Big Sand Lake

Vilas County, Wisconsin

Comprehensive Management Plan

May 2017

Sponsored by:

Big Sand Lake Property Owners Association

WDNR Grant Program

AEPP-436-14

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Onterra, LLC
Lake Management Planning

Big Sand Lake

Vilas County, Wisconsin

Comprehensive Management Plan

May 2017

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

Big Sand Lake Planning Committee

Bob Kelly
Tom Sipolt
Joe Robinson
Bob Remme
Mike Schulz
Tom O'Connell
Dru Claar
Dick Goff
Ken Musial
Matt Garni

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Kevin Gauthier

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1.0 INTRODUCTION

Big Sand Lake, Vilas County, is a 1,434 acre (based on 2013 orthophoto, Wisconsin Department of Natural Resources (WDNR) definition is 1,427 acres) deep lowland drainage lake with a maximum depth of 56 feet and a mean depth of 12.5 feet. This Wisconsin Trophic State Index status lake has a relatively small watershed when compared to the size of the lake. Big Sand Lake contains 54 native plant species, of which fern-leaf pondweed (*Potamogeton robbinsii*) is the most common plant. Fern-leaf pondweed is also the most frequent species in connected Long Lake. One submersed exotic plant species (Eurasian water milfoil) is known to exist in Big Sand Lake.

Field Survey Notes

This is one of the quintessential northern Wisconsin Lakes. Its clear waters support large amounts of recreational activity including water sports, wildlife viewing, and angling.

Photograph 1.0-1 Big Sand Lake, Vilas County

Lake at a Glance - Big Sand Lake

Morphology	
Acreage	1,434
Maximum Depth (ft)	56
Mean Depth (ft)	12.5
Shoreline Complexity	2.9
Vegetation	
Point-intercept Survey Dates	July 27 – 28, 2016
Community Mapping Survey Date	July 30, 2014
Number of Native Species	54
Threatened/Special Concern Species	-
Exotic Plant Species	Eurasian water milfoil
Simpson's Diversity	0.89
Average Conservatism	6.7
Water Quality	
Trophic State	Meso-eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.7
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	3:1

Big Sand Lake is located near Phelps, WI (Vilas County) and is a highly sought after location for recreationists and anglers. Big Sand Lake flows into neighboring Long Lake which flows through the Deerskin River into Scattering Rice Lake of the Eagle River Chain of Lakes. As outlined on the Big Sand Lake Property Owners Association's (BSLPOA) website, the BSLPOA has been created to maintain and improve the environmental quality of Big Sand Lake. They are dedicated to preserve and promote the natural resources of Big Sand Lake.

The non-native, invasive plant Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first discovered in Big Sand Lake in 1990. This spawned the BSLPOA to initiate the creation of a management plan for the system. In 2008, the BSLPOA successfully applied for WDNR grant funds for a five-year program to reduce EWM within Big Sand Lake. Big Sand Lake was treated for the next five years using both spot treatment and whole-lake treatment strategies resulting in differing levels of success. EWM control has been best demonstrated on Big Sand Lake using a whole-lake treatment strategy. To reflect the success and limitations learned, the BSLPOA has moved forward with updating their lake management plan to assure that the group is doing everything it can to protect the lake and maintain its eligibility for AIS control funds through the WDNR grant programs.

This report discusses the results of the studies conducted on Big Sand Lake in 2014-2016. These studies included an assessment of Big Sand Lake's stakeholders through a stakeholder survey, as well as the lake's water quality, watershed, shoreline, and aquatic plant community. Also included is the Implementation Plan which includes goals and actions specific to Big Sand Lake's current and future management that were developed by both members of the BSLPOA and Onterra ecologists.

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

On April 13th, 2015, Eddie Heath of Onterra met with six members of the Big Sand Lake Planning Committee for nearly 4 hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including Eurasian water milfoil treatment results, aquatic plant inventories, water quality analysis, shoreland assessment, fisheries, and watershed modeling were presented and discussed. Many concerns were raised by the committee, including EWM management, low water levels, and the fisheries.

Additional teleconferences and email correspondences took place between Onterra ecologists/planners and BSLPOA planning committee members to develop the implementation plan section.

Management Plan Review and Adoption Process

In October 2015, a draft of the Implementation Plan Section was provided to the Planning Committee for review. Based upon comments received, additional and revised management goals were created and discussed during additional teleconference calls.

In July 2016, a an official first draft of the Big Sand Lake Comprehensive Management Plan was supplied to the WDNR, Wisconsin Valley Improvement Company, Great Lakes Indian Fish and Wildlife Commission, Vilas County, and BSLPOA Planning Committee for review.

Written reviews of the draft plan were received from Michelle Nault (WDNR Water Resources Management Specialist) Scott Van Egeren (WDNR Water Resources Management Specialist), Dr. Susan Knight (Interim Director UW Trout Lake Station), Jordan Petchenik (NR Research Scientist), Steve Gilbert (NR Region Team Supervisor), and Kevin Gauthier (Water Resources Management Specialist). Their comments and how they were integrated into this document are included in Appendix G.

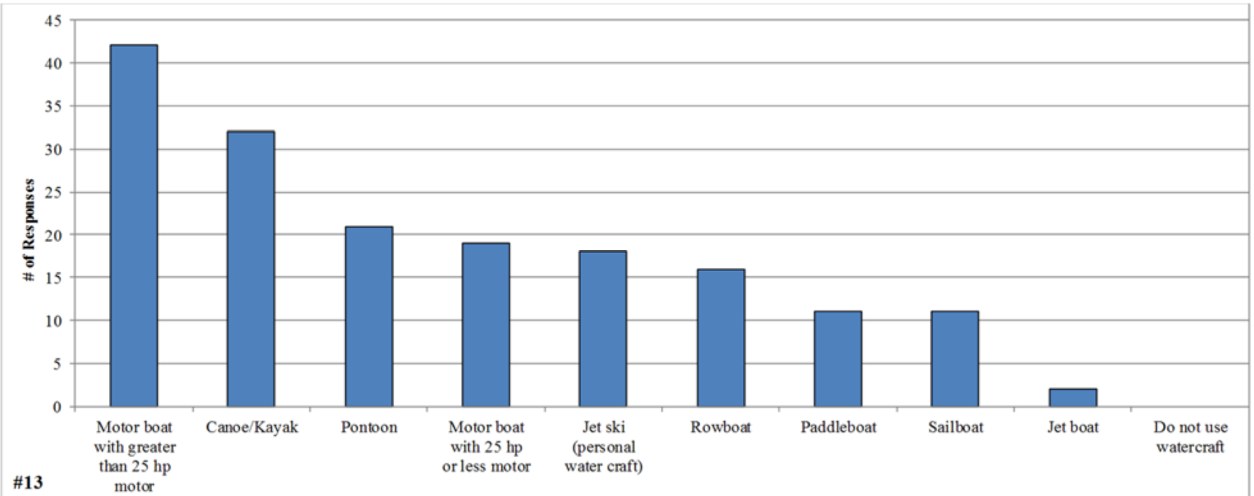
Stakeholder Survey

During October 2014, a five-page, 33-question survey was mailed to 177 riparian property owners in the Big Sand Lake watershed. Thirty-five percent of the surveys were returned and those results were entered into a spreadsheet by members of the Big Sand Lake Planning Committee. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Due to the low response rate, the following survey results should not be interpreted as being statistically representative of the population. At best, the results may indicate possible trends and opinions about stakeholder perceptions of Big Sand Lake, but cannot be stated with any statistical confidence. Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Big Sand Lake. The largest number of respondents (35%) are seasonal (summer only) residents, while 33% visit on weekends through the year and 11% live on the lake year-round. Sixty-nine% of stakeholders have owned their property for over 15 years, and 37% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, 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, larger motor boat, canoe/kayak, or a combination of these three vessels on Big Sand Lake (Question 13). Jet skis and smaller motor boats were also popular options. 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 14, several of the top recreational activities on the lake involve boat use. Although boat traffic was listed as a factor potentially impacting Big Sand Lake in a negative manner (Question 20), it was ranked 8th on a list of stakeholder's top concerns regarding the lake (Question 21).

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



Question 14: Please rank up to three activities that are important reasons for owning your property on or near the lake.

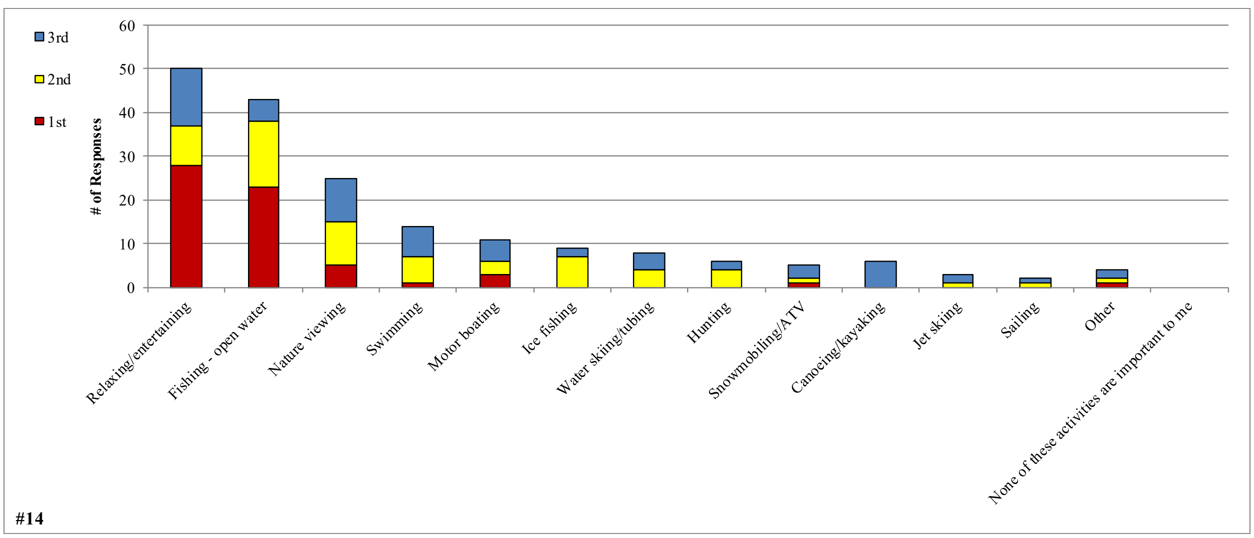
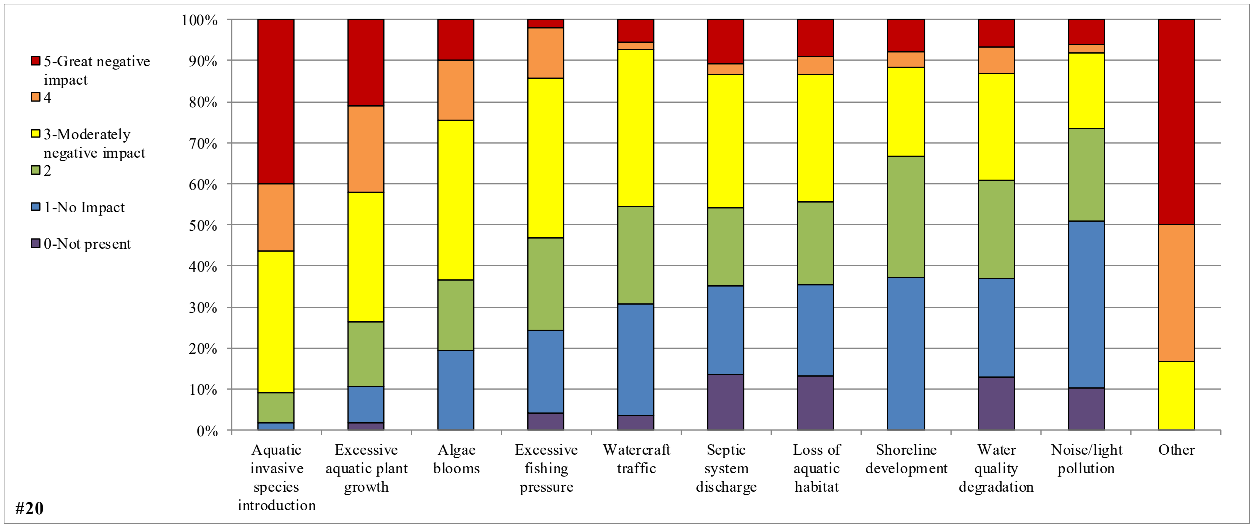


Figure 2.0-1. Select survey responses from the Big Sand Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 20: To what level do you believe these factors may be negatively impacting Big Sand Lake?



Question 21: Please rank your top three concerns regarding Big Sand Lake.

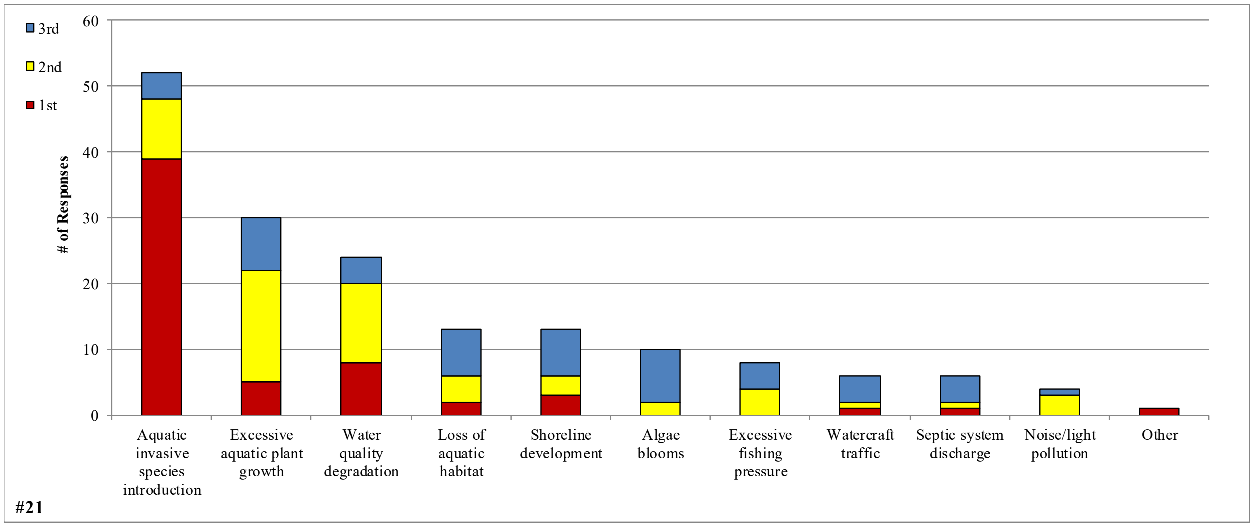


Figure 2.0-2. Select survey responses from the Big Sand Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Big Sand Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Big Sand 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 stratification, whether throughout the summer or periodically between mixing events, 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 turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can 'pump' phosphorus from the sediments to the water column throughout the growing season. In lakes that mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algae blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add large loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. 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 determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013) 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 Big Sand 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 four square miles.

