Williams Lake

Marquette County, Wisconsin

Comprehensive Management Plan

June 2007

Sponsored by:

Williams Lake Protection & Rehabilitation District

&

Wisconsin Department of Natural Resources
Lake Management Grant Program

(LPL-1012-05 & LPL-1013-05)

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Onterra LLC
Lake Management Planning

Williams Lake

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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:

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INTRODUCTION

Williams Lake is an approximate 71-acre, shallow, drainage lake with a maximum depth of 6-feet and a mean depth of approximately 4-feet. The lake is plagued by Eurasian water milfoil (*Myriophyllum spicatum*) and as a result, the Williams Lake Protection and Rehabilitation District (WLPRD) has sponsored harvesting efforts to provide relief to lake users. Although the lake is burdened with the Eurasian water-milfoil, the stakeholders appreciate the recreational and aesthetic value of the lake and are concerned about its health beyond the obvious exotic plant infestation. As a result, they have extended their management efforts beyond just battling the exotic milfoil to creating a better understanding of the ecology and function of their shallow lake.

The document is divided into three primary sections and each section is written for the understanding of laypersons and professionals alike. The Results and Discussion Section outlines the results of the water quality analysis, watershed assessment, and numerous aquatic plant surveys that were completed on the lake. It also discusses this information in terms of Williams Lake and in terms of raising the reader's understanding of lakes and their function in a more general sense.

The Summary and Conclusions Section is written to be somewhat of a *stand-alone* document. It highlights the important results of the project and elaborates upon their implications upon the management of the lake. This section also sets the tone for the Implementation Plan.

The Implementation Plan is essentially the path the WLPRD will use to manage the lake over the next few years. The lifespan of the Implementation Plan is intentionally ambiguous because it is intended to be a living document that can flex and change with the needs of the group and those of the lake ecosystem. It is based upon realistic *management goals*. Each management goal contains *management actions* designed to lead the WLPRD to the meeting of that goal. Specific *action steps* are listed as a part of each management action. The management actions also contain a *timeline* and *facilitator* to guide its implementation.

As stated above, this document, especially the Implementation Plan, is intended to be a living document. This means that its findings and actions must be continuously revisited to ensure that the original management goals are being met and changes to the lake and the needs of the group are being accounted for in the lake's future management.

STAKEHOLDER PARTICIPATION

Effective natural resource planning relies on a blend of science and sociology. The social component of this project included three types of stakeholder participation:

1. The conveying of general and specific project information, such as why the project is important, what activities will take place, and what the results were.
2. Stakeholder education on general lake ecology and other important topics related to appropriate lake stewardship.
3. Direct stakeholder input to the development of the management plan.

A description of each stakeholder participation event can be found below, while supporting materials can be found in Appendix A.

Kick-off Meeting

On May 14, 2005 a special meeting was held with the WLPRD to inform district members about the project that was to begin that spring. Tim Hoyman of Onterra presented background as to why the project was being completed, discussed fundamental aspects of lake ecology and lake management, and answered questions from the audience.

Project Update

A brief project update was supplied to Mr. Mike Hammer early in September 2005 for him to share with the district board during their next meeting.

Planning Meeting I

A meeting was held on April 1, 2006 to begin the development of the implementation plan. During the meeting, Tim Hoyman and Eddie Heath of Onterra delivered a detailed presentation of the project's results and their conclusions. Following the presentation, the group discussed preliminary management goals and methods and actions that could be used to meet the goals.

Project Summary and Comment Form

Many goals and management actions were discussed at the first planning meeting; however, based upon the calls received by Onterra and district board members, it was apparent that some of the goals and actions were being misunderstood by the district membership. To curb these misconceptions and gather stakeholder perspectives on the management of Williams Lake, a summary of project results, conclusions, and preliminary options was created. This summary was provided to each member household during May 2006. The final paragraph of the document requested written comments from each household. Thirteen households provided comments which helped create a better understanding of how district members would like to manage Williams Lake so their recreational needs could be met.

Planning Meeting II

The second planning meeting was held on July 22, 2006. The meeting included a discussion concerning the comments that were received and how the implementation plan would be altered to meet the needs of the district. General management goals and activities were the primary result of this meeting.

Project Wrap-up Meeting

The final meeting of the project was held on August 26, 2006. During the meeting, a presentation made by Tim Hoyman included a general explanation of the project goals and components, a revisit to some of the lake management concepts introduced during the Kick-off meeting, a detailed description of the study results and conclusions, and an outline of the draft implementation plan. The draft implementation plan was provided to Planning Committee members for comments a week before the meeting. A good discussion spurred by a question and answer period followed the presentation.

RESULTS & DISCUSSION

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 the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, not all chemical attributes collected may have a direct or clear bearing on the lake's ecology, but may be more useful as indicators of other problems. Finally, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often very subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analysis are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the ecology of the lake. In other words, the water quality that most impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Six 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 analysis is elaborated upon below.

Comparisons with Other Datasets

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to similar lakes in the area. In this document, a portion of the water quality information collected at Williams Lake is compared to other lakes in the region and state. 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 Williams Lake water quality analysis:

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

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

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

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

Lillie and Mason (1983) is an excellent source of data for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Marquette County lakes are included within the study's Central Region (Figure 1) and are among 44 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide natural lake means and historic data from Williams Lake are displayed in Figures 2-4. Please note that the data in these graphs represent values collected only during the summer months (June-August) and the growing season (April-November) from the deepest location in Williams Lake (Map 1). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments (see discussion under Internal Nutrient Loading).

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

Apparent Water Quality Index

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

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

Trophic State

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

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

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

The WTSI is used extensively by the WDNR and is reported along with lake data collected by Citizen Lake Monitoring Network volunteers. The methodology is also used in this document to analyze the past and present trophic state of Williams Lake.

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 is going to need 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 concerns whether or not the lake thermally stratifies, which is determined primarily through the temperature profiles. Lakes that show strong stratification during the summer and winter months need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

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

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

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

Williams Lake Water Quality Analysis

Williams Lake Long-term Trends

Unfortunately, very little long-term data exists for Williams Lake. In fact, total phosphorus (Figure 2) and chlorophyll-*a* (Figure 3) data are limited to the data collected during this project. Secchi disk transparency data (Figure 4) does exist back to 1990, but one large gap in the dataset does exist between 1991 and 1999.

In 2005, summer and growing season total phosphorus values bordered on fair to good, while chlorophyll-*a* values for the same time period were very good. Water clarity values would be considered fair during the summer and growing season of 2005. The mean Secchi disk values for 2005 and for all other years must be taken in the context that the lake is shallow, and as a result, the Secchi disk often hits the bottom before it disappears from sight. During the 2005 growing season, the Secchi disk hit the bottom during the August and November samplings. The result is average water clarity values for that time period being lower than reality. Determining how much lower is impossible because there is no way of adjusting for the Secchi disk hitting the bottom. In terms of the long-term water clarity dataset (Figure 4), it is important to remember that it is actually impossible for the water clarity values to extend into the good range because the lake is seldom over 6 feet deep.

Unlike the total phosphorus concentrations and the water clarity values, the chlorophyll-*a* levels collected during 2005 would be considered very good and much better than the mean values of the region and state. Although the relationship is not completely correlated, we can assume that these chlorophyll-*a* concentrations are somewhat normal for Williams Lake because the 2005 clarity values are comparable with the weighted mean values based upon the entire dataset.

