Long Lake

Vilas County, Wisconsin

Comprehensive Management Plan Update

July 2013

Sponsored by:

Long Lake of Phelps Lake District
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Onterra LLC
Lake Management Planning

Long Lake

Vilas County, Wisconsin

Comprehensive Management Plan Update

July 2013

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Long Lake Planning Committee

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Kevin Gauthier
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Data Resources

Data has been specifically provided for use in this report by the Wisconsin Department of Natural Resources, Great Lakes Indian Fish and Wildlife Commission, and Wisconsin Valley Improvement Company..

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1.0 INTRODUCTION

Long Lake, Vilas County, is an 872-acre drainage lake (Map 1) with a maximum depth of 95 feet and mean depth of approximately 30 feet. This deep, lowland drainage lake has a moderately large watershed when compared to the size of the lake. Long Lake contains 46 native plant species, of which fern pondweed is the most common plant.

Field Survey Notes

Our crews have spent much time on the lake over the years monitoring the herbicide treatment program. These surveys occur in the early spring and at end of the summer, so 2012 was the first year that we got to spend time on the lake during mid-summer. The lake buzzed with activity and friendly onlookers greeted us as we conducted our mid-summer surveys.

Photo 1.0-1 Long Lake, Vilas County

Lake at a Glance - Long Lake

Morphology	
Acreage	872 acres
Maximum Depth (ft)	95
Mean Depth (ft)	30
Shoreline Complexity	1.65
Vegetation	
Curly-leaf Survey Date	N/A
Comprehensive Survey Date	August 7, 2012
Number of Native Species	45 (35 from PI Survey)
Threatened/Special Concern Species	0
Exotic Plant Species	Eurasian water milfoil
Simpson's Diversity	0.91
Average Conservatism	6.5
Water Quality	
Trophic State	upper oligotrophic/lower mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.5-8.5
Watershed to Lake Area Ratio	15:1
Flushing Rate	0.54 times/year

Connected via the approximately 1.25 mile long Thoroughfare Creek, Big Sand Lake flows into Long Lake. Big Sand Lake is arguably the first lake in Vilas County to contain Eurasian water milfoil, with official records of this plant occurring in the lake in 1990. Long Lake flows through the Deerskin River into Scattering Rice Lake of the Eagle River Chain of Lakes.

In 2000 the presence of Eurasian water milfoil was verified by the Wisconsin Department of Natural Resources (WDNR) from Long Lake, although it was suspected of inhabiting the system for years before this date. In 2006, the WDNR completed a point-intercept aquatic plant survey, locating Eurasian water milfoil in approximately 26% of the littoral area of the lake (< 18ft).

During that timeframe the Long Lake of Phelps Lake District (LLPLD) was in the process of creating a lake management plan for the system with the aid of Northern Environmental, Inc. This plan was finalized in June 2007.

The LLPLD successfully applied for WDNR grant funds to initiate the control measures outlined within their management plan through 2012. The project was outlined to include herbicide treatment and associated monitoring activities during this timeframe, followed by a whole-lake assessment of the aquatic plant community, during the final year. In addition to these aquatic plant surveys, water quality, watershed, shoreline condition assessment, and fisheries data integration components were conducted. The culmination of this information, along with a stakeholder participation component, has resulted in a Comprehensive Lake Management Plan for Long Lake.

1.1 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 a single meeting that involved a focus group called a Planning Committee.

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

Planning Committee Meeting
On November 15th, 2012, Eddie Heath of Onterra met with six members of the LLPLD Planning Committee. The WDNR Lake Coordinator and the Invasive Species Coordinator for Vilas County were both invited but unable to be in attendance. The primary focuses of this meeting was the delivery of the study results and conclusions to the committee and begin developing management goals and actions for the Long Lake management plan. All study components including, Eurasian water milfoil treatment results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, and the majority of the discussion focused on the lake's fisheries and the presence of invasive species in the lake.

Management Plan Review and Adoption Process
Prior to the Planning Committee Meeting, a rough draft of the results sections (2.1-2.4) were provided to the Planning Committee. In late-November 2012 following the Planning Meeting, a draft of the Implementation Plan was provided to the Planning Committee for review. Based upon comments received, slight adjustments were made to this section.

In December 2012, a an official first draft of the Long Lake Comprehensive Management Plan was supplied to the WDNR, Wisconsin Valley Improvement Company, Great Lakes Indian Fish and Wildlife Commission, Vilas County, and LLPLD Planning Committee for review.

Comments were provided via email by the WDNR Lakes Coordinator on May 1, 2013. Many of these comments were editorial in nature and have been updated as appropriate. Through telephone conversations, the WDNR fisheries biologist made comments on the plan and this document reflects those revisions. The WVIC provided comments that were integrated in late-January, 2013.

The final report will be reviewed by the LLPLD Board of Commissioners and a vote to adopt the management plan will be held during the district's next official meeting. The plan will be implemented immediately following the vote to adopt has been concluded.

2.0 RESULTS & DISCUSSION

2.1 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. 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.

Another method includes recording the point halfway between the depth the Secchi disk disappears from site and the depth at which it reappears.

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.

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.

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.

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 publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) 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 Marl Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 2.1-1).

First, the lakes are classified into two main groups: shallow (mixed) or deep (stratified). Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or the entire lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). An equation developed by Lathrop and Lillie (1980) that incorporates the maximum depth of the lake and the lake's surface area is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
>> Headwater drainage lakes have a watershed of less than 4 square miles.
>>
>> Lowland drainage lakes have a watershed of greater than 4 square miles.

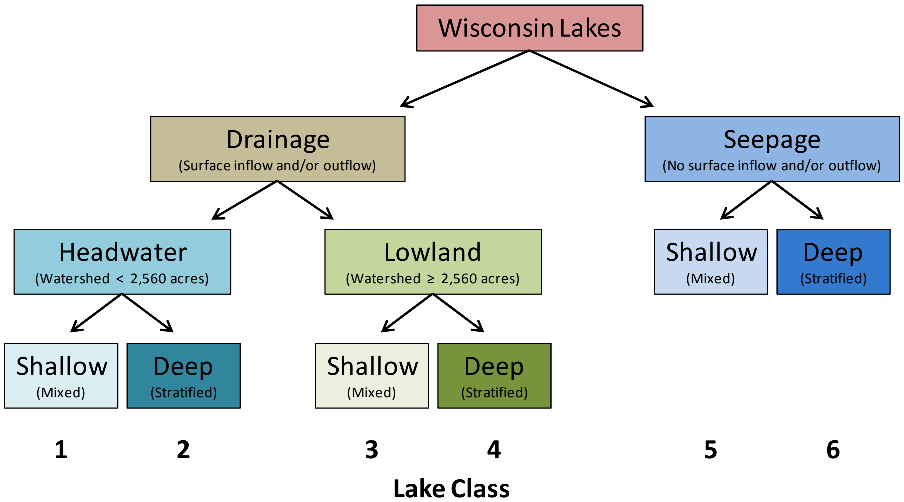

Figure 2.1-1. Wisconsin Lake Classifications. Long Lake is classified as a deep (stratified), lowland drainage lake (Class 4). Adapted from WDNR PUB-SS-1044 2008.

Long Lake is classified as a deep (stratified), lowland drainage lake (Class 4) (Figure 2.1-1). While not illustrated, deep (stratified) lakes that maintain a well-oxygenated bottom layer of water (hypolimnion) throughout the summer and support cold-water fish species such as trout are called *two-story* lakes. As will be discussed in the Fisheries Section, Long Lake contains cold-water fish species, and thus can be classified as a two-story lake. However, regional data for two-story lakes are not yet available, so the water quality of Long Lake will be compared to deep, lowland drainage lakes.

The WDNR developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six 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. 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 Northern Lakes and Forests (NLF) ecoregion (Figure 2.1-2).

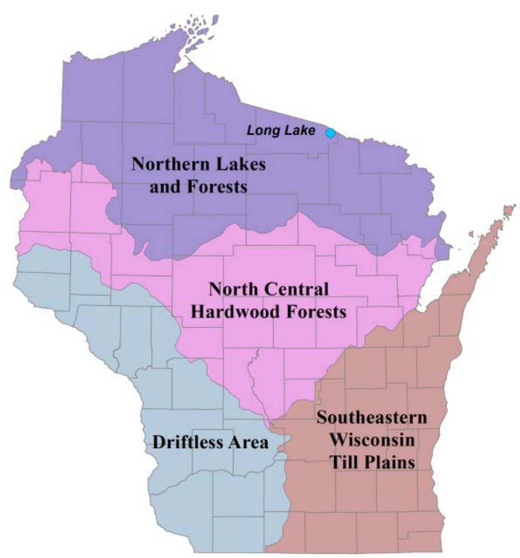

Figure 2.1-2. Location of Long Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is another useful tool in helping lake stakeholders understand the health of their lake compared to others 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, they 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 are displayed in Figures 2.1-3 - 2.1-6. Data collected from Long Lake were collected by the Wisconsin Valley Improvement Company (WVIC) and the Long Lake of Phelps District CLMN. Please note that the data in these graphs represent concentrations taken during the growing season (April-October). Since state and regional medians were calculated using summer (June, July, August) data, summer data for Long Lake has also been displayed. Furthermore, the phosphorus and chlorophyll-a data displayed represent samples taken near the surface. 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

Perception of water quality often varies greatly from person to person. This variance is due to differences in the tolerance and past experiences of people. In short, the water quality of a given lake might be poor to one person, but rather good to another person who has spent considerable time on other lakes that have poor water clarity, algae problems, or other water quality issues. By using factual, scientific data regarding water quality, we are able to say with certainty what the water quality of a lake is, and by comparing to historic data, learn for certain if the water quality has changed over time.

As previously stated, there are three primary parameters that are analyzed when assessing the water quality of a lake: total phosphorus, chlorophyll-*a*, and Secchi disk clarity. These three parameters yield a great deal of information about the lake's water quality and are closely correlated with one another. As discussed earlier, phosphorus is the limiting nutrient in the majority of Wisconsin's lakes, and increases in this plant nutrient often increases the growth and abundance of free-floating algae (measured by chlorophyll-*a*). The increase in free-floating algae decreases sunlight penetration into the water and lowers water clarity (measure by Secchi disk transparency). So, as phosphorus concentrations increase, algae (chlorophyll-*a*) increases, and water clarity (Secchi disk transparency) decreases. However, examining these data is not always this simple or straightforward as there are often other factors influencing the chemistry and clarity of a lake's water.

A moderate amount of total phosphorus data exists for Long Lake (Figure 2.1-3). Total phosphorus concentrations collected in the late 1970s and early 1980s were slightly higher than what has been recorded in most recent two decades. With the exception of total phosphorus concentrations in 2008, total phosphorus concentrations have remained relatively constant from 1993 to 2012. Analysis indicates that there is no detectible trend, positive or negative, in phosphorus concentrations over time within Long Lake at present. The weighted averages for both the growing season and summer total phosphorus concentrations fall well within the *Excellent* category for deep, lowland drainage lakes, and the summer average is significantly lower than the median values for deep, lowland drainage lakes within the state and lakes within the Northern Lakes and Forests (NLF) Ecoregion (Figure 2.1-3).

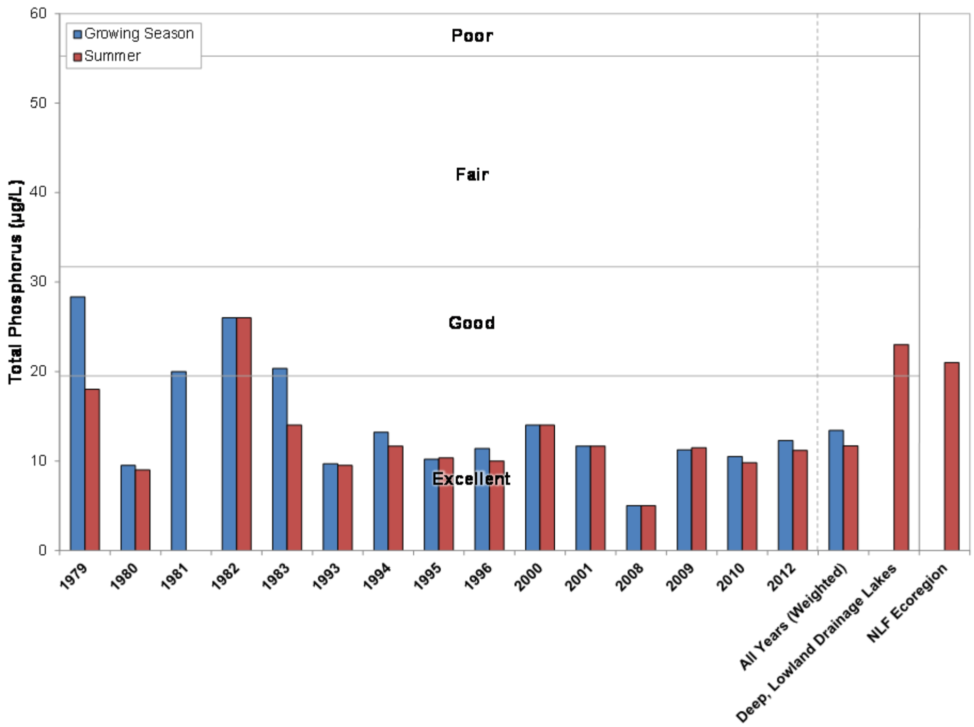

Figure 2.1-3. Long Lake annual average growing season and summer total phosphorus concentrations and state-wide class 4 lakes and regional median total phosphorus concentrations. Water Quality Index values adapted from WDNR PUB WT-913. Data compiled from SWIMS and WVIC databases.

Chlorophyll-*a* concentrations from Long Lake are available from the same time periods as total phosphorus (Figure 2.1-4). Like total phosphorus, chlorophyll-*a* concentrations have remained relatively constant over the time periods for which data are available. However, chlorophyll-*a* concentrations were slightly elevated in 2011. While elevated phosphorus concentrations were not recorded in 2011, Secchi disk clarity was approximately two feet lower than in 2010 and 2012, indicating higher algae concentrations. The weighted average for growing season and summer chlorophyll-*a* concentrations falls within the *Excellent* category for deep, lowland drainage lakes. The average summer chlorophyll-*a* concentration is significantly lower than the median values for other deep, lowland drainage lakes within Wisconsin as well as other lakes within the ecoregion (Figure 2.1-4).

Secchi disk transparency values represent the largest water quality data set collected from Long Lake (Figure 2.1-5). Overall, the weighted average growing season and summer Secchi disk transparency values fall within the *Excellent* category for deep, lowland drainage lakes, and greatly exceed the median transparency values for deep, lowland drainage lakes state-wide and lakes within the NLF Ecoregion (Figure 2.1-5). While no trends over time were apparent in the total phosphorus and chlorophyll-*a* data, analysis indicates that within the time period for which data are available, Secchi disk depth on Long Lake has increased. Average Secchi disk transparency values have increased from 12.5 feet in the period from 1979-1999 to 14.5 in the period from 2000-2012. A two-sample t-test (assuming unequal variances) indicated that there is a statistically valid difference in Secchi disk transparency from 1988-1999 and 2000-2012. Because there are no apparent trends in chlorophyll-*a* levels in Long Lake over time, it is believed that the increase in water clarity is not due to a decline in algae abundance.

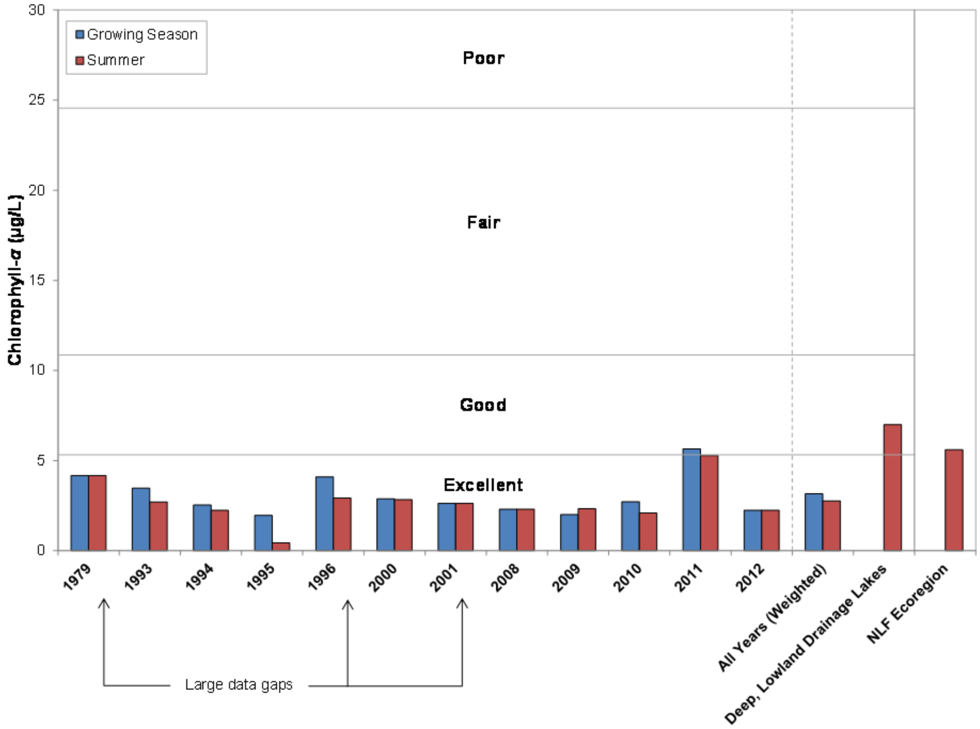

Figure 2.1-4. Long Lake annual average growing season and summer chlorophyll-*a* concentrations and state-wide class 4 lakes and regional median chlorophyll-*a* concentrations. Water Quality Index values adapted from WDNR PUB WT-913. Data compiled from SWIMS and WVIC databases.

Water clarity in Wisconsin's lakes is governed by two main parameters: *turbidity* and *true color*. Turbidity is a measure of the cloudiness of the water, or a measure of the capacity of suspended particles within the water to scatter and absorb light. If turbidity is high, light passing through the water will be absorbed or scattered in varying directions by suspended particles and less light will be able to penetrate into deeper water. In Wisconsin, the majority of particles that constitute turbidity are free-floating algae, but sources also include suspended particulates such as clays and silts delivered from runoff or resuspended bottom sediments. In contrast, true color is a measure of light scattered or absorbed by organic materials dissolved within the water once all of the suspended (non-dissolved) material has been removed. A number of lakes, particularly in northern Wisconsin, have natural dissolved organic materials that originate from decomposing plant material delivered from wetlands within the watershed. If these compounds are high enough, they 'stain' the water or give it a tea-color.

