Horsehead Lake

Oneida County, Wisconsin

Comprehensive Management Plan

June 2011

Sponsored by:

Horsehead Lake Protection & Rehabilitation District No. 1

LPL-1127-07 & LPL-1128-07

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Onterra LLC
Lake Management Planning

Horsehead Lake

Oneida County, Wisconsin

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

Horsehead Lake Planning Committee

Kris Batchelet
Dennis Batchelet
Pat Donnic
Jim Watters
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Wisconsin Dept. of Natural Resources

Mr. Kevin Gauthier
Mr. John Kubisiak

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1.0 INTRODUCTION

Horsehead Lake is an approximate 367 acre, spring lake with a maximum depth of 11 feet and a mean depth of 8 feet. The Horsehead Lake Protection and Rehabilitation District No.1 (HLPRD) has been active in the lake's management including the participation in the Citizen Lake Monitor Network (CLMN) that has provided water quality information to the Wisconsin Department of Natural Resources (WDNR).

In the summer of 2003, staff from the WDNR verified the presence of curly-leaf pondweed (*Potamogeton crispus*), a potentially harmful exotic species in the lake. The negative effects associated with exotic species include the loss of important native plant communities and their associated habitat value, water quality degradation, reductions in recreational opportunities, decreased aesthetic value, and loss of economic vitality. The presence of Curly-leaf pondweed in Horsehead Lake, along with abundant native plant biomass, has led to much concern within the HLPRD regarding the current and future condition of their highly valued lake and which spurred them to seek reliable and comprehensive information about these concerns and their affects on the lake. The stakeholders are concerned about the health of the lake beyond the plant issues and extended their management to creating a better understanding of the ecology and function of their shallow lake.

The primary goal of the project described within this report was to create a comprehensive management plan for Horsehead Lake. The project was designed to incorporate studies of the lake ecosystem and participation of the lake's stakeholders in the development of the management plan. Study components included water quality analysis, watershed assessment, numerous plant surveys, and compilation of available fishery information. Stakeholders were involved within the planning process through public meetings, planning meetings held with a sub-committee of the district, and disbursal of a stakeholder survey.

These technical and sociological aspects of the project were brought together to create the management plan for Horsehead Lake. The management plan is detailed in the section of this document titled "Implementation Plan". Within that section a series of *Management Goals* are listed. Each goal is described and beneath it, one or more *Management Actions* are discussed. The description of each action also contains a *Timeframe* for which the action will occur and a *Facilitator* that will carry out the action. If appropriate, *Action Steps* are also included to further guide the action's completion.

The Implementation Plan was created by the HLPRD Planning Committee with guidance from Onterra planners. During the development of the plan, the committee was educated about the ecology of their lake through an intense presentation of the project study results. Through the combination of that education regarding their lake and their involvement in the planning process, it was assured that the Implementation Plan meets the needs of the HLPRD and the lake alike. It also assures that the resulting plan is truly implementable by the district.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting

On June 2, 2007, Tim Hoyman, an Aquatic Ecologist and Planner with Onterra, met with the HLPRD. During the meeting, Tim completed a presentation describing the project's goals, its components, and the importance of district member's participation in the planning process. Tim also discussed general lake ecology topics such as eutrophication, human impacts on lakes, nutrient limitation, and the importance of aquatic plants.

Stakeholder Survey

During March 2008, a five-page, 22-question survey was mailed to 100 riparian property owners making up the Horsehead Lake district. Fifty-five percent of the surveys were returned and those results were entered into a spreadsheet by members of the Horsehead Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan.

Planning Committee Meeting I

On July 8, 2008, Tim Hoyman met with six members of the Horsehead Lake Planning Committee for approximately 3 ½ hours. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, including nuisance levels of aquatic plants, the newly discovered Eurasian water milfoil, low water levels, high levels of filamentous algae, and mechanical harvesting.

Planning Committee Meeting II

On August 6, 2008, Tim Hoyman again met with the members of the Planning Committee to further discuss the stakeholder survey results and begin developing management goals and actions for the Horsehead Lake management plan.

Implementation Plan Development

In October 2008, a draft implementation plan was provided via email to the Planning Committee. Over the next several months, comments were received from the committee and integrated within the second draft of Implementation Plan during October 2009. Also within that timeframe, specific attention was paid to developing a mechanical harvesting plan for the lake. Those discussions also included the comments and guidance provided by Mr. Kevin Gauthier, WDNR. During the summer of 2009, the mechanical harvesting plan contained within the Implementation Plan was implemented successfully by the district.

Project Wrap-up Meeting

On October 24, 2009, the HLPRD held a special meeting regarding the completion of the Horsehead Lake Management Planning Project. During the meeting, Tim Hoyman presented the results of the many studies that had been completed on the lake since 2007. He also answered many questions about the lake and how it should be managed.

Management Plan Review and Adoption Process

Sections of this report were reviewed by HLPRD planning committee members prior to the first Planning Meeting. Their responses helped to shape the Implementation Plan, which was sent to the committee in October of 2009. The HLPRD responded quickly with comments on the Implementation Plan, and on December 30 of 2009, a draft of the full Horsehead Lake Management Plan was supplied to the WDNR and the HLPRD Planning Committee.

The WDNR provided written comments to the draft management plan in April of 2011. This report reflects the integration of WDNR and HLPRD comments. The final report will be reviewed by the HLPRD Board of Directors and a vote to adopt the management plan will be held during the association's next annual meeting.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, not all chemical attributes collected may have a direct bearing on the lake's ecology, but may be more useful as indicators of other problems. Finally, 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 analysis 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 ecology 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.

Comparisons with Other Datasets

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 similar lakes in the area. In this document, a portion of the water quality information collected in Horsehead Lake are compared to other lakes in the region and state (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Horsehead Lake water quality analysis:

Phosphorus is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both *algae* and *macrophytes*. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.

Chlorophyll-*a* is the green pigment in plants used during *photosynthesis*. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Lillie and Mason (1983) is an excellent source of data for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Oneida County lakes are included within the study's Northeast Region (Figure 3.1-1) and are among 242 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide natural lake means and historic data from Horsehead Lake are displayed in Figures 3.1-2 – 3.1-4. Please note that the data in these graphs represent values collected only during the summer months (June-August) from the deepest location in Horsehead Lake (Map 1). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments (see discussion under Internal Nutrient Loading on page 9). Surface samples in Horsehead Lake were collected at a depth of 3 feet.

Figure 3.1-1. Location of Horsehead Lake within the regions utilized by Lillie and Mason (1983).

Apparent Water Quality Index

Water quality, like beauty, is often in the eye of the beholder. A person from southern Wisconsin that has never seen a northern lake may consider the water quality of their lake to be good if the bottom is visible in 4 feet of water. On the other hand, a person accustomed to seeing the bottom in 18 feet of water may be alarmed at the clarity found in the southern lake.

Lillie and Mason (1983) used the extensive data they compiled to create the *Apparent Water Quality Index* (WQI). They divided the phosphorus, chlorophyll-*a*, and clarity data of the state's lakes into ranked categories and assigned each a "quality" label from "Excellent" to "Very Poor". The categories were created based upon natural divisions in the dataset and upon their experience. As a result, using the WQI as an assessment tool is very much like comparing a particular lake's values to values from many other lakes in the state. However, the use of terms like, "Poor", "Fair", and "Good" bring about a better understanding of the results than just comparing averages or other statistical values between lakes. The WQI values corresponding to the phosphorus, chlorophyll-*a*, and Secchi disk values for Horsehead Lake are displayed on Figures 3.1-2 – 3.1-4.

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

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.

Carlson (1977) presented a trophic state index that gained great acceptance among lake managers. Because Carlson developed his TSI equations on the basis of association among water clarity, chlorophyll-*a*, and total phosphorus values of a relatively small set of Minnesota Lakes, researchers from Wisconsin (Lillie et. al. 1993), developed a new set of relationships and equations based upon the data compiled in Lillie & Mason (1983). This resulted in the Wisconsin Trophic State Index (WTSI), which is essentially a TSI calibrated for Wisconsin lakes. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Citizen Lake Monitoring Network volunteers.

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading*

In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

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

Candidate Lakes

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

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

If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

*Lack of sufficient temperature/dissolved oxygen profiles and hypolimnetic phosphorus data prevents these analyses from being performed. The explanation provided under this heading is strictly for the information of the reader.

Horsehead Lake Water Quality Analysis

Horsehead Lake Long-term Trends

Historic water quality data for Horsehead Lake was gathered from three sources: 1) the WDNR Surface Water Integrated Monitoring System (SWIMS), 2) The Environmental Protection Agency Storage and Retrieval System (STORET), and 3) HLPRD files. The HLPRD files contained a wealth of data from numerous past studies completed on Horsehead Lake for a variety of reasons. These data incorporated results collected for a reports completed by Lumberjack (1974) and Northern Lakes Services (1977 & 1993). In addition, the most recent water quality data consists of results from the HLPRD CLMN program. Together, these sources provided Horsehead Lake water quality data spanning from the mid 1970's to the present. However, it should be noted that the data is not continuous and, as a result, a distinct "trend" cannot be drawn completely. We cannot be certain if differences in one parameter are due to actual changes occurring within the system, or if variable environmental factors such as precipitation, temperature, etc. are influencing the lake on an annual basis. These fluctuations are often seen in lakes as a result of naturally occurring changing environmental conditions.

Total phosphorus levels during the mid 1970's were quite high and in the "Poor" classification of the WQI (Figure 3.1-2). Further, the values were much higher the State and regional means. Over the course of the next two decades the phosphorus levels decreased in the lake fluctuating within the "Good" and "Fair" categories, but still remained higher than the state and regional averages. Within the past 6 years, the levels have risen slightly, but are still below those found during the mid 1970's and higher than the state and regional averages.

The chlorophyll-*a* levels in the lake follow much the same pattern within Horsehead Lake (Figure 3.1-3). This is not surprising considering the relationship between chlorophyll-*a* and phosphorus as discussed above. The water clarity data (Figure 3.1-4) also follow this pattern with low clarities being found during the mid 1970's and better water clarity being found beginning in the mid 1990's. As with the phosphorus values, the chlorophyll-*a* and clarity values found in Horsehead are not as good as those found in the state or region.

A logical conclusion when interpreting these patterns would be that phosphorus inputs to Horsehead Lake have decreased since the 1970's, and while this may be possible, it is likely not probable. As discussed in the studies published in 1977 and 1993, a minimal amount of phosphorus was entering the lake from its watershed, and further, septic systems are not an issue. These potential inputs have likely not changed for the worse as the watershed modeling discussed below indicates that minor amounts of phosphorus still enter from the lake's primarily forested watershed. Also, as with the earlier studies, there is no indication with the water quality data or watershed assessment from this study that indicates septic systems are of a concern. So, we can conclude that the phosphorus inputs to the lake are roughly the same. Being that Horsehead Lake is quite shallow, we must consider that fact in our rationalization as to why overall water quality, especially water clarity has improved over the years.

In general, two types of plants grow in lakes; algae and macrophytes. Algae are a simple type of plant that comes in many forms. Some just float in the lake as a single cell, others float around in small colonies. Some types are attached to rocks, sediment, or even piers. Macrophytes are the vascular plants that grow in the lake – most with roots, stems, leaves, and flowers. Bulrushes, cattails, lilies, duckweeds, Eurasian water milfoil and curly-leaf pondweed are all examples of macrophytes.