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

Because Big Sand Lake possesses both two tributary inlets and an outlet, has a watershed that is greater than four square miles in area, and based upon its average depth relative to its area, Big Sand Lake is classified as a deep (stratified), lowland drainage lake (Category 5 on Figure 3.1-1).

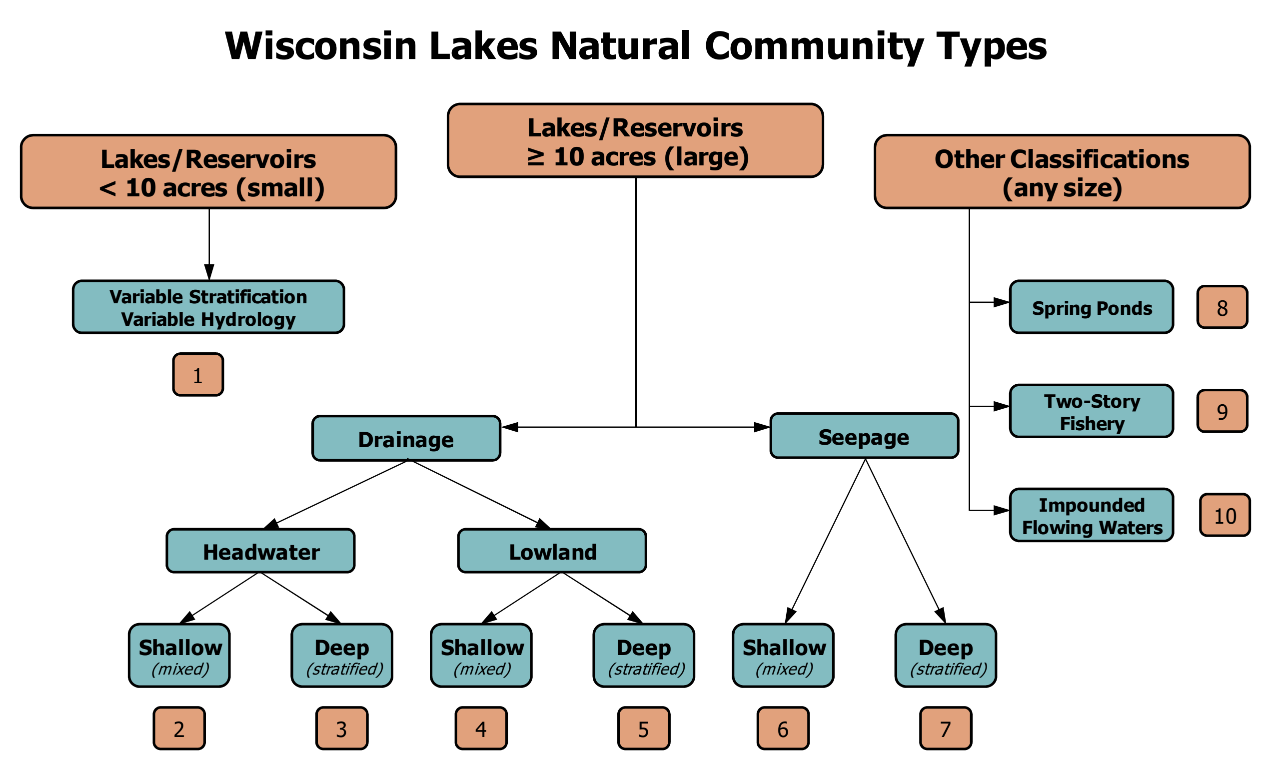


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Big Sand Lake is within the Northern Lakes and Forests ecoregion (Figure 3.1-2).

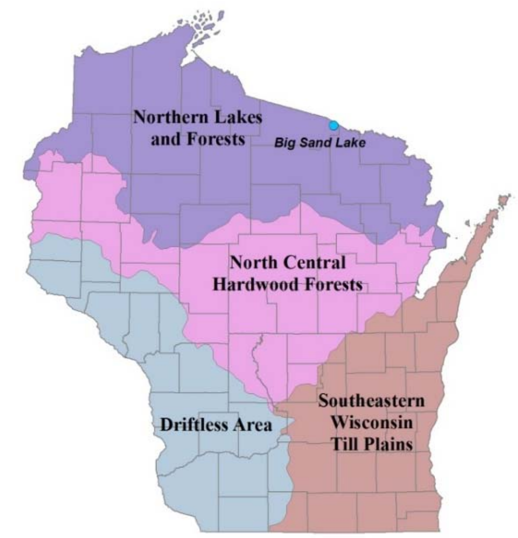


Figure 3.1-2. Location of Big Sand Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2014 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.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Big Sand Lake is displayed in Figures 3.1-3 - 3.1-7. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Big Sand Lake Water Quality Analysis

Big Sand Lake Long-term Trends

As a part of this study, Big Sand Lake stakeholders were asked about their perceptions of their lake's water quality through an anonymous stakeholder survey. The majority of respondents (97%) rated the current water quality of Big Sand Lake as *Good* or *Excellent*, while 3% rated it as *Fair* (Appendix B, Question #15). Approximately 29% of survey respondents indicated that the water quality of Big Sand Lake has *remained the same* since they first visited the lake, while approximately 44% believe the water quality has *somewhat* or *greatly improved*. Approximately 19% of respondents feel that water quality in Big Sand Lake has *somewhat degraded* since they first visited the lake (Appendix B, Question #16).

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions such as precipitation or lake thereof, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, as whether the lake health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, one can determine what the status of the lake is by comparison.

Volunteers have been actively collecting data since 2009 on Big Sand Lake, and continue to do so through the Citizens Lake Monitoring Network (CLMN) Program. Through this WDNR-sponsored program, volunteers are trained to collect water quality data on the lake. Samples are analyzed through the State Lab of Hygiene in Madison, WI and data are entered into the Surface Water Integrated Monitoring System (SWIMS), an online database which allows for quick access to all current and historical water quality data. This process allows stakeholders to become directly engaged in protecting their lake, while producing reliable and comparable data that managers may recall through a streamlined website. Historical and current water quality data are also available from the Wisconsin Valley Improvement Company (WVIC). Big Sand Lake and its involvement with the WVIC is discussed in more detail at the end of this section.

As previously mentioned, the three primary water quality parameters that are studied in lakes include total phosphorus, chlorophyll-*a*, and Secchi disk clarity. Historical near-surface (approximately within top 3-feet) total phosphorus data have been recorded since the 1970s but have been temporally sporadic until 2009 when CLMN volunteers have been collecting data annually (Figure 3.1-3). In the first two years where total phosphorus data are available, 1973 and 1974, near-surface total phosphorus concentrations were approximately two times higher than average annual values collected from 1979 to 2014. It is not known if the total phosphorus data from 1973 and 1974 are valid or erroneous. On occasion, data can be "misplaced" within the WDNR's database, and it's possible these data are from another lake.

In these cases, it is helpful to look at chlorophyll-*a* and Secchi disk data collected during this same time period, as these variables are usually correlated with one another. Unfortunately, chlorophyll-*a* data were not collected in 1973 or 1974; however, Secchi disk data were collected and were slightly lower than more recent values. The Secchi disk data provide more credibility to the total phosphorus concentrations measured in 1973 and 1974, though the reason behind these elevated phosphorus concentrations is unknown. Total phosphorus concentrations of this magnitude have not been measured since. Standard analysis indicates that two of the total phosphorus concentrations measured in 1974 were outlier values (>1.5 interquartile range), and for this reason, a separate weighted total phosphorus concentration was calculated without these values.

Near-surface total phosphorus concentrations have been slightly higher from 2009-2014 with an average growing season value of 18.4 µg/L compared to an average of 14.4 µg/L from 1979-2002. With the data that are available, it is not clear if this represents a positive trend in phosphorus concentrations over time or if it is due to the more sporadic data collection from 1979-2002. Overall, the weighted average near-surface summer total phosphorus concentration (excluding outlier data from 1974) falls in the *excellent* category for deep, lowland drainage lakes in Wisconsin, and is lower than the median values for other deep, lowland drainage lakes in the state and other lakes within the Northern Lakes and Forests ecoregion.

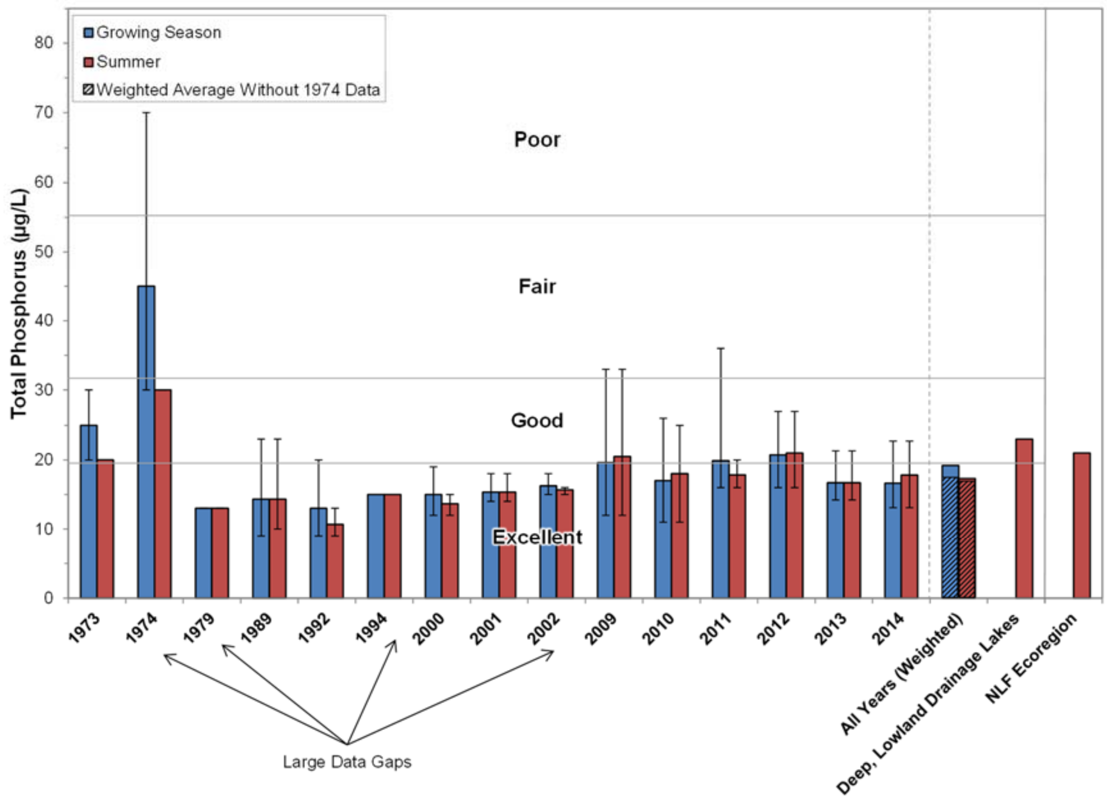


Figure 3.1-3. Big Sand Lake average annual near-surface total phosphorus concentrations. Error bars represent max and min values. Water Quality Index values adapted from WDNR PUB WT-913.

Often, near-surface water samples of phosphorus are analyzed because they are easy to collect and are representative of what is occurring in the littoral zone (sunlit, plant and algae growing area) of a lake. Figure 3.1-3 includes only data collected from the near-surface of Big Sand Lake. However, comparing surface and bottom phosphorus samples can be advantageous to understanding other nutrient dynamics in lakes, such as internal nutrient loading as discussed previously. Figure 3.1-4 displays data depicting surface and bottom phosphorus concentrations on dates in which both of these data types were available. During times in which a lake is mixed, we can expect phosphorus concentrations to be similar near the surface and the bottom of the lake. During times that the lake is stratified however, the near-bottom (within hypolimnion, typically collected at approximately 3 feet from the bottom) phosphorus concentration may be two to three times or more than what was observed in the surface waters. Under anoxic conditions, phosphorus may be released from the sediments which accounts for the higher concentrations.

Within the historical data available for Big Sand Lake, near-bottom total phosphorus concentrations were found to have exceeded 200 µg/L on August 8, 1974 and July 8, 1994. While some of these values exceed 200 µg/L, the majority fall below 50 µg/L. At this time, it is not believed that internal phosphorus loading from bottom sediments is a significant contributor the overall phosphorus budget in Big Sand Lake.

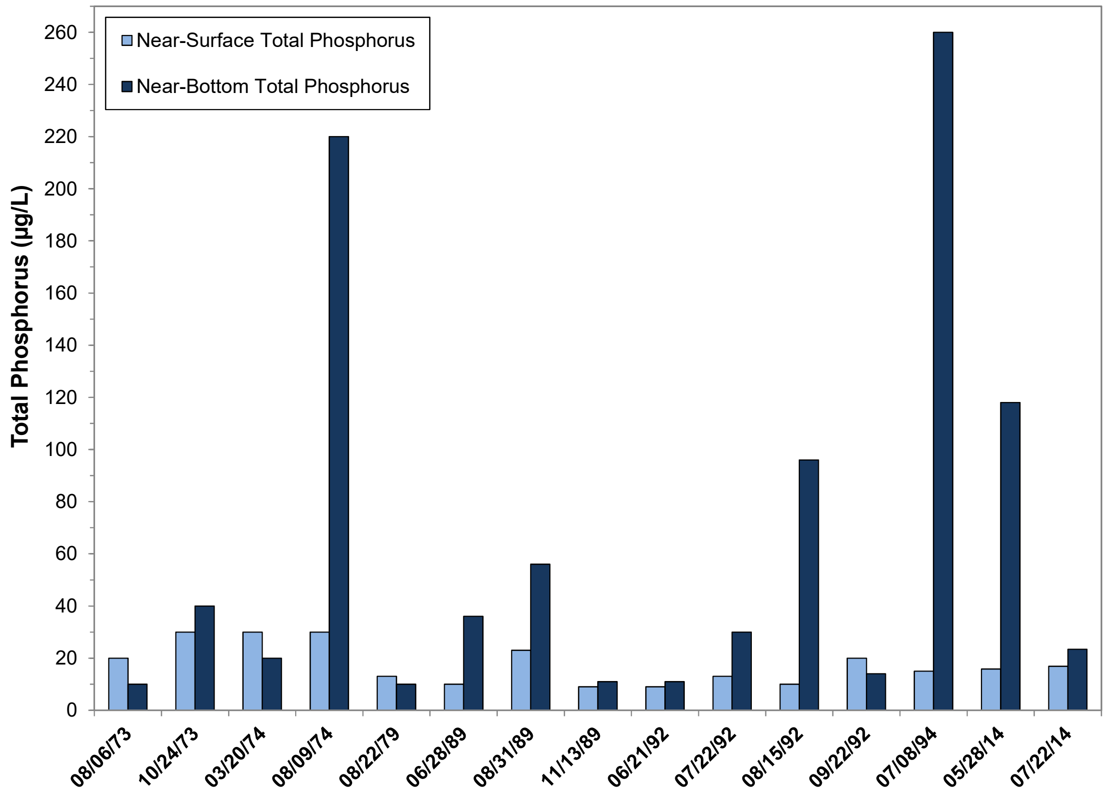


Figure 3.1-4. Big Sand Lake near-surface and near-bottom total phosphorus concentrations. Data collected from historical records (WDNR SWIMS) and Onterra 2014 sampling. All concentrations are actual values, not averages.