As mentioned earlier, it is not believed that the increase in water clarity observed over the last decade is due to a decline in algae, or a decline in turbidity. However, it is believed that the change in water clarity is due to a change in Long Lake's true color, or the amount of dissolved organic compounds within the water. While one would not consider Long Lake's water to be 'stained' by its appearance, following a rain event in 2009, Onterra ecologists observed water high in dissolved organic compounds flowing into the lake from one of the streams on the northwest side of the lake. As will be discussed next in the Watershed Section, Long Lake drains a number of nearby wetlands, and the dissolved organic compounds they deliver to the lake have an impact on the lake's water clarity. The increase in water clarity over the last decade is believed to be due to a decrease in the amount of dissolved organic compounds being delivered to the lake.

Annual precipitation data collected from a station near Lac Vieux Desert (NCDC 2012) indicates that overall precipitation during the period from 1988-1999 was 13 inches above normal, while from 2000-2011, total precipitation was 44 inches below normal. In addition, correlation analysis of Secchi disk depth and annual precipitation indicated an inverse relationship; as annual precipitation increased, Secchi disk depth decreased. In conclusion, it is believed that less precipitation over the most recent decade has decreased the amount of dissolved organic compounds being delivered from wetlands into the lake, and as a result, water clarity has increased on average by approximately two feet.

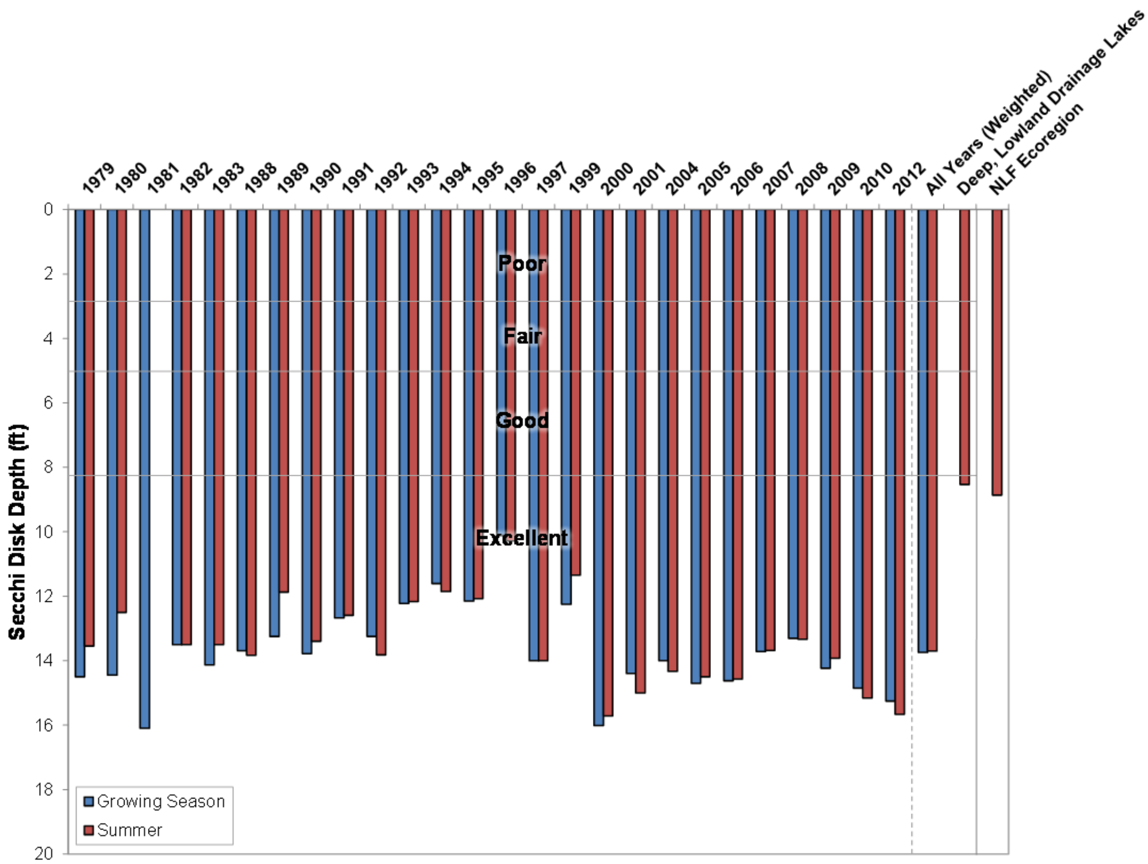

Figure 2.1-5. Long Lake annual average growing season and summer Secchi disk clarity values and state-wide class 4 lakes and regional median Secchi disk clarity values. Water Quality Index values adapted from WDNR PUB WT-913. Data compiled from SWIMS and WVIC databases.

Limiting Plant Nutrient of Long Lake

While total nitrogen concentrations were not measured as a part of this management plan update, using 1979 midsummer nitrogen and phosphorus concentrations from Long Lake, a nitrogen:phosphorus ratio of 25:1 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 2.1-6 contains the trophic state index (TSI) values for Long Lake. The TSI uses total phosphorus, chlorophyll-*a*, and Secchi disk transparency values to determine the trophic state (oligotrophic, mesotrophic, eutrophic) of the lake. In general, the biological parameters are the best values to use in judging a lake's trophic state, as water clarity can be affected by factors other than chlorophyll-*a* (e.g. suspended sediments, organic acids). Therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Long Lake is presently in an upper oligotrophic/lower mesotrophic state, and is of lower productivity than the majority of the lakes within the region and the state (Figure 2.1-6).

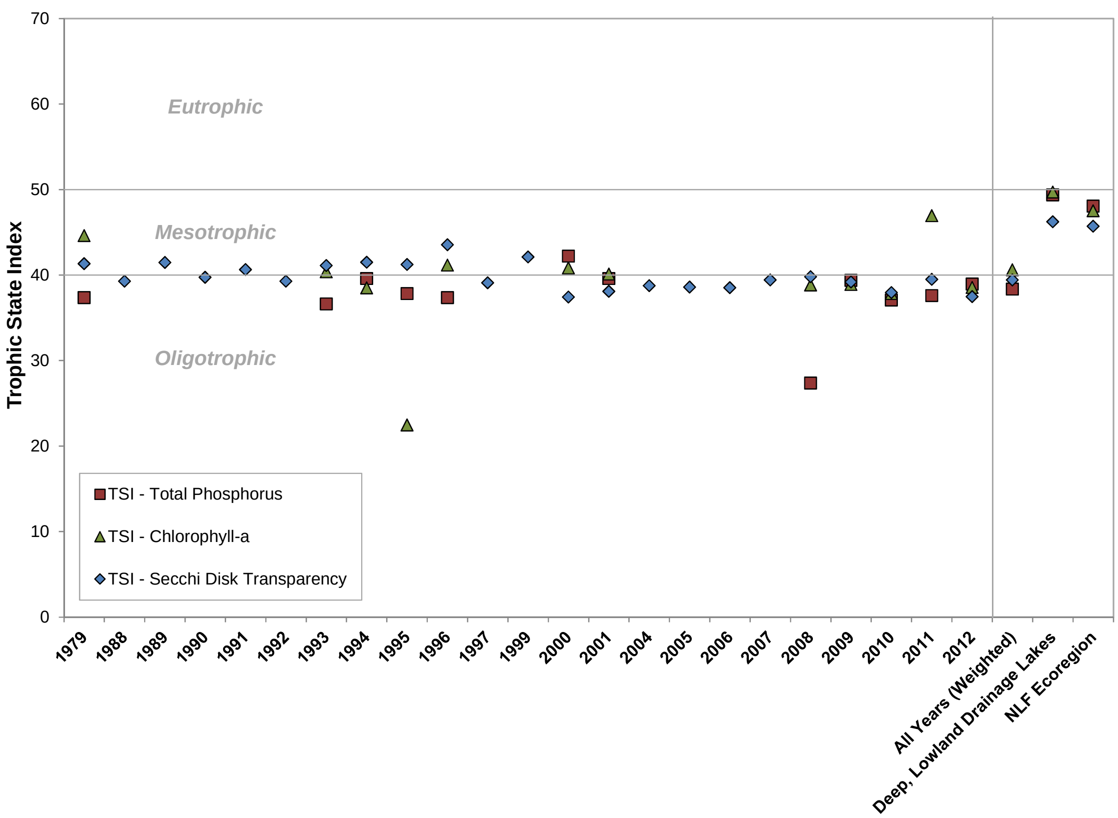

Figure 2.1-6. Long Lake, state-wide class 3 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193. Data compiled from SWIMS and WVIC databases.

Long Lake Zebra Mussel Suitability

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu).

Based upon this analysis, Big Sand and Long Lakes are considered "not suitable" for mussel establishment, whereas nearby North and South Twin Lakes are considered 'borderline suitable."

Dissolved Oxygen and Temperature in Long Lake

Dissolved oxygen and temperature were measured during four water quality sampling events by Long Lake Citizen Lake Monitor, John Rowe (Figure 2.1-7). During the spring, the lake is completely mixed from top to bottom, as indicated by the uniform temperature and dissolved oxygen from March. During the summer months, the lake becomes stratified, with a gradient developing for both temperature and dissolved oxygen. The profiles also indicate that the hypolimnion, or cool bottom layer of water, remains oxygenated during the summer months and thus is the reason why Long Lake can support a cold-water fishery.

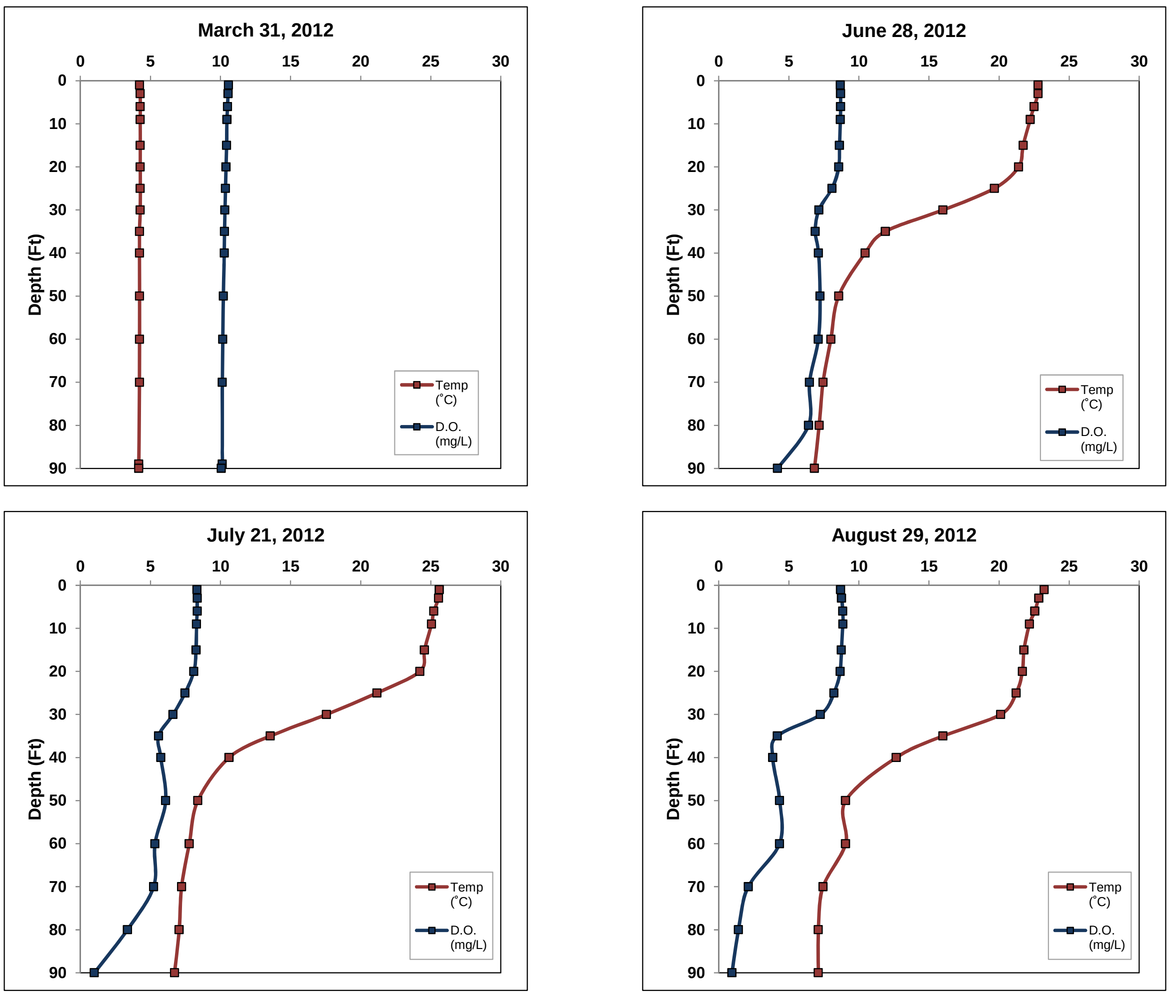

Figure 2.1-7. Long Lake 2012 dissolved oxygen and temperature profiles. Collected by John Rowe, Long Lake CLMN.

Long Lake Water Levels

Long Lake is one of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs used to maintain a nearly uniform flow of water as practicable in the Wisconsin river by storing surplus water in reservoirs for discharge when water supply is low to improve the usefulness of the rivers of the rivers for hydropower, flood control, and public use (Figure 2.1-8)

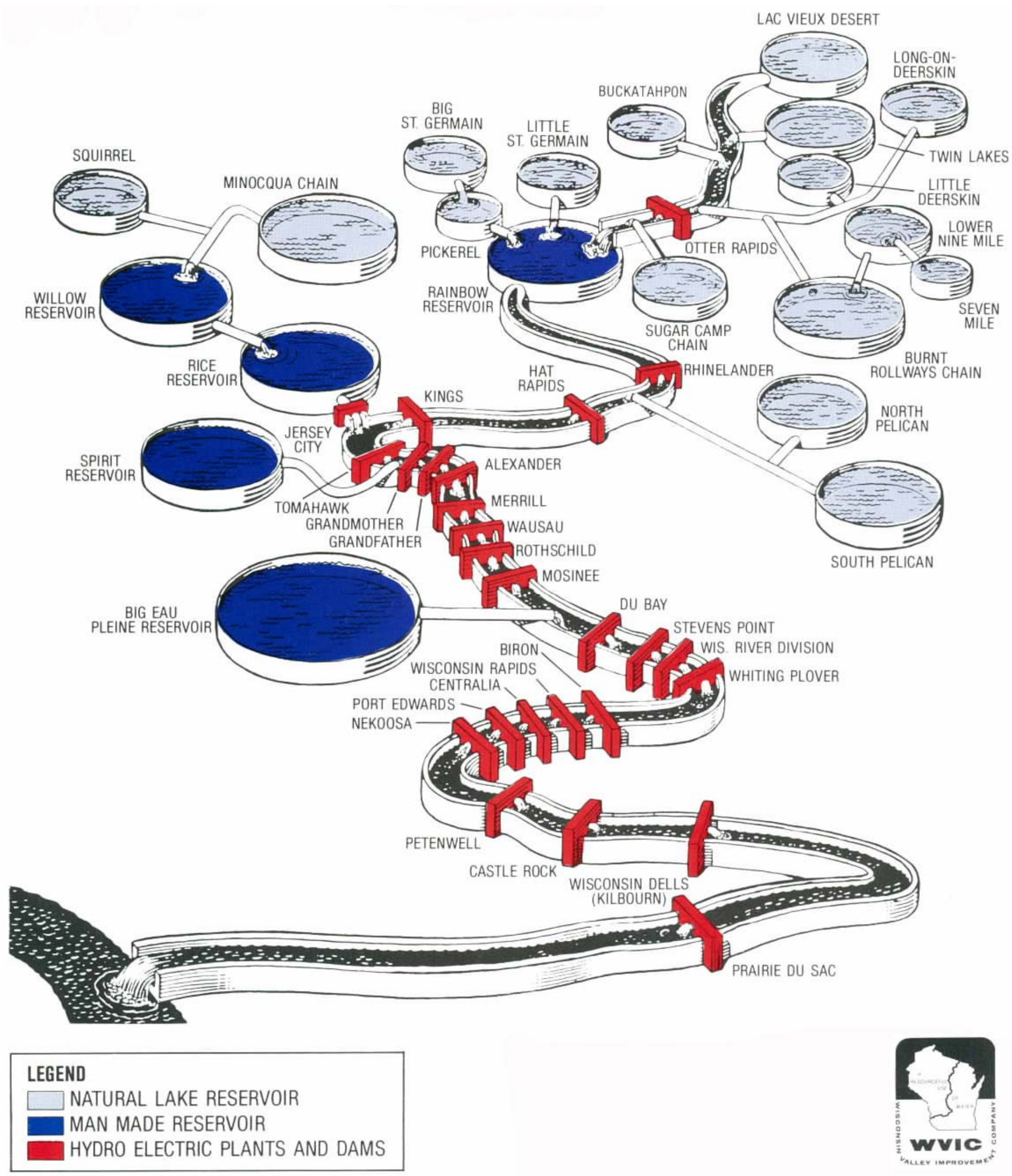

Figure 2.1-8. WVIC reservoir system. Adapted from WVIC website.

Hydroelectric power projects are licensed by the Federal Energy Regulatory Commission (FERC). As part of the FERC operation license, the minimum and maximum water levels are set for each waterbody. Natural lake reservoir water levels are maintained within a relatively narrow range in comparison to the five man-made reservoirs which exhibit changes of water levels that could span 10-20 feet in a single year. Long Lake is one of the natural lake reservoirs in the WVIC system, and has an operational range of less than 2 feet during the summer months. The water levels need to be kept between 1,698.43 and 1,696.51 between June 1 and September 30 of each year. Winter drawdowns cannot exceed 1,695.84, which is 2.59 feet below full pool.

In addition to establishing a range of water levels, minimum outflows are also set to make sure the downstream riverine systems are not negatively impacted by abnormally low flows. Long Lake must maintain a minimum flow and attempt not to exceed a 31 cubic foot per second discharge to protect and enhance the trout fishery and habitat below the dam. For these reasons, the WVIC may not be able to change the outflow at the dam to aid in water retention in association with an early-season herbicide treatment.

2.2 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.

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 exceeding 10-15:1, 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 (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. 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 affect 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.