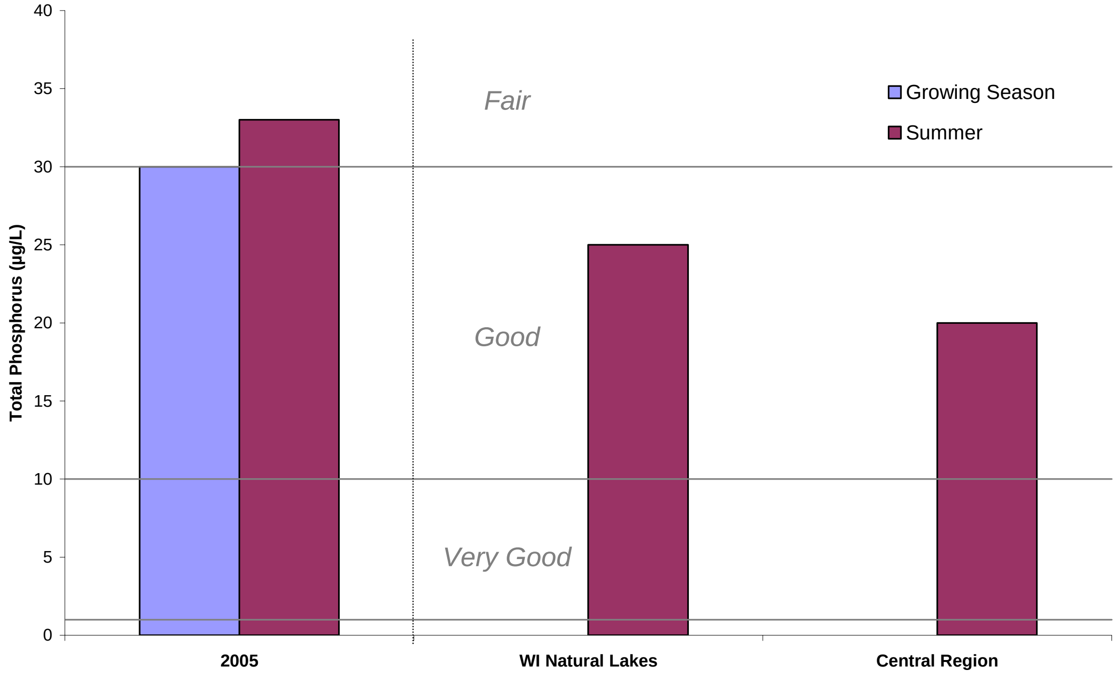

Figure 2. Williams Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

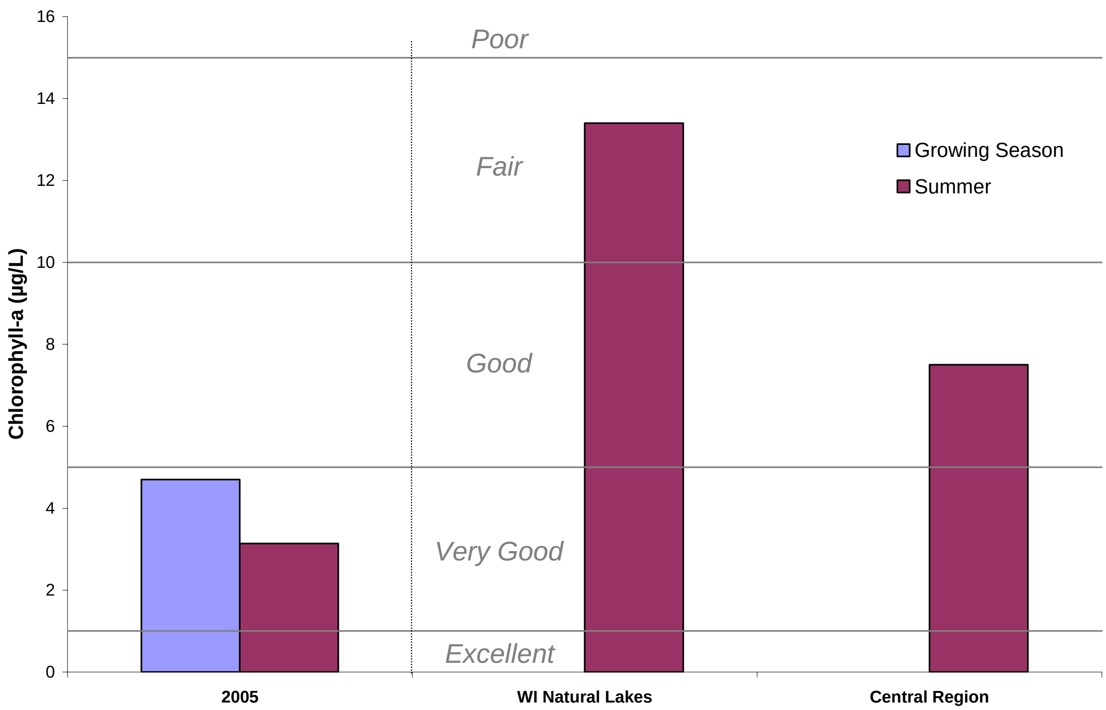

Figure 3. Williams Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

As with most shallow lake systems, the low algal abundance and good water clarity can likely be attributed to the high macrophyte (vascular plant) biomass. In shallow systems, algae and macrophytes fight to dominate the system. Lakes dominated by macrophytes are clearer and considered to be in a *clear state*, while systems dominated by algae are less clear and considered to be in a *turbid state*. For decades scientists believed that the battle for dominance revolved around competition for light and nutrients. However, in recent years, studies have shown that macrophytes provide important cover for macroscopic crustaceans, called zooplankton, that graze on algae. If the cover is lost, the zooplankton are freely preyed upon by fish. As the zooplankton numbers decrease, algal abundance increases and the waters become more turbid.

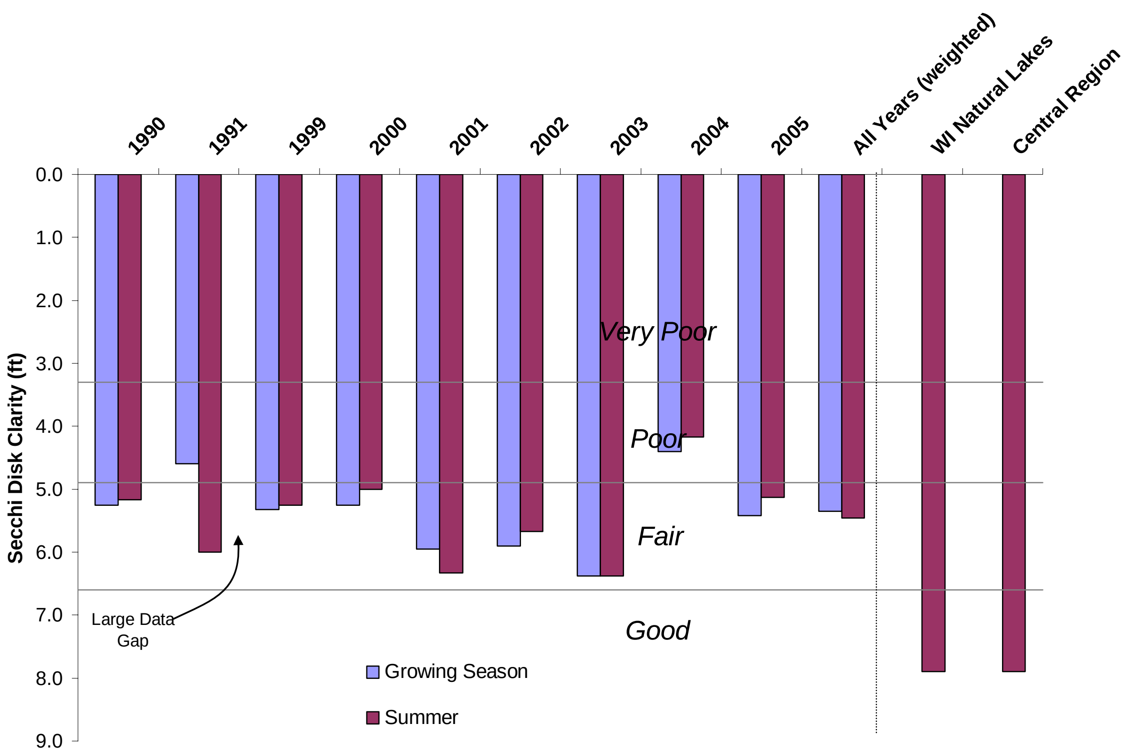

Figure 4. Williams Lake, regional, and state water clarity values. Mean values calculated with summer month sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Williams Lake Trophic State

Very little data is truly available for determining the trophic state of Williams Lake (Figure 5). Any of the water clarity data is suspect because of the limitations described in the section above. In fact, a Secchi disk depth of approximately 6.6 feet would be required for a WTSI value below 50, indicating that the lake is mesotrophic. This is of course impossible because the lake is only 6 feet deep. The chlorophyll-*a* data is also suspect because of the obvious impact that the high macrophytic biomass has on algae. Therefore, the only true parameter useable to determine the trophic state of Williams Lake is total phosphorus.

