DRAFT

Little Saint Germain Lake

Vilas County, Wisconsin

Comprehensive Management Plan

December 2017

Created by: Eddie Heath, Tim Hoyman, Paul Garrison, Brenton Butterfield, Todd Hanke
Onterra, LLC
De Pere, WI

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Acknowledgements

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

Little Saint Germain Lake Planning Committee

Tom Groth - Chairperson	Dennis Nielsen
Tom Schwartz	Mark Hiller
Cheryl Kelsey	Dave O'Malley

DRAFT

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOS

MAPS

APPENDICES

1.0 INTRODUCTION

According to the August 1975 recording sonar WDNR Lake Survey Map, Little Saint Germain Lake is 980 acres. The WDNR website list the lake as 972 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program (NAIP)* collected in June 2015. Based upon heads-up digitizing the water level from that photo, the lake was determined to be 979 acres. Water flows out of South Bay via Little Saint Germain Lake into the nearby Wisconsin River (Map 1). Water levels in the lake are artificially maintained approximately 5.0 feet higher than its natural level by a dam that is maintained by the Wisconsin Valley Improvement Company (WVIC). The WVIC utilizes Little Saint Germain Lake as a storage reservoir, where each winter it releases approximately 1.5 feet of water for use in hydroelectric power generation downstream on the Wisconsin River.

Though the WDNR lists the lake's general condition as "Poor" it is currently not listed as impaired. Combining Little Saint Germain Lake's high native aquatic plant species richness and the moderate average conservatism values yields FQI values that exceed the upper quartile values for lakes in the ecoregion (NLFL) and for lakes throughout Wisconsin.

Field Survey Notes

LSG is a difficult system to predict. Sometimes the waters are green and plant growth is minimal, other times large mats of plants inhibit even basic navigation in some areas. There is always a lot of users on LSG, and sometimes they are non-humans like bald eagles and loons. And almost every year, it snows on us while working on LSG.

Photograph 1.0-1. Little Saint Germain Lake

Lake at a Glance - Little Saint Germain Lake

Morphology	
Acreage	980
Maximum Depth (ft)	53
Shoreline Complexity	3.31
Vegetation	
Number of Native Species	*46*
Threatened/Special Concern Species	Vasey's pondweed – special concern
Exotic Plant Species	EWM, CLP, pale yellow iris, purple loosestrife
Simpson's Diversity	0.89
Average Conservatism	6.5
Water Quality	
Trophic State	Eutrophic (West Bay upper mesotrophic)
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	6.3:1

The primary citizen-based organization leading management activities on Little Saint Germain Lake is the Little Saint Germain Lake Protection and Rehabilitation District (LSGLPRD). The studies included within the current management planning project document the present state of the native and exotic plant populations, compare them to previous occurrences, and use this information to develop a plan for future management of exotic populations. Additionally, the LSGLPRD sought to examine their lake in a holistic manner, understanding the ecosystem and better protecting it from future threats. Shoreland and fish habitat assessment results educate riparian property owners about healthy shorelines and how they may be able to improve their property through BMPs and/or habitat improvements. A stakeholder survey was circulated to assess the needs and concerns of all property owners. Finally, water quality data and analysis collected through a concurrent USGS study was integrated into this project.

2.0 STAKEHOLDER PARTICIPATION

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

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

Planning Committee Meeting I
On April 25, 2017, Eddie Heath of Onterra met with six members of the Little Saint Germain Lake Planning Committee for nearly four hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The focus of this meeting was the shoreland condition assessment, aquatic plant survey results, and aquatic plant management. Many concerns were raised by the committee, including nuisance levels of aquatic plants, water levels, beaver population management, aquatic invasive species (AIS) management, and applicability of alum treatments.

Planning Committee Meeting II
On June 21, 2017, Eddie Heath and Tim Hoyman met with the members of the Planning Committee. The primary focus of this meeting was to go over the water quality, watershed, and fisheries information. The meeting also discussed the stakeholder survey results and began developing management goals and actions for the Little Saint Germain Lake management plan.

Management Plan Review and Adoption Process
On November 9, 2017, a draft outline of the Implementation Plan was provided to the Planning Committee for review. The Implementation Plan Section (5.0) was created based on the comments received. On December 13, 2017, a complete draft of the Comprehensive Lake Management Plan was provided to the LSGLPRD Planning Committee for initial review.

In mid-February 2017, an official first draft of the LSGLPRD's Comprehensive Management Plan was supplied to the WDNR, Wisconsin Valley Improvement Company, Great Lakes Indian Fish and Wildlife Commission, Vilas County, Town of St. Germain Lakes Committee, and LSGLPRD's Planning Committee for review.

Written reviews of the draft plan were received from XX. Their comments and how they were integrated into this document are included in Appendix E.

Stakeholder Survey

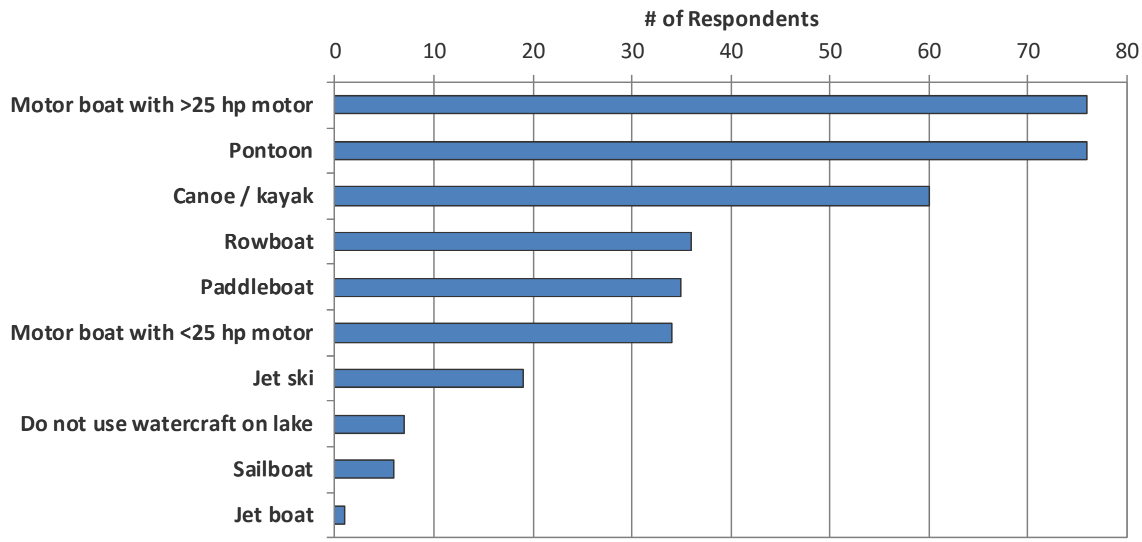
As a part of this project, a stakeholder survey was distributed to district members around Little Saint Germain Lake. The survey was designed by Onterra staff and the LSGLPRD's planning committee and reviewed by a WDNR social scientist. During January 2017, the eight-page, 35-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a third-party contractor for analysis. Thirty-three percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. Therefore, these data only represent those that responded, not the entire district. The LSGLPRD Planning Committee understands this limitation, but without a better set of information, feel that these data are sufficient to be included within management discussions to shape policies.

The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan. A general summary of the stakeholder respondents is discussed below. A similar survey was sent to LSGLPRD members in June 2008 with approximately 50% response rate. Comparisons between the surveys are made as appropriate.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Little Saint Germain Lake. The plurality of stakeholder survey respondents (29%) visit on weekends through the year, 25% are year-round residents, and 19% live on the lake during the summer months only. 75% of stakeholder respondents indicated they have owned their property for over 15 years, and 53% have owned their property for over 25 years.

The following sections (Water Quality & Watershed, Shoreland Condition, Aquatic Plants, and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a pontoon boat or a larger motor boat on Little Saint Germain Lake (Figure 2.0-1, top frame). Canoe/kayak were also a popular option, with 46% of survey respondents indicating the use of this type of non-motorized vessel. On a high-use lake such as Little Saint Germain Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 16 (Figure 2.0-1, bottom frame), several of the top recreational activities on the lake involve boat use. Although boat traffic was listed as a factor potentially impacting Little Saint Germain Lake in a negative manner (Figure 2.0-2, top frame), it was ranked 5th on a list of stakeholder's top concerns regarding the lake (Figure 2.0-2, bottom frame).

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



Question 16: Please rank up to three activities that are important reasons for owning your property on or near the lake.

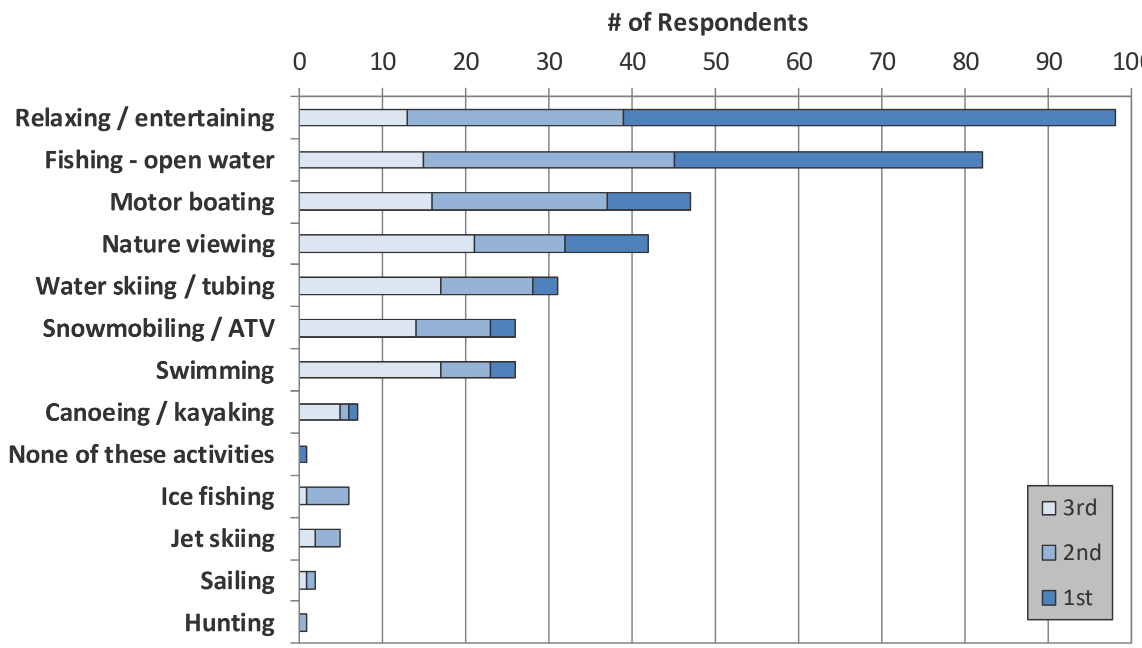
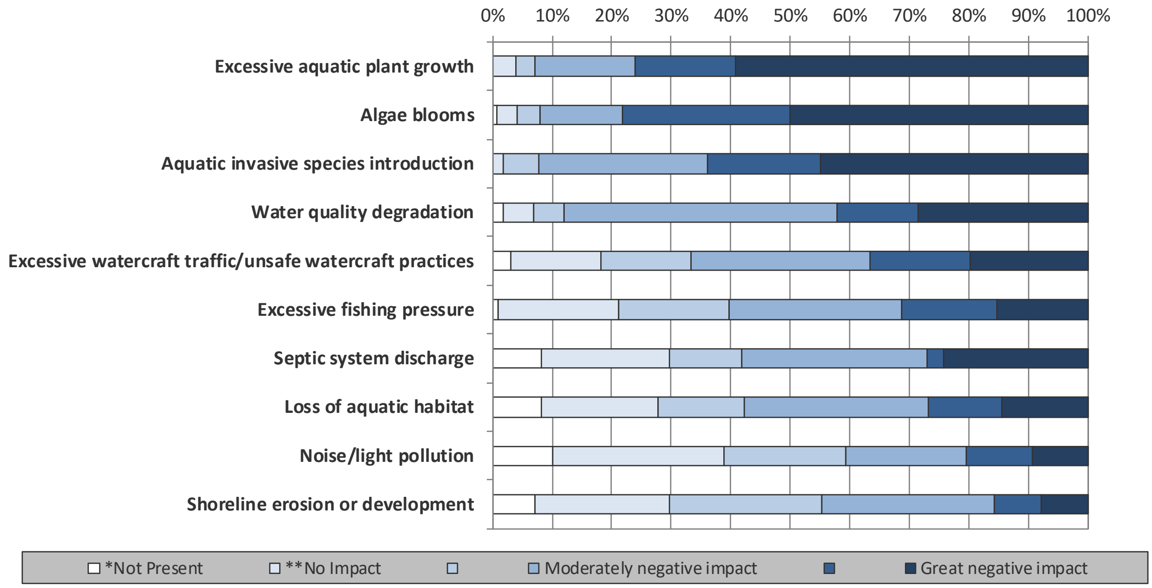


Figure 2.0-1. Select survey responses from the Little Saint Germain Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 22: To what level do you believe these factors may be negatively impacting Little Saint Germain Lake?



Question 23: Please rank your top three concerns regarding Little Saint Germain Lake.

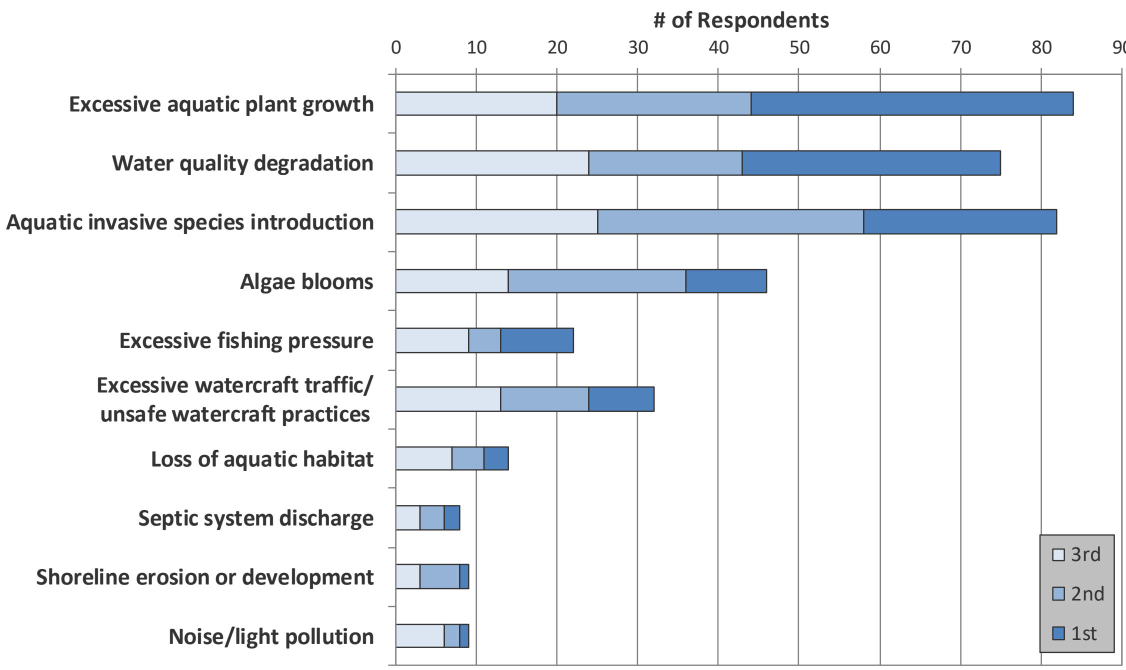


Figure 2.0-2. Select survey responses from the Little Saint Germain Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Little Saint Germain Lake Water Quality and Watershed

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected in Little Saint Germain Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix B). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in Little Saint Germain Lake's water quality analysis:

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

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

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days at a time).

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations consistently 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, several possibilities exist; 1) shoreland septic systems, 2) internal phosphorus cycling, 3) shoreland runoff, sediment resuspension, or 4) high nutrient groundwater input.

If the lake is considered a candidate for internal loading, the buildup of phosphorus in the hypolimnion is used to estimate that load.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2016 Consolidated Assessment and Listing Methodology (WisCALM) for CWA Section 303(d) and 305(b) Integrated Reporting* (WDNR 2015) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of the Little Saint Germain Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, hydrology. An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

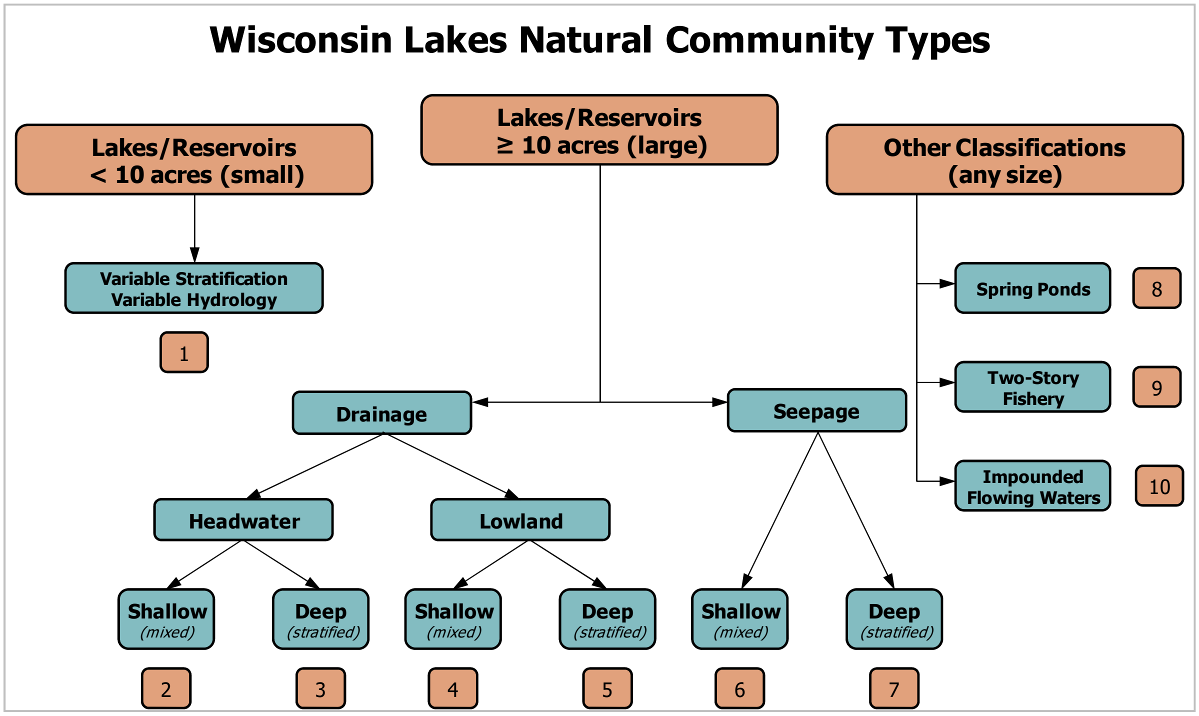


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013.

Garrison, et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Little Saint Germain Lake is within the Southeastern Wisconsin Till Plains ecoregion.

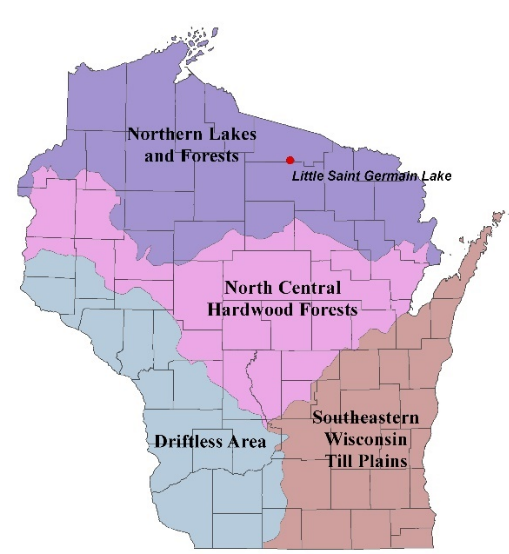


Figure 3.1-2. Location of the Little Saint Germain Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2016 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

Little Saint Germain Lake Water Levels

Little Saint Germain Lake is one of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs used to maintain a nearly uniform flow of water as practicable in the Wisconsin River by storing surplus water in reservoirs for discharge when water supply is low to improve the usefulness of the rivers of the rivers for hydropower, flood control, and public use (Figure 3.1-3).

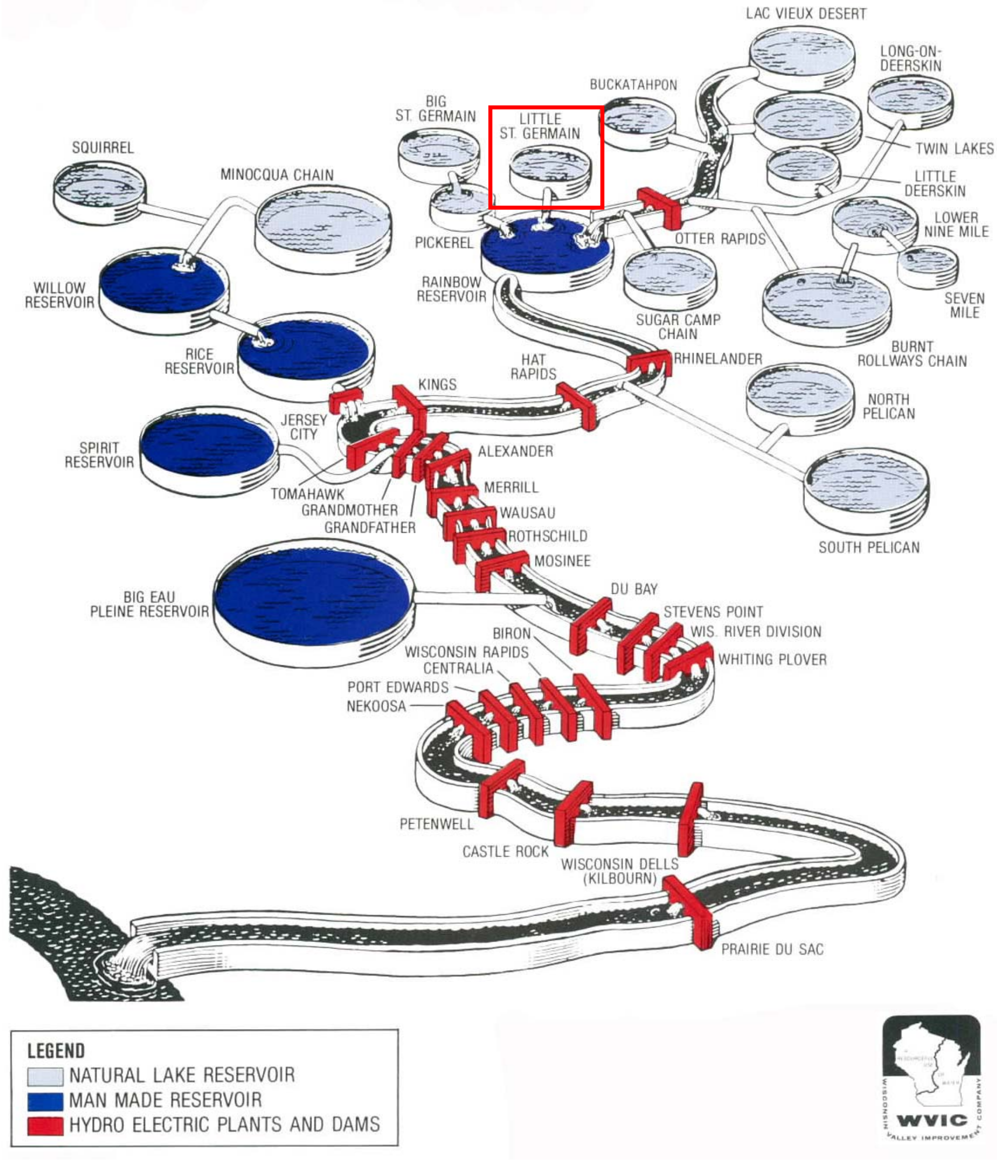


Figure 3.1-3. WVIC reservoir system. Little Saint Germain Lake is outlined in red. Adapted from WVIC website.

Hydroelectric power projects are licensed by the Federal Energy Regulatory Commission (FERC). As part of the FERC operation license, the minimum and maximum water levels are set for each waterbody. Natural lake reservoir water levels are maintained within a relatively narrow range in comparison to the five man-made reservoirs which exhibit changes of water levels that could span 10-20 feet in a single year.

Little Saint Germain Lake is one of the natural lake reservoirs in the WVIC system, and the 1996-2026 FERC operating order grants an operational range of 1.83 feet on a year-round basis. The water levels need to be kept between 1,613.88 and 1,612.05 feet (Figure 3.1-4), with a goal of operating near 1,613.71 feet between June 1 and September 15. Water levels are typically lowered in the winter months, but still within the operational range.

In addition to establishing a range of water levels, minimum outflows are also set by FERC to make sure the downstream riverine systems are not negatively impacted by abnormally low flows. Little Saint Germain Lake must maintain a flow of 5.6 cubic feet per second year-round.

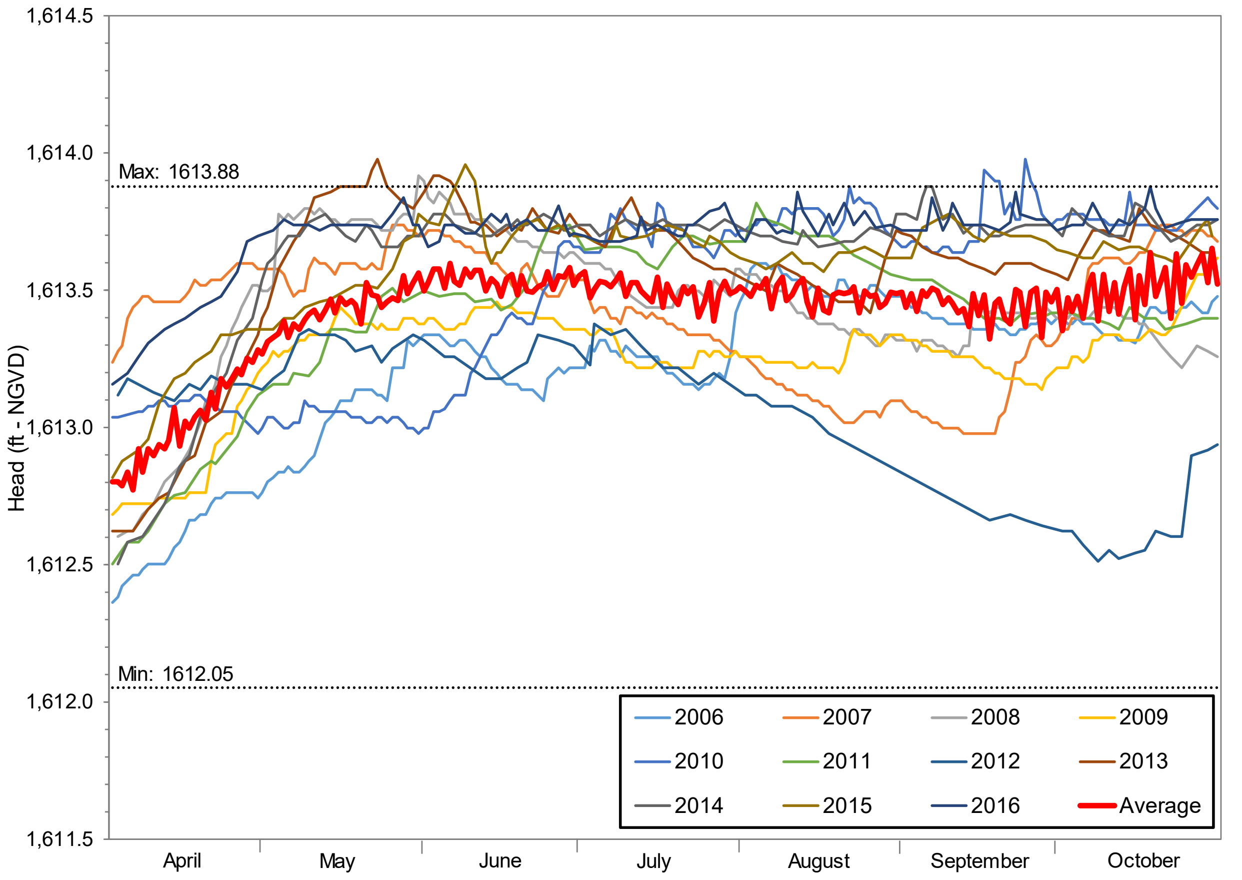


Figure 3.1-4. Little Saint Germain Lake water levels. Data provided by WVIC.

While Little Saint Germain Lake is typically referred to as having five basins, the function of the system is separated into four main basins, with East Bay and No Fish Bay being combined as East Bay (Figure 3.1-5, Table 3.1-1). Within the Water Quality Section of this report, the four basins as outlined in Table 3.1-1 will be investigated. In some reports, Lower East Bay is referred to as Upper East Bay. The major tributary entering the lake is Muskellunge Creek which enters the north end of East Bay. The major flow pattern is through East Bay through South Bay into Little Saint Germain Creek. Lower East Bay and East Bay are strongly connected and the water quality is similar in both bays. West Bay is somewhat isolated from the rest of the lake by the presence of a 5-foot sill which somewhat restricts waterflow between this bay and the rest of the lake.

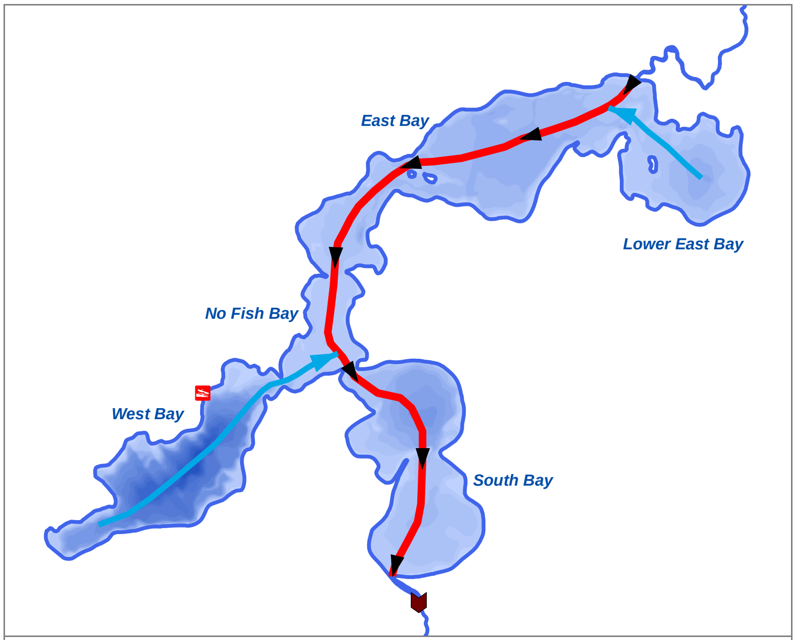


Figure 3.1-5. Morphometry of Little Saint Germain Lake

Table 3.1-1. Morphometric data and number of residences for the basins in Little Saint Germain Lake.

Basin	Maximum Depth (ft)	Mean Depth (ft)	Area (acres)	Volume (acre-feet)	Number of Residences
Lower East Bay	16	6.9	123	847	32
East Bay (Includes No Fish Bay)	15	7.5	401	3,007	155
South Bay	22	8.5	245	2,091	108
West Bay	53	22.8	210	4,789	88
Total	**53**	**11.0**	**979**	**10,734**	**383**

The lake's watershed is approximately 6,178 acres in size and is predominantly forest (68%), wetland (17%), and water (24%) (Figure 3.1-6, Robertson 2005). All of the bays have numerous riparian residences with East Bay having the most and Lower East Bay the fewest (Table 3.1-1).

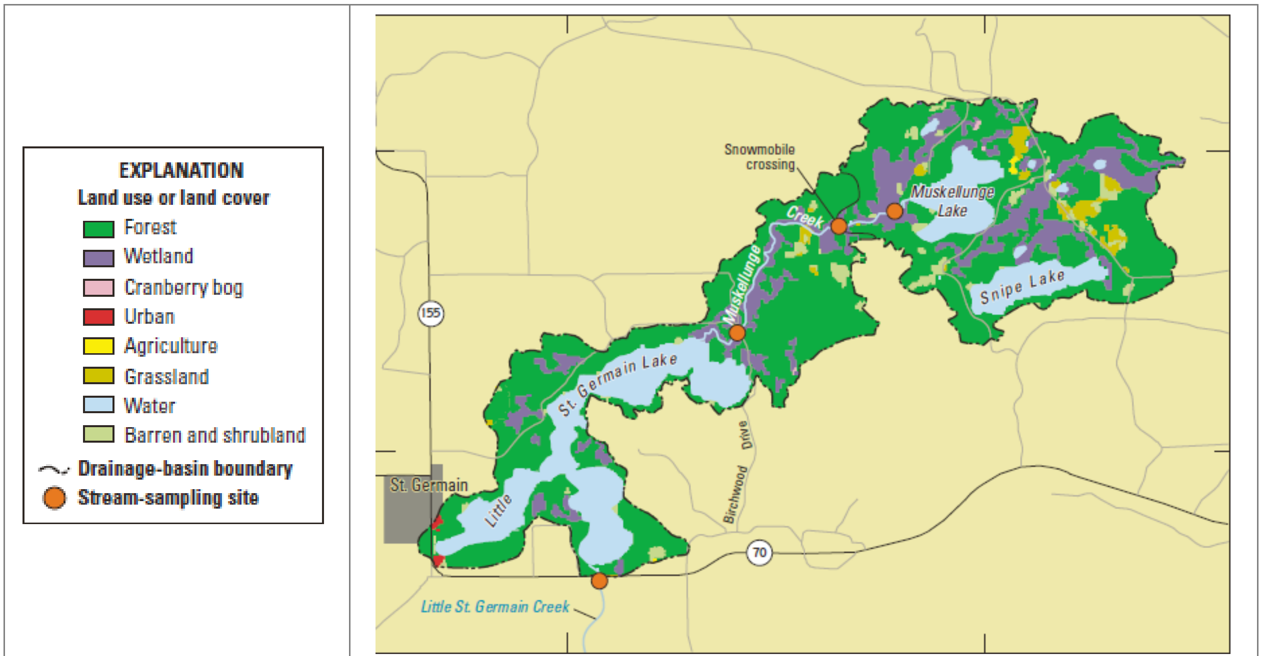


Figure 3.1-6. Drainage basin of Little Saint Germain Lake. Figure extracted from Roberston et al. 2005.

In the past, water quality studies have been conducted by the U.S. Geological Survey (Robertson et al. 2000, Robertson et al. 2005, Robertson et al. 2016) and Barr Engineering (Barr 2007). The first three studies described the annual trends of the trophic parameters in the major bays of the lake beginning in 1991 through 2013. These studies also estimated the hydrologic and phosphorus budgets for the lake. The Barr study estimated the amount of alum that would need to be applied to the lake sediments to reduce the input of phosphorus into the overlying waters and also provided a cost estimate for the alum application in the different bays.

This section will summarize these past studies and update the annual trends through 2016. This section will explain why water quality improvement is dependent upon reducing phosphorus input to the lake and summarize the sources of phosphorus. It will also explain how reducing phosphorus in the lake will reduce algal blooms and improve water clarity. Techniques to reduce phosphorus levels in the lake are suggested.

Little Saint Germain Lake Phosphorus, Chlorophyll-a, and Water Clarity

Comparison of Trophic Parameters in the Bays

The summer near surface total phosphorus concentrations are higher in Lower East and East bays and lowest in West Bay (Figure 3.1-7). During the period 2010-16, the highest phosphorus levels were in East Bay at nearly 70 µg/L followed by Lower East Bay at 62 µg/L. Concentrations in South Bay were 33 µg/L and in West Bay they were the lowest at 18 µg/L. The phosphorus levels in East and Lower East bays place those parts of the lake in the poor category. South Bay phosphorus levels are in the fair category and West Bay phosphorus levels are in the good category. Figure 3.1-7 also compares phosphorus concentrations in each bay with similar lakes throughout Wisconsin that have the same natural community type as Little Saint Germain Lake. If the four bays were considered separate lakes, Lower East, East, and South bays would be shallow lowland drainage lakes (SLDL) and West Bay would be a deep lowland drainage lake (DLDL). The phosphorus levels in Lower East and East bays are much higher than other similar lakes in the state and the concentrations are also much higher than other lakes in the Northern Lakes and Forest (NLF) Ecoregion. In South Bay, phosphorus concentrations are similar to other shallow lowland drainage lakes but higher than other lakes in the NLF ecoregion. Phosphorus concentrations in West Bay, a deep lowland drainage lake, are lower than other similar lakes and other lakes in the NLF ecoregion.