The surface water drainage basin, or watershed, for Long Lake encompasses approximately 14,211 acres across both Wisconsin and Michigan (Map 2). In fact, the eastern portion of the Long Lake's watershed represents the divide between the Great Lakes' and Mississippi River's drainage basins. Long Lake's watershed can be divided into its direct watershed, or the area of land which drains directly to Long Lake, and Big Sand Lake's watershed, or the area of land which drains into Big Sand Lake before flowing into Long Lake (Figure 2.2-1). The land cover within Long Lake's direct watershed includes forests (65%), forested and non-forested wetlands (13%), Long Lake itself (11%), pasture/grassland (10%), row crop agriculture (1%), and a quarry which was classified as medium urban density (<1%). Approximately 95% of Big Sand Lake's watershed is comprised of forests, open water, and wetlands. The majority of Long Lake's watershed is comprised of land cover types which deliver minimal amounts of pollutants (nutrients and sediments) to the lake.

The watershed area relative to the area of Long Lake yields a watershed to lake area ratio of 15:1, meaning that there are 15 acres of land draining to every one acre of Long Lake. As discussed previously, in watersheds with larger watershed to lake area ratios, the amount of land draining to the lake plays a larger role in influencing the lake's water quality and is not solely determined by the land cover types within the watershed. WiLMS estimated that the residence time, or time it takes for the water in Long Lake to completely replace itself is approximately one year and ten months.

Using WiLMS, the acreages of land cover types within Long Lake's direct watershed and total phosphorus data from Big Sand Lake were used to determine the annual potential phosphorus load to the lake. This modeling indicated that Long Lake potentially receives an estimated 1,295 pounds of phosphorus on an annual basis. While this seems high, it is important to remember that Long Lake's size and depth results in a very high volume of water. The phosphorus being loaded to the lake is spread out or diluted within this large volume and results in the low concentrations measured within the water. Using the annual potential phosphorus load, WiLMS predicted an in-lake growing season mean total phosphorus concentration of 16.0 µg/L. The actual in-lake growing season mean calculated from data collected from Long Lake yields a value of 11.4 µg/L, slightly lower but fairly similar to what the model predicted. This indicates that there are no unaccounted sources of phosphorus entering the lake.

The model indicated that forests within Long Lake's direct watershed account for the majority (32%) of the phosphorus entering the lake on an annual basis (Figure 2.2-2). Big Sand Lake's watershed accounts for 21% of the annual phosphorus load, while atmospheric deposition of phosphorus directly to the lake itself (18%), pasture/grassland (18%), wetlands (7%), row crop agriculture (4%), and the area of medium urban density (<1%) account for the remaining phosphorus (Figure 2.2-2).

To emphasize the importance of forested land cover within Long Lake's watershed, WiLMS was used to estimate the average growing season total phosphorus concentrations within the lake if 25% and 50% of the forested land cover were converted to row crops. The 25% and 50% forest-to-row crop conversion models predicted that average growing season total phosphorus concentrations would increase from the actual 11.4 µg/L measured to 24.0 µg/L and 32.0 µg/L, respectively. Using predictive equations by Carlson (1977), the increase in total phosphorus concentrations would result in an increase in algae abundance from the measured 3.2 µg/L to 4.6 µg/L for the 25% conversion model and 7.1 µg/L for the 50% conversion model. The resulting increase in algae abundance would result in lower water clarity; converting 25% of forested land cover to row crops would decrease water clarity from the growing season average Secchi disk depth of 13.7 feet to 9.0 feet, and a conversion of 50% would result in a decrease to 6.7 feet. These models illustrate the significance of forested land cover and other natural land cover types within Long Lake's watershed that create and maintain the lake's excellent water quality.

In 2007, Northern Environmental Technologies, Inc. completed a comprehensive management plan for Long Lake which included a watershed delineation land use characterization. The Long Lake watershed was concluded to encompass 11,810 acres. However, this delineation did not include contributions from nearby Smokey Lake, which straddles the Michigan/Wisconsin border to the northeast and is up-stream from Big Sand and Long Lakes. Therefore, Long Lake's watershed is approximately 20% larger (14,211 acres) than reported in 2007. Additionally, land cover types were classified in the 2007 report based upon a 1992 WISCLAND database. Within Map 2, land use was determined using data from a 2006 NLCD database. The land uses are not thought to have changed in this watershed substantially between these time periods, however the 2006 database may indicate some changes based upon a higher level of detection and accuracy. Therefore, due to the difference in the size of the watershed and the level of technology spanning the two studies, a side-by-side comparison between the 2007 and 2012 watershed study results is not applicable. The model output statistics can be found in Appendix B.

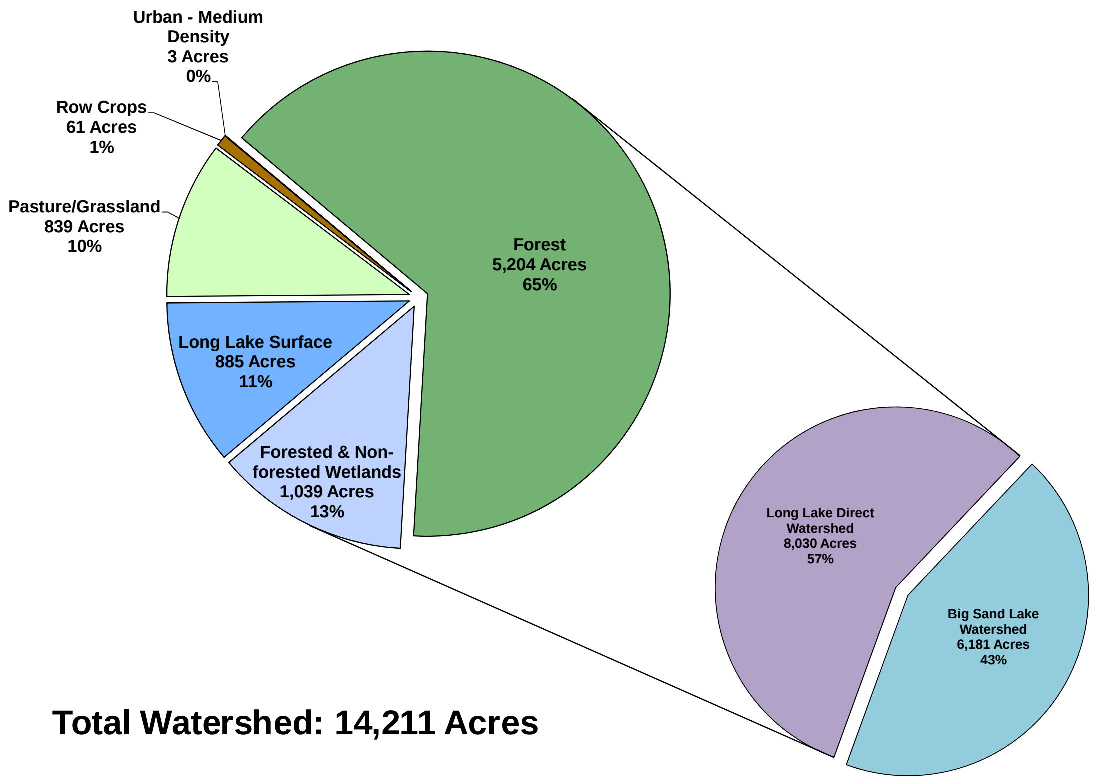

Figure 2.2-1. Long Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

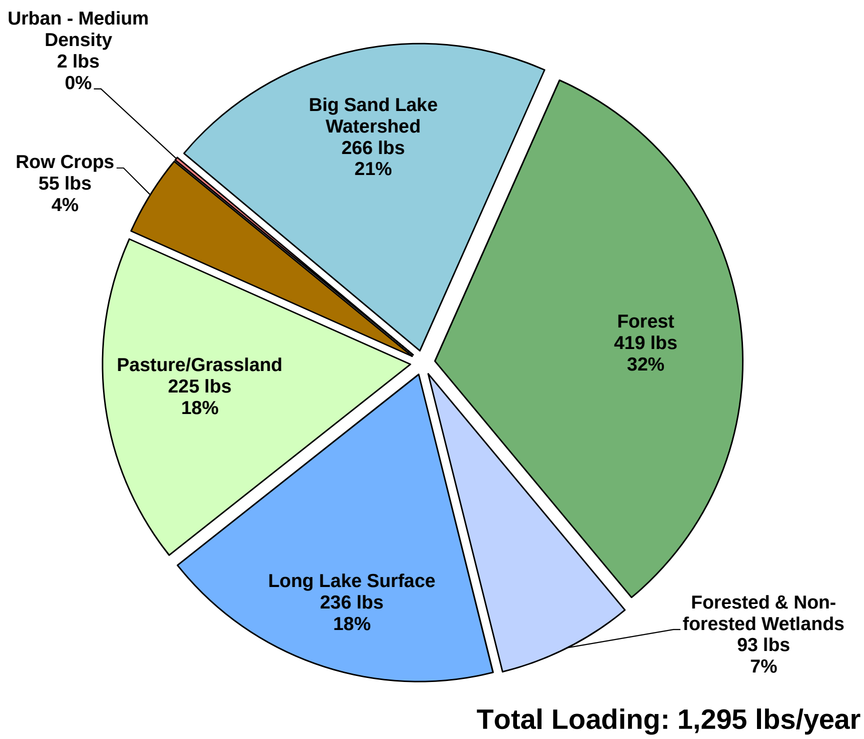

Figure 2.2-2. Long Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Shoreline Assessment

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to 35 feet shoreland). When a lake's shoreline is developed, the increased impervious surface, removal of natural vegetation, installation of septic systems, and other human practices can severely increase nutrient loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) affects on the lake is important in maintaining the quality of the lake's water and habitat. Along with this, the immediate shoreland area is often one of the easiest and most beneficial areas to restore.

The intrinsic value of natural shorelines 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 shoreline 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. 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.

Studies conducted on nutrient runoff from Wisconsin lake shorelines have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreline 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 shorelines – regular fertilizer application lawns (fertilizer with phosphorus), non-phosphorus fertilizer application sites, and unfertilized sites. 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 (Garn 2001). 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 species. Therefore, these studies show us that it is developed shoreland as well as 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 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.

While producing a completely natural shoreline 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. Locating 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.

A lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelines are more stressful on a lake ecosystem, while definite benefits occur from shorelines that are left in their natural state. Figure 2.2-3 displays a diagram of shoreline categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreline has been left in its original state.

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

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

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

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

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

Figure 2.2-3. Shoreline assessment category descriptions.

On Long Lake, the development stage of the entire shoreline was surveyed during the summer of 2012, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 2.2-4.

Long Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, the vast majority (6.3 miles) is of natural/undeveloped and developed-natural shoreline (Figure 2.2-4). 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, 0.4 miles of urbanized and developed–unnatural shoreline were observed. If restoration of the Long Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to the lake ecosystem. Map 3 displays the location of these shoreline lengths around the entire lake.

While producing a completely natural shoreline 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. Locating 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 increases the amount of habitat for wildlife.

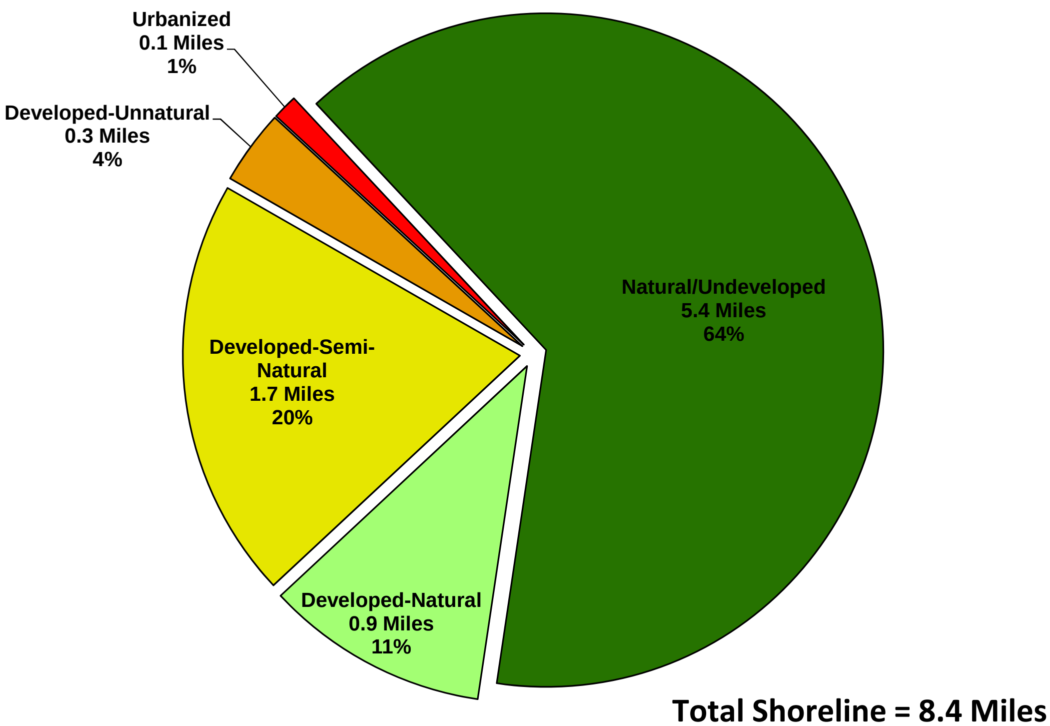

Figure 2.2-4. Long Lake shoreland categories and total lengths. Based upon a summer 2012 survey. Locations of these categorized shorelands can be found on Map 3.

2.3 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 shoreline 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. 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.

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 shoreline. 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 shoreline 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).

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, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:

- An upland buffer zone measuring 35’ x 100’.
- An aquatic zone with shallow-water and deep-water areas of 10’ x 100’ each.
- Site is assumed to need little invasive species removal prior to restoration.
- Site has a moderate slope.
- Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 100’ of biolog to protect the bank toe and each site would need 100’ of wavebreak and goose netting to protect aquatic plantings.
- Each site would need 100’ of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
- 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 shoreline erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • 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.

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. If these bottom screens are greater than 30 feet wide, a WDNR 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 Appendix F of Gettys et al. (2009).

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

Aquatic herbicides can be classified in many ways. Organization of this section follows Netherland (2009) in which mode of action (i.e. how the herbicide works) and application techniques (i.e. foliar or submersed treatment) group the aquatic herbicides. 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, trageted 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. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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 emergents 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

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 2.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreline. 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 shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline 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 shoreline 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 shoreline 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 2.1-1).

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 emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents 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 2.3-1). 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.

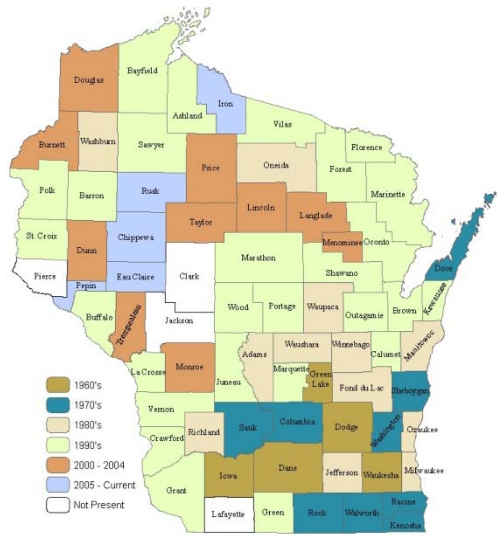

Figure 2.3-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

> **Littoral Zone** is the area of a lake where 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. Normally, the early-season aquatic invasive species (AIS) survey focused on locating potential occurrences of curly-leaf pondweed would be conducted first in late spring or early summer. However, Onterra ecologists have visited Long Lake on numerous occasions since 2008 and have not located curly-leaf pondweed; therefore, this meander-based survey of the *littoral zone* was not conducted as part of this management plan update. It is believed that curly-leaf pondweed either does not exist in Long Lake or exists at an undetectable level at this time. However, nearby Lac Vieux Desert and Kentuck Lake, as well as upstream Big Sand Lake, have documented occurrences of curly-leaf pondweed.

The comprehensive aquatic plant point-intercept and aquatic plant community mapping surveys were conducted on Long Lake on August 7, 2012 by Onterra. During these surveys, 48 species of aquatic plants were located in Long Lake (Table 2.3-1), only one of which is considered to be non-native: Eurasian water milfoil (*Myriophyllum spicatum*). Eurasian water milfoil is highly invasive, and will be discussed in detail in the Non-native Aquatic Plants Section. The aquatic plants located during a 2006 WDNR point-intercept survey on Long Lake are also displayed in Table 2.3-1. The raw data from the 2012 point-intercept survey has been provided electronically to the WDNR and can be found in Appendix C.

While sediment data was collected during the 2012 point-intercept survey, this data could only be determined at points that fell within 14 feet of water or less. Within this subset of points, 37% of the point-intercept sampling locations contained rock, 36% contained fine, organic matter (muck), while the remaining 27% contained sand. Map 4 illustrates the distribution of sediment types in Long Lake, and shows that the majority of point-intercept locations with mucky substrates were found in the southern portion of the lake and at the mouth of the inlet from Big Sand Lake, while areas of sand and rock dominate shallow areas throughout the rest of the lake.

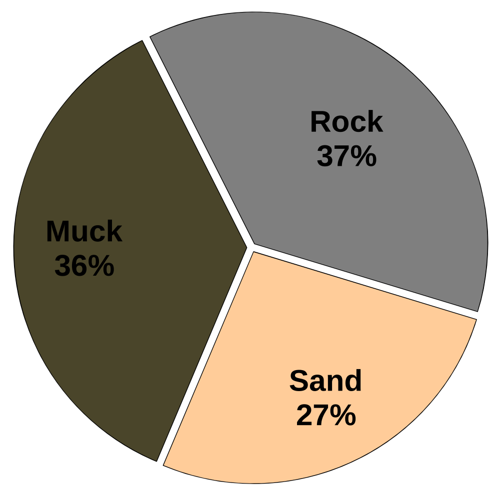

Figure 2.3-2. Long Lake proportion of substrate types. Created using data from 2012 aquatic plant point-intercept survey at points in 14 feet of water or less.

Like in 2006, aquatic plants were found growing to a depth of 18 feet in 2012. Of the 406 point-intercept sampling locations that fell at or within the maximum plant growth in 2012, approximately 80% of them contained aquatic vegetation, compared to approximately 69% in 2006. Map 5 illustrates that the majority of Long Lake is too deep to support aquatic plant growth, and the majority of aquatic vegetation is located in the shallower, southern portion of the lake and within the narrow littoral band in shallower, near-shore areas.

Table 2.3-1. Aquatic plant species located in Long Lake during 2006 & 2012 surveys.

