# Antigo Lake

**Langlade County, Wisconsin**

# Comprehensive Management Plan

**May 2013**

Sponsored by:

## Antigo Inland Lake Protection & Rehabilitation District

WDNR Grant Program

LPL-1363-10 & LPL-1364-10


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Onterra LLC
Lake Management Planning

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Langlade County, Wisconsin

# Comprehensive Management Plan

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Funded by: Antigo Inland Lake Protection & Rehabilitation District
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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:

**Antigo Lake Planning Committee**

Dale Soumis, Sarah Repp

**Organization**

Recreation and Cemetery Department staff

**Wisconsin Dept. of Natural Resources**

Jim Kreitlow
Kevin Gauthier
Dave Seibel

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# 1.0 INTRODUCTION

Antigo Lake is a 32-acre impoundment on Spring Brook Creek located in the center of the City of Antigo in Langlade County, Wisconsin (Map 1). The newly constructed Spring Brook Trail and boardwalk border this system and many citizens have taken advantage of the new biking and fishing areas. This highly eutrophic system contains 19 native aquatic plant species, of which common waterweed (*Elodea canadensis*) is the most dominant. The non-native, invasive plant species curly-leaf pondweed, purple loosestrife, reed canary grass, and pale-yellow iris are known to occur in this system.

**Field Survey Notes**

*Shorelands are dominated by emergent vegetation, including native cattails and non-native pale yellow iris, reed canary grass and some purple loosestrife. Large areas of curly-leaf pondweed observed during June survey.*

**Photograph 1.0-1 Antigo Lake, Langlade County**

## Lake at a Glance - Antigo Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 32 |
| Maximum Depth (ft) | 13 |
| Mean Depth (ft) | 7 |
| Shoreline Complexity | 13.4 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 10, 2010 |
| Comprehensive Survey Date | August 27, 2010 |
| Number of Native Species | 19 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | 4 |
| Simpson's Diversity | 0.84 |
| Average Conservatism | 5.8 |
| **Water Quality** | |
| Trophic State | Eutrophic |
| Limiting Nutrient | Transitional between Phosphorus & Nitrogen |
| Sensitivity to Acid Rain | Not Sensitive |
| Watershed to Lake Area Ratio | 1,136:1 |

The Antigo Inland Lake Protection and Rehabilitation District (AILPRD) was formed in 1974 by the City of Antigo for the purpose of rehabilitating the two-most downstream basins of the four that comprise the system. The boundaries of the AILPRD match the boundaries of the City of Antigo, and the city's council acts as the board of commissioners for the lake district.

Since its formation, the AILPRD has worked to enhance and protect Antigo Lake. Over the past thirty-plus years, the district (and city) has conducted numerous management actions aimed at improving the lake's water quality, plant community, and function as a flood control system. Dredging projects were implemented in the early 1990s and until recently, annual plant control treatments have been completed. Working with Langlade County, a detention pond was constructed in 2000 to slow and improve the quality of runoff entering the lake from the nearby fairgrounds. Being a Class I trout stream, the AILPRD has also partnered with Trout Unlimited to improve fishery habitat within Spring Brook Creek.

In recent years, the city has worked to obtain land within the Spring Brook corridor. In fact, the city holds nearly 95% of all properties in the flood plain and has a long-term goal of restoring the area more natural conditions; an area which includes much of the Antigo Lake shoreline. The most recent project completed by the City of Antigo was the creation of the Spring Brook Trail, which offers viewing areas and handicapped-accessible fishing piers around Antigo Lake. City ordinance prohibits the use of motorized watercraft on the lake, and users can access the lake via any public property bordering the lake.

Because the city considers the Spring Brook corridor "as an open space connection to the County's recreation and natural resource system", enhancement and protection of Antigo Lake and surrounding areas are one of the city's top priorities (Downtown Antigo and Springbrook Vision Plan – Schreiber/Anderson Associates, Inc., 2006). The lake's restoration is considered a critical part of the city's ultimate goal of preserving wildlife, enhancing and protecting environmentally sensitive areas, and stabilizing the ecology of the Spring Brook corridor to serve as a community observational and educational preserve.

The purpose of this project was to assess the overall ecological integrity of Antigo Lake in terms of the lake's water quality, watershed, aquatic plant community, and shoreline condition. It also integrates available fisheries information and any historic water quality and aquatic plant data that are available. The combination of these components and communications and partnerships with the AILPRD, the Wisconsin Department of Natural Resources (WDNR) specialists, and local municipalities will allow for the creation of an implementable and realistic long-term plan for the restoration and continued preservation of Antigo Lake.

## 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. Stakeholder participation materials may be found in Appendix A.

**Kick-off Meeting**
On July 27, 2010, a project meeting was held to introduce the project to the general public. The meeting was announced through a mailing and personal contact by AILPRD board members. The attendees observed a presentation given by Tim Hoyman, a limnologist and owner of Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

**Planning Meeting**
On September 12, 2011, Tim Hoyman met with Dale Soumis, City Administrator (now retired), Sarah Repp, Park, Recreation and Cemetery Department Director, and members of Ms. Repp's staff. The meeting was started with a presentation of the study results and discussion of their relevance to the management of Antigo Lake. Mr. Soumis and Ms. Repp stressed the importance of maintaining the public's access to the lake through fishing, paddle-sports, and nature viewing. Mr. Soumis gave Mr. Hoyman a tour of the Spring Brook corridor, highlighting the enhancement projects the city had completed in the area, the areas of the riverbed below the dam that they would like to restore, and the areas were access and viewing is being impeded by cattail growth.

**Project Wrap-up Meeting**
The Wrap-up meeting was held on January 29, 2013 at the City of Antigo City Hall. Tim Hoyman and Dan Cibulka presented the project results along with the Management Goals that are outlined in the Implementation Plan. These topics were discussed at length, and several changes were made prior to the plan being sent to the WDNR for review.

**Management Plan Review and Adoption Process**
Prior to the Planning Meeting, Onterra provided the Results Section of this report (Section 3.1-3.3) to members of the AILPRD. They reviewed this document and discussed the material during the Planning Meeting. An updated Results Section was included with the first draft of the full Management Plan, which was sent out on February 13, 2013 to the AILPRD and WDNR. A WDNR review was completed on March 15, 2013 and included comments and suggestions for integration into the plan. These last of these comments were addressed in early May of 2013, and the document was finalized at that time. The AILPRD and City of Antigo will formally approve of the Management Plan at the next board of directors meeting through an official vote.

# 3.0 RESULTS & DISCUSSION

## 3.1 Lake Water Quality

### *Primer on Water Quality Data Analysis and Interpretation*

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Antigo Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix B). 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 Antigo Lake's water quality analysis:

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

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

## Trophic State

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

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

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

## Limiting Nutrient

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

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

## Temperature and Dissolved Oxygen Profiles

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

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

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

## Internal Nutrient Loading

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

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

**Non-Candidate Lakes**

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

**Candidate Lakes**

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

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

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

## Comparisons with Other Datasets

The WDNR publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Antigo Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

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

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

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

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

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

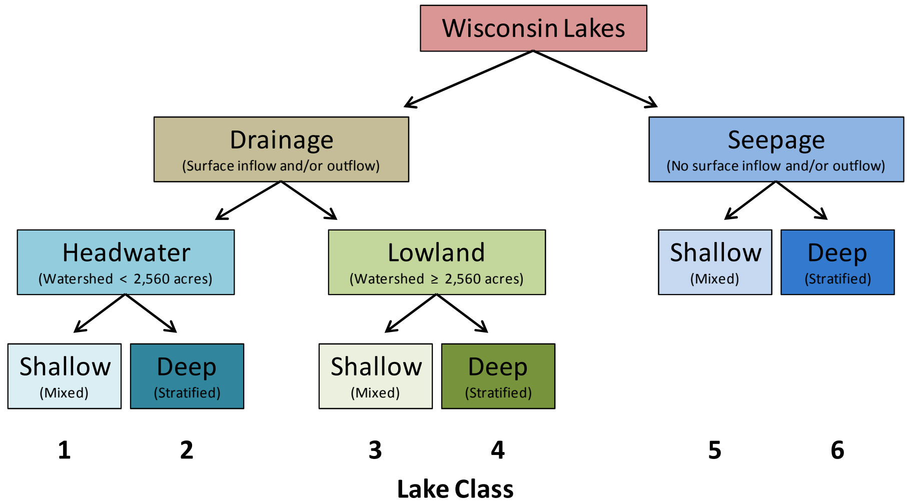


**Figure 3.1-1. Wisconsin Lake Classifications.** Antigo Lake is classified as shallow, lowland drainage lakes (Class 3). Adapted from WDNR PUB-SS-1044 2008.

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

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act (WDNR 2009). It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. In the report, they divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor". The categories were based on pre-settlement conditions of the lakes inferred from sediment cores and their experience.

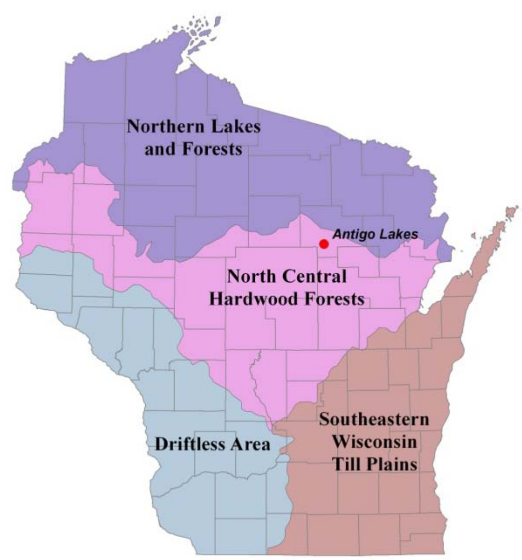


**Figure 3.1-2. Location of Antigo Lake within the ecoregions of Wisconsin.** After Nichols 1999.

These data along with data corresponding to statewide and regional lake median values, along with current data from the Antigo Lake is displayed in Figures 3.1-3 - 3.1-7. No historic water quality data was available from this system. Water quality was sampled on the three-most downstream basins of Antigo Lake (Map 1). Please note that the data in these graphs represent concentrations and depths taken only during the summer months (June-August). Furthermore, the phosphorus and chlorophyll-a data only represent surface (top 6 feet) levels. 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.

## *Antigo Lake Water Quality Analysis*

### Antigo Lake Long-term Trends

As discussed previously, in terms of scientific water quality monitoring, there are three water quality parameters that are of most interest: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Apart from a single sampling period in 1985, no other historical water quality data exists for Antigo Lake, and therefore it is impossible to determine if the water quality within this system has improved, declined, or remained relatively constant over time. However, the collection of data during the summer of 2010 does provide a snapshot of the current water quality conditions within Antigo Lake and creates a baseline for continued monitoring.

Being a man-made, impounded system, Antigo Lake falls under the shallow, lowland drainage lake category (Class 3) in the WDNR classification system discussed earlier (Figure 3.1-1). The thresholds in the following figures correspond to these lake types within the entire State of Wisconsin; they do not apply to the ecoregional median values as these were derived from a combination of all of the lake categories sampled within the ecoregion. Examination of the total phosphorus data collected in the summer of 2010 indicates that Antigo Lake contains an excessive amount of this nutrient (Figure 3.1-3). In June, phosphorus levels were relatively close to the median values for class 3 lakes and lakes within the ecoregion. However, these levels increased dramatically in July and August as Figure 3.1-1 illustrates. Summer averages of basins 1 and 3 fell in the *Fair* category, while levels in basin 2 are classified as *Poor*.

