Lake Mohawksin

Lincoln County, Wisconsin

Comprehensive Management Plan

June 2021

Official First Draft

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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:

Lake Mohawksin Planning Committee

David Soderberg - Chair	Mike Ackley	Donna Zinda
Roger Glocke	John Graf	Connie DeBels
Charlie Jarvis		

Allen (AJ) Theiler

DRAFT

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1.0 INTRODUCTION

Impounded by Pride's (Tomahawk) Dam, the Lake Mohawksin Waters represents the confluence of the Somo, Tomahawk, and Wisconsin Rivers (ergo Mo-hawk-sin) in Lincoln County. The Tomahawk Dam was first constructed in 1888, three years before the City of Tomahawk was incorporated. The dam was partially reconstructed in 1904 by the Tomahawk Pulp and Paper Company, later called the Tomahawk Hydro-Electric Company. In 1932, the dam began failing and ownership was transferred to the Wisconsin Public Service in 1934. The 1935 Public Service Commission of Wisconsin set the dam height to 14.5 feet and allows for water to be raised by 4 feet over this dam, corresponding with the boundaries shown in Figure 1.0-1. The approximate 2,900-acre area is comprised of surface waters and adjacent above water lands that are part of Wisconsin Public Service Corporation's (WPS) Federal Energy Regulatory Commission (FERC) project boundaries. About 2,100 acres of this system contains contiguous navigable waters which are surveyed as part of ongoing submergent aquatic invasive species (AIS) monitoring and management.

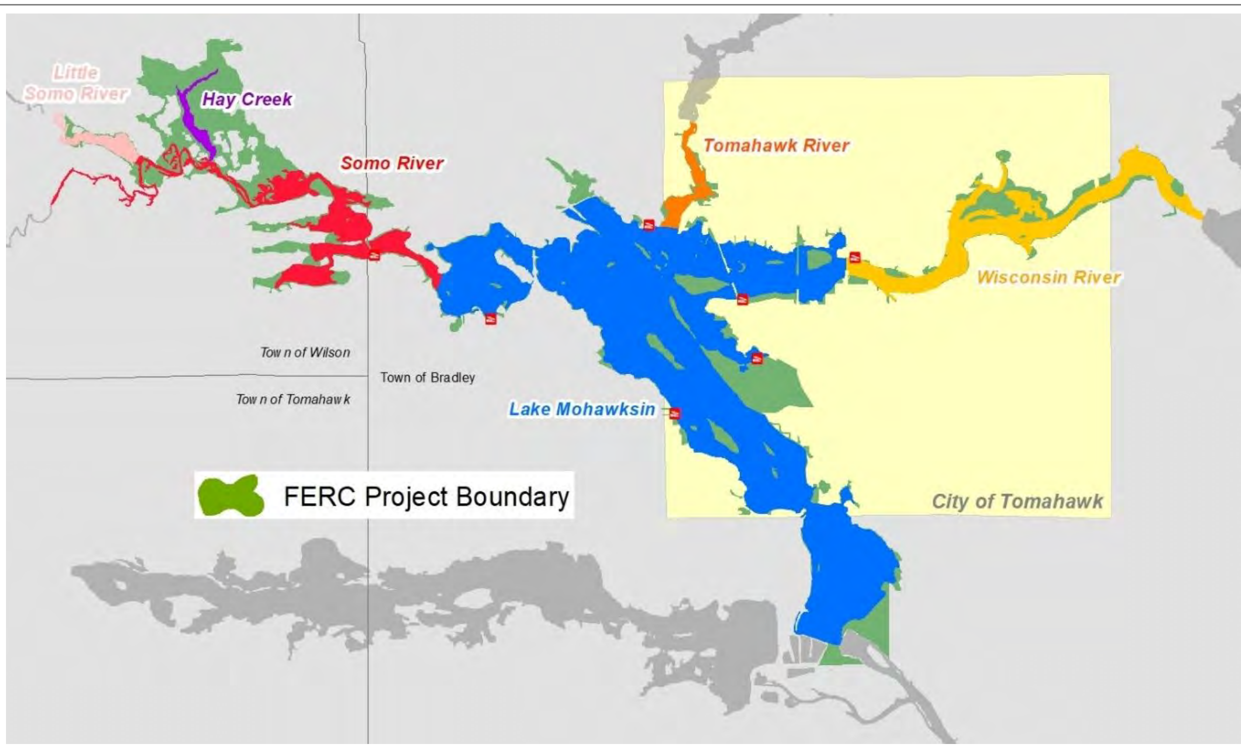


Figure 1.0-1. Lake Mohawksin Waters Project Location. Labeled and color-coded areas are those surface waters included in this project as identified by the WDNR.

Lake Mohawksin proper has a maximum depth of 25 feet and a mean depth of 9 feet. This eutrophic lake has a large watershed when compared to the size of the lake. Approximately 55 native plant species have been found within and along the margins of the Lake Mohawksin Waters, of which wild celery is the most common plant. Four exotic plant species are known to exist in Lake Mohawksin: Eurasian watermilfoil, curly-leaf pondweed, purple loosestrife, and pale-yellow iris.

In 2001 the presence of Eurasian watermilfoil (EWM) was verified by the Wisconsin Department of Natural Resources (WDNR). In 2006, Eurasian water milfoil was believed to cover at least 10-

15 surface acres within the confines of the flowage. A group of concerned lake stakeholders, led by Allen (AJ) Theiler, contacted the City of Tomahawk to discuss the situation and the possibility of forming a partnership to study the problem and determine possible paths to control the exotic plant. Over the course of a few weeks, Mr. Theiler and his group convinced the city to sponsor applications for WDNR Lake Planning Grant funds, rallied a group of musky anglers to perform informal mapping surveys of EWM colonies, enlisted assistance from the Lincoln County Land and Water Conservation Department to help with grant application preparation and digitizing of the Eurasian watermilfoil maps, started collecting water quality data as a part of the Citizens Lake Monitoring Network, and hired Onterra, LLC to complete formal aquatic plant surveys. Soon after, the group rallied other riparian stakeholders to form a lake association, the Friends of Lake Mohawksin (FOLM).

FOLM is a 501(c)(3) corporation with a goal of preserving and protecting Mohawksin waters and its surroundings, and to enhance the water quality, fishery, boating safety, and aesthetic values of Lake Mohawksin, as a public recreational resource for today and for future generations.

FOLM, with co-sponsorship form the City of Tomahawk, completed a *Comprehensive Lake Management Plan* in December 2010 (LPL-1115-07, LPL-1116-07). FOLM implemented the management goals and actions within that plan, including aquatic invasive species (AIS) management and monitoring through several additional WDNR grant-funded projects (AEPP-087-07, ACEI-056-09, ACEI-089-11, AIRR-176-15).

Using remaining funds from one of the AIS management grants (ACEI-089-11), FOLM is completing an *Updated Comprehensive Lake Management Plan*, of which this document is the final deliverable.

The Summary and Conclusions Section (4.0) provide a succinct overview of the health of the Lake Mohawksin Waters (Click Here).

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.

Planning Committee Meeting I

On October 12, 2020, Eddie Heath of Onterra met virtually with the FOLM Planning Committee for nearly 4 hours. Scott Van Egeren, local WDNR lakes biologist, was also in attendance. 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. Study components including AIS survey results, aquatic plant inventories, water quality analysis, watershed modeling, and shoreland assessment results were presented and discussed.

Planning Committee Meeting II

On January 14, 2021, Eddie Heath of Onterra met virtually with the FOLM Planning Committee for over 2 hours. The focus of this meeting was to develop management goals and associated management actions to serve as the Implementation Plan Section (5.0).

Planning Committee Meeting III

Based upon the discussion from previous planning meetings, a draft Implementation Plan Section (5.0) was created by Onterra and sent to the planning committee. Written comments were provided back to Onterra. In addition, the FOLM Planning Committee met virtually on April 6, 2021 for over 2 hours methodically going through each management action contained within the draft Implementation Plan Section (5.0).

Management Plan Review and Adoption Process

On May 14, 2021, an early draft of the complete Comprehensive Management Plan was provided to the FOLM Planning Committee and FOLM Board of Directors for review. Comments were aggregated by the FOLM Planning Committee Chair and provided to Onterra. These comments were addressed to result in the Official First Draft.

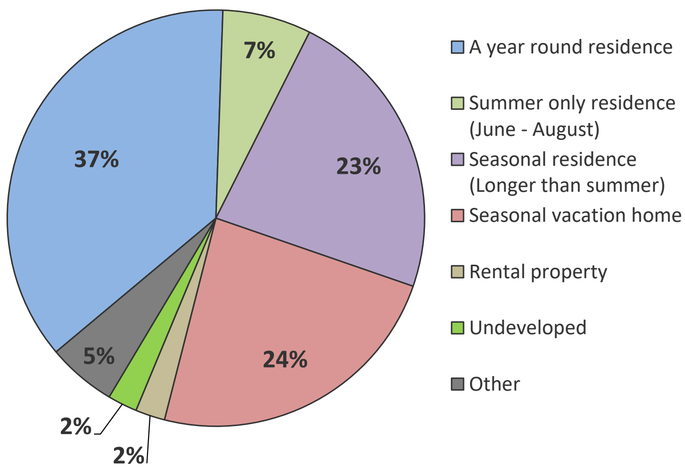
On June 25, 2021, the Official First Draft of the FOLM's Comprehensive Management Plan for Lake Mohawksin was supplied to WDNR (lakes and fisheries programs), Lincoln County, Great Lakes Indian Fish and Wildlife Commission, Lac du Flambeau Tribe, and Wisconsin Public Service to solicit comments.

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to all FOLM members and riparian property owners around the Lake Mohawksin Waters. The survey was designed by Onterra staff and the FOLM planning committee and reviewed by a WDNR social scientist. During February 2020, the nine-page, 45-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a third-party for analysis. Approximately 22.4% 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 the Lake Mohawksin Waters. Thirty-seven percent of stakeholder respondents live on the lake year-round, while 23% use their property as a seasonal residence, and 24% use it as a seasonal vacation home (Figure 2.0-1). Just under half of respondents us their property between zero and 100 days per year. Fifty-six percent of stakeholders have owned their property for over 15 years, and 31% have owned their property for over 25 years (Appendix B, Question #5).

Question 3: How is your property utilized?



Question 4: How many days each year is your property used by you or others?

Category (# of days)	Response	
0 to 100	62	47%
101 to 200	24	18%
201 to 300	5	4%
301 to 365	41	31%

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

Relaxing/entertaining was the highest ranked activities when riparians were asked why the own property on Lake Mohawksin (Figure 2.0-2). Riparian respondents also ranked *open water fishing, motor boating*, and *nature viewing* and as top reasons they choose to be a Lake Mohawksin riparian.

Question 15: Please rank up to three activities that are important reasons for owning or renting your property on Lake Mohawksin.

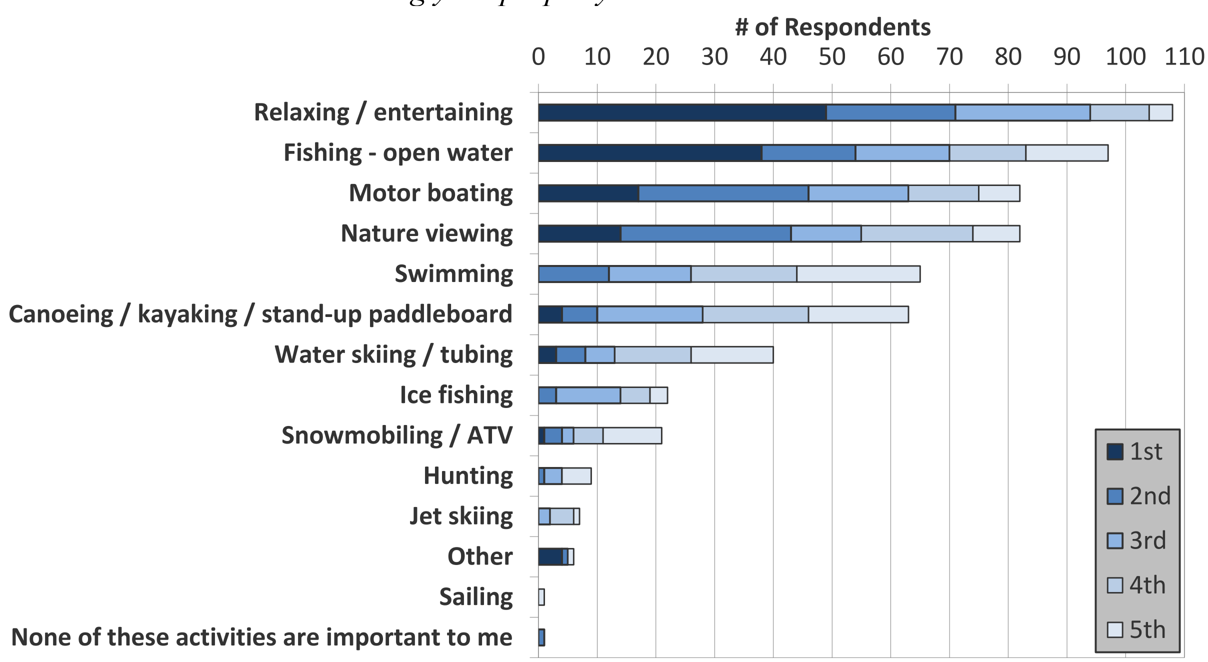


Figure 2.0-2. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Over 67% of survey respondents indicated that they use a pontoon boat, approximately 55% use a canoe/kayak/or stand-up paddleboard, and 50% use a motor boat with greater than 25 hp motor (Figure 2.0-3). Over 71% of respondents only use their watercraft on Lake Mohawksin and do not take to other waterbodies (Appendix B, Question #13).

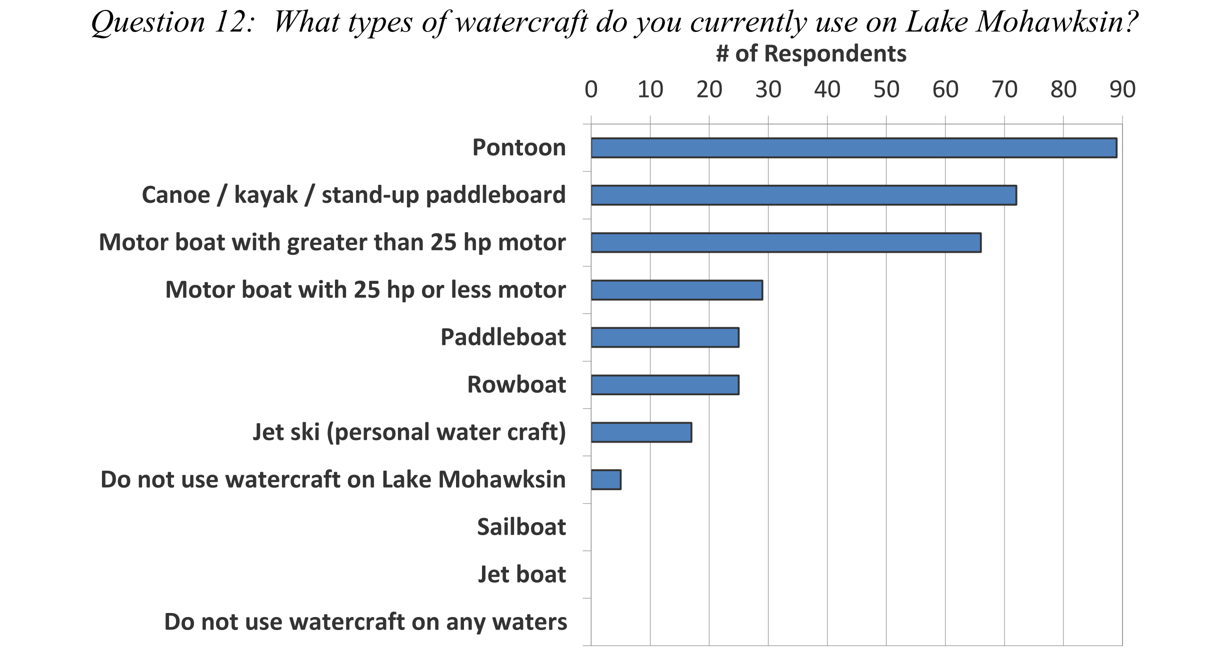


Figure 2.0-3. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Transient boating use and watercraft safety has been a topic at recent FOLM meetings, although these topics were not within the top 3 concerns of Lake Mohawksin by stakeholder respondents (Figure 2.0-4). Aquatic invasive species introduction was the greatest concern of Lake Mohawksin stakeholder survey respondents, followed by water quality degradation

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect to these particular topics.

Question 25: Please rank your top three concerns regarding Lake Mohawksin.

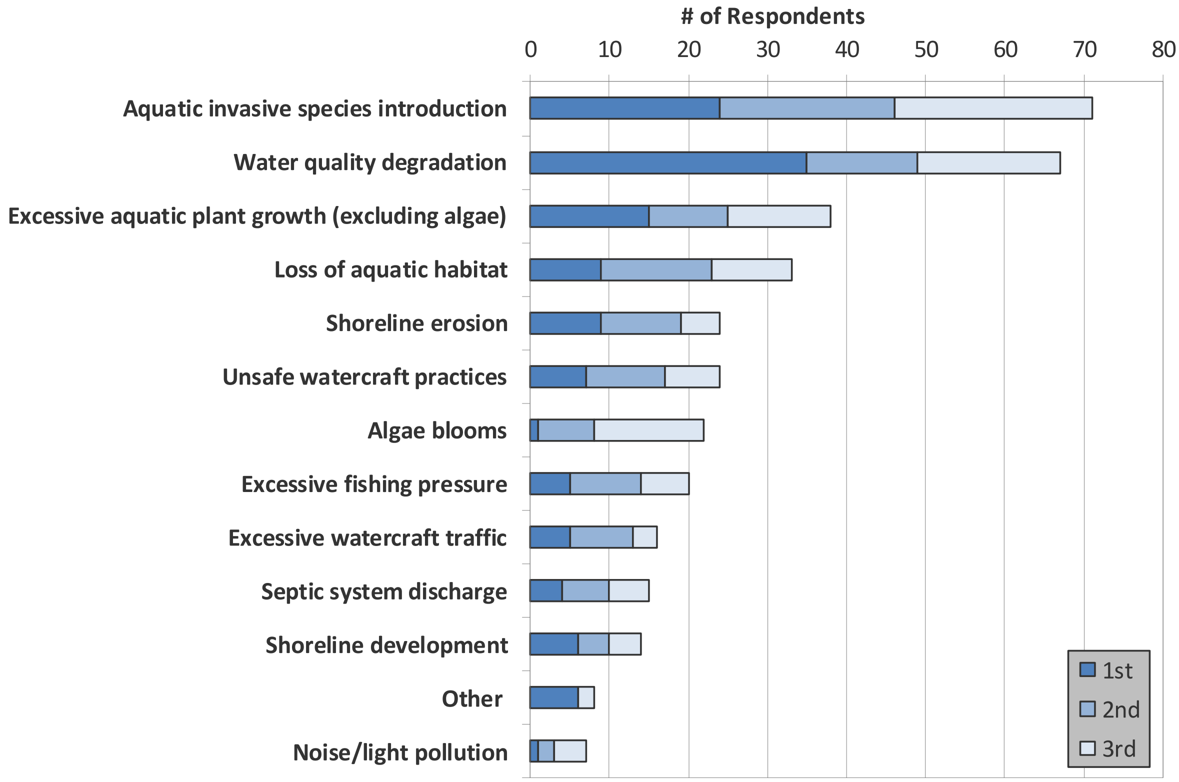


Figure 2.0-4. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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 Lake Mohawksin 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 Lake Mohawksin 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 et al. 1994) (Dinius 2007) (Smith et al. 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 processes 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 2018 Consolidated Assessment and Listing Methodology* (WDNR 2018) 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 Lake Mohawksin 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 (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, large watershed and hydrology, Lake Mohawksin is classified as a shallow lowland drainage lake for analysis purposes (category 4 on Figure 3.1-1).

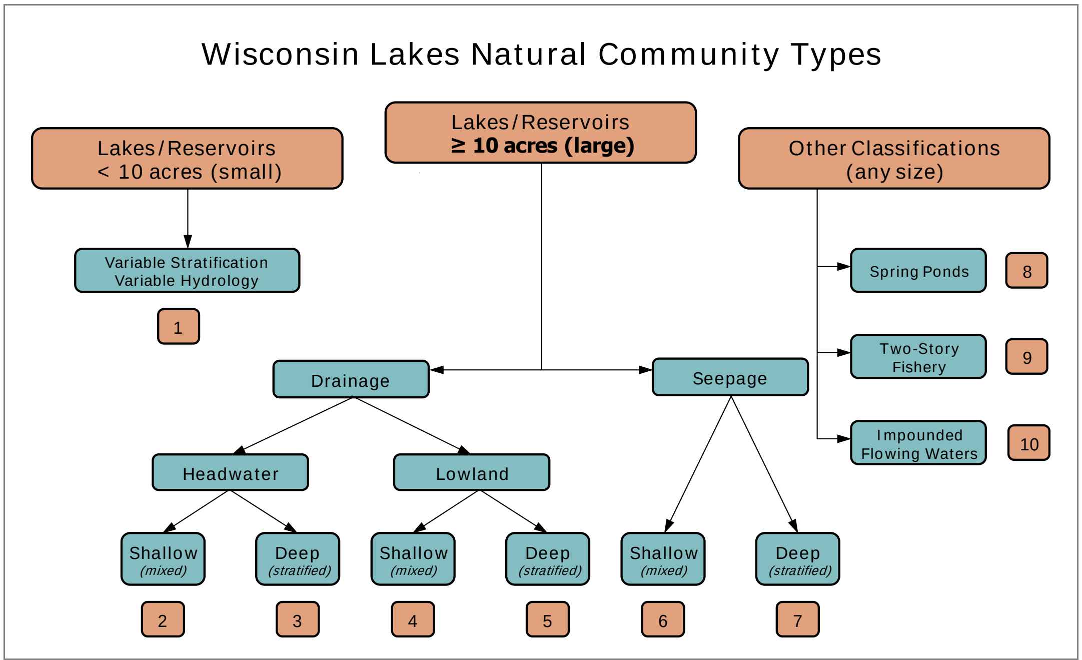


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

Garrison, et. al (2008) developed state-wide 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. Lake Mohawksin is within the Northern Lakes and Forests ecoregion.

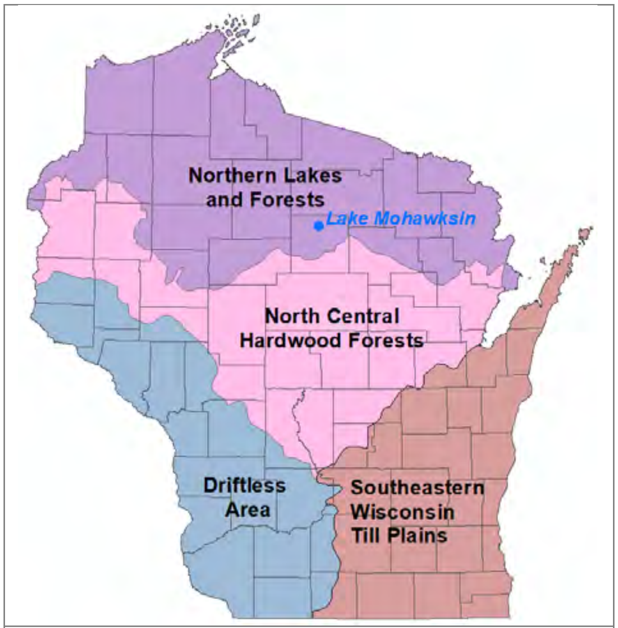


Figure 3.1-2. Location of Lake Mohawksin within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2018 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act. It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. In the report, they divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor". The categories were based on pre-settlement conditions of the lakes inferred from sediment cores and at what phosphorus concentrations nuisance algal blooms occur.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Lake Mohawksin is displayed in Figures 3.1-3 - 3.1-6. 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.

Lake Mohawksin Water Levels

The Wisconsin River Reservoir system consists of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs used to maintain a nearly uniform flow of water as practicable in the Wisconsin River by storing surplus water in reservoirs for discharge when water supply is low to improve the usefulness of the rivers of the rivers for hydropower, flood control, and public use (Figure 3.1-12). Of these 21 reservoirs, 16 are natural-lake reservoirs and 5 are man-made reservoirs constructed between 1911 and 1937. The man-made reservoirs account for 73% of WVIC's usable water storage.

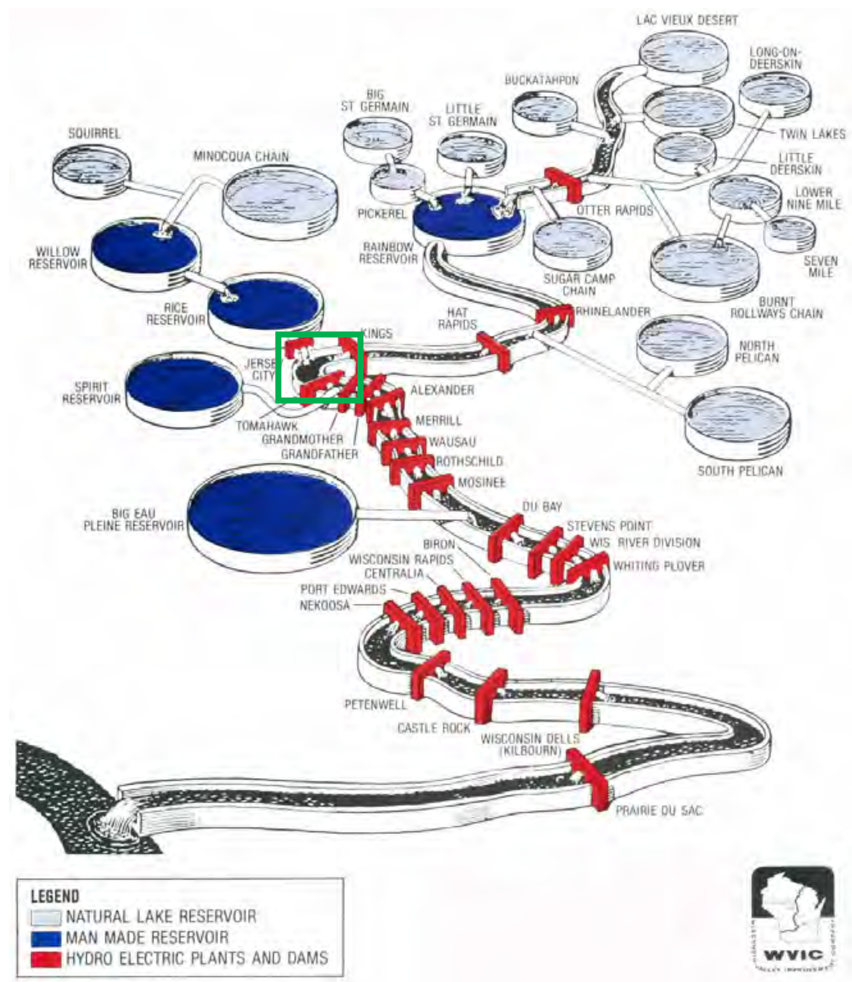


Figure 3.1-3. WVIC reservoir system. Lake Mohawksin is outlined in green. Adapted from WVIC website.

As will be discussed in the Watershed Assessment Section (3.2) Lake Mohawksin Waters represents the confluence of the So<u>mo</u>, Toma<u>hawk</u>, and Wiscon<u>sin</u> Rivers (ergo Mo-hawk-sin). It is impounded by the Tomahawk Dam hydroelectric plant (Photograph 3.1-1), owned by WEC Energy Group. This is one of 25 hydroelectric plants generating just over 12,000 megawatt hours per year.

Photograph 3.1-1. Tomahawk Dam, viewed from downstream. Photo credit: Wikipedia

Hydroelectric power projects are licensed by the Federal Energy Regulatory Commission (FERC). As part of the FERC operation license, the minimum and maximum water levels are set for each waterbody. Natural lake reservoir water levels are maintained within a relatively narrow range in comparison to the five man-made reservoirs which exhibit changes of water levels that could span 10-20 feet in a single year.

As one of the hydroelectric plants along the Wisconsin River, Lake Mohawksin's water levels are maintained in a relatively tight window through manipulation of water levels and flows on upstream reservoirs. The 1996-2026 FERC (No. 1940-029) operating order grants a maximum allowed daily water level fluctuation of Lake Mohawksin of 0.8 feet from the normal pool elevation of 1,435.1 feet National Geodetic Vertical Datum 1929, and maintains a continuous minimum flow of 162 cubic feet per second, whichever is less.

Using flow data provided by WEC Energy Group, Figure 3.1-4 shows the average monthly flow data from 2012 to spring 2020. Flows are highest on Lake Mohawksin during the spring (bottom figure). The top figure shows these data over time, while the bottom figure shows changes within a year. Linear trend analysis indicates that there is a statistically valid increasing trend in flows over this time period. Trend analysis conducted on the annual mean flow indicates a strong increasing relation ($r^2 = 0.78$). Changes in water flow can be a contributing factor to changes within the system. This could include changes in water quality parameters and changes in the aquatic plant community.

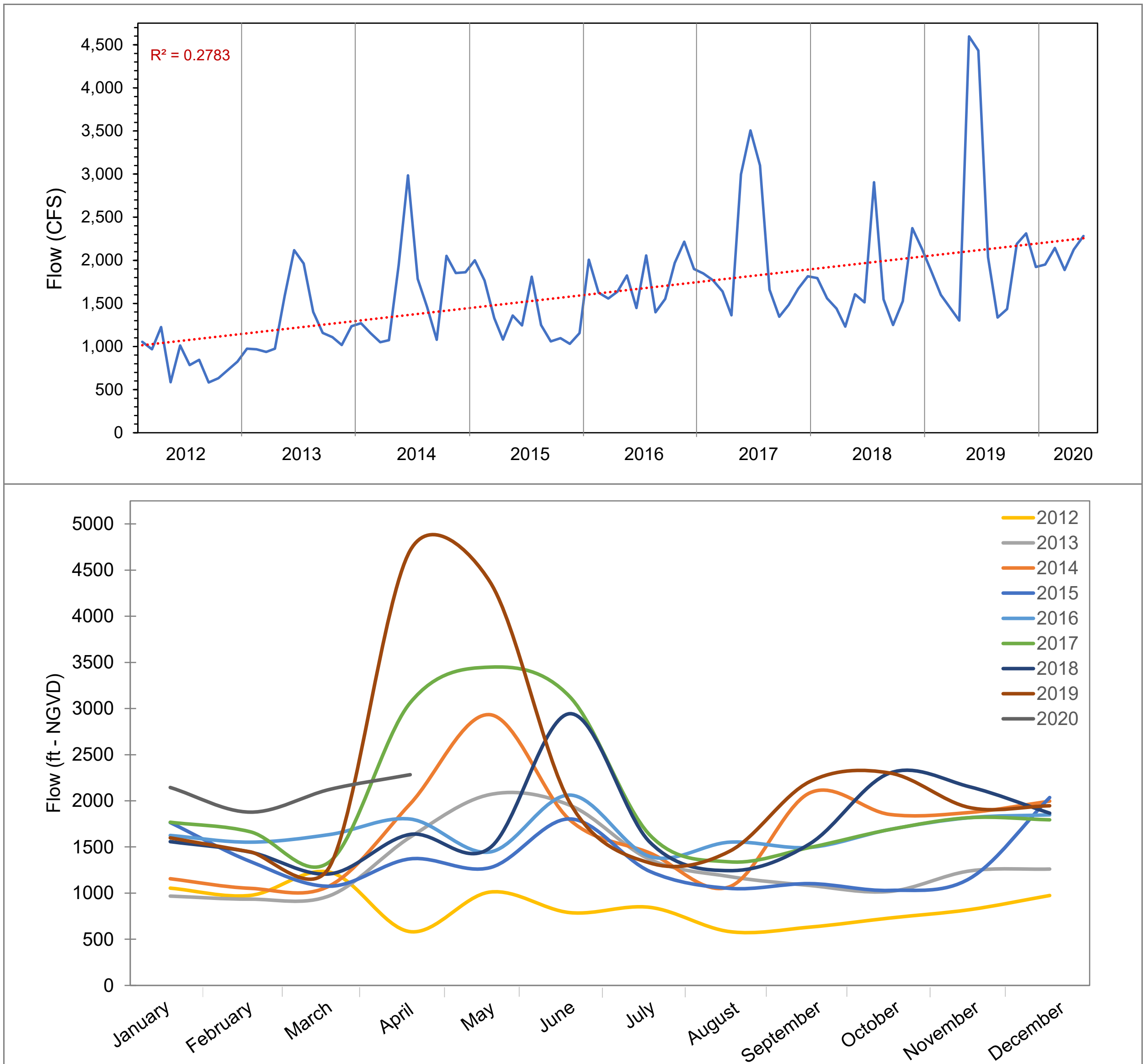


Figure 3.1-4. Average monthly flow rates at Tomahawk Dam. Raw data provided by WEC Energy Group

Lake Mohawksin Water Quality Analysis

Lake Mohawksin Long-term Trends

Water quality data was collected from Lake Mohawksin on six occasions in 2019/2020. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. These parameters were also sampled by a Citizen Lake Monitoring Network (CLMN) volunteer in 2019 at a separate sampling location. The CLMN data was collected from the deepest spot from Lake Mohawksin (Map 1, southern sampling location). However, the deep hole sampling location within the WDNR's database is at a different location (Map 1, northern sampling location). The samples taken from these locations produced similar results across all parameters and were therefore combined in the analysis figures. The 2019 Secchi disk measurements have also been provided separately in Figure 3.1-6 to represent the similarity of the measurements between the two 2019 sampling locations. No significant difference in results was observed between the two sites.

Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Lake Mohawksin has a hydraulic residence time about 4 days, much less than the 14-day standard used to differentiate waterbodies that function like a lake and those that function like a river. The Wisconsin Department of Natural Resources classifies Lake Mohawksin as impounded flowing waters for phosphorus standards. The reason for this classification is that with the short residence times the water quality of these water bodies is mostly reflective of the water quality of the incoming rivers. The short residence times also mean that in lake processes have little impact on the lake's water quality. For this report Lake Mohawksin will be treated as a shallow lowland drainage lake when comparing their water quality to other lakes within the ecoregion and state wide since there are not comparables for impounded flowing waters.

