DRAFT

Silver Lake

Waupaca County, Wisconsin

Comprehensive Management Plan

July 2022 (Version 2)

Official First Draft for Agency and Public Review

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Acknowledgements

This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

Silver Lake Planning Committee

Kristy Stacy*	Carl Lantz*	Carlo Lantz
Dell Mork	John Bertelson Jr.	Dana Rima
Michael Hafemann	Lou Demitriou	Renee Smith
Lindy McLaren	Dave Mork	

*A special thanks goes to these two district members. Kristy stepped directly into a leadership role by chairing the Planning Committee and Carl spent several hours discussing the history of Silver Lake, the Jorgens Park Preserve, and the changes in the watershed with Tim Hoyman while Onterra was developing the report sections.

Wisconsin Dept. of Natural Resources

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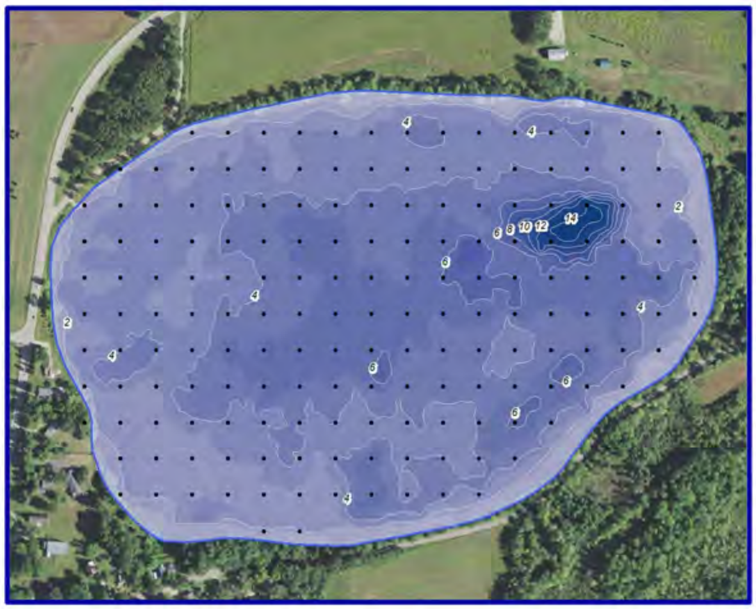
1.0 INTRODUCTION

According to the 1967 recording sonar WDNR Lake Survey Map, Silver Lake (Waupaca County) is 67.5 acres. The WDNR website currently lists the lake as 71 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in 2020. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 74 acres. Silver Lake is a shallow seepage lake with a maximum depth of 17 feet and a mean depth of 7 feet. The watershed encompasses an area of approximately 336 acres (0.5 square miles), and the lake drains via an intermittent to a wetland complex to the south. Surveys completed in 2020 found that the lake's aquatic plant community is largely dominated by coontail (*Ceratophyllum demersum*), common waterweed (*Elodea canadensis*), and the invasive Eurasian watermilfoil (*Myriophyllum spicatum*).

Lake at a Glance - Silver Lake

Morphometry	
Lake Type	Shallow Seepage
Surface Area (Acres)	74
Max Depth (feet)	17
Mean Depth (feet)	7
Perimeter (Miles)	1.3
Shoreline Complexity	1.1
Watershed Area (Acres)	336
Watershed to Lake Area Ratio	4:1
Water Quality (2005-2021)	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Avg Summer Phosphous (µg/L)	29.2
Avg Summer Chlorophyll-α (µg/L)	7.0
Avg Summer Secchi Depth (ft)	6.9
Summer pH	9.6
Alkalinity (mg/L as $CaCO_3$)	73.4
Vegetation (2005-2020)	
Number of Native Species	15
NHI-Listed Species	0
Exotic Species	3
Average Conservatism	5.0
Floristic Quality	15.0
Simpson's Diversity (1-D)	0.76



Descriptions of these parameters can be found within each respective section of this report
NHI = WDNR Natural Heritage Inventory Program

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter.

The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

General Public Meetings

The general public meetings were used to raise project awareness, gather comments, create the management goals and actions, and deliver the study results These meetings were open to anyone interested and were generally held during the summer, on a Saturday, to achieve maximum participation.

Kick-off Meeting

On May 22, 2021, a project kick-off meeting was held in Scandinavia to introduce the project to the general public. The meeting was announced through a mailing and personal contact by SSLD board members. The approximately 20 attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Tim's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question-and-answer session.

Project Wrap-up Meeting

TBD

Committee Level Meetings

Planning committee meetings, similar to general public meetings, were used to gather comments, create management goals and actions and to deliver study results. These two meetings were open only to the planning committee and were held during the week. The first, following the completion of the draft report sections of the management plan. The planning committee members were supplied with the draft report sections prior to the meeting and much of the meeting time was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The objective of the first meeting was to fortify a solid understanding of their lake among the committee members. The second planning committee meeting was held a few weeks after the first and concentrated on the development of management goals and actions that make up the framework of the implementation plan.

Planning Committee Meeting I

On April 13, 2022, Tim Hoyman of Onterra met with 10 members of the Silver Lake Planning Committee for over three hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including Eurasian watermilfoil treatment results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, including nuisance levels of aquatic plants and reduced recreational opportunities on the lake

Planning Committee Meeting II

On April 27, 2022, Tim Hoyman met with the members of the Planning Committee to discuss the stakeholder survey results and begin developing management goals and actions for the Silver Lake management plan.

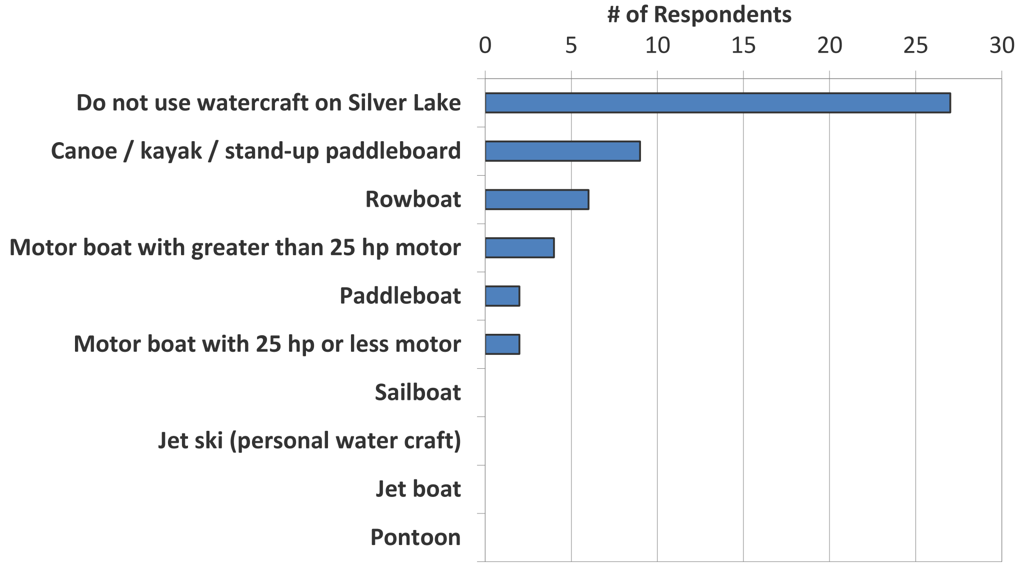
Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to Scandinavia Silver Lake District members /riparian property owners/ and renters around Silver Lake. The survey was designed by Onterra staff and the Scandinavia Silver Lake District planning committee and was reviewed by a WDNR social scientist. During November 2021, the six-page, 30-question survey was posted online through Survey Monkey for survey-takers to answer electronically. If requested, a hard copy was sent with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a Scandinavia Silver Lake District volunteer for analysis. Twenty-three percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people who use and care for Silver Lake. 80% of respondents indicated that they live on the lake as year-round residents, while 5% are rentals, 5% are a weekend, vacation, and/or holiday residence, and 3% are seasonal residence. 78% of respondents have owned their property for over 11 years, and 29% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate they do not use watercraft on Silver Lake (Question 13). About 21% of respondents use a canoe, kayak, or stand-up paddleboard. The top recreational activities on the lake involve canoe, kayak, or stand-up paddleboard use or are activities which can occur from shore. Top concerns of respondents were in relation to aquatic plants or water quality (Question 16).

Question 13: What types of watercraft do you currently use on Silver Lake?



Question 16: From the list below, please rank your top three concerns regarding Silver Lake, with the 1st being your top concern.

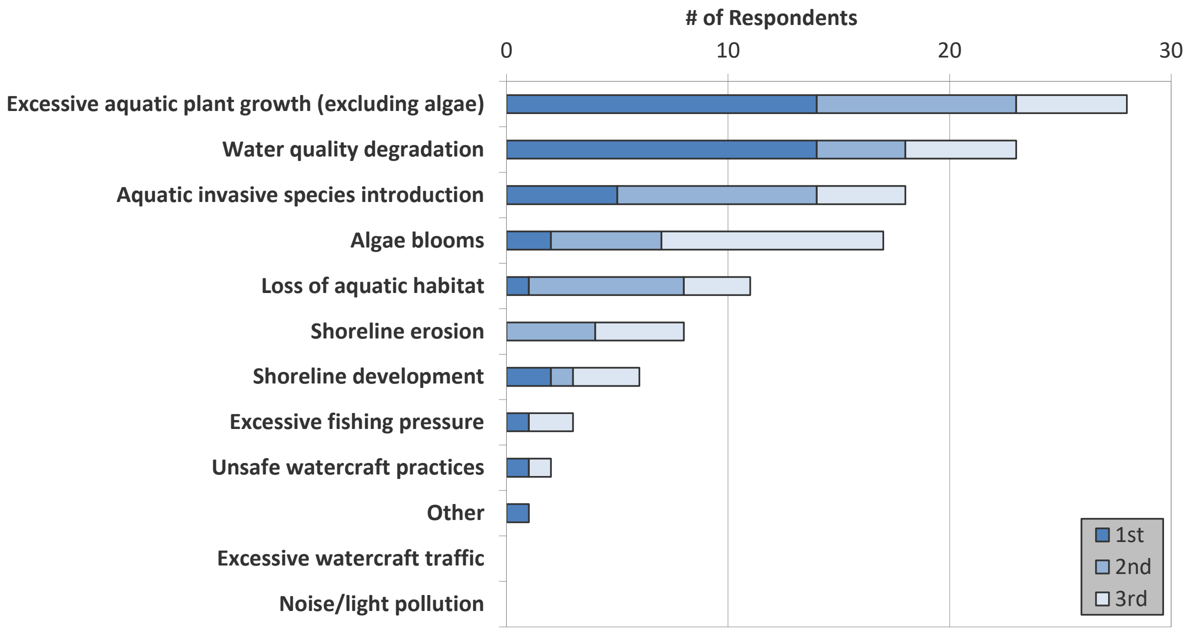


Figure 2.0-1. Select survey responses from the Silver Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

Will be completed in final draft

Note: ProcellaCOR trial treatment action was approved by the SSLD Board of Commissioners at their July 12, 2022 meeting.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analyses are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Silver Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Silver Lake water quality analysis:

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrants (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water (Canter, Nelson and Everett 1994) (Dinius 2007) (Smith, Cragg and Croker 1991).

Trophic State

Total phosphorus, chlorophyll-*a*, and water clarity values are directly related to the trophic state of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: oligotrophic, mesotrophic, and finally eutrophic. Every lake will naturally progress through these states and under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in many Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production.

> Trophic states describe the lake's ability to produce plant matter (production) and include three continuous classifications: Oligotrophic lakes are the least productive lakes and are characterized by being deep, having cold water, and few plants. Eutrophic lakes are the most productive and normally have shallow depths, warm water, and high plant biomass. Mesotrophic lakes fall between these two categories.

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a clearer understanding of the lake's trophic state while facilitating clearer long-term tracking. (Carlson 1977)presented a trophic state index that gained great acceptance among lake managers.

Limiting Nutrient

The limiting nutrient is the nutrient which is in shortest supply and controls the growth rate of algae and some macrophytes within the lake. This is analogous to baking a cake that requires four eggs, and four cups each of water, flour, and sugar. If the baker would like to make four cakes, he needs 16 of each ingredient. If he is short two eggs, he will only be able to make three cakes even if he has sufficient amounts of the other ingredients. In this scenario, the eggs are the limiting nutrient (ingredient).

In most Wisconsin lakes, phosphorus is the limiting nutrient controlling the production of plant biomass. As a result, phosphorus is often the target for management actions aimed at controlling plants, especially algae. The limiting nutrient is determined by calculating the nitrogen to phosphorus ratio within the lake. Normally, total nitrogen and total phosphorus values from the surface samples taken during the summer months are used to determine the ratio. Results of this ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is less than 10:1, it is considered nitrogen limited. Values between these ratios indicate a transitional limitation between nitrogen and phosphorus.

Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen profiles are created simply by taking readings at different water depths within a lake. Although it is a simple procedure, the completion of several profiles over the course of a year or more provides a great deal of information about the lake. Much of this information relates to whether the lake thermally stratifies or not, which is determined primarily through the temperature profiles. Lakes that show strong stratification during the summer and winter months need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epilimnion is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The hypolimnion is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The metalimnion, often called the thermocline, is the middle layer containing the steepest temperature gradient.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fish kills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading*

In lakes that support stratification, whether throughout the summer or periodically between mixing events, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes.

In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of the phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days or weeks at a time).
- Lakes with hypolimnetic total phosphorus values less than 200 µg/L.

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 µg/L.
- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

Specific to the final bullet-point, during the watershed modeling assessment, the results of the modeled phosphorus loads are used to estimate in-lake phosphorus concentrations. If these estimates are much lower than those actually found in the lake, another source of phosphorus must be responsible for elevating the in-lake concentrations. Normally, two possibilities exist: 1) shoreland septic systems, and 2) internal phosphorus cycling. If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2020 Consolidated Assessment and Listing Methodology* (WDNR 2019) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Silver Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, and hydrology. An equation developed by Lathrop and Lillie (Lathrop and Lillie 1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.

Drainage Lakes have surface water inflow and/or outflow in the form of rivers and/or streams.

Headwater drainage lakes have a watershed of less than 4 square miles.

Lowland drainage lakes have a watershed of greater than 4 square miles.

Because of its depth, small watershed and hydrology, Silver Lake is classified as a shallow seepage lake (category 6 on Figure 3.1-1).

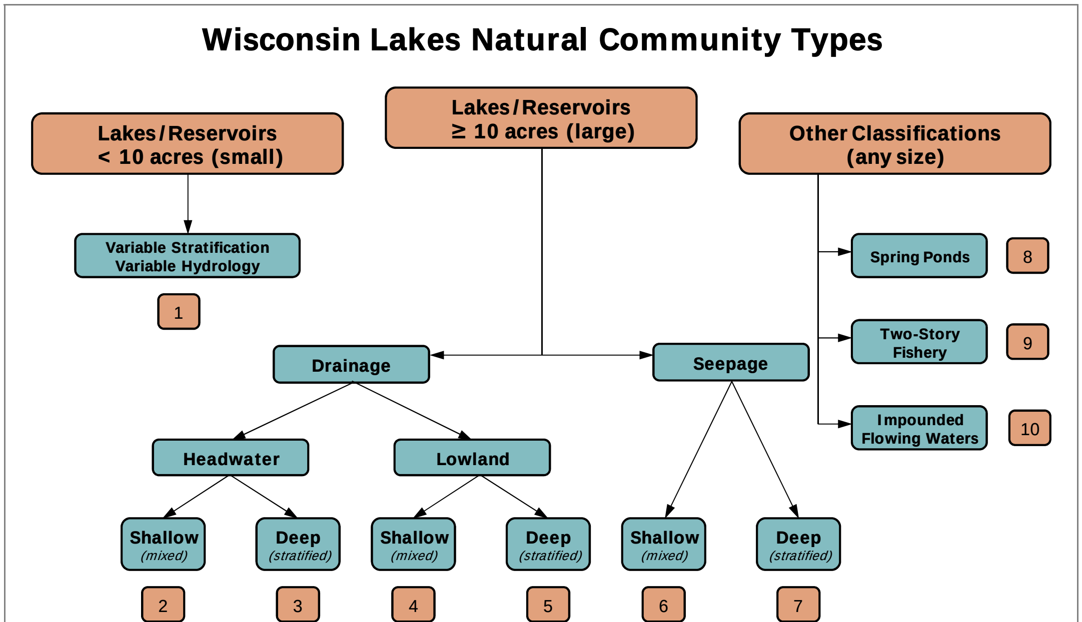


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

(Garrison et al. 2008) developed statewide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Silver Lake is within the North Central Hardwood Forests ecoregion.

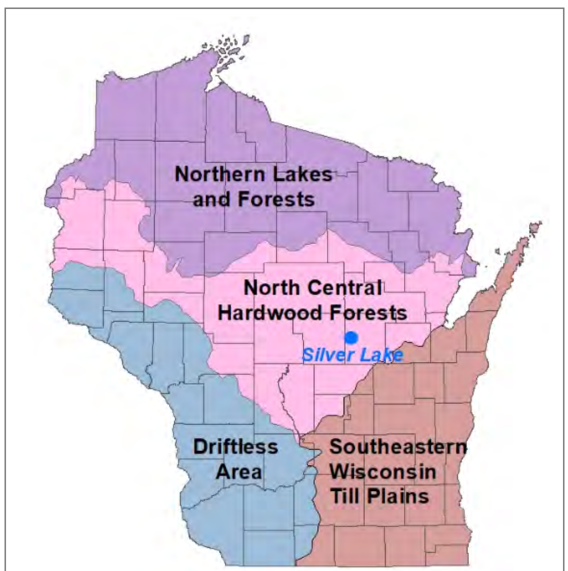


Figure 3.1-2. Location of Silver Lake within the ecoregions of Wisconsin. After (Nichols 1999).

The Wisconsin 2020 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Silver Lake is displayed in Figures 3.1-3 - 3.1-7. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Shallow Lakes and Alternative Stable States

Shallow lakes like Silver Lake are considered to exist in one of two general stable states: a turbid (low clarity) state dominated by algae (phytoplankton) and containing little submersed aquatic vegetation, or a clear state dominated by submersed aquatic vegetation and lower phytoplankton abundance (Scheffer and van Nes 2007). When in the clear state, aquatic vegetation reduces the suspension of bottom sediments, utilizes nutrients that would otherwise be available to phytoplankton, and provides refuge for zooplankton which predate upon phytoplankton. The aquatic plant community plays a vital role in maintaining this clear-water state. Once a lake transitions from a clear to turbid state, it is highly difficult to return it back to a clear state.

As is evidenced by water clarity data discussed later in this section, it appears that Silver Lake transitioned from a more turbid, algae-dominated state to a clear, aquatic plant-dominated state sometime between 2000-2004. Prior to Euro-American settlement and development within its watershed, Silver Lake was likely in a clear-water state. With the advent of agriculture and other human development within the watershed, excessive nutrient input resulted in the lake transitioning to a turbid, algae-dominated state with low water clarity. As mentioned, around 2000-2004, the lake shifted back to a state dominated by aquatic plants with high water clarity.

It was not likely a single event that caused the shift from a turbid to a clear state, but likely the combination and cumulation of BMPs that have taken place within the watershed. Nutrient runoff was likely reduced to a level at which aquatic plants could dominate and suppress the growth of free-floating algae. This shift to an aquatic plant-dominated states means much of nutrients (phosphorus) are now sequestered in the aquatic plant community and the periphyton (algae) that grow on them and are not measured in the water. While phosphorus concentrations within the water are currently lower, productivity in the lake is still very high as evidenced by the excessive aquatic plant growth present.

Background on Silver Lake Watershed Best Management Practices

Following the formation of the Silver Lake Rehabilitation District in 1977, a watershed study was completed in 1978-1979 in response to concerns regarding winter fish kills and turbid water. The study found that excessive nutrient runoff from agriculture within the watershed in combination with the lake's bullhead population were creating degraded water quality and habitat conditions. A treatment was completed in 1983 to eradicate the lake's bullhead population, while restocking with other fish species occurred in 1984. Water clarity was reported to have improved markedly in 1984 following the eradication of bullheads from the lake. An aeration system was installed in 1993 in an effort to prevent future winter fish kills.

Around 2006, a shallow sedimentation basin was created between State Highway 49 and the evergreens at the wayside. While the basin is not able to intercept and treat high water flows, it does treat typical flows that originate in the northern part of the watershed that make their way across the highway. Three family dairy farms were operated within the Silver Lake watershed for decades. Operation included feedlot use, feed and row crop agriculture, and the spreading of manure. The last two dairy farms ceased operation in 2011. The agricultural lands of two of the farms, with fields primarily north of STH 49, are now farmed by Concentrated Animal Feeding Operations (CAFOs) under nutrient management plans, which regulates liquid manure spreading and requires spreading to by knifed in to the soil to reduce runoff.

The third farm, with agricultural fields between STH 49 and the north shore of Silver Lake, also ceased operation around 2011. The farm's owners, Carsten and Dora Jorgens, left the land to four non-profit entities, and through the efforts of several citizens, the Scandinavia Booster Club, the Lions Club, and Chester Krause of Krause Publishing, the land was purchased and set aside as the Jorgens Park Preserve. The Friends of Jorgens Park Preserve, a non-profit corporation, was created and its board guides the maintenance of the park. The park encompasses approximately 40 acres on the north and east shores of the lake. Volunteers have worked to create a 9-acre prairie and plant trees on the northern portion of the property. Volunteers also battle invasive species on the property.

In 2013, BMPs were implemented to reduce nutrient runoff from the nearby Iola-Scandinavia School District's football field. These included the installation of a shallow berm and a sedimentation basin to slow and capture runoff before it entered the lake as well as applying phosphorus-free fertilizers. The combination of these BMPs likely resulted in the lake transitioning from a turbid, algae-dominated state to the current clear, aquatic plant-dominated state.

Silver Lake Water Quality Analysis

Limiting Plant Nutrient of Silver Lake

Using midsummer 2021 nitrogen and phosphorus concentrations from Silver Lake, a total nitrogen: total phosphorus (TN:TP) ratio of 40:1 was calculated, indicating the lake is phosphorus limited. However, historical data from 1989-1999, shows that nutrient limitation was transitional between phosphorus and nitrogen. Nitrogen also became the limiting nutrient at times because phosphorus concentrations were significantly higher. The average TN:TP ratio in 1989-1999 was 16:1 compared to 33:1 from 2005-2021 (Figure 3.1-3). As phosphorus concentrations declined, TN:TP ratios have increased and phosphorus has become the limiting nutrient since 2005. This finding indicates that Silver Lake is currently phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that reducing phosphorus inputs would likely reduce algal production and the production of some larger aquatic plant species (e.g., coontail).

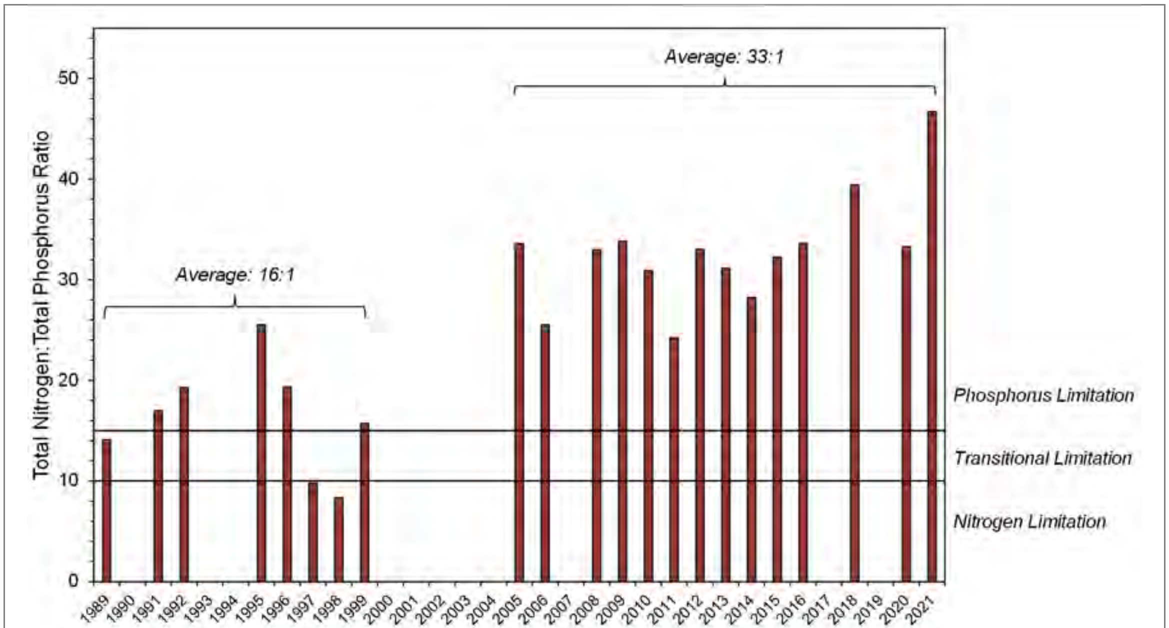


Figure 3.1-3. Silver Lake 1989-2021 total nitrogen: total phosphorus (TN:TP) ratios.

Total Phosphorus

Near-surface total phosphorus (TP) data from Silver Lake are available from 1988-1999 and 2005-2021 (Figure 3.1-4). There has been a marked decrease in TP concentrations between these two time periods. This change occurred sometime between 2000 and 2004, a period for which there are unfortunately no data. A non-paired T-Test indicates average annual phosphorus concentrations from 1988-1998 and 2005-2021 are statistically different (p-value < 0.05). The average growing season TP concentration from 1988-1998 of 74 µg/L declined to an average concentration of 28 µg/L from 2005-2021, representing a 62% decrease between these two time periods.

As shown in Figure 3.1-3, the average summer phosphorus concentrations between these two periods changed on the range from *Fair* in 1988-1999 to *Good* in 2005-2021 for Wisconsin's shallow seepage lakes. The weighted average summer TP concentration from 2005-2021 was 29.2 µg/L, falling into the *good* category for Wisconsin's shallow seepage lakes (Figure 3.1-4). Silver Lake's average summer TP concentrations are above the median concentration for Wisconsin's shallow seepage lakes (18.0 µg/L) and well below the median TP concentration for lakes within the NCHF ecoregion (52.0 µg/L). The average summer TP concentration in 2021 was 20.4 µg/L, falling below the long-term average. As discussed earlier, the decrease in TP concentrations likely represents a shift in the lake from a more turbid, algae-dominated state to a clear, aquatic plant-dominated state.

Available near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations for Silver Lake were also analyzed. Near-bottom concentrations on average are around 20 µg/L higher than those at the surface, indicating internal nutrient loading is occurring to a minimal extent in Silver Lake. While the lake is too shallow to develop strong thermal stratification and the development of an anoxic hypolimnion, anoxia likely develops below the dense aquatic plant beds. These dense beds reduce light penetration and oxygen production by photosynthesis by benthic algae on the bottom as well as inhibit water circulation. Anoxia below dense aquatic plant beds likely results in the release of phosphorus from bottom sediments. In addition, Silver Lake's pH was measured at >9.0 in 2021 due to high rates of photosynthesis. At these higher pH levels, phosphorus can also be released from bottom sediments regardless if oxygen is present or not. However, while near-bottom TP concentrations are slightly higher, internal loading does not appear to be a significant source of phosphorous to Silver Lake at this time.

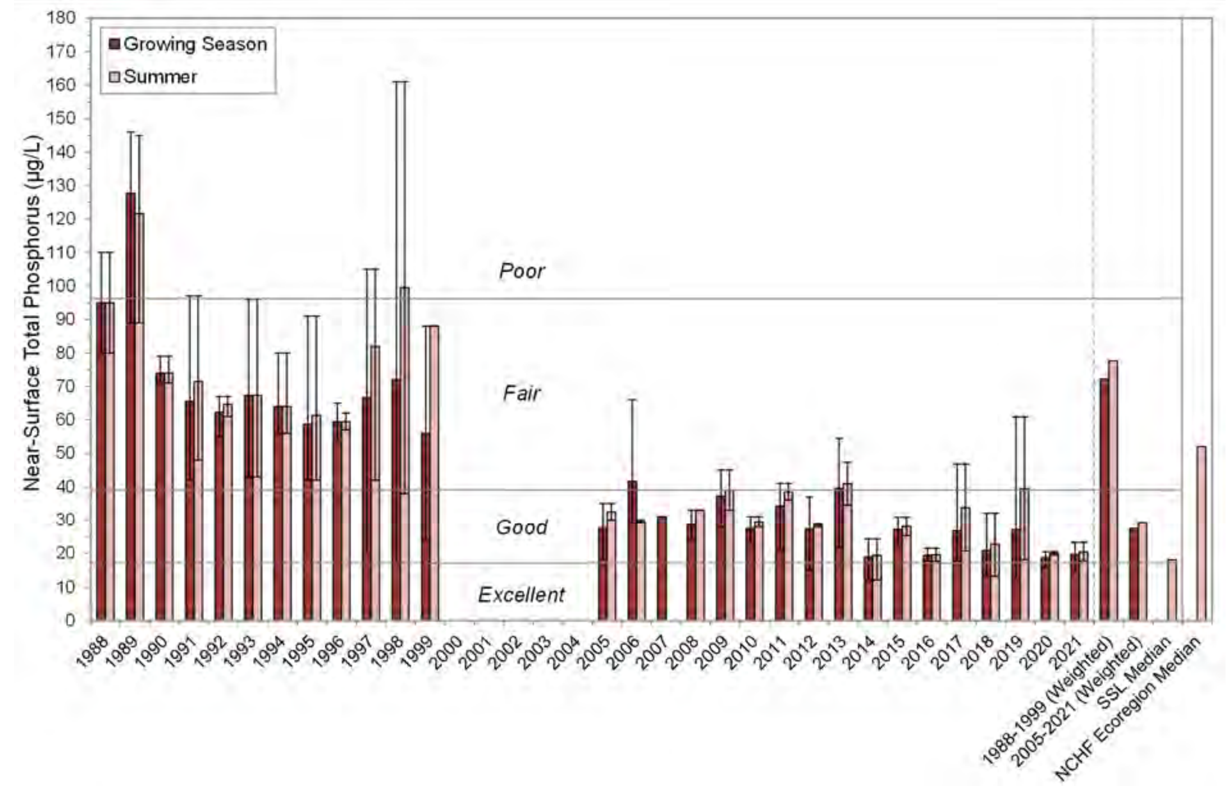


Figure 3.1-4. Silver Lake 2021 average near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for statewide shallow seepage lakes (SSL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Data shows near-surface phosphorus concentrations declined significantly between 1999 and 2005. This represented a shift from a turbid, algae-dominated state to a clear, aquatic plant-dominated state. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Chlorophyll-α

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from Silver Lake over the same time period as TP concentrations (Figure 3.1-5). Like TP, a non-paired T-Test indicates that average growing season chlorophyll-*a* concentrations from 1988-1998 and 2005-2021 are statistically different (p-value < 0.05). The average growing season chlorophyll-*a* concentration from 1988-1998 was 29.3 µg/L compared to 6.6 µg/L from 2005-2021, representing a decrease in concentration of 76%.