As discussed earlier, total phosphorus and algal abundance are positively correlated with one another. Summer chlorophyll-*a* levels closely mirrored the pattern of total phosphorus levels; as phosphorus increased, chlorophyll-*a* levels increased. Figure 3.1-2 indicates that chlorophyll-*a* levels, though higher than shallow, lowland drainage lake and ecoregional medians, were relatively low during the month of June. However, in July, levels slightly decreased in basin 1 but increased in basins 2 and 3. In August, levels in all three basins increased significantly, most notably in basin 2 which was nearly 20 times higher than in June.

The relationship between chlorophyll-*a* and Secchi disk transparency was also apparent on Antigo Lake. Secchi disk values were highest in June and lower in July and August (Figure 3.1-5). Overall, basin 3 had the highest water clarity values while basin 1 had the lowest, and despite the high chlorophyll-*a* values summer averages for all three basins fell within the *Good* category and are similar to shallow, lowland drainage and ecoregional lakes' medians.

Due to the absence of historic water quality data for Antigo Lake, no determinations regarding long-term trends in water quality can be made. However, given the size of the lake's watershed and location within an urban/agricultural landscape, it is likely that this system has been very productive since its creation.

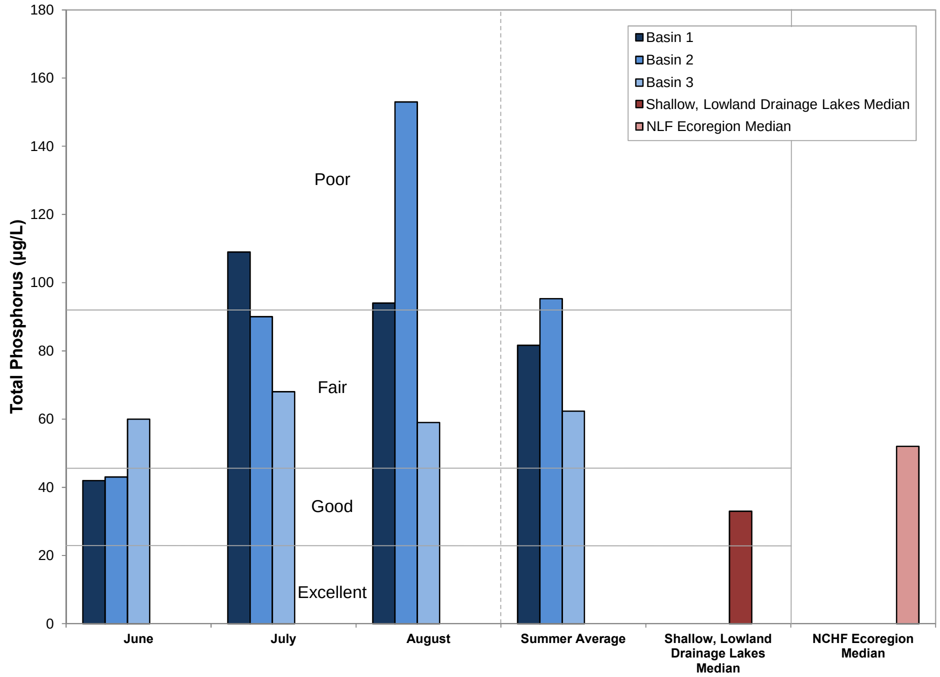


**Figure 3.1-3. Antigo Lake, state-wide shallow, lowland drainage lakes, and ecoregional total phosphorus concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

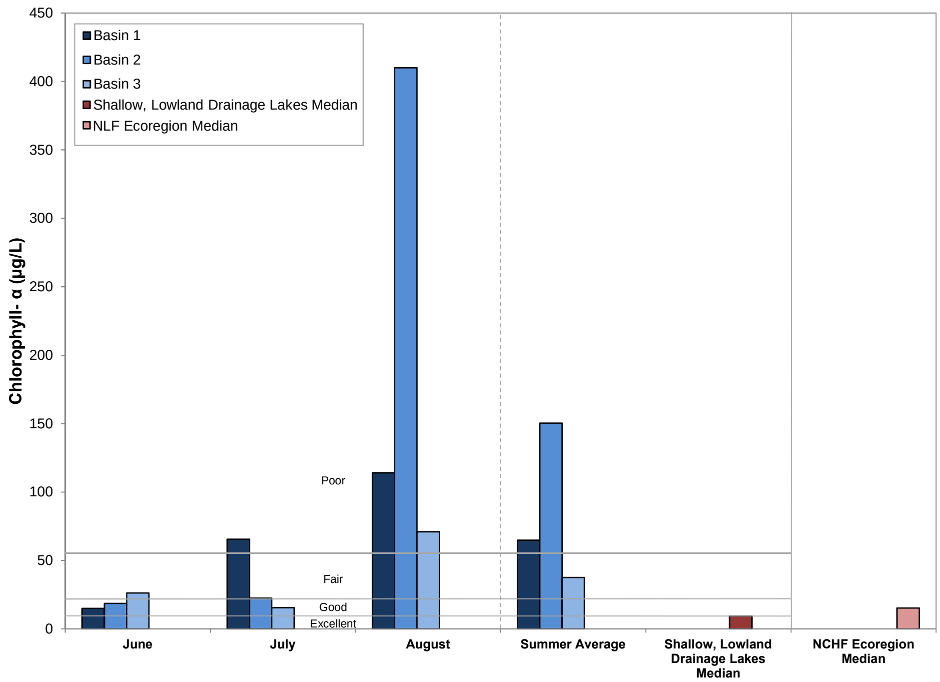


**Figure 3.1-4. Antigo Lake, state-wide shallow, lowland drainage lakes, and ecoregional chlorophyll-*a* concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

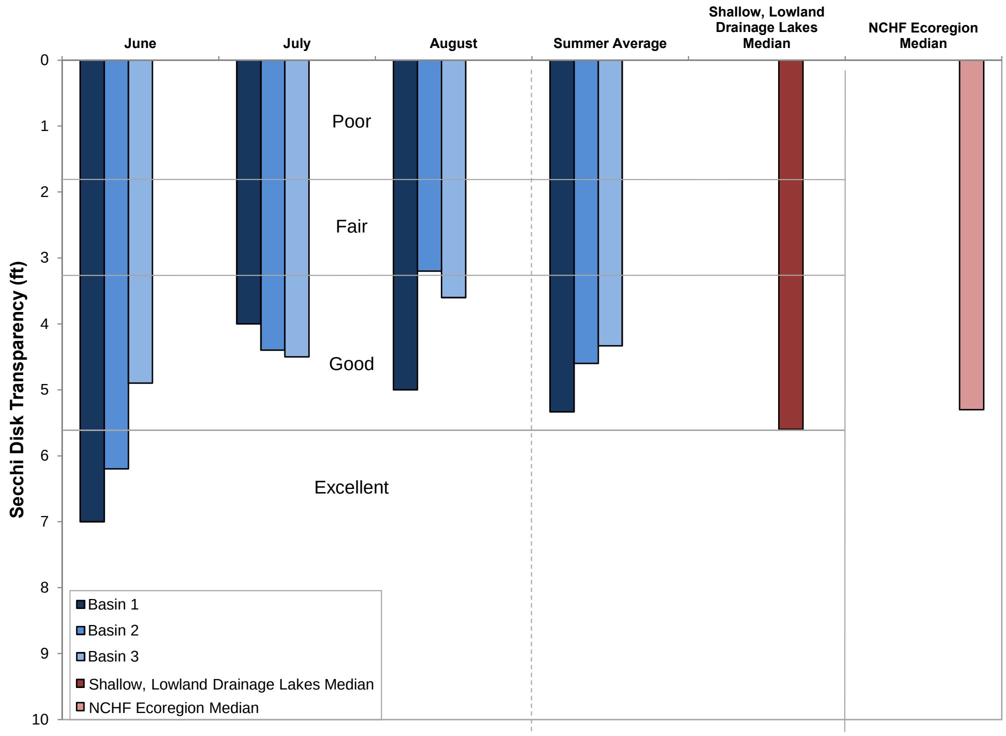


**Figure 3.1-5. Antigo Lake, state-wide shallow, lowland drainage lakes, and ecoregional Secchi disk values.** Water Quality Index values adapted from WDNR PUB WT-913.

The excessive amount of nutrients observed in Antigo Lake system is likely due to a select number of factors. First, Antigo Lake is extremely small in area and volume when compared to its watershed or area of land which this system drains (1,136:1). Antigo Lake drains approximately 35 square miles of land, 70% of which is comprised of agricultural and urban land cover. During rainfall events, these land cover types drastically increase surface water runoff which carries nutrients from fertilizers and sediments. The watershed of Antigo Lake will be discussed in greater detail in the following section.

Internal nutrient loading during the summer months is likely another factor contributing to the poor water quality in Antigo Lake. Temperature/dissolved oxygen profiles taken from each basin during the summer months indicate that anoxic (no oxygen) conditions exist within the hypolimnion (bottom layer) of water (Figure 3.1-6). This occurs when large amounts of dead algae and plant material sink to the bottom where they are decomposed by bacteria. This process rapidly consumes oxygen and adds nutrients to the bottom sediments. Nutrients are also added to the bottom sediments when water carrying sediment-bound phosphorus from the lake's watershed enters Antigo Lake's basins, slows down, and settles to the bottom. During times of stratification, when the hypolimnion becomes anoxic, the phosphorus that was bound to iron in the sediment is released into hypolimnion. Being shallow, Antigo Lake likely turns over during strong wind events, mixing the hypolimnetic phosphorus into the upper layers of water where it becomes available to plants and algae. This process, which could occur repeatedly in a month, is likely only one of the factors contributing to the increase in phosphorus levels observed over the summer.

Another likely cause of increasing phosphorus levels over the summer is the natural die-off of curly-leaf pondweed. Curly-leaf pondweed is prevalent in this system and the decomposition of the large biomass during mid-summer is most certainly releasing a significant amount of phosphorus into the water column. Using curly-leaf pondweed phosphorus release coefficients created for Big Chatec Lake in Sawyer County (Blumer, 2009) and the acreage of curly-leaf pondweed mapped in Antigo Lake in 2010, reveals that approximately 42 lbs of phosphorus may potentially be loaded to the system following the senescence of curly-leaf pondweed. Approximately 19 lbs are released in basin 1, 7 lbs in basin 2, and 15 lbs in basin 3.

### Limiting Plant Nutrient of Antigo Lake

Using midsummer nitrogen and phosphorus concentrations from each of the three basins in Antigo Lake, nitrogen to phosphorus ratios were calculated (Table 3.1-1). As discussed previously, production in the majority of Wisconsin lakes is limited by the availability of phosphorus. However, the ratios of nitrogen to phosphorus in Antigo Lake suggest that this system likely transitions between phosphorus and nitrogen limitation (Table 3.1-1). The abundance of phosphorus in this system makes it less likely to be a limiting nutrient in algae and plant production.