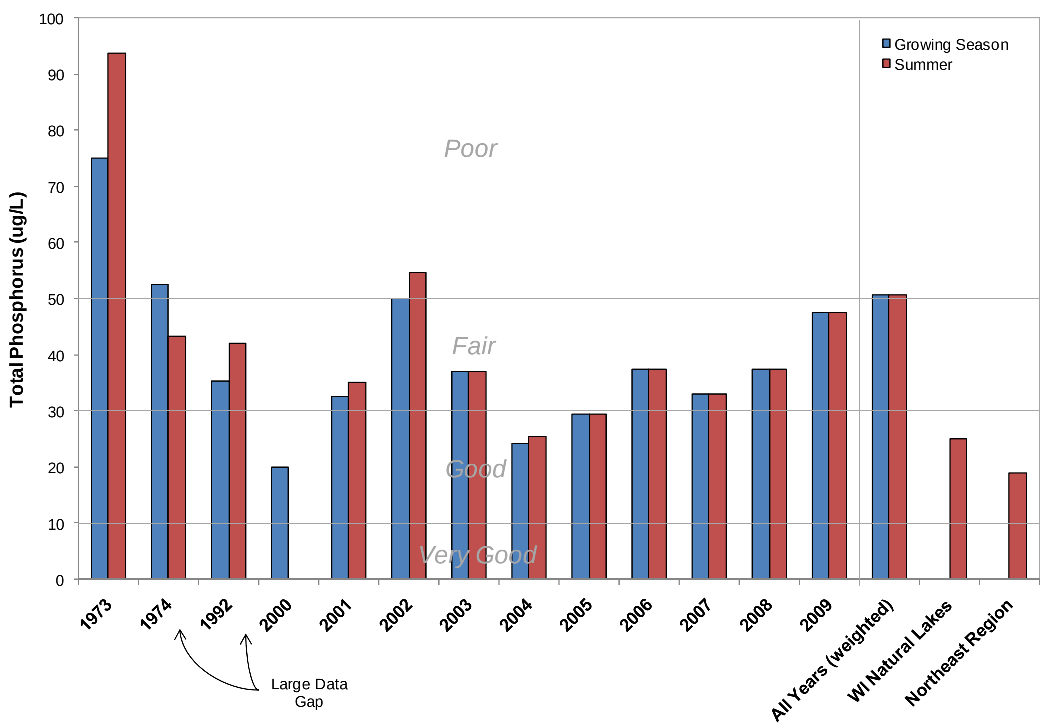


Figure 3.1-2. Horsehead Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

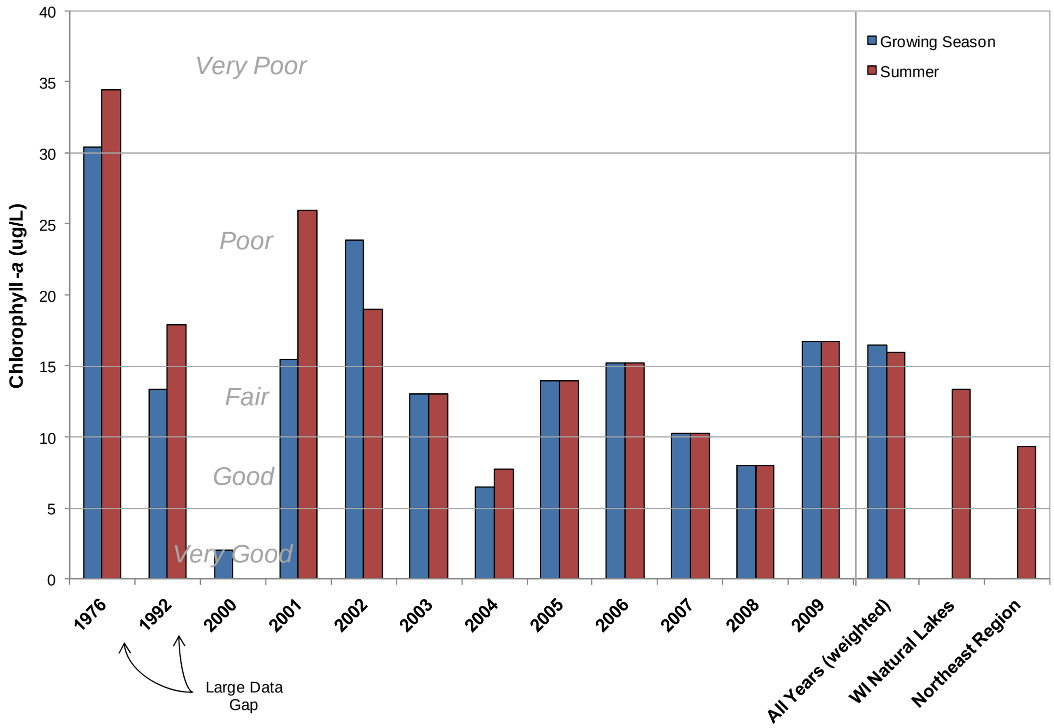


Figure 3.1-3. Horsehead Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

There is a constant battle between algae and macrophytes as they compete for light and nutrients. Although this occurs in all lakes to some extent, it is amplified in shallow lakes to the point that normally only one type of plant dominates the lake. In shallow lakes other interactions are also important, especially when macrophytes are the dominant plant form. Recent research has shown that macrophytes do much more than use nutrients and light that would otherwise be utilized by algae; they also provide cover for zooplankton. Zooplankton are the microscopic animals, mostly crustaceans, that graze on algae and help keep it from dominating the lake. The zooplankton are preyed upon by fish and insects, so they use the macrophytes as cover. Without the macrophytes, the zooplankton disappear and the algae flourish.

Lakes that are dominated by algae, are called "turbid state" lakes, while lakes dominated by macrophytes, are called "clear state" lakes. At this time, Horsehead Lake is in a clear state as it is dominated by macrophytes and is experiencing good water clarity. In the past, as discussed in the 1977 study, the lake was dominated by algae, which according to the report's authors, was limiting macrophytes growth. The report goes on to mention that actions should be taken to improve the macrophyte population in hopes of decreasing overabundant algae. The 1993 study also mentions a lake of macrophyte occurrence.

Sometime following the 1993 study, for an undetermined reason, the plants in Horsehead Lake began to flourish and as a result the lake switched from an algae-dominated turbid state to a macrophyte-dominated clear state. As a result, the open-water phosphorus concentrations have decreased over the years. It is not that the phosphorus is no longer in the lake, it is that it is not detectable in the open-water sampling that is completed as a part of a limnological study. The phosphorus that was once utilized by open-water (free-floating) algae is now bound within the macrophytes. During the earlier studies, the phosphorus concentrations were higher because when the water was collected, the algae were also collected, and the phosphorus that was bound within their cells made up a portion of the lake's *total phosphorus* concentration, which are the data displayed in Figure 3.1.2. In other words, total phosphorus concentration includes all phosphorus within the sample, whether it is tied up in algal cell, dissolved in the water, or attached to suspended particles. As the lake's available phosphorus shifted from the free-floating algae to the macrophytes, the sampling regime used to collect the data, indicated a decrease in total phosphorus concentrations. Naturally, the chlorophyll-*a* levels decreased and the water clarity increased.

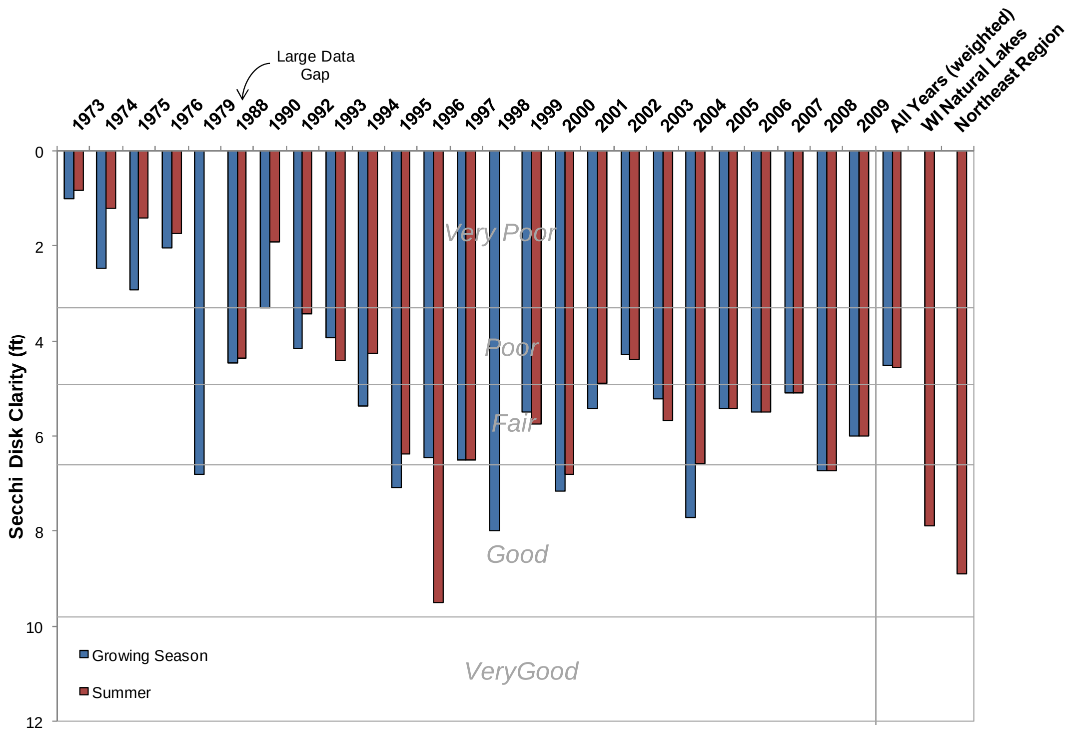


Figure 3.1-4. Horsehead Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Limiting Plant Nutrient of Horsehead Lake

Using 2007 midsummer nitrogen and phosphorus concentrations from Horsehead Lake, a nitrogen:phosphorus ratio of 25:1 was calculated. This finding indicates that Horsehead 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.

Horsehead Lake Trophic State

Figure 3.1-5 contain the WTSI values for Horsehead Lake. In general the WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower to mid eutrophic. The best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* WTSI values, it can be concluded that Horsehead Lake was in a highly eutrophic state early in the dataset, but in the past decade or so has primarily been in a mid to low eutrophic condition.

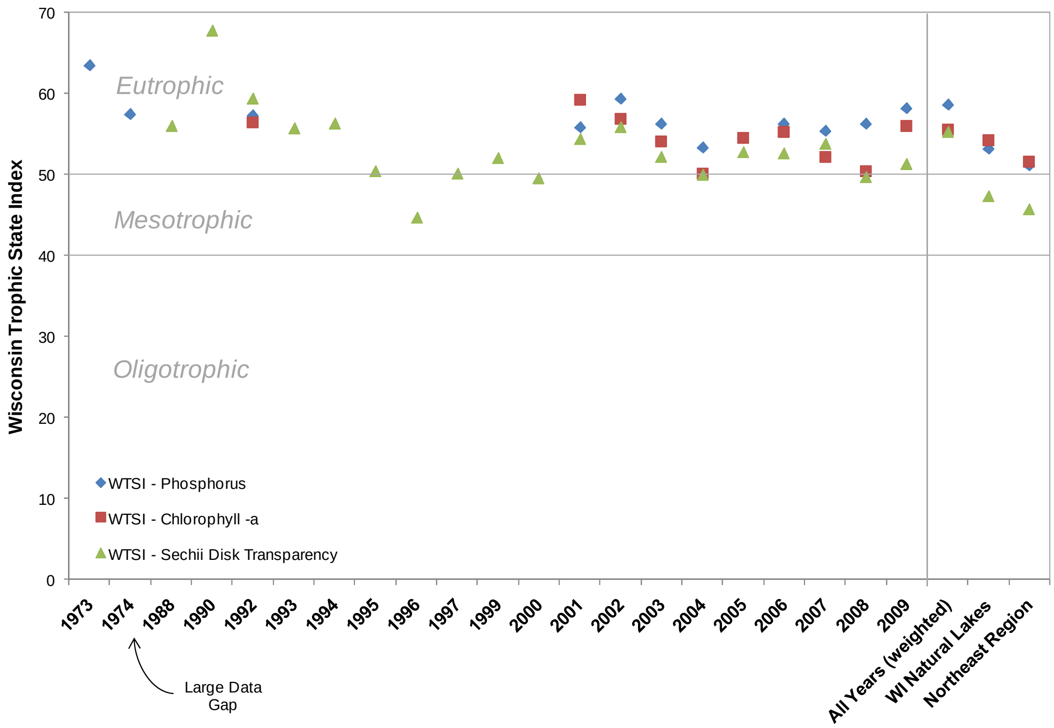


Figure 3.1-5. Horsehead Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Dissolved Oxygen and Temperature in Horsehead Lake

Historically, Horsehead Lake experienced very low dissolved oxygen levels during the winter months. This is a common occurrence in shallow, eutrophic lakes. The low dissolved oxygen levels occur as a result of the winter decomposition of the large amount of plant biomass these lakes support during the growing season. As the decomposition takes place, the lake's limited amount of oxygen present under the ice cover is consumed. At times, these levels were so low that fishkills occurred. In the mid 1970's, the HLPRD installed an aeration system that is in operation during the winter months. The operation of the aeration system has prevented significant fishkills from occurring since its installation.

Figure 3.1-6 contains the dissolved oxygen and temperature data collected by Onterra staff and the Horsehead Lake CLMN volunteers. The February 19, 2007 sample that was collected through the ice indicates that near the bottom of the lake, dissolved oxygen levels do decrease below 3.0 mg/l starting at approximately 5 feet. However, the water above that depth holds sufficient oxygen to support fish. The remaining profiles indicate high levels of oxygen are held throughout the summer and that the lake does not completely stratify.