Chlorophyll-*a*, like total phosphorus, has been periodically measured since the 1970s and annually since 2009 (Figure 3.1-5). Concentrations of chlorophyll-*a* are relatively variable within the lake from year to year, spanning the *excellent* to *fair* thresholds. Chlorophyll-*a* concentrations in 2012 were the highest recorded within the available dataset, and were nearly twice as high as those recorded in 2014. The growing season of 2012 was markedly warmer and longer than average, and the longer period of warmer water temperatures likely fueled higher levels of algae growth. Overall, the weighted summer average chlorophyll-*a* concentration for all years data are available falls within the *good* category for deep, lowland drainage lakes, and is comparable to the median value for other deep, lowland drainage lakes throughout Wisconsin and slightly higher than the median value for other lakes within the Northern Lakes and Forests ecoregion.

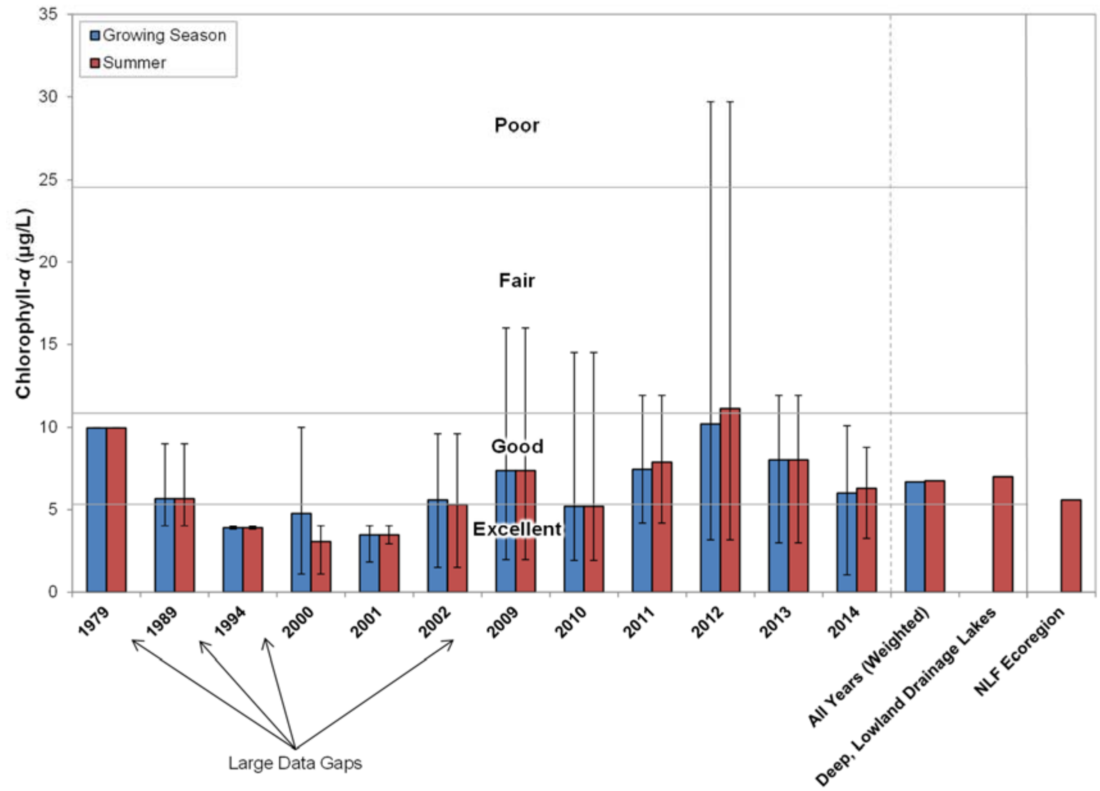


Figure 3.1-5. Big Sand Lake average annual chlorophyll-*a* concentrations. Error bars represent max and min values. Water Quality Index values adapted from WDNR PUB WT-913.

The error bars on Figure 3.1-5 illustrate the maximum and minimum chlorophyll-*a* concentrations recorded during the growing season and summer of each year. These demonstrate that there is wide variability in chlorophyll-*a* concentrations over the course of a single year. As is discussed later in this section, chlorophyll-*a* concentrations in Big Sand Lake tend to be lowest in the spring and increase over the course of the summer. As is discussed later in this section, total phosphorus concentrations in Big Sand Lake tend to increase slightly over the course of the growing season from an average of 13.5 µg/L in May to 20.1 µg/L in August. Big Sand Lake has a large surface area and relatively shallow depth, and the increase in phosphorus over the growing season is likely due to wind-induced sediment resuspension. However, this increase is relatively minor, and the increase in algal abundance over the course of the growing season is likely mainly driven by increasing water temperature.

Secchi disk transparency data are also available sporadically since the 1970s and annually since 2009 (Figure 3.1-6). The lowest Secchi disk transparencies were recorded in the 1970s, with a growing season average of 7.9 feet. Values increased in 1989 and have been relatively consistent through 2014, averaging 12.2 feet. Overall, the weighted average summer Secchi disk transparency value falls within the *excellent* category for deep, lowland drainage lakes in Wisconsin, and exceeds the median values for other deep, lowland drainage lakes within Wisconsin and for lakes within the Northern Lakes and Forests ecoregion.

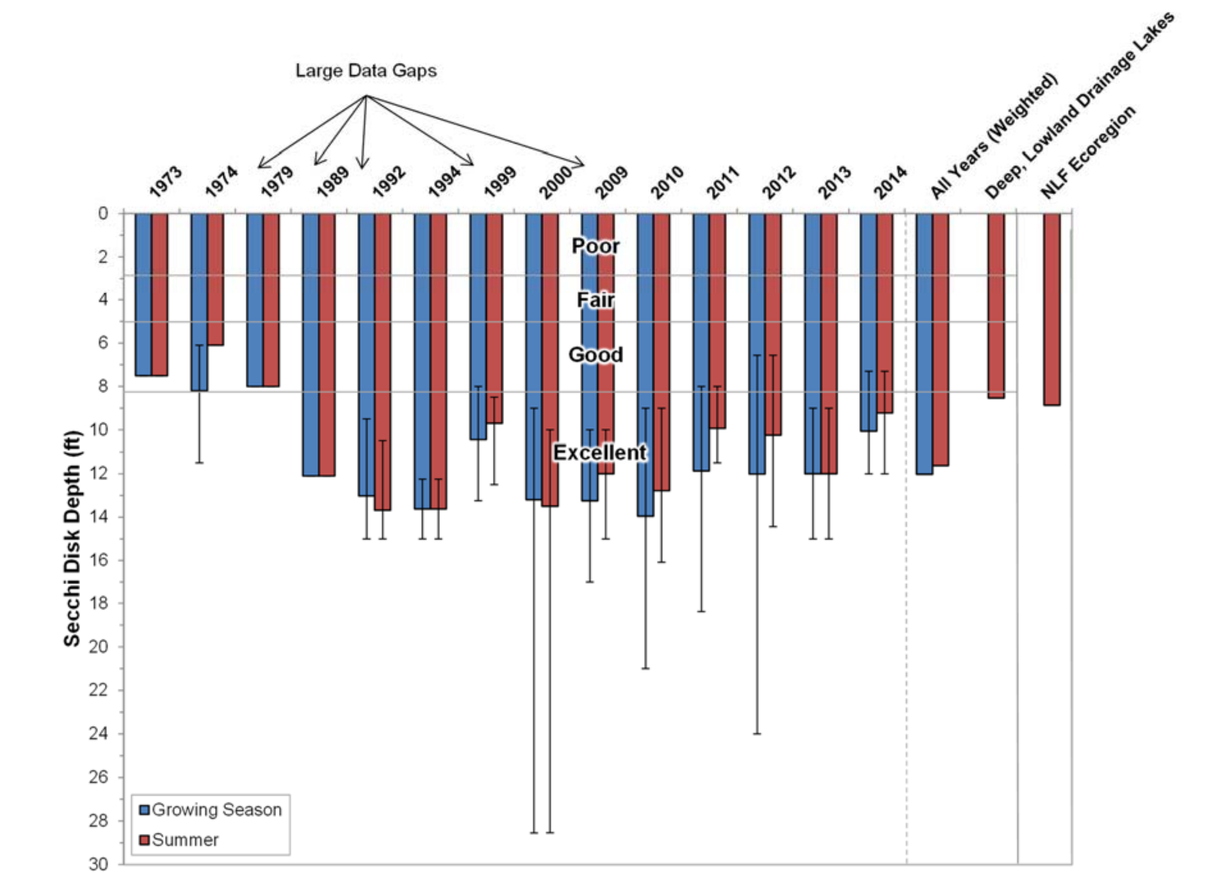


Figure 3.1-6. Big Sand Lake average annual Secchi depths. Error bars represent minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed earlier, algae concentrations are relatively low during the summer months on Big Sand Lake, but there are other factors that can affect a lake's water clarity. This includes dissolved organic compounds that originate within wetlands and forests within the lake's watershed and can give the water a stained appearance. These dissolved compounds can be measured through an analysis called *true color*. Water samples collected from Big Sand Lake in May and July 2014 were measured for true color and were found to be at the lower threshold (<20 Platinum-cobalt units, or PCU) of detection for this analysis. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as "high color". Having little color to the water increases its clarity. This indicates that Big Sand Lakes water clarity is mainly driven by algae, and because there is relatively low levels of algae and dissolved organic compounds, water clarity is high.

While there are no apparent trends in annual total phosphorus, chlorophyll-*a*, and Secchi disk transparency data in Big Sand Lake, these parameters exhibit patterns within a single growing season that is typical for a many Wisconsin Lakes. Figure 3.1-7 illustrates the May through August monthly averages for these three parameters over the time period for which data are available. As mentioned previously, total phosphorus concentrations tend to increase slightly over the course of the growing season in Big Sand Lake.

Increases in total phosphorus over the growing season are an indication of a level of internal nutrient loading; however, it is not believed that this phosphorus is originating from bottom sediments within the anoxic hypolimnion in the deep hole, but rather from wind-induced sediment resuspension. Given the lake's large surface area and relatively shallow depth, the lake is likely susceptible to some level of sediment resuspension. However, algal production is likely driven more by water temperature. Water clarity in Big Sand Lake is highest in spring when algal production is low, and declines through the summer as algal production increases. Water clarity is lowest in July and August and when algae production is highest.

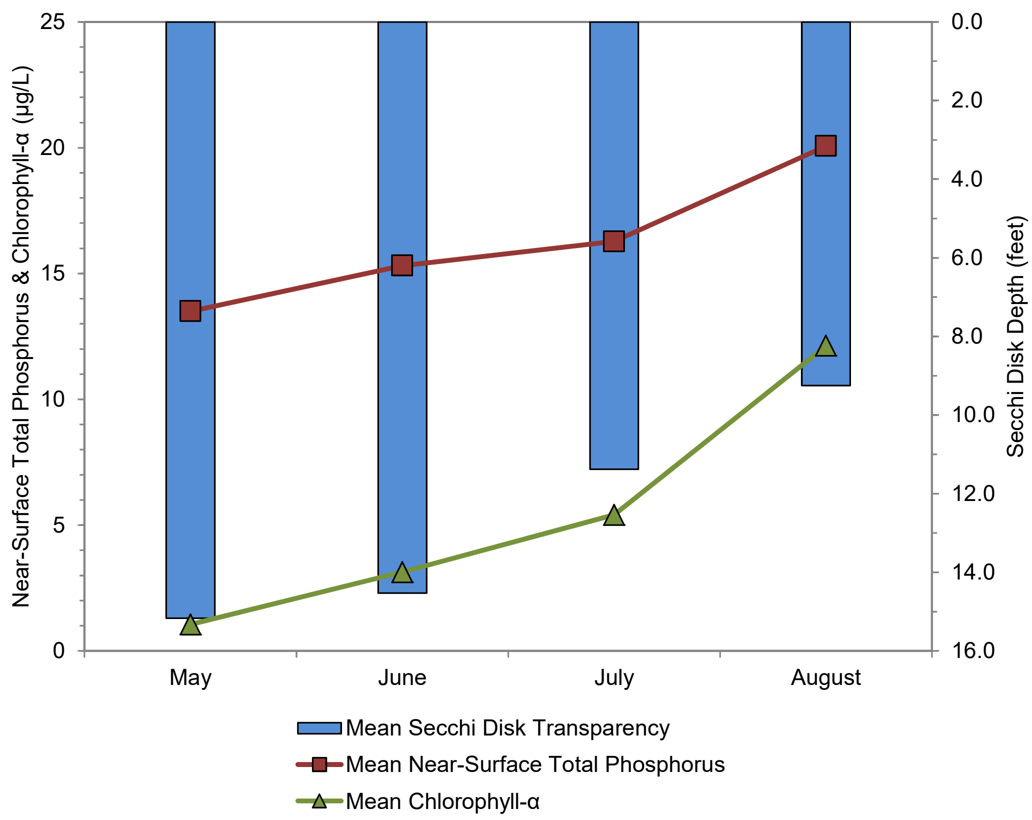


Figure 3.1-7. Big Sand Lake May-August monthly average Secchi disk transparency, near-surface total phosphorus, and chlorophyll-*a*. Data collected from historical records (WDNR SWIMS) and Onterra 2014 sampling.