**Table 3.1-1. Antigo Lake summer 2010 nitrogen-phosphorus ratios.** Created using data from summer 2010.

| | N:P Summer Ratio |
|---|---|
| Basin 1 | 12:1 |
| Basin 2 | 15:1 |
| Basin 3 | 14:1 |

### Antigo Lake Trophic State

Figure 3.1-6 contains the trophic state index (TSI) values for Antigo Lake. The TSI uses total phosphorus, chlorophyll-*a*, and Secchi disk transparency values to determine the trophic state (oligotrophic, mesotrophic, eutrophic) of the lake. In general, the biological parameters are the best values to use in judging a lake's trophic state, as water clarity can be affected by factors other than chlorophyll-*a* (e.g. suspended sediments, organic acids). Therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Antigo Lake is presently in a eutrophic/hypereutrophic state, or is highly productive. Hypereutrophic systems contain excessive amounts of nutrients which fuel nuisance aquatic plant growth and severe algae blooms, and have low water clarity.

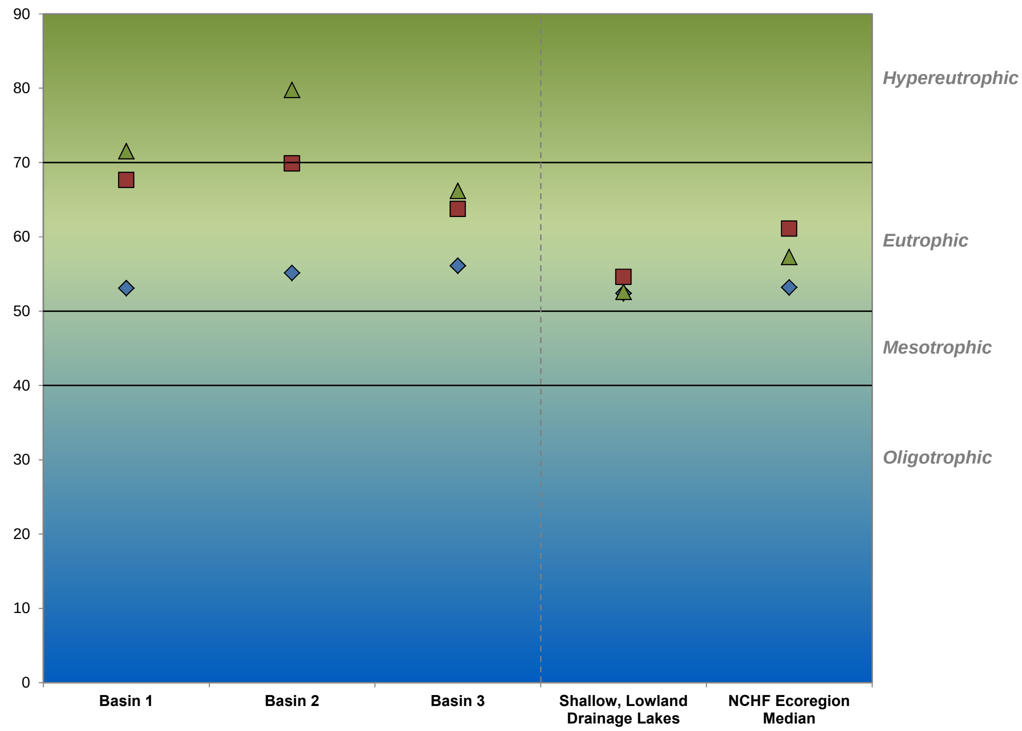


**Figure 3.1-6. Antigo Lake, shallow, lowland drainage lakes, and ecoregional Trophic State Index values.** Values calculated with summer month surface sample data using WDNR PUB-WT-193.

## Dissolved Oxygen and Temperature in Antigo Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Antigo Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-7. During the three sampling months the three basins were thermally stratified. All of the sampling periods, except the August profile for basin 1, indicate that the hypolimnion was devoid of oxygen.

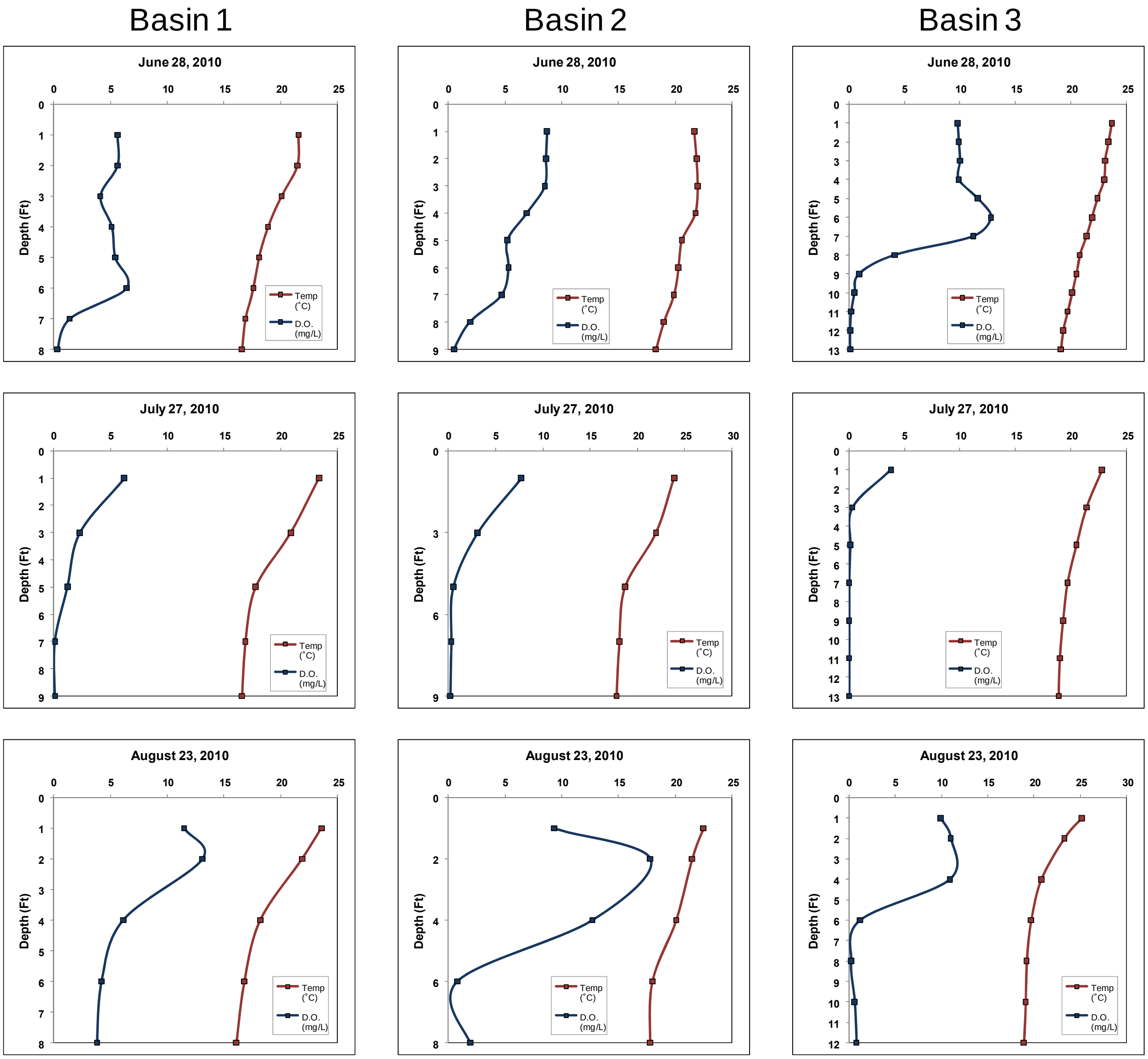


**Figure 3.1-7. Antigo Lake summer 2010 temperature and dissolved oxygen profiles.**

## Additional Water Quality Data Collected on Antigo Lake

Along with the water quality parameters discussed previously, calcium levels were also collected from Antigo Lake in 2010. Recently, calcium concentration has been used to determine a lake's suitability for sustaining a population of zebra mussels if ever introduced. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Antigo Lake was found to be 29.0 mg/L, placing Antigo Lake in the high susceptibility category for zebra mussel establishment if they are ever introduced.

## 3.2 Watershed Assessment

### *Watershed Modeling*

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

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

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

In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grass or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g. reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

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

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

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

The watershed surrounding Antigo Lake is approximately 22,731 acres (Map 2). The watershed to lake area ratio for Antigo Lake is approximately 1,136:1; an extremely large ratio. Lakes with a watershed to lake area ratio of this magnitude are likely to be eutrophic systems irrespective of the land cover types within their watershed. The majority of the land cover within Antigo Lake's watershed is comprised of row crops (37%), forest (28%), and pasture/grass (23%), while the remaining 12% is comprised of mixed agriculture, wetlands, high-density urban, low-density urban, and Antigo Lake itself (Figure 3.2-1).

Modeling of Antigo Lake's watershed using WiLMS indicated that approximately 11,060 lbs of phosphorus are added to the lake annually from its large drainage basin (Appendix C). However, it is believed that this load is overestimated due to limitations in the model when predicting phosphorus loads in systems with high flow rates such as Antigo Lake. Based upon average precipitation and evaporation figures for Langlade County and Antigo Lake's volume, the WiLMS modeling calculated that the entire volume of water in Antigo Lake is completely exchanged almost 16 times per year, or roughly 1.3 times per month. This flow rate is too high for the phosphorus prediction model to accurately predict the amount of phosphorus entering the system on an annual basis. Though 11,060 lbs of phosphorus is likely an overestimate, the amount of phosphorus entering the system is still very high and thus contributing to the hypereutrophic conditions measured during sometimes in the summer.

The WiLMS modeling predicts that the majority of the phosphorus (92%) inputted annually into Antigo Lake is delivered from row crops, pasture/grass, and mixed agriculture land cover types (Figure 3.2-2). While forest comprises 28% of Antigo Lake's watershed, it only accounts for approximately 5% of the total annual phosphorus load. Urban land cover types, wetlands, and atmospheric deposition of dust particles directly into the lakes themselves account for the remaining phosphorus budget (Figure 3.2-2).

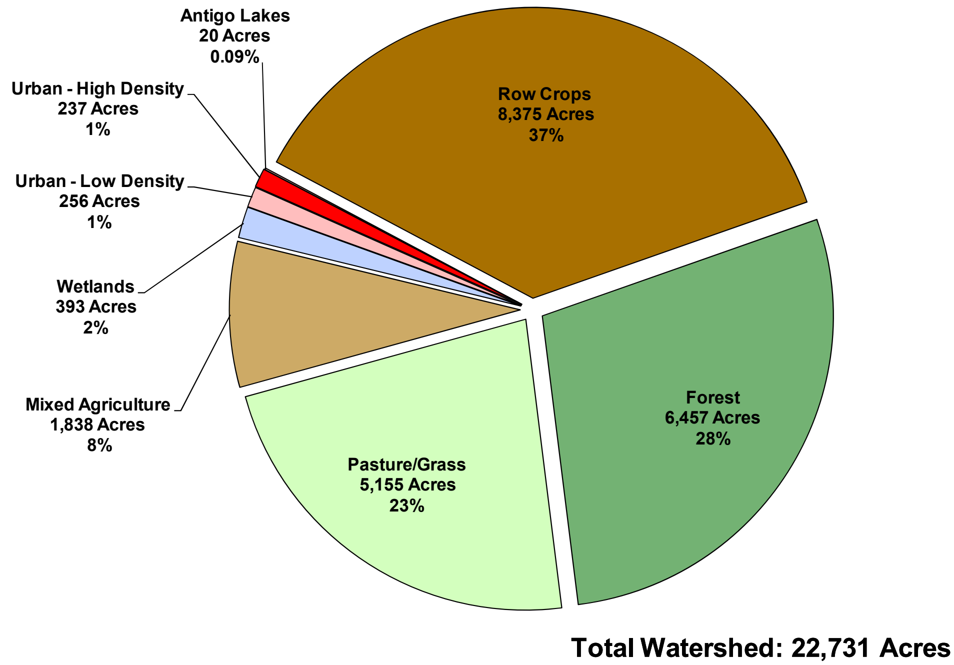


**Figure 3.2-1. Antigo Lake watershed land cover types in acres.** Based upon National Land Cover Database (NLCD – Fry et. al 2011).