Nuisance algal blooms typically occur when chlorophyll-*a* concentrations exceed 20 µg/L, so algal blooms were likely were likely common during the period from 1988-1999. The higher chlorophyll-*a* concentrations during this period provide evidence that the lake was likely in a turbid, algae-dominated state. The average summer concentration during this period was 36.4µg/L, falling into the *fair* category for Wisconsin's shallow seepage lakes and indicating algal blooms and turbid conditions were likely present. The weighted average summer chlorophyll-*a* concentration for 1988-1999 is well above the median concentration for Wisconsin's shallow seepage lakes (4.7 µg/L) and the median concentration for all lake types within the NCHF ecoregion (15.2 µg/L).

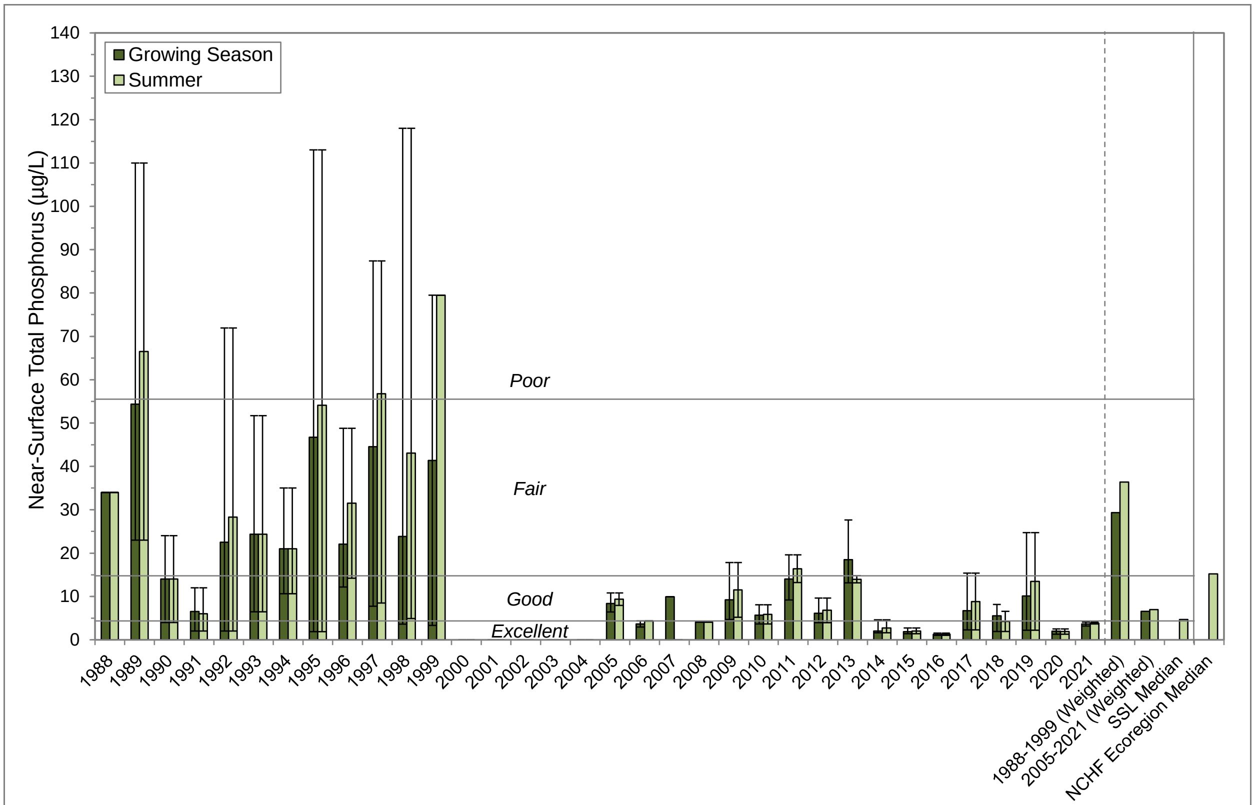


Figure 3.1-5. Silver Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for statewide shallow seepage lakes (SSL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

From 2005-2021, the weighted summer average chlorophyll-*a* concentration was 7.0 µg/L, falling into the *good* category for Wisconsin's shallow seepage lakes and indicative of a clear-water state. The weighted average summer chlorophyll-*a* concentration for 2005-2021 is between the median concentration for Wisconsin's shallow seepage lakes (4.7 µg/L) and the median concentration for all lake types within the NCHF ecoregion (15.2 µg/L). In 2021, the average summer chlorophyll-*a* concentration was 3.9 µg/L, falling below the weighted average for chlorophyll-*a* concentrations between 2005-2021. Given phosphorus is the limiting nutrient in Silver Lake, the decline in chlorophyll-*a* concentrations is attributable to decline in TP concentrations over this period.

To illustrate the relationship between TP and chlorophyll-*a*, summer TP concentrations were plotted against summer chlorophyll-*a* concentrations (Figure 3.1-6). Linear regression analysis shows there is a strong positive relationship between these two parameters (R^2 = 0.62); as TP concentrations increase, chlorophyll-*a* concentrations increase. While chlorophyll-*a* concentrations are positively correlated with TP, they are approximately 10 µg/L lower than predicted based on measured TP concentrations (Figure 3.1-6). This suggests that algal production is also being regulated or suppressed by the abundant aquatic plant growth found in Silver Lake.

In shallow lakes like Silver Lake, abundant aquatic plant growth suppresses algal growth in a few ways. Some aquatic plants, like those that dominate in Silver Lake, obtain most of their nutrients from the water and directly compete for nutrients with free-floating algae. Similarly, the periphyton, or algae which grow directly on aquatic plants, also absorb nutrients from the water, directly competing with free-floating algae. Certain aquatic plant species, like coontail found in Silver Lake, have also been shown to produce allelochemicals, designed to directly suppress algal growth. And finally, aquatic plants provide habitat and refuge for zooplankton which graze on and regulate algal growth.

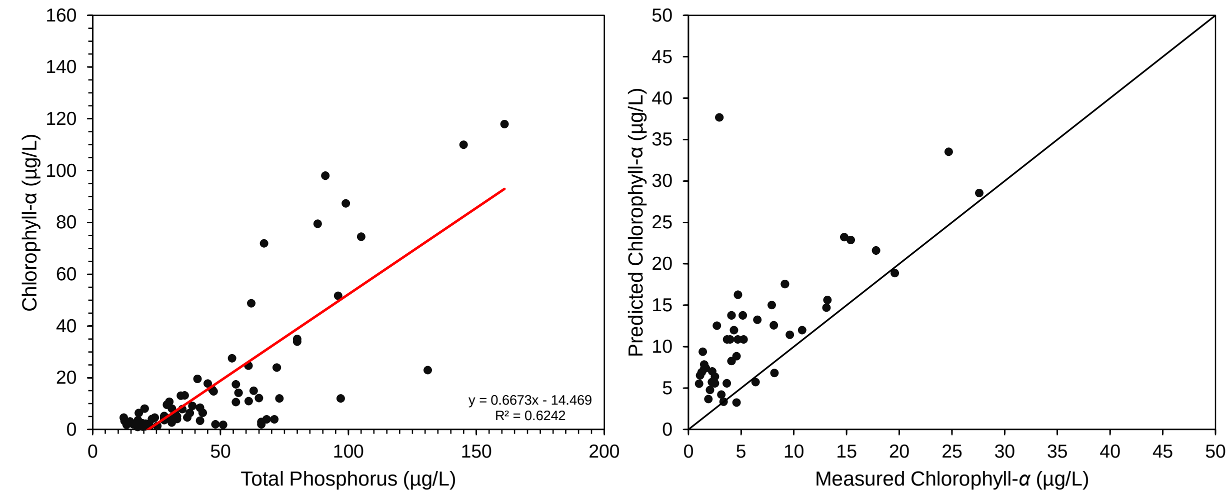


Figure 3.1-6. Silver Lake summer total phosphorus plotted against summer chlorophyll-α concentrations (left) and measured summer chlorophyll-α concentrations plotted against Carlson Trophic State Index-predicted chlorophyll-α concentrations based on measured total phosphorus (right). The chart on the left illustrates the positive relationship between total phosphorus and chlorophyll-α in Silver Lake, while the chart on the right illustrates that chlorophyll-α concentrations are lower than predicted. Concentrations are likely lower than predicted given the lake's abundant aquatic plant community and its effects on suppressing algal growth.

Water Clarity

Water clarity monitoring using Secchi disk depths has been conducted in Silver Lake in 1989-1999, 2001, 2005, 2007-2011, 2014-2015, and 2017-2021 (Figure 3.1-7). A non-paired T-Test shows that average growing season Secchi disk depths from 1988-1998 and 2005-2021 are statistically different (p-value < 0.05). The average growing season Secchi disk depth from 1988-1998 was 5.5 feet compared to 7.3 feet from 2005-2021, representing an increase in Secchi disk depth of 33%. Again, this also indicates that the lake experienced a transition from a more turbid, algae-dominated state to a clear, aquatic plant-dominated state.

The weighted average summer Secchi disk depth from 1988-1999 was 5.2 feet compared to 6.9 feet from 2005-2021, both of which fall into the *good* category for Wisconsin's shallow seepage lakes. A number of more recent Secchi disk readings were recorded as "hitting bottom", and these measurements were not included in the analysis. Because these higher measurements were not included, the average Secchi disk depth from 2005-2021 is likely higher than what is reported here. Silver Lake's average summer Secchi disk depth in 2005-2021 is 6.9 feet which falls between the median depth for all lake types within the SWTP ecoregion (5.3 feet) and median depth for

Wisconsin's shallow seepage lakes (8.5 feet). Secchi disk depths in 2021 were about average for Silver Lake, with growing season and summer mean depths of 7.3 and 6.9 feet, respectively.

Figure 3.1-8 illustrates the relationship between summer chlorophyll-*a* and Secchi disk transparency in Silver Lake. This relationship highlights how rapidly water clarity can decline with small increases in chlorophyll-*a* at lower concentrations. Once chlorophyll-*a* reaches or exceeds 20 µg/L, water clarity remains low between 2-3 feet. Maintaining chlorophyll-*a* concentrations below 20 µg/L will maintain higher water clarity conditions currently present in the lake.

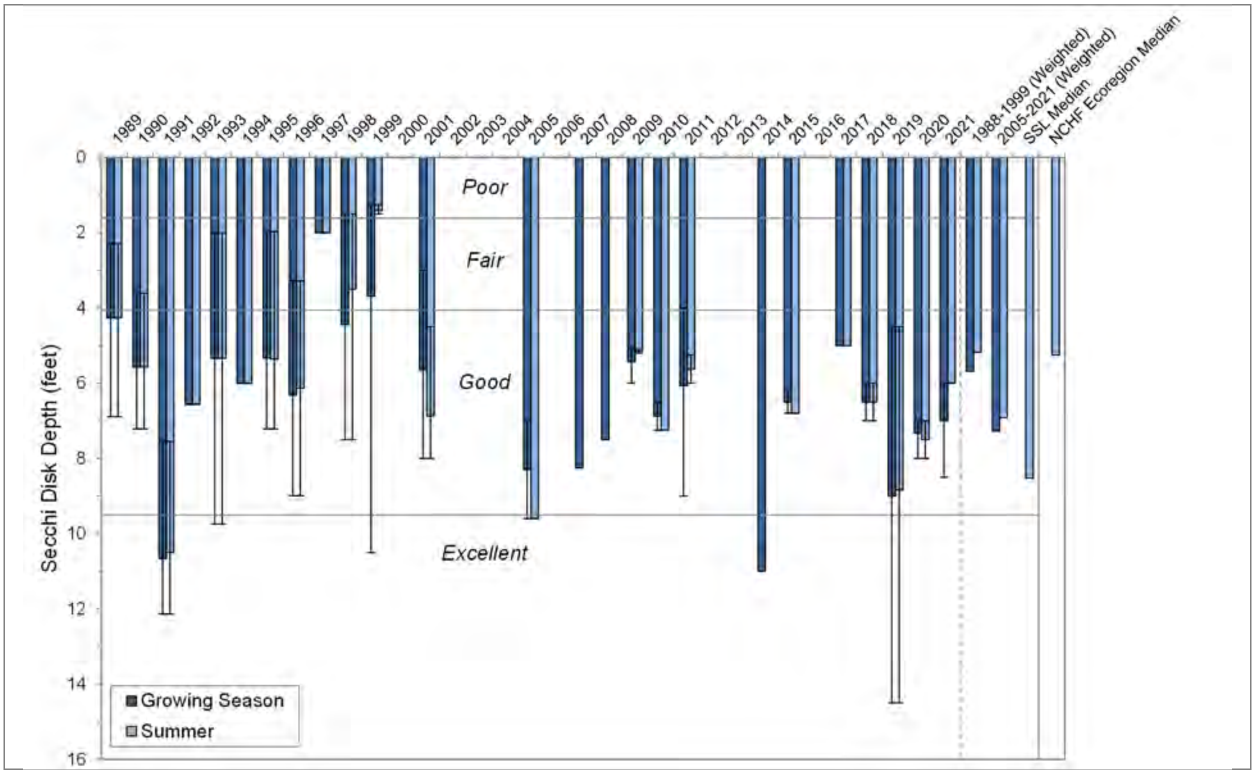


Figure 3.1-7. Silver Lake average annual Secchi disk depth measured at the deep hole sampling location and median Secchi disk depth for state-wide shallow seepage lakes (SSL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

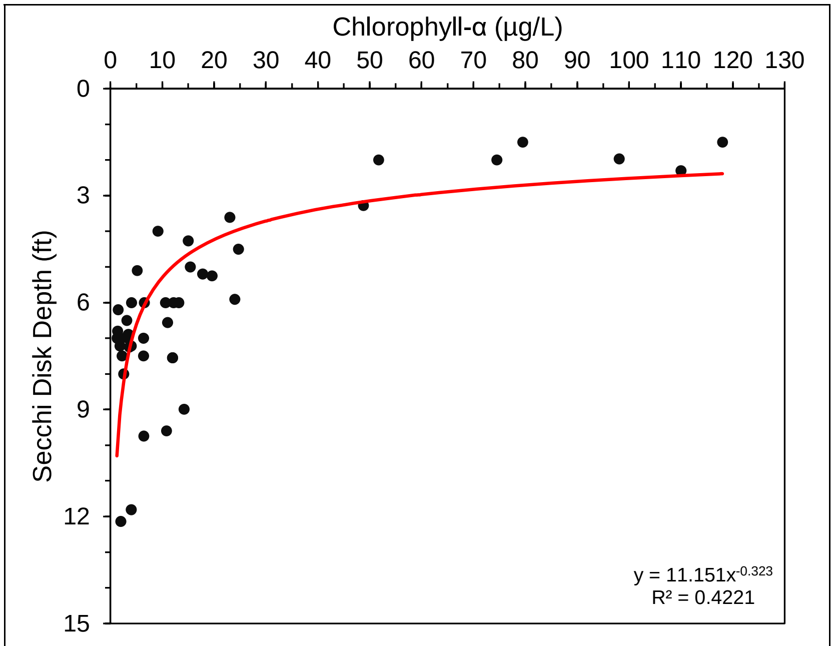


Figure 3.1-8. Silver Lake chlorophyll-α plotted against Secchi disk depth.

Silver Lake Trophic State

The Trophic State Index (TSI) values for Silver Lake were calculated using current and historical summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data (Figure 3.1-9). In general, the best values to use in judging a lake's trophic state are the biological parameters of total phosphorus and chlorophyll-*a* as Secchi disk transparency can be influenced by factors other than algae (e.g., dissolved organic material).

The data from Silver Lake show the lake has fluctuated between eutrophy and hypereutrophy (turbid state) in 1988-1999 to meso-eutrophy (clear-water state) in 2005-2021. Based on the weighted mean from 2005-2021, Silver Lake can currently be classified as being in an meso-eutrophic state, and its productivity is lower when compared to Wisconsin's shallow seepage lakes and all lake types within the NCHF ecoregion. However, most of the lake's productivity has shifted to the lake's aquatic plant community, which is not measured in this analysis. Given the excessive growth of aquatic plants, Silver Lake can be classified as a eutrophic system.

The closer the TSI values for phosphorus, chlorophyll, and Secchi disk are to one another indicates a higher degree of correlation between these parameters. In some years, the TSI value for chlorophyll is lower than that for phosphorus, indicating chlorophyll concentrations are lower than expected given the concentration of phosphorus. As discussed previously, chlorophyll-*a* concentrations are lower than predicted, likely due to the regulating effects of the lake's excessive aquatic plant growth.

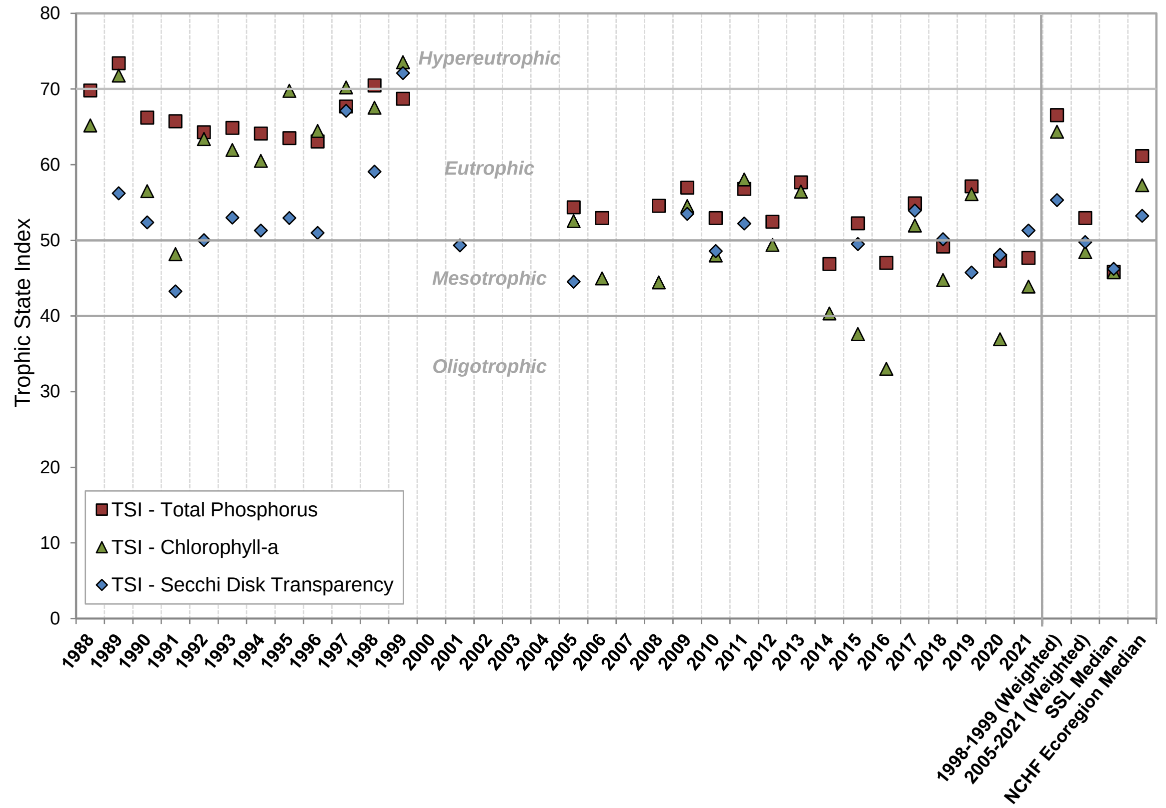


Figure 3.1-9. Silver Lake Trophic State Index (TSI). Values calculated with summer month surface sample data using WDNR PUB-WT-193. Silver Lake weighted average calculated using data from 1988-2021.

Dissolved Oxygen and Temperature in Silver Lake

Dissolved oxygen and temperature were measured twice during the growing season by WDNR staff and once in winter under the ice by Onterra. The WDNR measured temperature and dissolved oxygen at 1.0 and 2.0 meters in late-May and late-September (Table 3.1-1). These measurements indicated sufficient levels of oxygen at these depths. Onterra collected a temperature and dissolved oxygen profile in February of 2022 under the ice (Figure 3.1-10). These data show that the lake maintained sufficient levels of oxygen to support fish in the upper 7.0 feet of water. Insufficient oxygen levels (< 2.0 mg/L) were measured in deeper areas below 7.0 feet.

Table 3.1-1. Silver Lake dissolved oxygen and temperature data collected by the WDNR in 2021.

Date	Depth (Meters)	Dissolved Oxygen (mg/L)	Temperature (°C)
5/26/2021	1	10.4	21.9
	2	10.7	21.7
9/27/2021	1	7.1	17.9
	2	7.7	17.7

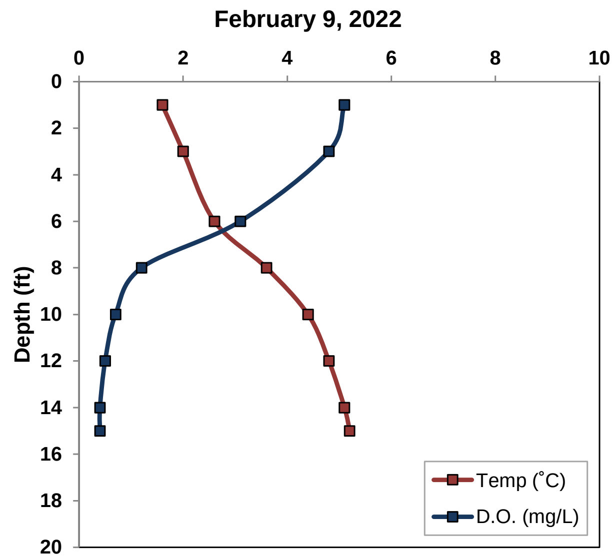


Figure 3.1-10. Silver Lake dissolved oxygen and temperature profiles collected by Onterra.

Additional Water Quality Data Collected at Silver Lake

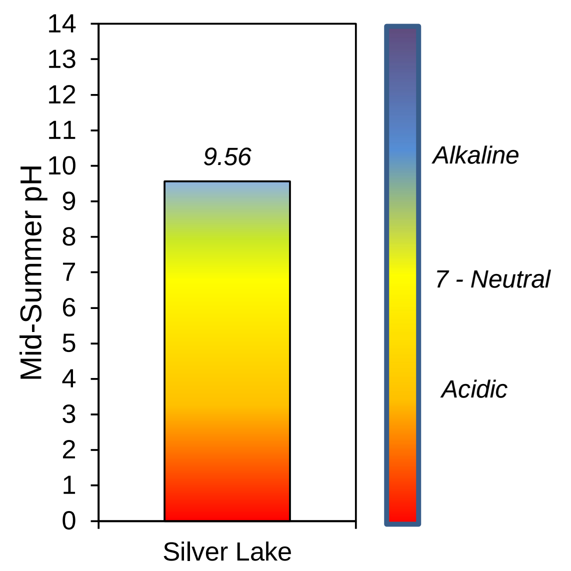


Figure 3.1-11. Silver Lake's 2021 mid-summer near-surface pH values.

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-a were collected as part of the project. These other parameters were collected to increase the understanding of Silver Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH-) and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The mid-summer pH of the water in Silver Lake was found to be alkaline with a value of 9.6 and falls above the normal range for Wisconsin Lakes (Figure 3.1-11). This is likely due to the high abundance of aquatic plants in Silver Lake which remove carbon dioxide from the water during photosynthesis, causing pH to be highly elevated.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO3-) and carbonate (CO3-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite (CaCO3) and/or dolomite (CaMgCO3). A lake's pH is primarily determined by the amount of alkalinity. Rainwater is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Silver Lake in 2021 was measured at 73.4 (mg/L as CaCO3), indicating there is sufficient buffering capacity to resist fluctuations in pH and the lake is not sensitive to acid rain (Figure 3.1-12). The long-term data shows alkalinity has remained relatively consistent between 1989 and 2021. The alkalinity in Silver Lake was measured between 65 and 84mg/L as $CaCO_3$ indicating the lake has a good capacity to resist fluctuations in pH and is not sensitive to acid rain.

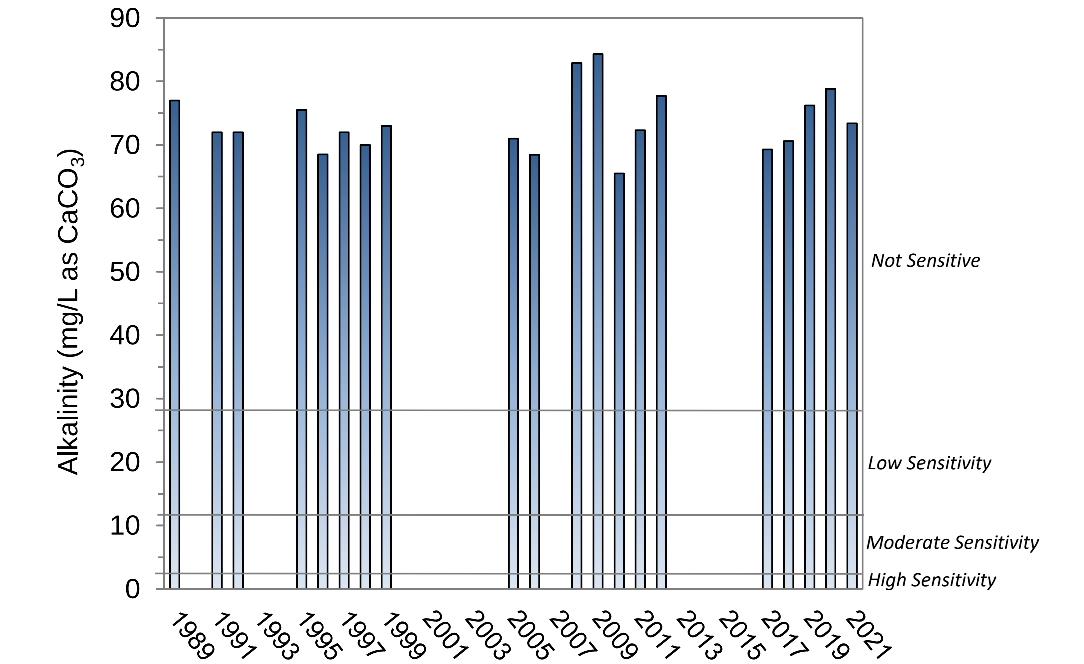


Figure 3.1-12. Silver Lake's 1989-2021 total alkalinity results. Samples collected from the near-surface deep hole sampling locations.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Silver Lake's pH of 9.6 falls slightly above this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Silver Lake in the past was found to be stable over the period from 1989-1999 between 14.0 and 16.0 mg/L, respectively, indicating the lake has a low susceptibility to zebra mussel establishment (Figure 3.1-13).

As previously discussed, a measure of water clarity once all of the suspended material (i.e., phytoplankton and sediments) have been removed, is termed true color, and measures how the clarity of the water is influenced by dissolved components. True color was measured at 20 SU in Silver Lake in 2021, indicating the water is slightly to lightly tea-colored (Figure 3.1-14). The concentration of these humic substances and resulting water clarity will fluctuate with changes in precipitation.

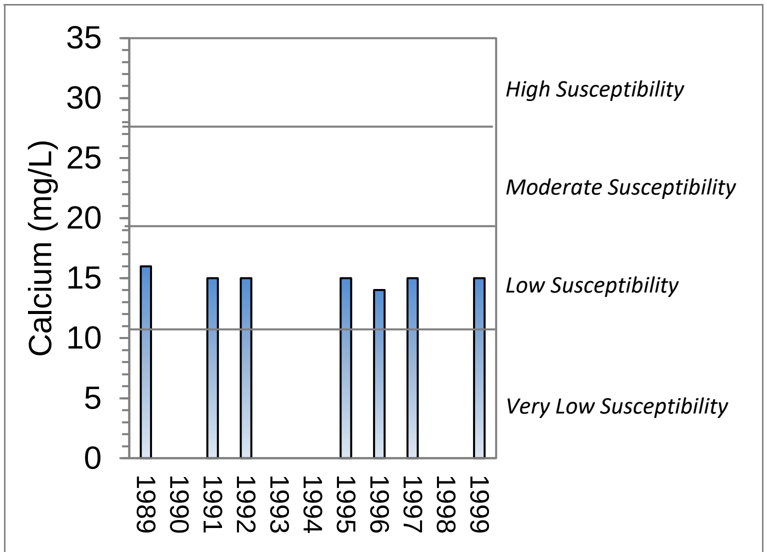


Figure 3.1-13. Silver Lake 1989-1999 calcium concentration data. Samples collected from the near-surface deep hole sampling locations.

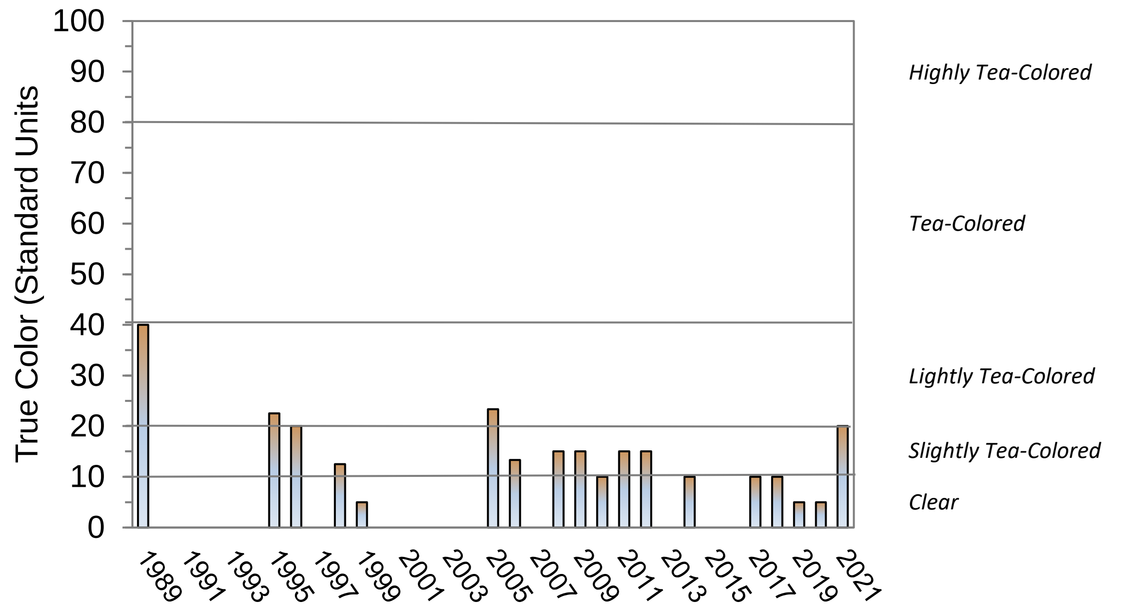


Figure 3.1-14. Silver Lake's True Color data. Samples collected from the near-surface deep hole sampling locations.