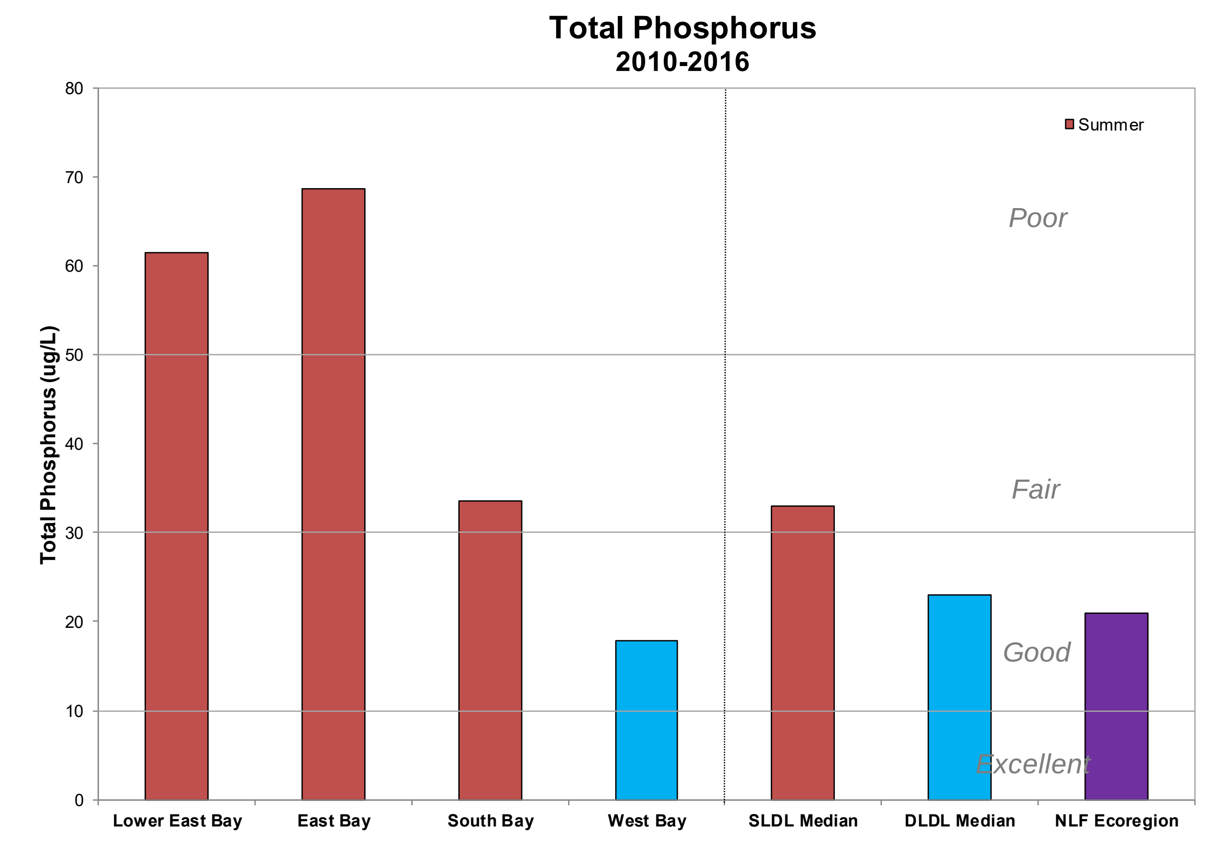


Figure 3.1-7. The median values of near-surface summer phosphorus concentrations in the four major bays for the period 2010-2016. The lake type of Lower East, East, and South bays is shallow lowland drainage lakes (SLDL) while West Bay is a deep lowland drainage lake (DLDL). Comparables include median values SLDL and DLDL type lakes and all lakes within the Northern Lakes and Forests (NLF) ecoregion.

Because phosphorus is the nutrient that determines the amount of algae that grows in the lake, chlorophyll-*a* concentrations were highest in Lower and East Bays and lowest in West Bay (Figure 3.1-8). As with phosphorus, chlorophyll-*a* levels in Lower East and East bays are much higher than compared to other shallow lowland drainage lakes and other lakes in the NLF ecoregion. In South Bay, chlorophyll-*a* concentrations are higher than the median value in other shallow lowland drainage lakes throughout the state and also higher than the median value in other lakes in the NLF ecoregion.

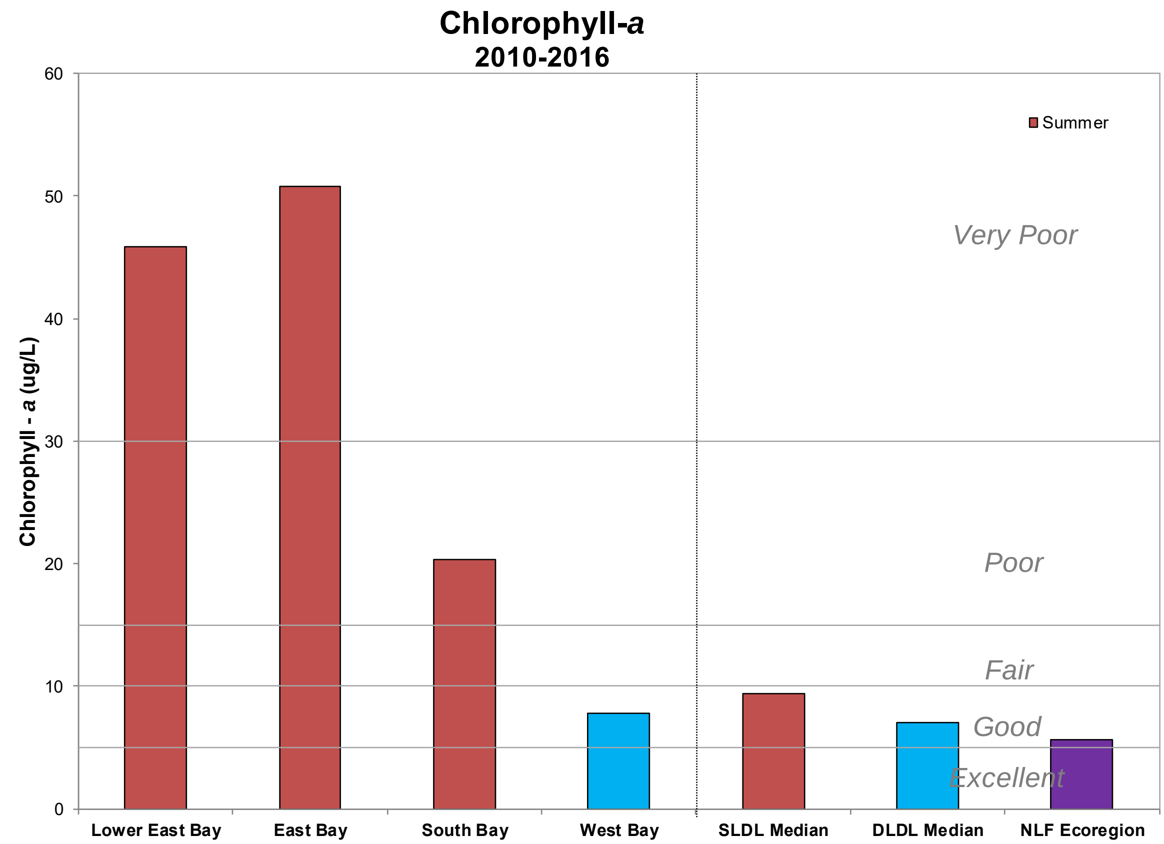


Figure 3.1-8. The median values of near-surface summer chlorophyll-a concentrations in the four major bays for the period 2010-2016. The lake type of Lower East, East, and South bays is shallow lowland drainage lakes (SLDL) while West Bay is a deep lowland drainage lake (DLDL). Comparables include median values SLDL and DLDL type lakes and all lakes within the Northern Lakes and Forests (NLF) ecoregion.

As described above, water clarity was determined with a Secchi disk. In most lakes, including Little Saint Germain Lake, the primary determinant of water clarity is the amount of algae in the water. As would be expected, the worst water clarity occurred in Lower East and East bays where the average summer Secchi disk transparency was about 3.5 feet (Figure 3.1-9). This clarity is worse than other shallow lowland drainage lakes where the median value is 2 feet better at 5.6 feet. The median value for other lakes in the NLF ecoregion is even better at nearly 9 feet. In South Bay, the average summer water clarity is nearly 6 feet which is better than other shallow lowland drainage lakes but not as good as other lakes in the NLF ecoregion. Only in West Bay, where water clarity is 9.3 feet, is it better than the median value for other deep lowland drainage lakes and other lakes in the NLF ecoregion.

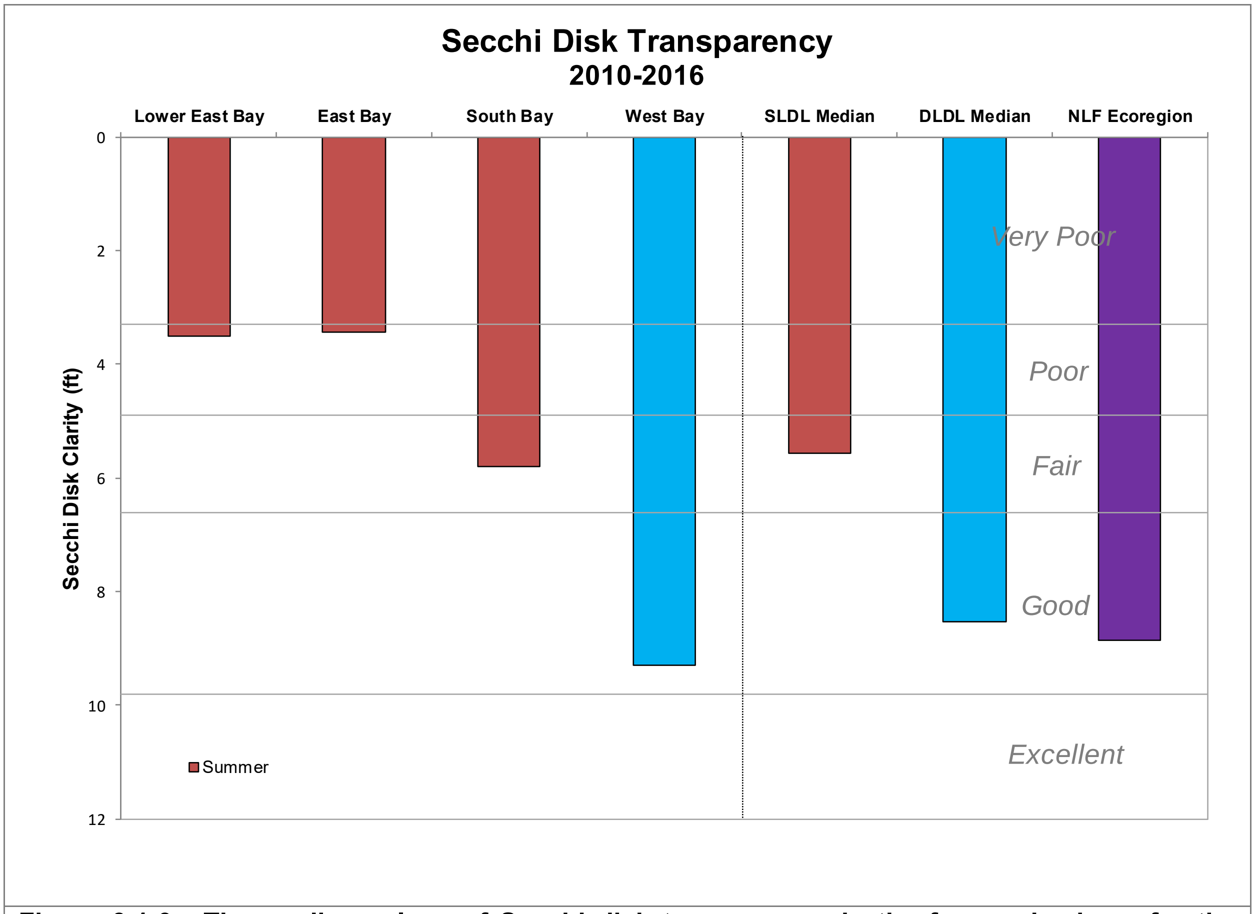


Figure 3.1-9. The median values of Secchi disk transparency in the four major bays for the period 2010-2016. The lake type of Lower East, East, and South bays is shallow lowland drainage lakes (SLDL) while West Bay is a deep lowland drainage lake (DLDL). Comparables include median values SLDL and DLDL type lakes and all lakes within the Northern Lakes and Forests (NLF) ecoregion.

As described earlier, the trophic state index (TSI) is used as an indication of the lake's productivity and is a useful tool for understanding the relationship between phosphorus, algae, and water clarity. With the exception of West Bay, the lake is classified as eutrophic suggesting that algal blooms are common and can reach nuisance levels (Figure 3.1-10). West Bay is classified as mesotrophic which indicates nuisance algal blooms are uncommon. The TSI values for all the bays except West Bay are higher than comparable lakes both of similar lake type or other lakes in the NLF ecoregion. The TSI value for West Bay is similar to the median value for other deep lowland drainage lakes and other lakes in the NLF ecoregion. The TSI equations were developed from data collected from many different lakes. In a "typical" lake the equation for phosphorus, chlorophyll-*a*, and Secchi depth should give about the same value. In all four bays in Little Saint Germain Lake, chlorophyll-*a* TSI values are higher than for phosphorus. This indicates that for some unknown reason, more algae is produced from a given phosphorus concentration than is normal for most other lakes.

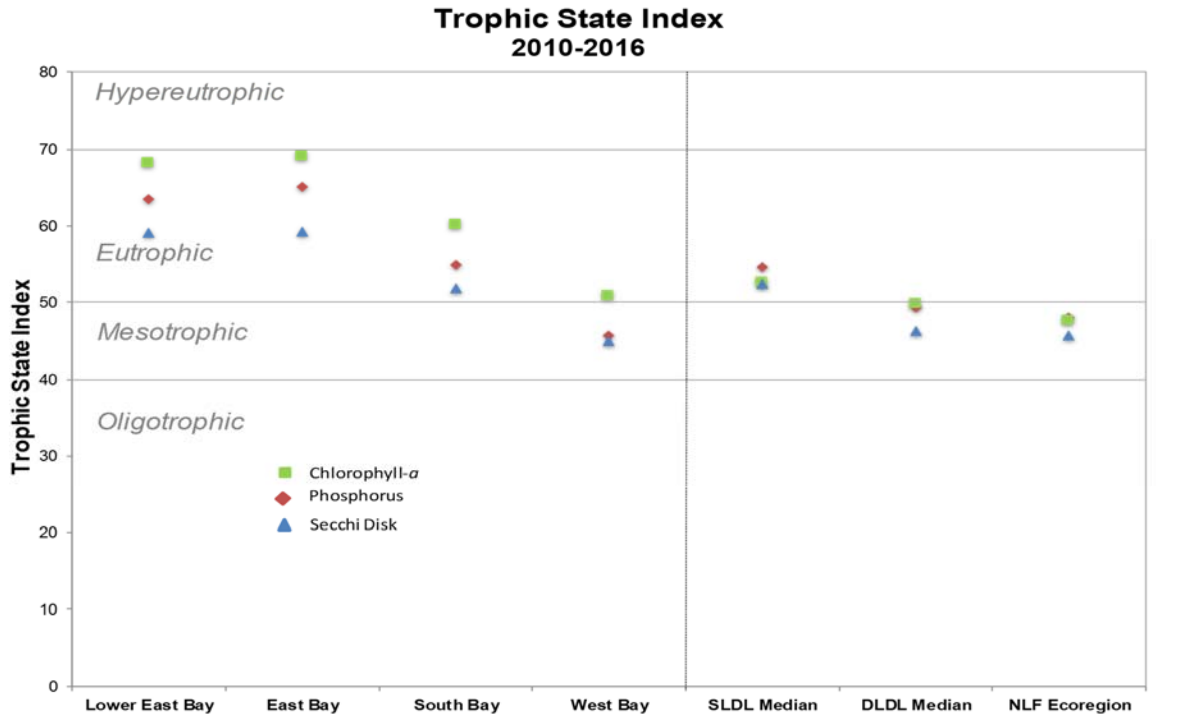


Figure 3.1-10. The Trophic State Index values in the four major bays for the period 2010-2016. The lake type of Lower East, East, and South bays is shallow lowland drainage lakes (SLDL) while West Bay is a deep lowland drainage lake (DLDL). Comparables include median values SLDL and DLDL type lakes and all lakes within the Northern Lakes and Forests (NLF) ecoregion.

Dissolved Oxygen and Temperature in the West Bay

In 2008, dissolved oxygen and temperature were collected on a monthly basis in the bays, including West Bay. Profiles depicting these data for West Bay are displayed in Figure 3.1-11. The temperature and dissolved oxygen data indicates West Bay remained stratified during the summer and the bottom waters became devoid of oxygen by mid-July.

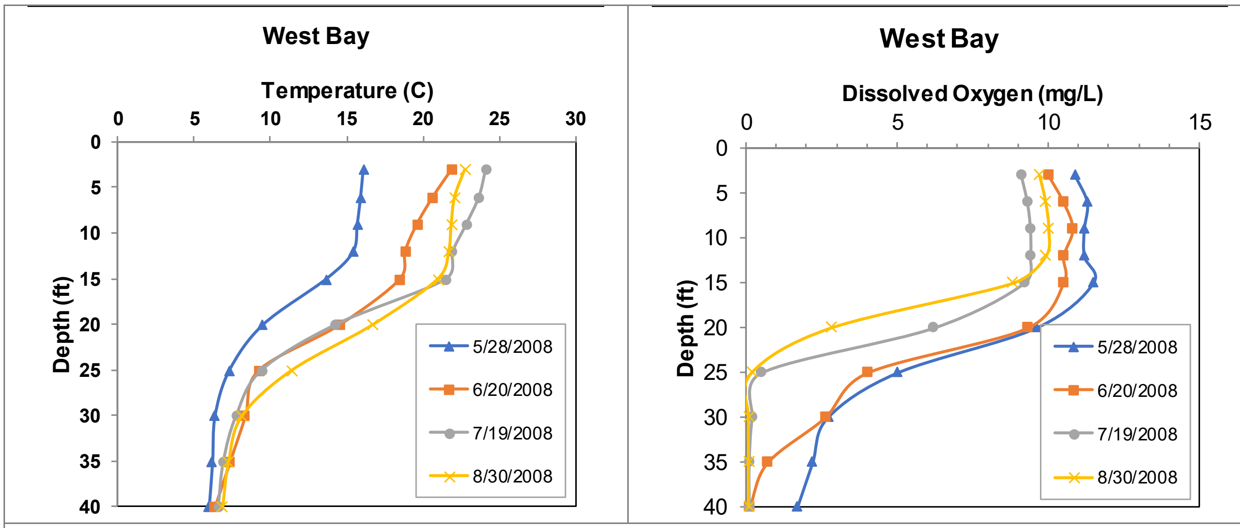


Figure 3.1-11. Temperature and dissolved oxygen profiles in West Bay during 2008.

West Bay 303(d) List Impairment Listing

The State of Wisconsin is required by law under the Clean Water Act to submit a list of lakes that do not meet specific water quality standards based upon lake type. The list of impaired waters, also known as the 303(d) list, is updated every two years. Each state is required to document the methodology used to assess the waterbodies. The WDNR developed and uses the Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) to set water quality standards and assess the state's waterbodies. The WDNR is currently using WisCALM 2016; however, a draft document is currently being reviewed for implementation in 2018.

At the present time, Little Saint Germain Lake is not listed as impaired because not enough data has been collected. However, the phosphorus concentrations found in Lower East Bay and East Bay would place it on the impairment list. Furthermore, West Bay is listed as a two-story fishery because of a low population of cisco (Lyons et al. 2015). This means the total phosphorus threshold is 15 µg/L, normally an amount that would be considered *excellent* for this lake type (deep lowland drainage lakes). But in order for a two-story lake to maintain oxygen in the hypolimnion for cold water fish species, even low total phosphorus concentrations can stimulate production that would lead to reduced oxygen levels.

As an example, during July and August of 2008, the hypolimnion in West Bay was depleted of oxygen (Figure 3.1-11) and the cisco population would have needed to move into the metalimnion (thermocline) to survive. In the 2018 WisCALM draft, the WDNR has proposed to examine two-story lakes by not only total phosphorus concentrations, but also by the quantity of cold water habitat available during the growing season for coldwater fish species (WDNR, in preparation). At this time, no habitat quantity has been listed as being sufficient for a healthy two-story lake. Cisco require dissolved oxygen of 3 mg/L or higher and prefer temperatures ranging from approximately 4-17°C (39.2-62.6°F), but can survive temperatures up to 22.8°C (73°F). During August 2008, the depth below 20 feet was devoid of oxygen meaning cisco would have to reside above this depth. At 20 feet the temperature was 16.7°C which is the upper limit of their preferred temperature. Above 20 feet the temperature was warmer. This means that in late summer, there is only a narrow band of water where cisco can thrive. In abnormally warm summers their zone of refuge could be smaller or disappear altogether.

Long Term Trends of the Trophic Parameters

Although Lower East, East, and South bays have higher phosphorus and algal concentrations than West Bay, the levels vary between years. Specifically, phosphorus, chlorophyll-*a*, and water clarity were significantly worse between 2001 and 2002. Phosphorus levels increased around 20 µg/L between those years and chlorophyll-*a* levels more than doubled (Figure 3.1-11). Although some work had been done in Muskellunge Creek around this time to reduce beaver impoundments, the change with the greatest impact appears to have been the onset of aeration during the winter to prevent fish kills. Robertson et al. (2016) speculated that winter aeration, resulted in higher rates of internal loading during the summer. They reasoned that release of phosphorus from the sediments that occurred during low oxygen levels in the winter did not occur with aeration. Instead this phosphorus is now released during the summer (will be discussed in more detail in the section on phosphorus loading) when it is available for algal growth.

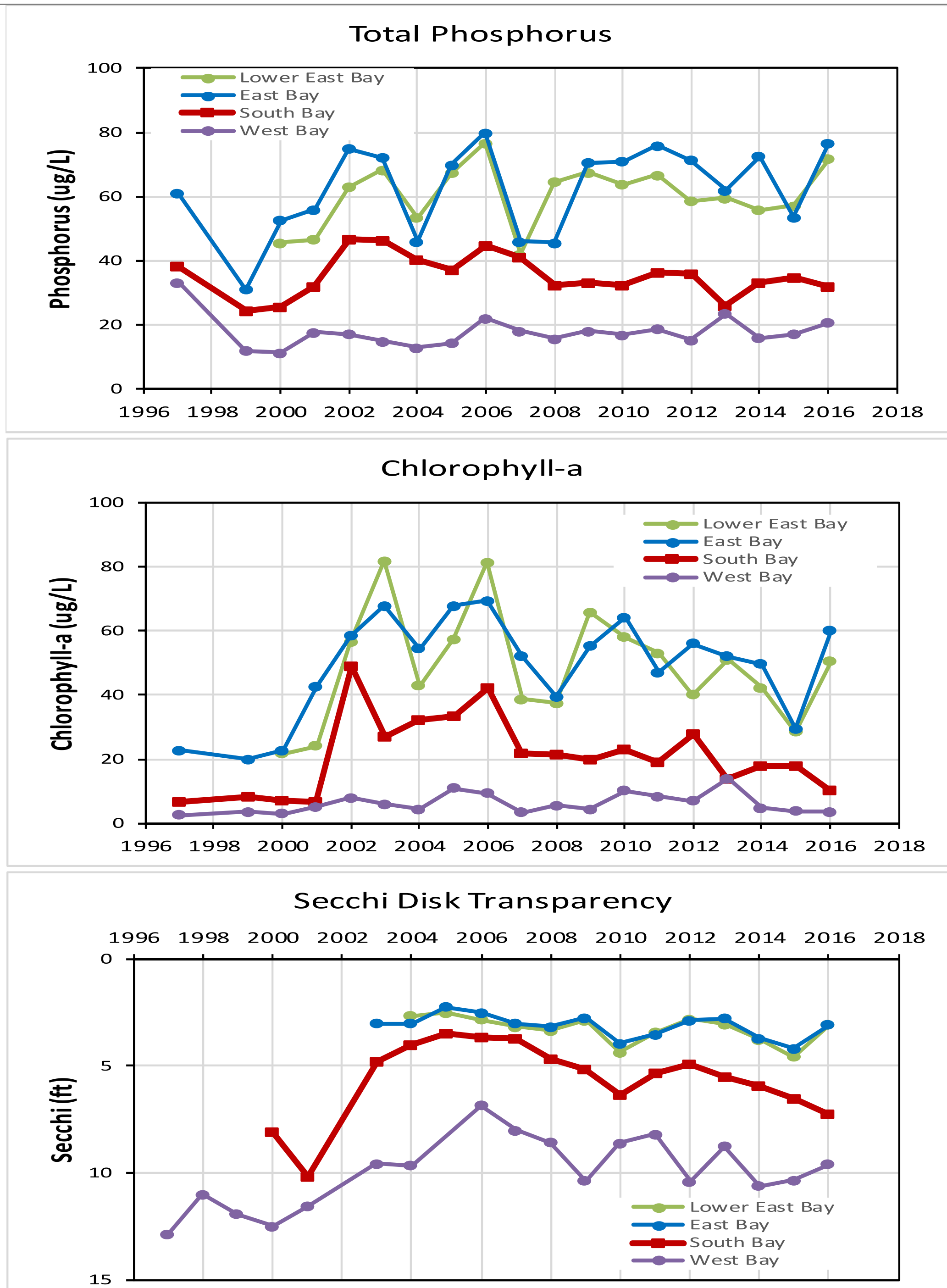


Figure 3.1-12. Annual mean values for near surface phosphorus, chlorophyll-a, and Secchi depth for the four major bays. After winter aeration began in the winter of 2001-2002, there was a significant increase in phosphorus and chlorophyll-*a* in Lower East, East, and South bays. In South Bay there was also a decline in water clarity. The trophic parameters in West Bay were not significantly impacted by the winter aeration.

Prior to winter aeration, the phosphorus released from the sediments was flushed out of the lake before the summer growing season. It is also likely that the cessation of winter fish kill also had an impact on the food web. It would be expected that lack of winterkill would increase the numbers of predatory fish which often means that the fish that feed on zooplankton are reduced. Zooplankton often are important for reducing algal levels since many of them feed on algae. Since the algal levels are higher following the use of winter aeration, it is likely that the change in timing of sediment phosphorus release is the most important factor for the increased concentrations of phosphorus and chlorophyll-*a* since 2001. The West Bay does not appear to have been impacted by the winter aeration in the other bays. Phosphorus levels did not increase after 2001 (Figure 23.1-10) and any increased chlorophyll-*a* occurred a number of years after winter aeration began.

Even with the increased levels of phosphorus and chlorophyll-*a* since 2001, there are still differences in the concentrations of phosphorus, and consequently chlorophyll-*a,* for the period 2002 to 2016. Specifically, 2004, 2007, and 2008 were years when phosphorus and chlorophyll-*a* concentrations were lower. In both 2004 and 2008 the summer temperatures were lower than normal. Precipitation appears to have a much smaller impact on summer algal levels as the highest annual and summer precipitation during the period was 2010, but chlorophyll-*a* concentrations were not very different from other years. Conversely, years with low annual and summer precipitation did not experience low algal levels, e.g. 2012.

Although phosphorus and chlorophyll-*a* concentrations have been higher since 2002 compared to pre-aeration levels, since 2010 there has been a change in the trends of the trophic parameters in the bays. While phosphorus concentrations in Lower East and East bays remain high, since 2010 the levels have generally been declining slightly (Figure 3.1-13). The improvement is more evident in chlorophyll-*a* concentrations during this time. In South and West bays phosphorus levels have been stable but chlorophyll-*a* concentrations have declined at a similar rate in both bays. In the shallower bays, the decline in chlorophyll-*a* concentrations since 2010 has been about 2 µg/L per year and it is about 1 µg/L in West Bay. In Lower East and East bays, the Secchi disk transparency has not changed while it has improved in South and West bays at a rate of about 0.2 feet per year. The reason water clarity has not improved in the Lower East and East bays is that the relationship between chlorophyll-*a* and water clarity is not linear but instead is polynomial at the algal concentrations present in these bays. This means that at the high chlorophyll-*a* concentrations in these bays (40-60 µg/L), a reduction of 20 µg/L only means an improvement of water clarity of less than one half foot.

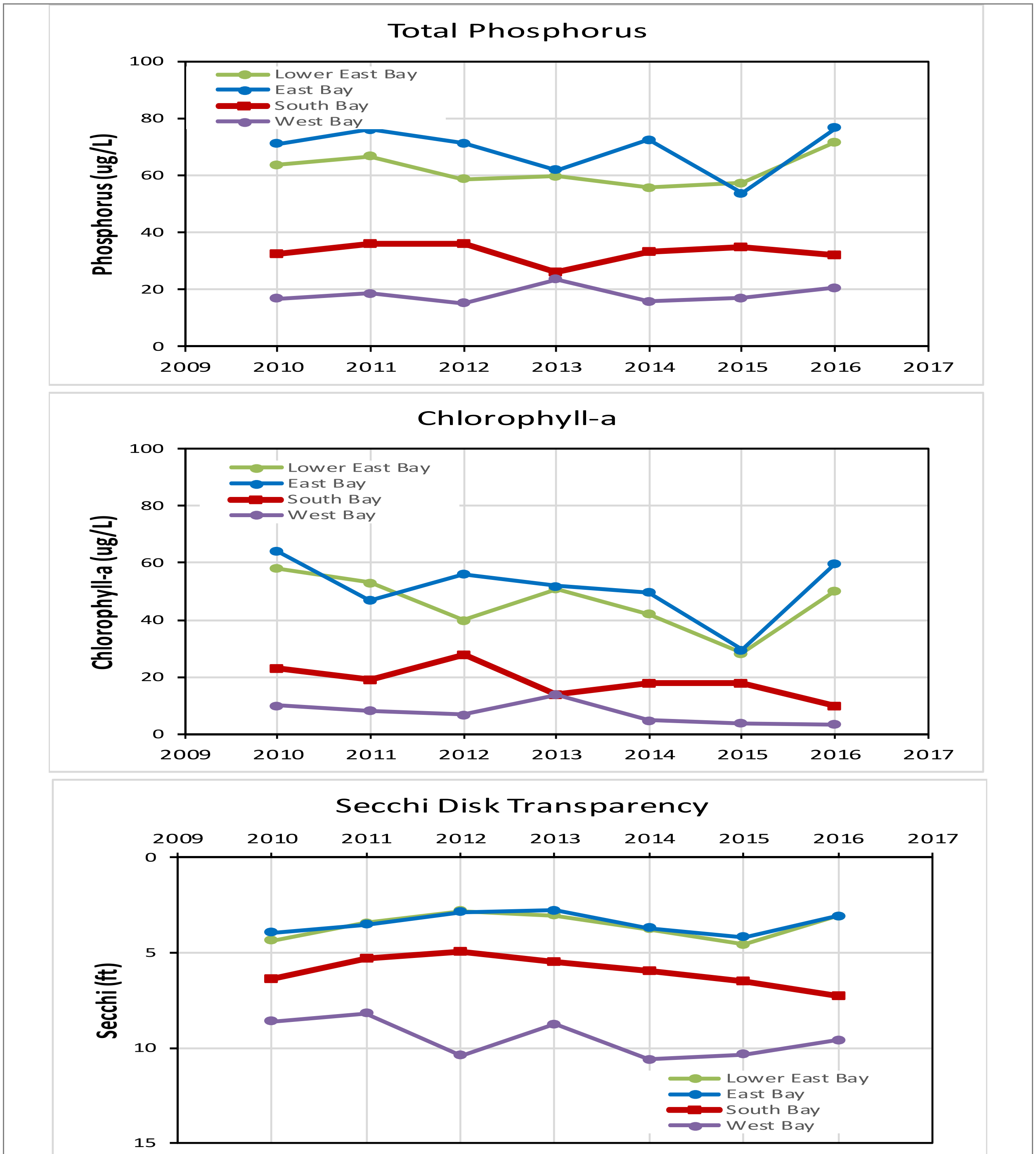


Figure 3.1-13. Annual mean values for near surface phosphorus, chlorophyll-a, and Secchi depth for the four major bays for the period 2010-2016. Although phosphorus and chlorophyll-a concentrations remain higher than prior to the onset of winter aeration, their concentrations have been declining in the last 7 years. Water clarity has also improved in South and West bays.

As mentioned above, the best water clarity occurs in West Bay followed by South Bay. Clarity declines in South Bay as a result of the bay stratifying, the bottom waters lose their dissolved oxygen, and phosphorus is released from the sediments. When the lake mixes during the summer this phosphorus in the deep waters is transported to the upper waters where it fuels algal growth. During the last few years, Secchi disk transparency in the South Bay is 6 feet or better until the end of June or late July (Figure 3.1-14). The reduction in clarity is weather dependent. When a mid-summer windy period occurs the bay mixes and an algal bloom soon follows. In Lower East and East Bays the first summer mixing period generally occurs earlier than in South Bay because these bays are shallower. The Secchi disk depth is less than 6 feet in most years by mid to late June although in 2011 it lasted until mid-July. It is likely that if sediment phosphorus release could be significantly reduced in these bays, Secchi disk depths of around 6 feet could be maintained into August.

Phosphorus Sources

The phosphorus concentrations that are found in Little Saint Germain Lake originate from two sources. External sources are those that are found outside the lake itself and come from the lake's watershed. Typically, the larger a lake's watershed is in relation to the surface area of the lake, the greater potential there is for elevated phosphorus concentrations in the lake. It is often thought that if the ratio of the watershed to lake area is greater than 10:1 then a lake will tend to have more algal problems. The ratio in Little Saint Germain Lake is 7:1 which is good for the lake.

More important than the size of the watershed is the land cover in the watershed. Some land covers export more phosphorus to the lake than others. For example, highly urbanized and agricultural row crops export the highest amounts of phosphorus while forest and wetlands export much less phosphorus. While riparian development that is around Little Saint Germain Lake does not export as much phosphorus as highly urbanized areas, undeveloped shorelines or those with extensive buffer strips along the shore export less phosphorus than properties with well-maintained lawns. Although lawn fertilizers presently do not contain phosphorus, developed properties produce more runoff during rain events which can wash grass clippings, leaves, and surface dust into the lake.

Phosphorus that is already present in a lake can also be a source of phosphorus in the lake water. This source is known as internal and is more important in some lakes than others. During the summer, shallow lakes tend to experience more internal loading than deep lakes because shallow lakes do not experience stratification to the same extent as deep lakes. Lakes with some types of submerged aquatic vegetation, e.g. curly-leaf pondweed, also can experience significant internal loading when these plants die in mid-summer.

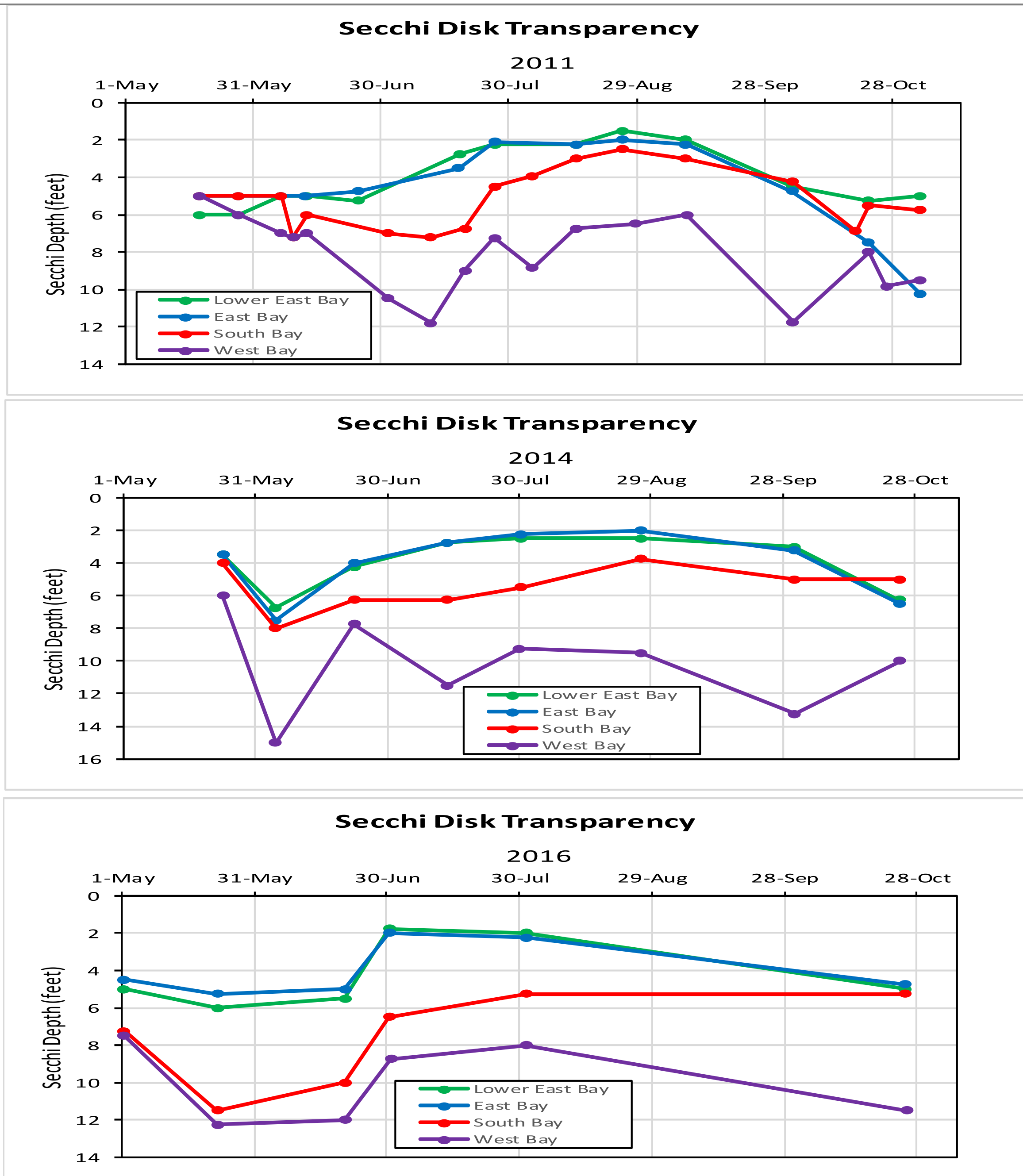


Figure 3.1-14. Seasonal Secchi disk transparency depths for 2011, 2014, and 2016. In South Bay water clarity is at least 6 feet until late June or mid-July. Water clarity degrades earlier in Lower East and East bays because sediment phosphorus is transported earlier into the upper waters to fuel algal blooms because of the bay's shallow depth.

External Phosphorus Sources

Studies by the USGS estimated the amount of water and phosphorus that enters Little Saint Germain Lake from its watershed (Robertson and Rose 2000, Robertson et al. 2005, Robertson et al. 2016). They reported that phosphorus loads for the years 1997, 1999, 2001, 2011, and 2012. The major source of water to the lake is from Muskellunge Creek which enters Little Saint Germain Lake on the north side of East Bay. The percentage that precipitation and groundwater contribute to the annual budget is variable, but each contribute around 25 percent of the annual input of water to the lake. Although groundwater enters the lake in all of the bays, the greatest input of groundwater occurs near the middle of the lake in No Fish Bay and the northeastern side of South Bay.