Near-surface total phosphorus data are available for Lake Mohawksin for the years 1979, and 2006-2019 (Figure 3.1-5). The mean summer total phosphorus concentration is 41.7 µg/L, placing the lake in the *good* category for Wisconsin's shallow lowland drainage lakes. Lake Mohawksin's average summer total phosphorus concentrations are higher than other shallow lowland drainage lakes in Wisconsin (median 33 µg/L) and much higher than other lakes within the North Lakes and Forests Ecoregion (NLF) (median 21 µg/L). Although phosphorus concentrations range from 37.9 to 61.5 µg/L they were always in the *good* category except for 2010. There is no trend either up or down during the period of record.

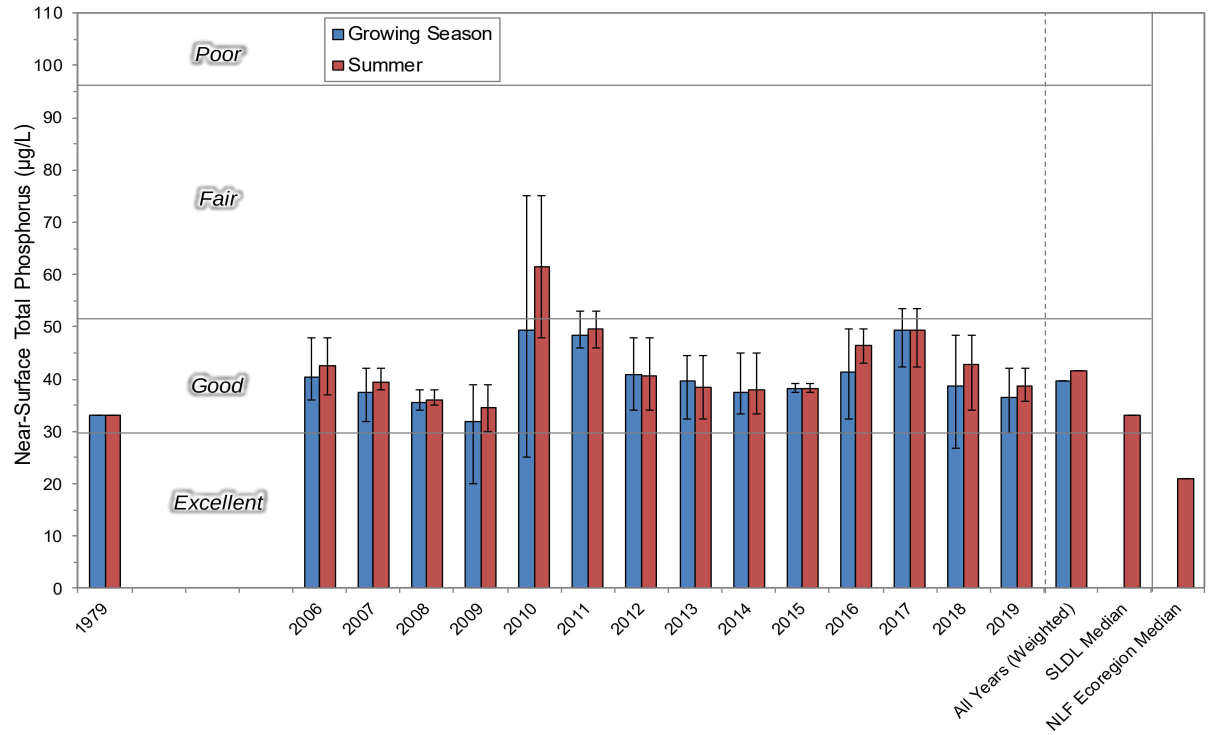


Figure 3.1-5. Lake Mohawksin, statewide shallow lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available in Lake Mohawksin for the same time period as phosphorus, 1979 and 2006-2019 (Figure 3.1-6). The mean summer chlorophyll-*a* concentration is 17.9 µg/L, placing the lake in the *good* category, for shallow lowland drainage lakes in Wisconsin. Lake Mohawksin's mean summer chlorophyll-*a* concentration is considerably higher than the median concentration for Wisconsin's shallow lowland drainage lakes (9.4 µg/L) and the median concentration for lakes within the North Lakes and Forests ecoregion (5.6 µg/L). Unlike phosphorus concentrations, chlorophyll-*a* concentrations have been lower the last few years compared with the period 2006-2013. It is unclear why this is occurring since phosphorus concentrations have been relatively stable. As will be detailed below, the algal community in 2019 was limited by a combination of phosphorus and nitrogen. It may be that nitrogen levels have been more variable than phosphorus.

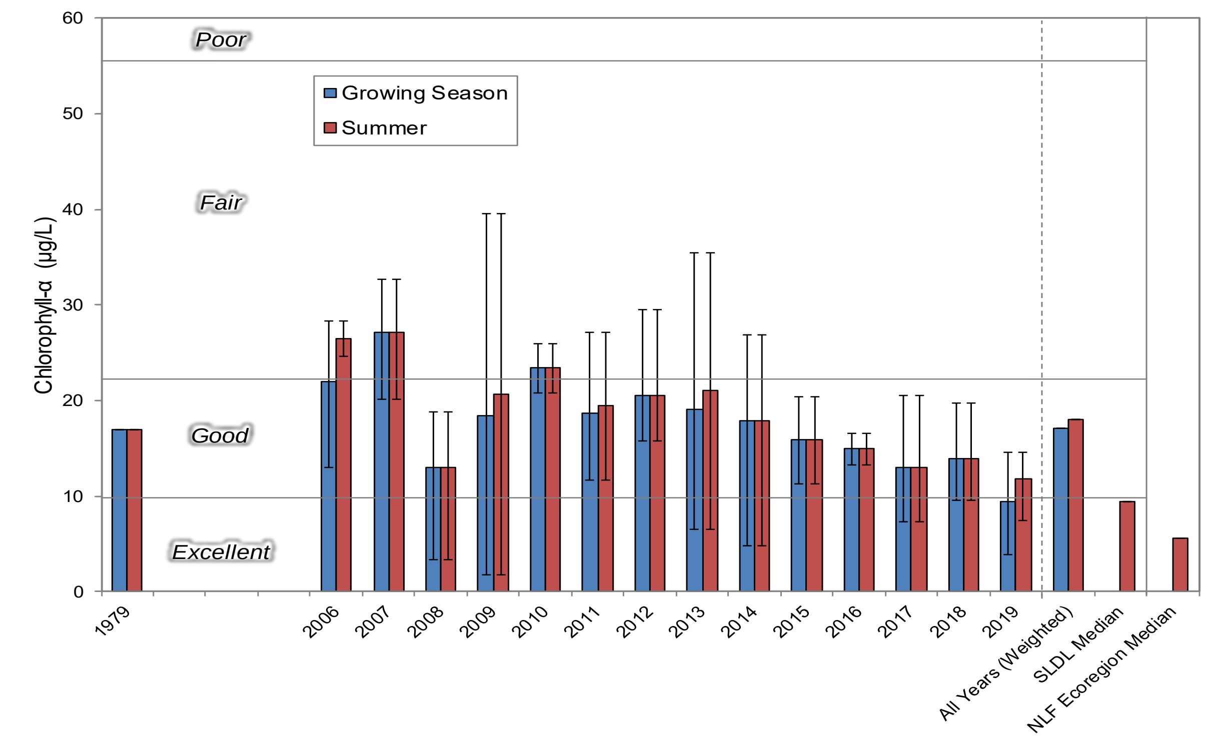


Figure 3.1-6. Lake Mohawksin, statewide shallow lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data, a measure of water clarity, are available in Lake Mohawksin for the years 1979, 2006-2010, and 2011-2019 (Figure 3.1-7). Mean summer Secchi disk depth has ranged from 3.0 feet in 2017 to 4.1 feet in 2012, with an overall weighted mean of 3.5 feet. This value places the lake in the *good* category for Wisconsin's shallow lowland drainage lakes and is the same categories for phosphorus and chlorophyll-a. This value is worse than the median values for other shallow lowland drainage lakes (5.6 feet) and lakes within the NLF Ecoregion (8.9 feet). Unlike chlorophyll-*a*, water clarity has remained largely unchanged for the years that data is available.

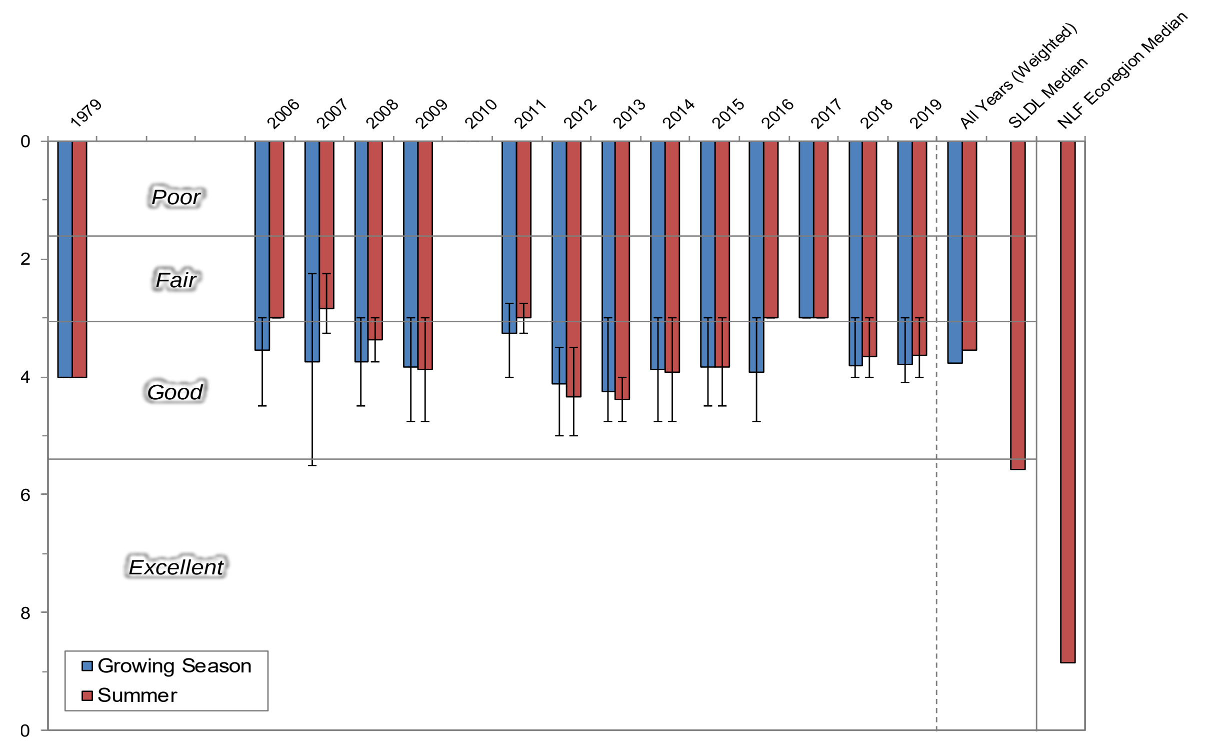


Figure 3.1-7. Lake Mohawksin, statewide shallow lowland drainage lakes, and regional Secchi disk transparency data. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

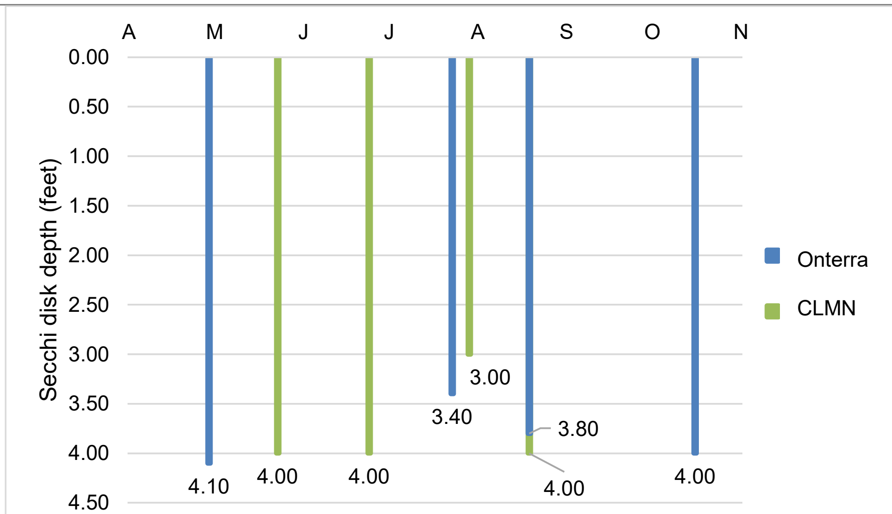


Figure 3.1-8. Lake Mohawksin 2019 Secchi Disk measurements taken between May and October. Measurements taken by Citizen lake monitoring volunteer at historic monitoring location shown in green, Onterra measurements taken at upstream location shown in blue.

Limiting Plant Nutrient of Lake Mohawksin

Using midsummer nitrogen and phosphorus concentrations from Lake Mohawksin, a nitrogen:phosphorus ratio of 14:1 was calculated. This finding indicates that Lake Mohawksin is in the transitional zone where the algae may be nitrogen or phosphorus limited. In general, research has shown that cutting phosphorus inputs in these types of lakes will limit plant growth within the lake.

Lake Mohawksin Trophic State

Figure 3.1-9 contains the WTSI values for Lake Mohawksin. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* WTSI values, it can be concluded that Lake Mohawksin is in a eutrophic state.

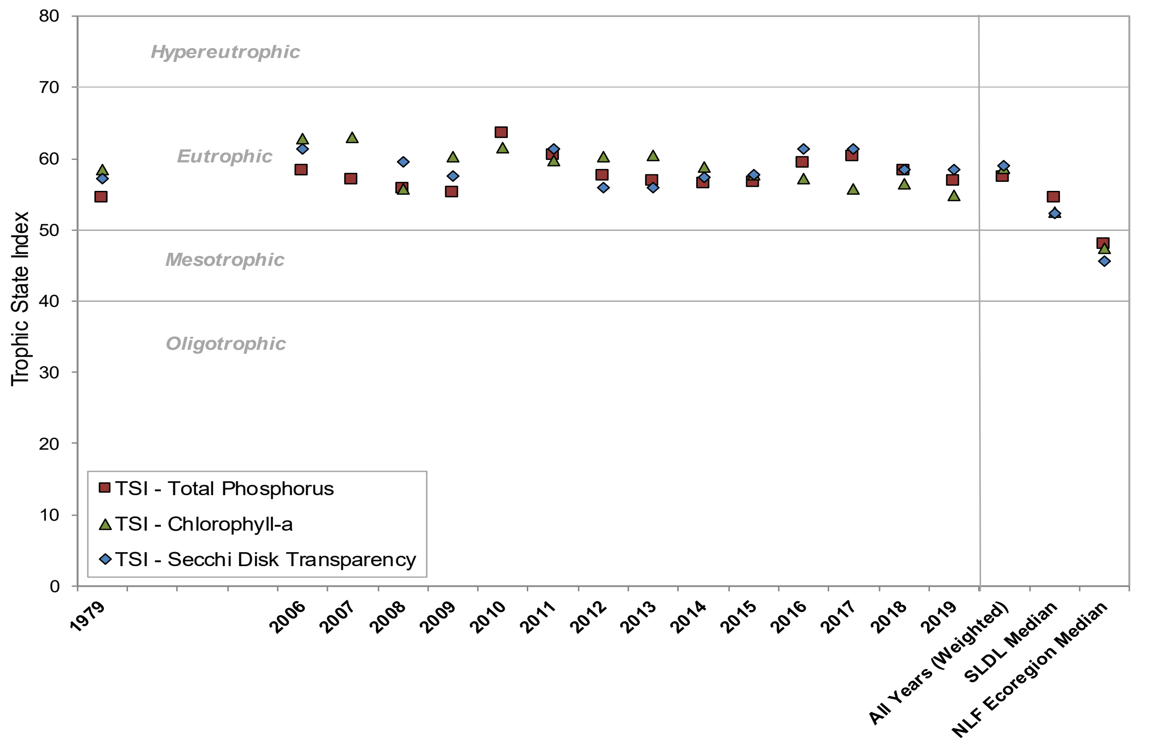


Figure 3.1-9. Lake Mohawksin, statewide, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Lake Mohawksin

The dissolved oxygen and temperature profiles presented below are a combination of data collected by Onterra staff and volunteers. As discussed above, Onterra staff sampled in a shallower area than where the volunteers have been collecting samples. The site where the volunteers have been sampling is deeper and provides a more accurate information of the profiles in the deepest waters. Graphs of those data are displayed in Figure 3.1-10.

Lake Mohawksin is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, once in spring and once in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Lake Mohawksin's deeper nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen. The profile collected during February 2020 was not collected in the deep hole so it is not possible to know if the bottom waters become anoxic. However, since much of the lake is relatively shallow and there is considerable flow from the incoming rivers, it is unlikely that winter fish kills occur.

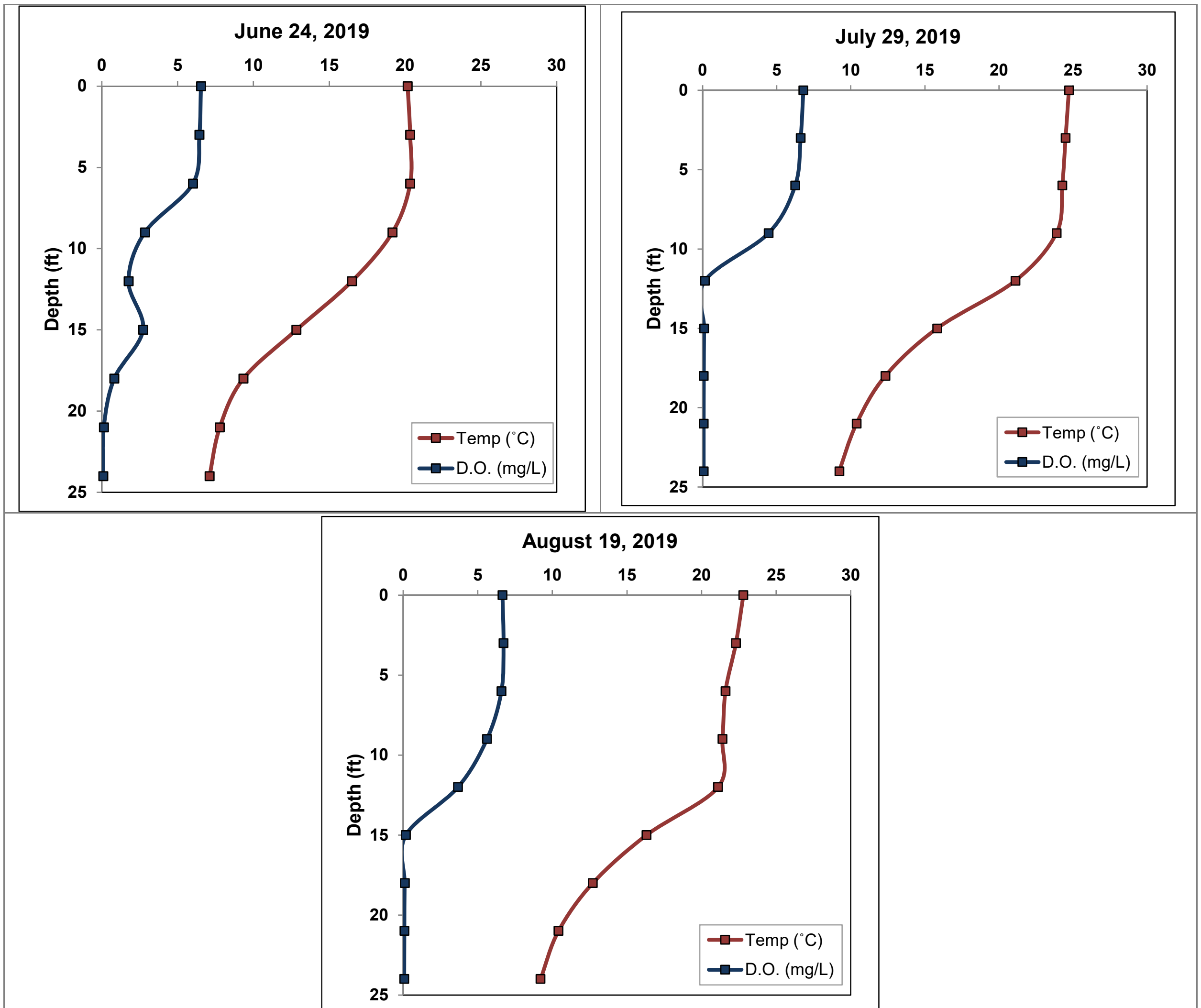


Figure 3.1-10. Lake Mohawksin dissolved oxygen and temperature profiles. These profiles were collected at the deep site (June, July, August) by volunteers.

Additional Water Quality Data Collected at Lake Mohawksin

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 Lake Mohawksin'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. Values were much lower in April compared with the July samples. The low values in April reflect concentrations during snowmelt when chemicals are diluted. The concentrations reported below, except calcium, reflect concentrations during July.

It is expected these concentrations will change from year to year depending upon precipitation and its impact on flows in the rivers.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Lake Mohawksin's surface water pH was measured at 7.4 during July 2019 (Figure 3.1-11). This value is near neutral and falls within the normal range for Wisconsin lakes.

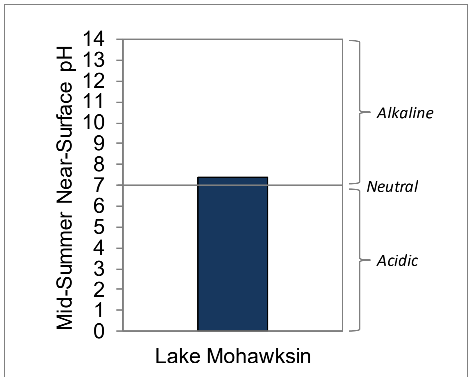


Figure 3.1-11. Lake Mohawksin mid-summer near-surface pH value.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Lake Mohawksin during July 2019 was measured at 28.2 (mg/L as $CaCO_3$) (Figure, 3.1-12) indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain. The concentration of alkalinity and related chemicals was much lower in April when compared with the mid-summer concentrations. This is because the April concentrations reflect the result of water derived largely from snow melt which contains low concentrations.

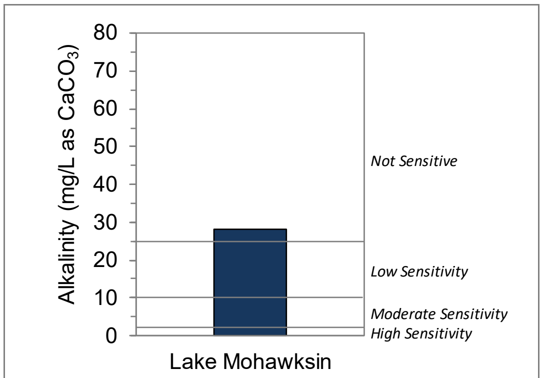


Figure 3.1-12. Lake Mohawksin summer total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

Samples of calcium were also collected from Lake Mohawksin during April 2019. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Lake Mohawksin's pH of 7.4 falls within 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 Lake Mohawksin was found to be 8.3 mg/L, which is below the optimal range for zebra mussels (Figure 3.1-13).

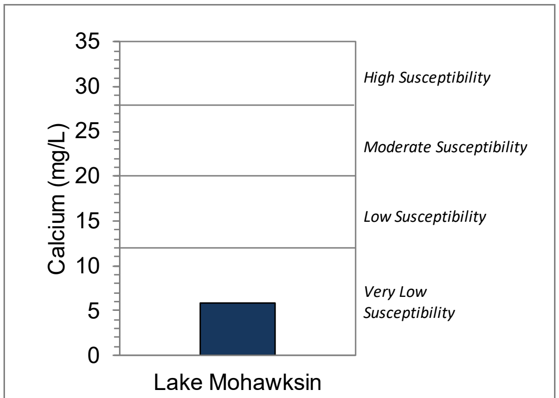


Figure 3.1-13. Lake Mohawksin summer calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

A measure of water clarity once all of the suspended material (i.e., algae and sediments) have been removed, is termed *true color*, and indicates the level of dissolved organic material within water. The highly colored water reduces water clarity as well as light penetration into the water column which can restrict algal growth. Water color in Lake Mohawksin in 2019 averaged 65 units which means the water was *tea-colored* (Figure 3.1-14).

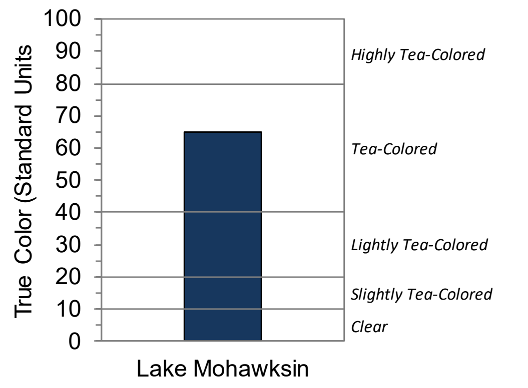


Figure 3.1-14. Lake Mohawksin true color value. Samples collected from the near-surface.

Blue-Green Algae Blooms

Blue-green algae blooms have been periodically noted on Lake Mohawksin Waters. Understanding algae dynamics in lakes is complicated because so many factors control growth rates of algae, such as light availability, nutrient levels, water temperatures, zooplankton populations, and interactions between algal species themselves. The complexity is compounded in systems like Lake Mohawksin.

Like 'true' algae, cyanobacteria or blue-green algae are able to convert sunlight into energy through the process of photosynthesis (Photograph 3.1-2). Many species of blue-green algae can naturally be found in Wisconsin waters, some of which can produce toxins potentially dangerous to people and animals. Exposure to these toxins occurs can be from ingestion of water, skin contact, and by inhaling aerosolized water droplets. It is unknown if the blue-green algae blooms noted in the past on Lake Mohawksin produced toxins.

Photograph 3.1-2. Blue-green algae bloom. Phillips Chain of Lakes, Price County. Photo credit: Onterra August 2013.

The largest risk of exposure consists of swallowing water containing the toxins, usually during water-sporting activities. Symptoms include nausea, vomiting, diarrhea and in severe cases, liver failure or paralysis. Skin contact with algae can produced blistering of the exposed skin. Allergy-like symptoms including coughing, watery eyes, and nose/throat irritation are most commonly associated when wind and motor boat activity cause the toxins to become aerosolized.

Stakeholder Survey Responses to Lake Mohawksin 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 3.1-15 and 3.1-16 display the responses of members of Lake Mohawksin stakeholders to questions regarding water quality and how it has changed over their years visiting Lake Mohawksin. These figures show both the most recent stakeholder survey data (2020), as well as from the previous lake management planning project (2007) to understand if shifts in perceptions have occurred.

Most respondents believe that the water quality of Lake Mohawksin is *good* to *fair*, with a shift from more respondents perceiving it as *fair* in 2007 and *good* in 2020 (Figure 3.1-15). When riparians were asked how the overall water quality has changed since first visiting Lake Mohawksin, *remained the same* was the most popular category in both years. The second-most popular option was *somewhat improved* in 2020 whereas *somewhat degraded* was the second-most popular option in 2007 (Figure 3.1-16).

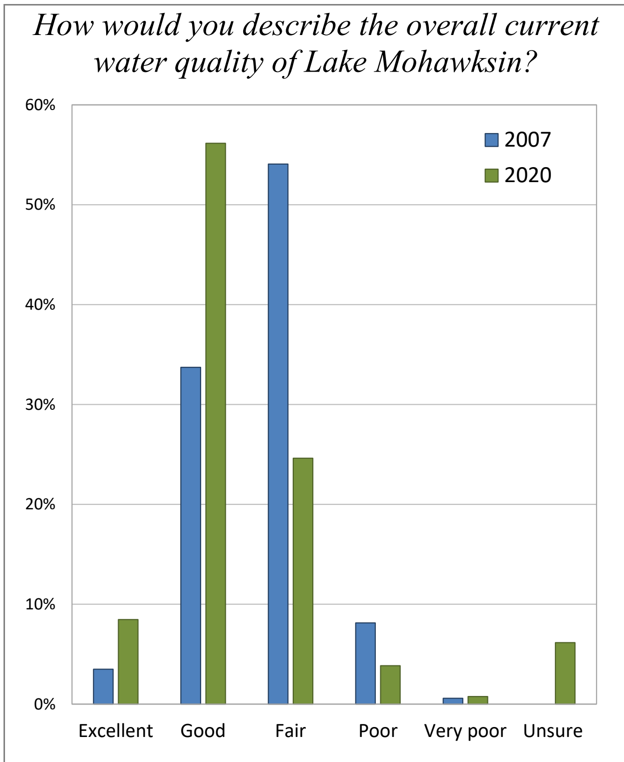


Figure 3.1-15. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

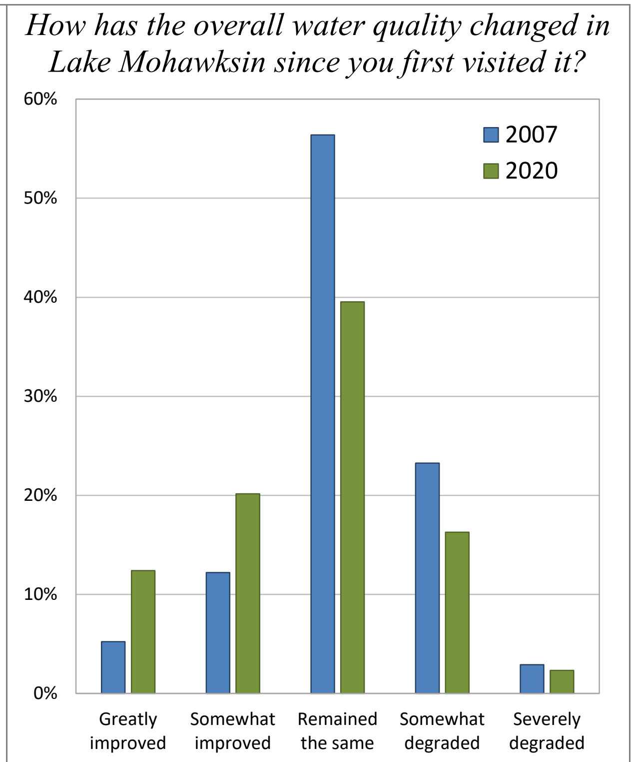


Figure 3.1-16. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Within the 2020 riparian stakeholder survey, respondents were asked what they perceive impacts water quality (Figure 3.1-17). The majority of respondents indicated water clarity was what they thought of when describing water quality. As discussed above, water clarity has remained largely unchanged for the years that data is available.

Aquatic plant was chosen as the second-most important aspect that riparians felt contributed to their evaluation of water quality. Aquatic plant growth can affect and be affected by water quality, but is not a water quality metric. As will be discussed in the aquatic plant section (3.4), some changes in aquatic plant populations have been noted between these two time periods, likely driven by increased precipitation and therefore increased water flows.

Question 20: Considering how you answered the questions above, what do you think of when describing water quality?

Answer Options	Response Percent	Response Count
Water clarity (clearness of water)	72.7%	93
Aquatic plant growth (not including algae blooms)	64.1%	82
Water color	43.8%	56
Algae blooms	44.5%	57
Smell	32.0%	41
Water level	24.2%	31
Fish kills	21.9%	28
Other	7.0%	9
	answered question	**128**
	skipped question	**6**

Figure 3.1-17. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.2 Watershed Assessment

Watershed Modeling

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.

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 size of the watershed, and 2) the land cover (land use) within the watershed. The impact of the watershed size is dependent on how large it is relative to the size of the lake. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drains 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.

The type of land cover that exists in the watershed determines 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. Vegetated areas, such as forests, grasslands, and meadows, allow the water to permeate the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas, minimize infiltration and increase surface runoff. The increased surface runoff associated with these land cover types leads to increased phosphorus and pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations. For these reasons, it is important to maintain as much natural land cover (forests, wetlands, etc.) as possible within a lake's watershed to minimize the amount runoff (nutrients, sediment, etc.) from entering the lake.

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 grass 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 plant 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 a change in plant 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, i.e., 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.

Lake Mohawksin Watershed Assessment – WiLMS Model

Lake Mohawksin, Lincoln County, is an approximately 2,100-acre flowage within 1.3-million-acre watershed resulting in a WS:LA ration of approximately 615:1. The lake is impounded by Pride's (Tomahawk) Dam and represents the confluence of the Somo, Tomahawk, and Wisconsin Rivers.

A reliable and cost-efficient method of creating a general picture of a watershed's effect on a lake can be obtained through a couple different methods. In the 2010 management plan for Lake Mohawksin, the Wisconsin Lake Modeling Suite (WiLMS) was primarily used. Within the 2010 management plan, land cover data from the 2006 National Land Cover Database (NLCD) were used (Fry et al. 2011). Map 2 shows the Lake Mohawksin watershed with land cover data updated from 2016 (Homer et al. 2016).

WiLMS modeling outputs 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. However, the modeling produced unreasonable and misleading results due to the limitation of the model. However, WiLMS model was determined useful in generating an estimate of hydrographic data for the lake. The flushing rate for Lake Mohawksin was estimated at approximately 80 times per year, which is a residence time of approximately 4 days. The high flushing rate combined with a watershed that is dominated by forests and wetlands leads to the acceptable water quality found in Lake Mohawksin. Basically, the rapid flushing of the lake's water prevents a buildup of nutrients and as a result, the buildup of algae within the lake. Therefore, collecting a water quality sample within the lake is much like collecting a water sample in a river – the water that is sampled on one day is different than the water sampled the next day.

Lake Mohawksin Watershed Assessment – TMDL Model

Section 303(d) of the Clean Water Act (CWA) requires states to determine which waterbodies are impaired and orchestrate a plan to reach the goal of restoring all identified impaired waters to meet applicable water quality standards (WDNR 2019). One of the tools WDNR biologists use to achieve this goal is to develop a total maximum daily load (TMDL) for an impaired waterbody. The primary objective of an approved TMDL is to establish pollutant load allocations to point and nonpoint sources in order to achieve pollutant load reductions needed to meet water quality goals (WDNR 2019). Meeting these water quality goals in turn should theoretically improve water quality and eventually lead to the delisting of the impaired waterbody from the impaired waters and restoration waters list.