Chloride levels in Silver Lake have been monitored periodically from 1989 to 2018 (Figure 3.1-15). Chloride occurs naturally in Wisconsin's waters at low levels (2-3 mg/L). Higher levels of chloride or trends in increasing chloride levels have been associated with the application of chloride-based road salts (typically sodium chloride) within the lake's watershed (Dugan 2017). Studies have shown that ecological impacts are often observed when chloride concentrations increase into the 100-1000s mg/L (Dugan 2017), and the Canadian government considers concentrations within this range to be chronically toxic (exposure to elevated concentrations over extended time periods) (Evans M. 2001).

Chloride concentrations in Silver Lake from 1989 to 2018 ranged from 10-12 mg/L, indicating chloride concentrations are slightly above natural background levels at this time. The elevated chloride levels are an indication that road salt application and/or fertilizer applications within the watershed are draining into the lake. While concentrations are not at levels which are considered to have significant effects on the lake's ecology, chloride should continue to be monitored to determine if concentrations are increasing and if any mitigation efforts can be taken to reduce chloride runoff.

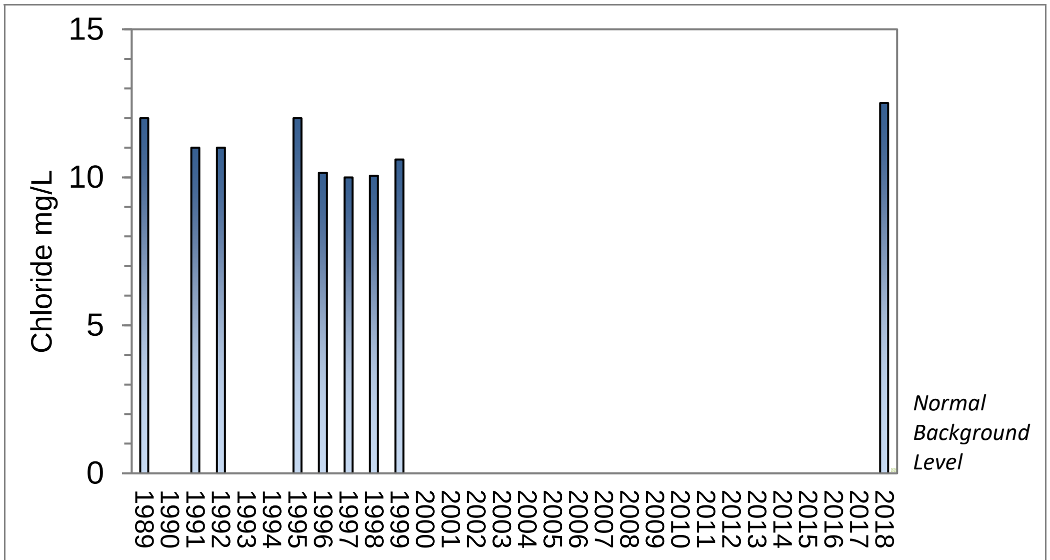


Figure 3.1-15. Silver Lake's Chloride data. Samples collected from the near-surface deep hole sampling locations.

Stakeholder Survey Responses to Silver Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.1-16 and 3.1-17 display the responses of members of Silver Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Silver Lake.

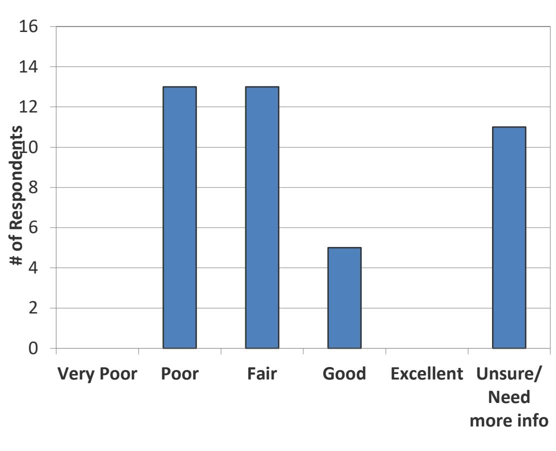


Figure 3.1-16. Stakeholder survey response Question #17. How would you describe the current water quality of Silver Lake?

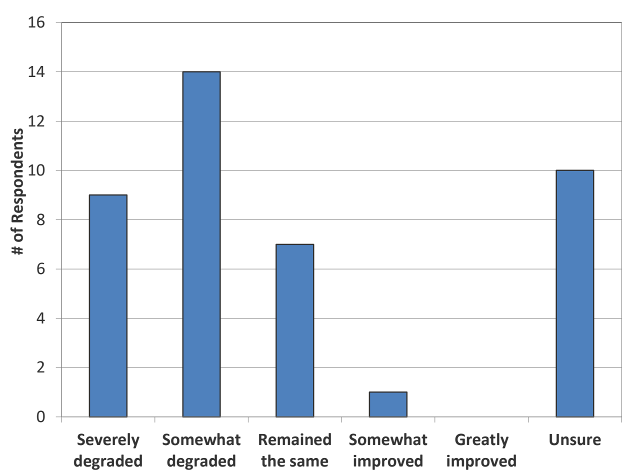


Figure 3.1-17. Stakeholder survey response Question #18. How as the water quality changed in Silver Lake since you first visited the lake?

Approximately 62% of stakeholders believe the current water quality condition of Silver Lake is either poor or fair. When asked what is the single most important aspect when considering water quality, 50% of respondents indicated that aquatic plants were the most important (Figure 3.1-18). While essential to the aquatic ecosystem, the level of aquatic plant growth is not taken into account when assessing a lake's water quality. Phosphorus, chlorophyll, and Secchi disk data all indicate the lake's water quality is overall good, the excessive aquatic plant growth is likely the reason why 62% of respondents indicated the lake's current water quality was fair or poor.

When asked about how Silver Lake's water quality has changed, 56% of responses believed water quality had either somewhat degraded or severely degraded. It is likely that the significant increase in aquatic plant abundance in recent years influenced the responses to this question.

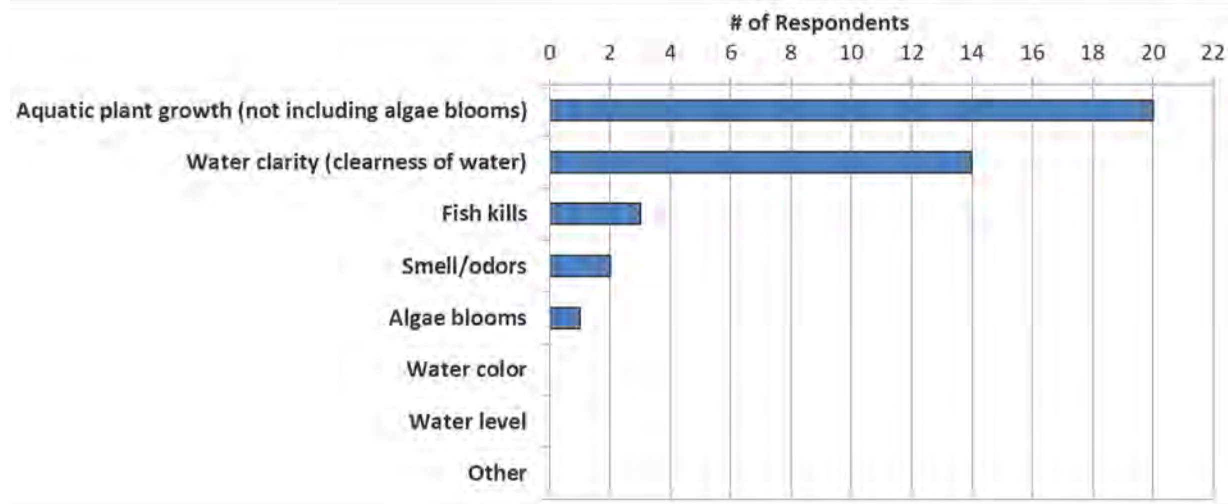


Figure 3.1-18. Stakeholder survey response Question #19. Which of the following answers is the single most important aspect when considering water quality?

3.2 Watershed Assessment

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake: 1) the land cover (land use) within the watershed and 2) the size of the watershed. The type of land cover and the amount of that land cover that exists in the watershed is largely going to determine the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Areas within a lake's watershed that are naturally vegetated (e.g., forests, grasslands, and wetlands) strongly influence the way water behaves on the land surface after it falls as precipitation or is released by the melting of snow (Silk & Ciruna, 2005).

Runoff is slowed down in areas with denser vegetation and increases the time it takes for precipitation from a storm event to reach the lake. This allows more water to soak into the soil and reduces the potential for flooding. Intact wetlands within a lake's watershed have been likened to the "kidneys of the landscape" as they filter out nutrients, sediments, and other pollutants from water which passes through them (Silk & Ciruna, 2005). The water quality within a lake is largely a reflection of the health of its watershed, and maintaining natural land cover within a lake's watershed is essential for maintaining good water quality.

Among the largest threats to a lake's water quality is the conversion of natural areas to agriculture and urban development. Conversion of natural areas to agriculture disrupts the hydrologic regime and increases surface runoff due to increased soil compaction and reduced water infiltration. Wetlands which were drained and converted to farmland were shown to increase runoff by 200-400% (Silk & Ciruna, 2005). Agriculture accounts for 60% of the pollutants in lakes and rivers in the United States due to increased runoff in combination with the application of fertilizers, pesticides, and manure.

Similar to agriculture, urban development can significantly alter the hydrologic regime within a watershed, primarily through the installation of impervious surfaces (e.g., roads, driveways, roof-tops) which decrease water infiltration and increase runoff. As impervious surface cover increases, the time it takes water from a storm event to reach the lake decreases. With the increase in water velocity and volume entering the water body, nutrient and sediment input also increase, degrading water quality. Nutrient input can also increase from urban areas as the result of fertilizer application, wastewater treatment facilities, and other industrial activities.

In addition to land cover within the watershed, the size of the watershed relative to the water volume within the lake also influences water quality. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drain to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load. In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems, the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grasslands or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g., reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

In systems with high WS:LA ratios, like those 10-15:1 or higher, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of primary production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see measurable changes in primary production. Both of these situations occur frequently in impoundments.

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper lake with a greater volume can dilute more phosphorus within its waters than a less voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (a residence time of years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time and lead to a problem such as internal nutrient loading. On the contrary, a lake with a higher flushing rate (low residence time of days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A lake's **flushing rate** is simply a determination of the time required for the lake's water volume to be completely exchanged. **Residence time** describes how long a volume of water remains in the lake and is expressed in days, months, or years. The parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

Watershed Modeling

A reliable and cost-efficient method of creating a general picture of a watershed's effect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface.

WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

Silver Lake Watershed Assessment

Silver Lake's watershed is relatively small, encompassing just 336 acres (0.5 square miles) (Figure 3.2-1 and Map 2). The lake is drained via an intermittent outlet through a culvert on the lake's southeast side. The 2020 aerial imagery indicate that 86 acres (26%) of Silver Lake's watershed is comprised of pasture/grassland/rural open space (urban-pervious), 79 acres (23%) is comprised of row crop agriculture, 74 acres (22%) is comprised of the lake's surface, 73 acres (22%) is comprised of upland forests, 21 acres (6%) is comprised of rural residential areas (urban-impervious), and 3 acres (1%) is comprised of non-forested wetlands (Figure 3.2-1 and Map 2).

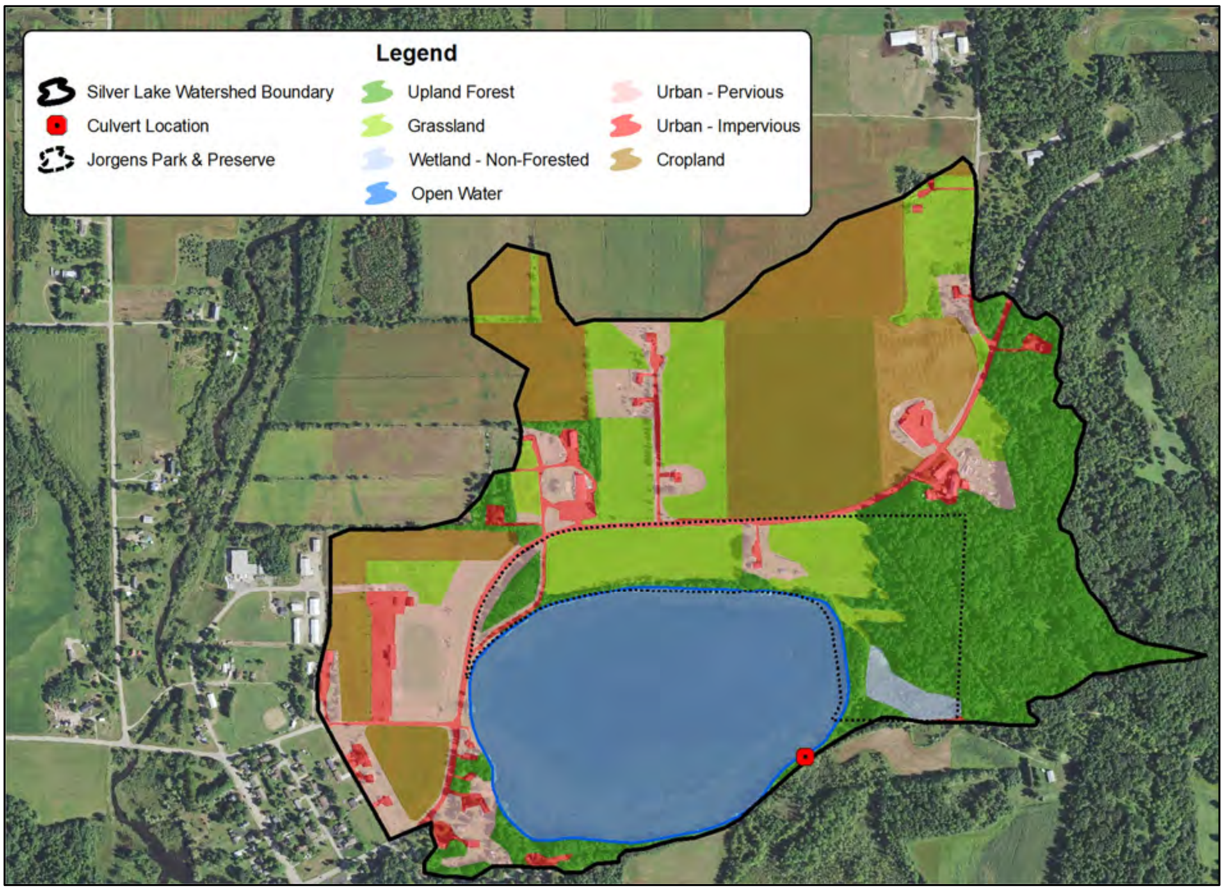


Figure 3.2-1. Silver Lake watershed and land cover types. Based upon NAIP 2020 aerial imagery.

Using the land cover types and their acreages within Silver Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Silver Lake from its watershed. The WiLMS model estimated that approximately 121 pounds of phosphorus are delivered to Silver Lake from its watershed on an annual basis (Figure 3.2-2). The model estimates that 58% (71 pounds) originates from row crop agriculture, 18% (22 pounds) originates from pasture/grasslands/urban-impervious areas, 16% (20 pounds) from atmospheric deposition onto the lake's surface, 6% (7 pounds) from upland forests, and 2% (2 pounds) from rural residential (urban-impervious) areas (Figure 3.2-2).

Based on this estimated annual loading, WiLMS predicted Silver Lake would have a mean growing season total phosphorus concentration of 60 µg/L, approximately 120% higher than the measured mean concentration measured from 2005-2021 of 27 µg/L.

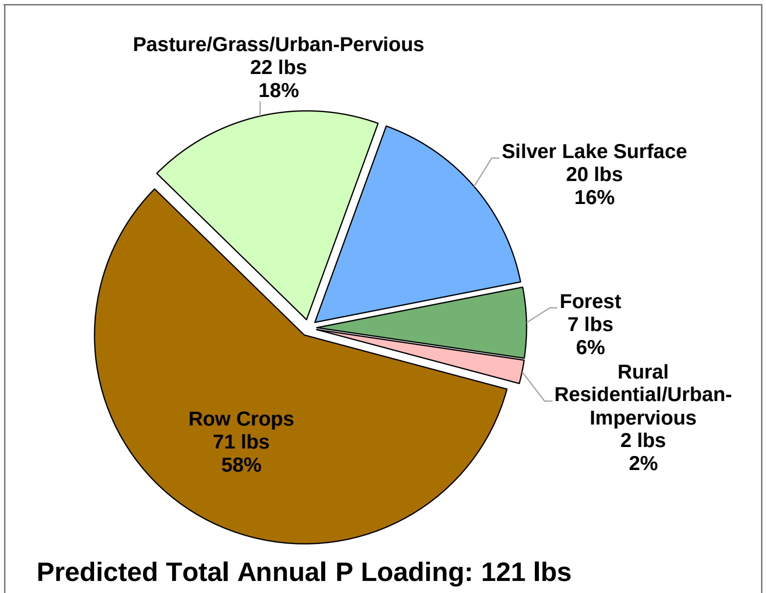


Figure 3.2-2. Silver Lake WiLMS model estimated annual watershed phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

As is discussed in the Water Quality Section (Section 3.1), it is believed Silver Lake transitioned from a turbid, algae-dominated state to a clear, aquatic-plant dominated state in the early 2000s. This shift resulted in more nutrients being allocated to and stored in the aquatic plant community, reducing nutrients in the water column where they would be measured by water quality sampling. Measured phosphorus concentrations in the lake are likely lower than the concentration predicted by WiLMS for this reason. In addition, the efforts that have been taken in the watershed to reduce nutrient runoff have also likely contributed to reduced phosphorus loading. The model provides an estimate of the potential amount of phosphorus that could originate from Silver Lake's watershed; however, it is likely lower than this based on the mitigation efforts that have been taken within the watershed. The predicted concentration of 60 µg/L is closer to the concentration of 72 µg/L measured in the period from 1988-1999 when the lake was in a turbid state. The lake's current aquatic plant community is an indicator that the lake is still receiving sufficient levels of nutrients to create excessive levels of aquatic plant growth.

The WiLMS model estimated that Silver Lake has a water residence time of approximately 1.2 years. In other words, on average, the water in Silver Lake is completely replaced once every 1.2 years. This is a relatively long water residence time, meaning that pollutants entering the lake will not leave the system very quickly and may accumulate over time. Even if nutrient loading from the watershed is minimized, it may take decades for nutrient levels within the lake decline, as they are likely being recycled within the lake's aquatic plant community.

3.3 Paleoecology

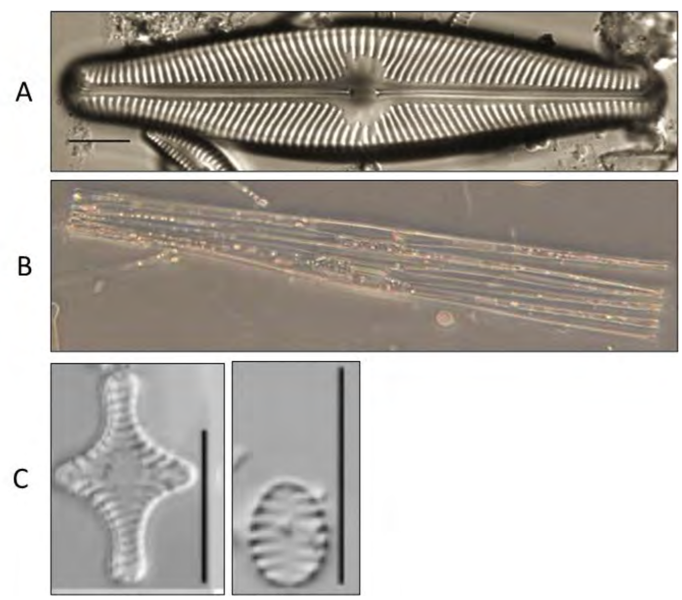
Primer on Paleoecology and Interpretation

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases, there is little or no reliable long-term data. They also want to understand when the changes occurred and what the lake was like before the transformations began. Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution.

These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants. The diatom community are especially useful in reconstructing a lake's ecological history as they are highly resistant to degradation and are ecologically diverse. Diatom species have unique features as shown in Photograph 3.3-1, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to objects such as aquatic plants or the lake bottom.

The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. By collecting an intact sediment core, sectioning it off into layers, and utilizing all of the information described above, paleoecologists can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

One often used paleoecological technique is collecting and analyzing top/bottom cores. The top/bottom core only analyzes the top (usually 1 cm) and bottom sections. The top section represents present day conditions and the bottom section is hoped to represent pre-settlement conditions by having been deposited at least 100 years ago. While it is not possible to determine the actual date of deposition of bottom samples, a determination of the radionuclide lead-210 estimates if the sample was deposited at least 100 years ago. The primary analysis conducted on this type of core is the diatom community leading to an understanding of past nutrients, pH, and general macrophyte coverage.



Photograph 3.3-1. Photomicrographs of the diatoms commonly found in the sediment core from Silver Lake. The top diatom (A) *Navicula aurora* was common in the bottom sample, grows on macrophytes, and indicates low to moderate nutrient levels. The middle diatom, *Fragilaria crotonensis* (B) floats in the open water and indicates moderate nutrient levels. *Staurosira construens* (C left) and *S. pinnata* (C right) are typically found growing on macrophytes and lake sediments. The top photo is from Bahls, L. (2011).

Silver Lake Paleoecological Results

A sediment core was extracted from the deep area of Silver Lake on September 14, 2021 (Photograph 3.3-2) to determine how the water quality and lake ecology has changed during the last century. The total length of the core was 36 cm. The core was brown throughout its length with plant fragments present throughout the entire core although there appeared to be a greater density of fragments in the bottom few centimeters. The top 1 cm was kept for diatom analysis as it is assumed to represent present day water quality conditions. The section 33-35 cm was kept for analysis of the diatom community and radiochemical analysis. It is assumed that this section represents conditions before the arrival Euro-American settlers in the nineteenth century but the radiochemical analysis will confirm this.

Multivariate Statistical Analysis

In order to make a comparison of environmental conditions between the bottom and top samples of the core from Silver Lake, an exploratory detrended correspondence analysis (DCA) was performed (Braak C.J.F. 2012). The DCA analysis has been done on many WI lakes to examine the similarities of the diatom communities between the top and bottom samples of the same lake.

Photograph 3.3-2. Photo of sediment core collected from Silver Lake.

The results revealed two clear axes of variation in the diatom data, with 32% and 21% of the variance explained by axis 1 and axis 2, respectively (Figure 3.3-1). Sites with similar sample scores occur in close proximity reflecting similar diatom composition. The arrows symbolize the trend from the bottom to the top samples.

The amount of change in Silver Lake is more than seen in nearly all of the lakes. While it is not possible to determine what environmental factors are ordering the diatom community in Silver Lake the changes are largely along the second axis.

While it is not possible to determine which were the most important environmental variables ordering the diatom communities, it is likely that the second axis reflects the abundance of benthic *Fragilaria* (Photograph 3.3-1B). These diatoms are often associated with macrophytes and floating algal mats. In Silver Lake, these diatoms were mostly found in the top sample. Since there were fragments of macrophytes throughout the core, the dominance of benthic *Fragilaria* at the top of the core likely signals a large increase in floating algal mats in recent times.

Diatom Community Changes

The diatom community in both samples was dominated by diatoms that grow attached to macrophytes and substrates such as floating algal mats. The reduction in the amount of planktonic diatoms in the top sample compared with the bottom sample suggests an increase in macrophytes and possibly a decline in water clarity. In the bottom sample *Navicula aurora* (Photograph 3.3-1A) and *Navicula radiofallax* were common. These taxa grow attached to macrophytes and other substrates and are usually found in relatively shallow lakes with low to moderate phosphorus levels. These large Navicula are replaced in the top sample by much smaller benthic *Fragilaria* (Photograph 3.3-1C, Figure 3.3-2). *Fragilaria capucina* was absent in the bottom sample but was common in the top sample (Figure 3.3-2). This diatom, along with benthic *Fragilaria*, is commonly associated with floating algal mats. These mats occur in lakes with elevated phosphorus concentrations.

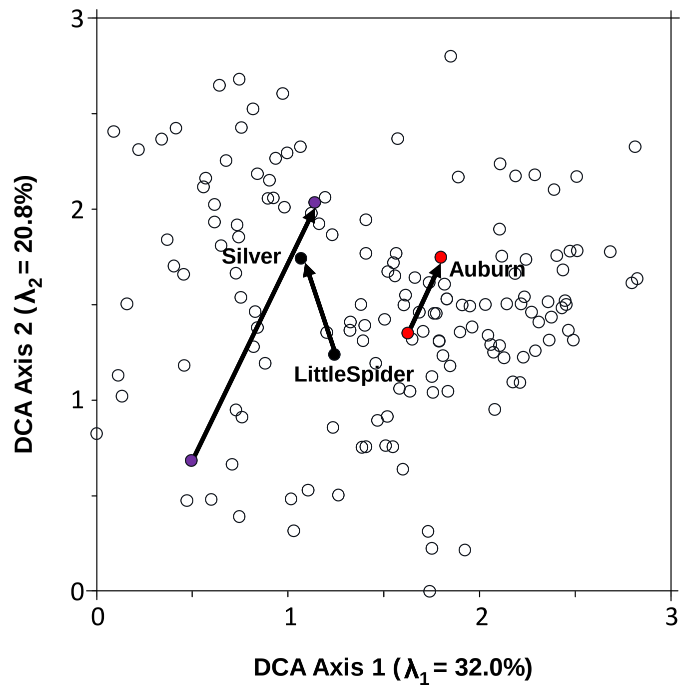


Figure 3.3-1. DCA plot of top/bottom samples from Silver Lake. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. Silver Lake has changed only a moderate amount since the arrival of Euro-American settlers over 100 years ago.

Lake Diatom Condition Index

The Lake Diatom Condition Index (LDCI) was developed by Dr. Jan Stevenson, Michigan State University (Stevenson, Zalack and Wolin 2013). The LDCI uses diatoms to assess the ecological condition of lakes. The LDCI ranges from 0 to 100 with a higher score representing better ecological integrity. The index is weighted towards nutrients, but also incorporates ecological integrity by examining species diversity where higher diversity indicates better ecological condition. The index also incorporates taxa that are commonly found in undisturbed and disturbed conditions. The breakpoints (poor, fair, good) were determined by the 25th and 5th percentiles for reference lakes in the Upper Midwest. The LDCI was used in the 2007 National Lakes Assessment to determine the biological integrity of the nation's lakes.

The LDCI analysis indicates the Silver Lake's biotic condition historically was good but it has declined to poor condition (Figure 3.3-3). The decline in the biotic index is primarily the result of diatoms that are associated with floating algal mats.

Inference models

Diatom assemblages have been used as indicators of trophic changes in a qualitative way (Bradbury 1975), (Carney 1982), (Anderson, Rippey and Stevenson 1990) but quantitative analytical methods exist. Ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration (Birks et al. 1990). Ecological preferences of diatom species are determined by relating modern limnological variables to surface sediment diatom assemblages. The species-environment relationships are then used to infer environmental conditions from fossil diatom assemblages found in the sediment core.

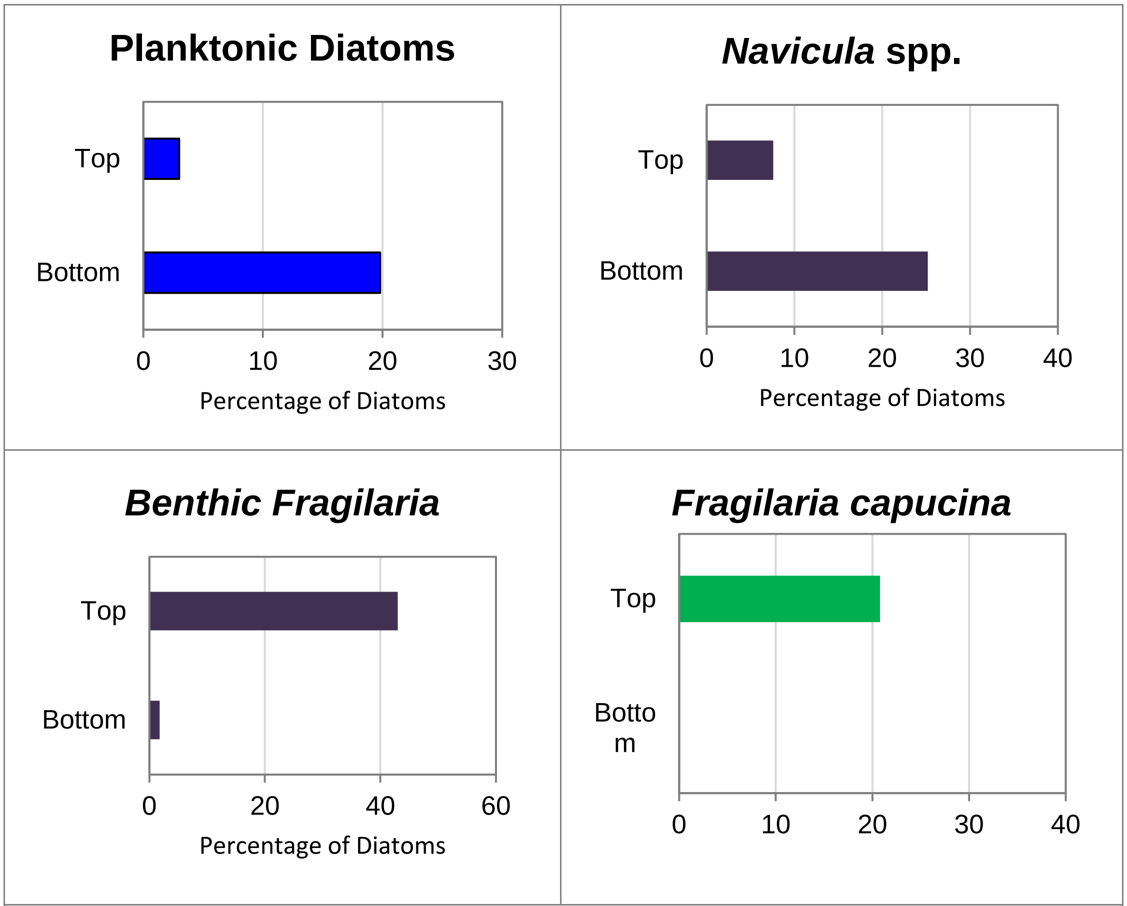


Figure 3.3-2. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Silver Lake. The top and bottom samples were dominated by diatoms that grow on the lake sediments or attached to substrates such as macrophytes (nonplanktonic diatoms). The increase in benthic *Fragilaria* and *F. capucina* in the top sample suggests an increase in nutrients and floating algal mats.

