2019	0	1	2	3	2	2	1	1	1.5
2020	0	1	2	3	2	1	3	2	1.8
2021	0	1	2	3	3	1	1	3	1.8
2022	0	1	2	3	3	2	1	3	1.9
2023	0	1	2	3	3	3	0	3	1.9
2024	0	1	2	3	3	3	0	3	1.9

Figure 3-299. Chart depicting a comparison of Middle Lake Hamilton's Lake Health Index scores from 2018 to 2024.

Lake Health Impacts/Challenges:

- Stormwater pollutant loading remains the primary factor likely impacting water quality. Since the majority of Middle Hamilton's drainage basin falls outside of Winter Haven's jurisdiction, the City is limited in its capacity to manage these potential pollution sources.
- Several of Little Lake Hamilton's water quality parameters are correlated with surface level, likely due to increased flushing during wetter periods. This means that drought conditions could result in water quality declines.
- The management of invasive species is a consistent concern. The current infestation almost certainly requires large-scale treatment which can have negative impacts on water quality and species diversity.

Lake Management Strategy:

- The City will provide support to Polk County as water quality management plans are developed and implemented.
- Due to the surface level correlations with water quality, One Water projects that focus on surface water storage and aquifer recharge can help to mitigate declines in surface level during drier periods.
- City staff will continue to monitor aquatic vegetation and share that information with Polk County and the FWC. Early detection and rapid response to invasive species is the best management strategy to prevent large-scale herbicide treatments and the potential water quality issues that follow.

Lake Management Summary

Using the Lake Health Index scores as a ranking system, the City is able to objectively prioritize management efforts for the study area lakes according to where the need is greatest. The following table displays the current priority ranking based on the 2024 Lake Health Index scores (Table 3-1).

Waterbody	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
Lake Idyl	0	0	0	0	0	3	0	2	0.6
Lake Hamilton	0	0	0	3	0	2	1	3	1.1
Lake Martha	3	0	1	1	0	1	3	0	1.1
Lake Elbert	3	0	0	1	0	2	3	1	1.3
Lake Jessie	0	2	1	2	1	3	0	1	1.3
Lake Mariana	0	1	1	3	0	2	3	0	1.3
Lake Ned	3	0	0	1	0	3	2	1	1.3
Lake Mariam	3	0	2	1	1	3	1	1	1.5
Lake Hartridge	1	0	0	3	0	3	3	3	1.6
Little Lake Hamilton	0	2	1	2	1	3	3	1	1.6
Lake Eloise	0	3	2	3	2	2	2	1	1.9
Lake Haines	0	3	3	1	2	1	3	2	1.9
Lake Link	3	1	2	1	2	2	3	1	1.9
Lake Pansy	3	1	2	1	1	2	3	2	1.9
Lake Smart	0	2	2	2	2	3	1	3	1.9
Middle Lake Hamilton	0	1	2	3	3	3	0	3	1.9
Lake Blue	0	2	2	3	1	3	3	2	2.0
Lake Cannon	2	2	2	2	2	3	1	2	2.0
Lake Silver	3	2	2	3	1	2	3	1	2.1
Lake Buckeye	3	2	2	2	2	3	1	3	2.3
Lake Fannie	3	3	3	2	2	2	0	3	2.3
Lake May	0	3	3	3	3	3	1	2	2.3
Lake Otis	3	2	2	1	1	3	3	3	2.3
Lake Shipp	0	3	3	3	3	3	1	2	2.3
Lake Spring	3	3	2	2	2	3	0	3	2.3
Lake Summit	3	3	2	1	3	3	2	1	2.3
Lake Howard	1	3	3	3	2	2	2	3	2.4
Lake Lulu	0	3	3	3	3	3	1	3	2.4
Lake Conine	3	3	3	2	3	2	1	3	2.5
Lake Deer	3	3	3	3	3	3	1	1	2.5
Lake Idylwild	2	3	2	3	3	3	1	3	2.5
Lake Rochelle	3	3	3	2	3	3	1	2	2.5
Lake Roy	3	3	2	3	2	3	3	1	2.5
Lake Maude	3	3	3	2	2	3	2	3	2.6
Lake Mirror	3	3	3	2	2	3	2	3	2.6
Lake Winterset	3	3	3	3	3	3	1	2	2.6
Lake Daisy	3	3	3	3	3	3	2	2	2.8

Table 3-1. 2024 Lake Health Index scores ranking the Winter Haven study area lakes from highest to lowest priority.

The highest ranked waterbodies possess similar qualities—exhibiting water quality impairments and/or multiple significantly deteriorating water quality trends. While the biological criteria also factor into these lake health scores, changes in vegetation abundance, invasive species presence, and species diversity are more variable and generally less impactful to overall lake health compared with water quality. Water quality issues are typically more challenging and costly to solve as well.

According to the 2024 Lake Health Index, the highest priority waterbodies include Lake Idyl (p. 148), a tie between Lake Hamilton (p. 129) and Lake Martha (p. 190), and a four-way tie among Lake Elbert (p.105), Lake Jessie (p. 160), Lake Mariana (p. 184), and Lake Ned (p. 214). The City and partnering agencies are engaged in various management strategies to improve the water quality in these lakes. These strategies can be reviewed in each lake's respective section (see the page numbers listed above). Specific management strategies are highlighted below:

Lake Idyl Water Quality Improvement Plan. The City submitted a restoration plan to the Florida Department of Environmental Protection (FDEP) aimed at addressing the pollutant sources to the lake. Projects associated with this plan include construction of stormwater improvements to reduce and treat runoff from the neighborhoods north of the lake and application of nutrient inactivation products to reduce internal pollutant loading from the lake sediments. Both of these projects will be dependent on funding availability. In 2024, the City submitted grant applications to FDEP seeking funding to assist with these projects.