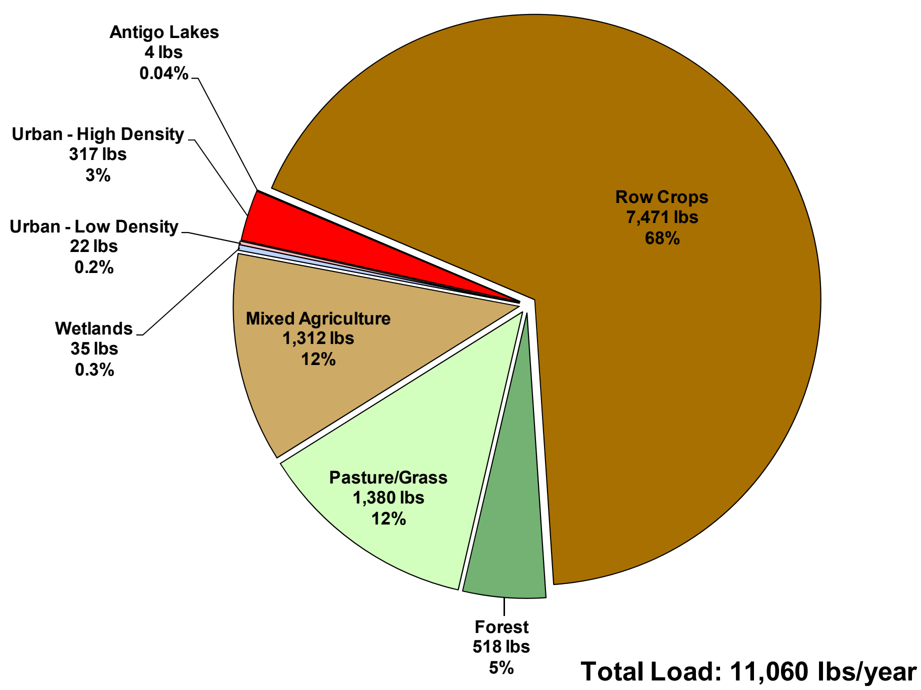


**Figure 3.2-2. Antigo Lake watershed phosphorus loading in pounds.** Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

The WiLMS modeling was also used to see if a significant reduction in phosphorus loading would occur if all of the row crops, pasture/grass, and mixed agriculture within the watershed were converted into forest. The model indicated that the annual phosphorus load to Antigo Lake system would be reduced by over 5 times. Though this is a significant reduction in phosphorus loading, the predicted growing season phosphorus would still fall into the eutrophic category. Using this reduced phosphorus value, Secchi disk transparency was predicted to increase by approximately one foot to 5.1 feet, while chlorophyll-*a* levels were reduced by almost 4 times to 10.5 µg/L. These values, though improved, would still be indicative of a eutrophic system.

Though converting all of the agricultural land cover to forest within Antigo Lake's system is an unrealistic scenario, it demonstrates that even if it were possible Antigo Lake would still be a productive, eutrophic system solely based on the size of the watershed relative to that of the lake; even large-scale restoration efforts would likely yield minimal improvements in water quality.

## 3.3 Shoreland Condition Assessment

### *The Importance of a Lake's Shoreland Zone*

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

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

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

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

### Shoreland Zone Regulations

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

#### Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more strict shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances of their own. County ordinances may be more restrictive than NR 115, but not less so. These policy regulations require each county to amend ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows (Note: counties must adopt these standards by February 2014, counties may not have these standards in place at this time):

- <u>Vegetation Removal</u>: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- <u>Impervious surface standards</u>: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface (but not more than 30%) on a lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner.

- <u>Nonconforming structures</u>: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- <u>Mitigation requirements</u>: New language in NR-115 specifies mitigation techniques that may be incorporated on a property to offset the impacts of impervious surface, replacement of nonconforming structure, or other development projects. Practices such as buffer restorations along the shoreland zone, rain gardens, removal of fire pits, and beaches all may be acceptable mitigation methods, dependent on the county.

- Contact the county's regulations/zoning department for all minimum requirements.

**Wisconsin Act 31**

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

## Shoreland Research

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

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

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

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

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

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

### National Lakes Assessment

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

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

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

## Native Species Enhancement

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

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

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

**Cost**

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

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

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

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

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

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

## *Antigo Lakes Shoreland Zone Condition*

### Shoreland Development

A lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelines are more stressful on a lake ecosystem, while definite benefits occur from shorelines that are left in their natural state. Figure 3.3-1 displays a diagram of shoreline categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreline has been left in its original state.


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

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

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

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

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

**Figure 3.3-1. Shoreline assessment category descriptions.**

On Antigo Lake, the development stage of the entire shoreline was surveyed during summer of 2010, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Antigo Lake has stretches of shoreland that fit four of the five shoreland assessment categories. In all, 0.7 miles of natural/undeveloped shoreline were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.6 miles of urbanized and developed–unnatural shoreline were observed. If restoration of Antigo Lake's shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreline lengths around the entire lake.

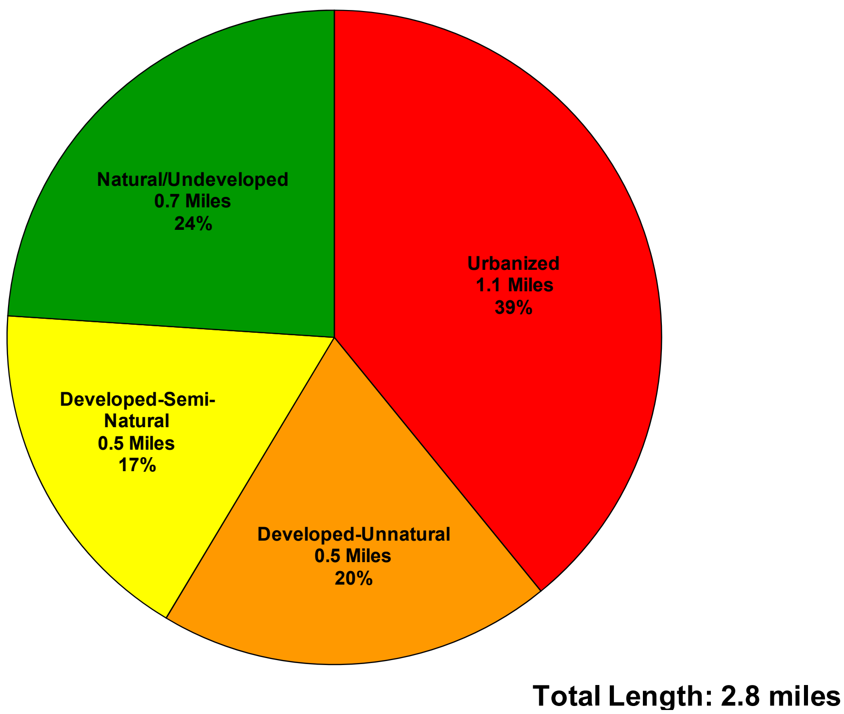


**Figure 3.3-2. Antigo Lake shoreland categories and total lengths.** Based upon a summer 2010 survey. Locations of these categorized shorelands can be found on Map 3.

While much developed shoreland surrounds Antigo Lake, it would be difficult to restore this completely because this land does belong to a park. However, park maintenance crews currently do not mow too close to the shoreland area. This will need to be continued in order to maximize the buffering capacity of the shoreland, and provide some habitat benefit to aquatic and terrestrial organisms.

# 3.4 Aquatic Plants

## Introduction

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

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

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

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

## *Aquatic Plant Management and Protection*

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 Antigo 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 Antigo Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

### Permits

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

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

## Manual Removal

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

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

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

**Cost**

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Very cost effective for clearing areas around docks, piers, and swimming areas.<br>• Relatively environmentally safe if treatment is conducted after June 15th.<br>• Allows for selective removal of undesirable plant species.<br>• Provides immediate relief in localized area.<br>• Plant biomass is removed from waterbody. | • Labor intensive.<br>• Impractical for larger areas or dense plant beds.<br>• Subsequent treatments may be needed as plants recolonize and/or continue to grow.<br>• Uprooting of plants stirs bottom sediments making it difficult to conduct action.<br>• May disturb benthic organisms and fish-spawning areas.<br>• 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*** | ***Disadvantages*** |
|---|---|
| • Immediate and sustainable control.<br>• Long-term costs are low.<br>• Excellent for small areas and around obstructions.<br>• Materials are reusable.<br>• Prevents fragmentation and subsequent spread of plants to other areas. | • Installation may be difficult over dense plant beds and in deep water.<br>• Not species specific.<br>• Disrupts benthic fauna.<br>• May be navigational hazard in shallow water.<br>• Initial costs are high.<br>• Labor intensive due to the seasonal removal and reinstallation requirements.<br>• Does not remove plant biomass from lake.<br>• Not practical in large-scale situations. |

## Water Level Drawdown

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

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

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

### Mechanical Harvesting

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

**Cost**

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

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

### Herbicide Treatment


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

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

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

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

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

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

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

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

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

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

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

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Herbicides are easily applied in restricted areas, like around docks and boatlifts.<br>• Herbicides can target large areas all at once.<br>• 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.<br>• Some herbicides can be used effectively in spot treatments.<br>• Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects) | • All herbicide use carries some degree of human health and ecological risk due to toxicity.<br>• Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly.<br>• 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.<br>• Many aquatic herbicides are nonselective.<br>• Some herbicides have a combination of use restrictions that must be followed after their application.<br>• Overuse of same herbicide may lead to plant resistance to that herbicide. |

## Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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

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

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

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

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

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

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

## Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Antigo 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 the comprehensive point-intercept surveys conducted in 2011 on Antigo Lake, plant samples were collected from plots laid out on a grid that covered the entire system (Map 1). Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage.

Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

**Species Diversity and Richness**

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Antigo Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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

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

### Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Antigo Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1).

> **Ecoregions** are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species or those encountered during other aquatic plan surveys.