Life Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (WDNR)	2012 (Onterra)
Emergent	*Acorus americanus*	Sweetflag	7		I
	Calla palustris	Water arum	9		I
	Carex retrorsa	Retrorse sedge	6		I
	Carex utriculata	Common yellow lake sedge	7		I
	Eleocharis palustris	Creeping spikerush	6	X	X
	Equisetum fluviatile	Water horsetail	7		X
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus acutus	Hardstem bulrush	5	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	X
	Scirpus cyperinus	Wool grass	4		I
FL	*Brasenia schreberi*	Watershield	7	X	X
	Nuphar variegata	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
	Polygonum amphibium	Water smartweed	5		I
FL/E	*Sparganium americanum*	Eastern bur-reed	8		X
	Sparganium angustifolium	Narrow-leaf bur-reed	9		I
	Sparganium emersum	Short-stemmed bur-reed	8		I
	Sparganium eurycarpum	Common bur-reed	5		I
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Isoetes spp.	Quillwort species	8	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic (Invasive)	X	X
	Najas flexilis	Slender naiad	6	X	X
	Najas guadalupensis	Southern naiad	7		X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton alpinus	Alpine pondweed	9		I
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton amplifolius x praelongus	Large-leaf x White-stem pondweed	NA		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	
	Potamogeton foliosus	Leafy pondweed	6	X	X
	Potamogeton gramineus	Variable pondweed	7	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X
	Potamogeton praelongus	White-stem pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	Potamogeton strictifolius	Stiff pondweed	8	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Ranunculus flammula	Creeping spearwort	9	X	X
	Utricularia intermedia	Flat-leaf bladderwort	9		I
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	NA	X	
	Juncus pelocarpus	Brown-fruited rush	8		X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent
X = Located on rake during point-intercept survey; I = Incidental Species

Of the 35 aquatic plant species recorded on the rake during the 2012 point-intercept survey, fern pondweed, common waterweed, and slender naiad were the three-most frequently encountered (Figure 2.3-3). Fern pondweed was located at approximately 35% of the point-intercept locations that fell within the littoral zone. As its name suggests, fern pondweed has the appearance of a terrestrial fern or the frond of a palm tree and prefers soft sediments. Often observed growing in thick, large beds, this species can often be found growing deeper than many other aquatic plants. Fern pondweed is usually low-growing within the water column and provides valuable structural habitat for aquatic organisms. In Long Lake, the majority of fern pondweed was found growing in the southern portion of the lake and near the mouth of the inlet from Big Sand Lake where sediments were soft in four to nine feet of water.

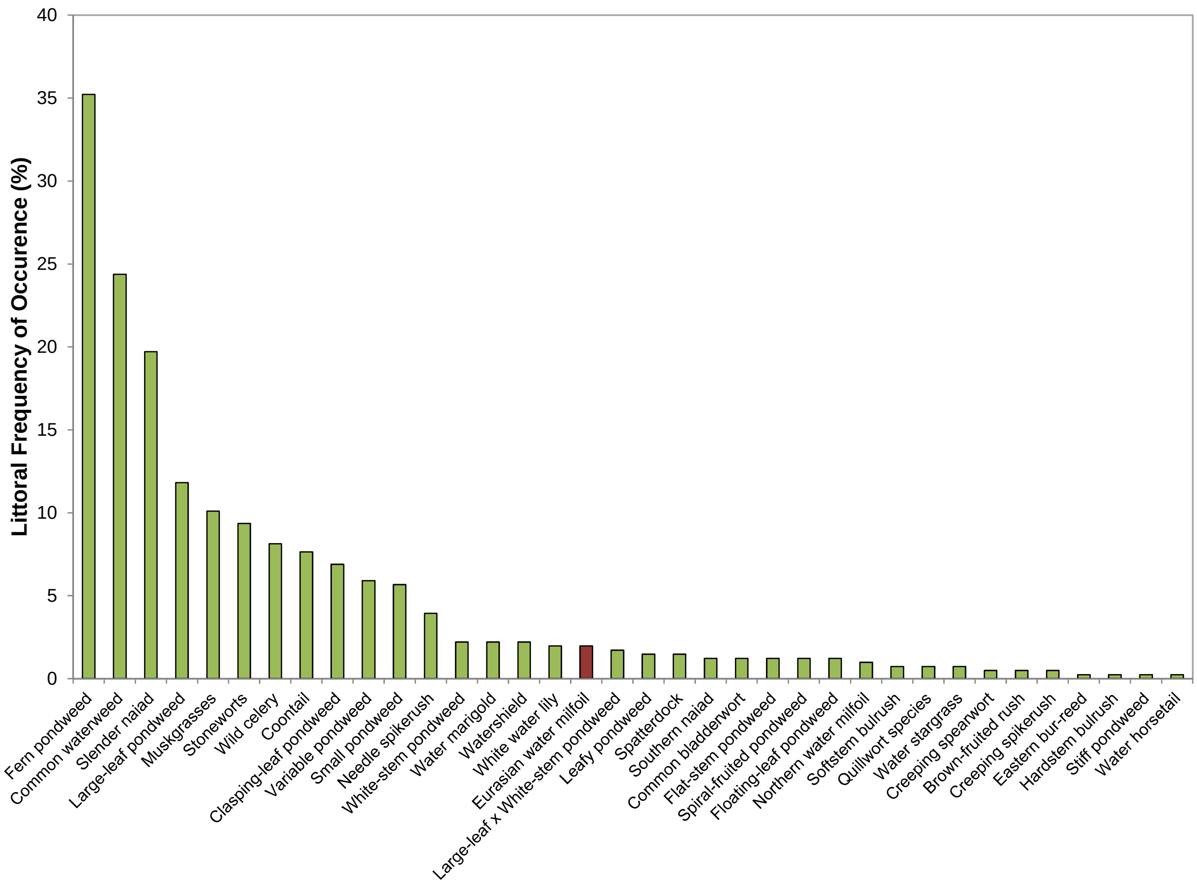

Figure 2.3-3. Long Lake 2012 aquatic plant littoral occurrence analysis. Created using data from 2012 aquatic plant point-intercept survey.

Common waterweed, located at approximately 24% of littoral point-intercept points in 2012 (Figure 2.3-3), is a species found in abundance across Wisconsin. Lacking true roots and able to obtain the majority of its nutrients directly from the water, common waterweed often forms large mats which break free from the bottom and can continue to grow suspended in the water column or floating on the lake's surface. While not problematic in Long Lake, in lakes with higher nutrient content, common waterweed can grow to excessive levels where it can interfere with recreational activity. In 2012, common waterweed was most abundant between six and thirteen feet of water. Common waterweed provides habitat and food sources to both aquatic and terrestrial wildlife.

Slender naiad was the third-most frequently encountered aquatic plant species located in Long Lake in 2012 with a littoral frequency of occurrence of approximately 20% (Figure 2.3-3). Being an annual, slender naiad produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. In Long Lake, slender naiad is most prevalent between one and five feet of water, growing in areas of sand.

Another naiad species, southern naiad, was located in Long Lake in 2012. While not a large constituent of Long Lake's aquatic plant community (littoral occurrence of 1.2%), southern naiad does constitute a large portion of Big Sand Lake's aquatic plant community as determined from a 2011 point-intercept survey. In fact, southern naiad forms dense, non-navigable beds in the shallow bay on the south end of Big Sand Lake. Unlike slender naiad, southern naiad is perennial, emerging from stems from the previous year. Emerging research is indicating that hybrids between southern naiad subspecies exist and are often observed acting aggressively, growing to nuisance levels and displacing other species (Les et al. 2010). While it is not known if the southern naiad populations in Long and Big Sand Lakes are of hybrid origin, future plant surveys will reveal if their populations are increasing.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total of 47 native aquatic plant species were located in Long Lake during the 2012 surveys, 35 were encountered on the rake during the whole-lake point-intercept survey. These 35 native species and their conservatism values were used to calculate the FQI of Long Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 2.3-4 compares the FQI components of Long Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Ecoregion as well as the entire State of Wisconsin. In 2012, Long Lake's native species richness (35) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.5) is slightly lower than the ecoregional median and higher than the state-wide median. Combining Long Lake's 2012 native species richness and average conservatism values yields an FQI value of 38.5, which exceeds the ecoregional and state median values (Figure 2.3-4). The FQI values from 2012 are also very similar to those calculated from the WDNR's point-intercept survey in 2006, suggesting that no significant changes in the quality of Long Lake's native aquatic plant community have changed over this time period. Overall, this analysis indicates that Long Lake's native aquatic plant community is of comparable quality to other lakes within the Northern Lakes and Forests Ecoregion, and of higher quality than most lakes in the state.

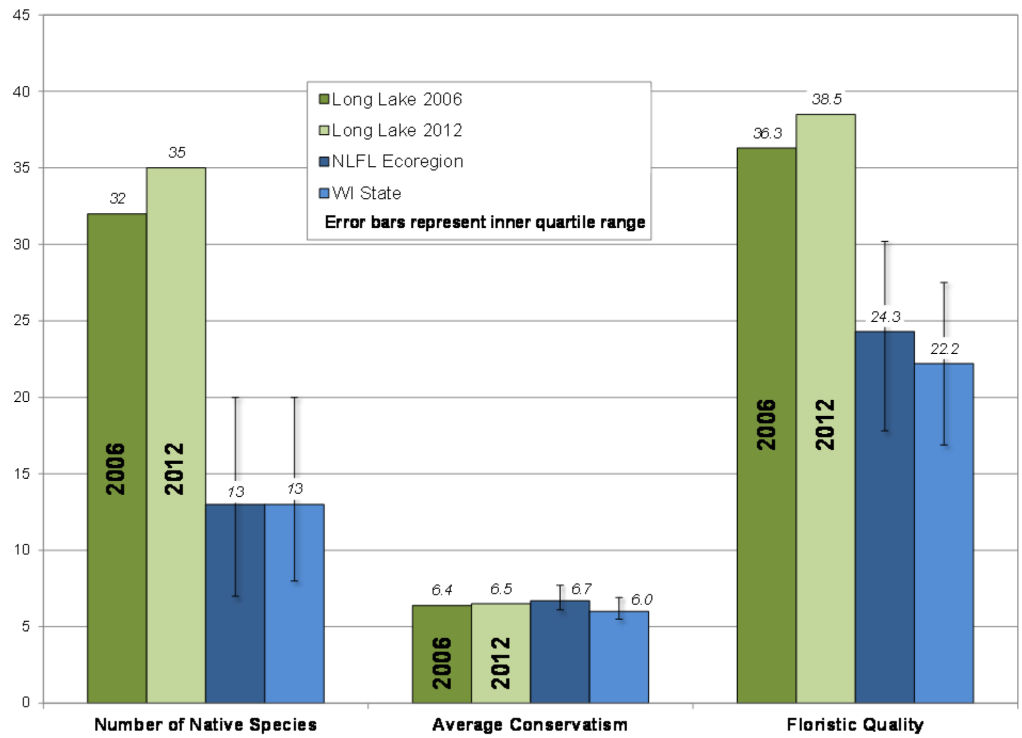

Figure 2.3-4. Long Lake Floristic Quality Assessment. Created using data from 2006 WDNR and Onterra 2012 aquatic plant point-intercept surveys.

As explained earlier, lakes with diverse aquatic plant communities 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 relatively 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.

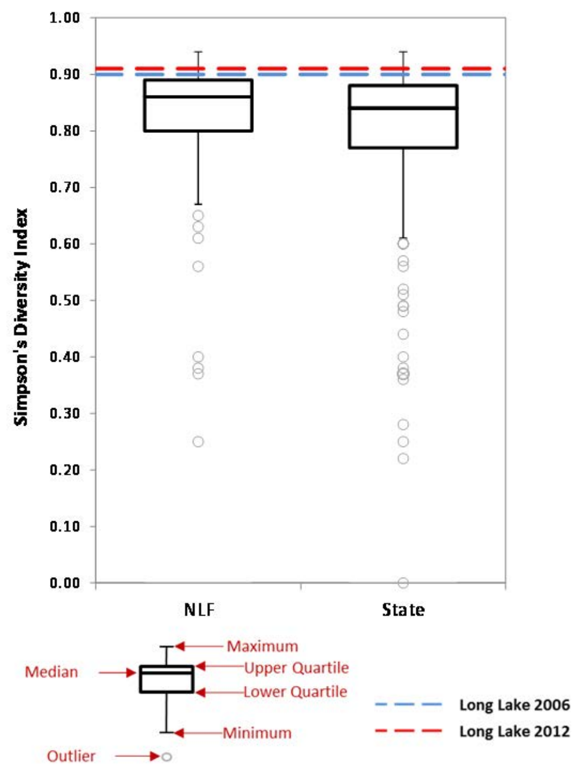

Figure 2.3-5. Long Lake species diversity index. Created using data from 2006 and 2011 point-intercept surveys.

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 obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLFL

Ecoregion (Figure 2.3-5). Using the data collected from the 2012 point-intercept survey, Long Lake's aquatic plant community was shown to have very high species diversity with a Simpson's diversity value of 0.91. This diversity value falls above the upper quartile for lakes within ecoregion and the state (Figure 2.3-5). This value indicates that if two individual aquatic plants were randomly sampled from Long Lake's aquatic plant community, there would be a 91% probability that they would be of different species. Species diversity in 2006 was calculated to be very similar to 2012 with a diversity value of 0.90 (Figure 2.3-5).

As explained previously in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plant species is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while fern pondweed was found at approximately 35% of the littoral sampling locations in Long Lake in 2012, its relative frequency of occurrence is 20%. Explained another way, if 100 plants were randomly sampled from Long Lake, 20 of them would be fern pondweed. Figure 2.3-6 displays the relative frequency of occurrence of aquatic plant species from the 2012 point-intercept survey and illustrates that aquatic plant community of Long Lake is not overly-dominated by a single or few species.

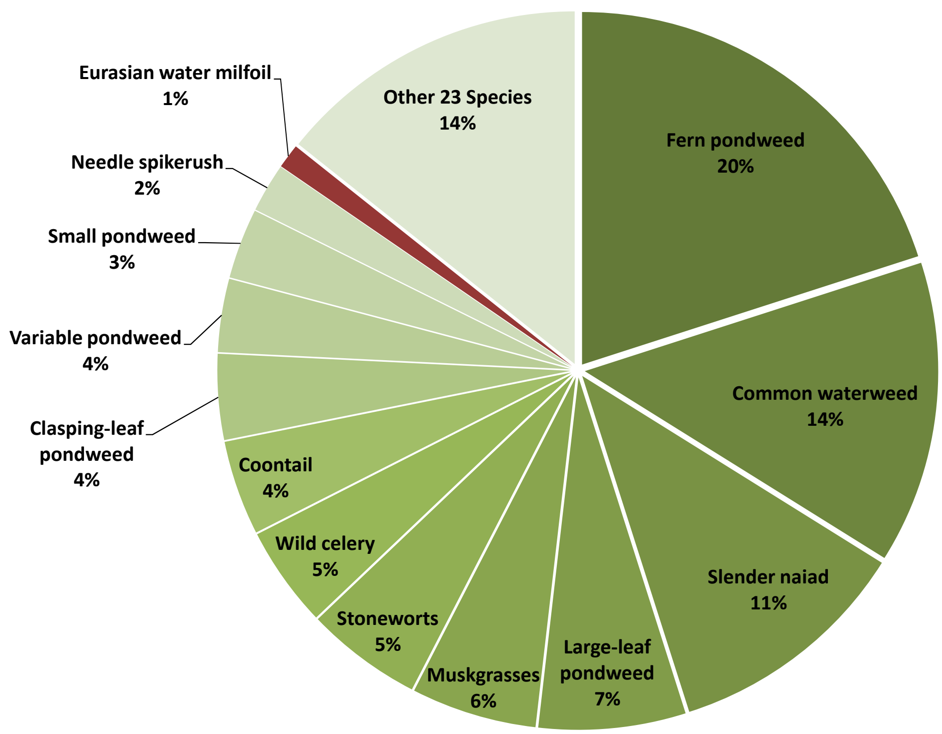

Figure 2.3-6. Long Lake 2012 aquatic plant relative occurrence analysis. Created using data from 2011 aquatic plant point-intercept survey.

The quality of Long Lake's aquatic plant community is also indicated by the high number of native emergent and floating-leaf plant species that occur throughout the lake. Eighteen emergent and floating-leaf aquatic plant species were located in Long Lake during the 2012 plant surveys (Table 2.3-1). The 2012 community map (Map 6 & 7) indicates that approximately 23 acres (3%) of the 885-acre lake contain these types of plant communities (Table 2.3-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can become quite sparse along the shores of receding water lines.

Continuing the analogy that the community map represents a 'snapshot' of the important 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 the 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 2.3-2. Long Lake acres of floating-leaf and emergent plant communities. Created from the 2012 community mapping survey.

Plant Community	Acres
Emergent	12.2
Floating-leaf	7.8
Mixed Emergent & Floating-leaf	2.5
Total	**22.6**

Non-native Plants in Long Lake

Eurasian water milfoil

Eurasian water milfoil was first documented in Long Lake by the WDNR in 2000, though it is believed to have inhabited this system for a number of years before this date. Following the finalization of a lake management plan by Northern Environmental, Inc. in 2007, the LLPLD successfully applied for WDNR grant funds in August of 2009 to initiate Eurasian water milfoil control measures outlined within their management plan. The funds were to cover the first of a five-year program aimed at significantly reducing the Eurasian water milfoil population within the lake. Annual early-season herbicide treatments have been conducted since 2008 under this grant-funded program. Acreage of Eurasian water milfoil was reduced by 93% from 2011 to 2012, and 97% from 2009 to 2012, representing a reduction of nearly 94 acres (Figure 2.3-7).

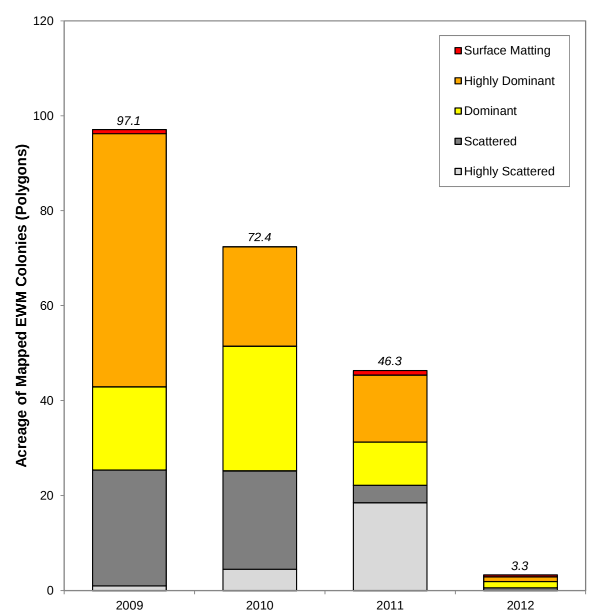

Figure 2.3-7. Acreage of Eurasian water milfoil in Long Lake from 2009 to 2012.