Unfortunately, the only total phosphorus data available for Williams Lake was collected during 2005. Using the single mean of 33 µg/L, a WTSI value of 55.4 is calculated indicating that

Williams Lake is eutrophic. This is not surprising considering the large amount of plant biomass that is in the lake and the size of the lake's watershed (see Watershed section).

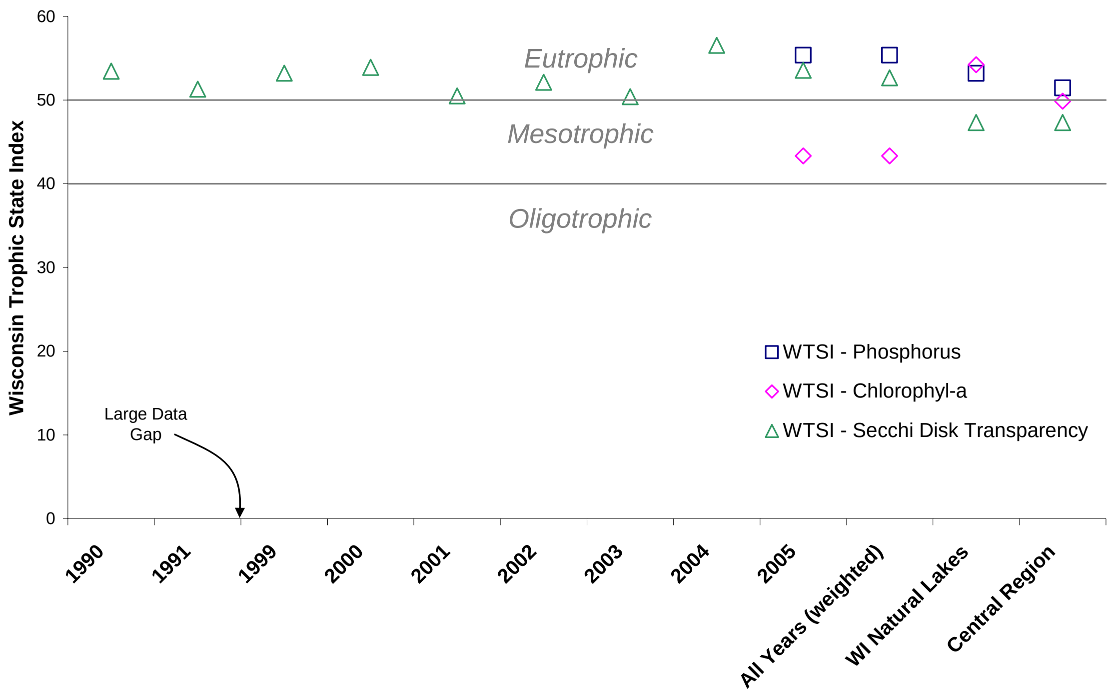

Figure 5. Williams Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Limiting Plant Nutrient in Williams Lake

Like most Wisconsin Lakes, Williams Lake would be considered phosphorus limited. This is indicated by the mid summer 2005 nitrogen to phosphorus ratio of 22.5:1.

Dissolved Oxygen, Temperature, and Internal Nutrient Loading in Williams Lake

Williams Lake would be considered a *polymictic* lake, meaning that it mixes many times throughout the year. This is shown in Figure 6 by the only slight differences in temperature with depth in each sampling's profile. For comparison, Figure 7 contains a profile taken in a stratified lake during mid summer. William Lake's shallow depth is the primary reason for its polymictic nature. As winds blow across the lake, the moderate amount of temperature stratification that occasionally occurs is easily upset. The mixing indicated in the winter profile (Feb. 15, 2006) is the result of the winter aeration system operating only 100 yards or so from the sampling site.

As a result of the near continuous mixing, the dissolved oxygen levels remain sufficient to support the lake's fishery throughout the year. It is likely that the lake would not hold sufficient oxygen throughout the winter if the aeration system was not used.

Also because of this continuous mixing and resulting oxic conditions, Williams Lake is not a good candidate for internal phosphorus loading.

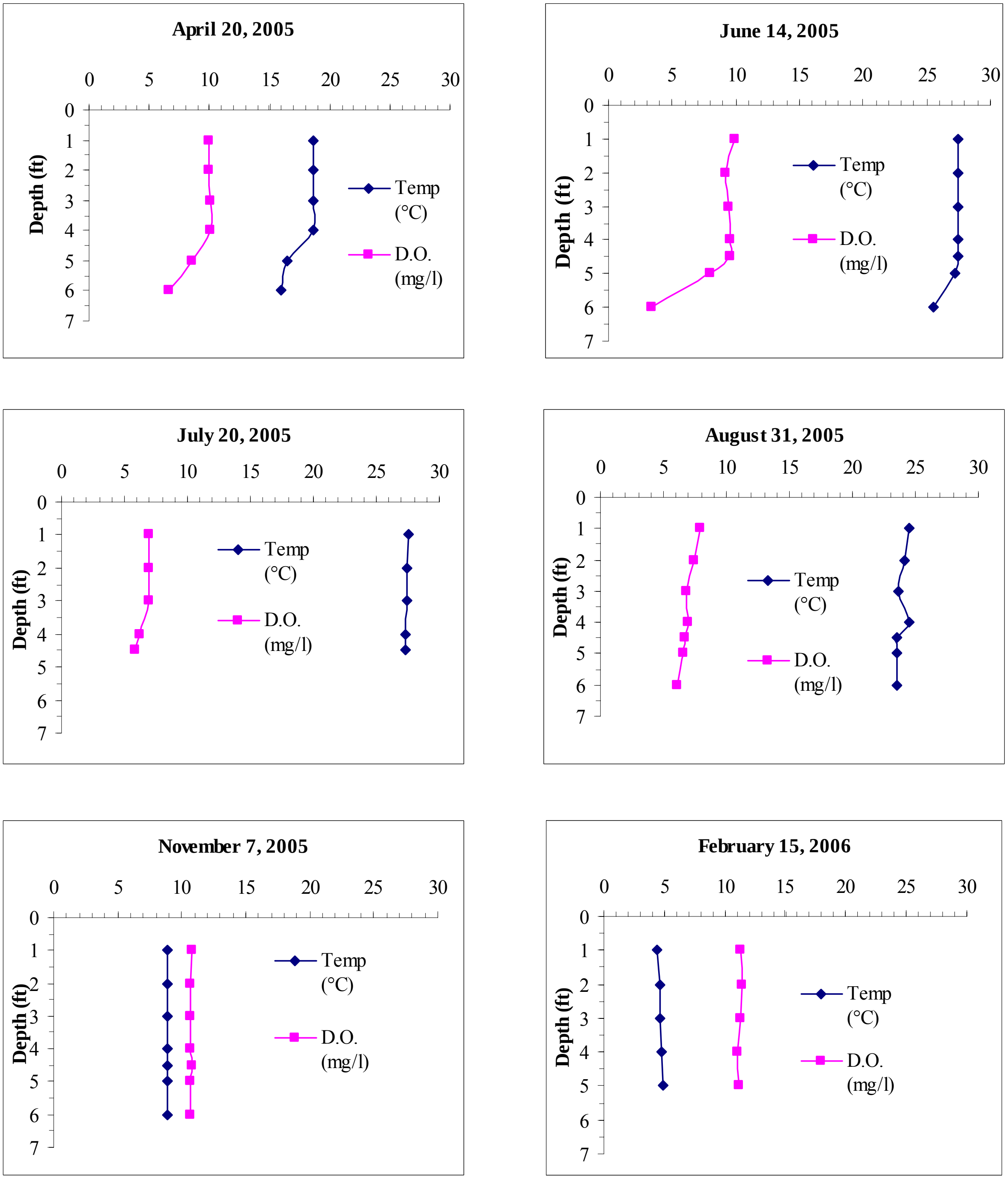

Figure 6. Williams Lake dissolved oxygen and temperature profiles collected during 2005 and 2006.

Watershed Analysis

The full Williams Lake watershed encompasses approximately 2,097 acres (Map 2). Roughly 650 acres, or 31% of the watershed, flows through Metcalf Lake before it enters Williams Lake. In the text below, the watershed area that flows directly to Williams Lake, without flowing through Metcalf Lake, is referred to as the *direct* Williams Lake watershed. The area that flows through Metcalf Lake before entering Williams Lake is referred to as the Metcalf Lake subwatershed.