### Community Mapping

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

### Exotic Plants

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

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

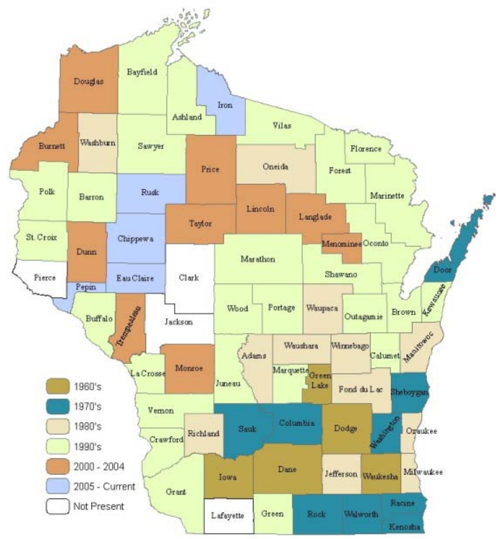


**Figure 3.4-1. Spread of Eurasian water milfoil within WI counties.** WDNR Data 2011 mapped by Onterra.

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

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

## Aquatic Plant Survey Results

As mentioned above, numerous plant surveys were completed as a part of this project. On June 10, 2010, a survey was completed on Antigo Lake that focused upon curly-leaf pondweed. This meander-based survey found significant amounts of this invasive aquatic plant throughout the project area. Because of is frequency within Antigo Lake, curly-leaf pondweed will be discussed in depth in the next section.

The comprehensive aquatic plant point-intercept survey was conducted on Antigo Lake on August 27, 2010 by Onterra (data provided in Appendix D). Additional surveys targeted at mapping emergent and floating-leaf aquatic vegetation were also completed on August 27, 2010 to create the community map. During the point-intercept and aquatic plant mapping surveys, 23 species of aquatic plants were located in Antigo Lake (Table 3.4-1), four of which are considered non-native, invasive species: curly-leaf pondweed, purple loosestrife, reed canary grass, and pale-yellow iris. Because of their ecological importance, these invasive species will be discussed in the Non-native Aquatic Plant Section. Eurasian water milfoil was not located at any time throughout the 2010 surveys.

**Table 3.4-1. Aquatic plant species located in Antigo Lake during the 2010 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2010 Onterra |
|---|---|---|---|---|
| Emergent | *Glyceria grandis* | American manna grass | 6 | I |
| | *Iris pseudacorus* | Pale-yellow iris | Exotic | I |
| | *Leersia oryzoides* | Rice cut grass | 3 | I |
| | *Lythrum salicaria* | Purple loosestrife | Exotic | I |
| | *Phalaris arundinacea* | Reed canary grass | Exotic | X |
| | *Schoenoplectus tabernaemontani* | Softstem bulrush | 4 | I |
| | *Typha sp.* | Cattail sp. | 1 | X |
| FL | *Nymphaea odorata* | White water lily | 6 | X |
| Submergent | *Callitriche palustris* | Common water starwort | 8 | I |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | I |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Potamogeton crispus* | Curly-leaf pondweed | Exotic | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Ranunculus aquatilis* | White water-crowfoot | 8 | X |
| | *Stuckenia pectinata* | Sago pondweed | 3 | I |
| S/E | *Sagittaria cuneata* | Arum-leaved arrowhead | 7 | X |
| FF | *Lemna trisulca* | Forked duckweed | 6 | X |
| | *Lemna turionifera* | Turion duckweed | 9 | X |
| | *Spirodela polyrhiza* | Greater duckweed | 5 | X |

*FL = Floating-leaf; S/E = Submergent & Emergent; FF = Free-floating*
*X = Located on the rake during the 2010 point-intercept survey; I = Incidental Species*

Sediment data gathered during the 2010 point-intercept survey indicates that 64% of the point-intercept locations contained fine organic sediments (muck), 30% contained sand, and 6% contained rock (Figure 3.4-2). Map 4 illustrates that the majority of the three downstream basins were mainly comprised of muck while the upstream Spring Brook Creek section contained sand and rock. This system, particularly the lower three basins, contain substrate that is very conducive for supporting lush aquatic plant growth.

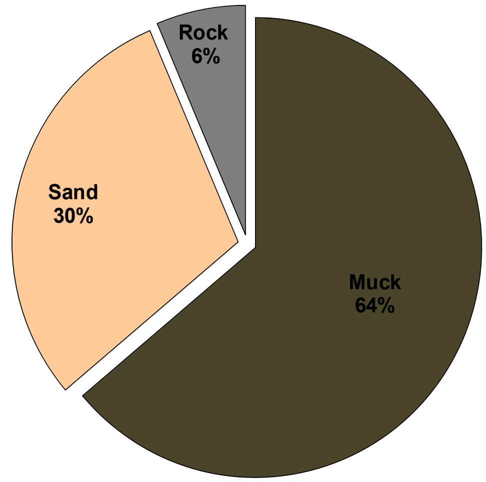


**Figure 3.4-2. Antigo Lake proportion of substrate types within littoral areas.** Created using data from the 2010 aquatic plant point-intercept survey.

Map 5 shows that the majority of Antigo Lake is highly vegetated, with approximately 71% if the 94 point-intercept sampling locations that fell within the maximum depth of plant growth (10 feet) containing aquatic plant growth. The nutrient-rich water and a predominant substrate of organic material within Antigo Lake provide ideal conditions for abundant plant growth.

Common waterweed, coontail, northern water milfoil, and flat-stem pondweed were the four-most frequently encountered native aquatic plant species during the 2010 point-intercept sampling survey (Figure 3.4-3). Common waterweed and coontail are found in waterbodies throughout North America, and under certain conditions can grow at densities which hamper navigation and recreational activities. Because both of these species have the ability to attain nutrients directly from the water, they do not produce extensive root systems making them susceptible to uprooting by wave-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats. If they completely detach from the bottom, they are subject to wind and water currents and form large piles on or near shore. Both species are also able to tolerate low-light conditions. That plus their ability to obtain nutrients directly from the water allow then to thrive in productive systems.

Northern water milfoil, arguably Wisconsin's most common native milfoil species, does well in lakes with soft sediments and higher water clarity. It is often falsely identified as Eurasian water milfoil with its feather-like leaves and 'reddish' appearance observed in late summer as it reacts to sun exposure. The feathery foliage of northern water milfoil traps detritus and provides habitat for filamentous algae, in turn creating valuable habitat for aquatic invertebrates. Flat-stem pondweed, one of many pondweed species found in Wisconsin, is very common and as its name suggests has a conspicuously flattened stem.

During the 2010 summer surveys, Onterra ecologists found navigation within Antigo Lake to be extremely difficult due to the excessive aquatic plant growth. In June during the curly-leaf pondweed survey, navigation was primarily hampered by curly-leaf pondweed matting at the surface. As discussed earlier, curly-leaf dies back in late June to early July and its occurrence within Antigo Lake as determined during the late-August point-intercept survey is grossly underestimated. Had the point-intercept survey been conducted in June, curly-leaf pondweed would have likely been the most frequently encountered species in the system at that time. However, navigation difficulties in late-summer were primarily due to nuisance growth of native aquatic plant species; primarily common waterweed and coontail.

It is unrealistic to quantitatively define the term "nuisance," as this designation is subjective by nature. However, WDNR Science Services researchers indicate that nuisance levels of a given aquatic plant species likely occur when the littoral frequency of occurrence exceeds 35% (Alison Mikulyuk, personal comm.). In Antigo Lake, common waterweed and coontail (and likely curly-leaf pondweed in June) exceed this relatively arbitrary benchmark (Figure 3.4-3).

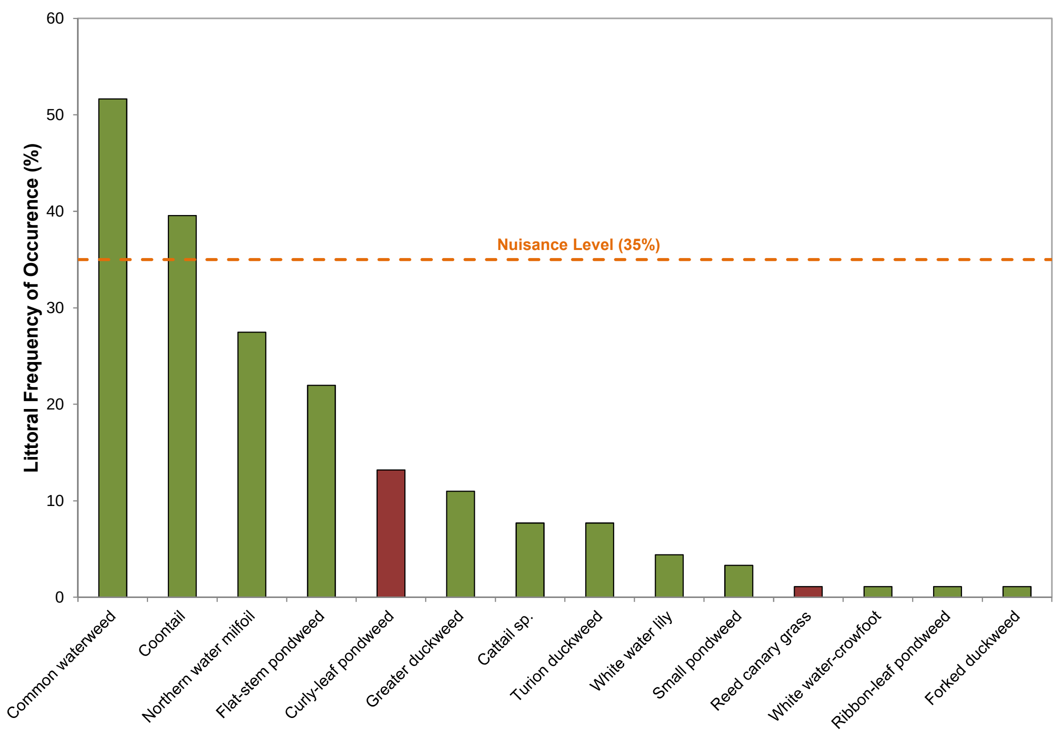


**Figure 3.4-3. Antigo Lake aquatic plant littoral frequency of occurrence analysis.** Created using data from August 2010 point-intercept survey. Exotic species indicated with red.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while 19 native aquatic plant species were located in Antigo Lake during the 2010 surveys, only 12 were encountered on the rake during the point-intercept survey. These 12 native species and their conservatism values were used to calculate the FQI of Antigo Lake's aquatic plant community in 2010 (equation shown below).

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

Figure 3.4-4 displays the FQI of Antigo Lake's aquatic plant community from 2010 survey. The native species richness in 2010 (12) is lower than the *median* values for lakes in both the North Central Hardwood Forests Ecoregion as well as the entire state (Figure 3.4-4).

Data collected from the aquatic plant surveys indicate that the average conservatism value falls between the North Central Hardwood Forests and Wisconsin State medians (Figure 3.4-4), signifying that Antigo Lake's plant community is comparable to those of other lakes within the ecoregion and state. The species that comprise the Antigo Lake's plant community are mainly composed of species that are indicative of a more disturbed system. Combining the system's native species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 19.9; slightly below both the ecoregion and state medians (Figure 3.4-4).

