Long Lake

Fond du Lac County, Wisconsin

Comprehensive Management Plan

March 2015

Sponsored by:

Long Lake Preservation Association, LLC

WDNR Grant Program

AEPP-432-14

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Onterra, LLC
Lake Management Planning

Long Lake

Fond du Lac County, Wisconsin

Comprehensive Management Plan

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Long Lake Planning Committee

Mark Patton
Rich Clements
Dave Murphy
Tom Hinchliffe
Tim Vanthoff

Wisconsin Dept. of Natural Resources

Mary Gansberg

TABLE OF CONTENTS

TABLES

PHOTOS

MAPS

FIGURES

APPENDICES

A. Public Participation Materials
B. Stakeholder Survey Response Charts and Comments
C. Water Quality Data
D. Watershed Analysis WiLMS Results

1.0 INTRODUCTION

Long Lake, Fond du Lac County, is a 454-acre lowland drainage lake with a maximum depth of 47 feet and a mean depth of 22 feet. This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Long Lake contains 42 native plant species, of which muskgrasses is the most common plant. Six exotic plant species are known to exist in Long Lake.

Field Survey Notes

Right in the heart of the Kettle Moraine State Forest (Northern Unit), our crews always enjoy the landscape views and wildlife that surround Long Lake. The clear water and sandy beaches make this lake a haven for recreational activity. Long Lake has a littoral ring of various-leaved water milfoil as dense as we have ever seen. We even had it genetically tested to confirm it wasn't an invasive variety.

Photo 1.0-1 Long Lake, Fond du Lac County

Lake at a Glance - Long Lake

Morphology	
Acreage	454
Maximum Depth (ft)	47
Mean Depth (ft)	22
Shoreline Complexity	
Vegetation	
Curly-leaf Survey Date	June 25, 2014
Comprehensive Survey Date	August 28, 2013 (WDNR)
Number of Native Species	42
Threatened/Special Concern Species	None
Exotic Plant Species	Eurasian water milfoil, hybrid water milfoil, purple loosestrife, reed canary grass, curly-leaf pondweed, common reed
Simpson's Diversity	0.80
Average Conservatism	5.5
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.3
Sensitivity to Acid Rain	
Watershed to Lake Area Ratio	27:1

The Long Lake Preservation Association (LLPA) is a non-stock non-profit corporation dedicated to enhancing, preserving, and protecting the quality of Long and Tittle Lakes and its north and south channels for the benefit of the general public for future generations through effective environmental and education policies.

Long Lake's main public access location is within the State Forest campground. This launch contains two launching lanes, with a boarding dock and ADA accessibility features. In addition to this public access location, the LLPA maintains an access location in Chinatown. Long Lake has two public beaches and a good portion of its shoreland is under state ownership through the Kettle Moraine State Forest Northern Unit. The State Forest campground on Long Lake holds roughly 200 camp sites, with flush and vault toilets as well as showers.

Long Lake is classified as an Area of Special Natural Resource Interest (ASNRI) by the Wisconsin Department of Natural Resources (WDNR), and has several shoreland areas classified under the WDNR's Public Rights Features (PRF) as critical habitat under the Public Rights Feature Sensitive Areas of Lakes WDNR designation. Anglers flock to this well-known fishing lake to participate in a number of fishing tournaments sponsored by the Long Lake Fishing Club (LLFC), including the LLFC Ice Fisheree Tournament, Glenn Henning Memorial Fishing Tournament and George Hudson Memorial Fishing Tournament. The LLFC also holds several other, family friendly activities through the year, including the 5 to 95 Fish Camp (June), The Great Pumpkin Experience (October) and Snow Golf (January). These events are widely attended by the community.

It is likely through the great public access and extracurricular activities that have introduced several aquatic invasive species (AIS) to this lake. Long Lake is known to hold the following invasives: banded mystery snail, Chinese mystery snail, curly-leaf pondweed, Eurasian water-milfoil (and hybrid water milfoil), purple loosestrife, common reed (*Phragmites*), reed canary grass and zebra mussels. The LLPA contracted with Onterra, LLC in 2010 to conduct a three-year, AIS monitoring project for Long Lake. Specifically, the objective of this project was to monitor and assess herbicide treatments for curly-leaf pondweed (CLP) and Eurasian water milfoil (EWM) from 2011-2013. With remaining funds from this WDNR grant-funded project, this project was extended to include active management and monitoring in 2014.

In addition to further monitoring and strategic treatment of EWM and CLP within the lake, the LLPA became interested in creating a management plan for other reasons as well. Primarily, they were interested in gaining a better understanding of lake ecology and the overall condition of their lake. In the end, the information obtained through this planning process will help guide future LLPA plans and programs, including management of AIS as well as protection of native species habitats. Acting proactively to complete a lake management plan fits within the mission of the LLPA; *"the Long Lake Preservation Association is dedicated to enhancing, preserving and protecting the quality of Long and Tittle lakes including the north and south channels for future generations through effective environmental and education policies."*

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 and the completion of a stakeholder survey

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

AIS Information Meeting & Pre-Kick-off Meeting

On April 19, 2014, a general AIS Informational Meeting was held at the Osceola Town Hall. The full room of attendees (~50) observed a presentation given by Eddie Heath an aquatic ecologist with Onterra. The presentation discussed the active management history of Long Lake, including past herbicide treatments and mechanical harvesting. The presentation also iterated the importance of proper planning and monitoring to ensure that the activities were not having negative impacts on the lake.

Kick-off Meeting

On June 7, 2014, a project kick-off meeting was held at the Osceola Town Hall to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Long Lake Preservation Association (LLPA) board members. The approximately 20 attendees observed a presentation given by Tim Hoyman, aquatic ecologist and Managing Member of Onterra. Mr. Hoyman’s presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting

Originally, the Planning Committee was to be comprised of an equal number of folks from the LLPA and the Long Lake Fishing Club (LLFC). However, the LLFC declined to be included in the planning effort. Although the LLFC has been a partner to the LLPA in the battle against AIS on the lake, a segment of this group has strongly opposed the use of aquatic herbicides on the lake. This has led to strife between the groups and the rationale for the LLFC not having representation within the planning process.

On October 29, 2014, Eddie Heath of Onterra met with four members of the Long Lake Planning Committee for nearly 4 hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including aquatic invasive species (AIS) treatment results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed.

Planning Committee Teleconference

Based upon the discussions held at the Planning Committee Meeting, a draft Implementation Plan Section (5.0) was drafted and distributed to the Planning Committee. On November 20, 2014, the Planning Committee held a meeting to discuss the draft Implementation Plan Section. The official first draft of the LLPA's Comprehensive Lake Management Plan for Long Lake reflects the comments received following this meeting.

Project Wrap-up Meeting

Planned for Summer 2015

Management Plan Review and Adoption Process

As discussed above, prior to the Planning Committee Meeting, a draft of the Results and Discussion Sections (3.0) were provided to the meeting attendees to aid in the delivery of these materials at the meeting. Based upon the discussions that occurred at the Planning Committee Meeting, a draft of the Implementation Plan Section (5.0) was created by Onterra and provided to the Planning Committee for review.

In November 2014, the first draft of the LLPA's Comprehensive Lake Management Plan for Long Lake was distributed for official review to state, county, and municipal contacts. The LLPA also personally forwarded the draft document to the president of the LLFC. The draft report has been made available for download during the review period on LLPA's website. Review comments from agency staff are provided directly to Onterra. Review comments from interested stakeholders will be sent to the LLPA Planning Committee per instructions on the website. These comments will be pooled together and sent to Onterra.

Following written comments from the WDNR Regional Lake Coordinator (Mary Gansberg), a meeting was held at Onterra's offices in De Pere, WI between LLPA Planning Committee Members and Mary Gansberg. This meeting focused on the strengthening of the Implementation Plan Section, particularly the topics of AIS management and native plant mechanical harvesting.

This report reflects the integration of all comments received as well as the previously discussed meeting with WDNR. The final report will be reviewed by the LLPA Board of Directors and a vote to adopt the management plan will be held during the association's next annual meeting. On January 26th, 2015, the LLPA Board of Directors adopted the AIS management goals outlined within the Implementation Plan Section per a formal resolution to apply for AIS Established Population Control Grants.

Stakeholder Survey

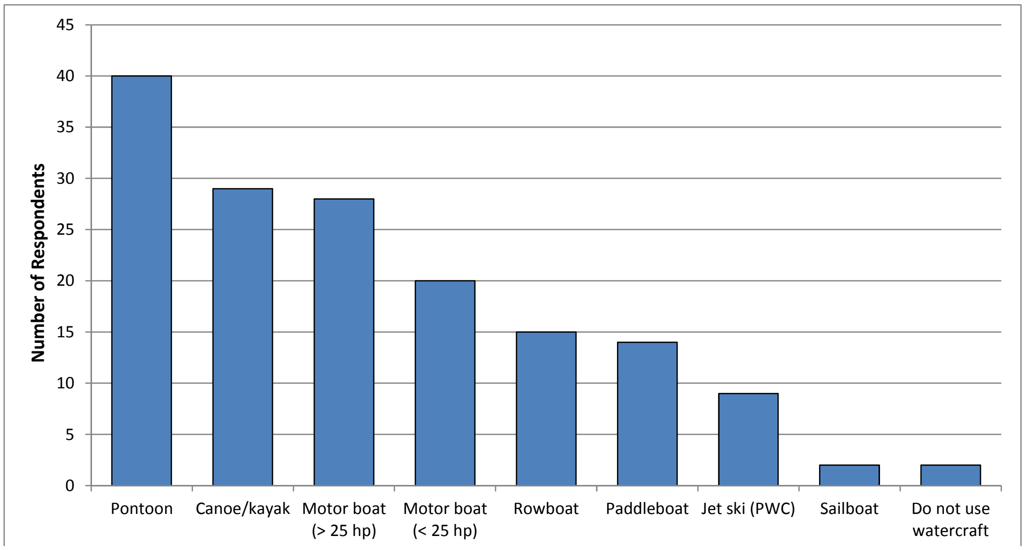
During October 2014, a seven-page, 30-question survey was made available either as an online survey or a paper version. Postcard notifications announcing the survey were mailed to 292 riparian property owners in the Long Lake watershed. Approximately one week later, a follow-up postcard was again mailed to the same riparian property owners. 69 stakeholders responded to the survey (approximately 24 percent return rate), either in electronic or paper form. Those results were entered into a spreadsheet by a third party entity (Business Connection). The data were summarized and analyzed 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.

In instances where stakeholder survey response rates are below 60%, the results should not be interpreted as being a statistical representation of the population. However, the results *may* follow public opinion, particularly on contentious issues. The 24% response rate observed for Long Lake is relatively low and the data generated need to be qualified by the low response rate.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Long Lake. The majority of stakeholder respondents (38%) are year round residents, while 30% visit on weekends through the year, and 23% are seasonal residents (Appendix B, Question #1). 61% of stakeholders have owned their property for over 15 years, 26% for over 20 years, and 13% for over 25 years (Appendix B, Question #3).

Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. Almost 60% of survey respondents indicate that they use a pontoon boat; and slightly under half indicate they use a canoe/kayak and a motor boat with greater than 25 horsepower motor (Appendix B, Question #13). On a narrow lake such as Long Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 14, several of the top recreational activities on the lake involve boat use. Boat traffic was listed as a factor potentially impacting Long Lake in a negative manner (Question 20) and was ranked 4th on a list of stakeholder's top concerns regarding the lake (Question 21).

Question 13: What types of watercraft do you currently use on the lake?



Question 14: Please rank up to three activities that are important reasons for owning your property on or near the lake.

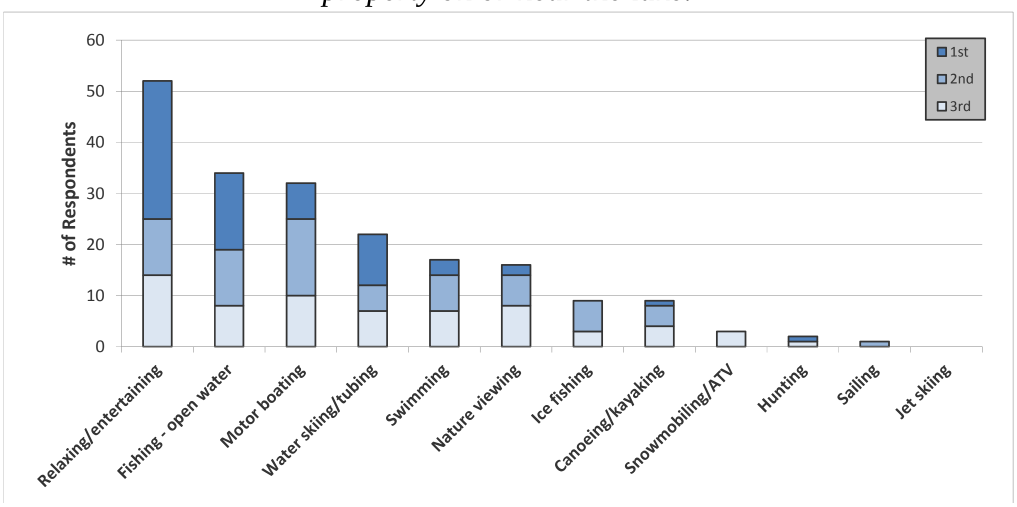
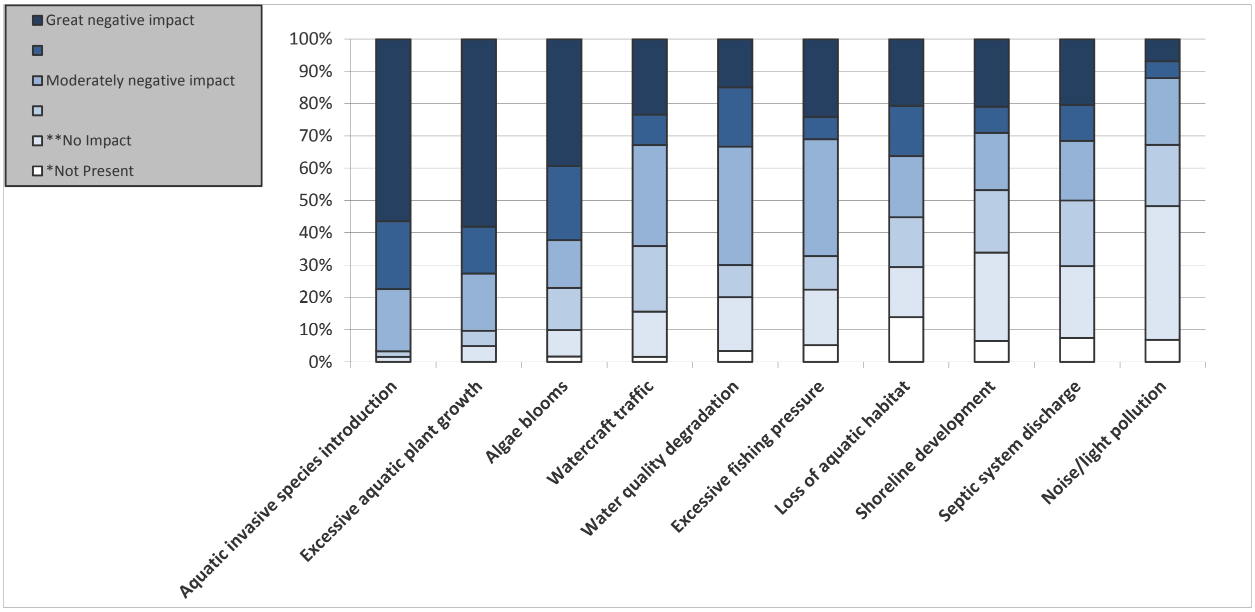


Figure 2.0-1. Select survey responses from the Long Lake Stakeholder Survey. Excludes respondents that answered *None of these activities are important to me* and *Other*. Additional questions and response charts may be found in Appendix B.

Question 20: To what level do you believe these factors may be negatively impacting Long Lake?



Question 21: Please rank your top three concerns regarding Long Lake.

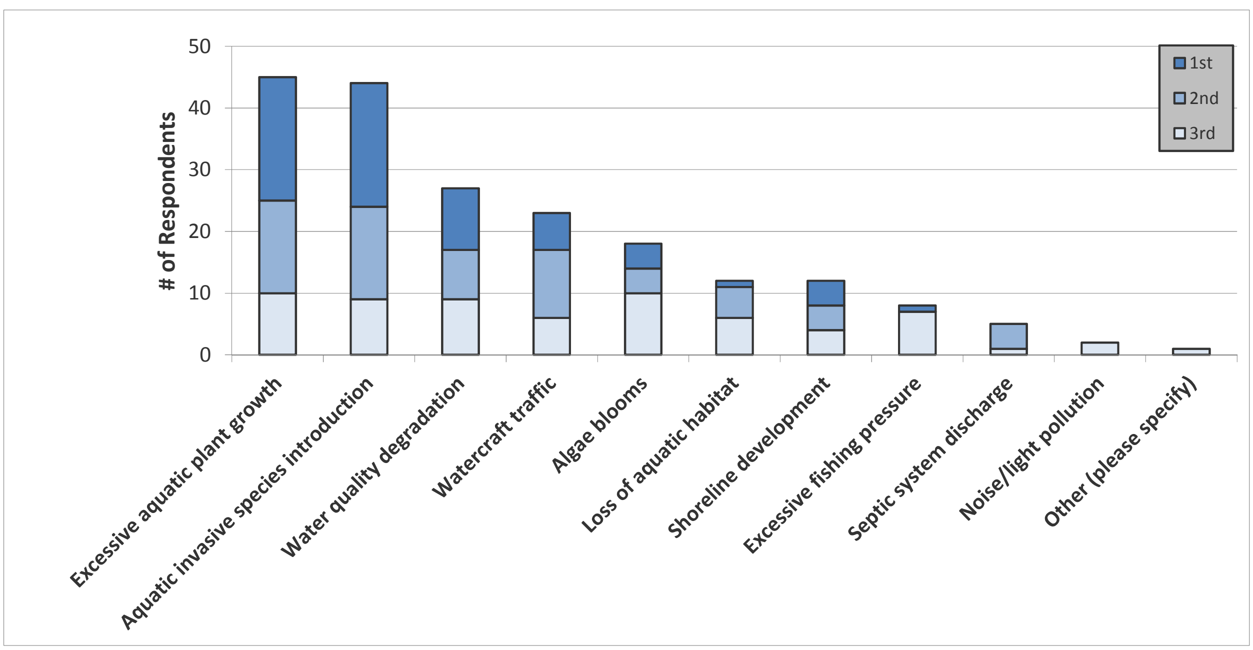


Figure 2.0-2. Select survey responses from the Long Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on 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 analysis 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 Long Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Long Lake's 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 quadrates (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, and 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 more clear 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.

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

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epiliminion 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.

Internal Nutrient Loading*

In lakes that support strong stratification, 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 the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae 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 screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. months 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 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013) 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 Long Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, 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 four square miles.
> >
> > Lowland drainage lakes have a watershed of greater than four square miles.

Because Long Lake possesses tributary inlets and an outlet, has a watershed that is greater than four square miles in area, and its results from the Lathrop and Lillie equation, Long Lake is classified as a deep (stratified), lowland drainage lake (Category 5 on Figure 3.1-1).

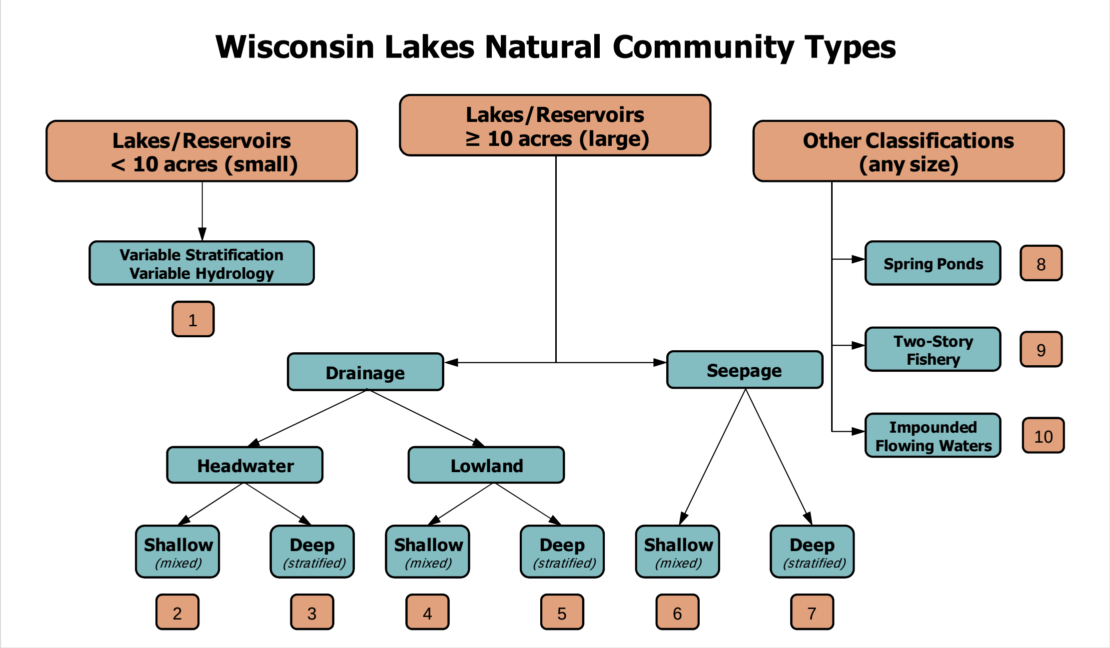


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A. Long Lake is classified as a deep (stratified), lowland drainage lakes (class 5).

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. Long Lake is within the Southeastern Wisconsin Till Plains ecoregion (Figure 3.1-2).

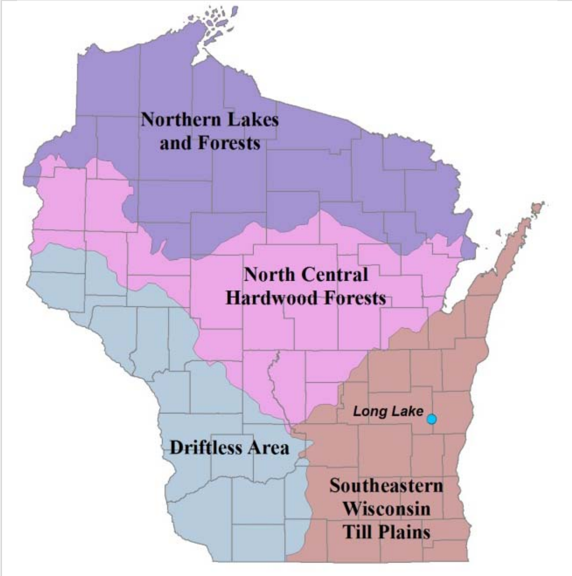


Figure 3.1-2. Location of Long Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2014 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Long Lake is displayed in Figures 3.1-3 - 3.1-9. 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 comparative 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.

Long Lake Water Quality Analysis

Long Lake Long-term Trends

As a part of this study, Long Lake stakeholders were asked about their perceptions of their lake's water quality through an anonymous stakeholder survey. Approximately 60% of stakeholder respondents indicated that the water quality of Long Lake was *Good* or *Excellent* (Appendix B, Question #15). The respondents also indicate that they perceive that the water quality has degraded (pooled *severely degraded* and *somewhat degraded*, 54%) or remained the same (20%) since first visiting the lake (Appendix B, Question #16).

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions such as precipitation or lake thereof, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, as whether the lake health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, one can determine what the status of the lake is by comparison.

LLPA volunteers have been actively collecting data since 2009 on Long Lake, and continue to do so through the Citizens Lake Monitoring Network (CLMN) Program. Through this WDNR-sponsored program, volunteers are trained to collect water quality data on the lake. Samples are analyzed through the State Lab of Hygiene in Madison, WI and data are entered into the Surface Water Integrated Monitoring System (SWIMS), an online database which allows for quick access to all current and historical water quality data. This process allows stakeholders to become directly engaged in protecting their lake, while producing reliable and comparable data that managers may recall through a streamlined website.

As previously mentioned, the three primary water quality parameters that are studied in lakes include total phosphorus, chlorophyll-*a*, and Secchi disk clarity. Historical near-surface total phosphorus data have been collected from Long Lake an annual basis almost consecutively since 1988 through the WDNR's Long-Term Trend Monitoring and Citizen Lakes Monitoring Network (CLMN) programs (Figure 3.1-3). Over this time period, average growing season near-surface total phosphorus values have ranged from 15.0 μg/L in 1995 to 28.0 μg/L in 2008, with all annual averages falling within the *excellent* or *good* categories for deep, lowland drainage lakes. Trends analysis (Mann-Kendall Test) revealed that no significant trend (positive or negative) within the near-surface total phosphorus data from 1988-2014. The weighted average summer near-surface total phosphorus for all data from 1988-2014 falls within the *excellent* category for deep, lowland drainage lakes, and falls below the median values for both state-wide deep, lowland drainage lakes and lakes within the Southeastern Wisconsin Till Plains (SWTP) ecoregion.

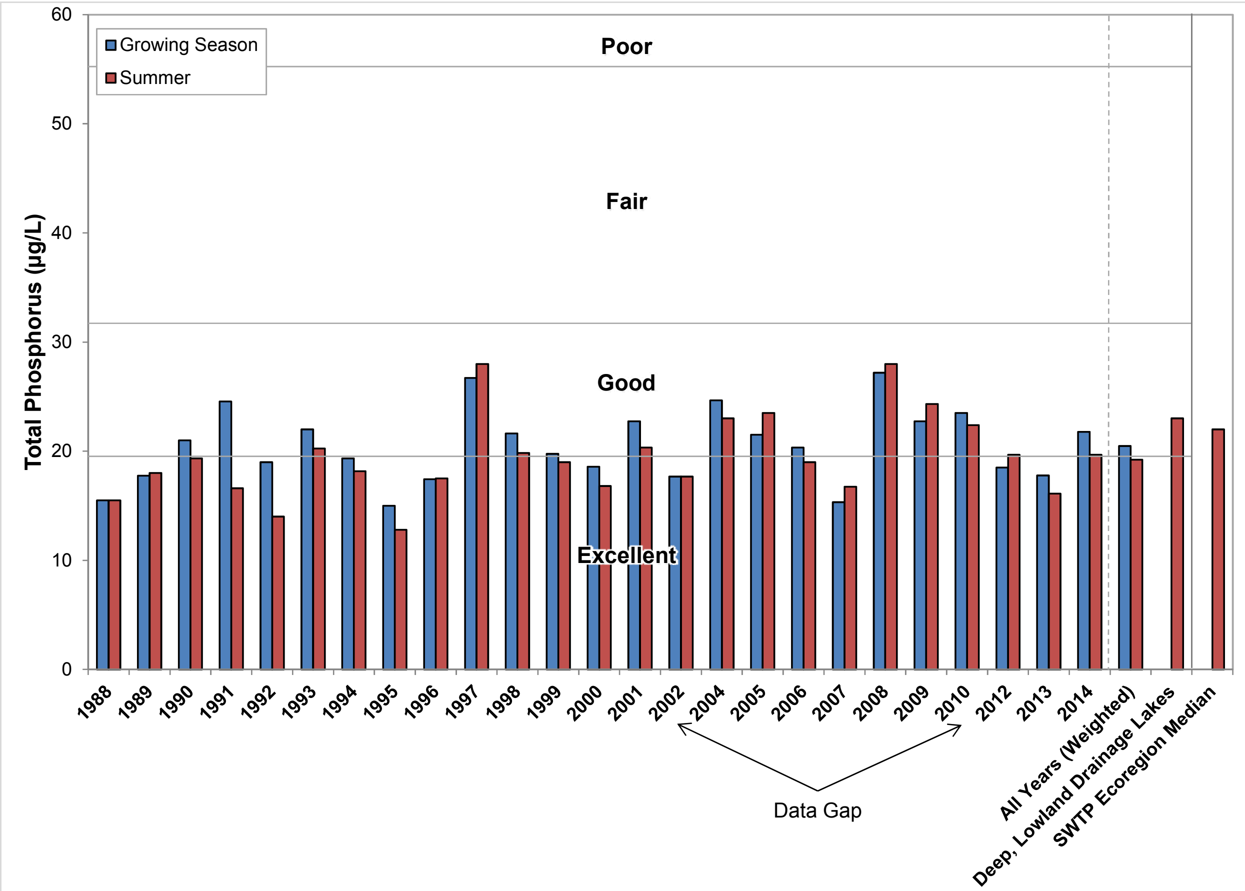


Figure 3.1-3. Long Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, lowland drainage lakes and Southeast Wisconsin Till Plain (SWTP) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

As illustrated in Figure 3.1-3, annual near-surface total phosphorus concentrations in Long Lake can be variable from year to year. For example, total phosphorus concentrations nearly doubled from 2007 to 2008. As will be discussed in the Watershed Section, Long Lake drains a relatively large portion of land, or has a large watershed. The majority of the phosphorus present in Long Lake originates and is delivered to the lake from its watershed via runoff. The amount of precipitation that falls within Long Lake's watershed, primarily in the spring, is largely going to dictate how much phosphorus is transported to the lake on an annual basis. Figure 3.1-4 displays April-June total precipitation data recorded in nearby Plymouth, WI from 1988-2014, and illustrates, in general, that phosphorus in Long Lake tends to increase in years with higher amounts of spring precipitation. These annual differences in precipitation drive the variability in total phosphorus concentrations observed in Long Lake.

Often, near-surface water samples of phosphorus are analyzed because they are easy to collect and are representative of what is occurring in the littoral zone (sunlit, plant and algae growing area) of a lake. However, comparing near-surface and near-bottom phosphorus samples can be advantageous to further understand the limnological processes of the lake. During times in which a lake is mixed, we can expect phosphorus concentrations to be similar near the surface and near the bottom of the lake. During times that the lake is stratified however, the bottom phosphorus concentration may be two to three times or more than what was observed in the surface waters. Under anoxic conditions, phosphorus may be released from the sediments which accounts for the higher concentrations. In 2014, total phosphorus concentrations were similar during spring turnover, while near-bottom phosphorus increased to 159 µg/L. Historical near-bottom total phosphorus data from Long Lake indicate that concentrations rarely exceed 200 µg/L, and average values fall around 130 µg/L. At this time, it is not believed that internal phosphorus loading from bottom sediments is a significant source of phosphorus to Long Lake.