Lake Hamilton Water Quality Restoration Plan. Polk County Environmental Lands submitted a restoration plan to FDEP with projects that are designed to improve water quality in the three Hamilton waterbodies (i.e. Lake Hamilton, Middle Lake Hamilton, Little Lake Hamilton). The projects detailed in this plan include: stormwater enhancements at Lake Eva and Lake Henry restoration projects designed to improve water quality from these lakes to downstream receivers, street sweeping within the Lake Hamilton drainage basins, groundwater seepage study to provide evidence as to the impacts from septic systems, and a City of Lake Hamilton septic to sewer conversion.

Lake Martha SAV Planting. A lack of submerged aquatic vegetation in Lake Martha has resulted in diminished fish and wildlife habitat and capacity to buffer against stormwater pollutant loads. In 2024, the City partnered with the Florida Fish and Wildlife Commission (FWC) to transplant Illinois pondweed from Lake Hartridge into Lake Martha. This native species was planted along the Lake Martha boatramp and Kiwanis Park shorelines. Unfortunately, the remnant grass carp originally stocked in 2011 to combat hydrilla ended up destroying the new plantings. City staff are exploring alternative options to increase SAV presence in the currently denuded lake; possibly replanting with carp-exclusion cages.

Lake Elbert Green Stormwater Infrastructure. The Lake Elbert trail project, started in 2024, includes several raingardens and bioswales along the trail to help filter runoff from Lake Elbert Drive. The neighborhoods surrounding Lake Elbert were constructed before current stormwater management regulations were in place. As a result, these residential and commercial areas lack meaningful stormwater treatment features. City staff plan to prioritize public education and outreach activities in these communities to reduce residential runoff and pollutant loading.

Comparing the Lake Health Index scores over time provides insights into how successful these management strategies have been. Taking the mean of Lake Health criteria values from 2018 to

2024 shows that Winter Haven's lakes have improved in most areas (Table 3-2). The following are some highlights of this comparison:

Year	Impairment	Chla Trend	TN Trend	TP Trend	Clarity Trend	Vegetation Abundance	Invasive Presence	Diversity	Lake Health Score
2018	1.3	1.8	1.9	2.2	2.1	2.2	1.3	1.3	1.8
2019	1.5	1.9	2.0	2.2	2.1	2.3	1.1	2.0	1.9
2020	1.5	1.9	2.1	2.2	2.1	2.4	1.3	1.5	1.9
2021	1.7	1.9	2.1	2.0	2.1	2.3	1.3	1.7	1.9
2022	1.7	1.9	2.1	2.0	2.2	2.5	1.5	1.9	2.0
2023	1.8	1.9	2.0	2.2	1.9	2.5	1.5	2.1	2.0
2024	1.8	2.0	2.0	2.1	1.7	2.6	1.7	2.0	2.0

Table 3-2. Mean Lake Health Index scores for all Winter Haven area lakes from 2018 to 2024.

The impairment criterion is based on the annual average concentrations of chlorophyll-a, total nitrogen, and total phosphorus compared to State and Federal regulatory thresholds. Since 2018, several lakes have started to meet the Numeric Nutrient Criteria (NNC), resulting in gradual improvements to the impairment criterion scores: Lakes Cannon, Conine, Deer, Fannie, Idylwild, Otis, and Rochelle are the waterbodies that have started to meet the NNC for one or more parameters. Fortunately, none of the lakes in the study have undergone significant declines in this criterion since monitoring began.

The chlorophyll-a (Chla) trends have exhibited a slight trend toward improvement; with 2024 having the best average trend scores on record. Chlorophyll-a trend scores improved for Lakes Deer, Otis, Pansy, and Little Hamilton from 2023 to 2024, with a slight downgrade in Lake Buckeye's trend score.

The total nitrogen (TN) trends have remained relatively static, fluctuating between an annual average of 1.9 to 2.1. The average TN trend score remained the same from 2023 to 2024 due to slight increases in the scores for Lakes Deer and Fannie, but slight declines in the scores for Lakes Buckeye and Spring.

The total phosphorus (TP) trends have undergone marginal variation with annual average scores vascillating between 2.0 and 2.2. The average TP trend score decreased slightly from 2023 to 2024 due to slight decreases in the scores for Lakes Cannon, Jessie, Spring, and Summit; despite slight increases in the TP scores for Lakes Hartridge, Ned, and Silver.

The water clarity trends have undergone considerable declines in recent years with large decreases in annual average trend scores in 2023 and 2024. The latest decrease was due to a decline in Secchi depth trend scores for Lakes Buckeye, Eloise, Fannie, Haines, Howard, Jessie, Mariam, Mirror, Silver, and Spring. Fortunately, most of these decreased trend scores were due to shifts in statistical significance for lakes that are currently meeting water quality targets. None of the trend score decreases were indicative of a change to significantly deteriorating water clarity. It should also be noted that Lakes Deer and Link underwent increases to their clarity trend scores; with the trend in Lake Deer shifting to significant improving.

The vegetation abundance criterion scores have undergone a steady increase from 2018 to 2024, with the latest annual average abundance scores the highest on record. While Lakes Haines, Link, and Mariana underwent slight decreases in vegetation coverage, these were more than made up for by improved abundance scores for Lakes Buckeye, Daisy, Hamilton, Ned, Rochelle,

Silver, Smart, and Little Hamilton. It should be noted that several of these lakes (Daisy, Hamilton, Ned, and Silver) have traditionally supported very sparse vegetation communities—indicating substantial improvements for these waterbodies.

The nature of invasive plants allows them to quickly spread, taking over vegetation communities within the lakes. As a result, this criterion has the capacity to shift considerably from year to year. That said, the annual average scores for this criterion have generally increased over time. From 2023 to 2024, Lakes Daisy, Deer, Elbert, Haines, Link, Mariam, Maude, May, Mirror, Otis, Pansy, Roy, and Summit exhibited decreases in the abundance of invasive plant species. This more than made up for the slight increases in invasive plants in Lakes Buckeye, Hamilton, Jessie, Ned, and Shipp. Monitoring for invasive species is the primary means of preventing these scores from declining—indicating that these monitoring efforts have been successful.