The largest source of phosphorus from external sources is from Muskellunge Creek (Figure 3.1-15). While some of the phosphorus is exported from Muskellunge Lake which is upstream, much of the phosphorus enters the stream between Muskellunge and Little Saint Germain lakes. In the past, impoundments created by beavers have been a significant source of phosphorus to the lake. The impoundments become devoid of oxygen in their bottom waters resulting in phosphorus entering the stream and ultimately ending up in East Bay. Since the late 1990s the number and size of beaver impoundments have been reduced which has reduced the amount of phosphorus entering the lake from Muskellunge Creek by about 50 percent. The second most important phosphorus source is groundwater. Riparian development contributes about 12 percent of the annual phosphorus load from external sources.

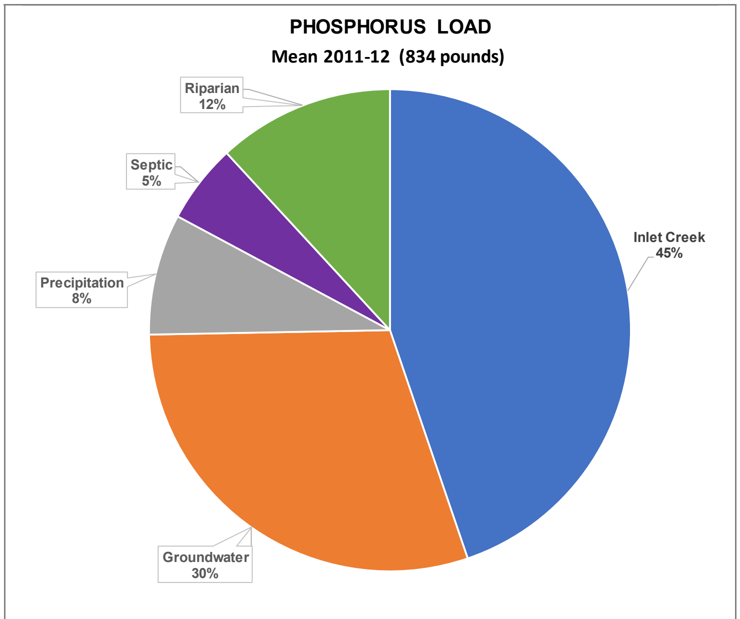


Figure 3.1-15. Sources of phosphorus from the lake's watershed. The inlet creek and groundwater data is from an article by Robertson et al. (2016) of the USGS.

Internal Phosphorus Sources

West Bay is deep enough that when the lake stratifies in mid-spring it remains that way until fall overturn. This is why phosphorus levels are near steady or decline during the summer (Figure 3.1-16). The other bays are shallower and periodically mix during the summer. While the bays are stratified, their bottom waters become devoid of dissolved oxygen and phosphorus is released from the sediments. When the bays mix phosphorus concentrations in the upper waters increase.

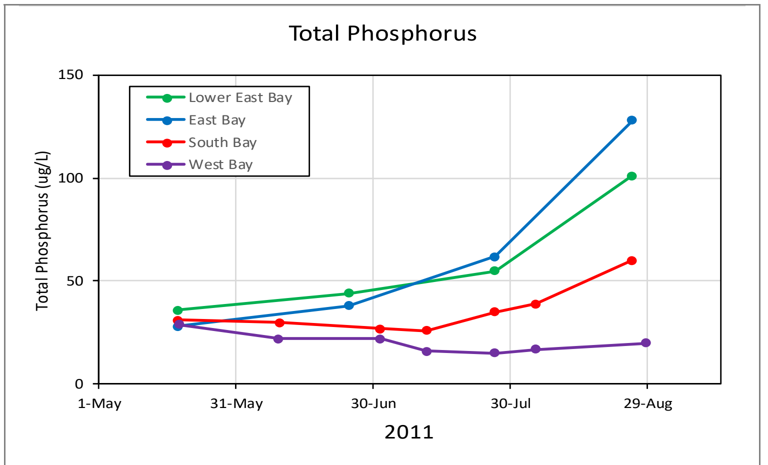


Figure 3.1-16. Seasonal near surface total phosphorus concentrations in the four major bays.

In a typical deep lake, phosphorus concentrations are highest in the spring and fall during turnover. Concentrations are elevated during the spring largely because of the phosphorus that enters the lake from snowmelt. As some of the phosphorus settles to the bottom of the lake, concentrations in the upper waters decline or remain unchanged throughout the summer. An example of this trend in West Bay happened in 2011 with the highest concentration occurring at the first sampling date in mid-May (Figure 3.1-16). In South Bay phosphorus concentrations declined from mid-May until late July when they increased through August. In Lower East and East bays, phosphorus levels continually increased from mid-May through August at a higher rate than they did in South Bay. The increase in phosphorus concentrations in the shallow bays throughout the summer is because of sediment release of phosphorus from the sediments. When the weather is warm and there is little wind, the shallow bays stratify with the bottom waters losing nearly all of their dissolved oxygen. When this happens, iron in the sediments which is insoluble in the presence of oxygen, changes to a form where it becomes soluble in water. Because much of this iron is combined with phosphorus, when it becomes soluble phosphorus also is released from the sediments. The longer the bottom waters have no oxygen, the more iron and phosphorus is released from the sediments. When a wind event occurs this high phosphorus water at the bottom of the lake is mixed into the surface waters where algae are able to use it. This results in increased algal levels and frequently nuisance algal blooms occur. In deep lakes, such as West Bay, the bottom waters lose their dissolved oxygen and phosphorus is released from the sediments. These lakes are deep enough that the lake only mixes in the fall as air temperatures decline and thus this phosphorus does not contribute to summer algal blooms.

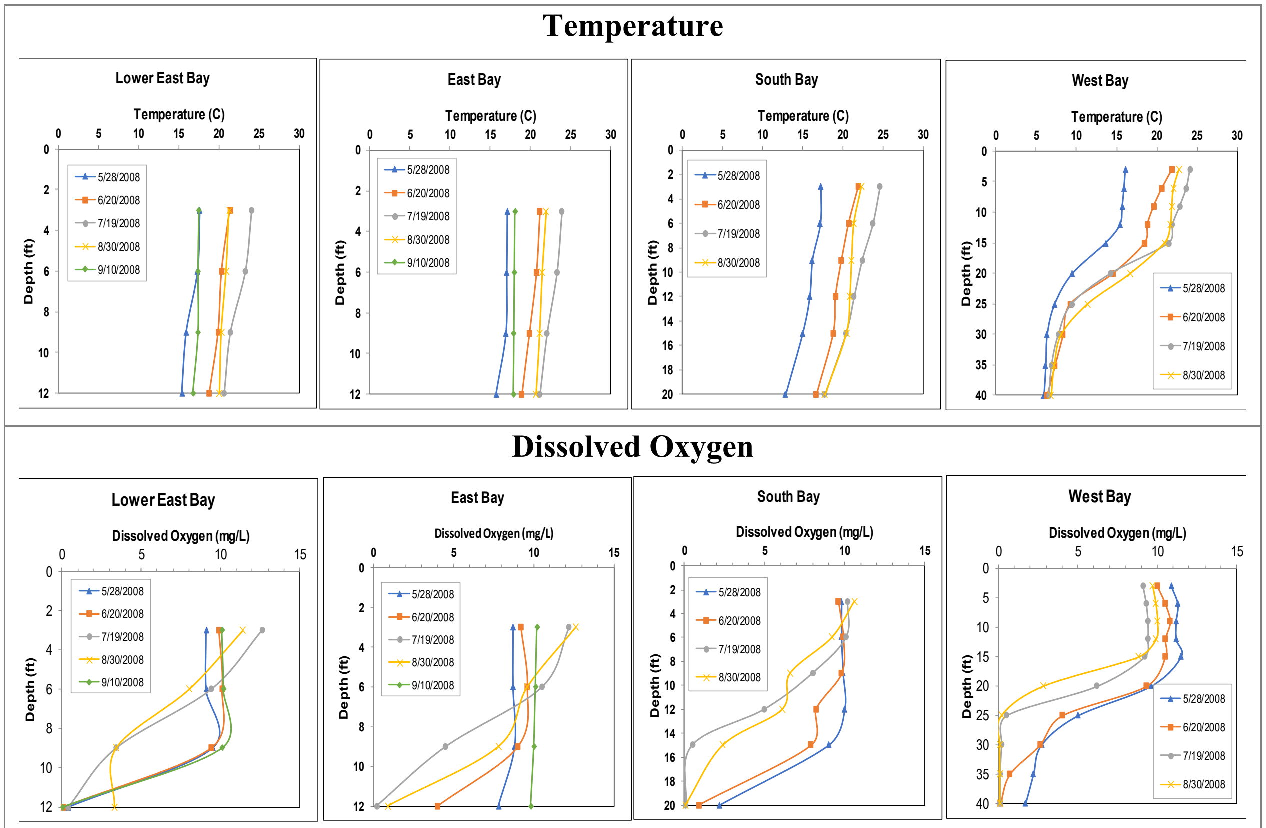


Figure 3.1-17. Profiles of temperature and dissolved oxygen in the four bays during the summer of 2008. Mixing during the summer occurs in Lower East, East, and South bays as indicated by the increase in water temperature at the bottom of these bays. The bottom waters of all the bays become devoid of oxygen during at least part of the summer.

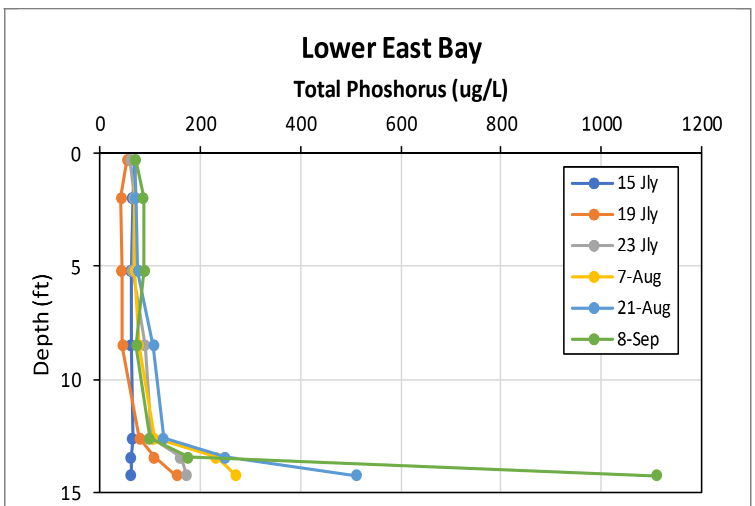


Figure 3.1-18. Total phosphorus profiles in Lower East Bay during the summer 2008. When the bottom waters are devoid of oxygen the phosphorus concentration increases as it is released from the sediments.

It was expected that this was occurring in the shallow bays in Little Saint Germain Lake. In 2008 more frequent temperature and dissolved oxygen profiles were collected. Phosphorus profiles were also collected for phosphorus in Lower East and East bays. Temperature and dissolved oxygen profiles are shown in Figure 3.1-17. In all of the bays the bottom waters had no oxygen at least on some of the sampling dates. In the three shallow bays, the temperature in the bottom waters increase throughout the summer which is an indication that these bays have mixed between sample days. By contrast the temperature in the bottom waters of West Bay are similar throughout the summer because this bay does not mix. The phosphorus profiles collected from Lower East and East bays in 2008 show that phosphorus is being released from the sediments as concentrations are much higher in the bottom most sample when these waters have no oxygen (Figure 3.1-18).

The amount of internal loading from the three shallow bays was estimated from increase in the phosphorus mass of these bays during the summer. The amount of internal loading varies from year to year, but it is highest in East Bay because of its larger water volume. Phosphorus concentrations are similar in the bottom waters in Lower East and East bays. Of the three shallow bays, South Bay has the least internal loading, which is reflected in the lower summer phosphorus concentrations in the surface waters.

The phosphorus concentrations in the surface waters of the Little Saint Germain Lake are the result of phosphorus from external sources, e.g. Muskellunge Cr., and internal sources, e.g. deep-water sediments. A complete picture of phosphorus loading to the lake must include both sources. When including internal sources, the largest source of phosphorus to the lake is deep water sediments followed by Muskellunge Creek (Figure 3.1-19). The Lower East and East Bays receive a higher amount of internal loading compared with the other bays. The relatively large percentage of internal loading indicates that in order to reduce algal blooms in Little Saint Germain Lake, internal sources must be reduced.

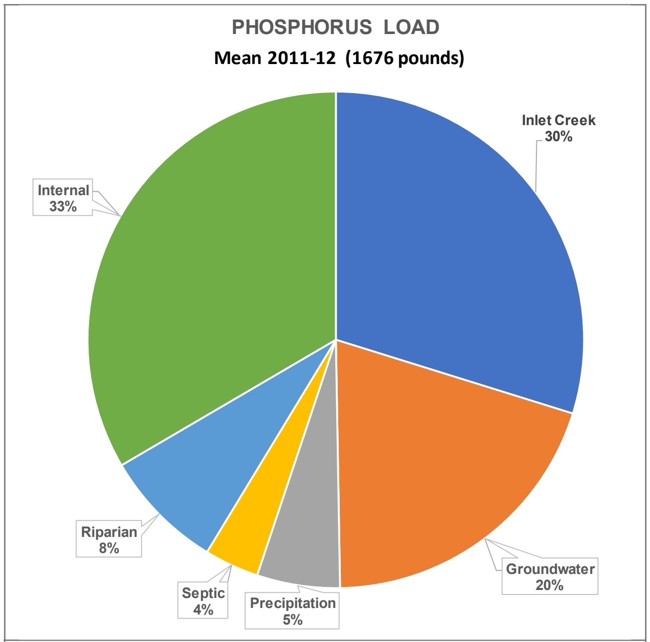


Figure 3.1-19. Sources of phosphorus from the lake's watershed and within the lake. The inlet creek and groundwater data is from an article by Robertson et al. (2016) of the USGS. Phosphorus released from the sediments is the largest source. In the shallow bays this source comprises an even greater source.

As discussed in the section on long-term trends and shown in Figure 3.1-12, after the winter aeration began phosphorus and chlorophyll-*a* concentrations sometimes varied between years. It is not likely this is because of differences in annual precipitation, but more likely dependent upon the amount of internal loading in a given year. A study conducted by Onterra in Kentuck Lake found that in shallow lakes, like Lower East, East, and South bays, during cooler years the periods of stratification last for shorter periods of time and are less frequent. This means that the periods of no oxygen in the bottom waters are shorter and less phosphorus is released from the sediments. Another factor that can influence the longevity of stratification is the depth of the water. When the lake level is higher, depending upon climate, stratification may last longer and the amount of phosphorus that builds up in the bottom waters can be greater before the lake mixes. The lake level in Little Saint Germain Lake is controlled by a dam where the stream leaves South Bay. The amount of internal loading each year during the period 2010-16 was compared to summer temperatures and the lake level (Figure 3.1-20). In East Bay, internal loading was less in years with cooler temperatures (2013-16) when compared to warmer years. Differences in lake level did not appear to significantly influence the amount of internal loading. In both Lower East Bay and South Bay, temperature appeared to be less important in controlling the amount of internal loading than did lake level. Although lake level was only low one year (2012), during that year these bays had much less internal loading. It is not likely the lower internal load in 2012 was the result of external loading as the USGS study estimated that loading from Muskellunge Creek was similar in 2011 and 2012 (Robertson et al. 2016). Perhaps with the lower lake level experienced in 2012 in Lower East and South bays, it does not take as much wind to mix the bays.

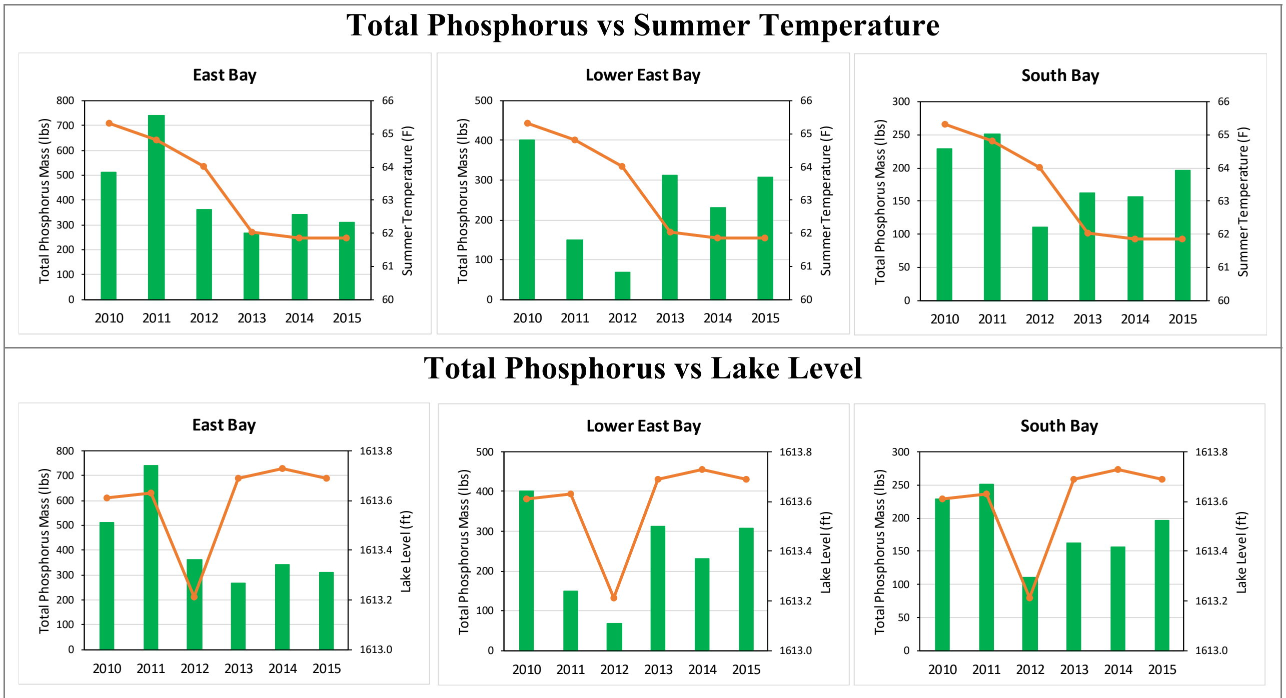


Figure 3.1-20. Internal loading in the shallow bays compared with summer temperature (upper panel) and summer lake level (lower panel). In East Bay the amount of internal loading is most influenced by the summer temperature while lake level is more important in Lower East and South bays.

A report recently written by the USGS (Dantoin and Robertson, In press) examined potential improvements to the water quality of Little St. Germain Lake by changing the timing of when water is released from the lake into Little St. Germain Creek. They report that the most phosphorus would be released if the majority of the water was released in September, after summer stratification, and February, the height of winter stratification. They estimated that increased water releases would potentially reduce total phosphorus levels in the South Bay by 1 to 2.5 µg/L over the long term. This could result in a lowering of chlorophyll-*a* concentrations by about 1 µg/L and an improvement in growing season Secchi disc transparency by less than a foot. It is not likely water clarity during the summer would be significantly improved as internal loading of phosphorus occurs during the summer has a significant impact on summer algal levels and thus water clarity.

Dantoin and Robertson point out potential negative impacts from the timed release of water. Changing the timing of the release of the water would alter how residents manage shoreland structures since a September release would lower lake levels during a time when seasonal recreation is occurring and a February release would disrupt ice cover along the shoreline. A previous study by the USGS (Robertson et al. 2005) found that the phosphorus concentrations in the groundwater entering Little St. Germain Lake are relatively high. Dantoin and Robertson point out that lowering the lake level in September may increase groundwater flow into the lake by increasing the gradient between the surface of the lake and the surrounding groundwater. The increased flow of high phosphorus groundwater could be prevented if the increased water release from the lake only occurred in February. A February release would likely mean that less water could be released thus less phosphorus would be exported from the lake.

Blue-Green Algae Blooms

Blue-green algae blooms have been periodically noted on Little Saint Germain Lake (Photograph 3.1-1). Understanding algae dynamics in lakes is complicated because so many factors control growth rates of algae, such as light availability, nutrient levels, water temperatures, zooplankton populations, and interactions between algal species themselves. The complexity is compounded in high-nutrient systems like Little Saint Germain Lake.

Photograph 3.1-1. Blue-green algae bloom on Little Saint Germain Lake. Photo credit: Onterra.

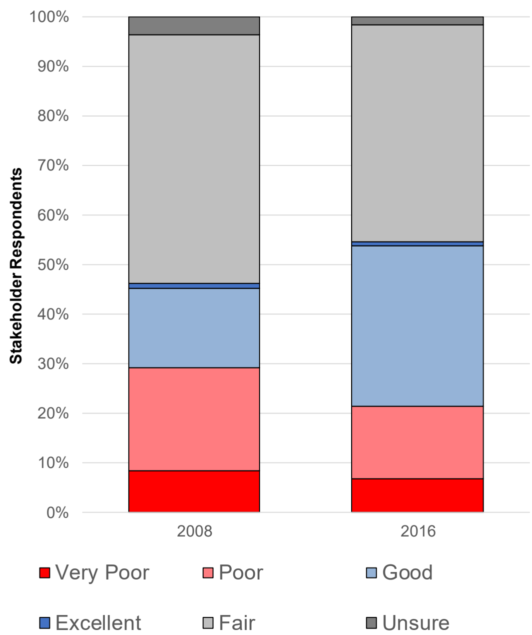
Like 'true' algae, cyanobacteria or blue-green algae are able to convert sunlight into energy through the process of photosynthesis. Many species of blue-green algae can naturally be found in Wisconsin waters, some of which can produce toxins potentially dangerous to people and animals. Exposure to these toxins occurs can be from ingestion of water, skin contact, and by inhaling aerosolized water droplets. It is unknown if the blue-green algae blooms noted in the past on Little Saint Germain Lake produced toxins.

The largest risk of exposure consists of swallowing water containing the toxins, usually during water-sporting activities. Symptoms include nausea, vomiting, diarrhea and in severe cases, liver failure or paralysis. Skin contact with algae can produced blistering of the exposed skin. Allergy-like symptoms including coughing, watery eyes, and nose/throat irritation are most commonly associated when wind and motor boat activity cause the toxins to become aerosolized.

Water Quality and Watershed Summary

In 2016, 33% of stakeholder respondents described the water quality of Little Saint Germain Lake as being *good* or *excellent* as opposed to 17% in 2006 (Figure 3.1-21, left frame). This is in contrast to 58% of respondents in 2016 indicating the lake has been *severely degraded* or *somewhat degraded* over time, up from 50% in 2008 (Figure 3.1-21, right frame). In 2008, water quality degradation and algae blooms were ranked as more pressing concerns to stakeholder respondents than excessive plant growth. In 2016, excessive plant growth was ranked as a more pressing concern that both water quality degradation and algae blooms.

Question 13: How do you describe the current water quality of Little Saint Germain Lake



Question 14: How has the water quality changed in Little Saint Germain Lake

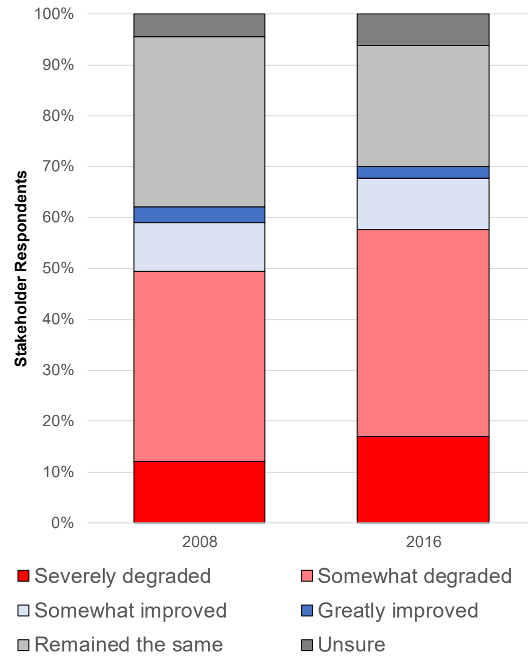


Figure 3.1-21. Select survey responses from the Little Saint Germain Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

The Little Saint Germain Lake of today is largely the result of a dam that was placed across the outlet on the southern end of South Bay. The major inlet to the lake is Muskellunge Creek which flows from Muskellunge Lake which is a few miles upstream from Little Saint Germain Lake. The water of the lake flushes around once every 2.2 years although the water residence time in the shallow bays often is less than one year. Little Saint Germain Lake consists of four major bays: Lower East, East, South, and West. In many ways, these can be considered separate, but connected lakes. In this report, these four bays are generally treated as lakes. West Bay is the deepest and when the lake stratifies in May it remains that way until fall mixing. Lower East and East bays are the shallowest and they stratify and mix periodically throughout the summer. South Bay is deeper than the Lower East and East bays, and mixes during the summer, but not as frequently as the shallower bays.

Water quality conditions are best in the deep West Bay and the worst in the shallow Lower East and East bays. The latter bays experience frequent and persistent algal blooms during the summer. Algal blooms occur in South Bay but they are not as intense. Algal species data is limited from this lake but a sample collected in 2005 identified blue-green algae as an important component of the algal community during the summer blooms. Blue-green algae are known to produce toxins which can be harmful to animals, including pets. While no toxins have been found in the lake, sampling has been infrequent and none has been done in the last 10 years. Algal levels are high enough during the summer that toxins may be present, but the algal levels are below what are considered hazardous so toxins would likely not be common.

The reason that algal levels are elevated in the shallower bays is because of phosphorus which is released from the sediments when the bays are stratified. In Lower East, East, and South bays, when temperatures are warm and winds are light, the waters become stratified, meaning surface waters do not mix with the deeper water. This allows the bottom waters to lose their dissolved oxygen. In the absence of oxygen, phosphorus in the sediments, which is bound with iron, moves out of the sediments and into the bottom waters. Subsequently, when a windy period occurs, this high-phosphorus bottom water mixes with the surface waters. The higher phosphorus concentrations then fuel algal growth resulting in poor water clarity. In Lower East and East bays, depending upon climatic conditions, this can happen frequently during the summer. This also happens in South Bay, but because it is deeper, the mixing is less frequent. This "pumping" of sediment phosphorus into the lake is called internal loading and is the reason why water clarity is worse in Lower East, East, and South bays compared with West Bay. The amount of internal loading that occurs during the summer varies between years depending upon the climatic conditions. During cool windy summers stratification is shorter and less phosphorus is released from the sediments. In Lower East and South bays, less phosphorus is released from the sediments when lake levels are lower. This likely is because the bays do not stratify as intensely with lower lake levels and the periods of anoxia are less frequent and of shorter duration.

In Little Saint Germain Lake, internal loading is the single largest source of phosphorus. In the shallower bays, internal loading is even more important. Muskellunge Creek is nearly as important as internal loading as a source of phosphorus to the lake. A report by the USGS found that much of the phosphorus in the creek originates between the outlet of Muskellunge Lake and where the creek enters East Bay. An important phosphorus source is impoundments formed by beaver dams. These impoundments can create conditions where phosphorus is released from the bottom sediments much like what happens in Lower East and East bays. Since the late 1990s efforts have been ongoing to minimize the beaver impoundments and this has significantly reduced phosphorus loading from Muskellunge Creek.

The beginning of winter aeration during the winter of 2001-2002 resulted in a significant increase in phosphorus and algal concentrations in the shallow bays. It is thought this aeration has prevented sediment phosphorus release during the winter. Prior to 2002, much of the internal phosphorus loading that occurred during the winter was flushed out of the lake before the following summer. With aeration there is more sediment phosphorus available to be released during the summer. Phosphorus and algal concentrations have been declining in all of the bays during the last 7 years, but the levels are still higher than they were prior to aeration. The LSGLPR should discuss the possibility of discontinuing the winter aeration which may return phosphorus and algal levels in the shallow bays to conditions experienced prior to 2002. Not using aeration during the winter may result in winter fishkills.

Alum Treatment

In order to improve water clarity in Lower East, East, and South bays it will be necessary reduce the amount of phosphorus that enters the water from the bottom sediments (internal loading). At the present time, the Secchi disk depth (water clarity) is at least 6 feet in South Bay until mid-July in most years, but often in Lower East and East Bays water clarity drops below 6 feet by mid-June. If internal loading can be reduced enough, a 6-foot water clarity could be maintained into mid-August or later. Internal loading could be reduced by either restricting the amount of time the bottom waters are devoid of oxygen, or adding a chemical that would inactivate the phosphorus even when oxygen is absent. It may be possible to modify the present aeration system so that the deep waters in the bays will remain mixed most of the summer.

Addition of aluminum salt, usually in the form of aluminum sulfate (alum), is a useful technique for reducing internal phosphorus loading in lakes. It has been used for many years including the first lake that was treated in the USA, Horseshoe Lake, WI, which was treated in 1970. Alum is effective because after binding with phosphorus, the bond of the aluminum and phosphorus is not sensitive to dissolved oxygen levels like iron is. In other words, even under anoxic conditions the phosphorus remains bound with the aluminum and does not move from the sediments into the lake water. Lake sediments contain elevated levels of phosphorus, some of which are bound with iron. When the sediments become anoxic, the iron and phosphorus bond is broken and these elements migrate upward towards the bottom water of the lake. If the bottom waters are anoxic (absence of oxygen), phosphorus and iron migrate into the water column and when the lake mixes, or during summer wind events in shallow lakes, these elements move to the surface waters. Alum can be applied to a lake as a slurry where it precipitates to the lake bottom. This alum layer on the sediments acts a barrier to phosphorus moving into the bottom waters of the lake even in the absence of oxygen. Alum is effective because it permanently binds with the phosphorus. Unlike iron, the aluminum-phosphorus bond is not affected by anoxic conditions.

In Wisconsin over 18 lakes have been treated with alum, while over 26 lakes in Minnesota and Michigan have been treated with alum. Alum is usually applied as aluminum sulfate which reacts quickly with water to form an aluminum hydroxide floc with a high affinity for phosphate and dissolved organic P compounds. The floc quickly settles to the bottom within 24 hours and sooner in shallower lakes. Immediately after settling to the bottom, the floc is susceptible to redistribution but within months it gets mixed into the surface sediment.

One of the lakes in Wisconsin that has been treated with alum is East Alaska Lake in Kewaunee Co. Onterra was involved in the design and oversaw the project. The treatment occurred in October 2011 and to date has been very successful. The cost of the alum treatment was about $165,000 and the application rate was 132 g/m^2 Al.

A 2007 report (Barr 2007) modeled potential water quality improvements from an alum treatment (Table 3.1-2). If East Bay was targeted with an alum application, the water transparency of East Bay would increase from 2.8 feet to 4.2 feet and downstream South Bay would increase from 4.4 feet to 6.0 feet. If East Bay and South Bay would be treated with alum, South Bay's water clarity was modeled to increase to 7.6 feet.

Table 3.1-2. Expected Improvement from an Alum Treatment in Little Saint Germain Lake. Table extracted from Barr 2017.

Alum Treated Area	East Bay/Upper East Bay			South Bay[2]		
	Total Phosphorus (mg/L)	Chlorophyll a (µg/L)	Secchi disc depth (ft)	Total Phosphorus (µg/L)	Chlorophyll a (µg/L)	Secchi disc depth (ft)
No Treatment	0.062	38	2.8	0.046	19	4.4
East/Upper East Bay Only[1]	0.033	15	4.2	0.028	10	6.0
South Bay Only	0.062	38	2.8	0.035	13	5.3
South Bay and East/Upper East	0.033	15	4.2	0.019	6	7.6

(1)Average of modeling results for 2001, 2002, and 2007. Average for June through August period.
(2)Average of modeling results for the year 2002.

The Barr (2007) report estimated that an alum treatment of Lower East and East bays would cost less than $400,000 and treating the South Bay would cost an additional $450,000 (Table 3.1-3). Table 3.1-3 updates these costs based upon 2017 estimates.

Table 3.1-3. Potential alum treatment costs.

Bay	Treatment Area (ac)	Total Gallons	Gallons of Alum per Acre	Al Dose (g/m2 Al)	Estimated Cost (2007)	Estimated Cost (2017)
East Bay	325	365,565	1,125	61.6	$365,565	$658,017
South	162	443,202	2,736	149.8	$443,202	$797,764
Total	487	808,767	---	---	**$808,767**	**$1,455,781**

Many other lakes in Wisconsin that have been treated with alum have been successful in the sense that phosphorus and algal concentrations are much less than they were prior to treatment. Treatments that have not been successful did not have enough alum applied. There was not enough aluminum to combine with most of the mobile sediment phosphorus. Some lakes did not add enough alum because for financial reasons. A couple other lakes were under dosed because the dosage was incorrectly determined. Calculations to determine the appropriate dose are much advanced now compared to early years. Now the amount of mobile sediment phosphorus is determined and this aids in calculating the amount of alum that should be added. Since elements other than phosphorus bind with aluminum more alum is added than just what is needed to combine with all of the phosphorus.

An anticipated response to increasing water transparency would be an increase in aquatic plant growth within Little Saint Germain Lake, particularly rooted submersed plants. As will be discussed within the Aquatic Plant Section (3.3), the LSGLPRD periodically conducts mechanical harvesting of nuisance plants. However, the nuisance-causing plants are primarily comprised of non- or loosely-rooted species such as southern naiad, coontail, and common waterweed. Increased water clarity would likely not impact the populations of these species. The population and footprint of aquatic invasive species like EWM and CLP would likely increase if water transparency increases, likely requiring additional management if an alum treatment occurs.

It is recommended that before giving consideration to a future alum treatment on Little Saint Germain Lake, an updated feasibility study be conducted. Updates in science and planning over the past decade would likely result in a revised dosing strategy as well as a better understanding of outcomes and longevity of the control measure.

3.2 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more strict shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

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

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
    - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

Photograph 3.2-1. Example of coarse woody habitat in a lake.

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

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

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

National Lakes Assessment

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

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

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

Native Species Enhancement

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

Photograph 3.2-2. Example of a biolog restoration site.

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

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

Cost

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

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

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

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5' x 35' areas.
- Plant spacing for the aquatic zone would be 3 feet.

- Each site would need 70' of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

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

Little Saint Germain Lake Shoreland Zone Condition

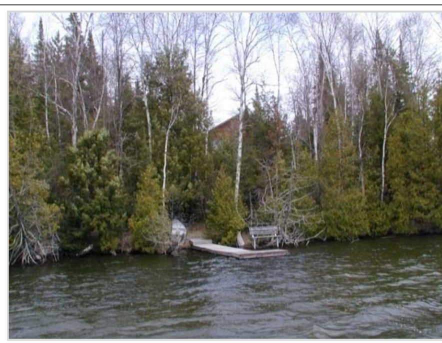
Shoreland Development

Little Saint Germain Lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.2-1 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.

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

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

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



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

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

Figure 3.2-1. Shoreland assessment category descriptions.

On Little Saint Germain Lake, the development stage of the entire shoreland was surveyed during the fall of 2016, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.2-1.

Little Saint Germain Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 7.6 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 3.4 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Little Saint Germain Lake's shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 2 displays the location of these shoreland lengths around the entire lake.

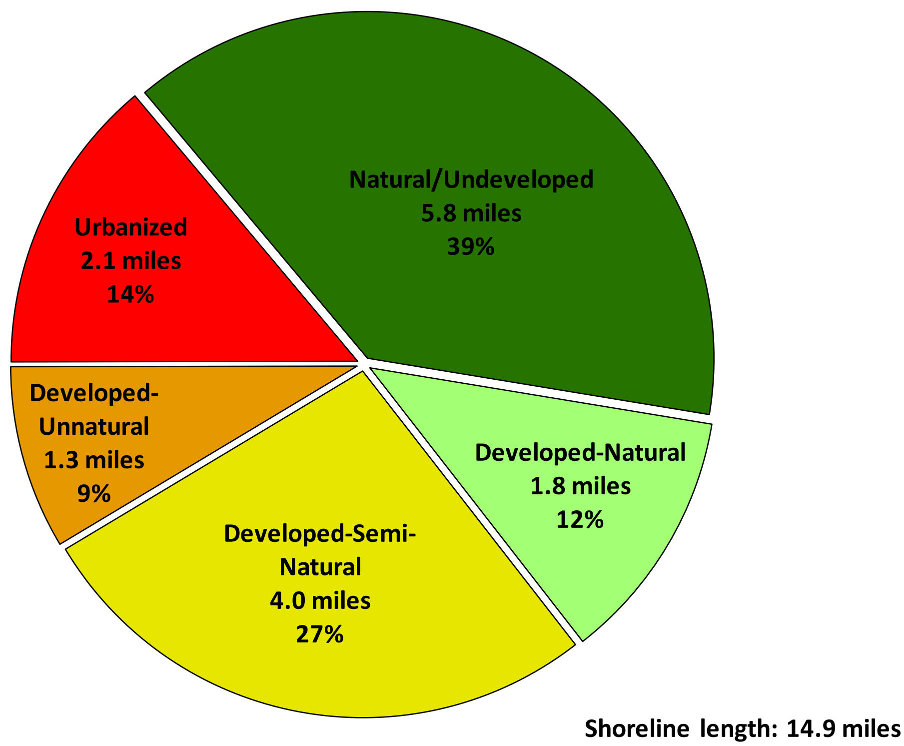


Figure 3.2-2. Little Saint Germain Lake shoreland categories and total lengths. Based upon an Fall 2016 survey. Locations of these categorized shorelands can be found on Map 2.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Through financial assistance from a WDNR Lake Protection Grant, WDNR Science Services, Michigan Technological University School of Forest Resources and Environmental Science, and regional environmental consultants conducted shoreline habitat restorations on 6 private properties (4 separate landowners). The principal investigators of what has been called the Wisconsin Lakeshore Restoration Project, had higher expectations of enrollment into this program; but requirements such as restrictive covenants on the property deeds, 3-year required deer-proof fence, and periodic follow-up visits by researchers (including WDNR staff) were hypothesized as factors that lead to lower enrollment. In 2011 and 2012, 639 trees, 2,524 shrubs, 10 vines, 158 ferns, and 10,000 forbes/grasses/sedges were planted in addition to installing shoreline erosion measures and rain gardens (Haskell and Meyer 2014).