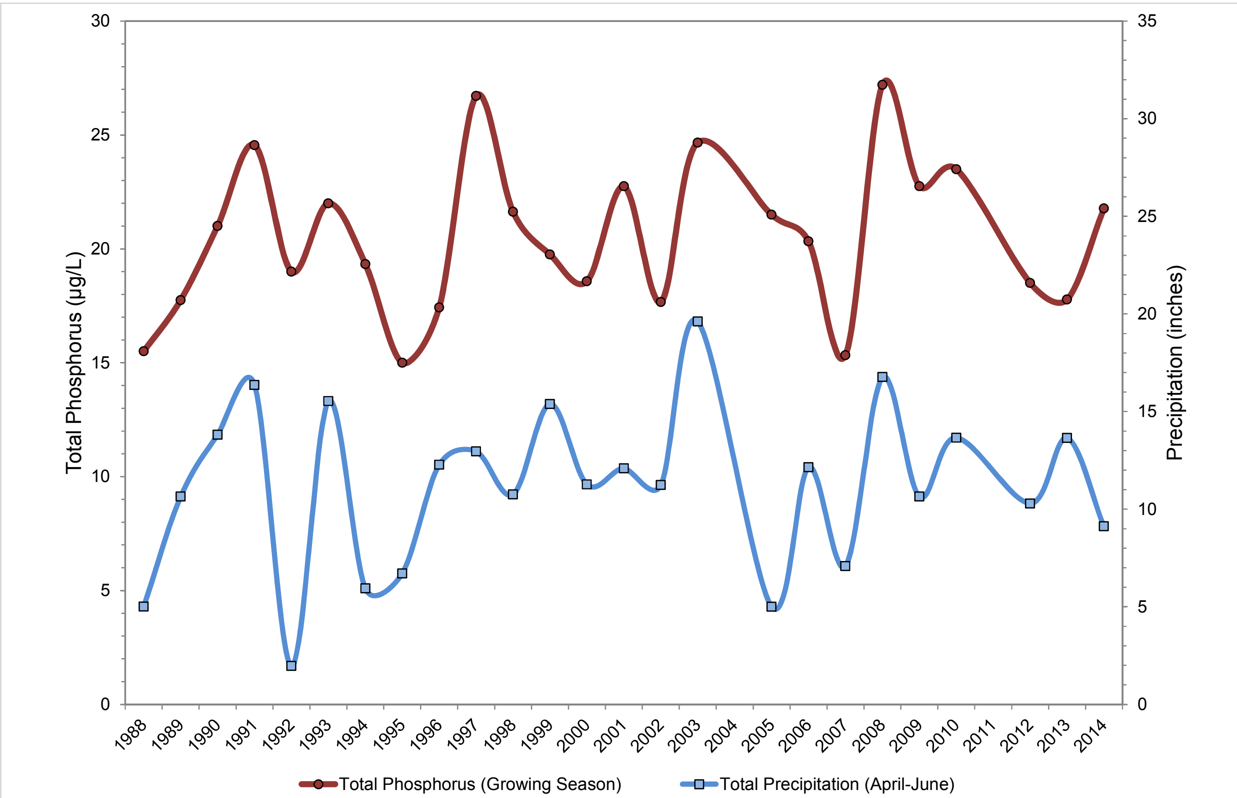


Figure 3.1-4. 1988-2014 April-June total precipitation from Plymouth, WI compared to Long Lake average annual growing season near-surface total phosphorus concentrations. Precipitation data obtained from National Climatic Data Center (2014).

Chlorophyll-*a* concentrations, like total phosphorus, have been recorded almost consecutively on an annual basis since 1988 (Figure 3.1-5). Average growing season concentrations of chlorophyll-*a* range from 11.8 µg/L in 1990 to 2.9 µg/L in 2007, spanning the thresholds of *excellent* to *fair* for deep, lowland drainage lakes in Wisconsin. Trends analysis (Mann-Kendall Test) revealed that there is a statistically valid declining trend in chlorophyll-*a* concentrations within Long Lake over this time period. In most instances, a declining trend in algal abundance is a result of reduced amounts of nutrients, primarily phosphorus, entering the lake. Remediation efforts within a lake's watershed are often completed to reduce phosphorus loads to lakes, which results in less algae and higher water clarity. Because chlorophyll-*a* concentrations are generally positively correlated with total phosphorus, this is the first area to look for an explanation for declining chlorophyll-*a* concentrations.

However, as discussed previously, near-surface total phosphorus concentrations have not exhibited this same pattern of decline over this time period, indicating the reduction in algal abundance is not due to a reduction in phosphorus. Prior to 2001, chlorophyll-*a* concentrations tended to be more variable from year to year, like total phosphorus. This variability is to be expected given varying concentrations of phosphorus from year to year, for reasons discussed earlier. The average chlorophyll-*a* concentration from 1988-2000 was 6.5 µg/L. From 2001-2014, less variation was observed in chlorophyll-*a* concentrations despite variable total phosphorus concentrations, and the average chlorophyll-*a* concentration over this time period was 4.0 µg/L. It is believed that the reduction in algal abundance observed in Long Lake over the past 15 years or so is a result of the establishment of a population of the non-native, invasive filter-feeding zebra mussel. Zebra mussels and their effects on Long Lake's water quality will be discussed in the next section.

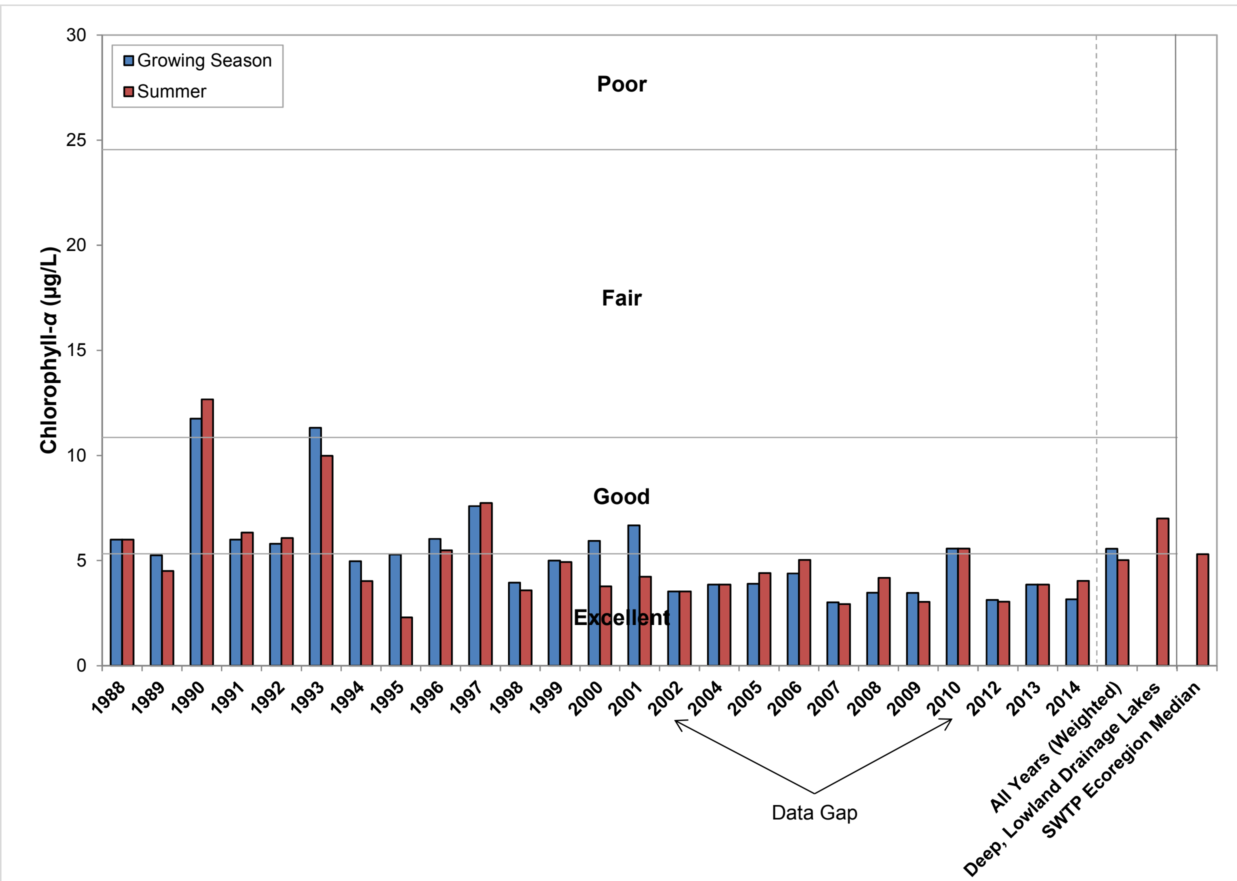


Figure 3.1-5. Long Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide deep, lowland drainage lakes and Southeastern Wisconsin Till Plain (SWTP) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Overall, the weighted summer average chlorophyll-*a* concentration for all years data are available falls within the *excellent* category for deep, lowland drainage lakes, and is lower than the median values for other deep, lowland drainage lakes throughout Wisconsin and for lakes within the SWTP ecoregion.

Secchi disk transparency data are available annually almost consecutively from 1986-2014 (Figure 3.1-6). Annual average growing season Secchi disk depths range from 7.7 feet in 1991 to 17.5 feet in 2007, with a growing season weighted average of 10.7 feet. Average annual Secchi disk depth falls within the *excellent* category for deep, lowland drainage lakes for most years. Trends analysis (Mann-Kendall Test) indicated a statistically valid increase in Secchi disk transparency over this time period, an expected trend given the decline in chlorophyll-*a* concentrations. Average growing season Secchi disk depth from 1986-2000 was 9.9 feet compared to an average of 12.6 feet from 2001-2014.

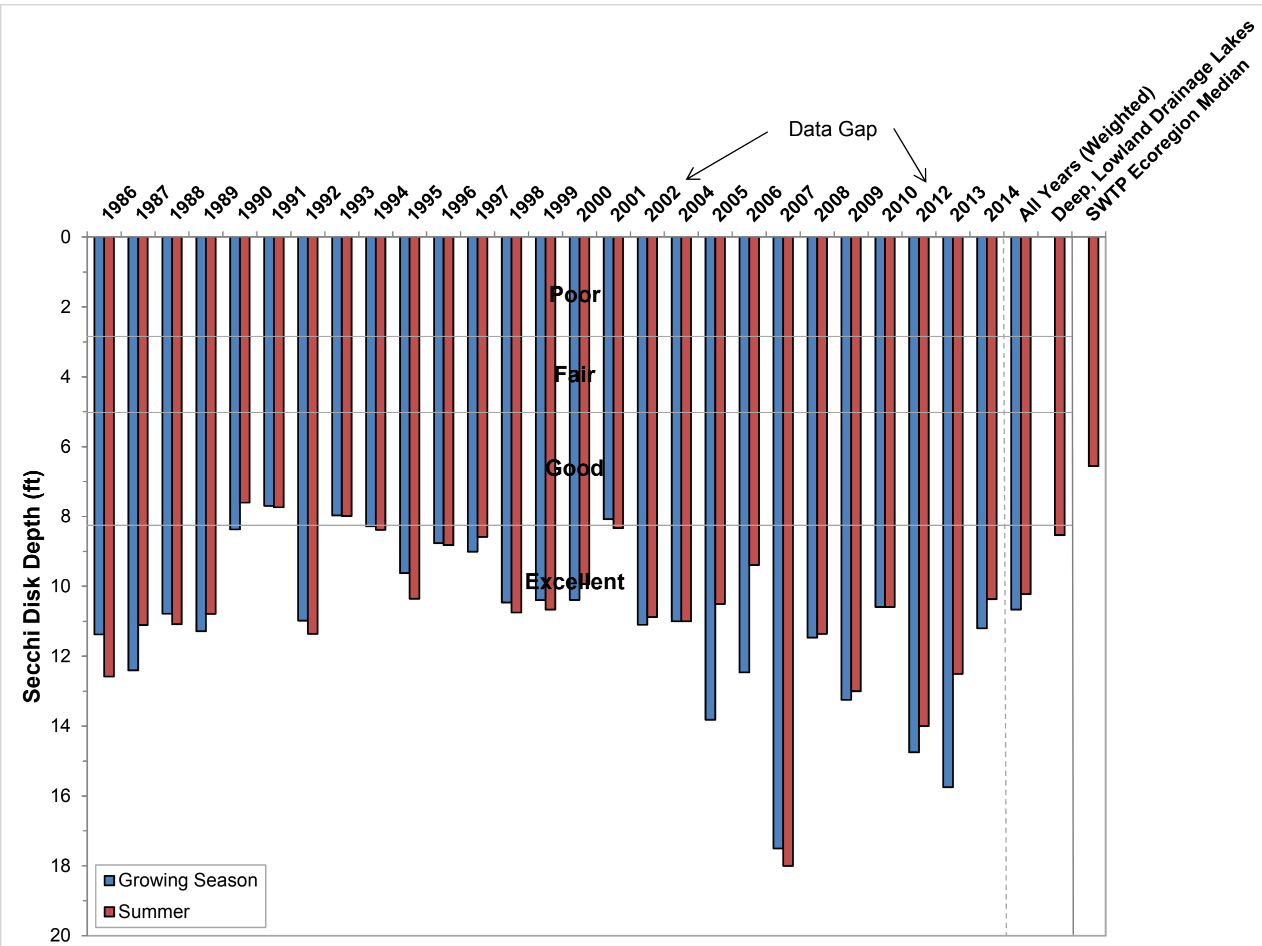


Figure 3.1-6. Long Lake average annual Secchi depths and median Secchi disk depths for state-wide deep, lowland drainage lakes and Southeast Wisconsin Till Plain (SWTP) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

The relationship between chlorophyll-*a* and Secchi disk transparency is logarithmic (Carlson 1977), meaning that small magnitude changes in chlorophyll-*a* concentrations will have larger magnitude changes on water transparency. This relationship can be observed in these data from Long Lake, with the magnitude of Secchi disk transparency increase being greater than the magnitude of decline of chlorophyll-*a*. It is believed the zebra mussel population increased water clarity in Long Lake by directly filtering algae from the water. As mentioned, the effects of zebra mussels on Long Lake's water quality will be discussed in more detail in the next section. Overall, the weighted average summer Secchi disk transparency value (10.2 feet) falls within the *excellent* category for deep, lowland drainage lakes in Wisconsin, and exceeds the median values for other deep, lowland drainage lakes within the state and for lakes within the SWTP ecoregion.

As discussed earlier, algae concentrations are low during the summer months on Long Lake, but there are other factors that can affect a lake's water clarity. This includes dissolved organic compounds that originate within wetlands and forests within the lake's watershed and can give the water a stained appearance. These dissolved compounds can be measured through an analysis called *true color*. Water samples collected from Long Lake in May and July 2014 were measured for true color. In May 2014, true color was measured at 20 platinum-cobalt units (PCU), which Lillie and Mason (1983) categorize lakes with 0-40 PCU as having 'low' color. However, during the July 28, 2014 sampling event, color was measured at 500 PCU, the maximum range of the scale, placing this sample within the 'high color' category. **Please Note:** Onterra has contacted the lab to double check this value, as it almost certainly is incorrect.

As will be discussed within the Watershed Section, Long Lake has nearly 2,000 acres of wetlands within its watershed, and being a drainage lake, Long Lake is likely susceptible to "pulses" of dissolved organic compounds being flushed from these wetlands following larger precipitation events. Precipitation data recorded at a nearby weather station indicates the area around Long Lake received nearly 0.5 inches of rain on July 27th, 2014, one day before the samples were collected. The runoff from the precipitation event likely delivered a pulse of dissolved organic compounds to Long Lake from the watershed, giving the water a more stained appearance. In addition, Secchi disk transparency on July 28th, 2014 was recorded at 7.1 feet, lower than expected based solely on the chlorophyll-*a* concentration measured of 3.35 µg/L. This indicates that water clarity was being influenced by factors other than algae. Long Lake's water clarity may periodically and temporarily decline following precipitation events as these compounds are delivered to the lake.

Zebra Mussels in Long Lake

Photo 3.1-1. Non-native zebra mussels (*Dreissena polymorpha*) attached to a native plain pocketbook mussel (*Lampsilis cardium*). Photo credit: Onterra, LLC.

Zebra mussels (*Dreissena polymorpha;* Photo 3.1-1), first documented in Long Lake in 2001, are native to the Caspian, Black, and Azov Seas, and were introduced to the Great Lakes through the ballast water of trans-Atlantic shipping vessels in the mid- to late 1980s (Karatayev et al. 1997; Reed-Andersen et al. 2000). Since their introduction to the Great Lakes, zebra mussels have at present spread to 168 habitable inland waterbodies in Wisconsin (WDNR 2014). Like other invasive species, zebra mussels can drastically alter aquatic ecosystems and generate negative economic impacts by interfering with recreation, navigation, and industrial operations (Mellina et al. 1995; Reed-Andersen et al. 2000).

Zebra mussels require certain habitat requirements to establish and maintain a population. These requirements primarily include pH, calcium concentration, and suitable substrates (Ramcharan et al. 1992; Mellina et al. 1995). The commonly accepted pH range for zebra mussels is 7.0 to 9.0. Calcium concentrations of >12 mg/L are considered suitable for zebra mussels; however, waterbodies with calcium concentrations of >28 mg/L are considered to be highly susceptible to their establishment if they are introduced.

The pH and calcium concentration within a lake largely depends on the geology of the lake's surficial and ground watersheds. In 2014, samples collected from near Long Lake's surface had a pH value of 8.3 and a calcium concentration of 47 mg/L, indicating the environment within Long Lake is highly suitable for supporting a zebra mussel population. In addition, a whole-lake point-intercept survey conducted by the WDNR in 2013 indicates that the majority of the lake's littoral zone is comprised of hard substrates (sand or rock), which can support the largest and densest populations of mussels (Reed-Andersen et al. 2000). Aquatic plants also provide habitat for zebra mussels (Reed-Andersen et al. 2000), and the 2013 point-intercept survey indicated that 91% of Long Lake's littoral zone is vegetated.

Numerous studies have shown that following the establishment of zebra mussels, many lakes experience increased water clarity as a result of decreased suspended material within the water from the filtering of zebra mussels (MacIsaac 1996; Karatayev et al. 1997; Reed-Andersen et al. 2000; Zhu et al. 2006). Zebra mussels are very efficient filter feeders, and water that has been filtered is almost entirely devoid of suspended particles (Karatayev et al. 1997). Even unwanted particles (e.g. clay particles) that pass through the zebra mussel are deposited to the sediment as pseudofeces (Karatayev et al. 1997).

As mentioned in the previous section, it is believed that the establishment of zebra mussels in Long Lake too has had detectable effects on its water quality. Specifically, trends analysis

(Mann-Kendall Test) found a statistically valid declining trend in chlorophyll-*a* concentrations, while the same test found a statistically valid increasing trend in Secchi disk transparency (Figure 3.1-7). In addition, Analysis of Variance (ANOVA) found that chlorophyll-*a* concentrations were significantly lower (p-value = 0.005) post-zebra mussel discovery (2001-2014) when compared to concentrations pre-zebra mussel discovery (1988-2000). Similarly, Secchi disk transparency was significantly higher (ANOVA p-value = 4.7 x 10^{-8}) post-zebra mussel discovery when compared to pre-zebra mussel discovery.

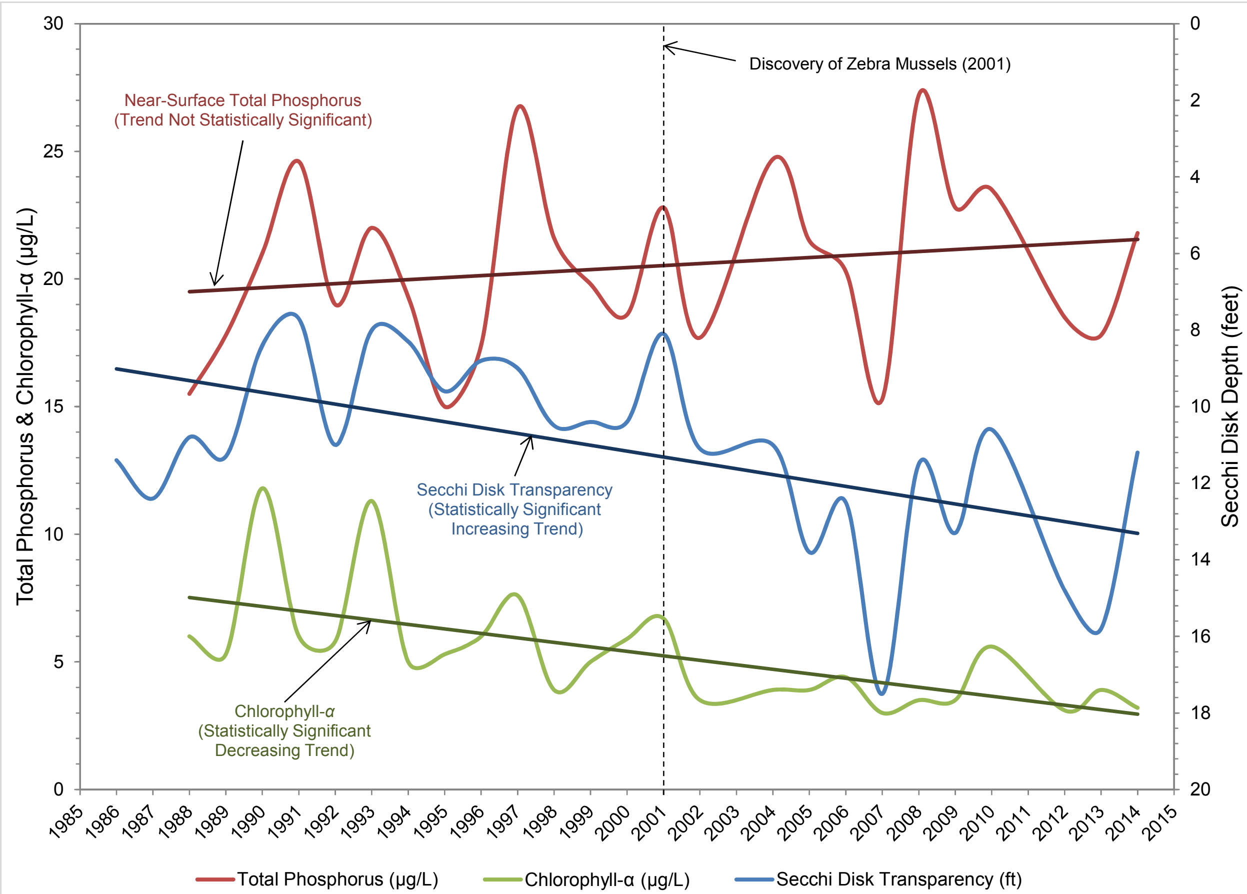


Figure 3.1-7. Trends analysis of historical average annual growing season near-surface total phosphorus, chlorophyll-α, and Secchi disk transparency from Long Lake. Mann-Kendall Test was used to determine statistical significance.

Table 3.1-1. Results of ANOVA Test on water quality parameters from Long Lake pre- and post-zebra mussel discovery. P-value is significant at the α = 0.05 level.

Parameter	1988-2000 Average	2001-2014 Average	P-value
Near-Surface Total Phosphorus (µg/L)	19.6	21.0	0.207
Chlorophyll-α (µg/L)	5.9	4.0	0.005
Secchi Disk Depth (feet)	9.9	12.6	4.7E-08

While declines in chlorophyll-*a* concentrations and resulting increased water clarity can often be attributed to reductions in nutrients entering the lake due to watershed remediation, there was no statistically valid trend (positive or negative) in near-surface total phosphorus values from 1988-

2014 (Figure 3.1-7), and near-surface total phosphorus concentrations were not statistically different (ANOVA p-value = 0.207) pre- and post-zebra mussel discovery. These data indicate zebra mussels are not removing significant amounts of nutrients from the water thus causing a decline in algae, but rather are directly filtering algae from the water. Studies conducted by Mellina et al. (1995) found a similar result, where zebra mussels reduced algal levels but not nutrients, and they termed this a *decoupling* of the phosphorus-chlorophyll-*a* relationship.

To illustrate this, Figure 3.1-8 displays Long Lake's average July and August near-surface total phosphorus and chlorophyll-*a* concentrations. Also displayed is the Carlson (1977) predicted chlorophyll-*a* concentrations based on the actual average July and August near-surface total phosphorus concentrations that were measured. As illustrated, prior to the discovery of zebra mussels, actual chlorophyll-*a* concentrations were highly correlated with near-surface total phosphorus concentrations and fell relatively close to Carlson's predicted chlorophyll-*a* values. Post-zebra mussel discovery, actual chlorophyll-*a* values begin to deviate from the predicted values, and are lower than what would be predicted based on the total phosphorus concentrations. Again, this demonstrates that the zebra mussel population in Long Lake is suppressing algal levels, creating chlorophyll-*a* levels that are lower than what would be expected given the amount of phosphorus within the lake. The zebra mussel population appears to prevent the larger fluctuations in algal levels that were recorded in the lake prior to their discovery.

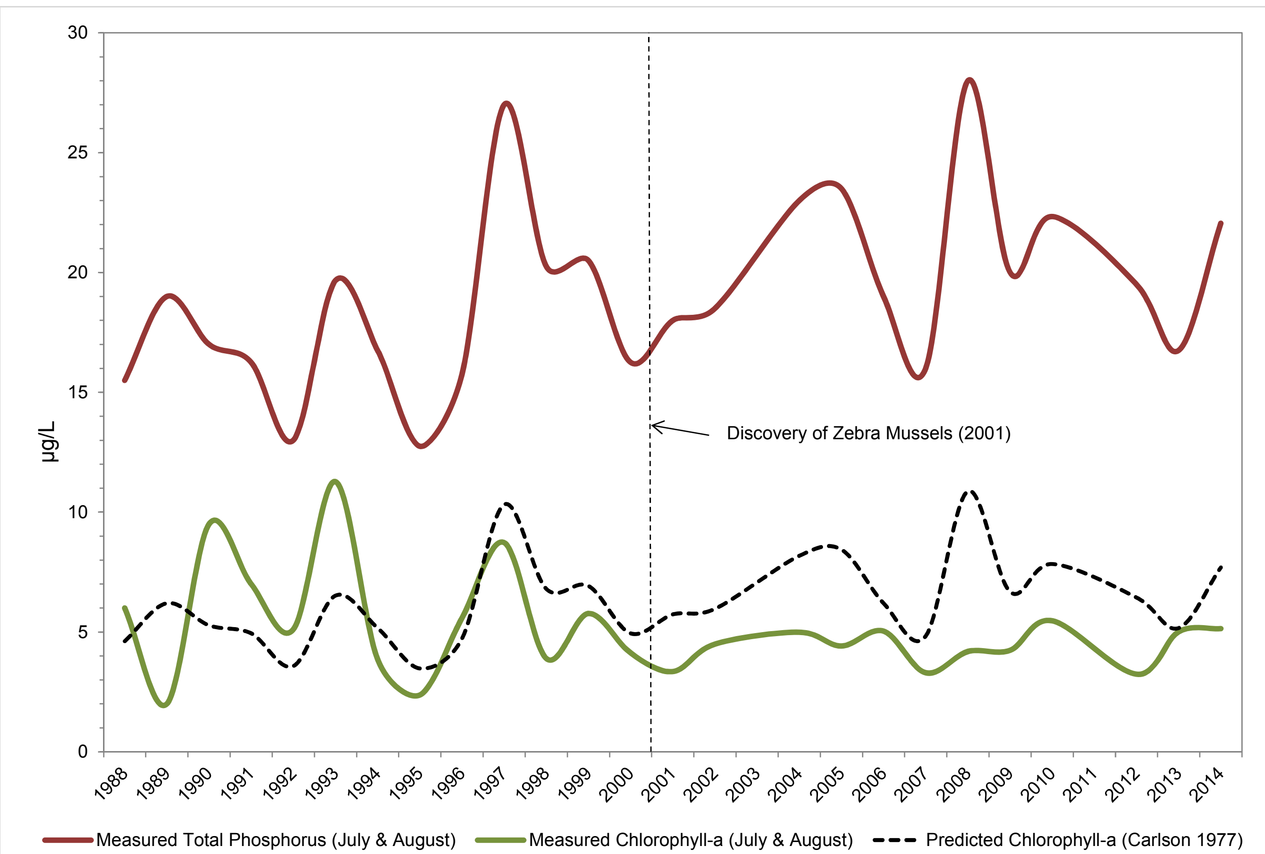


Figure 3.1-8. Long Lake average annual July and August near-surface total phosphorus concentrations and chlorophyll-α concentrations compared to predicted chlorophyll-α concentrations. Predicted chlorophyll-α concentrations calculated using July and August near-surface total phosphorus concentrations (Carlson 1977).

In summary, this analysis of Long Lake's water quality data indicates that the establishment of zebra mussels is the cause of the observed decline in algal abundance and subsequent increase in water clarity over the past 13-14 years. The decline in chlorophyll-*a* was apparent around the discovery of zebra mussels in Long Lake in 2001; however, it is believed they were most likely introduced to the lake some time before. Studies have shown that zebra mussels usually do not have detectable effects on the lake's ecosystem until their population rapidly expands about five to 10 years after their introduction (Karatayev et al. 1997). The detectable decoupling of the phosphorus-cholorphyll-*a* relationship in Long Lake appears to begin around when zebra mussels were discovered, indicating they were likely introduced to the lake sometime in the early-to-mid 1990s. Given Long Lake's proximity (~20 miles) to Lake Michigan, it is not surprising that zebra mussels were introduced to the lake relatively shortly after their introduction to the Great Lakes. At present, there are no methods for controlling a lake-wide population of zebra mussels.