Due to the ability for aquatic vegetation communities to shift based on both natural ecological dynamics and human-mediated management efforts, the species diversity criterion has the capacity to undergo the most volatility out of all the lake health metrics. This is evidenced by the fluctuation in annual average diversity scores from 1.3 to 2.1. From 2023 to 2024, almost every lake in the study area underwent some change in their diversity criterion score. Unfortunately, there was a slight net decreased in average diversity during this period. That said, 2024's average diversity score is still relatively high compared with previous years.

Overall, the annual average Lake Health Index (LHI) scores have steadily increased from a score of 1.8 in 2018 to the current average of 2.0 achieved in 2022, 2023, and 2024. It is worth noting that the outcomes of lake management efforts are often incremental which is why the average LHI values have not exhibited substantial changes during this time frame. Additionally, some management strategies can have unintended consequences on other aspects of lake health—the short-term water quality impacts from invasive plant treatment efforts, for example. Therefore, the slow, but steady upward trend towards higher LHI scores is a success worth underscoring. Considering the state of other waterbodies throughout Florida, even maintaining consistent lake health can be viewed as an achievement.

While these scores show general improvement, many individual waterbodies still aren't meeting the high standards set forth by both the State of Florida and the City of Winter Haven. There is still much to accomplish to meet these goals. It will take the combined efforts of the City, partner organizations, local stakeholders, and Winter Haven residents in order to make these improvements a reality. Please reach out to the Winter Haven Natural Resources Division if you would like more information about a specific lake or management strategy.

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Phone: 863-291-5881

#4 | Appendix



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4.2 Data Sources:

Water Quality Data

Collected from: <https://polk.wateratlas.usf.edu/datadownload/>; Surface Water Quality

Parameters:

- Alkalinity, Total (hydroxide+carbonate+bicarbonate)
- Chlorophyll-a, corrected for pheophytin
- Nitrogen, Total
- Phosphorus as P, Total
- Secchi disk depth
- True Color, Total

Data Sources:

- POLKCO_NRD_WQ
- WIN_21FLPOLK
- WIN_21FLCEN
- LAKEWATCH_V
- SWFWMD_LAKES_WQ
- STORET_21FLTPA
- LEGACYSTORET_21FLA
- USGS_NWIS

Hydrologic Data

Southwest Florida Water Management District Environmental Data Portal: <https://www.swfwmd.state.fl.us/resources/data-maps/environmental-data-portal>

- Rainfall
- Lake (surface elevation)
- Well (Upper Floridan Aquifer elevation)

University of Florida IFAS Extension; Florida Automated Weather Network: <https://fawn.ifas.ufl.edu/data/>

- Rainfall
- Evapotranspiration

City of Winter Haven Lake Level Sensors: <http://hydrometcloud.com/hydrometcloud/index.jsp>

- Lake (surface elevation)

Biological Data

Aquatic vegetation abundance collected using SONAR devices (e.g. Lowrance, Garmin, etc.).

SONAR data is processed using BIOBASE:

<https://www.biobasemaps.com/Solutions/AquaticPlants>

Species data is collected using the Florida Fish and Wildlife Commission (FWC) point-intercept sampling methodology.

- Collected by City of Winter Haven staff, Polk County staff, and FWC staff.

4.3 Supplemental Data

Annual Geometric Mean Data

Table 4-1. Annual geometric mean corrected chlorophyll-a concentrations from 2004 – 2024 for all study area lakes.

Waterbody	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Lake Blue	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	60.0	51.3	82.6
Lake Buckeye	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	9.3	18.1	20.7
Lake Cannon	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	35.0	18.3	25.7
Lake Conine	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	15.1	25.6	17.9
Lake Daisy	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	3.0	2.6	3.3
Lake Deer	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	4.2	10.1	4.1
Lake Elbert	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	13.0	8.0	10.4
Lake Eloise	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	16.9	28.3	27.6
Lake Fannie	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	12.4	11.3	7.6
Lake Haines	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	18.5	25.5	18.0
Lake Hamilton	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	48.2	31.4	38.2
Lake Hartridge	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	26.1	20.1	23.9
Lake Howard	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	33.4	23.0	22.6
Lake Idyl	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	17.4	17.1	24.3
Lake Idylwild	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	21.6	14.8	24.2
Lake Jessie	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	27.0	20.8	29.7
Lake Link	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	13.0	15.6	19.9
Lake Lulu	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	19.8	23.1	26.9
Lake Marian	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	13.1	5.6	5.7
Lake Mariana	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	35.6	28.8	41.5
Lake Martha	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	9.3	6.7	9.3
Lake Maude	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	8.1	10.9	4.6
Lake May	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	35.6	26.6	30.8
Lake Mirror	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	13.4	24.0	22.7
Lake Ned	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	11.9	16.3	13.1
Lake Otis	10.4						21.9	18.3	23.2	20.3	16.3	17.3	13.9	13.5	18.3	17.7	15.1	19.3	13.3	15.2	15.2
Lake Pansy	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	13.1	21.0	10.9
Lake Rochelle	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	14.9	15.8	10.9
Lake Roy	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	8.0	13.7	8.3
Lake Shipp	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	30.9	35.2	31.2
Lake Silver		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	7.2	6.5	5.4
Lake Smart	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	28.0	22.1	13.5
Lake Spring	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	13.1	11.8	17.3
Lake Summit	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	5.0	4.8	4.8
Lake Winterset	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	3.1	4.3	3.8
Little Lake Hamilton	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	20.5	20.9	17.8
Middle Lake Hamilton	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	24.7	21.3	18.0

Table 4-2. Annual geometric mean total nitrogen concentrations from 2004 - 2024 for all study area lakes.