The Wisconsin River TMDL study area extends from the headwaters in Vilas County to Lake Wisconsin in Columbia County, terminating at the Alliant Energy Hydrodam at Prairie du Sac. The TMDL area covers 9,156 square miles, approximately 15 percent of the state of Wisconsin. The U.S. EPA approved the Wisconsin River TMDL on April 26, 2019.

Lake Mohawksin's watershed (red outline) lies within the WDNRs total maximum daily load (TMDL) project area (Figure 3.2-1). There are four regions within the project area, headwaters, upper, central and lower regions (Figure 3.2-1). Lake Mohawksin's watershed combined with the downstream Spirit River Watershed comprises almost the entirety of the headwaters region. The headwaters region is characterized as primarily having glacial lakes, small connecting streams, rare aquatic species, widespread forests, and extensive wetlands (WDNR 2019).

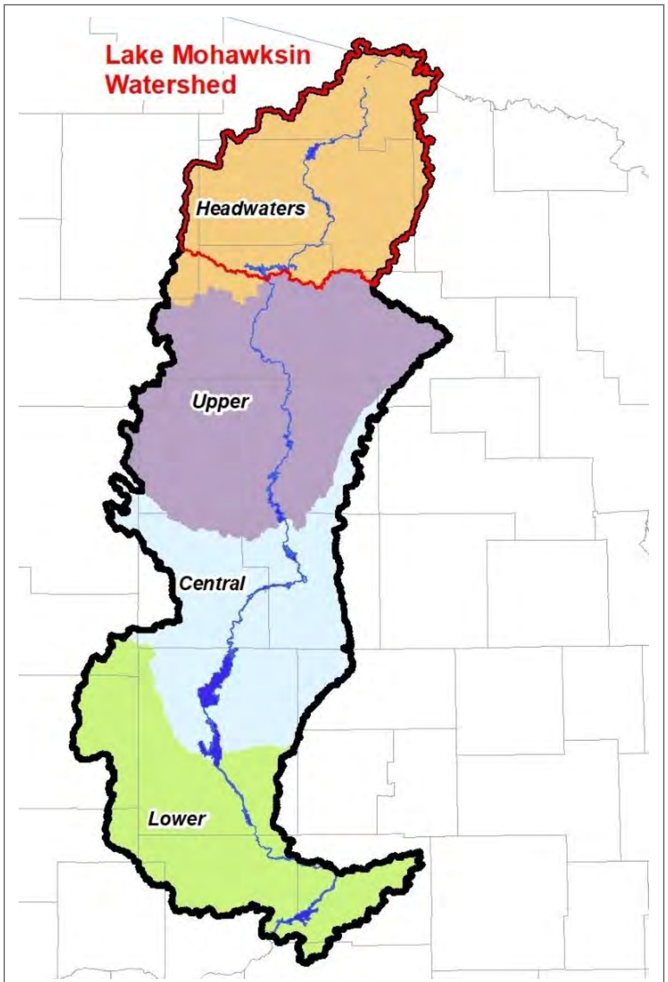


Figure 3.2-1. Wisconsin River TMDL Area and Lake Mohawksin Watershed. TMDL per WDNR 2019.

The WDNR completed extensive water quality monitoring during 2009-2013 of the streams, rivers, lakes, and reservoirs within the Wisconsin River Basin was done to gain an understanding of the water quality conditions within the system. These results were used to understand how a watershed would respond under certain circumstances and to determine areas where water quality standards were not being met.

Sources of phosphorus loading were assessed within the project area to determine if there were areas of high phosphorus loading. The WDNR recognized these pollutant sources as either *point* or *nonpoint sources*.

A point source is any detached transmission from the natural landscape which discharges a polluted material, such as from a pipe or ditch. Wastewater treatment facilities and concentrated animal feeding operation (CAFO) are the main point-sources investigated as part of the TMDL. Within the Lake Mohawksin watershed there are eight wastewater treatment facilities (WWTFs). There are six municipal WWTFs, Three Lakes, Eagle River, Phelps, Lakeland, Rhinelander, and Lake Tomahawk and two industrial WWTF, Expera Specialty Solutions near Rhinelander and WDNR Art Oehmcke State Fish Hatchery. A concentrated animal feeding operation (CAFO) is a facility which houses 1,000 or more farm animals for agricultural purposes. Wastewater from these operations is high in suspended solids and phosphorus concentrations. There are no CAFOs located within the Lake Mohawksin watershed.

Onterra LLC Lake Management Planning

Non-point sources are diffuse sources on the landscape such as runoff from agricultural land, forest, or wetland areas. As referenced as part of the WiLMS modeling, landcover is an important component to the delivery of phosphorus to waterbodies and is also used within the TMDL modeling.

To assess pollutant load development, the Wisconsin River TMDL area was broken down into 337 subbasins. A phosphorus load was generated from each subbasin based upon point and non-point sources to further analyze specific areas within the TMDL project area. The TMDL uses a variety of models, including FLUXMASTER, WinSLAMM, and SWAT.

The TMDL indicated that Lake Mohawksin's watershed generates 150,000 lbs of phosphorus annually. The majority of the phosphorus comes in over the Kings Dam, which includes not only the Wisconsin River sub-watershed, but the upstream Gilmore Creek, Eagle River, and Pelican River sub-watersheds.

Table 3.2-1. Annual phosphorus load partitioned by watershed. WDNR 2019.

	Size	Phosphorus (lbs)	Phosphorus per acre
Eagle River	151,509	11,400	0.075
Gilmore Creek	53,467	3,200	0.060
Pelican River	169,545	12,800	0.075
Somo River	87,021	12,800	0.147
Tomahawk River	356,536	23,400	0.066
Wisconsin River	471,994	86,400	0.183
Total	1,290,072	**150,000**	

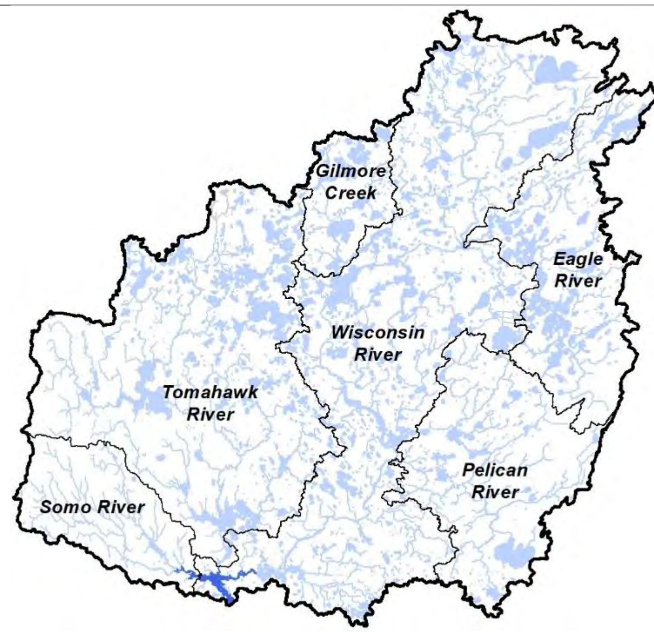


Figure 3.2-2. Lake Mohawksin Sub-watersheds. WDNR 2019.

According to the 303(d) section of the Federal Clean Water Act, each state is required to identify waters not meeting water quality standards. Within the Lake Mohawksin watershed there were 32 impaired waters identified (Table 3.2-2). Of the 32 impaired waters, 19 documented excessive amounts of phosphorus as their reason for being an impaired water. These waters specifically have the potential to negatively impact the Lake Mohawksin watershed by increasing the amount of phosphorus flowing downstream towards the lake.

Table 3.2-2. WDNR TMDL watershed and ecological landscape. TMDL for total phosphorus in the Wisconsin River Basin (WDNR 2019).

Major Tributary Watershed	Impaired water	Pollutant
Eagle River	Medicine Lake (3 Lakes Chain)	Mercury
	Big Fork Lake (3 Lakes Chain)	Mercury & Total Phosphorus
	Big Lake (3 Lakes Chain)	Mercury & Total Phosphorus
	Big Stone Lake (3 Lakes Chain)	Mercury & Total Phosphorus
	Deer Lake (3 Lakes Chain)	Mercury & Total Phosphorus
	Dog Lake (3 Lakes Chain)	Mercury & Total Phosphorus
	Laurel Lake (3 Lakes Chain)	Mercury & Total Phosphorus
	Mud Lake	Total Phosphorus
	Sevenmile Lake	Total Phosphorus
	Cranberry Lake	Unknown (Excess Algal Growth)
	Eagle Lake (Eagle Chain)	Unknown (Excess Algal Growth)
Gilmore Creek	Big Saint Germain Lake	Total Phosphorus
	Content Lake	Total Phosphorus
	Pickerel Lake	Unknown (Excess Algal Growth)
Pelican River	Moen Lake	Mercury
	Enterprise Lake	Unknown (Excess Algal Growth)
	Pelican Lake	Unknown (Excess Algal Growth)
Somo River	None	
Tomahawk River	Big Arbor Vitae Lake	Total Phosphorus
	Kawaguesaga Lake	Total Phosphorus
	Little Bearskin Lake	Total Phosphorus
	Minoqua Lake	Total Phosphorus
	Little Arbor Vitae Lake	Unknown (Eutrophication)
	Bearskin Lake	Unknown (Excess Algal Growth)
	Hancock Lake	Unknown (Excess Algal Growth)
Wisconsin River Headwaters	Upper Buckatabon Lake	Mercury
	Dam Lake (Sugar Camp Chain)	Total Phosphorus
	Lower Buckatabon Lake	Total Phosphorus
	Myrtle Lake	Total Phosphorus
	Sand Lake (Sugar Camp Chain)	Total Phosphorus
	Twin Lakes	Total Phosphorus
	Boot Lake	Unknown (Eutrophication, excess Algal Growth)
	Muskellunge Lake	Unknown (Excess Algal Growth)

3.3 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 shoreland). 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 2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. 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 et al. 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.

Photograph 3.3-1. Example of coarse woody habitat in a lake.

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 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.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin et al. 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 nations 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) (Radmoski 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 3.3-2. 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 3.3-1).

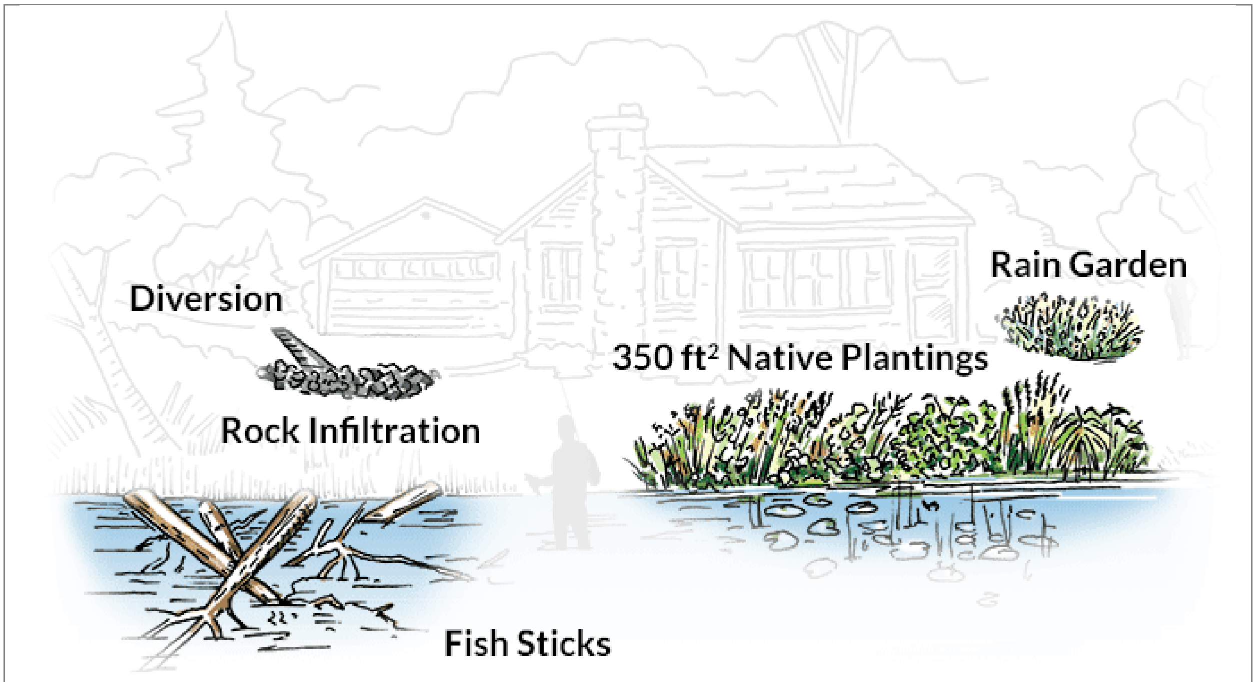


Figure 3.3-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- 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.

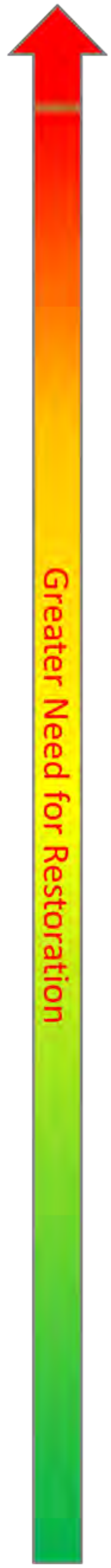
Lake Mohawksin Shoreland Zone Condition

Shoreland Development

Lake Mohawksin's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-2 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.

The entire shoreland of the Lake Mohawksin Waters (49.1 miles, including islands) was surveyed during the early fall of 2019 using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-3.

The Lake Mohawksin Waters has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 34.5 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-3). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 7.5 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Lake Mohawksin shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.



Urbanized: This type of shoreline has essentially no natural habitat. Areas that are mowed or unnaturally landscaped to the water's edge and areas that are rip-rapped or include a seawall would be placed in this category.

Developed-Unnatural: This category includes shorelines that have been developed, but only have small remnants of natural habitat yet intact. A property with many trees, but no remaining understory or herbaceous layer would be included within this category. Also, a property that has left a small (less than 30 feet), natural buffer in place, but has urbanized the areas behind the buffer would be included in this category.

Developed-Semi-Natural: This is a developed shoreline that is mostly in a natural state. Developed properties that have left much of the natural habitat in state, but have added gathering areas, small beaches, etc within those natural areas would likely fall into this category. An urbanized shoreline that was restored would likely be included here, also.

Developed-Natural: This category includes shorelines that are developed property, but essentially no modifications to the natural habitat have been made. Developed properties that have maintained the natural habitat and only added a path leading to a single pier would fall into this category.

Natural/Undeveloped: This category includes shorelines in a natural, undisturbed state. No signs of anthropogenic impact can be found on these shorelines. In forested areas, herbaceous, understory, and canopy layers would be intact.

Figure 3.3-2. Shoreland assessment category descriptions.

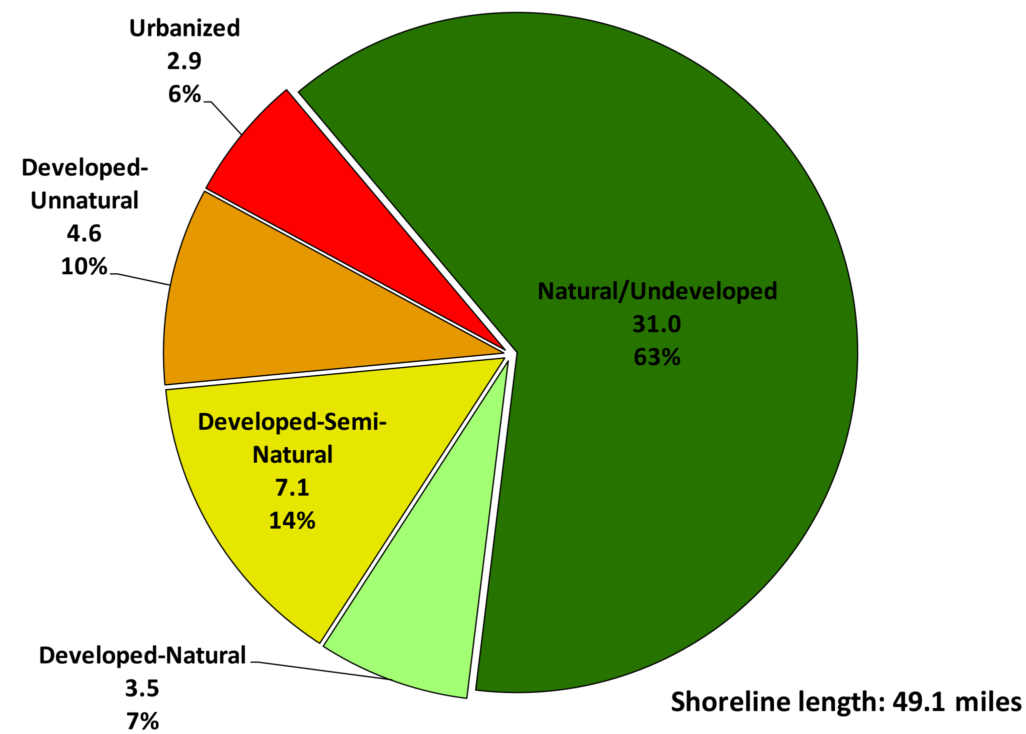


Figure 3.3-3. Lake Mohawksin shoreland categories and total lengths. Based upon a Fall 2019 survey. Locations of these categorized shorelands can be found on Map 3.

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.

3.4 Aquatic Plants

Introduction

Photograph 3.4-1. Example of emergent and floating-leaf communities.

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.

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 Lake Mohawksin, 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 Lake Mohawksin 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 (Hand-Harvesting & DASH)

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.

Photograph 3.4-2. Example of aquatic plants that have been removed manually.

Manual removal or hand-harvesting of aquatic invasive species has gained favor in recent years as an alternative to herbicide control programs. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process.

Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,000 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,000 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

Advantages	***Disadvantages***
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • 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 3.4-3. 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

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.

Photograph 3.4-4. Liquid herbicide application. Photo credit: Amy Kay, Clarke.

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 et al. 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. Table 3.5-1 provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from (Netherland 2009).

Table 3.4-1. 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 submergen 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

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.

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 Lake Mohawksin; 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 Lake Mohawksin in 2016. 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 Lake Mohawksin, 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 Lake Mohawksin to be compared to other lakes within the region and state.

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

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 Lake Mohawksin is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forests ecoregion 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 Lake Mohawksin 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 3.4-1). 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.

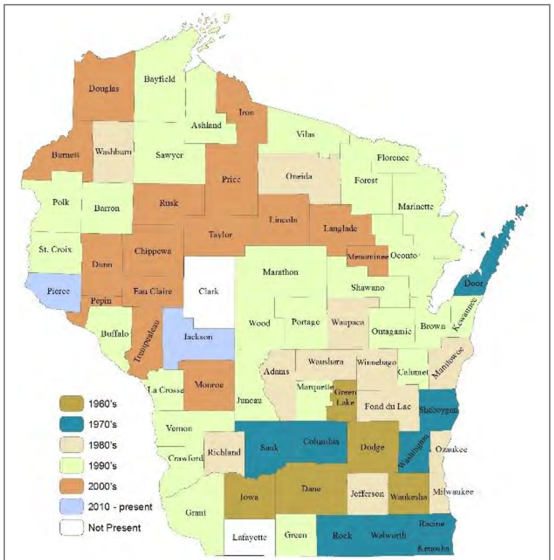


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

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.

Lake Mohawksin Aquatic Plant Survey Results

The first whole-lake aquatic plant point-intercept survey was completed on Lake Mohawksin in 2006 as part of the development of the lake's first management plan. The extent of the point-intercept survey grid was limited by the WDNR to include only the lake-lake parts of the system (Figure 3.4-2). A replicate point-intercept survey was conducted in 2013 as part of an update to the aquatic plant section and again in 2019 as part of this management plan update. During 2006, 2013, and 2019 an additional survey aimed at understanding the footprint of the emergent and floating-leaf plant community was also conducted.

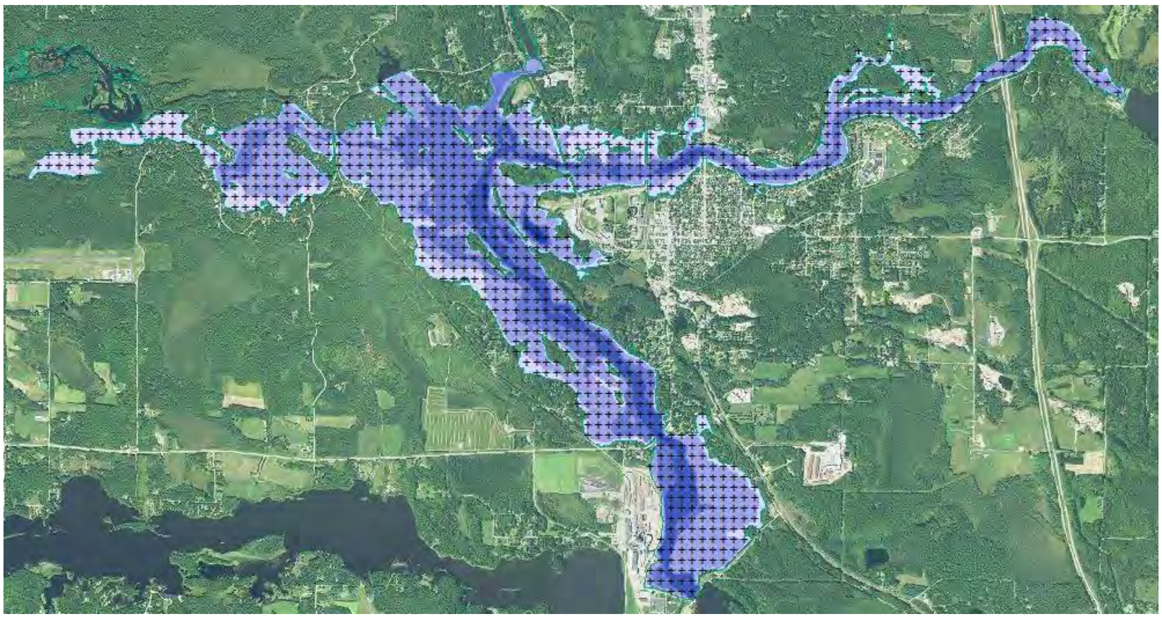


Figure 3.4-2. Lake Mohawksin whole-lake point-intercept survey sampling locations. Grid and project extent created by WDNR

Since 2006, a total of approximately 80 species of plants were located within and along the margins of the Lake Mohawksin Waters (Table 3.4-2 and 3.4-3). Four species are considered non-native species and will be specifically discussed in a sperate sub-section: Eurasian watermilfoil, curly-leaf pondweed, and purple loosestrife, and pale-yellow iris. Two species are listed by the Natural Heritage Inventory as being species of special concern: northern naiad and vasey's pondweed.

Table 3.4-2. Submergent aquatic plant species located on Lake Mohawksin.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2006	2013	2019
Submergent	*Bidens beckii*	Water marigold	Native	8	X	X	X
	Callitriche palustris	Common water starwort	Native	8			I
	Ceratophyllum demersum	Coontail	Native	3	X	X	X
	Ceratophyllum echinatum	Spiny hornwort	Native	10		X	X
	Chara spp.	Muskgrasses	Native	7		X	
	Elatine minima	Waterwort	Native	9	I		
	Elodea canadensis	Common waterweed	Native	3	X	X	X
	Elodea nuttallii	Slender waterweed	Native	7	X	X	X
	Heteranthera dubia	Water stargrass	Native	6	X		X
	Myriophyllum heterophyllum	Various-leaved watermilfoil	Native	7	X	X	X
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X
	Myriophyllum verticillatum	Whorled watermilfoil	Native	8		I	X
	Najas flexilis	Slender naiad	Native	6	X	X	X
	Najas gracillima	Northern naiad	Native - Special Concern	7	X		
	Najas guadalupensis	Southern naiad	Native	7		X	
	Nitella spp.	Stoneworts	Native	7	X	X	X
	Potamogeton alpinus	Alpine pondweed	Native	9		I	
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7			X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A		I	
	Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	X	X	X
	Potamogeton foliosus	Leafy pondweed	Native	6	X		X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7	X		
	Potamogeton natans	Floating-leaf pondweed	Native	5	X	X	X
	Potamogeton nodosus	Long-leaf pondweed	Native	5		X	
	Potamogeton obtusifolius	Blunt-leaved pondweed	Native	9		X	
	Potamogeton praelongus	White-stem pondweed	Native	8	X	X	X
	Potamogeton pusillus	Small pondweed	Native	7	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8	X	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8		I	
	Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	X	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A			X
	Stuckenia pectinata	Sago pondweed	Native	3	I		
	Utricularia gibba	Creeping bladderwort	Native	9			X
	Utricularia intermedia	Flat-leaf bladderwort	Native	9			X
	Utricularia minor	Small bladderwort	Native	10		X	X
	Utricularia vulgaris	Common bladderwort	Native	7	X	X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey

Table 3.4-3. Emergent and floating leaf aquatic plant species located on Lake Mohawksin.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2006	2013	2019
Emergent	*Calla palustris*	Water arum	Native	9	X	I	I
	Carex comosa	Bristly sedge	Native	5	I		
	Carex utriculata	Common yellow lake sedge	Native	7		I	
	Dulichium arundinaceum	Three-way sedge	Native	9	I	X	I
	Eleocharis palustris	Creeping spikerush	Native	6	X	X	X
	Equisetum fluviatile	Water horsetail	Native	7		I	
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A			I
	Iris versicolor	Northern blue flag	Native	5	X		
	Juncus effusus	Soft rush	Native	4			I
	Juncus filiformis	Thread rush	Native	7	I		
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	I	I	I
	Pontederia cordata	Pickerelweed	Native	9	X	X	X
	Sagittaria latifolia	Common arrowhead	Native	3	X	I	I
	Sagittaria rigida	Stiff arrowhead	Native	8	X	X	
	Schoenoplectus acutus	Hardstem bulrush	Native	5		I	
	Schoenoplectus pungens	Three-square rush	Native	5		I	
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	X	X	X
	Scirpus cyperinus	Wool grass	Native	4		I	
	Sparganium eurycarpum	Common bur-reed	Native	5			X
	Typha latifolia	Broad-leaved cattail	Native	1	I		I
	Typha spp.	Cattail spp.	N/A	N/A		I	I
	Zizania palustris	Northern wild rice	Native	8	X	X	
	Zizania spp.	Wild rice sp.	Native	8			X
Floating leaf	*Brasenia schreberi*	Watershield	Native	7	X	X	X
	Nuphar variegata	Spatterdock	Native	6	X	X	X
	Nuphar X rubrodisca	Intermediate pondlily	Native	9		I	X
	Nymphaea odorata	White water lily	Native	6	X	X	X
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9			I
	Sparganium fluctuans	Floating-leaf bur-reed	Native	10	X		X
FL/E	*Sparganium emersum var. acaule*	Short-stemmed bur-reed	Native	8	X	I	X
	Sparganium eurycarpum	Common bur-reed	Native	5	X	X	
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9		X	
SE	*Eleocharis acicularis*	Needle spikerush	Native	5	I		X
	Sagittaria cuneata	Arum-leaved arrowhead	Native	7		X	
	Sagittaria graminea	Grass-leaved arrowhead	Native	9		X	I
	Schoenoplectus subterminalis	Water bulrush	Native	9			X
FF	*Lemna trisulca*	Forked duckweed	Native	6	X	X	I
	Lemna turionifera	Turion duckweed	Native	2		X	X
	Lemna minor	Lesser duckweed	Native	5	X		X
	Spirodela polyrhiza	Greater duckweed	Native	5	I	X	X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey

The sediment within littoral areas of Lake Mohawksin is very conducive for supporting lush aquatic plant growth. Data from the 2019 point-intercept survey indicate that approximately 74% of the sampling locations located within the littoral zone contained fine organic sediment (muck), 21% contained sand, and 5% contained rock (Figure 3.4-3).

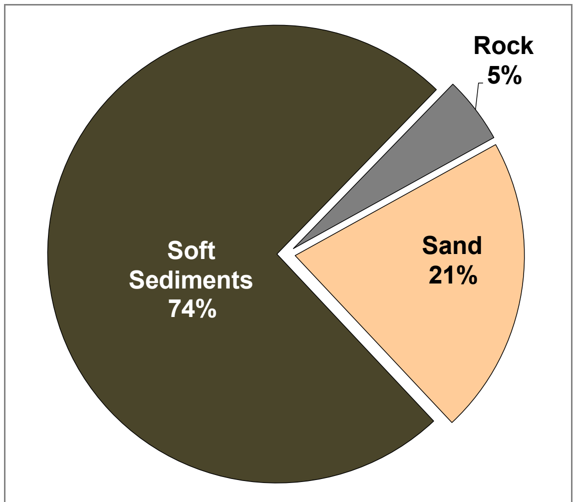


Figure 3.4-3. Lake Mohawksin proportion of substrate types within littoral areas. Created using 2019 point-intercept data.

As discussed in the water quality section, the water clarity in Lake Mohawksin is relatively low which limits sunlight penetration and restricts aquatic plants from inhabiting deeper areas of the lake. Figure 3.4-4 shows that the majority of the aquatic vegetation in Lake Mohawksin grows between 1 and 6 feet.

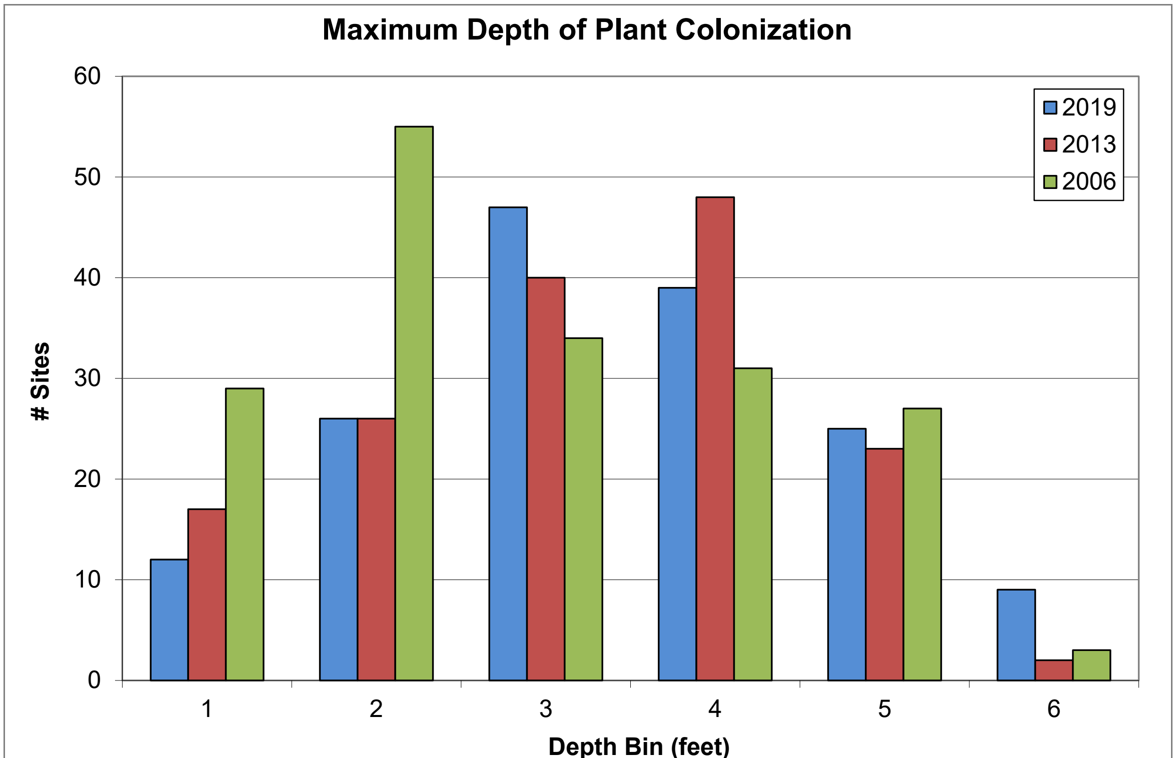


Figure 3.4-4. Maximum depth of plant colonization for Lake Mohawksin aquatic plant species. Created using 2006, 2013, and 2019 aquatic plant point-intercept survey data.

During 2019, approximately 58.5% of the littoral point-intercept sampling locations (6 feet of water or less) contained aquatic vegetation (Figure 3.4-5). About the same amount of vegetation was noted in 2006 (59.7%) and slightly less vegetation was observed in 2013 (53.2%).

Total Rake Fullness (TRF) values were recorded at each sampling location as a part of the point-intercept survey methodology during 2013 and 2019 (Figure 3.4-5). During the 2019 survey two-thirds of the sampling locations that contained vegetation were giving a rating of 1. This indicates that where vegetation is present, it is typically at relatively low densities. Map 4 shows the TRF data from the 2019 survey. The majority of the aquatic vegetation in Lake Mohawksin is located within the shallow bays and near-shore areas.