Limiting Plant Nutrient of Long Lake

Using midsummer nitrogen and phosphorus concentrations from Long Lake, a nitrogen:phosphorus ratio of 29:1 was calculated. This finding indicates that Long Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Long Lake Trophic State

Figure 3.1-9 contains the Trophic State Index (TSI) values for Long Lake. The TSI values are calculated with annual average summer month Secchi disk, chlorophyll-*a*, and total phosphorus values. In general, the best values to use in judging a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors such as dissolved organic compounds. The weighted TSI values from 1988-2000 (pre-zebra mussel discovery) show that total phosphorus, chlorophyll-*a*, and Secchi disk transparency were closely correlated with one another, as indicated similar TSI values. However, from 2001-2014, average chlorophyll-*a* and Secchi disk transparency TSI values are lower than the average total phosphorus TSI value, and is an indication of the breakdown of the phosphorus-chlorophyll-*a* relationship believed to have been caused by the introduction of zebra mussels.

While zebra mussels have lowered the trophic state of the pelagic (open water) zone of Long Lake by lowering algal abundance, in reality, they have transferred the pelagic zone's productivity to the benthic (bottom zone), incorporating nutrients into themselves as well as depositing nutrients to the sediment. While the most recent water quality data indicate that Long Lake is currently in a lower mesotrophic state, a large portion of its productivity is likely found in the benthic zone and within its abundant aquatic plant community. Because of this, it is more appropriate to classify Long Lake as being in a mesotrophic state. Long Lake is in a lower productivity state than other deep, lowland drainage lakes in Wisconsin as well as other lakes within the SWTP ecoregion.

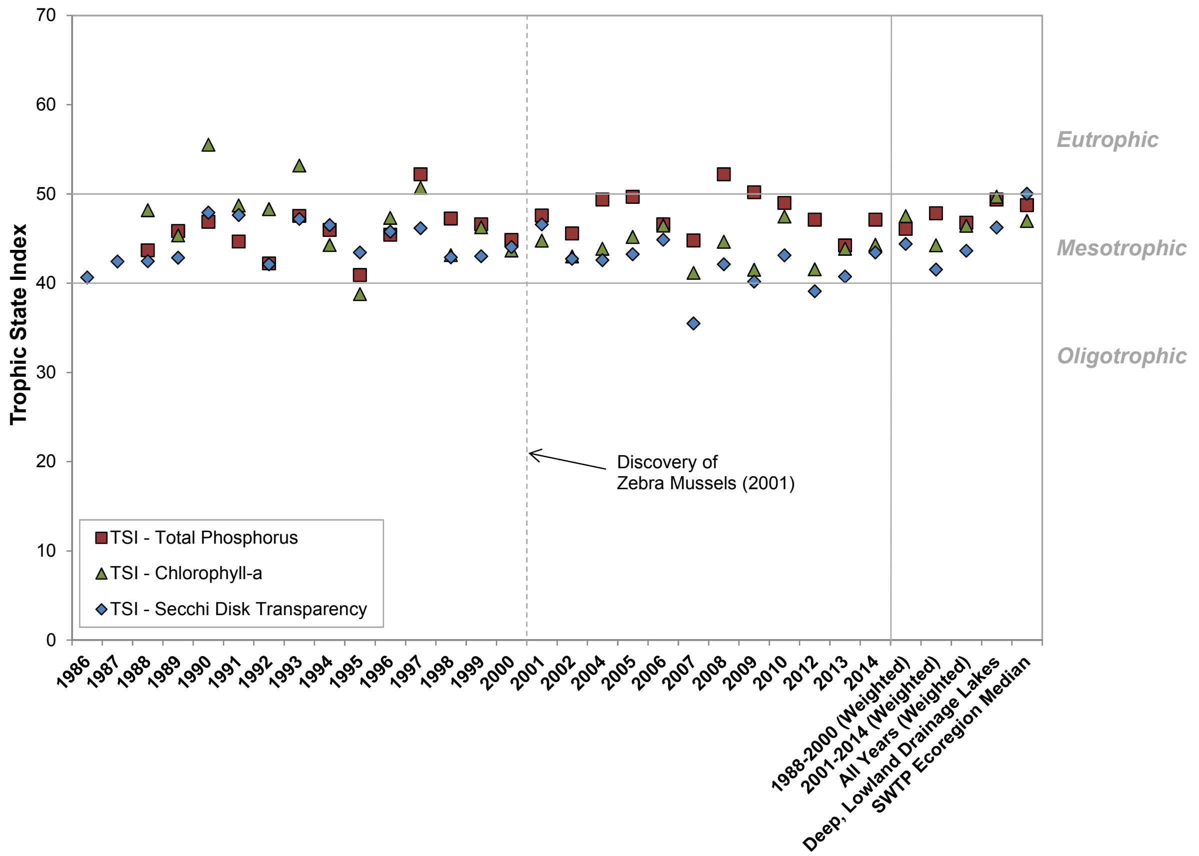


Figure 3.1-9. Long Lake, state-wide deep, lowland drainage lakes, and Southeast Wisconsin Till Plain (SWTP) Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Long Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Long Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-10. These data indicate that Long Lake stratifies during the summer, with the colder, denser bottom layer of water (hypolimnion) becoming anoxic during the summer. This thermal behavior is typical for deep lakes with moderate productivity.

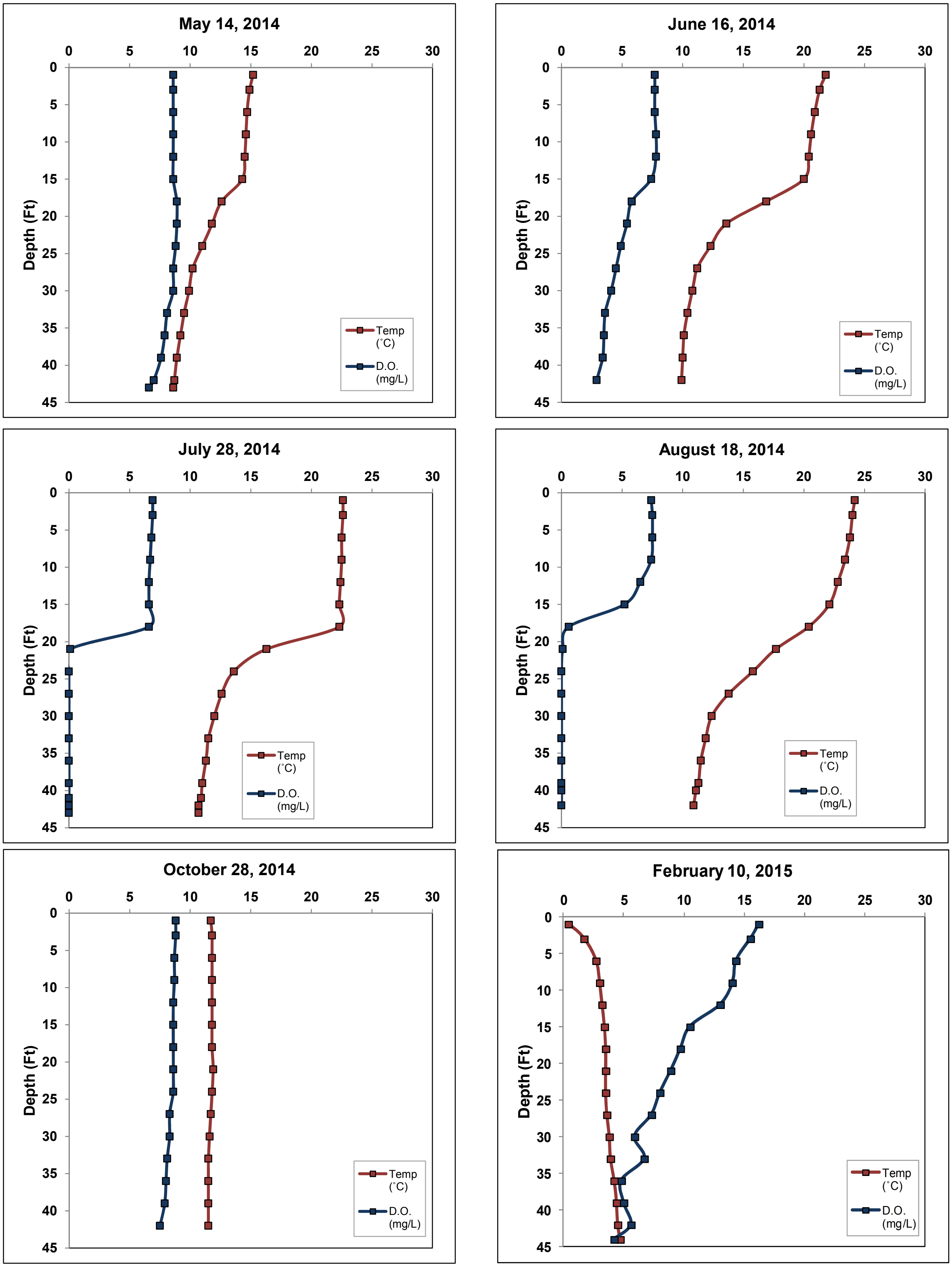


Figure 3.1-10. Long Lake temperature and dissolved oxygen profiles.

3.2 Watershed Assessment

Watershed Modeling

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.

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.

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.

A reliable and cost-efficient method of creating a general picture of a watershed's effect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

Long Lake Watershed

The surface water drainage basin, or watershed, for Long Lake encompasses approximately 12,829 acres across both Fond du Lac and Sheboygan Counties (Map 2). Forests and row crop agriculture are the largest land cover types within Long Lake's watershed, comprising 28% of the land cover each (Figure 3.2-1). Pasture/grass is the third-largest land cover type (24%), followed by wetlands (14%), Long Lake's surface (4%), rural residential areas (2%), and urban areas of both medium and high density (<1% each).

The watershed area relative to the area of Long Lake yields a watershed to lake area ratio of 27:1, meaning that there are 27 acres of land draining to every one acre of Long Lake. As discussed previously, in watersheds with large watershed to lake area ratios, the sheer size of the watershed regardless of the land cover types within the watershed may dictate the lake's water quality. Based on the size of Long Lake's watershed, the average precipitation in Fond du Lac County, and the volume of Long Lake, WiLMS estimated that the residence time or time it takes for the water in Long Lake to completely replace itself is approximately 0.88 years or 321 days. This flushing rate will likely be higher following large precipitation events and lower during periods of drought.

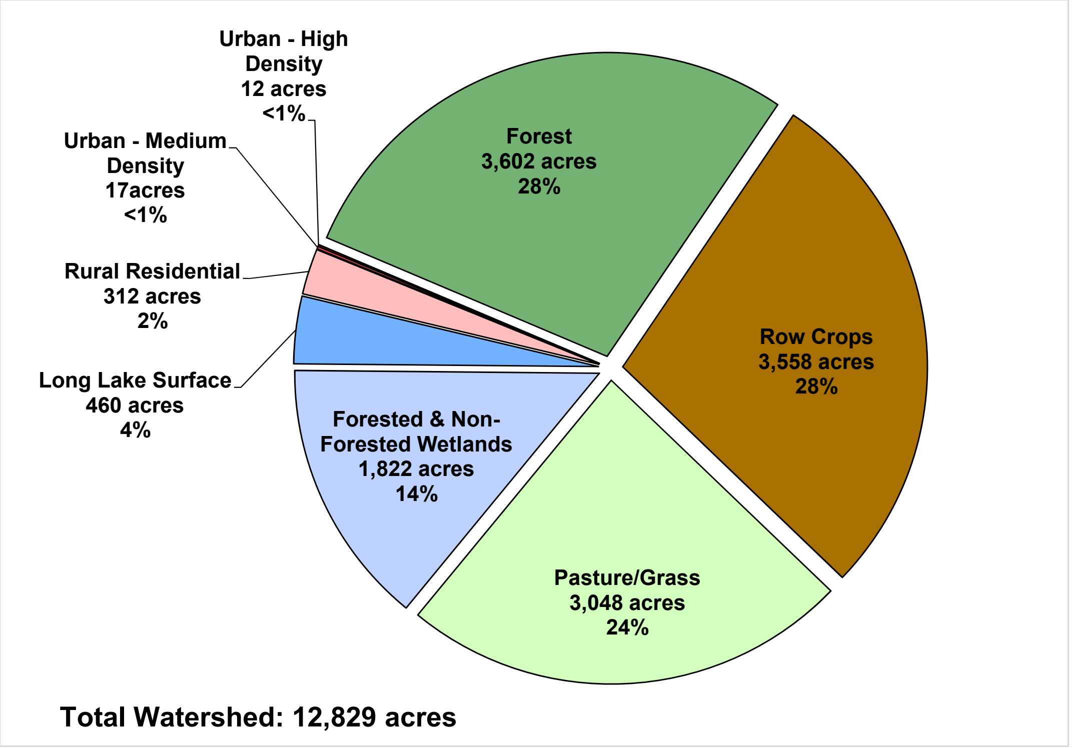


Figure 3.2-1. Long Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using WiLMS, the acreages of land cover types within Long Lake's watershed were used to determine the annual potential phosphorus load to the lake. This modeling indicated that Long Lake potentially receives an estimated 4,416 pounds of phosphorus on an annual basis. Using this annual potential phosphorus load, WiLMS predicted an in-lake average growing season total phosphorus concentration of 75.0 μg/L, which is 3.5 times higher than the average growing season mean of 20.5 μg/L actually measured within the lake from 1988-2014. The WiLMS model of Long Lake's watershed predicts that there should be significantly more phosphorus within the lake given the land cover types and their acreages within the watershed. However, WiLMS does not take into account the location of these land cover types relative to the lake or to each other.

For instance, WiLMS indicates that row crop agriculture within Long Lake's watershed contributes the majority of phosphorus to the lake, approximately 3,175 lbs per year, or 69% of the lake's annual phosphorus load. However, because the phosphorus measured within Long Lake is significantly lower than what is predicted by WiLMS indicates that most of the phosphorus from the areas of agriculture is not reaching the lake. Map 2 illustrates that the majority of land cover immediately around Long Lake and its tributaries are comprised of intact wetlands and forests. These areas likely act as a buffer between the lake and the areas of row crop agriculture and pasture/grass, absorbing and trapping phosphorus from these areas before it can enter the lake. Despite having a watershed largely comprised of agriculture, the water quality in Long Lake is more reflective of a lake with a watershed comprised entirely of natural land cover types. This highlights the importance of maintaining these natural buffer areas within the watershed, as they are the reason for Long Lake's excellent water quality.

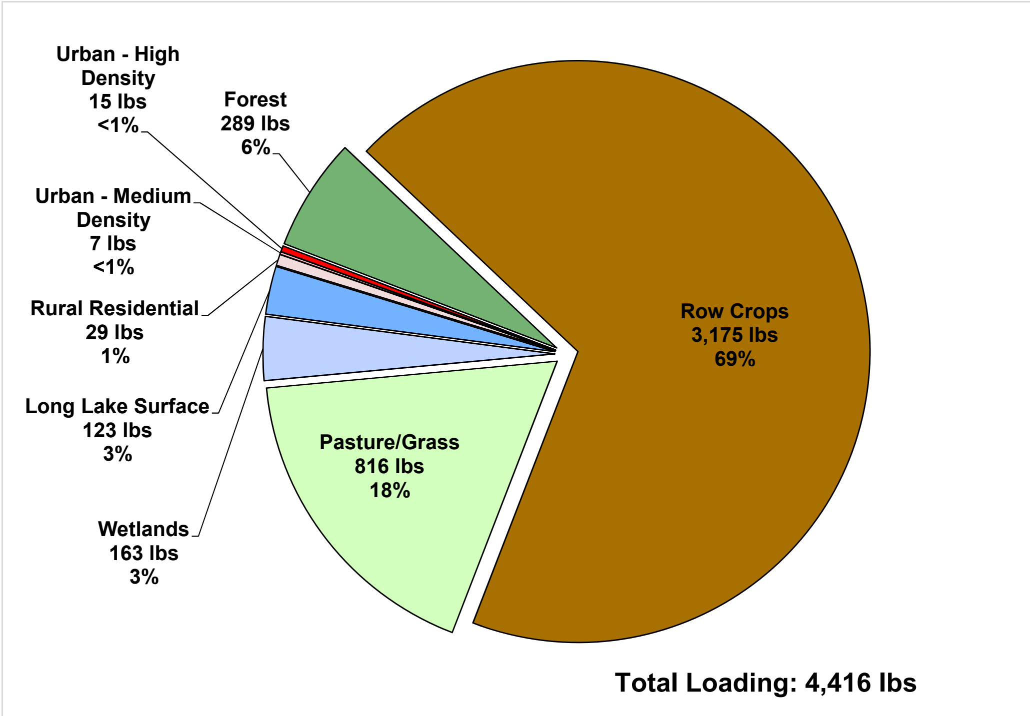


Figure 3.2-2. Long Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Approximately 60% of stakeholder survey respondents indicated they utilized a holding tank and 32% utilized a conventional septic system (Figure 3.2-3). Approximately 100% of stakeholder respondents indicate they have their septic system pumped in 4 years or less (Appendix B, Question #6).

Holding tanks allow for the temporary collection and storage of the wastewater until it can be removed and properly disposed of by a licensed waste hauler. When functioning properly, there are no impacts on the adjacent lake from holding tanks. However, holding tanks are failure prone, either by cracking and leaking out unprocessed waste water, or by illicit pumping activities by the homeowner.

Question 5: What type of septic system does your property utilize?

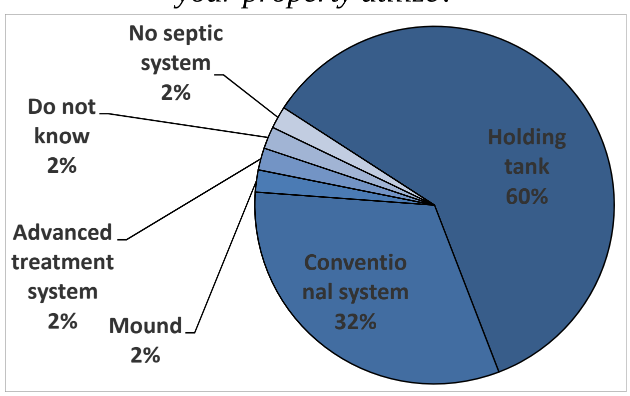


Figure 3.2-3. Select survey responses from the Long Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Mound and conventional systems function similarly; mounds are used when the groundwater is not deep enough to support a conventional system. Properly functioning mound and conventional septic systems will remove most disease-causing organisms and nutrients from the waste water. However, these systems will not remove or treat most household pollutants or chemicals.

3.3 Shoreland Condition Assessment

The Importance of a Lake's Shoreland Zone

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 more strict shoreland ordinances. Passed in February of 2010, a revised 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 of their own. The revised NR 115 was once again examined in 2012 after some Wisconsin counties identified some provisions that were unclear or challenging to implement. The revisions proposed through Board Order WT-06-12 went into effect in December of 2013. These policy regulations require each county a ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows:

- 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 the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. No permit is required for removal of vegetation that meets any of the above criteria. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- 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. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: New 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, dependent on the county.

- For county-specific requirements on this topic, it is recommended that lake property owners contact the county's regulations/zoning department.

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. Ground-water 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.

Photo 3.3-1. Example of a coarse woody habitat along natural lakeshore

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 in 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 (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*". The results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect and restore lakes. This will become increasingly important as development pressured on lakes continue to steadily grow.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & 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).

Photo 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.

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do nott allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.

- An aquatic zone with shallow-water 2 - 5' x 35' areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70' of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

Advantages	***Disadvantages***
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreland erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Once native plants are established, they require less water, maintenance, no fertilizer; provide wildlife food and habitat, and natural aesthetics compared to ornamental (non-native) varieties. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Long Lake Shoreland Zone Condition

Shoreland Development

Long Lake'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 3.3-1 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.

Urbanized: This type of shoreland 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 shorelands 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 shoreland 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 shoreland that was restored would likely be included here, also.

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

Figure 3.3-1. Shoreland assessment category descriptions.

On Long Lake, the development stage of the entire shoreland was surveyed during the fall of 2014, 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 3.3-1.

Long Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.0 miles (50%) of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). 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, 3.1 miles (39%) of urbanized and developed–unnatural shoreland were observed. If restoration of the Long Lake 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.

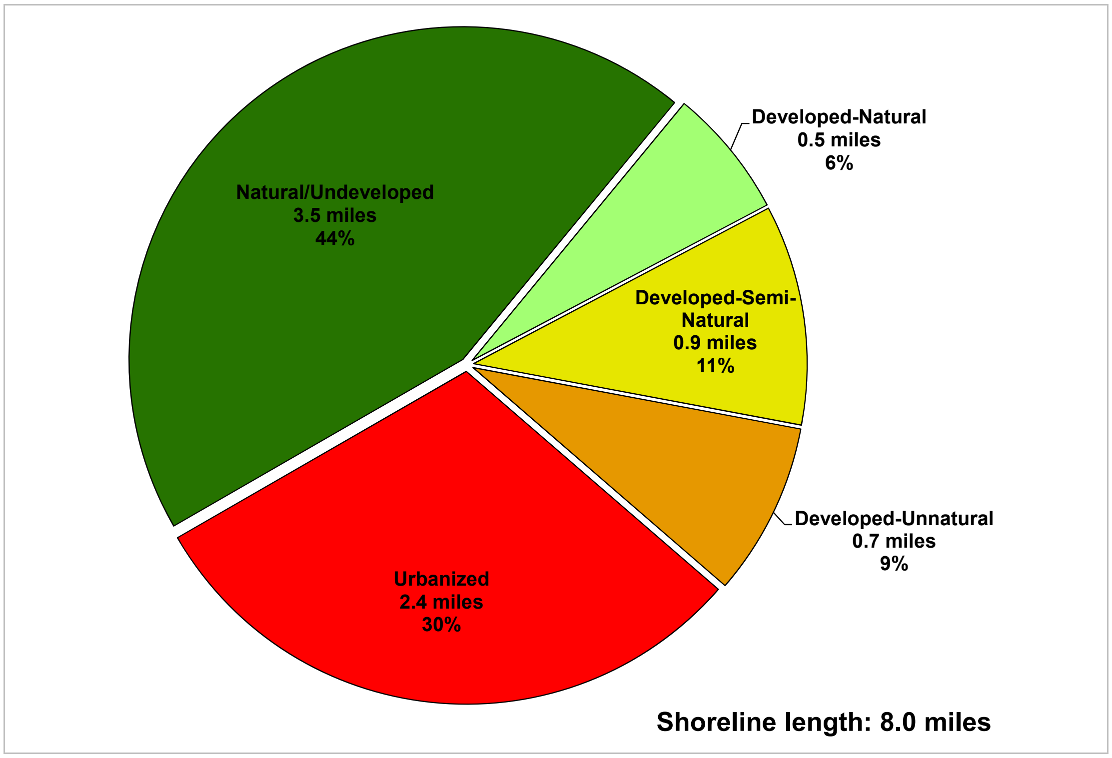


Figure 3.3-2. Long Lake shoreland categories and total lengths. Based upon a fall 2014 survey. Locations of these categorized shorelands can be found on Map 3.

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, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

Long Lake was surveyed in the fall of 2014 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 40 total pieces of coarse woody habitat were observed along 8.0 miles of shoreline (Map 4), which gives Long Lake a coarse woody habitat to shoreline mile ratio of 5:1. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

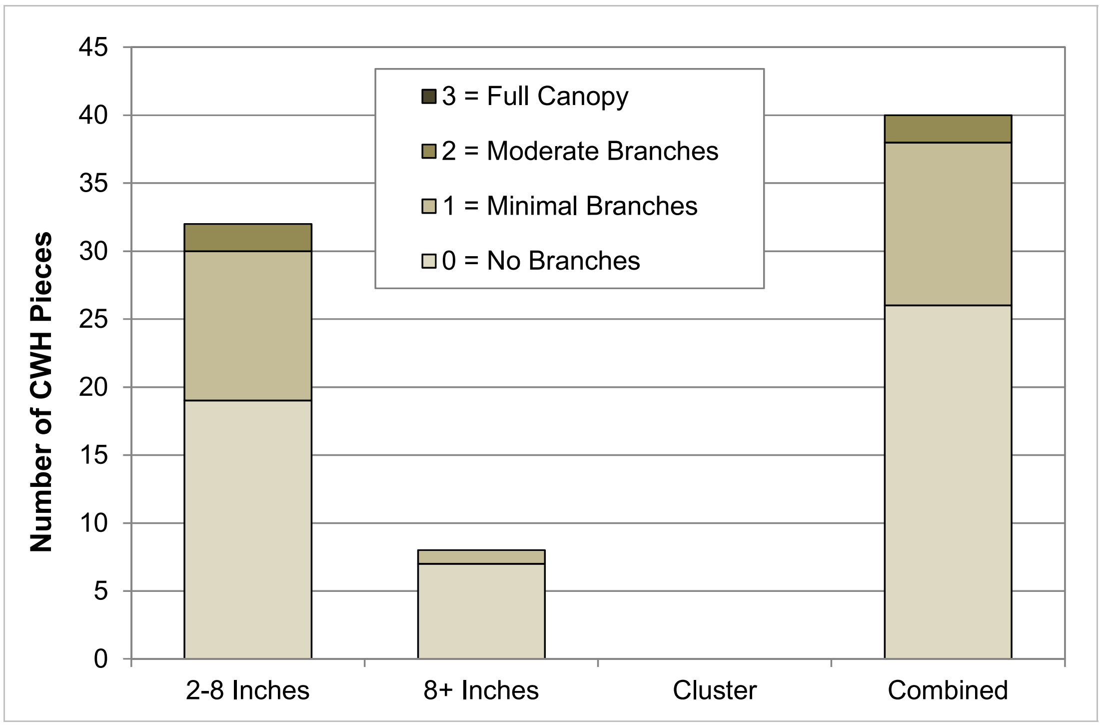


Figure 3.3-3. Long Lake coarse woody habitat survey results. Based upon a fall 2014 survey. Locations of Long Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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 water-milfoil (*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 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

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

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.

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

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

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

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

Cost

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

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

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.

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 the appendix 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. The table below provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from Netherland (2009).

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

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

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; Eurasian water milfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • 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 fishkills 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 water-milfoil 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 water-milfoil 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 water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

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

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific 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 life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain 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 Long Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Species Diversity and Richness

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to a diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

Simpson's diversity index is used to determine this diversity in a lake ecosystem. Simpson's diversity (1-D) is calculated as:

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

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

A box plot or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

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. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Long Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-1) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreland. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreland complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreland complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Long Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1). Ecoregional and state-wide medians were calculated from whole-lake point-intercept surveys conducted on 392 lakes throughout Wisconsin by Onterra and WDNR ecologists.

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.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. 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 survey and does not include incidental species or those encountered during other aquatic plan surveys.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergent species include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergent and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

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 water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian water-milfoil 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 water-milfoil 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 water-milfoil 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.

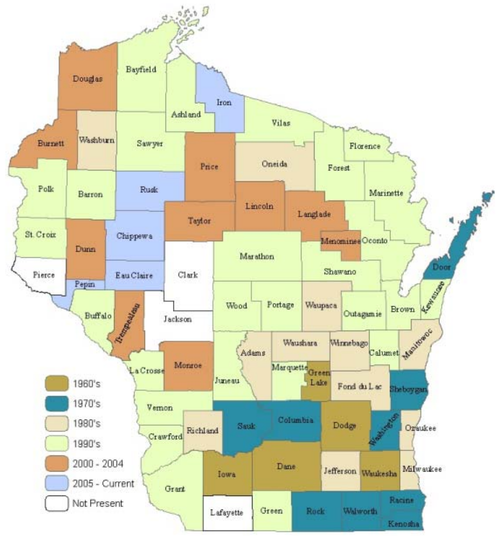


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 water-milfoil, 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 water milfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

Aquatic Plant Survey Results

> The **Littoral Zone** is the area of a lake where adequate sunlight is able to penetrate down to the sediment and support aquatic plant growth.

As mentioned above, numerous plant surveys were completed as a part of this project. On June 25, 2014, an Early-Season Aquatic Invasive Species (ESAIS) Survey was completed on Long Lake. This meander-based survey of the *littoral zone* focused upon locating occurrences of the non-native, invasive plant curly-leaf pondweed. Curly-leaf pondweed was first discovered in Long Lake in 2005 (documented by the WDNR in 2007), and the LLPA has been actively managing the population via herbicide control since its discovery. Because of its significance, the curly-leaf pondweed population and its management will be discussed in detail in the following Non-Native Aquatic Plants in Long Lake Section.

Whole-lake aquatic plant point-intercept surveys were completed by the WDNR on Long Lake in the summers of 2007, 2010, and 2013 in Long Lake, while Onterra ecologists completed the emergent and floating-leaf aquatic plant community mapping survey on August 5, 2014. Over the course of these surveys, a total of 47 aquatic plant species were located – six of which are considered to be non-native, invasive species: common reed, curly-leaf pondweed, Eurasian water milfoil, hybrid water milfoil, purple loosestrife, and reed canary grass (Table 3.4-1). Because of their significance, these non-native plants in Long Lake will be discussed in the following Non-Native Aquatic Plants in Long Lake Section.