Waterbody	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Lake Blue	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	3242.9	1764.8	3033.4
Lake Buckeye	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	757.2	1046.8	966.0
Lake Cannon	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	1304.0	848.1	1120.8
Lake Conine	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	936.7	1356.4	1043.6
Lake Daisy	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	376.1	377.8	449.4
Lake Deer	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	774.9	1052.8	763.0
Lake Elbert	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	777.9	544.2	594.1
Lake Eloise	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	948.5	1100.2	1275.0
Lake Fannie	1003.1	997.5	863.4	913.5	1326.9	1401.4	1288.3	1727.9	1453.5	1389.2	1114.5	970.3	989.2	870.0	873.5	750.3	899.2	842.5	869.8	841.1	795.5
Lake Haines	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	1126.9	1483.9	1287.1
Lake Hamilton	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	2332.5	1685.8	1946.2
Lake Hartridge	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	1252.3	1172.1	1258.8
Lake Howard	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	1283.1	1054.2	1438.5
Lake Idyl	594.0	649.8	630.0	544.4	530.0	1000.0	557.8	546.8	529.6	619.3	825.2	850.2	850.2	1797.4	1446.9	1000.4	1266.9	1254.0	971.5	1079.4	1143.8
Lake Idylwild	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	1069.6	927.6	1101.5
Lake Jessie	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	1091.1	929.6	1087.8
Lake Link	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	769.6	834.4	1030.1
Lake Lulu	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	1051.3	1051.3	1230.4
Lake Marlam	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	1012.2	877.8	993.7
Lake Mariana	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	1589.7	1110.7	1659.1
Lake Martha	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	545.7	505.5	550.0
Lake Maude	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	760.5	787.1	611.9
Lake May	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	1224.8	1053.5	1269.9
Lake Mirror	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	810.6	1067.1	914.9
Lake Ned	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	814.4	965.0	977.6
Lake Otis	600.0						970.0	1095.3	985.8	921.0	788.0	819.8	681.1	673.0	769.7	634.2	753.1	933.5	750.9	727.3	806.5
Lake Pansy	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	739.2	876.3	726.9
Lake Rochelle	1274.2	1322.9	1084.7	1228.4	1249.6	1603.5	1346.9	1208.9	1306.6	1319.5	1426.7	1154.0	946.5	942.1	934.6	792.8	914.3	1114.2	916.4	1228.1	798.4
Lake Roy	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	697.8	1000.3	823.7
Lake Shipp	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	1235.8	1433.9	1424.0
Lake Silver		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	591.2	560.3	708.1
Lake Smart	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	1327.8	1460.9	1152.0
Lake Spring	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	611.5	613.2	872.6
Lake Summit	798.0	764.0	836.8	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	870.2	758.2	701.2
Lake Winterset	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	523.1	621.6	511.3
Little Lake Hamilton	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	1388.8	1332.1	1345.0	1405.2
Middle Lake Hamilton	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	1467.0	1273.3	1507.2

Table 4-3. Annual geometric mean total phosphorus concentrations from 2004 – 2024 for all study area lakes.

Waterbody	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Lake Blue	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	74.6	50.5	73.0
Lake Buckeye	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	24.0	40.6	27.7
Lake Cannon	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	39.3	29.3	44.2
Lake Conine	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	66.7	62.7	36.1
Lake Daisy	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	15.4	16.7	20.7
Lake Deer	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	18.7	28.8	29.6
Lake Elbert	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	19.2	17.7	24.0
Lake Eloise	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	23.3	28.2	39.0
Lake Fannie	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	59.2	33.2	30.0
Lake Haines	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	80.3	118.3	51.9
Lake Hamilton	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	50.1	42.8	47.5
Lake Hartridge	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	18.1	21.0	35.4
Lake Howard	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	28.1	28.4	28.9
Lake Idyl	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	62.3	52.6	85.1
Lake Idylwild	46.3	46.4	44.8	40.2	37.3	35.5	35.2	41.7	35.1	35.1	36.0	32.4	30.0	31.0	39.7	34.0	34.4	44.7	46.6	33.7	38.0
Lake Jessie	53.0	53.1	48.4	40.5	46.9	38.2	41.7	37.5	33.7	29.2	30.7	27.7	23.9	25.0	23.9	27.4	26.9	38.4	27.7	32.3	30.3
Lake Link	26.0						27.5	37.5	33.7	35.1	31.0	30.9	38.0	38.3	34.6	31.7	38.9	45.0	35.0	35.9	34.9
Lake Lulu	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	35.0	35.9	34.9
Lake Mariam	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	61.0	72.6	91.7
Lake Mariana	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	31.4	31.6	34.7
Lake Martha	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	16.2	18.6	17.9
Lake Maude	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	48.9	32.2	23.9
Lake May	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	48.0	50.7	51.8
Lake Mirror	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	24.4	38.1	38.7
Lake Ned	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	30.8	34.1	23.6
Lake Otis	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	26.7	27.2	31.2
Lake Pansy	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	30.6	35.7	24.1
Lake Rochelle	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	60.9	57.7	25.7
Lake Roy	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	13.7	16.9	24.6
Lake Shipp	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	34.0	48.4	38.8
Lake Silver		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	16.8	19.5	19.4
Lake Smart	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	56.2	34.1	26.7
Lake Spring	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	24.1	28.5	47.6
Lake Summit	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	18.1	26.0	49.4
Lake Winterset	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	11.1	16.5	17.0
Little Lake Hamilton	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	30.0	32.8	32.5
Middle Lake Hamilton	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	54.4	51.0	56.6

Table 4-4. Annual geometric mean Secchi depth from 2004 – 2024 for all study area lakes.