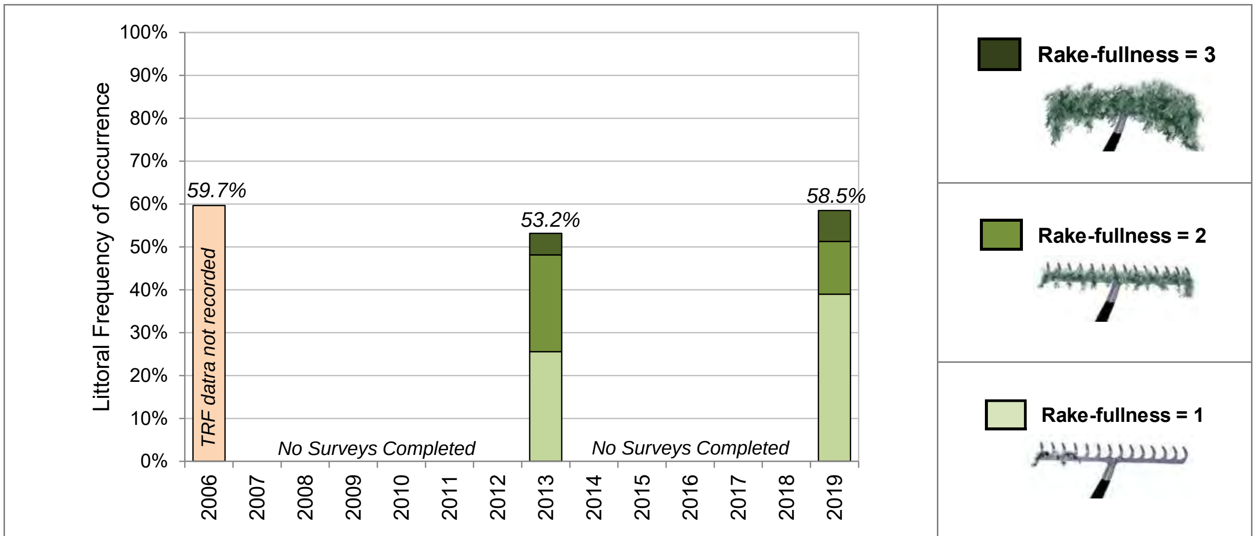


Figure 3.4-5. Lake Mohawksin LFOO and TRF data. LFOO = Littoral frequency of occurrence, TRF = total rake fullness. Note that TRF was not recorded in 2005.

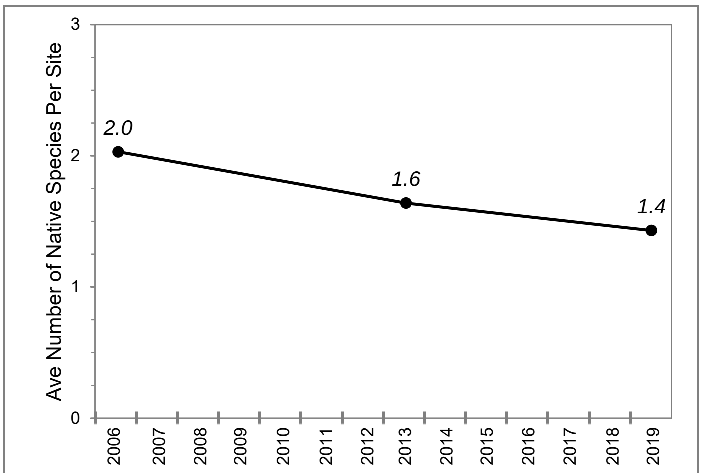


Figure 3.4-6. Average number of native species per sampling site in Lake Mohawksin.

Figure 3.4-6 shows the average number of native species present on the sampling rake with in the littoral zone. This metric helps to indicate the species abundance and distribution across sampling locations. The average number of native species per site has declined from 2 species per site in 2006 to approximately 1.4 in 2019. Map 5 shows the species richness from the 2019 point-intercept survey.

Wild celery was the most common aquatic plant located during the 2019 point-intercept survey (22.0%), followed by coontail (15.2%). Almost a dozen other aquatic plants were found at a littoral frequency of occurrence near 5% (Figure 3.4-7).

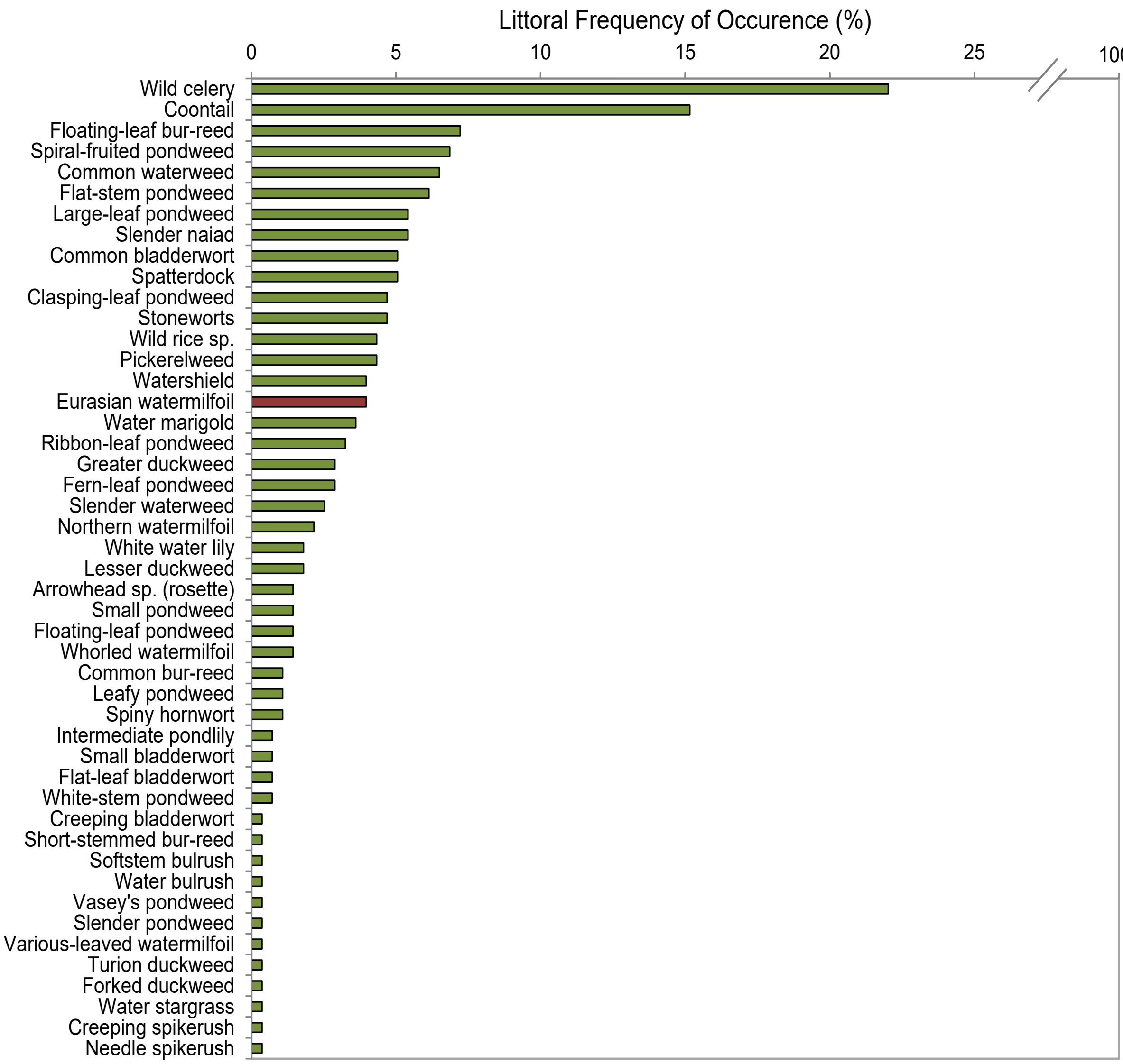


Figure 3.4-7. Lake Mohawksin aquatic plant littoral frequency of occurrence. Created using data from Onterra 2019 whole-lake point-intercept survey.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations are driven by a combination of interacting natural factors including variations in water levels, temperature, ice and snow cover (winter light availability), nutrient availability, changes in water flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006). Figure 3.4-8 investigates the population dynamics of few select species from Lake Mohawksin.

Wild celery, the most frequent species in 2019, contains a basil rosette, which means that the long, grass-like leaves extend in a circular fashion from the base of the plant located at the sediment-water interface (Photograph 3.4-5). To keep the leaves standing in the water column, lacunar cells in the leaves trap air and gasses making them more buoyant. Towards the late-summer when water celery is at its peak growth stage, it is easily uprooted by wind and wave activity. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife and are an important component of the Lake Mohawksin ecosystem. The population of wild celery has been relatively stable since 2006 (Figure 3.4-7).

Photograph 3.4-5. Wild celery (*Vallisneria americana*). Photo credit Onterra.

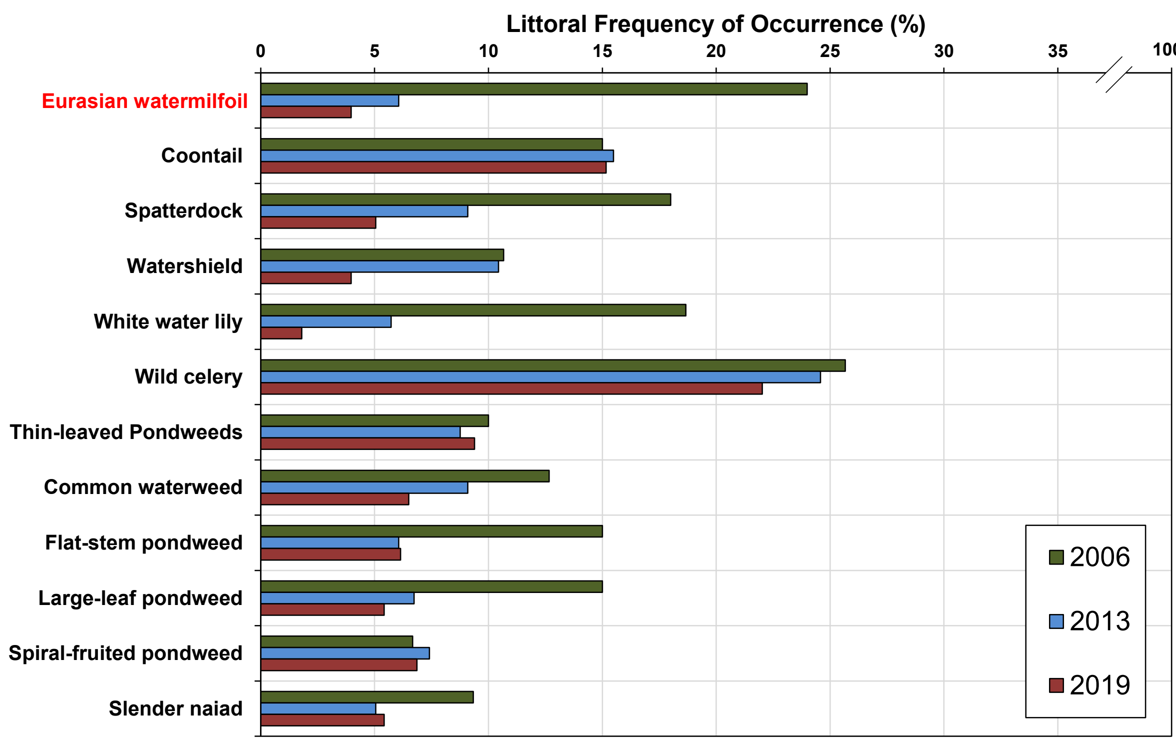


Figure 3.4-8. Lake Mohawksin aquatic plant littoral frequency of occurrence of select species. Created using data from 2006, 2013, and 2019 surveys.

Coontail was the second-most frequent species in 2019. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface (Photograph 3.4-6). Because it lacks true roots, coontail derives all of its nutrients directly from the water (Gross, Erhard and Ivanyi 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in productive waterbodies with higher nutrients and lower water clarity. Coontail provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and helps to improve water clarity. Coontail populations have remained relatively constant since 2006 (Figure 3.4-7)

		
Photograph 3.4-6. Coontail (*Ceratophyllum demersum*). Photo credit Onterra.	**Photograph 3.4-7. Common waterweed** (*Elodea canadensis*) Photo credit: Onterra**.**	**Photograph 3.4-8. Large leaf pondweed (Potamogeton amplifolius).** Photo credit Onterra.

Like coontail, common waterweed obtains the majority of its nutrients directly from the water. While common waterweed can be found growing in many of Wisconsin's waterbodies, excessive growth of common waterweed is often observed in waterbodies with higher nutrients. It can tolerate the low light conditions found in eutrophic systems better than many other aquatic plant species. For these reasons, common waterweed has competitive advantages over other aquatic plant species that favor its growth in productive systems. Common waterweed had its highest population in 2006, and has had a lower but stable population since 2013 (Figure 3.4-7).

Large-leaf pondweed, often called "cabbage" due to its appearance, has the broadest leaf of any pondweed in the Midwest (Photograph 3.4-8). The leaves are arched and slightly folded, and though often found in a greenish color can take on a reddish appearance in the late summer. Large-leaf pondweed is also referred to by anglers as musky weed or musky cabbage, as this plant provides excellent cover for ambush predators. Like common waterweed, large-leaf pondweed was most prevalent in 2006 and has maintained a lower but stable population since 2013 (Figure 3.4-7).

Lake Mohawksin has three primary floating-leaf species: spatterdock, white-water lily, and watershield (Photograph 3.4-9). These species all had higher populations in 2006 compared with 2013 and 2019 (Figure 3.4-7). Within the riparian stakeholder survey, some respondents indicated a noticeable reduction in the population of these species.

Photograph 3.4-9. Floating-leaf species common on Lake Mohawksin.
White water lily (Nymphaea odorata; top left), yellow water lily (Nuphar variegata; top right), and water shield (Brasenia schreberi; bottom). Photo credit Onterra.

As explained above in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at 22% of the sampling locations in Lake Mohawksin, its relative frequency of occurrence is 15% (Figure 3.4-9). Explained another way, if 100 plants were randomly sampled from Lake Mohawksin, 15 of them would be wild celery. From 2006 to 2019 Eurasian watermilfoil and floating leaf species have comprised a smaller proportion of the overall plant population, while small pondweeds, wild celery, and coontail have shown an increase. Variations in frequencies of occurrence with aquatic plant species in Lake Mohawksin may be a function of water flow changes.

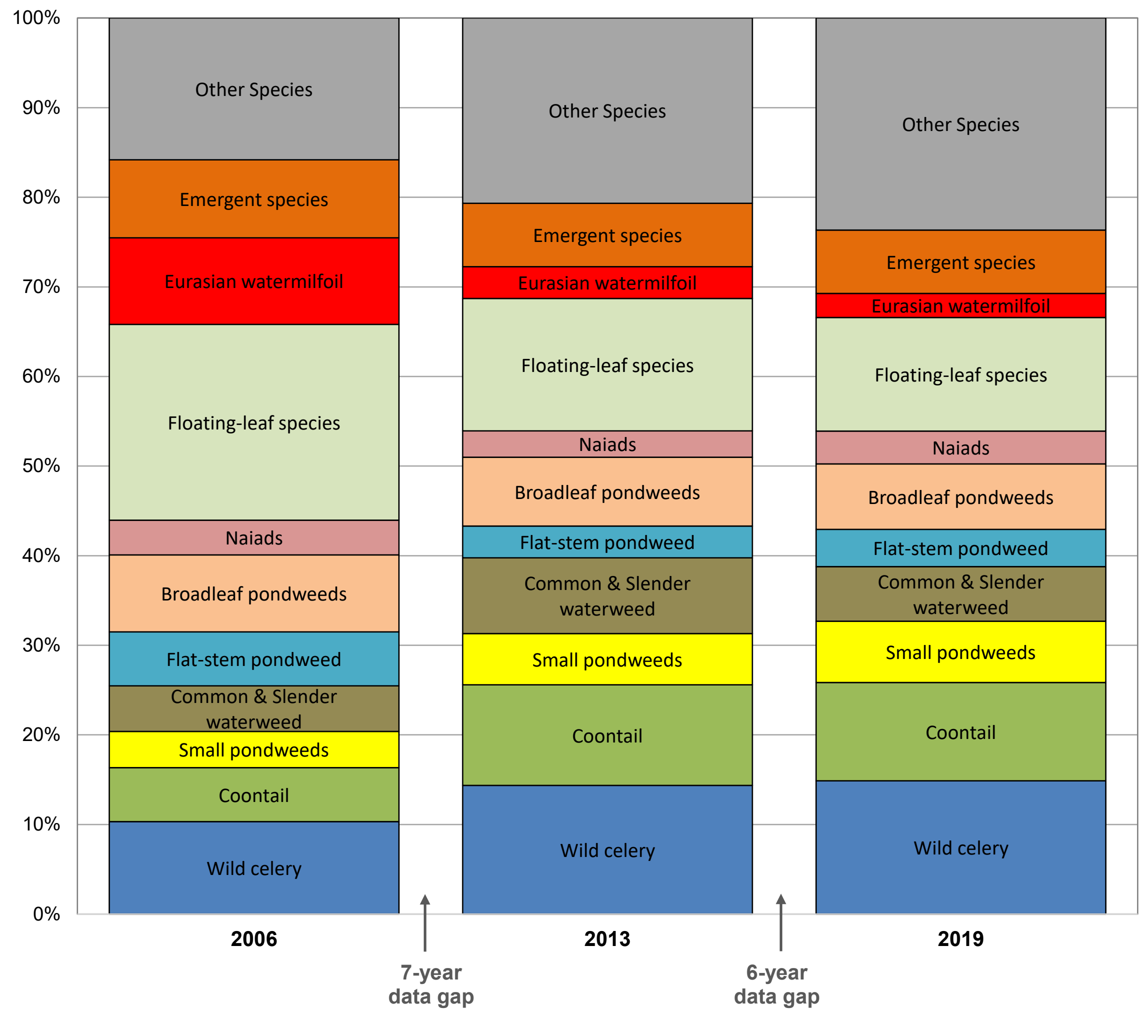


Figure 3.4-9. Relative frequency of occurrence analysis of Lake Mohawksin.

As discussed previously, 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 58 native aquatic plant species were located in Lake Mohawksin during the 2019 surveys, only 46 were encountered on the rake during the point-intercept survey and the additional 12 were located during other survey work. Figure 3.4-6 shows that the native species richness for Lake Mohawksin is well above the Northern Lakes and Forests Ecoregion and Wisconsin State medians.

The species that are present in Lake Mohawksin are indicative of very high-quality conditions. Data collected from the aquatic plant surveys show that the 2019 average conservatism value (6.8) is in-line the Northern Lakes and Forest Lakes Ecoregion and Wisconsin State medians (Figure 3.4-6), indicating that the majority of the plant species found in Lake Mohawksin are considered sensitive to environmental disturbance and their presence signifies excellent environmental conditions.

Combining Lake Mohawksin's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in an exceptionally 2019 high value of 46.4, well above the median values for the ecoregion and state (Figure 3.4-10), and further illustrating the quality of Lake Mohawksin's plant community.

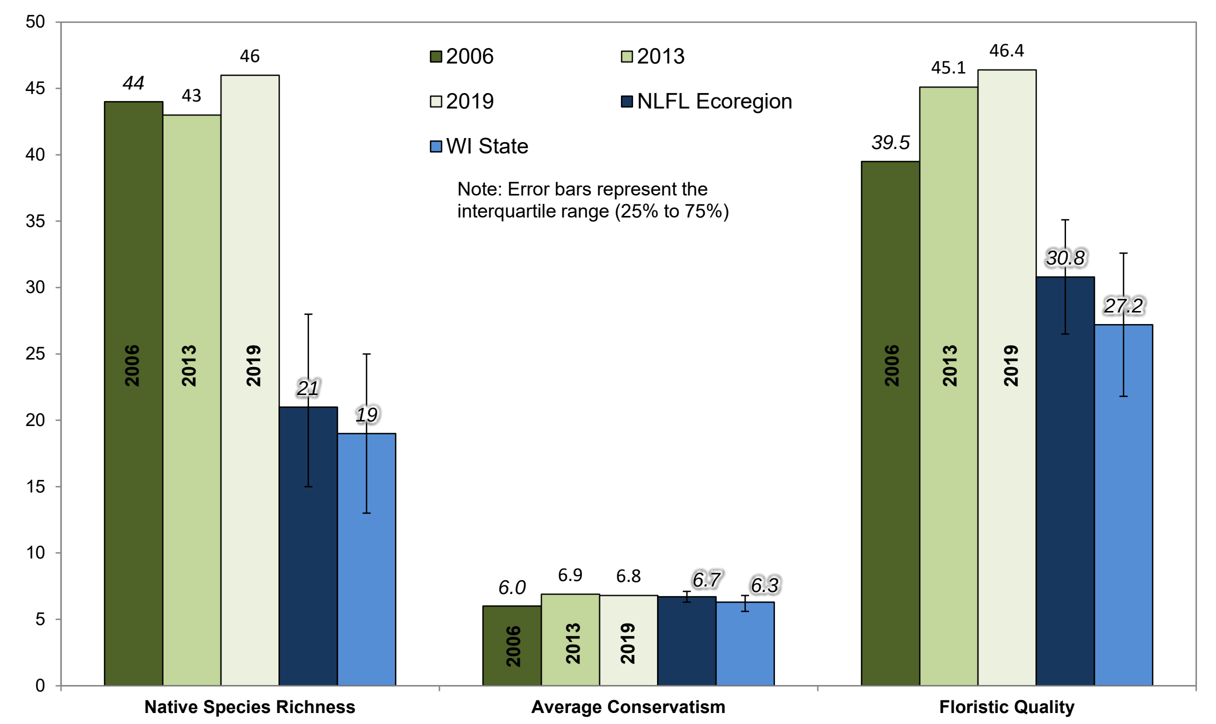


Figure 3.4-10. Lake Mohawksin Floristic Quality Assessment. Analysis following Nichols (1999) where NLFL = Northern Lakes and Forest Lakes Ecoregion.

Because Lake Mohawksin contains a high number of native aquatic plant species, one may assume their aquatic plant communities have high species diversity. However, as discussed earlier, species diversity is also influenced by how evenly the plant species are distributed within the community. Lake Mohawksin is not overly dominated by a few species, rather have a relatively even distribution of its many aquatic plant species. Lake Mohawksin's Simpson's Diversity Index (1-D) was found to be 0.95 out of 1.0. This means you have a 95% chance of the next plant species encountered being different from the previous one.

The quality of Lake Mohawksin's plant community is indicated by the high incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The 2019 community map indicates that approximately 193.6 acres contain these types of plant communities within the same boundaries as used for the point-intercept survey (Figure 3.4-1 and Map 6-Map 8). Approximately 18 floating-leaf and emergent species were located on Lake Mohawksin, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

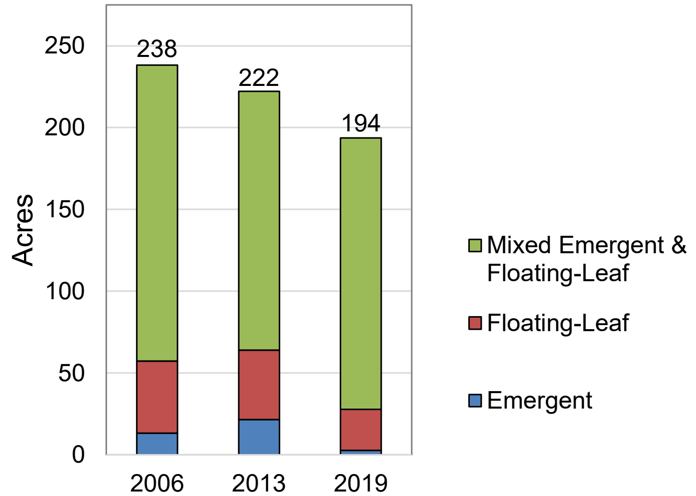


Figure 3.4-11. Lake Mohawksin emergent and floating-leaf areal cover. Created using data from 2006, 2013, and 2019 community mapping surveys.

Photograph 3.4-10. Pickerelweed (*Pontederia cordata*). Photo credit: Onterra.

Because the community map represents a ‘snapshot’ of the important emergent and floating-leaf plant communities, comparing survey to replicates in the past and future can provide a valuable understanding of the dynamics of these communities within Lake Mohawksin. This is important 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.

Overlaying the 2006, 2013, and 2019 community mapping surveys, most of the changes in the footprint of floating-leaf and emergent communities are small, but add up on a system as large as the Lake Mohawksin Waters. Within the southern lobe of Lake Mohawksin, a few areas of expansion were observed (Figure 3.4-12). Please note this figure only shows the communities delineated with polygons or areas; point-based data is not shown. In 2006, Area A contained a 2.3-acre colony of floating-leaf bur-reed and white water lily. In 2013, this area was reduced to 0.1 acres. In 2019, only a handful of bur-reeds were observed at this location. Similarly, Area B contained a mix of floating-leaf and emergent species occupying a 5.1-acre footprint. This was reduced to 2.8 acres in 2013 and 2.7 acres in 2019. The most likely cause for these changes likely relates to the increase in water flows over this time period.

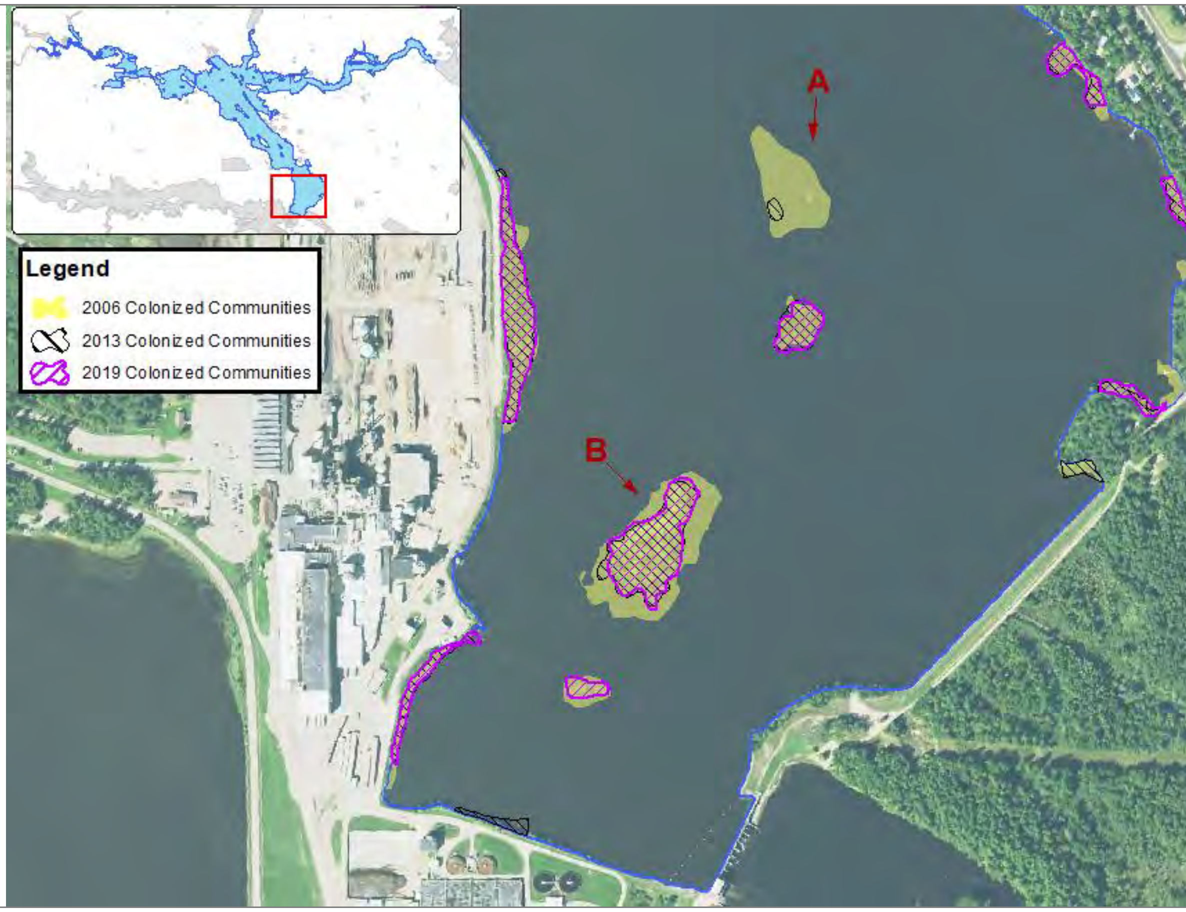


Figure 3.4-12. Select Comparison of 2006, 2013, 2019 emergent and floating-leaf plant communities.

Non-Native Aquatic Plants in Lake Mohawksin

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 submergent exotics, curly-leaf pondweed and Eurasian watermilfoil, and two emergent exotics, purple loosestrife and pale-yellow iris, are the primary targets of this extra attention.

Except for the emergent and floating-leaf community data discussed in Figure 3.4-11 and Figure 3.4-12, all the aquatic plant data discussed so far was collected as part of point-intercept surveys. The subsequent materials will also incorporate data from AIS mapping surveys. Additional explanation about how these two surveys differ is discussed below.

Point-Intercept Surveys

The point-intercept survey provides a standardized way to gain quantitative information about a lake's aquatic plant population through visiting predetermined locations and using a rake sampler to identify all the plants at each location. The point-intercept survey can be applied at various scales. The point-intercept survey is most often applied at the whole-lake scale. These data from Lake Mohawksin were discussed as part of the previous sub-section (Section 3.4). If a smaller area is being studied, a modified and finer-scale point-intercept sampling grid may be needed to produce a sufficient number of sampling points for comparison purposes. This sub-sample point-intercept survey methodology is often applied over management areas such as herbicide application sites. This type of sampling has been conducted in association with some of the herbicide spot treatments that took place from 2007-2014.

AIS Mapping Surveys

While completing the point-intercept survey, it is common to see a particularly plant species, such as EWM or CLP, very near the point-intercept sampling location but not yield it on the rake sampler. Particularly in low-density colonies such as those designated by Onterra as *highly scattered* and *scattered*, large gaps between AIS plants may exist resulting in these species not being present at a particular pre-determined point-intercept sampling location in that area. While the point-intercept survey is a valuable tool to understand the overall plant population of a lake or a target area, it does not offer a full account (census) of where a particular species exists in the lake. A species-specific mapping survey, such as an EWM or CLP mapping survey, approximates a census of where that species exists in the surveyed boundaries.

Photograph 3.4-11. EWM mapping survey on a Waushara County, WI lake. Photograph credit Onterra.

During an AIS mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat (Photograph 3.4-11). Field crews supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The EWM population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies greater than 40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (less than 40 feet in diameter), *clumps of plants*, or *single or few plants*.

Overall, each survey has its strengths and weaknesses, which is why both are utilized in different ways as part of this overall project.

Curly-leaf pondweed

Photograph 3.4-12. Curly-leaf pondweed located in Lake Mohawksin. (Onterra, 2016)

Some basic life-cycle information for curly-leaf pondweed (CLP) was provided in the primer of the Aquatic Plants section. As mentioned previously, CLP (Photograph 3.4-12) is typically at peak growth early in the growing season. The advanced growth in spring gives the plant a significant head start over native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition (James et al. 2002). However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Plants can be killed by physical removal (i.e., hand-pulling) or through herbicide treatment. Not all of the turions produced each year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Normally a control strategy for an established CLP population includes multiple years (5 or more) of controlling the same area to deplete the existing turion bank within the sediment. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species.

During an AIS mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.

During 2013 surveys on the Lake Mohawksin Waters, Onterra ecologists encountered a number of CLP occurrences in the eastern, Wisconsin River, arm of the lake (Photograph 3.4-14). Upstream Lake Alice is known to harbor an established population of CLP, reported as potentially occupying over 60 acres of the lake in 2016. In 2014 the FOLM successfully applied for an AIS-EDR grant funded project with a goal of understanding the population of CLP within the Lake Mohawksin Waters. Surveys conducted in 2014 to 2020 have identified low density CLP occurrences in the eastern lobe of the Lake Mohawksin Waters and essentially no CLP elsewhere in the system (Map 9). Professional hand-harvest contractors were deployed in 2016-2018. CLP populations were left unmanaged in 2019 and 2020, where they remained of similarly low size and density.

Pale-yellow Iris (Iris pseudacorus)

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers (Photograph 3.4-13). 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.

Photograph 3.4-13. Pale-yellow iris. Clump of the non-native pale-yellow iris mixed with the native blue-flag iris (left) and large, contiguous colony of pale-yellow iris on the shores of an Oneida County Lake (right). Photo credit Onterra.

Pale-yellow iris is typically in flower during the second half of June. The foliage of pale-yellow iris and northern blue flag iris (valuable native species) is too similar to make a definitive identification based off of this alone. Positive ID really needs to come from the flowers or the seed pods, which come after the flower is pollinated.

A survey completed in 2019 found PYI in only two occurrences along the margins of the Lake Mohawksin Waters (Map 6). It is possible that additional occurrences may exist but escaped detection. Control of PYI includes digging and removing the entire plant, cutting leaves below the water's surface, cutting flowers before they can go to seed, and herbicide applications for larger colonies.

Eurasian Watermilfoil

Eurasian watermilfoil 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. It actually spreads 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 sometimes 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. However, in some lakes, EWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

EWM was officially documented in Lake Mohawksin in 2001 by the WDNR, but anecdotal reports of its presence in the system go back to the mid-1990s. Genetic analysis has indicated that Lake Mohawksin contains populations of both pure-strain EWM and populations of hybrid EWM

(*Myriophyllum spicatum x sibiricum*, HWM). Although an exhaustive and systematic study of hybridity was not conducted on Lake Mohawksin, the majority of samples analyzed on Lake Mohawksin consist of pure-strain EWM and this genotype is assumed to comprise the majority of the invasive milfoil population of the system. Unless specifically indicated, this report will use "EWM" when discussing the invasive milfoil (EWM and HWM) population of Lake Mohawksin.

Starting in 2008, late-season EWM mapping surveys commenced on Lake Mohawksin using a consistent density rating system (Figure 3.4-13). Please note that this figure only represents only the acreage of mapped EWM polygons, not EWM mapped within point-based methodologies (*Single or Few Plants, Clumps of Plants,* or *Small Plant Colonies*). Said another way, EWM marked with point-based mapping methods do not contribute to colonized acreage as shown on Figure 3.4-13. Map 10 shows the entire EWM footprint from 2008-2020, including the point-based EWM occurrences. Map 11 and Map 12 shows the EWM mapping data from 2019 and 2020, respectively.