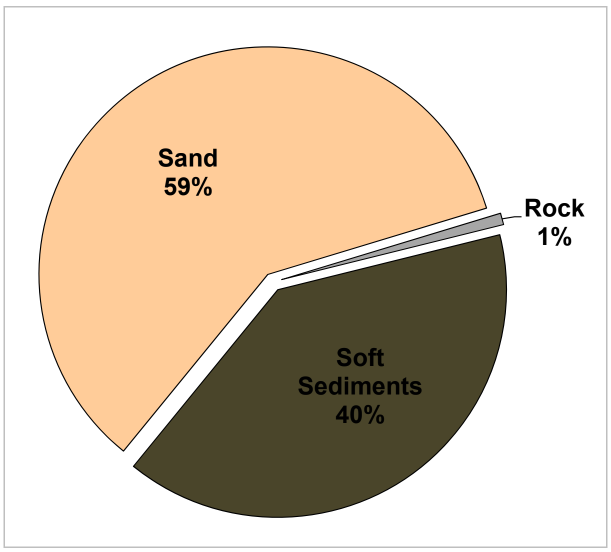


Figure 3.4-2. Long Lake 2013 proportion of substrate types. Please note sediment data were only collected at sites less than 15 WDNR 2013 whole-lake point-intercept survey.

During the WDNR's 2013 whole-lake point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that the majority (59%) of point-intercept locations less than 15 feet contained sand, 40% contained soft sediments, and 1% contained rock (Figure 3.4-2). Map 5 displays the distribution of substrate types in Long Lake as determined from the 2014 point-intercept survey. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

During the 2013 point-intercept survey, aquatic plants were found growing to a maximum depth of 19 feet. As discussed in the Water Quality Section, Long Lake has high water clarity which allows sunlight to penetrate further into the water column and support plant photosynthesis at greater depths. Of the 294 point-intercept locations that fell at or below 19 feet, 92% contained aquatic vegetation, indicating Long Lake's littoral zone is highly vegetated; only the deepest areas of Long Lake do not support aquatic plants (Map 6).

Table 3.4-1. Aquatic plant species located on Long Lake during WDNR 2007, 2010, and 2013 point-intercept surveys and Onterra 2014 community mapping survey.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2007 (WDNR)	2010 (WDNR)	2013 (WDNR)	2014 (Onterra)
Emergent	*Carex* sp.	Sedge sp.	N/A				I
	Decodon verticillatus	Water-willow	7				I
	Eleocharis robbinsii	Robbins' spike-rush	10		X		
	Lythrum salicaria	Purple loosestrife	Exotic				I
	Phalaris arundinacea	Reed canary grass	Exotic			X	
	Pontederia cordata	Pickerelweed	9				I
	Sagittaria latifolia	Common arrowhead	3				I
	Schoenoplectus acutus	Hardstem bulrush	5	X	X		I
	Schoenoplectus acutus	Hardstem bulrush	5	X	X		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4				I
	Sparganium sp.	Bur-reed species	N/A	X			
	Typha spp.	Cattail spp.	1				I
	Zizania spp.	Wild rice Species	8				I
FL	*Brasenia schreberi*	Watershield	7			X	
	Nuphar variegata	Spatterdock	6	X	X	X	I
	Nymphaea odorata	White water lily	6	X	X	X	I
FL/E	*Sparganium eurycarpum*	Common bur-reed	5				
	Sparganium fluctuans	Floating-leaf bur-reed	10	X			
Submergent	*Bidens beckii*	Water marigold	8		X	X	
	Ceratophyllum demersum	Coontail	3	X	X	X	
	Chara spp.	Muskgrasses	7	X	X	X	
	Elodea canadensis	Common waterweed	3	X	X	X	
	Heteranthera dubia	Water stargrass	6	X	X	X	
	Myriophyllum heterophyllum	Various-leaved water milfoil	7		X	X	
	Myriophyllum sibiricum	Northern water milfoil	7	X	X	X	
	Myriophyllum sibiricum X spicatum	Hybrid water milfoil	Exotic				I
	Myriophyllum spicatum	Eurasian water milfoil	Exotic				
	Najas flexilis	Slender naiad	6			X	
	Nitella spp.	Stoneworts	7	X	X	X	
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X	X	X	
	Potamogeton foliosus	Leafy pondweed	6	X			
	Potamogeton friesii	Fries' pondweed	8	X	X		
	Potamogeton illinoensis	Illinois pondweed	6		X	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X		
	Ranunculus aquatilis	White water-crowfoot	8	X	X		
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X			
	Stuckenia pectinata	Sago pondweed	3	X	X	X	
	Utricularia vulgaris	Common bladderwort	7	X	X	X	
	Vallisneria americana	Wild celery	6	X	X		
FF	*Lemna minor*	Lesser duckweed	5	X	X	X	
	Lemna trisulca	Forked duckweed	6	X	X	X	
	Spirodela polyrhiza	Greater duckweed	5	X	X		
	Wolffia sp.	Watermeal species	N/A	X		X	
S/E	*Sagittaria cuneata*	Arum-leaved arrowhead	7				I
	Sagittaria sp.	Arrowhead sp.	N/A			X	

FL = Floating-leaf; FL/E = Floating-leaf & Emergent; FF = Free-floating; S/E = Submergent & Emerge
X = Located on rake during point-intercept survey; I = Located during community mapping survey
** = Species listed as 'special concern' in Wisconsin by the WDNR Natura Heritage Inventory*

Of the 47 aquatic plant species located in Long Lake since 2007, 22 were physically encountered on the rake during the 2013 whole-lake point-intercept survey. Of these 22 species, muskgrasses, coontail, and various-leaved water milfoil were the three-most frequently encountered. Muskgrasses, a genus of macroalgae, were the most abundant aquatic plant in Long Lake in 2013 with a littoral frequency of occurrence of approximately 47% (Figure 3.4-3). Several species of muskgrasses occur in Wisconsin, though the WDNR's study did not identify these plants to the species level. As their name suggests, many muskgrasses exude a strong, skunk-like odor. They are usually found in lakes with higher alkalinity and can be found growing in sandy or mucky substrates. Muskgrasses often grow in large beds providing both structural habitat and sources of food for both aquatic and terrestrial organisms.

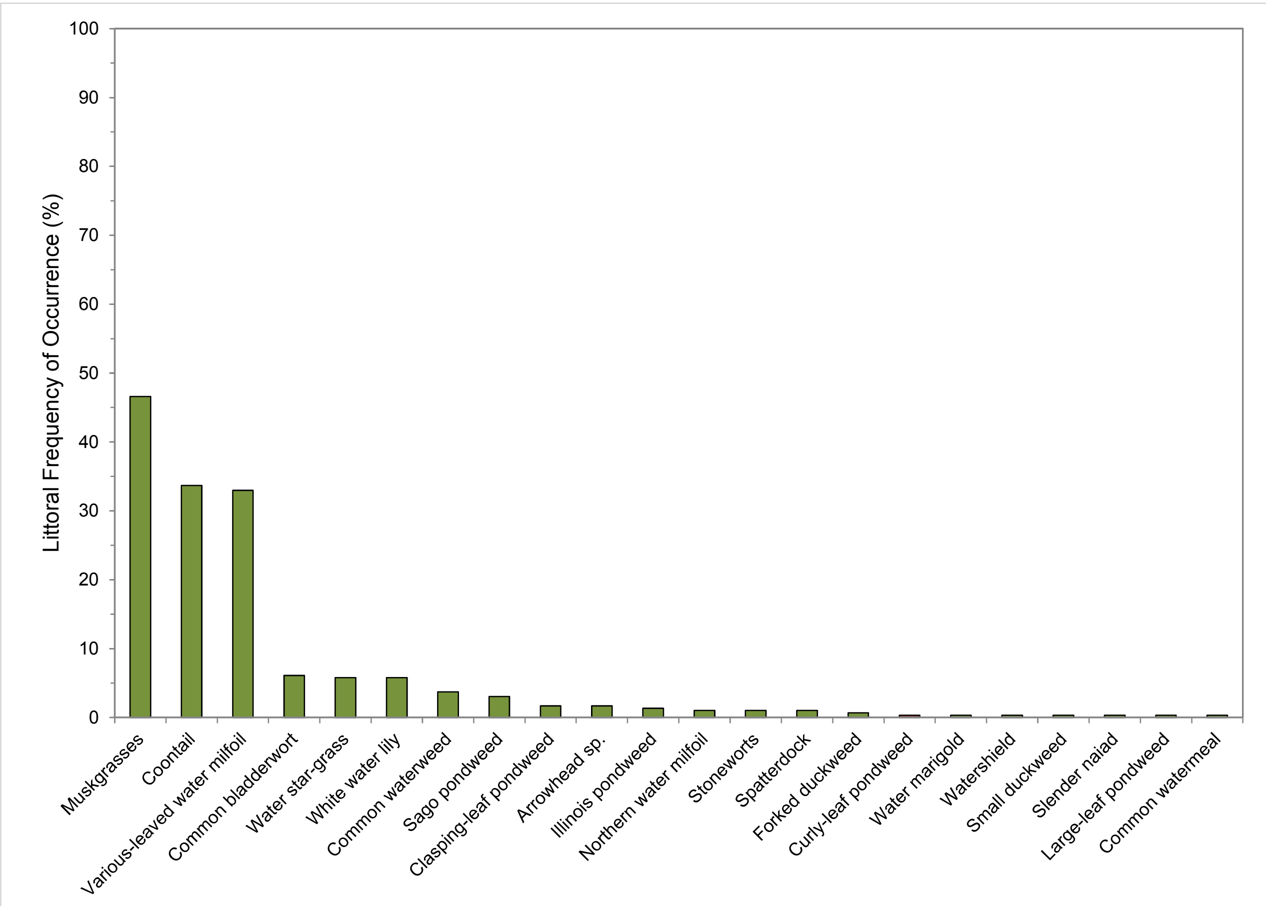


Figure 3.4-3. 2013 littoral frequency of occurrence of aquatic plant species in Long Lake. Created using data collected from 294 littoral sampling locations during the WDNR 2013 whole-lake point-intercept survey. Exotic species indicated in red.

Coontail, arguably the most common aquatic plant species in Wisconsin, was the second-most frequently encountered aquatic plant in Long Lake 2013 with a littoral frequency of occurrence of approximately 34% (Figure 3.4-3). It possesses bushy whorls of stiff leaves that resemble the shape of a raccoon's tail. Lacking roots, this species obtains the majority of its nutrients directly from the water and can grow prolifically in nutrient-rich water, often attaining nuisance levels and forming dense mats at the surface. Also able to tolerate low-light conditions, coontail is usually one of the most dominant species found in eutrophic lakes. The dense foliage of coontail provides excellent habitat for aquatic invertebrates and fish, especially in deeper water where other native aquatic plants cannot grow. While coontail has the capacity to grow to nuisance levels, no surface-matted areas of coontail were observed on Long Lake.

Various-leaved water milfoil, one of seven native milfoil species that can be found in Wisconsin, was the third-most abundant aquatic plant in Long Lake in 2013 with a littoral frequency of occurrence of approximately 33% (Figure 3.4-3). Like most of the other milfoil species in Wisconsin, various-leaved water milfoil has dense whorls of finely-dissected leaves which provide habitat for periphyton and trap detritus. In Long Lake, various-leaved water milfoil can be found growing in dense beds throughout shallower areas around the lake. These beds provide valuable structural habitat for aquatic organisms.

However, in Long Lake, some of these various-leaved water milfoil beds mat on the surface, where they can hinder navigation (Photo 3.4-1). Onterra ecologists had not observed various-leaved water milfoil growing to the densities present in Long Lake. In the northeastern United States, there is an invasive strain of various-leaved water milfoil, and because of its behavior in Long Lake, Onterra ecologists sent specimens from Long Lake to the Annis Water Resources Institute at Grand Valley State University in Michigan to undergo DNA analysis. Their results revealed that the various-leaved water milfoil present in Long Lake is of the *continental* strain, the strain that is not considered to be invasive.

Photo 3.4-1. Various-leaved water milfoil (*Myriophyllum heterophyllum*) in Long Lake.

Because ecologists from the WDNR have conducted whole-lake point-intercept surveys on Long Lake in 2007, 2010, and 2013, these data can be compared to determine if any changes in aquatic plant species' occurrence have occurred over this time period. Figure 3.4-4 displays the littoral frequency of occurrence of submersed native aquatic plant species in Long Lake from 2007, 2010, and 2013 that had an occurrence of at least 5% in one of the three surveys. Due to different aquatic plant identification skills among the WDNR surveyors, the various-leaved water milfoil was often misidentified as a different native milfoil species. Because of this and because another native milfoil is present in Long Lake, northern water milfoil, the occurrences of various-leaved water milfoil and northern water milfoil were combined for this analysis. It is also important to note that the 2007 survey was conducted in early June in order to document the occurrence of CLP within the lake. The 2010 and 2013 surveys were conducted much later in the growing season (August and September) and therefore there is flaw in directly comparing these datasets. However, it allows for a general understanding of how the plant community has changed over this period.

The WDNR data indicates that the combined occurrences of northern and various-leaved water milfoils, white water-crowfoot, sago pondweed, Fries' pondweed, and clasping-leaf pondweed all exhibited statistically valid reductions in their occurrence from 2007-2013 (Chi-square $\alpha = 0.05$) (Figure 3.4-4). These data also indicate that coontail, common bladderwort, and muskgrasses exhibited statistically valid increases in their occurrence from 2007-2013.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, and disease among other factors. It is not known which factor(s) caused the detected changes in occurrence of the aquatic plant species discussed in Long Lake. Small fluctuations in the occurrence of certain species over time are to be expected. However, if large reductions in occurrence or a complete loss of a species were observed, it may indicate an environmental disturbance such as pollution or displacement from invasive species. The large declines of white water-crowfoot are likely related to the phenology of this species, as it is typically observed more abundant early in the growing season and senesces (dies off) as the summer progresses. Conversely, common bladderwort is less abundant in early June when the 2007 point-intercept survey was conducted and therefore the increases observed within Figure 2.4-4 are likely a result of sampling at different times of the years. While small increases and decreases of other species were noted over this time period, these are likely a result of natural interannual variation.

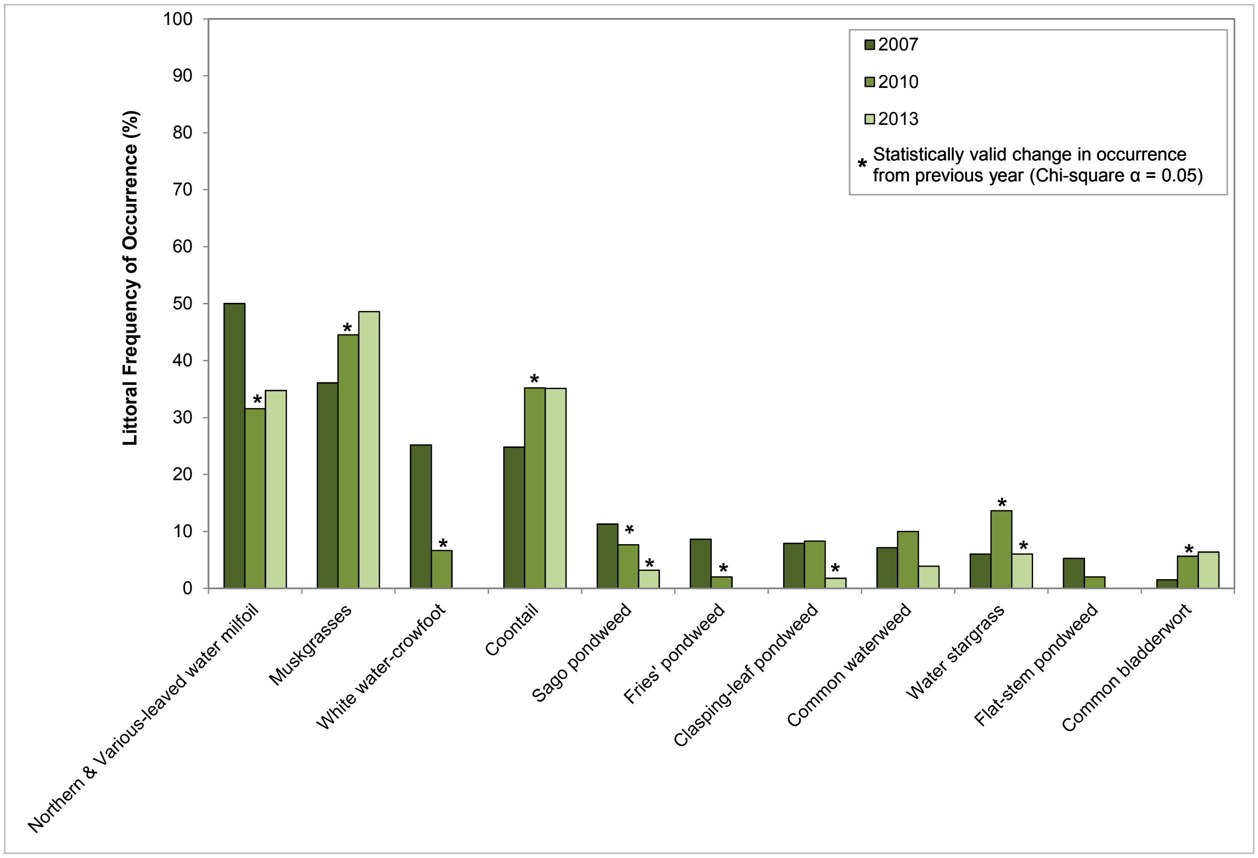


Figure 3.4-4. Littoral frequency of occurrence of select aquatic plant species in Long Lake from 2007, 2010, and 2013. Please note that only those species with a littoral frequency of occurrence of at least 5% in one of the three surveys are included. Created using WDNR 2007, 2010, and 2013 whole-lake point-intercept survey data.

As discussed in the primer section, the calculations used to create 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 each point-intercept survey and does not include species located during Onterra's 2014 community mapping survey. The native species encountered on the rake during the 2007, 2010, and 2013 point-intercept surveys and their conservatism values were used to calculate the FQI of Long Lake's aquatic plant community (equation shown below).

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Figure 3.4-5 compares Long Lake's FQI components to median values of lakes within the Southeast Wisconsin Till Plain (SWTP) ecoregion and lakes throughout Wisconsin. The number of native species detected during each point-intercept survey ranged from 26 in 2010 to 21 in both the 2007 and 2013 surveys. All of these species richness values fall above the median values for lakes within the SWTP ecoregion and for lakes throughout Wisconsin. Long Lake's average conservatism values were 5.9, 6.2, and 5.5 in 2007, 2010, and 2013, respectively. These values fall above the median value for lakes within the SWTP ecoregion, but fall below the median for value for lakes throughout the state. The FQI values, which incorporate both species richness and the average conservatism, fall above the median value for lakes in the SWTP ecoregion and are more comparable to the median value for lakes state-wide. Overall, this analysis indicates that the aquatic plant community of Long Lake is of higher quality than most lakes in the SWTP ecoregion and more comparable to lakes throughout Wisconsin.

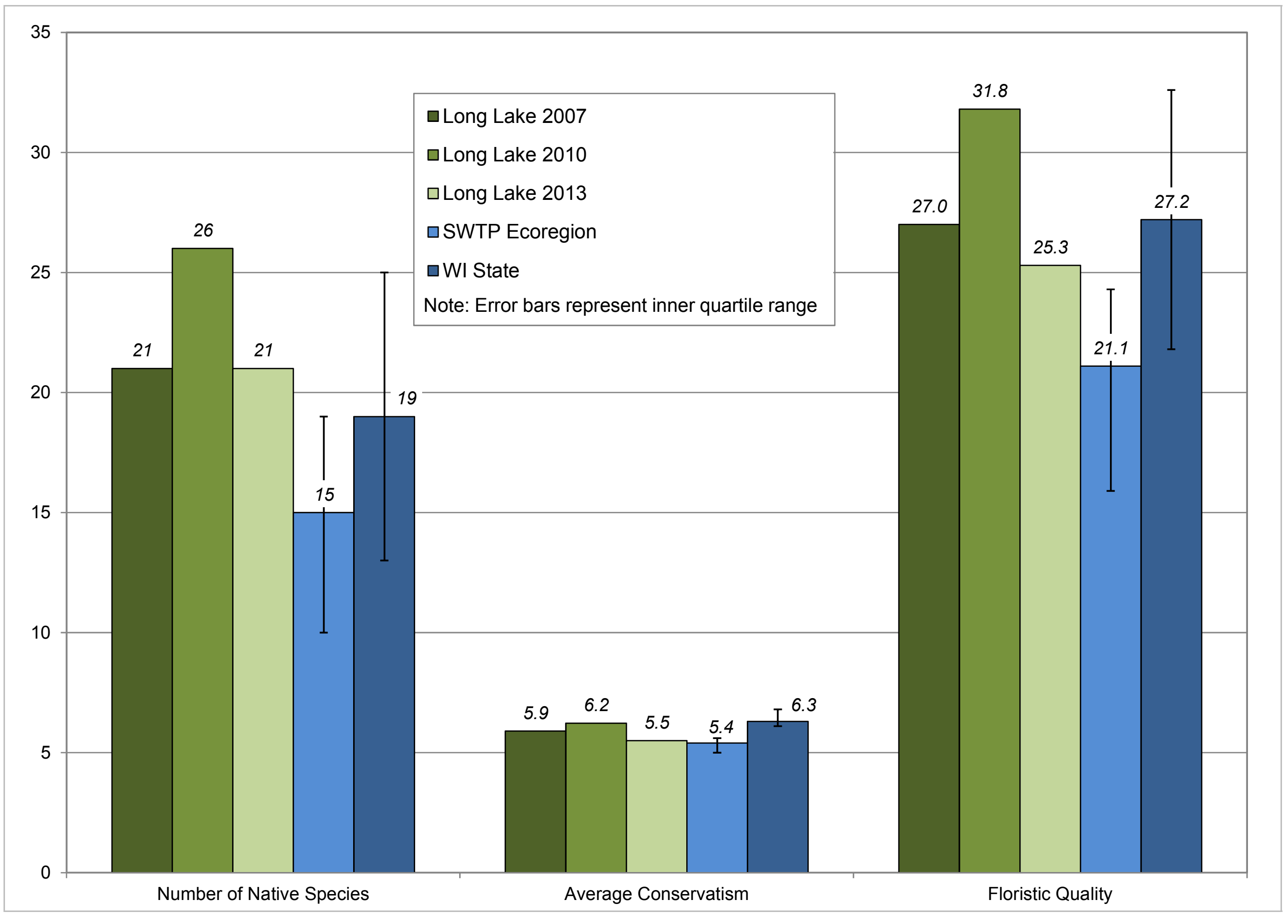


Figure 3.4-5. Long Lake Floristic Quality Assessment. Created using data from WDNR 2007, 2010, and 2013 whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data.

As explained earlier, lakes with diverse aquatic plant communities are believed to have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Long Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Long Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the SWTP Ecoregion (Figure 3.4-6). Simpson's Diversity Index values were calculated for Long Lake using the 2007, 2010, and 2013 whole-lake point-intercept data. In 2007 and 2010, Long Lake had high species diversity, with values of 0.92 and 0.89, respectively. Both of these values exceeded the median diversity value for lakes in the SWTP ecoregion and for lakes throughout the state. However, species diversity was 0.80 in 2013, falling below the median value for lakes in the SWTP ecoregion and near the lower quartile for lakes in the state. In other words, if two individual aquatic plants were randomly sampled from Long Lake in 2013, there would be an 80% probability that they would be different species.

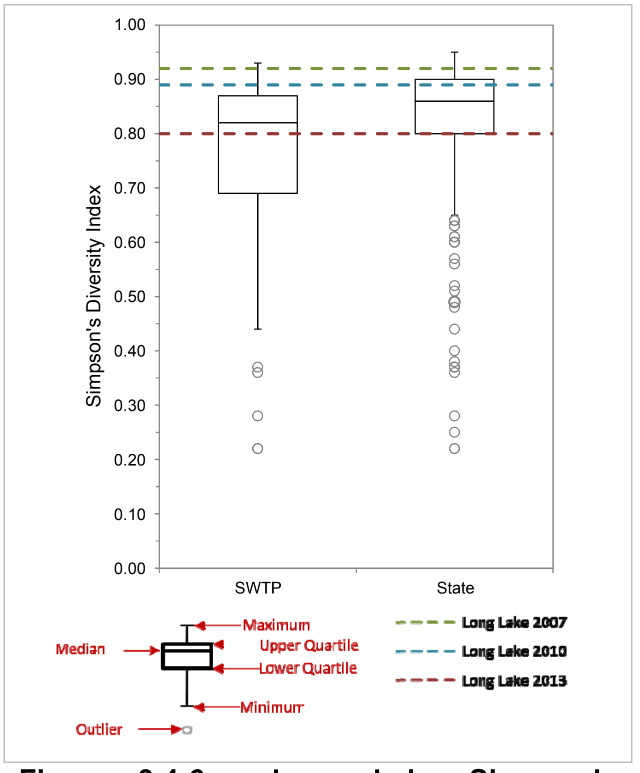


Figure 3.4-6. Long Lake Simpson's Diversity Index. Created using data from WDNR 2007, 2010, and 2013 whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data.

As discussed earlier, many aquatic plant species saw reductions in their occurrences in 2013 when compared to 2007 and 2010 – the reason for which is not clear. The low diversity in 2013 is due to a dominance of the plant community by three species: muskgrasses, coontail, and various-leaved water milfoil. Figure 3.4-7 displays the relatively frequency of occurrence of aquatic plant species from 2013. As discussed previously, 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, muskgrasses were found at 47% of the littoral sampling locations in Long Lake in 2013, their relative frequency of occurrence was 31%. Explained another way, if 100 plants were randomly sampled from Long Lake in 2013, 31 of them would be muskgrasses. Greater than 75% of Long Lake's plant community was comprised of just three species in 2013.

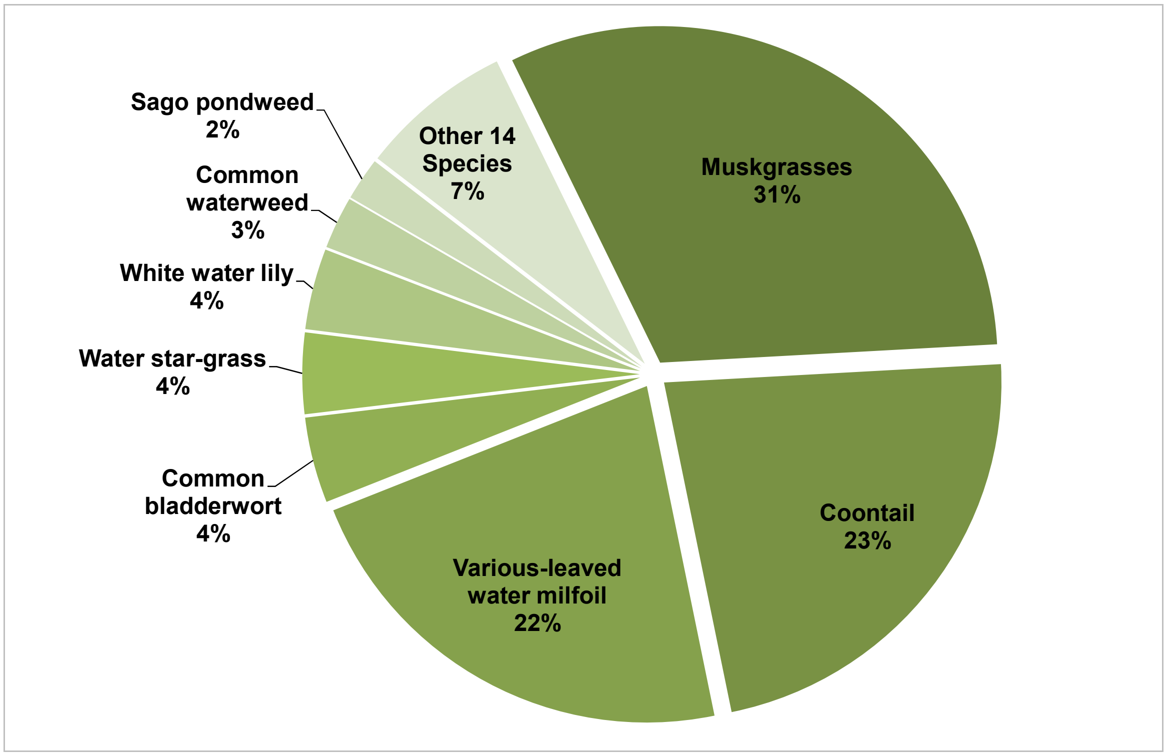


Figure 3.4-7. Relative frequency of occurrence of aquatic plant species in Long Lake in 2013. Created using data from WDNR 2013 whole-lake point-intercept survey.

As mentioned, Onterra ecologists also conducted an aquatic plant community mapping survey in 2014 aimed at mapping communities of emergent and floating-leaf vegetation. During this survey, approximately 47.8 acres of emergent and floating-leaf aquatic plant communities comprised of 13 native species were delineated (Table 3.4-1, Table 3.4-2, Map 7 and 8). Continuing the analogy that the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Long Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines 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 shorelines.

Table 3.4-2. Acres of emergent and floating-leaf aquatic plant communities on Long Lake in 2014. Created using data from 2014 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	6.6
Floating-leaf	38.5
Mixed Emergent & Floating-leaf	2.7
Total	**47.8**

Non-native Aquatic Plants in Long Lake

Eurasian water milfoil and Curly-leaf pondweed

Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first documented in Long Lake in 2002. In 2013, EWM specimens from Long Lake were sent to the Annis Water Resources Institute at Grand Valley State University in Michigan for DNA analyses, and their results revealed that Long Lake contains both pure strain EWM and hybrid water milfoil (*M. sibiricum X spicatum*; HWM). Hybrid water milfoil is a cross between EWM and the indigenous northern water milfoil. EWM in Long Lake has been periodically targeted for control via herbicides since 2007.

Curly-leaf pondweed (*Potamogeton crispus*; CLP) is listed as being officially documented from Long Lake in 2007, though it is believed to have been introduced to the lake some time earlier. Since 2005, the LLPA has been actively managing the CLP population within Long Lake utilizing herbicide treatments. In 2010, the LLPA contracted with Onterra to plan and monitor their aquatic invasive species control plan.

Background on Herbicide Application Strategy

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 dilute herbicide concentration within aquatic systems. Understanding concentration-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 a joint research project between the WDNR, USACE, and private consultants. Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) spot treatments and 2) whole-lake 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, and the strategy utilized to date on Long Lake.