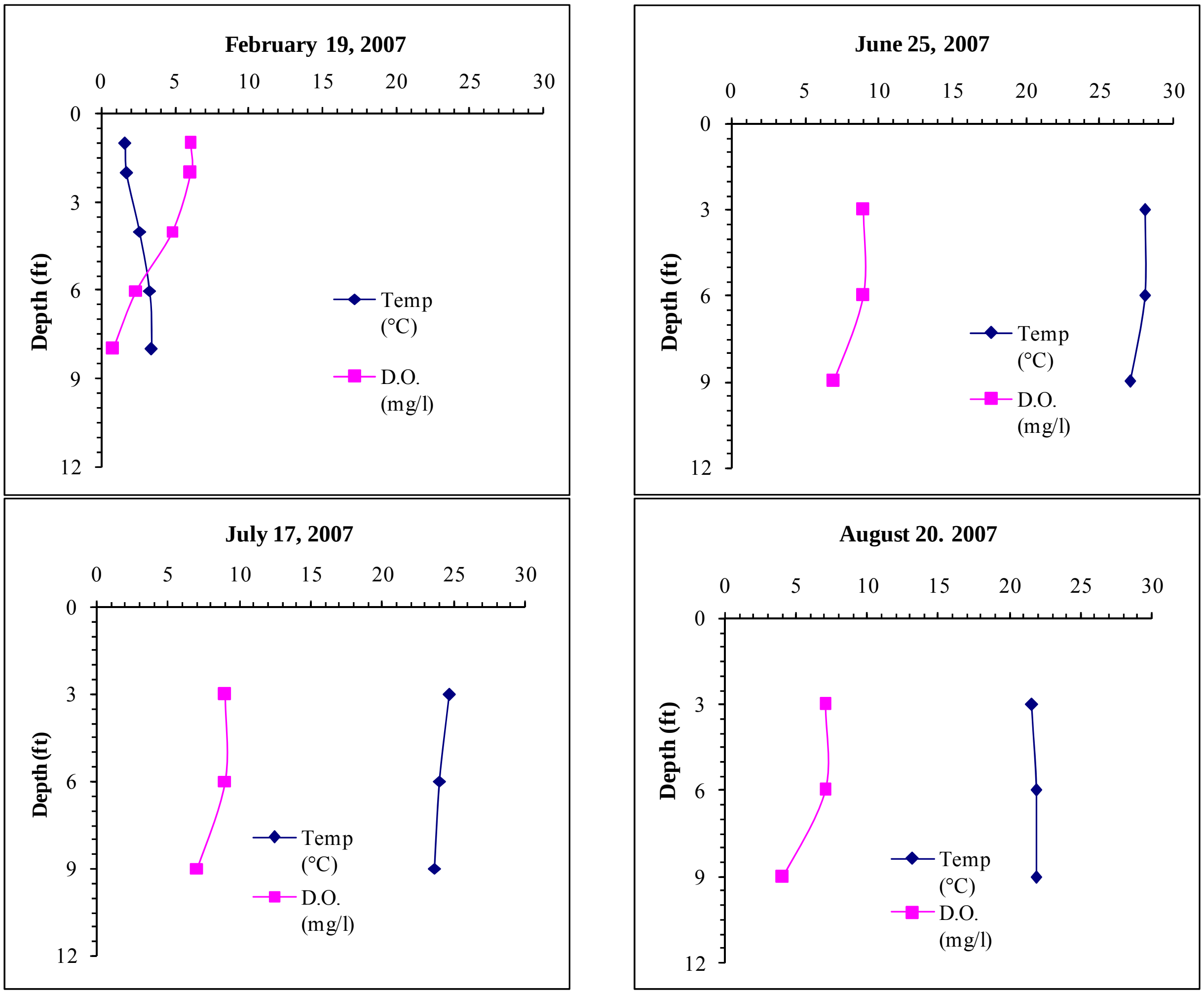


Figure 3.1-6. Horsehead Lake dissolved oxygen and temperature profiles. February 19, 2007 data collected by Onterra; remaining data collected by CLMN volunteers.

Other Water Quality Data Collected at Horsehead Lake

Alkalinity, pH, and calcium analysis was also performed on some of the water quality samples collected from Horsehead Lake. Alkalinity values ranged between 41 and 44 mg/l as $CaCO_3$ during the summer months indicating that the lake has a high buffering capacity against acid rain. During the same time, the lake's pH hovered around 8.8 or slightly above neutral (7.0). The pH value is normal for a lake such as Horsehead and is well within the optimal range for zebra mussels. However, calcium analysis from a sample collected during June 2007 returned a value of 12.1 mg/l, which is at the very low end for zebra mussels. Please note that zebra mussel presence has not been sampled on Horsehead Lake.

3.2 Watershed Assessment

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. These parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake; 1) the size of the watershed, and 2) the land cover (land use) within the watershed. The impact of the watershed size is dependent on how large it is relative to the size of the lake. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drains to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load.

The type of land cover that exists in the watershed determines the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows allow the water to permeate the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas minimize infiltration and increase surface runoff. The increased surface runoff associated with these land cover types leads to increased phosphorus and pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

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 (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 could be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading would 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 can be 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, as well as 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.

Horsehead Lake's watershed, including the surface of the lake, encompasses approximately 1,021 acres (Map 2). Other studies completed on the lake measured the watershed at 1,090 and approximately 1,200 acres. The reason for these discrepancies is not known, however, the earlier studies were completed before Geographic Information System (GIS) software was commonly used so it is likely that the acreage determinations were estimated or calculated by hand. Review of the watershed boundaries determined during this study and use of GIS software in calculating its acreage makes the 1,021-acre determination the most appropriate; therefore, that figure will be used in this assessment.

The WS:LA ratio for Horsehead Lake is approximately 2:1, which would be considered low and indicate that groundwater plays the majority role in maintaining water levels within the lake. Examination of watershed land cover (Map 2 and Figure 3.2-1) indicates that the majority of the watershed (55%) draining to Horsehead Lake is forested. As mentioned above, forested areas deliver the least amount of phosphorus to a lake. The remaining 45% of the watershed consists of the lake surface itself and small amounts of grassed areas and wetlands. These three categories also deliver minimal amounts of pollutants to a lake.

Modeling of the Horsehead Lake watershed using WiLMS indicated that approximately 162 lbs of phosphorus are added to the lake annually through its drainage basin. Being that the lake's WS:LA ratio is so low, the majority (64%) of that phosphorus is input through the lake's surface via atmospheric fallout (Figure 3.2-2). Essentially, as it rains and snows, the precipitation picks up dust in the atmosphere and deposits it in the lake. Dust and other particles are also deposited within the lake through wind actions. The dust and other particles contain small amounts of phosphorus, which over the course of a year adds up to approximately 103 lbs.
The other land cover types deliver the remaining 36% of the lake's annual phosphorus with forested areas making up about 28% of the total phosphorus load.

In the big picture of Horsehead Lake's ecology, the addition of 162 lbs of phosphorus per year is not that much. However, when considering the ecology of the lake, specifically, its trophic state (see Water Quality Section), we must consider the lake's morphology, its age, and its flushing rate. Although Horsehead Lake's water levels are maintained by a dam, the majority of its volume is natural; therefore, the lake is considered natural. Still, even with the additional depth attributed to the dam, the lake is still shallow. Based upon average precipitation and evaporation figures for Oneida County and the lake's volume (2,740 acre-feet), the WiLMS modeling calculated a flushing rate of about 30% of its volume per year. This means that Horsehead Lake's water is exchanged very slowly and replaced about every 3.3 years (water residence time). As a result of this low flushing rate (high residence time) the nutrients that enter Horsehead Lake tend to remain in the lake because they are not "flushed out". We also know that the lake is over 10,000 years old because it was created by the last glacier occurring in Wisconsin. Even when it was first created, Horsehead Lake was likely not very deep.

Considering the information in the preceding paragraph, we can draw the conclusion that nutrients (and sediments) have accumulated in Horsehead Lake over its lifespan. This is a normal occurrence within all natural lakes and is called *eutrophication*. The rate of nutrient and sediment accumulation has most likely been accelerated by human activity (road construction, logging, building construction, etc.) within the lake's watershed (*cultural eutrophication*). Over the course of time, the majority of the nutrient load that has entered the lake has remained there. A portion of those nutrients are recycled through the lake annually and utilized by the lake's plant population. As discussed in the Water Quality Section, prior to the mid 1990's, those nutrients were used primarily by algae and now are utilized by macrophytes.

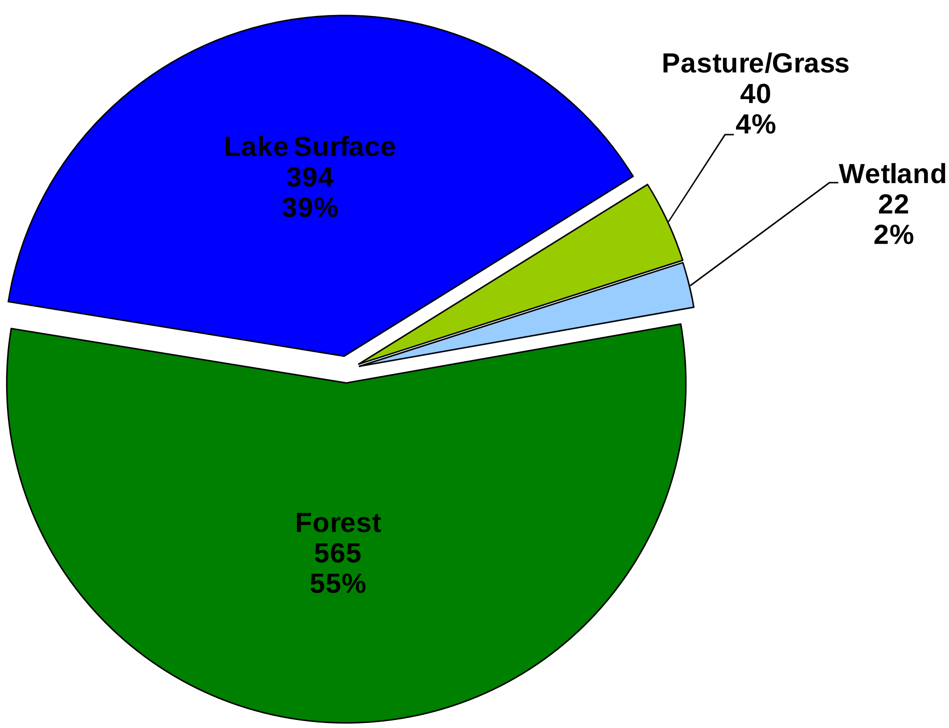


Figure 3.2-1. Horsehead Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

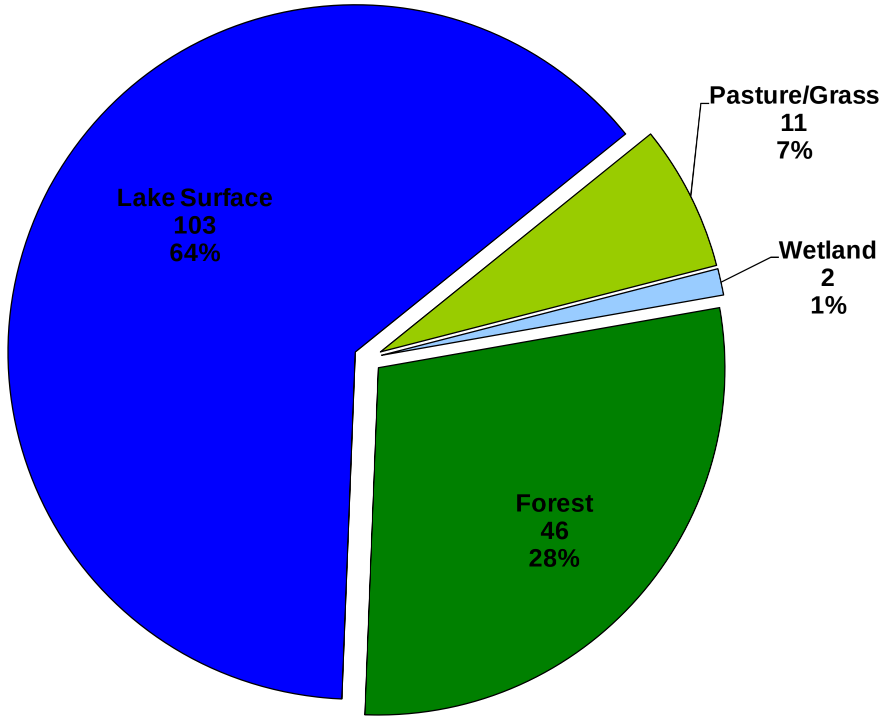


Figure 3.2-2. Horsehead Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Both of the 1977 and 1993 studies indicate that septic systems were likely not contributing significant amounts of phosphorus to the lake. The 1977 study included intense water quality monitoring of wells placed throughout the shorelands of Horsehead Lake. The results of that study indicated that the quality of the groundwater entering the lake was good. Water quality monitoring during the 1993 project supported the same conclusions.

The scope of this project did not include specific groundwater monitoring or the inclusion of septic system modeling within WiLMS. Based upon the Phosphorus Prediction and Uncertainty Analysis within WiLMS, it can be concluded that the expected in-lake phosphorus values are in line with those collected at that lake; therefore, it is not believed there is a major source of unaccounted phosphorus entering the lake.

3.3 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 affects 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 numbers of predator fish and 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

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

Important Note:
Even though most of these techniques are not applicable to Horsehead 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 Horsehead Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Permits

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

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 resuspension 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.

Disadvantages

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.

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 $1200 to $11,000.

Advantages

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.

Disadvantages

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 harvest remaining plants
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.

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

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.

Disadvantages

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.

Advantages

Inexpensive if outlet structure exists.
May control populations of certain species, like Eurasian water-milfoil for up to two years.
Allows some loose sediments to consolidate.
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.

Disadvantages

May be cost prohibitive if pumping is required to lower water levels.
Has the potential to upset the lake ecosystem and have significant affects 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 (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).
Permitting process requires an environmental assessment that may take months to prepare.
Unselective.

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.

Costs

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

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.

Disadvantages

Initial costs and maintenance are high if the lake organization intends to own and operate the equipment.
Multiple treatments may be required during the growing season because lower portions of the plant and root systems are left intact.
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.
Larger harvesters are not easily maneuverable in shallow water or near docks and piers.
Bottom sediments may be resuspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

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 does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

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.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*).. Glyphosate is also marketed under the name Roundup®; this formulation is not permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothal (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothal (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions apply.