**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.

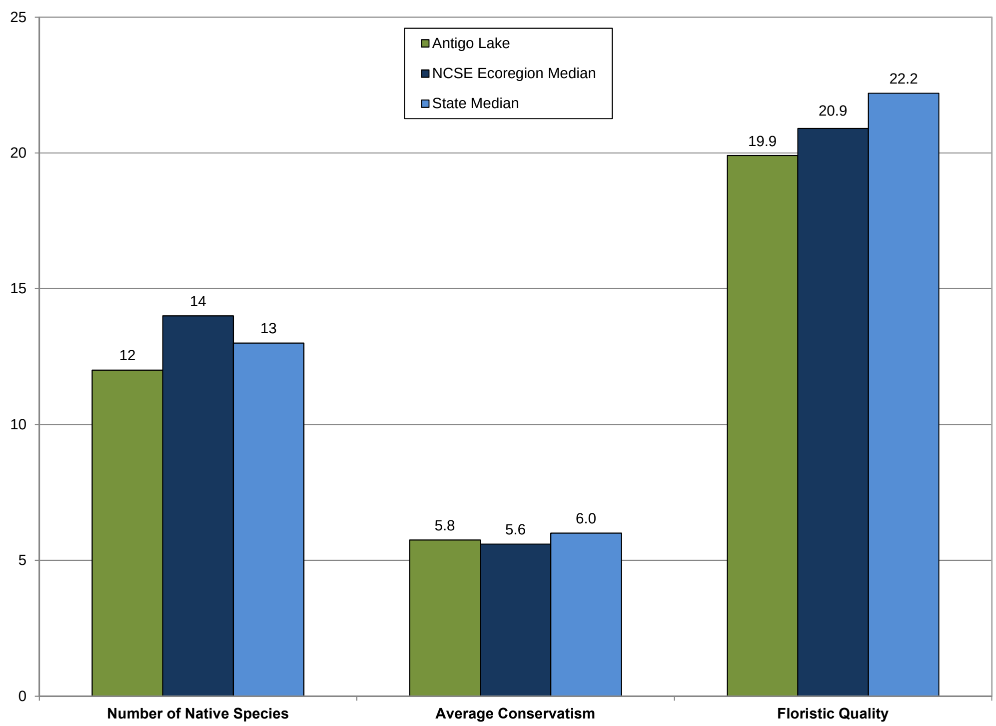


**Figure 3.4-4. Antigo Lake Floristic Quality Assessment.** Created using data from 2010 surveys. Analysis follows Nichols (1999).

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. A plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish and other wildlife with diverse structural habitat and various sources of food. As discussed earlier, species diversity is influenced by how evenly the plant species are distributed within the community, as well as how many species are present. Using the data collected from the 2010 point-intercept survey, Antigo Lake's plant community was shown to have moderate diversity with a Simpson's diversity value of 0.83 (Figure 3.4-5).

While a method of characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Antigo Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 71 lakes within the North Central Hardwood Forests Ecoregion (Figure 3.4-5). Antigo Lake's value ranks equal to the regional and state median values.

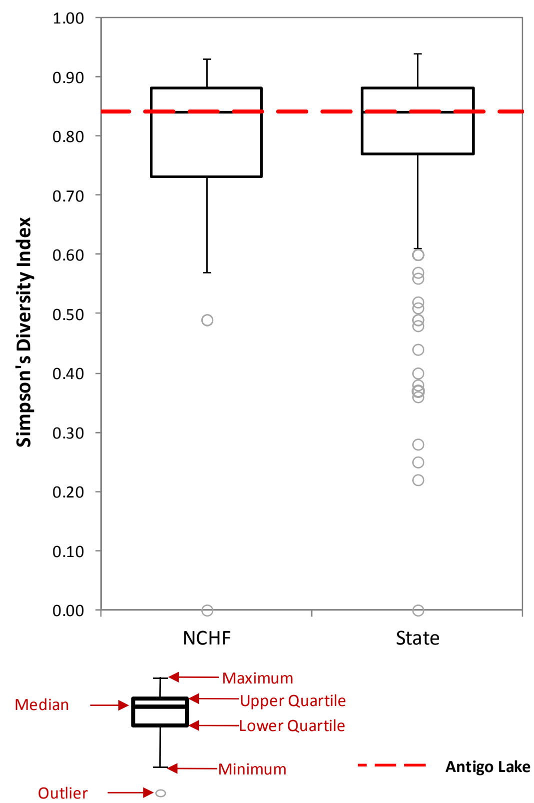


**Figure 3.4-5. Antigo Lake species diversity index.** Created using data from 2010 aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

As explained previously in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plant species is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while common waterweed was found at almost 52% of the sampling locations in Antigo Lake in 2010, its relative frequency of occurrence is 27%. Explained another way, if 100 plants were randomly sampled from Antigo Lake, 27 of them would be common waterweed. Figure 3.4-6 displays the relative frequency of occurrence of aquatic plant species from the 2010 point-intercept survey and illustrates the uneven distribution of species, or low species diversity, with common waterweed and coontail together accounting for nearly 50% of the lake's plant community.

Antigo Lake system has a high incidence of emergent and floating-leaf plant communities. The 2010 community map indicates that approximately 11.4 acres (35.6%) of the 32-acre system contains these types of plant communities (Table 3.4-2 and Map 6). Five native floating-leaf and emergent species were located in Antigo Lake providing valuable fish and wildlife habitat important to the ecosystem of the lake. However, the majority of these emergent plant communities are dominated by dense stands of cattail (*Typha sp.*). In 2009, the City of Antigo was permitted to remove sections cattails to permit viewing access as well as the construction of piers.

Continuing the analogy that the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the Antigo Lake system. 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.

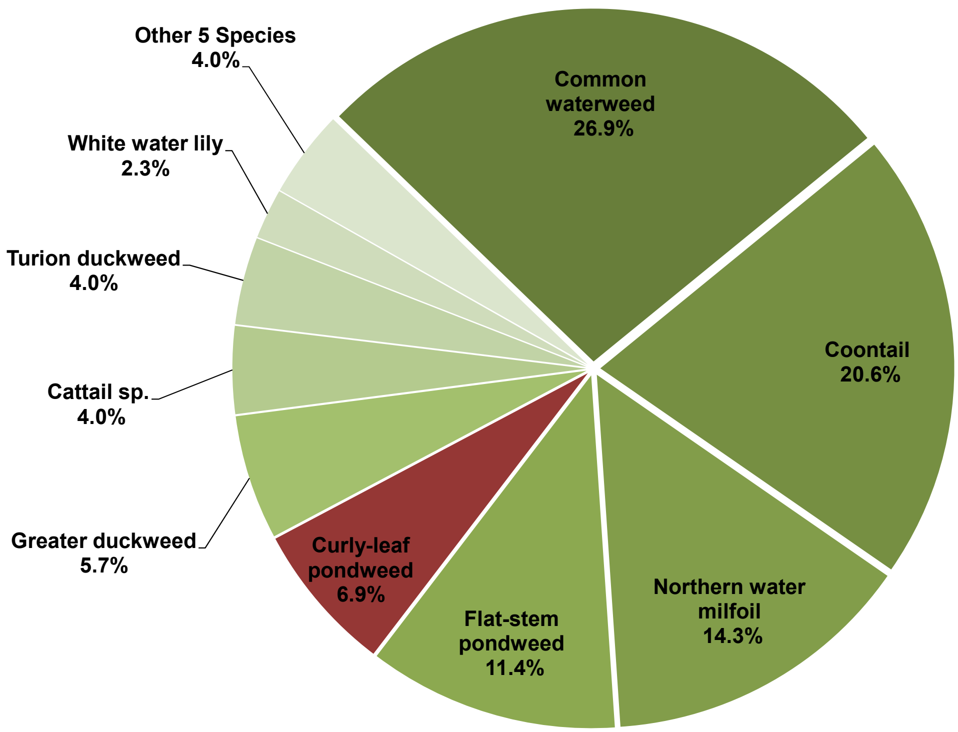


**Figure 3.4-6. Antigo Lake aquatic plant relative occurrence analysis.** Created using data from August 2010 aquatic plant point-intercept survey. Exotic species indicated with red.

**Table 3.4-2. Antigo Lake acres of floating-leaf and emergent plant communities.** Created using data from 2010 community mapping survey.

| Plant Community | Acres |
|---|---|
| Floating-leaf | 0.6 |
| Emergent | 10.8 |
| Mixed Floating-leaf and Emergent | 0.1 |
| **Total** | 11.4 |

## *Non-native Aquatic Plants*

### Curly-leaf pondweed

During the curly-leaf pondweed survey in June 2010, approximately 8.4 acres of curly-leaf pondweed were mapped in Antigo Lake's system (Map 7). Large areas of this plant were located in all three basins as well as approximately one mile upstream in Spring Brook where Onterra ecologists were no longer able to navigate. Onterra ecologists drove to where North Avenue and Highway 64 cross Spring Brook and checked these areas and did not locate any curly-leaf pondweed.

As discussed in greater detail in the Water Quality Section, the large amount of curly-leaf pondweed senescing in early summer is likely releasing a significant amount of phosphorus into the Antigo Lake ecosystem, and may partially explain why phosphorus levels dramatically increased in July and August. This large release of phosphorus fuels summer algae blooms as were observed and indicated by the extremely high chlorophyll-*a* values.

While eradication of curly-leaf pondweed from Antigo Lake system is unrealistic, reducing its occurrence within the three basins may be possible with the use of herbicides. Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to dilute herbicide concentration within aquatic systems. Understanding concentration-exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of a joint research project between the WDNR and USACE. This research has focused on spot-treatment scenarios as well as whole-lake treatments, as discussed earlier in this section.

Whole-lake treatments are typically conducted when the target plant is spread throughout much of the lake, similar to what has been observed in Antigo Lake. Map 7 indicates that curly-leaf pondweed has colonized areas throughout Antigo Lake. An additional advantage of conducting a whole-lake treatment is that there is less importance on delineating specific treatment areas, as the herbicide is equally distributed throughout the entire lake. Therefore, a low-dose whole-lake liquid endothall treatment is proposed for Antigo Lake. Current research appears to indicate that whole-lake liquid endothall treatments are effective on curly-leaf pondweed when the target whole-lake herbicide concentration is between 0.75 ppm active ingredient (a.i.) and 0.5 ppm a.i. and is maintained for approximately 14 days. However, due to the high flow through this system, a slightly higher target concentration of 1.02 ppm was proposed, which would yield basin wide concentrations of 710 µg/L (0.710 ppm). The herbicide was applied over the treatment areas displayed on Map 8 at a rate to achieve basin-wide control.

Monitoring of the remaining herbicide concentrations was conducted in coordination with the United States Army Corps of Engineers (USACOE), WDNR and volunteers from the City of Antigo. Water quality samples were taken in various locations following the herbicide treatment, with these samples being preserved and sent to the USACOE laboratory in Gainsville, Florida for analysis. A lake-wide target concentration of 710 µg/L was exceeded only slightly, at 740 µg/L from zero to seven days after treatment. A report by the USACOE regarding the herbicide monitoring on the Antigo Lakes is attached as Appendix E.

A similar treatment, though at a slightly lower dose, is being proposed at the time of this writing for spring of 2013. Curly-leaf pondweed management typically takes numerous years of continuous herbicide applications in order to deplete the sediment of the accumulating turion base. That being said, the AILPRD and City of Antigo are prepared to take on curly-leaf pondweed management as a long-term project.

## Emergent Plants of Concern

### Pale-yellow iris

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering throughout shoreline areas on Antigo Lake during the June curly-leaf pondweed survey (Map 6). At the time of this report, it appears that the only means of control are continual hand removal and monitoring.

### Purple loosestrife

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

Purple loosestrife populations were located in the most upstream portion of Antigo Lake (Map 6). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Antigo Lake.

### Reed canary grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach three to six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines.

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

At this time, populations are extensive on Antigo Lake's shorelines (Map 6). During the community mapping survey of Antigo Lake, Onterra ecologists mapped numerous occurrences of reed canary grass along the shoreline of the lake with sub-meter GPS technology.