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.

Long Lake Treatment History

The herbicide treatments that occurred on Long Lake from 2000-2006 were not targeting EWM or CLP but were conducted to control nuisance growth of native aquatic plants (including algae) to improve navigation in specific areas of the lake (Figure 3.4-8). These treatments were all less than five acres in size and used a variety of different herbicides. While a small treatment was conducted in 2007 aimed at controlling nuisance native plants, this year saw the first treatment on Long Lake targeting EWM and CLP. Approximately four acres of EWM were applied with liquid 2,4-D and approximately eight acres of CLP were applied with liquid endothall in 2007. Liquid endothall treatments targeting CLP continued in 2009 and 2010.

In 2010, the LLPA contracted with Onterra and initiated a three-year aquatic invasive species monitoring and control project, aimed at reducing the CLP and EWM populations in Long Lake from 2011-2013. The monitoring and treatments of CLP will be discussed first, followed by a discussion on the monitoring of treatment of EWM. The goal of the CLP control project was to reduce the treatable acreage of CLP within the lake over the course of this period. Curly-leaf pondweed primarily reproduces annually via structures called turions (asexual reproductive structures). The majority of the turions are produced along the stem in the leaf axils and fall to the bottom of the lake in early summer when the plants die back. Some turions are produced lower on the plant and along the underground rhizome. The turions lie dormant until autumn when they germinate to produce small winter foliage. While not really growing, the fact that these plants exist under the ice gives this plant a head start on outcompeting many of our native species in the spring. The intent of any CLP treatment is to kill the plants before they produce and release their turions. A single year of treatment effectively controls a single year of CLP without allowing it to produce subsequent generations. Still, in most scenarios, treatment areas need to be focused on for 5-7 years until the turion base within that area is exhausted.

In April of 2011, Onterra ecologists visited Long Lake to conduct a meander-based survey of littoral areas to locate and map CLP in order to create treatment areas for 2011. Mapping of CLP in the early spring is not Onterra's standard protocol as it is difficult and sometimes impossible to accurately identify treatable areas as the plants are smaller at this time of year. Normally, CLP is mapped in mid-to-late June when these plants are at or near their peak growth. The LLPA understood that if weather or lake conditions would not permit an effective survey, no treatments would occur during the spring of 2011. During the late-April survey, despite very clear water, CLP was not able to be viewed from the surface. A submersible video camera was then lowered which revealed that the CLP was still very small and growing close to the bottom. It was determined that it was still too early to accurately assess and map CLP within the lake, and Onterra ecologists returned in mid-May and completed the survey. Following this survey, approximately 42 acres of CLP were applied with liquid endothall at a rate of 1.9 ppm active ingredient (ai) (Figure 3.4-8). Please refer to the 2011 Treatment Report for further details.

Prior to 2011, no formal monitoring of the CLP treatments in Long Lake had occurred. While quantitative data regarding the 2011 CLP treatment were not able to be collected due to the timing of the start of the project in the spring, Onterra ecologists visited Long Lake in June 2011 to assess the treatment areas and to map CLP throughout the entire lake. This survey revealed that the 2011 treatment was met with mixed results, with some areas showing signs of success while others still had significant amounts of CLP within them. In addition, CLP was located outside of the treatment areas indicating it had gone undetected during the May pre-treatment survey, which is a major limitation of using an early spring survey to plan a treatment for that same spring.

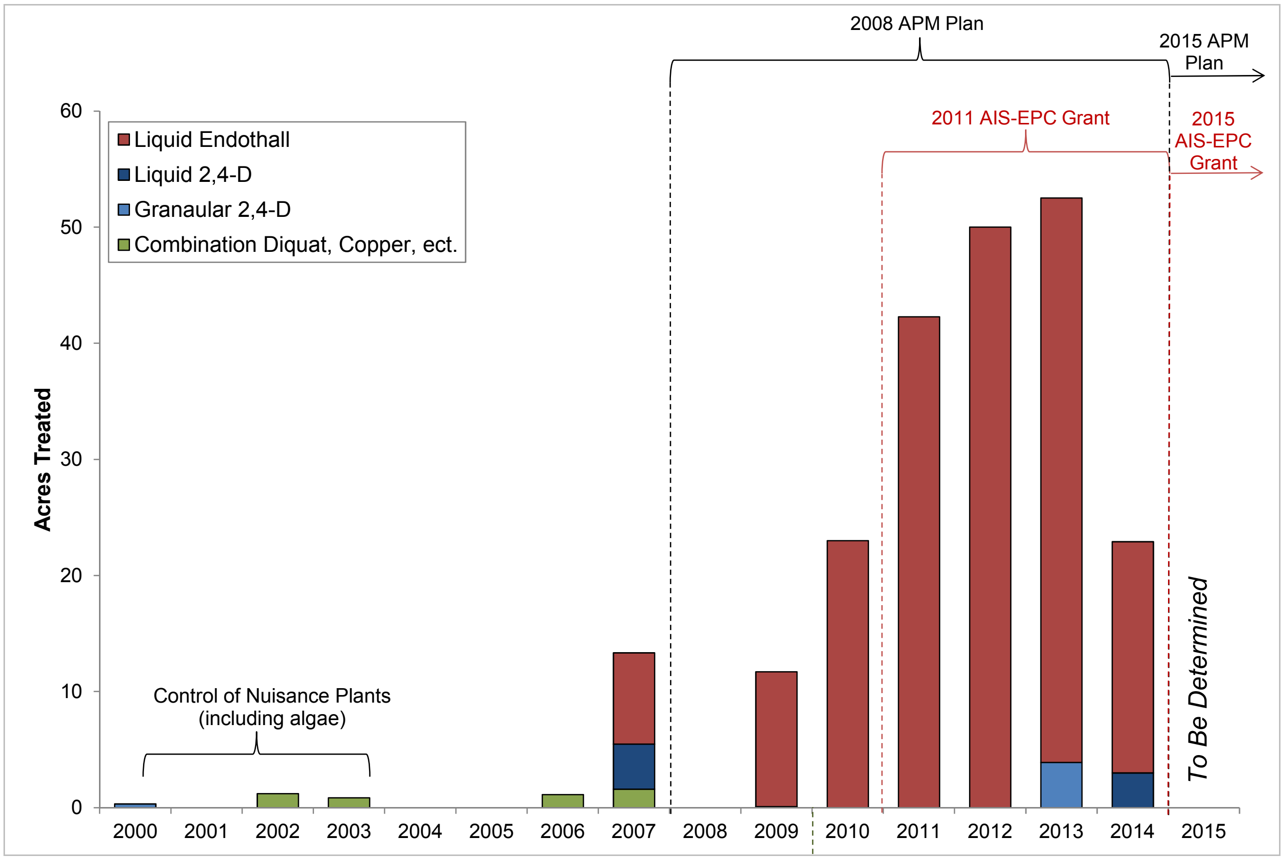


Figure 3.4-8. Long Lake historical treatment acreage.

Over half of the 2011 treatment acreage (22.8 acres) were comprised by four treatment sites that were approximately five acres or larger. All of these treatment sites were considered successful as evidenced by having few or no CLP occurrences within them following the treatment (Map 9). The remaining treatment areas fell into what is termed the "micro-treatment" subcategory. Emerging information suggests that in order for an application of 1.9 ppm ai endothall to be effective at controlling CLP, the concentration likely needs to be maintained for at least 8-12 hours (or longer). That length of exposure time is very difficult to achieve, especially in micro-treatment situations. Some of the micro-treatments were shown to be effective likely because they were all positioned in relatively sheltered areas where dilution of herbicide has been shown to be less rapid. Many of the narrow treatment sites along the western part of the lake were found to contain CLP following the treatment, likely indicating that the treatment was not completely effective in these areas.

While the 2011 treatment killed CLP that sprouted from turions in 2011, many viable turions produced in previous years were likely still present within the sediment in these areas. It is unknown exactly how long turions can remain viable in the sediment, but it is believed to be at least 3-5 years. For this reason, all of the areas that were treated in 2011 were proposed to be retreated in 2012. Multiple years of treatment over these same areas in most instances needs to occur to kill CLP sprouting from previously deposited turions.

One of the major goals of the AIS project is to monitor the treatment effectiveness and 'tune' or refine the treatment strategy in order for the most effective results to be achieved. With the new information learned, treatment areas proposed for 2012 that were less than five acres were proposed to be treated with liquid endothall at an increased rate of 2.5 ppm ai, while treatments greater than five acres will be treated at a rate of 2.0 ppm ai. A few of the 2012 proposed treatment sites were approaching a point at which the herbicide application areas are too small to consistently predict if the endothall will cause CLP mortality, regardless of the dose rate. Therefore, potential treatment sites less than 0.5 acres were not proposed for treatment due to their extremely small size and unlikely nature of being successful. Following the 2012 pre-treatment survey, approximately 52 acres of CLP were applied with liquid endothall in 2012 (Figure 3.4-8). Please refer to the 2012 Treatment Report for further details.

The post-treatment survey of the 2012 CLP treatment areas revealed that the treatment was highly successful, with most areas exhibiting reductions in CLP (Map 9). However, for reasons discussed previously regarding the sprouting of still dormant turions, the 2012 CLP treatment areas were proposed to be retreated in 2013. Like in 2012, the application rate of the herbicide was proposed to be increased to 3.0 ppm ai for areas of less than five acres, while areas greater than five acres would be applied at a rate of 2.5 ppm ai. Following the 2013 pre-treatment survey, a total of 48.6 acres of CLP were applied with liquid endothall (Figure 3.4-8). Qualitative assessment of the 2013 treatment indicated that CLP density was reduced in most areas, indicating a successful treatment. As in the past treatments, the 2014 treatment strategy proposed retreating all areas treated in 2013 to target dormant turions. Please refer to the 2013 Treatment Report for further details.

During the 2014 pre-treatment survey, CLP could not be located in a number of the proposed treatment areas, indicating that the multiple years of treatment has exhausted the turion base within these areas. The proposed 2014 CLP treatment of 48.6 acres was reduced to 19.9 acres following this survey (Figure 3.4-8). Liquid endothall was applied to the 2014 treatment areas at a rate of 2.5-3.5 ppm ai. Post-treatment survey results showed that CLP was reduced in all of the 2014 treatment areas, indicating a successful treatment (Map 10). Single plants were located widely scattered throughout littoral areas, but only a few small colonized of CLP were located outside of the 2014 treatment areas.

It is difficult, if not impossible, to assess the efficacy of a single year of treatment on a lake's CLP population. CLP naturally senesces (dies back) in early summer, making it is difficult to determine if a reduction in CLP following a spring treatment was caused by the treatment, natural senescence, or both. However, quantitative sub-sample point-intercept data collected annually in the spring prior to treatment within treatment areas allows for a determination if the CLP population is being reduced over time. As discussed, the goal of CLP management is to annually kill the plants before they are able to produce and deposit new turions, and thus, overtime, deplete the existing turion bank within the sediment. Over the course of multiple annual CLP treatments, these annual sub-sample point-intercept surveys should quantitatively document a reduction in CLP occurrence as the turion base is depleted.

In Long Lake, quantitative evaluation was made through the collection of data at 115 point-intercept sub-sample locations located within CLP treatment areas from 2012-2014 (Figure 3.4-9). At each of these locations, the presence (or absence) of CLP was recorded. The presence of native aquatic plant species were not recorded as most of these plants are not actively growing at this time of year. Comparing these data from year to year allows for a statistical comparison of CLP occurrence and a quantitative determination of the CLP population over time.

Figure 3.4-10 displays the frequency of occurrence of CLP from these 115 point-intercept sampling locations from April 2012, May 2013, June 2013, and June 2014. Comparing the 2012 pretreatment CLP occurrence (17.4%) with the 2014 pretreatment CLP occurrences shows a statistically valid reduction in its occurrence over the course of the project. The reduction in CLP occurrence recorded in 2014 indicates that the repeat treatments since 2011 are beginning to deplete the turion base in Long Lake, and consequently, less CLP is sprouting.

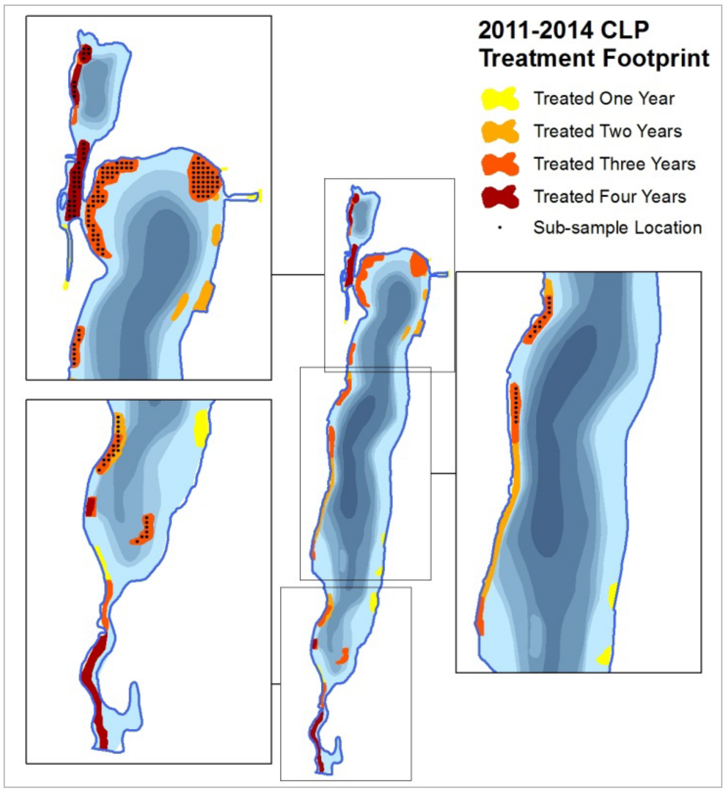


Figure 3.4-9. 2011-2014 treatment footprint and sub-sampling monitoring plan. 115 sub-sample locations located in areas of Long Lake targeted for multiple years of CLP treatment.

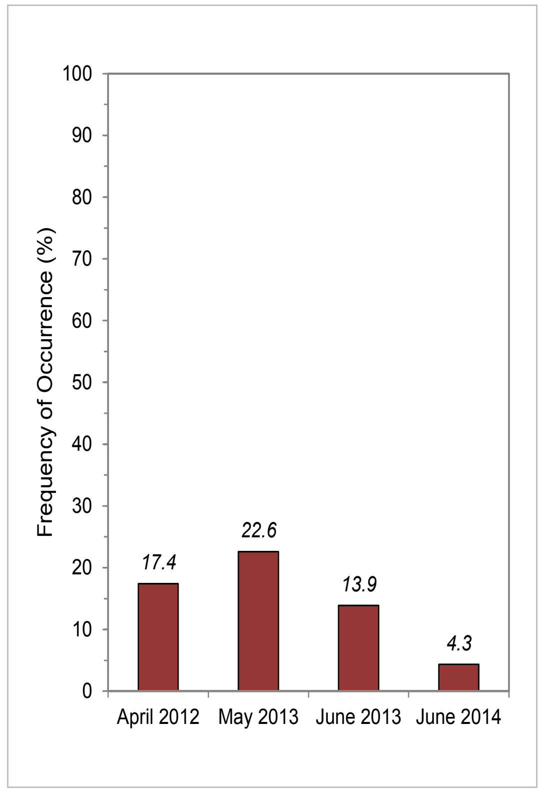


Figure 3.4-10. Sub-sampling monitoring results. Frequency of occurrence of CLP as determined from 115 sub-sample point-intercept locations in Long Lake.

Eurasian water milfoil surveys were also conducted by Onterra since 2011 (Map 11); however, a treatment was not found to be warranted until 2013 where approximately 3.9 acres were applied with granular 2,4-D at rates of 3.5 and 4.0 ppm acid equivalent (ae) (Figure 3.4-8). Please refer to the yearly treatment reports for further details. The treatment areas were too small to conduct quantitative monitoring, but qualitative assessments of the EWM treatment areas following the 2013 treatment indicated that the density of EWM had been reduced in both treatment areas. The 2013 EWM treatment was deemed highly successful. In 2014, approximately 3.0 acres of EWM was targeted for treatment within the southern channel of the lake. This area was applied with liquid 2,4-D at a rate of 3.0 ppm ae. The 2014 post-treatment survey revealed this treatment was highly successful, as very little EWM was located within this area (Map 12). The 2014 lake-wide survey for EWM indicated that the EWM population in Long Lake is currently very small, mainly comprised of single plants (Maps 11 and 12).

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

Purple loosestrife populations were located primarily along the northern and southern shores of Long Lake (Map 6 and 7) in 2014. The abundance of this plant is of concern, and it may spread further throughout the system if management of its population is not conducted. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal.

Reed canary grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach three to six feet in height. Reed canary grass was recorded during the WDNR 2013 point-intercept survey on Long Lake; however, the occurrence of this species was not recorded during Onterra's 2014 community mapping survey (Map 6 and 7). Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and exposed lake shorelands.

Reed canary grass is difficult to eradicate; at the time of this writing there is no efficient control method. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

Common Reed (aka *Phragmites*)

Common reed (*Phragmites australis* subsp. *australis*) is a tall, perennial grass that was introduced to the United States from Europe. A native strain (*P. australis* subsp. *americanus*) of this species also exists in Wisconsin and the plant material collected from Long Lake in 2014 was inconclusive to whether it was the native or non-native train. Suspected to be the non-native strain, this species can form towering, dense colonies that overtake native vegetation and replace it with a monoculture that provides inadequate sources of food and habitat for wildlife.

Because this species has the capacity to displace the valuable wetland plants along the exposed shorelines, it is recommended that additional plant samples are collected and investigated for identification. Additional information regarding the control of common reed is included within the Implementation Plan Section (5.0).

3.5 Fisheries Data Integration

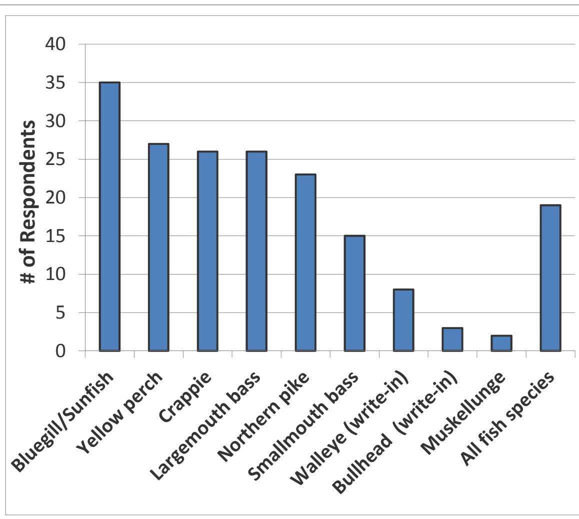
Fisheries management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Long Lake. The goal of this section is to provide an overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by LLPA stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2014).

Long Lake Fishery

Long Lake Fishing Activity

According to stakeholder survey respondents, *Open Water Fishing* and *Ice Fishing* were the 2nd and 7th activities that were considered the most important reasons for owning or renting property on Long Lake (Appendix B, Question #14). As a part of this study, Long Lake stakeholders were asked about their perceptions of their lake's quality of fishing through an anonymous stakeholder survey. As shown on Figure 3.5-1, the stakeholders that responded to the survey have fished on the lake for a large number of years and largely target panfish species. Approximately 39% of stakeholder respondents indicated that the quality of Long Lake's fishery was *Fair*, with more respondents describing the fishery as better than *Fair* (pooled *Good* and *Excellent*, 41%) in comparison to *Poor* (20%) (Appendix B, Question #11). The respondents also indicate that the quality of fishing gotten worse (pooled *Much Worse* and *Somewhat Worse*, 53%) or has remained the same (24%) since first fishing on the lake (Appendix B, Question #12). Only 22% of stakeholder respondents described the quality of fishing as getting better (pooled *Much Better* and *Somewhat Better*).

Question 10: What species of fish do you like to catch on Long Lake?



Question 8: For how many years have you fished on Long Lake?

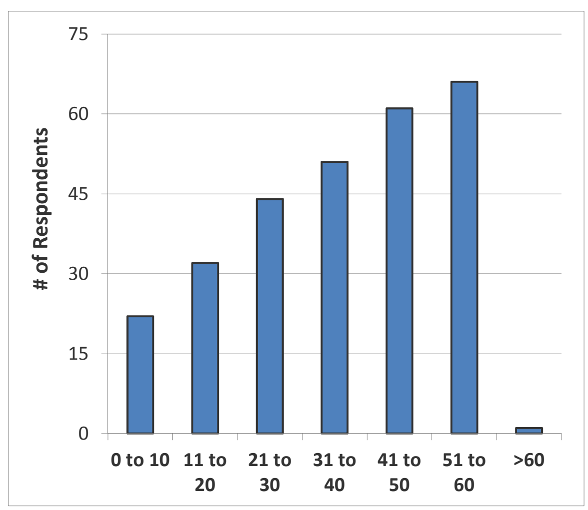


Figure 3.5-1. Select survey responses from the Long Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Table 3.5-1 shows the popular game fish that are present in the system. 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 Long Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous 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 3.5-2.

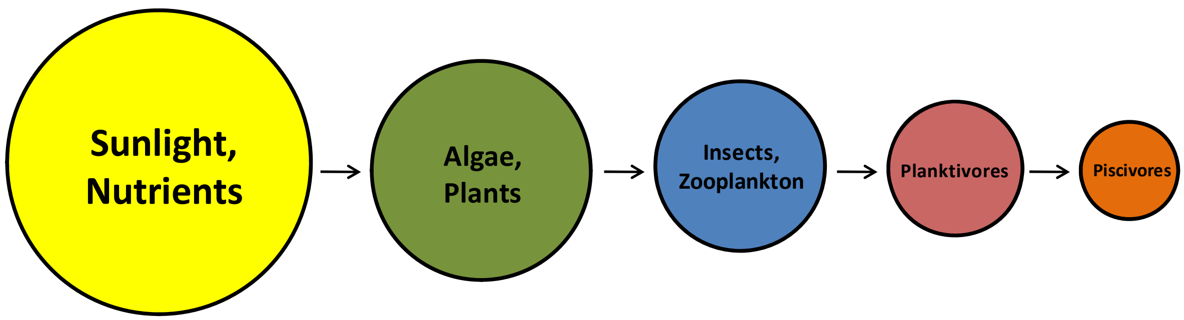


Figure 3.5-2. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Long Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Long Lake should be able to support an appropriately sized population of predatory fish (piscovores) when compared to eutrophic or oligotrophic systems.

Table 3.5-1. Gamefish present in the Long Lake with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Common Carp	*Cyprinus carpio*	47	April - August	Shallow, weedy areas from 3 - 6 ft	Insect larvae, crustaceans, mollusks, some fish and fish eggs
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
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
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass	*Micropterus 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, wave-washed 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

Long Lake Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities.

Table 3.5-2 displays the historic stocking records for Long Lake. Walleye stocking continues to be an emphasis in Long Lake with the purpose of maintaining recreational opportunity as natural reproduction of walleye has had limited or no success.

Table 3.5-2. Fish stocking data available from the WDNR from 1983 to 2014 (WDNR 2014).

Year	Species	# Stocked	Avg. Length (inches)
1983	Walleye	427,000	1
1984	Walleye	22,000	1
1984	Walleye	460,000	2
1985	Walleye	32,512	3
1985	Walleye	2,038,515	1
1986	Walleye	19,440	3
1987	Walleye	70,824	4
1988	Walleye	1,672	5
1989	Walleye	25,667	3.33
1990	Walleye	4,240	4
1991	Walleye	25,895	4
1992	Walleye	6,470	4
1993	Walleye	4,617	3
1995	Walleye	25,052	3.7
1996	Walleye	4,000	5
1997	Walleye	23,130	3.05
1998	Walleye	100,000	
1999	Walleye	41,700	1.5
2001	Walleye	41,700	1.3
2003	Walleye	41,695	1.5
2003	Walleye	150,000	0.5
2004	Northern Pike	240,000	1
2005	Walleye	24,552	1.7
2009	Walleye	14,495	1.8
2011	Walleye	16,050	1.9
2013	Walleye	14,570	2

Long Lake Substrate and Near Shore Habitat

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

According to the point-intercept survey conducted by Onterra, 59% of the substrate sampled in the littoral zone on Long Lake was sand, 40% was soft sediments (muck) and the remaining 1% was rock (Map 5). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Walleye is one species that does not provide parental care to its eggs (Becker 1983). 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 in muck as well.

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. In Long Lake, 40 pieces of coarse woody habitat, or 5 per mile, were identified in 2014. While it is unknown what the extent of woody habitat was pre-development, as stated within the Shoreland Development Section researchers have identified undeveloped lakes with as many as 345 pieces per shoreline mile (Christensen et al. 1996).

Long Lake Regulations and Management

Long Lake is located within southern Wisconsin and special regulations may occur that differ from those in other areas of the state. Long Lake is in the southern large and smallmouth bass management zone. Table 3.5-3 displays the 2014-15 regulations for species that may be found in Long Lake. Please note that this table is intended to be for reference purposes only, and anglers should visit the WDNR website (http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.5-3. WDNR fishing regulations for Long Lake, 2014-2015.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth and smallmouth bass	May 3, 2014 to March 1, 2015	The minimum length limit is 14" and the daily bag limit is 5
Northern pike	May 3, 2014 to March 1, 2015	No minimum length limit and the daily bag limit is 5.
Walleye, sauger, and hybrids	May 3, 2014 to March 1, 2015	The minimum length limit is 15" and the daily bag limit is 5.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.

Travis Motl, WDNR fisheries biologist for Fond du Lac County, indicated that the lake is currently managed for largemouth bass, northern pike, walleye and panfish due to the specifics of the lake ecosystem and angler interest in these species. In email correspondence, Mr. Motl discussed the regulation rationale for northern pike: "The Long Lake northern pike population is self-sustaining, had a relatively high density and is slow growing when compared to regional averages. The regulation aims maximize the yield of the resource, including the slower growing and abundant male northern pike. The regulation allows the harvest of male northern pike which previously were an unused resource. The regulation significantly increases effort for the species, especially during winter. The previous 26" minimum size limit had decreased effort, especially on waters such as Long Lake where anglers cannot reasonably expect to be able to harvest a legal fish." Currently, Long Lake is meeting management goals with regards to all fish species except walleye. Mr. Motl indicates that limiting factors for walleye populations include a lack of consistent, quality large fingerling walleye stocking in the past as well as a lack of spawning habitat or access to spawning habitat .

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 Long Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake
3) Collect sociological information from Long Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

These objectives were fulfilled during the project and have led to a better understanding of the Long Lake ecosystem, the people who care about the lake, and what needs to be completed to protect, monitor, and enhance the lake. Overall, the results of the studies that were conducted on Long Lake in 2014 are indicative of a relatively healthy ecosystem.

Analysis of the historic water quality data collected indicates that Long Lake's water quality overall falls within the *Good* to *Excellent* category for deep, lowland drainage lakes in Wisconsin. Trophic state analysis indicates that Long Lake is mesotrophic, meaning that it has moderate amounts primary production. Water quality impacts were also observed from the colonization of zebra mussels, particularly the decoupling of the phosphorus-chlorophyll-*a* relationship as free-floating algal levels (chlorophyll-α) were reduced but not nutrients levels. As water quality parameters shift, a responding shift in the aquatic plant community and fisheries may also be observed in the future.

About 39% of Long Lake's shoreline consisted of the two most impactful categories (*urbanize*d and *developed–unnatural* shoreland, whereas 50% consisted of shorelines in the two most ecologically beneficial categories (*developed–natural* and *undeveloped*). It is fundamental to the health of Long Lake to preserve natural shorelands and take considerable steps towards shifting the proportion of developed shorelines into less impactful categories.

By all standard metrics, the vegetation surveys revealed that the aquatic plant community of Long Lake is of higher quality than the majority of lakes within the ecoregion and is in line with lakes throughout the state. The analysis also indicates that the aquatic plant community remains largely unchanged since 2007. However, aquatic invasive species in some areas has reached levels that can have negative impacts to the ecosystem as well as cause user recreational conflicts. The LLPA is intending on applying for WDNR AIS Established Population Control grant funds to aid in a multi-year AIS control program on Long Lake. The goal of this program is to continue to reduce the amount of curly-leaf pondweed and Eurasian water milfoil/hybrid water milfoil within the lake to more manageable levels – perhaps levels that on an annual basis require minimal or no use of herbicides and can be appropriately controlled using hand removal methods. This control program is discussed in greater detail in the Implementation Plan Section.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the LLPA Planning Committee and ecologist/planners from Onterra. It represents the path the LLPA 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 Long Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

While the LLPA Board of Directors is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee or an individual director (e.g. Education and Communication Committee, Water Quality Director/Committee, Invasive Species Committee, Shoreland Improvement Director/Committee). The LLPA will be responsible for deciding whether the formation of sub-committees and or directors is needed to achieve the various management goals.