A large portion of the direct Williams Lake watershed is forested, with the largest portion of the Metcalf Lake subwatershed being in pasture/grass (Figure 7). A small portion of the direct watershed is in row crops, while approximately 20% of the Metcalf Lake subwatershed is in row crops.

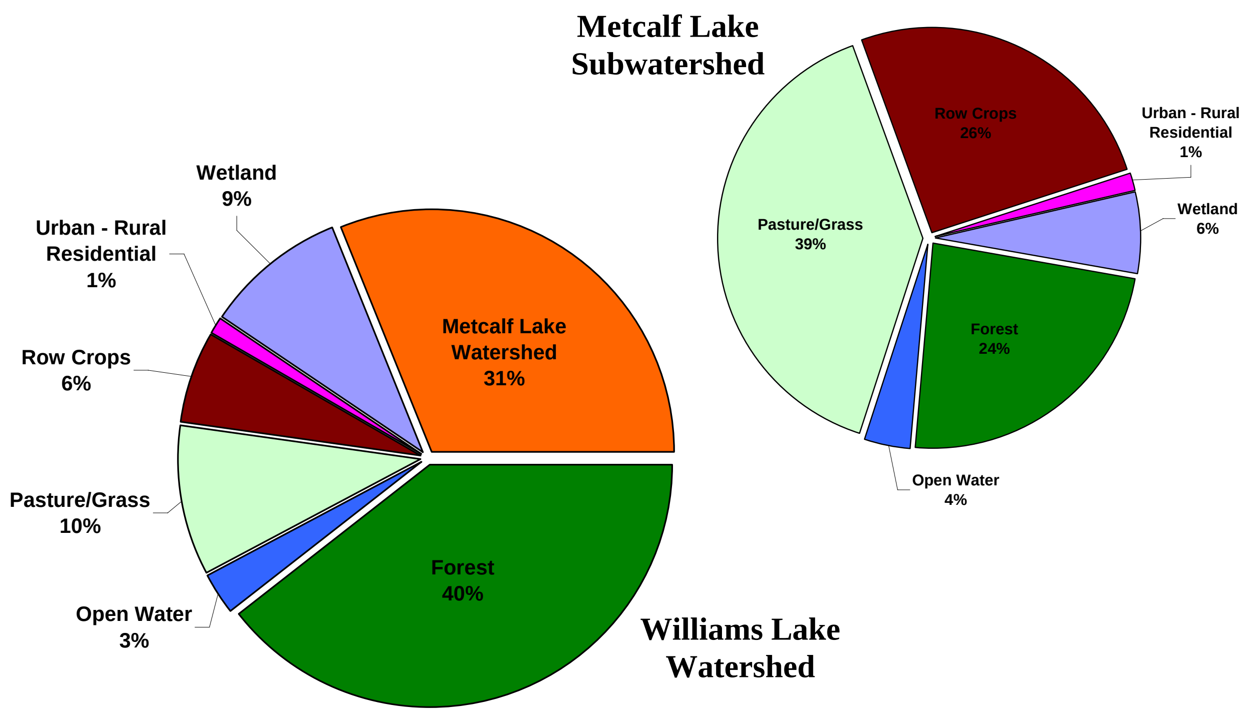

Figure 7. Williams Lake watershed land cover types, including Metcalf Lake subwatershed.

Land cover in a lake's watershed is import in lake management because each type of land cover exports different amounts of sediment and nutrients to the lake. Vegetated areas such as forests, grasslands, and meadows export the least because they allow most of the precipitation that falls on them to percolate to the groundwater resulting in very little overland runoff. Row crops and developed areas prevent the water from permeating to the groundwater and produce a great deal of surface runoff. The surface runoff picks up sediment, nutrients, and other pollutants and carries them to the lake.

Modeling of the land cover types found within the Williams Lake watershed estimates approximately 363 lbs. of phosphorus enters the lake annually. This load accounts for the entire

Williams Lake watershed, including the Metcalf Lake subwatershed. During the modeling procedures, the Metcalf Lake subwatershed is treated as a point-source to Williams Lake. By doing this, the model estimates the amount of settling that may occur as the water flows through Metcalf Lake before it enters Williams Lake.

Not surprisingly, the highest percentage of the phosphorus load originates from the row crop areas of the direct Williams Lake watershed (Figure 8). This is despite the fact that only 6% of the direct watershed is in row crops. Further, the forested areas that make up 40% of the direct Williams Lake watershed only export 19% of the lake's total phosphorus load.

The phosphorus loaded to Williams Lake from its watershed is responsible for the productive nature of the lake as described in the Water Quality Section. In some instances, reducing external phosphorus loads can lead to lower production within in lake. However, it the case of Williams Lake, significant reductions in phosphorus loads would not necessarily lead to a lower trophic state. For example, the discussion above states that row crops export the highest amount of phosphorus, especially when compared to forested areas. Logically, converting land used for row crops to forested areas would reduce phosphorus loads to the lake. In any lake ecosystem, this would be true; however, the caveat is whether or not the reduction is sufficient to lower the production rate within the lake and as a result lower the trophic state.

The scenario of reforesting all of the row crop areas within the Williams Lake watershed can be modeled using the similar procedures as described above. The results of the modeling effort indicate that the annual phosphorus load reaching Williams Lake would be reduced to approximately 215 lbs – a 40% reduction. This is a substantial reduction in annual phosphorus loading; however, further analysis indicates that the load would support growing season phosphorus concentrations exceeding 18 μg/L. Unfortunately, a lake with average phosphorus concentrations at that level would still be considered eutrophic.

Essentially, the modeling indicates that even with drastic changes in the watershed, that Williams Lake would still be productive. In other words, it would still support a high level of plant growth. This is the case because of the amount of land that drains to the lake. The watershed to lake area ratio expresses how much land drains to each acre of a lake. In the case of Williams Lake, the watershed to lake area ratio is 33:1. Data from Lillie and Mason (1983) suggest that Wisconsin lakes with relatively low watershed to lake area ratios of 5:1 still average summer phosphorus values considered as mildly eutrophic.

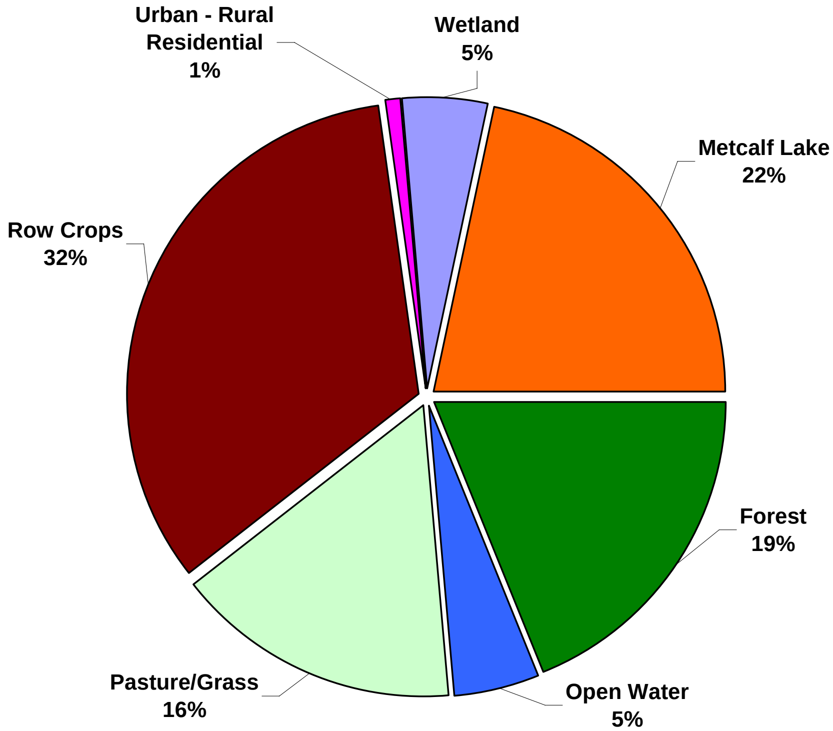

Figure 8. Williams Lake estimated annual phosphorus load by land cover type, including Metcalf Lake subwatershed inputs as a point-source.