Every year, aquatic plants within the treatment areas were quantitatively and qualitatively assessed to determine not only if the treatments were effective at causing Eurasian water milfoil mortality, but to ensure that the treatments were not having significant adverse impacts to native flora. Because these surveys are focused on the treatment areas themselves, they do not look at the aquatic plant community on a lake-wide level. Because of this, it is recommended that for large scale treatment programs (>10 acres), a whole-lake point-intercept survey to be conducted every five years to affirm that the treatments are not impacting native aquatic plants on a lake-wide level. The 2012 whole-lake point-intercept survey was not only conducted to aid in the lake management plan update, but to determine if any significant changes have occurred in the lake's aquatic plant community since the Eurasian water milfoil control program was initiated. This section will discuss the comparisons between the 2006 and 2012 whole-lake point-intercept surveys. For information regarding a specific year's treatment and sub-sample point-intercept data within treatment areas, please see the respective year's annual treatment report.

Over the course of the Eurasian water milfoil control project, the whole-lake point-intercept data revealed that Eurasian water milfoil was reduced from a littoral frequency of occurrence of 20.6% in 2006 to 2.2% in 2012 (Figure 2.3-8). Chi-square analysis indicates that this represents a statistically valid reduction in occurrence of nearly 92%.

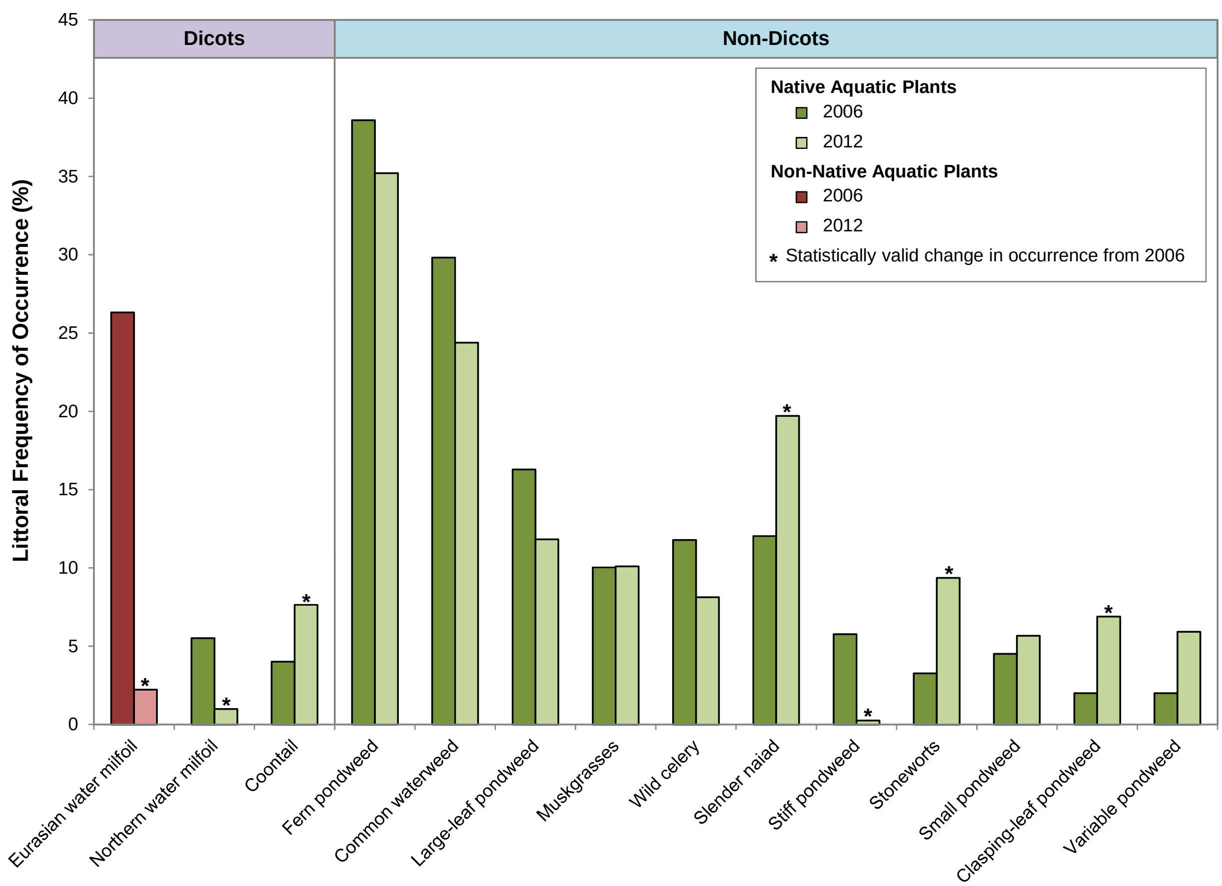

Figure 2.3-8. Littoral frequency of occurrence of select aquatic plant species in Long Lake from the 2006 and 2012 point-intercept surveys. Created using data from WDNR 2006 and Onterra 2012 point-intercept surveys.

In the previous section, the native aquatic plant community of Long Lake was shown to have maintained its high quality throughout this five-year project. Only two native aquatic plant species, northern water milfoil and stiff pondweed, exhibited statistically valid reductions in occurrence between the 2006 and 2012 surveys (Figure 2.3-8). Like Eurasian water milfoil, northern water milfoil is a dicot and is particularly susceptible to these types of herbicide treatments. Efforts are taken to minimize impacts to the species by applying herbicides early in the spring before these plants are actively growing. On a positive note, another native dicot, coontail, saw a statistically valid increase in occurrence from 2006 to 2012 (Figure 2.3-8). However, unlike Eurasian water milfoil, stiff pondweed is a non-dicot and is not thought to be sensitive to dicot-selective herbicides, though emerging data is suggesting that certain monocot species may be prone to decline following treatment. The non-dicot slender naiad saw a statistically valid increase in occurrence of 64% between the 2006 and 2012 surveys (Figure 2.3-8).

Overall, this five-year Eurasian water milfoil control project on Long Lake has decreased the targeted Eurasian water milfoil population markedly. Treatment effectiveness is largely a result of treating particular areas multiple times on an annual basis to reduce the population to levels that no longer warrant treatment. The 2006 and 2012 whole-lake point-intercept data show that there were only minor impacts to two native species on a lake-wide level, and the plant community maintained high quality and diversity over the course of the control project.

2.4 Fisheries Data Integration

Fishery management is an important aspect in the 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 (Appendix D). The goal of this section is to provide a summary overview of the data that is readily available, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the LLPLD 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 and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2012 & GLIFWC 2012A and 2012B).

Long Lake Fishery

Long Lake Fishing Background

Table 2.4-1 shows the popular game fish that are present in the system, and Table 2.4-2 displays several key non-gamefish that are present. 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 piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 2.4-1.

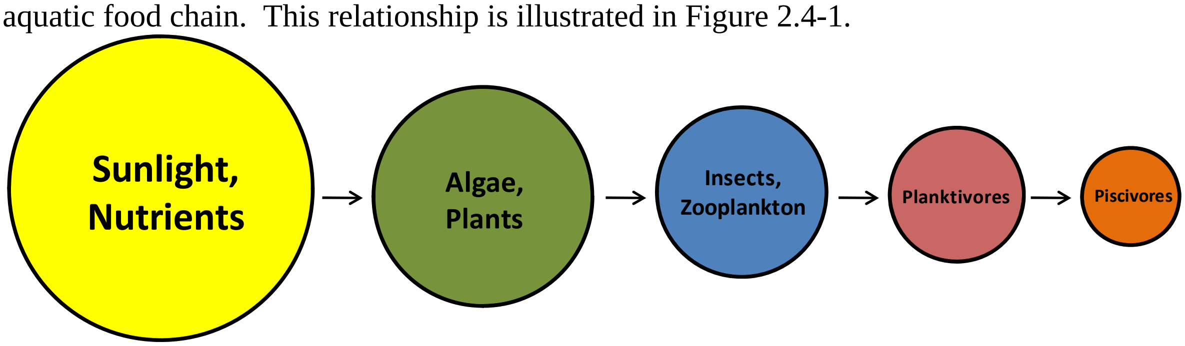

Figure 2.4-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Long Lake is an upper oligotrophic/lower mesotrophic system, meaning it has high water clarity, but a low amount of nutrients and thus low primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscovores) because the supporting food chain is relatively small.

Table 2.4-1. 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 Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody habitat, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
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
Lake Trout	*Salvelinus namaycush*	20	Mid October - Early December	Rocky bars free of silt, with current	Opossum shrimp, fish, insects, fish eggs, other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
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, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Table 2.4-2. Important non-gamefish present in the Long Lake

Common Name	Scientific Name
Cisco	*Coregonus artedii*
Rainbow smelt	*Osmerus mordax*

Long Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 2.4-2). Long Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. This highly structured process begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then an "allowable catch" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% of a lake's fishing stock, but may vary on an individual lake basis. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The allowable catch number is then reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level". The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent, or declaration. This result is called the quota, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal quota and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

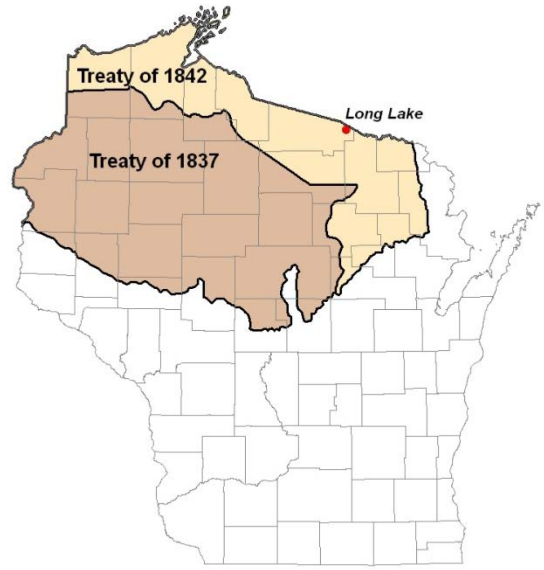

Figure 2.4-2. Location of Long Lake within the Native American Ceded Territory (GLIFWC 2012B). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2010B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly quota is determined each morning by 9 a.m. based on the data collected from the successful spearers.

Harvest of a particular species ends once the quota is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 2.4-3. One common misconception is that the spear harvest targets the large spawning females. Figure 2.4-3 shows that the opposite is true with only 10% of the total walleye harvest (239 fish) since 1998 comprising of female fish on Long Lake. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2010B). This regulation limits the harvest of the larger, spawning female walleye.

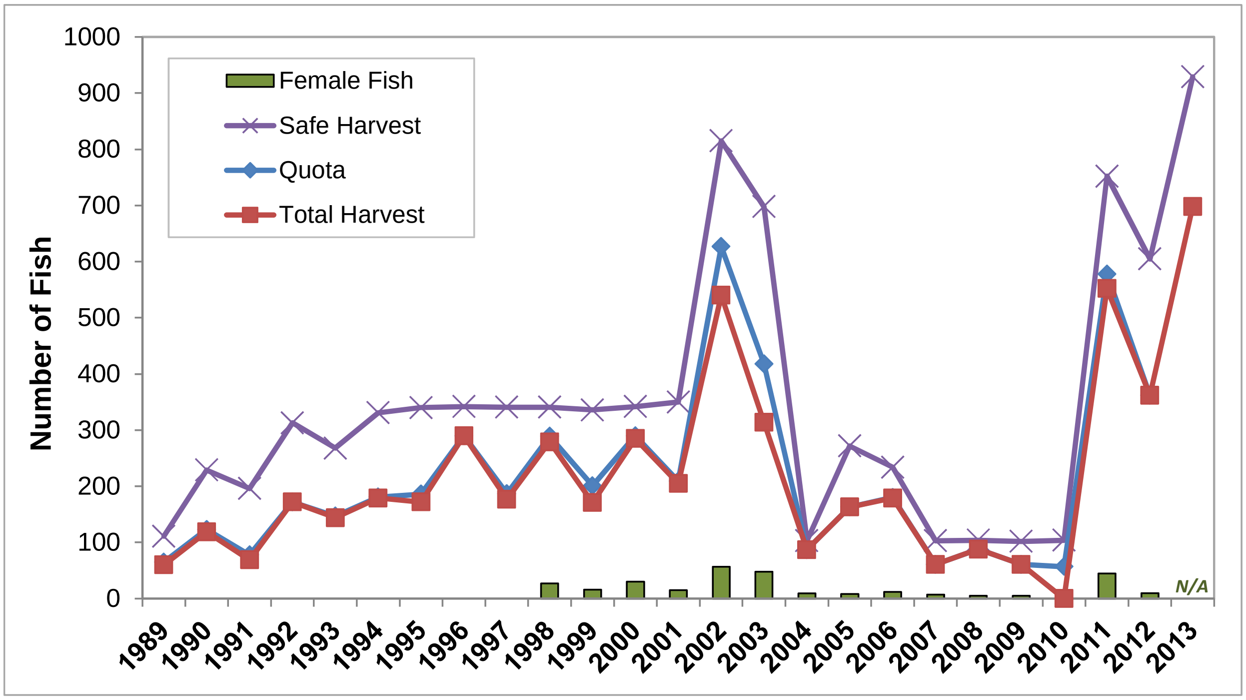

Figure 2.4-3. Walleye open water spear harvest data. Annual walleye spear harvest statistics are displayed since 1989 (T. Cichosz, WDNR, personal communication).

Figure 2.4-4 displays the Native American open water muskellunge spear harvest since 1998. Since 1998, only two muskellunge have been harvested.

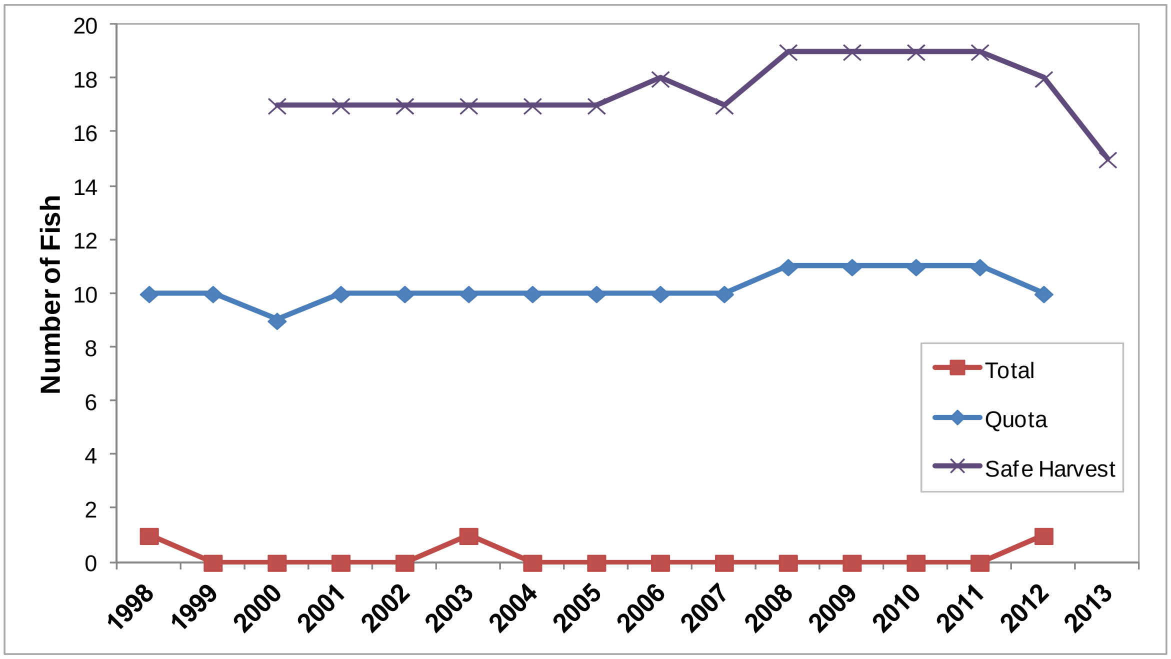

Figure 2.4-4. Muskellunge open water spear harvest data. Annual muskellunge spear harvest statistics are displayed since 1998 (T. Cichosz, WDNR, personal communication).

Long Lake Fish Stocking

To assist in meeting fisheries management goals, fish may be stocked in a waterbody that were raised in nearby permitted hatcheries. Stocking is done to assist the population of a species due to a lack of natural reproduction, or to otherwise enhance angling opportunities. Stocking records from 1972 are provided in Table 2.4-3.

Table 2.4-3. Walleye stocking data available from the WDNR from 1972 to 2013. Lines with grey shading indicate LLPLD private stocking. Data obtained from WDNR 2012 and LLPLD (D. Anderson, personal communication).

Year	Species	# Stocked	Age Class
1972	Brook Trout	4,000	Yearling
1974	Brook Trout	10,000	Yearling
1975	Brook Trout	10,000	Yearling
1985	Brown Trout	25,000	Fingerling
1986	Brown Trout	25,000	Fingerling
1987	Brown Trout	132,000	Fingerling
1988	Brown Trout	42,000	Fingerling
1989	Brown Trout	20,500	Fingerling
1990	Brown Trout	21,000	Fingerling
1991	Brown Trout	10,380	Fingerling
1992	Brown Trout	10,000	Fingerling
1993	Brown Trout	10,000	Fingerling
1994	Brown Trout	10,000	Fingerling
1995	Brown Trout	10,000	Fingerling
1996	Brown Trout	6,000	Fingerling
2005	Lake Trout	5,573	Large Fingerling
2012	Lake Trout	8,327	Yearling
2013	Lake Trout	4,389	Yearling
1976	Rainbow Trout	10,000	Yearling
1977	Rainbow Trout	10,000	Yearling
1978	Rainbow Trout	10,000	Yearling
1979	Rainbow Trout	5,000	Yearling
1980	Rainbow Trout	1,500	Yearling
1973	Walleye	21,904	Fingerling
1976	Walleye	15,000	Fingerling
1986	Walleye	40,000	Fingerling
1989	Walleye	392,000	Fry
1990	Walleye	360,000	Fry
1991	Walleye	1,000,000	Fry
1992	Walleye	660,000	Fry
2001	Walleye	43,600	Small Fingerling
2003	Walleye	42,636	Small Fingerling
2005	Walleye	43,778	Small Fingerling
2007	Walleye	7,229	Large Fingerling
2008	Walleye	3,000	Large Fingerling
2009	Walleye	8,720	Large Fingerling
2010	Walleye	3,000	Large Fingerling
2011	Walleye	8,718	Large Fingerling
2012	Walleye	3,000	Large Fingerling

The LLPLD has stocked walleye within the lake through a WDNR permit in 2008, 2010 and 2012. The WDNR stocked fish are marked with oxytetracycline (OTC) markers, an antibiotic that leaves a "marker" on a calcified tissue part called an otolith that is located in a fleshy cavity under and slightly behind the fish's brain. Anglers catching fish marked with OTC cannot see any difference in the fish – it takes immersion of the otolith under a high-powered microscope that contains a UV light. Fisheries managers may look for signs of OTC in fish when sampling occurs. This allows for data to be collected on the survival rates of stocked fish.