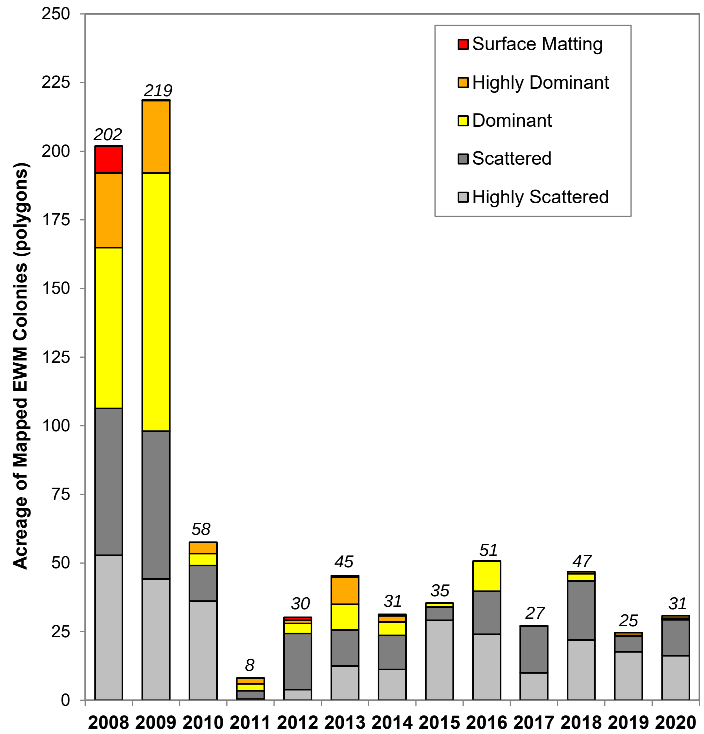


Figure 3.4-13. Acreage of mapped EWM colonies on Lake Mohawksin from 2008 to 2019. Data from Onterra Late-summer EWM mapping surveys.

The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. Prior to approximately 2010, the BMP for managing EWM was through 2,4-D 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 to cause mortality as the herbicide dissipates out of the spots rapidly.

At the start of the timeframe, FOLM initiated granular 2,4-D spot treatments (Figure 3.4-14). In 2010, large areas were targeted for herbicide treatment. Many of these treatments were in semi-enclosed bays of the system and the control efforts were fairly successful. Emerging research now understands that concentrations and exposure times (CETs) can be more easily met in these protected and enclosed areas. Areas that were targeted in more exposed parts of Lake Mohawksin were less successful.

A trial set of sites was targeted in spring 2011-2013 with a granular combination of 2,4-D and triclopyr. These were in exposed areas where granular 2,4-D treatments had only provided seasonal reductions. Unfortunately, these treatments also did not meet expectations.

Emerging research at that time demonstrated that liquid herbicide treatments provided more consistent results at a fraction of the cost of granular products, which prompted FOLM to move towards liquid herbicides in 2013 and 2014. The liquid 2,4-D treatments were conducted in semi-protected parts of the system and were considered generally successful, meaning they provided at least 2 years of reduced EWM within the application area.

A series of diquat treatments were conducted in 2013, targeting EWM within the main part of Lake Mohawksin that experienced the highest flow. This contact herbicide was suspected as only needing 4-6 hours of exposure time compared with 24 or more hours required from 2,4-D or triclopyr. A part of the joint WDNR and US Army Corps of Engineers research project, these spot treatments was monitored through the aid of a specialized dye (rhodamine WT) that was mixed with the herbicide and applied to the site, serving as a surrogate to how much herbicide is present in the site. Data collectors were placed within each treatment site and monitored the amount of dye that was present in the water at 10-minute increments. Dye concentrations were reduced below detectable levels by approximately 1 hour after treatment. Based upon these findings, it is clear that there is currently not an herbicide that can be effective with this short of exposure time.

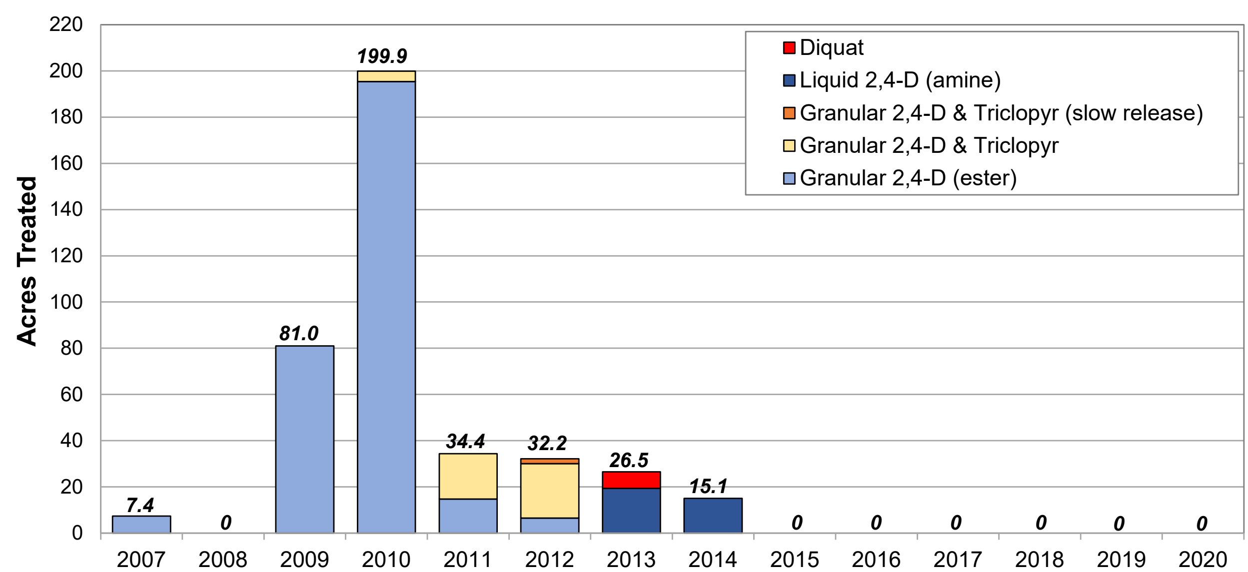


Figure 3.4-14. Lake Mohawksin herbicide treatment history.

Within an update to the FOLM's EWM management strategy in 2014, they developed a threshold (trigger) for conducting herbicide treatments: to target colonized areas of EWM with a density of *dominant* or greater and adjacent areas of EWM that are not within areas of higher water exchange. Since 2014, no areas have exceeded this trigger and herbicide management has not occurred on Lake Mohawksin from 2015 to present.

As a part of this management planning effort, FOLM asked riparian stakeholders questions about their level of support for future herbicide management of EWM. Approximately 68% of respondents indicated support (pooled *moderately support* and *strongly support*) for future herbicide management, 12% opposed (pooled *moderately oppose* and *completely oppose*), and 20% where *unsure/neutral* (Figure 3.4-15). Over 50% of the respondents that were opposed to the herbicide indicated they had that opinion because the *future impacts are unknown*, *potential* *impacts to human health*, *potential impact to non-plant species*, and *potential impacts to native plants* (Figure 3.4-16).

Question 28. What is your level of support or opposition for future aquatic herbicide use to target Eurasian watermilfoil?

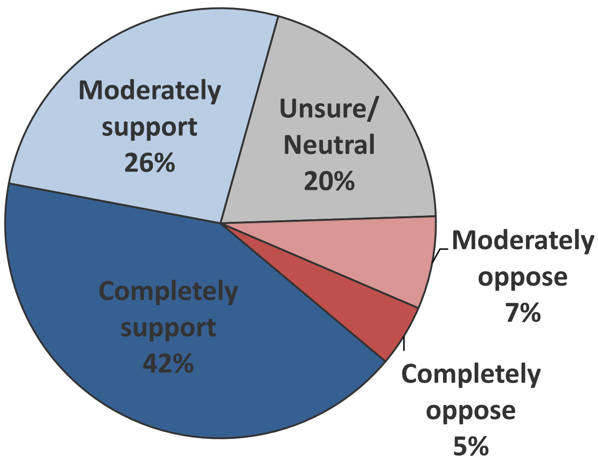


Figure 3.4-15. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 29. You selected "Moderately oppose" or "Completely oppose" on Question #28, what is the reason or reasons you oppose the future use of aquatic herbicides to target Eurasian watermilfoil?

Answer Options	Response Percent	Response Count
Future impacts are unknown	80.0%	12
Potential impacts to human health	73.3%	11
Potential impacts to native (non-plant) species such as fish, insects, etc.	60.0%	9
Potential impacts to native aquatic plant species	53.3%	8
Ineffectiveness of herbicide strategy	20.0%	3
Potential cost of treatment is too high	13.3%	2
Another reason	13.3%	2
	answered question	15
	skipped question	119

Figure 3.4-16. Select survey responses from the Lake Mohawksin Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Purple Loosestrife (Lythrum salicaria)

Like pale-yellow iris, purple loosestrife is a perennial, herbaceous wetland plant native to Europe and was likely brought over to North America as a garden ornamental (Photograph 3.4-14). 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 can also spread from root or stem fragments.

Photograph 3.4-14. The non-native wetland plant, purple loosestrife. Photo credit Onterra.

Purple loosestrife has been present along the shorelines of Lake Mohawksin Waters for decades. One of the management goals developed during the development of Lake Mohawksin management plan was to initiate efforts to reduce the occurrence of purple loosestrife beginning in 2010. Dedicated volunteers have been mapping and performing localized control efforts. Wisconsin Public Service (WPS) also periodically conducts visual AIS surveys, especially of purple loosestrife as part of their Federal Energy Regulating Commission (FERC) license requirements. WPS currently performs a visual survey of the entire Lake Mohawksin Waters once every 3 years (2020, 2023, 2026, etc.), Onterra's 2019 survey found that the occurrence of purple loosestrife appears to be lower than in 2008, but still occupies the same areas of the lake (Figure 3.4-17)

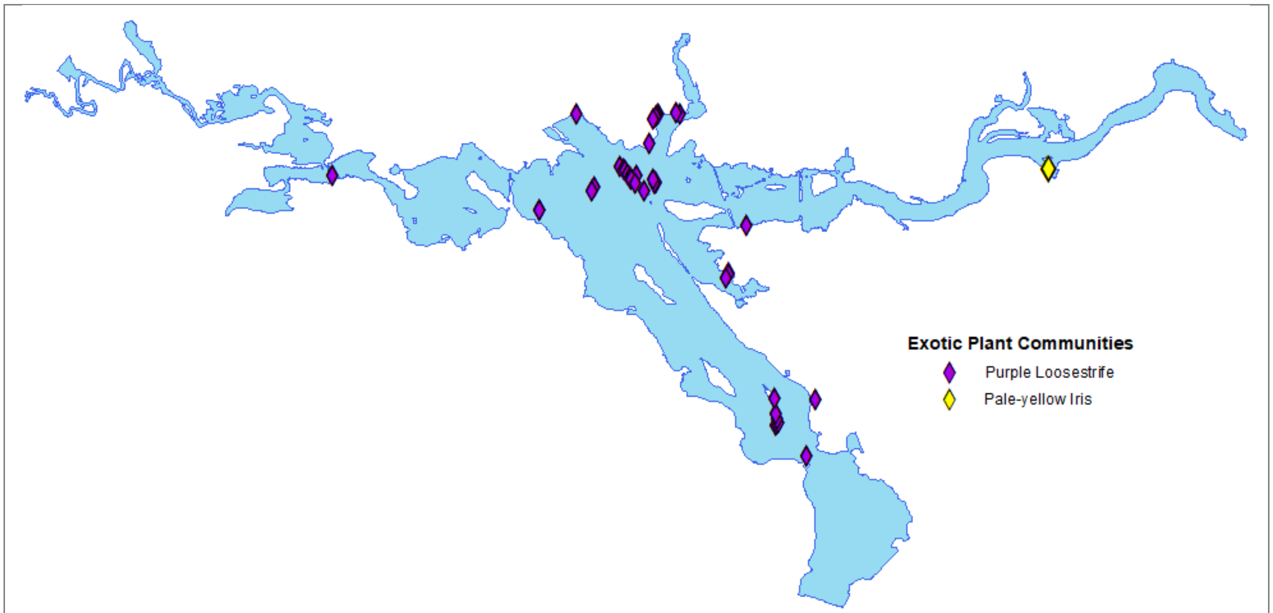


Figure 3.4-17. Lake Mohawksin emergent AIS. Onterra, 2019.

3.5 Aquatic Invasive Species in Lake Mohawksin

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Lake Mohawksin within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are four AIS present (Table 3.5-1).

Table 3.5-1. AIS present within Lake Mohawksin

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil/ hybrid watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Pale yellow iris	*Iris pseudacorus*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.4 – Aquatic Plants
Invertebrates	Rusty crayfish	*Orconectes rusticus*	Section 3.5 – AIS in Lake Mohawksin

Figure 3.5-1 displays the aquatic invasive species that Lake Mohawksin stakeholders believe are in Lake Mohawksin. Only the species present in Lake Mohawksin are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

- http://dnr.wi.gov/topic/invasives/
- https://nas.er.usgs.gov/default.aspx
- https://www.epa.gov/greatlakes/invasive-species

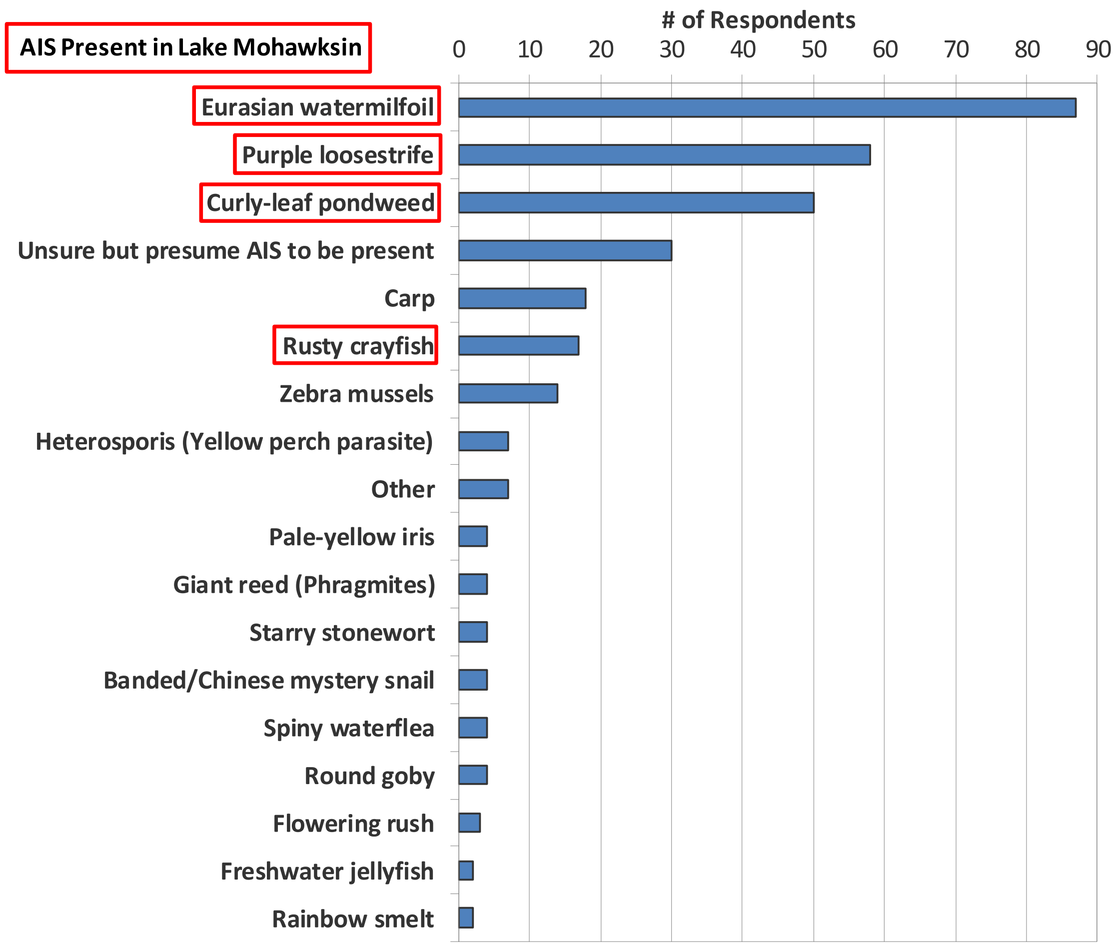


Figure 3.5-1. Stakeholder survey response Question #24. Which aquatic invasive species do you believe are in Lake Mohawksin?

Aquatic Animals

Rusty Crayfish

Photograph 3.5-1. Rusty crayfish. Photo credit: GLIFWC

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell (Photograph 3.5-1). They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake. This aquatic invasive species was verified in Lake Mohawksin in 2002. Rusty crayfish are most problematic in clear water and hard substrate lakes. Lake Mohawksin is a much different lake than those parameters and it is suspected that rusty crayfish will not have a major influence on the ecology of Lake Mohawksin.

Mystery snails

There are four types of mystery snails found within Wisconsin waters, with the brown mystery snail (*Campleoma decisum*) being the only species native. They are called mystery snails because the give birth to fully developed snails that mysteriously appear in spring. The two primary non-native mystery snails in Wisconsin are the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow, or within backwaters of flowing systems like exist in Lake Mohawksin.

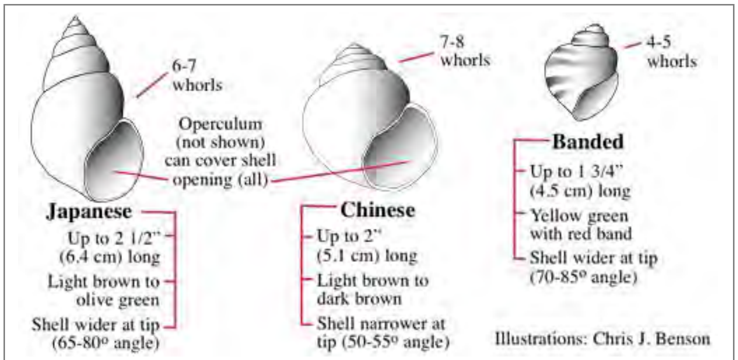


Figure 3.5-2. Identification of non-native mystery snails. Courtesy of Minnesota Sea Grant: (http://www.seagrant.umn.edu/ais/mysterysnail).

They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009). Currently the Japanese mystery snail (*Cipangopaludina japonica*) has only been documented from a handful of waterbodies in northwestern Wisconsin. Chinese and banded mystery snails are common throughout WI and likely the number of waters they inhabit is underreported. While the Chinese and banded mystery snails are not currently listed as present in Lake Mohawksin, they have both been verified in the Tomahawk River to the north, which means they are potential located throughout the system but have not been specifically surveyed for.

Most riparians find the most concerning aspect of a mystery snail population is the periodic die-off of snails. During a periodic die-off, large numbers of snails can accumulate along shorelines. Along with an inconvenience of large half-broken shells, the dead snails impart a strong fishy odor.

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 Lake Mohawksin. 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) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Dave Seibel (WDNR 2020 & GLIFWC 2019).

Lake Mohawksin 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 Lake Mohawksin 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.

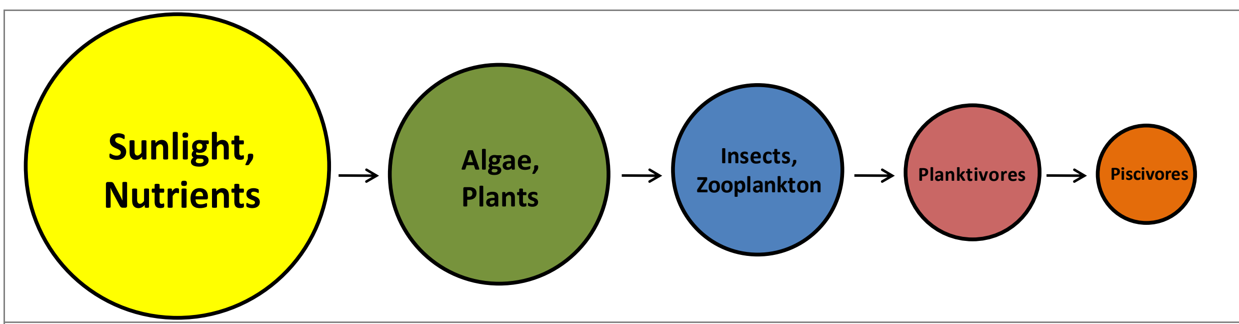


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Lake Mohawksin is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Lake Mohawksin should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past WDNR surveys of Lake Mohawksin include black bullhead (*Ameiurus melas*), blacknose shiner (*Notropis heterolepis*), bowfin (*Amia calva*), burbot (*Lota lota*) golden redhorse (*Moxostoma erythrurum*), golden shiner (*Notemigonus crysoleucas*), johnny darter (*Etheostoma nigrum*), logperch (*Percina caprodes*), rock bass (*Ambloplites rupestris*), shorthead redhorse (*Moxostoma macrolepidotum*), silver redhorse (*Moxostoma anisurum*), trout perch (*Percopsis omiscomaycus*), white crappie (*Pomoxis annularis*), white sucker (*Catostomus commersonii),* yellow bullhead *(Ameiurus natalis)*.

Table 3.6-1. Gamefish present in Lake Mohawksin 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 macrchirus)*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass *(Micropterus salmoides)*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge *(Esox masquinongy)*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
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
Smallmouth Bass *(Micropteris dolomieu)*	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye *(Sander vitreus)*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch *(Perca flavescens)*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

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.

The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 3.6-1. Fyke net an electroshocking boat.

Fish Stocking

Photograph 3.6-2. Muskellunge fingerling.

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. Lake Mohawksin was periodically stocked from 1972-2006 with Muskellunge (Table 3.6-2). Stocking efforts discontinued after 2006 because natural reproduction was occurring. Surveys planning to be conducted in 2020 and 2022 will evaluate if natural reproduction is still providing a sufficient population (Dave Seibel, personal communication).

Table 3.6-2. Stocking data available for Muskellunge in Lake Mohawksin (1972-Present).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	UNSPECIFIED	FINGERLING	1,000	9
1975	UNSPECIFIED	FINGERLING	1,003	11
1977	UNSPECIFIED	FINGERLING	3,987	7.67
1978	UNSPECIFIED	FINGERLING	400	9
1982	UNSPECIFIED	FINGERLING	3,796	9
1984	UNSPECIFIED	FINGERLING	1,200	11
1986	UNSPECIFIED	FINGERLING	2,483	10.5
1988	UNSPECIFIED	FINGERLING	2,500	10.33
1990	UNSPECIFIED	FINGERLING	2,500	10.67
1992	UNSPECIFIED	FINGERLING	1,625	10
1998	UNSPECIFIED	LARGE FINGERLING	2,500	12.23
2000	UNSPECIFIED	LARGE FINGERLING	2,500	10.85
2002	UNSPECIFIED	LARGE FINGERLING	953	10.7
2004	UNSPECIFIED	LARGE FINGERLING	954	11.1
2006	UPPER WISCONSIN RIVER	LARGE FINGERLING	955	10.7

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water) was the second important reason for owning property on or near Lake Mohawksin (Question #17). Figure 3.6-2 displays the fish that Lake Mohawksin stakeholders enjoy catching the most, with walleye, bluegill/sunfish and crappie being the most popular. Approximately 75% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.6-3). Approximately 68% of respondents who fish Lake Mohawksin believe the quality of fishing has remained the same or gotten worse since they first started to fish the lake (Figure 3.6-4).

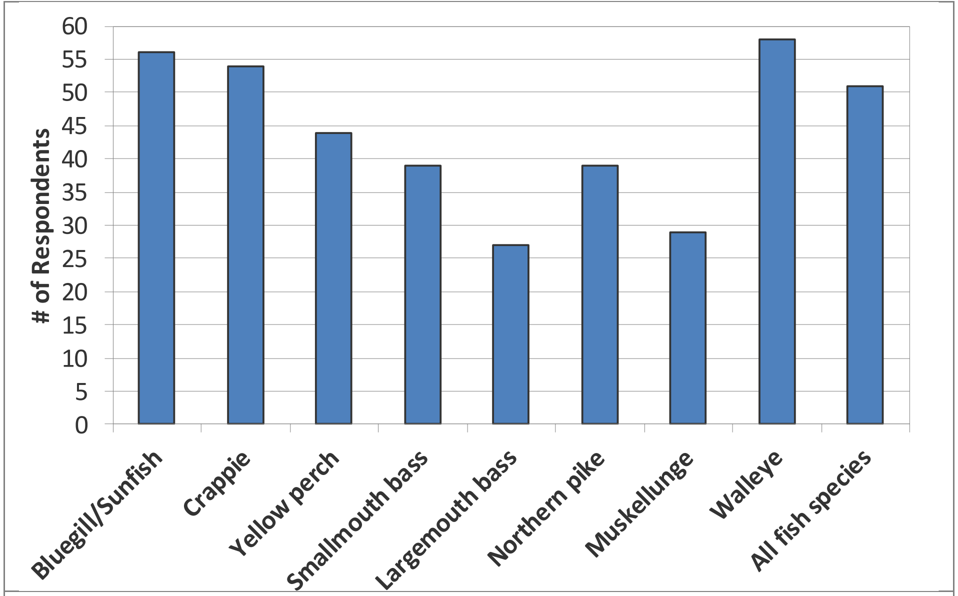


Figure 3.6-2. Stakeholder survey response Question #9. What species of fish do you like to catch on Lake Mohawksin?

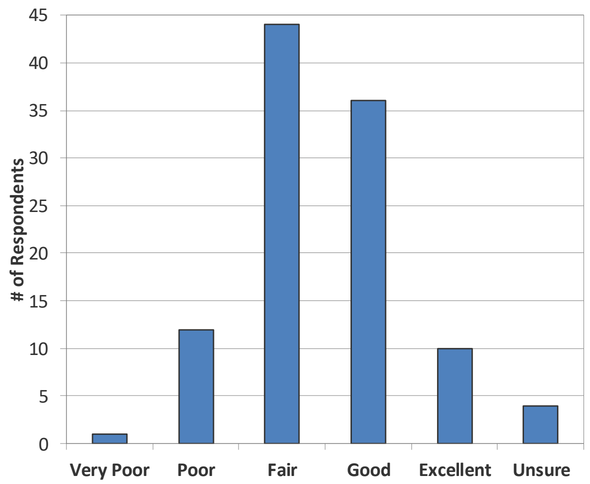


Figure 3.6-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on Lake Mohawksin?

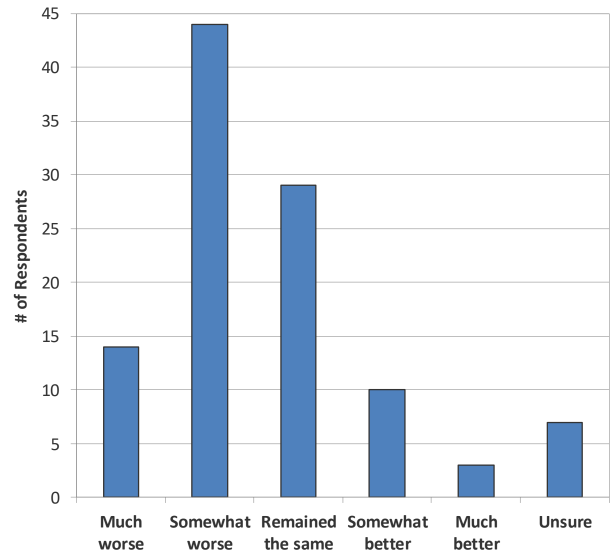


Figure 3.6-4. Stakeholder survey response Question #11. How has the quality of fishing changed on Lake Mohawksin since you started fishing the lake?

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. A creel survey was completed on Lake Mohawksin during the 2009 fishing season (Table 3.6-3).

Table 3.6-3. Creel Survey Data from 2009

Species	Directed Effort/acres (Hours)	Percent of Total	Total Catch	Specific catch rate (Hours/Fish)*	Total Harvest	Specific harvest Rate (Hours/Fish)*
Walleye	26.2	33.6	20,550	2	626	50
Muskellunge	9.3	11.9	609	20	0	
Northern Pike	11.6	14.9	6,246	7.1	646	33.3
Smallmouth Bass	8.5	10.9	6,422	3.2	176	
Largemouth Bass	4.7	6.0	539	33.3	0	

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed. In April 2009, the WDNR surveyed Lake Mohawksin with the primary objective to assess the lake's adult walleye population. The surveys used both fyke net and electrofishing methods. Muskellunge data was also collected and used to complete an adult muskellunge population estimate. Final population estimates for both walleye and muskellunge can be found in tables 3.6-4 and 3.6-5. Additional data provided about other gamefish species encountered in 2009 will be listed in the Gamefish section below and within the 2009 fishery information sheet within Appendix E.

Gamefish

The gamefish present on Lake Mohawksin represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch walleye on Lake Mohawksin (Figure 3.6-2). Brief summaries of gamefish with fishable populations in Lake Mohawksin are provided based off of the report submitted by WDNR fisheries biologist David Seibel following the fisheries survey completed in 2009 (Appendix E).

Walleyes have been a pillar in Wisconsin's fish communities for centuries. Their statewide range and mild flavor have made them one of the most popular fish to catch in Wisconsin. Lake Mohawksin has a moderate-density walleye population with strong, natural reproduction. During the initial fyke net surveys, 2,120 walleyes were captured and marked. In 2009537 fish were then captured a week later during the electroshocking survey, of which 127 were previously marked. Based on these results, biologist estimated Lake Mohawksin's walleye population to be 9,063 adult fish, or 4.7 fish/acre. This is an increase from a 1995 estimate of 5,147 adult walleyes (Table 3.6-4). Of the 9,000 fish in 2009, approximately 28% of the fish were estimated to be above the legal harvest size of 15 inches. The largest walleye captured during this survey was a 28.2-inch female (Figure 3.6-5).

Table 3.6-4. WDNR Adult Walleye Population Estimate 1995 and 2009.

Year	Primary Recruitment Source	Population Estimate	Lower 95 C.I.	Number / Acre	# Adults <12 Inches / Acre	# Adults 12-15 Inches / Acre	# Adults 15-20 Inches / Acre	# Adults >20 Inches / Acre
1995	Natural	5,147	3,989	2.7	0.4	1.5	0.4	0.5
2009	Natural	9,063	-	4.7	-	-	-	-

Muskellunge, the state fish of Wisconsin, are also a popular sportfish in Lake Mohawksin. The size, elusiveness, and tenacity of these fish when hooked is what drives many Wisconsin anglers to pursue them. A 2009 population estimate for muskellunge found approximately 338 adult fish in Lake Mohawksin, a slight decrease from 2003 where 519 adult fish were estimated (Table 3.6-7). Still, Lake Mohawksin is categorized as a Class A1 muskellunge lake, meaning there is potential to produce trophy-sized fish. 96 muskellunge were captured during the 2009 survey, in which 26 fish were longer than 40 inches. The largest muskellunge captured was a 45.9-inch female.

Table 3.6-5. WDNR Adult Muskellunge Population Estimate 2003 and 2009.

Year	Primary Recruitment Source	Population Estimate	Number / Acre
2003	Natural	519	0.3
2009	Natural	338	0.2

Northern Pike are considered common in Lake Mohawksin. While not a primary target for this survey, 393 northern pike were captured in fyke nets and the electrofishing survey. Of the 393 Northern pike captured, only 31 of these fish measured greater than 26 inches. The largest pike captured was a 37.2-inch female.

Smallmouth bass are also considered common in Lake Mohawksin. In 2009, 151 smallmouth bass were captured. Of these 151 fish, 80 measured greater than 14 inches and the largest specimen measured 20.2 inches.

Largemouth bass are considered present in Lake Mohawksin. During the 2009 survey, 17 largemouth bass were captured as incidental catches. Lengths of these fish were still recorded. The biggest largemouth bass captured was 17.7 inches long.

Panfish

During the 2009 survey, numerous **bluegill** and **yellow perch** were captured in fyke nets. Moderate amounts of **black crappie** and **pumpkinseed** were also caught in the fyke nets. **Rock bass** and **white crappie** were among other panfish species present as well. Exact numbers and length were not specifically recorded for these species during this survey.

Lake Mohawksin Spear Harvest Records

Figure 3.6-5. Location of Lake Mohawksin within the Native American Ceded Territory. This map (GLIFWC 2017) was digitized by Onterra; therefore, it is a representation and not legally binding.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.6-5). Lake Mohawksin falls within the ceded territory based on the Treaty of 1837. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest represents the number of fish that can be harvested by tribal members through the use of high efficiency gear such as spearing or netting without influencing the sustainability of the population. This does not apply to angling harvest which is considered a low-efficiency harvest regulated statewide by season length, size and bag limits. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through high efficiency methods. By March 15th of each year the relevant Native American communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal members annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

Tribal members may harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2017). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and

24 inches and one of any size over 20 inches (GLIFWC 2017). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Spearfishing of a particular species ends once the declared harvest is reached in a given lake. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 3.6-6 from 2000-2019. As many as 352 walleye have been harvested from Lake Mohawksin in the past (2012), but the average harvest is roughly 141 fish in a given year. Spear harvesters on average have taken 31% of the declared quota.

Muskellunge open water spear harvest records are provided in Figure 3.6-7 from 2000-2019. As many as two muskellunge have been harvested from Lake Mohawksin in the past (2018), however the average harvest is less than 1 fish in a given year. Spear harvesters on average have taken 1.2% of the declared quota.