Advantages

Herbicides are easily applied in restricted areas, like around docks and boatlifts.
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.

Disadvantages

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 herbicides are nonselective.
Most herbicides have a combination of use restrictions that must be followed after their application.
Many herbicides are slow-acting and may require multiple treatments throughout the growing season.

Cost

Herbicide application charges vary greatly between $400 and $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

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 waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*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 not 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. Wisconsin is also using two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These biocontrol insects are not covered here because purple loosestrife is predominantly a wetland species.

Advantages

Milfoil weevils occur naturally in Wisconsin.
This is likely an environmentally safe alternative for controlling Eurasian water-milfoil.

Disadvantages

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.

Cost

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

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, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities, may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. 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 Horsehead 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 Horsehead 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, relative frequency of occurrence is used to describe how often each species occurred in the plots that contained vegetation. 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

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.

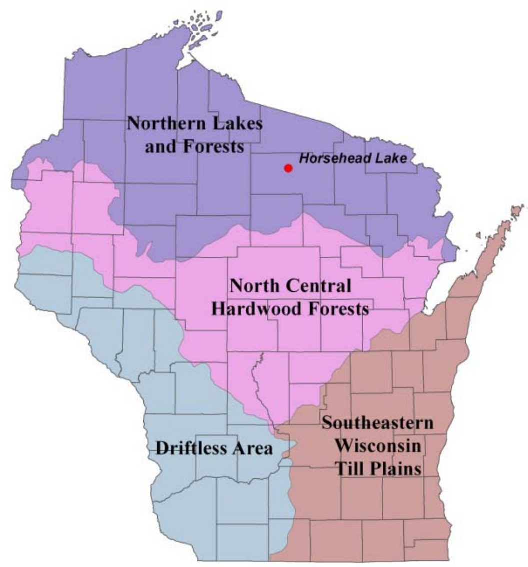


Figure 3.3-1. Location of Horsehead Lake within the ecoregions of Wisconsin. After Nichols 1999.

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.

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 Horsehead Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.3-1).

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.

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 3.3-2). 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

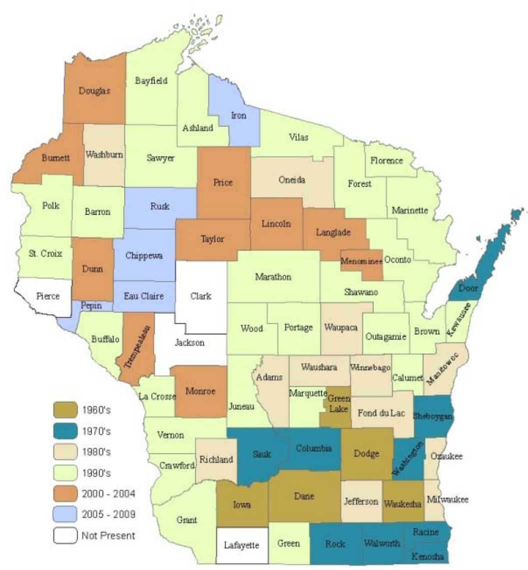


Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2009 mapped by Onterra.

submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

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

As mentioned above, numerous plant surveys were completed as a part of this project. In June 13, 2007, a survey was completed Horsehead Lake that focused upon curly-leaf pondweed. Numerous occurrences of curly-leaf pondweed were mapped during the survey (Map 3), with the most being located in the shallow area at the lake's south end. In very few locations, the plant was found to dominate those areas.

The point intercept survey was conducted on Horsehead Lake in July of 2007 by Onterra. Additional surveys were completed by Onterra on Horsehead Lake to create the aquatic plant community map (Map 4) during August 2007.

During the point-intercept and aquatic plant mapping surveys, 28 species of plants were located in Horsehead Lake (Table 3.3-1), two are considered non-native species: Eurasian water milfoil and curly-leaf pondweed. These exotic species will be discussed in depth in a separate section below. Native plants were found on 96% of all the point-intercept locations sampled, including at the deepest location in the lake (11 feet).

Of the 28 native species found on Horsehead Lake, 19 are narrow-leaf species (monocot), six are broad-leaf (dicot) species and one is a macro-algae (stoneworts). Wild celery is a turbidity tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Northern water milfoil is usually found in soft sediments and its feathery foliage traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

Horsehead Lake has a high number of aquatic plant species, and because of this, one may assume that the system would also have a very high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influences the diversity. The diversity index (Simpson's 1-D) for Horsehead Lake's plant community (0.78) shows that the lake has an uneven distribution (relative frequency) of plant species throughout the lake. Figure 3.3-3 and Table 3.3-3 clearly show that the lake is dominated by 4 species (flat-stem pondweed, fern pondweed, common waterweed, and coontail). These species are typical in productive lakes that contain highly organic (mucky) substrates. Common waterweed and coontail are largely non-rooted plants which have the ability to be moved throughout the system by water currents and have the capacity to aggregate and form dense mats at the surface as they become entangled in rooted plants. Formulating management actions aimed at controlling these species can be difficult, as the nuisance conditions may not occur in the same parts of the lake each year.

Results from the stakeholder survey indicate that excessive aquatic plant growth is the primary concern facing the lake (Appendix B, Question #14). Approximately 93% of respondents state that aquatic plant growth impacts their recreational use of the lake (Appendix B, Question #16) and over 87% feel that aquatic plant control is needed on the lake (Appendix B, Question #17). Only 5 respondents indicated that they weren't at least moderately supportive of mechanical harvesting occurring on the lake (Appendix B, Question #18).

The 2007 community map indicates that there are many areas of the lake where important floating-leaf and emergent communities can be found (Table 3.3-1, Map 4). While all these plant communities are valuable, the softstem bulrush colony located in open water in the constriction between the two basins is of particular importance. Wave action caused by excessive boat traffic has thought to be one of the principal factors in the decline of bulrush populations throughout the state. Galatowitsch and Vandebosch (2008) reported that wave action caused significant physical damage to many plants in water less than 32 centimeters (12.5 inches). A dam on Horsehead Lake exists, keeping the lake artificially higher than in its history and minimizing natural fluctuations in water levels. Natural water level fluctuations are known to be very important to bulrush survival. Perennial emergents respond well to falling water levels as they can contribute to increased nutrient levels that are valuable to the plant's root/rhizome systems as well as facilitate seed germination.

Table 3.3-1. Horsehead Lake acres of plant community types from the 2007 community mapping survey.

Plant Community	Acres
Emergent	0.4
Floating-leaf	0.8
Mixed Floating-leaf and Emergent	12.5
Total	13.7

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 Horsehead Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines. Many studies have documented the adverse affects of motorboat traffic on aquatic plants (e.g. Murphy and Eaton 1983, Vermaat and de Bruyne 1993, Mumma et al. 1996, Asplund and Cook 1997). In all of these studies, lower plant biomasses and higher turbidity were associated with motorboat traffic. Results of the stakeholder survey indicate that of the top four most common watercraft types used on Horsehead Lake, three are motorized and have the greatest ability to affect aquatic plant growth (Appendix B, Question #5).

Table 3.3-2. Aquatic plant species located in Horsehead Lake during aquatic plant surveys.

Life Form	Common Name	Scientific Name	Coefficient of Conservatism	2007 Survey	1992 Survey	1976 Survey
Emergent	*Alisma trivale*	Northern water plantains	4	X		
	Calla palustris	Water arum	9	X		
	Carex comosa	Bristly sedge	5	X		
	Pontederia cordata	Pickerelweed	9		X	
	Sagittaria latifolia	Common arrowhead	3	X	I	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I	X
	Typha latifolia	Broad-leaved cattail	1	X	I	X
Floating Leaf	*Brasenia schreberi*	Watershield	7	X		
	Nuphar variegata	Spatterdock	6	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X
	Polygonum amphibium	Water smartweed	5	X	X	X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	X		
	Sparganium eurycarpum	Common bur-reed	5	X		
Submergent	*Ceratophyllum demersum*	Coontail	3	X		
	Elodea canadensis	Common waterweed	3	X	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X		X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	I		
	Nitella sp.	Stoneworts	7	X		
	Potamogeton amplifolius	Large-leaf pondweed	7	X		
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X	X	
	Potamogeton gramineus	Variable pondweed	7	X		
	Potamogeton pusillus	Small pondweed	7	X	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X		X
	Potamogeton robbinsii	Fern pondweed	8	X		X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X
	Stuckenia pectinata	Sago pondweed	3	X		X
	Vallisneria americana	Wild celery	6	X		X
FF	*Lemna minor*	Lesser duckweed	5	X	X	X
S/E	*Juncus pelocarpus*	Brown-fruited rush	8	X		

X = Present, I = Incidental
FL/E = Floating Leaf and Emergent
FF = Free Floating
S/E = Submergent and Emergent

Data collected from the aquatic plant surveys indicate that the number of native plants in Horsehead Lake is higher than the state median and the Northern Lakes ecoregion median (Figure 3.3-4). However, Horsehead Lake's aquatic plant community contains a lower average conservatism value than both comparative datasets. These data show that while many species exist within the lake, many are indicative of a disturbed system. Combining the lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in an high value of 28.6 (calculation shown below); again, above the median values of the state and ecoregion (Figure 3.3-4).

Median Value This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

FQI = Average Coefficient of Conservatism (5.6) * √ Number of Native Species (26)
FQI = 28.6

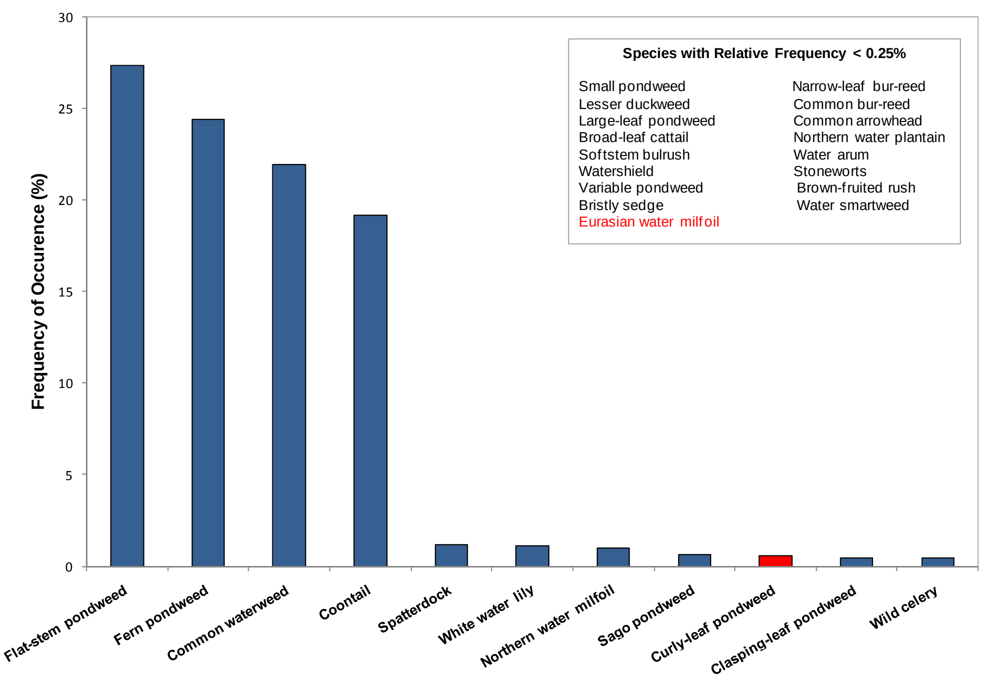


Figure 3.3-3 Horsehead Lake aquatic plant occurrence analysis. Created using data from 2007. Exotic species indicated with red.

Scientific Name	Common Name	Relative & Littoral Frequency
Potamogeton zosteriformis	Flat-stem pondweed	27.3725
Potamogeton robbinsii	Fern pondweed	24.3922
Elodea canadensis	Common waterweed	21.9608
Ceratophyllum demersum	Coontail	19.1373
Nuphar variegata	Spatterdock	1.1765
Nymphaea odorata	White water lily	1.0980
Myriophyllum sibiricum	Northern water milfoil	1.0196
Stuckenia pectinata	Sago pondweed	0.6275
Potamogeton crispus	Curly-leaf pondweed	0.5490
Potamogeton richardsonii	Clasping-leaf pondweed	0.4706
Vallisneria americana	Wild celery	0.4706
Lemna minor	Lesser duckweed	0.2353
Potamogeton pusillus	Small pondweed	0.2353
Typha latifolia	Broad-leaved cattail	0.1569
Potamogeton amplifolius	Large-leaf pondweed	0.1569
Sagittaria latifolia	Common arrowhead	0.0784
Schoenoplectus tabernaemontani	Softstem bulrush	0.0784
Carex comosa	Bristly sedge	0.0784
Sparganium eurycarpum	Common bur-reed	0.0784
Polygonum amphibium	Water smartweed	0.0784
Brasenia schreberi	Watershield	0.0784
Potamogeton gramineus	Variable pondweed	0.0784
Nitella sp.	Stoneworts	0.0784
Juncus pelocarpus	Brown-fruited rush	0.0784
Sparganium angustifolium	Narrow-leaf bur-reed	0.0784
Calla palustris	Water arum	0.0784
Alisma trivale	Northern water plantains	0.0784
Myriophyllum spicatum	Eurasian water milfoil	0.0000

Table 3.3-3 Horsehead Lake aquatic plant occurrence analysis. Created using data from 2007. Exotic species indicated with red.