Aquatic Plants

Introduction

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

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the *periphyton* attached to them as their primary food source. The plants also provide cover for feeder fish and *zooplankton*, stabilizing the predator-prey relationships within the system.

Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by *phytoplankton*, which helps to minimize nuisance algal blooms.

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

When plant abundance negatively affects the lake ecosystem and limits the use of the resource, plant management and control may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods. No lake 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.

Please note: Although many of the control techniques outlined in this section are not applicable to Williams Lake at this time, 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**.**

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 plant removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that length. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR. It is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management Specialist.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects. The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind. 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 because of the reduced canopy and decrease filtration of potentially harmful nutrients and pollutants before they enter the lake. Furthermore, the dumping of sand or rock to create beach areas or shoreline enhancement destroys spawning, cover and feeding areas utilized by aquatic wildlife.

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 the shoreland's natural function.

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

Cost

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

- The single site used for the estimate indicated above has the following characteristics:
    - An upland buffer zone measuring 35' x 100'.
    - An aquatic zone with shallow-water and deep-water areas of 10' x 100' each.
    - Site is assumed to need little invasive species removal prior to restoration.
    - Site has a moderate slope.
    - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
    - Plant spacing for the aquatic zone would be 3 feet.
    - Each site would need 100' of biolog to protect the bank toe and each site would need 100' of wavebreak and goose netting to protect aquatic plantings.
    - Each site would need 100' of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
    - There is no hard-armor (rip-rap or seawall) that would need to be removed.
    - The property owner would maintain the site for weed control and watering.

Advantages

Improves the aquatic ecosystem through species diversification and habitat enhancement.
Assists native plant populations to compete with exotic species.
Increases natural aesthetics sought by many lake users.
Decreases sediment and nutrient loads entering the lake from developed properties.
Reduces bottom sediment resuspension and shoreline erosion.
Lower cost when compared to rip-rap and seawalls.
Restoration projects can be completed in phases to spread out costs.
Many educational and volunteer opportunities are available with each project.

Disadvantages

Property owners need to be educated on the benefits of native plant restoration before they are willing to participate.
Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in.
Monitoring and maintenance are required to assure that newly planted areas will thrive.
Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Manual Removal

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

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width.

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

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1200 to $11,000 and permits may be required.

Advantages

Very cost effective for clearing areas around docks, piers, and swimming areas.
Relatively environmentally safe if treatment is conducted after June 15th.
Allows for selective removal of undesirable plant species.
Provides immediate relief in localized area.
Plant biomass is removed from waterbody.

Disadvantages

Labor intensive.
Impractical for larger areas or dense plant beds.
Subsequent treatments may be needed as plants recolonize and/or continue to grow.
Uprooting of plants stirs bottom sediments making it difficult to harvest remaining plants
May disturb *benthic* organisms and fish-spawning areas.
Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant colonization on top of the screen.

Cost

Material costs range between $.20 and $1.25 per square-foot and require a permit. 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 are about $120 each year.

Advantages

Immediate and sustainable control.
Long-term costs are low.
Excellent for small areas and around obstructions.
Materials are reusable.
Prevents fragmentation and subsequent spread of plants to other areas.

Disadvantages

Installation may be difficult over dense plant beds and in deep water.
Not species specific.
Disrupts benthic fauna.
May be navigational hazard in shallow water.
Initial costs are high.
Labor intensive due to the seasonal removal and reinstallation requirements.
Does not remove plant biomass from lake.

Not practical in large-scale situations.

Water Level Drawdown

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

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive. A permit is needed to conduct a water level manipulation.

Advantages

Inexpensive if outlet structure exists.
May control populations of certain species, like Eurasian water-milfoil for up to two years.
Allows some loose sediments to consolidate.
May enhance growth of desirable emergent species.
Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.

Disadvantages

May be cost prohibitive if pumping is required to lower water levels.
Has the potential to upset the lake ecosystem and have significant affects on fish and other aquatic wildlife.
Adjacent wetlands may be altered due to lower water levels.
Disrupts recreational, hydroelectric, irrigation and water supply uses.
May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).
Permitting process requires an environmental assessment that may take months to prepare.
Unselective.

Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor.

Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the later route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

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

Advantages

Immediate results.
Plant biomass and associated nutrients are removed from the lake.
Select areas can be treated, leaving sensitive areas intact.
Plants are not completely removed and can still provide some habitat benefits.
Opening of cruise lanes can increase predator pressure and reduce stunted fish populations.
Removal of plant biomass can improve the oxygen balance in the littoral zone.
Harvested plant materials produce excellent compost.

Disadvantages

Initial costs and maintenance are high if the lake organization intends to own and operate the equipment.
Multiple treatments may be required during the growing season because lower portions of the plant and root systems are left intact.
Many small fish, amphibians and invertebrates may be harvested along with plants.
There is little or no reduction in plant density with harvesting.
Invasive and exotic species may spread because of plant fragmentation associated with harvester operation.
Larger harvesters are not easily maneuverable in shallow water or near docks and piers.
Bottom sediments may be resuspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

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

1. *Contact herbicides* act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to the applicator, fish, amphibians, reptiles, birds, and non-target plant species, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use. The lake group must also take into consideration that even though these chemicals are labeled for aquatic use by the Environmental Protection Agency for use in aquatic systems, there are still inherent risks in their use because they have not been tested under all possible environmental conditions.

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

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

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

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

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

<u>2,4-D</u> (Navigate®, Aqua-Kleen®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water milfoil without affecting the majority of our native plants, which are narrow-

leaved species (monocots). However, some native species, like northern water milfoil, coontail, and bladderwort, are dicots; therefore great care must be taken when using 2,4-D in proximity of these important plants. Many times, treating in early spring, before native species start to grow, can reduce the risk to native dicots considerably. Drinking and irrigation restrictions may apply. A chemical treatment permit is needed for this management technique.

Advantages

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

If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil.

Some herbicides can be used effectively in spot treatments.

Disadvantages

Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly.

Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them.

Many herbicides are nonselective.

Most herbicides have a combination of use restrictions that must be followed after their application.

Many herbicides are slow-acting and may require multiple treatments throughout the growing season.

Cost

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

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is not need for either biocontrol insect. However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water-milfoil. Wisconsin is also using two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These biocontrol insects are not covered here because purple loosestrife is predominantly a wetland species.

Advantages

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

Disadvantages

Stocking and monitoring costs are high.
This is an unproven and experimental treatment.
There is a chance that a large amount of money could be spent with little or no change in Eurasian water-milfoil density.

Cost

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

Primer on Aquatic Plant Data Analysis & Interpretation

Aquatic plants are a fundamental part in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. With periodic monitoring and proper analysis, these changes are can be detected and provide critical information for management decisions.

As described in more detail in the methods section, two aquatic plant surveys were completed on Williams Lake during 2005; the first looked strictly for curly-leaf pondweed, and the second inventoried all native and non-native aquatic species found in the lake. 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.

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 loses 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 Williams Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, relative frequency of occurrence is used to describe how often each species occurred in the plots that contained vegetation. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be as diverse as 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 diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality index of Williams Lake are compared to lakes in the same ecoregion (Figure 9) and in the state.

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 with species that are normally found in disturbed systems having lower coefficients, while species frequently found in pristine systems having 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.

Figure 9. Location of Williams Lake within the ecoregions of Wisconsin. After Nichols 1999.

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 future surveys. 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 completely 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.

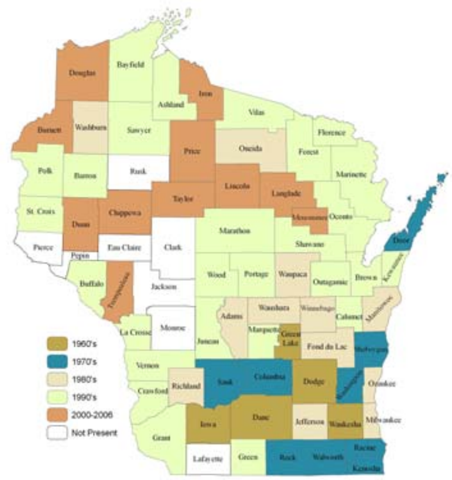

Figure 10. Spread of Eurasian water milfoil among WI counties. WDNR Data 2006 mapped by Onterra.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 10). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads mostly 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.