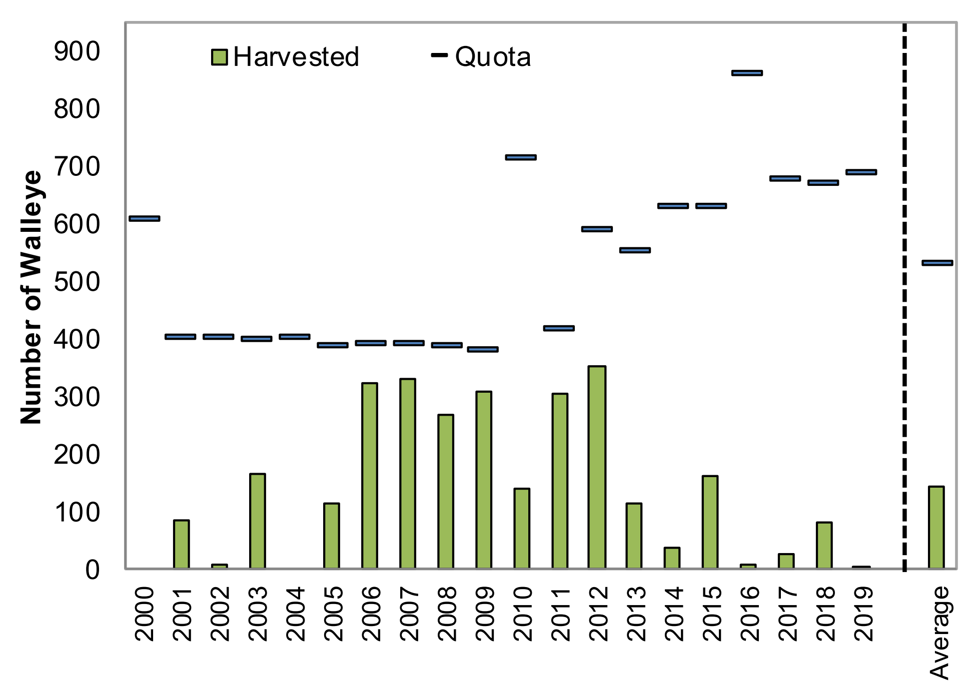


Figure 3.6-6. Lake Mohawksin walleye spear harvest data. (GLIFWC 2000-2019).

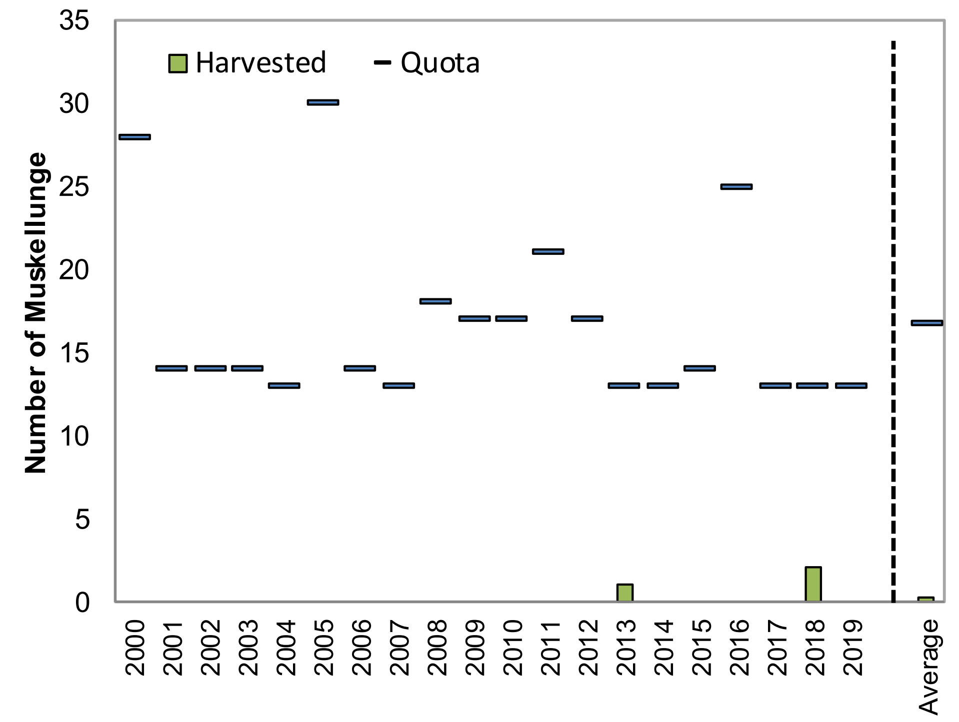


Figure 3.6-7. Lake Mohawksin muskellunge spear harvest data. (GLIFWC 2000-2019).

Lake Mohawksin 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 Onterra in 2019, 74% of the substrate sampled in the littoral zone of Lake Mohawksin were soft sediments, 21% was composed of sand and 5% were composed of rock.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2009).

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 et al. 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 Friends of Lake Mohawksin 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 Lake Mohawksin.

Fishing Regulations

Regulations for Lake Mohawksin fish species as of March 2020 are displayed in Table 3.6-6. New to 2020, catch and release fishing for bass in now open effective April 1, 2020. Additionally, open water fishing for muskellunge has been extended until December 31. 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 3.6-6. WDNR fishing regulations for Lake Mohawksin (As of March 2020).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	Open All Year
Smallmouth bass	5	14"	Open All Year
Largemouth bass	5	14"	Open All Year
Muskellunge and hybrids	1	45"	May 23, 2020 to December 31, 2020
Northern pike	5	None	Open All Year
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	Open All Year
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10 fish	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks, baits, or

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 3.6-8. 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

Currently, fisheries biologists will continue to monitor both walleye and muskellunge recruitment. A WDNR muskellunge population estimate survey is tentatively planned to begin in spring 2020 for Lake Mohawksin. Any muskellunge caught will be measured, marked, and released during this survey. Other fish species captured in the fyke nets will be recorded but not measured. A comprehensive survey of Lake Mohawksin's fishery is also scheduled for 2022. All fish species will be recorded and measured during this survey. Muskellunge captured in this survey with marked fins from the earlier 2020 survey will be recorded and used to finalize the muskellunge population estimate.

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 Lake Mohawksin ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil and curly-leaf pondweed.
3) Collect sociological information from Lake Mohawksin 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 Lake Mohawksin ecosystem, the folks that care about the lakes, and what steps can be taken by the FOLM to protect and enhance the system.

FOLM's participation in the Citizens Lake Monitoring Network program since 2006 has allowed for consistent water quality data being available. Lake Mohawksin contains *good* water quality compared to other shallow lowland drainage lakes. Lake Mohawksin is classified as a eutrophic lake being shallow, warm, and having high plant biomass though it is too shallow generally to exhibit marked thermal stratification. Water clarity, total phosphorus, and chlorophyll-a parameters are all similar to mean values of other shallow lowland drainage lakes. The water clarity of Lake Mohawksin is largely impacted by staining compounds called organic acids, which gives the lake a tea-color, restricting sunlight penetration and plant growth to shallower areas up to about six feet deep. Increases in precipitation can flush more of these tannins into the lake, decreasing water clarity. Lake water pH is around 7.4 in July, being considered close to *neutral*. While this is the preferred pH for zebra mussels (an invasive species), the low amount of calcium within the flowage suggests *very low susceptibility* for zebra mussel establishment.

The Lake Mohawksin Waters covers about 2,100 acres of navigable waters. The Lake Mohawksin watershed is incredibly large – almost 615 times larger than the system itself. The streams that enter the flowage have much land from which to draw water; however, with this water comes nutrients, sediment, and staining compounds from the watershed as well. But in having this large of a watershed, the system has a high flushing rate that pushes phosphorus through before used by algae. At times, large nutrient pulses from precipitation events in the watershed may result in periodic algal blooms especially in more stagnant parts of the system. Analysis of water flow at the dam indicates increased flows since 2012, with high spring spikes in many years.

Lake Mohawksin is known for its natural scenic beauty. The shoreland condition assessment found that 70% of Lake Mohawksin's shoreline consisted of shorelines in the two most ecologically beneficial categories (*developed–natural* and *undeveloped*), whereas only 16% were categorized as being within the two most impactful categories (*urbanize*d and *developed–unnatural*).

Lake Mohawksin is a popular destination for anglers that target plentiful gamefish, including trophy-sized muskellunge. Riparian stakeholder respondents believe the fishery is currently *fair* to *good* and that the fishery has *remained the same* or has become *somewhat* worse since they first started fishing the lake. The next comprehensive fisheries survey is planned by the WDNR to occur in 2022 or 2023.

Since 2006, approximately 80 different species of plants were located within and along the margins of the Lake Mohawksin Waters, much higher than most Wisconsin systems. Lake Mohawksin contains a wide range of habitats, including sandy shoals, sediment-rich backwater bays, and riverine areas. Different aquatic plant species favor these habits and results in the high species richness. A statistical measurement of aquatic plant diversity indicates that there is a 95% chance of the next plant species encountered being different from the previous one. Lake Mohawksin waters also harbors two species listed by the Natural Heritage Inventory as being species of special concern: northern naiad and vasey's pondweed. Since 2006, some of the more-prevalent species like coontail and water celery have had relatively stable populations. However, most other species are declining during this time period, likely related to the increased flow. Most notable to anglers and lake users, this includes large-leaf pondweed (aka musky cabbage) and all floating-leaf species (i.e., white water lily, spatterdock, and watershield). Continued monitoring of these populations will be important to understand if these populations are able to recover.

Two primary non-native submergent aquatic plant species are known to exist in Lake Mohawksin: Eurasian watermilfoil and curly-leaf pondweed. In recent years there has been a change in preferred strategy amongst many lake managers and regulators when it comes to established aquatic invasive species populations, especially established Eurasian watermilfoil populations. Instead of chasing the entire Eurasian watermilfoil population with management, perhaps focusing on the areas that are causing the largest impacts can be more economical and cause less ecological stress to the lake. As part of this planning effort, FOLM created a plan for Eurasian watermilfoil management with aquatic herbicides when navigation and recreation are impeded – which has historically proven effective on Lake Mohawksin. Approximately 68% of respondents to the stakeholder survey indicated support (pooled *moderately support* and *strongly support*) for future herbicide management, 12% opposed (pooled *moderately oppose* and *completely oppose*), and 20% where *unsure/neutral*. Curly-leaf pondweed was found in a 2013 survey in the eastern Wisconsin river arm of the lake, hand harvesting was carried out in 2016 and 2018 and recent surveys have only found low density populations.

The shorelines of Lake Mohawksin Waters also contain a few non-native emergent plans, including purple loosestrife and pale-yellow iris. FOLM is seeking partnership with Wisconsin Public Service in monitoring and managing these species to ensure the natural habitat and nutrient buffering qualities of the near-shore area continue to function at a high level.

Through the process of this lake management planning effort, the FOLM has learned much about their system, both in terms of its positive and negative attributes. The FOLM continues to be tasked with properly maintaining and caring for this resource. It is particularly important to protect high quality aspects of the Lake Mohawksin ecosystem.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the FOLM Planning Committee and ecologist/planners from Onterra. It represents the path FOLM 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 Lake Mohawksin 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: Increase the FOLM's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Give consideration to the creation of an *Education Committee*
Timeframe:	Ambition to establish by end of 2021
Facilitator:	Board of Directors
Description:	By demonstrating a clear mission, the *Education Committee* would be responsible for marketing and public relations, educating its constituents, and overall increasing the FOLM's capacity to influence Lake Mohawksin. The *Education Committee* would be the facilitator for a number of management actions outlined below. The *Education Committee* would deliver an oral report at the association's annual meeting of the previous year's accomplishments and the direction being considered for the following year. This committee would be comprised of 2-3 individuals, with at least one member being on the FOLM board of directors.
Action Steps:	
	See description above.

Management Action:	Bolster communication abilities and pursue additional communication avenues
Timeframe:	In Progress
Facilitator:	Education Committee
Description:	Education represents an effective tool to address many lake issues. The FOLM aims to send out regularly distributed newsletters (at least once per year) and maintain an updated website (mohawksinwaters.lakekit.net). The webpage is a useful repository for

	association information; including meeting minutes and announcement, general association information, and educational materials. However, it requires that the interested individual check back for updates periodically; therefore, it is not reliable for disseminating information quickly. The committee would also investigate creating and moderating a dedicated FOLM Facebook Page, allowing another resource for building a sense of community, as well as providing information on upcoming events or providing links to educational pieces posted on the website. This can include announcements, pictures, short videos, and links to websites. Links to websites are useful because they allow the association to keep their followers informed regarding updates and additions made to the FOLM webpage. The disadvantage to utilizing Facebook is that it requires users to have a subscription, which is free, and check their newsfeed regularly. As social media platforms and use evolves, investigate opportunities for the FOLM to use additional and/or alternative platforms to provided content to its audience. Email is another useful form of electronic communication that allows the association to disseminate news quickly at low cost. Emails can contain short informational pieces, pictures, and links to information on the web. The FOLM has made it a priority to build a complete and updated email list, which will allow more rapid and cost-effective means of providing information to association members. The association is considering additional ways to improve upon its communication capacity, such as employing a Constant Contact email marketing campaign. These mediums allow for exceptional communication with association members. This level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings.
Action Steps:	
	See description above

<u>Management Action:</u>	Participate in annual Wisconsin Lakes and Rivers Convention
Timeframe:	Annually
Facilitator:	FOLM Board of Directors
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources,

	Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and associations. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/association. The FOLM will sponsor the attendance of 1-3 association members annually at the convention. Following the attendance of the convention, the members will report specifics to the board of directors regarding topics that may be applicable to the management of Lake Mohawksin and operations of the FOLM. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the association membership at the annual meeting. Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/default.aspx In addition to the state-wide conference, local counties occasionally hold more focused conferences where FOLM would attempt to have representation present.
Action Steps:	
	See description above.

Management Action:	Routinely educate and communicate with all lake stakeholders
Timeframe:	In progress
Facilitator:	Education Committee
Description:	The FOLM will make the education of lake-related issues a priority. One of the first tasks would be to disseminate the information contained within this *Comprehensive Management Plan*, allowing it to be better understood by association members. To accomplish this task, the Education Committee plans to highlight key topics from the plan and share educational materials on the subjects over time. The FOLM believes that creating smaller modules of information and spreading out the delivery over time will be an effective educational initiative. As a part of the planning process, the FOLM identified key topics which they believe the association members would appreciate additional educational opportunities. These may include educational

	materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. *Example Educational Topics* • Importance of natural landscapes • Development of a courtesy code • General lake ecology • Aquatic invasive species identification • Septic system maintenance • Shoreline habitat restoration and protection • Litter • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Shoreline erosion – individuals, wildlife • Bluegreen algae
Action Steps:	
	See description above.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years
Facilitator:	Education Committee
Description:	Formal riparian stakeholder user surveys have been performed by the association in 2007 and 2020. Approximately once every 5-6 years, an updated stakeholder survey would be distributed to the Lake Mohawksin riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2020, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

Management Action:	Continue FOLM's involvement with other entities that have responsibilities in managing (management units) Lake Mohawksin
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The purpose of the FOLM is to maintain, protect, and improve the quality of lakes for the landowners and those that use the lake for recreation purposes. 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 FOLM actively engage with all management entities to enhance the association's 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.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Wisconsin Department of Natural Resources	Fisheries Biologist (Dave Seibel – 715.623.4190)	Manages the fishery of the system.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Scott Van Egeren 715-471-0007)	Oversees management plans, grants, all lake activities.	Once a year, or more as necessary.	Information on updating a lake management plans, submitting grants r permits, and to seek advice on other lake issues.
	Warden (Patrick Novesky – 715.891.0598)	Oversees regulations handed down by the state.	As needed. May contact WDNR Tip Line (1.800.847.9367) as needed also.	Suspected violations pertaining to recreational activity, including fishing, boating safety, ordinance violations, etc.
	CLMN Director (Sandra Wickman – 715.365.8951)	Training and assistance on CLMN activities.	Twice a year or more as needed.	Contact to arrange for training as needed, in addition to planning out monitoring and reporting of data.
	AIS Regional Coordinator (Alan Wirt - 715-365-8905)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	AIS training and ID, AIS monitoring techniques
Lincoln County Land Services Department	County Zoning (Mike Huth – 715.539.1087)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
City of Tomahawk	Clerk/Treasurer (Amanda Bartz 715.453.4040)	Local unit of government	As needed: (cityoftomahawkwi.com)	Aspects that involve the government such as building and zoning, municipal sewer, funding opportunities, grant applications, CBCW, events, ordinances etc. FOLM provides regular updates to these municipalities on the health of the lake and efforts to maintain it.
Town of Bradley	Town Clerk (Kari Kiser - 715.453.3326)		As needed: (townofbradley.org)	
Town of Wilson	Town Clerk (Teresa Lepkowski- (715.453.7526)		As needed: (townofwilson.com)	
Wisconsin Public Service	Jessica Roloff, (jessica.roloff@wecenergygroup.com)	Owns & operates hydro dam	As needed	Conducts environmental surveys, such as AIS mapping & water quality monitoring as part of FERC license.
UW-Extension	Program Coordinator (Erin McFarlane – 715.346.4978)	Clean Boats Clean Waters Program	As needed.	May be contacted to set up CBCW training sessions, report data, etc.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on lake issues.	As needed. May check website (wisconsinlakes.org) often for updates.	May attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, training, habitat enhancement techniques, etc.

Management Goal 2: Manage Aquatic Invasive Species and Prevent Establishment of New Aquatic Invasive Species

Management Action:	Give consideration to the creation of an *Aquatic Plant and Aquatic Invasive Species Management Committee*
Timeframe:	Summer 2021
Facilitator:	Board of Directors
Description:	The creation of a dedicated committee will ensure that division of labor occurs within the FOLM. The *Aquatic Plant and Aquatic Invasive Species Management Committee* would be charged with AIS management, Clean Boats Clean Waters watercraft inspections, future AIS aquatic plant and animal (e.g., rusty crayfish, zebra-mussel) monitoring activities. The *Aquatic Plant and AIS Management Committee* would also deal with funding, cost analysis, risk assessment, treatment strategy, and data review. This committee would be comprised of 2-4 individuals, with at least one member being on the FOLM board of directors.
Action Steps:	
	See description above.

Management Action:	Monitor Lake Mohawksin entry points for Aquatic Invasive Species
Timeframe:	Ongoing
Facilitator:	Aquatic Plant and Aquatic Invasive Species Management Committee
Description:	The intent of this program would not only be to prevent additional invasive species from entering the Lake Mohawksin Waters through its public access locations, but also to prevent the infestation of other waterways with invasive species that originated in the system. FOLM would ensure that all landings have updated signage as it relates to aquatic invasive species. FOLM will promote watercraft inspection programs (Clean Boat Clean Waters program), through interested riparian volunteers as well as Tree Haven (UW-Steven's Point) students. It would be most helpful to have watercraft monitors at the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. FOLM will also engage with local fishing clubs such as the Mohawksin Muskie Masters, providing information about AIS spread and watercraft decontamination.

	Based upon modeling by the University of Wisconsin Center for Limnology, Lake Mohawksin is one of the state's top 300 AIS Prevention Priority Waterbodies. This means that Lake Mohawksin has a high number of boats arriving from lakes that have AIS (receiving) and a high number of boats moving from Lake Mohawksin to uninvaded waters (sending). Therefore, the WDNR encourages additional supplemental prevention efforts above just watercraft inspections, offering additional grant funds for these activities for applicable lakes. Supplemental prevention efforts such as decontamination stations (e.g., pressure washer) and remote video surveillance (e.g., I-Lids™) could be funded through this program.
Action Steps:	
	See description above.

<u>Management Action:</u>	Conduct nuisance management actions towards Eurasian Watermilfoil
Timeframe:	Ongoing
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	FOLM participated in the forefront of field research, engaging in projects with the WDNR, US Army Corps of Engineers Research and Development Center (USACE), SePRO, and Onterra that aimed to increase the efficacy and longevity of herbicide management of EWM. While some herbicide treatments showed promise, the unpredictability of spot treatments state-wide has resulted in less favorability of this strategy with WDNR regulators. This is particularly true in areas of increased water exchange via flow. In recent years there has been a change in preferred strategy amongst many lake managers and regulators when it comes to established EWM populations. Instead of chasing the entire EWM population with management, perhaps focusing on the areas that are causing the largest impacts can be more economical and cause less ecological stress. The WDNR supports using the management method that will impart the least stress on the overall ecosystem. As a part of the planning process, the FOLM Planning Committee discussed aquatic plant management alternatives such as mechanical harvesting. Due to the shallow water and high number of obstacles (i.e., stumps, woody debris) within the Lake Mohawksin Waters, this form of management is not likely applicable.

Within an update to the FOLM's EWM management strategy in 2014, they developed a threshold (trigger) for conducting herbicide treatments:

> *to target colonized areas of EWM with a density of dominant or greater and adjacent areas of EWM that are not within areas of higher water exchange.*

Since 2014, no areas have exceeded this trigger and herbicide management has not occurred on Lake Mohawksin from 2015 to present. As a part of this management planning process, FOLM would like to modify their trigger as follows:

> *Herbicide treatment would be considered when the following criteria are met:*
>
> *1) colonized areas of EWM with a density of dominant or greater*
>
> *2) are not within areas of higher water exchange where herbicide effectiveness is questioned*
>
> *3) prioritize high use or riparian frontage*

If FOLM's trigger is reached, they would start educating themselves on what is considered a best management practice (BMP) for EWM herbicide management. This would likely include devising a strategy where a sufficiently large treatment area can be constructed to hold concentration and exposure times for exposed sites. Protected areas would consider additive impacts within an Area of Potential Impact (AOPI), such that if levels reach whole-basin concentrations, they are accounted for in the treatment and monitoring strategy. Future spot herbicide treatments would consider herbicides thought to be effective under short exposure situations. 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 that are employed for invasive watermilfoil control in Wisconsin. Advancements in research into new herbicides and use patterns will need to be integrated into future management strategies, including effectiveness, native plant selectivity, and environmental risk profile.

If FOLM decides to pursue future herbicide management towards EWM, the following set of bullet points would occur:

- Early consultation with WDNR would occur.
- The preceding annual AIS monitoring report would outline the precise control and monitoring strategy.

	- Monitoring EWM efficacy by comparing annual late-summer EWM mapping surveys. - Give consideration to pretreatment invasive watermilfoil genetic testing (i.e., fingerprinting), as both EWM and HWM are known from Lake Mohawksin Waters. - If grant funds are being used or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with the *Draft Aquatic Plant Treatment Evaluation Protocol (October 1, 2016) –* *Click Here* This generally consist of collecting quantitative point-intercept sub-sampling on sites before the treatment (pre) and summer following the treatment (post). Herbicide concentration monitoring may also occur surrounding the treatment in these instances. • An herbicide applicator firm would be selected in late-winter and a conditional permit application would be applied to the WDNR. • A focused pretreatment survey would take place approximately a week or so prior to treatment (approx. 2-3 weeks after ice-out). This site visit would evaluate the growth stage of the EWM (and native plants) as well as to confirm the proposed treatment area extents and water depths. This information would be used to finalize the permit, potentially with adjustments and dictate approximate ideal treatment timing. • Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would occur. This would consist of the herbicide treatment occurring towards the beginning of the growing season (typically in June), active growth tissue is confirmed on the target plants, and is after Native American open-water spear harvest has concluded.
Action Steps:	
	See description above.

Management Goal 3: Monitor Aquatic Vegetation on Lake Mohawksin

Management Action:	Periodically monitor the Eurasian Watermilfoil population
Timeframe:	Periodic: every 2-3 years or when prompted
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	As the name implies, the Late-Season EWM Mapping Survey is completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For the Lake Mohawksin Waters, this survey would likely take place in mid-August to the end of September, dependent on the growing conditions of the particular year. This survey would include a complete meander survey of the system's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). Late- Season EWM Mapping Surveys have been conducted annually on Lake Mohawksin since 2008, allowing for lake stakeholders to understand annual EWM populations as well as population dynamics which proved to be useful. These surveys are used as the trigger within the previous management goal for management. Unless prompted by a specific rationale, such as areas suspected to have reached the trigger for management discussed above, FOLM will conduct this mapping survey at 2–3-year intervals. This will allow the dataset to stay current but balances the financial costs of the effort. FOLM is currently working with Wisconsin Public Service (WPS) to find commonality and efficiencies with the ongoing environmental monitoring they are conducting as part of their Federal Energy Regulating Commission (FERC) license requirements. WPS currently performs a visual survey of the entire Lake Mohawksin Waters once every 3 years (2020, 2023, 2026, etc.), documenting all non-native aquatic plant species encountered within the lake and along the shoreline. For FOLM's lake planning purpose, a more detailed and density-driven EWM mapping survey is required than what WPS needs to satisfy their FERC license requirements. It may be beneficial for both entities (FOLM and WPS) to contract this survey to share costs and ensure the proper level of data is being collected. FOLM will also investigate grant funding opportunities to help fund this survey in 2022 or 2023. This will likely consist of a Surface Water Education Grant, which are due on November 1 of each year, with intent materials being due 60 days prior (September 2).
Action Steps:	
	See description above.

Management Action:	Periodically monitor the Curly-leaf Pondweed population
Timeframe:	Periodic: every 3-4 years or when prompted
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	As discussed in the Aquatic Plant Section (3.4), CLP was first recorded from Lake Mohawksin during 2013. Surveys conducted in 2014 to 2020 have identified low density CLP occurrences in the eastern lobe of the Lake Mohawksin Waters and essentially no CLP elsewhere in the system (Map 8). Professional hand-harvest contractors were deployed in 2016-2018. CLP populations were left unmanaged in 2019 and 2020, where they remained of similarly low size and density. In some lakes, particularly in northern Wisconsin, CLP appears to integrate itself within the aquatic plant community without becoming a nuisance or having a measurable impact to the ecological function of the lake. At this time, it appears that the CLP population of Lake Mohawksin does not warrant management. FOLM would give consideration to periodically monitoring the CLP population within Lake Mohawksin, likely at 3-4-year intervals. These surveys will help further the understanding of this species within Lake Mohawksin. A lake-wide or focused (Wisconsin River Section) CLP mapping survey would be completed during mid- to late-June while the plant is at its peak growth stage for the year.
Action Steps:	
	See description above

Management Action:	Periodically monitor the non-native emergent plant population
Timeframe:	Annually as volunteerism allows
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	For approximately the past decade, FOLM volunteers lead by Marie Schultz have monitored and managed the purple loosestrife population within the Lake Mohawksin Waters. In regards to management, this included hand-removal, cutting/removing seed heads, and *Galerucella* spp. beetle release. FOLM will continue to support this volunteer effort. It may also be possible to add in a late-June focused survey for pale-yellow iris. This would correspond to when this non-native species is in bloom and it is easy to identify.
Action Steps:	
	See description above

Management Action:	Coordinate Periodic Point-Intercept Surveys
Timeframe:	Periodic: every 5 years
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) has been conducted on Lake Mohawksin in 2006, 2013, and 2019. At each point-intercept location within the *littoral zone,* information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR generally indicates that repeating a point-intercept survey every five years will generally suffice to meet WDNR planning requirements unless large-scale aquatic plant management is taking place and more frequent monitoring is requested for the specifically targeted areas. The FOLM has noticed some relatively large aquatic plant population changes in Lake Mohawksin during the time period of study, likely a result of increased precipitation in the watershed that has increased flow in the system. By continuing to periodically conduct these surveys, the FOLM may gain more insight into the factors that are causing the plant shifts.
Action Steps:	
	See description above.

Management Action:	Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
Timeframe:	Period: every 10 years or when prompted
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	This survey would delineate the margins of floating-leaf (e.g., water lilies) and emergent (e.g., cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. This survey has been conducted on Lake Mohawksin in 2006, 2013, and 2019, noting changes in these communities during the period of

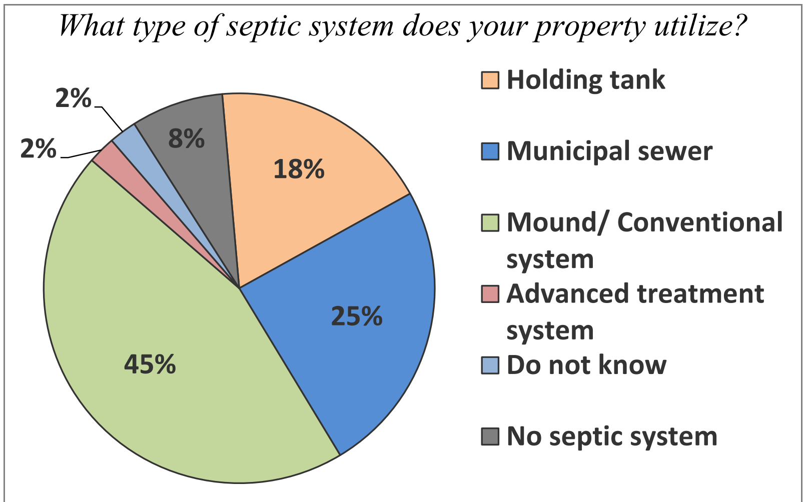
	study. As discussed above, this is theorized to be a result of increased precipitation in the watershed that has increased flow in the system. In order to continue to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Lake Mohawksin, a community mapping survey would be conducted approximately every 10 years unless a specific rationale prompts a shorter interval. Such a rationale would include timing the survey to occur at near high and near low water flows. If another survey takes place in 2025 or 2026 this would again be near the low water level/flow according to recent predictions (Watras et al. 2013). It would be good to collect repetitive data in both the highest and lowest water levels to determine if changes are due to water level or some other environmental or human cause.
Action Steps:	
	See description above.

Management Goal 4: Maintain Current Water Quality Conditions

<u>Management Action:</u>	Monitor water quality parameters through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Adam Faufau
Description:	Monitoring water quality is an important 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. Early discovery of negative trends may lead to the reason of why the trend is occurring. Volunteer water quality monitoring should be completed annually by Lake Mohawksin riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The FOLM currently monitor a single site in Lake Mohawksin (at the deep hole) under the advanced CLMN program. This includes collecting Secchi disk transparency, as well as sending in water chemistry samples (chlorophyll-*a*, and total phosphorus) to the Wisconsin State Laboratory of Hygiene (WSLH) for analysis. The samples are collected three times during the summer and once during the spring. It is important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS). In addition, the CLMN volunteer collects a temperature and dissolved oxygen profile with a FOLM-owned probe.

	As a part of this management planning process, it has been determined that the location of where the CLMN volunteer collects the data does not correspond with the location shown in the WDNR database. FOLM will work with Onterra and the WDNR to straighten out these data and determine the most appropriate sampling location for Lake Mohawksin. It also must be noted that the CLMN program may be changing in the near future with sample analysis cost coverage not available annually. Recently there has been a move to have new CLMN volunteers collect samples for three years and then stop so that additional lakes can be funded. If a long-term record is desired by the FOLM then it will be important to maintain the volunteer data collection without a lapse. The FOLM board will need to review the specifics of the revised program when available and potentially modify this management action.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and report results to association members during annual meeting.
2.	CLMN volunteer and/or FOLM board would facilitate new volunteer(s) as needed

Management Action:	Investigate septic system compliance
Timeframe:	Ambition to establish by end of 2021
Facilitator:	Board of Directors
Description:	A common concern amongst lake groups is the role of faulty septic systems delivering excess nutrients and pollutants to a lake. The potential impacts of septic systems on a lake ecosystem are complex. A failing septic system may not necessarily be impacting the lake if it is located in an area where groundwater is leaving the lake, while a properly functioning septic system may impact the lake if groundwater is passing through it and into the lake. A portion of Lake Mohawksin is located within the City of Tomahawk, which contains a municipal sewer system. Of the stakeholder survey respondents, 25% indicated they were connected to the municipal sewer system. The remainder of stakeholder survey respondents indicated they had either no septic system (8%) or some type of private onsite wastewater treatment system (POWTS). In Wisconsin, POWTS need to be inspected or pumped once every 3 years. Lincoln County is responsible for tracking the maintenance records. FOLM would like to work with the County to understand the percent compliance of Lake Mohawksin riparian properties with POWTS

	maintenance. FOLM would publicize this metric to help motivate greater compliance.
	 **Figure 5.0-1. Select survey responses from the Lake Mohawksin Stakeholder Survey.** Additional questions and response charts may be found in Appendix B.
Action Steps:	
	See description above.

Management Goal 5: Improve Lake and Fishery Resource

Management Action:	Educate stakeholders on the importance of shoreland condition and shoreland restoration and protection
Timeframe:	Summer 2021
Facilitator:	Education Committee
Description:	The shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. As discussed in the Shoreland Condition Section (3.3), the Healthy Lakes & Rivers Grant program provides cost share for implementing the following best practices: • Rain Garden • Rock Infiltration • Diversion • Native Plantings • Fish Sticks

	The cost share allows $1,000 per practice, up to $25,000 per annual grant application. More details and resources for the program are included within the Shoreland Condition Section (3.3) and can be found at: https://healthylakeswi.com The *Education Committee* would focus specific education on the importance of shoreland condition and the resources that are available (planning and funding). Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative. The *Education Committee* would also strive to initiate a Healthy Lakes shoreline restoration project to serve as a demonstration site, being publicized to lake users so they may want to follow suit on their properties. Approximately 63% of Lake Mohawksin's shoreline is *natural/undeveloped*. While a portion of this shoreline is already protected by being owned by a Township or the State of Wisconsin, the privately owned areas could be the focus of preservation efforts. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Oneida County Land & Water Conservation Department. Several websites of interest include: • Conservation easements or land trusts: (www.northwoodslandtrust.org) • UW-Extension Shoreland Restoration: (https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/ecology/shoreland/default.aspx) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/) WDNR land acquisition grants are available to pay for the costs of property purchases and conservation easements. Scott Van Egeren (WDNR lakes biologist) or Jill Sunderland (WDNR environmental grants specialist) can be contacted with questions about this specific grant program.
Action Steps:	
	See description above

Management Action:	Investigate initiating a Loon Watch program
Timeframe:	As applicable
Facilitator:	Board of Directors
Description:	The FOLM has passively monitored Loon activity and has interest in enrolling in the Loon Watch Program in conjunction with the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide an understanding of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. This program could also involve the placement of artificial loon nesting platforms. If a volunteer or set of volunteers emerge, FOLM would facilitate the enrollment within the Loon Watch Program. FOLM would also share results related to sightings and other metrics associated with this program within the newsletter and at annual meetings.
Action Steps:	
	See description above

6.0 METHODS

Lake Water Quality

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Lake Mohawksin (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred once in spring and three times during the summer. In addition to the samples collected by FOLM members, professional water quality samples were collected with a 3-liter Van Dorn bottle at subsurface (S) and near bottom (B) depths once in spring, summer, winter, and fall. Although FOLM members collected a spring total phosphorus sample, professionals also collected a near bottom sample to coincide with the bottom total phosphorus sample. During each professional sampling event, a temperature and dissolved oxygen profile was completed using a HQ30d with a LDO probe. Secchi disk transparency was also included during all monitoring visits.