Waterbody	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Lake Blue	1.18	1.81	1.66	1.00	1.26	0.98	1.50	1.13	1.86	1.18	1.43	1.42	1.30	1.18	1.22	1.29	1.31	1.01	0.97	1.20	0.92
Lake Buckeye	3.26	3.31	5.26	3.97	4.65	5.25	5.81	6.89	9.29	9.11	6.59	8.27	7.06	7.26	8.86	7.00	10.93	8.72	6.26	3.26	3.46
Lake Cannon	2.46	2.64	3.49	3.07	2.70	2.29	2.60	2.51	2.65	2.13	2.23	3.89	3.14	3.45	3.14	2.36	3.24	3.00	2.22	2.91	2.52
Lake Conine	2.38	2.47	2.56	2.02	2.31	2.08	2.40	2.27	2.46	2.51	2.67	3.47	3.70	3.24	3.96	3.67	3.52	3.11	3.63	3.04	3.06
Lake Daisy	5.68	5.80	6.00	5.45	4.50	5.03	7.06	6.46	5.80	5.16	6.47	6.63	6.59	5.00	5.69	5.56	6.40	8.26	10.06	7.60	6.11
Lake Deer	5.68	4.56	4.96	2.83	2.37	2.35	2.71	4.48	2.28	2.37	4.11	4.07	5.39	4.83	8.18	6.28	6.03	4.50	7.26	4.68	7.14
Lake Elbert	9.19	7.54	9.62	12.05	12.61	11.76	13.73	9.69	9.28	11.09	8.65	8.84	10.70	8.03	8.63	6.53	5.96	6.24	5.09	5.64	4.74
Lake Eloise	2.36	2.16	2.31	2.21	2.40	2.85	2.40	2.16	2.53	2.01	2.06	2.34	2.13	2.88	2.61	3.11	2.86	2.09	3.15	2.71	2.12
Lake Fannie	2.75	3.43	3.11	2.51	1.38	1.38	1.64	1.31	1.68	2.07	2.29	3.40	3.51	3.62	3.75	3.59	4.16	2.57	3.22	2.73	2.94
Lake Haines	2.51	2.10	2.46	2.29	2.31	2.43	2.78	3.05	2.19	2.32	2.72	2.92	3.01	3.32	2.94	3.07	2.90	2.95	2.60	2.07	2.33
Lake Hamilton	2.30	3.21	1.78	2.30	2.30	1.70	1.74	2.11	1.75	1.83	2.16	2.18	2.14	1.54	1.74	2.05	1.91	1.63	1.38	1.67	1.58
Lake Hartridge	4.16	4.86	3.85	3.72	3.61	2.97	2.74	2.35	2.25	1.91	1.86	2.36	2.16	2.52	2.34	2.47	2.26	2.55	1.98	2.30	2.32
Lake Howard	1.80	2.12	1.96	1.23	1.64	1.78	2.66	2.14	1.87	1.92	1.95	2.25	1.93	2.47	2.66	2.39	2.13	2.09	1.82	2.55	1.89
Lake Idyl	5.91	6.89	6.76	6.50	9.34	4.40	3.94	8.80	7.85		7.24	5.00	5.96	2.27	2.68	3.51	2.62	2.65	4.35	3.51	4.53
Lake Idylwild	2.60	3.07	2.92	2.60	2.36	2.03	2.32	2.53	2.47	2.16	2.48	3.60	3.70	2.77	2.93	3.23	3.47	3.25	2.78	3.37	2.62
Lake Jessie	2.62	2.76	2.65	2.65	2.58	2.36	2.39	2.59	2.42	2.50	2.47	3.45	3.29	2.35	2.76	2.44	2.68	2.55	2.32	2.62	2.49
Lake Link	4.27						7.55	5.08	3.52	3.80	4.73	4.92	5.17	3.70	3.68	4.51	4.61	3.37	3.80	3.67	3.03
Lake Lulu	1.86	2.19	1.80	1.68	1.75	1.90	2.07	2.15	2.34	2.31	2.98	2.92	2.42	2.19	2.35	2.55	2.65	2.39	2.59	2.52	1.87
Lake Marian	1.51	1.88	1.82	0.98	2.18	2.08	2.25	2.90	2.84	2.94	2.91	2.00	2.16	0.99	1.72	1.51	2.28	1.67	2.24	1.41	1.82
Lake Mariana	2.12	2.53	2.63	2.47	2.18	1.95	2.53	1.95	2.24	1.83	1.72	2.11	2.84	1.65	2.03	1.82	2.03	1.67	1.77	2.30	1.79
Lake Martha	9.68	10.12	13.06	11.40	7.24	7.85	6.29	5.09	5.30	5.96	6.59	5.32	4.67	4.55	4.87	5.80	6.19	5.35	5.40	5.90	5.25
Lake Maude	3.81	5.04	9.48	8.49	5.46	3.03	3.85	4.08	4.72	6.12	7.40	6.44	6.58	6.99	10.45	10.98	10.36	10.33	6.42	3.73	7.43
Lake May	1.39	2.03	1.64	1.18	1.42	1.39	2.04	1.79	1.79	1.91	2.43	2.92	2.05	2.19	2.53	2.24	2.57	2.25	2.11	1.87	2.09
Lake Mirror	2.04	2.64	3.12	2.74	2.47	2.97	3.49	4.10	4.92	3.33	5.25	6.43	4.24	3.67	3.48	3.58	4.11	4.30	4.13	2.60	2.89
Lake Ned	7.41	5.70	7.75	7.29	6.63	5.61	6.33	7.69	4.10	3.95	4.17	3.97	3.59	3.79	3.85	4.00	3.71	3.57	3.40	2.66	3.57
Lake Otis	5.25						3.94	3.38	2.62	3.03	4.07	4.00	5.17	4.41	3.85	4.28	3.69	3.30	4.37	4.09	3.78
Lake Pansy	4.18	5.09	3.87	2.77	3.29	3.43	4.45	4.61	3.51	2.61	3.85	4.00	3.79	3.27	4.33	3.83	4.22	3.81	3.68	3.25	3.84
Lake Rochelle	2.29	2.47	3.17	2.42	2.23	2.15	2.62	3.23	2.32	2.51	2.47	3.69	4.12	3.88	3.96	4.00	2.74	3.66	3.52	1.94	3.13
Lake Roy	3.88	4.60	4.77	3.39	2.58	3.15	3.72	5.39	4.17	3.24	4.86	6.72	5.84	6.02	4.55	4.84	5.54	3.55	5.08	3.59	4.62
Lake Shipp	1.62	1.80	1.39	1.15	1.80	1.59	2.02	1.68	1.74	1.80	2.29	2.20	2.12	2.24	2.10	2.34	2.42	2.39	2.07	2.11	1.99
Lake Silver		6.80	6.74	7.53	7.09	3.82	4.33	5.56	6.31	7.01	6.44	4.26	4.20	3.40	6.27	5.66	5.17	7.82	7.20	6.09	6.57
Lake Smart	2.27	2.86	2.76	1.67			1.64	1.66	1.73		2.79	2.80	2.95	2.17	3.38	2.86	2.76	2.83	2.06	2.78	2.34
Lake Spring	4.12	3.44	3.53	3.75	4.24	5.31	8.45	6.90	6.89	7.76	5.04	5.39	6.56	5.77	5.40	6.67	6.02	5.87	5.62	5.64	4.82
Lake Summit	3.59	5.10	6.15	5.32	4.31	4.59	5.98	5.75	7.22	7.27	7.61	7.34	8.22	6.38	7.56	7.35	5.93	6.96	8.02	6.70	7.66
Lake Winterset	3.36	4.59	5.43	5.88	5.03	5.35	6.88	8.05	8.97	8.98	10.57	10.92	10.19	5.72	7.34	9.09	8.44	12.39	13.75	8.39	11.13
Little Lake Hamilton	4.59	3.53	4.29	2.66	1.99	2.46		2.55	1.80	2.62	2.16	3.81	3.12	2.23	2.88	3.25	2.91	2.96	2.77	2.48	2.40
Middle Lake Hamilton	2.46	2.44	2.57	2.12	1.97	1.64	1.73	1.86	1.80	1.92	2.27	2.68	2.86	2.14	2.40	2.83	2.91	2.67	2.58	2.53	2.39