Long Lake Fish Populations

On lakes located within ceded territory, monitoring of fish populations (specifically walleye and muskellunge) occurs on a regular basis. The WDNR and GLIFWC play roles in conducting studies such as fall recruitment surveys, spring assessment surveys and comprehensive fish population surveys. These surveys assist fisheries managers in setting the safe harvest level for the lake, as well as determining if angler bag limits and size restrictions are set appropriately. Figure 2.4-5 displays walleye population characteristics from three of these comprehensive surveys, conducted in 1991, 2001 and 2012.

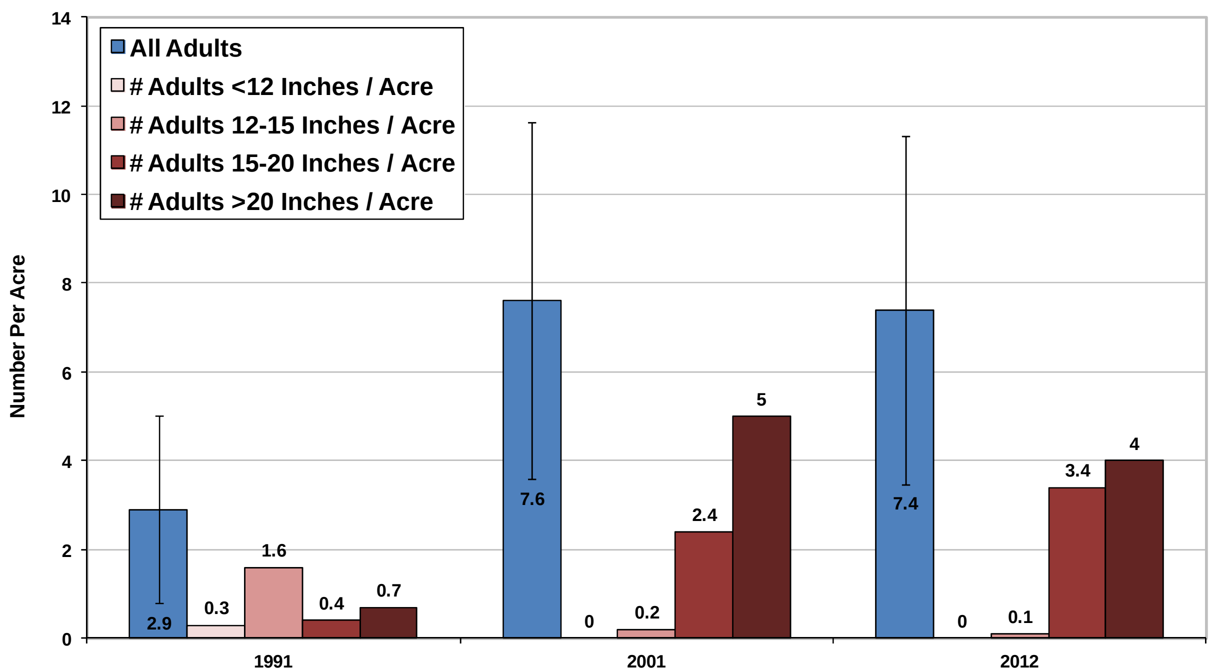

Figure 2.4-5. Walleye population estimates, 1991, 2001 and 2012. Walleye population estimates as determined through WDNR fisheries surveys (WDNR 2012).

During the most recent of these surveys, conducted in 2012, it was estimated that the walleye population consisted of 6,472 adult fish, or 7.4 fish per acre. Roughly 75% of the adult walleye population were legal-size; that is, 18 inches or larger. Muskellunge were sampled, however in 30 days of sampling only six adult muskellunge were observed. According to discussions held between the LLPLD and the WDNR, approximately 300 muskellunge will be stocked in the lake in 2013. Bass species were sampled infrequently, indicating that walleye are the predominant predator species in the lake.

Rainbow smelt (*Osmerus mordax*) were found in great abundance during 2012 as well. Smelt are a detrimental exotic species that have been introduced to the Great Lakes region from their native range, which includes Atlantic drainages in both the United States and Canada. Its impact on Great Lakes fish communities has been studied extensively, both in terms of it competing for resources with lake herring (*Coregonus artedii*) and whitefish (*Coregonus clupeaformis*) as well as becoming a primary prey fish for most salmonid species and lake trout (*Salvelinus namaycush*). In Wisconsin lakes, smelt have been thought to compete with yellow perch for food (Fuller et al 2012) and potentially prey on young walleye (Mercado-Silvia et al. 2007). Currently, the WDNR is stocking lake trout in Long Lake to help address smelt issues. The WDNR is also stocking large walleye fingerlings in Long Lake, as it is suspected that these fish are too large to be preyed upon by rainbow smelt. In 2013, the trout were not stocked at the shallow bay where the boat landing is located, rather at a riparians property where the large fingerlings would have a better chance of getting to deep water and avoiding predation. A copy of the WDNR's 2012 fisheries survey information sheet, the 2009 WDNR Fisheries Rule Development Proposal, and October 2012 commissioner's meeting notes on the Long Lake Fishery are provided in Appendix D.

Long Lake Fishing Regulations

Because Long Lake is located within ceded territory special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may exist. Prior to 2010, there was a 15 inch minimum size limit and 5 fish bag limit (typically reduced to 2 walleye in most years based upon tribal declarations). Through an administrative rule change brought forth by the LLPLD and the WDNR, the size limit was increased to 18 inches and the daily bag limit was reduced to 3 fish. These rule changes were put into effect to protect the female walleye populations from anglers and also reduce the smelt population in the lake.

The northern region of Wisconsin has regulations for bass, muskellunge and pike species that differ from waterbodies in the southern part of the state. For bass species, there is a catch-and-release season that exists from the first Saturday in May through the third Friday in June. After the third Friday in June, five bass of both species may be harvested, and a minimum length limit for each species has been set to 14". Long Lake is in the northern half of the muskellunge and northern pike management zone. Prior to 2010, a 34 inch size limit was in affect for muskellunge. A proposed rule change aimed at increasing the size structure of the muskellunge was put into effect in 2010. Currently muskellunge must be 50" to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and five pike may be kept in a single day. Lake trout, which are stocked in Long Lake, must be 30" in length to be harvested and only a single fish may be taken per day. Statewide regulations apply for all other fish species.

Long Lake Substrate Type

According to the point-intercept survey conducted by Onterra, 37% of the substrate sampled in the littoral zone on Long Lake was rock, with 36% being classified as muck and 27% being classified as sand (Map 4, Figure 2.3-2). 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. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

3.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three main objectives:

1) Collect and analyze current and historic baseline data to increase the general understanding of the Long Lake ecosystem and determine if changes have or are occurring over time.
2) Collect detailed information regarding non-native invasive plant species within the lake.
3) Work with the LLPLD Planning Committee to develop realistic and implementable lake management goals.

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 2012 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 *Excellent* category for deep, lowland drainage lakes in the Wisconsin. Trophic state analysis indicates that Long Lake is upper oligotrophic/lower mesotrophic, meaning that it has low primary production. While no trends over time were apparent in biological parameters investigated (i.e. total phosphorus and chlorophyll-*a*), analysis indicates that water transparency in Long Lake has increased by just over 2 feet during this past decade (2000-current) in comparison with the previous decade (1988-1999). While specific data were not available, it is likely that this increase in clarity is not caused by decreases in algae or turbidity, but decreases in organic compounds entering the lake. These tannic acids can give the lake a brown tint and originate from decomposing plant material (especially coniferous trees) that dissolves in rain water which eventually flows into Long Lake. With significantly less precipitation occurring over the most recent decade, less organic acids were delivered to the lake and affecting its clarity. Continued monitoring of Long Lake's transparency, as well as other biological parameters, will be important to verify the cause of the increased transparency or whether it is a symptom of a greater, unknown issue.

The water quality of Long Lake is largely driven by the landscape in which is resides. For every acre of Long Lake, there are 15 acres of land draining to the lake. Long Lake's watershed is in excellent shape, with the majority being comprised of intact forests and wetlands. While the majority is comprised land cover types which export minimal amounts of phosphorus, its size delivers almost 1,300 pounds of phosphorus on an annual basis. While this is a relatively large amount of phosphorus, Long Lake's large water volume dilutes the phosphorus, resulting in the low concentrations measured within the water. Also, the amount of phosphorus entering into Long Lake would be higher if it were not for Big Sand Lake intercepting the water from just under half of Long Lake's overall watershed and acting as a large detention basin.

Watershed modeling predicted phosphorus levels that were slightly higher than what was actually measured within the lake. This is believed to be due to the model's limitations and the fact that Long Lake's inlet is relatively close to its outlet. If the measured phosphorus values in Long Lake would have been higher than the model predicted, recommendations for further investigation of unaccounted sources of phosphorus such as internal nutrient loading and septic system leakage would occur. But since the model overestimated the amount of phosphorus that was actually present in the lake, it is likely that neither septic system leakage nor internal nutrient loading is occurring.

The 2012 shoreline assessment survey revealed that three quarters of Long Lake's shoreline is currently in a natural (developed and undeveloped) state. These areas are important for maintaining the integrity of the lake's environment as they buffer runoff from the immediate watershed and provide essential habitat for aquatic and terrestrial wildlife. While it may be of interest for Long Lake stakeholders to restore some of the more developed shorelines around the lake, it may be even more important and feasible to preserve the shoreline areas that are currently undeveloped. The LLPLD has determined to make shoreland preservation an important educational initiative, including providing information on converting large private parcels into land trusts. Much of the property along the eastern shoreline of Long Lake is already protected by restrictive environmentally-conscious covenants as a part of the Poh-Wah-Gom Passage Association.

Over the past 5 years, great strides in Eurasian water milfoil management have been made, although slightly slower than many would have anticipated. Long Lake was one of the first lakes in northern Wisconsin to use liquid 2,4-D to control Eurasian water milfoil and to enroll in what is now a joint WDNR and US Army Corps of Engineer research project aimed at monitoring herbicide concentrations in association with the implementation of chemical control strategies.

By all standard metrics, the 2012 vegetation surveys revealed that Long Lake contains a high quality aquatic plant community and remains largely unchanged since surveys were last conducted in 2006. However, Eurasian water milfoil left unchecked in Long Lake will likely spread and threaten the native aquatic plant community of the system. The LLPLD is currently applying for WDNR AIS Control and Prevention grant funds to aid in a five-year Eurasian water milfoil control program on Long Lake. The goal of this program is to continue to reduce the amount of Eurasian water milfoil within the lake to more manageable levels – perhaps levels that on an annual basis require minimal 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.

4.0 IMPLEMENTATION PLAN

During the planning meeting, the Long Lake Planning Committee discussed the results of the 2012 management plan study with ecologists/planners from Onterra and closely examined Long Lake as well as the people who live around it. The Planning Committee discussed the strengths and weaknesses of Long Lake and its stakeholders, as well as the opportunities and threats they face. These issues were discussed in terms of 1) feasibility of addressing the issue, and 2) level of the issue's importance. As a result of the discussion, the LLPLD was able to identify goals for protection and enhancing Long Lake, as well as communicating and education individuals who use the lake.

The implementation plan presented below represents the path the LLPLD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and achievable, as are the action steps required to reach these goals. The implementation plan is a living document that 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 lake's stakeholders.

Management Goal 1: Increase LLPLD'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: LLPLD Commissioners

Description: Education represents an effective tool to address many lake issues. While the LLPLD does not regularly distribute a newsletter, they have found that their website (www.LLPLD.org) allows for exceptional communication with district members. This level of communication is important within a management group because it facilitates the spread of important district news, educational topics, and even social happenings. The district's website contains a wealth of information, including a blog where district members can discuss current lake-related topics. It also provides a medium for the recruitment of volunteers through a fill-able form which allows perspective volunteers to identify what type of activity they would be interested in volunteering for.

The LLPLD has embraced the use of social media by having a Facebook® group page. This further increases the district'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 LLPLD 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 treatment and monitoring updates
- Basic lake ecology
  - Water clarity and watershed connection
  - Role of phosphorus
- Boating ordinances (slow-no-wake rules)
- Pier rules
- Loon nesting
- Noise, air, and light pollution
- Shoreline habitat restoration and protection
- Septic system maintenance
- Fishing regulations

Action Steps:

See description above as this is an established program.

Management Action: Continue LLPLD's involvement with other entities that have responsibilities in managing (management units) Long Lake

Timeframe: Continuation of current efforts

Facilitator: LLPLD Commissioners

Description: The LLPLD was founded specifically to enhance the lake's fishery and protect the lake from aquatic invasive species. The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation.

It is important that the LLPLD actively engage with all management entities to enhance the district'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 Phelps Chamber of Commerce	President (Renee Snook - phelpschamber @gmail.com	Provides information and networking related to the advancement of the Long Lake community.	Once a year, or more as needed. May check website (http://www.phelpscofc.org/ for updates.	The Chamber of Commerce serves a valuable role in promoting local businesses, tourism, and community within the Long Lake area.
Town of Phelps Lakes Committee	Chairman (Dave Roberts 715 545-2829)	Long Lake falls within the Town of Phelps.	Once a year, or more as needed. May check website (http://townofphelps.com/town-lakes-committee-) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Vilas County Lakes & Rivers Association	President(Rollie Alger–president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	AIS Coordinator (Ted Ritter – 715.479.3738)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: Report activities to Mr. Ritter
Vilas County Land and Water Conservation Department	Conservation specialist (Mariquita Sheehan – 715.479.3721)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Steve Gilbert – 715.358.9229)	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 (Kevin Gauthier – 715.365.8937)	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.
	Warden (Tim Price – 715.545.3045)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day).	Contact regarding suspected violations pertaining to recreational activity on Pelican 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.
Wisconsin Valley Improvement Company	Director of Environmental Affairs (Cathy Wendt – 715.848.2976 Ext. 310	Within the confines of their FERC license, operates the dam on Long Lake.	Once a year, or more as issues arise.	In addition to water-level communications, WVIC collects periodic water quality data and has provided financial assistance for the renovation of the Long Lake boat landing.

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: John Rowe and LLPLD Commissioners

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.

Water quality data is currently been collected by the Wisconsin Valley Improvement Corporation (WVIC) for a 3-year period, once every 10 years. The next sampling period will be conducted in 2020-2023.

In addition to the WVIC's efforts, 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. Using a probe owned by the Phelps Town Lakes Committee, dissolved oxygen levels are also measured periodically by the LLPLD. These readings are collected in conjunction with the regularly scheduled CLMN water sample collection. Collecting a temperature and dissolved oxygen profile on the lake towards the end of the winter (late February) would also provide important information for lake managers and fisheries biologists.

It is the responsibility of the current CLMN volunteer in conjunction with the LLPLD 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 district members during annual meeting.
2. CLMN volunteer and/or LLPLD 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 implementation of an herbicide application strategy to control Eurasian water milfoil infestation on Long Lake.

Timeframe: Continuation of current efforts

Facilitator: LLPLD Commissioners with professional help as needed

Description: As described in the Aquatic Plant Section, one of the most pressing threats to the health of Long Lake's aquatic plant community is Eurasian water milfoil. The 2012 Eurasian water milfoil peak-biomass map indicates that although efforts to control this invasive species in recent years have greatly reduced its density, this plant still can be found at low densities throughout much of the lake (Map 8).

At this time, the most feasible method of control is herbicide applications – specifically, early spring treatments with an auxin herbicide like 2,4-D. The treatments would occur when surface water temperatures are between to 50-60°F.

On July 7, 2012 the LLPLD has approved a measure (40 in favor, 0 against, 0 abstain) to move forward with a five-year control strategy for Eurasian water milfoil in Long Lake. The LLPLD is currently in the process of applying for WDNR grant funds to cover up to 50% of the project costs. The objective of this management action is not to eradicate Eurasian water milfoil from Long Lake, as that would be impossible. The objective is to reduce Eurasian water milfoil to more manageable levels. In other words, the goal is to reduce the amount of Eurasian water milfoil in Long Lake to levels that may be suitable for smaller treatment areas or hand removal efforts to keep it under control.

The impacts to native submersed species are believed to occur when the non-native species reaches an aerial coverage of approximately 50% (dominance). 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 Eurasian water milfoil 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 LLPLD. The LLPLD acknowledges the difficulty that associates conducting spot treatments within the narrow littoral bands along the steep slopes of the lake. In order to build off their the successes that have come slowly over the past five years, the LLPLD would like to take an aggressive approach to Eurasian water milfoil management in the next five years, whereas all areas of colonized Eurasian water milfoil will be considered for treatment. The LLPLD's treatment threshold (trigger) would also extend to immediately adjacent areas of Eurasian water milfoil mapped with point-based techniques, with areas mapped as 'small plant colonies' being targeted if possible. Using this rationale, approximately 48 acres are preliminarily proposed for 2013 (Map 8).

Monitoring is a key aspect of any AIS control project, both to create the treatment areas and monitor the action's effectiveness. The monitoring would also facilitate the "tuning" or refinement of the control strategy as the control project progresses. It must be noted that this portion of the management plan (control plan) would be intended to span approximately 5-6 years before it would need to be updated to account for changes within the ecosystem. To complete this objective efficiently, a cyclic series of steps is used to plan and implement the treatment strategies. The series includes:

1. A lake-wide assessment of Eurasian water milfoil completed while the plant is at peak biomass (August-September)
2. Creation of control strategy for the following spring.
3. Verification and refinement of treatment plan immediately before control strategies are implemented
4. Completion of control strategy
5. Assessment of control strategy

Once Step 5 is completed, the process would begin again that same summer with the completion of a peak biomass survey. The survey results would then be used to create the next spring's control strategy (Step 2).

Two types of monitoring would be completed to determine treatment effectiveness; 1) quantitative monitoring using WDNR protocols, and 2) qualitative monitoring using observations at individual treatment sites and on a treatment wide basis. Results of both of these monitoring strategies would be used to create the subsequent treatment strategies. Comparing the monitoring results from the pretreatment and post treatment surveys would determine the effectiveness of the treatment on a site-by-site basis and on a treatment wide basis (which in the case of a small lake, would likely be lake-wide). Qualitatively, a successful treatment on a particular site would include a reduction of exotic density as demonstrated by a decrease in density rating. Quantitatively, a successful treatment would include a significant reduction in Eurasian water milfoil frequency following the treatments as exhibited by at least a 50% decrease in exotic frequency from the pre- and post treatment point-intercept sub-sampling.