All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (WSLH). The parameters measured, sample collection timing, and designated collector are contained in the table below.

	Spring		June	July		August	Fall		Winter	
Parameter	**S**	**B**	**S**	**S**	**B**	**S**	**S**	**B**	**S**	**B**
Dissolved Phosphorus	●	●							●	●
Total Phosphorus	●♦	●	♦	●♦	●	♦	●	●	●	●
Total Nitrogen	●	●	■	●		■			●	●
Chlorophyll-*a*	●		♦	●♦		♦	●			
True Color	●			●						
Hardness	●									
Total Suspended Solids	●	●					●	●		
Laboratory Conductivity	●	●		●	●					
Laboratory pH	●	●		●	●					
Total Alkalinity	●	●		●	●					
Calcium	●									

♦ indicates samples collected as a part of the Citizen Lake Monitoring Network.
■ indicates samples collected by volunteers under proposed project.
●indicates samples collected by consultant under proposed project.

Watershed Analysis

The watershed analysis began with an accurate delineation of Lake Mohawksin's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – (Homer et al. 2016)) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on Lake Mohawksin to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) (Hauxwell et al. 2010) was used to complete this study.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types within Lake Mohawksin (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) receiver with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

AIS Mapping Surveys

During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat. Field crews may supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to EWM locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*

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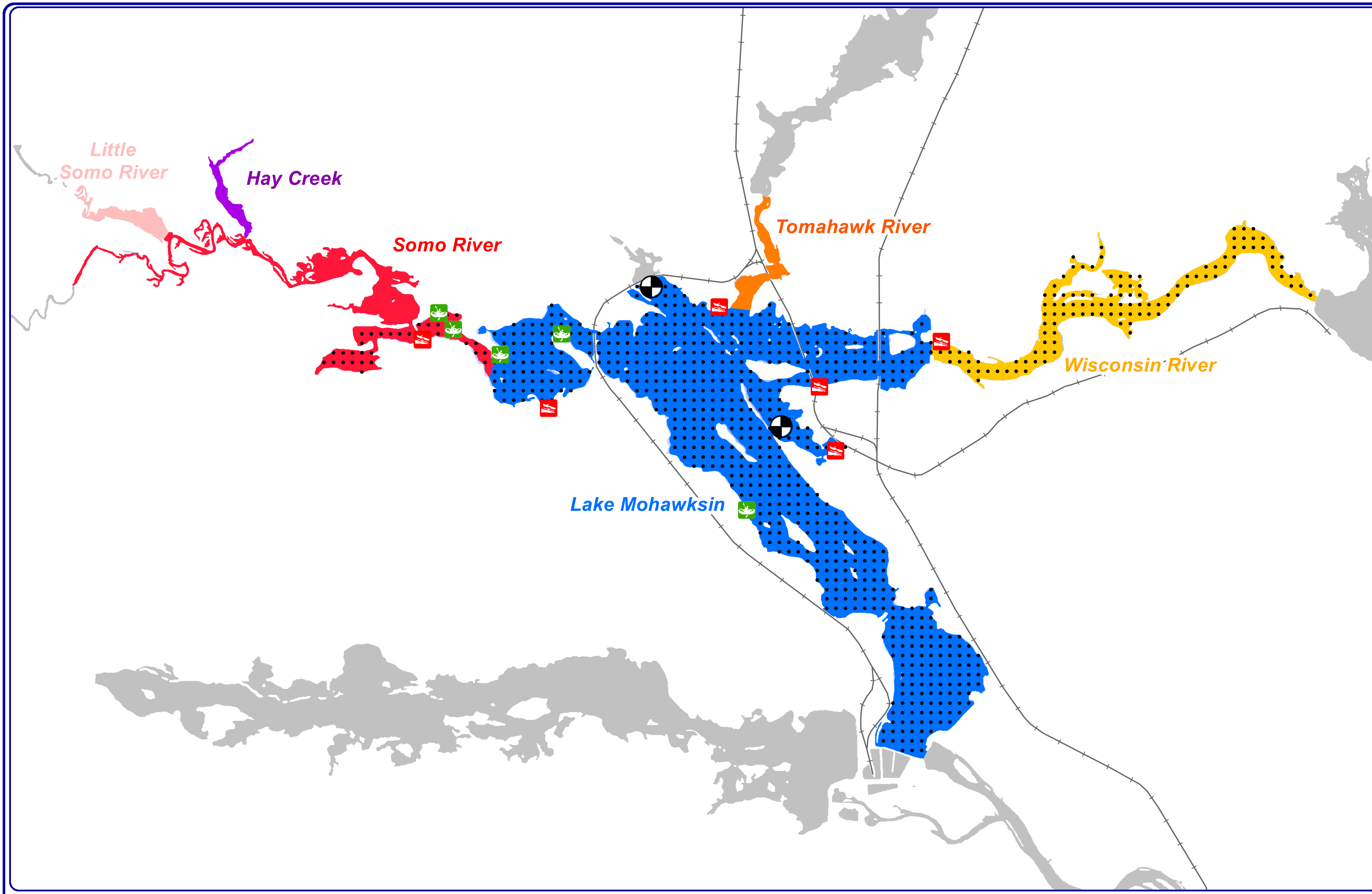

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Miles

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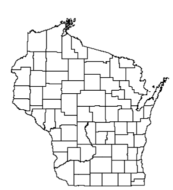
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

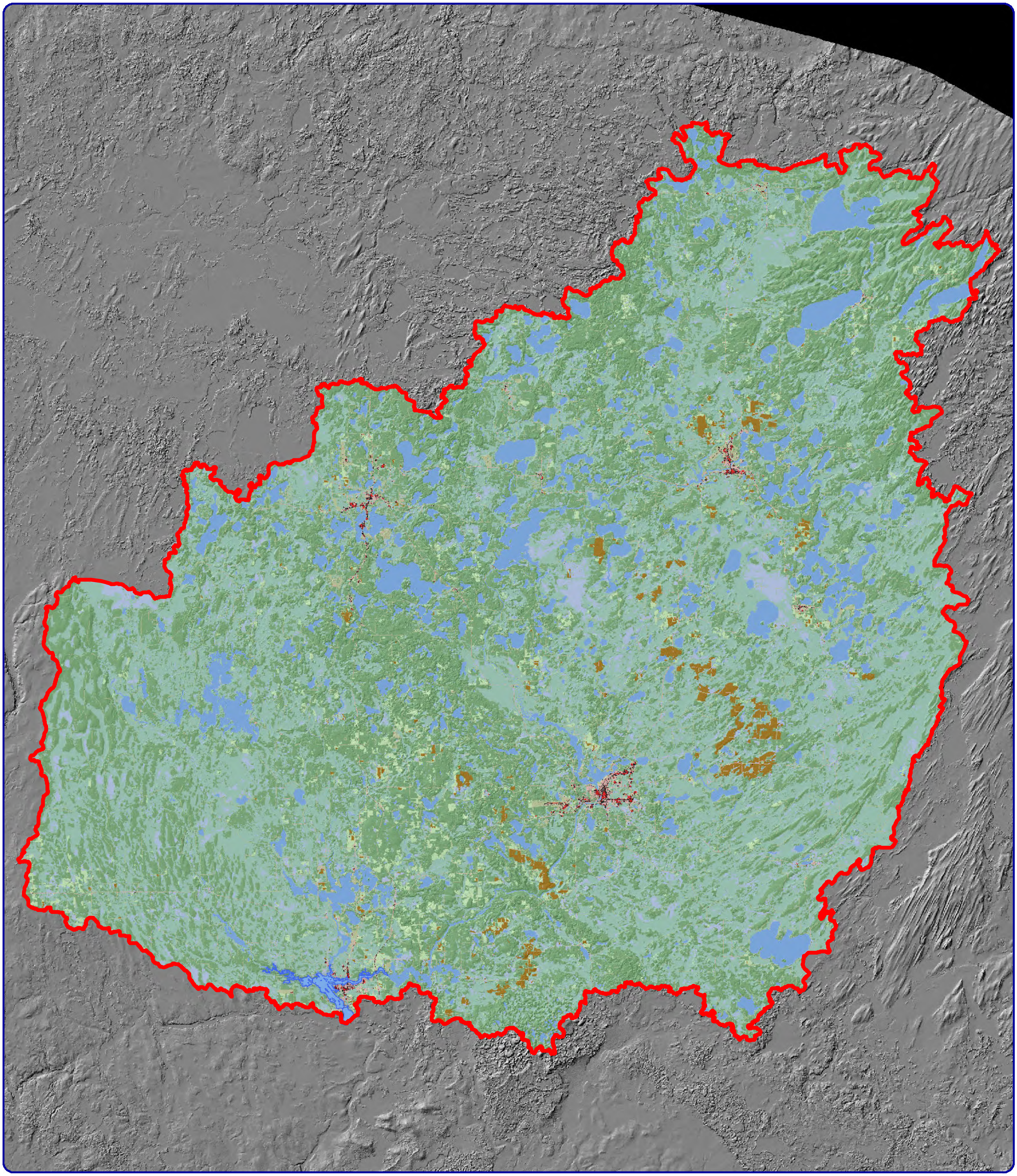
Sources:
Roads and Hydro: WDNR
Map Date: July 27, 2020


Project Location in Wisconsin

Legend

- Point-Intercept Survey Location
  95-meter spacing, 832 total points
- Water Quality Sample Location
- Public Boat Landing
- Carry-in Access

Map 1
Lake Mohawksin Waters
Lincoln County, Wisconsin
Project Location & Lake Boundaries



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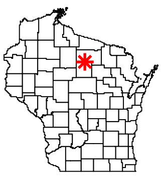
Sources:
Hydro: WDNR
Orthophotography: NAIP 2017
Land Cover: NLCD, 2016
Watershed Boundaries: Onterra, 2020
Map Date: January 9, 2020 JMB



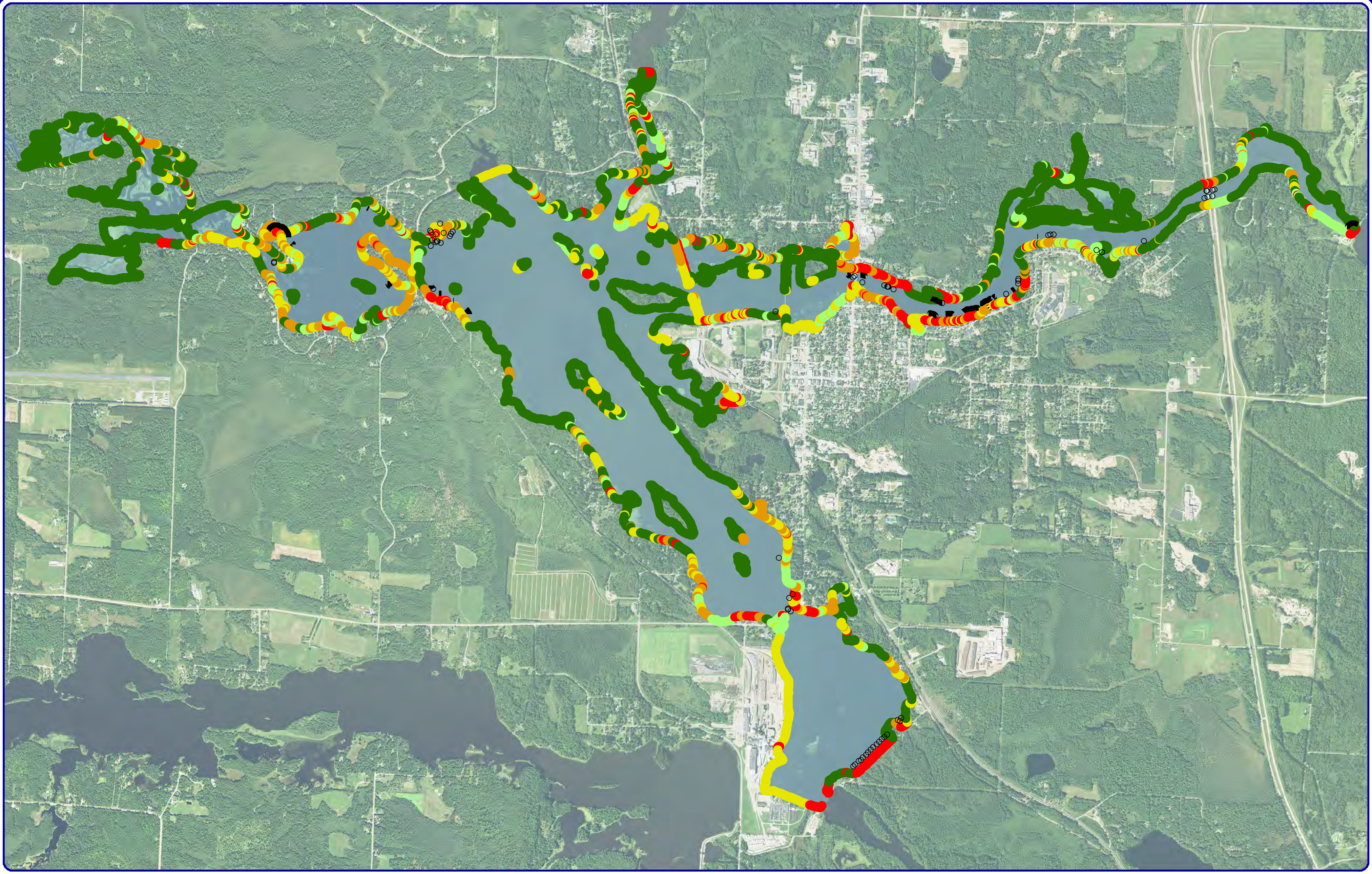
Extent of large map shown in red.

Legend

- Forest
- Forested Wetlands
- Pasture/Grass
- Open Water
- Wetland
- Row Crop Agriculture
- Rural Open Space
- Rural Residential
- Urban - High Density
- Urban - Medium Density
- Lake Mohawksin Watershed Boundary

Map 2
Lake Mohawksin
Lincoln County, Wisconsin

Watershed Boundaries & Land Cover Types



3,250

Feet

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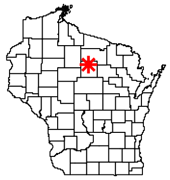
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: November 11, 2019 AMS
Filename: Lake_Mohawksin_SA_2019.mxd



Project Location in Wisconsin

Legend

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall Modifier

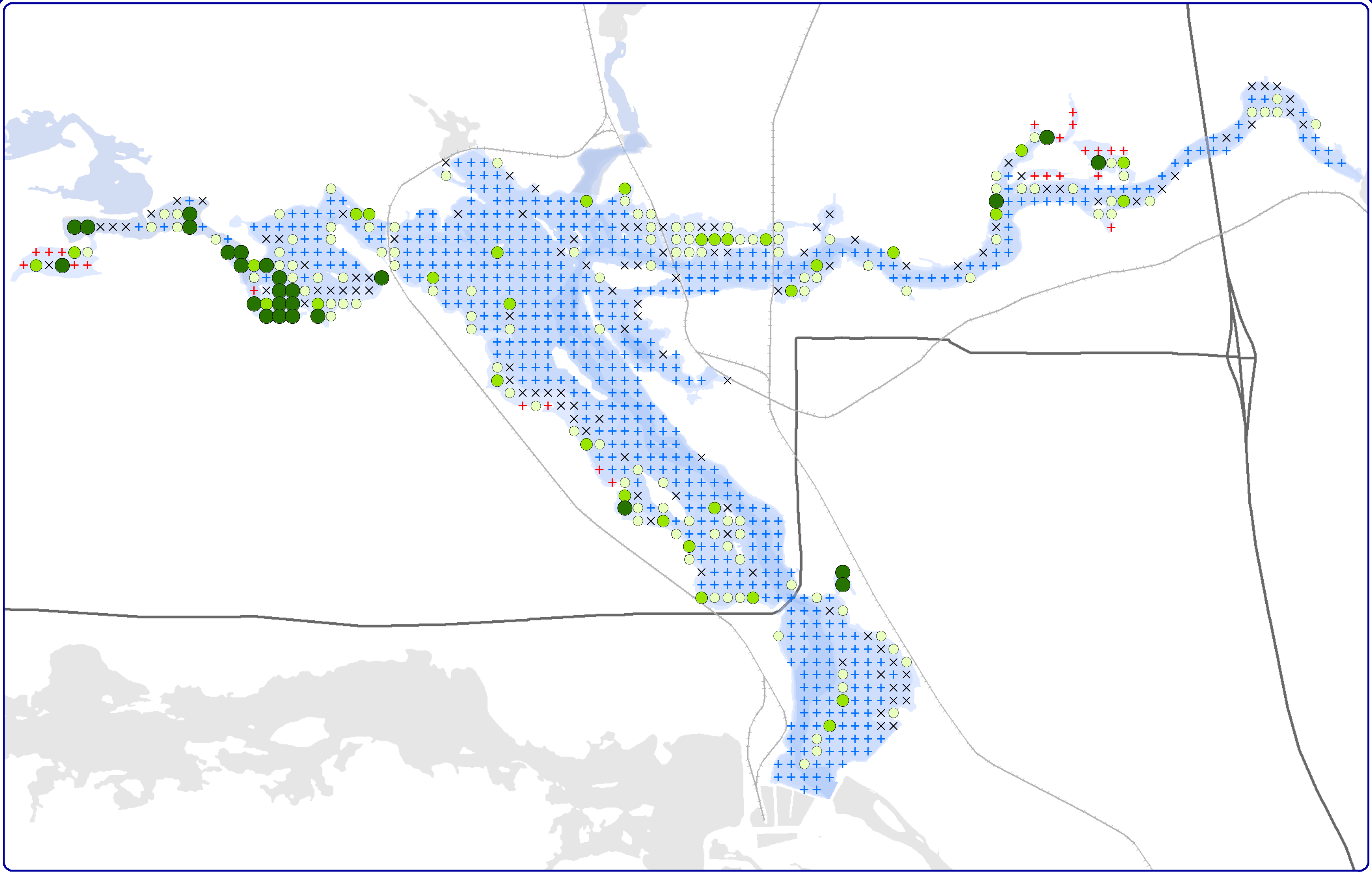
- Masonary/Metal/Wood
- Rip-Rap/Placed Stone

Map 3

Lake Mohawksin

Lincoln County, Wisconsin

Shoreland Condition Assessment



3,400
Feet

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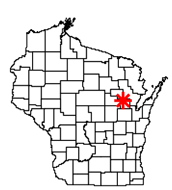
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2019
Map Date: July 10, 2020



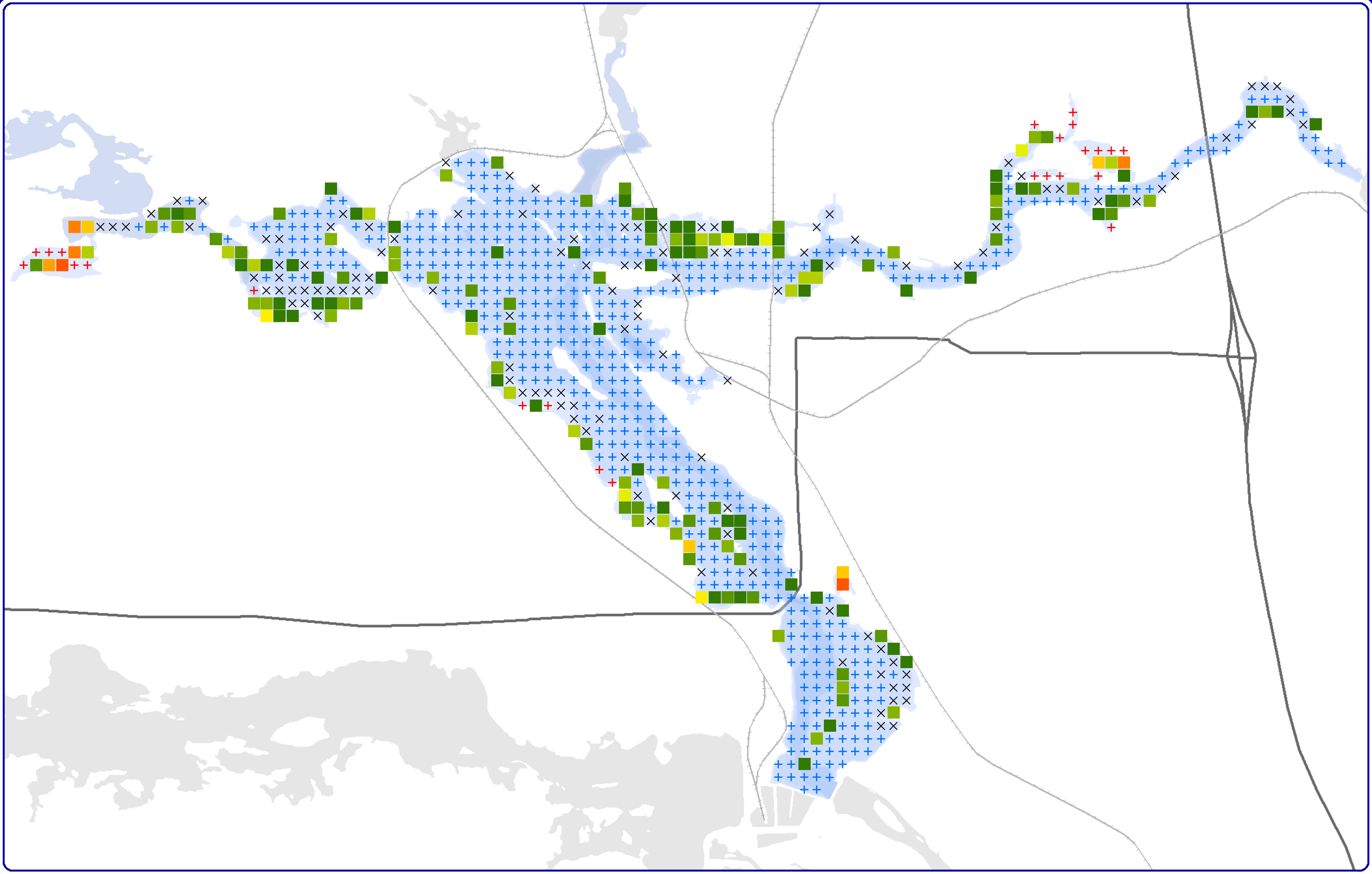
Project Location in Wisconsin

Legend

- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- No Vegetation
- Too Deep
- Non-navigable/ Temporary Obstacle

Map 4
Lake Mohawksin
Shawano County, Wisconsin

2019 PI Survey: Total Rake Fullness



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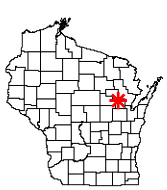
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2019
Map Date: July 10, 2020



Project Location in Wisconsin

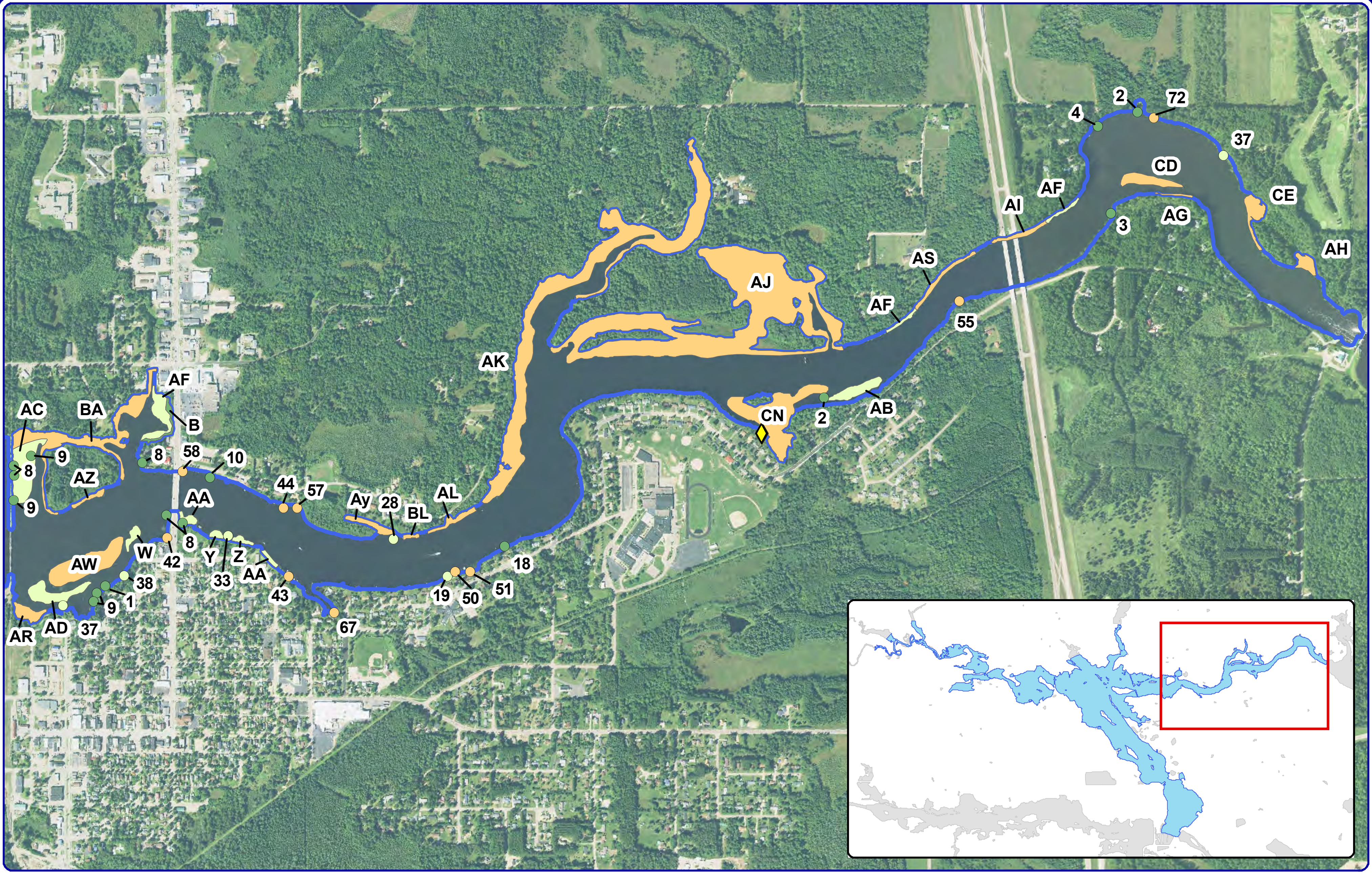
Legend

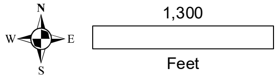
Number of Native Species per Site
1 2 3 4 5 6 7 8 9 10 11

\+ Too Deep
\+ Non-navigable/Temporary Obstacle

Map 5
Lake Mohawksin
Shawano County, Wisconsin

2019 PI Survey:
Native Species Richness





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Lake Management Planning
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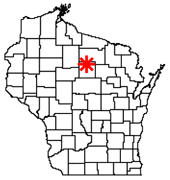
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 4, 2019 AMS
Filename: Moh_Comm_East_2019.mxd



Project Location in Wisconsin

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Pale-Yellow Iris

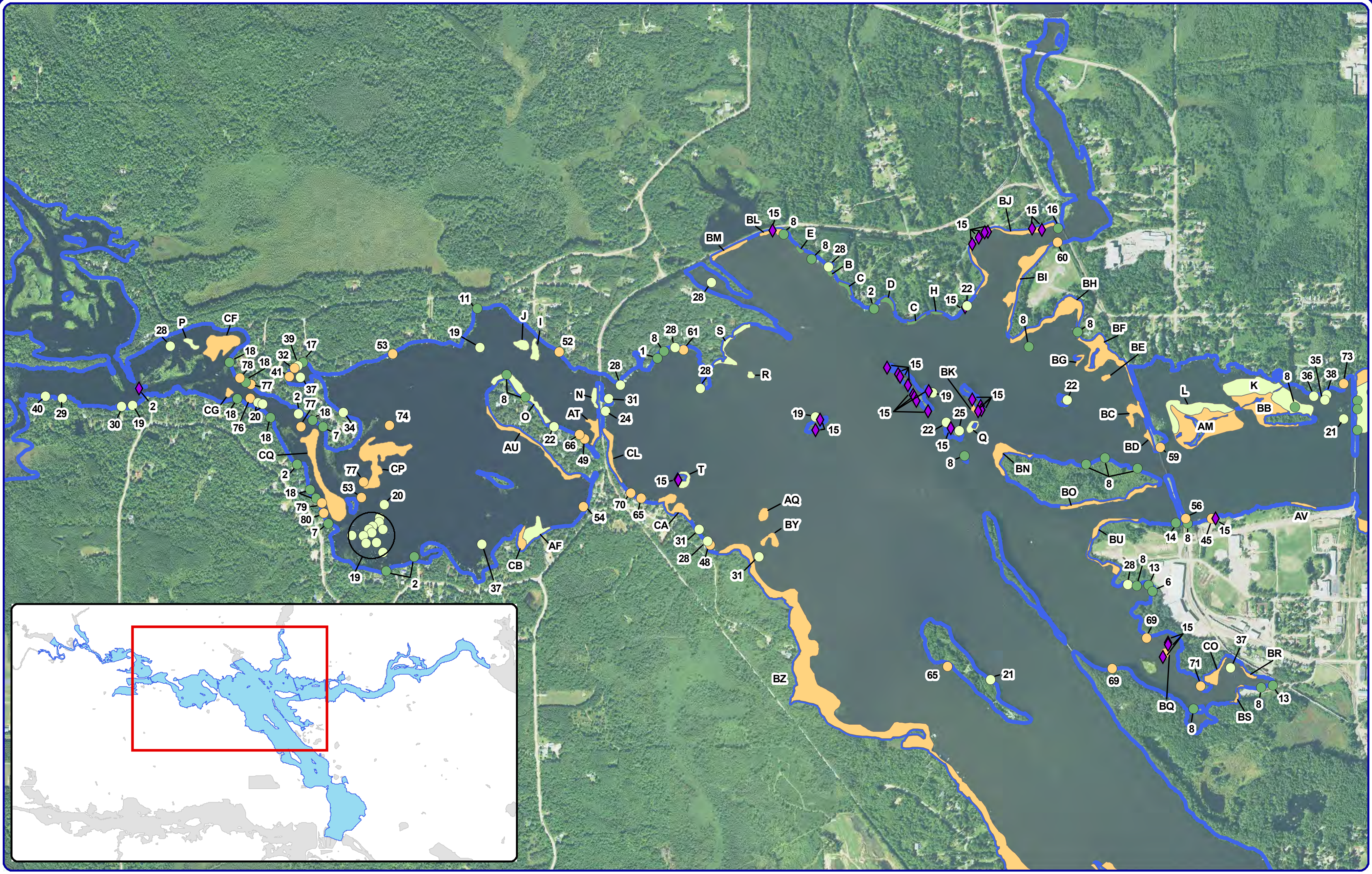
Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 6

Lake Mohawksin

Lincoln County, Wisconsin

Aquatic Plant Communities



1,600

Feet

Onterra, LLC
Lake Management Planning
815 Prosper Road
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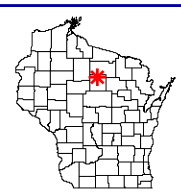
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 6, 2019 AMS
Filename: Moh_Comm_West_2019.mxd



Project Location in Wisconsin

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple Loosestrife

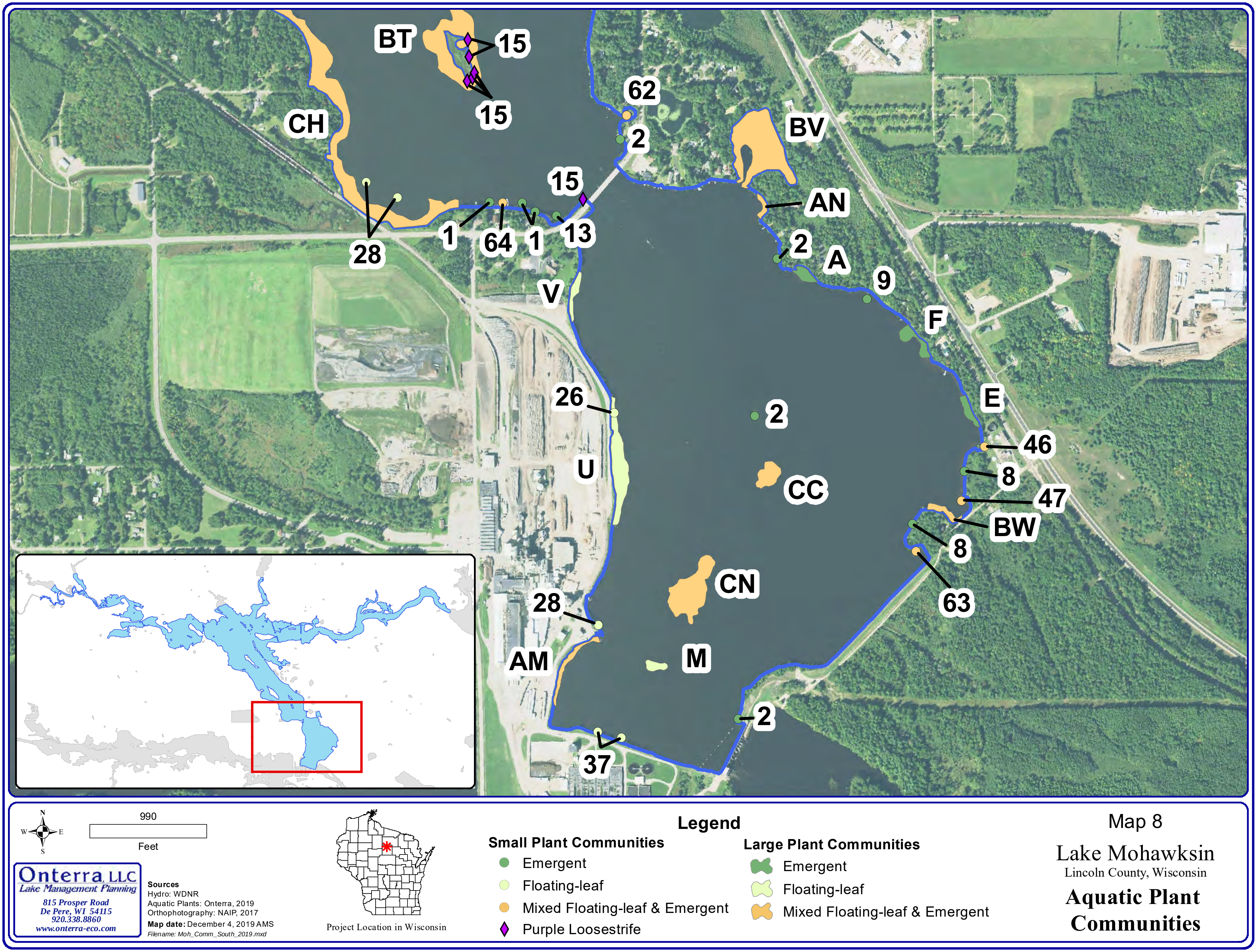
Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 7