Weighted averaging calibration and reconstruction (Birks et al. 1990) were used to infer historical water column summer average phosphorus concentration in the sediment cores. A training set that consisted of 60 stratified lakes was used. Training set species and environmental data were analyzed using weighted average regression software (Juggins 2014).

The diatom inferred phosphorus concentration in the top sample is 28 µg/L which is similar the same as the long term mean summer concentration during the last fifteen years of 30 µg/L. This suggests that the model accurately represents the phosphorus concentrations in the lake. Phosphorus concentrations at the present time are almost double as what they were historically at 16 µg/L (Table 3.3-1). The diatoms in the top sample do not represent phosphorus conditions in the lake during the latter part of the twentieth century. At that time there was a farm on the hill on the northeastern part of the lake which likely contributed a significant amount of nutrients. The mean summer phosphorus concentration for the period 1988-1999 was 77 µg/L.

In summary, Silver Lake historically had very good water quality and contained a healthy macrophyte community. Historically the lake's biotic index was in the good category. At the present time the biotic index is poor, largely as a result of higher phosphorus concentrations. At the present time the diatom community is dominated by taxa that are associated with floating algal mats.

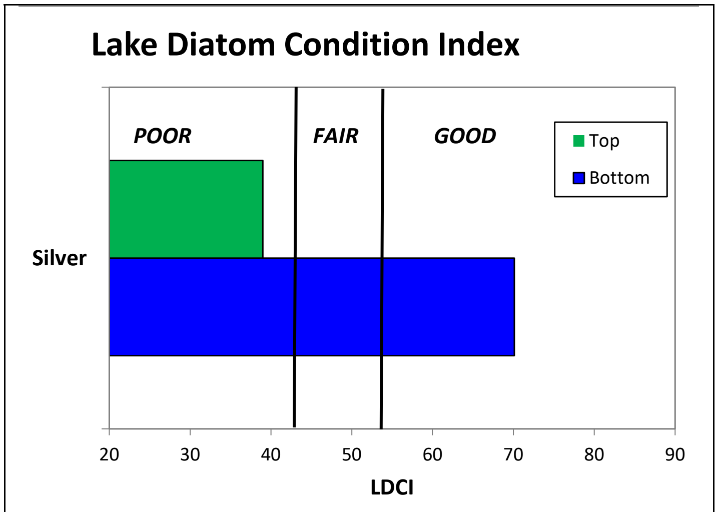


Figure 3.3-3. The Lake Diatom Condition Index (LDCI) for Silver Lake. The biotic integrity was fair historically and remains so at the present time.

Table 3.3-1. Diatom inferred phosphorus concentrations in core samples (μg/L).

Lakes	**Phosphorus**
Silver Top	28
Silver Bottom	16

3.4 Shoreland Condition

Lake Shoreland Zone and its Importance

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet inland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) effects on the lake is important in maintaining the quality of the lake's water and habitat.

The intrinsic value of natural shorelands is found in numerous forms. Vegetated shorelands prevent polluted runoff from entering lakes by filtering this water or allowing it to slow to the point where particulates settle. The roots of shoreland plants stabilize the soil, thereby preventing shoreland erosion. Shorelands also provide habitat for both aquatic and terrestrial animal species. Many species rely on natural shorelands for all or part of their life cycle as a source of food, cover from predators, and as a place to raise their young. Shorelands and the nearby shallow waters serve as spawning grounds for fish and nesting sites for birds. Thus, both the removal of vegetation and the inclusion of development reduces many forms of habitat for wildlife.

Some forms of development may provide habitat for less than desirable species. Disturbed areas are often overtaken by invasive species, which are sometimes termed "pioneer species" for this reason. Some waterfowl, such as geese, prefer to linger upon open lawns near waterbodies because of the lack of cover for potential predators. The presence of geese on a lake resident's beach may not be an issue; however, the feces the geese leave are unsightly and pose a health risk. Geese feces may become a source of fecal coliforms as well as flatworms that can lead to swimmers' itch. Development such as rip rap or masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails; this is not desirable for lakes that experience problems with swimmers' itch, as the flatworms that cause this skin reaction utilize snails as a secondary host after waterfowl.

In the end, natural shorelines provide many ecological and other benefits. Between the abundant wildlife, the lush vegetation, and the presence of native flowers, shorelands also provide natural scenic beauty and a sense of tranquility for humans.

Shoreland Zone Regulations

Wisconsin has numerous regulations in place at the state level which aim to enhance and protect shorelands. Additionally, counties, townships and other municipalities have developed their own (often more comprehensive or stronger) policies. At the state level, the following shoreland regulations exist:

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. Revised in February of 2010, and again in October of 2014, the finalized NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below.

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed 35 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: In general, the amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit, up to 30% for residential land use. Exceptions to this limit do exist if a county has designated highly-developed areas, so it is recommended to consult county-specific zoning regulations for this standard.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed, but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet. Other specifications must be met as well, and local zoning regulations should be referenced.

Mitigation requirements: Language in NR-115 specifies mitigation techniques that may be incorporated on a property to offset the impacts of impervious surface, replacement of nonconforming structure, or other development projects. Practices such as buffer restorations along the shoreland zone, rain gardens, removal of fire pits, and beaches all may be acceptable mitigation methods. Mitigation requirements are county-specific and any such projects should be discussed with local zoning to determine the requirements.

Wisconsin Act 31

While not directly aimed at regulating shoreland practices, the State of Wisconsin passed Wisconsin Act 31 in 2009 in an effort to minimize watercraft impacts upon shorelines. This act prohibits a person from operating a watercraft (other than personal watercraft) at a speed in excess of slow-no-wake speed within 100 feet of a pier, raft, buoyed area or the shoreline of a lake. Additionally, personal watercraft must abide by slow-no-wake speeds while within 200 feet of these same areas. Act 31 was put into place to reduce wave action upon the sensitive shoreland zone of a lake. The legislation does state that pickup and drop off areas marked with regulatory markers and that are open to personal watercraft operators and motorboats engaged in waterskiing/a similar activity may be exempt from this distance restriction. Additionally, a city, village, town, public inland lake protection and rehabilitation district or town sanitary district may provide an exemption from the 100-foot requirement or may substitute a lesser number of feet.

Shoreland Research

Studies conducted on nutrient runoff from Wisconsin lake shorelands have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreland development on nutrient (phosphorus and nitrogen) export to these lakes (Graczyk et al. 2003). During the study period, water samples were collected from surface runoff and ground water and analyzed for nutrients. These studies were conducted on several developed (lawn covered) and undeveloped (undisturbed forest) areas on each lake. The study found that nutrient yields were greater from lawns than from forested catchments, but also that runoff water volumes were the most important factor in determining whether lawns or wooded catchments contributed more nutrients to the lake. Groundwater inputs to the lake were found to be significant in terms of water flow and nutrient input. Nitrate plus nitrite nitrogen and total phosphorus yields to the ground-water system from a lawn catchment were three or sometimes four times greater than those from wooded catchments.

A separate USGS study was conducted on the Lauderdale Lakes in southern Wisconsin, looking at nutrient runoff from different types of developed shorelands – regular fertilizer application lawns (fertilizer with phosphorus), non-phosphorus fertilizer application sites, and unfertilized sites (Garn 2002). One of the important findings stemming from this study was that the amount of dissolved phosphorus coming off of regular fertilizer application lawns was twice that of lawns with non-phosphorus or no fertilizer. Dissolved phosphorus is a form in which the phosphorus molecule is not bound to a particle of any kind; in this respect, it is readily available to algae. Therefore, these studies show us that it is a developed shoreland that is continuously maintained in an unnatural manner (receiving phosphorus rich fertilizer) that impacts lakes the greatest. This understanding led former Governor Jim Doyle into passing the Wisconsin Zero-Phosphorus Fertilizer Law (Wis Statue 94.643), which restricts the use, sale, and display of lawn and turf fertilizer which contains phosphorus. Certain exceptions apply, but after April 1 2010, use of this type of fertilizer is prohibited on lawns and turf in Wisconsin. The goal of this action is to reduce the impact of developed lawns, and is particularly helpful to developed lawns situated near Wisconsin waterbodies.

Shorelands provide much in terms of nutrient retention and mitigation, but also play an important role in wildlife habitat. Woodford and Meyer found that green frog density was negatively correlated with development density in Wisconsin lakes (Woodford and Meyer 2003). As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay, Gillum and Meyer 2002). And studies on shoreland development and fish nests show that undeveloped shorelands are preferred as well. In a study conducted on three Minnesota lakes, researchers found that only 74 of 852 black crappie nests were found near shorelines that had any type of dwelling on it (Reed 2001). The remaining nests were all located along undeveloped shoreland.

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means. Coarse woody habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which is important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

Photograph 3.4-1. Example of coarse woody habitat in a lake.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin, Willis and St. Stauver 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. 2005 found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

With development of a lake's shoreland zone, much of the coarse woody habitat that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800's), the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions due to logging practices. However, with changes in the logging industry and increasing development along lake shorelands, coarse woody habitat has decreased substantially. Shoreland residents are removing woody debris to improve aesthetics or for recreational opportunities such as boating, swimming, and ironically, fishing.

National Lakes Assessment

Unfortunately, along with Wisconsin's lakes, waterbodies within the entire United States have shown to have increasing amounts of developed shorelands. The National Lakes Assessment (NLA) is an Environmental Protection Agency sponsored assessment that has successfully pooled together resource managers from all 50 U.S. states in an effort to assess waterbodies, both natural and man-made, from each state. Through this collaborative effort, over 1,000 lakes were sampled in 2007, pooling together the first statistical analysis of the nation's lakes and reservoirs.

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nation's lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009).

Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003) (Radomski and Goeman 2001) (Elias and Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photograph 3.4-2. Example of a biolog restoration site.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality (Figure 3.4-1).

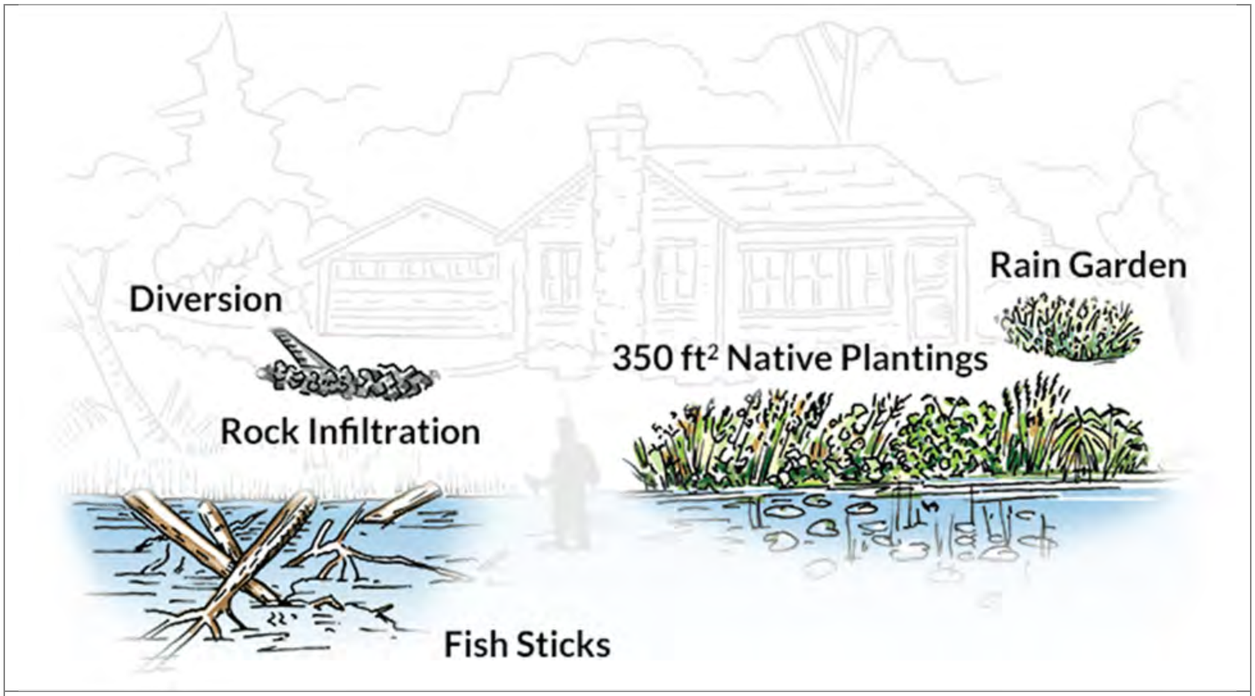


Figure 3.4-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- Rain Gardens: This upland best practice consists of a landscaped and vegetated shallow depression aimed at capturing water runoff and allowing it to infiltrate into the soil.
- Rock Infiltration: This upland best practice is an excavated pit or trench, filled with rock, that encourages water to infiltrate into the soil. These practices are strategically placed at along a roof line or the downward sloping area of a driveway.
- Diversion: This best practice can occur in the transition or upland zone. These practices use berms, trenches, and/or treated lumber to redirect water that would otherwise move downhill into a lake. Water diversions may direct water into a Rock Infiltration or Rain Garden to provide the greatest reductions in runoff volumes.
- Native Plantings: This best practice aims to installing native plants within at least 350 square-foot shoreland transition area. This will slow runoff water and provide valuable habitat. One native planting per property per year is eligible.
- Fish Sticks: These in-lake best practices (not eligible for rivers) are woody habitat structures that provide feeding, breeding, and nesting areas for wildlife. Fish sticks consist of multiple whole trees grouped together and anchored to the shore. Trees are not felled from the shoreline, as existing trees are valuable in place, but brought from a short distance or dragged across the ice. In order for this practice to be eligible, an existing vegetated buffer or pledge to install one is required.

The Healthy Lakes and Rivers Grant Program allows partial cost coverage for implementing best practices. Competitive grants are available to eligible applicants such as lake associations and lake districts. The program allows a 75% state cost share up to $1,000 per practice. Multiple practices can be included per grant application, with a $25,000 maximum award per year. Eligible projects need to be on shoreland properties within 1,000 feet of a lake or 300 feet from a river. The landowner must sign a Conservation Commitment pledge to leave the practice in place and provide continued maintenance for 10 years. More information on this program can be found here:

https://healthylakeswi.com/

It is important to note that this grant program is intentionally designed for relatively simple, low-cost, and shovel-ready projects, limiting 10% of the grant award for technical assistance. Larger and more complex projects, especially those that require engineering design components may seek alternative funding sources potentially through the County. Small-Scale Lake Planning Grants can provide up to $3,000 to help build a Healthy Lakes and Rivers project. Eligible expenses in this grant program are surveys, planning, and design.

Silver Lake Shoreland Zone Condition

Shoreland Development

On Silver Lake, the development stage of the entire shoreland was surveyed on September 27, 2021 by Waupaca County. A draft WDNR Lake Shoreland & Shallows Habitat Monitoring Field Protocol (WDNR, Lake Shoreland & Shallows Habitat Monitoring Field Protocol 2020) was utilized to evaluate the shoreland zone on a parcel-by-parcel basis beginning at the estimated high-water level mark and extending inland 35 feet. This area accounts for a total of 13.8 acres around Silver Lake. The immediate shoreline was surveyed and classified based upon its potential to negatively impact the system due to development and other human impacts. Within the shoreland zone the natural vegetation (canopy cover, shrub/herbaceous) was given an estimate of the percentage of the plot which is dominated by each category (Photo 3.4-3). Human disturbances (impervious surface, manicured lawn, agriculture, number of buildings, boats on shore, piers, boat lifts, sea wall length and other similar categories) were also recorded by number of occurrence or percentage during the survey.

Photograph 3.4-3. Example of canopy, shrub and herbaceous layers.

For this management plan, the percent canopy cover, percent shrub/herbaceous, percent manicured lawn and percent impervious surfaces are primarily focused upon to assess the shoreline for development and determine a need for restoration. In general, developed shorelands impact a lake ecosystem in a negative manner, while definite benefits occur from shorelands that are left in their natural state or a near-natural state.

Canopy cover was defined as an area which is shaded by trees that are at least 16 feet tall (Photograph 3.4-3). Approximately 9.7 acres (70%) of the shoreland zone around Silver Lake was in 60% canopy cover or greater. About one acre (7%) of the shoreland zone had less than 20% canopy cover (Map 3).

Shrub and herbaceous layers are small trees and plants without woody stems less than 16 feet tall (Photograph 3.4-3). Overall, the shrub and herbaceous layer covered 40% or less of the shoreland zone parcels around Silver Lake (Map 4).

A manicured lawn is defined as grass that is mowed short and is direct evidence of urbanization. Having a manicured lawn poses a risk as runoff will carry pollutants, such as lawn fertilizers, into the lake. Approximately 11.7 acres of the 13.8 total acres (84%) of shoreland zone was covered with 20% or less of manicured lawn (Map 5). This considered good and reduces the effects of runoff greatly.

Impervious surface is an area that releases all or a majority of the precipitation that falls onto it (e.g., rooftops, concrete, stairs, boulders and boats flipped over on shore). Similar to a manicured lawn, having large areas of impervious surfaces can poses runoff risks. Fortunately, 11.8 acres (85%) of the shoreland zone surrounding Silver Lake contains 10% or less of impervious surfaces (Map 6).

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, un-sloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

Coarse woody habitat locations were not specifically recorded during the 2021 shoreline survey, however, surveyors noted woody habitat was quite prevalent along areas of undeveloped shoreline.

3.5 Aquatic Plants

Introduction

Although the occasional lake user considers aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, the plants are actually an essential element in a healthy and functioning lake ecosystem. It is very important that lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative effects on it.

Photograph 3.5-1. Example of emergent and floating-leaf communities.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*). In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreland erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These species will be discussed further in depth in the Aquatic Invasive Species section. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant abundance negatively affects the lake ecosystem and limits the use of the resource, plant management and control may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods. No aquatic plant management plan should only contain methods to control plants, they should also contain methods on how to protect and possibly enhance the important plant communities within the lake. Unfortunately, the latter is often neglected and the ecosystem suffers as a result.

Aquatic Plant Management and Protection

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no "silver bullets" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Important Note:
Even though most of these techniques are not applicable to Silver Lake, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake**.** The techniques applicable to Silver Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

Permits are required for chemical and mechanical manipulation of native and non-native plant communities. Large-scale protocols have been established for chemical treatment projects covering >10 acres or areas greater than 10% of the lake littoral zone and more than 150 feet from shore. Different protocols are to be followed for whole-lake scale treatments (≥160 acres or ≥50% of the lake littoral area). Additionally, it is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Manual Removal

Photograph 3.5-2. Example of aquatic plants that have been removed manually.

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width. Please note that the use of powered cutters may require a mechanical harvesting permit to be issued by the WDNR.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15^{th}.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1,200 to $11,000.

Advantages	***Disadvantages***
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15^{th}. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb benthic organisms and fish-spawning areas.

	• Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant colonization on top of the screen. Please note that depending on the size of the screen a Wisconsin Department of Natural Resources permit may be required.

Cost

Material costs range between $.20 and $1.25 per square-foot. Installation cost can vary largely, but may roughly cost $750 to have 1,000 square feet of bottom screen installed. Maintenance costs can also vary, but an estimate for a waterfront lot is about $120 each year.

Advantages	***Disadvantages***
• Immediate and sustainable control. • Long-term costs are low. • Excellent for small areas and around obstructions. • Materials are reusable. • Prevents fragmentation and subsequent spread of plants to other areas.	• Installation may be difficult over dense plant beds and in deep water. • Not species specific. • Disrupts benthic fauna. • May be navigational hazard in shallow water. • Initial costs are high. • Labor intensive due to the seasonal removal and reinstallation requirements. • Does not remove plant biomass from lake. • Not practical in large-scale situations.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive. If a hydro-electric facility is operating on the system, the costs associated with loss of production during the drawdown also need to be considered, as they are likely cost prohibitive to conducting the management action.

Advantages	***Disadvantages***
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian watermilfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant effects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed and reed canary grass. • Permitting process may require an environmental assessment that may take months to prepare. • Non-selective.

Mechanical Harvesting

Photograph 3.5-3. Mechanical harvester.

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Cost

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages	***Disadvantages***
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact. • Plants are not completely removed and can still provide some habitat benefits. • Opening of cruise lanes can increase predator pressure and reduce stunted fish populations. • Removal of plant biomass can improve the oxygen balance in the littoral zone. • Harvested plant materials produce excellent compost.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required. • Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Herbicide Treatment

Photograph 3.5-4. Liquid herbicide application. Photo credit: Amy Kay, Clarke.

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers. Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is becoming more prevalent. Resource managers employ strategic management techniques towards aquatic invasive species, with the objective of reducing the target plant's population over time; and an overarching goal of attaining long-term ecological restoration. For submergent vegetation, this largely consists of implementing control strategies early in the growing season; either as spatially-targeted, small-scale spot treatments or low-dose, large-scale (whole lake) treatments. Treatments occurring roughly each year before June 1 and/or when water temperatures are below 60°F can be less impactful to many native plants, which have not emerged yet at this time of year. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb the herbicide.

While there are approximately 300 herbicides registered for terrestrial use in the United States, only 13 active ingredients can be applied into or near aquatic systems. All aquatic herbicides must be applied in accordance with the product's US Environmental Protection Agency (EPA) approved label. There are numerous formulations and brands of aquatic herbicides and an extensive list can be found in Appendix F of (Gettys 2009).

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if, "you are standing in socks and they get wet." In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high-water mark require herbicides specifically labeled by the United States Environmental Protection Agency

Aquatic herbicides can be classified in many ways. Organization of this section follows Netherland (2009) in which mode of action (i.e., how the herbicide works) and application techniques (i.e., foliar or submersed treatment) group the aquatic herbicides. The table below provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from (Netherland 2009).

The arguably clearest division amongst aquatic herbicides is their general mode of action and fall into two basic categories:

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

Table 3.5-1. Common herbicides used for aquatic plant management.

General Mode of Action		Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; invasive watermilfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance species including duckweeds, targeted AIS control when exposure times are low
		Flumioxazin	Inhibits photosynthesis & destroys cell membranes	Nusiance species, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Florpyrauxifen -benzyl	arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr	Submersed species, largely for invasive watermilfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for invasive watermilfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	Emergent species with potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to reduce herbicide concentration within aquatic systems. Understanding concentration and exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of an ongoing cooperative research project between the Wisconsin Department of Natural Resources, US Army Corps of Engineers Research and Development Center, and private consultants (including Onterra). This research couples quantitative aquatic plant monitoring with field-collected herbicide concentration data to evaluate efficacy and selectivity of control strategies implemented on a subset of Wisconsin lakes and flowages. Based on their preliminary findings, lake managers have adopted two main treatment strategies: 1) whole-lake treatments, and 2) spot treatments.

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant affects outside of that area. Spot treatments typically rely on a short exposure time (often hours) to cause mortality and therefore are applied at a much higher herbicide concentration than whole-lake treatments. This has been the strategy historically used on most Wisconsin systems.

Whole-lake treatments are those where the herbicide is applied to specific sites, but when the herbicide reaches equilibrium within the entire volume of water (entire lake, lake basin, or within the epilimnion of the lake or lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire lake or basin. The application rate of a whole-lake treatment is dictated by the volume of water in which the herbicide will reach equilibrium. Because exposure time is so much longer, target herbicide levels for whole-lake treatments are significantly less than for spot treatments.

Cost

Herbicide application charges vary greatly between $400 and $1,500 per acre depending on the chemical used, who applies it, permitting procedures, and the size/depth of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g., mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata),* respectively.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian watermilfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian watermilfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1000 or more.

Advantages	***Disadvantages***
• Milfoil weevils occur naturally in Wisconsin. • Likely environmentally safe and little risk of unintended consequences.	• Stocking and monitoring costs are high. • This is an unproven and experimental treatment. • There is a chance that a large amount of money could be spent with little or no change in Eurasian watermilfoil density.

Wisconsin has approved the use of two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These beetles were imported from Europe and used as a biological control method for purple loosestrife. Many cooperators, such as county conservation departments or local UW-Extension locations, currently support large beetle rearing operations. Beetles are reared on live purple loosestrife plants growing in kiddy pools surrounded by insect netting. Beetles are collected with aspirators and then released onto the target wild population. For more information on beetle rearing, contact your local UW-Extension location.

In some instances, beetles may be collected from known locations (cella insectaries) or purchased through private sellers. Although no permits are required to purchase or release beetles within Wisconsin, application/authorization and release forms are required by the WDNR for tracking and monitoring purposes.

Cost

The cost of beetle release is very inexpensive, and in many cases is free.

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations may lead to long-term control.	• Although considered "safe," reservations about introducing one non-native species to control another exist. • Long range studies have not been completed on this technique.

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, such as variable water levels or negative, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as emergent or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Silver Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Silver Lake in 2005, 2012, and 2020. The list also contains the growth-form of each plant found (e.g., submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Silver Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys (equation shown below). This assessment allows the aquatic plant community of Silver Lake to be compared to other lakes within the region and state.

$$FQI = \text{Average Coefficient of Conservatism} * \sqrt{\text{Number of Native Species}}$$

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

$$D = \sum (n/N)^2$$

where:
n = the total number of instances of a particular species
N = the total number of instances of all species and
D is a value between 0 and 1

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species.

The Simpson's Diversity Index value from Silver Lake is compared to data collected by Onterra and the WDNR Science Services on 85 lakes within the North Central Hardwood Forests ecoregion (NCHF) and on 392 lakes throughout Wisconsin.

Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within each lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Silver Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian watermilfoil are the primary targets of this extra attention.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.5-1). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

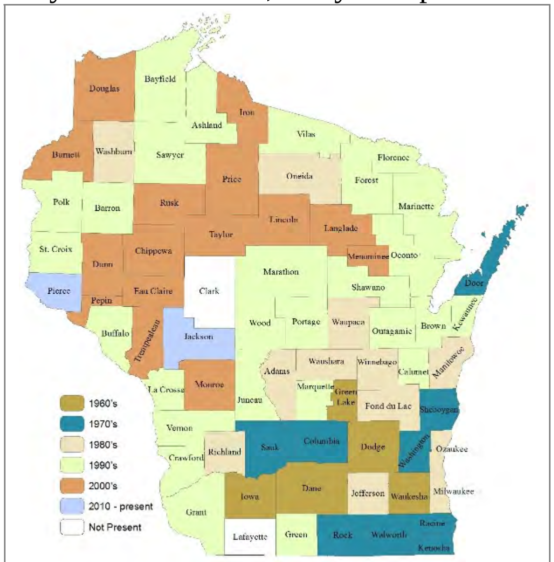


Figure 3.5-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly – leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native vegetation. Like Eurasian watermilfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian watermilfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer. Aquatic invasive species mapping methodology is discussed in Section 6.0, Methods.

Silver Lake Aquatic Plant Survey Results

The first survey completed on Silver Lake was an early-season aquatic invasive species (ESAIS) survey completed on May 27, 2021. The goal of this survey was to identify and assess new or existing occurrences of invasive plant species in the lake, with a particular focus on species that are most likely to be observed at this time of year: curly-leaf pondweed and pale-yellow iris. During this survey, Onterra ecologists mapped a small population of curly-leaf pondweed and one occurrence of pale-yellow iris on the shoreline. Eurasian watermilfoil was also mapped during the ESAIS survey to serve as a guide during the late-season AIS survey when Eurasian watermilfoil is at peak growth. In addition, other non-native plant species found in Silver Lake include ornamental water lily and purple loosestrife. These non-native plants in Silver Lake are discussed in detail in the subsequent Non-Native Aquatic Plants section.

Whole-lake point-intercept surveys have been completed on Silver Lake in 2005 (WDNR), 2012 (Cason & Associates), and 2020 (Golden Sands RC&D). The emergent and floating-leaf plant community mapping survey was conducted on Silver Lake in July 2021, and the late-season AIS survey was completed in August of 2021. Over the course these surveys, a total of 22 aquatic plant species were located, 17 of which are considered native to Wisconsin (Table 3.3-1).

Lakes in Wisconsin vary in their morphometry, water chemistry, substrate composition, and management, all factors which influence aquatic plant community composition. Substrate data collected from the point-intercept surveys show that most of Silver Lake is comprised of soft, organic sediments. These nutrient-rich sediments are conducive for supporting lush aquatic plant growth. In addition to nutrient-rich sediments, higher levels of nutrients entering the lake from the watershed also fuel aquatic plant growth, especially non-rooted species like coontail and common waterweed which derive most of their nutrients from the water. The combination of organic sediments, high nutrients, and clear water creates ideal conditions for the formation of nuisance aquatic plant growth in Silver Lake.

In July of 2021, Onterra ecologists completed an acoustic survey on Silver Lake (bathymetric results on Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. The 2021 aquatic plant bio-volume data are displayed in Figure 3.5-2 and Map 8. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in black. As illustrated, the majority of Silver Lake supports aquatic vegetation, and where vegetation is present, it occupies most of the water column. The areas of red on Figure 3.5-2 indicate aquatic plant growth is at or very near the surface of water. As is discussed later in this section, much of the surface-matted growth is comprised of the invasive Eurasian watermilfoil and the native species coontail.