In conjunction with the WDNR and United States Army Corps of Engineers (USACE), herbicide concentration monitoring has been historically conducted by LLPLD volunteers. In accordance with a monitoring plan developed by these entities and the district's lake management consultant, water samples are collected at multiple locations throughout the lake would take place 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.

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, 2013 grant cycle and the approved project would have a timeline of 2013-2017.

In the final year of the project, a series of comprehensive studies would be conducted on Long Lake, including a full-lake point-intercept survey and floating-leaf and emergent plant community mapping survey. The results of these studies would be compared to studies conducted as a part of this management planning project and allow the LLPLD to 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 plan.
4. Revisit control plan in 5-6 years.
5. Update management plan to reflect changes in control needs and those of the lake ecosystem.

<u>Management Action:</u> Continue Clean Boats Clean Waters watercraft inspections at Long Lake public access location

Timeframe: Continuation of current effort

Facilitator: LLPLD Commissioners

Description: Currently the LLPLD monitors the public boat landing using training provided by the Clean Boats Clean Waters program. Long Lake is an extremely popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. 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.

Due to the large number of activities that volunteers are called upon on Long Lake (AIS monitoring, stakeholder education, ect.), paid watercraft inspectors would be sought to monitor the Long Lake's single public boat landing. In 2012, the LLPLD utilized approximately 245 hours of paid watercraft inspections through Vilas County's student intern program and plans to continue that level of commitment throughout the next 5 years.

Action Steps:

See description above as this is an established program.

Management Action: Enhance volunteer Eurasian water milfoil surveillance monitoring and hand removal program

Timeframe: Initiate in 2013

Facilitator: LLPLD Commissioners

Description: In lakes without AIS, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. Even in lakes where these plants occur, monitoring for new colonies is essential to successful control. LLPLD members have been trained on AIS identification and surveillance monitoring strategies and have been carrying out these activities for over 5 years. However, the LLPLD would like to enhance the framework of this program.

As discussed within the first management action of Goal 3, professional Eurasian water milfoil surveys would be conducted annually during the late-summer. These data are used to develop the following spring's treatment strategy. The LLPLD has purchased a hand-held GPS unit that is capable of supporting basemaps (Photo 4.0-1). Prior to the start of summer, the LLPLD's GPS would be loaded with basemaps of the spring's treatment areas as well as the previous summer's Eurasian water milfoil locations.

Photo 4.0-1. GPS unit with basemap

As a part of the control program, the volunteers will focus on parts of the system that did not contain Eurasian water milfoil in the previous surveys. The LLPLD volunteers would provide locations of Eurasian water milfoil and other aquatic invasive species for professional ecologists to focus their efforts upon, making more efficient use of professional time while engaging stakeholders in the program. Volunteer-based surveys could be enhanced through the use of aqua-scopes and/or underwater cameras, especially for locating the outward extents of Eurasian water milfoil growing in deeper water.

Further, the LLPLD and the district's lake management consulting firm would identify specific areas for hand removal. Small isolated infestations of Eurasian water milfoil can most appropriately be controlled using manual removal methods, likely through scuba or snorkeling efforts with scuba methodologies likely being more suitable for Long Lake. 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 would need to be paid to all plant fragments that may detach during the control effort. During the subsequent Eurasian water milfoil peak-biomass mapping survey, professional ecologists would visit all marked locations and assess if the plant was successfully removed.

Within each year's annual treatment report, a description of that year's surveillance and hand removal activities would be included along with a map of the specific locations. Volunteers conducting surveillance monitoring would input all records into the online SWIMS database in accordance with CLMN protocols. This would include surveys where aquatic invasive species were not identified.

Action Steps:

1. Basemaps are periodically loaded by consultant on district-owned GPS unit(s)
2. LLPLD volunteers conduct surveillance monitoring surveys as described above
3. LLPLD volunteers conduct hand-removal activities as discussed above
4. LLPLD volunteers transfer data to consultant for integration and graphical representation during annual treatment report
5. Consultant uses LLPLD spatial data as focus areas during subsequent Eurasian water milfoil surveys

Management Goal 4: Improve Fishery Resource and Fishing

Management Action: Continue to work with fisheries managers to enhance the overall fishery on Long Lake

Timeframe: Continuation of current effort

Facilitator: Dan Anderson

Description: The LLPLD would like to continue its relationship with the WDNR fisheries biologist to protect and enhance the overall fishery of Long Lake. Being partially founded on the idea of improving the fishery of the lake, the LLPLD has identified the following fisheries-related issues as priorities:

- Continue the walleye stocking program
- Increase walleye recruitment within the lake
- Sustain a two-tiered fishery on the lake
- Limit the impact that rainbow smelt have on the Long Lake ecosystem

The LLPLD is eager to address these and other fisheries issues as appropriate based upon guidance from the WDNR fisheries biologist.

Action Steps:

See description above as this is an established program.

5.0 METHODS

Lake Water Quality

No water quality data was collected as a part of this project. All historic data was obtained through the WDNR's Surface Water Integrated Monitoring System online database.

Watershed Analysis

The watershed analysis began with an accurate delineation of Long Lake's drainage area using U.S.G.S. topographic survey maps, base GIS data from the WDNR, and a PDF map from Long Lake's 2007 Lake Management Plan authored by Northern Environmental, Inc. 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

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 7, 2012. A point spacing of 47 meters was used resulting in approximately 1,616 sample locations.

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 2012 point-intercept and community mapping survey were collected, vouchered, and sent to the University of Wisconsin – Steven's Point Herbarium in the fall of 2012 where there identifications were verified. A set of samples was also provided to the LLPLD.

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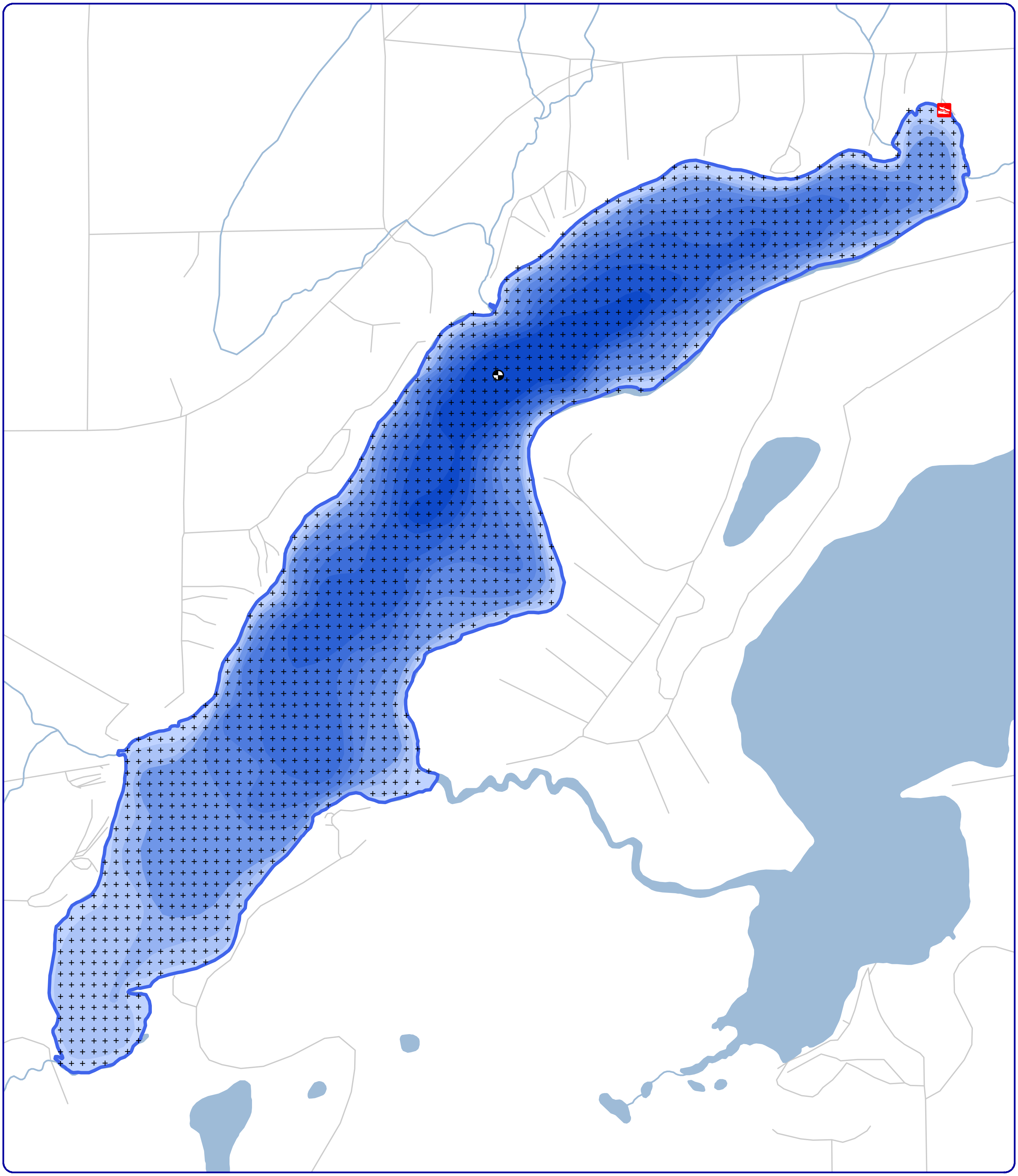


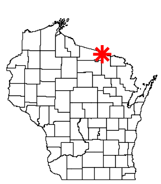
N
W E
S

1,750

Feet

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro:WDNR
Map Date: October 9, 2012
Filename: Map1_LongV_Location.mxd



Project Location in Wisconsin

Legend

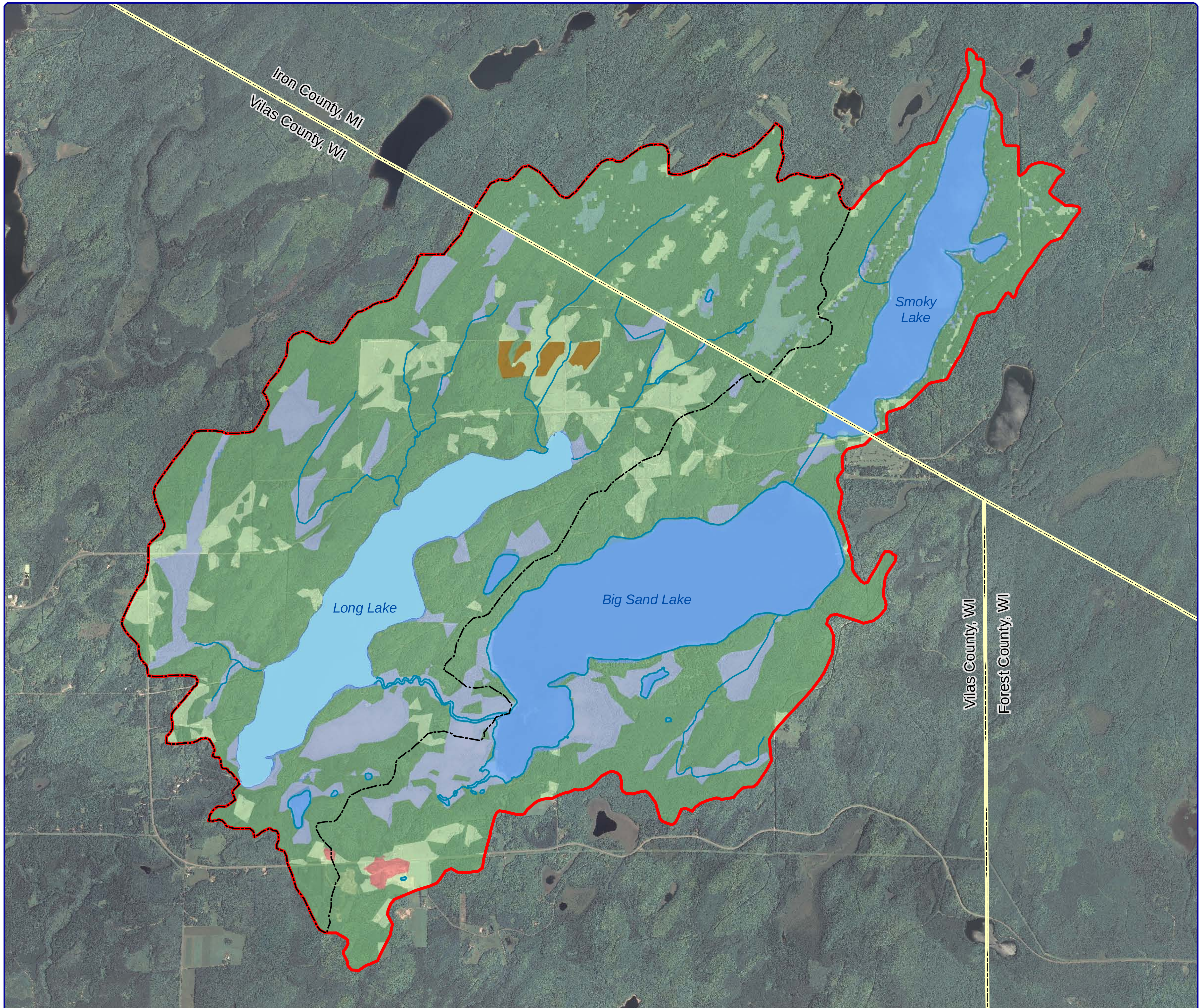
Long Lake ~872 Acres
WDNR Definition

Public Access

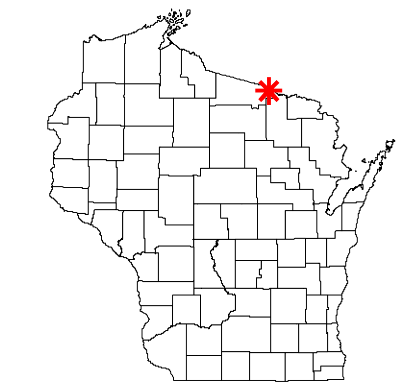
Point-Intercept Survey Location
47-meter spacing, 1,116 total points

Water Quality
Sampling Location

Map 1
Long Lake
Vilas County
Project Location & Lake Boundaries



Map 2
Long Lake
Vilas County, Wisconsin
Watershed Boundary & Land Cover Types



Project Location in Wisconsin

Legend
- Long Lake Direct Watershed Boundary
- Long Lake Watershed Boundary

Land Cover Types
- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Long Lake
- River or Stream
- Pasture/Grass
- Urban - Medium Density

N W E S

3,700 Feet

Sources:
Land Cover: NCLD, 2006
Hydro: WDNR
Orthophotography: NAIP, 2010
Map Date: October 8, 2012
Filename: Map2_LongV_Watershed.mxd

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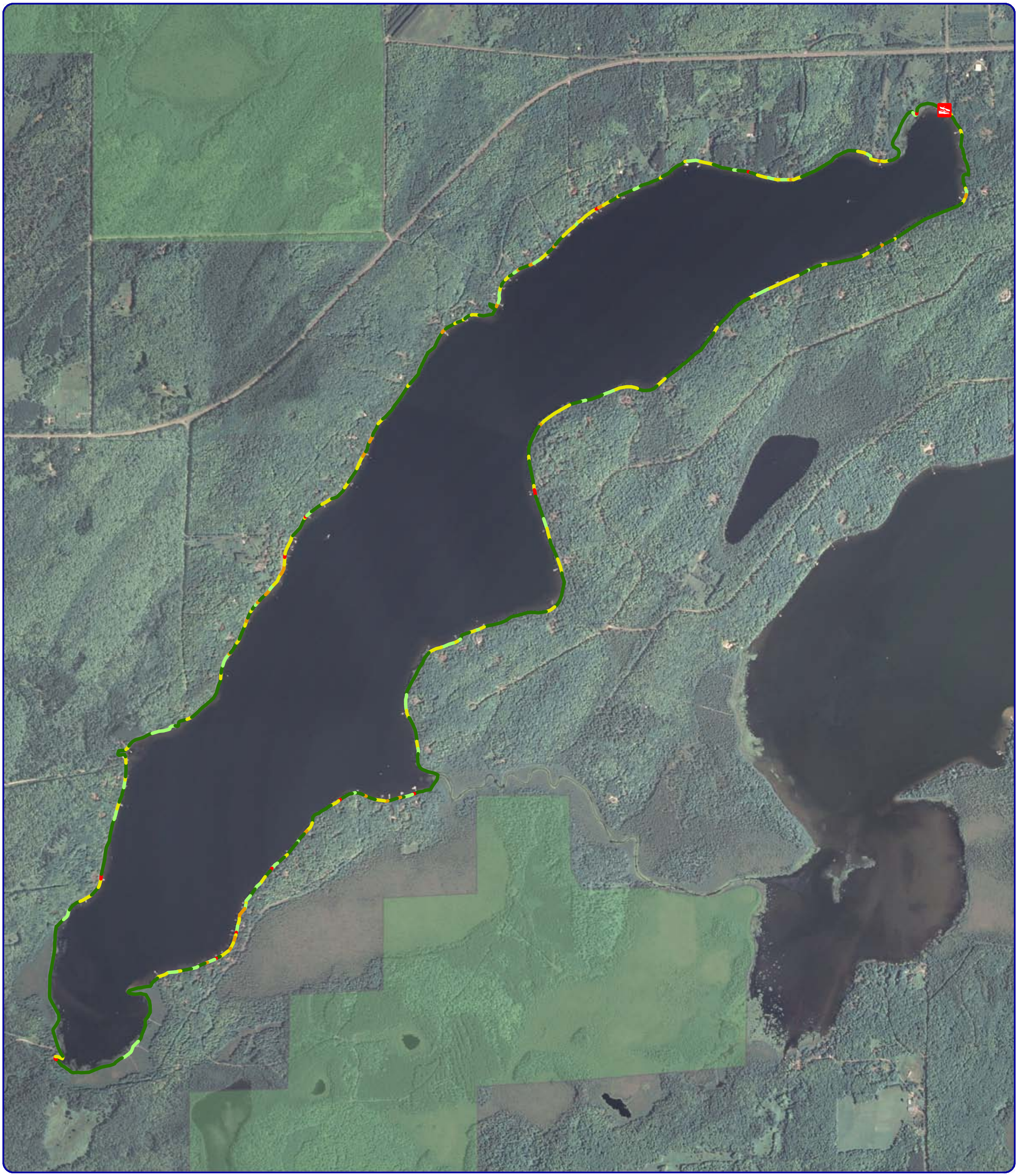