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.

2005 Williams Lake Aquatic Plant Surveys

The aquatic plant surveys completed in 2005 discovered 31 aquatic plant species within Williams Lake (Table 1). Two of these species, curly-leaf pondweed and Eurasian water milfoil, are non-natives in Wisconsin and are expanded upon below.

Table 1. Aquatic plant species located in Williams Lake during 2005 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2000	2005
Emergent	*Carex comosa*	Bristly sedge	5		X
	Iris versicolor	Northern blue flag	5		X
	Sagittaria latifolia	Common arrowhead	3		X
	Schoenoplectus acutus	Hardstem bulrush	5		X
	Schoenoplectus pungens	Three-square rush	5		X
	Typha angustifolia	Narrow-leaved cattail	1		X*
	Typha latifolia	Broad-leaved cattail	1		X
FF	*Lemna minor*	Lesser duckweed	5	X	X
	Lemna trisulca	Forked duckweed	6		X
	Spirodela polyrrhiza	Greater duckweed	5		X
FL	*Brasenia schreberi*	Watershield	7		X
	Nuphar variegata	Spatterdock	6	X[1]	X
	Nymphaea odorata	White water lily	6	X[2]	X
Suberment	*Ceratophyllum demersum*	Coontail	3		X
	Chara sp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Elodea nuttallii	Slender waterweed	7		X
	Heteranthera dubia	Water stargrass	6		X
	Myriophyllum sibiricum	Northern water milfoil	7	X[3]	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X[3]	X
	Najas flexilis	Slender naiad	6	X	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic		X
	Potamogeton gramineus	Variable pondweed	7		X
	Potamogeton illinoensis	Illinois pondweed	6	X	X
	Potamogeton praelongus	White-stem pondweed	8	X	
	Potamogeton pusillus	Small pondweed	7		X
	Potamogeton richardsonii	Clasping-leaf pondweed	5		X
	Potamogeton zosteriformis	Flat-stem pondweed	6		X
	Stuckenia pectinata	Sago pondweed	3	X	X
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5		X

FF = Free Floating
FL = Floating Leaf
FL/E = Floating Leaf and Emergent
S/E = Submergent and Emergent
* = Incidental occurrence
X[1] = Reported as *Nuphar* sp. and as an incidental occurence
X[2] = Reported as *Nymphaea* sp.
X[3] = Both species reported as presented, refered to as *Myriophyllum* sp. and not differentiated

Table 1 lists the species located within Williams Lake during surveys completed in 2000 (Aron & Assoc. 2000) and in 2005. Although it is impossible to determine the exact reasons, the differences between the lists are likely caused by differences in plant sampling techniques and effort. For instance, the results of the 2000 survey did not include any emergent species. It is highly unlikely that the emergent species found during the 2005 survey suddenly appeared between 2000 and 2005; however, it is likely that the survey completed in 2000 did not consider the emergents to be lake species, but instead considered them wetland species. Furthermore, the fact that curly-leaf pondweed is listed in the 2005 survey results and not in those of 2000 is not necessarily an indication that curly-leaf pondweed did not occur within Williams Lake until after 2000. In fact, it may have been there before 2000, but was not located during the survey completed in that year because it was completed in July, possibly after the majority of the biomass had died. Conversely, this project included a survey completed during the early summer specifically looking for curly-leaf pondweed. In the end, we cannot assume that the differences between the two species lists indicate changes in the Williams Lake ecosystem.

The occurrence analysis of the 2005 aquatic plant survey data (Figure 11) indicates that Williams Lake is dominated by four submergent species; slender naiad, Eurasian water milfoil, Illinois pondweed, and muskgrasses. Considering that the entire lake basin is 6 feet or less in depth and available for plant growth, it is not surprising that the aquatic plant community is dominated by submergent species. However, the level of dominance may be misleading because of the plant survey crew's inability to reach all areas of the lake due to shallow depths. In fact, 42% of the large basin's surface area is dominated by floating-leaf species (Map 3) and within that area, 49% of the points were not reachable. If all of those points were able to be sampled and each point contained white water lily (very likely), the relative frequency of that species would have surpassed common waterweed. Although this is not a major increase relative frequency, it does clarify that floating-leaf species are a very important component within the Williams Lake plant community.

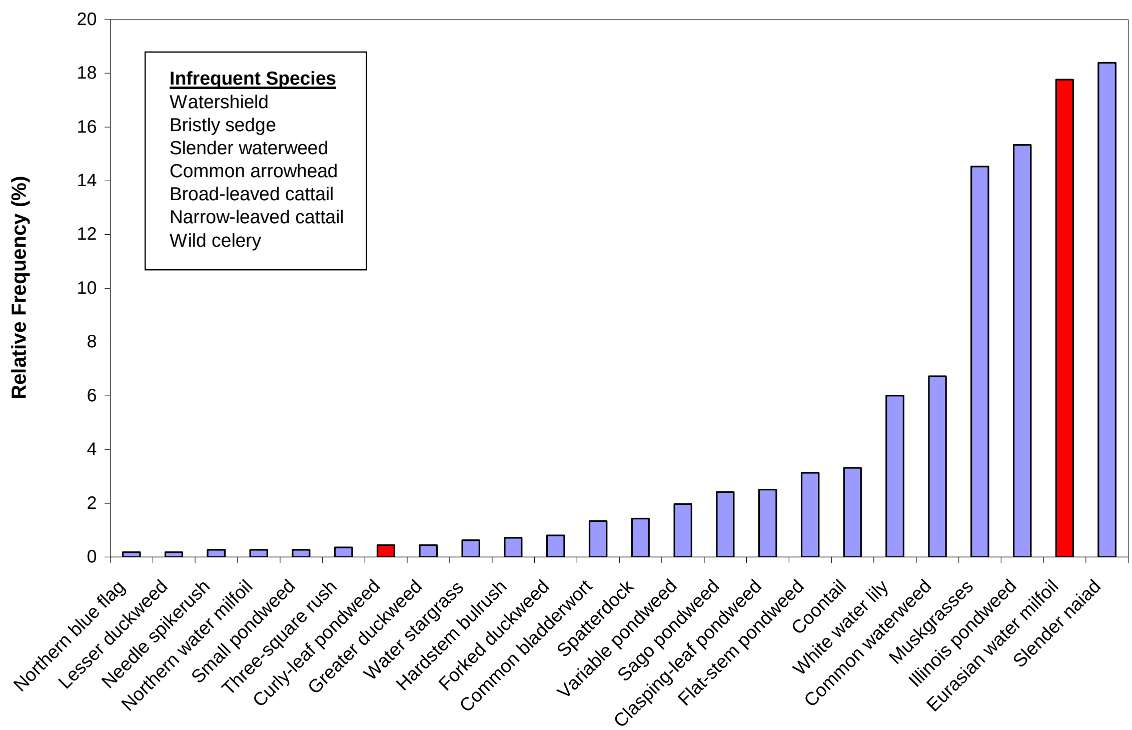

Figure 11. Williams Lake occurrence analysis of 2005 aquatic plant survey data. Exotic species indicated in red.

Williams Lake would be considered a moderately diverse system with a Simpson's Diversity value of 0.88. For comparison, unimpaired lakes in northern Wisconsin that were sample during 2004 and 2005 were found to have diversities ranging from 0.90 to 0.93, while during that same timeframe, Buffalo Lake, a highly impaired system, was found to have a diversity value of 0.84. Williams Lake is an excellent example of a system that has high species richness, but is not highly diverse. This is true because Williams Lake's plant community is highly dominated by four or five species. If the relative frequencies of all the species were more evenly distributed, Williams Lake would be considered more diverse.

As described above, the FQA mathematically combines a lake's species richness and average conservatism values to obtain the lake's floristic quality (Nichols 1999). These component values and resulting floristic quality values for Williams Lake (2000 and 2005 surveys) are displayed with corresponding median values from the state and ecoregion in Figure 12. The reasoning for the differences in species richness between the 2000 and 2005 datasets are explained above. The differences between the 2005 survey data and the state and ecoregion medians are real. Often, this is not the case because the researchers that developed the FQA only included certain plants as "lake plants", while many aquatic plant surveys include all plants within the lake and even on the immediate shoreline as lake plants. As result, the species richness of some lakes may be unrealistically higher than the state and ecoregion medians because the same plant species were not considered in each study. In the case Williams Lake, only a single plant (northern blue flag) was included within the 2005 species richness that was not included in Nichols 1999; therefore, the comparisons made between the two datasets are valid.