Limiting Plant Nutrient of Big Sand Lake

Using midsummer nitrogen and phosphorus concentrations from Big Sand Lake, a nitrogen:phosphorus ratio of 25:1 was calculated. This finding indicates that Big Sand Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Big Sand Lake Trophic State

Figure 3.1-8 contains the Trophic State Index (TSI) values for Big Sand Lake. The TSI values are calculated with annual average summer month Secchi disk, chlorophyll-*a*, and total phosphorus values. In general, the best values to use in judging a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors such as dissolved organic compounds. Within the most recent 15 years, chlorophyll-*a* and total phosphorus TSI values range from mesotrophic to upper eutrophic. The weighted average TSI values for chlorophyll-*a* and total phosphorus indicate the lake is currently in a meso-eutrophic state, and is similar to the trophic states of other deep, lowland drainage lakes in Wisconsin and other lakes within the Northern Lakes and Forests ecoregion.

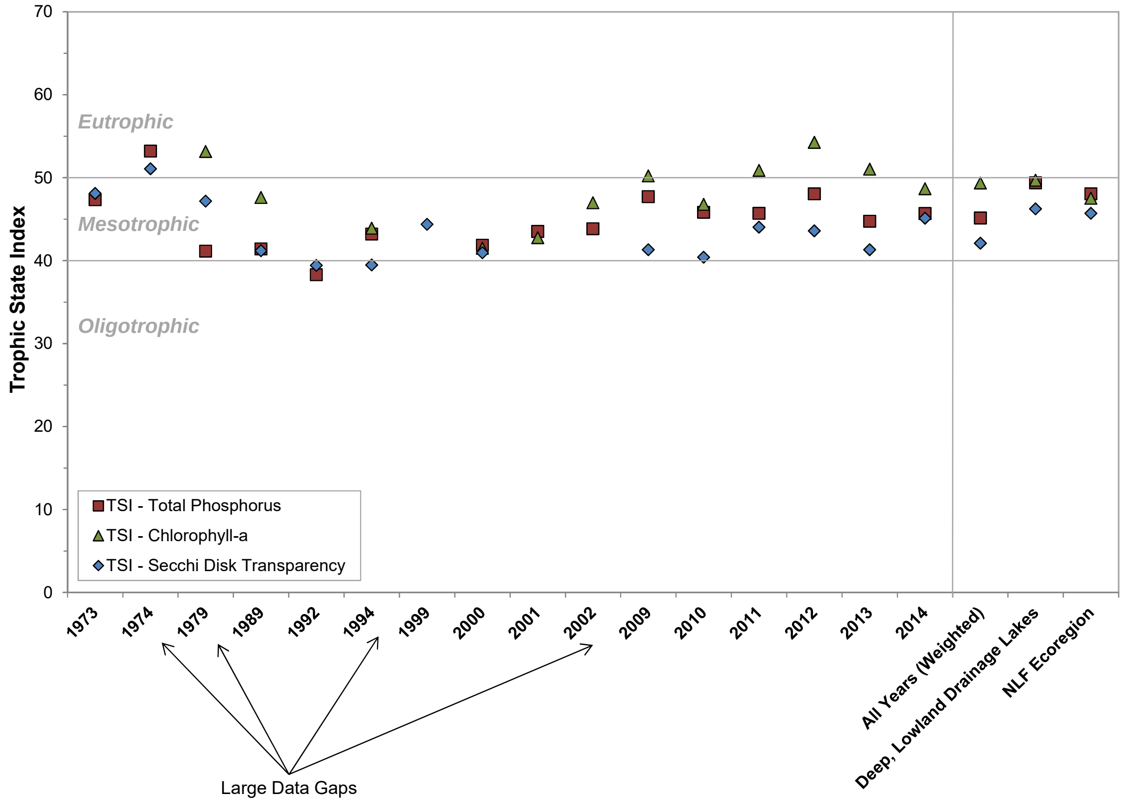


Figure 3.1-8. Big Sand Lake, state-wide deep, lowland drainage lakes, and Northern Lakes and Forests ecoregional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Big Sand Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Big Sand Lake by Onterra staff and during the summer months by the CLMN volunteer. Profiles depicting these data are displayed in Figure 3.1-9. These data indicate that Big Sand Lake stratifies during the summer, with the colder, denser bottom layer of water (hypolimnion) becoming anoxic during the summer, and the lake mixes or turns over in the spring and fall. This thermal behavior is typical for deep lakes with more productivity. A temperature and dissolved oxygen profile was also collected on February 17, 2015. These data indicate that the lake was inversely stratified, with the coldest water near the surface and warmer water of approximately 40°F near the bottom. Dissolved oxygen data indicate that water was sufficiently oxygenated under the ice to a depth of 24 feet, while anoxic conditions were present below 24 feet.

The dissolved oxygen and temperature profiles displayed in Figure 3.1-9 were collected from Big Sand Lake's deep hole. This deeper area Big Sand Lake is relatively small, and the majority of the lake is relatively shallow with a mean depth of around 13 feet. Lake managers use what is called the Osgood Index which is used to determine whether a lake is *dimictic* or *polymictic*. Dimictic lakes completely mix or turnover two times per year, once in spring and again in fall. In contrast, polymictic lakes have the potential to completely or partially mix multiple times per year. In contrast to the Lathrop/Lillie equation which uses a lakes surface area and maximum depth to determine if a lake is *deep (stratified)* versus *shallow (mixed)*, The Osgood Index uses the lakes surface area relative to its mean depth to determine if it's dimictic or polymictic. While the Lathrop/Lillie equation indicates Big Sand is classified as a deep (stratified) lake, the Osgood Index (Big Sand value of 1.6) indicates the lake is polymictic.

The discrepancy in results between these two equations indicates that Big Sand Lake straddles the boundary between a dimictic and polymictic system. While the small area of the lake that is 57 feet deep remains stratified throughout the summer, the majority of the water column (30 feet and less) throughout the rest of the lake is being mixed by wind-driven water movement. While the shallower areas of Big Sand Lake may stratify during periods of calm weather, this stratification is likely rapidly broken upon the next wind event.

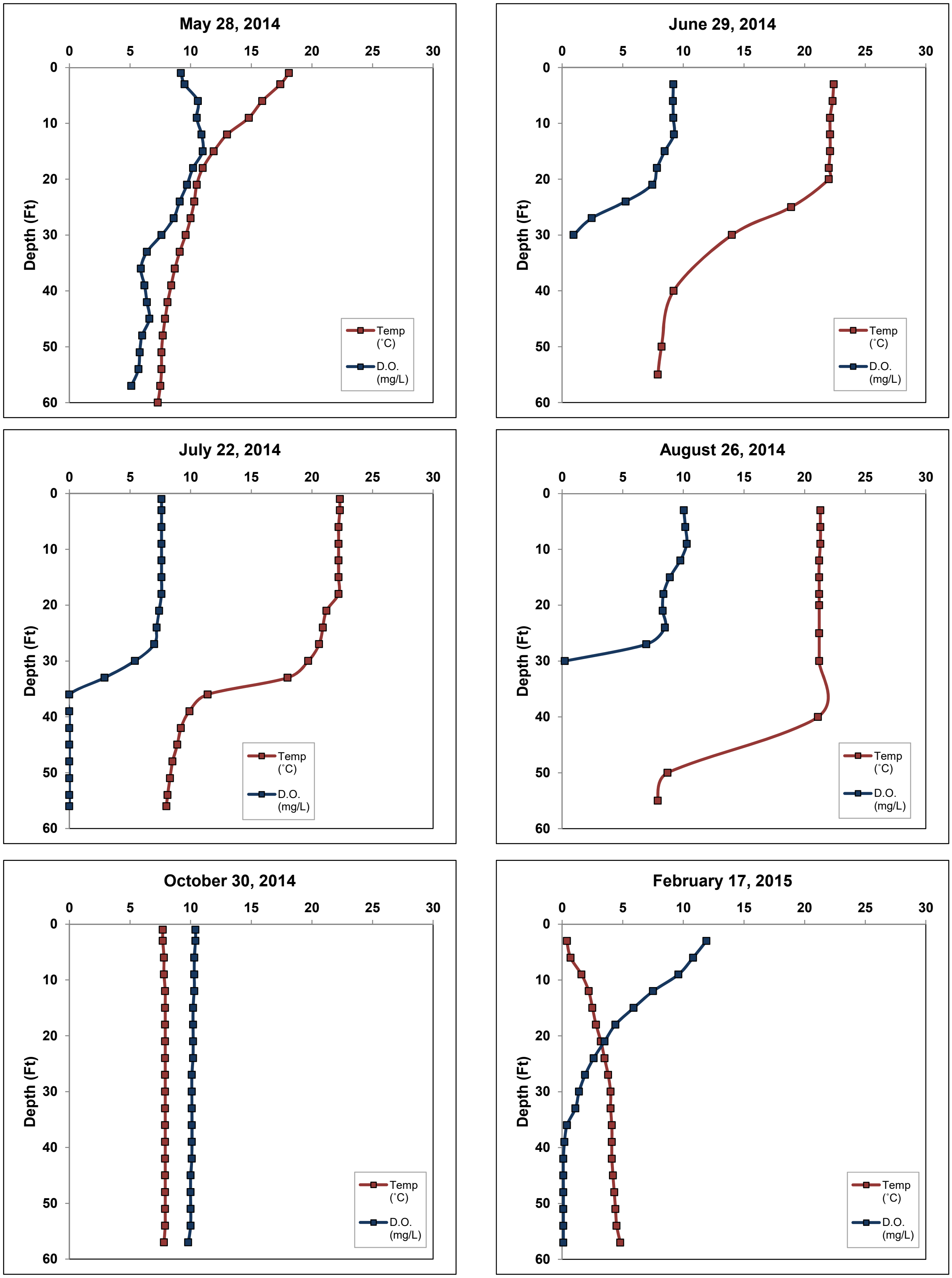


Figure 3.1-9. Big Sand Lake temperature and dissolved oxygen profiles.

Additional Water Quality Data Collected at Big Sand Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Big Sand Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in Big Sand Lake was found to be slightly alkaline with near-surface water values of 7.7 in May and July, 2014.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The near-surface alkalinity in Big Sand Lake was measured at 35.4 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Sand Lake's pH of 7.7 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The near-surface calcium concentration of Big Sand Lake was found to be 8.6 mg/L, indicating Big Sand Lake falls within the very low susceptibility category for zebra mussel establishment. Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. Their analysis did not locate any larval zebra mussels within the 2014 samples.

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

Big Sand Lake Water Levels

Together, Big Sand Lake, upstream Smoky Lake, and downstream Long Lake are 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 3.1-10).

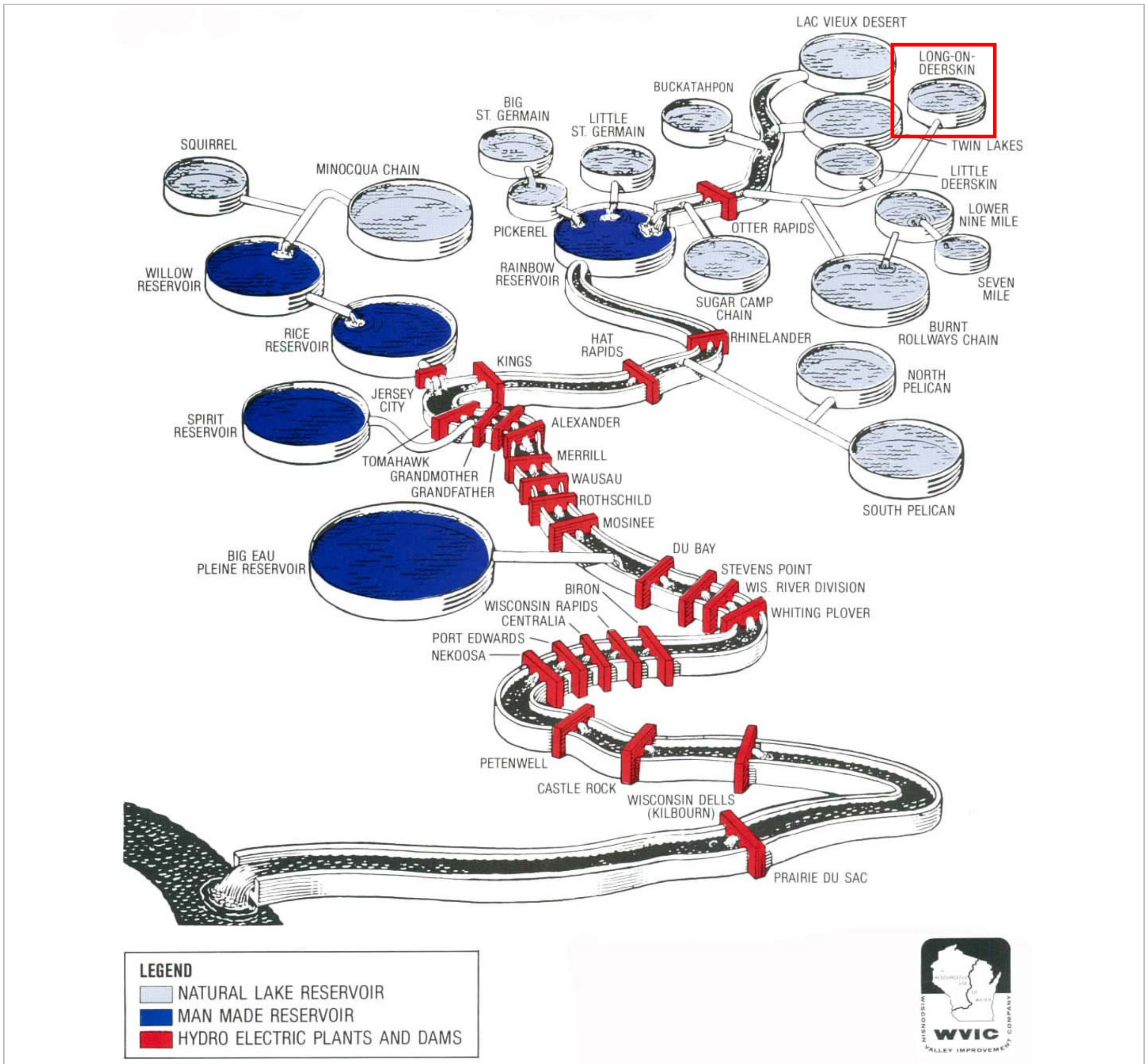


Figure 3.1-10. WVIC reservoir system. Long Lake system which includes Big Sand is outlined in red. Adapted from WVIC website.