Table 3.5-2. Aquatic plant species located on Silver Lake during 2005, 2012, 2020, and 2021 surveys.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2005 (DNR)	2012 (Cason)	2020 (Golden Sands	2021 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	Native	5				
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A				
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A		I		
	Schoenoplectus acutus	Hardstem bulrush	Native	5		I	I	
	Scirpus atrocinctus	Black-girdled wool-grass	Native	7				
Submergent	*Ceratophyllum demersum*	Coontail	Native	3	X	X	X	
	Chara spp.	Muskgrasses	Native	7	X	X	X	
	Elodea canadensis	Common waterweed	Native	3	X	X	X	
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X			
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X	
	Najas flexilis	Slender naiad	Native	6		X	X	
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X	X	X	
	Potamogeton illinoensis	Illinois pondweed	Native	6			I	
	Potamogeton praelongus	White-stem pondweed	Native	8	X	X	X	
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X	X	
	Stuckenia pectinata	Sago pondweed	Native	3	X	X	X	
	Utricularia vulgaris	Common bladderwort	Native	7			I	
SE	*Eleocharis acicularis*	Needle spikerush	Native	5	X			
FF	*Spirodela polyrhiza*	Greater duckweed	Native	5		X	X	
	Wolffia columbiana	Common watermeal	Native	5	X		X	

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
Note: 2021 survey only focused on emergent and floating-leaf species

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. Results from the 2005, 2012, and 2020 point-intercept surveys show the entire lake is littoral, with maximum depth of plants being 16 feet in 2005 and 2020 and 18 feet in 2012. In 2020, 100% of the sampling locations contained aquatic plants. Of the 22 total aquatic plant species located in the lake in the 2005, 2012, and 2020 surveys, 14 were encountered directly on the rake during the three point-intercept surveys. The remaining eight species were located incidentally, meaning they were observed while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community.

Coontail was the most frequently encountered species in all three point-intercept surveys, with a littoral frequency of occurrence ranging from 84% to 94% (Figure 3.5-3). Because coontail does not produce true roots, it is often found growing amongst other aquatic plants or matted at the surface. Coontail derives all of its nutrients directly from the water column, and this ability, along with a tolerance for low-light conditions, allows coontail to become abundant in water bodies with high nutrients and lower water clarity. Coontail provides excellent habitat for invertebrates and fish because of the dense whorls of leaves that grow around its stem.

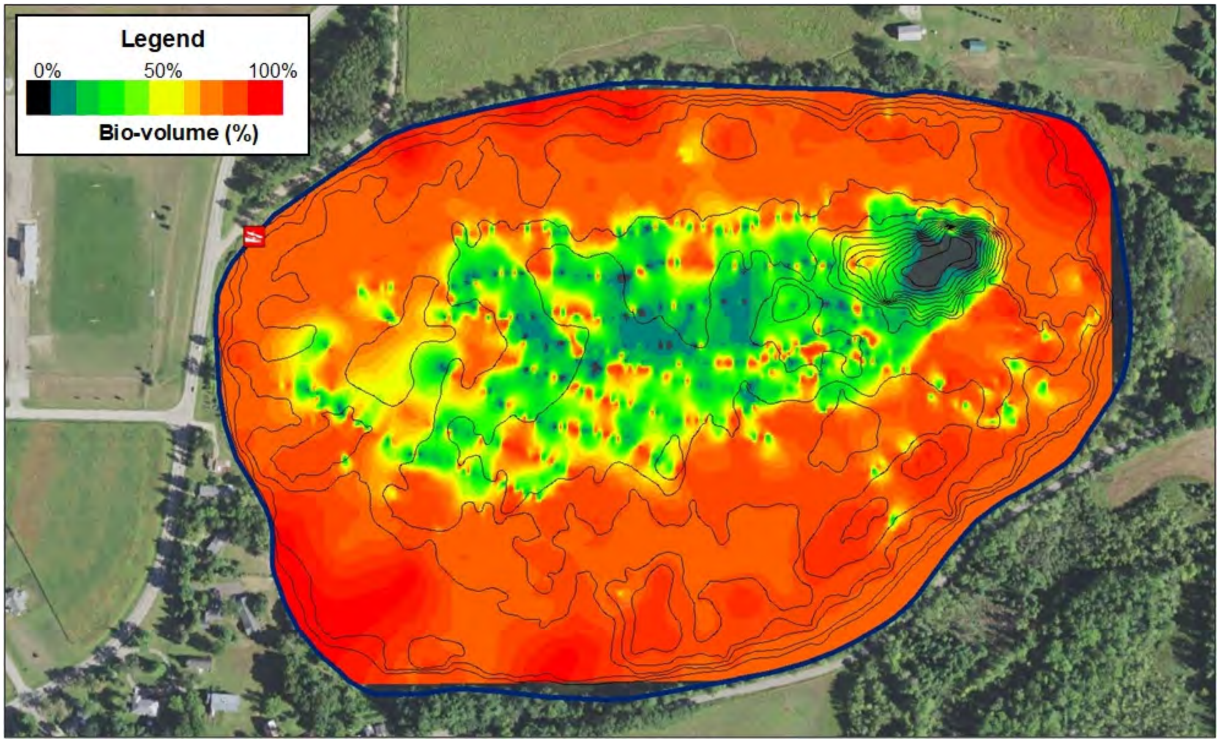


Figure 3.5-2. Silver Lake July 2021 aquatic plant bio-volume. Data show that most of Silver Lake contains aquatic plants which grow at or near the surface of the water. Created using data from July 2021 acoustic survey data. Contour lines represent one-foot increments.

Research shows that coontail has the ability to inhibit phytoplankton production (Gross 2003), as well as playing an important role in maintaining water clarity under high phosphorous concentrations (Mjelde M. 2003). While coontail is one of the primary species creating nuisance conditions in Silver Lake, this species is maintaining the current clear water state found in Silver Lake by suppressing algal production. While the lake has shifted to a clear water state, the shear abundance of coontail is still an indication that nutrient levels and inputs to Silver Lake are still high.

Common waterweed was the second most common native species encountered during the three point-intercept surveys. The littoral frequency of occurrence for common waterweed has fluctuated over the years, with statistically valid differences being seen between 2005 and 2020 (Figure 3.5-3 and Figure 3.5-4). The littoral frequency of occurrence of common waterweed increased from 44% in 2005 to 72% in 2012, before falling back to 57% in 2020. These fluctuations year to year have been seen in other waterbodies in Wisconsin. Like coontail, common waterweed is tolerant of high-nutrient, low-light conditions. The plant has blade-like leaves that grow in whorls of three along a long, slender stem that helps stabilize bottom sediments and provide structural habitat and food for wildlife. And like coontail, the abundance of common waterweed is maintaining Silver Lake's clear water state.

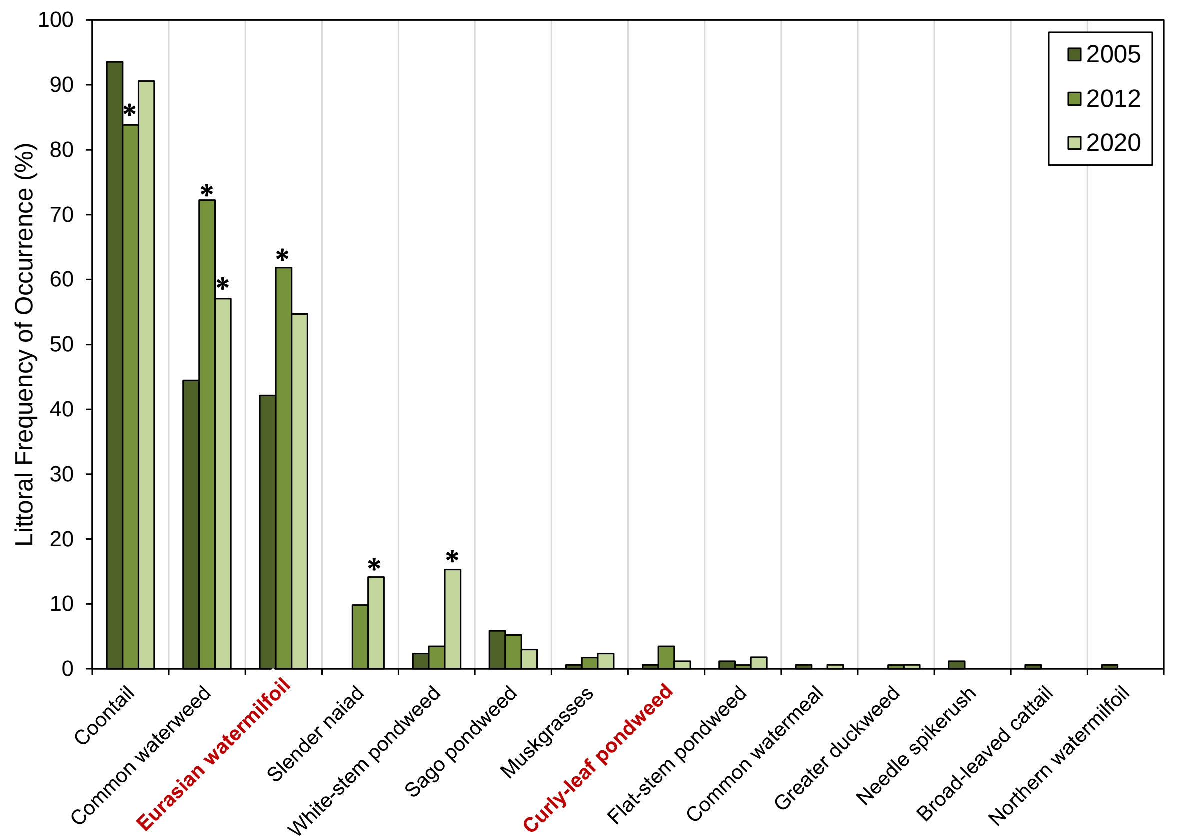


Figure 3.5-3. Littoral frequency of occurrence of aquatic plant species in the 2005, 2012, and 2020 surveys of Silver Lake. * = Statistically valid change in occurrence from 2008 (Chi-square α = 0.05). Non-native species indicated with red. Created using data from 2005, 2012, and 2020 aquatic plant point-intercept surveys.

White-stem pondweed was the third-most encountered native plant in the 2020 point-intercept survey (Figure 3.5-3 and Figure 3.5-4). This plant had a statistically significant increase in occurrence in the 2020 survey when compared to 2012, increasing from 4% to 15%. White stem pondweed is one of the largest pondweed species found in Wisconsin, and its increase in 2020 could be an indicator of improving conditions in terms of water clarity. White-stem pondweed prefers higher water clarity, and is not considered to be tolerant of turbid, low light conditions. Similarly, slender naiad was recorded in 2012 and 2020 after not being recorded in 2005. Like white-stem pondweed, slender naiad is typically found in lakes with higher clarity, and its increase in 2012 and 2021 likely indicate increases in water clarity.

The calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while 13 native aquatic plant species were located in Silver Lake during the 2020 surveys, nine were encountered on the rake during the point-intercept survey. Native species richness ranged from 8 to 10 across the three point-intercept surveys, and is well below the median species richness values for other lakes in the NCHF ecoregion and lakes across Wisconsin.

The average conservatism of these native species ranged from 4.8 to 5.1, again falling below the median values for lakes in the NCHF ecoregion and lakes throughout the state (Figure 3.5-5). The lower conservatism values indicate Silver Lake's aquatic plant community is comprised primarily of species that are more tolerant of degraded ecological conditions, such as coontail and common waterweed. Using native species richness and average conservatism values to generate the Floristic Quality Index values yields low values across all three survey years. Again, these values fall well below median values for lakes in the ecoregion and the state, and indicate that Silver Lake's aquatic plant community is indicative of disturbed, degraded conditions.

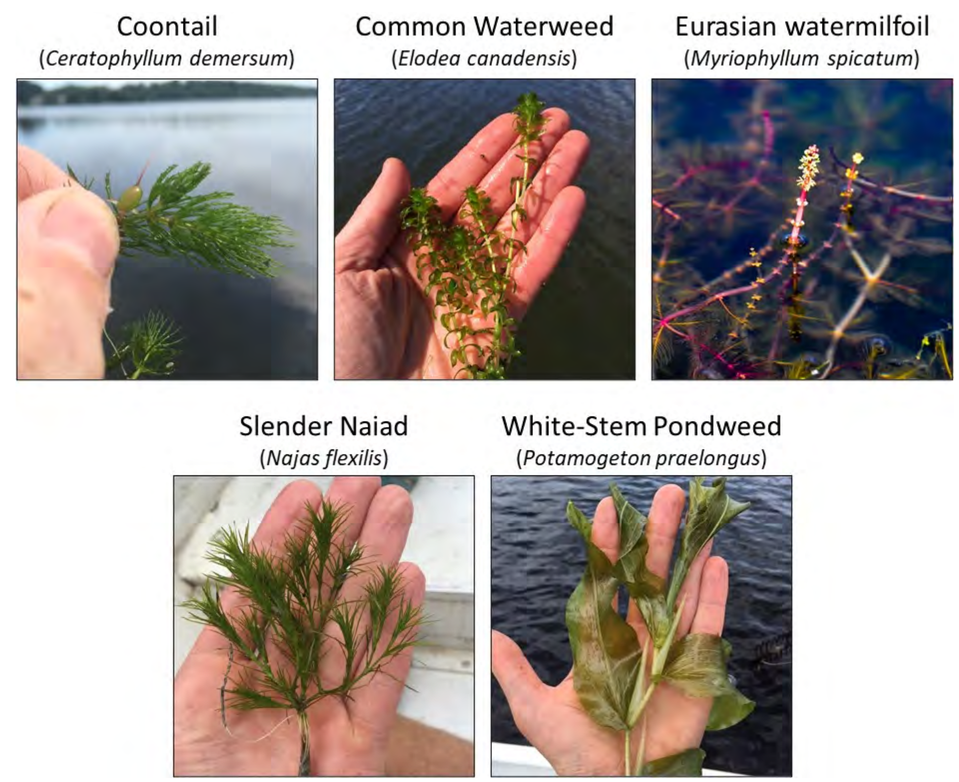


Figure 3.5-4. Five most common aquatic plant species in Silver Lake. Photo credit Onterra.

While the history of excessive nutrient input into Silver Lake has led to degraded conditions, the lake's smaller size, circular shape, and more uniform substrate types also likely contribute to the lower species richness found in the lake. Studies have shown that the number of aquatic plant species present tends to increase with the area of suitable habitat as well as increasing *shoreline complexity* (Lacoul and Freedman 2006). Shoreline complexity is an index that relates the area of the lake to the perimeter of its shoreline. If a lake were a perfect circle, its shoreline complexity value would be 1.0. The farther a lake deviates from a perfect circle, the higher its shoreline complexity value is. Lakes with greater shoreline complexity harbor more areas that are sheltered from wind and wave action creating a greater diversity of habitats for aquatic plants. Silver Lake is highly circular with a low shoreline complexity value of 1.1. The lake's low shoreline complexity and relatively uniform depth and substrate results in fewer habitat types for different aquatic plant species.

Simpson's Diversity Index is a measure of both the number of aquatic plant species in a given community and their abundance. This measurement is important because plant communities with higher diversity are believed to be more resilient to disturbances and natural fluctuations that affect plant growth (e.g., changes water clarity, water levels, etc.). Plant communities with higher diversity also provide more diversity in habitat types and food sources for invertebrates, fish, and other wildlife. Higher species diversity leads to a healthier and more adaptive system that is resistant to disturbance and more stable over time. Unlike species richness which is simply the number of aquatic plant species within the community, species diversity considers how evenly those species are distributed throughout the community.

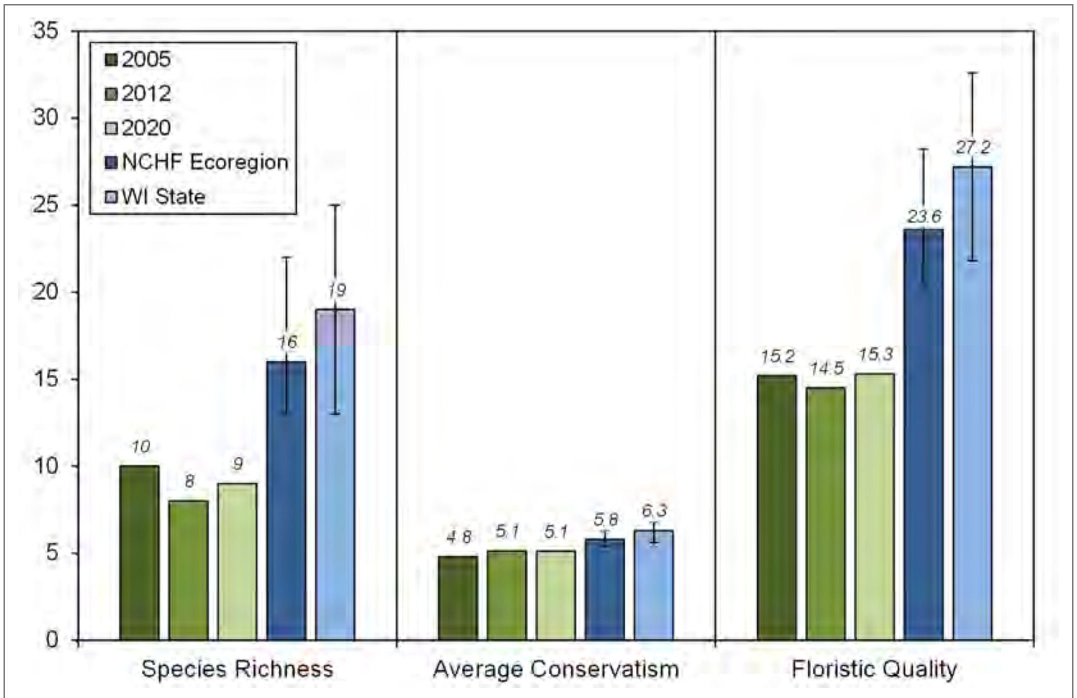


Figure 3.5-5. Silver Lake Floristic Quality Assessment. Created using data from 2005, 2012, and 2020 surveys. Analysis following (Nichols 1999) where NLFL = Northern Lakes and Forest Lakes Ecoregion.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Silver Lake's diversity values rank. Silver Lake's species diversity fell below the NCHF ecoregion median of 0.84 in all three point-intercept years. While Silver Lake's diversity value increased to 0.82 in 2012, diversity values fell below the 25th percentile for the ecoregion in 2005 and 2020 (Figure 3.5-5). These low diversity values indicate the lake is dominated by just a few plant species: coontail, common waterweed, and Eurasian watermilfoil. Looking at the relative occurrence of these aquatic

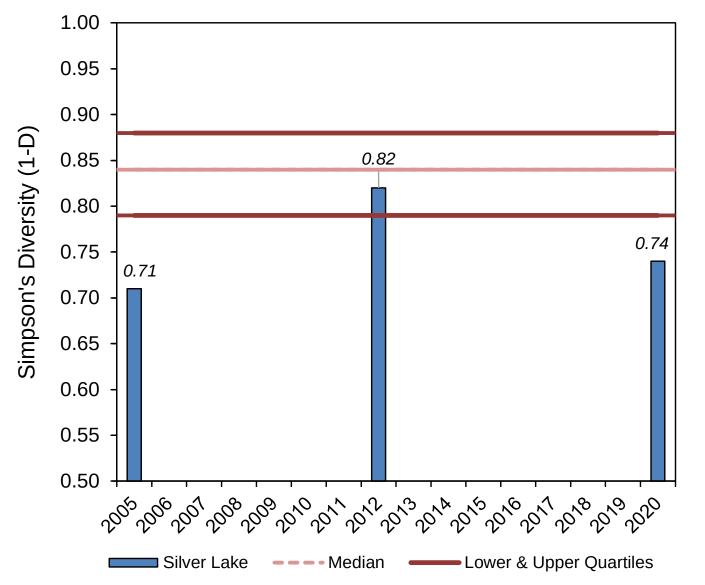


Figure 3.5-6. Silver Lake species diversity index. Created using data from 2005, and 2012, and 2020 aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

plant species from 2020 shows that these three species account for 84% of the lake's aquatic plant community.

In 2021, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaved plant communities in Silver Lake. Emergent and floating-leaf plant communities are a wetland community type dominated by species such as cattails, bulrushes, and water lilies. Like submersed aquatic plant communities, these communities also provide valuable habitat, shelter, and food sources for organisms that live in and around the lake. In addition to those functions, floating-leaf and emergent plant communities provide other valuable services such as erosion control and nutrient filtration. These communities also lessen the force of wind and waves before they reach the shoreline which serves to lessen erosion. Their root systems also stabilize bottom sediments and reduce sediment resuspension. In addition, because they often occur in near-shore areas, they act as a buffer against nutrients and other pollutants in runoff from upland areas.

Results found that Silver Lake does not support any large communities of emergent and/or floating-leaf aquatic plants. The communities that are present are comprised of small, isolated colonies of mostly emergent plants immediately adjacent to shore. In total, seven emergent and floating-leaf plant species were identified (Table 3.5-1). The location of the plants observed in the July 2021 community map survey can be seen in Map 7.

Given the limited occurrence of native emergent and floating-leaf plant communities in Silver Lake, they should be a focus of protection and enhancement. This is important to note because these communities are often negatively affected by recreational use and shoreland development. Radmoski and Goeman 2001 found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Non-Native Aquatic Plants in Silver Lake

Curly-leaf Pondweed (*Potamogeton crispus*)

Curly-leaf pondweed (CLP; Photograph 3.5-5) was first documented in Silver Lake in 1992. Curly-leaf pondweed's primary method of propagation is through the production of numerous asexual reproductive structures called turions. Once mature, these turions break free from the parent plant and may float for some time before settling and overwintering on the lake bottom. Once favorable growing conditions return (i.e., spring), new plants emerge and grow from these turions. Many of the turions produced by CLP begin to sprout in the fall and overwinter as small plants under the ice. Immediately following ice-out, these plants grow rapidly giving them a competitive advantage over native vegetation. Curly-leaf pondweed typically reaches its peak biomass by mid-June, and following the production of turions, most of the CLP will naturally senesce (die back) by mid-July.

Photograph 3.5-5. Curly-leaf pondweed plants. Locations of CLP in Silver Lake can be found on map 9. Photo credit Onterra.

If the CLP population is large enough, the natural senescence and the resulting decaying of plant material can release sufficient nutrients into the water to cause mid-summer algal blooms. In some lakes, CLP can reach growth levels which interfere with navigation and recreational activities. However, in other lakes, CLP appears to integrate itself into the plant community and does not grow to levels which inhibit recreation or have apparent negative impacts to the lake's ecology. Because CLP naturally senesces in early summer, surveys are completed early in the growing season in an effort to capture the full extent of the population.

An Early-Season AIS Survey was completed on May 27, 2021 to try and capture the full extent of CLP in Silver Lake. The survey found that the CLP population in Silver Lake is quite small. In all, a small clump of a half dozen was observed as well as a handful of isolated single plant occurrences. Given the smaller size of the plant population, it is not likely that the senescence of any CLP in Silver Lake has a detectable impact on the lake's water quality at this time

Hybrid Watermilfoil (*Myriophyllum sibiricum* x *M. spicatum*)

Eurasian watermilfoil (EWM) is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties. Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed but by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, EWM has two other competitive advantages over native aquatic plants: 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, and instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil was first documented in Silver Lake in 1993.

Figure 3.5-7 shows a cross-section of a whorl of four EWM leaves. One of the primary ways to distinguish between different species of watermilfoils is to count the number of leaflets on each leaf. As shown on Figure 3.5-7, northern watermilfoil (green triangles) typically has leaflet counts under 23 whereas EWM typically has leaflet counts over 25. Hybrid watermilfoil (HWM) leaflet counts overlap with both these ranges, making field identification difficult. While leaflet counts can be a relatively definitive way to differentiate between EWM and northern watermilfoil, this method is less definitive in distinguishing HWM from EWM and northern watermilfoil. DNA testing is required to determine if a system has EWM vs HWM, often times having both.

Photograph 3.5-6. Surface-matted HWM colony in Silver Lake, July 2021. Photo credit Onterra.

In 2021, Onterra staff collected two samples of suspected HWM plants and submitted them to Montana State University to be tested for hybridity. In February of 2022, results confirmed one of the plants sent in was HWM. No genetic results were able to be collected from the second plant sample. While the distribution of pure strain EWM compared to HWM cannot be determined without extensive genetic testing, this report will use "HWM" when discussing the invasive milfoil population of Silver Lake unless specifically stated otherwise.

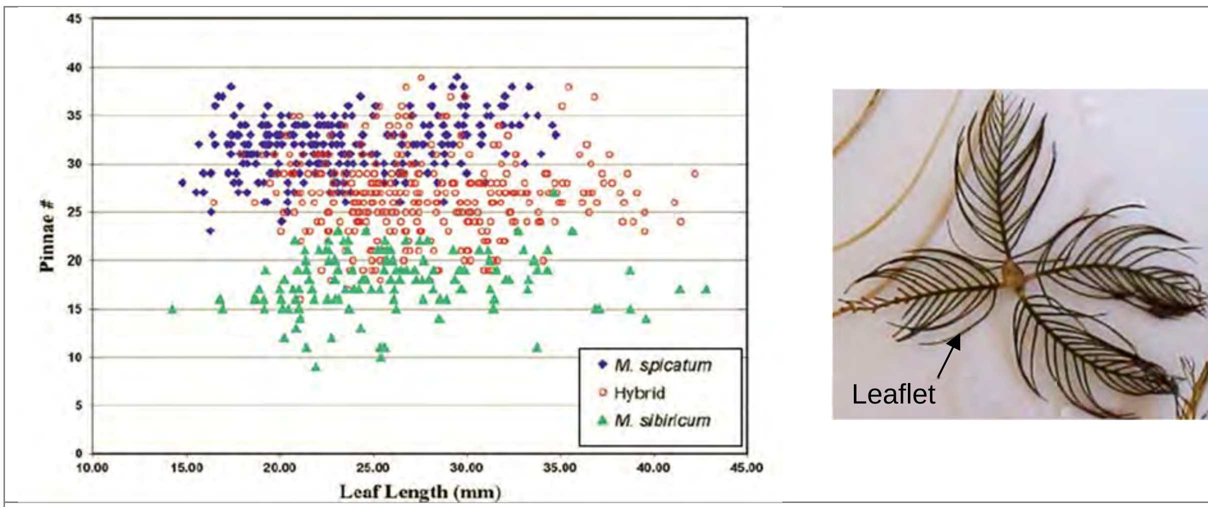


Figure 3.5-7. Pinnae (leaflet) counts from three watermilfoil species. Extracted and modified from (Moody and Les 2007). Leaf length spreads out the data but is not important here.

The 2020 point-intercept survey found that HWM had a littoral frequency of occurrence of almost 55%, representing a slight decline since 2012 but was not statistically valid (Figure 3.5-8). The 2020 point-intercept survey found that HWM is found throughout a large area of Silver Lake, including in water up to 12 feet deep.

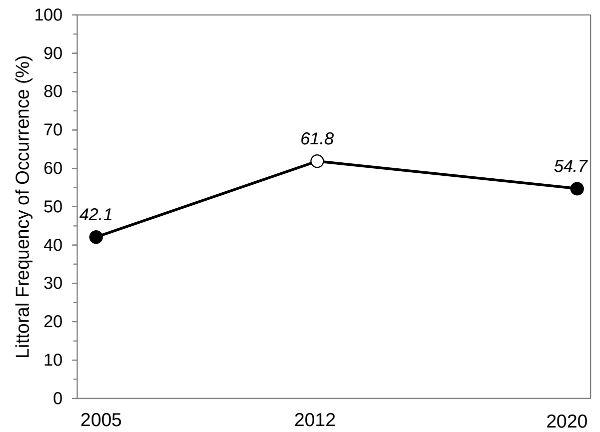


Figure 3.5-8. Littoral frequency of occurrence of Eurasian watermilfoil in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square $\alpha = 0.05$).

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake to understand where recreation and navigation impairment exists and how to direct management activities. Within this project, a series of AIS mapping surveys allowed this level of data to be understood.

As a part of this project, HWM was initially mapped during the Early-Season AIS Survey to get a first look at the distribution of this species. In total, a little over 49 contiguous acres of HWM was mapped already in May (Map 10). HWM continues to grow throughout the summer months and therefore, a Late-Season HWM Mapping Survey was completed in August when HWM is typically at or near its peak-biomass for the growing season. While HWM can be found throughout the littoral zone of Silver Lake, nearly 59 acres of contiguous HWM colonies were mapped in Silver Lake in the August 2021 mapping survey (Map 11). Approximately 15.3 acres were comprised of either *highly scattered* or *scattered* HWM and 23.3 acres were comprised of *dominant* or *highly dominant* HWM colonies. *Surface matted* colonies of HWM accounted for the remaining 20.3 acres. These areas are the densest colonies of HWM and were most present in a ring around the entire shoreline. It is likely these mats of HWM would greatly interfere with recreation. HWM was also mapped during August 2022 (Map 12). Based upon the 2022 survey, it appears the Silver Lake population has become slightly denser throughout the lake.

Future AIS Management Philosophy

During the Planning Committee meetings held as part of this project, three broad Eurasian watermilfoil management goals were discussed including a generic potential action plan to help reach each of the goals. During these discussions, conversation regarding risk assessment of the various management actions was also discussed.

1. Let Nature Take its Course: On some lakes, invasive plant populations plateau or reduce without active management. Some lake groups decide to periodically monitor the EWM population, either through an EWM mapping survey or a whole-lake point-intercept survey, but may not coordinate active management (e.g., hand-harvesting or herbicide treatments). Individual riparians could choose to hand-remove the EWM within their recreational footprint, but the lake group would not assist financially or by securing permits if necessary. In most instances, the lake group may select an EWM population threshold or trigger where they would revisit their management goal if the population reached that level.

2. Nuisance Control: The concept of ecosystem services is that the natural world provides a multitude of services to humans, such as the production of food and water (provisioning), control of climate and disease (regulating), nutrient cycles and pollination (supporting), and spiritual and recreational benefits (cultural). Some lake groups acknowledge that the most pressing issues with their AIS population is the reduced recreation, navigation, and aesthetics compared to before the AIS became established in their lake. Particularly on lakes with large EWM populations that may be impractical or unpopular to target on a lake-wide basis, the lake group would coordinate (secure permits and financially support the effort) a strategy to improve the navigability within the lake. This is typically accomplished by targeting EWM populations in high-use parts of the through mechanical harvesting or spot herbicide treatments and allowing other areas of low use to remain unmanaged.

3. Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with EWM populations, that may mean to manage the EWM population at a reduced level with the perceived goal to allow the lake to function as it had prior to EWM establishment. Due to the inevitable collateral impacts from most forms of EWM management, lake managers and natural resource regulators question whether that is an achievable goal.