Within the 2016 stakeholder survey sent to Little Saint Germain district members, 58.4% of respondents indicating they had interest in participating in a grant-funded shoreland restoration project (Appendix B, Question 33).

Haskell et al. 2017 focused on the assessment of wildlife habitat from this study, which included a restoration on a privately-owned property on Little Saint Germain Lake. The data indicate clear increases in habitat quantity and complexity metrics, especially within the understory. More information on the Wisconsin Lakeshore Restoration Project can be found here:

www.uwsp.edu/cnr-ap/UWEXLakes/Pages/resources/WiLakeshoreRestorationProject/press.aspx

Coarse Woody Habitat

Little Saint Germain Lake was surveyed in 2016 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

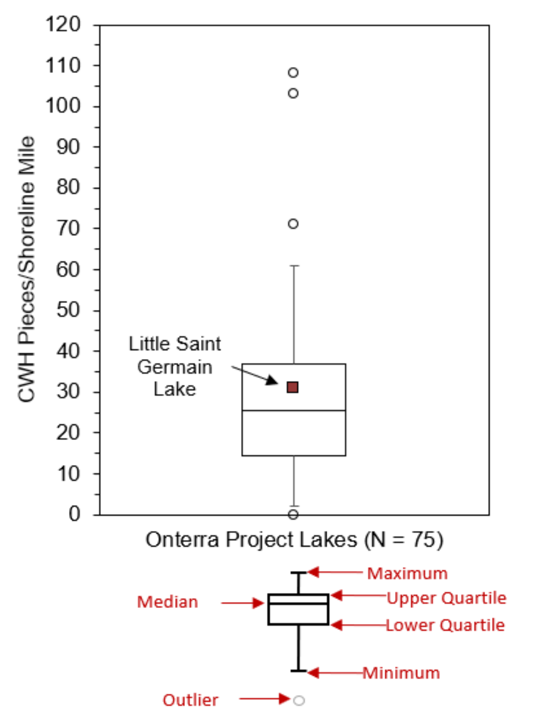


Figure 3.2-3. Little Saint Germain total number of coarse woody habitat (CWH) pieces per shoreline mile. State-wide comparative data available from 75 lakes surveyed by Onterra since 2012.

Onterra has completed coarse woody habitat surveys on 75 lakes throughout Wisconsin since 2012. Figure 3.3-3 displays the number of coarse woody habitat pieces per shoreline mile from Little Saint Germain Lake and how it compares with data from the 75 lakes surveyed. During the survey on Little Saint Germain Lake, 456 total pieces of coarse woody habitat were observed along 14.9 miles of shoreline, which gives the lake a coarse woody habitat to shoreline mile ratio of 31:1 (Figure 3.3-4). The number of coarse woody habitat pieces per shoreline mile in Little Saint Germain Lake exceeded the median for these 75 lakes. Although the methodology is much different, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Most of the coarse woody habitat located on Little Saint Germain Lake was between 2 and 8 inches in diameter (Figure 3.3-4).

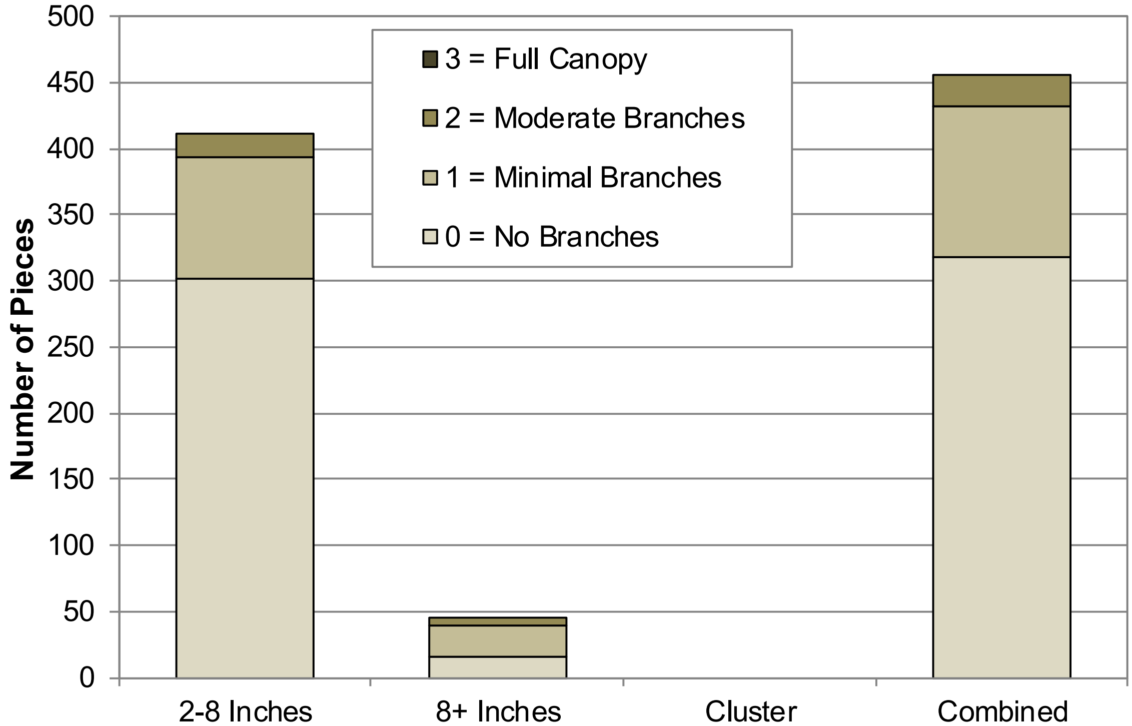


Figure 3.2-4. Little Saint Germain Lake coarse woody habitat survey results. Based upon a Fall 2016 survey. Locations of Little Saint Germain Lake coarse woody habitat can be found on Map 3.

In 2011 and 2012, 16 trees were placed at four locations in No Fish Bay or East Bay (Haskell and Meyer 2014).

3.3 Aquatic Plants

Introduction

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

Photograph 3.3-1. Example of emergent and floating-leaf communities.

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

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

Photograph 3.3-2. Example of aquatic plants that have been removed manually.

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

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

Cost

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

Advantages	*Disadvantages*
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb benthic organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Bottom Screens

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

Cost
Material costs range between $.20 and $1.25 per square-foot. Installation cost can vary largely, but may roughly cost $750 to have 1,000 square feet of bottom screen installed. Maintenance costs can also vary, but an estimate for a waterfront lot is about $120 each year.

Advantages	***Disadvantages***
• Immediate and sustainable control. • Long-term costs are low. • Excellent for small areas and around obstructions. • Materials are reusable. • Prevents fragmentation and subsequent spread of plants to other areas.	• Installation may be difficult over dense plant beds and in deep water. • Not species specific. • Disrupts benthic fauna. • May be navigational hazard in shallow water. • Initial costs are high. • Labor intensive due to the seasonal removal and reinstallation requirements. • Does not remove plant biomass from lake. • Not practical in large-scale situations.

Water Level Drawdown

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

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

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

Mechanical Harvesting

Photograph 3.3-3. Mechanical harvester.

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

Cost

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

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

Herbicide Treatment

Photograph 3.3-4. Granular herbicide application.

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

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

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

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

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

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

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

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

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

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

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

Cost

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

Advantages	*Disadvantages*
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively.

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

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

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

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

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

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

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

Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Little Saint Germain Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Point-intercept survey

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was used to complete the whole-lake point-intercept surveys on Little Saint Germain Lake in 2008, 2013, and 2016. Based upon guidance from the WDNR, a point spacing (resolution) of 75 meters was used resulting in 699 sample locations (Map 1). A point-intercept survey was also conducted in 2004; however, this was when this survey methodology was in its infancy, and a larger resolution was used (100 meters) which resulted in only 364 total sampling points. While fewer locations were sampled in 2004, the data can still be compared to those collected in the 2008, 2013, and 2016 surveys.

At each point-intercept location within the littoral zone, information regarding the depth, substrate type (muck, sand, or rock), and the plant species sampled along with their relative abundance (Figure 3.3-1) on the sampling rake was recorded. A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 15 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 15 feet. Depth information was collected using graduated marks on the pole of the rake or using an onboard sonar unit at depths greater than 15 feet. Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately "feel" the bottom with this sampling device. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

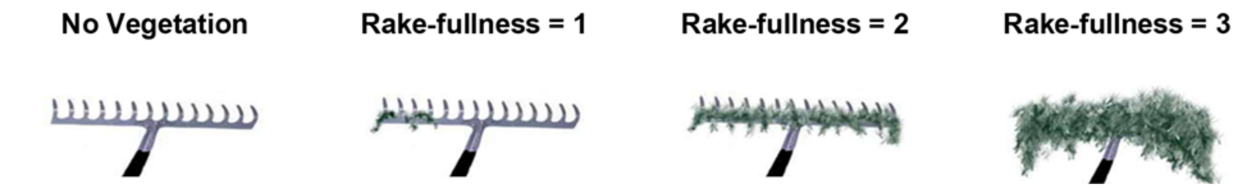


Figure 3.3-1. Aquatic plant rake-fullness ratings. Adapted from Hauxwell et al (2010).

When appropriate, a modified point-intercept sub-sampling methodology was used within AIS herbicide treatment areas in an effort to quantitatively evaluate success of the treatment. These efforts are discussed thoroughly in annual treatment reports produced for the Little Saint Germain Lake 2009-2016.

Community mapping survey

The point-intercept methodology is very useful for capturing the species richness and diversity (discussed below) of a submersed aquatic plant community. However, often the presence of emergent or floating-leaf vegetation is not adequately sampled with this survey type. Emergent and floating-leaf vegetation are often found within shallow reaches of a lake and thus can be hard to access in watercraft. To document the presence of these aquatic plant communities, a community mapping survey was conducted on Little Saint Germain Lake in 2004, 2008, 2013, and 2016. During these surveys, emergent and floating-leaf aquatic plant communities were documented with sub-meter accuracy GPS technology in two formats, point-based and polygon-based methods. A single GPS waypoint was taken at the location of smaller communities (less than 40 ft diameter or length) while polygons were delineated around larger communities. Species presence was also documented in order of most prevalent within the community to least prevalent. As previously discussed, differences in these communities between time periods may indicate environmental disturbances or recoveries in a lake ecosystem.

Aquatic invasive species peak-biomass surveys

When studying invasive plants like CLP and EWM, methodologies such as the point-intercept survey can be difficult to properly assess abundance and distribution of these species due to their, often, low abundance in the lake and the tendency for these species to form colonies. To adequately assess the CLP population within Little Saint Germain Lake, Onterra staff carried out an Early-Season AIS Survey in the early summer of 2016. Surveys to locate CLP are normally conducted in early summer because this is when this plant reaches its peak growth before senescing (dying back) in late June to early July. This survey required that CLP treatments occur in Little Saint Germain Lake in 2016 to allow the CLP population to reach its full potential. In contrast to CLP, EWM reaches its peak growth in late summer, and to assess the EWM population, Onterra ecologists conducted Late-Summer Peak-Biomass Surveys annually on Little Saint Germain Lake from 2007-2016.

During these surveys, plants are denoted with either point-based or polygon-based methods as described above in the community mapping discussion. Point-based CLP/EWM locations are described as *Single or Few Plants, Clumps of Plants* or as a *Small Plant Colony*. Polygon-base distinctions include *Highly Scattered* and *Scattered* for lightly dense areas, with *Dominant*¸ *Highly Dominant* and *Surface Matted* left to describe denser CLP/EWM colonies. These surveys produce maps which depict success/failures of herbicide treatments based upon qualitative observations. Additionally, they produce information that is vital for management planning for the following year.

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Little Saint Germain Lake in 2016. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Little Saint Germain Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys (equation shown below). This assessment allows the aquatic plant community of Little Saint Germain Lake to be compared to other lakes within the region and state.

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

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from Little Saint Germain Lake is compared to data collected by Onterra and the WDNR Science Services on 77 lakes withn the Southeast Wisconsin Till Plain ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within each lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Little Saint Germain Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

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 watermilfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.3-2). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

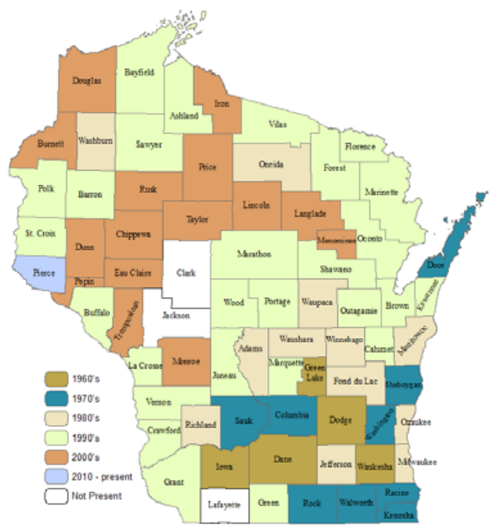


Figure 3.3-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

Comprehensive aquatic plant inventories were completed on Little Saint Germain Lake four times – once in 2004, 2008, 2013, and 2016 by Onterra. A total of 73 aquatic plant species were located from Little Saint Germain Lake (46 in 2004, 54 in 2008, 51 in 2013, and 46 in 2016), four of which are considered to be a non-native and invasive species: Eurasian watermilfoil, curly-leaf pondweed, pale yellow iris, and purple loosestrife (Table 3.3-1).

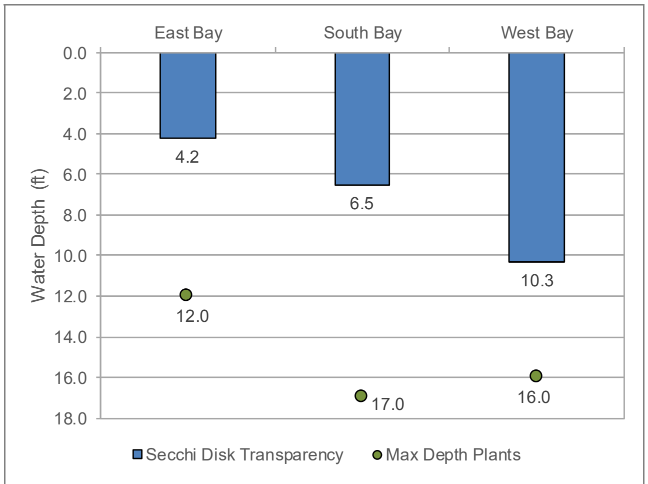


Figure 3.3-3. 2016 average Secchi disk transparency and maximum depth of aquatic plant growth.

During the 2016 point-intercept survey, aquatic plants were found growing to a maximum depth of 17 feet in South Bay, 16 feet in West Bay, but only to 12 feet in East Bay (includes Lower East Bay). Historical water quality data from Little Saint Germain Lake indicates that water clarity is generally highest in West Bay and South Bay and lower in East Bay (Onterra 2010), and this continued to be the case in 2016. Data collected by Citizen Lake Monitoring Network volunteers indicates that average Secchi disk transparency was 10.3, 6.5, and 4.2 feet in West Bay, South Bay, and East Bay, respectively. Water clarity (light penetration) determines how deep aquatic plants can grow, and in general, aquatic plants grow two to three times the depth of the average Secchi disk depth. The maximum depth of aquatic plants within the bays of Little Saint Germain Lake in 2016 follows this relationship (Figure 3.3-3).

Of the points that fell within the littoral zone in 2016 (littoral frequency), 47% contained aquatic vegetation, compared to 56% in 2008. However, plants were only found growing to a maximum depth of 17 feet in 2016, which results in a lower number of littoral sampling locations in 2016 when compared to 2013 (maximum depth of plants 20 feet). Comparing the number of sampling locations that contained aquatic vegetation in 2013 and 2016 shows that the occurrence of vegetation was also not similar between these two surveys; 314 and 264 sampling locations contained aquatic vegetation in 2013 and 2016, respectively (Figure 3.3-4).

Table 3.3-1. Aquatic plant species found in Little Saint Germain Lake during 2004, 2008, 2013, and 2016 studies.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2004	2008	2013	2016
Emergent	*Bolboschoenus fluviatilis*	River bulrush	5		I	I	
	Calla palustris	Water arum	9	I	I	I	I
	Carex comosa	Bristly sedge	5		I		I
	Carex utriculata	Common yellow lake sedge	7			I	I
	Dulichium arundinaceum	Three-way sedge	9	I	X		
	Eleocharis erythropoda	Bald spike-rush	3		I		
	Eleocharis palustris	Creeping spikerush	6	I	X	X	X
	Iris pseudacorus	Pale yellow iris	Exotic				I
	Iris versicolor	Northern blue flag	5		I		
	Juncus effusus	Soft rush	4		I		
	Juncus pelocarpus	Brown-fruited rush	8	X	X		
	Lythrum alatum	Winged loosestrife	6		I		
	Lythrum salicaria	Purple loosestrife	Exotic		I	I	
	Pontederia cordata	Pickerelweed	9	I	X	X	I
	Sagittaria latifolia	Common arrowhead	3	I	I	I	I
	Scirpus cyperinus	Wool grass	4				I
	Schoenoplectus acutus	Hardstem bulrush	5	I	X	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I	I	I	
	Typha spp.	Cattail spp.	1	I	I	I	I
	Zizania palustris	Northern wild rice	8			X	
FL	*Brasenia schreberi*	Watershield	7		X	I	I
	Nuphar variegata	Spatterdock	6	X	X	I	I
	Nymphaea odorata	White water lily	6	X	X	I	I
	Persicaria amphibia	Water smartweed	5				I
FL/E	*Sparganium americanum*	Eastern bur-reed	8			X	I
	Sparganium androcladum	Shining bur-reed	8		I		
	Sparganium angustifolium	Narrow-leaf bur-reed	9		X	I	I
	Sparganium emersum	Short-stemmed bur-reed	8		X		
	Sparganium eurycarpum	Common bur-reed	5	I	I	X	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X			
Submergent	*Bidens beckii*	Water marigold	8	X			X
	Ceratophyllum demersum	Coontail	3	X	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X	X
	Elatine minima	Waterwort	9	X		X	X
	Elodea canadensis	Common waterweed	3	X	X	X	X
	Heteranthera dubia	Water stargrass	6	X	X	X	X
	Isoetes lacustris	Lake quillwort	8	X		X	X
	Lobelia dortmanna	Water lobelia	10	X	X	X	
	Myriophyllum alterniflorum	Alternate-flowered water milfoil	10			I	
	Myriophyllum sibiricum	Northern water milfoil	7	X	X	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	I	X	X	I
	Myriophyllum tenellum	Dwarf water milfoil	10	X		X	X
	Najas flexilis	Slender naiad	6	X	X	X	X
	Najas guadalupensis	Southern naiad	7			X	X
	Nitella spp.	Stoneworts	7	X	X		X
	Potamogeton alpinus	Alpine pondweed	9	X	X		
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	X
	Potamogeton berchtoldii	Slender pondweed	7			X	
	Potamogeton crispus	Curly-leaf pondweed	Exotic	I	X	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X		
	Potamogeton foliosus	Leafy pondweed	6	X	X	X	
	Potamogeton gramineus	Variable pondweed	7	X	X	X	X
	Potamogeton illinoensis	Illinois pondweed	6	X	X	X	
	Potamogeton nodosus	Long-leaf pondweed	7	I			
	Potamogeton obtusifolius	Blunt-leaf pondweed	9			X	
	Potamogeton praelongus	White-stem pondweed	8	X	X	X	X
	Potamogeton pusillus	Small & Slender pondweed	7	X	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8		I		
	Potamogeton strictifolius	Stiff pondweed	8			X	X
	*Potamogeton vaseyi**	Vasey's pondweed	10		X		
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	X
	Ranunculus aquatilis	White water-crowfoot	8	X	X	X	X
	Utricularia vulgaris	Common bladderwort	7		X	X	
	Vallisneria americana	Wild celery	6	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X	X	X
	Sagittaria graminea	Grass-leaved arrowhead	9	X	X		I
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A			X	X
FF	*Lemna minor*	Lesser duckweed	5	X	X	X	X
	Lemna trisulca	Forked duckweed	6	X	X	X	X
	Spirodela polyrhiza	Greater duckweed	5	X	X	X	
	Wolffia columbiana	Common watermeal	5	X			

FL = Floating-leaf; FL/E = Floating-leaf and Emergent; S/E = Submergent and Emergent; FF = Free-floating
X = Located on rake during point-intercept survey; I = Incidentally located
** = Species listed as 'special concern' in Wisconsin*

Figure 3.3-4 illustrates the distribution of aquatic plants in Little Saint Germain Lake from the 2008, 2013, and 2016 surveys, and shows that distribution of aquatic plants was similar between these three surveys. Aquatic vegetation total rake fullness (TRF) ratings recorded in 2016 also indicate that where vegetation is present, it is also moderately dense, with 30% of the littoral sampling locations containing aquatic plants with TRF ratings of 2 or 3 (Figure 3.3-5).

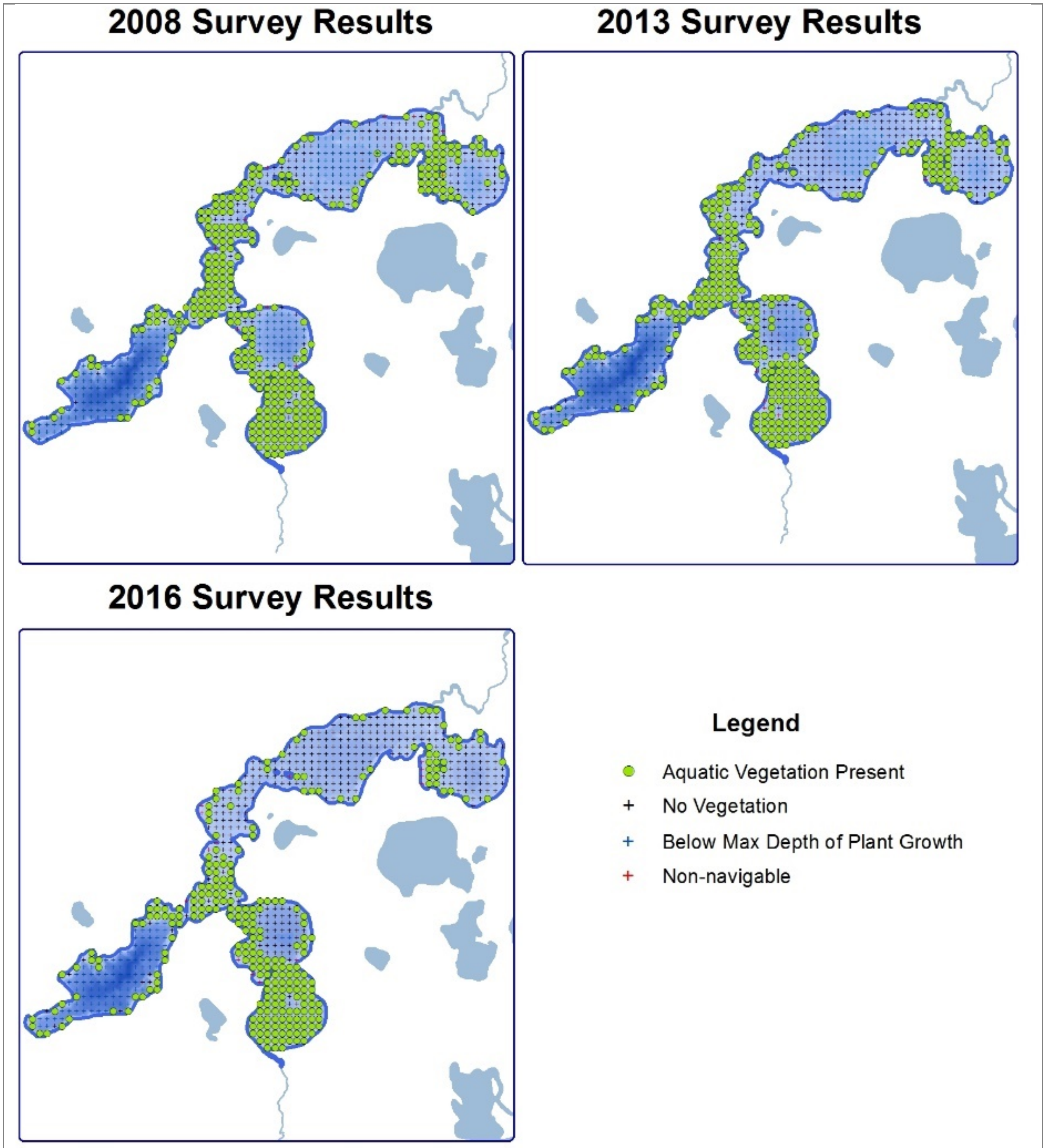


Figure 3.3-4. Distribution of aquatic vegetation in Little Saint Germain Lake in 2008, 2013, & 2016.

During the 2016 whole-lake point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 76% of the point-intercept locations less than 15 feet deep contained soft sediments (muck), 17% contained sand, and 7% contained rock (Figure 3.3-6).

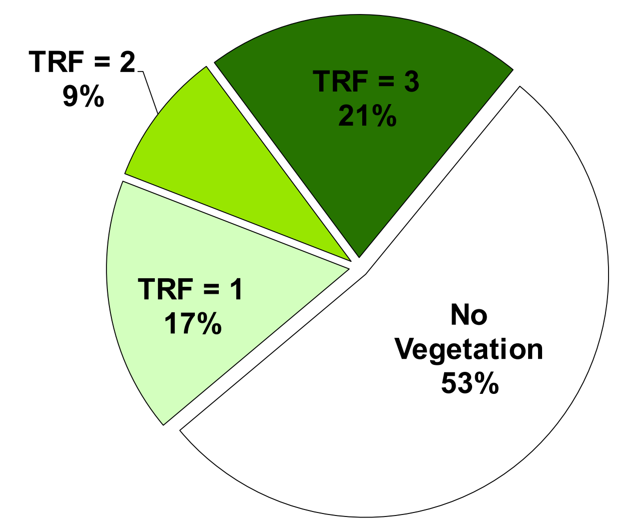


Figure 3.3-5. Little Saint Germain 2016 aquatic plant total rake fullness (TRF) ratings. Created using data from the 2016 point-intercept survey.

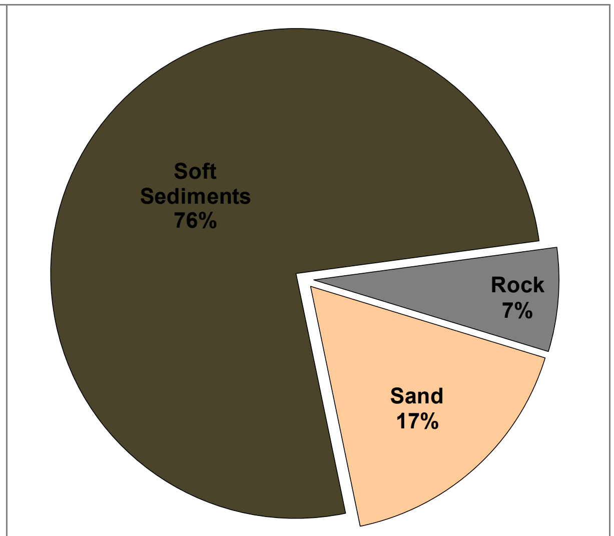


Figure 3.3-6. Little Saint Germain 2016 proportion of substrate types. Created using data from the 2016 point-intercept survey.

The variations in substrate type provide different habitats for aquatic plants, and along with other varying characteristics among Little Saint Germain Lake's basins such as water chemistry, clarity, and depth, create an aquatic plant species-rich environment. Of the 43 native aquatic plant species located during 2016 surveys on Little Saint Germain Lake, 32 were physically encountered on the rake during the whole-lake point-intercept survey (Figure 3.3-7). The remaining 11 species were located incidentally. Of the 32 native species encountered on the rake in 2016, southern naiad, coontail, and common waterweed were the three most frequently encountered (Figure 3.3-7).

Aquatic plants can be placed in one of two general groups, based upon their form of growth and habitat preferences. These groups include the isoetid growth form and the elodeid growth form. Little Saint Germain Lake has both isoetid and elodeid species within its waters. Plants of the isoetid growth form are small, slow growing, and inconspicuous submerged plants. They often have evergreen leaves located in a rosette and are usually found growing in sandy soils within the near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000). Some common isoetid species in Little Saint Germain Lake include quillwort, needle spikerush, and dwarf watermilfoil. Submersed species of the elodeid growth form have leaves on tall, erect stems which grow upwards into the water column. Examples of Little Saint Germain Lake elodeid species include southern naiad, muskgrasses, white-stem pondweed and northern watermilfoil.

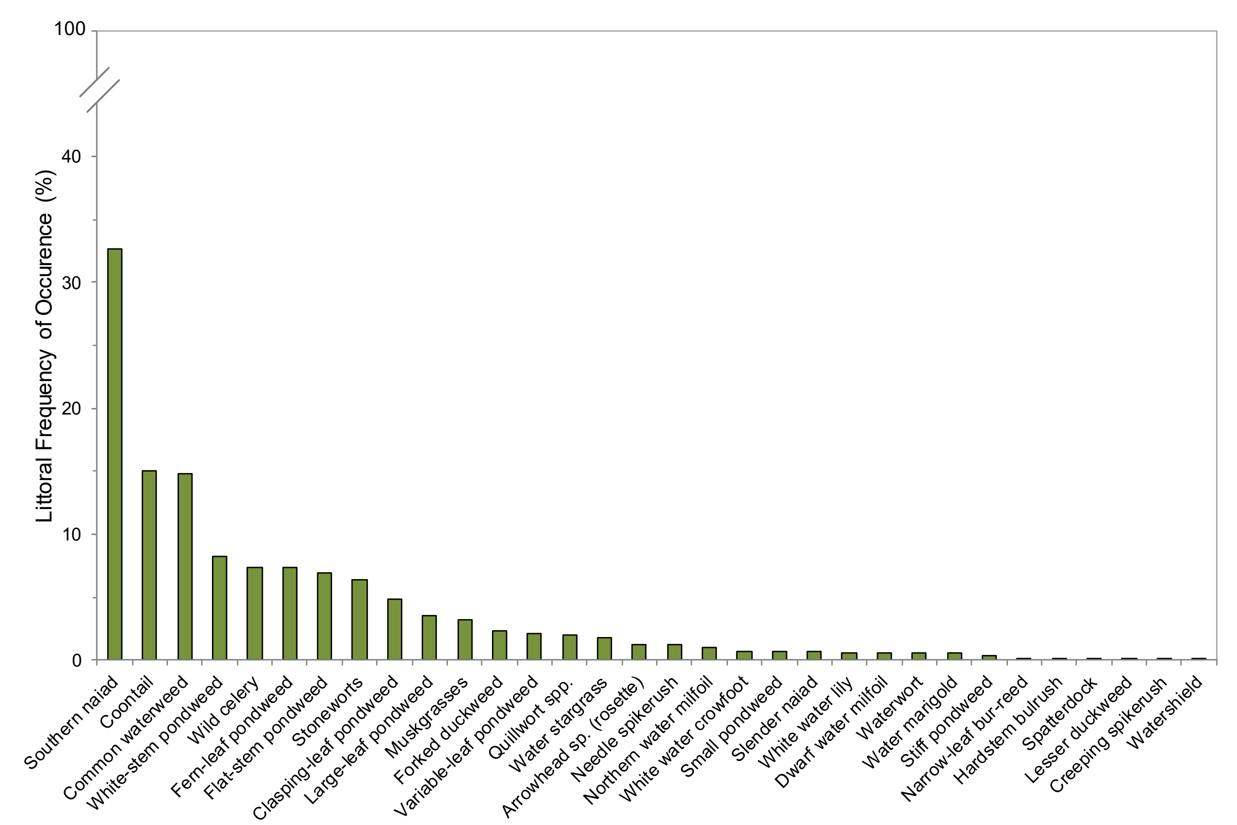


Figure 3.3-7. Little Saint Germain Lake aquatic plant littoral frequency of occurrence. Created using data from August 2016 surveys.

Alkalinity is the primary water chemistry factor determining whether a lake is dominated by plant species of the isoetid or elodeid growth form (Vestergaard and Sand-Jensen 2000). Most elodeids are restricted to lakes of relatively higher alkalinity, as their carbon demand for photosynthesis cannot be met solely by the dissolved carbon dioxide (CO_2) present in the water, and they must acquire additional carbon through bicarbonate (HCO_3^-). While isoetids are able to grow in lakes of higher alkalinity, their short stature makes them poor competitors for light, and they are usually outcompeted and displaced by the taller elodeids. Thus, isoetids are most prevalent in lakes of low alkalinity where they can avoid competition from elodeids. However, in lakes with intermediate alkalinity levels, like Little Saint Germain Lake, we see a mixed community of both, with isoetids inhabiting the shallow, sandy/rocky areas and elodeids thriving in the deeper areas of softer sediment.

With a littoral frequency of occurrence of 33%, southern naiad was the most frequently encountered aquatic plant in Little Saint Germain Lake in 2016 (Figure 3.3-7). Southern naiad was not recorded in Little Saint Germain Lake during the 2004 and 2008 surveys, and it is believed that it may have been misidentified as slender naiad. These two species are morphologically similar, and distinguishing between them in the field is often difficult. While closely related to slender naiad, southern naiad is often perennial and lacking fruit (Les et al. 2010). Emerging research is indicating that hybrids between southern naiad subspecies exist and are often observed growing aggressively and reaching nuisance levels in certain lakes. Historically, the LSGLPRD conducted mechanical harvesting on the lake to create navigation corridors for riparians and lake users. These efforts largely targeted common waterweed and coontail. As these populations have fluctuated downward in recent years (Figure 3.3-9, Figure 3.3-10) and southern naiad populations have increased (Figure 3.3-8), the mechanical harvesting efforts have focused on southern naiad in Little Saint Germain. Like coontail and common waterweed, naiad species dislodge and form surface mats that interfere with ecosystem services the lake provides such as navigation, recreation, and aesthetics (Photograph 3.3-5). Often the plants that are being harvested are not growing in place, rather have uprooted and aggregated.

Slender & Southern naiad (*Najas flexilis & N. guadalupensis*)

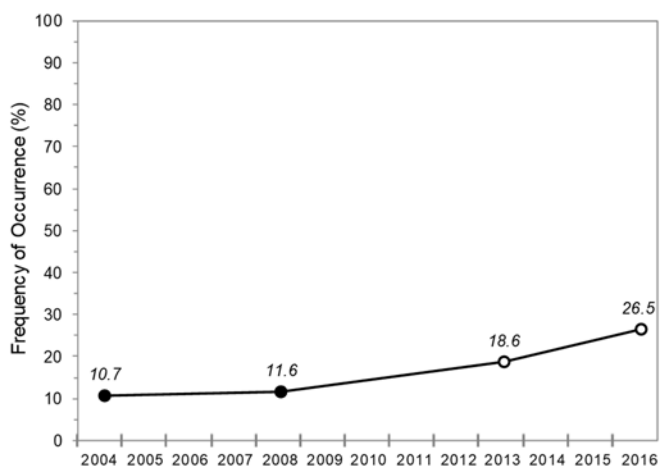


Figure 3.3-8. Frequency of occurrence naiad species in Little Saint Germain Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 3.3-5. Southern naiad being removed from a riparian's shoreline.

Coontail (*Ceratophyllum demersum)*

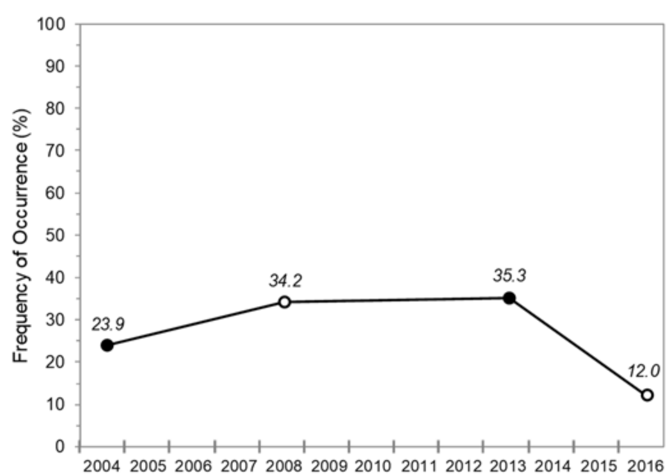


Figure 3.3-9. Frequency of occurrence of coontail in Little Saint Germain Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Coontail was the second-most frequently encountered aquatic plant in Little Saint Germain Lake in 2016 with a littoral frequency of occurrence of approximately 15% (Figure 3.3-7). Arguably the most common aquatic plant in Wisconsin, coontail possesses whorls of stiff leaves. Lacking roots, coontail can grow entangled amongst rooted vegetation and obtain all of its nutrients directly from the water. Also able to tolerate low-light conditions, it is often one of the most abundant aquatic plants in more productive lakes. Its dense foliage offers excellent habitat to aquatic organisms, especially in deeper water where many other plants are unable to grow. However, under certain conditions, most often in lakes with excessive nutrients, coontail can grow to levels which can interfere with recreation on the lake. In 2016, coontail was most abundant between 4 and 9 feet of water in Little Saint Germain Lake.

Common waterweed, the third-most abundant aquatic plant in Little Saint Germain Lake in 2016 with a littoral frequency of occurrence of approximately 15% (Figure 3.3-7), is often one of the more dominant aquatic plants in Wisconsin's lakes and can be found throughout North America. Like coontail, it is able to tolerate low-light conditions and obtain the majority of its nutrients directly from the water, and can thrive in more productive lakes. Because of its prevalence in many of Wisconsin's lakes, common waterweed is an important component of many aquatic ecosystems where it provides structural habitat and absorbs nutrients that would otherwise be available to free-floating algae. In Little Saint Germain Lake, common waterweed and coontail were frequently found growing together, and common waterweed too was most abundant between 4 and 9 feet of water.

Like coontail, common waterweed has the capacity to grow to excessive levels and mat on the water's surface, which was what was observed in 2012 in No Fish Bay (Photograph 3.3-6). Lakes around the state experienced excessive growth of aquatic plants in 2012 with the early ice-off and higher-than-normal temperatures.