Horsehead is fortunate to have comparable vegetation data from studies conducted by Northern Lakes Services in 1976 and 1992. Figure 3.3-4 shows that there are many more species present in the lake during the current study than were present in both previous surveys. As elaborated on in the Water Quality Section, both of these studies state that macrophyte growth was limited on Horsehead Lake at that time, largely because it existed in an algae-dominated state where light penetration was inhibited. By comparing the coefficient of conservatism values (Figure 3.3-4), the plant composition in 1976 and 1992 (Table 3.3-2) is even more indicative of a disturbed system than its current condition. These data clearly show that the aquatic plant community of Horsehead Lake has improved since these surveys. Pickerel weed was the only plant species located in a past survey that was not located in the current study. This plant was located in 1992 along the northeast shoreline of the island located in the northern basin of the lake.

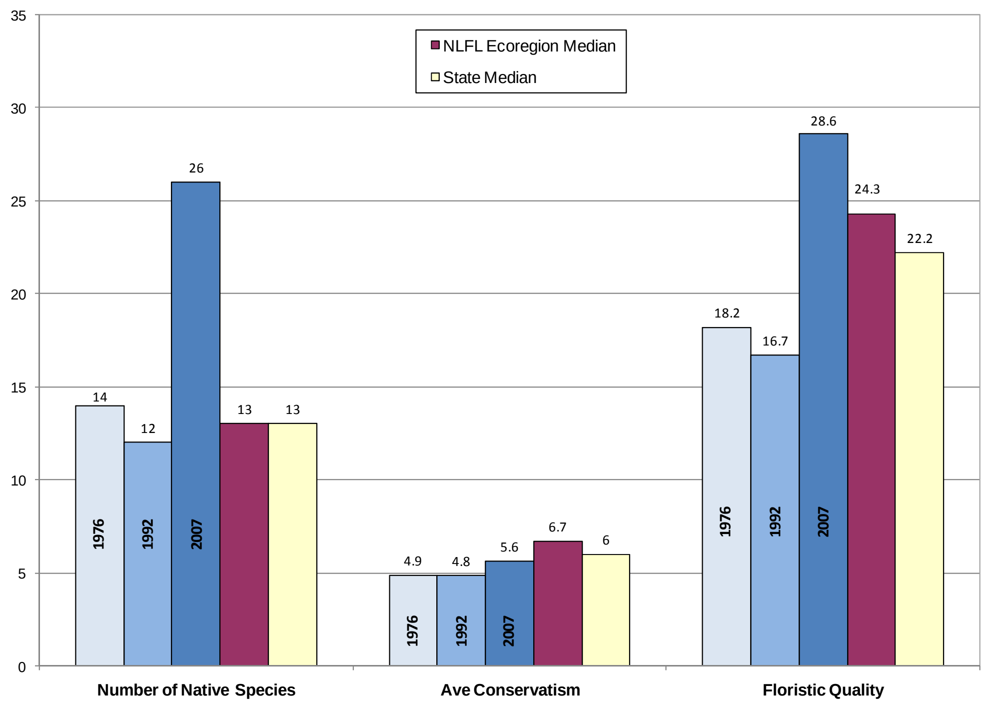


Figure 3.3-4. Horsehead Lake Floristic Quality Assessment. Created using data from 2007 (current study), 1992, and 1976. Analysis following Nichols (1999).

Exotic Plants in Horsehead Lake

As described above, two exotic plants were located within Horsehead Lake during this project's studies, curly-leaf pondweed and Eurasian water milfoil. Both of these species are a concern when found in any lake, but are even more when the lake in question uses mechanical harvesting to control nuisance plant levels as this practice accelerates the exotic's spread.

Curly-leaf pondweed spreads primarily through the turions it produces, while Eurasian water milfoil is spread primarily through fragmentation. In the case of Horsehead Lake's harvesting operations, both in the past and as described in the Implementation Plan found later in this document, this activity is completed by a contractor during a single site-visit during late July. By that time, the curly-leaf pondweed has senesced and the turions the population produced have settled to the bottom taking them out of the harvester's range. Turions can still be spread by the harvesting operation, but it is minimized.

Curly-leaf pondweed was first documented from Horsehead Lake in 1992. Map 3 displays the locations where curly-leaf pondweed existed in 1992. Examination of the map shows that curly-leaf pondweed was first found on the east shore of the southern basin and over the course of the next 15 years has spread to occupy much of the southern basin and sporadically within the northern basin. While this spread is concerning, it must be noted that curly-leaf pondweed is not causing navigation issues within the lake. Further, at these low densities, it is not currently making a significant impact on the lake's ecology.

Eurasian water milfoil was first located in 2007 during the surveys associated with the current study. A few plants have been found in a single location near the lake's south landing (Map 3).

At the time of the finding, all observed plants were carefully removed, including the roots, using a rake. Subsequent site visits in 2008 and 2009 also observed a few Eurasian water milfoil plants and they were removed in the same manner. Because Horsehead Lake has the capacity to support a large biomass, the spread of Eurasian water milfoil to other areas of the lake is a primary concern. Avoiding that area with the mechanical harvester will naturally prevent the activity from spreading that exotic plant.

3.4 Fishery

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2009).

Table 3.4-1. Gamefish present in the Horsehead 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 debris, 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 inverts
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pikes, 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 (ter. and aq.)
Rock Bass*	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1cm-1m deep	Crustaceans, insect larvae, and other inverts
Yellow bullhead	*Ameiurus natalis*	7	May – July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent vegetation	Small fish, aquatic invertebrates

**Rock bass were last documented by WDNR personnel in 1974, and were not captured in a 2010 survey.*

Based on data collected from the stakeholder survey fishing was the highest ranked important or enjoyable activity on Horsehead Lake (Appendix B, Question #6). Approximately 86.8% of these same respondents believed that the quality of fishing on Horsehead Lake was either fair or poor (Appendix B, Question #8) and approximately 92% believe that the quality of fishing has remained the same or gotten worse since they have obtained their property (Appendix B, Question #9). However, the majority (56%) of these respondents have only owned their property on Horsehead Lake for 10 years or less (Appendix B, Question #3). Actually, a 1974 report by Lumberjack indicates that at that time, "*the present lake is essentially worthless for fishing purposes.*" Without disputing whether the quality of fishing has gotten worse over time, due to the length of property ownership of many of the stakeholder respondents, this comparison is likely rooted in recent history.

Table 3.4-1(above) shows the popular game fish and that are present in Horsehead Lake. Management actions that may need to be taken if Eurasian water milfoil establishment occurs on Horsehead Lake likely would include herbicide applications. These applications should occur in May when the water temperatures are below 60°F and the majority of the lake's native plants have not begun growing. Yellow perch is one species that could be affected by early season herbicide applications, as the treatments could eliminate nursery areas for the emerged fry of these species.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.4-1). LakeName 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. Studies suggest that up to 35% of a lake's walleye population and 20% of a muskellunge population can be removed annually without adverse affects. Each year, a "Safe Harvest" level is set at 35% of the walleye population and 20% of the muskellunge population. 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. In late winter, the six Wisconsin Chippewa Bands declare their intent to harvest a tribal quota. The tribal quota is a portion of the safe harvest. Daily bag limits for walleye are then adjusted 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).

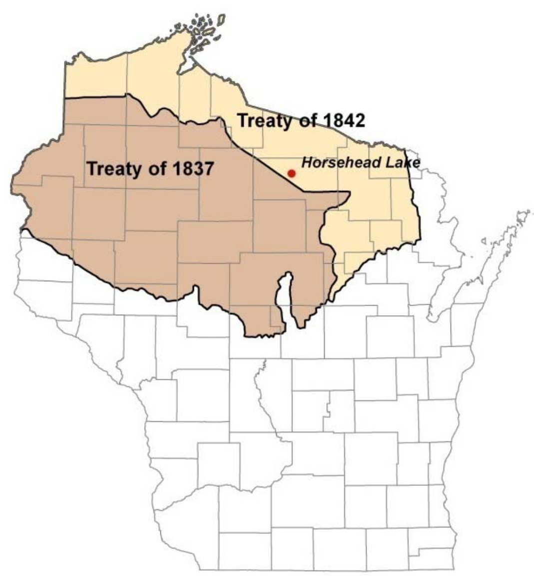


Figure 3.4-1. Location of Horsehead Lake within the Native American Ceded Territory (GLIFWC 2009). This map was digitized by Onterra; therefore it is a representation and not legally binding.

A harvest has never been declared on Horsehead Lake. While walleye and muskellunge populations may have existed once in the lake, their populations are such that the WDNR does not list Horsehead Lake as 'musky-' or walleye-waters. Since tribal spearing is focused upon these two species, the information contained here is probably more informational than applicable to Horsehead Lake.

Some stocking of walleye and northern pike has occurred in Horsehead Lake, as well as an isolated stocking of tiger muskies (Table 3.4-2). Stocking of walleye no longer continues because the WDNR has determined the habitat is unsuitable for natural recruitment of this species. As discussed further below, the habitat is more suitable for species such as panfish and bass.

Table 3.4-2. Fish stocking data available from the WDNR from 1972 to 2009 (WDNR 2009).

Year	Species	Age Class	# Stocked	Average Fish Length (in)
1976	Tiger Musky	Fingerling	479	9.00
1981	Walleye	Fry	500,000	NA
1984	Walleye	Fingerling	12,800	3.00
1985	Walleye	Fingerling	18,000	2.00
1990	Northern Pike	Fry	109,605	1.00
1992	Northern Pike	Fry	117,600	1.00
1993	Northern Pike	Fry	737,300	0.50
1994	Northern Pike	Fry	65,000	0.40

According to the point-intercept survey conducted by Onterra in 2007, the vast majority of the substrate sampled in the littoral zone on Horsehead Lake was muck (99%), followed by sand (0.8%), and rock (0.2%). 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. 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 do not get buried in sediment and suffocate. 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.

Because of the high abundance of aquatic vegetation and mucky sediments, the fishery of Horsehead Lake is likely always going to consist of panfish, bass, and a single apex predator – likely northern pike. As stated within the Water Quality Section, winter decomposition of aquatic plants has historically produced large fish kills in the past. These events may affect fish that are less tolerant of such conditions (such as bluegill) more so than fish that are tolerant (northern pike). An aeration system was installed by Aquatic Biologists Inc. during the mid-1970's to combat the low oxygen levels and appears to have reduced the severity of the winter fish kills.

At this time, little is known about the composition of the Horsehead Lake Fishery. Based upon personal communications with John Kubisiak, WDNR fisheries biologist, a spring 2010 survey of Horsehead Lake was completed as scheduled, and a report is currently being drafted. The information gathered will be vital to understanding the Horsehead Lake fishery and determine future management goals.

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Horsehead Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian water milfoil and curly-leaf pondweed.
3) Create a better understanding of the harvesting needs of the HLPRD and with that information update the lake's harvest plan.
4) Collect sociological information from Horsehead Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

These four objectives were fulfilled during the project and have led to a good understanding of the Horsehead Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

Overall, the studies that were completed on Horsehead Lake indicate that it is healthy in terms of its watershed and water quality. With the exception of two exotic species found in the lake, the aquatic plant community is also believed to be healthy.

The watershed of the lake, as discovered in earlier studies, is dominated by land cover types that deliver a minimal amount of phosphorus to the lake. However, the lake's shallow nature and long residence time have led to a buildup of nutrients and sediments within the lake. As a result, the nutrients are recycled through the system, now in the form of aquatic macrophytes, and prior to the early 1990's in the form of algae.

Although there is a large amount of plant biomass in Horsehead Lake, its water quality, especially as indicated in its water clarity, is fair to good. Macrophytic plant growth dominates the lake's plant community allowing the lake to maintain its water clarity and remain in a "clear state". In the past, when algal biomass dominated the plant community, water clarity was much worse and the lake was considered to be in a "turbid state".

Over the course of the last 1 ½ decades, the water quality on the lake has improved. This is attributed to the switch from an algae-dominated system to a macrophyte-dominated system as described above and within the Water Quality Section. Still, among some stakeholders, the water quality of the lake is still believed to be in less than a fair condition (Appendix B, Question # 10) and many believe the water quality has actually worsened over the years they have owned their property (Appendix B, Question # 11). From these same questions, it can also be seen that many riparians believe the lake has fair water quality and the water quality has either remained or improved somewhat.

While the watershed is in great condition, the HLPRD still needs to be concerned with the impacts of shoreland properties on the lake's health. The concerns revolve around the developed areas of the lake as it is these areas that can have the greatest impact. Increases in impervious surfaces, urbanization of shorelines, removal of large woody debris (tree falls), and faulty septic systems act in a cumulative manner and degrade the lake in terms of it water quality and habitat value. While evidence of these impacts were not focused upon or detected during this project, it is likely that the anthropogenic affects have accelerated the eutrophication of the lake.