For newly introduced EWM populations, the entire population may be targeted through hand-harvesting or herbicide spot treatments. Herbicide spot treatments, particularly historical treatments with 2,4-D, generally lead to short term EWM population reductions with reductions largely being limited to a season or two. This type of strategy can be analogous to the "whack-a-mole" arcade game; where areas are targeted, rebound, and then are targeted again on an every-other-year basis. As new areas emerge and get factored into the strategy, it becomes harder to manage all the areas. Typically, if management is withheld at this stage, the EWM will rebound to its full capacity within a year. The repeated need for exposing the same areas of the system to herbicides as is required when engaged in an annual spot treatment program has gone out of favor with some lake managers due to concerns over the non-target impacts that can accompany this type of strategy. In recent years, lake managers have sought actions that achieve multiyear EWM population suppression, such as whole-lake treatments or spot treatments with chemistries theorized to require shorter exposure times. The EWM population reductions are more commensurate with the financial costs and risks of the treatment.

Whole-Lake 2,4-D & Endothall

In lakes that have both EWM and CLP, combination treatments of 2,4-D and endothall are common in spot treatment scenarios. The simultaneous exposure to endothall and 2,4-D has been shown to provide increased control of EWM in outdoor growth chamber studies (Madsen et al. 2010). A handful of HWM treatments in Wisconsin have conducted combination whole-lake 2,4-D/endothall treatment targeting approximately 0.25 ppm ae and 0.75 ppm ai, respectively with promising results of control and selectivity towards native plants. However, some of these treatments have had similarly quick target species recovery. Native aquatic plants in Auburn Lake that are particularly susceptible to this herbicide use include flat-stemmed pondweed (*Potamogeton zosteriformis*), other pondweeds (*Potamogeton* spp.) perhaps to a lesser degree, and slender naiad (*Najas flexilis*).

Whole-Lake Pelletized Fluridone

Fluridone is a systematic herbicide that disrupts photosynthetic pathways (carotenoid synthesis inhibitor). This herbicide requires long exposure times (>90 days) to cause mortality to HWM and therefore is only applicable to whole-lake use-patterns. Herbicide concentrations within the lake are kept at target levels by periodically adding additional herbicide (bump treatments) over the course of the summer based upon herbicide concentration monitoring results.

The use of fluridone has a checkered past in Wisconsin, as early implemented treatments (mid-2000s) resulted in native plant impacts that exceeded acceptable levels (Wagner et al. 2007). These collateral impacts are based upon liquid fluridone treatments, typically employed at 6 ppb with a bump treatment later in the summer to bring the concentration back up to 6 ppb. This fluridone use-pattern, commonly referred to as 6-bump-6, produces two relatively high herbicide pulses that taper off slowly as the herbicide degrades. Manufacturers of fluridone (SePRO) believe that the high herbicide pulses are the mechanism causing the native plant impacts.

A somewhat newer use-pattern of fluridone uses a pelletized product that gradually reaches a peak concentration over time (extended release) and results in a lower, sustained lake-wide herbicide concentration (2.0 to 3.0 ppb). This "low-and-long" fluridone strategy is most effective when concentrations can be maintained over 2.0 ppb for 120 days and when herbicide can still be detected in the lake the following ice-out approximately one year after the initial treatment took place.

Within a few limited Wisconsin field-trials, this use-pattern of fluridone appears to provide a similar level of efficacy as the 6-bump-6 approach, but with a lower (but still notable) magnitude of native plant impacts (Heath et al. 2018). In addition to HWM, native aquatic plants in Auburn Lake that are usually impacted by fluridone include the naiads (*Najas* spp.) and common waterweed (*Elodea canadensis*).

Spot Treatments with Short CET Herbicides

An alternative to whole-lake population control is targeting nuisance areas with spot treatments. As previously discussed, many spot treatments targeting invasive watermilfoils are limited to a single season of effectiveness. Some feel that the financial costs and ecological risks are not commensurate with the gains made from these seasonally effective treatments.

To gain multi-year EWM suppression, future spot herbicide treatments would likely need to consider herbicides (diquat, florpyrauxifen-benzyl, etc.) or herbicide combinations (2,4-D/endothall, diquat/endothall, etc.) thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides (e.g., 2,4-D, triclopyr). At the time of this writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike ™) are examples of herbicides with reported short exposure time requirements.

ProcellaCOR™ (florpyrauxifen-benzyl) is a relatively new herbicide that has shown promise in spot treatments in Wisconsin Lakes in recent years. The manufacturer is currently working towards new formulations and guidance for whole-lake use patterns. ProcellaCOR™ is in a new class of synthetic auxin mimic herbicides (arylpicolinates) with short concentration and exposure time (CET) requirements compared to other systemic herbicides. Uptake rates of ProcellaCOR™ into EWM were two times greater than reported for triclopyr (Haug 2018)(Vassios et al. 2017). ProcellaCOR™ is primarily degraded by photolysis (light exposure), with some microbial degradation. The herbicide is relatively short-lived in the environment, with half-lives of 4-6 days in aerobic environments and 2 days in anerobic environments (WSDE 2017). The product has a high affinity for binding to organic materials (i.e., high KOC).

A series of spatially-targeted spot treatments with this chemistry may reduce nuisance conditions in high-use areas for multiple seasons post treatments. Because this herbicide is active at low concentrations, attention to additive impacts of multiple spot treatments in a given area should be discussed. Native watermilfoils including northern watermilfoil are known to be highly susceptible to ProcellaCOR™ with populations of this species showing little to no signs of recovery during the year after treatment. Silver Lake has a very low population of northern watermilfoil and the plant has not been recorded on the previous two point-intercept surveys.

Question 23: What is your level of support or opposition for the future use of aquatic herbicides and mechanical harvesting to manage Eurasian watermilfoil in Silver Lake?

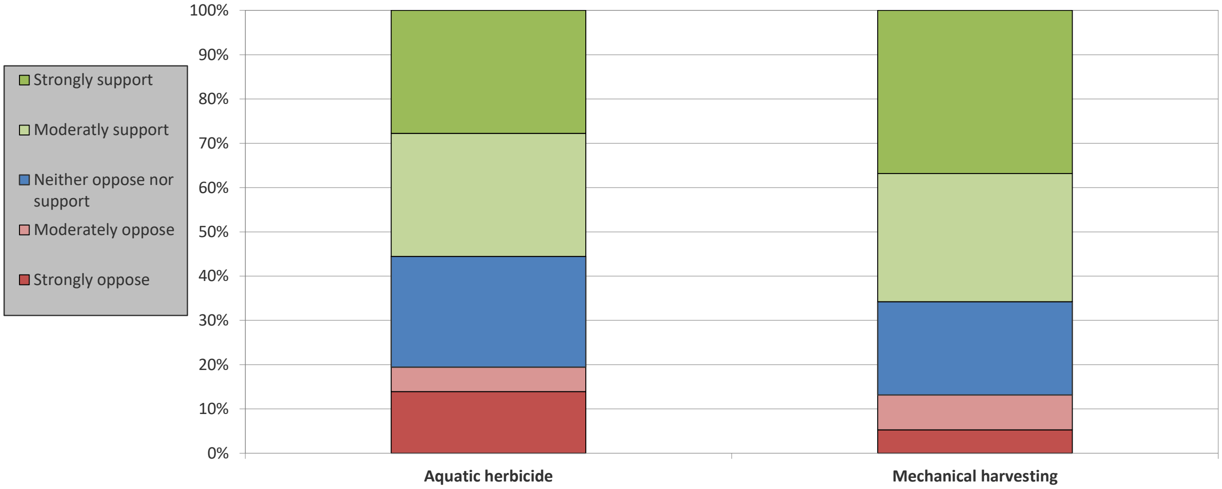


Figure 3.5-9. Survey responses to question 23 from the Silver Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Pale-yellow Iris (Iris pseudacorus)

Pale-yellow iris (Photograph 3.5-3) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin’s wetland areas forming large monotypic colonies and displacing valuable native wetland species. Several pale-yellow iris plants were located along the shoreline of Silver Lake in 2021 (Map 7). This plant should be removed, likely dug out with a shovel, including all of the below-ground rhizomes and disposed of in a landfill. Some individuals show sensitivity to the sap, so care should be taken to avoid contact with the skin when hand-removing the plant.

Photograph 3.5-3. Pale-yellow iris plant. Locations in Silver Lake can be found on Map 7. Photo credit Onterra.

Northern blue-flag iris (*Iris versicolor*) is a native iris. The native iris can be easily distinguished from the non-native iris simply be the color of its flower which is blueish to purple. Northern blue-flag and pale-yellow iris plants typically bloom in early-summer between approximately late-May and early July in Wisconsin, making this the ideal timeframe to distinguish between the two. During other times of the year, the iris plant's long blade-like leaves can look very similar between the native and non-native species making identification more difficult.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental (Photograph 3.4-8). This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. purple loosestrife locations identified during the 2021 community mapping survey can be found on Map 7.

Photograph 3.5-4. Purple loosestrife in shoreland area of Silver Lake. Photo credit Onterra.

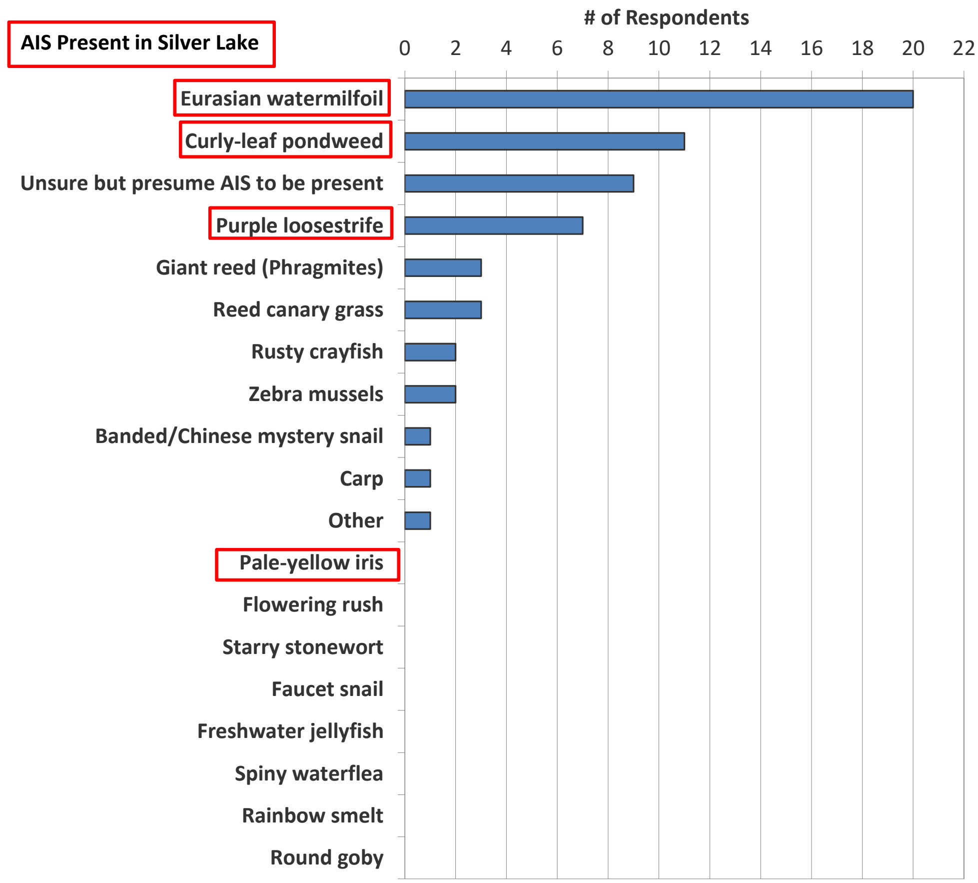


Figure 3.5-10. Stakeholder survey response Question #22. Which aquatic invasive species do you believe are present in or immediately around Silver Lake?

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Silver Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) and personal communications with DNR Fisheries Biologist Jason Breeggemann (WDNR 2021)

Silver Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Silver Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

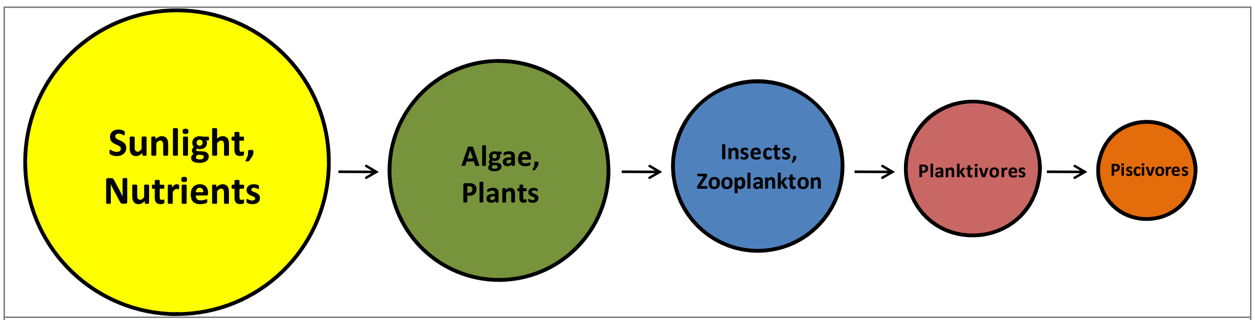


Figure 3.6-1. Aquatic food chain. Adapted from (Carpenter, Kitchell and Hodgson 1985)

Silver Lake is a meso-eutrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Silver Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 3.6-1 shows the popular game fish present in the system.

Table 3.6-1. Gamefish present in Silver Lake with corresponding biological information (Becker 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie (Pomoxis nigromaculatus)	7	May - June	Near Chara or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (Lepomis macrochirus)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other
Green Sunfish (Lepomis cyanellus)	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small
Largemouth Bass (Micropterus salmoides)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other
Northern Pike (Esox lucius)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (Lepomis gibbosus)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Walleye (Sander vitreus)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released. A one-night electrofishing survey was conducted on Silver Lake on May 23, 2017 (Appendix E). The primary objective of this survey was to examine species composition, abundance, and size structure metrics. All 1.3 miles of shoreline was surveyed with a boomshocker and length was recorded for any species of fish encountered.


Photograph 3.6-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Silver Lake was stocked on four occasions from 1998 to 2014 with largemouth bass and multiple times between 1972-2013 with northern pike (Table 3.6-2).

Photograph 3.6-2. Largemouth bass fingerling.

Table 3.6-2. Stocking data available for largemouth bass in Silver Lake (1998-2013).

Year	Age Class	# Fish Stocked	Avg Fish Length (in)
1998	LARGE FINGERLING	450	5.0
2012	LARGE FINGERLING	1,700	3.0
2013	LARGE FINGERLING	1,699	2.1
2014	LARGE FINGERLING	1,690	3.2

Table 3.6-3. Stocking data available for northern pike in Silver Lake (1972-2013).

Year	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	FRY	165,000	1
1976	FRY	100,000	-
1978	FRY	75,000	-
1979	FRY	75,000	-
1983	FINGERLING	350	9
1984	FINGERLING	350	9
1985	FINGERLING	400	9
1985	FRY	70,000	1
1986	FINGERLING	400	9
1987	FINGERLING	900	9
1991	FINGERLING	272	7
1992	FINGERLING	340	8
2009	LARGE FINGERLING	1,069	9.45
2012	SMALL FINGERLING	6,799	3.5
2013	SMALL FINGERLING	6,000	4.6

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water and ice) was the most important reason for owning property on or near Silver Lake (Question #10). Figure 3.6-2 displays the fish that Silver Lake stakeholders enjoy catching the most, with bluegill and crappie being the most popular. Approximately 27% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.6-3). Approximately 91% of respondents who fish Silver Lake believe the quality of fishing has remained the same or gotten worse since they first started to fish the lake (Figure 3.6-4).

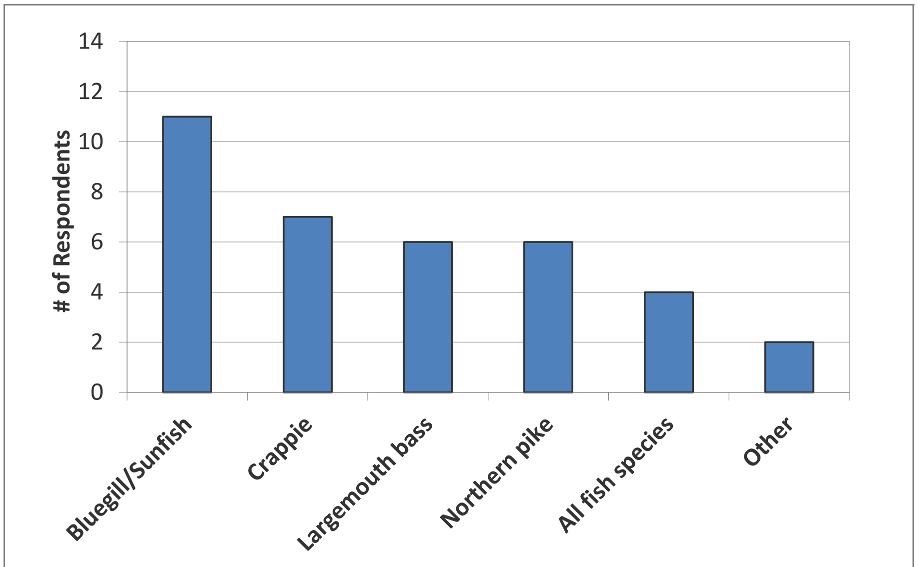


Figure 3.6-2. Stakeholder survey response Question #10. What species of fish do you like to catch on Silver Lake?

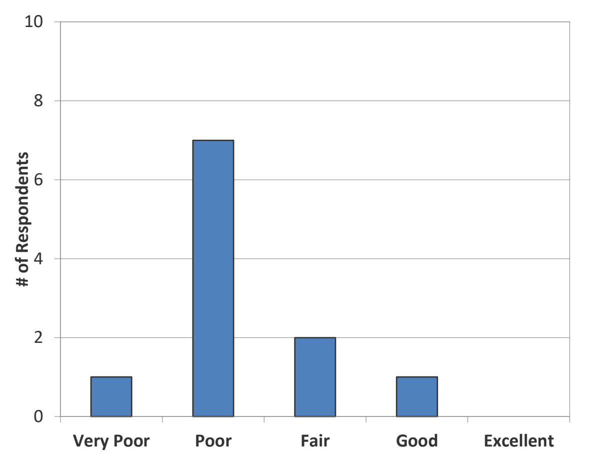
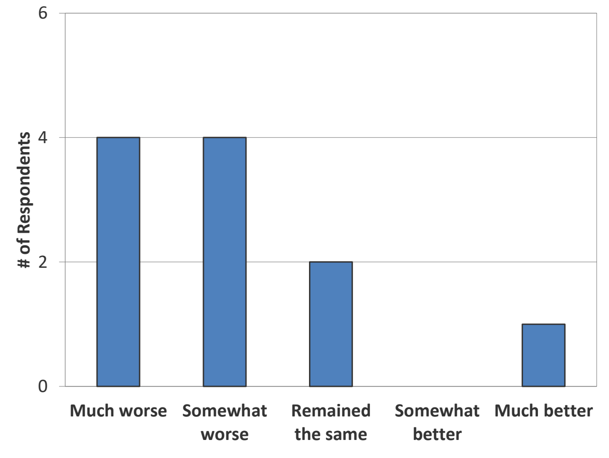
	

Figure 3.6-3. Stakeholder survey response Question #11. How would you describe the current quality of fishing on Silver Lake?	**Figure 3.6-4. Stakeholder survey response Question #12.** How has the quality of fishing changed on Silver Lake since you started fishing the lake?

Fish Populations and Trends

Utilizing the fish sampling techniques mentioned above and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. One method used in calculating the numbers captured is catch per unit effort (CPUE). This number provides a standardized way to compare fish abundances between years when the amount of fishing effort (number of nights' fyke nets are set) differs. When comparing within the same year, CPUE indexes are compared to statewide data by percentiles (Niebur 2015). For example, if a CPUE is in the 90^{th} percentile, it is higher than 90% of the other CPUEs in the state (Niebur 2015). Additionally, growth metrics can be calculated by selecting individuals from a specific length range and examining otoliths and spines. The average age is then compared to a statewide database and are given a percentile rank. Data from the 2017 electrofishing survey, found in Appendix E, examines abundance rankings and growth metrics for both panfish and largemouth bass. Ultimately, these data show a panfish and largemouth bass dominated fishery. Abundance metrics show high percentile ranks for black crappie, bluegill, largemouth bass, and pumpkinseed; the four most common species captured in the 2017 survey. When examining size metrics for these same four species, bluegill and largemouth had low percentile ranks while black crappie and pumpkinseed had moderate rankings. This is one example of how data is analyzed by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present on Silver Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch largemouth bass and northern pike on Silver Lake (Figure 3.6-2). Brief summaries of gamefish with fishable populations in Silver Lake are provided based off of the report submitted by WDNR fisheries biologist Jason Breeggemann following the fisheries survey completed in 2017 (Appendix E).

Largemouth bass are considered common in Silver Lake. From 1998-2014, 5,539 large fingerlings were stocked over four stocking events. In the 2017 electrofishing survey, 85 largemouth bass were captured and were the dominate gamefish species in Silver Lake (Appendix

E). Approximately 85% of the bass captured measured 14 inches or less. Silver Lake has history of repeated winterkills and the high number of small individuals collected in the 2017 survey may be an indicator of this (DNR communications, Jason Breeggemann).

Northern Pike are considered present in Silver Lake. Only nine individuals were captured during the 2017 survey, however, electroshocking is not the most effective method of surveying for northern pike. Between 2009 and 2013, almost 14,000 fingerling pike were stocked in Silver Lake (Appendix E).

Walleye are currently listed as a species present in Silver Lake by the DNR, however no walleye stocking events have occurred since the 1980's. Natural recruitment has never been documented and is not expected to be occurring.

Panfish

The panfish present on Silver Lake represent different population dynamics depending on the species. Abundant panfish populations are present, with quality sized individuals present as well. The results for the stakeholder survey show anglers prefer to catch bluegill and crappie on Silver Lake (Figure 3.6-2). Brief summaries of panfish with fishable populations in Silver Lake are provided based off of the WDNR fisheries survey completed in 2017.

Bluegill are the most abundant panfish on Silver Lake. While most of the bluegills captured during the 2017 survey were smaller individuals, some quality sized individuals were also captured. The largest fish captured measured nine inches. A small sample of bluegills were collected to examine growth rates. These fish measured between 5.5 to 6.5 inches and showed an average age of three years. This is considered a very high growth rate and ranked in the 100th percentile for the state (Appendix E).

Pumpkinseed were the second most common panfish captured in the 2017 survey. In total, 54 pumpkinseeds were recorded. These fish measured 2.8 to 7.5 inches in length, with 15 of the 30 fish measuring greater than six inches. Silver Lake ranked in the 57th percentile for pumpkinseed size metrics (Appendix E).

Black crappie are also present in Silver Lake. In the 2017 survey, 30 crappies were captured, measuring 5.8 to 12.0 inches in length. The average size measured 8.2 inches and ranked in the 64th percentile for the state. Several fish from 7.5 to 8.4 inches were collected to measure growth rates. With an average age of 7.4 years, the growth rate was very low, ranking in the 4th percentile when compared to other lakes in the state (Appendix E).

Fish Kill

Silver Lake has experienced periodic fish kills over winter caused by a lack of dissolved oxygen in the water. It is likely anoxic conditions can develop during the winter months when dissolved oxygen is depleted from biological processes in which oxygen is consumed. At least 10 fish kills have been recorded between 1959-1981. While no other fish kills have officially been recorded, data from recent surveys indicate that partial fish kills have occurred in recent years. In a 2009 electrofishing survey, only five bluegills were sampled, as well as several black bullheads and various minnow species. This indicates a severe winterkill had occurred in recent years even though no kills were officially recorded. Because of this, fingerling largemouth and northern pike were stocked from 2012-2014. Similarly, data from the 2017 survey shows a high density of small, fast-growing bluegills, which may be an indicator that a partial fish kill occurred in 2013 or 2014 (Appendix E). The year one classes of fish immediately following a disturbance often experience low competition for resources, allowing for quick growth. Gamefish populations appear to be rebounding naturally after this event.

Aeration

In 1984, the Scandinavia Silver Lake Rehabilitation District began working with the village of Scandinavia to install an aeration system in Silver Lake to maintain sufficient dissolved oxygen levels to avoid further fish kills. Aeration is a process where air is circulated through an aquatic system for the purpose of re-oxygenating the water. To address winter oxygen depletion, aeration is a common technique. Many believe that the aeration process itself re-oxygenates a lake by providing an air source to the water. While some oxygen may be provided to the lake in this manner, the greatest oxygen accumulation actually occurs through the creation of open water during the winter months, allowing for atmospheric exchange of oxygen with the open water. The overarching goal of winter aeration is to open an area of ice for this oxygen exchange, essentially creating a refuge for fish to last through the winter months. Therefore, it is not necessary to aerate large areas of a lake. Commonly, fish biologists refer to >1 to several acres of aerated area as a “refuge” where fish can overwinter.

In general, aeration systems are best suited in waters greater than five feet of depth within several hundred feet of shoreline. Because aeration units are power operated, an electrical source must be located near the unit. The aerator must be situated on public land or on private land with the landowner’s permission. Usually for an aeration system to be installed off of a private landowner’s property, the landowner must obtain a water regulations permit and become liable for the system, in accordance with Wisconsin Statute 167.26.

Silver Lake Fish Habitat

Substrate Composition

Just as forest wildlife require proper trees and understory growth to flourish, fish require certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Lakes with primarily a silty/soft substrate, many aquatic plants, and coarse woody debris may produce a completely different fishery than lakes that are largely sandy/rocky, and contain few aquatic plant species or coarse woody habitat.

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye are another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn and care for their eggs in muck as well.

According to the point-intercept survey conducted by Golden Sands in 2020, nearly 100% of the substrate sampled in the littoral zone of Silver Lake was composed of soft sediments.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats and spawning areas. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

Photograph 3.6-3. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

Fish cribs are a type of fish habitat structure placed on the lakebed. These structures are more commonly utilized when there is not a suitable shoreline location for fish sticks. Installing fish cribs may also be cheaper than fish sticks; however some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure. Having multiple locations of fish cribs can help mitigate that issue.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills, Bremigan and Haynes 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (Neuswanger and Bozek 2004).

Placement of a fish habitat structure in a lake may be exempt from needing a permit if the project meets certain conditions outlined by the WDNR's checklists available online:

(https://dnr.wi.gov/topic/waterways/Permits/Exemptions.html)

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption requested.

If interested, the Scandinavia Silver Lake Rehabilitation District, may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for Silver Lake.

Fishing Regulations

Regulations for Silver Lake fish species as of December 2021 are displayed in Table 3.6-4.

For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-4. WDNR fishing regulations for Silver Lake (As of December 2021).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass	5	14"	May 1, 2021 to March 6, 2022
Northern pike	5	None	May 1, 2021 to March 6, 2022
Walleye, sauger, and hybrids	3	18"	May 1, 2021 to March 6, 2022
Bullheads	Unlimited	None	Open All Year

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed; however, this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-8. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

Fish Consumption Guidelines for Most Wisconsin Inland Waterways		
	Women of childbearing age, nursing mothers and all children under 15	**Women beyond their childbearing years and men**
Unrestricted*	-	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout
1 meal per week	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout	Walleye, pike, bass, catfish and all other species
1 meal per month	Walleye, pike, bass, catfish and all other species	Muskellunge
Do not eat	Muskellunge	-

**Doctors suggest that eating 1-2 servings per week of low-contaminant fish or shellfish can benefit your health. Little additional benefit is obtained by consuming more than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 3.6-5. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

Fishery Management & Conclusions

Silver Lake is currently managed as largemouth bass and bluegill fishery. Based on findings from the survey conducted in 2017, good numbers of panfish and predators were recorded and stocking is not scheduled to occur. One objective highlighted was the management of invasive plants. Invasive plants create dense beds of vegetation that hinder a predator’s ability to prey on smaller fish. This can lead to a high population of slow-growing fish, reducing the overall size of both gamefish and panfish. Silver Lake is currently on an eight-year survey rotation with the next survey scheduled for 2025. If the bass population is still dominated by small individuals, a special harvest regulation may be considered.

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three objectives;

1) Collect baseline data to increase the general understanding of the Silver Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil.
3) Collect sociological information from Silver Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The three objectives were fulfilled during the project and have led to a good understanding of the Silver Lake ecosystem, the folks that care about the lake, and what needs to be completed to protect and enhance it.

Silver Lake has changed greatly in recent decades. Overall, since the early 2000s, the lake has better water quality, but has seen a tremendous increase in vascular plant occurrence. These two traits are closely related in Silver Lake, primarily because of the level of nutrients in the lake and due to the lake's shallow depths. This relationship is not new to Silver Lake. Paleoecological analysis of bottom sediments indicate that even 150 or more years ago, before European settlement, that the lake had high vascular plant biomass and high levels of nutrients. The biggest difference between the lake at that time and now, is moderately higher nutrient levels and the composition of the plant population the lake supports, specifically several exotics, and lesser quality species that typically thrive in disturbed systems.

Shallow lakes are special in that they typically occur in one of two stable states; either a clear state or a turbid state. Basically, shallow lakes are either algae dominated with reduced water clarity, or dominated by macrophytic (vascular) plant growth with clearer water. This is partially driven by the fact that nutrients are essentially not taken out of the system by settling to a deep portion of the lake. In shallow lakes, the nutrients are recycled to a great degree; further, a large portion of the lake is subject to aquatic plant growth. The Water Quality Section 3.1 includes a detailed description of these alternate stable states and what determines the state in which a lake will exist.

Silver Lake has an excellent historical water quality database because it has been a part of the WDNR Long-Term Lake Monitoring Program for decades. With the exception of 2000-2004 when funding was not available, multiple growing season data points are available from present back to 1988. This dataset clearly indicates a transition of Silver Lake from a turbid state to a clear state between the lake 1990s and 2005. In fact, water clarity values increased at least by 33% over that timeframe. The exact level of increase cannot be determined because Secchi disk readings often reached the bottom of the lake, so the actual depth of clarity could not be determined. The transition of the lake was likely brought on by the summation of several factors, including the reduction of abnormally high bullhead population, reduction of nutrient inputs from the watershed, and an increase in vascular plants within the lake.

Over the past two decades, the Silver Lake watershed has experienced several changes, including the removal of animal feedlots, conversion of agricultural practices to include nutrient management plans, and the addition of settling basins to treat incoming flows. Likely the most significant change seen in the lake's watershed was the citizen-driven conversion of lake side farm fields to the Jorgens Park Preserve.