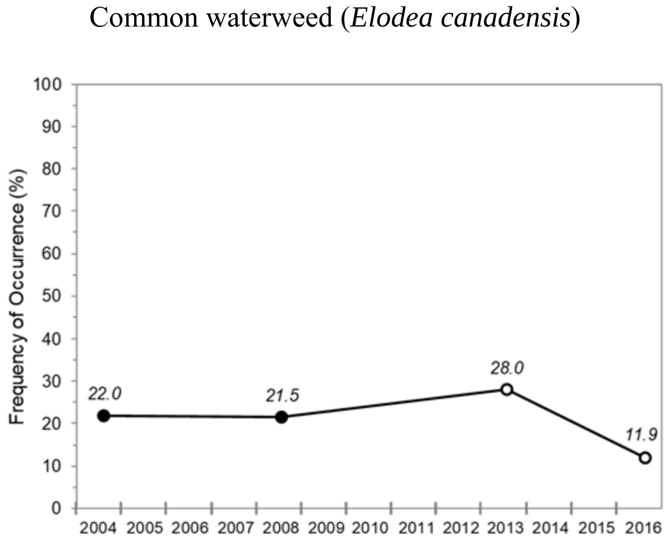
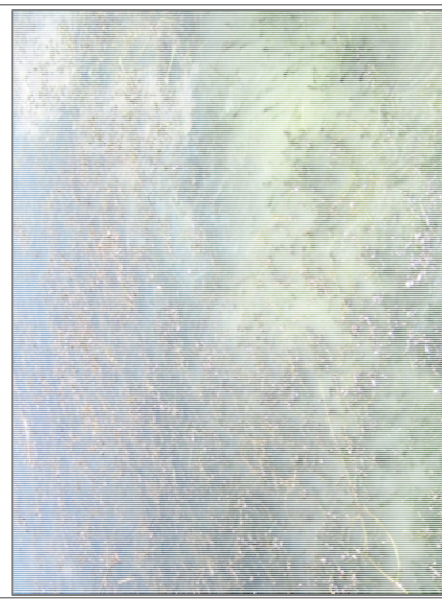


Figure 3.3-10. Frequency of occurrence of common waterweed in Little Saint Germain Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).



Photograph 3.3-6. Excessive growth of common waterweed. No Fish Bay, Little Saint Germain Lake in 2012.

Because point-intercept surveys were conducted in 2004, 2008, and 2013 the occurrences of aquatic plants species can be compared to those recorded in 2016. However, because the maximum depth of aquatic plant growth differed among these surveys, the number of littoral sampling locations differed. Because of this, just the frequency of occurrence (not littoral) of aquatic plant species within Little Saint Germain Lake was compared between these four surveys. Rather than dividing the number of sampling locations where a species was found by the total number of sampling locations that fell within the littoral zone (littoral frequency of occurrence), the number of sampling locations a species was found was divided by the total number of sampling locations within the lake (394 for 2004, 699 for 2008, 699 for 2013, and 699 for 2016).

Figure 3.3-8 and 3.3-9 displays the 2004, 2008, 2013, and 2016 frequency of occurrence of native aquatic plant species in Little Saint Germain Lake that had an occurrence of at least 4% in one of the four surveys. As discussed above, the population of some species like coontail, common waterweed, northern watermilfoil, flat-stem pondweed, and clasping-leaf pondweed are currently at the lowest levels since this form of monitoring began.

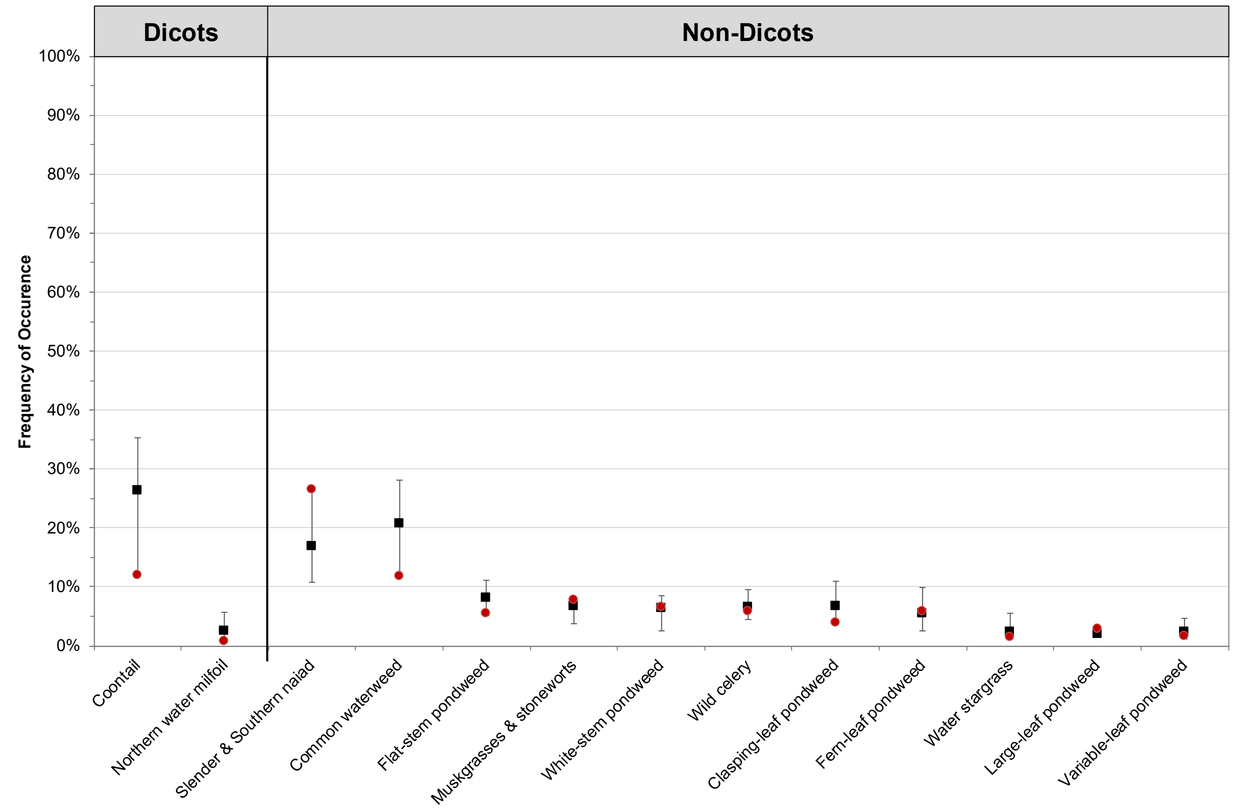


Figure 3.3-11. Littoral occurrence of native aquatic plant species from Little Saint Germain Lake. Square symbol represents mean frequency of occurrence from 2004, 2008, 2013, and 2016 surveys, error bars represent range of annual frequencies from these surveys, red circle represents 2016 frequency of occurrence.

It is plausible that the herbicide treatment strategy conducted on Little Saint Germain Lake could have influenced native plant populations from 2004 to 2016. The two groups of flowering plants, dicots and monocots/macroalgaes, differ in some of their morphological characteristics as well as their physiology. Due to these differences, it has historically been thought that monocot and macroalgae species are not susceptible to dicot-selective herbicides like 2,4-D. Emerging evidence by researchers with the US Army Corps of Engineers and WDNR may indicate that some monocot species can become impacted by 2,4-D under certain circumstances (herbicide dose, exposure time, etc.). Onterra's experience is that northern watermilfoil and coontail are species that tend to decline following 2,4-D management actions; fern-leaf pondweed and flat-stem pondweed are particularly vulnerable to endothall treatments.

Ongoing research indicates that some native species rebound quickly following impact from herbicide treatment, whereas other species are slower to recover. Continued monitoring will be important to tease out the inter-annual population fluctuations of these plants versus the true collateral effects the herbicide treatment strategy is causing to these valuable plant species.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total 43 native aquatic plant species were located in Little Saint Germain Lake during the 2016 surveys, 32 were encountered on the rake during the point-intercept survey. These 32 native species and their conservatism values were used to calculate the FQI of Little Saint Germain Lake's aquatic plant community in 2016.

Figure 3.3-12 compares the FQI components of Little Saint Germain Lake from the 2004, 2008, 2013 and 2016 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. All four surveys' species richness values greatly exceed the upper quartile values for lakes in the NLFL Ecoregion and for lakes throughout Wisconsin. Littoral area, water clarity, depth and sediment variation, shoreline complexity, and water chemistry are all factors that influence aquatic plant species richness. As discussed earlier, the basins of Little Saint Germain Lake offer a wide variety of habitat types for aquatic plants and create a species-rich environment.

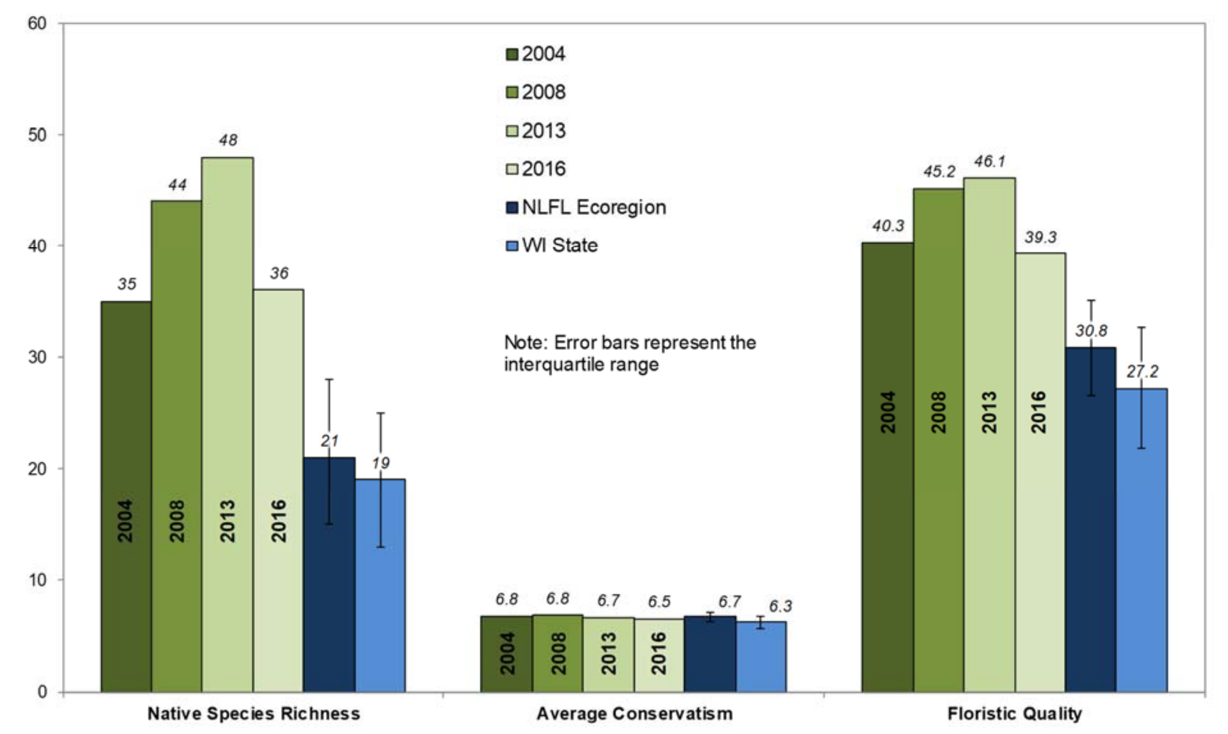


Figure 3.3-12. Little Saint Germain Lake Floristic Quality Assessment. Created using data from 2004, 2008, 2013, and 2016 surveys.

The average conservatism values for Little Saint Germain Lake's aquatic plant community were 6.8 in 2004 and 2008, 6.6 in 2013 and 6.5 in 2016 (Figure 3.3-10). These values fall around the median value (6.7) for lakes in the NLFL Ecoregion and the upper quartile value for lakes throughout Wisconsin, indicating Little Saint Germain Lake's aquatic plant community is of similar quality to other lakes' in the northern region and of higher quality than most lakes' in the state. Combining the high native species richness and the moderate average conservatism values yields FQI values that exceed the upper quartile values for lakes in the NLFL Ecoregion and for lakes throughout Wisconsin.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Little Saint Germain Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.3-13). Using the data collected from the 2004, 2008, 2013, and 2016 point-intercept surveys, Little Saint Germain Lake's aquatic plant community was shown to have high species diversity in 2004, 2013 and 2016 with a Simpson's diversity values of 0.90, 0.89, and 0.89, respectively, and moderate diversity in 2008 with a value of 0.85. In other words, if two individual aquatic plants were randomly sampled from Little Saint Germain Lake in 2016, there would be an 89% probability that they would be different species.

As explained earlier, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while southern naiad was found at approximately 33% of the littoral sampling locations in Little Saint Germain Lake in 2016, its relative frequency of occurrence is 25%. Explained another way, if 100 plants were randomly sampled from Little Saint Germain Lake, 25 of them would be southern naiad. Figure 3.3-14 displays the relative occurrence of aquatic plant species from Little Saint Germain Lake in 2016, and illustrates that the aquatic plant community is not overly-dominated by one or few species, leading to high species diversity.

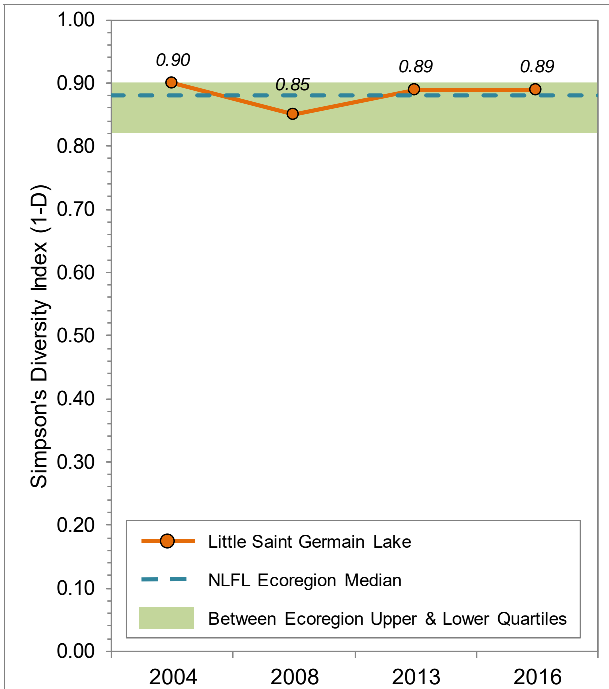


Figure 3.3-13. Little Saint Germain Lake Simpson's Diversity Index. Created using data from 2004, 2008, 2013 and 2016 point-intercept surveys.

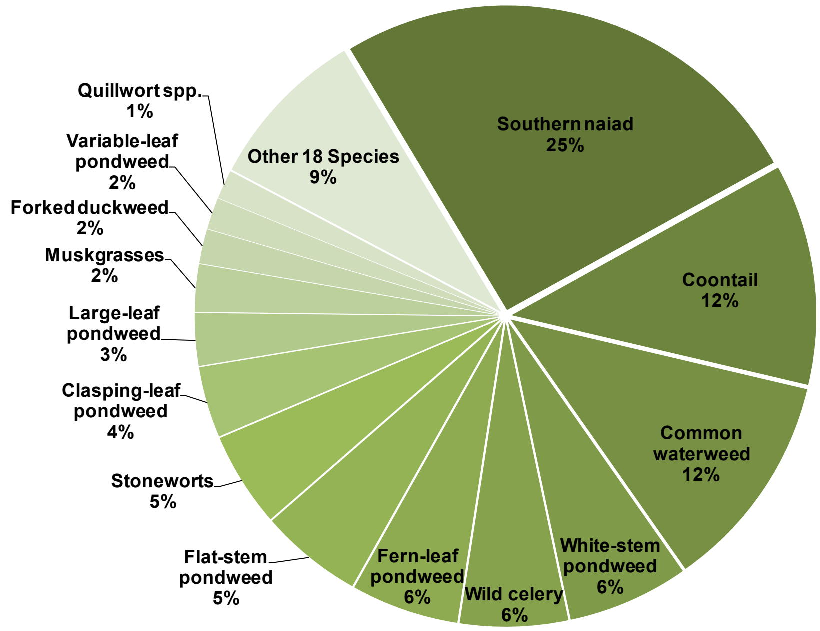


Figure 3.3-14. Little Saint Germain Lake relative plant littoral frequency of occurrence. Created using data from August 2016 surveys.

A major limitation of the point-intercept method is the inability to use this technique to evaluate emergent and/or adjacent wetland areas due to the inability to navigate in these areas. These communities serve as a different, and sometimes preferred, type of habitat within a lake environment for mammals, birds, amphibians and fish. These communities are often impacted by recreational lake use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

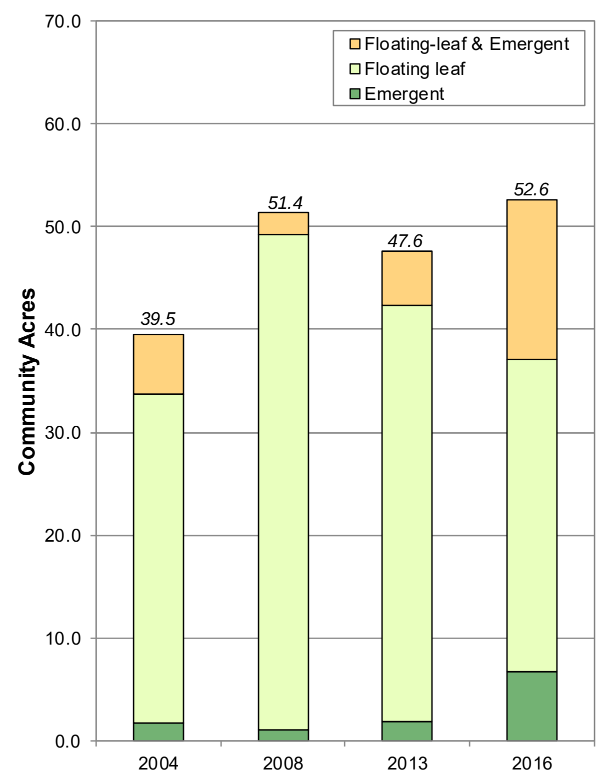


Figure 3.3-15. Little Saint Germain Lake emergent and floating-leaf areal cover. Created using data from 2004, 2008, 2013 and 2016 community mapping surveys.

Mapping of emergent and floating-leaf communities took place in 2004, 2008, 2013 and 2016 by Onterra staff (Figure 3.3-15, Map 4). These communities increased by approximately 12 acres from 2004 to 2008, retracted by approximately 3.8 acres from 2008 to 2013 and increased again by approximately five acres from 2013 to 2016.

Non-native Plants in Little Saint Germain Lake

Curly-leaf pondweed

Curly-leaf pondweed (Photograph 3.3-7) was first documented in Little Saint Germain Lake in 2000. Since its discovery, the LSGLPRD has been very proactive in managing this invasive plant through localized herbicide spot treatments. Reliable anecdotal data suggests that in 2003, CLP could be observed growing in dense colonies with some surface matting occurring. Only localized occurrences of this type of growth have been observed on the lake since that first treatment.

Photograph 3.3-7. Curly-leaf pondweed, a non-native, invasive aquatic plant. Photo credit Onterra.

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced in one year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Normally a control strategy for an established CLP population includes 5-7 years of treatments of the same area to deplete the existing turion bank within the sediment. Johnson et al. (2012) investigated 9 midwestern lakes that received five consecutive annual large-scale endothall treatments to control CLP. The greatest reductions in CLP frequency, biomass, and turions was observed in the first 2 years of the control program, but continued reductions were observed following all five years of the project.

The LSGLPRD has targeted roughly the same areas for CLP control from 2003 to 2008 (Figure 3.3-16). Starting in 2009, the CLP treatment acreage on Little Saint Germain started to decline as insufficient CLP had been located within areas targeted for a number of years. No treatments targeting CLP occurred in 2013 as lake managers wanted to better understand the population of this species in absence of a treatment. In 2014, approximately 20 acres were treated for CLP control. However, Lower East Bay was targeted with a large-scale combination 2,4-D/endothall treatment primarily for EWM control. Because endothall was a component of that herbicide strategy, the acreage is included on Figure 3.3-16.

CLP treatment acreage continued to decline in 2015 and 2016. No CLP treatments occurred in 2017 on Little Saint Germain Lake, allowing the CLP population to be documented in absence of an herbicide control measure (Map 5). Only a few areas of colonized CLP were located during this survey, of which all but 0.1 acre were comprised of *scattered* or *highly scattered* CLP.

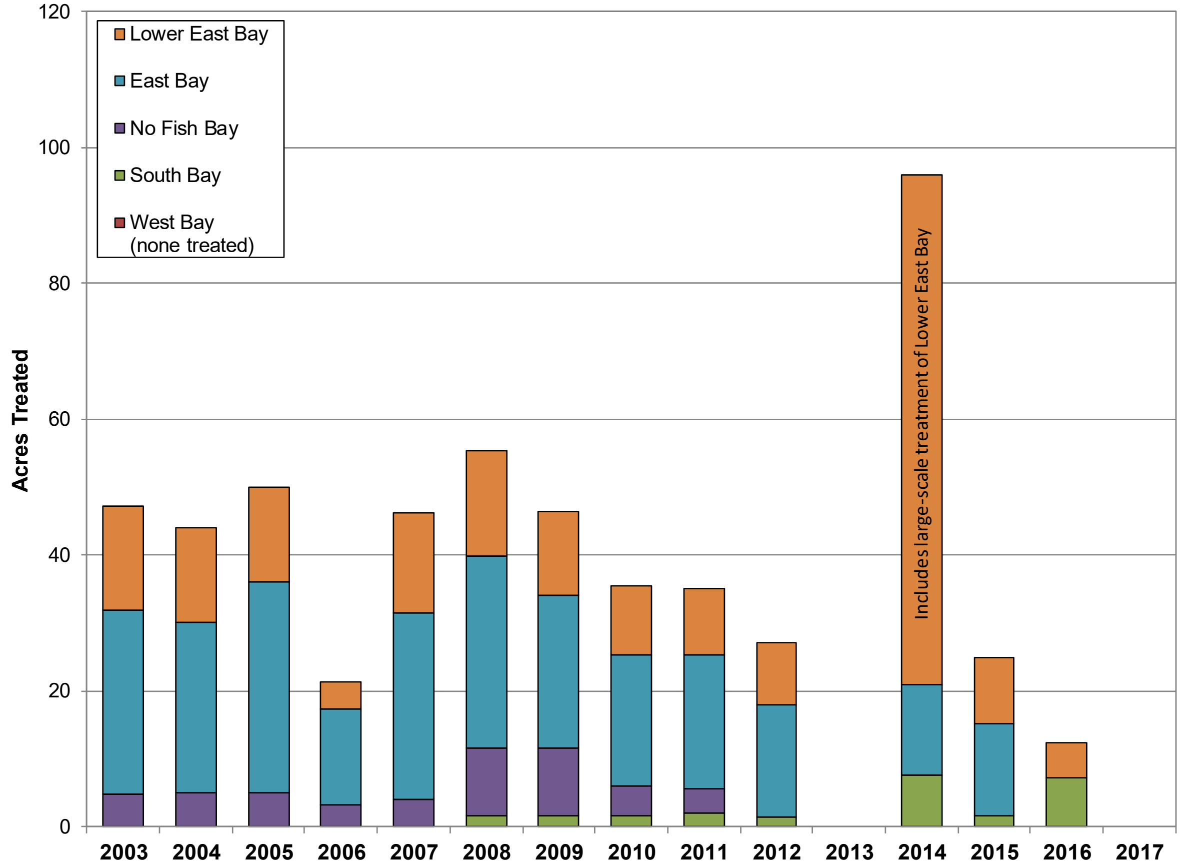


Figure 3.3-16. Little Saint Germain Lake annual CLP treatment history by basin, 2003-2017.

Eurasian watermilfoil

Eurasian watermilfoil (Photograph 3.3-8) was first documented in Little Saint Germain Lake in 2003. Since its discovery, the LSGLPRD has been active in managing this invasive plant through a combination of localized herbicide spot treatments and manual hand-removal.

Photograph 3.3-8. Eurasian watermilfoil, a non-native, invasive aquatic plant. Photo credit Onterra.

Up until late-2010, granular 2,4-D spot treatments were conducted based upon surface acreage of the lake, and not based upon the depth of the water within that area. During the winter of 2010-2011, it became more common for application rates of granular 2,4-D to be formulated based upon the volume of water in which the herbicide application would occur.

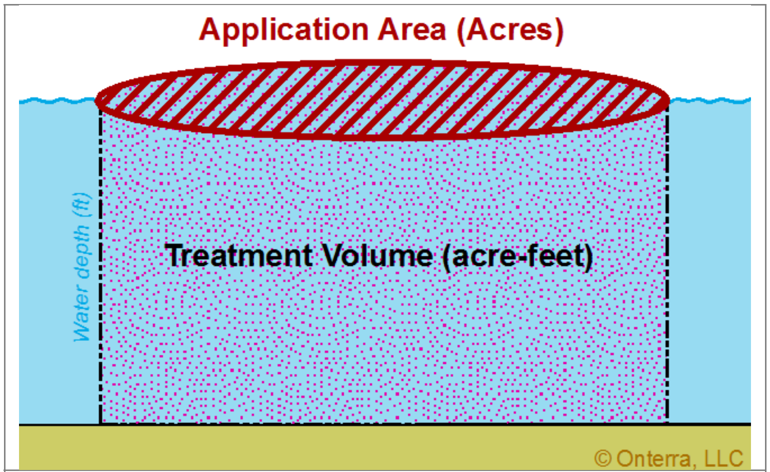


Figure 3.3-17. Herbicide Spot Treatment diagram.

This means that sufficient 2,4-D was applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal the desired concentration (Figure 3.3-17). This standard method for determining spot treatment use rates is not without flaw, as no physical barrier keeps the herbicide within the *Treatment Volume* and herbicide dissipates horizontally out of the area before reaching equilibrium (Figure 3.3-17). While lake managers may propose that a particular volumetric dose be used, such as 4.0 ppm ae, it is understood that actually achieving 4.0 ppm ae within the water column is not likely due to dissipation and other factors. And particularly with granular herbicides it is theorized that some of the 2,4-D granules sink into or bind with the sediment, not allowing a portion of the product to be included within herbicide measurements within the water column. Granular herbicides are also thought to release the herbicide more slowly in certain situations (e.g. lower pH); however more research is needed to quantify these statements.

With this new information, a different strategy was adopted in 2011 where EWM treatment areas would be targeted with granular 2,4-D but with a volume-based concentration. At that time the most commonly used granular 2,4-D product (ester form, Navigate®) had an EPA-approved label that only allowed the product to applied at a rate of up to 200 lbs/acre. The depth of the proposed 2011 treatment areas on Little Saint Germain Lake would not allow Navigate® to be used at a rate high enough to target the EWM at the desired concentration within the treatment volume (Figure 3.3-18).

Another granular 2,4-D product (amine form, Sculpin G®) was approved for use up to 4.0 ppm ae and became a more commonly used herbicide in Wisconsin lakes for the next few years. This product was also comprised of a different chemical variation of 2,4-D. The active ingredient of Navigate® is an ester formulation of 2,4-D, whereas Sculpin G® uses the amine version of 2,4-D. While both herbicide formulations quickly dissociate into the acid form of 2,4-D when exposed to water, the ester formulation has been shown to be more toxic to aquatic invertebrates and fish than the amine version. Updated EPA registration currently allows Navigate ® to be applied up to 4.0 ppm ae, although it carries a 24-hour swimming restriction whereas Sculpin G ® does not have any use restrictions.

Ongoing research conducted by WDNR, US Army Corps of Engineers Research and Development Center, and private consultants (including Onterra) shows that mid-depth water samples of granular herbicide treatments actually had lower concentrations than if liquid herbicides are used. The same data also do not show longer exposure times with granular herbicides. While research continues to occur on the subject, the use of liquid herbicides has become more favorable in recent years. In 2014, liquid herbicides were used in the large-scale treatment of Lower East Bay. Spot treatments that occurred in 2015 and 2016 were conducted using liquid 2,4-D formulations.

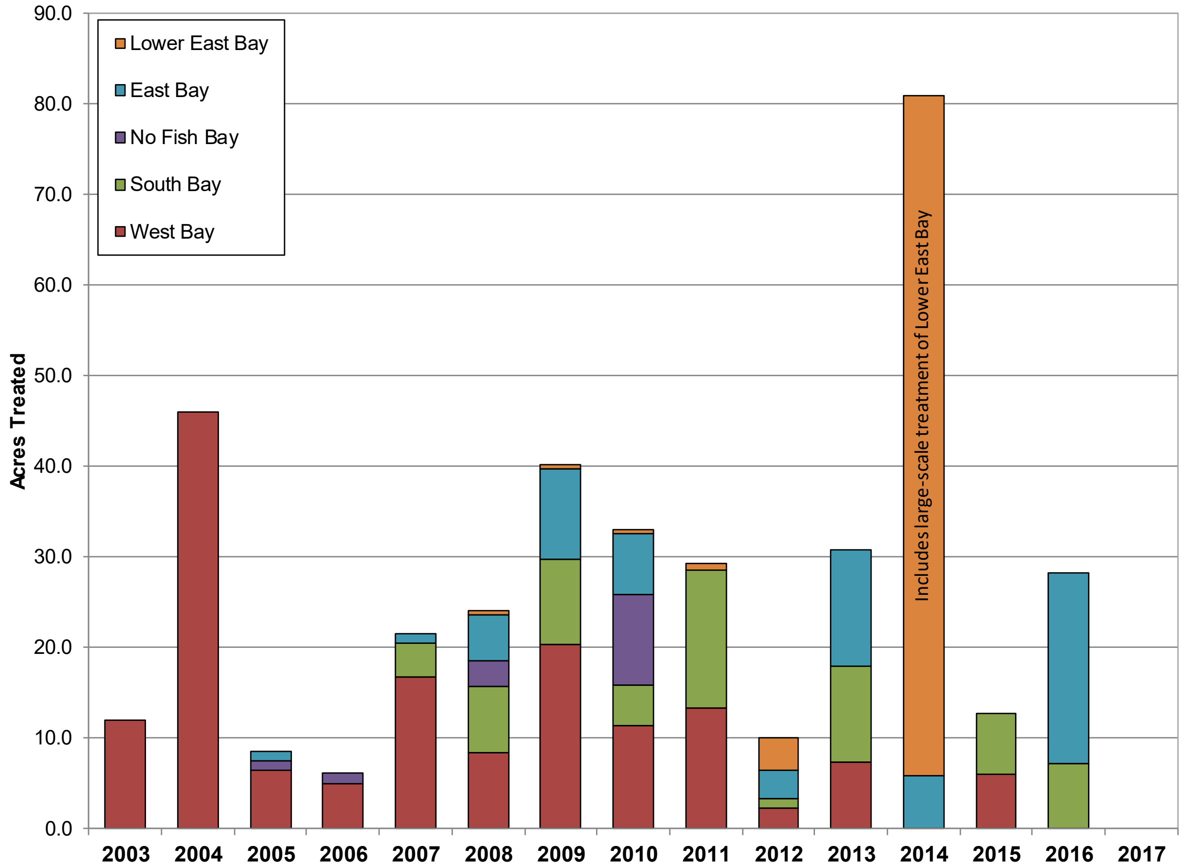


Figure 3.3-18. Little Saint Germain Lake annual EWM treatment history by basin. 2003-2017.

Subsequent research has helped understand that the herbicide concentrations and exposure times of large (> 5 acres each) treatment sites are higher and longer than for small sites (Nault et al. 2015). These data also showed that concentrations were not higher for granular products compared to liquid, and therefore liquid amine 2,4-D treatments have become the standard in Wisconsin. Research also indicates that higher herbicide concentrations and exposure times are observed in protected parts of a lake compared with open and exposed parts of the lake. Areas targeted containing water exchange (i.e. flow) are often not able to meet herbicide concentration-exposure time (CET) requirements for control.

Over the course of the past ten years, approximately 203 surface acres of Little Saint Germain Lake have been targeted for strategic control of EWM through herbicide treatments. As shown on the pie chart within Figure 3.3-19 the vast majority (85%) of this footprint consists of acreage that was only treated once or twice during this ten-year period. Acreage that was only treated once or twice may be a result of an effective treatment, where repeat treatments were not warranted. Areas that were targeted for three or more years of treatment over the time period are areas where success criteria were continually not met. In some instances, this was the result of a seemingly successful treatment where EWM rebounded and warranted additional treatment. All treatments conducted since 2007 were considered spot treatments, except the large-scale treatment of Lower East Bay in 2014.

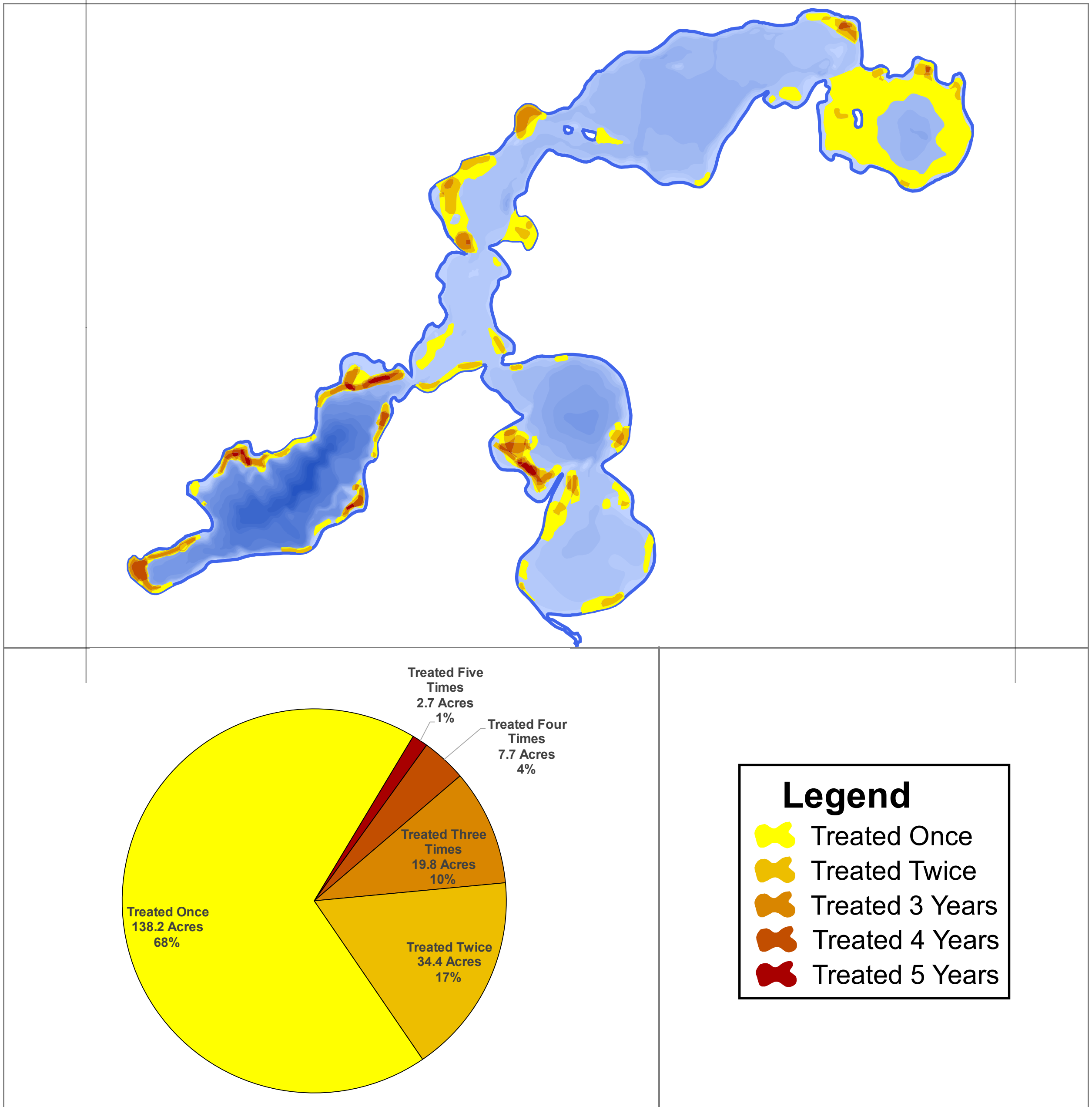


Figure 3.3-19. Surface acreage of EWM treated on Little Saint Germain Lake. 2007-2016

From an ecological perspective, large-scale treatments are those where the herbicide may be applied to specific sites, but when the herbicide dissipates from where it was applied and reaches equilibrium within the entire mixing volume of water (of the lake, lake basin, or within the epilimnion of the lake or lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire treated volume. A recent article by Nault et al. 2018 investigated 28 large-scale herbicide treatments in Wisconsin and found that "herbicide dissipation from the treatment sites into surrounding untreated waters was rapid (within 1 day) and lakewide low-concentration equilibriums were reached within the first few days after application." WDNR administrative code defines large-scale treatments as those that exceed 10% of the littoral zone (NR 107.04[3]). As spot treatments approach 10% of a lake's area, they are more likely to have large-scale impacts, which is why the WDNR has this check mechanism within the permitting process.

Predicting success and native plant impacts from large-scale treatments is also better understood than for spot treatments. However, with any large-scale chemical treatment, both the positive and negative effects of this type of treatment strategy are anticipated to occur at a lakewide scale, whereas the impacts from spot treatments are mostly contained within and around the application sites.

Efficacy

Figure 3.3-20 includes the entirety of Onterra-monitored 2,4-D large-scale treatments in the Northern Lakes and Forests Ecoregion that have progressed to at least 1 year after treatment (YAT). Also included on this figure are two lakes that received large-scale 2,4-D treatments that were monitored by WDNR as part of the EWM Long-Term Trends project discussed above. Properly implemented large-scale herbicide treatments can be highly effective, with minimal EWM, often zero, being detected for a year or two following the treatment (Figure 3.4-17). Some large-scale treatments have been effective at reducing EWM populations for 5 or more years following the application, whereas others have rebounded sooner (i.e. South Twin ’16, Sandbar ‘11).