Linear Regression Statistics

Table 4-5. Trendline statistics for linear regressions of chl-a, TN, TP, and Secchi depth from 2004 - 2024. Stats include regression direction (+/-), R-squared value, and p-value.

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	-	0.0978	0.168	-	0.1737	0.060	-	0.0009	0.898	-	0.3414	0.005
Lake Buckeye	-	0.0394	0.388	+	0.1195	0.125	-	0.0488	0.336	-	0.0436	0.364
Lake Cannon	-	0.0534	0.313	+	0.0040	0.786	-	0.0255	0.489	-	0.0431	0.366
Lake Conine	-	0.6686	0.000	+	0.5633	0.000	-	0.4476	0.001	-	0.0858	0.198
Lake Daisy	-	0.4377	0.001	+	0.2674	0.016	-	0.5614	0.000	-	0.5755	0.000
Lake Deer	-	0.3699	0.003	+	0.2986	0.010	-	0.2304	0.028	-	0.3463	0.005
Lake Elbert	+	0.5878	0.000	-	0.5211	0.000	+	0.4938	0.000	+	0.0006	0.919
Lake Eloise	-	0.2213	0.031	+	0.1151	0.132	-	0.0822	0.208	-	0.2631	0.017
Lake Fannie	-	0.4144	0.002	+	0.1727	0.061	-	0.2161	0.034	-	0.0903	0.186
Lake Haines	-	0.3402	0.006	+	0.0987	0.166	-	0.2027	0.041	+	0.1040	0.154
Lake Hamilton	+	0.7032	0.000	-	0.3705	0.003	+	0.6668	0.000	-	0.6398	0.000
Lake Hartridge	+	0.3036	0.010	-	0.5622	0.000	+	0.2829	0.013	-	0.2169	0.033
Lake Howard	-	0.4015	0.002	+	0.1534	0.079	-	0.3823	0.003	-	0.4721	0.001
Lake Idyl	+	0.3291	0.008	-	0.4031	0.003	+	0.4601	0.001	+	0.5698	0.000
Lake Idylwild	-	0.2390	0.025	+	0.1942	0.046	-	0.0362	0.409	-	0.3102	0.009
Lake Jessie	-	0.0499	0.331	-	0.0016	0.862	+	0.0029	0.816	-	0.1233	0.119
Lake Link	+	0.1751	0.107	-	0.2336	0.058	-	0.0107	0.703	+	0.0050	0.794
Lake Lulu	-	0.4342	0.001	+	0.2974	0.011	-	0.2829	0.013	-	0.4709	0.001
Lake Mariam	+	0.2175	0.033	-	0.0055	0.749	-	0.0377	0.399	+	0.0736	0.234
Lake Mariana	+	0.0499	0.330	-	0.2412	0.024	+	0.0336	0.426	-	0.2858	0.013
Lake Martha	+	0.3614	0.004	-	0.5232	0.000	+	0.0821	0.208	+	0.0177	0.566
Lake Maude	-	0.3221	0.007	+	0.1520	0.081	-	0.2408	0.024	-	0.0329	0.431
Lake May	-	0.4911	0.000	+	0.3632	0.004	-	0.5283	0.000	-	0.5477	0.000
Lake Mirror	-	0.2079	0.038	+	0.0975	0.168	-	0.4469	0.001	-	0.1136	0.136
Lake Ned	+	0.6071	0.000	-	0.7332	0.000	+	0.5621	0.000	+	0.1555	0.077
Lake Otis	-	0.0155	0.646	-	0.0107	0.703	-	0.0332	0.499	+	0.0007	0.924
Lake Pansy	+	0.0899	0.199	-	0.0139	0.621	-	0.0413	0.390	+	0.0019	0.857
Lake Rochelle	-	0.7080	0.000	+	0.2039	0.040	-	0.4063	0.002	-	0.0493	0.334
Lake Roy	-	0.2611	0.018	+	0.0918	0.182	-	0.0952	0.173	-	0.3239	0.007
Lake Shipp	-	0.3858	0.003	+	0.5490	0.000	-	0.4269	0.001	-	0.3417	0.005
Lake Silver	-	0.0502	0.342	-	0.0002	0.952	-	0.0761	0.239	-	0.2731	0.018
Lake Smart	-	0.2090	0.056	+	0.0916	0.222	-	0.0974	0.207	-	0.2023	0.061
Lake Spring	-	0.1888	0.049	+	0.1181	0.127	-	0.1447	0.089	-	0.0228	0.513
Lake Summit	-	0.6679	0.000	+	0.5199	0.000	-	0.2621	0.018	+	0.0026	0.827
Lake Winterset	-	0.6647	0.000	+	0.5878	0.000	-	0.6059	0.000	-	0.4703	0.001
Little Lake Hamilton	-	0.0034	0.808	-	0.1111	0.151	+	0.0124	0.640	-	0.1683	0.072
Middle Lake Hamilton	+	0.1224	0.120	+	0.2070	0.038	-	0.1315	0.106	-	0.2878	0.012

Table 4-6. 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.