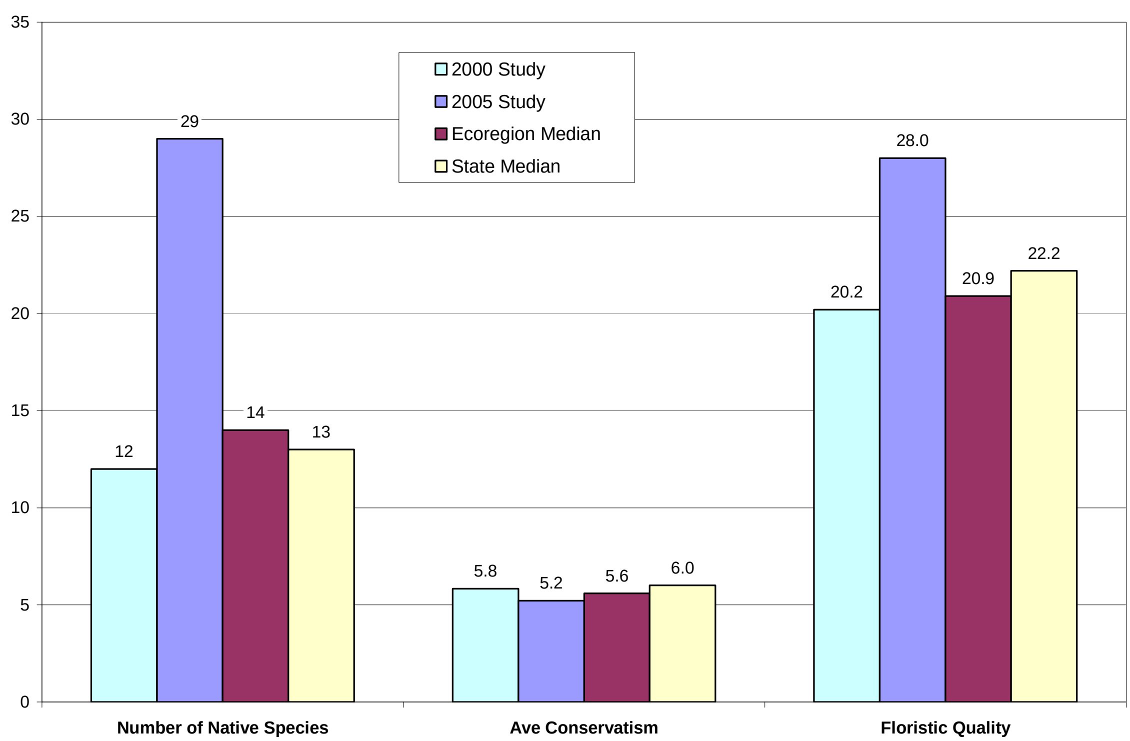

Figure 12. Floristic Quality Analysis using 2000 and 2005 aquatic plant survey data from Williams Lake. Analysis following Nichols 1999.

Although the species richness of Williams Lake is considerably higher than most lakes found in the state and ecoregion, its average coefficient of conservatism is slightly lower than the ecoregion median and much lower than the median value for the state. Combining the species richness and average coefficient of conservatism values of the 2005 Williams Lake data produces a relatively high floristic quality for the lake. Overall this means that Williams Lake has an aquatic plant community of high floristic quality that is made up of species indicative of disturbed systems.

Exotic Plant Species

Curly-leaf Pondweed

A meander survey of Williams Lake was completed on May 31, 2005 expressly for mapping curly-leaf pondweed occurrences. The survey results are contained within Map 4 and indicate that although curly-leaf pondweed occurs in many areas of the lake, it certainly has not spread to the point that it should be considered a substantial infestation. In fact, it may be that the plant was introduced to the lake within the last decade and has been found early before dense stands have developed and negative impacts to the lake have arisen. Those negative impacts may include reduced species diversity, mid summer phosphorus spikes, and navigational difficulties. In a nutrient-rich and productive system such as Williams Lake, curly-leaf pondweed could take over large portions of the lake's substrate, preventing growth of native plants. Then, in early July, die back with the decomposition of the dead plants resulting in increased phosphorus levels that fuel mid summer algae blooms. Once this pattern begins, it is very difficult to break because of curly-leaf pondweed's ability to start growing very early in spring which gives it a definite advantage over native plants.

Eurasian Water Milfoil

Unfortunately, Eurasian water milfoil was found to occur in nearly all areas of Williams Lake (Map 5), with nearly 73% of the 272 points sampled during July 2005 containing the exotic plant. In some lakes, Eurasian water milfoil occurs in dense colonies, while in others its extents are limited to a scattering in certain areas of the lake. In both of these cases, the Eurasian water milfoil may be limited by substrate type or depth. In Williams Lake, these two factors do not restrict Eurasian water milfoil growth; still the plant does not occur in dense stands throughout much of the lake. Instead, it occurs in moderate to low densities over almost the entire lake (Figure 13). It is important to note that the 2005 studies were completed while normal harvesting activities were taking place on Williams Lake; therefore, the results and subsequent conclusions of the studies may be somewhat unrealistic. However, the fact remains that Eurasian water milfoil is one of the most abundant plants in the lake – second only to slender naiad (Figure 11).

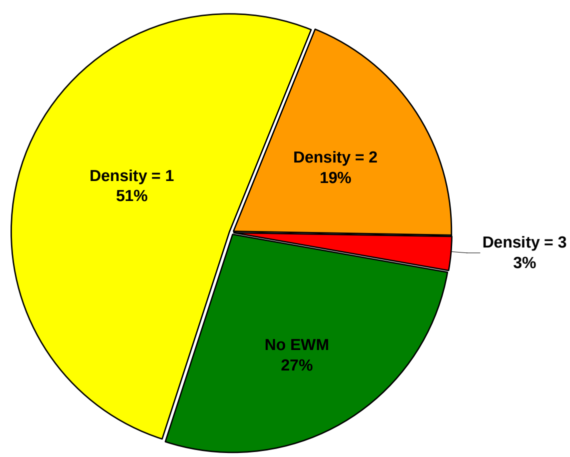

Figure 13. Percentage of total points sampled (272) containing varying densities of Eurasian water milfoil in Williams Lake. Densities based upon rake fullness as described in Methods Section.

SUMMARY AND CONCLUSIONS

The water quality of assessment of Williams Lake was severely limited by the nearly complete lack of historic data. With the exception of Secchi disk readings that date back to the early 1990's, there is no water quality data available for the lake; therefore, many assumptions must be made when judging the lake's health and trophic state over time.

The water quality data collected during 2005 indicates that Williams Lake has relatively high phosphorus values that could support abundant algal populations within the lake. However, Williams Lake does not support high algal abundances, instead the 2005 studies found chlorophyll *a* values in Williams Lake considered to be very good and that those values were lower than average values found in similar lakes of the state and region. The low algal abundance within the lake leads to clear water and as a result high Secchi disk values. Determining the actual extent of the Secchi disk values is impossible because their depth is often limited by the depth of the lake.

Trophic state analysis using Williams Lake total phosphorus values indicates that the lake is eutrophic, or moderately productive. This is likely a conservative estimate because the Wisconsin Trophic State Index (WTSI) does not account for the productivity of macrophytes, in fact, it relies completely on the relationship between phosphorus, chlorophyll *a*, and water clarity. Considering the incredible amount of macrophytic plant biomass within the lake, it is quite obvious that Williams Lake is highly productive. It is also quite obvious that if the vascular plants did not exist, Williams Lake would be drastically different because it would be dominated by algal productivity and as a result, be incredibly turbid and green.

As with most lake ecosystems in Wisconsin, phosphorus is controlling the productivity within Williams Lake and in the case of this particular lake, the majority of that phosphorus is coming from the watershed. As described in the Watershed Section, even with major changes in the watershed, including the conversion of all row crop areas to forest, the watershed would still supply sufficient phosphorus to the Williams Lake to keep it in a eutrophic state. This is because for every acre of Williams Lake, there are 33 acres of land draining to it. Essentially, Williams Lake will always be able to support high plant biomasses.