As discussed above, a large-scale treatment of Lower East Bay occurred in 2014 and subsequent EWM treatments within these areas have not been warranted to date. However, the AIS population of this bay has been increasing each year during the period of no herbicide management.

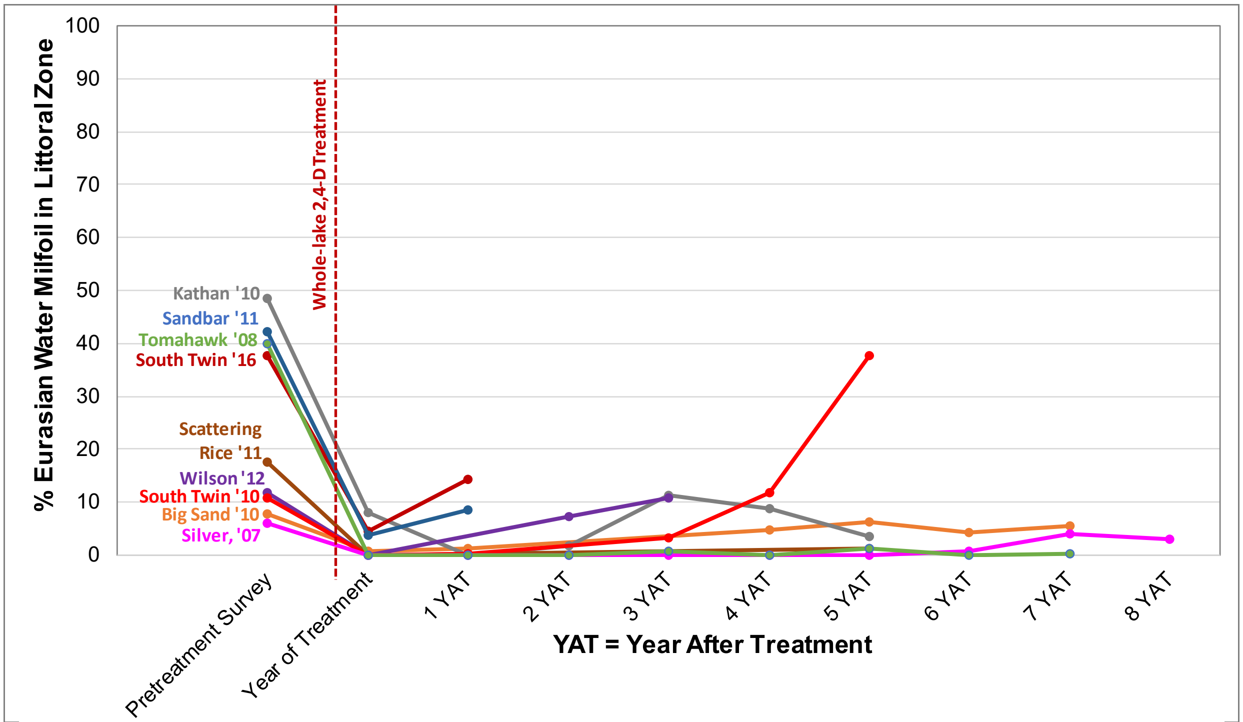


Figure 3.3-20. Littoral frequency of occurrence of EWM in lakes managed with large-scale 2,4-D treatments. South Twin ’10 had treatment at 6 YAT, Kathan ’10 had treatment at 6 YAT, Sandbar ’11 had treatment at 2 YAT, Silver ’07 had treatment at 9 YAT. All others are ongoing.

Selectivity

Some native plants are quite resilient to large-scale 2,4-D treatments, either because they are inherently tolerant of the herbicide's mode of action or they emerge later in the year than when the herbicide is active in the lake. Other species, particularly dicots, some thin-leaved pondweeds, and naiad species, can be impacted and take a number of years to recover. Often during the year of treatment, overall native plant biomass can be lessened but typically (not always) rebounds the following year. However, the preceding statements are a bit of a generalization because some case studies have had varying levels of EWM control even at high concentration and exposure times and others case studies had collateral native plant impacts greater than would be assumed considering the concentrations and exposure times achieved.

Toxicity

The use of any aquatic herbicide poses environmental risks to non-target plants and aquatic organisms. The majority of available toxicity data has been conducted as part of the EPA product registration process. These laboratory studies are attempted to mimic field settings, but can underestimate or overestimate the actual risk (Fairbrother and Kapustka 1996). Federal and state pesticide regulations and strict application guidelines are in place to minimize impacts to non-target organisms based on the organismal studies. The use of aquatic herbicides includes regulatory oversight and must comply with the following list. Additional information from the WDNR on aquatic herbicide regulation is included within Appendix C.

- Labeled and registered with U.S. EPA's office of Pesticide Programs;
- Registered for sale and use by the Department of Agriculture, Trade, and Consumer Protection (DATCP);
- Permitted by the Wisconsin Department of Natural Resources (WDNR); and
- Applied by a DATCP-certified and licensed applicator,

The EPA-approved maximum application rate for liquid 2,4-D amine is 4.0 ppm acid equivalent (ae). At these rates, there are no restrictions on swimming or fish consumption. There are irrigation restrictions such that specific plants, particularly dicot species, should not be watered with concentrations above 0.07 ppm ae for concerns of herbicidal impacts. The EPA's maximum contaminant level of public drinking water (sole water source) for 2,4-D amine is 0.07 ppm ae.

As outlined within the WDNR's 2,4-D chemical fact sheet (Appendix C), there are human risks of being exposed to 2,4-D, especially for high-exposure populations (herbicide applicators and farmers). These include lymphoma and endocrine disruption (tier 1 screening by EPA). 2,4-D is currently classified by EPA as a Group D herbicide, which indicates that the inability to prove or disprove that there is human carcinogenicity (USDA FS 2006). The World Health Organization classifies 2,4-D as being "possibly carcinogenic to humans."

Curly-leaf pondweed is generally treated with the chemical endothall, although increasing use-patterns with combinations of 2,4-D have occurred. Endothall can be applied as a monoamine salt (Hydrothol) or a dipotassium salt (Aquathol K). Monoamine salts are highly toxic to aquatic invertebrates and fish so it is recommended that it not be used in areas where fish are considered an important resource (Appendix C). Dipotassium salt forms of endothall, which have been used on herbicides have been shown to have low to no toxicity to fish and other invertebrates when used at label rates.

The EPA-approved maximum application rate for the dipotassium of endothall is 5.0 ppm active ingredient (ai). At these rates, there are no restrictions on swimming or fish consumption. The EPA's maximum contaminant level of public drinking water (sole water source) for endothall is 0.1 ppm acid equivalent.

It is important to note that US EPA registration of aquatic herbicides requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with their intended use. For herbicides like 2,4-D, the historic registration was aimed at spot-treatment use patterns (high concentrations, short exposure times). Therefore, only limited organismal toxicity data is available for concentrations and exposure times consistent with whole-lake treatment use patterns (low concentrations, long exposure times). Highlighted below is a recent and relevant research project from Wisconsin consistent with large-scale 2,4-D use patterns.

Because of their durability as a laboratory species, fathead minnows are often the subject of organismal toxicity studies. The LC50 (lethal concentration when half die) for fathead minnow exposure to 2,4-D (amine salt) has been determined to be 263 ppm ae sustained for 96 hours, a thousand times higher than fish would be exposed to in a large-scale treatment (target of approximately 0.3 ppm ae). With the assistance of a WDNR AIS-Research Grant, DeQuattro and Karasov (2015) investigated the impacts on fathead minnow of 2,4-D concentrations more relevant to what would be observed in large-scale treatments. The focus of their investigations was on reproductive toxicity and/or possible endocrine disruption potential from the herbicide. The study revealed morphological changes in reproducing male fathead minnows, such that they had lower tubercle scores (analogous to smaller antlers on a male white-tail deer) with some 2,4-D products/use-rates and not with others. This may suggest that the "inert" carrier may be the cause, not the 2,4-D itself. At a static exposure of 0.05 ppm ae for 58 days (fish exposed for 28 days then eggs they laid were continued to be exposed for 30 more days post fertilization) uncovered a reduction in larval fathead survival from 97% to 83% at the lowest dose of one herbicide that was tested (no reduction at higher doses)

A current cooperative UW-Steven's Point and WDNR research project entitled *Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes* was conducted in response to this laboratory work to see if changes could be observed in a series of field trials. Three lakes were given large-scale 2,4-D amine treatments and a paired set of three lakes served as untreated reference lakes. The limnological, zooplankton, fisheries, and aquatic plant communities of these lakes were thoroughly sampled during the year prior to treatment, the year of treatment, and the year after treatment. A plethora of important data came from the study; however, measurable impacts from the herbicide treatments on the zooplankton and fisheries were not documented.

Figure 3.3-21 shows the acreages of colonized EWM within Little Saint Germain Lake mapped by Onterra from 2008 to 2017. The EWM population expanded during 2015 to approximately 20.4 acres, and following the spring 2016 herbicide treatment, was reduced to 3.9 acres in 2016 (Figure 3.3-21). No herbicide management occurred in 2017, although professional hand-harvesting was implemented on few select areas. The EWM increased in 2017 in the absence of management (Map 6), but continues to be relatively low amount of milfoil with the majority being comprised of low density occurrences or EWM marked with point-based methods (Figure 3.3-21). Map 7 shows the EWM progression from 2014-2017 on Little Saint Germain Lake.

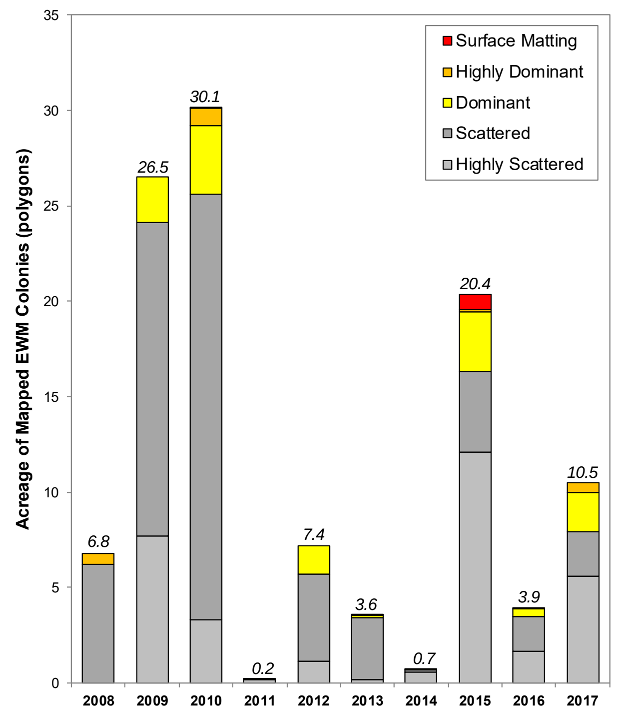


Figure 3.3-21. Acreage of mapped EWM colonies in Little Saint Germain Lake from 2008-2016.

2017 Pilot Hand-Harvesting Program

Hand-harvesting control methods may pose a challenge on Little Saint Germain due to low water clarity and plethora of native plants in the targeted areas. For this reason, the LSGLPRD decided to conduct a trial program in 2017. While volunteer efforts have their role in the management of many lakes, the LSGLPRD decided that hiring a third-party firm to conduct these efforts would be appropriate for a pilot program. This would insure they would have an appropriate amount of effort (i.e. person-hours). Traditional hand-harvesting consists of a trained snorkelers or divers to swim to the bottom of the lake and extract an individual EWM plant, roots and all. The plants are transported to the surface one at a time, or are put in a mesh bag underwater until brought to the surface. While on the surface, the plants are placed onto a transport boat until disposal.

Where water clarity is high and target plants are growing in deeper water, a Diver Assisted Suction Harvesting (DASH) program is generally recommended. During this process a scuba diver manually extracts the plant (roots and all) and then feeds the removed plants into vacuum tube that transports the plant to a bin on a boat. They do not, however, simply vacuum the plants up, as that would also take in large amounts of sediment and would be considered suction dredging (requires elaborate permitting). A mechanical harvesting permit from the WDNR is needed (fee of $30 per acre) to use the DASH system. The DASH system is said to be more efficient, as the diver does not have to go to the surface to hand the pulled plants to someone on a boat. The DASH system also is theorized to cause less fragmentation, as the plants are immediately transported to the surface using the vacuum technology. However, the costs of conducting hand-harvesting with one of these firms is more expensive than just hiring trained divers and/or snorkelers.

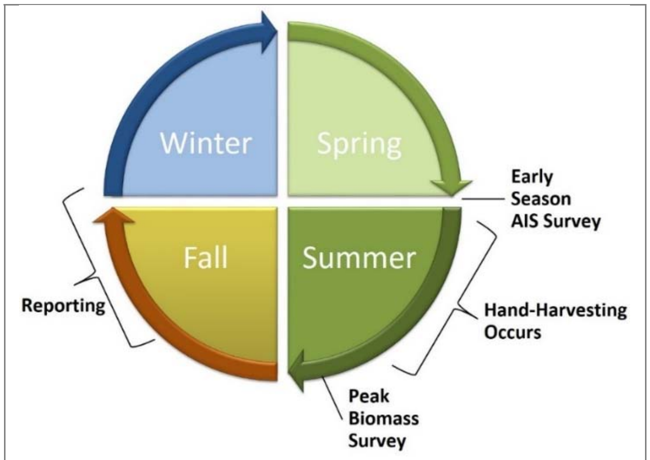


Figure 3.3-22. Hand-harvesting project timeline diagram.

Based on the 2016 Late-Summer EWM Peak-Biomass Survey results, a preliminary strategy was devised where three locations in the system were to be targeted with hand-harvesting. Aquatic Plant Management (APM), LLC was contracted to conduct the 2017 hand-harvesting efforts (Figure 3.3-22).

During the 2017 Early Summer AIS Survey (ESAIS), the mapping of the EWM populations yielded a revised and final hand-harvesting strategy. This two-tiered strategy included targeting some areas with DASH and other areas with traditional hand-harvesting strategies where the agility of having professional divers/snorkelers may be advantageous (Map 8). Onterra provided the hand-harvesting firm with the spatial data from the ESAIS Survey to coordinate the removal efforts. Unfortunately, the content of Onterra's letter report was unintentionally overlooked by the contractor. This miscommunication resulted in only two areas being targeted for removal, both with DASH.

During the week of July 17, 2017, they focused their efforts on A-17 and focused on E-17 during the week of August 8, 2017. Approximately 400 cubic feet of EWM was removed during roughly 53 crew-hours (243 person-hours) of effort.

Table 3.3-2. 2017 EWM Hand-Removal Program. Data provided by APM, LLC.

Date	Removal Site	Crew Hours	EWM Removed (cubic feet)
7/17/2017	A-17	4.42	70
7/18/2017	A-17	4.75	95
7/19/2017	A-17	4.75	39
7/20/2017	A-17	4.25	23
7/21/2017	A-17	4.76	26
	Subtotal	*22.93*	*253*
8/9/2017	E-17	6.49	17
8/10/2017	E-17	2.91	20
8/11/2017	E-17	2.91	28
8/14/2017	E-17	5.75	38
8/15/2017	E-17	6.24	22
8/16/2017	E-17	5.92	37
	Subtotal	*30.22*	*145*
	Grand Total	***53.15***	***398***

A *dominant* EWM colony within A-17 was reduced to *single plants* following the hand-harvesting effort, exceeding expectations of Onterra (Figure 3.3-23). APM reported a Secchi disk reading of approximately 9 feet in West Bay during the removal efforts.

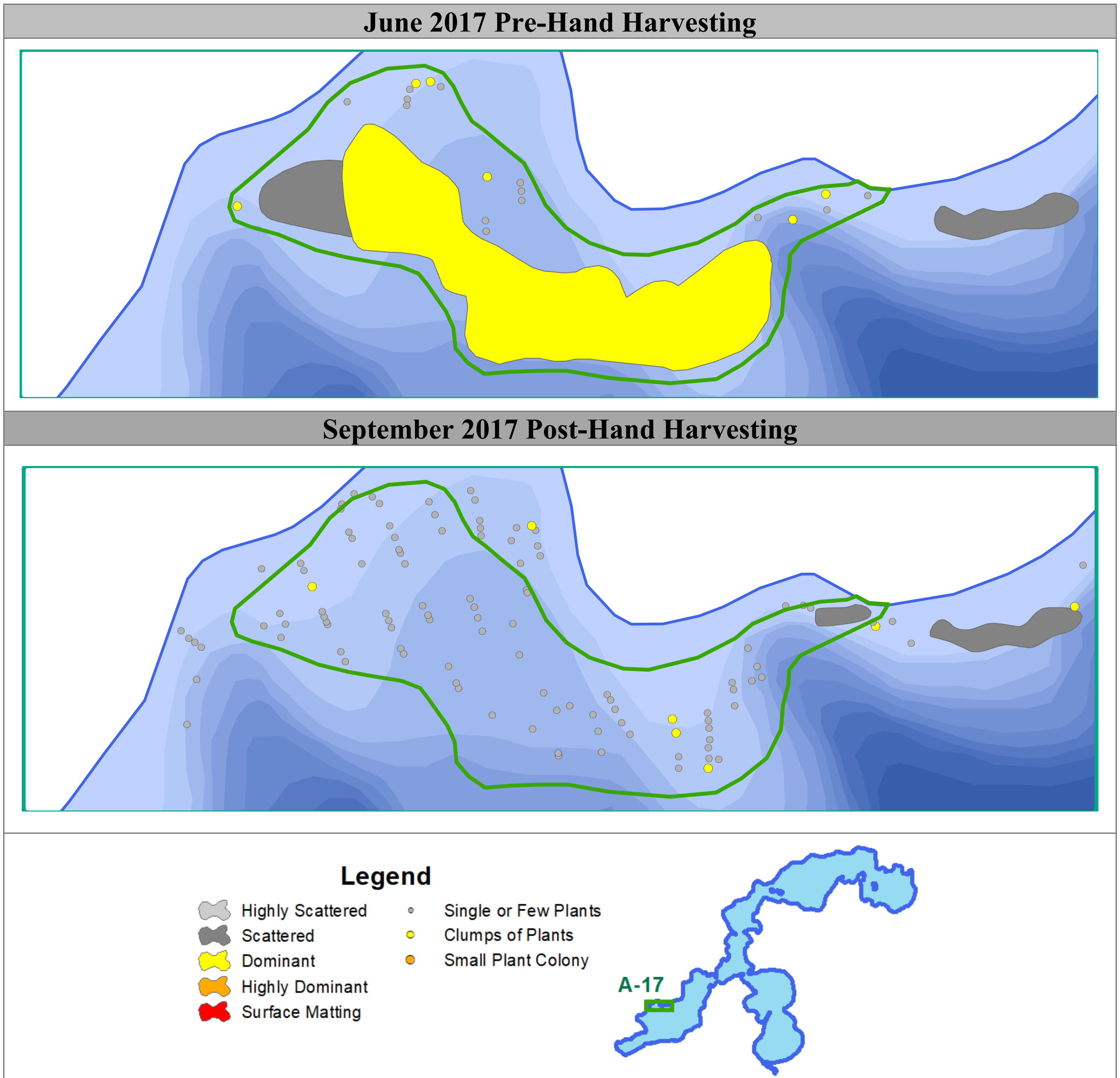


Figure 3.3-23. June 2017 pre- and September 2017 Post- Professional Hand-Harvesting EWM Survey Results in site A-17.

The control efforts in Lower East Bay (E-17) were not as successful as in West Bay (Figure 3.3-24). A Secchi disk reading of 2 feet was recorded in this bay during the hand-removal process, with thick lily pads and native vegetation confounding the hand-removal process.

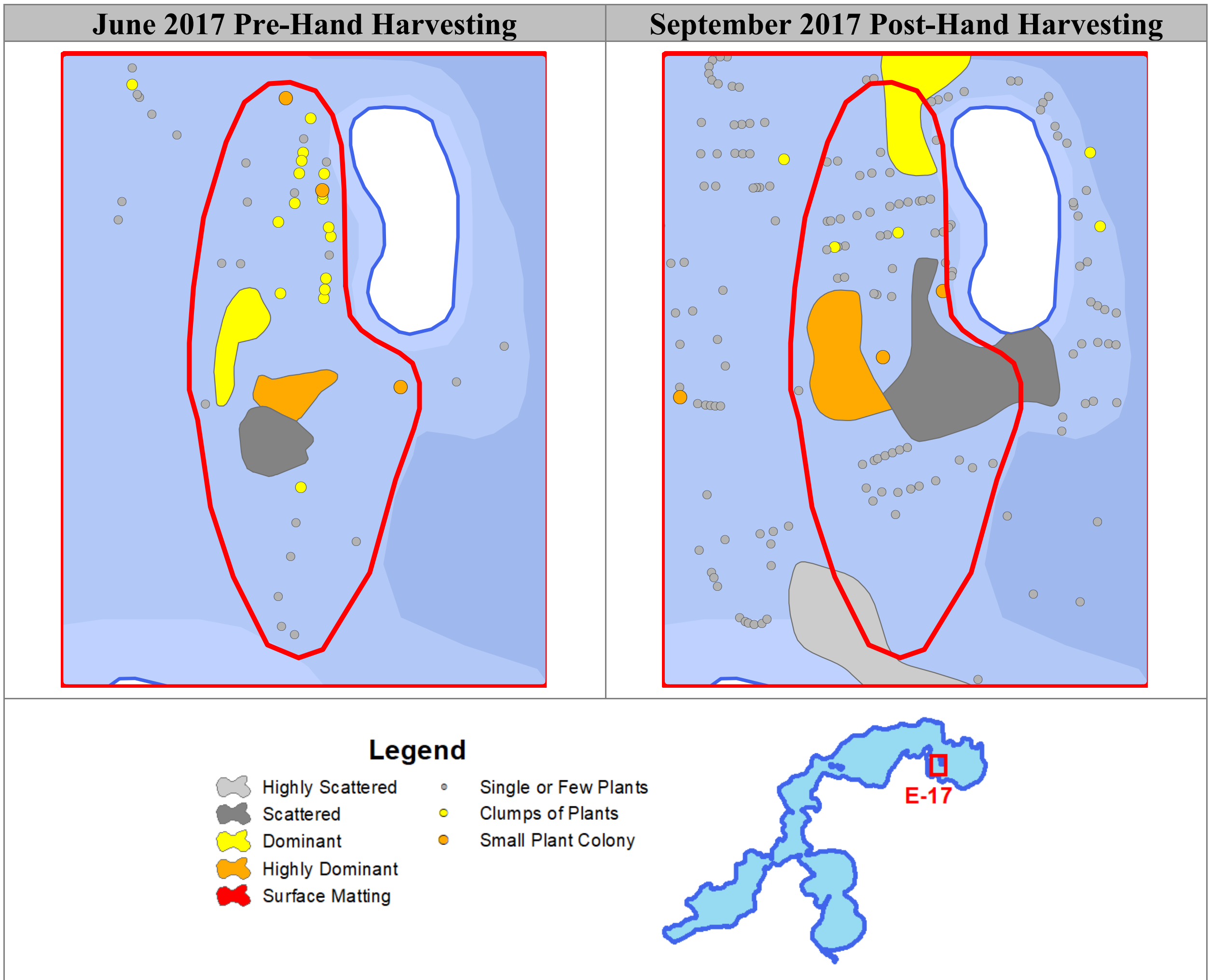


Figure 3.3-24. June 2017 pre- and September 2017 Post- Professional Hand-Harvesting EWM Survey Results in site E-17. APM, LLC's report refers to E-17 as B-17, the naming convention from the preliminary strategy.

The professional hand-harvesting actions undertaken in 2017 in Little Saint Germain Lake yielded mixed results in controlling the EWM within the targeted locations. The hand-harvesting in West Bay was effective, likely due to better water clarity for the divers to operate in as well as being conducted a little earlier in the growing season before native vegetation amassed large amounts of biomass and interfered with the control measures. This information is valuable for the LSGLPRD to consider when applying a hand-harvesting EWM control strategy in the future.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes are not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 3.4-25). The upper frame of Figure 3.4-25 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected "unmanaged lakes" were moved into the "managed" category as the EWM populations were targeted for control by the local lake organization.

Some lakes, such as Hancock Lake, maintained low EWM populations over the study averaging a littoral occurrence of 2.3% between 2008 and 2015. At these low levels, there are likely no observable ecological impacts to the lake and are no reductions in ecosystem services to lake users. The EWM population of Hancock Lake has increased in recent years to almost 32% in 2017, which corresponds to 11 years after its initial detection.

Eurasian watermilfoil populations in other lakes, such as Bear Paw Lake and Little Bearskin Lake trended to almost 25% only three years following initial detection. The EWM population of Bear Paw Lake declined to below 2% by six years after detection and has increased to approximately 6% in 2017 (10 years after initial detection). The EWM population on Little Bearskin Lake followed a similar trend, but the magnitude of the decline was less and was just below 10% in 2017 (9 years after initial detection).

Boot Lake is a eutrophic system with low water clarity (approx. 3-ft Secchi depth) due to naturally-high phosphorus concentrations. It is hypothesized that water clarity conditions in some years may favor EWM growth whereas changes in these conditions may keep the population suppressed in other years. Since 2011, the EWM population of Boot Lake has stabilized around 10%, corresponding to 11-17 years following initial detection.

Rapid and large fluctuations in the occurrence of EWM like those observed on Weber Lake have also been documented. The EWM population in 2010-2011 was approximately 20% before rapidly increasing above 50% in 2012, corresponding with six years after being initially detected in the lake. Then the population declined to under 10% in 2015 and 2016, and has rebounded to approximately 17% in 2017.

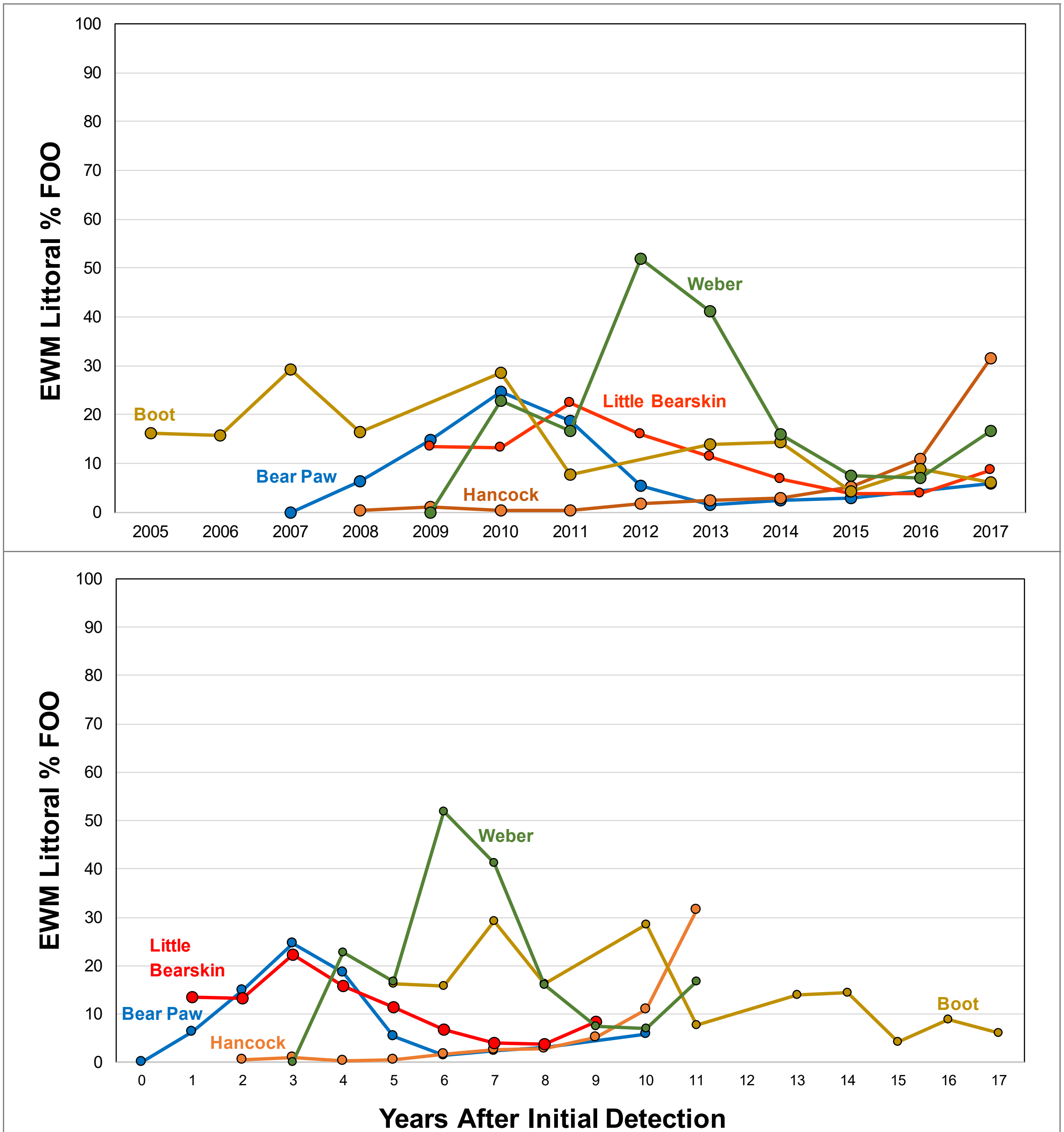


Figure 3.3-25. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Regional climatic factors also seem to be a driver in EWM populations, as many

EWM populations declined in 2015 even though the lakes were at vastly different points in time following initial detection within the lake.

Within this same study, eight lakes were in the managed category. As discussed above, the list of lakes in this category was initially shorter, but some lakes that were originally in the unmanaged category had lake groups that opted to conduct herbicide treatment strategies to reduce the EWM population within the lake (Figure 3.3-26).

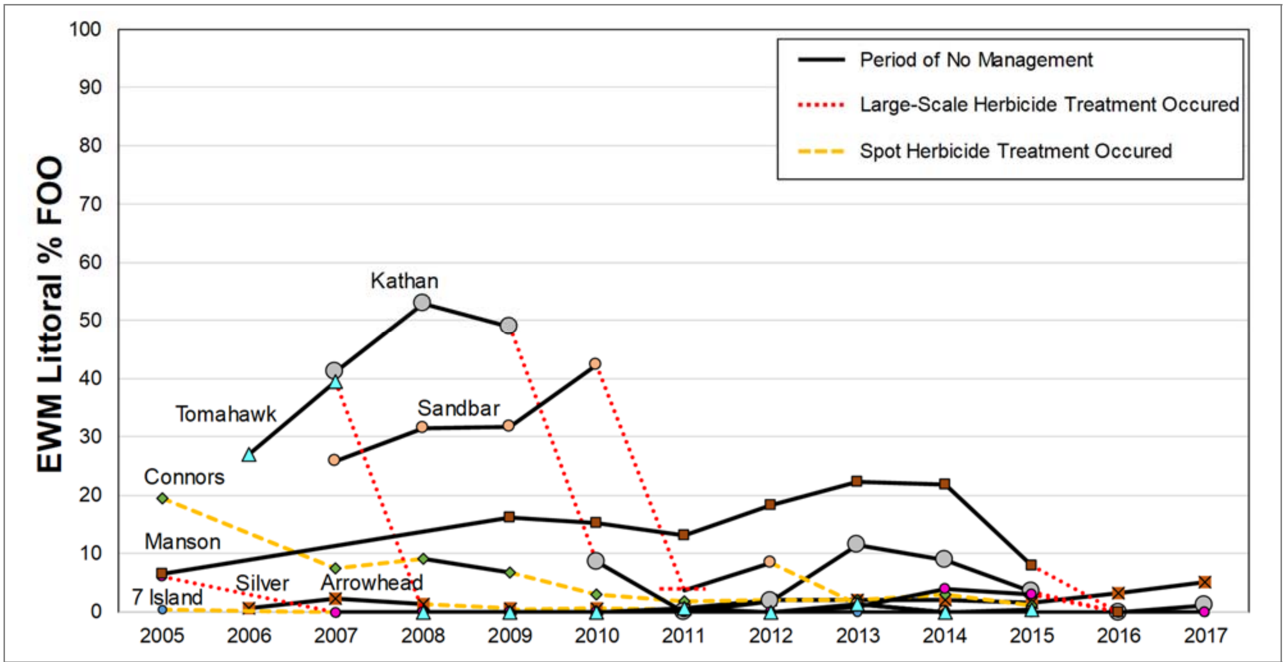


Figure 3.3-26. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion with management. Data provided by and used with permission from the WDNR Bureau of Science Services.

Some of the lakes within the study conducted large-scale (whole-lake) herbicide treatments and had large reductions of EWM. Sandbar Lake conducted a follow-up large-scale treatment a few years after large-scale management, whereas Kathan Lake and Silver Lake conducted a second large-scale treatment after 6 and 9 years following the first, respectively.

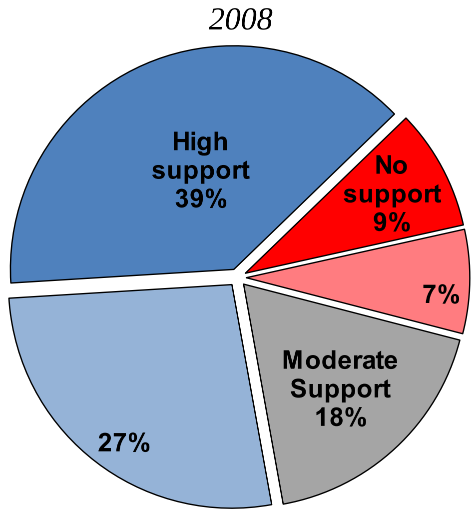
Other lakes conducted more frequent spot treatments to reduce or maintain a low EWM population within the lake. The 2005 spot treatment on Connors Lake may have been close to approaching a large-scale treatment, as almost 8% of the lake was targeted for control. Seven Island Lake conducted a large spot treatment in a bay of the lake in 2005 and has not conducted additional herbicide management to date. After a few largely unsuccessful herbicide treatments from 2008 to 2010 on Arrowhead Lake, herbicide management was abandoned and the population has slowly increased to just over 5% after 6 years.

The study results clearly show that management can be effective to reduce and maintain lowered EWM populations.

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. The return rate of the survey was approximately 33%. In instances where stakeholder survey response rates are 60% or above, the results can be interpreted as being a statistical representation of the population.

The planning committee wanted to understand the stakeholders' perceptions on the use of various active management techniques (Figure 3.4-27). Within the 2016 survey, 64% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of responsibly using herbicides in Little Saint Germain, whereas 12% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses). This compares with 66% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of herbicide control whereas 16% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses).

Question 25: What is your level of support for the responsible use of Herbicide Control on Little Saint Germain Lake



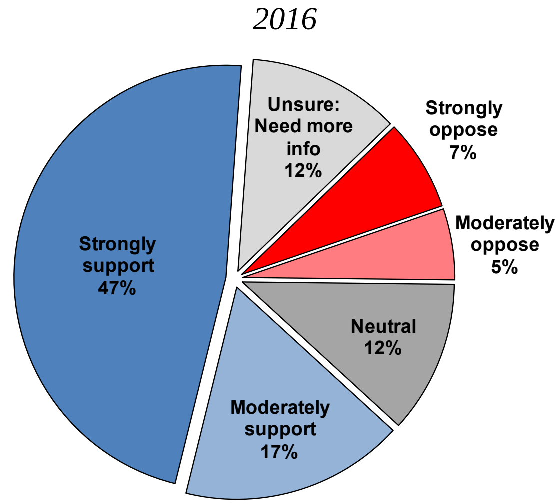
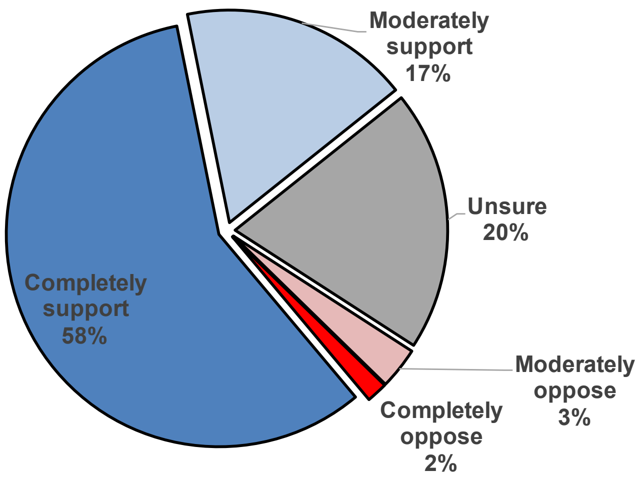


Figure 3.3-27. Select survey responses from the LSGLPRD Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Numerous past herbicide treatments have occurred on Little Saint Germain Lake. Only 5.5% of stakeholder respondents in 2016 indicated they did not know herbicides were being applied on the lake to control AIS. Approximately 75% of survey respondents indicated they were supportive (pooled *completely supportive* and *moderately supportive* responses) of the past herbicide use (Figure 3.4-28, left frame) and 83% (pooled *completely supportive* and *moderately supportive* responses) were supportive of future AIS control strategies using herbicides (Figure 3.4-28, right frame).

Question 29: How do you feel about the past use of herbicides to treat AIS in previous years?



Question 30: What is your level of support or opposition for future aquatic herbicide use to target AIS in Little Saint Germain Lake?