### Cattail species

Two species of cattail can be found in Wisconsin, broad-leaved cattail (*Typha latifolia*) and narrow-leaved cattail (*Typha angustifolia*). Broad-leaved cattail is considered to be indigenous to North America while narrow-leaved cattail is believed to have been introduced from Europe and is considered to be ecologically invasive. While there are certain characteristics that differentiate these two species, hybridization between them (*T. x glauca*) is believed to be very common, making positive identification without DNA analysis difficult. Flowering specimens observed within Antigo Lake in 2010 exhibited characteristics of both, suggesting the cattail population may be a hybrid. Regardless of being introduced or not, both cattail species under the right conditions have the capacity to act aggressively, or invasively, displacing other emergent aquatic plant species.

The growth of cattails on the Antigo Lake system can be considered excessive. While these plants do provide value to the ecosystem in terms of habitat, food, nutrient uptake, and erosion control, their large monotypic stands are decreasing species diversity and hindering the public's access and viewing of the lake. In the past, the City of Antigo has mechanically removed sections of the cattail population via a backhoe. However, this is not the most ecologically-sound method for removal as it is intrusive in nature and exposes open soil to potential invasion by non-native plants. A detailed method utilizing a water-level drawdown and application of herbicides to select areas of cattails is discussed within the Implementation Plan.

# 4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Antigo Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on curly-leaf pondweed and native cattails.
3) Identify areas the AILPRD may focus upon for restoration of the lake ecosystem.

The studies conducted on Antigo Lake show that the ecosystem has several pressing issues that are of concern to the City of Antigo and the district. It is clear that the ecosystem is quite productive – with non-native and native plants alike thriving to nuisance conditions and algae blooms occurring frequently. These plant communities are supported by abundant nutrients that are supplied to the lakes through a very large watershed and likely internal sources. This watershed encompasses over 22,700 acres of land, and holds large tracts of developed land cover types such as row crops (37% of the total watershed), pasture/grass (23%) and mixed agriculture (8%). The presence of row crops within a watershed is not ideal for a lake, as this land cover type easily allows surface water to drain away, carrying with it much soil and nutrients. Modeling of the lake's watershed indicates that roughly 68% of Antigo Lake's annual phosphorus load comes from row crops within the watershed.

As stated within the Water Quality Section, there are a number of factors contributing to the large amount of nutrients found in Antigo Lake. The most apparent is the large watershed, with large amounts of agriculture or otherwise developed land. Additionally, internal recycling of nutrients is thought to play a role in the lake. When the lake is void of oxygen in the lower layer of water (hypolimnion), nutrients that are bound in the sediments of the lake can be released into the water column. Another factor increasing phosphorus concentrations within the lake is the natural die-off of curly-leaf pondweed. When this exotic plant dies off in mid-summer, the sudden increase in decomposing material provides the water with more nutrients. In lakes that have small curly-leaf pondweed populations, the increase in nutrients is not noticeable. However, in lakes with a substantial population, a noticeable increase of water column nutrients is possible. In the end, the water quality of Antigo Lake is very poor. However, the conditions observed in the lake are not unexpected given it has a large watershed dominated by developed land uses as well as internal nutrient loading and curly-leaf pondweed factors.

Potentially impacting the water quality of Antigo Lake is the urbanized shoreland surrounding the waterbody. While much developed shoreland can be found here, it would be difficult to restore this completely because this land does belong to a park and access/viewing is expected. However, park maintenance crews currently do not mow too close to the shoreland area. This will need to be continued in order to maximize the buffering capacity of the shoreland, and provide some habitat benefit to aquatic and terrestrial organisms.

The conditions of the aquatic plant community indicate that the lake is displaying signs of high nutrient input and human disturbance in the watershed. The native aquatic plant community includes many species that are indicative of disturbed aquatic systems, such as common water weed, coontail and cattails. Some of these species were found at "nuisance" levels, meaning their littoral frequency of occurrence rating was higher than an arbitrary benchmark (35%) set by

WDNR Science Services researchers. Additionally, the species richness observed during 2010 surveys was found to be fairly low; in fact, the species richness of Antigo Lake is lower than the median number of species for lakes within the local ecoregion and across the state. A lack of richness in a lake's aquatic plant community is another sign of human disturbances on the ecosystem.

It is obvious that the cattail population along the lake's shoreland is substantial. Cattail species are commonly found in disturbed and undisturbed systems. While they are typically considered a native species, they are invasive because they can form large monocultures. The state of cattail growth around Antigo Lake is such that viewing and access corridors have been closed off entirely, thereby limiting access and recreational opportunity on the lake. In 2009, the City of Antigo was permitted to remove sections of cattails to permit viewing access as well as the construction of piers to the lake. Additional management of cattails is recommended to provide recreational opportunity and viewing of the lake. The methodology of managing cattail stands along Antigo Lake is discussed in the Implementation Plan of this report.

Another sign of human disturbance on a lake is the presence of several aquatic invasive species, specifically curly-leaf pondweed, pale yellow iris, purple loosestrife and reed canary grass. As discussed within the Aquatic Plant Section, some biological and chemical management techniques are effective for purple loosestrife; however, pale yellow iris and reed canary grass are more difficult to control. Presently, they can be found along much of the Antigo Lake shoreline. Curly-leaf pondweed, a submergent invasive aquatic plant, can be found throughout much of the lake in the spring and early to mid summer. This plant is effective at forming dense, monotypic cultures and displacing native plants.

Curly-leaf pondweed has likely been in the Antigo Lake ecosystem for quite some time to grow to the extent that is now present. As a result, the plant has likely built a large turion base as well, which will continue to produce new plants for years to come. A 2012 herbicide treatment was implemented to begin bringing down the plant's abundance to more controllable levels. Applications for curly-leaf pondweed control occur in early spring, as this action targets the plant prior to its producing turions. As discussed within the Implementation Plan, this control strategy takes numerous years of effort as the turion base must be exhausted in order to achieve relief from this aggressively growing plant.

It is clear that Antigo Lake is suffering from many human-induced ailments. High nutrient content, algae blooms, developed shoreland and excessive native aquatic plants and the presence of several exotic species are all signs of an ecosystem that has seen the effects of human disturbance in the watershed. In accordance with the City of Antigo's Vision Plan (2006), the goals set forth by the City of Antigo Board of Directors, and the steps outlined within the Implementation Plan of this document, efforts to begin remediation and restoration of the Spring Brook Creek area and Antigo Lakes are underway. These initiatives aim to not only restore some of the ecological functions that used to exist in Antigo Lake, but also enhance its serene and natural landscape and improve its visual and recreational setting as well.

# 5.0 IMPLEMENTATION PLAN

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

## *Management Goal 1. Control Strategic Areas of Dense Cattail Growth for Viewing, Access and Fire-Control Purposes.*

**Management Action:** Maintain reasonable access and viewing corridors through cattail-dense shoreland areas.

**Timeframe:** Begin 2013.

**Facilitator:** City of Antigo Park, Recreation and Cemetery Department

**Description:** Much work has been done to provide public access to the shorelands of Antigo Lake, including the City of Antigo purchasing 95% of the floodplain area. The city now has a long-term goal of maintaining public access and rehabilitating much the area back to near-native condition. However, the current nutrient-rich and disturbed conditions of this area are prime for growth of cattails. This is certainly evident in the naturalized area north of the first basin, where a boardwalk takes visitors through areas of thick cattail growth. Indeed, much of the shoreland of all three basins holds thick cattail growth as well. While this plant provides some natural habitat benefits, its growth is monotypic in nature and also blocks viewing of the Antigo Lake by people on trails, or those resting on a park bench. Anglers cannot cast from shore with these dense stands in the way, and some wildlife may have difficulty accessing the water as well.

In the past, the City of Antigo has managed cattail growth through mechanical means, by removing areas of cattails and sediment via a backhoe. This is not an ideal way to manage cattails due to its intrusive nature, but also because this exposes open soil which may become infested by an invasive plant (which are often called "pioneer species" as well due to their ability to be the first to arrive at a newly developed site). A more controlled, less intensive way of managing cattails would be through altering water levels and applying herbicide.

Viewing and access corridors of 30-40 feet have been identified along several areas of the shoreline (Table 5.0-1 and Map 9). These corridors are located in front of viewing platforms, park benches, carry-in access points, etc. Some of these areas are currently in need of control, while others are not but likely will in the coming years. During the summer months, the water level would be brought down briefly and cattails cut at the new water level. Water levels would be restored, and the cattails allowed to grow until they break the surface of the water. In the late summer, a treatment would occur using the herbicide Imazapyr (Polaris) according to manufacturer specifications. This herbicide is similar to Habitat, but safer to use over the open water as it rapidly becomes inactive when reaching the lake bottom substrate. The timing of herbicide application is important, because in the mid to late summer carbohydrates are at a minimum because the plant has invested much energy into growing early in the year. The plant is actively storing carbohydrates in the roots, so movement of herbicide within the plant occurs well at this time.

**Table 5.0-1. Antigo Lake cattail management areas.**

| Site | Description | Appr. Shoreline Length (ft) |
|---|---|---|
| 1 | Fishing pier north of dam. | 40 |
| 2 | Bench area in Antigo Lake Park | 40 |
| 3 | Bench area in Antigo Lake Park | 30 |
| 4 | Swing in Antigo Lake Park | 30 |
| 5 | Bench area in Antigo Lake Park | 40 |
| 6 | Bench area, picnic area with grill, and fishing pier in Antigo Lake Park | 40 |
| 7 | Carry-in site by Hudson St. bridge | 30 |
| 8 | ADA fishing pier in Antigo Lake Park | 40 |
| 9 | Little League Park picnic area. Also used as a carry-in access. | 30 |
| | **Total** | **320** |

Following successful removal of cattails utilizing the above described method, it would be advantageous for the AILPRD to re-plant these areas with native, low-growing aquatic species such as pickerelweed (*Pontederia cordata*) or water smartweed (*Polygonum amphibium*). The AILPRD may elect to conduct this management action itself or seek a qualified nursery or other professional group to do so. Herbicide applications must be conducted by individuals with a license to apply herbicides in the aquatic environment. WDNR permits for aquatic herbicide applications would be required.

During this planning process, this approach was discussed with the WDNR. A plan of action whereby 3-4 areas of cattail management would be undertaken in 2013-2014 was developed, followed by remaining areas and also private property locations in subsequent years should this methodology prove successful. While this is a fairly new methodology, the hope is that maintenance treatment of cattail management areas would only occur every 2-3 years.

**Action Steps:**

1. See above description.

**Management Action:** Protect City of Antigo boardwalk from fire hazard.

**Timeframe:** Begin 2013.

**Facilitator:** City of Antigo Park, Recreation and Cemetery Department

**Description:** The boardwalk that stretches north from basin three of the Antigo Lakes takes visitors on a scenic, winding path that travels 2,000 feet up Spring Brook Creek and ends at Byrne Road. This boardwalk runs through very dense cattail stands, which occur primarily along the first 800 feet of the path which leads north from East 2nd avenue. Because of the close proximity of the cattails to the boardwalk, City of Antigo Fire Department officials have expressed concern over the matter as a fire hazard. When the biomass is dry, during spring or fall, fire may occur as the result of vandalism, natural causes, etc. With a clear buffer along each side of the boardwalk, fire department officials could drag hose on this path without worry of fire reaching them.