Currently, the high biomass of plants in Williams Lake is in the form of macrophytes and not algae. This is important because in shallow, productive lakes, like Williams Lake, there is a constant battle between two plant groups – the macrophytes and algae. The two groups compete for nutrients, space, and light and in the end, one group will dominate the lake. In Williams Lake, the macrophytes are in control. If the macrophytes were not the dominate plant group, Williams Lake would be very turbid with algal growth. Therefore, it is obvious that the aquatic plants in Williams Lake are important to the health and condition of the lake beyond that of providing fish habitat.

The 2005 studies showed that the plant community is moderately diverse and because of the high number of species found in the lake, it is of high floristic quality. The problem is that much of the biomass within the lake is currently in the form of exotic plants. As stated in the Aquatic Plants Section, there are very few dense colonies of Eurasian water milfoil within Williams Lake, but instead the plant occurs in almost all areas of the lake in light to moderate densities.

As a result, the canopying of the plant is a nuisance over much of the lake's surface area, which restricts recreational use, whether it is fishing, swimming, or boating.

Although it does not work to reduce the occurrence of Eurasian water milfoil, at the present time harvesting is really the only option for maintaining the aesthetics and creating the recreational areas desired by the Williams Lake stakeholders. Wide-scale use of granular 2,4-D (Navigate®), although selective against Eurasian water milfoil, would be cost-prohibitive, while a whole-lake treatment using fluridone (Sonar®) would be risky considering it is known to impact some of the more abundant plants in Williams Lake, such as slender naiad, waterweed, and coontail. At the surface, the latter may seem appealing, but killing off a large portion of the plants within the lake could have drastic results and could possibly convert Williams Lake from a macrophyte-dominated lake to a turbid lake dominated by algae.

Research is currently being completed on large-scale applications of low dosages of liquid 2,4-D, which is much less costly than the granular form but still considered selective towards Eurasian water milfoil. A lake-wide treatment aimed at controlling both curly-leaf pondweed and Eurasian water milfoil using a combination of liquid 2, 4-D at 1.0 ppm and endothal at 0.5 ppm (or appropriate chemical concentrations based on most widely accepted practices at that time) when water temperatures are around 60°F may be a feasible management strategy as the technology and supporting research continue to move forward. Treatments of this nature would likely need to be repeated during subsequent years and the ability of attaining a multi-year chemical treatment permit would have significant advantages. It would be appropriate to discontinue harvesting operations during the treatment years to allow for adequate assessment of the management strategy and limit fragments and turions to be spread around the lake.

Winter drawdown would likely have positive results by reducing Eurasian water milfoil within the lake. Unfortunately, only Packers Bay could realistically be lowered significantly without the use of pumps, which would be costly.

Curly-leaf pondweed was shown to occur in limited areas through out the lake, but has not reached nuisance levels. Yet, if the plant is left unchecked, it will likely take advantage of the nutrient-rich waters and continue to spread and become denser. Over time curly-leaf pondweed may become more of a problem in Williams Lake than Eurasian water milfoil. Attacking the problem now, while densities are still manageable will be key to successfully controlling this exotic species.

IMPLEMENTATION PLAN

Management Goal 1: Maintain Current Recreational Opportunities and Aesthetics of Williams Lake

Management Action: Mechanical harvesting to control Eurasian water milfoil.
Timeframe: In progress
Facilitator: District Commissioners
Description: As described in the Aquatic Plant Section, Eurasian water milfoil occurs in the vast majority of Williams Lake. As early as mid May, the plant canopies and forms a thick mat of vegetation leading to decreased lake aesthetics and recreation. Since 1991, the WLPRD has harvested to reduce the impact of Eurasian water milfoil. In 2000, the district adopted a formal harvest plan (Aron & Associates 2000) which included three types of harvesting; primary channels (10 acres), secondary channels (4 acres), and Eurasian water milfoil canopy harvesting (31 acres), leading to approximately 45 acres of harvesting annually. Please note that GIS analysis of a rectified harvest map indicates that the actual total harvest area is approximately 27.7 acres. The original plan called for the Eurasian water milfoil canopy harvesting areas to be cut to 1-2 feet below the water surface. The district has discovered that due to the rapid growth of the plant that they must harvest to approximately 4 feet below the surface to maintain control of the plant.

Map 6 indicates the areas that will be harvested to meet this goal. Areas currently containing important floating-leaf and emergent species have been excluded from the harvesting plan to maintain habitat value. Two exceptions occur on the east shore of the lake in order to provide access to riparians. A secondary benefit to the new harvesting plan will the reduction of plant biomass that may lead to anoxic conditions during winter decomposition.

Action Steps:

1. Obtain harvesting permit from WDNR.
2. Follow harvesting plan as indicated in Map 6.

Management Goal 2: Reduce Occurrence of Curly-leaf Pondweed

Management Action: Early-season harvesting of curly-leaf pondweed.
Timeframe: Begin spring 2007
Facilitator: District Commissioners
Description: During May 2005 curly-leaf pondweed was found to occur in Williams Lake in numerous locations within Williams Lake (Map 4). The WLPRD realizes that its current harvesting activities are likely leading to accelerated spread of the plant throughout the lake. To curb this spread and possibly reduce the overall occurrence of the plant, the district will begin to harvest specific areas of the lake (Map 6) in late April before turions are produced. The premise being that the harvesting will reduce the ability of the curly-leaf pondweed to produce turions. As a result, the normal harvesting activities of the district will not spread the turions to new locations. Furthermore, as the turion base is reduced over the course of several years, the lake-wide occurrence of curly-leaf pondweed may be reduced.

An important component of this management action will be curly-leaf pondweed monitoring by district volunteers. These efforts will be undertaken to direct harvesting activities and monitor the action's effectiveness.

Action Steps:

1. Recruit and train volunteer monitors.
2. Obtain harvesting permit from WDNR (first year based upon Map 6).
3. Map curly-leaf occurrences approximately 2 weeks after ice-out.
4. Devise harvesting plan based upon monitoring results.
5. Evaluate and update management action annually.

Management Goal 3: Maintain Current Water Quality Conditions

Management Action: Expand current water clarity monitoring to include enhanced water quality monitoring based upon WDNR Citizen Lake Monitors Network (CLMN) protocol.
Timeframe: Start in 2007
Facilitator: Geoff and Mary Sue Iverson
Description: Monitoring of water quality is an important aspect of all lake management efforts. The district is currently monitoring water clarity through the WDNR CLMN and will enhance its monitoring by collecting water samples for chlorophyll-*a*, total phosphorus, and dissolved oxygen analysis.

Action Steps:

1. Contact Mr. Mark Sesing, WDNR to enroll in program.
2. Collect and analyze samples as described in protocol.
3. Report results to district on an annual basis.

Management Action: Reduce phosphorus and sediment loads from immediate watershed.
Timeframe: Begin 2007
Facilitator: Mary Murren
Description: The Williams Lake watershed is rather large when compared to the size of the lake, as a result, the impacts that are most controllable at this time originate along the lake's immediate shoreline. These sources include faulty septic systems, the use of phosphorus-containing fertilizers, and shoreland areas that are maintained in an unnatural manner. To reduce these impacts, the district will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include news letter articles and guest speakers at district meetings.
Action Steps:

1. Facilitator gathers appropriate information from WDNR, UW-Extension, Marquette County and other sources.
2. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for district meetings.

METHODS

Lake Water Quality

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

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

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 4.

Aquatic Vegetation

A quantitative aquatic vegetation survey was conducted during July 2005 using the point-intercept method as described in "Appendix C" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin - Draft, (April 25, 2005) was be used to complete the study. Based upon advice from the WDNR, a point spacing of 30 meters was used resulting in approximately 329 points (57 points were unreachable) (Appendix C). Furthermore, all species found outside the set points would be recorded to provide a complete species list for the lake.

Watershed Analysis

The watershed analysis began with an accurate delineation of Williams Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) were then combined to determine the preliminary watershed land cover classifications. These data along with modified data representing the different scenarios outlined in the management plan were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003).

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