N
W E
S

1,800

Feet

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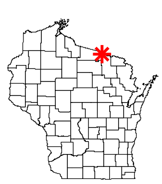
Sources:
Roads and Hydro:WDNR
Shoreline Survey: Onterra, 2012
Map Date: October 9, 2012
Filename: Map3_LongV_SA.mxd



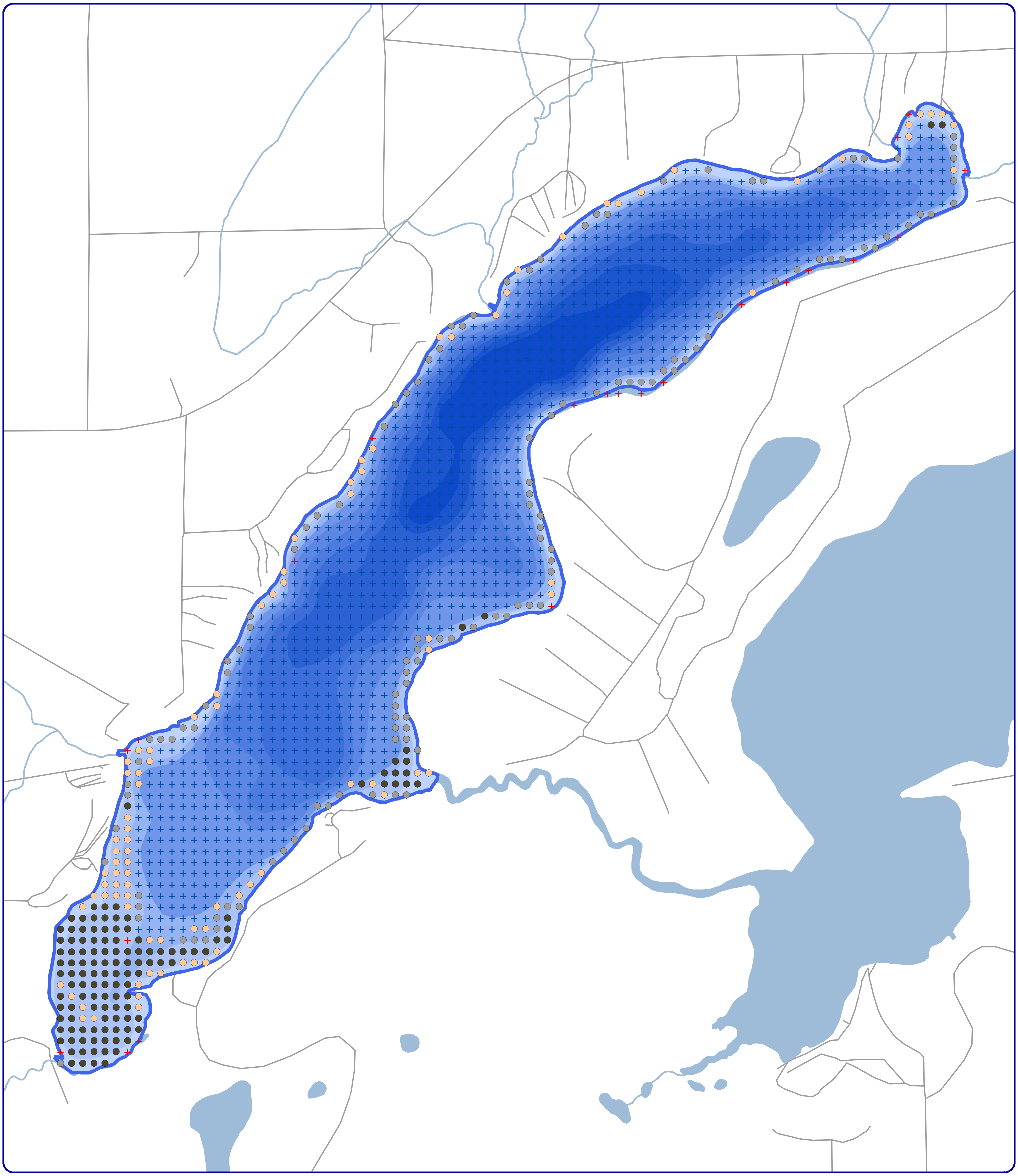
Project Location in Wisconsin

Legend

Shoreline

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized
- Wisconsin State Forest
- Public Access

Map 3
Long Lake
Vilas County
2012 Shoreline Condition



N
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1,750
Feet

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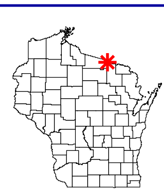
Sources:
Roads and Hydro:WDNR
PI Survey: Onterra, 2012
Map Date: October 9, 2012
Filename: Map4_LongV_SubstratePI.mxd



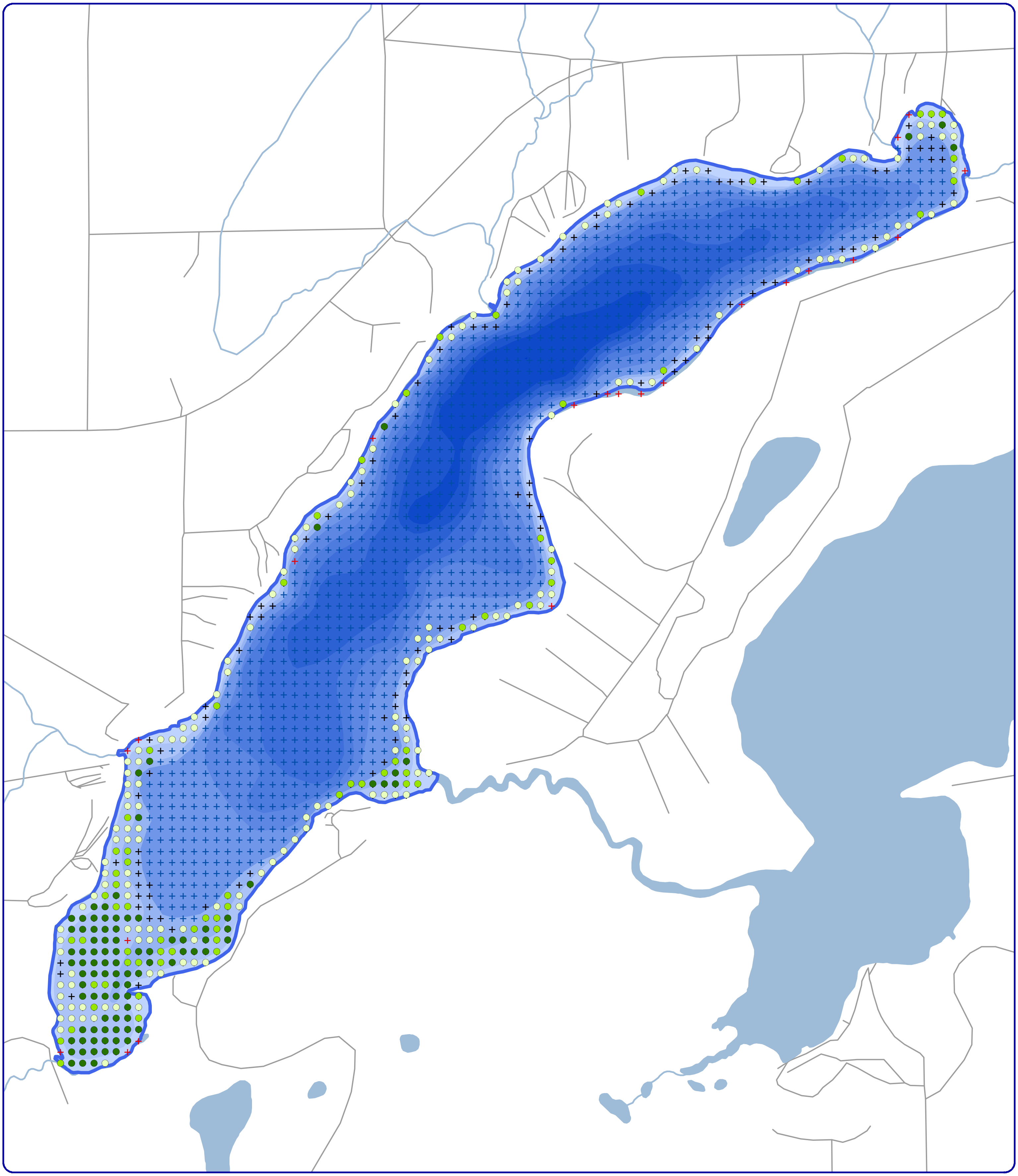
Project Location in Wisconsin

2012 PI Survey Substrate Data

- Muck
- Rock
- Sand
- Too Deep
- Non-navigable

Map 4
Long Lake
Vilas County

2012 PI Survey: Substrate Types



N
W E
S

1,750

Feet

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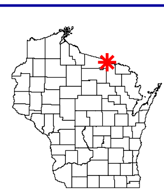
Sources:
Roads and Hydro:WDNR
PI Survey: Onterra, 2012
Map Date: October 9, 2012
Filename: Map5_LongV_TRFPI.mxd

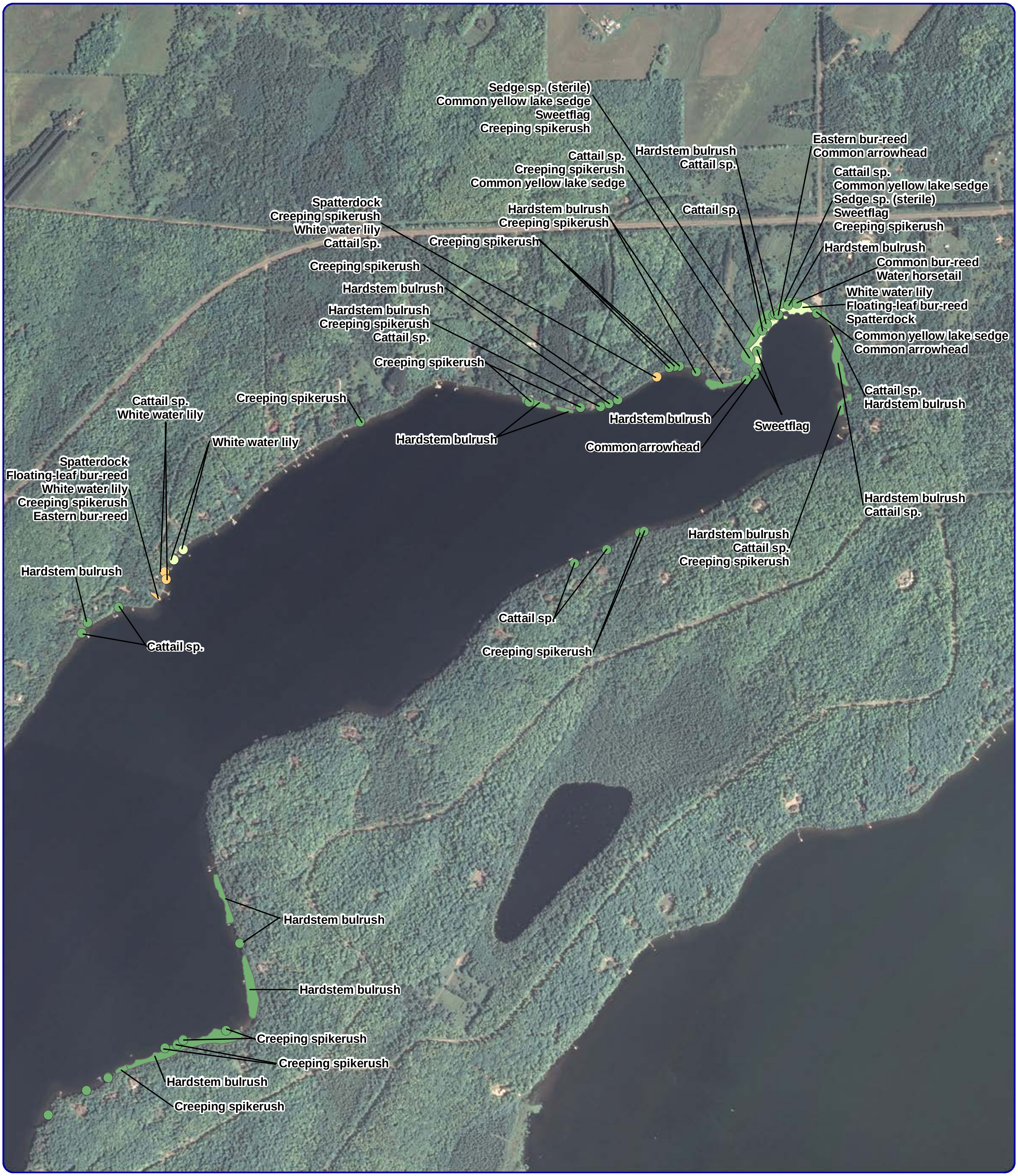


Project Location in Wisconsin

2012 PI Survey Vegetation Data

- Total Rake-fullness = 1
- Total Rake-fullness = 2
- Total Rake-fullness = 3
- No Vegetation
- Too Deep
- Non-navigable

Map 5
Long Lake
Vilas County
2012 PI Survey: Aquatic Vegetation Distribution



N
W E
S

1,200

Feet

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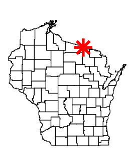
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: October 8 2012
Filename: *LongVilas_CM_North_2012.mxd*



Project Location in Wisconsin

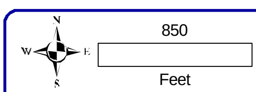
Legend

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

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

Map 6
Long Lake
Vilas County, Wisconsin

Aquatic Plant Communities



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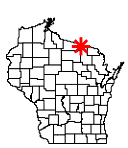
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: October 8 2012
Filename: *LongVilas_CM_South_2012.mxd*



Project Location in Wisconsin

Legend

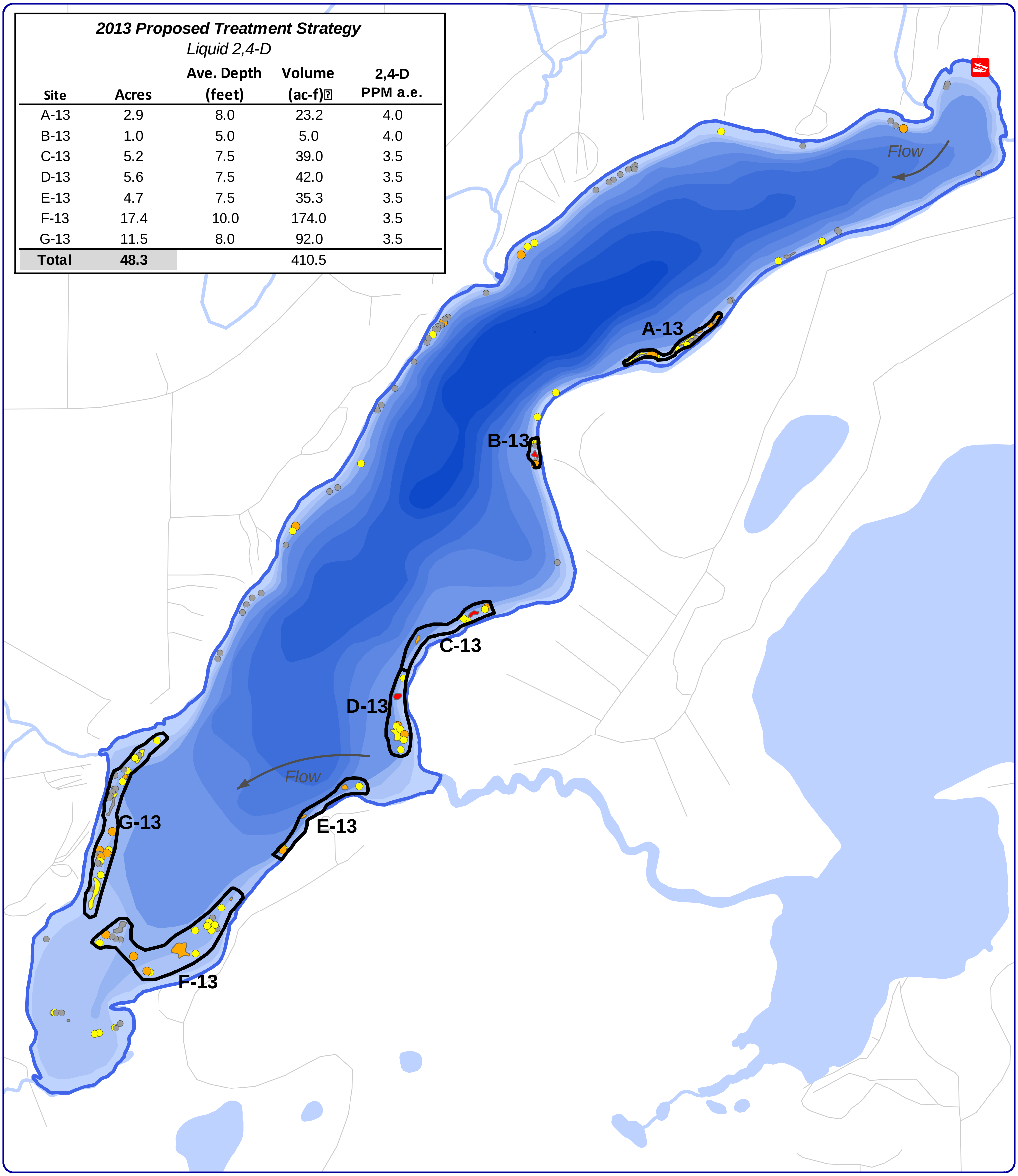
Small Plant Communities	Large Plant Communities
Emergent	Emergent
Floating-leaf	Floating-leaf
Mixed Floating-leaf & Emergent	Mixed Floating-leaf & Emergent

Map 7
Long Lake
Vilas County, Wisconsin
Aquatic Plant Communities

2013 Proposed Treatment Strategy

Liquid 2,4-D

Site	Acres	Ave. Depth (feet)	Volume (ac-f)	2,4-D PPM a.e.
A-13	2.9	8.0	23.2	4.0
B-13	1.0	5.0	5.0	4.0
C-13	5.2	7.5	39.0	3.5
D-13	5.6	7.5	42.0	3.5
E-13	4.7	7.5	35.3	3.5
F-13	17.4	10.0	174.0	3.5
G-13	11.5	8.0	92.0	3.5
Total	**48.3**		410.5	



1,650

Feet

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Lake Management Planning

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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2012
Map Date: November 29, 2012
Filename: *LongV_EWM_T2013Cond1.mxd*

Project Location in Wisconsin

Legend

- Highly Scattered *(None)*
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2013 Proposed Treatment Strategy

Map 8

Long Lake

Vilas County, Wisconsin

2012 EWM Locations & 2013 Proposed Treatment Strategy v1