As a result of this fire safety concern, the city wishes to properly manage cattails in this area. While cattail management within the Antigo Lakes basins would be for the purpose of viewing corridor creation and lake access, this action is specifically for fire control protection. A 10-foot width of cattails immediately bordering the boardwalk, on both sides, will be controlled for the first 800 feet of its length. The AILPRD may elect to conduct this management action itself or seek a qualified nursery or other professional group to do so. The proper methodology for this control plan would be to mechanically remove dead biomass during ice over in the winter months.

**Action Steps:**

1. See above description.

## *Management Goal 2. Control and Monitor Aquatic Invasive Species of Concern Within and Around Antigo Lake.*

**Management Action:** Initiate/continue herbicide application strategy to control curly-leaf pondweed infestation on Antigo Lake.

**Timeframe:** Continue in 2013.

**Facilitator:** City of Antigo Park, Recreation and Cemetery Department

**Applicable Grant:** AIS Education, Prevention, and Planning for monitoring.

**Description:** As described in the Aquatic Plant Section, one of the most pressing threats to the health of Antigo Lake's aquatic plant community is curly-leaf pondweed. In 2010, the first year it was accurately mapped, the invasive plant was located throughout most of the lake (Map 7). A 2012 herbicide treatment occurred, targeting this species at a whole-lake level (Map 8).

At this time, the most feasible method of control is to continue herbicide applications – specifically, early spring treatments with endothall. The treatments would occur each year for the next four years when surface water temperatures are close to 50°F. In addition to the time of the year and temperature at which treatments occur, other factors such as water movement act to change the in lake concentration of herbicide. In conjunction with the WDNR, herbicide concentration monitoring at multiple locations throughout the lake would take place to understand the concentration/exposure time of the herbicide at different time periods and locations following the treatment, similar to what was conducted in the 2012 treatment. This information would indicate whether or not the amount of herbicide applied is sufficient for causing curly-leaf pondweed mortality and if any adjustments in treatment strategy need to be made.

The objective of this management action is not to eradicate curly-leaf pondweed from Antigo Lake, as that would be impossible. The objective is to reduce curly-leaf pondweed to more manageable levels. In other words, the goal is to reduce the amount of curly-leaf pondweed in Antigo Lake to levels that may be suitable for smaller treatment areas to keep it under control. Ultimately, if a population is reached that is not found to be colonized (mapped through point-based as opposed to polygon-based methodologies), the AILPRD would not initiate herbicide treatments. However, continued monitoring by volunteer or professional means would be crucial to continue.

Monitoring is a key aspect of any AIS control project, both to create the treatment areas and monitor the action's effectiveness. The monitoring would also facilitate the "tuning" or refinement of the control strategy as the control project progresses. It must be noted that this portion of the management plan (control plan) would be intended to span approximately four years before if would need to be updated to account for changes within the ecosystem. The ability to tune the control strategies is important because it allows for the best results to be achieved within the plan's lifespan. The series includes:

1. A lake-wide assessment of curly-leaf pondweed completed while the plant is at peak biomass (late Spring 2013-2016). Essentially, areas mapped during the previous peak biomass survey would be revisited to determine density levels and if colonial expansion has occurred.
2. Application during the February 1st, 2013 grant cycle for a WDNR Aquatic Invasive Species - Education, Prevention, and Control Grant.
3. Verification and refinement of early-season curly-leaf pondweed treatment areas in spring of 2013-2016.
4. Updated treatment areas submitted to the WDNR to serve as the final treatment permit, followed by completion of a curly-leaf pondweed herbicide treatment.
5. Areas surveyed (post-treatment survey) to determine treatment efficacy and strategy for the following year. The crux of this

activity is included within Step 1.

6. Reports generated on treatment success level and following year's strategy.

In addition to refining each year's treatment areas, a series of comprehensive studies would be conducted on Antigo Lake to gain an understanding on what is occurring with the native and non-native aquatic plant communities. Monitoring would occur during early spring following a protocol currently being developed by the WDNR, and in general, would use guidance supplied in Aquatic Plant Management In Wisconsin (2010) and Pre and Post AIS Chemical Herbicide Treatment Monitoring (Draft) (April 2008). In general, control areas would be quantitatively monitored before and after treatments. At each point, a rake tow would be taken and if curly-leaf pondweed is located, its abundance estimated on the rake using a scale of 1-3. Depth and substrate would also be noted for each point. These data would then be used for comparisons with similar data collected after the treatment.

Quantitative sampling would be conducted the spring just previous to the treatment (pretreatment) and the spring following the treatment (post treatment). Because of the early senescence of this species, a post treatment survey a few weeks following the treatment would not differentiate if a reduction in occurrence can be attributed to the herbicide application or the natural die-off of this species.

In each year of the project, a comprehensive, full-lake point-intercept survey would be conducted. The results of this survey would be compared to past studies conducted as a part of the management planning project.

Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program will be sought to partially fund this control program. Specifically, funds would be applied for under the Established Population Control classification. These funds will be applied for in the February 1st, 2013 grant cycle in order to allow the AILPRD time to financially prepare for their portion of the project costs. The approved project would have a timeline of 2013-2016.

**Action Steps:**

1. See above description.

**Management Action:** Reduce occurrence of purple loosestrife on Antigo Lake shorelands.

**Timeframe:** Begin 2013.

**Facilitator:** City of Antigo Park, Recreation and Cemetery Department

**Description:** Purple loosestrife can be found in low occurrence along the shorelands of Antigo Lake's shorelands (Map 6). The purple loosestrife occurrences appear to be at an early stage of development with only a few individual plants observed. As with any invasive species, control strategies on an early developing population are more effective than on well-established colonies. In regards to purple loosestrife, this hardy perennial is more resilient the longer it is allowed to grow in one location as its root crown becomes more robust. It also produces a large seed bank which germinates years after the parent plant is controlled and requires continued management.

Manually removing isolated purple loosestrife plants is likely the best control strategy at this time. The plant should be dug out of the ground, roots and all. If flowers or seeds are present at the time of the extraction, the flower heads should be carefully cut off and bagged to make sure seeds don't inadvertently get spread around during removal. Plants and seed heads should either be burned or bagged and put into the garbage.
Information sources, such as the WDNR, UW-Extension, Langlade County Land and Water Conservation Department may be used to properly identify purple loosestrife and provide guidance on the correct time of the year to perform management actions.

Important aspects of this management action will be the monitoring and record keeping that will occur in association with the control efforts. These records will include maps indicating infested areas and associated documentation regarding the actions that were used to control the areas, the timing of those actions, and the results of the actions. These maps and records will be used to track and document the successfulness of the program and to keep the AILPRD and all other management entities updated.

**Action Steps:**

1. Recruit AILPRD members or city staff to begin monitoring and control efforts.
2. Group completes field surveys to identify infested areas
3. Initiate manual removal control methods
4. Monitor results and reapply control as necessary
5. Keep stakeholders and managers informed regarding program results

## Management Goal 3. Investigate Restoration of Outlet Stream.

**Management Action:** Hire qualified consultant to design/implement restoration project.

**Timeframe:** Begin 2013.

**Facilitator:** City of Antigo Park, Recreation and Cemetery Department

**Applicable Grant:** Urban Nonpoint Source & Storm Water Management Grants Program

**Description:** The Spring Brook outlet stream leaves Antigo Lake at the southern most part of its third basin, and flows south eventually reaching the Eau Claire River. The outlet corridor is highly channelized, with non-native plant species encompassing the stream bank for most of its path out of the City of Antigo. The city council has expressed interest in restoring at least a portion of this stream to a more native, hydraulically correct state. Restoration of a stream, including altering its hydrology, is a complicated process that is best left to a professional fluvial geomorphologist to oversee. A city staff member will contact Interfluve (Madison office – 608-441-0342) to discuss the possibility of beginning a restoration project on Spring Brook. Additionally, this staff member will contact local WDNR fisheries biologist (Dave Seibel – 715-623-4190) and water resource management specialist (Jim Klosiewski – 715-365-8992) to be involved with the project, as well as ascertain what previous studies have been conducted on the stream.

**Action Steps:**

1. See above description.

## Management Goal 4. Monitor the Water Quality of Antigo Lake.

**Management Action:** Initiate monitoring of water quality parameters in Antigo Lake.

**Timeframe:** Begin 2013.

**Facilitator:** City of Antigo Park, Recreation and Cemetery Department

**Description:** Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends will likely aid in an earlier definition of what may be causing the trend.

Monitoring of the water quality of Antigo Lake has not been conducted prior to this lake management planning project. The City of Antigo City Council realizes this is an important step in guiding the health of this ecosystem. Monitoring of water quality parameters will begin in 2013, either by trained volunteers or paid city employees. These two options are discussed below:

1. The Citizens Lake Monitoring Network (CLMN) is a WDNR

program in which volunteers are trained to collect water quality information on their lake. At this time, there are no AILPRD members currently collecting data as a part of the CLMN. Volunteers trained by the WDNR as a part of the CLMN program begin by collecting Secchi disk transparency data for at least one year, then if the WDNR has availability in the program, the volunteer may enter into the *advanced program* and collect water chemistry data including chlorophyll-a, and total phosphorus. The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. The State Lab of Hygiene in Madison conducts the chemical analysis of the water samples, and, as a part of this program, enters data to the WDNR database which is available through their Surface Water Integrated Monitoring System (SWIMS).

2. Monitoring may be conducted by city employees if interest in the CLMN program is not held, or if the CLMN is not accepting new participants into its advanced monitoring program. City employees may collect samples to be analyzed by the State Lab of Hygiene in Madison on a contract basis. This way, data would be entered into SWIMS and available for future reference.

It is the responsibility of the city council to coordinate new volunteers or delegate new paid employees to this task as needed. When a change in the collection person occurs, it will be the responsibility of the city council to arrange for proper training, either through an appropriate county organization, WDNR or UW-Extension.

**Action Steps:**

1. Recruit facilitator.
2. City council decides if CLMN approach or paid employee monitoring is appropriate for Antigo Lake
3. If CLMN approach is desired, city council will contact Sandra Wickman of the WDNR (715-365-8951) for monitoring training, materials, etc.
4. If paid employee approach is desired, training should be arranged through proper organization (WDNR, UW-Extension, county representative, etc.). Chemical analysis should be contracted through the State Lab of Hygiene and data entered into the WDNR's online database (SWIMS).

# 6.0 METHODS

## Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Antigo Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with an integrated sampler at the surface. Sampling occurred three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

| Parameter | June | July | August |
|---|---|---|---|
| Total Phosphorus | ● | ● | ● |
| Chlorophyll a | ● | ● | ● |
| Total Kjeldahl Nitrogen | ● | ● | ● |
| Nitrate-Nitrite Nitrogen | ● | ● | ● |
| Ammonia Nitrogen | ● | ● | ● |
| Calcium | | ● | |

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

## Watershed Analysis

The watershed analysis began with an accurate delineation of Antigo Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – Fry et. al 2011) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

## Aquatic Vegetation

### *Curly-leaf Pondweed Survey*

Surveys of curly-leaf pondweed were completed on Antigo Lake during a June 10, 2010 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 Antigo Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on August 27, 2010. A point spacing of 30 meters was used resulting in approximately 137 points.

### *Community Mapping*

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

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

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