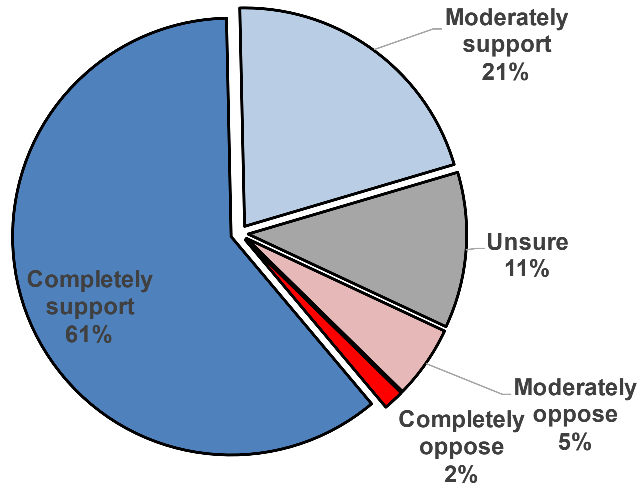


Figure 3.3-28. Select survey responses from the LSGLPRD Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Of the nine respondents that indicated they either *moderately oppose* or *completely oppose* the future use of aquatic herbicides, the reason(s) they opposed is shown in Table 3.3-3.

Table 3.3-3. Select survey responses from the LSGLPRD Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

31. What is the reason(s) you oppose the future use of aquatic herbicides to target AIS in Little Saint Germain Lake?		
Answer Options	**Response Percet**	**Response Count**
Potential cost of treatment is too high	22.2%	2
Potential impacts to native aquatic plant species	44.4%	4
Potential impacts to native (non-plant) species such as fish, insects, etc.	88.9%	8
Potential impacts to human health	66.7%	6
Future impacts are unknown	44.4%	4
Another reason (please specify below):	33.3%	3
	answered question	**9**

Pale yellow iris

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering along some of the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale yellow iris on Little Saint Germain Lake can be viewed on Map 4 At this time, there are a few locations where this plant is located. Visiting these locations in mid-June and hand pulling the plant, using care not to spread the reproductive seeds, is likely the best way to control this species for now.

Mechanical Harvesting

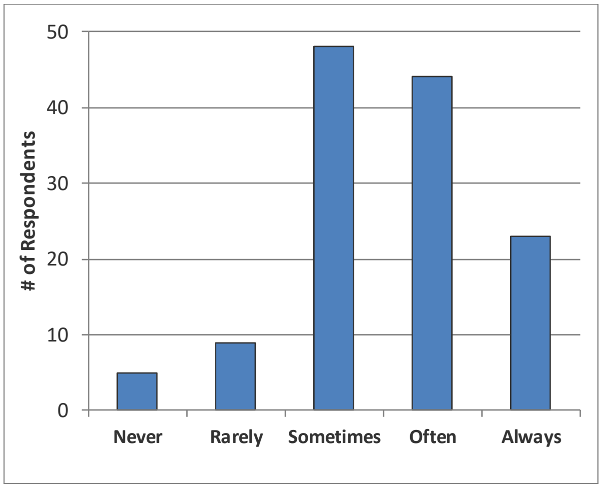
The LSGLPRD supports the reasonable and environmentally sound actions to facilitate navigability on Little Saint Germain Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than absolutely necessary.

A stakeholder survey was sent to Little Saint Germain Lake riparians during January 2017. The response rate was only moderate (33%), therefore the results *may* follow public opinion but cannot be interpreted as being a statistical representation of the population. In instances where stakeholder survey response rates are 60% or above, the results can be interpreted as being a statistical representation of the population. While the survey response rate may not be sufficient to be a statistical representation of the population, the LSGLPRD believe the sentiments of the stakeholder respondents is sufficient to provide a generalized indication of riparian preferences and concerns.

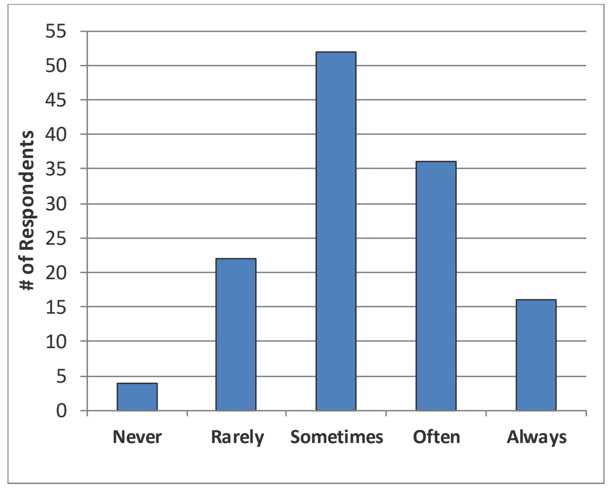
When asked how often aquatic plant growth during the open water negatively impacts enjoyment of Little Saint Germain Lake, the plurality of stakeholder survey respondents (37%) indicated *sometimes*, 37% indicated *often*, 18% indicated *always*, and 11% indicated *rarely* or *never* (Figure 3.3-29, top left frame). Stakeholders were also asked if free-floating algae (i.e. algal blooms) negatively impacts their enjoyment of the lake. The plurality (40%) of stakeholders indicated *sometimes*, 28% indicated *often*, 17% indicated *rarely*, 12% indicated *always*, and 3% indicated *never* (Figure 3.3-29, top right frame). These results indicate that the majority of Little Saint Germain stakeholder respondents believe recreational use of Little Saint Germain Lake is hindered by excessive aquatic plant growth but excessive free-floating algae and algae blooms also have large of an impact on their enjoyment.

Given the excessive aquatic plant growth and presence of aquatic invasive species in areas of Little Saint Germain Lake, the majority (92%) of stakeholder survey respondents indicated that they believe aquatic plant control is *definitely* or *probably* needed in Little Saint Germain Lake, while 5% indicated they are *unsure* if aquatic plant control is needed, and 3% indicated *probably* or *definitely* no (Figure 3.3-29, bottom right frame). The majority (73%) of respondents were supportive (pooled *Strongly Support* and *Moderately Support*) of the responsible use of mechanical harvesting on Little Saint Germain Lake, whereas just 7% were not supportive (pooled *Strongly Oppose* and *Moderately Oppose*). Approximately 20% of stakeholder respondents indicated they were *Neutral* or *Unsure* regarding the responsible use of mechanical harvesting to manage aquatic plants in Little Saint Germain Lake (Figure 3.3-29).

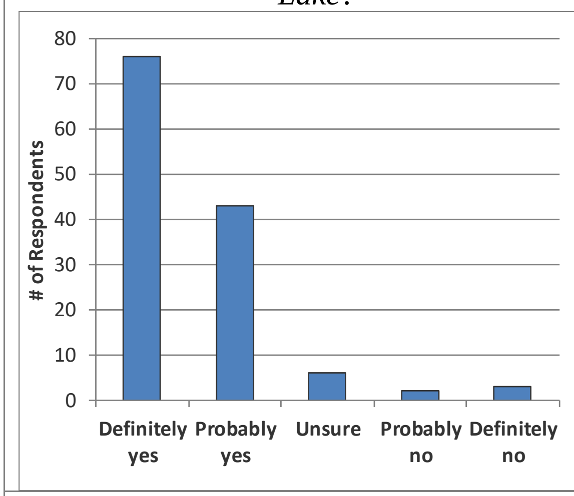
Question 24. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Little Saint Germain Lake?



Question 25: During open water season how often does free-floating or algae blooms negatively impact your enjoyment of Little Saint Germain Lake?



Question 26. Do you believe aquatic plant control is needed on Little Saint Germain Lake?



Question 27. What is your level of support for the responsible use of Mechanical Harvesting on Little Saint Germain Lake?

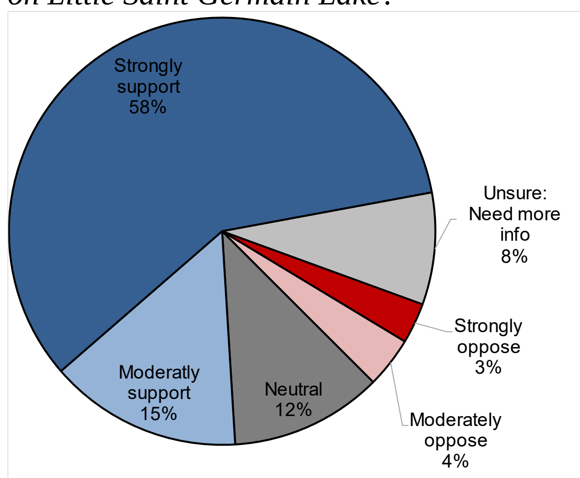


Figure 3.3-29. Select survey responses from the LSGLPRD Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.4 Aquatic Invasive Species in Little Saint Germain Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Little Saint Germain Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are five AIS present (Table 3.4-1).

Table 3.4-1. AIS present within Little Saint Germain Lake.

Type	Common name	Scientific name	Location within the report
Plants	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.3 – Aquatic Plants
	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.3 – Aquatic Plants
	Pale yellow iris	*Iris pseudacorus*	Section 3.3 – Aquatic Plants
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 3.4 Aquatic Invasive Species
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.4 Aquatic Invasive Species

Figure 3.4-1 displays the 13 aquatic invasive species that Little Saint Germain Lake stakeholders believe are in Little Saint Germain Lake. Only the species present in Little Saint Germain Lake are discussed below or within their respective locations listed in Table 3.4-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

- http://dnr.wi.gov/topic/invasives/
- https://nas.er.usgs.gov/default.aspx
- https://www.epa.gov/greatlakes/invasive-species

Aquatic Animals

Mystery snails

There are two types of mystery snails found within Wisconsin waters, the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009).

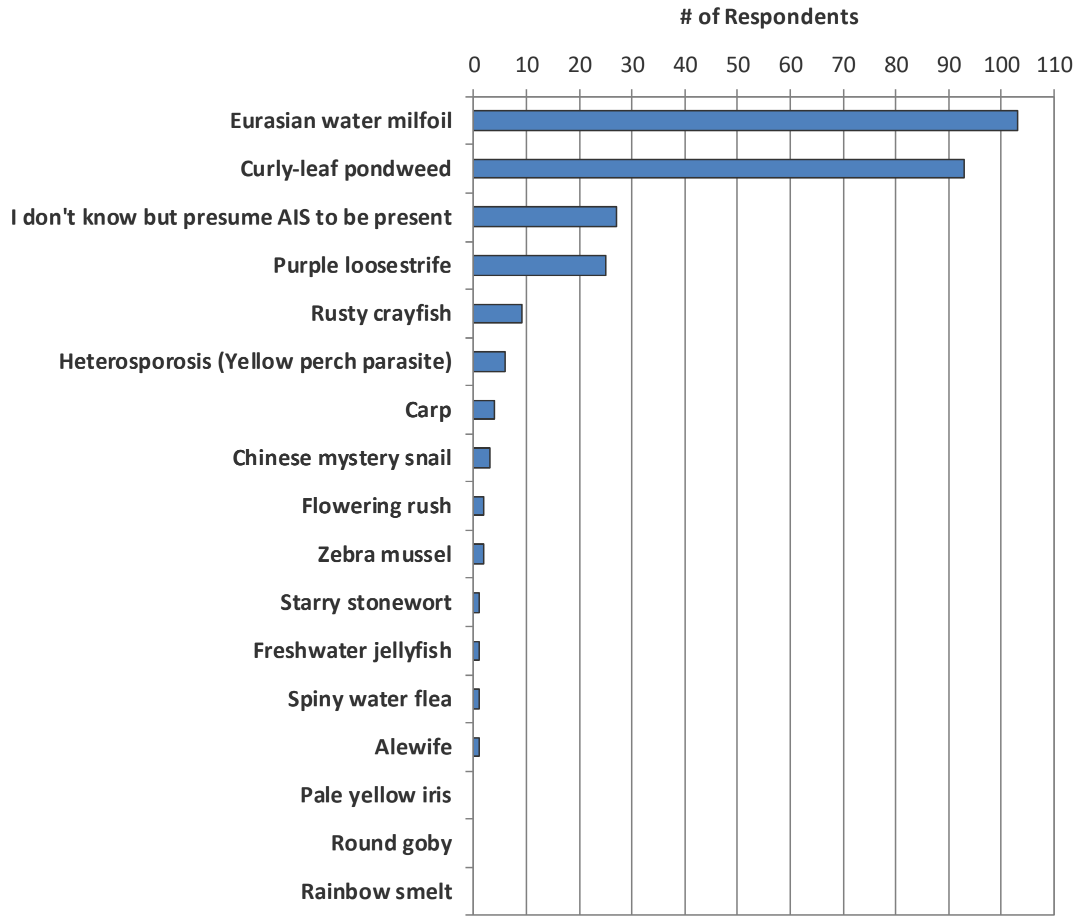


Figure 3.4-1. Stakeholder survey response Question #20. Which aquatic invasive species do you believe are in Little Saint Germain Lake?

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Little Saint Germain Lake. The goal of this section is to provide an overview of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR), the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2017 & GLIFWC 2016, Appendix D).

Little Saint Germain Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Little Saint Germain Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

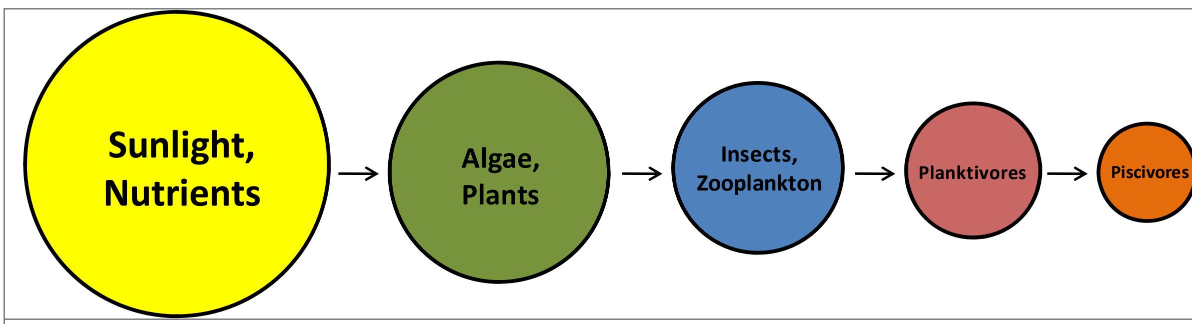


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Little Saint Germain is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Little Saint Germain Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 3.5-1 shows the gamefish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in Little Saint Germain Lake include white sucker (*Catostomus commersonii*), central mudminnow (*Umbra limi*) and the golden shiner (*Notemigonus crysoleucas*).

Table 3.5-1. Gamefish present in Little Saint Germain Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead (*Ameiurus melas*)	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Cisco (*Coregonus artedii*)	22	Late November - Early December	No clear substrate preference.	Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling invertebrates.
Largemouth Bass (*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead (*Ameiurus natalis*)	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.5-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip) then release the captured fish.

The other commonly used sampling method is electroshocking (Photograph 3.5-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 3.5-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photo 3.6-2). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Tables 3.6-2, 3.6-3 and 3.6-4 display historical stocking efforts of muskellunge, walleye and largemouth bass in Little Saint Germain Lake.

Photograph 3.5-2. Fingerling Muskellunge.

Future stocking efforts of walleye will be consistent following Little Saint Germain Lakes' inclusion in the Wisconsin Walleye Initiative. The Initiative was made possible by the governor's office, Department of Natural Resources and statewide partners to maintain the walleye population in Wisconsin's lakes and improve walleye fisheries in lakes capable of sustaining the sportfish (WDNR 2014). Lakes chosen to be included were selected based upon anticipated fingerling survival, natural reproduction opportunities, public access, tribal interest (for ceded territory lakes) and potential impacts to tourism (WDNR 2014). Stocking rates are randomly assigned and Little Saint Germain Lake was selected to receive the second top stocking rate (15 large fingerling walleye/acre) (WDNR 2013). Beginning in 2013 and in odd years thereafter, Little Saint Germain Lake will receive the assigned stocking rate of walleye as funding allows (WDNR 2014).

Table 3.5-2. Stocking data of Muskellunge available for Little Saint Germain Lake (1972-2016).

Year	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Fingerling	1,827	12.00
1973	Fingerling	1,119	11.00
1973	Fry	35,000	1.60
1974	Fingerling	1,242	9.00
1976	Fingerling	500	11.00
1979	Fingerling	1,876	8.50
1983	Fingerling	1,804	10.00
1984	Fingerling	1,916	11.33
1985	Fingerling	2,945	11.33
1986	Fingerling	2,209	12.00
1987	Fingerling	5,694	11.67
1988	Fingerling	2,249	10.29
1990	Fingerling	1,900	11.00
1996	Fingerling	2,021	10.77
1998	Large Fingerling	1,774	12.15
1998	Fry	80,000	NA
2000	Large Fingerling	1,800	10.80
2002	Large Fingerling	490	10.70
2004	Large Fingerling	490	10.05
2006	Large Fingerling	490	10.20
2008	Large Fingerling	490	10.4
2010	Large Fingerling	368	12.7
2012	Large Fingerling	490	10.4
2013	Large Fingerling	980	11.35
2014	Large Fingerling	1006	9.4
2016	Large Fingerling	973	10.3

Table 3.5-3. Stocking data of Walleye available for Little Saint Germain Lake (1972-2017).

Year	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Fry	500,000	NA
1973	Fry	2,000,000	NA
1974	Fingerling	16,320	3.00
1974	Fry	450,000	1.00
1975	Fingerling	31,600	NA
1975	Fry	1,000,000	NA
1976	Fry	500,000	0.30
1977	Fry	750,000	NA
1978	Fry	100,000	2.00
1979	Fry	1,033,000	NA
1981	Fingerling	13,000	2.00
1982	Fingerling	66,000	2.00
1984	Fingerling	50,000	2.00
1985	Fingerling	100,000	2.00
1986	Fingerling	50,000	3.00
1987	Fingerling	150,000	1.00
1989	Fingerling	69,800	0.50
1996	Fry	500,000	NA
1999	Large Fingerling	4,704	7.80
2000	Large Fingerling	4,329	8.00
2001	Large Fingerling	9,850	7.65
2003	Large Fingerling	4,900	7.70
2005	Small Fingerling	49,000	1.6
2011	Small Fingerling	34,300	2
2013	Large Fingerling	14,699	7.12
2015	Large Fingerling	14,574	7.9
2017	Large Fingerling	14,494	6.57

Table 3.5-4. Stocking data of Largemouth Bass available for Little Saint Germain Lake (1972-2000).

Year	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Fingerling	2,200	5.00
1973	Fingerling	424	3.00
1986	Fingerling	3,750	4.00
1997	Large Fingerling	550	3.40
1998	Large Fingerling	934	5.40
1999	Large Fingerling	674	4.80
2000	Large Fingerling	3,000	2.00

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second important reason for owning property on or near Little Saint Germain Lake (Question #16), relaxing/entertaining was the first most important reason. Figure 3.5-2 displays the types of fish Little Saint Germain Lake stakeholders enjoy catching the most, with crappie, walleye and bluegill being the most popular. Approximately 80% of landowners who fish Little Saint Germain Lake believe the current quality of fishing is fair or good, compared to 18% that described the quality of fishing as very poor or poor (Figure 3.5-3). Approximately 85% of these same respondents believed that the quality of fishing on the lake either remained the same or had gotten worse since they first started fishing the lake (Figure 3.5-4).

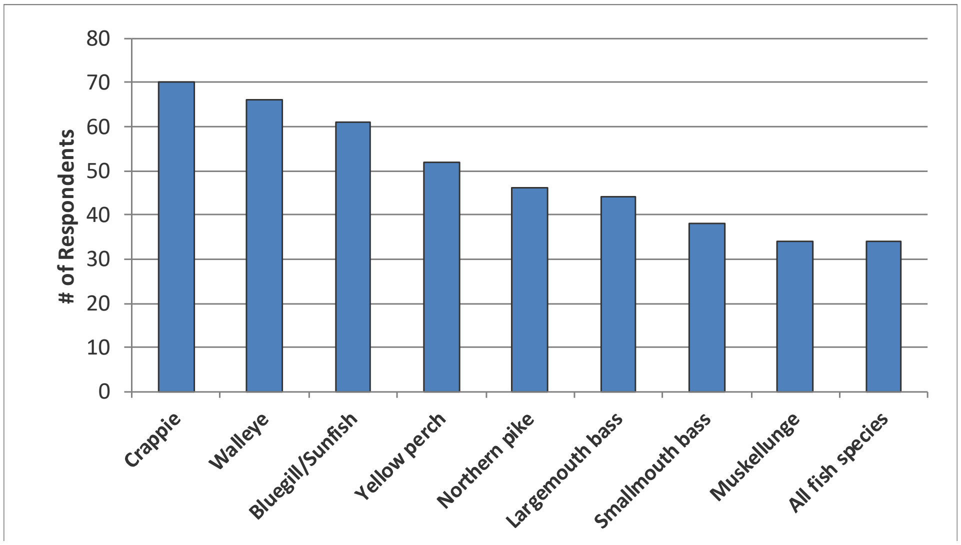


Figure 3.5-2. Stakeholder survey response Question #10. What species of fish do you like to catch on Little Saint Germain Lake?

Figure 3.5-3. Stakeholder survey response Question #11. How would you describe the current quality of fishing on Little Saint Germain Lake?

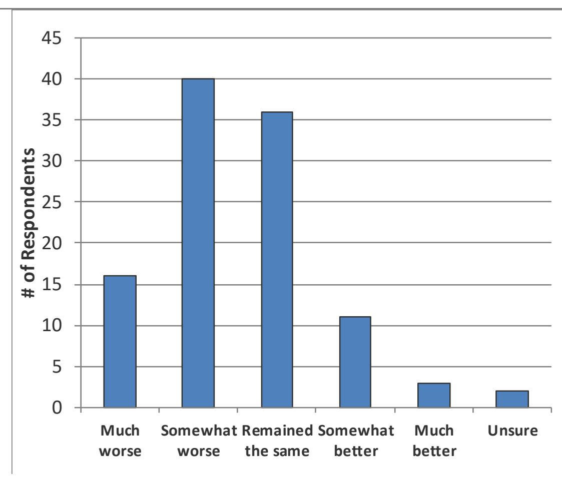


Figure 3.5-4. Stakeholder survey response Question #12. How has the quality of fishing changed on Little Saint Germain Lake since you started fishing the lake?

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. A creel survey was completed on Little Saint Germain Lake during the 1997-98 and 2015-16 fishing seasons (Table 3.5-5, Appendix D).

Table 3.5-5. Creel Survey data for 1997-98 and 2015-16 fishing seasons.

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch	Catch / Acre	Harvest	Harvest / Acre	Hours of Directed Effort / Fish Caught	Hours of Directed Effort / Fish Harvested
Largemouth Bass	1997-98	195	10.2	2035	2.1	60	0.1	4.9	166
	2015-16	217	30.6	21082	21.7	561	0.6	1.4	53
Smallmouth Bass	1997-98	195	10.7	1225	1.3	23	0.02	8.5	451
	2015-16	217	26.8	1266	1.3	0	0	20.6	0
Muskellunge	1997-98	195	24.1	658	0.8	39	0.04	24.1	600
	2015-16	217	13.2	295	0.3	0	0	19.5	0
Northern Pike	1997-98	195	30.6	21152	21.8	2220	2.3	1.4	13
	2015-16	217	18.7	6513	6.7	728	0.7	2.8	25
Walleye	1997-98	195	15.8	1973	2.0	213	0.2	7.8	72
	2015-16	217	18.3	2187	2.3	310	0.3	8.1	57

Total angler effort was somewhat higher in 2015-16 (217 hours/acre) compared to the 1997-98 season (195 hours/acre). Anglers directed the largest amount of effort towards largemouth and smallmouth bass during the 2015-16 season compared to the 1997-98 season that saw the majority of effort directed at northern pike and muskellunge (Table 3.5-5.)

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present on Little Saint Germain Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch walleye on Little Saint Germain Lake (Figure 3.5-2). Brief summaries of popular gamefish present in Little Saint Germain Lake are provided based off of the report submitted by WDNR fisheries biologist Steve Gilbert following the fisheries survey completed in 2015.

Walleyes are an important sportfish for Little Saint Germain Lake. From 2000 to 2015 83,300 small fingerlings and 48,352 large fingerling walleyes have been stocked (Table 3.5-2). The walleye population estimate after the 2015 survey was 2,586 adult walleye (2.6 fish/acre). Nearly 96% of the adult walleye captured were 15 inches or greater. Primarily the walleye fishery is supported by stocking efforts but some natural reproduction does occur (Boehm 2017).

Largemouth bass are considered abundant in Little Saint Germain Lake. From 1972 to 2000 6,374 fingerlings and 5,158 large fingerlings were stocked (Table 3.5-4). The largemouth bass population estimate after the 2015 survey was 7,812 fish (8.0 fish/acre). Only 26% of the largemouth bass captured were 14 inches or greater in length.

Northern Pike are considered common in Little Saint Germain Lake. No attempt at a population estimate was made and the average length of fish captured was considered poor with only 7% being greater than 26 inches in length.

Muskellunge, like walleye, are also considered a valued sportfish of Little Saint Germain Lake. Occurring mainly in even years, from 2000 to 2016, 7,577 large fingerling muskellunge have been stocked (Table 3.5-2). During the 2015 survey, about 26% of the muskellunge captured were greater than 40 inches in length. A 2016 muskellunge survey determined the population estimate was 0.3 muskellunge/acre.

Smallmouth bass are present in Little Saint Germain Lake but in low numbers. No population estimate was attempted and 40% of the captured fish were 14 inches or greater in length.

Panfish

The panfish present on Little Saint Germain Lake represent different population dynamics depending on the species. Abundant panfish populations are present but are lacking numbers of quality sized fish. The results for the stakeholder survey show anglers prefer to catch crappie, bluegill/sunfish and yellow perch on Little Saint Germain Lake (Figure 3.5-2). Brief summaries of popular panfish present in Little Saint Germain Lake are provided based off of the WDNR fisheries survey completed in 2015 (Gilbert 2015).

Bluegill are the most abundant panfish on Little Saint Germain Lake, however, few quality sized fish were captured during the 2015 survey. No bluegill, of the random sample measured were greater than 8 inches in length.

Black crappie is another panfish in high abundance but lacking quality sized fish. Only 2% of a random sample of black crappies measured were 10 inches or larger.

Yellow perch were not found in as high abundances as bluegill and crappie but are still considered to have a moderately sized population. Only 15% were 8 inches or longer in length.

Ceded Territory Spear Harvest Records

Figure 3.5-5. Location of Little Saint Germain Lake within the Native American Ceded Territory (GLIFWC 2016). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-5). Little Saint Germain Lake falls within the Ceded Territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for Ceded Territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the Ceded Territory. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through tribal or recreational harvesting means. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009).

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2016). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations.

Walleye open water spear harvest records are provided in Figure 3.5-6 from 1999 to 2017. As many as 77 walleyes have been harvested from the lake in the past (1999), however the average harvest is roughly 36 fish in a given year. Walleye spear harvesters on average have taken 52% of the declared quota. The 2015 WDNR Fisheries Survey, showed a dense and healthy population of walleye in Little Saint Germain Lake. This resulted in an increase of the walleye safe harvest level and tribal spearing quota during the 2016 season as seen in Figure 3.5-6.

Muskellunge open water spear harvest records are provided in Figure 3.5-7 from 1999 to 2017. As many as 8 muskellunge have been harvested from the lake in the past (2006), however the average harvest is 3 fish in a given year. Muskellunge spear harvesters on average have taken 35% of the declared quota.

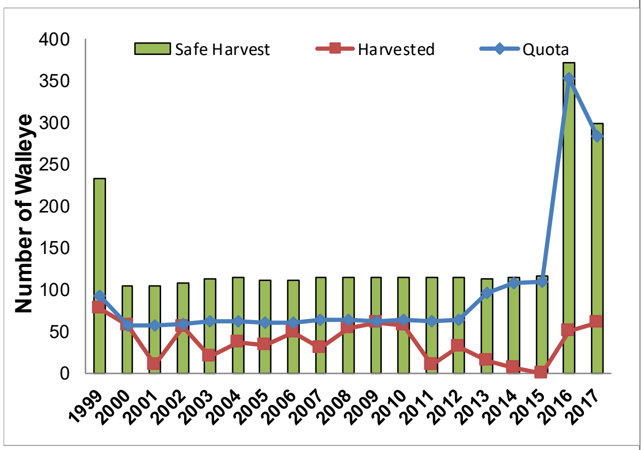


Figure 3.5-6. Little Saint Germain Lake walleye spear harvest data. (GLIFWC 1999-2017)

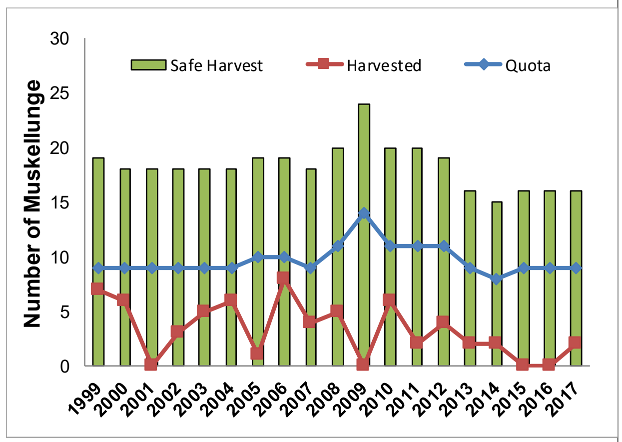


Figure 3.5-7. Little Saint Germain Lake muskellunge spear harvest data. (GLIFWC 1999-2017)

Little Saint Germain Lake Fish Habitat

Aeration

According to a USGS study, dissolved oxygen levels on Little Saint Germain Lake were found to be low and at levels that could cause fishkills and reduced reproduction potential. The LSGLPRD decided to install three aeration systems on the lake, one in Lower East Bay, one in South Bay, and another near the inlet from Muskellunge Creek (Figure 3.5-8). The aeration system in front of Muskellunge creek was too shallow to function effectively and was discontinued.

Wisconsin statues prescribe a detailed safety structure when placing aerations systems on a lake, including safety barriers of fence posts, roping, reflectors, and warning signs. As soon as the ice conditions allow the proper safety barriers to be put into place, the aeration systems are activated. The systems maintain about an acre of open water throughout the winter. All safety barriers require removal after the spring ice-out.

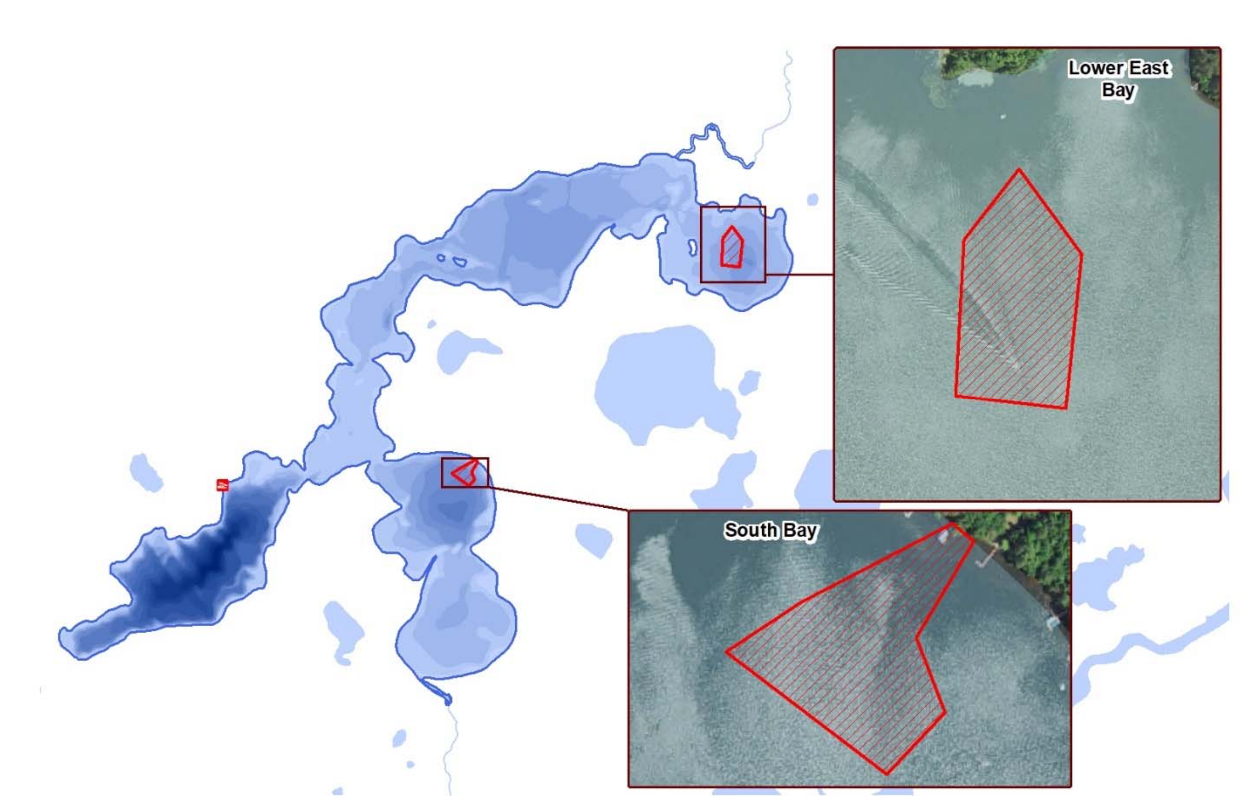


Figure 3.5-8. Little Saint Germain aeration locations.

Two-Story Fishery

Little Saint Germain Lake is unique compared to most lakes in Wisconsin in that it is a two-story fishery. A two-story fishery is capable of supporting both a warm-water and cold-water fishery. The top-story supports warmer water species such as bass and pike. The lower-story is colder, deeper, and well oxygenated and supports species such as cisco or trout. A 2014 survey conducted by the WDNR found Cisco (*Coregonus* spp.) in Little Saint Germain Lake in low relative abundance (Lyons, et al 2015).

Substrate Composition

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

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye are another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn and care for their eggs in muck as well.

According to the point-intercept survey conducted by Onterra in 2016, 76% of the substrate sampled in the littoral zone of Little Saint Germain Lake was soft sediments, 17% was sand with the remaining 7% composed of rock substrate.

Coarse Woody Habitat and Fish Sticks Program

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006).

Photograph 3.5-3. Fish Stick Example. (Photo courtesy of WDNR 2013)

The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas (WDNR 2014). Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.5-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. A fall 2016 coarse woody habitat survey documented 31 pieces of coarse woody per mile of shoreline on Little Saint Germain Lake. Tree drops have taken place on Little Saint Germain in the past. During 2011 and 2012, 16 trees were placed at four locations in No Fish Bay and East Bay during a shoreland restoration project coordinated by the Michigan Technological University and the WDNR (Haskell and Meyer 2014).

Regulations and Management

Special fisheries regulations are in place for some species in Little Saint Germain Lake. A 45-inch minimum size limit for muskellunge was proposed and approved in 2009 by the WDNR. The purpose of the new regulation was to provide more conservative protection to produce trophy muskellunge (Gilbert 2009). A slot limit for walleye is also in place which will protect 20" to 24" fish from harvest and allow more fish to reach trophy size. Little Saint Germain Lake falls into the northern bass management zone in Wisconsin and thus smallmouth bass may not be harvested (catch and release only) from May 6, to June 16, 2017. Beginning in 2016, the WDNR developed special regulations for panfish in select Wisconsin lakes in an effort to determine the best regulation that will increase the average size of bluegill and crappie on select lakes that have been identified by biologists as having an underperforming pan fishery. More detailed information on this program is available on the WDNR website (*dnr.wi.gov*). Little Saint Germain Lake was one of the lakes included within the new panfish regulations which keeps the daily bag limit at 25 fish, however only 10 may be of any one species.

Table 3.5-6 displays regulations for Little Saint Germain Lake gamefish species as of February 2018. For specific fishing regulations, anglers should visit the WDNR website (*www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.5-6. WDNR fishing regulations for Little Saint Germain Lake as of February 2018.

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25 panfish may be kept but only 10 of any one species	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 6, 2017 to June 16, 2017
Smallmouth bass	5	14"	June 17, 2017 to March 4, 2018
Largemouth bass	5	14"	May 6, 2017 to March 4, 2018
Muskellunge and hybrids	1	45"	May 27, 2017 to November 30, 2017
Northern pike	5	None	May 6, 2017 to March 4, 2018
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 6, 2017 to March 4, 2018
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	25 pounds plus one more fish of either species in total	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks, baits, or lures maximum per boat.

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.5-9. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

Fish Consumption Guidelines for Most Wisconsin Inland Waterways		
	Women of childbearing age, nursing mothers and all children under 15	**Women beyond their childbearing years and men**
Unrestricted*	-	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout
1 meal per week	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout	Walleye, pike, bass, catfish and all other species
1 meal per month	Walleye, pike, bass, catfish and all other species	Muskellunge
Do not eat	Muskellunge	-

**Doctors suggest that eating 1-2 servings per week of low-contaminant fish or shellfish can benefit your health. Little additional benefit is obtained by consuming more than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 3.5-9. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

4.0 SUMMARY AND CONCLUSIONS

The biology and chemistry of Little Saint Germain Lake has been studied intensely over the past decade or more. These studies have included analysis of the lake's water quality, assessments of its watershed, and various surveys of its aquatic plant community. The current management planning project incorporates the work of these past studies and distills the information for use in creating realistic management decisions.

As discussed in the water quality section, much of Little Saint Germain Lake is considered highly eutrophic. The largest source of phosphorus in Little Saint Germain is due to internal nutrient loading. This allows phosphorus to be released from the lake bottom periodically when the lake stratifies and then de-stratifies, potentially a number of times throughout the year. Addition of aluminum salt, usually in the form of aluminum sulfate (alum), is a useful technique for reducing internal phosphorus loading in lakes. A 2007 Barr Engineering Study looked at the feasibility of conducting an alum treatment in East Bay and South Bay. At the current time, the LSGLPRD is not perusing an alum treatment on the lake primarily due to cost, uncertain longevity of the control action, and concern for increases in AIS population following an increase in water clarity. If the LSGLPRD is to consider an alum treatment in the future, it is recommended to first conduct an updated feasibility study and adopt more recent advancements in technology and research.

While the aeration program that began in 2001-2002 may have been beneficial to the lake's fish populations, this management action resulted in a significant increase in phosphorus and algal concentrations in the shallow bays (Lower East Bay, East Bay, No Fish Bay, and South Bay). Prior to installing the aeration system, it is believed that a large portion of the internal phosphorus loading that occurred during the winter was flushed out of the lake during the spring high-flow period before the growing season truly began. The LSGLPRD should discuss the pros and cons of continuing the aeration program with lake and fisheries managers moving forward.