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 4-7. Stormwater pollutant loading rates for all study area lakes.

Waterbody	Drainage Basin Area (Acres)	Total TN Load	Total TP Load	TN Load/Acre	TP Load/Acre
Lake Blue	183.72	871.51	154.23	4.74	0.84
Lake Buckeye	305.78	867.10	154.76	2.84	0.51
Lake Cannon	1039.11	3863.09	637.80	3.72	0.61
Lake Conine	796.43	2836.20	474.36	3.56	0.60
Lake Daisy	356.67	1717.66	382.25	4.82	1.07
Lake Deer	377.43	1451.11	261.19	3.84	0.69
Lake Elbert	605.00	2365.80	385.07	3.91	0.64
Lake Eloise	1981.43	3875.24	665.40	1.96	0.34
Lake Fannie	2208.68	4133.27	717.67	1.87	0.32
Lake Haines	2317.85	5701.02	1055.90	2.46	0.46
Lake Hamilton	4177.60	6701.70	1167.79	1.60	0.28
Lake Hartridge	920.07	2658.28	458.94	2.89	0.50
Lake Henry	2409.92	6902.81	1379.68	2.86	0.57
Lake Howard	1869.01	6321.28	1097.50	3.38	0.59
Lake Idyl	230.98	934.96	154.55	4.05	0.67
Lake Idylwild	225.44	669.14	121.61	2.97	0.54
Lake Jessie	973.41	3871.23	652.31	3.98	0.67
Lake Link	63.11	197.24	31.74	3.13	0.50
Lake Lulu	1006.48	2791.48	483.02	2.77	0.48
Lake Mariam	622.11	1609.45	274.81	2.59	0.44
Lake Mariana	1935.67	6530.83	1160.57	3.37	0.60
Lake Martha	307.50	1217.07	199.11	3.96	0.65
Lake Maude	385.75	1900.55	320.03	4.93	0.83
Lake May	353.57	1732.69	292.88	4.90	0.83
Lake Mirror	277.95	749.60	120.88	2.70	0.43
Lake Ned	256.97	1002.90	202.66	3.90	0.79
Lake Otis	586.90	2291.05	372.60	3.90	0.63
Lake Pansy	243.82	880.73	111.22	3.61	0.46
Lake Rochelle	1669.70	3002.65	522.22	1.80	0.31
Lake Roy	353.73	1448.34	241.53	4.09	0.68
Lake Shipp	910.64	3614.35	654.69	3.97	0.72
Lake Silver	164.17	633.20	106.11	3.86	0.65
Lake Smart	642.59	1673.37	348.90	2.60	0.54
Lake Spring	120.18	520.71	90.81	4.33	0.76
Lake Summit	166.52	513.32	82.73	3.08	0.50
Lake Winterset	1074.54	2258.84	407.59	2.10	0.38
Little Lake Hamilton	1015.97	1472.72	198.04	1.45	0.19
Middle Lake Hamilton	1539.88	11621.29	1072.03	7.55	0.70

Table 4-8. Count and density of known OSTD systems within each lake drainage basin.

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 4-9. List of aquatic plant species detected in Winter Haven area lakes.

Common Name	Scientific Name	Common Name	Scientific Name
Alligator Weed	Alternanthera philoxeroides	Red Maple	Acer rubrum
American Lotus	Nelumbo lutea	Redtop Panicum	Panicum rigidulum
Bald Cypress Pond Cypress	Taxodium spp.	Road Grass	Eleocharis baldwinii
Banana Lily	Nymphoides aquatica	Rosy Camphorweed	Pluchea rosea
Bladderwort	Utricularia spp.	Rush Fuirena	Fuirena scirpoidea
Brazilian Pepper	Schinus terebinthifolius	Sacred Lotus	Nelumbo nucifera
Bulrushes	Scirpus spp.	Sawgrass	Cladium jamaicense
Burhead Sedge	Oxycaryum cubense	Soft Rush	Juncus effusus
Buttonbush	Cephalanthus occidentalis	Southern naiad	Najas guadalupensis
Carolina Willow	Salix caroliniana	Spatterdock	Nuphar advena
Cattail	Typha spp.	Stonewort Nitella	Nitella spp.
Climbing Hempweed	Mikania scandens	Swamp Bay	Persea palustris
Coontail	Ceratophyllum demersum	Sweetbay Magnolia	Magnolia virginiana
Duck Potato	Sagittaria lancifolia	Torpedograss	Panicum repens
Duckweed	Lemna spp.	Water Hyacinth	Eichhornia crassipes
Eel Grass	Vallisneria americana	Water Lettuce	Pistia stratiotes
Egyptian Paspalidium	Paspalidium geminatum	Water Pennywort	Hydrocotyle spp.
Elodea Waterweed	Egeria densa	Water Spangles	Salvinia minima
Filamentous Algae	Lyngbya species	Wild Taro	Colocasia esculenta
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		-
Pickernelweed	Pontederia cordata		-
Primrose Willow	Ludwigia spp.		-

Table 4-10. Percent area coverage values from 2018 – 2024 for all study area lakes.