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.

There is no dam present on Big Sand Lake, but downstream Long Lake is one of the natural lake reservoirs in the WVIC system, and that dam (Long-on-Deerskin Dam) has an operational range of less than 2 feet during the summer months. Big Sand Lake is listed as having relatively the same surface elevation as Long Lake except when beavers dam the thoroughfare between Big Sand Lake and Long Lake. The water levels need to be kept between 1,698.43 and 1,696.51 feet between June 1 and September 30 of each year (Figure 3.1-11). Winter drawdowns cannot exceed 1,695.84 feet, which is 2.59 feet below full pool. In addition to establishing a range of water levels, minimum outflows are also set to make sure the downstream riverine systems are not negatively impacted by abnormally low flows. Long Lake must maintain a minimum flow and attempt not to exceed a 31 cubic foot per second discharge to protect and enhance the trout fishery and habitat below the dam.

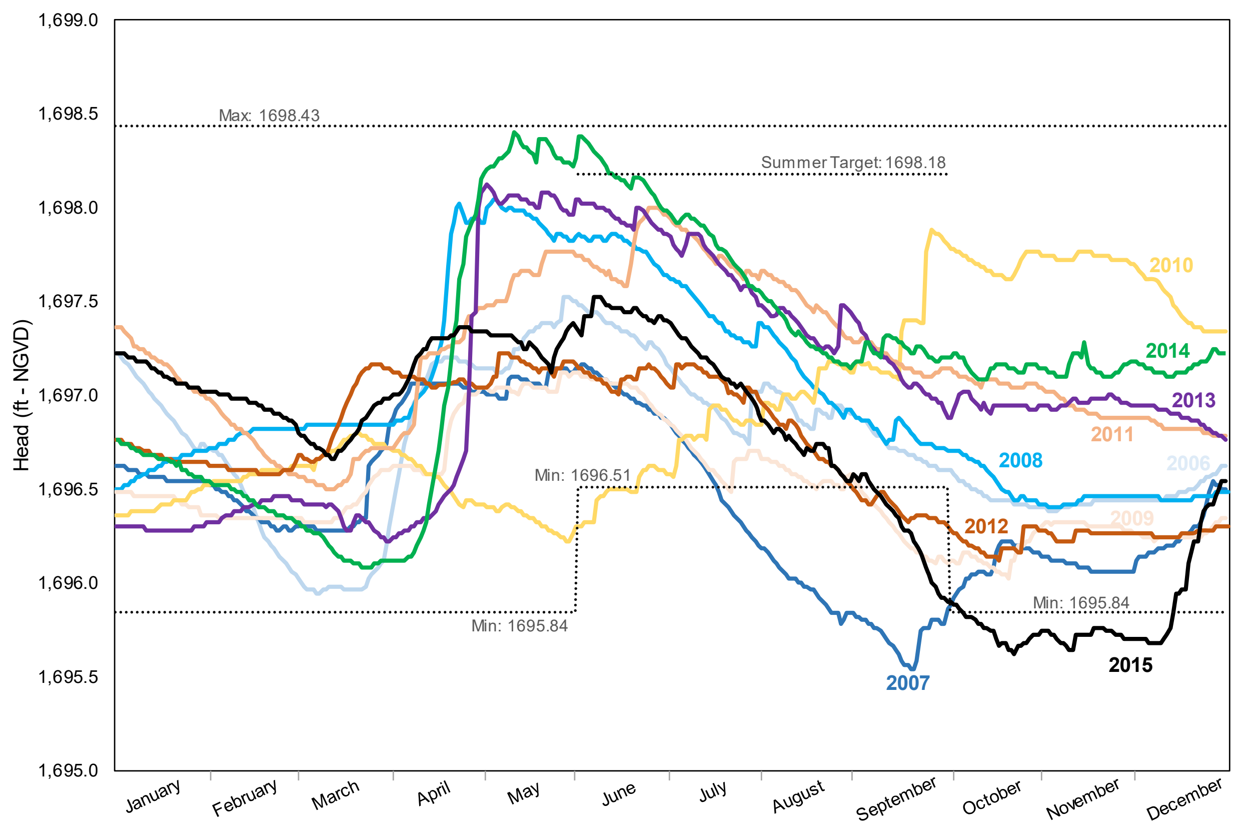


Figure 3.1-11. Long-on-Deerskin Dam Annual Water levels. Data provided by WVIC.

Figure 3.1-12 shows how the past 10 summers compared to the average. On average, water levels drop on Big Sand Lake approximately 0.5 feet between the beginning of June to the end of September. For the most part, native plants grow to the height of the water in which they reside, with only their reproductive structures breaking the surface. But when water levels go down over the course of the summer, the foliage of aquatic plants is now at the water's surface and can manifest the nuisance conditions.

The summer of 2007 clearly had the lowest water levels. Higher than average summer water levels were observed in 2011, 2013, 2014, and the second half of the summer of 2010.

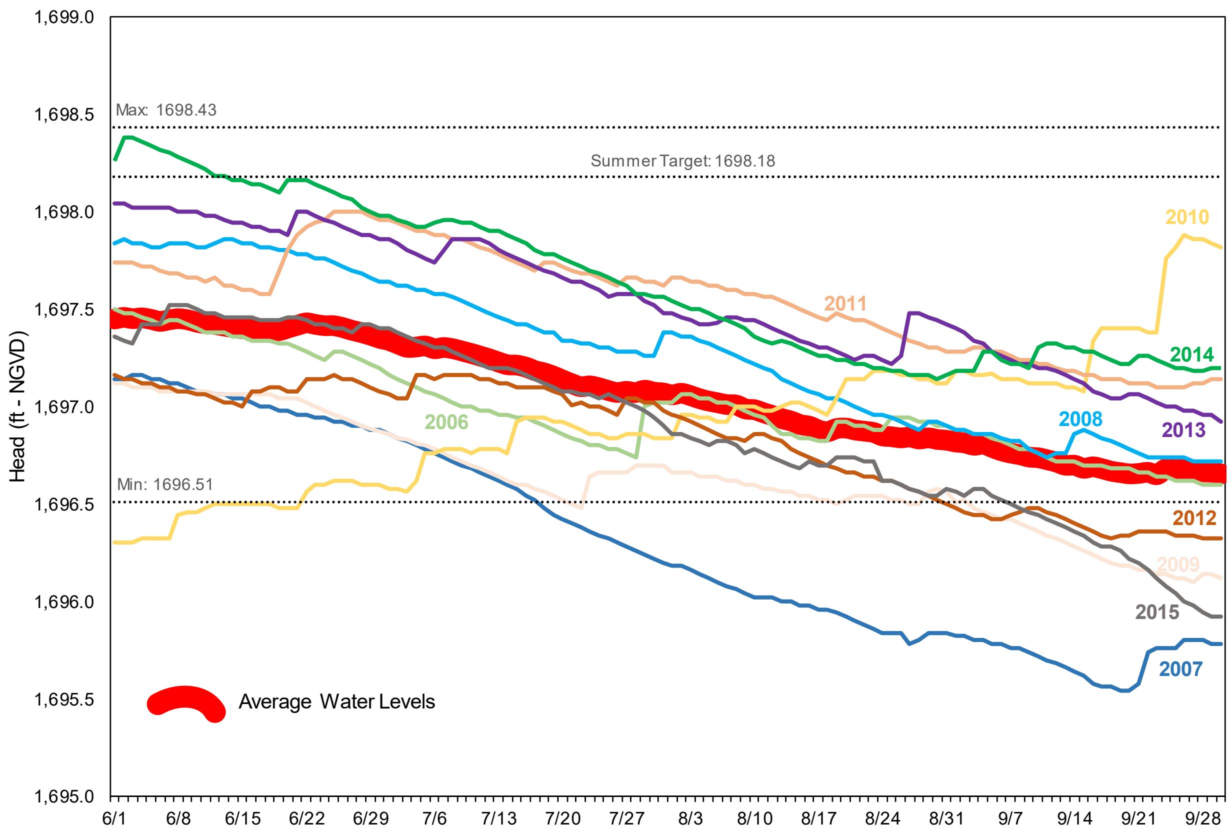


Figure 3.1-12. Long-on-Deerskin Dam Summer Water levels. Data provided by WVIC.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Big Sand Lake Watershed

The surface water drainage basin, or watershed, for Big Sand Lake encompasses approximately 5,893 acres across both Wisconsin and Michigan and includes Smoky Lake (Map 2). While Smoky Lake does not often exchange water directly into Big Sand Lake, it is still technically in Big Sand's topographic watershed. The eastern portion of the Big Sand Lake's watershed represents the divide between the Great Lakes' and Mississippi River's drainage basins. The watershed can be divided into its direct watershed, or the area of land which drains directly to Big Sand Lake, and Smoky Lake's watershed, or the area of land which drains into Smoky Lake before entering into Big Sand Lake (Figure 3.2-1).

The majority of Big Sand Lake's direct watershed is comprised of the lake's surface itself (39%), forests (29%), wetlands (18%), pasture/grass (6%), row crop agriculture (1%), rural residential areas (<1%), and areas with medium and high urban density (<1%) (Figure 3.2-1). The majority of Big Sand Lake's watershed is comprised of land cover types which deliver the least amount of phosphorus and sediments to the lake.

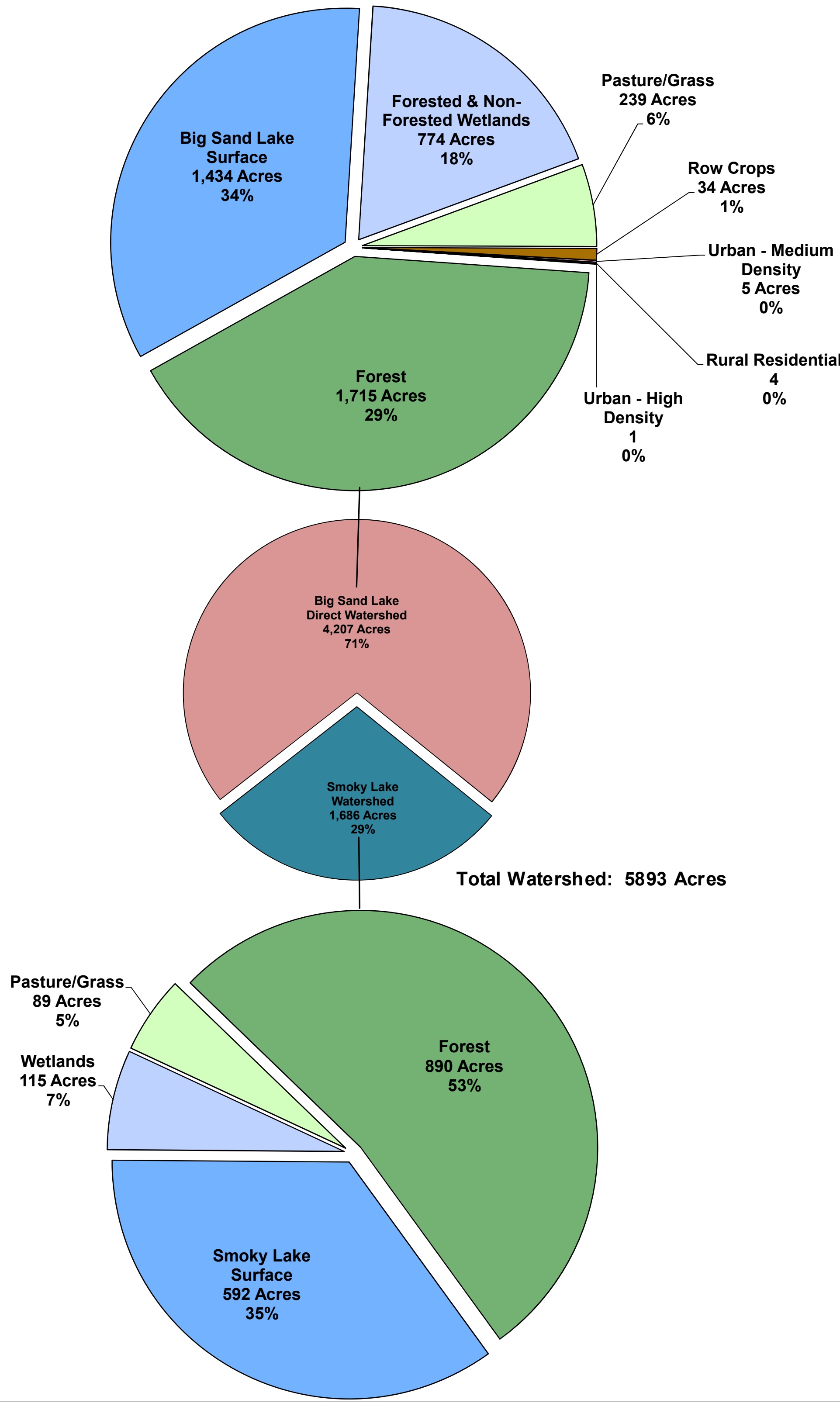


Figure 3.2-1. Big Sand Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

The watershed area relative to the area of Big Sand Lake yields a watershed to lake area ratio of 3:1, meaning that there are 3 acres of land draining to every one acre of Big Sand Lake. As discussed previously, in watersheds with small watershed to lake area ratios, the type of land cover within the watershed has a greater influence over the lake's water quality. WiLMS estimated that the residence time or time it takes for the water in Big Sand Lake to completely replace itself is approximately 3.3 years.

Using WiLMS, the acreages of land cover types within Big Sand Lake's direct watershed and total phosphorus data from Smoky Lake were used to determine the annual potential phosphorus load to the lake. This modeling indicated that Big Sand Lake potentially receives an estimated 731 pounds of phosphorus on an annual basis. While this seems high, it is important to remember that Big Sand Lake's size and depth results in a high volume of water. The phosphorus being loaded to the lake is spread out or diluted within this large volume and results in the lower concentrations measured within the water. Using the annual potential phosphorus load, WiLMS predicted an in-lake growing season mean total phosphorus concentration of 17.0 μg/L, nearly identical to the actual growing season average of 17.3 μg/L calculated from data collected from Big Sand Lake from 1979-2014. This indicates that the lake's watershed and phosphorus inputs were modeled accurately, and that there are no unaccounted sources of phosphorus entering lake.