Lake Mohawksin

Lincoln County, Wisconsin

Aquatic Plant Communities


BT
15
15
CH
62
2
BV
15
AN
28
1
64
1
13
2
A
9
V
F
E
26
2
46
U
8
CC
47
BW
8
63
CN
28
AM
M
2
37
990
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S
Onterra, LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
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Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 4, 2019 AMS
Filename: Moh_Comm_South_2019.mxd
Project Location in Wisconsin
Legend
Small Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Purple Loosestrife
Large Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Map 8
Lake Mohawksin
Lincoln County, Wisconsin
Aquatic Plant Communities

Lake Mohawksin 2019 Emergent & Floating-Leaf Plant Species

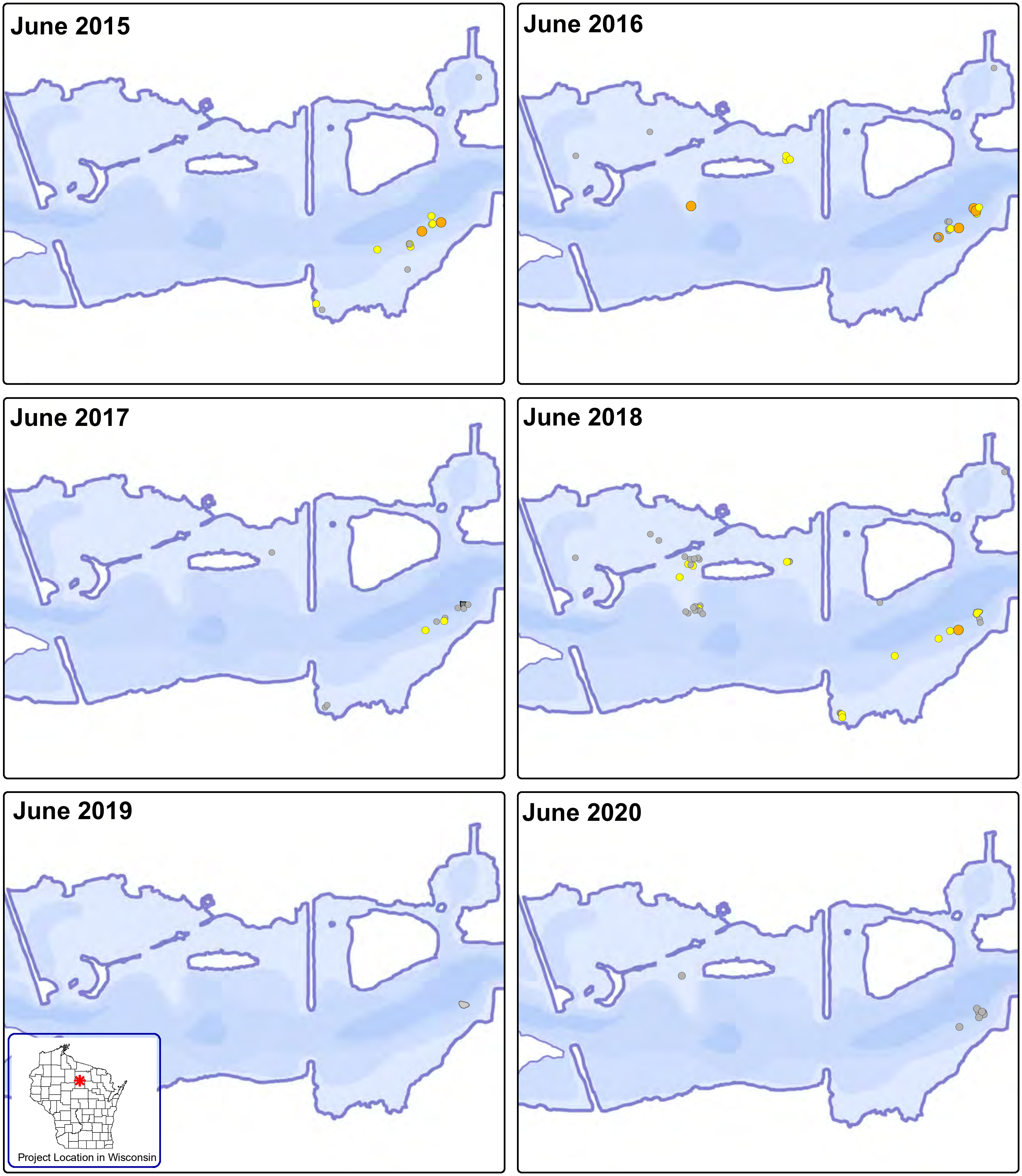
Corresponding Community Polygons and Points are displayed on Lake Mohawksin- Map 6-8

Large Plant Community (Polygons)											
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Species 9**	**Species 10**	**Acres**
A	**Common arrowhead**	**Pickerelweed**									0.34
B	**Pickerelweed**										0.40
C	**Pickerelweed**	**Common bur-reed**									0.42
D	**Pickerelweed**	**Common bur-reed**	**Cattail sp.**								0.27
E	**Pickerelweed**	**Common bur-reed**									0.14
F	**Pickerelweed**	Common arrowhead									0.46
G	**Pickerelweed**	**Common bur-reed**									0.54
H	**Softstem bulrush**										0.11
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Species 9**	**Species 10**	**Acres**
I	**Floating-leaf bur-reed**	**Spatterdock**	Wild rice sp.	Watershield							0.50
J	**Floating-leaf bur-reed**	**Spatterdock**	**White water lily**	Watershield	Wild rice sp.						0.44
K	**Floating-leaf bur-reed**	Watershield	White water lily								4.86
L	**Floating-leaf bur-reed**	**Watershield**	White water lily	Spatterdock							2.53
M	**Floating-leaf bur-reed**	Spatterdock									0.30
N	**Floating-leaf bur-reed**	**Spatterdock**									0.34
O	**Floating-leaf bur-reed**	**Spatterdock**	Watershield								1.63
P	**Spatterdock**	**White water lily**	**Wild rice sp.**								0.31
Q	**Spatterdock**	**Intermediate pond lily**									0.31
R	**Spatterdock**	**Floating-leaf bur-reed**									0.16
S	**Spatterdock**	**Floating-leaf bur-reed**									0.88
T	**Spatterdock**	Floating-leaf bur-reed	Intermediate pond lily								0.53
U	Spatterdock	Watershield	White water lily								2.00
V	Spatterdock	Watershield									0.41
W	**Watershield**	Arrowhead sp. (sterile)	Floating-leaf bur-reed	White water lily							0.47
X	**Watershield**	Spatterdock									0.43
Y	**Watershield**	Floating-leaf bur-reed									0.24
Z	**Watershield**	Floating-leaf bur-reed	Spatterdock	Intermediate pond lily							0.27
AA	**Watershield**	Spatterdock									0.22
AB	**Watershield**	Spatterdock	White water lily	Intermediate pond lily	Floating-leaf bur-reed						1.34
AC	**Watershield**	White water lily	Spatterdock								3.18
AD	**White water lily**	Watershield	Floating-leaf bur-reed	Spatterdock							1.80
AF	**White water lily**	**Floating-leaf bur-reed**									1.83
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Species 9**	**Species 10**	**Acres**
AG	**Common bur-reed**	**Watershield**									1.08
AH	**Common bur-reed**	**White water lily**	**Grass-leaved arrowhead**	**Pickerelweed**	Misc. Wetland Species						0.16
AI	**Common bur-reed**	**White water lily**	**Broad-leaved cattail**	**Grass-leaved arrowhead**	Common arrowhead	Floating-leaf bur-reed	Wild rice sp.				0.68
AJ	**Common bur-reed**	**Watershield**	**White water lily**	**Spatterdock**	Cattail sp.	Pickerelweed	Wild rice sp.	Common arrowhead	Grass-leaved arrowhead		0.57
AK	**Common bur-reed**	**Pickerelweed**	**White water lily**	**Watershield**	Floating-leaf bur-reed	Spatterdock	Grass-leaved arrowhead	Wild rice sp.			29.88
AL	**Common bur-reed**	**Floating-leaf bur-reed**	**Spatterdock**	**White water lily**	Intermediate pond lily	Pickerelweed	Softstem bulrush				18.19
AM	**Common bur-reed**	**Pickerelweed**	**Floating-leaf bur-reed**	**Watershield**	White water lily	Spatterdock	Softstem bulrush	Softstem bulrush			0.60
AN	**Common bur-reed**	**Pickerelweed**	**White water lily**								5.08
AO	**Common bur-reed**	**Pickerelweed**	**Floating-leaf bur-reed**		White water lily	Spatterdock					0.19
AP	**Common bur-reed**	**Pickerelweed**	**Spatterdock**		White water lily	Watershield	Floating-leaf bur-reed				0.52
AQ	**Common bur-reed**	**Spatterdock**	**Floating-leaf bur-reed**	**Pickerelweed**							0.49
AR	**Floating-leaf bur-reed**	**Watershield**	**Spatterdock**	**White water lily**	Pickerelweed	Grass-leaved arrowhead					0.41
AS	**Floating-leaf bur-reed**	**Spatterdock**	**Common bur-reed**	**Common arrowhead**	White water lily						0.88
AT	**Floating-leaf bur-reed**	**Spatterdock**	**Watershield**	**Pickerelweed**							0.74
AU	**Floating-leaf bur-reed**	**Spatterdock**	**White water lily**	**Wild rice sp.**							0.62
AV	**Pickerelweed**	**Watershield**	**Floating-leaf bur-reed**	**Spatterdock**	Common bur-reed						1.47
AW	**Pickerelweed**	**Common bur-reed**	**Watershield**	**White water lily**	Spatterdock						0.21
AX	**Pickerelweed**	**Watershield**	**Floating-leaf bur-reed**	Common bur-reed							4.07
AY	**Pickerelweed**	**Spatterdock**	**White water lily**	**Floating-leaf bur-reed**							0.16
AZ	**Pickerelweed**	**Watershield**	**Floating-leaf bur-reed**								0.69
BA	**Pickerelweed**	**Common bur-reed**	**Watershield**	**White water lily**	Wild rice sp.						0.37
BB	**Pickerelweed**	**Common bur-reed**	**Watershield**	**White water lily**	Intermediate pond lily						5.30
BC	**Pickerelweed**	**Spatterdock**	**Floating-leaf bur-reed**								3.04
BD	**Pickerelweed**	**Floating-leaf bur-reed**	**Intermediate pond lily**								0.81
BE	**Pickerelweed**	**Watershield**	**Spatterdock**								0.24
BF	**Pickerelweed**	**Common bur-reed**	**Floating-leaf bur-reed**	**Spatterdock**	White water lily	Intermediate pond lily	Creeping spikerush				0.18
BG	**Pickerelweed**	**Common bur-reed**	**Spatterdock**								2.60
BH	**Pickerelweed**	**Common bur-reed**	**Watershield**	**White water lily**	Floating-leaf bur-reed	Softstem bulrush					2.17
BI	**Pickerelweed**	**Common bur-reed**	**Watershield**	**Floating-leaf bur-reed**	Spatterdock						2.09
BJ	**Pickerelweed**	**Common bur-reed**	**Floating-leaf bur-reed**	**Watershield**	White water lily	Spatterdock					1.48
BK	**Pickerelweed**	**Intermediate pond lily**	**Floating-leaf bur-reed**								0.31
BL	**Pickerelweed**	**Watershield**	**Floating-leaf bur-reed**								0.31
BM	**Pickerelweed**	**Spatterdock**	**Common bur-reed**								0.52
BN	**Pickerelweed**	**Common bur-reed**	**Spatterdock**								1.20
BO	**Pickerelweed**	**Watershield**	**Spatterdock**								1.14
BP	**Pickerelweed**	**Common bur-reed**	**Spatterdock**	**Watershield**							1.02
BQ	**Pickerelweed**	**Three-way sedge**	**Spatterdock**	**Soft rush**							0.31
BR	**Pickerelweed**	**White water lily**	**Watershield**	**Common bur-reed**							0.20
BS	**Pickerelweed**	**Watershield**	**Common bur-reed**	**Three-way sedge**							0.16
BT	**Pickerelweed**	**Softstem bulrush**	**Common bur-reed**	**Watershield**	Spatterdock	Floating-leaf bur-reed					3.89
BU	**Pickerelweed**	**Common bur-reed**	**Spatterdock**	**Watershield**							0.55
BV	**Pickerelweed**	**Common bur-reed**	**White water lily**	Spatterdock							4.77
BW	**Pickerelweed**	**Common bur-reed**	**Spatterdock**	**Creeping spikerush**							0.34
BX	**Pickerelweed**	**Creeping spikerush**	**Common arrowhead**	**Intermediate pond lily**	Watershield	Floating-leaf bur-reed					0.44
BY	**Pickerelweed**	**Creeping spikerush**	**Spatterdock**	**Intermediate pond lily**	Floating-leaf bur-reed	White water lily					0.54
BZ	**Pickerelweed**	**Common bur-reed**	**Spatterdock**	**Floating-leaf bur-reed**	Creeping spikerush	White water lily	Intermediate pond lily	Misc. Wetland Species	Watershield		21.61
CA	**Pickerelweed**	**Common bur-reed**	**Spatterdock**	**Floating-leaf bur-reed**	Watershield						1.12
CB	**Pickerelweed**	**Common bur-reed**	**White water lily**	**Misc. Wetland Species**							0.45
CC	**Softstem bulrush**	**Common bur-reed**	**Spatterdock**	**Watershield**	Pickerelweed						0.76
CD	**Spatterdock**	**Common bur-reed**	**White water lily**	Floating-leaf bur-reed							1.33
CE	**Spatterdock**	**Common bur-reed**	**Common arrowhead**	Pickerelweed	Grass-leaved arrowhead	Wild rice sp.					1.22
CF	**Spatterdock**	**Wild rice sp.**	**Pickerelweed**								2.09
CG	**Spatterdock**	**Wild rice sp.**									0.19
CH	**Spatterdock**	**Common bur-reed**	**Pickerelweed**	**Watershield**	Floating-leaf bur-reed	Creeping spikerush	White water lily				6.54
CI	**Spatterdock**	**Intermediate pond lily**	**Watershield**	**White water lily**	Common bur-reed						1.58
CJ	**Spatterdock**	**Intermediate pond lily**	**Pickerelweed**	**Common bur-reed**							0.51
CK	**Spatterdock**	**Common bur-reed**	**Pickerelweed**	**White water lily**	Intermediate pond lily	Creeping spikerush	Floating-leaf bur-reed				10.63
CL	**Spatterdock**	**Watershield**	**Pickerelweed**	**Floating-leaf bur-reed**	Common bur-reed						0.80
CM	**Watershield**	**Common bur-reed**	**Spatterdock**	**Floating-leaf bur-reed**	Pickerelweed						2.66
CN	**White water lily**	**Spatterdock**	**Wild rice sp.**	**Watershield**	Common bur-reed	Pickerelweed	Intermediate pond lily				6.09
CO	**White water lily**	**Watershield**	**Pickerelweed**								0.66
CP	**Wild rice sp.**	**Floating-leaf bur-reed**	**Spatterdock**								3.60
CQ	**Wild rice sp.**	**Spatterdock**	**Pickerelweed**	**Floating-leaf bur-reed**	White water lily						3.44

Lake Mohawksin 2019 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Lake Mohawksin- Map 6-8

Small Plant Community (Points)								
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
1	**Common bur-reed**	**Pickerelweed**						
2	**Common bur-reed**							
3	**Common bur-reed**	Grass-leaved arrowhead						
4	**Common bur-reed**	Common arrowhead	Pickerelweed					
5	**Common bur-reed**	**Pickerelweed**						
6	**Common bur-reed**	**Pickerelweed**	Cattail sp.					
7	**Grass-leaved arrowhead**							
8	**Pickerelweed**							
9	**Pickerelweed**	Common bur-reed						
10	**Pickerelweed**	Cattail sp.						
11	**Pickerelweed**	**Common bur-reed**	**White water lily**					
12	**Pickerelweed**	**Wild rice sp.**						
13	**Pickerelweed**	**Common bur-reed**						
14	**Pickerelweed**	Three-way sedge						
15	**Purple loosestrife**							
16	**Softstem bulrush**							
17	**Water arum**	**Common bur-reed**						
18	**Wild rice sp.**							
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
19	**Floating-leaf bur-reed**							
20	**Floating-leaf bur-reed**	**Wild rice sp.**						
21	**Floating-leaf bur-reed**	**Watershield**	White water lily					
22	**Floating-leaf bur-reed**	**Spatterdock**						
24	**Floating-leaf bur-reed**	**Watershield**	**Pickerelweed**	Spatterdock	Arrowhead sp. (sterile)			
25	**Intermediate pond lily**	**Floating-leaf bur-reed**						
26	**Intermediate pond lily**							
27	**Pickerelweed**	Common bur-reed	Watershield	Arrowhead sp. (sterile)				
28	**Spatterdock**							
29	**Spatterdock**	**White water lily**	**Floating-leaf bur-reed**					
30	**Spatterdock**	**Floating-leaf bur-reed**						
31	**Spatterdock**	Floating-leaf bur-reed						
32	**Water arum**	**White water lily**						
33	**Watershield**	Spatterdock						
34	**Watershield**	**White water lily**						
35	**Watershield**	Floating-leaf bur-reed						
36	**Watershield**	White water lily						
37	**White water lily**							
38	**White water lily**	Watershield						
39	**White water lily**	**Spatterdock**						
40	**White water lily**	**Spatterdock**	**Narrow-leaf bur-reed**					
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
41	**Arrowhead sp. (sterile)**	**Water arum**	**Common bur-reed**	White water lily	Watershield	Wild rice sp.		
42	**Cattail sp.**	**Pickerelweed**	**Watershield**	Common bur-reed				
43	**Cattail sp.**	**Watershield**	Floating-leaf bur-reed					
44	**Common arrowhead**	**Pickerelweed**	Watershield	Floating-leaf bur-reed				
45	**Common bur-reed**	Intermediate pond lily						
46	**Common bur-reed**	**Cattail sp.**	Pickerelweed	Spatterdock				
47	**Common bur-reed**	Spatterdock	Pickerelweed					
48	**Common bur-reed**	**Pickerelweed**	**Spatterdock**	Watershield	Floating-leaf bur-reed			
49	**Common bur-reed**	**Floating-leaf bur-reed**	Pickerelweed					
50	**Floating-leaf bur-reed**	Spatterdock	Common bur-reed					
51	**Floating-leaf bur-reed**	**Watershield**	**Wild rice sp.**	Pickerelweed	Common bur-reed			
52	**Floating-leaf bur-reed**	Arrowhead sp. (sterile)						
53	**Floating-leaf bur-reed**	**Wild rice sp.**						
54	**Floating-leaf bur-reed**	Wild rice sp.						
55	**Grass-leaved arrowhead**	**Floating-leaf bur-reed**						
56	**Pickerelweed**	White water lily						
57	**Pickerelweed**	Floating-leaf bur-reed	White water lily	Watershield				
58	**Pickerelweed**	**Common bur-reed**	White water lily	Cattail sp.	Wild rice sp.			
59	**Pickerelweed**	**White water lily**						
60	**Pickerelweed**	**Common bur-reed**	Spatterdock	Floating-leaf bur-reed				
61	**Pickerelweed**	**Spatterdock**	Floating-leaf bur-reed					
62	**Pickerelweed**	**Common bur-reed**	Cattail sp.	Spatterdock				
63	**Pickerelweed**	**Common bur-reed**	Spatterdock	Cattail sp.				
64	**Pickerelweed**	**Common bur-reed**	Spatterdock					
65	**Pickerelweed**	Spatterdock						
66	**Pickerelweed**	**Floating-leaf bur-reed**	Spatterdock					
67	**Spatterdock**	**Grass-leaved arrowhead**						
68	**Spatterdock**	**Pickerelweed**						
69	**Spatterdock**	Pickerelweed						
70	**Spatterdock**	**Watershield**	Pickerelweed	Arrowhead sp. (sterile)				
71	**Watershield**	**Floating-leaf bur-reed**	Pickerelweed					
72	**White water lily**	**Common bur-reed**	Floating-leaf bur-reed					
73	**White water lily**	**Watershield**	Common bur-reed	Grass-leaved arrowhead	Pickerelweed			
74	**Wild rice sp.**	**Floating-leaf bur-reed**	**Watershield**					
75	**Wild rice sp.**	**Floating-leaf bur-reed**						
76	**Wild rice sp.**	**Spatterdock**	**Floating-leaf bur-reed**					
77	**Wild rice sp.**	**Floating-leaf bur-reed**						
78	**Wild rice sp.**	**White water lily**						
79	**Wild rice sp.**	**Spatterdock**						
80	**Wild rice sp.**	**Spatterdock**	**Grass-leaved arrowhead**					



N
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1,100
Feet

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

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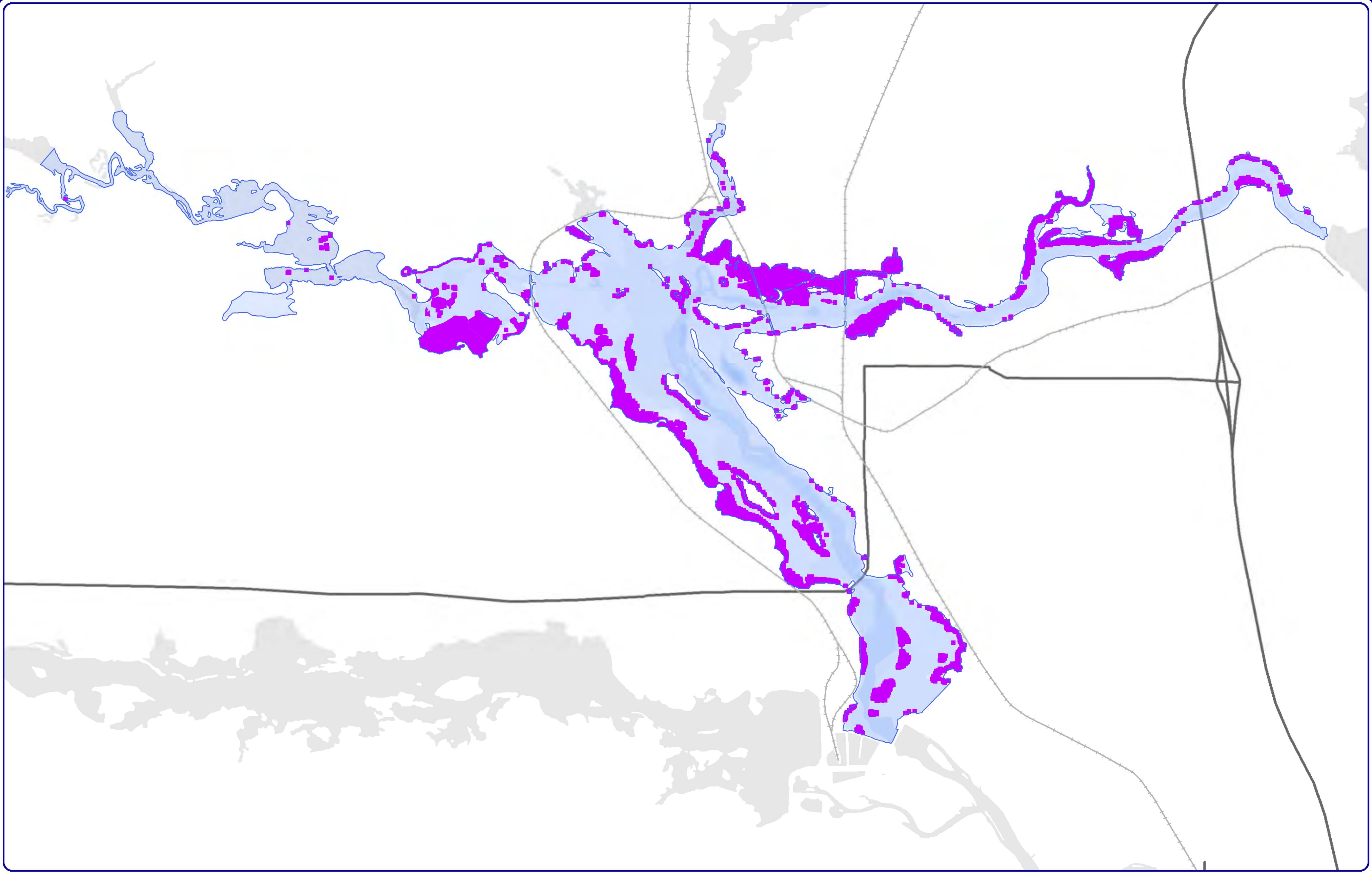
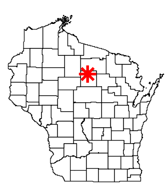
Sources
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2015-2020

Map Date: July 28, 2020 AMS
Filename: *Map9_Moh_CLP_2015-2020.mxd*

Map 9
Lake Mohawksin
Lincoln County, Wisconsin

2015-2020 CLP Survey Results





4,200
Feet

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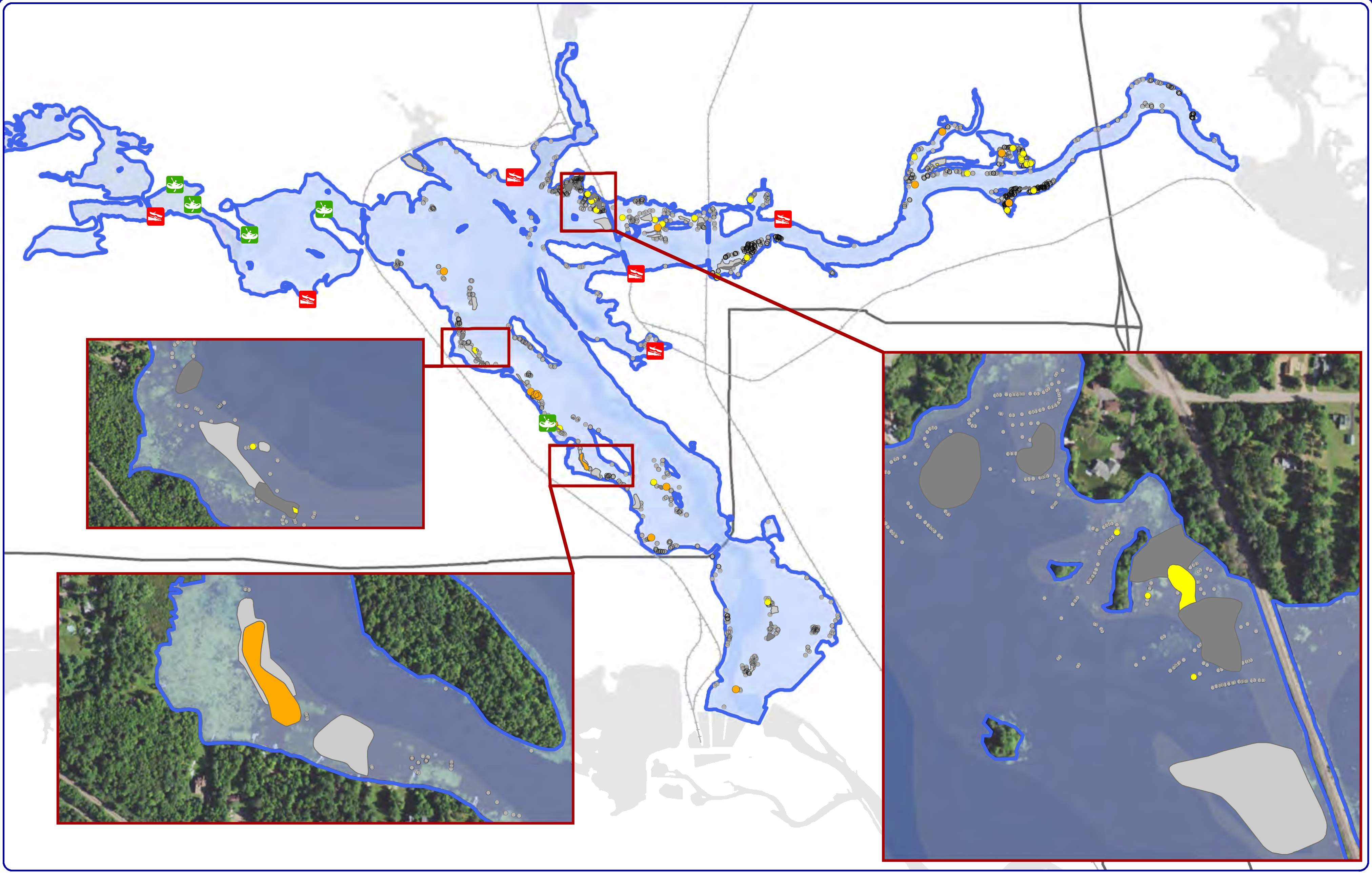
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2008-2019
Map Date: July 10, 2020

Legend

EWM Occurence From Any Year

Map 10
Lake Mohawksin
Shawano County, Wisconsin

2008-2020 EWM Footprint



3,600
Feet

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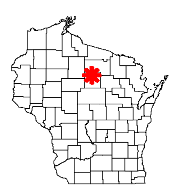
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2019
Orthophtography: NAIP, 2020
Map Date: November 1, 2019 AMS
Filename:Moh_EWMPB_Sept19.mxd



Project Location in Wisconsin

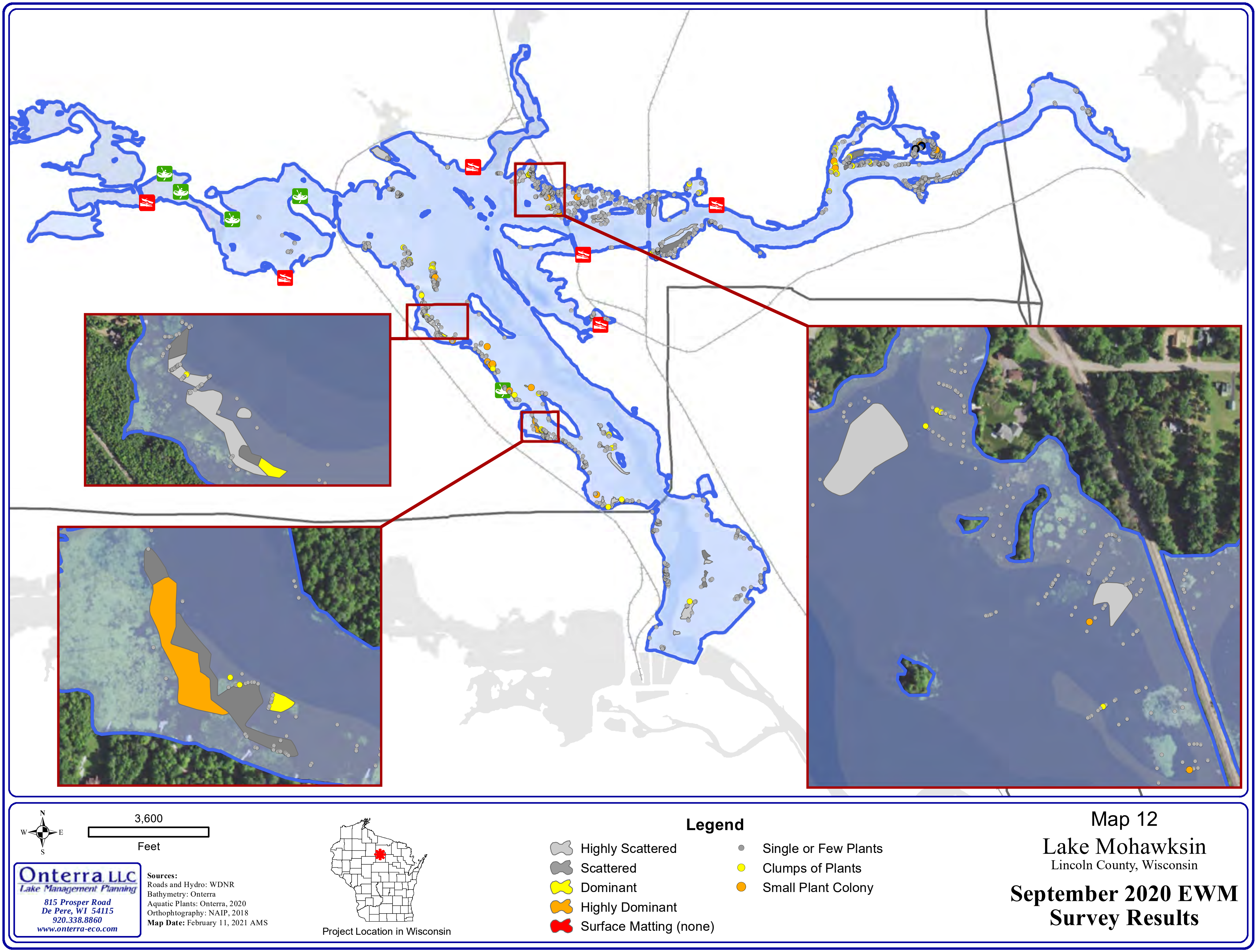
Legend

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

Map 11

Lake Mohawksin
Lincoln County, Wisconsin

September 2019 EWM Survey Results


3,600
Feet
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2020
Orthophotography: NAIP, 2018
Map Date: February 11, 2021 AMS
Project Location in Wisconsin
Legend
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting (none)
Single or Few Plants
Clumps of Plants
Small Plant Colony
Map 12
Lake Mohawksin
Lincoln County, Wisconsin
September 2020 EWM
Survey Results