As described in the plant section, two exotic species were located within the lake (curly-leaf pondweed and Eurasian water milfoil). Both of the species can greatly upset the plant communities within lakes they infest. In the case of Horsehead Lake, only one occurrence of Eurasian water milfoil was found so this exotic currently has no real impact on the lake's ecology. Curly-leaf pondweed's spread throughout much of the lake has been documented between a study completed in 1992 and this current study. Still, curly-leaf pondweed does not dominate large areas of the lake and as a result, the lake's ecology is impacted to a small degree. In essence, curly-leaf pondweed is not truly behaving as an invasive plant at this time.

Both of these exotic species need to monitored closely by the district. If either appears to be spreading, control actions need to be taken before they take over large areas of the lake.

Due to the lake's productive nature, native aquatic plants reach nuisance levels and impact recreation on the lake. The district has sponsored contracted mechanical harvesting on the lake since 2005. Harvesting targets flat-stem pondweed, which is common throughout much of the littoral zone. It also targets species such as coontail and common waterweed, which lack true roots and are often moved around the lake in large masses by wave action and currents. Harvesting takes place during a single week in late July; therefore, curly-leaf pondweed is avoided as the majority of its biomass has died back by that time. Eurasian water milfoil is also avoided in the single location it was found. By evading these two exotic species, the harvesting activities are not spreading them to any great degree.

Within the comments provided with some of the returned surveys, many stakeholders voiced concern with excessive algae blooms. This though is also portrayed in Question #14 (Appendix B) as the third greatest concern on the lake behind excessive plant growth and water quality degradation. Through discussions at the public meetings and during the planning meetings, it was determined that the concern mainly rests with excessive amounts of filamentous algae. This form of algae begins its growth on the bottom of the lake and has the ability to draw nutrients from the lake sediments. As discussed earlier, the sediments in Horsehead Lake have built up over the course of the lakes existence and contain high amounts of nutrients. Many productive lakes experience this type of algal growth and unfortunately there are not practical methods to control it.

Approximately 71% of the stakeholders that responded to the survey have fished on Horsehead Lake in the past 3 years (Appendix B, Question #7). Of those that fish, over 65% believe the fishing on the lake is fair to poor and roughly 58% believe it has gotten worse over the time they have owned their property (Appendix B, Questions 8 & 9, respectively). At this time, very little data is available regarding the fishery of Horsehead Lake. Fortunately, the WDNR has scheduled fish surveys to begin during the spring of 2010. Once the studies are complete, the WDNR will be able to assist the HLPRD in improving the fishery, if possible.

5.0 IMPLEMENTATION PLAN

The intent of this project was to complete a *comprehensive* management plan for Horsehead Lake. As described in the proceeding sections, a great deal of study and analysis were completed involving many aspects of the Horsehead Lake ecosystem. This section stands as the actual "plan" portion of this document as it outlines the steps the Horsehead Lake Protection and Rehabilitation District will follow in order to manage Horsehead Lake, its watershed, and the district itself.

The implementation plan is broken into individual *Management Goals*. Each management goal has one or more management actions that if completed, will lead to the specific management goal in being met. Each management action contains a timeframe for which the action will be taken, a facilitator that will initiate or carry out the action, a description of the action, and if applicable, a list of prospective funding sources and specific actions steps.

Management Goal 1: Understand and Maintain Current Water Quality in Horsehead Lake

Management Action: Continue collecting water quality data on Horsehead Lake as a part of the WDNR Citizens Lake Monitoring Network.

Timeframe: Ongoing

Facilitator: Dennis and Kris Batchelet

Prospective Funding: Funded through WDNR Program

Description: Currently monitoring of water quality is conducted by an HLPRD volunteer through the program's advanced protocol. It is important to continue this monitoring as early discovery of negative trends may more easily lead to the reason as to why the trend is developing. The volunteer monitoring of the water quality is a large commitment and new volunteers may be needed in the future as the volunteer's level of commitment changes. It is also important to have others involved if a temporary substitute is needed to collect samples while the normal volunteer is unavailable. It is the responsibility of this actions facilitator to coordinate new volunteers as needed. Note: 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: See description above.

Management Action: Reduce phosphorus and sediment loads from immediate watershed.

Timeframe: Begin 2010

Facilitator: Board of Directors to recruit facilitator.

Prospective Funding: WDNR Small-scale Lake Management Planning Grant, Aquatic Invasive Species- Education, Prevention, and Planning Grant

Description: Horsehead Lake has a relatively small watershed draining to it and as a result, the impacts that are most controllable at this time originate along the lake's immediate shoreline. These sources include faulty septic systems, the use of phosphorus-containing fertilizers, shoreland areas that are maintained in an unnatural manner, and impervious surfaces. To reduce these impacts, the district will conduct an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include news letter articles and guest speakers at district meetings.

Action Steps:

1. Recruit facilitators
2. Facilitators summarize educational material collected from WDNR, UW-Extension, and County Land Conservation sources for the creation of informative materials
3. Facilitators disperse materials to stakeholders

Management Action: Gain an understanding of filamentous algae within Horsehead Lake

Timeframe: Begin 2010

Facilitator: Board of Directors to recruit facilitator.

Prospective Funding: WDNR Small-scale Lake Management Planning Grant

Description: Horsehead Lake stakeholders have raised concerns over large mats of filamentous algae observed growing on aquatic vegetation and shoreline structures. Based on anecdotal accounts, the filamentous algae population has increased within the past few years. Abnormal algal growth is often associated with increased concentrations of nutrients, specifically phosphorus, that enter the lake through natural or human-induced sources. During the current study, no examination of filamentous algae was conducted as it was beyond the scope of the project. An identification of the algal species and their ecology are needed to create management goals associated with them. Mr. Jim Kreitlow in the Rhinelander WDNR Service Center is proficient in algae identification and should be the first contact for this part of the task.

Action Steps:

1. Recruit facilitators
2. Facilitators gather appropriate information from WDNR, UW-Extension, Oneida County and other sources on appropriate survey methodology
3. If necessary, retain consultant to coordinate monitoring strategy
4. Obtain WDNR grant
5. Study results will determine appropriate management action, if needed

Management Action: Complete Shoreland Condition Assessment as a part of next management plan update

Timeframe: Begin 2009

Facilitator: Board of Directors

Description: As the discussed above, unnatural shorelands can negatively impact the health of a lake, both by decreasing water quality conditions as well as removing valuable habitat for fish and other aquatic species that reside within the lake. Understanding the shoreland conditions around Seven Island Lake will serve as an educational tool for lake stakeholders as well as identify areas that would be suitable for restoration. Shoreland restorations would include both in-lake and shoreline habitat enhancements. In-lake enhancements would include the introduction of course woody debris, a fisheries habitat component lacking around the shores of Horsehead Lake. Shoreline enhancements would include leaving 30-foot no-mow zones or by planting native herbaceous, shrub, and tree species as appropriate for Lincoln County. Ecologically high-value areas delineated during the survey would also be selected for protection, possibly through conservation easements or land trusts (www.northwoodslandtrust.org).

Projects that include shoreline condition assessment and restoration activities will be better qualified to receive state funding in the future. These activities could be completed as an amendment to this management plan and would be appropriate for funding through the WDNR small-scale Lake Planning Grant program.

Action Steps: See description above.

Management Goal 2: Control and Prevent Aquatic Invasive species within Horsehead Lake

Management Action: Monitor and control Eurasian water milfoil within Horsehead Lake.

Timeframe: Begin 2010

Facilitator: Board of Directors to recruit facilitator.

Prospective Funding: WDNR Small-scale Lake Management Planning Grant, Aquatic Invasive Species- Education, Prevention, and Planning Grant

Description: As described in the Aquatic Plant Section, Eurasian water milfoil was first found in Horsehead Lake during the summer of 2007. At that time, all known plants were removed including roots. The site was also searched during June and September 2008 and a few whole plants were removed at that time.

The WDNR Citizen Lake Monitoring Network includes the monitoring of aquatic invasive species. In fact, the University of Wisconsin Extension has created a protocol and provides training specific to the identification and monitoring of Eurasian water milfoil. Members of the HLPRD will attend a UW Extension training session on Eurasian water milfoil monitoring during the spring or early summer of 2010 (Contact: Laura Herman, UW-Extension, 715.365.8998). Surveys will commence following the protocol during that same summer

Since Eurasian water milfoil has already been found in Horsehead Lake, it is likely that it will be found again during the volunteer surveys. If only a few plants are located within a small area (<10 plants in 100 sq.ft.), they will be manually removed by the volunteers by hand or with a rake. Great care will be taken to ensure that the entire plant is removed. Each removal site will be recorded with GPS coordinates. If applicable, the harvester operator will be provided with the Eurasian water milfoil coordinates so no harvesting will occur in the area. If a greater amount of Eurasian water milfoil is located than can be effectively removed manually, GPS coordinates will be recorded at numerous locations around the beds and the WDNR will be contacted.

Once the WDNR has been contacted, it is likely that an AIS Early Detection & Response Grant would be initiated. Professional assistance will be recruited in order to map the Eurasian water milfoil and create a treatment plan. That plan will include treatment areas, dosages, and a monitoring strategy. Depending on the extent of the infestation, the HLPRD may need to update their management plan to include a long-term control plan for Eurasian water milfoil. Once that plan is accepted by the WDNR, the district will be eligible to receive grant monies under the AIS Established Infestation Control Grant to help fund the control program.

Action Steps: See description above.

<u>Management Action:</u> Monitor curly-leaf pondweed within Horsehead Lake.

Timeframe: 2011

Facilitator: Board of Directors

Prospective Funding: WDNR Small-scale Lake Management Planning Grant, Aquatic Invasive Species- Education, Prevention, and Planning Grant

Description: The first mapping of curly-leaf pondweed occurred during the summer of 2007 (Map 3) and although it can assumed that the plant's density is increasing over time, it cannot be quantified with a single survey. As discussed earlier in this document, in some lakes, curly-leaf pondweed exists much as a native species and does not significantly impact the ecology of the lake. At this time, curly-leaf pondweed is not believed to be impacting the lake in a significantly negative manner; therefore, the district has opted to continue monitoring the plant instead of initiating a control program.

During the summer of 2010 the curly-leaf pondweed mapping survey will be repeated on Horsehead Lake. The results of that survey will be compared with those of the 2007 survey to determine if the plant is spreading and becoming denser within the lake. If it is spreading and becoming denser, a control strategy will be devised and the management plan will be updated to include those actions. If curly-leaf pondweed population is found to be remaining approximately the same, an appropriate monitoring strategy will be formulated.

Action Steps:

1. Obtain survey bids from professional lake management firms during fall of 2010.
2. Apply for a WDNR grant during February 1, 2011 cycle.
3. Follow steps outlined in description above.

Management Goal 3: Maintain Navigation in Open Water and Near-shore Areas on Horsehead Lake

<u>Management Action:</u> Use contracted harvesting services to maintain reasonable navigation on Horsehead Lake.

Timeframe: Enter timeframe here

Facilitator: Horsehead Lake P & R District Board of Directors

Prospective Funding: WDNR Small-scale Lake Management Planning Grant (GPS purchase and training)

Description: Over the past 5 years, the district has contracted to have harvesting of primarily native plants completed on Horsehead Lake. The harvesting normally occurs in July or August is completed in areas specified by the district. The purpose of the harvesting is to increase navigability in certain areas of the lake that contain dense, nuisance levels of native aquatic plants.

The areas of Horsehead Lake requiring mechanical harvesting change annually; therefore, the harvesting plan must remain flexible. However, the WDNR permitting process requires specifics regarding areas of the lake that are slated for harvesting. To accommodate the WDNR permitting process and the flexible harvesting needs of the Horsehead Lake P & R District, a new method for determining and reporting annual harvesting needs by the district has been developed.

Map 5 includes 144 acres of Horsehead Lake that are available for harvesting based upon past harvesting needs of the district. Harvesting only occurs in areas with developed shoreline, with the exception of the lane that extends to the public boat landing on the southern end of the lake. The vast majority of the northern portion of the lake is considered a conservation area; therefore, no harvesting is considered for that area. The following guidelines must be considered in regards to this harvesting plan:

1. No more than 75 acres may be harvested in any year.
2. The plan must be updated and resubmitted to the WDNR if the district purchases its own harvesting equipment.

GPS technology exists to more easily and accurately determine the areas for harvesting by the district. Essentially, a background map can be loaded on a standard handheld GPS unit which would allow district volunteer to know exactly where they are in relation to the lake's shore and the harvesting grid found on Map 5. The volunteers could also collect points within the grid squares they believe would be included in that year's harvesting. The points could then be downloaded to a computer and emailed to the harvesting contractor for use in the contractor's GPS.

Action Steps:

1. District volunteers survey lake and mark quarter-acre squares on Map 5 for harvesting.
2. Squares are tallied and the sum acreage of that year's harvesting is calculated.
3. Harvesting map and estimated acreage are provided to WDNR 14 days prior to expected harvesting dates.

6.0 METHODS

Lake Water Quality

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

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

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Horsehead Lake during a June 13, 2007 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Horsehead 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 "Appendix C" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2007) was used to complete this study on July 30, 2007. A point spacing of 52 meters was used resulting in approximately 500 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Horsehead 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.