The model indicated that atmospheric deposition of phosphorus (dust particles) directly to the lake surface itself is the largest contributor of phosphorus to the lake with 384 lbs. (53%) per year (Figure 3.2-2). Forests account for 137 lbs. (19%), wetlands for 68 lbs. (9%), pasture/grass for 64 lbs. (9%), row crop agriculture for 31 lbs. (4%), urban areas for 4 lbs. (<1%), and the export from rural residential areas was negligible.

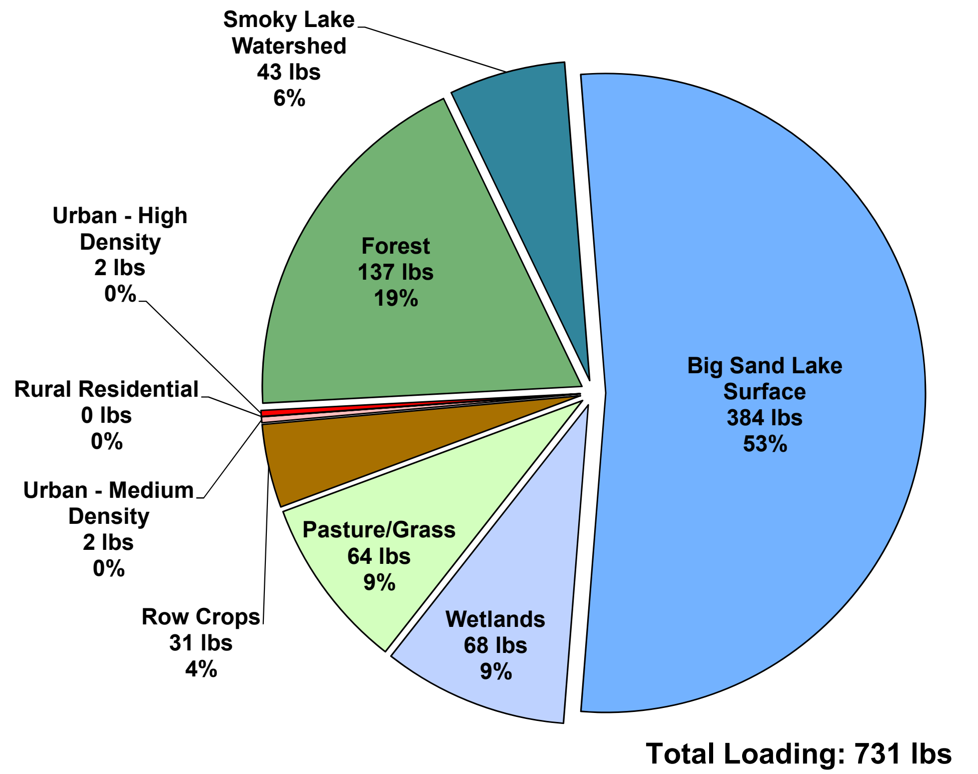


Figure 3.2-2. Big Sand Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

To emphasize the importance of natural land cover within Big Sand Lake's watershed and that relatively small changes within the watershed can have significant impacts to the lake's water quality, WiLMS was used to estimate the average growing season total phosphorus concentrations within the lake if 25% and 50% of the forested land cover were converted to row crops. The 25% and 50% forest-to-row crop conversion models predicted that average growing season total phosphorus concentrations would increase from the actual 17.3 µg/L measured to 23.0 µg/L and 28.0 µg/L, respectively. Using predictive equations by Carlson (1977), this increase in total phosphorus concentrations would result in an increase in algae abundance from the measured 6.9 µg/L to 8.2 µg/L for the 25% conversion model and 10.9 µg/L for the 50% conversion model. The resulting increase in algae abundance would result in lower water clarity; converting 25% of forested land cover to row crops would decrease water clarity from the growing season average Secchi disk depth of 12.0 feet to 6.0 feet, and a conversion of 50% would result in a decrease to 4.9 feet. These models illustrate the significance of forested land cover and other natural land cover types within Big Sand Lake's watershed that create and maintain the lake's excellent water quality.

3.3 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 swimmer's 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, a revised NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances of their own. The revised NR 115 was once again examined in 2012 after some Wisconsin counties identified some provisions that were unclear or challenging to implement. The revisions proposed through Board Order WT-06-12 went into effect in December of 2013. These policy regulations require each county a ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows:

- 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 the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. No permit is required for removal of vegetation that meets any of the above criteria. 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 entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- 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. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

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

- For county-specific requirements on this topic, it is recommended that lake property owners contact the county’s regulations/zoning department.

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 3.3-1. Coarse woody habitat

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 (NLA) is an Environmental Protection Agency sponsored assessment that has successfully pooled together resource managers from all 50 U.S. states in an effort to assess waterbodies, both natural and man-made, from each state. Through this collaborative effort, over 1,000 lakes were sampled in 2007, pooling together the first statistical analysis of the nation's lakes and reservoirs.

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

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

Native Species Enhancement

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

Photograph 3.3-2. 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 not 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.

Big Sand Lake Shoreland Zone Condition

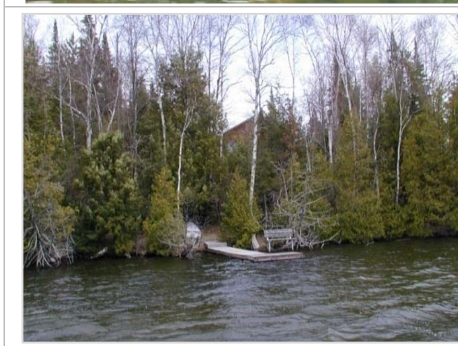
Shoreland Development

Big Sand 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 3.3-1 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 shoreland 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 shorelands 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 shoreland 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 shoreland that was restored would likely be included here, also.



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

Figure 3.3-1. Shoreland assessment category descriptions.

On Big Sand Lake, the development stage of the entire shoreland was surveyed during fall of 2014, 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 3.3-2.

Big Sand Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 6.4 miles (71%) 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, 0.9 miles (9%) of urbanized and developed–unnatural shoreland were observed. If restoration of the Big Sand Lake 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 3 displays the location of these shoreland lengths around the entire lake.

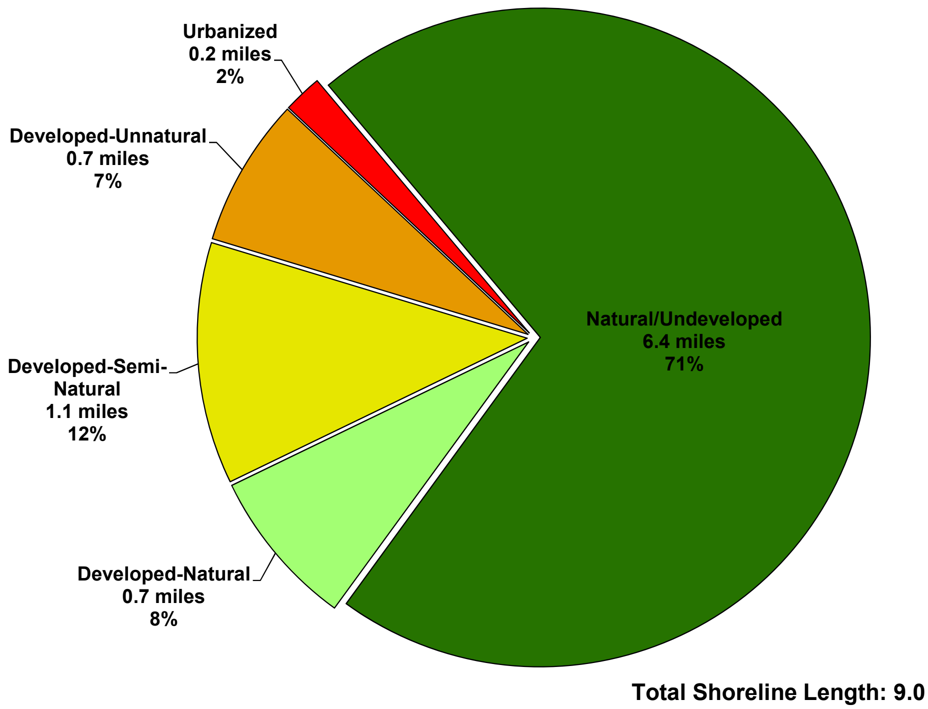


Figure 3.3-2. Big Sand Lake shoreland categories and total lengths. Based upon a fall 2014 survey. Locations of these categorized shorelands can be found on Map 3.

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.

Coarse Woody Habitat

Big Sand Lake was surveyed in 2014 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 three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) 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.

During this survey, a total of 83 pieces of coarse woody habitat were observed along 9.0 miles of shoreline, which gives Big Sand Lake a coarse woody habitat to shoreline mile ratio of 9:1. To put this into perspective, 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). Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Map 4.

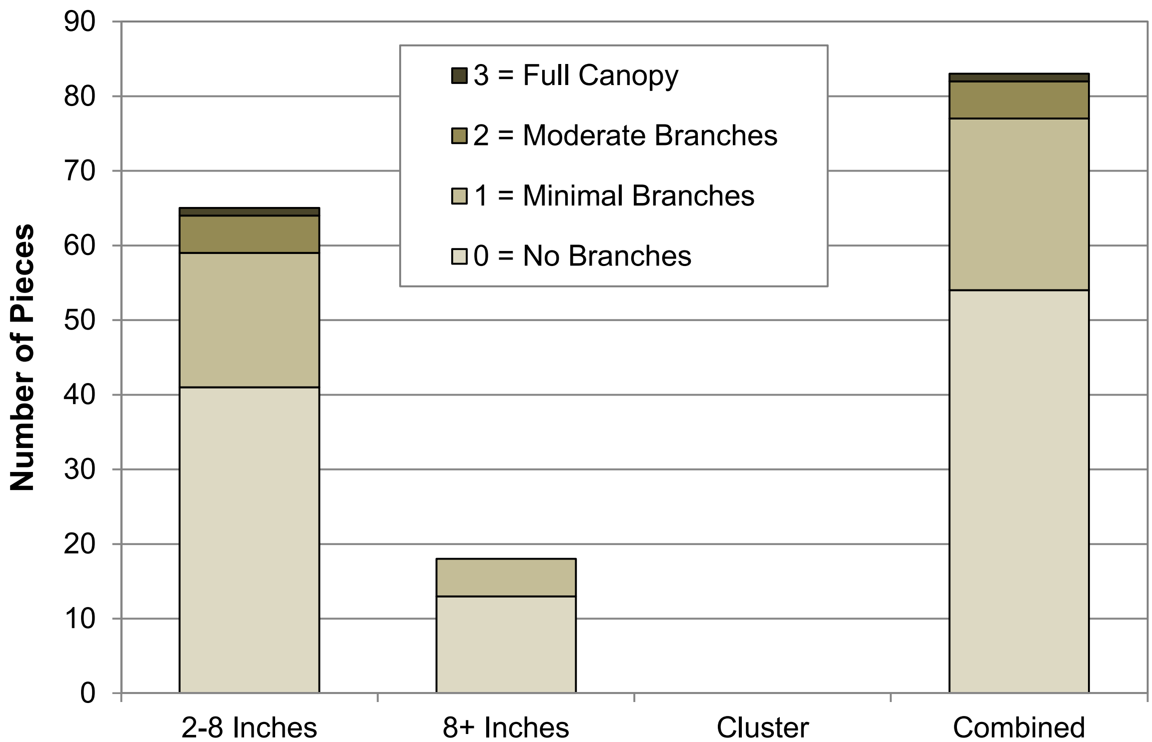


Figure 3.3-3. Big Sand Lake coarse woody habitat survey results. Based upon a Fall 2014 survey. Locations of Big Sand Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

Photograph 3.4-1. Native aquatic plants

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 invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

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

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

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. 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 3.4-2. Nuisance native aquatic plants. Southern naiad (*Najas guadalupensis*) after being raked from a shoreline.

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 15^{th}.

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 15^{th}. • 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 3.4-4. Herbicide applicator. Applying granular herbicides with a gravity-fed dispersion method.

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 water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

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

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Big Sand Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity and Richness

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Big Sand Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-1) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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

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

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Big Sand Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1). Ecoregional and state-wide medians were calculated from whole-lake point-intercept surveys conducted on 392 lakes throughout Wisconsin by Onterra and WDNR ecologists.

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

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

Community Mapping

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

Exotic Plants

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

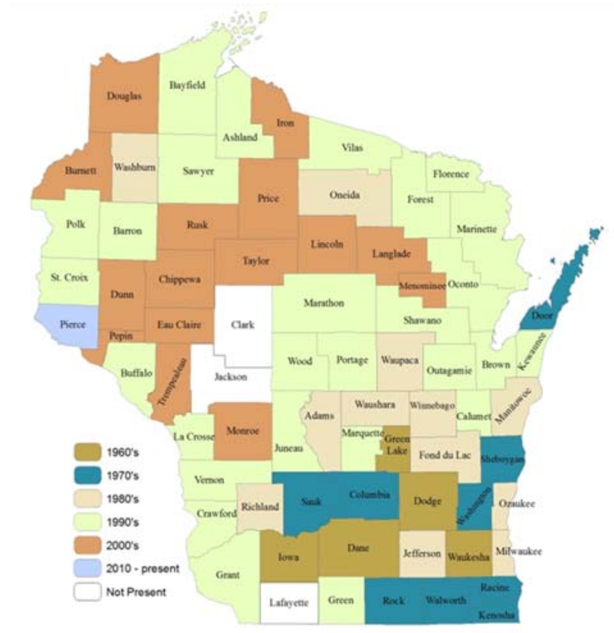


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

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

Aquatic Plant Survey Results

Since 2006, a number of aquatic plant surveys have been completed on Big Sand Lake. Most of these surveys have been directed at understanding the response of Eurasian water milfoil and native aquatic plants to herbicide applications, while studies completed in 2014 as part of the lake management planning project were designed to gain further insight into the lake's aquatic plant community. Six whole-lake aquatic plant point-intercept surveys have been completed on Big Sand Lake since 2006. The point-intercept survey completed in 2006 was conducted by the WDNR, while point-intercept surveys in 2010, 2011, 2014, 2015, and 2016 were completed by Onterra. In addition to point-intercept surveys, Onterra also completed a survey in 2014 to assess Big Sand Lake's emergent and floating-leaf aquatic plant communities.