The non-native, submergent, aquatic plant, Eurasian watermilfoil was first documented in Silver Lake in 1993. In the mid-1990s management actions were started to attempt to control the plant's spread. By the early 2000s management actions came to an end. Quantitative aquatic plant studies completed in 2005, 2012, and 2020 indicate that three species dominate the Silver Lake plant community; coontail, common waterweed, and Eurasian watermilfoil. Further, their abundancies within the lake have occurred in that order in each survey. Specimens collected as a part of this project were subjected to DNA analysis that indicates a large portion of the milfoil population is a hybrid between the native, northern watermilfoil and the non-native, Eurasian watermilfoil. Hybrid watermilfoil (HWM) has been shown to be more invasive and tolerant of many commonly used herbicides, making control more difficult.

The plant community in Silver Lake, as described above, is highly dominated by two native species and one non-native species. Most of the other species that exist in the lake are not considered high quality species. Specifically, most of the species that exist are those that can tolerate the high levels of disturbance that have occurred in the lake since European settlement. However, even though the plant population is not considered high quality, it is directly responsible for maintaining the lake's current clear state. Over management of the Silver Lake aquatic plant population would likely lead to a transition of the lake back to a turbid state. That fact weighs heavily in all aquatic plant management options for the lake.

Controlling HWM on a lake-wide scale in Silver Lake through herbicide treatments would be difficult. This is not just because of the abundance of HWM, but also because the lake's most dominant plant, coontail, would also be highly impacted by any herbicide that would be effective at controlling HWM; including 2,4-D and ProcellaCOR. As described above, significant alterations to the aquatic plant biomass in the lake could result in 'flipping' the lake back to a turbid state. Completing a lake-wide treatment to control HWM would result in unintended reductions in coontail as well; therefore, lake-wide HWM control is not currently be considered on Silver Lake.

In general, three AIS management perspectives exist; 1) let nature take its course, 2) nuisance management to assure recreational opportunities, and 3) lake-wide population control. More specific information on these perspectives, as well as information on particular herbicides, is contained near the end of the Aquatic Plant Section 3.5.

During the planning process, the three perspectives were considered. Lake-wide population control is not being considered at this time for the reasons described above. No management actions have occurred on the lake since the early 2000s and as documented by studies completed in 2020 and 2021, the majority of the lake currently exhibits nuisance levels of aquatic plants and is essentially unusable for recreational enjoyment. Therefore, the planning committee considered two options for providing nuisance relief in order to enhance recreational opportunities; 1) an integrated management approach utilizing mechanical harvesting and limited herbicide use to create navigation and fish cruising lakes within the lake, and 2) the trial use of a newer herbicide, ProcellaCOR, to treat two four-acre, high-use areas in Silver Lake to control HWM.

Ultimately, the trial ProcellaCOR treatment was chosen as the primary aquatic plant management action. Implementation of the trial treatment will only occur if state funding is gained. This is considered a ‘trial treatment’ because the use of ProcellaCOR in lakes with dense plant populations and high alkalinity values, both of which are characteristics of Silver Lake, have not shown as high of a level of effectiveness as lakes with less dense aquatic plant populations and lower alkalinities. These factors contribute to an increased breakdown of the herbicide’s active ingredient into a less impactful metabolite. The trial treatment is proposed to occur in the spring of 2023 and would be accompanied by quantitative monitoring of target and non-target species before and after the treatment, as well as monitoring of herbicide concentrations during and immediately after the treatment. The treatment is recommended to occur as early in the proper seasonal spectrum as possible because the pH is likely to be less and the HWM biomass at a slightly lower level. The results of the 2023 treatment would dictate further aquatic plant management actions on Silver Lake, which could include additional ProcellaCOR treatments or the use of the integrated aquatic plant management option considered earlier.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Scandinavia Silver Lake District Planning Committee and ecologist/planners from Onterra. It represents the path the SSLD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Silver Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain Silver Lake's Water Quality in its Current 'Clear State'

Management Action:	**Create informational communication regarding Silver Lake's historical and current water quality conditions.**
Timeframe:	Early 2023
Facilitator:	Board of Commissioners
Description:	In terms of water clarity and open water algae blooms, Silver Lake experienced a significant increase in water quality since the early 2000's. The lake is currently in a "Clear State' when it was once in a 'Turbid State'. While the lake is still highly productive and showing symptoms of past nutrification, the lake is now in better ecological health than when it was dominated by phytoplankton, which caused the lake's water to be murky. A solid understanding of this fact is important in motivating district members to protect, or possibly improve, the lake's current state of water quality. The Water Quality Section 3.1 and Watershed Assessment Section 3.2 discuss the current and historical water quality of Silver Lake, in detail. A description of 'Clear' and 'Turbid' states is also discussed. District volunteers will summarize this information in the form of a simple document that can be posted on the district website and distributed at district events.
Action Steps:	See description above.

Management Action:	**Monitor Secchi disk transparency through WDNR Citizens Lake Monitoring Network.**
Timeframe:	Begin summer 2023.
Facilitator:	Board of Commissioners
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be

used for long-term trend analysis. This SSLD and this project benefited from the water quality data gathered through the WDNR Long-Term Trends Monitoring Program, which has facilitated consistent sampling of Silver Lake since 1989.

Volunteers from the SSLD will collect Secchi disk clarities through the WDNR Citizen Lake Monitoring Program (CLMN). Participation in the CLMN Secchi disk program will supplement the WDNR water quality collections. It will also provide the necessary WDNR credentials to access Silver Lake water quality data through the Surface Water Integrated Management System (SWIMS) database, and if needed, allow for quicker advancement to the CLMN Advanced Water Quality Program, in the event the WDNR stops collecting water quality information at Silver Lake. The CLMN Advanced Water Quality Program funds and trains volunteers to collect lake water quality samples for analysis by the Wisconsin State Laboratory of Hygiene. CLMN data are automatically entered on SWIMS.

Action Steps:

1. Facilitator recruits volunteer from district.
2. Volunteer collects Secchi disk data following CLMN protocol.
3. Volunteer reports CLMN and WDNR Long-Term Trends results to district at annual meeting and via website.

Management Goal 2: Increase Scandinavia Silver Lake Capacity to Manage Silver Lake

Management Action:	**Create a district-specific communication strategy for district events and business.**
Timeframe:	Early 2023.
Facilitator:	Board of Commissioners
Potential Grant:	Surface Water Education Grant
Description:	A disadvantage of having a Village Board act as the Lake District Board of Commissioners is that district communications and functions become mixed with and indiscernible from village business. The written stakeholder survey created as a part of this management project was only provided to district households, and yet, 36% of respondents stated they had never heard of the SSLD, while 62% answered that they were never a member of the district. To alleviate this issue, the district will devise its own strategy to communicate with district members regarding district events and business. This strategy will include lake-related educational communications, developing and maintaining a district specific portion

of the village website, and maintaining partnerships with other management units involved with Silver Lake.

Action Steps:

1. District Board of Commissioners will recruit volunteers to function as an education and communication committee for the SSLD.
2. Committee creates draft communication strategy and determines possible budgetary needs.
3. If needed, the committee will contact WDNR regional staff to discuss applying for a Surface Water Education Grant to cover 67% of the costs involved with implementing items like modifying the website and creating district wide mailings.

Management Action:	Develop partnerships with other entities that have responsibilities in managing Silver Lakes
Timeframe:	Early 2023
Facilitator:	SSLD Education and Communication Committee
Description:	The purpose of the SSLD is to protect and promote the health Silver Lake The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the SSLD actively engage with all management entities to enhance the understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page:
Action Steps:	
	See table guidelines on the next pages.

Table 5.0-1 Management Partner List.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Golden Sands Resource Conservation & Development Council	Staff (715.343.6215)	Nonprofit organization that covers central WI	Once a year, or more as issues arise.	Provide information on conservation and natural resource preservation
Waupaca County Highway Department	Commissioner (Casey Beyersdorf, casey.beyersdorf@co.waupaca.wi.us or 715.258.7152)	Maintains STH 49 & 161.	As needed	Contact to discuss debris management in Hwy 49 & 161 culverts
Waupaca County Land Conservation Department/ Committee	County Conservationist (Brian Haase - Brian.Haase@co.waupaca.wi.us or 715.258.6482)	Oversees conservation efforts for land and water projects.	Continuous as it relates to lake and watershed activities	Can aid with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Aaron Oconnell – 920.420.9203, aaronr.oconnell@wisconsin.gov)	Manages the fishery of Lake Iola.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery and fish structure
	Lakes Coordinator (Ted Johnson – TedM.Johnson@wisconsin.gov 920.424.2104)	Oversees management plans, grants, all lake activities.	Continuous as it relates to lake management activities	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues including AIS management.
	Citizens Lake Monitoring Network contact (Ted Johnson – 920.424.2104)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Early spring: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
University of Wisconsin – Extension Lakes Program	Eric Olson, Director and Lakes Specialist (715.346.2192) Paul Skawinski, Citizens Lake Monitoring Network Educator (715.346.4853)	Provide general information regarding lakes and lake districts. Assist in CLMN training and education.	As needed.	The UW-Ext Lakes Program is a resource for educational materials and guidance regarding lakes, lake monitoring, and the operations of lake management districts.
Wisconsin Lakes	General staff (608.661.4313 or info@wisconsinlakes.org)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	LILD members may attend WL's annual conference to keep up-to-date on lake issues.

Management Action:	Assure consistent funding for lake management activities on Silver Lake.
Timeframe:	Early 2023
Facilitator:	Board of Commissioners
Description:	Lake management and lake management planning, even with occasional state grant funding, costs money. Until 2021, most lake management-related costs have been funded through donations by civic groups and non-profit organization, such as the Booster Club and the Jorgans Park Preserve. To fund the implementation of this plan and other activities that may take place in the future, the District Board of Commissioners will develop a lake district budget that will include appropriate funding from state grants, local organizations, and an annual lake district levy. The lake district budget and levy amount will need to be approved by the district membership at the district's annual meeting.
Action Steps:	
1.	Develop lake district budget for 2-3 years into the future. This may include bid lettings for specific actions, as needed.
2.	Determine sources for funding, including local groups, state grants, and district levy.
3.	Present budget to district membership and vote on levy.

Management Goal 3: Assure Recreational Opportunities on Silver Lake

Management Action:	Use integrated pest management to control nuisance aquatic plants and provide access to open water.
Timeframe:	Begin 2023
Facilitator:	Board of Commissioners
Potential Grant:	Small-Scale AIS Control Grant
Description:	Nuisance aquatic plants, as documented by the 2020 point-intercept survey, the AIS surveys conducted as a part of this project, and the biovolume assessment, also completed as a part of this project, hamper many recreational actives on Silver Lake, including passive and motorized boating and fishing. As discussed in the Aquatic Plant Section 3.5, hybrid watermilfoil occurs in Silver Lake to a great degree; however, it is the third most common species in the lake behind coontail and common waterweed. HWM does provide substrate for coontail and common waterweed to thrive upon; therefore, removing a portion of the HWM may also

	alleviate some of the issues brought on by the high biovolume of plants hampering recreational activities on the lake. ProcellaCOR has shown promising results in many EWM and HWM treatments over the past 3-4 years in Wisconsin. However, in lakes with dense plants and elevated pH, like Silver Lake, treatment efficacy appears to be somewhat lower; therefore, the SSLD would conduct a trial ProcellaCOR treatment on Silver Lake and monitor the results closely to determine its effectiveness on HWM and on reducing nuisance levels of coontail and common waterweed. The preliminary treatment plan is shown in Map 12. The SSLD would only complete this trial treatment with financial support through a WDNR Small-scale AIS Control Grant; therefore, an elevated level of monitoring would be completed as a part of that project. The monitoring would include pre- and post-treatment subsample point-intercept surveys over the treatment areas the year before treatment, year of treatment, and the year following treatment (Map 12). Further, annual mapping surveys would be completed during those three years. Finally, herbicide concentration monitoring, with samples being collected by district volunteers, would be conducted following a WDNR-approved sampling design.
Action Steps:	
1.	Request a declaration of edibility for AIS grant from WDNR Regional Lakes Biologist for this APM activity.
2.	Submit preapplication materials to WDNR for Small-Scale AIS Control Grant funds by September 15, 2022.
3.	Submit final application materials by November 15, 2022.
4.	Implement project after receiving funding news in February 2023.

Management Action:	Conduct periodic quantitative vegetation monitoring on Silver Lake.
Timeframe:	Point-Intercept Survey every 5 years, Community Mapping every 10 years, AIS survey as deemed necessary by SSLD.
Facilitator:	Board of Commissioners
Potential Grant:	Surface Water Planning Grant
Description:	As part of the ongoing AIS and vegetation management program, a whole-lake point-intercept survey will be conducted at a minimum once every 5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Silver Lake and allow for periodic, lakewide surveillance of the lake for new and existing AIS. A point-intercept survey was conducted on Silver Lake in 2020; therefore, the next survey would be completed in 2025.

In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Silver Lake, a community mapping survey would be conducted approximately every 10 years. A community mapping survey was conducted on Silver Lake in 2021 as a part of this management planning effort. The next community mapping survey will be completed in 2030 to coincide with the point-intercept survey that would potentially occur 5 years after the 2025 point-intercept survey discussed above. Note that the community mapping survey should be done during the same summer as a point-intercept survey, so the schedule of point-intercept surveys, as laid out above, would be the determinant of the community mapping survey.

AIS surveys would be completed at the discretion of the SSLD, but would likely coincide with the plant surveys described above to increase grant-funding possibilities.

Action Steps:

See description above.

6.0 METHODS

Will be completed in final version.

7.0 LITERATURE CITED

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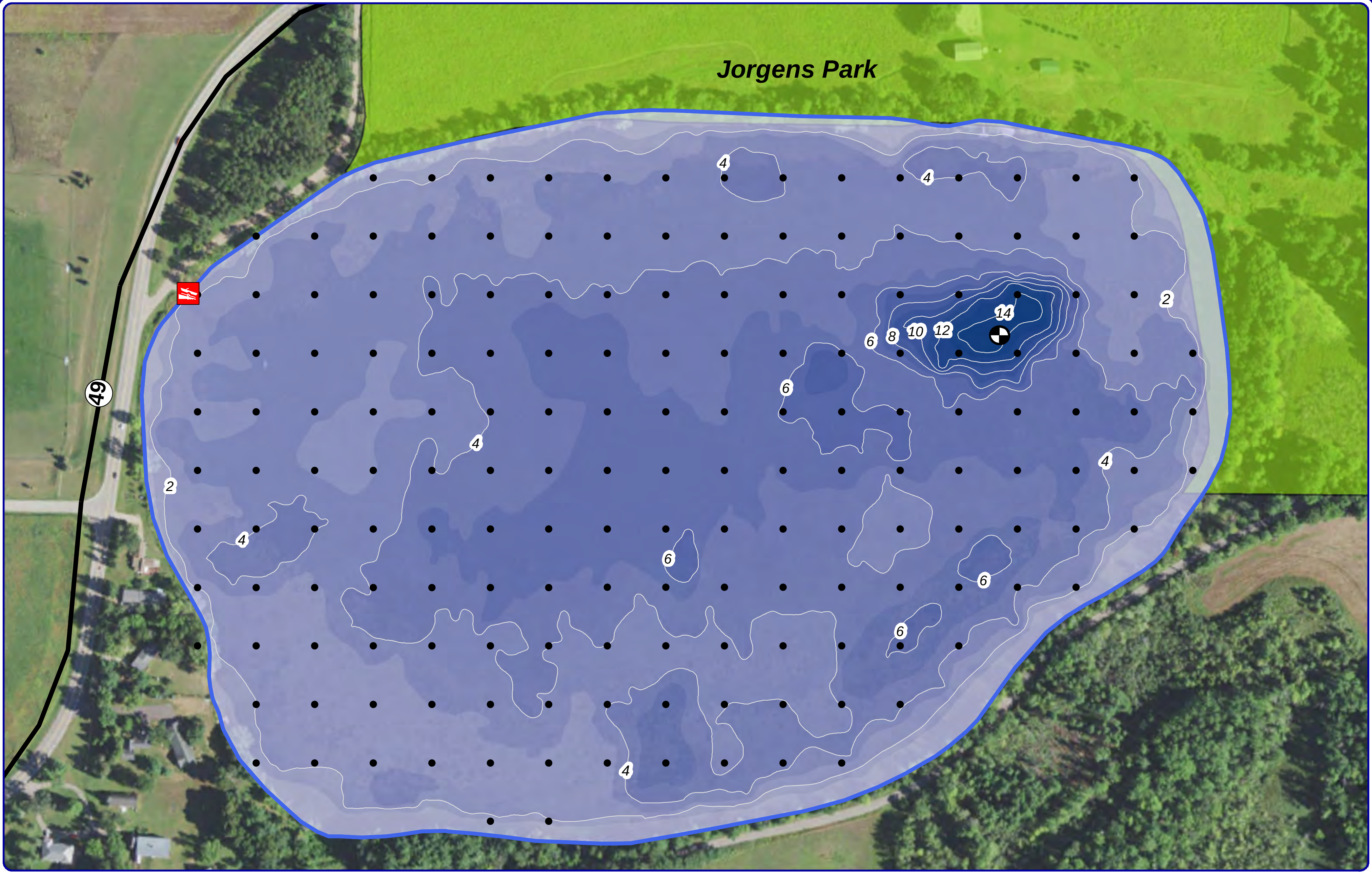

280
Feet

Onterra LLC
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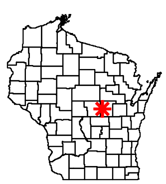
www.onterra-eco.com

Sources:
Hydro: WDNR
Bathymetry: Onterra 2021
Orthophotography: NAIP 2020
Map Date: February 10, 2022 - EJH



Project Location in Wisconsin

Legend

Silver Lake ~ 71 acres
Onterra Definition

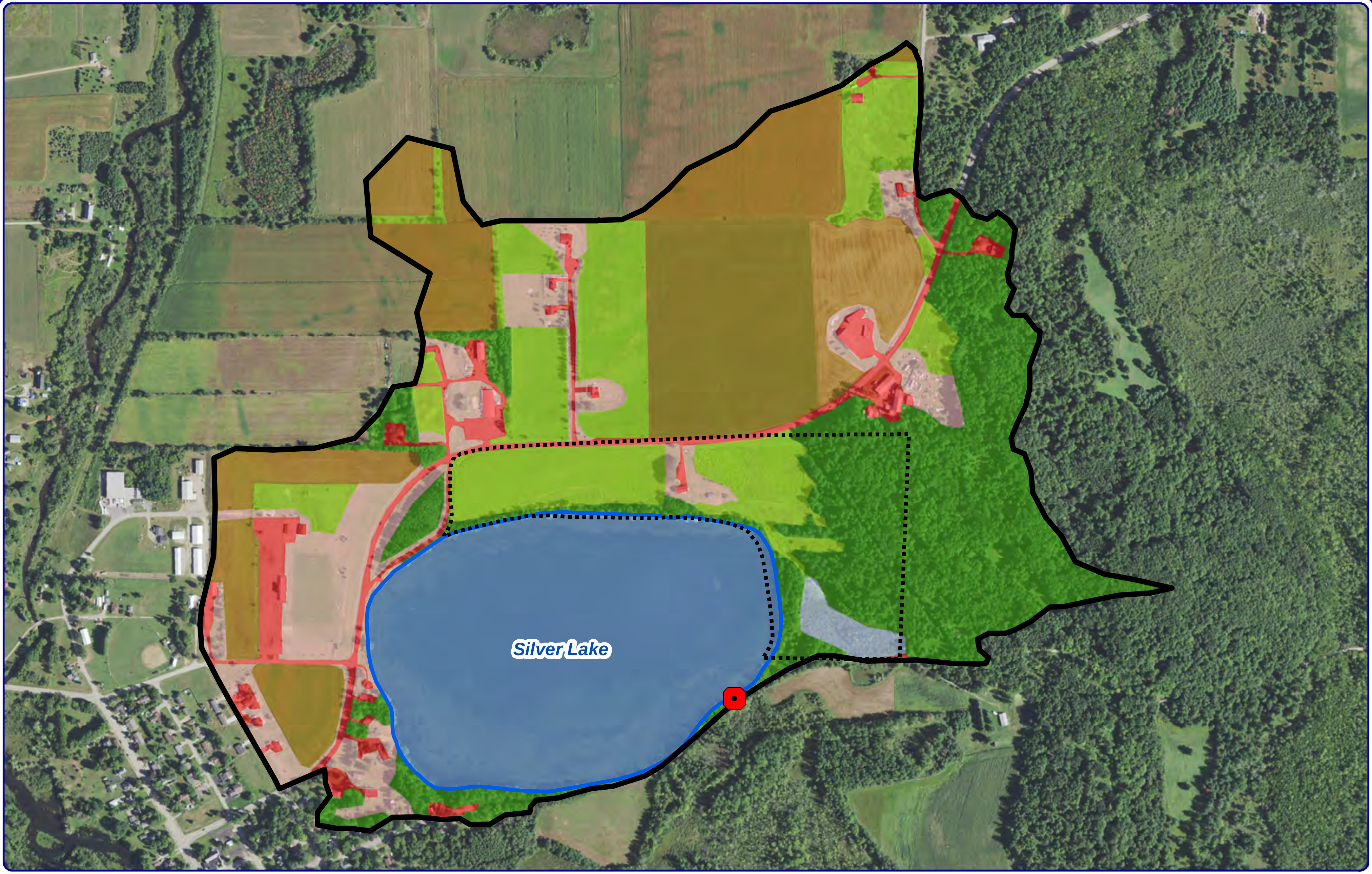
Point-intercept Sample Location
40-meter spacing, 173 points

2021 Water Quality Sampling Location

Public Access

Jorgens Park and Preserve

Map 1
Silver Lake
Waupaca County, Wisconsin
Project Location & Lake Boundaries



N
W E
S

750

Feet

Legend

- Silver Lake Watershed Boundary
- Culvert Location
- Jorgens Park & Preserve
- Upland Forest
- Grassland
- Wetland - Non-Forested
- Open Water
- Urban - Pervious
- Urban - Impervious
- Cropland

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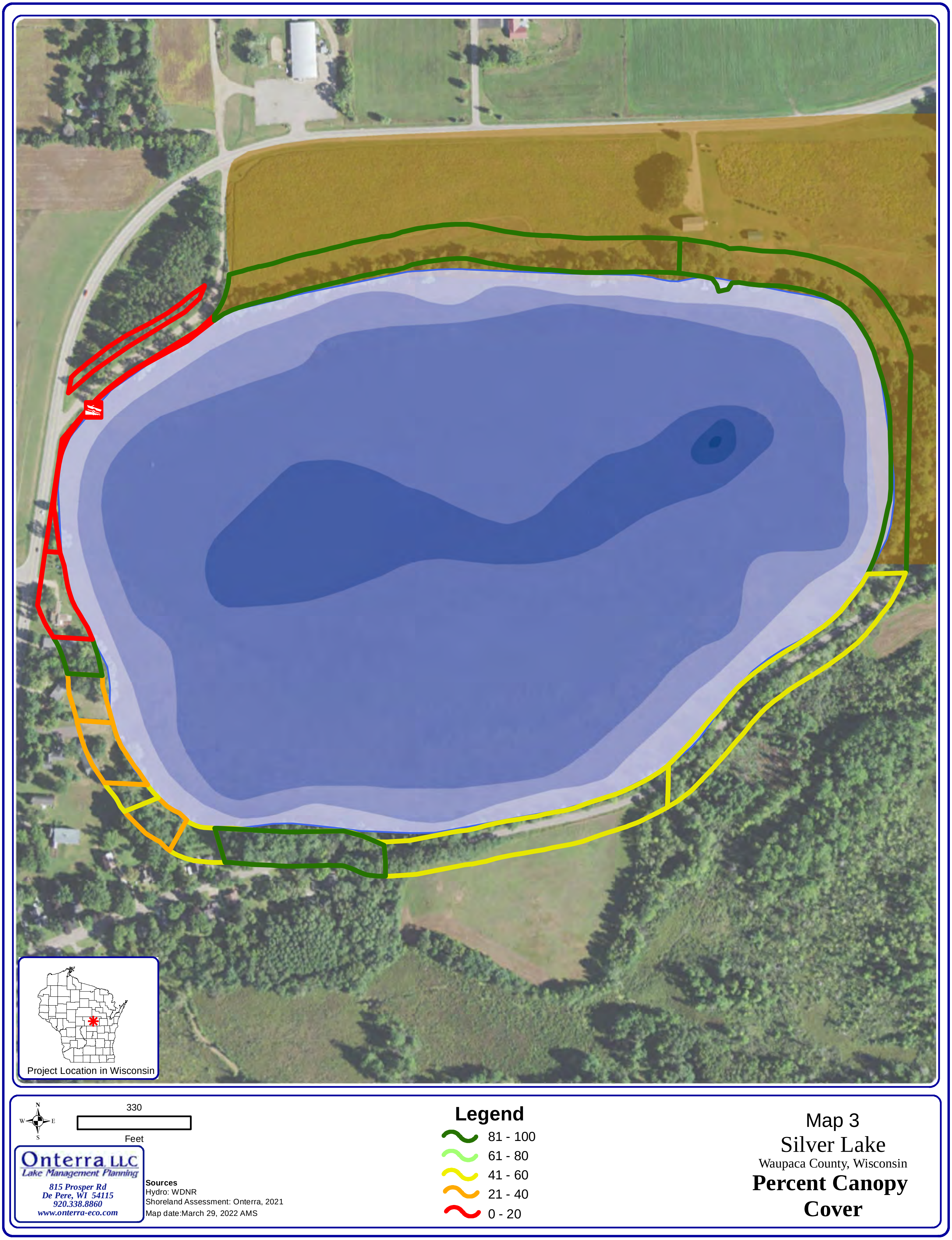
Sources:
Hydro: WDNR
Bathymetry: Onterra, 2021
Orthophotography: NAIP 2020
Land Cover: NAIP 2020
Watershed Boundaries: Onterra, 2022
Map date: February 25, 2022 BTB
Filename: Map2_SilverW_WS.mxd

Map 2

Silver Lake

Waupaca County, Wisconsin

Watershed Boundary & Land Cover Types



Project Location in Wisconsin
330
Feet
Legend
81 - 100
61 - 80
41 - 60
21 - 40
0 - 20
Map 3
Silver Lake
Waupaca County, Wisconsin
Percent Canopy Cover
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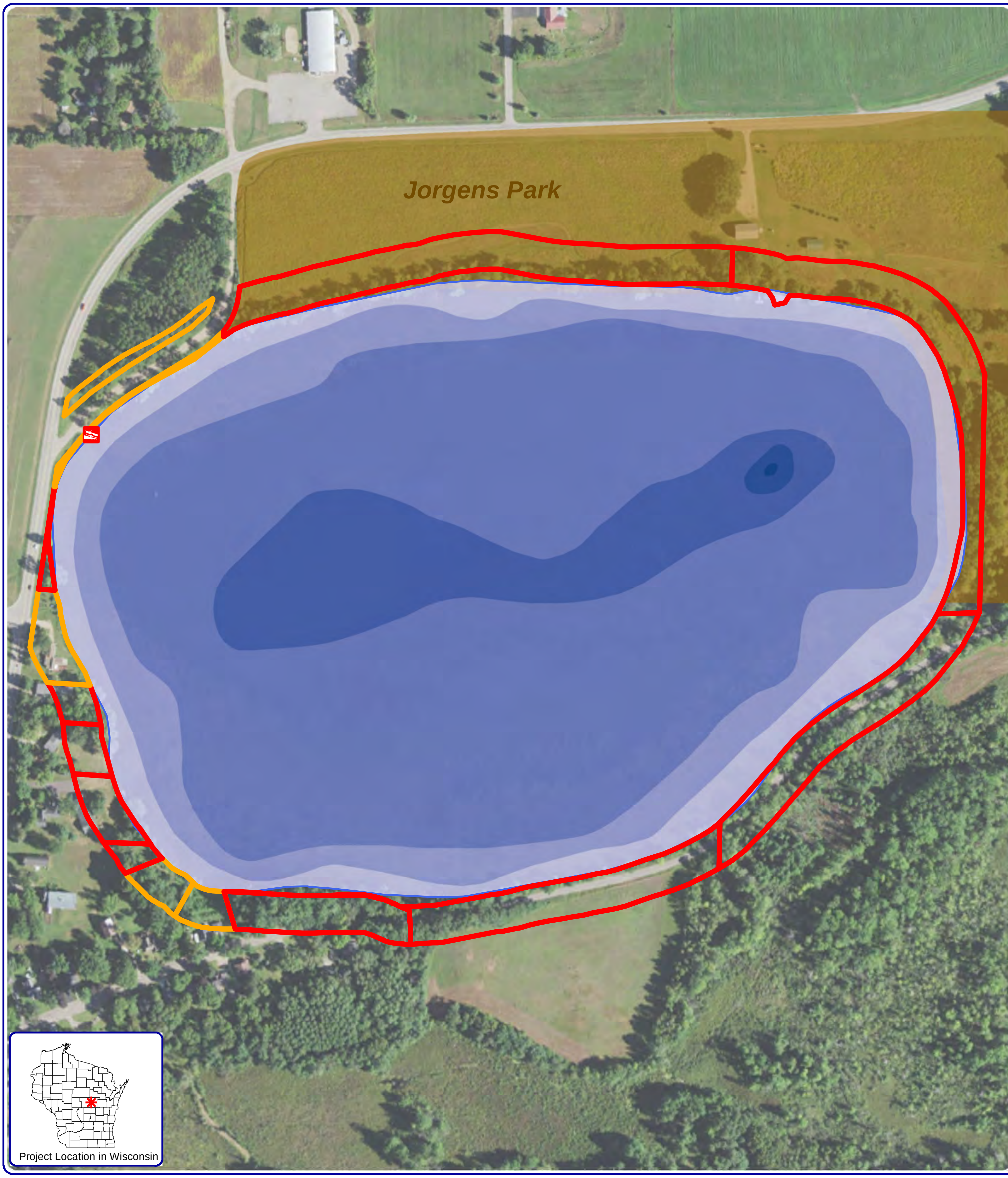
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2021
Map date:March 29, 2022 AMS



330

Feet

Legend

- 0-20
- 21-40
- 41 - 60
- 61-80
- 81-100

Jorgens Park Preserve

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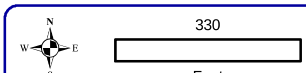
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2021
Map date:March 30, 2022 AMS