Management Goal 1: Increase LLPA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Use education to promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	LLPA Board of Directors – possibly formation of an Education and Communication Committee
Description:	Education represents an effective tool to address many lake issues. The LLPA regularly distributes quarterly newsletters and maintains a website (http://longlakepreservation.org/). 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. The LLPA will also give consideration to the use of social media by having a Facebook® group page. This would further increase the association's ability to communicate with interested stakeholders by allowing them to post information and social messages, as well as building a sense of community. The LLPA will continue to make the education of lake-related issues a priority. 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* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology • Zebra mussels and their role of increasing filamentous algae • Sedimentation • Boating safety (promote existing guidelines, recommendations, water patrol) • Noise, air, and light pollution • Shoreline habitat restoration and protection • Fireworks • Fishing regulations and overfishing • Minimizing disturbance to spawning fish
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Continue LLPA's involvement with other entities that have responsibilities in managing (management units) Long Lake
Timeframe:	Continuation of current efforts
Facilitator:	LLPA Board of Directors – possibly formation of an Education and Communication Committee
Description:	The LLPA is dedicated to enhancing, preserving and protecting the quality of Long and Tittle lakes including the north and south channels for future generations through effective environmental and education policies. The LLPA promotes policies and practices that protect the interests of Long Lake stakeholders and enhance their ability to maximize enjoyment of their shared resource. 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. The LLPA has a long and continued partnership with the Town of Osceola. With the assistance of the LLPA, the Town has created ordinances to protect the shoreline of Long Lake. First, a 200 ft slow-no-wake ordinance for all watercraft was put into place. The LLPA places and maintains buoys around the lake outlining this area. Secondly, the LLPA supports the Water Patrol, an augmented enforcement entity of the Town of Osceola that enforces slow-no-wake zones, AIS watercraft inspections, and full lake slow-no-wake emergency rules that go into effect during high water to protect

	shorelines from erosion. The LLPA will keep the Long Lake Fishing Club (LLFC) informed on project components, particularly as they relate to the fishery. The LLPA will also be working with the Boy Scouts of America and the Kettle Moraine State Forest Northern Unit to implement additional tree drops, building off a past project the LLFC conducted with the WDNR (M. Sesing) to increase fishery habitat in the lake, as outlined in Goal 4 of Plan. Recently the LLPA co-sponsored a grant-funded stream restoration project with the LLFC, WDNR, and, DOT at the north end of Long Lake. The WDNR/DOT will be conducting the restoration project and the LLFC and the LLPA will be responsible for future maintenance of the project. It is important that the LLPA 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 pages:
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Osceola	Barb Klumpyan, Clerk (sbklumpyan@yahoo.com)	Long Lake falls within the Town of Osceola	Once a year, or more as needed. May check website (http://www.townofosceola.org) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Fond du Lac County Land and Water Conservation Dept.	Paul Tollard, County Conservationist (paul.tollard@wi.nacdnet.net)	Oversees conservation efforts for land and water projects.	As needed	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Travis Motl, Fisheries Biologist (travis.motl@wisconsin.gov)	Manages the fishery of Long Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Mary Gansberg–(Mary.Gansberg@wisconsin.gov)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Kyle Kosin, Conservation Warden (262.626.2116)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367)	Contact regarding suspected violations pertaining to recreational activity on Long Lake, include fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	LLPLD members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.
Long Lake Fishing Club	General email address: (llfclegend@sbcglobal.net)	Parallel association to LLPA, with more emphasis on fisheries	As needed	Ensure there is not a duplication of management and/or monitoring activities
Boy Scouts of America (Potawatomi Area Council)	Camp Long Lake: 920.533.8258	Camp Long Lake is operated by the Boy Scouts, located on the northern shores of Long and Tittle Lake.	Once a year, or more as opportunities to work together arise	Contact to solicit possible assistance in conducting lake stewardship activities as part of the camp experience

Management Goal 2: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	LLPA Board of Directors – possibly formation of a Water Quality Director or Committee
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 has been completed annually by Long Lake 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. Data has been collected through the advanced CLMN program in the past on Long Lake. The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. It is the responsibility of the current CLMN volunteer in conjunction with the LLPA Commissioners to coordinate new volunteers as needed. When a change in the collection volunteer occurs, Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also 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) by the volunteer.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
2.	CLMN volunteer and/or LLPA Commissioners would facilitate new volunteer(s) as needed
3.	Coordinator contacts Sandra Wickman (715.365.8951) to acquire necessary materials and training for new volunteer (s)

Management Goal 3: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Long Lake

Management Action:	Continue Spot Treatment Herbicide Control Strategy targeting CLP on Long Lake
Timeframe:	Continuation of current effort
Facilitator:	LLPA Board of Directors – possibly formation of an AIS Committee

Description: One of the most feasible methods of CLP control is through the use of herbicide applications - specifically, early-spring treatments with endothall. A stakeholder survey was sent to Long Lake riparians during November 2014. The response rate was relatively low (24%), therefore the results *may* follow public opinion but cannot be interpreted as being a statistical representation of the population.

Approximately 88% of stakeholder respondents indicated they believe aquatic plant control is need on Long Lake by answering either *Definitely Yes* or *Probably Yes*, whereas approximately 6% of respondents did not feel aquatic plant control was needed by answering either *Definitely No* or *Probably No* (Appendix B, Question #23).

Figure 5.0-1 shows the level of stakeholder respondent support for the responsible use of herbicide (chemical) control of aquatic plants on Long Lake. The majority (66%) of respondents were supportive (pooled *Highly Support* and *Moderately Supportive*) of this technique, whereas just 11% were not supportive (pooled *Not Supportive* and *Moderately Unsupportive*). Approximately 23% of stakeholder respondents indicated they were *Neutral* or *Unsure* regarding the responsible use of herbicide methods to manage aquatic plants in Long Lake. 57% of stakeholder survey respondents indicated that they would like to learn more about aquatic invasive species impacts, means of transport, identification, control options, etc. (Question #25). The LLPA would like to address these issues through an educational initiative. LLPA members would create

Question 24: What is your level of support for the responsible use of Herbicide (chemical) Control on Long Lake?

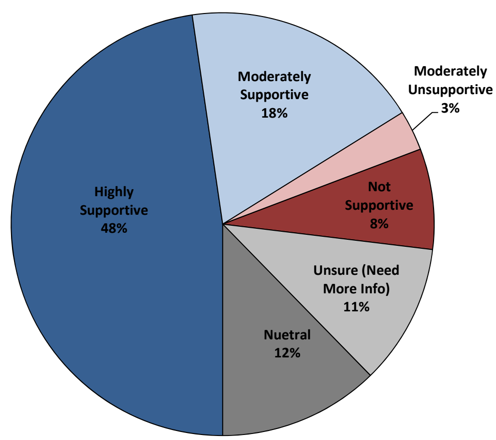


Figure 5.0-1. Select survey responses from the Long Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

educational pieces within its newsletters, as well as solicit area research managers (e.g. WDNR, Fond du Lac County AIS Coordinator, etc) to present at association meetings.

As described in the Aquatic Plant Section (3.4), the goal of CLP management is to annually kill the plants before they are able to produce and deposit new turions, and thus, overtime, deplete the existing turion bank within the sediment. As a result, curly-leaf pondweed treatments traditionally occur each year when surface water temperatures are between 50°F and 60°F.

After multiple years of treatment, the turion base becomes exhausted and the curly-leaf pondweed infestation becomes significantly less. Normally a control strategy such as this includes 5-7 years of treatments of the same area. Based upon the low quantities of CLP located during the 2014 survey, it is believed that the turion bank is in the process of becoming exhausted.

The objective of this management action is not to eradicate curly-leaf pondweed from Long Lake, as that would be impossible with the current tools available. The objective is to bring curly-leaf pondweed down to more easily controlled levels. In other words, the goal is to reduce the amount of curly-leaf pondweed in Long Lake to levels that may be suitable for smaller treatment areas or hand removal efforts to keep it under control. To complete this objective efficiently, a cyclic series of steps is used to plan and implement this control strategy.

1. A lake-wide assessment of curly-leaf pondweed completed while the plant is at peak biomass (late June).
2. Verification and refinement of early-season curly-leaf pondweed treatment areas prior to treatment implementation.
3. Updated treatment areas submitted to the WDNR to serve as the final treatment permit, followed by completion of a curly-leaf pondweed herbicide treatment.
4. Areas surveyed (post-treatment survey) to determine treatment efficacy and strategy for the following year.
5. Reports generated on treatment success level and following year's strategy.

Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program will be sought to partially fund this control program. Specifically, funds would be applied for under the Established Population Control classification. These funds will be applied for in the February 1st, 2015 grant cycle.

The impacts to native submersed species are believed to occur when the non-native species reaches an aerial coverage of approximately 50%

(*dominant*). Therefore, by minimizing the occurrence of these dense stands, the exotic's impact on the lake's ecology will also be minimized. While less dense AIS colonies (scattered and highly scattered) may not have the same level of impact on the ecology of the lake, their potential for expansion, both in area and density, is also of great concern to the LLPA. The LLPA acknowledges the difficulty that associates conducting spot treatments within narrow littoral bands. In order to build off their successes, the LLPA would like to take an aggressive approach to CLP management whereas:

- All areas targeted the previous year would be considered for treatment. Based upon the pretreatment survey, these areas may be reduced or removed.
- All areas of colonized CLP will be considered for treatment during the following spring. The LLPA's treatment threshold (trigger) would also extend to immediately adjacent areas of CLP with point-based techniques, with areas mapped as *small plant colonies* being targeted if possible.

The preliminary 2015 CLP treatment strategy for Long Lake utilizes these triggers and outlines approximately 22 acres for treatment (Map 9). Each proposed treatment site would be evaluated during the spring prior to the treatment to determine if sufficient CLP sprouted within these areas to warrant treatment. Similar to the past few years, the final permitted treatment acreage is suspected to decrease considerably from the preliminary strategy. Please note that M-15 was not considered for treatment due to its small size (<2 acres) and resulting low-likelihood of a successful treatment due to dilution.

In accordance with a monitoring plan developed the association's lake management consultant, water samples would be collected by volunteers at multiple locations throughout the lake to understand the concentration/exposure time of the herbicide at different time periods and locations following the treatment. This information would indicate whether or not the amount of herbicide applied is sufficient for causing native and non-native plant mortality and if any adjustments to the treatment strategy need to be made.

The LLPA's control efforts would contain a formal monitoring strategy consistent with the Appendix D of the WDNR Guidance Document, *Aquatic Plant Management in Wisconsin* (WDNR 2010). This form of monitoring is required by the WDNR for all large scale herbicide applications (exceeding 10 acres in size or 10% of the area of the water body that is 10 feet or less in depth) and grant-funded projects where scientific and financial accountability are required. Sub-sample point-intercept data would be used to understand efficacy of the treatment and a whole-lake point-intercept survey conducted at the end of the multi-year project would allow an understanding of selectivity toward the

	native plant community. In the final year of the project, the LLPA would revisit their management plan as it applies to AIS control and monitoring. Based upon the information gained during the multi-year control project, the LLPA would update their management plan as appropriate.	
Action Steps:		
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.	
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.	
3.	Initiate control and monitoring plan.	
4.	Update management plan to reflect changes in control needs and those of the lake ecosystem.	

Management Action:	Continue Targeting EWM/HWM on Long Lake with Spot Herbicide Treatments and Hand-Harvesting, as Appropriate
Timeframe:	Continuation of current effort
Facilitator:	LLPA Board of Directors – possibly formation of an AIS Committee
Description:	Currently the population of EWM and HWM are low within Long Lake (Map 12), but their potential for expansion, both in area and density, is also of great concern to the LLPA **Hand-removal Control Strategy** If professional surveys reveal areas of EWM/HWM that are comprised of single plants or clumps of plants and are not 'colonized', the LLPA may organize efforts to hand-remove the plants. This task may be conducted through volunteer-based efforts, professional efforts, or a combination of volunteer and professionals. In order for this technique to be successful, the entire plant (including the root) needs to be removed from the lake. During manual extraction, careful attention needs to be paid to all plant fragments that may detach during the control effort. Additional guidance on hand-removal methods can be found within educational pamphlet, *Eurasian Water Milfoil Manual Removal*, co-authored by the Lumberjack Resource Conservation & Development (RC&D) Council, Inc. and Golden Sands RC&D Council, Inc. This pamphlet can be obtained by contacting the Golden Sands RC&D (www.goldensandsrcd.org). Distinguishing AIS from native look-a-likes is very important. LLPA volunteers would attend CLMN workshops to gain this training. The LLPA would also encourage its volunteer monitors to purchase a field guide to aquatic plants, such as *Through the Looking Glass* (Borman et al. 1997) which can be purchased through the CLMN website under 'publications.'

	To conduct a successful hand-harvesting control program, volunteers and professionals must be able to exchange up-to-date and accurate location data of the target species. For this project, AIS location data would be provided through regular surveys competed by both professionals and volunteers (e.g. Adopt-a-Shoreline). The designated LLPA GPS unit would be updated with the AIS occurrence data following Onterra surveys. Following LLPA surveys and hand-harvesting efforts, GPS data would be provided to Onterra for use in subsequent monitoring of the lake. If professional hand-harvesting strategy is devised, it would be the responsibility of the LLPA to contract with a third-party firm able to complete the hand-harvesting efforts to the specifications outlined by the lake management consultant. Professional hand-harvesting activities would take place following the June Early-season AIS Survey and prior to the late-season EWM/HWM Peak-Biomass Survey. The lake management consultant would provide GPS data to the professional hand-harvesting firm relating to where the control efforts would take place. The firm would provide detailed information relating to their efforts (hours broken down by diving/scuba, quantity of EWM/HWM removed, assessment of native plant bi-catch, etc.) following the activities being conducted. **Herbicide Control Strategy** If professional surveys locate areas of colonized EWM/HWM, the most feasible method of control will likely be herbicide applications – specifically, early spring treatments with an auxin-mimic herbicide like 2,4-D. As outlined within the previous management goal aimed at controlling CLP within Long Lake, a formal monitoring strategy consistent with the Appendix D of the WDNR Guidance Document, *Aquatic Plant Management in Wisconsin* (WDNR 2010) would be implemented if herbicide treatments targeting EWM/HWM cumulatively exceed 10 acres.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3.	Initiate control and monitoring plan.
4.	Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at Long Lake public access location
Timeframe:	Continuation of current effort
Facilitator:	LLPA Board of Directors – possibly formation of an AIS Committee
Description:	Currently the LLPA monitors the public boat landing using training provided by the Clean Boats Clean Waters program. The intent of the boat inspections would not only be to prevent additional invasives from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasives that originated in Long Lake. The goal would be to cover the landing 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. The LLPA have set a target of approximately 200 hours of watercraft inspections for 2015 and beyond. If insufficient volunteerism occurs to reach this goal, the LLPA would consider augmenting volunteers with paid inspectors.
Action Steps:	
	See description above as this is an established program.

Management Action:	Reduce occurrence of purple loosestrife on Long Lake.
Timeframe:	Initiate 2015
Facilitator:	LLPA Board of Directors – possibly formation of an AIS Committee
Description:	During the 2014 aquatic plant surveys, purple loosestrife was located in a number of locations along Long Lake's shoreline (Maps 7 & 8). These perennials have been shown to out-compete native wetland plants for space and resources. Manually-removing isolated purple loosestrife plants are likely the best control strategy at this time. Once the property owner grants permission to remove the plant, it should be dug out of the ground, roots and all. If flowers or seeds are present at the time of the extraction, the flower heads should be carefully cut off and bagged to make sure seeds don't inadvertently get spread around during removal. Plants and seed heads should either be burned or bagged and put into the garbage. Sources such as the UW-Extension and Fond du Lac County would be used to provide expertise on purple loosestrife identification, as well as the proper time to perform management actions. Important aspects of this management action will be the monitoring and record keeping that will occur in association with the control efforts. These records will include maps indicating infested areas and associated documentation regarding the actions that were used to

	control the areas, the timing of those actions, and the results of the actions. These maps and records will be used to track and document the successfulness of the program and to keep the LLPA and other management entities updated.
Action Steps:	
1.	See description above

Management Action:	Reduce occurrence of common reed (*Phragmites*) on Long Lake.
Timeframe:	Initiate 2015
Facilitator:	LLPA Board of Directors – possibly formation of an AIS Committee
Description:	Common reed, an invasive species was found growing on the wetland peninsula between Tittle and Long Lake. As discussed within the Aquatic Plant Section (3.4), additional plant material from Long Lake is needed to determine if the common reed is a native or non-native strain.  **Photo 5.0-1. Common reed from Long Lake.** Common reed control has been most effective utilizing a foliar application of an enzyme-specific herbicide (imazapyr or glyphosate) applied to the plants during the late summer as the plants are actively transporting sugars and nutrients from their leaves to their rhizomes in preparation for over wintering. This will ensure translocation of the herbicide to the rhizomes where the entire plant can be controlled. The WDNR was awarded over $800,000 through a Great Lake Research Initiative (GLRI) grant program to help control common reed populations

	along the Lake Michigan shoreline, which includes Fond du Lac County. The LLPA would work with the WDNR to be involved with this project if applicable.
Action Steps:	
1.	See description above

Management Goal 4: Improve Fishery Resource and Fishing by protecting and restoring the shoreland condition of Long Lake

Management Action:	Investigate restoring highly developed shoreland areas around Long Lake
Timeframe:	Initiate 2015.
Facilitator:	LLPA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	As discussed in the Shoreland Condition Section (3.3), 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. In 2014, the shoreland assessment survey indicated that 3.1 miles, or 39% of Long/Title Lake's 8.0-mile shoreline, consists of Urbanized or Developed-Unnatural areas. Fortunately, restoration of the shoreland zone can be less expensive, less time-consuming and much easier to accomplish than restoration efforts in other parts of the watershed. Cost-sharing grants and Fond du Lac County staff devoted to these types of projects give private property owners the funds and informational resources to restore quality shoreland habitat to their lakeside residence. Map 3 indicates the locations of Urbanized and Developed-Unnatural shorelands on Long Lake. These shorelands should be prioritized for restoration. The LLPA would acquire information from and work with appropriate entities such as Paul Tollard from Fond du Lac County Land and Water Conservation Department to research grant programs, shoreland restoration techniques and other pertinent information that will help the LLPA. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, properties with restoration on their shorelands could serve as demonstration sites. Other lakeside property owners could have the opportunity to view a shoreland that has been restored to a more natural state, and learn about

<table>
<tr><td></td><td>the maintenance, labor, and cost-sharing opportunities associated with these projects.

The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
Maximum of $1,000 per 350 ft² of native plantings (best practice cap)
Implemented according to approved technical requirements (WDNR, County, Municipal, etc) and complies with local shoreland zoning ordinances
Must be at least 350 ft² of contiguous lakeshore; 10 feet wide
Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years
Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available</td></tr>
<tr><td>Action Steps:</td><td></td></tr>
<tr><td>1.</td><td>Recruit facilitator from Planning Committee</td></tr>
<tr><td>2.</td><td>Facilitator contacts the Fond du Lac County Land and Water Conservation department to gather information on initiating and conducting shoreland restoration projects. If able, the County Conservationist would be asked to speak to LLPA members about shoreland restoration at their annual meeting.</td></tr>
<tr><td>3.</td><td>The LLPA would encourage property owners that have restored their shorelines to serve as demonstration sites.</td></tr>
</table>

Management Action:	Protect natural shoreland zones around Long Lake
Timeframe:	Initiate 2015
Facilitator:	LLPA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	Approximately 4.0 miles (50%) of Long Lake's shoreline was found to be in either a natural or developed-natural state. It is therefore very important that owners of these properties become educated on the benefits their shoreland is providing to Long Lake, and that these shorelands remain in a natural state. Map 3 indicates the locations of Natural and Developed-Natural shorelands on Long Lake. Many, but not all of these are lands are owned by the State of Wisconsin (Kettle Moraine State Forest) or the Boy Scouts of America (Camp Long Lake). These shorelands should be prioritized for education initiatives and physical preservation. A Planning Committee appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the LLPA in preserving the Long Lake shoreland. 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 Fond du Lac County Land and Water Conservation Department. Several websites of interest include: • Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands) • Conservation easements or land trusts: (http://www.glaciallakes.org/) • UW-Extension Shoreland Restoration: (www.uwex.edu/ces/shoreland/Why1/whyres.htm) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)
Action Steps:	
1.	Recruit facilitator (potentially same facilitator as previous management action).
2.	Facilitator gathers appropriate information from sources described above.

Management Action :	Coordinate with WDNR, Boy Scout Camp, LLFC, and private landowners to expand coarse woody habitat in Long Lake
Timeframe:	Initiate 2015
Facilitator:	LLPA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee

Description:	LLPA stakeholders must realize the complexities and capabilities of the Long Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.5) discuss the benefits of coarse woody habitat in detail.
	
	The LLPA will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with WDNR fisheries biologist.
	
	The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or :
	  o The landowner would need to commit to leaving the area un-mowed
	  o The landowner would need to implement a native planting (also cost share thought this grant program available)
	• Coarse woody habitat improvement projects require a general permit from the WDNR
	• Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:	
1.	Recruit facilitator from Planning Committee (potentially same facilitator as previous management actions).
2.	Facilitator contacts Mary Gansberg (WDNR Lakes Coordinator) and Travis Motl (WDNR Fisheries Biologist) to gather information on initiating and conducting coarse woody habitat projects.
3.	The LLPA would encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

Management Goal 5: Maintain Navigability on Long Lake

Management Action :	Support responsible actions to gain reasonable navigational access to open water areas of Long Lake
Timeframe:	Continuation of Current Effort
Facilitator:	LLPA Board of Directors – possibly formation of a Mechanical Harvester Director or Committee
Description:	The LLPA understands the importance of native aquatic vegetation on Long Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, caused largely by native vegetation such as various-leaved water milfoil (*Myriophyllum heterophyllum*). Onterra ecologists had not observed various-leaved water milfoil growing to the densities present in Long Lake. In the northeastern United States, there is an invasive strain of various-leaved water milfoil, and because of its behavior in Long Lake, Onterra ecologists sent specimens from Long Lake to the Annis Water Resources Institute at Grand Valley State University in Michigan to undergo DNA analysis. Their results revealed that the various-leaved water milfoil present in Long Lake is of the *continental* strain, the strain that is not considered to be invasive. The LLPA supports the reasonable and environmentally sound actions to facilitate navigability on Long Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than absolutely necessary. A stakeholder survey was sent to Long Lake riparians during November 2014. The response rate was relatively low (24%), therefore the results *may* follow public opinion but cannot be interpreted as being a statistical representation of the population.

Question 24: What is your level of support for the responsible use of Mechanical Harvesting on Long Lake?

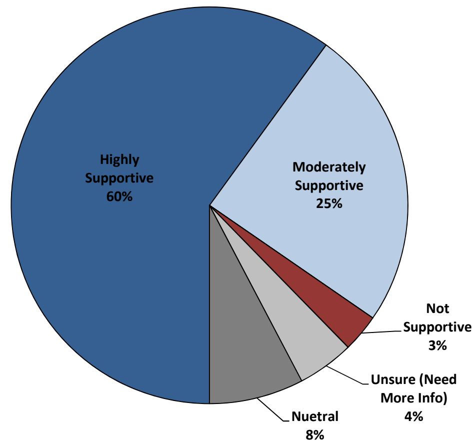


Figure 5.0-2. Select survey responses from the Long Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Approximately 89% of stakeholder respondents indicated they believe aquatic plant control is need on Long Lake by answering either *Definitely Yes* or *Probably Yes*, whereas approximately 6% of respondents did not feel aquatic plant control was needed by answering either *Definitely No* or *Probably No* (Appendix B, Question #23). Figure 5.0-2 shows the level of stakeholder respondent support for the responsible use of mechanical harvesting of aquatic plants on Long Lake. The majority (85%) of respondents were supportive (pooled *Highly Support* and *Moderately Supportive*) of this technique, whereas just 3% were not supportive (pooled *Not Supportive* and *Moderately Unsupportive*). Approximately 12% of stakeholder respondents indicated they were *Neutral* or *Unsure* regarding the responsible use of mechanical harvesting to manage aquatic plants in Long Lake.

<u>Short-Term Strategy</u>

The WDNR oversees the management of aquatic plants on inland lakes. The manual cutting and raking of native aquatic plant species within a 30-foot-wide area containing a pier, boatlift, or swim raft is exempt from a state permit provided that the cut plants are removed from the lake. However, the use of mechanized or mechanical devices requires a WDNR permit.

In order to alleviate navigation impediments caused by the vegetation, a mechanical harvesting firm has been contracted by the LLPA to harvest approximately 4 acres annually. The lanes displayed on Map 17 are 30-foot wide common use lanes marked by LLPA volunteers in 2013. The total cutting area depicted consists of 3.9 acres, or approximately 0.1% of the lake's littoral surface area. The LLPA will utilize this mechanical harvesting plan in 2015 if needed.

	Long-Term Strategy Along with other state statues, the WDNR administrative code NR 109 is followed regarding permit issuance for removal of aquatic plants. The purpose of this code is to ensure that control of aquatic plants is permitted "in a manner consistent with sound ecosystem management, shall consider cumulative impacts, and shall minimize the loss of ecological values in the body of water." The WDNR has requested a more precise plan that gives comprehensive guidance on the use of a mechanical harvesting operation, some of which are outlined below: • Documentation of conditions that warrant mechanical harvesting o Navigation impediment due to aquatic plant growth o Justification for needing to transverse areas that have aquatic plant growth impeding navigation • Practicality of mechanical harvesting o Plant composition, plant densities, and depth of plant growth o Project Design (e.g. water depth, transportation corridor, etc) o Logistics (e.g. cutting depth, off-loading location, disposal sites, decontamination procedures) • Development of thresholds (i.e. triggers) of when mechanical harvesting would be implemented The LLPA will commence a project during the summer of 2015 that will collect the information needed to develop a formal mechanical harvesting plan per the specifics outlined above. The public will also be given an opportunity to provide input into the plan. The developed mechanical harvesting plan will be utilized in 2016 and beyond, serving as an addendum to this this management plan.
Action Steps:	
1.	See description above

Management Action :	Investigate conducting advanced studies to understand sedimentation within the lake.
Timeframe:	Continuation of Current Effort
Facilitator:	LLPA Board of Directors
Description:	Sedimentation or "silt build-up" is a natural process that occurs as a lake ages. Sedimentation rates can increase when near shore areas of the lake are in an unnatural state (manicured lawns and impervious surfaces). As discussed within the Shoreland Condition Section (3.3), 39% of Long Lake's shoreland was considered *Urbanized* or *Developed-Unnatural*. Long Lake also supports a

	large biomass of aquatic plants. The decomposition of these plants contributes greatly to the organic sediments found within the lake. Long Lake endures a large amount of recreational use, largely through motor boat traffic. As the 3rd and 4th most highly ranked activity regarding the justification for owning property on the lake (Appendix B, Question #14), motor boat traffic and water skiing/tubing (respectively) can re-suspend fine particulate matter and contribute to sedimentation being transferred with wave action toward nearshore areas of the lake. In addition to causing turbidity and sedimentation, boating close to the shoreline can cause shoreline erosion, release nutrients such as phosphorus in the water column which can contribute to algal growth, as well as be harmful to fish habitat as propellers uproot plant populations. Onterra ecologists discussed a number of potential ways to better understand sedimentation levels and rates within the waterbody, including advanced acoustic data collection and/or paleoecological coring. **Acoustic Survey** Acoustic surveys are conducted by systematically collecting continuous, advanced sonar data across the lake. These data allow for an advanced bathymetric (contour) map of the lake to be created as well as an understanding of sediment composition (hardness) within the lake. This is typically the first step in understanding where sedimentation is occurring and what parts of the lake are potentially impacted by the phenomenon. **Paleoecological Coring** This process involves collecting sediment cores from various locations within the lake. Through sophisticated processes, an understanding of the past chemical environment (nutrient levels) can be understood, as well as the rate of sediment build-up. These studies are important to understand the root cause of sedimentation, whether it is occurring naturally/at a natural rate, and if there are solutions to slow the rate of sedimentation or mitigate the effects of sedimentation.
Action Steps:	
1.	See description above

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Long Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

Parameter	Spring		June		July		August		Fall		Winter	
	S	B	S	B	S	B	S	B	S	B	S	B
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●					●	●
Chlorophyll a	●		●		●		●		●			
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Total Suspended Solids	●	●	●	●	●	●	●	●	●	●	●	●
Calcium	●											

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 5.

Watershed Analysis

The watershed analysis began with an accurate delineation of Long Lake'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 – Fry et. al 2011) 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)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Long Lake during a June 25, 2014 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Long Lake 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) was used to complete this study on August 28, 2013 by the WDNR. A point spacing of 50 meters was used resulting in approximately 723 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Long Lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT Global Positioning System (GPS) 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.

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium. A set of samples was also provided to the Long Lake Preservation Association, LLC.

2014 Treatment Monitoring

The methodology used to monitor the 2014 herbicide treatments is included within the results section under the heading: *Treatment Monitoring.*

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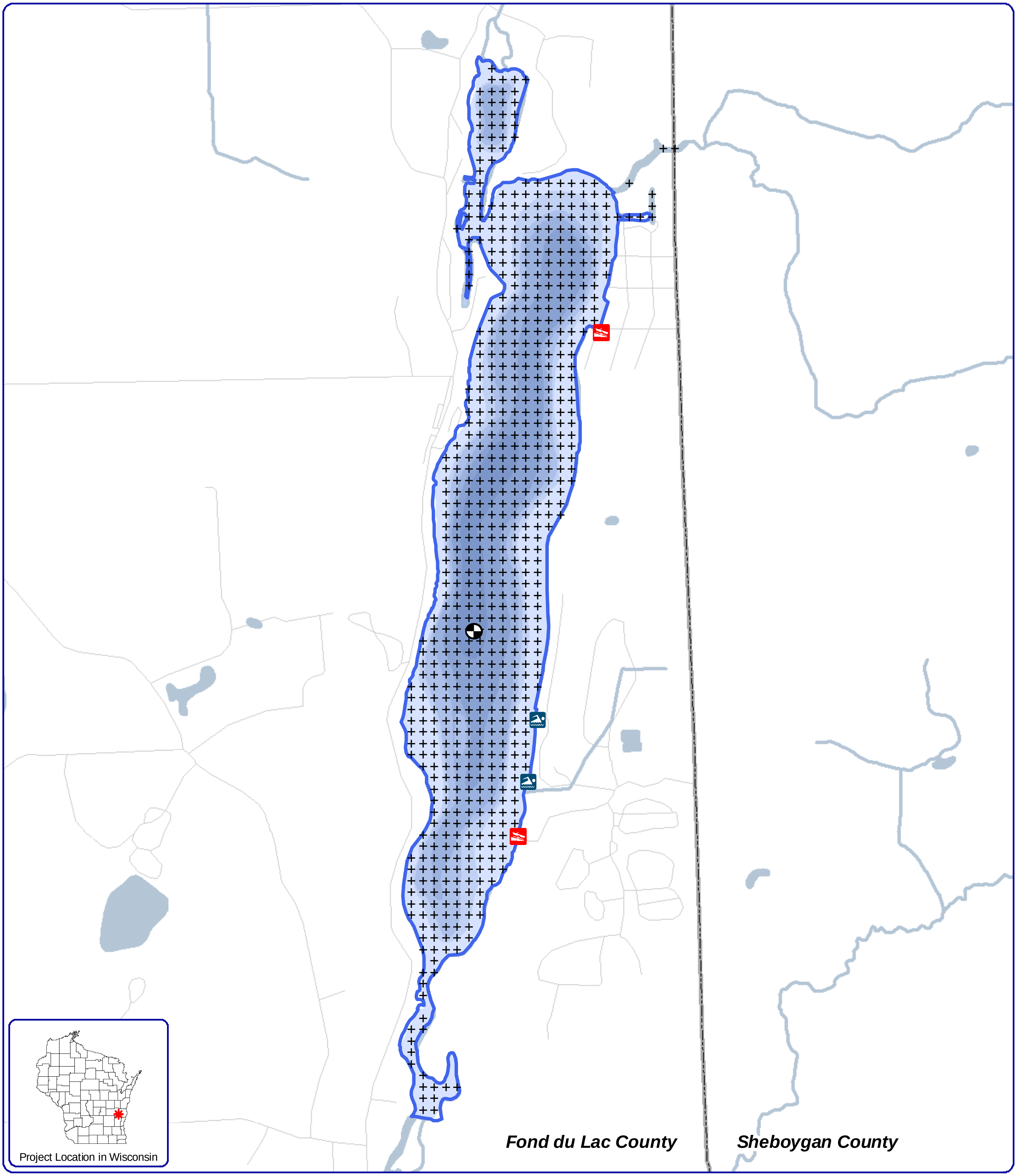
Wisconsin Department of Natural Resources (WDNR). 2013. Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM). Bureau of Water Quality Program Guidance.