Over the course of the surveys from 2006-2016, a total of 62 aquatic plant species were located (Table 3.4-1). Two of these species are considered to be non-native, invasive species: Eurasian water milfoil and curly-leaf pondweed. The latter is listed as being verified in Big Sand Lake following the 2006 point-intercept survey. However, no voucher specimen for curly-leaf pondweed was submitted, and it is possible that the positive verification was the result of an error while recording during the survey. Curly-leaf pondweed has not been observed in Big Sand Lake in any of the subsequent surveys. Non-native aquatic plants in Big Sand Lake are discussed in further detail within the following Non-Native Aquatic Plant Section.

Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, and recreational use, and all of these factors influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants, and generally leads to a higher number of aquatic plant species within the lake.

During the point-intercept surveys, information regarding substrate type were collected at locations sampled with a pole-mounted rake (less than 15 feet). The 2016 data indicate that 58% of the point-intercept locations in 15 feet of water or less contained soft sediments, 37% contained sand, and 5% contained rock (Figure 3.4-2). Most of the locations containing soft sediments were located within the western half of lake, while most of the areas containing sand or rock were located in the eastern half of the lake. The combination of both soft and hard substrates in Big Sand Lake creates habitat types which support different aquatic plant community assemblages.

Aquatic plants were found growing to a maximum depth ranging from 18.0 feet in 2010 to 20.0 feet in 2011, 2014, 2015, and 2016. As is discussed within the Water Quality Section, Big Sand Lake has high water clarity which allows sunlight to penetrate further into the water column and support aquatic plant growth at deeper depths. Of the 623 point-intercept sampling locations that were shallower than the maximum depth of plant growth (the littoral zone), approximately 81% contained aquatic vegetation (Figure 3.4-3).

Table 3.4-1. Aquatic plant species located in Big Sand Lake during WDNR 2006 and Onterra 2010-2016 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2006	2010	2011	2014	2015	2016
Emergent	*Bolboschoenus fluviatilis*	River bulrush	5				I		
	Calla palustris	Water arum	9				I		
	Carex utriculata	Common yellow lake sedge	7				I		
	Dulichium arundinaceum	Three-way sedge	9				I		
	Eleocharis palustris	Creeping spikerush	6	X	X	X	X	X	X
	Equisetum fluviatile	Water horsetail	7			X			
	Phragmites australis subsp. *americanus*	Giant reed	5				I		
	Sagittaria latifolia	Common arrowhead	3		X		I		
	Schoenoplectus acutus	Hardstem bulrush	5	X	X	X	X	X	X
	Schoenoplectus pungens	Three-square rush	5						X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X			X	X	
	Sparganium americanum	American bur-reed	8				I		
	Typha latifolia	Broad-leaf cattail	1		X		I		
FL	*Brasenia schreberi*	Watershield	7	X	X	X	X	X	X
	Nuphar variegata	Spatterdock	6	X	X	X	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X	X	X	X
	Persicaria amphibia	Water smartweed	5				I		
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9		X		I		X
	Sparganium fluctuans	Floating-leaf bur-reed	10				X		
Submergent	*Bidens beckii*	Water marigold	8	X	X	X	X	X	X
	Ceratophyllum demersum	Coontail	3	X	X	X	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X	X	X	X
	Elatine minima	Waterwort	9		X	X	I	X	X
	Elodea canadensis	Common waterweed	3	X	X	X	X	X	X
	Elodea nuttallii	Slender waterweed	7	X		X			
	Eriocaulon aquaticum	Pipewort	9			X	X	X	X
	Heteranthera dubia	Water stargrass	6	X			X		X
	Isoetes spp.	Quillwort species	8	X	X	X	X	X	X
	Lobelia dortmanna	Water lobelia	10		X		I		X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X	X	X	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X	X	X	X	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X	X	X	X	X	X
	Najas flexilis	Slender naiad	6	X	X	X	X	X	X
	Najas guadalupensis	Southern naiad	7			X	X	X	X
	Nitella spp.	Stoneworts	7	X	X	X			
	Potamogeton alpinus	Alpine pondweed	9	X					
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	X	X	X
	Potamogeton amplifolius x *praelongus*	Large-leaf x White-stem pondweed	N/A				X	X	X
	Potamogeton berchtoldii	Slender pondweed	7					X	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X					
	Potamogeton foliosus	Leafy pondweed	6	X			X	X	X
	Potamogeton gramineus	Variable pondweed	7	X	X	X	X	X	X
	Potamogeton illinoensis	Illinois pondweed	6	X	X	X	X	X	X
	Potamogeton praelongus	White-stem pondweed	8	X	X	X	X	X	X
	Potamogeton praelongus x *richardsonii*	White-stem X Clasping-leaf pondweed	N/A				X	X	X
	Potamogeton pusillus	Small pondweed	7	X	X	X		X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	X	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8				X		
	Potamogeton strictifolius	Stiff pondweed	8	X			X	X	X
	*Potamogeton vaseyi**	Vasey's pondweed	10				I		
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	X	X	X
	Ranunculus aquatilis	White water-crowfoot	8	X				X	X
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X			X		X
	Stuckenia pectinata	Sago pondweed	3	X					
	Utricularia intermedia	Flat-leaf bladderwort	9				X	X	X
	Utricularia vulgaris	Common bladderwort	7	X	X		X	X	X
	Vallisneria americana	Wild celery	6	X	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X		X	X	X	X
	Juncus pelocarpus	Brown-fruited rush	8	X	X	X	X	X	X
	Sagittaria cuneata	Arum-leaved arrowhead	7				I		
	Schoenoplectus subterminalis	Water bulrush	9				I		

FL = Floating-leaf; FL/E = Floating-leaf & Emergent; S/E = Submergent & Emergent
X = Located on rake during point-intercept survey; I = Incidentally located
** = Native species listed as special concern in WI*

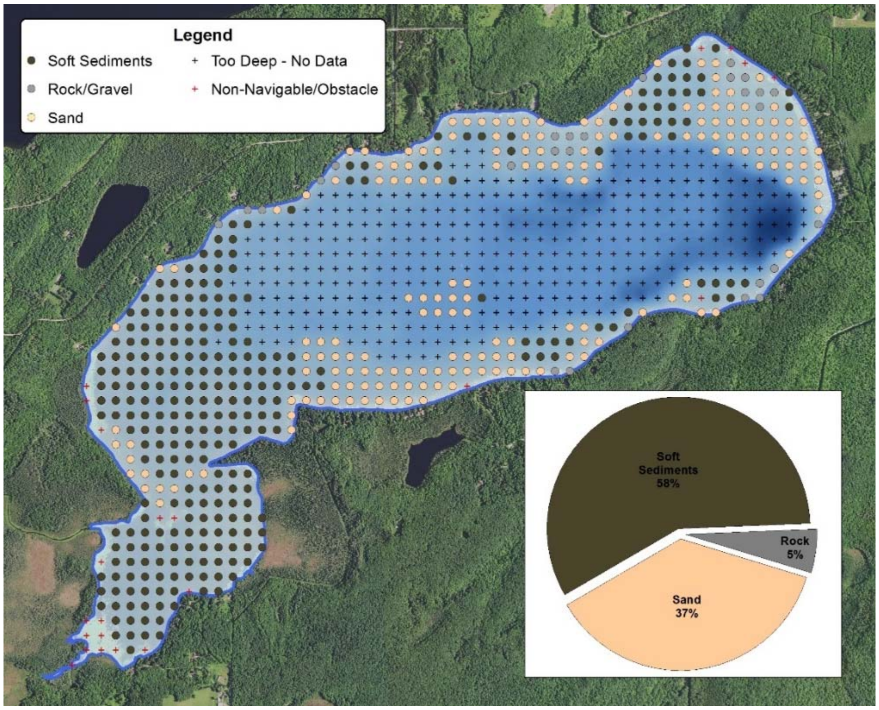


Figure 3.4-2. Big Sand Lake 2016 substrate types. Please note sediment data were only recorded at locations ≤ 15 feet. Created using data from 2016 point-intercept survey.

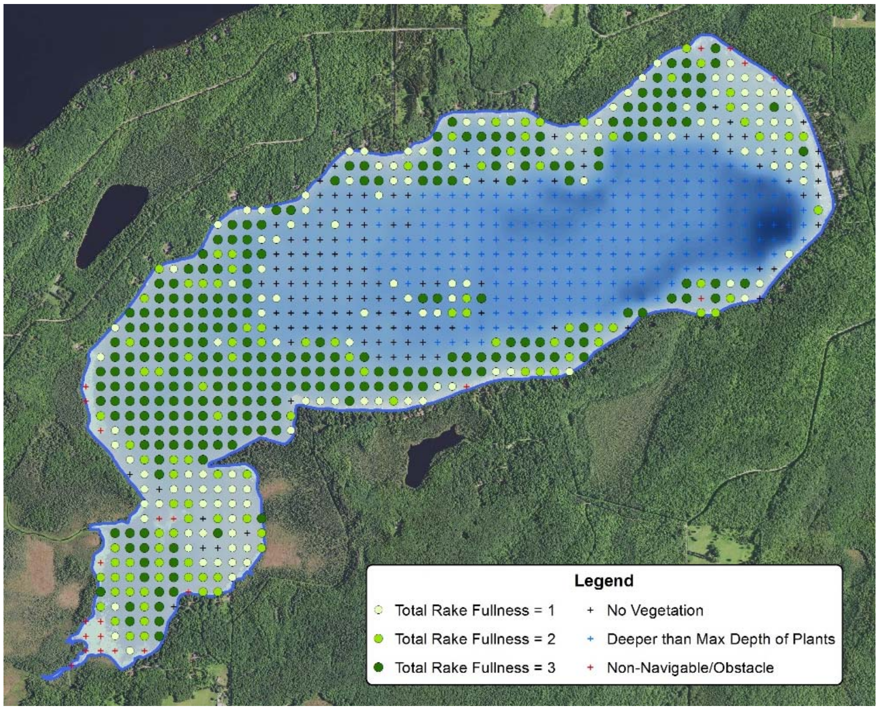


Figure 3.4-3. Big Sand Lake 2016 vegetation distribution and total rake fullness ratings. Created using data from 2016 point-intercept survey.

Photo 3.4-5. Fern pondweed (*Potamogeton robbinsii*), a common plant in northern Wisconsin lakes. Photo credit Onterra.

Of the 62 aquatic plant species located in Big Sand Lake since 2006, 41 were physically encountered on the rake during the 2016 whole-lake point-intercept survey. Of these 41 species, fern pondweed, southern naiad, common waterweed, and coontail were the four-most frequently encountered (Figure 3.4-4). Fern pondweed was the most abundant aquatic plant in Big Sand Lake in 2016 with a littoral frequency of occurrence of approximately 46%. As its name indicates, this plant resembles a terrestrial fern frond in appearance (Photo 3.4-5), and is often a dominant species in plant communities of northern Wisconsin lakes. Fern pondweed is generally found growing in thick beds over soft substrates, where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. In 2016, fern pondweed was abundant throughout littoral areas of Big Sand Lake, and was only absent from near-shore areas with sandy substrates.

Southern naiad was the second-most frequently encountered aquatic plant in Big Sand Lake in 2016 with a littoral frequency of occurrence of approximately 37% (Figure 3.4-4). Southern naiad was not recorded during the 2006 and 2010 point-intercept surveys, and was first recorded during the 2011 point-intercept survey with a littoral frequency of occurrence of approximately 17%. It has since been increasing in its occurrence in each survey completed since 2011, and is now the second-most abundant plant within the lake. Southern naiad in Big Sand Lake is discussed in further detail later in this section.

With littoral frequencies of occurrence of approximately 22% and 16% in 2016, common waterweed and coontail were the third- and fourth-most frequently encountered aquatic plant species in Big Sand Lake, respectively (Figure 3.4-4). Both common waterweed and coontail are found throughout lakes in Wisconsin and North America, and are often dominant in areas with soft sediments. Their dense foliage provides valuable aquatic habitat while their ability to derive nutrients directly from the water aid in improving water quality. In 2016, common waterweed was found across littoral depths in areas with soft sediments, while coontail was primarily found in deeper in 10 to 15 feet of water over soft sediments.

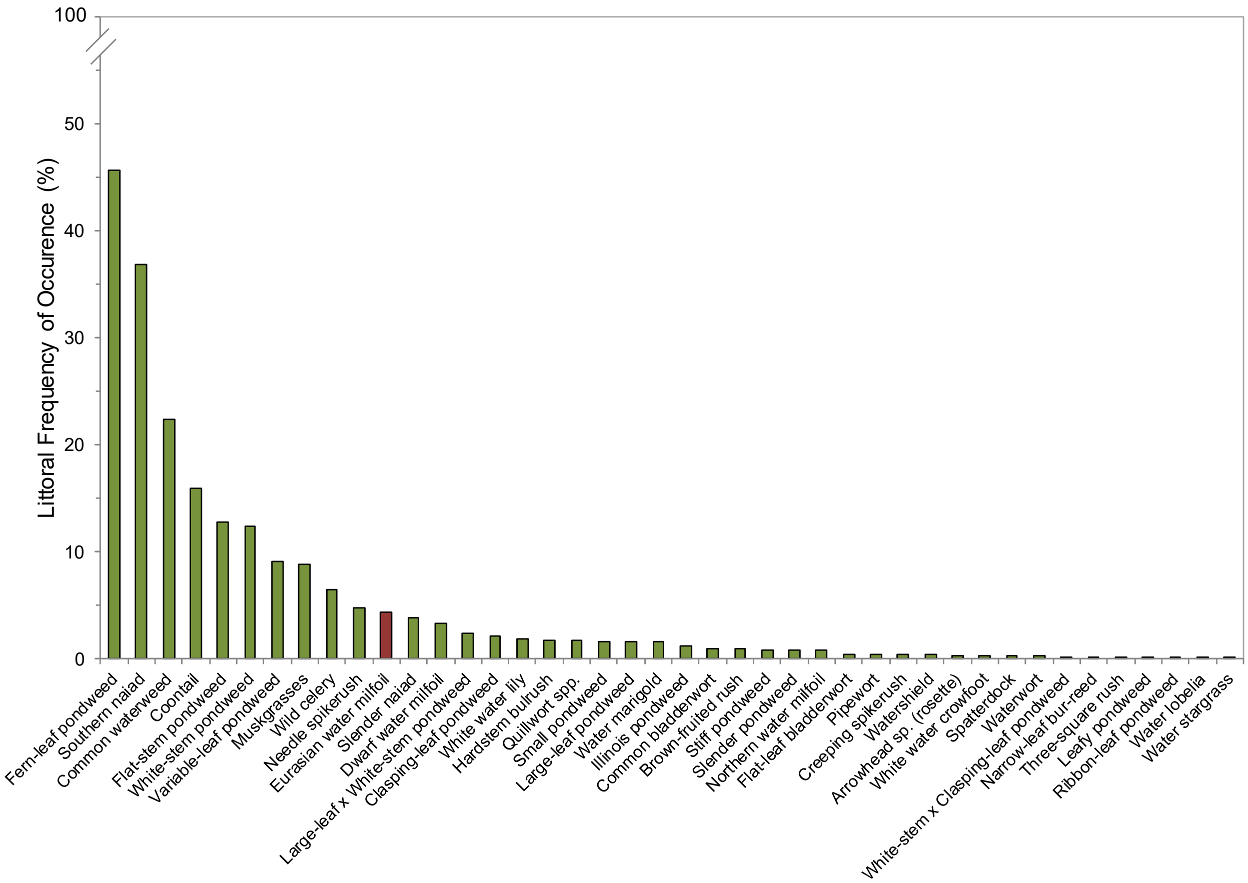


Figure 3.4-4. Big Sand Lake 2016 littoral frequency of occurrence of aquatic plant species. Created using data collected from 623 littoral sampling locations during the 2016 whole-lake point-intercept survey. Exotic species indicated in red.