Watershed Analysis

The watershed analysis began with an accurate delineation of the Horsehead Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) 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)

7.0 LITERATURE CITED

Asplund, T.R. and C.M. Cook. 1997. Effects of motor boats on submerged aquatic macrophytes. Lake and Reservoir Mangement 13(1): 1-12.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press. London, England.

Canter, L.W., D.I. Nelson, and J.W. Everett. 1994. Public Perception of Water Quality Risks – Influencing Factors and Enhancement Opportunities. Journal of Environmental Systems. 22(2).

Carlson, R.E. 1977 A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Dinius, S.H. 2207. Public Perceptions in Water Quality Evaluation. Journal of the American Water Resource Association. 17(1): 116-121.

Elias, J.E. and M.W. Meyer. 2003. Comparisons of Undeveloped and Developed Shorelands, Northern Wisconsin, and Recommendations of Restoration. Wetlands 23(4):800-816. 2003.

Galatowitsch, S.M. and D. Vanderbosch. 2008. Factors affecting revegetation success in lakeshore restorations. Project 2006 MN 153B Minnesota Department of Natural Resources Publication.

Great Lakes Indian Fish and Wildlife Service. 2009. Interactive Mapping Website. Available at http://www.glifwc-maps.org. Last accessed December 2009.

Jennings, M. J., E. E. Emmons, G. R. Hatzenbeler, C. Edwards and M. A. Bozek. 2001. Is littoral habitat affected by residential development and landuse in watersheds of Wisconsin lakes? Lake and Reservoir Management. 19(3):272-279.

Lillie, R.A., and J.W. Mason. 1983. Limnological characteristics of Wisconsin lakes. Technical Bulletin No. 138. Wisconsin Department of Natural Resources.

Lillie, R.A., S. Graham, and P. Rasmussen. 1993. Trophic state index equations and regional predictive equations for Wisconsin lakes. Research Management Findings 35. Wisconsin Department of Natural Resources.

Lumberjack Resource Conservation & Development Project. 1974. Horsehead Lake Preliminary Report.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2): 133-141

Northern Lakes Services, Crandon, WI 1977. Limnological Study of Horsehead Lake, Oneida County, Wisconsin, December 28, 1975 – November 15, 1976.

Northern Lakes Services, Crandon, WI 1993. Limnological Study of Horsehead Lake, Oneida County, April 1992 – November 1992.

Omernick, J.M. and A.L. Gallant. 1988. Ecoregions of the Upper Midwest states. U.S. Environmental Protection Agency Report EPA/600/3-88/037. Corvallis, OR. 56p.

Mumma, M.T., C.E. Cichra, and J.T. Sowards. 1996 Effects of recreation the submersed aquatic plant community of Rainbow River, Florida. Journal of Aquatic Plant Management 34: 53-56.

Murphy, K.J. and J.W. Eaton. 1983 Effects of pleasure-boat traffic on macrophyte growth in canals. Journal of Applied Ecology 20: 713-729.

Panuska, J.C., and J.C. Kreider. 2003 Wisconsin Lake Modeling Suite Program Documentation and User's Manual Version 3.3. WDNR Publication PUBL-WR-363-94.

Radomski P. and T.J. Goeman. 2001 Consequences of Human Lakeshore Development on Emergent and Floating-leaf Vegetation Abundance. North American Journal of Fisheries Management. 21:46–61.

Scheuerell M.D. and D.E. Schindler. Changes in the Spatial Distribution of Fishes in Lakes Along a Residential Development Gradient. Ecosystems (2004) 7: 98–106.

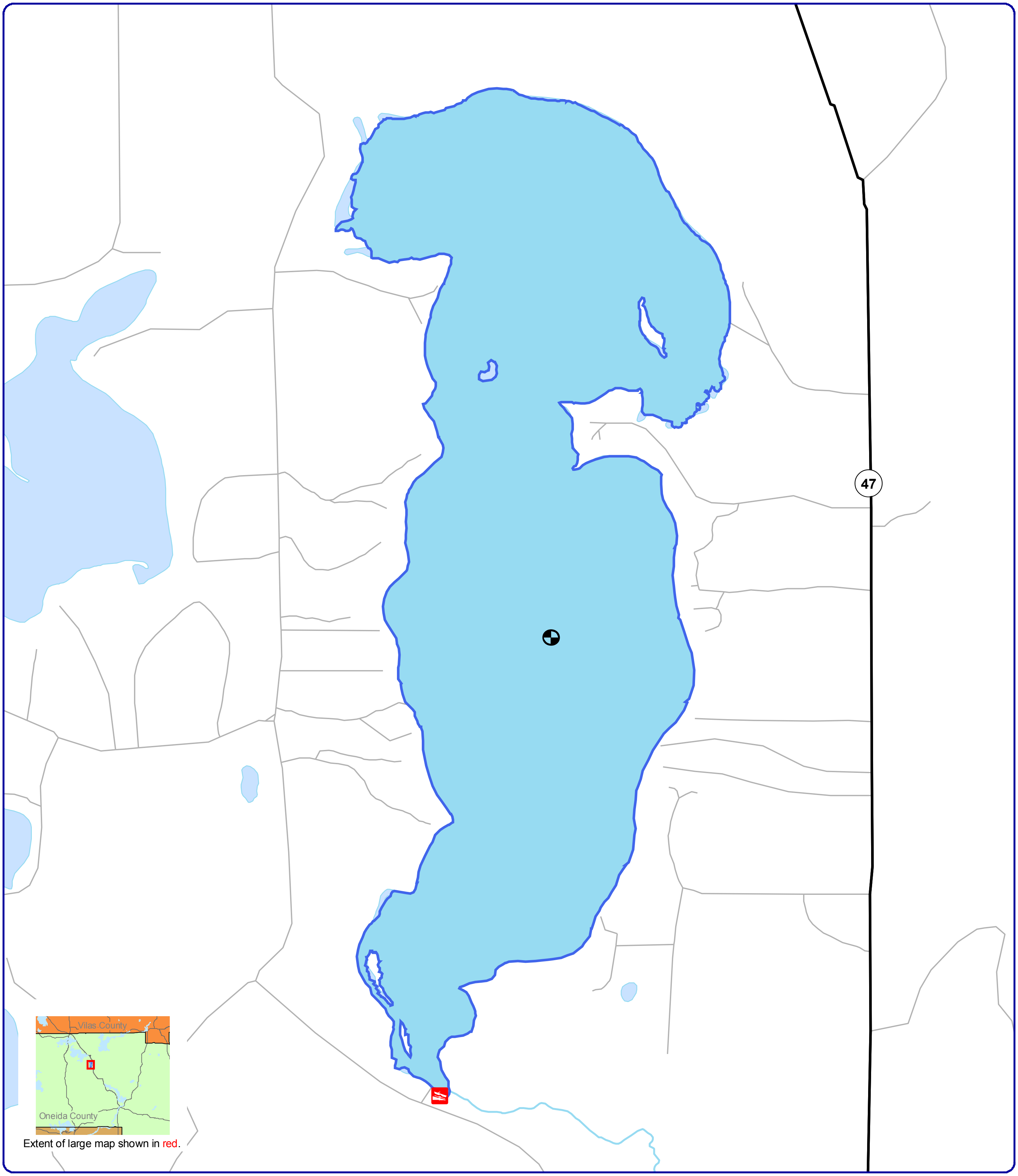
Smith D.G., A.M. Cragg, and G.F. Croker.1991. Water Clarity Criteria for Bathing Waters Based on User Perception. Journal of Environmental Management. 33(3): 285-299.

United States Department of the Interior – Bureau of Indian Affairs. 2007. Fishery Status Update in the Wisconsin Treaty Ceded Waters. Fourth Edition.

Vermatt, J.E., and R.J. de Bruyne. 1993. Factors limiting the distribution of submerged waterplants in the lowland river Vecht (The Netherlands). Freshwater Biology 30: 147-157.

Wisconsin Department of Natural Resources. 2007. Aquatic Plant Management in Wisconsin. Available at: http://www.uwsp.edu/cnr/uwexlakes/ecology/APMguide.asp. Last accessed December 2009.

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2009. Fish Stocking Summaries. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed December 2009.



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Feet

Onterra LLC
Lake Management Planning
135 South Broadway Suite C
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR

Map Date: April 2, 2008

Project name: Map1_Horsehead_Location.mxd

Legend

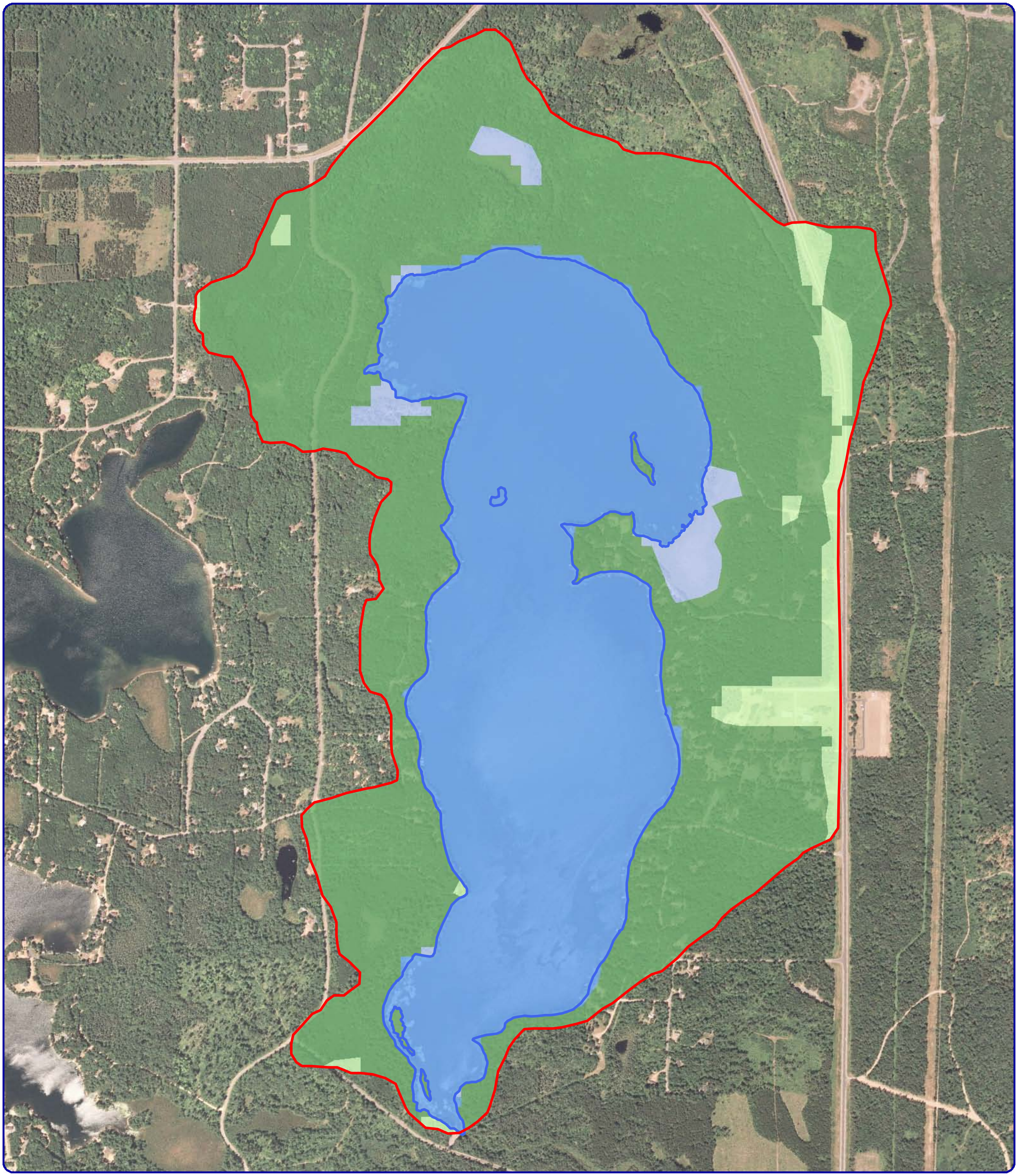
Horsehead Lake ~ 389 acres

Water Quality Sample Location

Public Access

Map 1
Horsehead Lake
Oneida County, Wisconsin

Project Location and Water Quality Sampling Site



1,250

Feet

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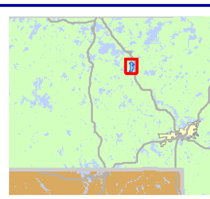
Sources:
Watershed: WDNR and Onterra
Landcover: WISCLAND
Roads and Hydro: WDNR
Orthophotography: NAIP, 2005
Map Date: July 2, 2008



Extent of large map shown in red.