Woodford, J.E. and M.W. Meyer. 2003. Impact of Lakeshore Development on Green Frog Abundance. Biological Conservation. 110, pp. 277-284.

Zhu, B., D.G. Fitzgerald, C.M. Mayer, L.G. Rudstam, and E.L. Mills. 2006. Alteration of Ecosystem Function by Zebra Mussels in Oneida Lake: Impacts on Submerged Macrophytes. Ecosystems 9: 1017-1028.



Legend

Long Lake ~423acres
WDNR Definition

Point-Intercept Survey Location
50-meter spacing, 725 total points

Water Quality Sampling Location

Boat Landing

Public Beach

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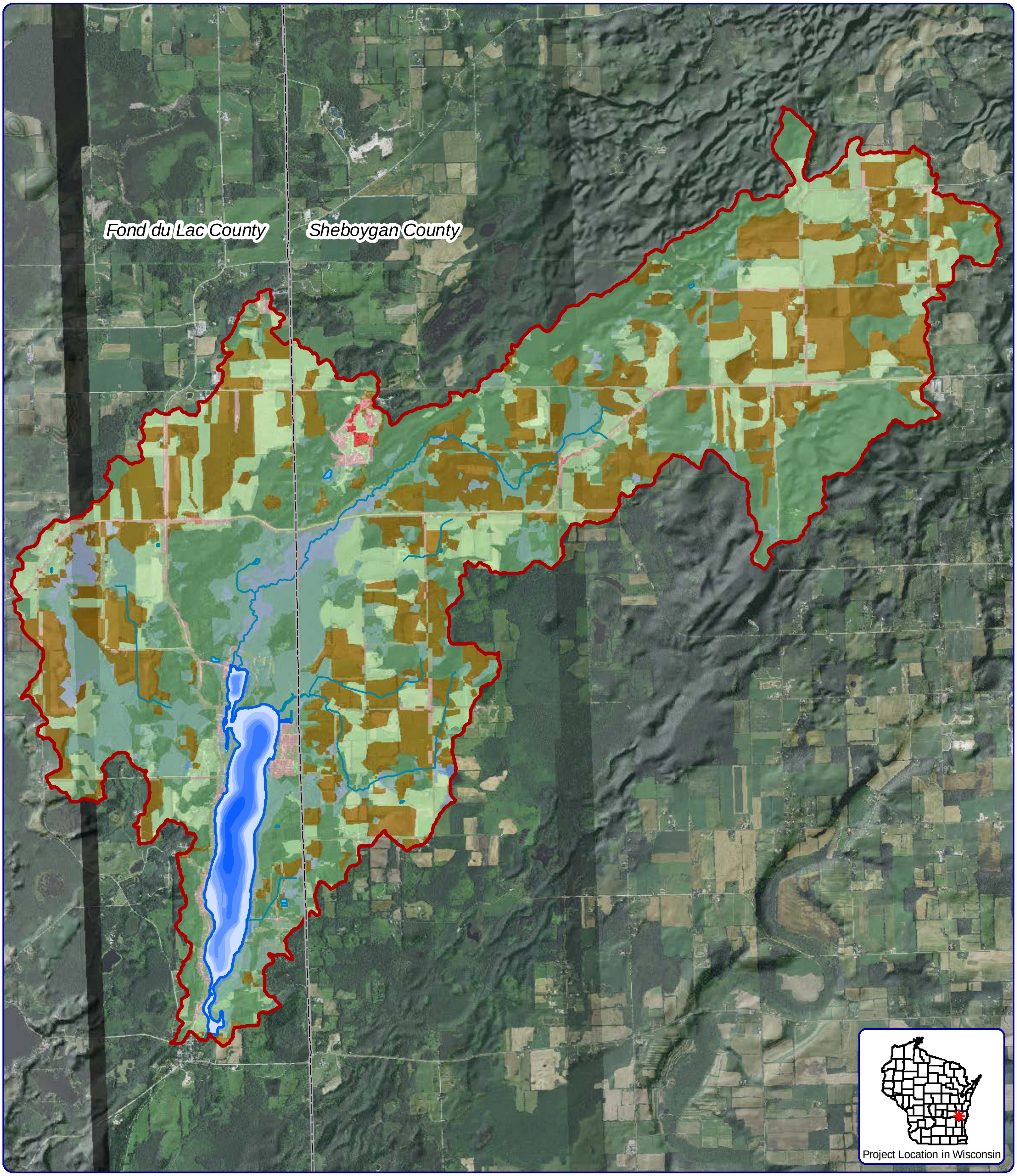
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1967; digitized by Onterra
Map Date: October 24, 2014
Filename: Map1_LongFDL_Location.mxd

Map 1
Long Lake
Fond du Lac County, Wisconsin

Project Location & Lake Boundaries



Legend

Land Cover Types

- Long Lake Watershed Boundary
- Long Lake
- Forest
- Forested Wetlands
- Wetlands
- Rural Open Space
- Pasture/Grass
- Row Crops
- Rural Residential
- Urban - Medium Density
- Urban - High Density

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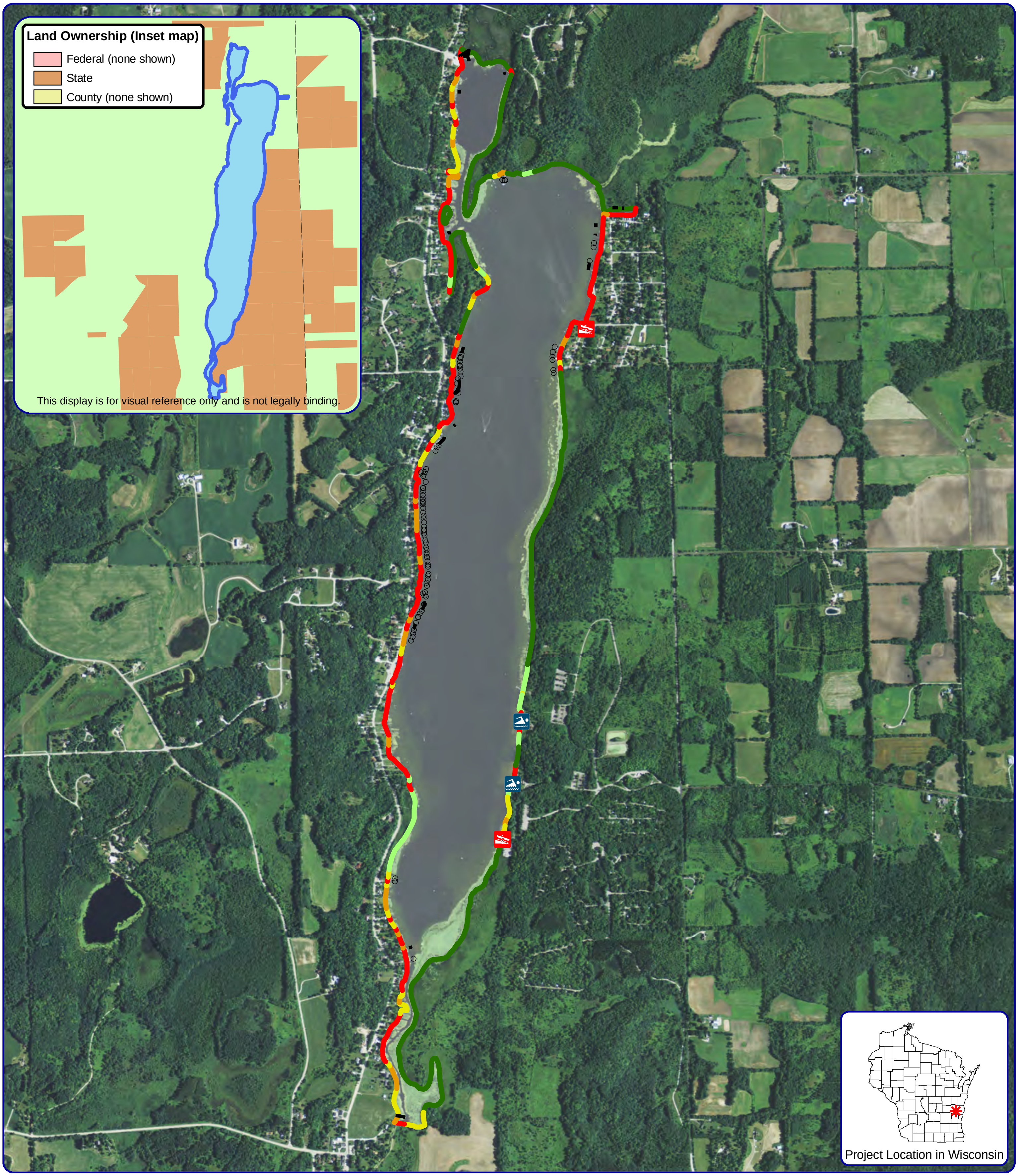
Sources:
Hydro and Bathymetry: WDNR
Land Cover: NLCD, 2006
Bathymetry: Onterra, 2014
Orthophotgraphy: NAIP, 2013
Map Date: October 1, 2014
Filename: Map2_LongFDL_WS.mxd

Map 2

Long Lake

Fond du Lac County, Wisconsin

Watershed Boundaries & Land Cover Types



N
W E
S

1,800

Feet

Legend

Natural/Undeveloped

Developed-Natural

Developed-Semi-Natural

Developed-Unnatural

Urbanized

Seawall

Masonary/Wood

Rip-Rap

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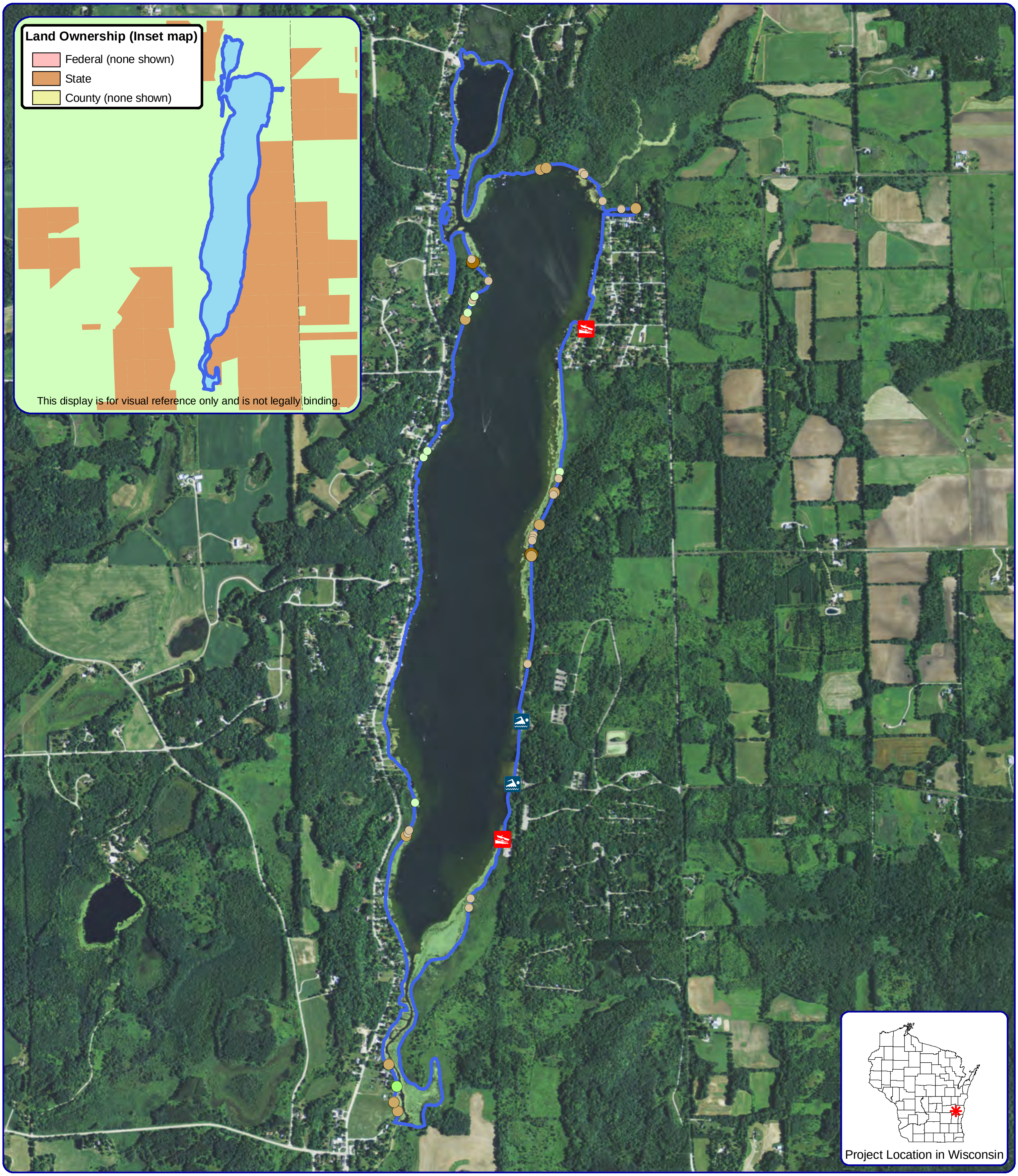
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: October 3, 2014
Filename: Map3_LongFDL_SCA_2014.mxd

Map 3

Long Lake

Fond du Lac County, Wisconsin

2014 Shoreland Condition Assessment



N
W E
S
1,800
Feet

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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: October 3, 2014
Filename: Map4_LongFDL_CWH_2014.mxd

Legend

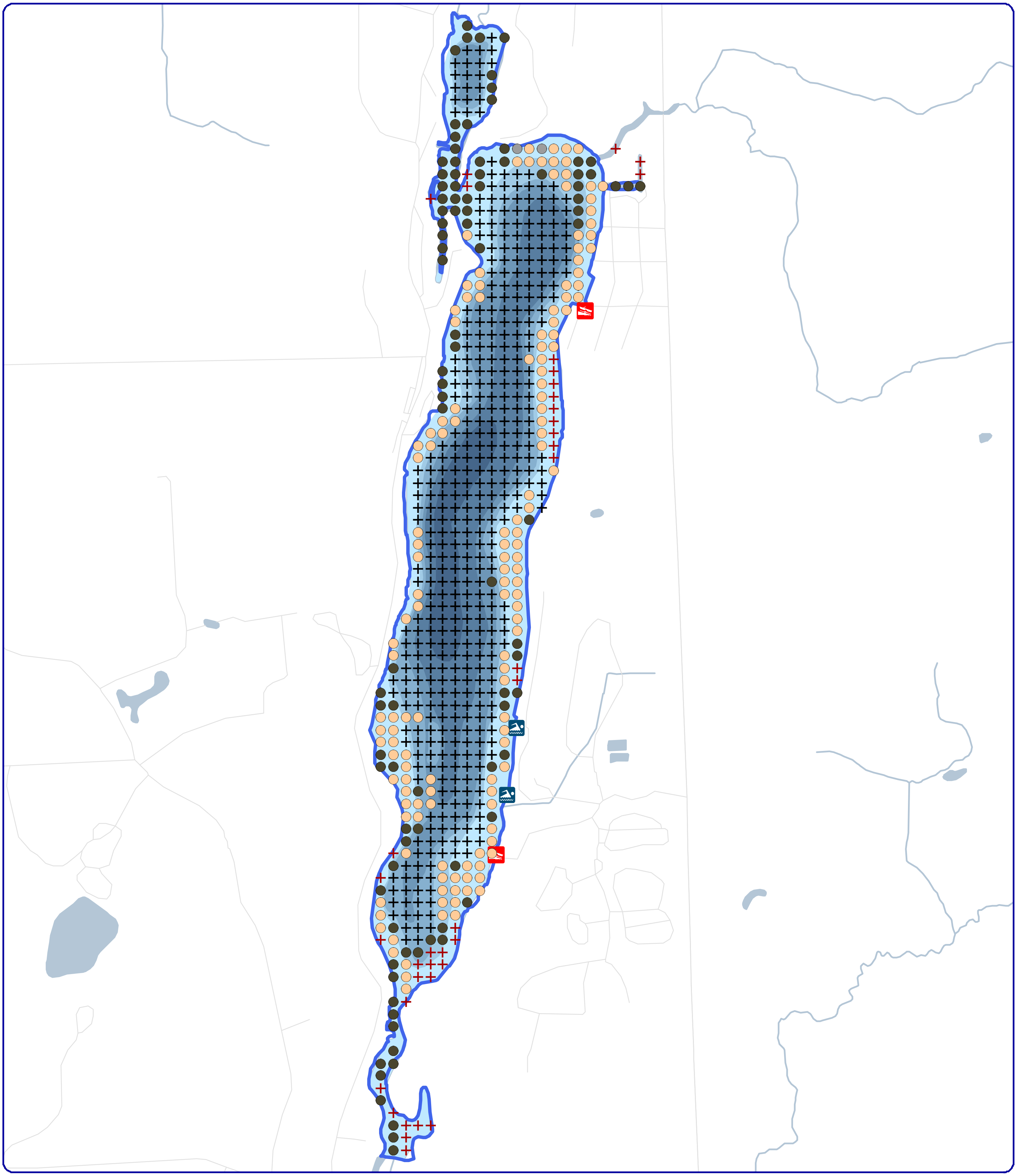
2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches (none)
Minimal Branches	Minimal Branches	Minimal Branches (none)
Moderate Branches	Moderate Branches (none)	Moderate Branches (none)
Full Canopy (none)	Full Canopy (none)	Full Canopy (none)

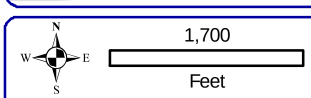
Map 4

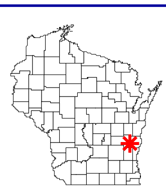
Long Lake

Fond du Lac County, Wisconsin

2014 Coarse Woody Habitat






Project Location in Wisconsin

Legend

- Soft Sediments
- Rock
- Sand
- No Data
- Non-Navigable

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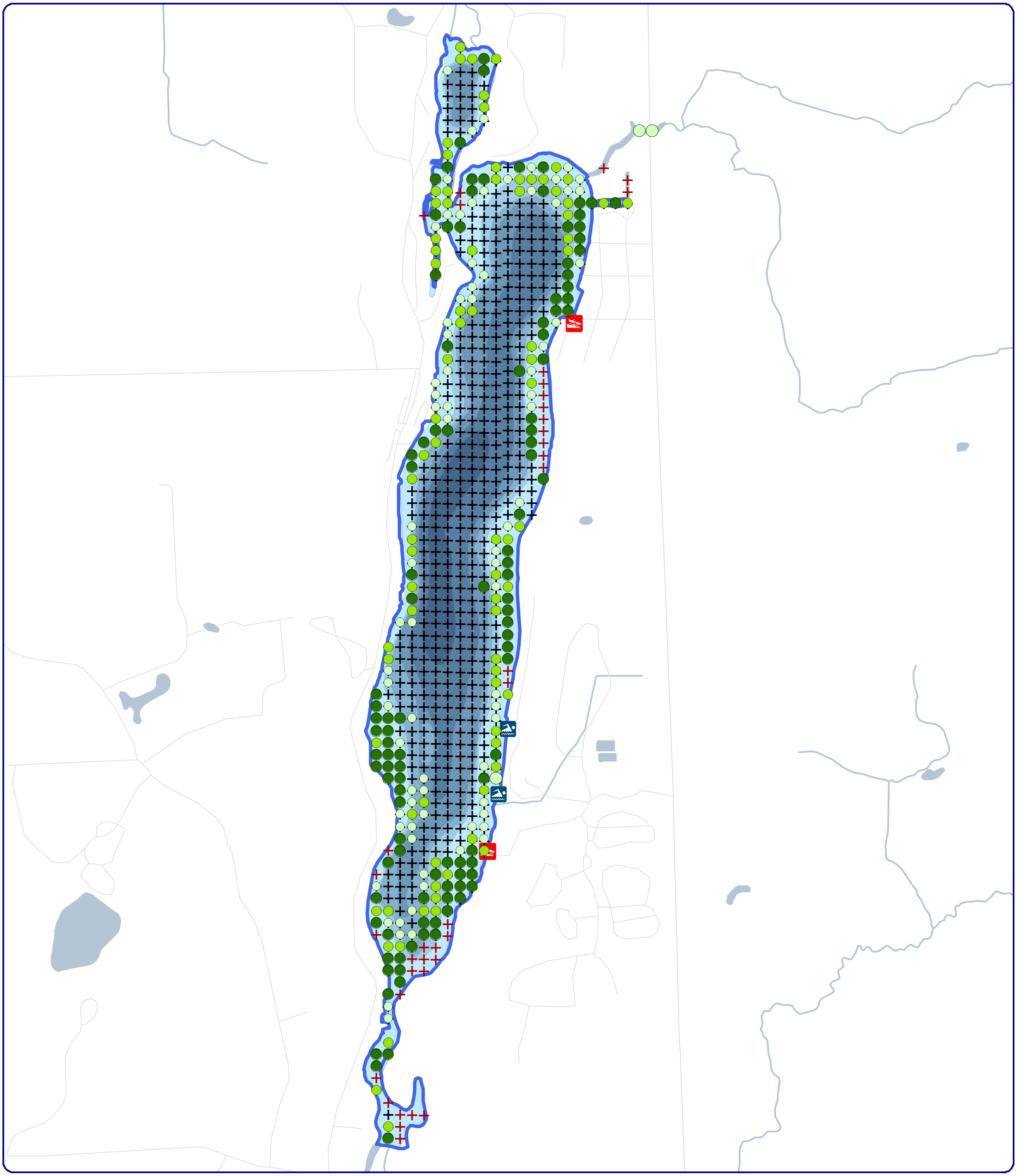
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: WDNR, 2013
Map Date: October 6, 2014
Filename: Map5_LongFDL_Sed_2013.mxd

Map 5
Long Lake
Fond du Lac County, Wisconsin
2013 PI Survey: Substrate Types



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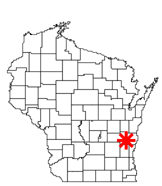
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: WDNR, 2013
Map Date: October 6, 2014
Filename: Map6_LongFDL_TRF_PI_2013.mxd



Project Location in Wisconsin

Legend

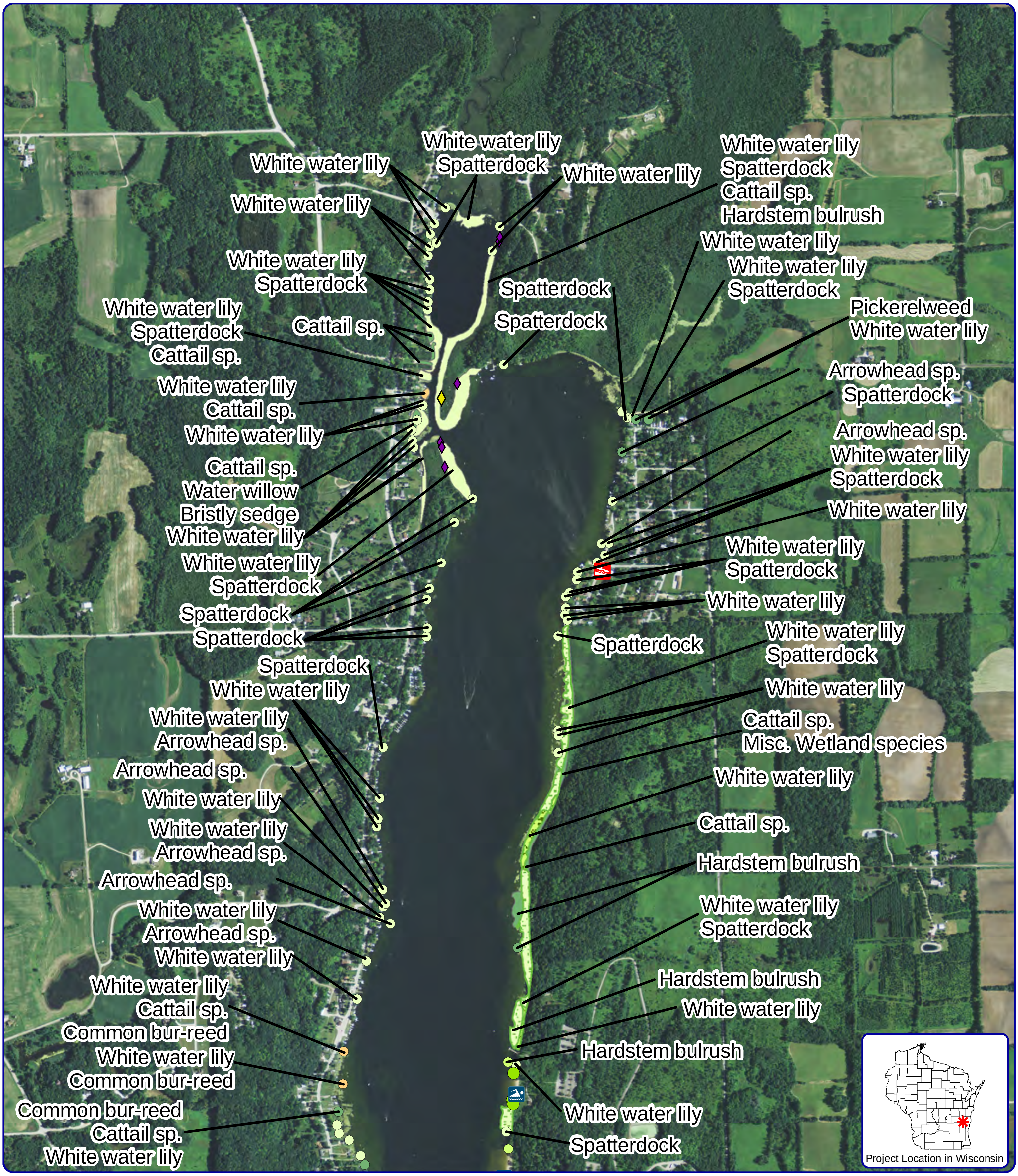
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- \+ No Data
- \+ Non-Navigable

Map 6

Long Lake

Fond du Lac County, Wisconsin

2013 PI Survey: Aquatic Plant Distribution



N
W
E
S

1,350

Feet

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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2014
Map Date: October 2, 2014
Filename: Map7_LongFDL_Comm_2014.mxd