Muskellunge Creek is also a major source of phosphorus to Little Saint Germain, especially when impoundments are formed by beaver dams. These impoundments can create conditions where phosphorus is released from the bottom sediments in the same manner of internal nutrient loading that occurs in the lake proper. Since the late 1990s efforts have been ongoing to minimize the beaver impoundments and this has significantly reduced phosphorus loading from Muskellunge Creek.

Internal nutrient loading in Little Saint Germain also influences the aquatic plant management of the lake. The conditions in some years may cause large algal blooms that stifle aquatic plant growth, including AIS. But in other years, the clearer water but nutrient-rich sediments can cause large growths of native and non-native plant species. The results of the stakeholder survey indicate that respondents were very concerned with excessive plant growth and how it reduces navigation, recreation, aesthetics, and overall enjoyment of the lake. As a part of this project, the LSGLPRD has developed a concise mechanical harvesting plan that can be enacted if conditions appear to be favorable for a year of nuisance plant growth.

The native plant community of Little Saint Germain Lake has remained resilient following more than a decade of AIS-targeted herbicide management, increased nutrient loading, and consistent human use of the lake and the near-shoreland zone of the lake. While changes in individual species population have been observed, the majority of species have fluctuated within a narrow range since 2004.

The LSGLPRD has also reviewed its ongoing AIS management plan. The populations of EWM and CLP are both currently low in the lake and not likely causing measurable impacts to the function of the ecosystem nor are they causing wide-scale nuisance conditions that impede lake users from using and recreating on the lake. The current low CLP population is due to fewer turions sprouting each year, likely reflecting a successful control strategy of targeting CLP populations for numerous years before they are able to contribute to the turion bank in the sediment. EWM population control on Little Saint Germain has been more mixed over the years, with many individual herbicide treatments falling short of success goals due to the inability of maintaining sufficient concentrations and exposure times. While many of the more-recently employed EWM-targeted herbicide treatments have been more effective, it is unclear what impact the control strategy has had on lake-wide EWM populations.

The next phase of AIS management on Little Saint Germain Lake includes the development of concise thresholds that when surpassed, would trigger management such as targeted hand-harvesting, herbicide spot-treatment, or large-scale herbicide treatment. The overarching goal would be to keep these populations managed and lowered in the lake, but acknowledging that the conditions of Little Saint Germain Lake (i.e. low water clarity and role of internal nutrient loading) may be more of a driver of the AIS population trajectory than management efforts themselves.

With over 380 residences on Little Saint Germain, the principal investigators of the Wisconsin Lakeshore Restoration Project were discouraged by only getting 4 property owners (6 parcels) to participate in a shoreland restoration project that had no out-of-pocket costs to the riparian. However, that project may have sparked the interest of more riparians with 73 anonymous stakeholder respondents (58.4% of survey respondents) indicating in 2016 that they had interest in participating in a grant-funded shoreland restoration project. The LSGLPRD has outlined a way to be supportive of educating and encouraging district members to conduct shoreline restorations while fully supporting individual property rights.

5.0 IMPLEMENTATION PLAN

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

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

Management Goal 1: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Little Saint Germain Lake

Management Action:	Continue Clean Boats Clean Waters watercraft inspections
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors or possible coordinator
Description:	Currently the LSGLPRD monitors the single public boat landings using training provided by the Clean Boats Clean Waters program. Little Saint Germain Lake are an extremely popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasive species that originated in Little Saint Germain Lake. The goal would be to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. Due to the large number of activities that volunteers are called upon on Little Saint Germain Lake (AIS monitoring, stakeholder education, etc.), paid watercraft inspectors would be sought. The LSGLPRD intends to utilize 200 hours of paid watercraft inspections through Vilas County's student intern program.
Action Steps:	

	See description above as this is an established program.

Management Action:	Coordinate volunteer monitoring of AIS
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors or possible coordinator
Description:	LSGLPRD members have received past training on AIS identification from Onterra and Vilas County staff. The LSGLPRD also has purchased a dedicated GPS to transfer information to and from professional surveyors. These surveys would be conducted to augment professional surveys, not replace them. As a goal, the LSGLPRD would like to find a coordinator who is responsible for recruiting riparian property owners to participate in looking for AIS in the water and along specific stretches of shorelines.
Action Steps:	
1.	Volunteers from LSGLPRD update their skills by attending a training session conducted by WDNR/UW-Extension through the AIS Coordinator for Vilas County (Cathy Higley – 715.479.3738).
2.	Trained volunteers recruit and train additional association members.
3.	Complete lake surveys following protocols.
4.	Report results to consultant and LSGLPRD, entering hours spent into SWIMS.

Management Action:	Coordinate annual professional monitoring of AIS, particularly EWM and CLP
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors or possible coordinator
Description:	As the name implies, the EWM peak-biomass survey is completed when the plant is at its peak growth, allowing for a true assessment of the amount of this exotic within the lake. For Little Saint Germain Lake, this survey will likely take place in late-August or September. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using sub-meter GPS technology. This survey would serve three main roles: 1) document the EWM population at the peak of its growth stage in a given year, 2) access the management efforts that took place over the summer, and 3) be used to propose management for the following year. If the management strategy for a given year contains a professional

	hand-harvesting component, an Early Season AIS (ESAIS) Survey would be conducted during June to setup that years' program. With direction from the NSTLRSA, the consultant would coordinate the professional hand-harvest effort by designing the strategy (prioritization if needed) and providing the spatial data to the third-party firm as appropriate. The ESAIS Survey would also be important for monitoring the CLP population, which is at its peak growth stage during this time period.
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Conduct EWM Population Control on Little Saint Germain using Hand-Harvesting and Herbicide Spot Treatments
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors or possible coordinator
Description:	The EWM population of Little Saint Germain is currently at relatively low population levels. At these low levels, the EWM population is not likely causing measurable negative ecological impacts to the system. Along with being a source population for future expansion, the EWM populations may be diminishing the navigability, recreation, aesthetics in localized areas. *<u>Hand-Harvesting</u>* If areas of EWM are comprised of point-based mapping (i.e. *single plants*, *clumps of plants*, or *small plant colonies*) or low-density colonies (i.e. *highly scattered* or *scattered*), the LSGLPRD will consider them applicable for hand-harvesting. The LSGLPRD will prioritize areas of hand-harvesting depending on the overall EWM population, available resources, and strategic location of the EWM populations that meet this criterion. Past hand-harvesting activities have proven more effective in the clearer water of West Bay whereas herbicide treatments have proven least effective on West Bay compared with other parts of Little Saint Germain Lake due to narrow littoral zones and water exchange from large temperature differentials in the deepest basin. The hand-harvesting would occur following the June ESAIS Survey in roughly mid-June to mid-September. Conducting hand-harvesting earlier or later in the year can reduce the effectiveness of the strategy, as plants are more brittle and extraction of the roots more difficult. A late-summer EWM survey will occur following the hand-harvesting activities to assess the control efforts and to initiate the following years planning. If a Diver Assisted Suction Harvest (DASH) component is utilized, the

	LSGLPRD and contracted firm would be responsible for the WDNR permit procedures. The contracted firm would be guided with GPS data from the consultant following the ESAIS Survey and would track their efforts (when, where, time spent, quantity removed) for post assessments. *Herbicide Spot Treatment* If the following trigger is met, the LSGLPRD would consider conducting herbicide spot treatments: "colonized (polygons) areas where a sufficiently large treatment area can be constructed to hold concentration and exposure times." It is believed that these areas are too large to be controlled using hand-harvesting techniques. It is likely that these areas may be small (3-5 acres) and would need to be conducted with herbicides that require short exposure times, such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.). If large areas (>5 acres) or sites in protected parts of the lake are to be targeted with an herbicide spot treatment, more traditional systemic herbicides like 2,4-D may be appropriate. If populations exceed spot-treatment thresholds, large-scale (whole-basin) herbicide strategies may be given consideration. In late-winter, an herbicide applicator firm would be selected and a conditional permit application would be applied to the WDNR. The herbicide treatment would occur when surface water temperatures are roughly below 60°F and active growth tissue is confirmed on the target plants. A pretreatment survey, a week or so prior to treatment would be used to finalize the permit, potentially with adjustments, and dictate approximate ideal treatment timing. If individual treatment sizes exceed 10 acres, a quantitative (sub-sample point-intercept) monitoring component may be required by the WDNR. Overall, the LSGLPRD will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen.
Action Steps:	
	See description above

Management Action:	Conduct CLP Population Control on Little Saint Germain Herbicide Spot Treatments
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors or possible coordinator
Description:	As described in the Aquatic Plant Section (3.3), the goal of CLP management is to annually kill the plants before they are able to produce and deposit new turions, and thus, overtime, deplete the existing turion bank within the sediment. As a result, curly-leaf pondweed treatments traditionally occur each year when surface water temperatures are between 50°F and 60°F.

Based upon the low quantities of CLP located during the 2016 survey, it is believed that the turion bank on Little Saint Germain has been considerably reduced during the past decade of active management. The CLP management strategy for the LSGLPRD has evolved into a strategy to maintain the currently low population. The difficulty of any maintenance strategy is to balance a level of CLP population tolerance while not allowing the population to return to pre-management levels.

If the following trigger is met, the LSGLPRD would consider conducting herbicide spot treatments for CLP: "colonized areas where a sufficiently large treatment area can be constructed to hold concentration and exposure times (preference to *dominant* or greater density CLP populations)." In order to reach the appropriate concentration and exposure time requirements for endothall to effectively kill CLP, only sites that are larger areas (approximately >5 acres) or sites in protected parts of the lake are appropriate for control. Even in some cases where larger treatment areas can be constructed, their narrow shape or exposed location within a lake may result in insufficient herbicide concentrations and exposure times for long-term control

To assist in the logistics and planning of CLP to be targeted for herbicide control, the LSGLPRD would use the following guidelines:

- All areas targeted the previous year would be considered for treatment and included within each year's conditional permit application. Based upon the pretreatment survey, these areas may be reduced or removed.
- All areas of colonized CLP exceeding a *dominant* density rating will be considered for treatment during the following spring, subject to confirmation during a pretreatment survey. The LSGLPRD's treatment threshold (trigger) may also extend to immediately adjacent colonies of CLP that are below this density-based threshold.

As outlined within the previous management goal aimed at controlling EWM, a formal monitoring strategy consistent with the Appendix D of the WDNR Guidance Document, *Aquatic Plant Management in Wisconsin* (WDNR 2010) would be implemented if an herbicide treatment site targeting CLP approaches/exceeds 10 acres. If planning allows, comparing annual spring pretreatment sub-sample point-intercept surveys would be the most appropriate way to determine if the strategy is effective. However, this monitoring method is not able to document the effectiveness of an individual treatment nor the native plant impacts from the control measure. Project goals change, funding sources are not always clear, and decisions are often made in the field; therefore, pretreatment data and post treatment data may not always

	match entirely, so it needs to be understood that judgements in treatment impacts and management decisions need to be made with limited data at times. Overall, the LSGLPRD will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen.
Action Steps:	
	See description above

Management Action:	Coordinate Periodic Quantitative Vegetation Monitoring
Timeframe:	Point-Intercept Survey every 3-4 years, Community Mapping every 7-8 years
Facilitator:	Board of Directors or possible coordinator
Description:	A whole-lake point-intercept survey should be conducted on Little Saint Germain Lake at a minimum once every 3-4 years. This will allow an understanding of the submergent aquatic plant community dynamics within Little Saint Germain Lake. Point-intercept surveys have been conducted on the lake during 2004, 2008, 2013, and 2016 (every 3-5 years). In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Little Saint Germain Lake, a community mapping survey would be conducted every 7-8 years. The community mapping survey has been conducted on Little Saint Germain Lake approximately every 3-5 years in the past as part of each lake management planning project update.
Action Steps:	
	See description above as this is an established program.

Management Goal 2: Maintain Navigability on Little Saint Germain Lake

Management Action:	Support responsible actions to gain reasonable navigational access to open water areas of Little Saint Germain Lake
Timeframe:	Continuation of Current Effort
Facilitator:	Board of Directors or possible coordinator
Description:	The LSGLPRD understands the importance of native aquatic vegetation on Little Saint Germain Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, caused largely by native vegetation such as southern naiad (*Najas guadalupensis*), common waterweed (*Elodea canadensis*), and coontail (*Ceratophyllum demersum*). The LSGLPRD supports the reasonable and environmentally sound actions to facilitate navigability on Little Saint Germain Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than absolutely necessary. The WDNR oversees the management of aquatic plants on inland lakes. The manual cutting and raking of native aquatic plant species within a 30-foot-wide area containing a pier, boatlift, or swim raft is exempt from a state permit provided that the cut plants are removed from the lake (and wild rice is not being removed). However, the use of mechanized or mechanical devices requires a WDNR permit. Current management of nuisance levels of native aquatic plants occurs on portions of Little Saint Germain Lake using contracted mechanical harvesting services. The areas of Little Saint Germain Lake requiring mechanical harvesting change annually, so the LSGLPRD initially proposes that four main areas in the system are proposed for harvesting (Map 9). Two areas in South Bay and one area in No Fish Bay are directed toward assisting riparian access to the lake. Another harvesting area allows navigation access between No Fish Bay and the southern part of East Bay, which has become inundated with southern naiad in recent years. Each year previous to the growing season, the LSLPRD applies for a mechanical harvesting permit from the WDNR. When submergent species are the target plant, the threshold (trigger) for harvesting set by the LSGLPRD is when the plants reach the surface and have aggregated masses of coontail, southern naiad, common waterweed, and other non-rooted plant species forming a mat. Map 9 shows the mechanical harvesting plan for Little Saint

	Germain Lake. This plan includes a 30 ft-wide common-use navigation lane which aims to reduce plant material in front of riparian properties as well as create a navigation framework to allow navigation access to the deeper parts of the lake. Lake-ward access spokes (30-ft wide) would periodically connect the center navigation lane with deeper water and cut on an "as needed" basis. 10-ft wide riparian access spokes have been constructed to allow access to the common-use center lane. The LSGLPRD would visit the need for each of the riparian access lanes to be harvested on an annual basis. Prior to mechanical harvesting of each year, an Early Season AIS (ESAIS) Survey will be conducted to locate AIS within Little Saint Germain Lake. The data from the ESAIS Survey would be overlaid on the Mechanical Harvesting Map. Colonies of EWM located during the ESAIS Survey would either be targeted for professionally-based hand-harvesting prior to mechanical harvesting, or these areas would be avoided for mechanical harvesting through an updated map and strategy. In areas where CLP was located, mechanical harvesting would not occur until after the week of Independence Day, when CLP populations would have mostly senesced (died back) for the year. The contracted mechanical harvesting firm would utilize GPS technology to ensure mechanical harvesting occurs as designed for that year. Each year, updated spatial data would be provided to the chosen mechanical harvesting firm. If documentation of cutting (i.e. GPS tracklog) is required by the WDNR, it would be the responsibility of the mechanical harvesting firm to forward that information on as appropriate. The LSGLPRD followed the fore mentioned strategy in 2016, but did not conduct mechanical harvesting activities in 2017 as the plant community was only locally impacting navigation and recreation; not wide-scale enough to justify the costs and logistics of contracting an effort.
Action Steps:	
1.	See description above

Management Goal 3: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors or possible coordinator
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Water quality data is currently being collected by the Wisconsin Valley Improvement Corporation (WVIC) for a 3-year period, once every 10 years. The next sampling period will be conducted in 2020-2022. In addition to the WVIC's efforts, volunteer water quality monitoring should be completed annually by Little Saint Germain Lake riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The LSGLPRD currently has advanced CLMN sampling occurring in the four main basins of the lake. Samples are collected three times during the summer and once during the spring, as well as water temperature profiles at the lake's deep hole using Vilas County's dissolved oxygen and temperature probe. Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to enroll in this program, ensure the proper training occurs, and the necessary sampling materials are received. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.
Action Steps:	
1.	Contact Sandra Wickman (715.365.8951) to enroll in the CLMN program.
2.	Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
3.	CLMN volunteer and/or LSGLPRD would facilitate new volunteer(s) as needed

Management Action:	Control beavers and beaver dams in the Muskellunge Creek
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors or possible coordinator
Description:	Phosphorus inputs from Muskellunge Creek could be almost as large of a source as internal sources. The beaver dams can create conditions where phosphorus is released from nutrient rich sediments and then flows into Little Saint Germain Lake. Since the late 1990s efforts by the USDA with support from the LSGLPRD have been ongoing to minimize the beaver impoundments and this has significantly reduced phosphorus loading from Muskellunge Creek. Since 2006, 68 beaver dams have been removed in the Muskellunge Creek.
Action Steps:	
	See description above as this is an established program.

Management Action:	Educate stakeholders on blue-green algae blooms and how to document their occurrences
Timeframe:	Ongoing
Facilitator:	Board of Directors or possible coordinator
Description:	As discussed within the Water Quality Section, Little Saint Germain Lake has experienced blue-green algae blooms on an occasional basis. Some species of blue-green algae can produce toxins which can be hazardous to human and animal health through ingestion or direct contact. Toxins are not always produced during these blooms and the conditions that lead to toxin production are not well understood. Therefore, because toxin production cannot be predicted, water use warnings are issued when there are high concentrations of blue-green algae present. The LSGLPRD will include information on blue-green algae blooms within their newsletter informing people to avoid contact with the water, including their pets, if it resembles "pea-soup." Because dogs and other domestic animals actively drink water from lakes, these symptoms can be much more developed and can lead to death in some instances. If you suspect an illness, either from a human or an animal, the case should be reported to the Wisconsin Department of Health Services: *http://dhs.wi.gov/eh/bluegreenalgae* Please note that this resource solely collects information for tracking blue-green algae outbreaks within the state. Individuals or animals experiencing severe symptoms should consult the

	appropriate medical attention immediately. The following information was provided by WDNR state-wide algae specialist, Gina LaLiberte: For a good rule of thumb, if you can wade knee-deep into water (without disturbing the sediment) and cannot see your feet, you should stay out. Algae cell densities are high enough that if the algae are producing toxins, you could become ill if you swallow water or inhale water droplets. Small children and animals should always be kept away from water in these conditions. The Department of Natural Resources' recommendations for staying safe are: • Do not swim in water that looks like "pea soup", green or blue paint, or that has a scum layer or puffy blobs floating on the surface. • Do not boat, water ski, etc. over such water (people can be exposed through inhalation). • Do not let children play with scum layers, even from shore. • Do not let pets or livestock swim in, or drink, waters experiencing blue-green algae blooms. • Do not treat surface waters that are experiencing blue-green algae blooms with any herbicide or algaecide--toxins are released into the water when blue-green algae cells die. • Always take a shower after coming into contact with any surface water (whether or not a blue-green algae bloom appears to be present; surface waters may contain other species of potentially harmful bacteria and viruses). • Pets should be washed off immediately after swimming, before they groom.
Action Steps:	
	See description above

Management Goal 4: Increase LSGLPRD's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Use education to promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors or possible coordinator
Description:	Education represents an effective tool to address many lake issues. The LSGLPRD distributes a single newsletter each year prior to the annual meeting. The LSGLPRD also maintains a large email distribution list, a website (http://www.littlesaint.org/), and a Facebook page (@LittleStGermainLake). These mediums allow for exceptional communication with association members. This level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings. The LSGLPRD has noted difficulties getting sufficient volunteerism to create the education pieces for use within its education and outreach program. The LSGLPRD will work with UW-Extension Lakes staff (Patrick Goggin: Patrick.Goggin@wisconsin.gov) to use stock articles as appropriate to lessen the workload and ensure the messaging is accurate. *www.uwsp.edu/cnr-ap/UWEXLakes* *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology • Boating safety (promote existing guidelines, Vilas County Courtesy Code) • Shoreline habitat restoration and protection • Fireworks use and impacts to the lake • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Recreational use of the lakes • Blue-green algae blooms and health
Action Steps:	
	See description above as this is an established program.

Management Action:	Continue LSGLPRD's involvement with other entities that have responsibilities in managing (management units) Little Saint Germain Lake
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors or possible coordinator
Description:	The LSGLPRD's mission is to educate citizens on issues that affect the quality of life on and around the lakes; to provide a collective voice to address issues that may concern lake front property owners; to maintain a working relationship with the DNR and other organizations that can influence the quality of the lakes; to create a sense of community and stewardship for the fragile resource of the lakes; to recommend and work toward zoning that will protect land owners from undesirable land and water use." The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation.It is important that the LSGLPRD actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page:
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of St. Germain Lakes Committee	Chairman (Ted Ritter Tritter3@frontier.com)	Little Saint Germain Lake falls within the Town of St. Germain and has representation on this committee	LSGLPRD representative attend committee meetings	Committee was formed to pool resources from the town's 5 main lake organizations and involving the township government opportunities.
Vilas County Lakes & Rivers Association	President (Rollie Alger– president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	Invasive Species Coordinator (Cathy Higley – 715.479.3738)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: Report activities to Coordinator
Vilas County Land & Water Conservation Department.	Conservation specialist (Mariquita Sheehan – 715.479.3721)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Hadley Boehm– 715-356-5211 ext. 246)	Manages the fishery of Little Saint Germain Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.8937)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	As needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	LSGLPRD members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.
Wisconsin Valley Improvement Company	Ben Niffenegger or Peter Hansen (715.848.2976)	Within the confines of their FERC license, operates the dam on Little Saint Germain Lake.	Once a year, or as needed.	General water-level communications.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 7-8 years
Facilitator:	Board of Directors or possible coordinator
Description:	Approximately once every 7-8 years, an updated stakeholder survey would be distributed to the Little Saint Germain Lake riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2016, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

Management Goal 5: Improve Lake and Fishery Resource of Little Saint Germain Lake

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Initiate 2018
Facilitator:	Board of Directors or possible coordinator
Description:	As discussed in the Shoreland Condition Section (3.3), the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. Numerous properties on Little Saint Germain Lake have been restored over the past 10 years, allowing a large set of demonstration sites for riparians to view and understand what they may look like on their property. As discussed within the Shoreland Conditional Section (3.2), riparian participation in past restoration programs, even those with no financial responsibility from the landowner, were low. A number of factors were cited, including the fact that a grass roots effort originating from the district may get more buy-in that a project partially being led by the WDNR. The LSGPLRD has discussed shoreline restoration at numerous past meetings, including showing some of the preliminary results of the studies occurring along its shorelines. The LSGPLRD Board of Directs believes its constituents are concerned about perceived overreach of property rights and policing of shorelines when the topic is discussed. The LSGLPRD will continue to provide information to district members on shoreland restoration. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through Vilas County. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap) • Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances • Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide • Landowner must sign Conservation Commitment pledge to

	leave project in place and provide continued maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available
Action Steps:	
	See description above

Management Action:	Protect natural shoreland zones around Little Saint Germain Lake
Timeframe:	Initiate 2018
Facilitator:	Board of Directors or possible coordinator
Description:	Approximately 7.6 miles (51%) of the Little Saint Germain Lake's shoreline was found to be in either a *natural* or *developed-natural* state. It is therefore very important that owners of these properties become educated on the benefits their shoreland is providing to the Twin, and that these shorelands remain in a natural state. Map 2 indicates the locations of Natural and Developed-Natural shorelands on Little Saint Germain Lake. Private shorelands that are in either a *natural* or *developed-natural state* should be prioritized for education initiatives and physical preservation. A Planning Committee appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the LSGLPRD in preserving Little Saint Germain Lake shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Vilas County Land and Water Conservation Department. Several websites of interest include: • Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands) • Conservation easements or land trusts: (http://www.northwoodslandtrusts.org/) • UW-Extension Shoreland Restoration: (www.uwex.edu/ces/shoreland/Why1/whyres.htm) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)
Action Steps:	
1.	Recruit facilitator (potentially same facilitator as previous management action).

2.	Facilitator gathers appropriate information from sources described above.

Management Action:	Coordinate with WDNR and private landowners to expand coarse woody habitat in Little Saint Germain Lake
Timeframe:	Initiate 2018
Facilitator:	Board of Directors or possible coordinator

Description:	LSGLPRD stakeholders must realize the complexities and capabilities of Little Saint Germain Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.2) and Fisheries Data Integration Section (3.5) discuss the benefits of coarse woody habitat in detail.
	
	The LSGLPRD will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with WDNR fisheries biologist.
	
	The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or :
	    o The landowner would need to commit to leaving the area un-mowed
	    o The landowner would need to implement a native planting (also cost share thought this grant program available)
	• Coarse woody habitat improvement projects require a

	general permit from the WDNR • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years
Action Steps:	
1.	Recruit facilitator from Planning Committee (potentially same facilitator as previous management actions).
2.	Facilitator contacts Kevin Gauthier (WDNR Lakes Coordinator) and Hadley Boehm (WDNR Fisheries Biologist) to gather information on initiating and conducting coarse woody habitat projects.
3.	The LSGLPRD would encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

Management Action:	Continue the winter aeration program
Timeframe:	Ongoing
Facilitator:	Board of Directors or possible coordinator
Description:	As discussed within the Fisheries Data Integration Section (3.5), the LSGLPRD maintains and operates two aeration systems during the winter months. An aspect of the aeration program includes placing and removing the safety barriers required by Wisconsin statues. Even though the winter aeration may be contributing to increased algal levels in the lake, the LSGLPRD will continue to operate the winter aeration equipment to reduce the frequency of fishkills and improve the health of the fishery.
Action Steps:	
	See description above

6.0 METHODS

Early-Season AIS Survey

Early-Season AIS Surveys have been completed on Little Saint Germain Lake each year during roughly June. During 2017, these surveys occurred on June 22 and June 26. This was slightly later in the growing season than previous years to ensure the CLP population had adequate opportunity to be at its peak growth stage. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Little Saint Germain Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them.

Point-intercept Survey

The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on August 30-31, 2016. A point spacing of 75 meters was used resulting in approximately 699 points. During the survey, 634 sampling locations were visited and 560 ultimately were considered less than or equal to the maximum of plant growth.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Little Saint Germain Lake (emergent and floating-leaved vegetation) were mapped using a ruggedized laptop (Toughbook by Panasonic) with a blue-toothed Trimble Global Positioning System (GPS) receiver with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

Representatives of all plant species located during the point-intercept and community mapping survey that were not located during a previous survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium. Hence, all species present in Little Saint Germain Lake have been vouchered with the herbarium.

7.0 LITERATURE CITED

Ahrenstorff T. D., G. G. Sass. 2009. The influence of littoral zone coarse woody habitat on home range size, spatial distribution, and feeding ecology of largemouth bass (*Micropterus salmoides*). Hydrobiologia. 623:223-233.

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

Barr. 2007. Evaluation of the Cost and Benefit of Applying Aluminum (alum) to Little St. Germain Lake Sediments. Limnol. Oceanogr. 22:361-369.

Bajer, P.G. and P.W. Sorensen. 2015. Effects of common carp on phosphorus concentrations, water clarity, and vegetation density: a whole system experiment in a thermally stratified lake. Hydrobiologia. Vol. 746. 30 –311.

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

Boston, H.L. and M.S. Adams. 1987. Productivity, growth, and photosynthesis of two small ‘isoetid’ plants, *Littorella uniflora*, and *Isoetes macrospora*. J. Ecol. 75: 333 – 350.

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

Carpenter, S.R., Kitchell, J.F., and J.R. Hodgson. 1985. Cascading Trophic Interactions and Lake Productivity. BioScience, Vol. 35 (10) pp. 634-639.

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

Christensen, D.L., B.J. Herwig, D.E. Schindler and S.R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecological Applications. Vol. 6, pp 1143-1149.

Dantoin, E.D. and D.M. Robertson. In Press. Anticipated Changes in Phosphorus Export from Little St. Germain Lake, Wis., Caused by Changes in the Timing of Water Releases. US Geological Survey Water Resources Investigations Report _____.

DeQuattro, Z.A. and W.H. Karasov. 2015. Impacts of 2,4-dichlorophenoxyacetic acid aquatic herbicide formulations on reproduction and development of the fathead minnow (*Pimephales promelas*). Environmental Toxicology and Chemistry. 35(6).: 1478-1488.

Dinius, S.H. 2007. Public Perceptions in Water Quality Evaluation. Journal of the American Water Resource Association. 17(1): 116-121.

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

Fairbrother, A., and L.A. Kapustka. 1996. Toxicity Extrapolations in Terrestrial Systems. Ecological Planning and Toxicology, Inc. (ept). July 5, 1996.

Fischer J.R. and R.M. Krogman. 2013. Influences of native and non-native benthivorous fishes on aquatic ecosystem degradation. Hydrobiologia. Vol. 711. 187–199.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Garn, H.S. 2002. Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Two Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigations Report 02-4130.

Garrison, P., Jennings, M., Mikulyuk, A., Lyons, J., Rasmussen, P., Hauxwell, J., Wong, D., Brandt, J. and G. Hatzenbeler. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. Pub-SS-1044.

Gilbert, S. 2015. Little Saint Germain Lake 2015 Fisheries information sheet. Unpublished Report. Wisconsin Department of Natural Resources. Woodruff, WI. 2 pages.

Graczyk, D.J., Hunt, R.J., Greb, S.R., Buchwald, C.A. and J.T. Krohelski. 2003. Hydrology, Nutrient Concentrations, and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999-2001. USGS Water-Resources Investigations Report 03-4144.

Gettys, L.A., W.T. Haller, & M. Bellaud (eds). 2009. *Biology and Control of Aquatic Plants: A Best Management Handbook.* Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp. Available at http://www.aquatics.org/bmp.htm.

Glomski, L. M. and M. D. Netherland. 2010. Response of Eurasian and hybrid water milfoil to low use rates and extended exposures of 2,4-D and Triclopyr. Journal of Aquatic Plant Management 48:12–14.

Great Lakes Indian Fish and Wildlife Service. 2017A. Interactive Mapping Website. Available at http://maps.glifwc.org. Last accessed November 2017.

Great Lakes Indian Fish and Wildlife Service. 2017B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Regulations/WI_Spearing.pdf. Last accessed November 2017.

Halverson & Blonski 2016. Creel Survey Report Little Saint Germain 2015-16. Wisconsin Department of Natural Resources. 18 pages.

Hanchin, P.A., Willis, D.W. and T.R. St. Stauver. 2003. Influence of introduced spawning habitat on yellow perch reproduction, Lake Madison South Dakota. Journal of Freshwater Ecology 18.

Haskell, D.E. & M.W.Meyer. 2014. Restoring Lakeshore Habitat on Little St. Germain Lake, Vilas County. Lake Protection Grant LPT 344-10. 127 pages.

Haskell, D.E., C.R. Webster, A.L. Bales, M.W. Meyer, and D.J. Flaspholer. 2017. Assessment of Wildlife Habitat Attributes at Restroation Projets on Northern Wisconsin Lakehores. Noertheastern Naturalist. 24(4):391-412.

Jennings, M. J., E. E. Emmons, G. R. Hatzenbeler, C. Edwards and M. A. Bozek. 2003. Is littoral habitat affected by residential development and landuse in watersheds of Wisconsin lakes? Lake and Reservoir Management. 19(3):272-279.

Johnson JA, AR Jones & RM. Newman. 2012: Evaluation of lakewide, early season herbicide treatments for controlling invasive curlyleaf pondweed (Potamogeton crispus) in Minnesota lakes, Lake and Reservoir Management, 28:4, 346-363

Johnson, P.T.J., J.D. Olden, C.T. Solomon, and M. J. Vander Zanden. 2009. Interactions among invaders: community and ecosystem effects of multiple invasive species in an experimental aquatic system. Oecologia. 159:161–170.

Krueger, J. 1998-2014. Wisconsin Open Water Spearing Report (Annual). Great Lakes Indian Fish and Wildlife Commission. Administrative Reports. Available at: http://data.glifwc.org/reports/. Last accessed May 2017.

Kujawa, E.R., P. Frater, A. Mikulyuk, M. Barton, M. Nault, S. Van Egeren, and J. Hauxwell. 2017. Lessons from a decade of lake management: effects of herbicides on Eurasian watermilfoil and native plant communities. Ecosphere. 8(4): 1-16.

Lathrop, R.D., and R.A. Lillie. 1980. Thermal Stratification of Wisconsin Lakes. Wisconsin Academy of Sciences, Arts and Letters. Vol. 68.

Lin Y. and C.H. Wu. 2013. Response of bottom sediment stability after carp removal in a small lake. Ann. Limnol. – Int. J. Lim. Vol. 49. 157–168.

Lindsay, A., Gillum, S., and M. Meyer 2002. Influence of lakeshore development on breeding bird communities in a mixed northern forest. Biological Conservation 107. (2002) 1-11.

Lutze, Kay. 2015. 2015 Wisconsin Act 55 and Shoreland Zoning. State of Wisconsin Department of Natural Resources

Lyons, J., J. Kampa, T.Parks, and G.Sass. 2015. The Whitefishes of Wisconsin’s Inland Lakes: The 2011-2014 Wisconsin Department of Natural Resources Cisco and Lake Whitefish Survey. Internal Report of Wisconsin Dept. of Natural Resources. pp. 13.

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

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

Nault, M.N., A. Mikulyuk, J. Hauxwell, J. Skogerboe, T. Asplund, M. Barton, K. Wagner, T.A. Hoyman, and E.J. Heath. 2012. Herbicide Treatments in Wisconsin Lakes. NALMS Lakeline. Spring 2012: 21-26.

Nault, M.N., S. Knight, S. VanEgeren, E.J. Heath, J. Skogerboe, M. Barton, and S., Provost. 2015. Control of invasive aquatic plants on a small scale. NALMS Lakeline. Spring 2015: 35-39.

Nault, M. 2016. The science behind the “so-called” super weed. Wisconsin Natural Resources 2016: 10-12.

Nault ME, M Barton, J Hauxwell, EJ Heath, TA Hoyman, A Mikulyuk, MD Netherland, S Provost, J Skogerboe & S Van Egeren. 2018: Evaluation of large-scale low-concentration 2,4-D treatments for Eurasian and hybrid watermilfoil control across multiple Wisconsin lakes, Lake and Reservoir Management (TBD)

Netherland, M.D. 2009. Chapter 11, "Chemical Control of Aquatic Weeds." Pp. 65-77 in *Biology and Control of Aquatic Plants: A Best Management Handbook,* L.A. Gettys, W.T. Haller, & M. Bellaud (eds.) Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp

Newbrey, M.G., Bozek, M.A., Jennings, M.J. and J.A. Cook. 2005. Branching complexity and morphological characteristics of coarse woody structure as lacustrine fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 62: 2110-2123.

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

Olszyk, D. 1980. Biological Effects of Acid Rain. Testimony, Wis. Public Service Commission Docket No. 05-EP-2. 5 pp.

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

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

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

Reed, J. 2001. Influence of Shoreline Development on Nest Site Selection by Largemouth Bass and Black Crappie. North American Lake Management Conference Poster. Madison, WI.

Robertson, D.M. and W.J. Rose. 2000. Hydrology, water quality, and phosphorus loading in Little.St. Germain Lake, Vilas County, Wisconsin. US Geological Survey Water Resources Investigations Report 2000-4209.

Robertson, D.M., W.J. Rose, and D.A. Saad. 2005. Hydrology, water quality, and phosphorus loading in Little.St. Germain Lake, Wisconsin with special emphasis on the effects of winter aeration and ground-water inputs. US Geological Survey Water Resources Investigations Report 2005-5071.

Robertson, D.M., W.J. Rose, and P.C. Reneau. 2016. Interannual and long-term changes in the trophic state of a multibasin lake: effects of morphology, climate, winter aeration, and beaver activity. Can. J. Fish. Aquat. Sci. 73:445-460.

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In: Gene E. Likens, (Editor) Encyclopedia of Inland Waters. Vol. 1, pp. 60-69 Oxford: Elsevier.

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

Shaw, B.H. and N. Nimphius. 1985. Acid Rain in Wisconsin: Understanding Measurements in Acid Rain Research (#2). UW-Extension, Madison. 4 pp.

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

Solomon, C.T., J.D. Olden, P.T.J Johnson, R.T. Dillon Jr., and M.J. Vander Zanden. 2010. Distribution and community-level effects of the Chinese mystery snail (*Bellamya chinensis*) in northern Wisconsin lakes. Biol Invasions. 12:1591–1605.

Spangler, G.R. 2009. "Closing the Circle: Restoring the Seasonal Round to the Ceded Territories". Great Lakes Indian Fish & Wildlife Commission. Available at: http://www.glifwc.org/minwaajimo/Papers/Spanger%20paper%20-%20FINAL.pdf

USDA FS [United States Department of Agriculture Forest Service]. 2006. 2,4-D Human Health and Ecological Risk Assessment, Final Report, September 30, 2006

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

United States Environmental Protection Agency. 2009. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. EPA 841-R-09-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

Vander Zanden, M.J. and J.D. Olden. 2008. A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65 (7): 1512-22.

Vestergaard, O. and K. Sand-Jensen. 2000. Alkalinity and trophic state regulate aquatic plant distribution in Danish lakes. Aquatic Botany. (67) 85-107.

Vermaat, J.E. and R.J. De Bruyne. 1993. Factors limiting the distribution of submersed waterplants in the lowland River Vecht (The Netherlands). Freshwat. Biol. 30: 147 – 157.

Weber, M.J., M.J. Hennen, and M.L. Brown. 2011. Simulated population responses of common carp to commercial exploitation. North American Journal of Fisheries Management. Vol. 31. 269–279.

Whittier, T.R., Ringold, P.L., Herlihy, A.T. and S.M Pierson. 2008. A calcium-based invasion risk assessment for zebra and quagga mussels (*Dreissena* spp). Frontiers In Ecology and the Environment. Vol. 6(4): 180-184

Wisconsin Department of Natural Resources – Bureau of Science Services. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. PUB-SS-1044.

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2014. Fish sticks: Improving lake habitat with woody structure. Available at: http://dnr.wi.gov/topic/fishing/documents/outreach/FishSticksBestPractices.pdf

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2017. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed November 2017.

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

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