Map 4

Silver Lake

Waupaca County, Wisconsin

Percent Shrubs & Herbaceous



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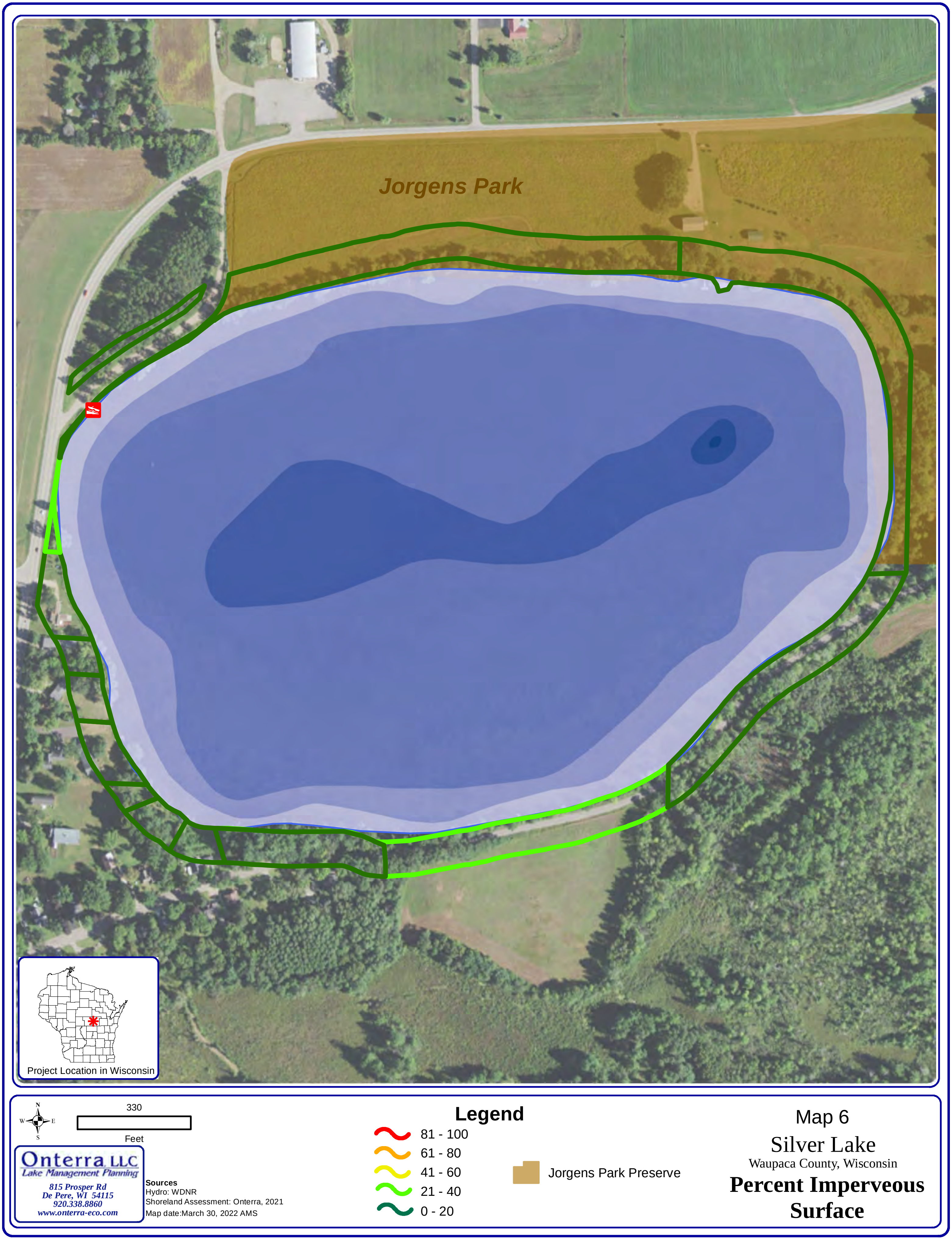
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2021
Map date:March 30, 2022 AMS

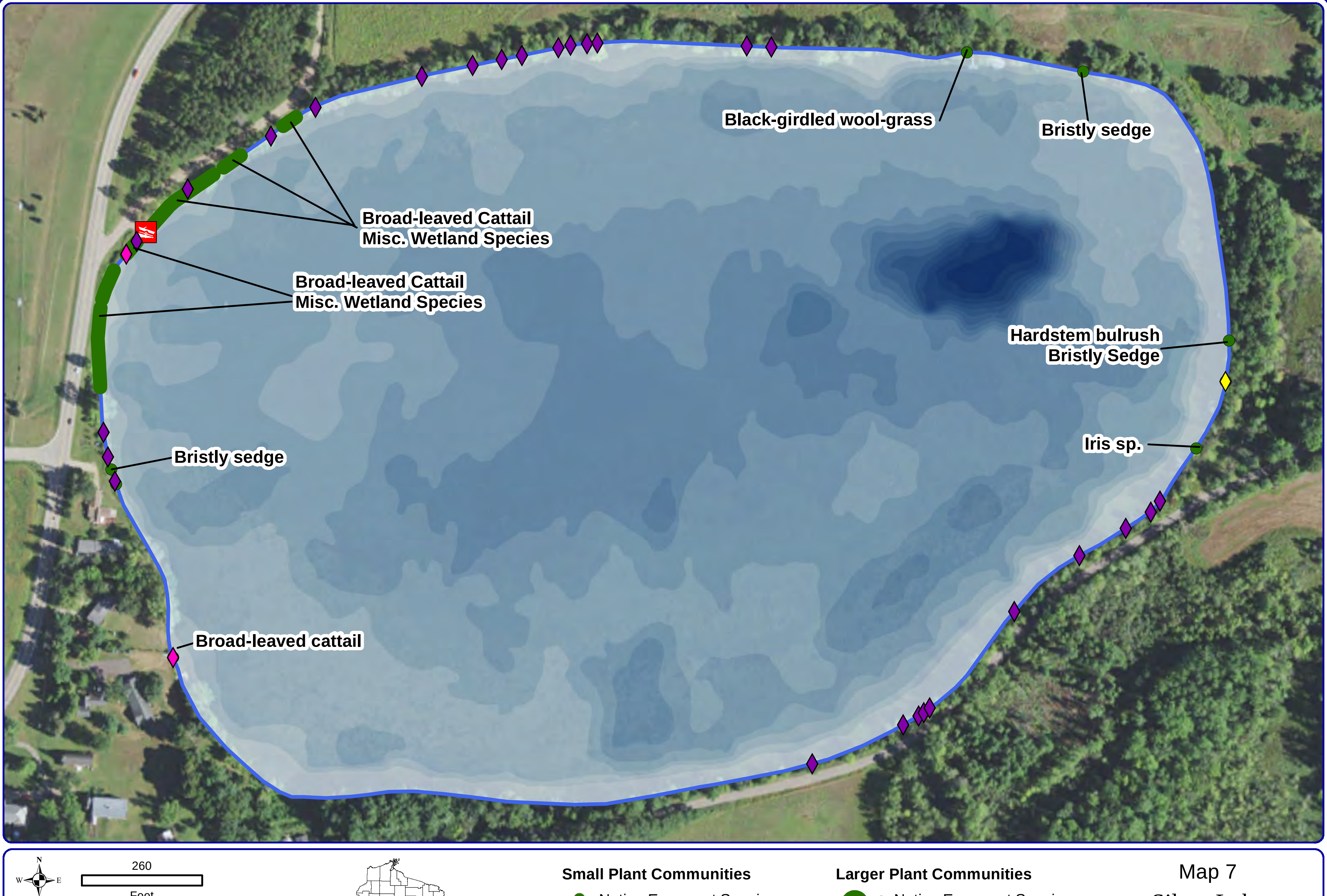
Legend

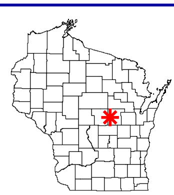
- 81 - 100
- 61 - 80
- 41 - 60
- 21 - 40
- 0 - 20

Jorgens Park Preserve

Map 5
Silver Lake
Waupaca County, Wisconsin
Percent Manicured Lawn


Jorgens Park
Project Location in Wisconsin
N
W
E
S
330
Feet
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2021
Map date:March 30, 2022 AMS
Legend
81 - 100
61 - 80
41 - 60
21 - 40
0 - 20
Jorgens Park Preserve
Map 6
Silver Lake
Waupaca County, Wisconsin
Percent Imperveous Surface





Project Location in Wisconsin

Small Plant Communities

- Native Emergent Species
- Non-Native Purple Loosestrife
- Non-Native Ornamental Lily
- Non-Native Pale-yellow Iris

Larger Plant Communities

- Native Emergent Species

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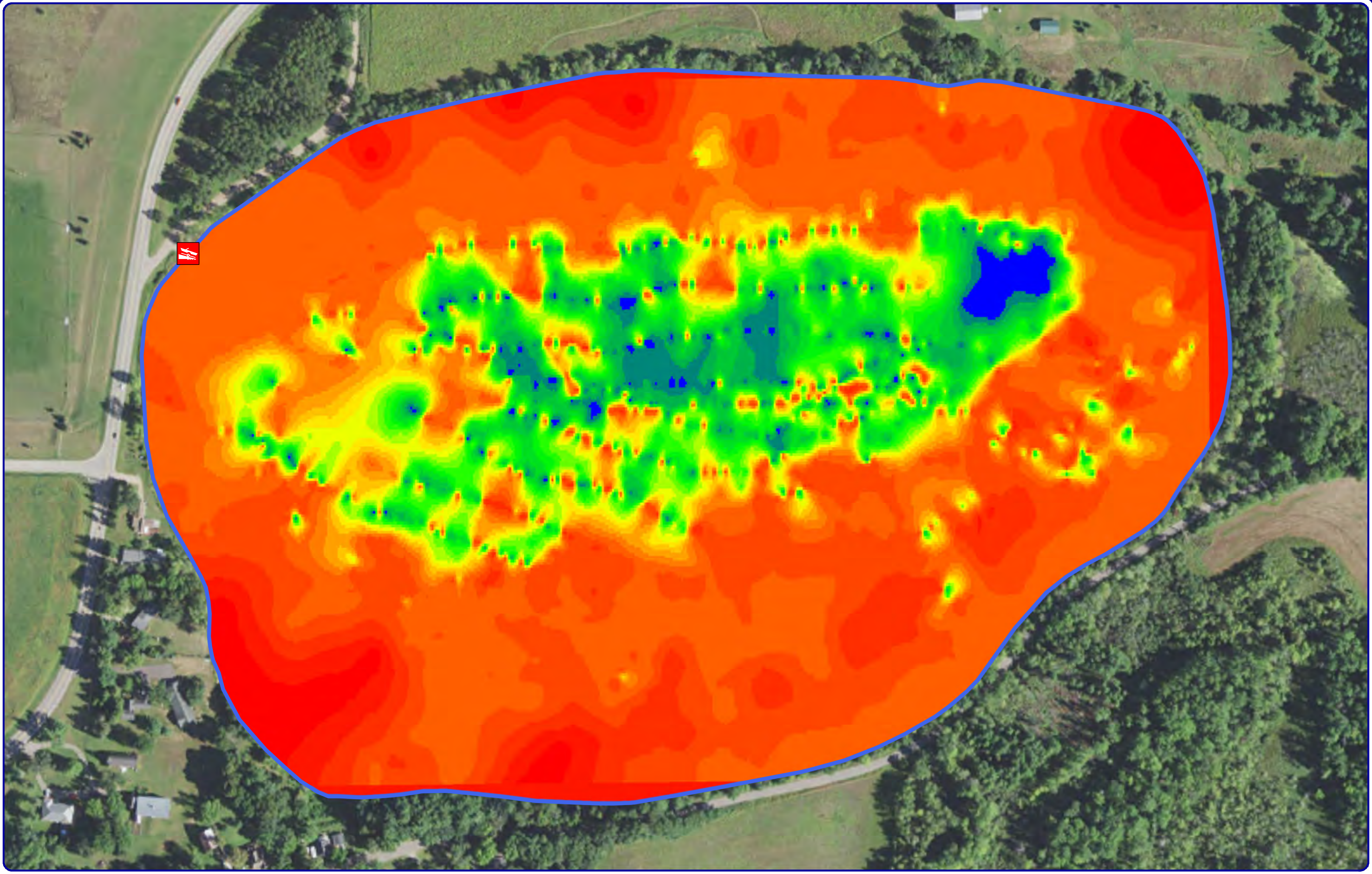
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2021
Orthophotography: NAIP, 2020
Map date: October 5, 2021 AMS

Map 7

Silver Lake

Waupaca County, Wisconsin

Aquatic Plant Communities



280
Feet

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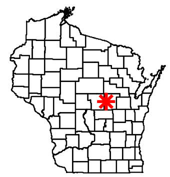
Sources:
Hydro: WDNR
Bio-volume: Onterra 2021
Orthophotography: NAIP 2020
Map Date: February 10, 2022 - EJH



Project Location in Wisconsin

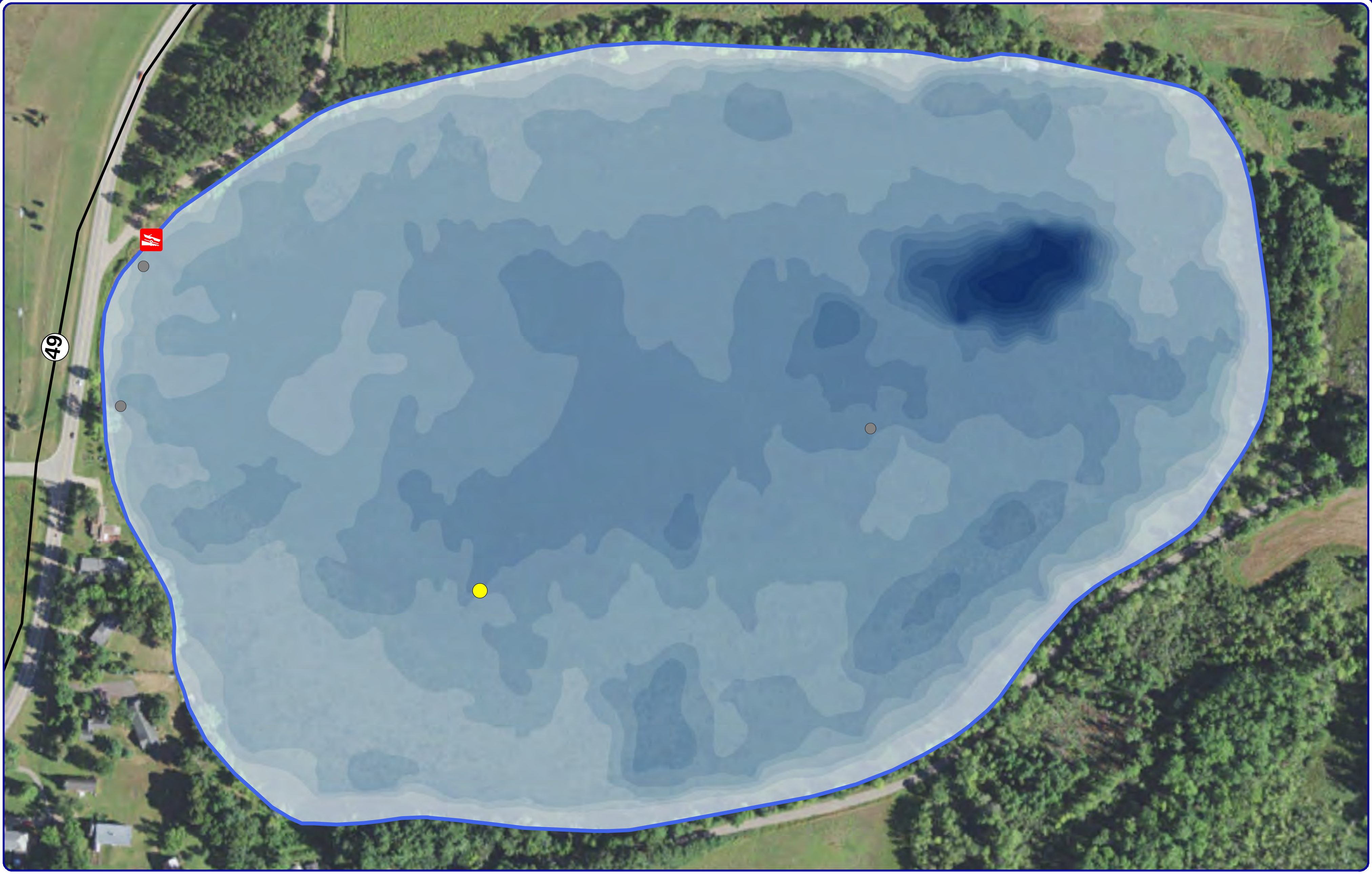
Legend

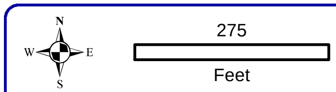
0% 50% 100%

Bio-volume (%)

Map 8
Silver Lake
Waupaca County, Wisconsin

July 2021 Acoustic Survey Results- Aquatic Plant Bio-Volume





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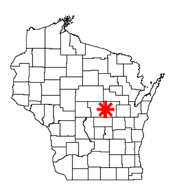
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2021

Map Date: July 19, 2021 AMS/JMB
Filename:Silver_Waupaca_CLP_May21.mxd



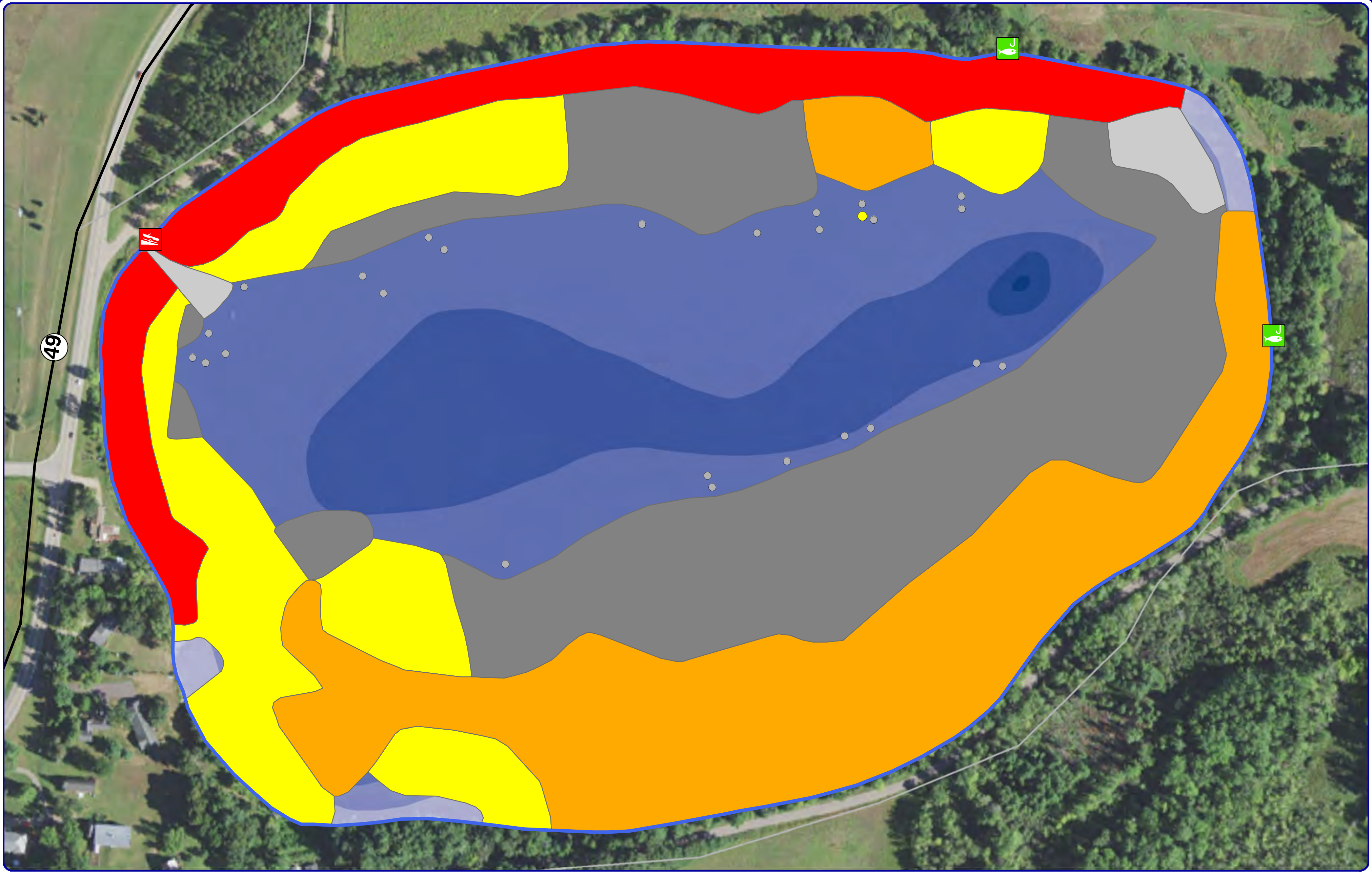
Project Location in Wisconsin

Legend

- Highly Scattered *(None)*
- Scattered *(None)*
- Dominant *(None)*
- Highly Dominant *(None)*
- Surface Matting *(None)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(None)*

Map 9
Silver Lake
Waupaca, Wisconsin

May 2021 CLP Survey Results



N
W E
S

275
Feet

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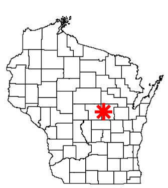
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2021
Map Date: July 19, 2021 AMS/JMB
Filename:Silver_Waupaca_EWM_May21.mxd

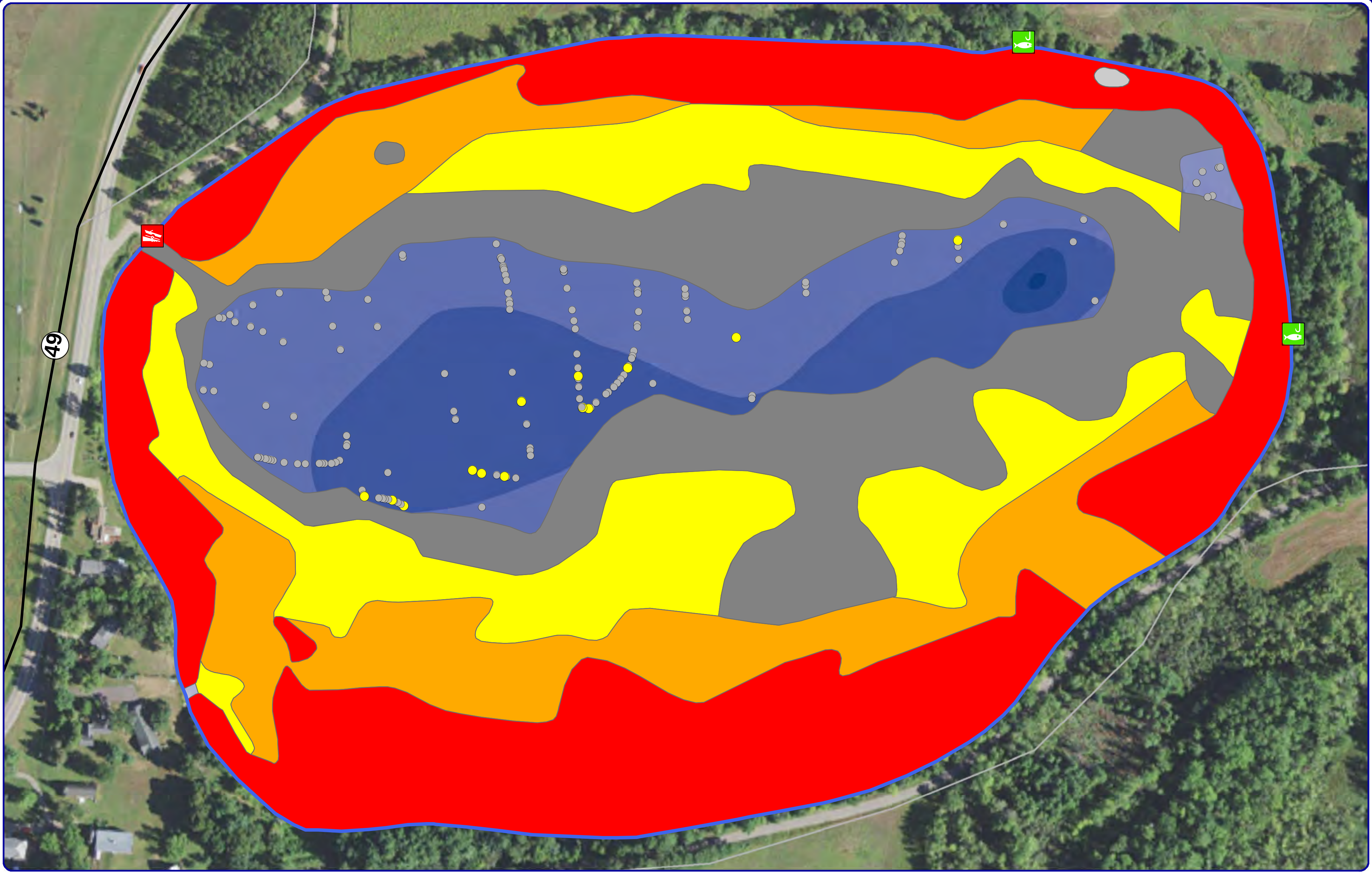

Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(None)*

Map 10
Silver Lake
Waupaca, Wisconsin

May 2021 HWM
Survey Results



275
Feet

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815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2021
Map Date: September 2, 2021 AMS/JMB
Filename:Silver_Waupaca_EWM_Aug21.mxd

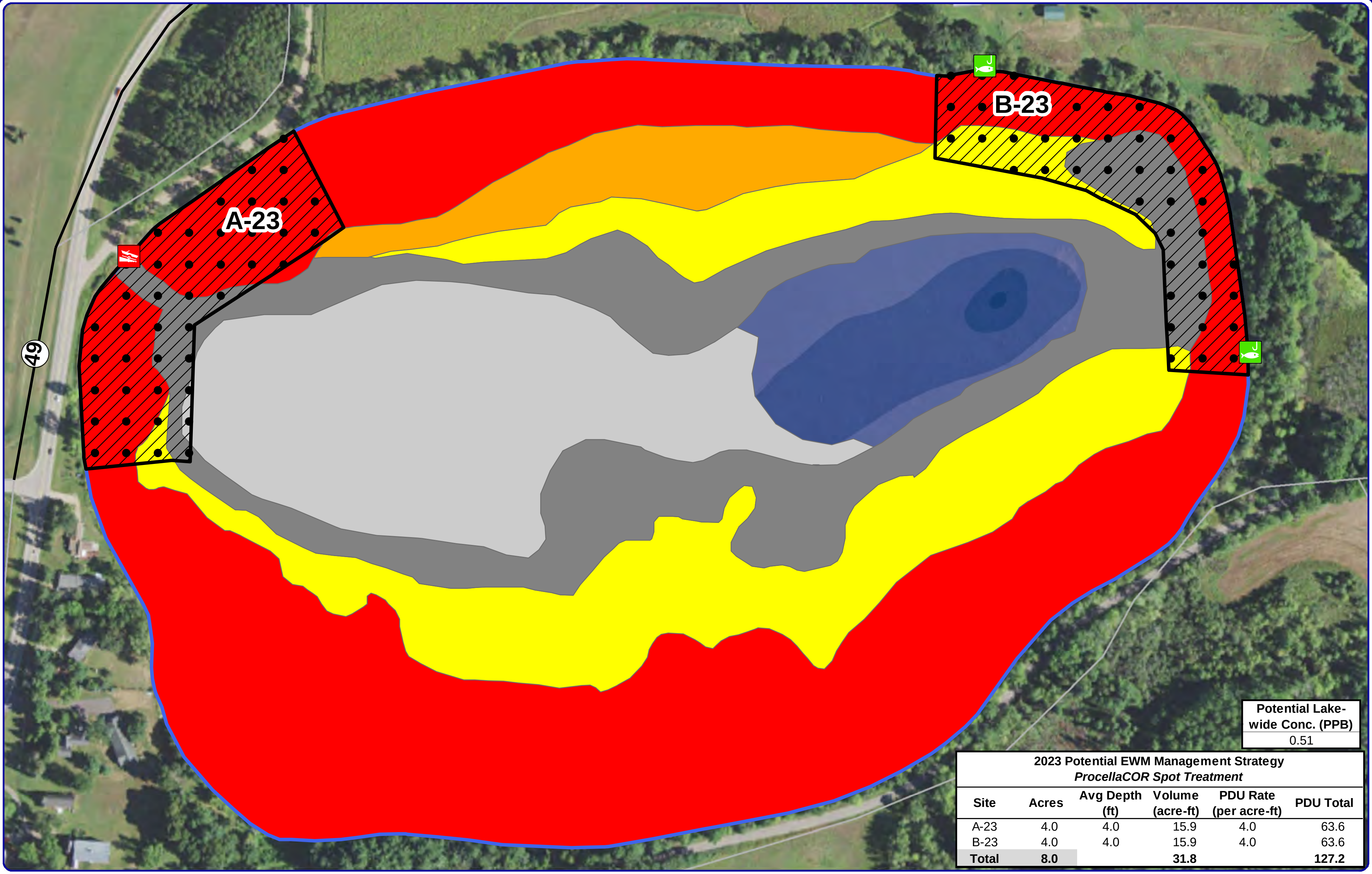
Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony *(None)*

Map 11
Silver Lake
Waupaca, Wisconsin

August 2021 HWM Survey Results



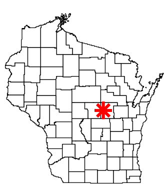
Potential Lake-wide Conc. (PPB)
0.51

2023 Potential EWM Management Strategy
ProcellaCOR Spot Treatment

Site	Acres	Avg Depth (ft)	Volume (acre-ft)	PDU Rate (per acre-ft)	PDU Total
A-23	4.0	4.0	15.9	4.0	63.6
B-23	4.0	4.0	15.9	4.0	63.6
Total	**8.0**		**31.8**		**127.2**

N W E S

275
Feet



Project Location in Wisconsin

Legend

HWM Survey Results ***(08/29/2022)***

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Fishing Pier
- Preliminary Herbicide Application Area
- Sub Point-Intercept Survey Sampling Location (20-meter spacing, n=85)

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Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Orthophoto: NAIP 2020
Aquatic Plants: Onterra, 2022
Map Date: August 30, 2022 - EJH

Map 12
Silver Lake
Waupaca, Wisconsin

Preliminary HWM Treatment Scenario v4