Legend

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

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

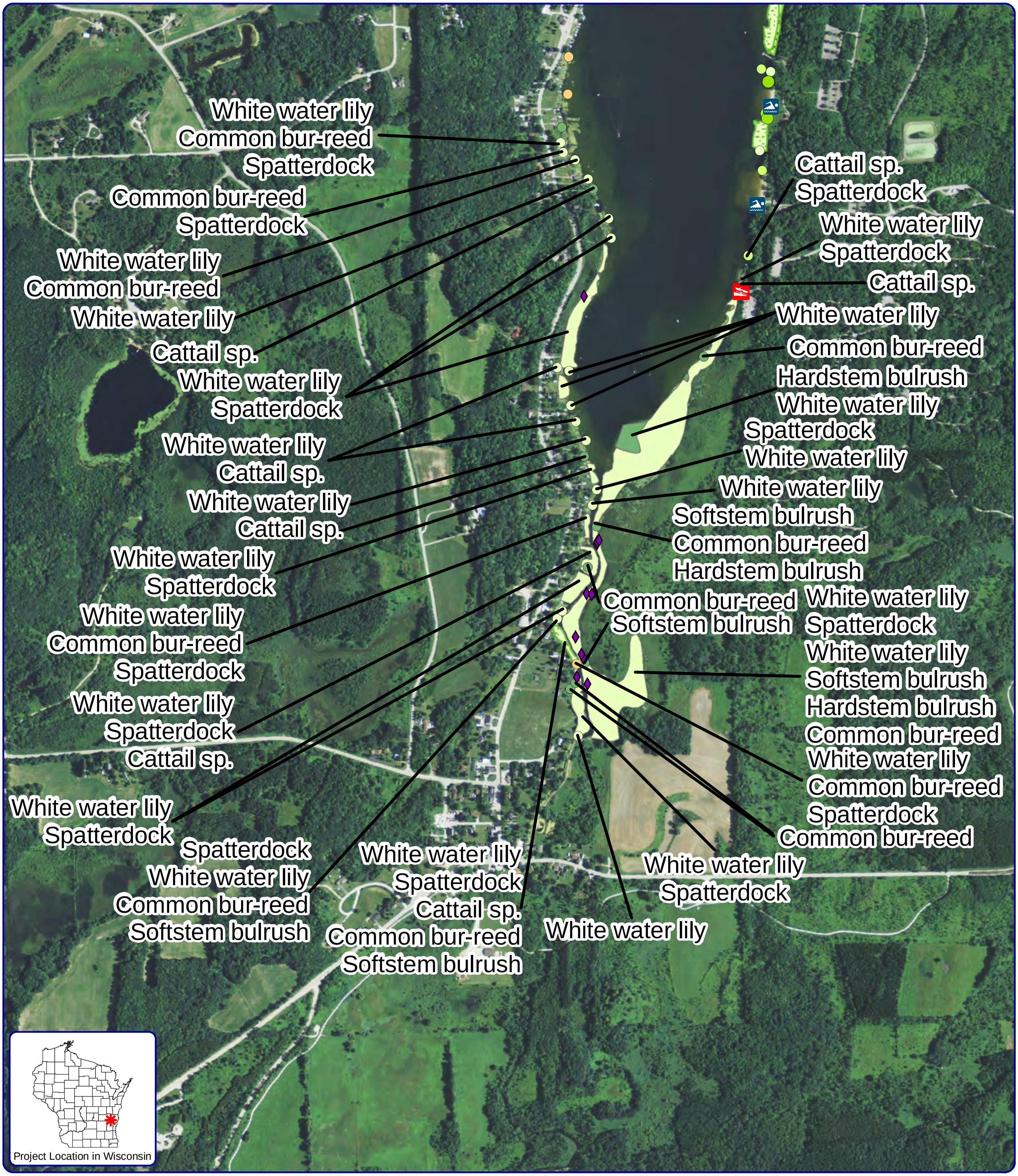
Wild Rice Communites
- Single of Few Plants
- Clumps of Plants
- Small Plant Colony
- Dense Rice

Map 7

Long Lake - North

Fond du Lac County, Wisconsin

2014 Plant Survey: Community Mapping



N
W E
S

1,150

Feet

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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2014
Map Date: October 2, 2014
Filename: Map8_LongFDL_Comm_South_2014.mxd

Legend

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

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

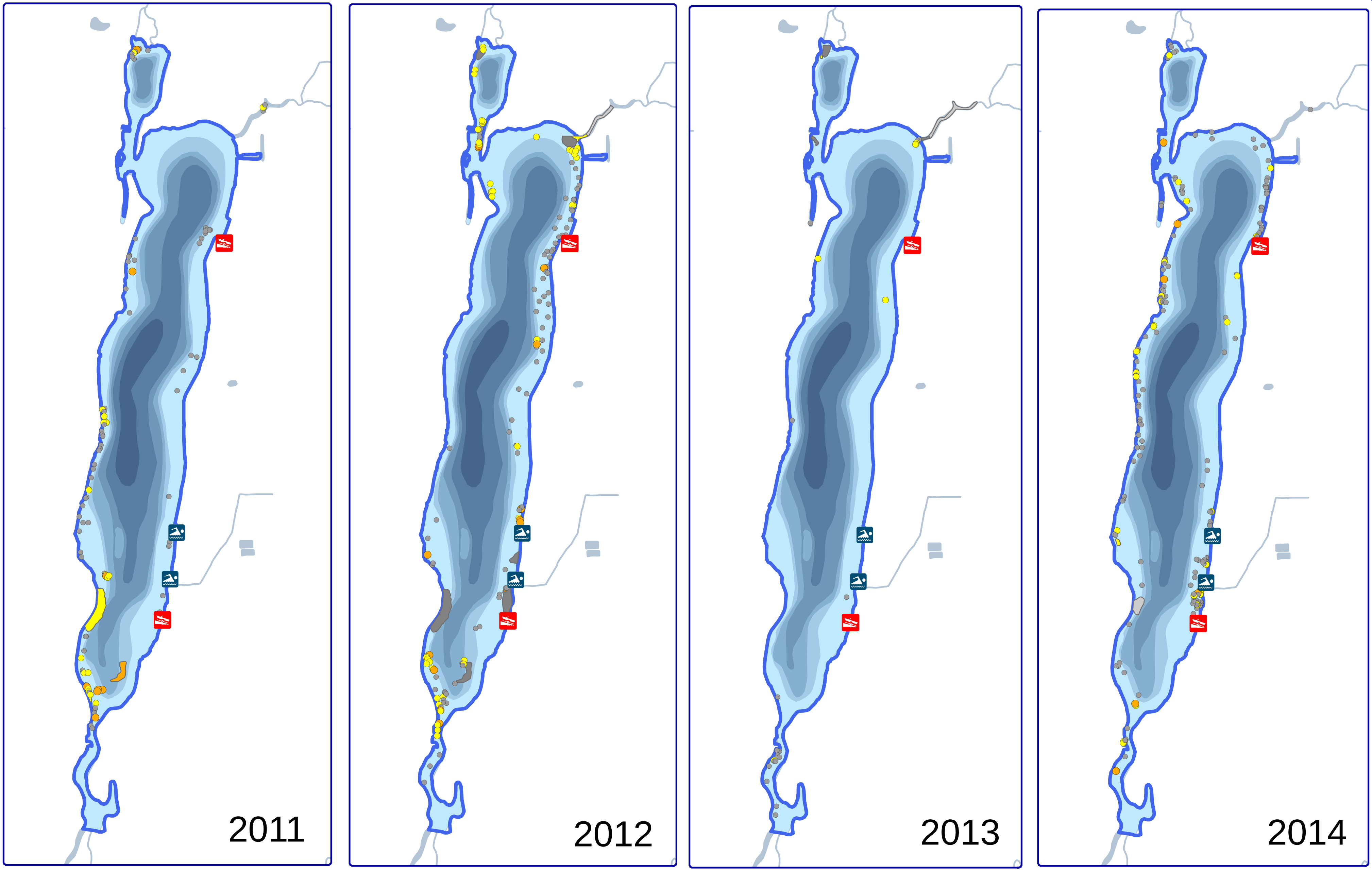
Wild Rice Communites
- Single of Few Plants
- Clumps of Plants
- Small Plant Colony
- Dense Rice

Map 8

Long Lake - South

Fond du Lac County, Wisconsin

2014 Plant Survey: Community Mapping



N
W E
S
2,500
Feet

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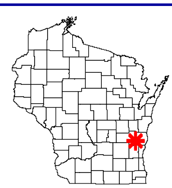
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra
Map Date: November 14, 2014
Filename: Long_FDL_CLPPB_Series.mxd



Extent of large map shown in red.

Legend

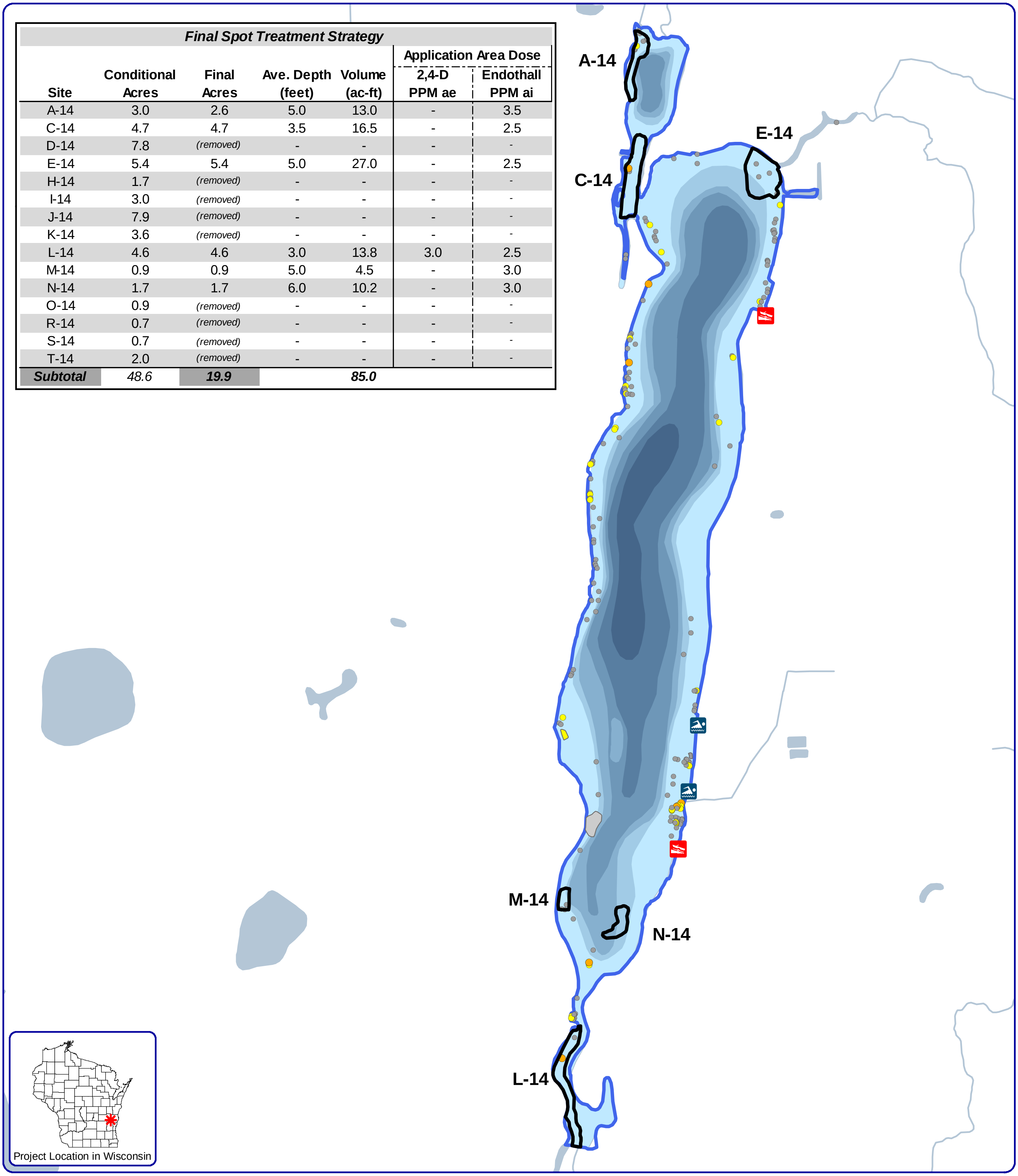
Curly-leaf Pondweed

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Boat Landing
- Public Beach

Map 9
Long Lake
Fond du Lac County, Wisconsin
2011-2014 CLP PB Series

Final Spot Treatment Strategy

Site	Conditional Acres	Final Acres	Ave. Depth (feet)	Volume (ac-ft)	Application Area Dose: 2,4-D PPM ae	Application Area Dose: Endothall PPM ai
A-14	3.0	2.6	5.0	13.0	-	3.5
C-14	4.7	4.7	3.5	16.5	-	2.5
D-14	7.8	*(removed)*	-	-	-	-
E-14	5.4	5.4	5.0	27.0	-	2.5
H-14	1.7	*(removed)*	-	-	-	-
I-14	3.0	*(removed)*	-	-	-	-
J-14	7.9	*(removed)*	-	-	-	-
K-14	3.6	*(removed)*	-	-	-	-
L-14	4.6	4.6	3.0	13.8	3.0	2.5
M-14	0.9	0.9	5.0	4.5	-	3.0
N-14	1.7	1.7	6.0	10.2	-	3.0
O-14	0.9	*(removed)*	-	-	-	-
R-14	0.7	*(removed)*	-	-	-	-
S-14	0.7	*(removed)*	-	-	-	-
T-14	2.0	*(removed)*	-	-	-	-
Subtotal	*48.6*	***19.9***		***85.0***		



1,850
Feet

Legend

Curly-leaf pondweed (June 2014)
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Spring 2014 Final Treatment Area
- Boat Landing
- Public Beach

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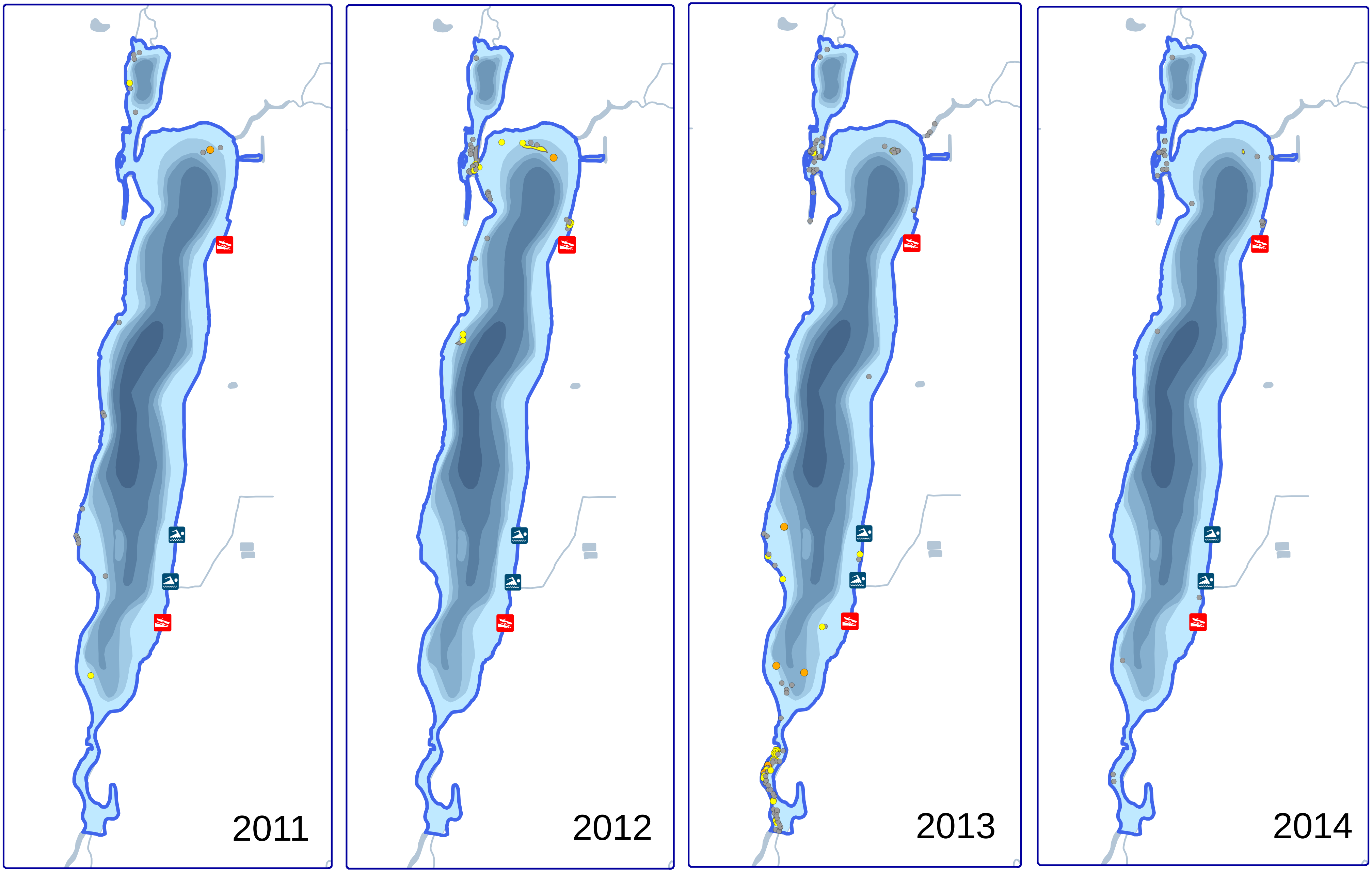
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, June 2014
Map Date: October 24, 2014
Filename: Map10_LongFDL_CLP_T2014.mxd

Map 10
Long Lake
Fond du Lac County, Wisconsin
Spring 2014 Final CLP Treatment Areas & June 2014 CLP Locations



N
W E
S
2,500
Feet

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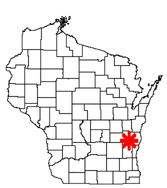
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra
Map Date: November 14, 2014
Filename: Long_FDL_EWMPB_Series.mxd



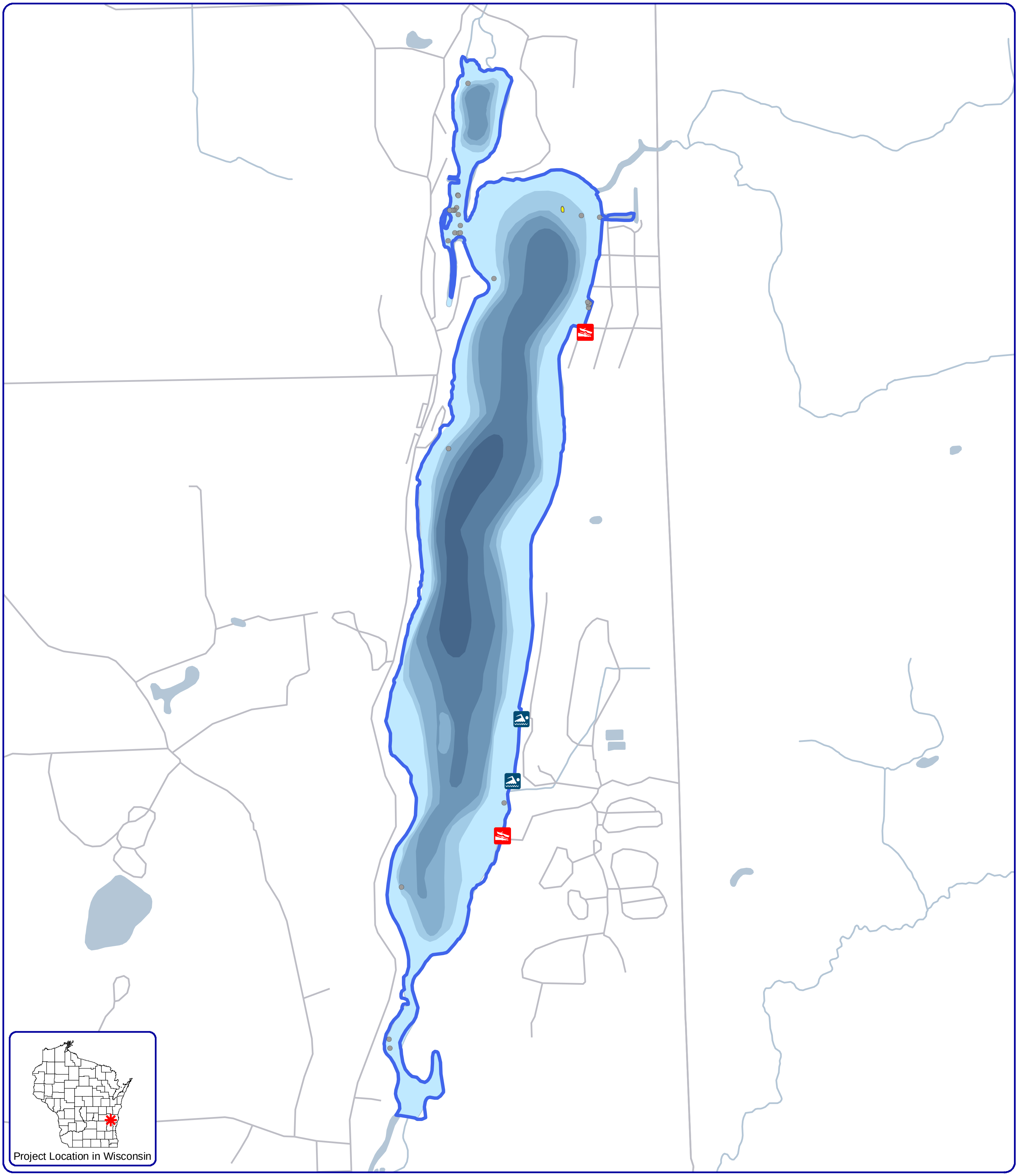
Extent of large map shown in red.

Legend

Eurasian water milfoil

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Boat Landing
- Public Beach

Map 11
Long Lake
Fond du Lac County, Wisconsin
2011-2014 EWM
PB Series



N
W E
S

1,850
Feet

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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, August 2014
Map Date: October 24, 2014
Filename: Map12_LongFDL_EWM_Aug14.mxd

Legend

Eurasian water milfoil (August 2014)

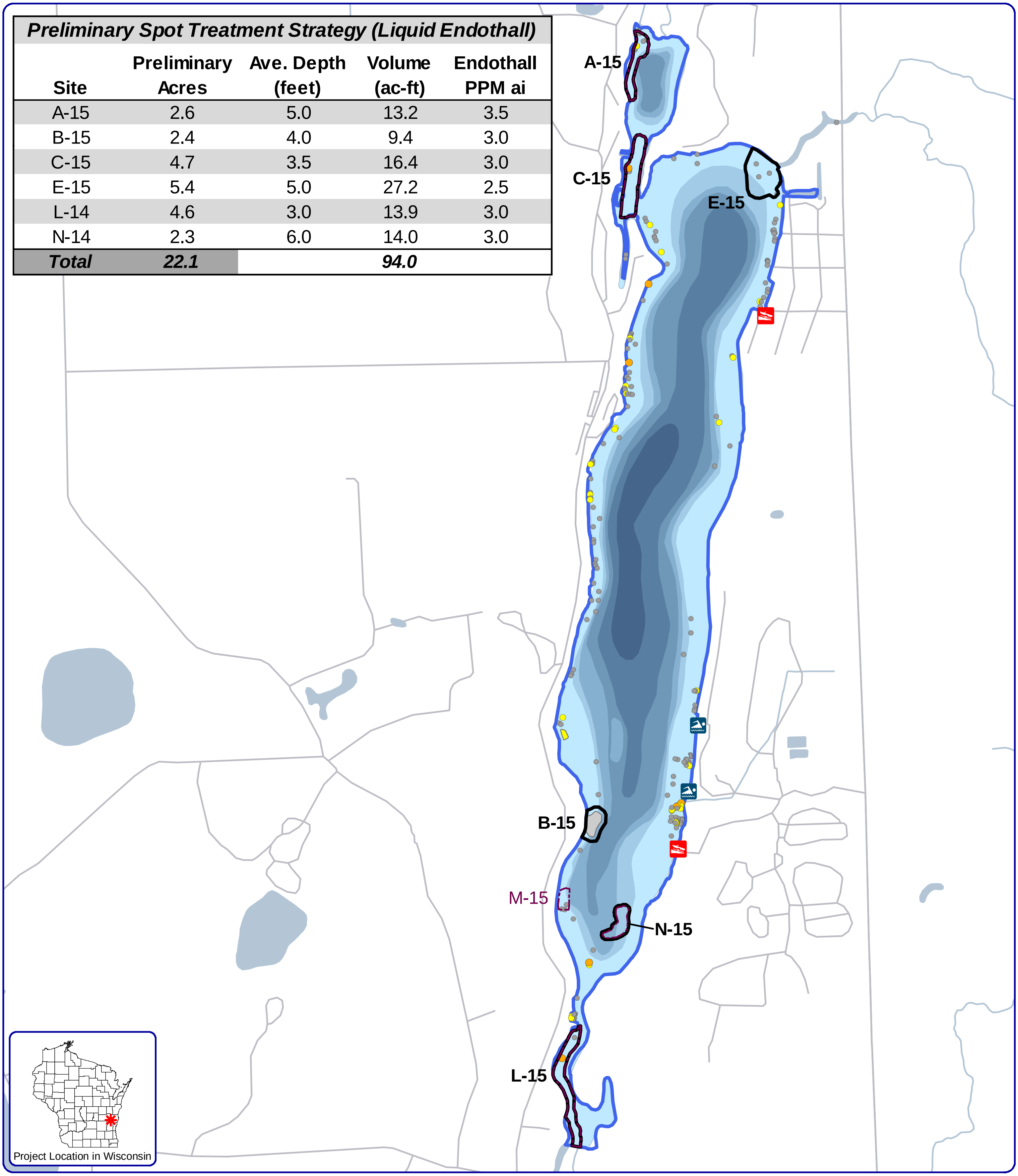
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Boat Landing
- Public Beach

Map 12
Long Lake
Fond du Lac County, Wisconsin

August 2014
EWM Locations

Preliminary Spot Treatment Strategy (Liquid Endothall)

Site	Preliminary Acres	Ave. Depth (feet)	Volume (ac-ft)	Endothall PPM ai
A-15	2.6	5.0	13.2	3.5
B-15	2.4	4.0	9.4	3.0
C-15	4.7	3.5	16.4	3.0
E-15	5.4	5.0	27.2	2.5
L-14	4.6	3.0	13.9	3.0
N-14	2.3	6.0	14.0	3.0
Total	***22.1***		***94.0***	



N
W E
S
1,850
Feet

Legend

Curly-leaf pondweed (June 2014)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2014 Final CLP Treatment Area
- 2015 Preliminary CLP Treatment Area
- Boat Landing
- Public Beach

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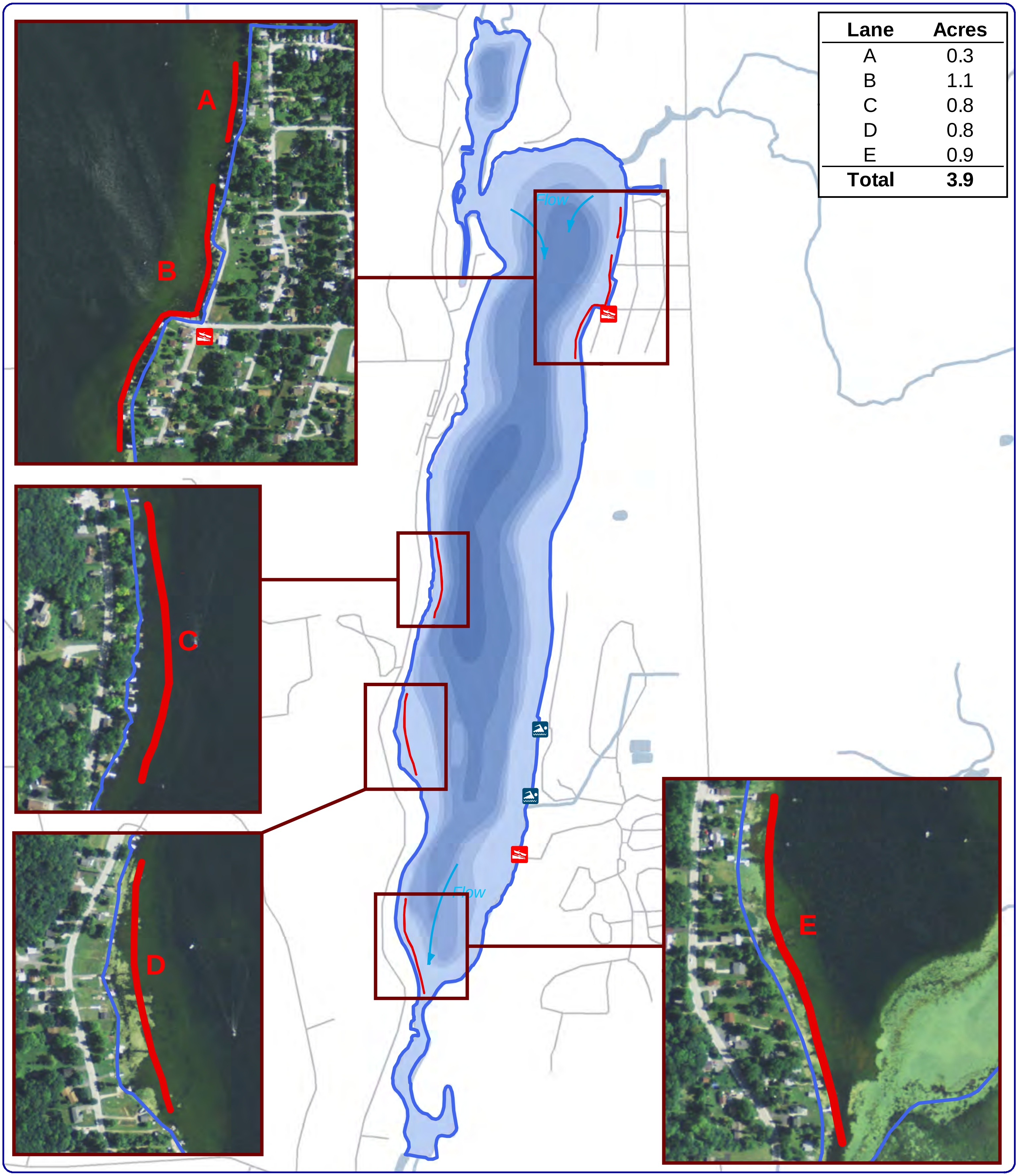
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, June 2014
Map Date: November 11, 2014
Filename: Map2_LongFDL_CLP_T2015_Prelim1.mxd

Map 13

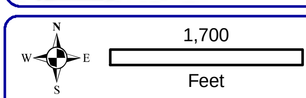
Long Lake

Fond du Lac County, Wisconsin

2015 Preliminary CLP Treatment Strategy



Lane	Acres
A	0.3
B	1.1
C	0.8
D	0.8
E	0.9
Total	**3.9**



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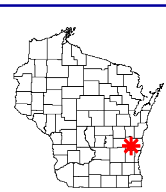
Sources:
Roads and Hyrdo: WDNR
Bathymetry: WDNR 197, Digitized by Onterra
Aquatic Plants: Onterra, 2013
Map Date: February 13, 2014
Filename: LongFDL_MechHarvest_2013_v1.mxd


Project Location in Wisconsin

Legend

30-foot wide harvest lane

Map 14
Long Lake
Fond du Lac County, Wisconsin

2013 Mechanical Harvest Plan