Legend

Watershed Boundary

Land Cover Types

Pasture/Grass

Forest

Open Water

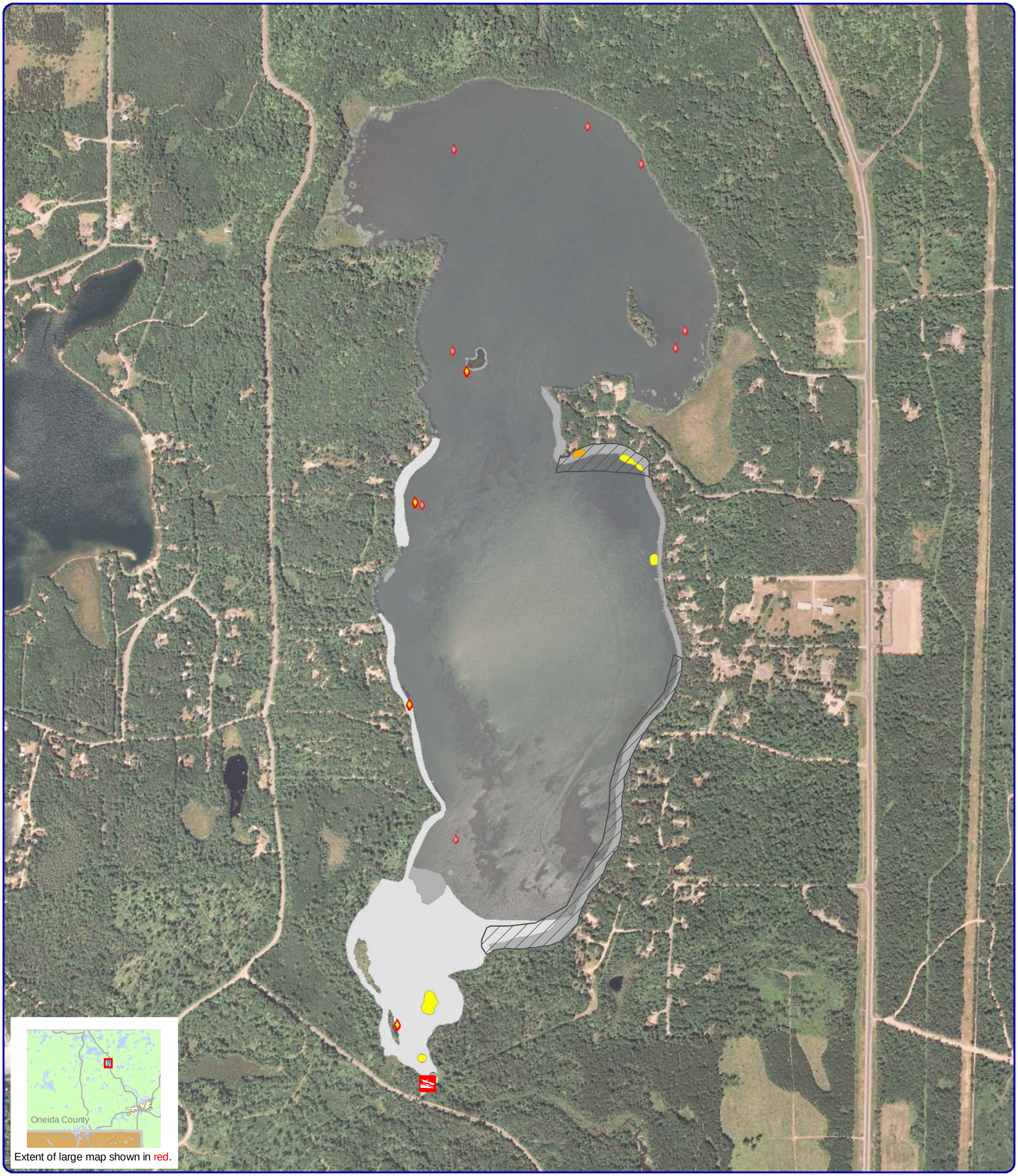
Wetland

Map 2

Horsehead Lake

Oneida County, Wisconsin

Watershed and Land Cover Types



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1992 CLP Survey Results

CLP Survey Results (June 2007)
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting *(*None Found)*

CLP Survey Results (June 2007)
- Single or Few Plants
- Clumps of Plants

EWM Survey Results (Aug 2007)
- Single or Few Plants
- Clumps of Plants

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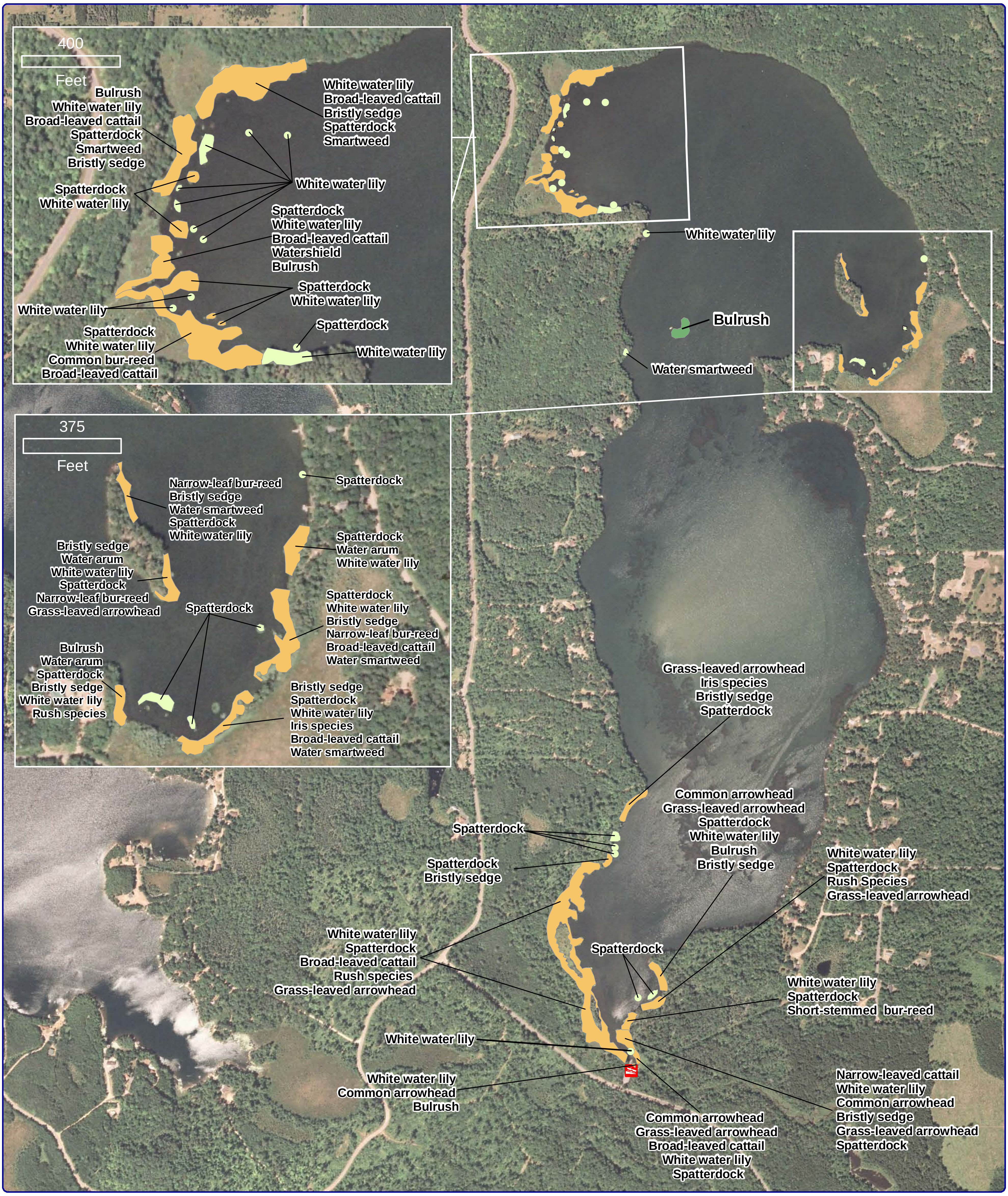
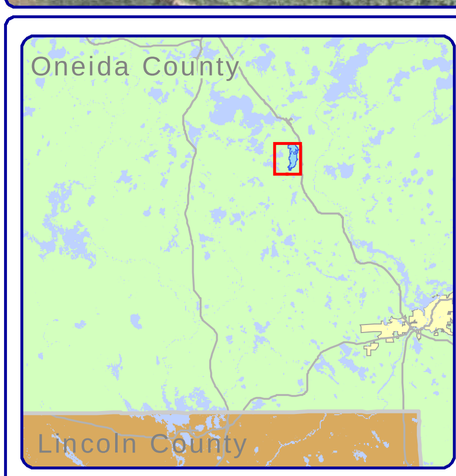
Sources:
Roads and Hydro: WDNR
Orthophotography: NAIP 2005
Aquatic Plant Survey: Onterra, 2007
Map Date: April 16, 2008

Map 3
Horsehead Lake
Oneida County, Wisconsin

Curly Leaf Pondweed and EWM Locations





Extent of large map shown in red.

Sources:
Roads & Hydro: WDNR
Orthophotography: NAIP 2005
Aquatic Plant Survey: Onterra, 2007
Map date: April 7, 2008

Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Public Boat Landing

Map 4
Horsehead Lake
Oneida County, Wisconsin

Aquatic Plant Communities

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825
Feet

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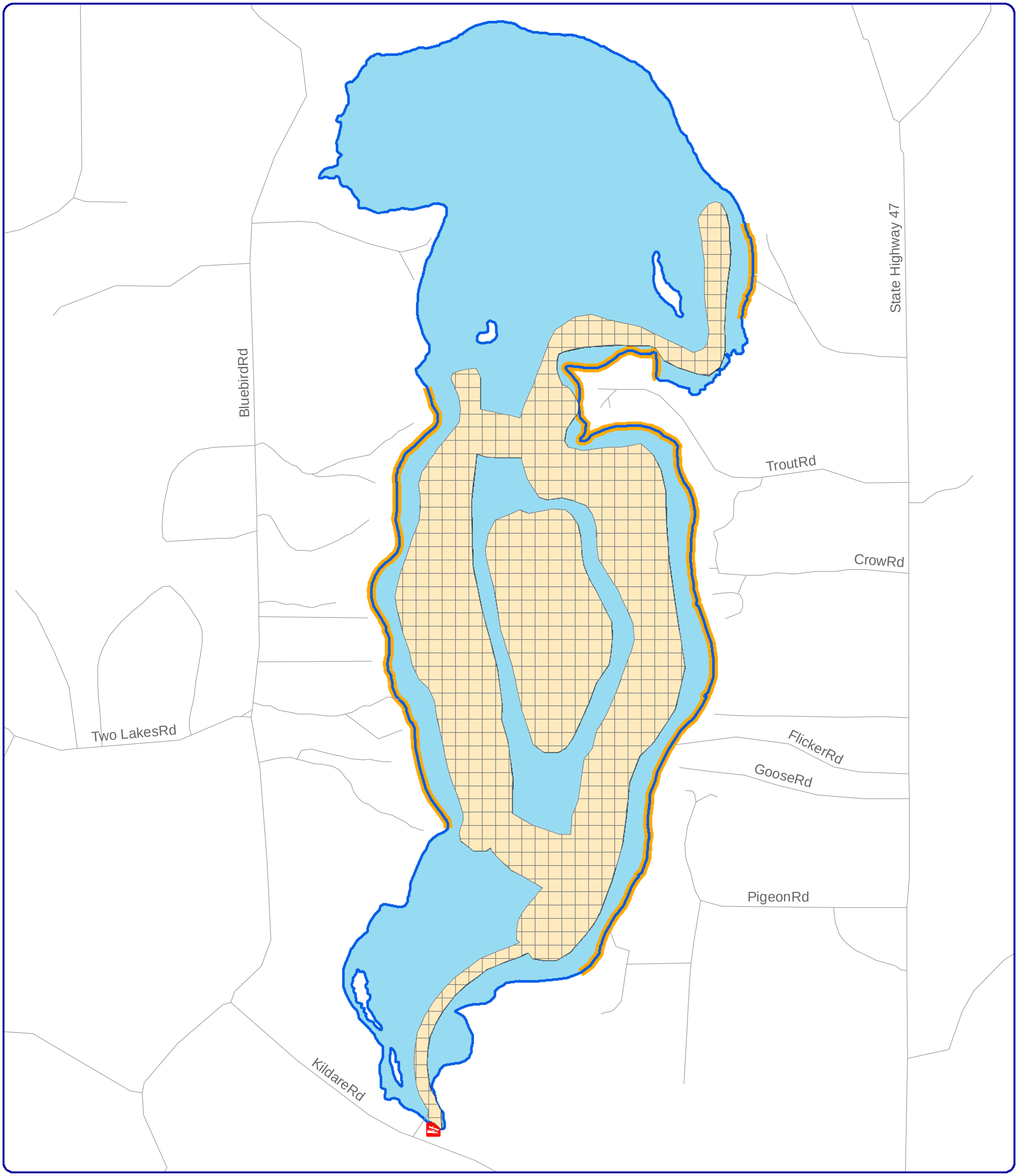

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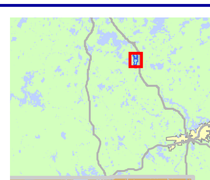
Sources:
Roads & Hydro: WDNR
Orthophotography: NAIP 2005
Map Date: June 24, 2009
File Name: HH_Harvest_AreaswithGrid_Jun09_v1



Extent of large map shown in red.

Legend

Potential Harvesting Areas (144 acres)

Developed Shoreline

Boat Landing

Map 5

Horsehead Lake

Oneida County, Wisconsin

Harvesting Plan