Waterbody	2018	2019	2020	2021	2022	2023	2024
Lake Blue	19.5	6.5		17.6	46.9	78.9	78
Lake Buckeye	98	99.7	99.1	98.9	98.8	20.1	55.2
Lake Cannon	32.4	34.9	33.6	37.1	31.8	30.5	34.1
Lake Conine	29	38.8	36.5	24.2	25.7	23.1	28.1
Lake Daisy	3.4	14.3	9	21.7	31.1		32.3
Lake Deer	83.6	91	57.6	80.3	71.9	86.6	90.6
Lake Elbert	59.7	58.9	54.9	48.4	46.4	23.3	18.2
Lake Eloise	12.2	17.1	36.7	29	17.6	17	18.2
Lake Fannie	26.9	26.2	13.3	21.4	26.6	21	23.1
Lake Haines	24.1	26	34.7	10.4	7.5	31	12.1
Lake Hamilton	7.7	8.8	9.5	9.6	10.2	13.5	15.8
Lake Hartridge	35.6	39.7	63.1	36.4	37.9	42.4	43.1
Lake Howard	28.35	29	30	39.2	27.1	27.6	26.4
Lake Idyl	52.9	3.6	35.2	52.9	53	50.5	87.6
Lake Idylwild	49.1	52.5	54	66.7	58.9	60.4	87
Lake Jessie	35.7	51.6	36.1	34.7	43.5		86.3
Lake Link	53.5		47.7	26.5	24.6	34.9	25.8
Lake Lulu	37.5	40	38.2	38.9	45.7	46.3	46.2
Lake Mariam	5.8	20	13.5	45.7	34.9	96.9	85.8
Lake Mariana	22.4	26.1	27.3	24.5	27.8	31.4	27.7
Lake Martha	0.7	3.1	4.1	4.3	7.8	7.3	4.8
Lake Maude	96.2	99.1	99.1	96.3	71.6	79.3	43.4
Lake May	56	69.7	71	78	63.2	76.7	97.1
Lake Mirror	42.9	43.6	39.9	41.7	49.3	48.4	62.1
Lake Ned	7	13.6	4.8	10.1	16	27.5	42.4
Lake Otis	21.2	23.3	27.7	11.4	19.6	31.9	30.9
Lake Pansy	20.4	45	24.1	31	15.1	20.6	20.7
Lake Rochelle	34.3	33.9	34.1	31.5	43.8	27	45.9
Lake Roy	53.5	17	29.9	32.9	34.8	43.3	43
Lake Shipp	49.3	52.3	56.4	50.7	51.8	50.6	52.5
Lake Silver	1	7.3	2.4	1.7	2.3	5	18.8
Lake Smart	13.1	30.6	16.6	28.9	61.9	28.5	80.4
Lake Spring	56.7	57.8	60.4	53.9	56.3	56.9	56.1
Lake Summit	59.5	48.4	61.2	54.8	63	54.3	55.7
Lake Winterset	28.1	36.3	37.5	44.7	56	44.7	42.3
Little Lake Hamilton	18.2	17.4	15.9	14.9	21.3	18.6	35
Middle Lake Hamilton	12.3	19	12.2	8.6	21.8	61.2	52.9

Table 4-11. Invasive species percentage values from 2018 to 2024 for all study area lakes.

Waterbody	2018	2019	2020	2021	2022	2023	2024
Lake Blue	0	0	0	0	0	0	0
Lake Buckeye	14.18	11.32	13.14	6.8	2.98	2.22	6.61157
Lake Cannon	1.89	1.47	3.1	7.04	1.17	6.98	5.309735
Lake Conine	13.29	25.24	16.87	10.84	6.02	6.1	3.947368
Lake Daisy	0	0	0.94	0.65	0.66	5.1	0.719424
Lake Deer	8.13	26.33	15.33	28.39	19.05	17.78	2.739726
Lake Elbert	9.31	11.83	15.48	20.22	38.32	1.75	0
Lake Eloise	1.26	2.3	1.61	1.03	1.13	0.42	0.917431
Lake Fannie	16.41	17.79	11.81	14.37	16.97	13.86	11.06383
Lake Haines	24.07	28.99	25.76	4.29	5.19	4.76	0
Lake Hamilton	1.39	0.74	3.73	3.6	0	5.83	5.740181
Lake Hartridge	0	1.81	0.43	0	0.97	0	0
Lake Howard	0.96	0	0	0	0	0.52	0.423729
Lake Idyl	4.35	16.67	13.33	24	6.06	15.38	26.08696
Lake Idylwild	1.76	3.76	3.14	5.94	3.65	7.37	3.191489
Lake Jessie	1.27	6.33	4.65	11.84	2.55	5.14	11.11111
Lake Link	10.71	0	0	5.66	5.45	2	0
Lake Lulu	4.07	1.55	0	1.63	3.55	3.12	2.590674
Lake Mariam	30.65	23.6	3.03	0	2	11.32	6.818182
Lake Mariana	1.63	0	0	0.57	0	0	0
Lake Martha	0	2.33	0	0	0	0	0
Lake Maude	2.86	4.38	2.23	5.69	1.63	2.88	2.459016
Lake May	7.37	11.32	11.32	13.83	18.33	17.24	5.228758
Lake Mirror	0.65	3.36	3.68	1.23	7.14	2.99	1.898734
Lake Ned	5.81	5.48	0	0	1.27	0	1.075269
Lake Otis	3.96	11.16	0	1.18	2.29	2.53	0
Lake Pansy	13.16	12.5	16	21.28	6.06	1.64	0
Lake Rochelle	8	22.5	20.11	15.48	14.71	7.37	7.29927
Lake Roy	17.69	4.76	1.08	7.81	1.55	4.62	0
Lake Shipp	3.68	6.25	6.63	1.8	2.33	1.67	5.294118
Lake Silver	0	0	0	0	0	0	0
Lake Smart	1.33	12.9	2.25	3.16	3.39	4.44	6.666667
Lake Spring	17.81	18.64	17.65	11.86	5.8	22.5	13.51351
Lake Summit	4.4	3.45	4.21	2.86	4.96	3.7	1.123596
Lake Winterset	3.09	7.93	6.49	13.82	17.55	7.89	6.372549
Little Lake Hamilton	1.27	0	1.86	3.43	0	0	0
Middle Lake Hamilton	3.85	3.29	0	2.61	6.34	25	21.73913

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