Given that six whole-lake point-intercept surveys have been completed on Big Sand Lake since 2006, these data can be compared to determine how the plant community has changed over time, particularly following three large-scale and two small-scale herbicide treatments. Figures 3.4-5 and 3.4-6 display the littoral frequency of occurrence of native aquatic plant species in Big Sand Lake as determined from the surveys completed from 2006-2016. The aquatic plants are divided between dicotyledons (dicots; Figure 3.4-5) and non-dicotyledons (non-dicots; Figure 3.4-6). The occurrence of Eurasian water milfoil (EWM) in Big Sand Lake is discussed in the subsequent Non-Native Aquatic Plant Section.

Eurasian water milfoil (EWM) is a dicot, and the herbicides (2,4-D) which have been used in Big Sand Lake in an effort to control EWM were historically believed to only have impacts to dicot species. While herbicide application strategies are implemented to maximize target plant (EWM) impacts and minimize impacts to native species, certain native aquatic plants are susceptible to the type of herbicide application strategy that has been utilized in Big Sand Lake. And while it was historically believed that only dicot native species (e.g. northern water milfoil) were sensitive to 2,4-D treatments, research conducted by the US Army Corps of Engineers and the WDNR have shown that certain non-dicot native plants are sensitive as well.

Over the course of the 2006-2016 surveys, a total of 10 native dicots have been located on the rake during the point-intercept surveys. Of these 10 species, only dwarf water milfoil (*M. tenellum*) exhibited a statistically valid change in its littoral occurrence from 2006 to 2016, increasing from an occurrence of 1.2% in 2006 to 3.4% in 2016 (Figure 3.4-5). Coontail (*C. demersum*), the most abundant native dicot and one of the most abundant plants in Big Sand Lake, did not exhibit any statistically valid changes in its occurrence between the 2006 and 2016 surveys. Thirty-six native non-dicots have been recorded on the rake over the course of the 2006-2016 point-intercept surveys (Figure 3.4-6). Of these 36 species, 11 have exhibited statistically valid changes in their littoral occurrence between 2006 and 2016; seven have declined in their occurrence while four have increased. The species that have had a littoral frequency of occurrence of at least 5% in one of the surveys and have shown statistically valid changes in their occurrence between 2006 and 2016 are discussed below.

Common waterweed (Elodea canadensis)

Common waterweed was the second-most frequently encountered aquatic plant during the 2006 point-intercept survey in Big Sand Lake with a littoral occurrence of 46.3% (Figure 3.4-6). In 2010, the occurrence of common waterweed declined to 26.9%, a reduction of 42%. Since 2010, the occurrence of common waterweed has ranged from 34.0% in 2011 to 19.2% in 2014. The most recent survey in 2016 revealed common waterweed had an occurrence of 22.3%, representing a 52% reduction in occurrence since 2006. Common waterweed is one of the non-dicots which have been shown to be susceptible to 2,4-D treatments, and its decline between 2006 and 2010 is likely a result of the large-scale treatments completed in 2008, 2009, and 2010.

The current lower level of common waterweed within the lake could be due to lack of recovery from the large-scale treatments, competition with southern naiad, a combination of both, or other environmental factors. Michelle Nault, WDNR water resources management specialist has reported large, interannual population fluctuations of common waterweed in northern Wisconsin lakes that have not undergone herbicide treatments (personal comm. 2014). However, the factors which drive these fluctuations are not understood.

Slender/Small pondweed (Potamogeton berchtoldii & P. pusillus)

Prior to 2011, slender pondweed (*P. berchtoldii*) was considered to be a subspecies of small pondweed (*P. pusillus*) until genetic studies warranted classification of slender pondweed as a distinct species. Specimens collected from Big Sand Lake and verified at the UW-Stevens Point herbarium indicate that the lake harbors populations of both slender and small pondweed. However, since it is often highly difficult to differentiate between these two plants in the field and since slender pondweed was not separated from small pondweed during the 2006 and 2010 studies, the occurrences of these species have been lumped together for this analysis and will hereafter be referred to as small pondweed.

In 2006, small pondweed was the third-most frequently encountered native aquatic plant with a littoral frequency of occurrence of 19.3% (Figure 3.4-6). Following the three large-scale treatments, the occurrence of small pondweed was reduced to a littoral occurrence of 1.5%, a statistically valid reduction of 92%. In 2011 and 2014, the occurrence of small pondweed was not statistically different from 2010 with littoral occurrences of 1.0 and 0.7%, respectively. In 2015, the littoral occurrence of small pondweed increased slightly to 2.6%, and its littoral occurrence was similar in 2016 at 2.4%. The littoral occurrence of 2.4% in 2016 represents a statistically valid reduction of 88% since 2006.

The large reduction of small pondweed following the large-scale treatments and its lack of recovery is the largest concern regarding Big Sand Lake's aquatic plant community and the continuation of EWM management. Not only was small pondweed one of the most abundant native aquatic plants in 2006, it was also one of the deepest growing, with an average recorded depth of 14.0 feet. The majority of the sampling locations containing small pondweed were located in deeper areas of the littoral zone within the western half of the main body of the lake. Subsequent surveys since 2006 indicate that a portion of this area has not been recolonized by small pondweed, or by any other aquatic plants, and remains unvegetated. Small pondweed is one of the non-dicot aquatic plant species that has shown to be sensitive to 2,4-D. Continued monitoring of Big Sand Lake's aquatic plant community will be needed to determine if the small pondweed population shows signs of recovery towards 2006 levels.

Southern naiad (Najas guadalupensis)

Southern naiad was not recorded during the 2006 and 2010 point-intercept surveys, and was first recorded during the 2011 point-intercept survey with a littoral frequency of occurrence of approximately 17%. It has since been increasing in its occurrence in each survey completed since 2011, and was the second-most frequently encountered aquatic plant in 2016 with a littoral frequency of occurrence of 37% (Figure 3.4-6). Southern naiad is similar to slender naiad, a native plant also found in Big Sand Lake, and they are often difficult to separate (Photo 3.4-6). The fact that southern naiad was not recorded in 2010 but had a littoral occurrence of 17% in 2011 indicates that a portion of the plants identified as slender naiad in 2010 were likely southern naiad.

Photo 3.4-6. Slender naiad (*Najas flexilis*; left) and southern naiad (*N. guadalupensis*; right) from Big Sand Lake. Photo credit Onterra.

It is currently not known why the southern naiad population in Big Sand Lake has been increasing rapidly over the past five years. This increase in southern naiad has been observed in other area lakes (Michelle Nault and Susan Knight, personal comm.). One concern has been that the large-scale 2,4-D herbicide treatments completed on Big Sand Lake have favored the competition of southern naiad over other native species that are prone to decline following these treatments. In other words, the concern is that southern naiad is 'filling in' areas of the lake once occupied by other native aquatic plants which saw declines following the herbicide treatments.

While the point-intercept data indicate that the majority of the southern naiad population has been increasing in areas of the lake which had lower occurrences of 2,4-D sensitive species (i.e. common waterweed and small pondweed) prior to the herbicide treatments, the bay on the southwest end has seen a shift from a high occurrence of common waterweed in 2006 to a high occurrence of southern naiad in 2016 (Photo 3.4-7). In 2006, approximately 60% of the 110 sampling locations within this bay contained common waterweed compared to 33% in 2016. Southern naiad was located as approximately 65% of these sampling locations in 2016. However, it is not known if this shift is a result of the herbicide treatments as other area lakes that have not undergone any herbicide treatments are also seeing increases in southern naiad (Susan Knight, personal comm.).

Photo 3.4-7. Surface matted vegetation primarily comprised of southern naiad (*N. guadalupensis*) in the southwestern bay of Big Sand Lake in 2012. Photo credit Onterra.

While southern naiad is native to North America, its invasive behavior in Big Sand Lake and other area lakes may indicate that this species was not historically present in these waterbodies and was recently introduced. Or, if southern naiad was historically present in these waterbodies, recent environmental conditions, whatever they may be, are favoring the rapid expansion of this plant within these lakes. The primary concern with the increasing southern naiad population is the displacement of other native aquatic plant species. Apart from the decline in common waterweed and increase in southern naiad within the southwestern bay, the data do not indicate that any other native aquatic plant species are being displaced in areas where southern naiad is expanding. In summary, it is now known why southern naiad populations are increasing in Big Sand Lake and other northern Wisconsin lakes, and its invasive behavior and potential impacts to ecosystem functions warrants further study.

Flat-stem pondweed (Potamogeton zosteriformis)

Flat-stem pondweed had a littoral frequency occurrence of 4.7% in 2006, and between 2011 and 2014, its occurrence increased to 13.1% (Figure 3.4-6). Since 2014, its occurrence has remained between 12.8 and 13.6%. Like small pondweed, flat-stem pondweed has been shown to be susceptible to 2,4-D treatments, but in Big Sand Lake there was not a detectable effect on this population. A portion of the flat-stem pondweed population in Big Sand Lake does overlap with where the majority of small pondweed was located in 2006, and the increase of flat-stem pondweed may represent its expansion into areas previously occupied by small pondweed.

Muskgrasses (Chara spp.)

Muskgrasses had a littoral frequency of occurrence of 3.4% in 2006 and their occurrence fluctuated slightly between 2010 and 2014. Since 2014, their occurrence has increased to an occurrence of 8.8% in 2016. This increase has been most notable in shallow sandy areas in eastern side of the lake. The reasons for the recent increase in muskgrasses in Big Sand Lake are not known.

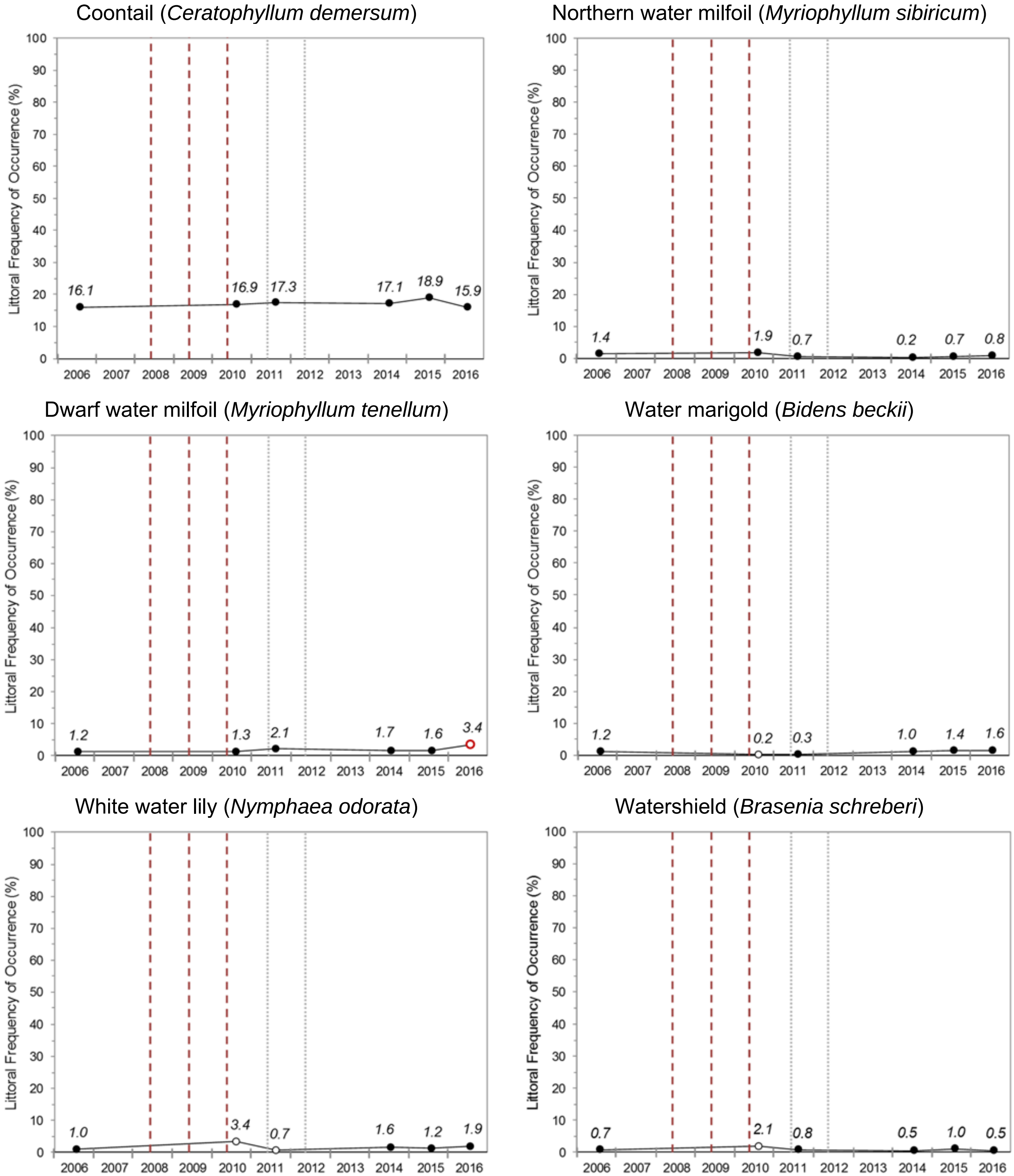


Figure 3.4-5. Littoral frequency of occurrence of native dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

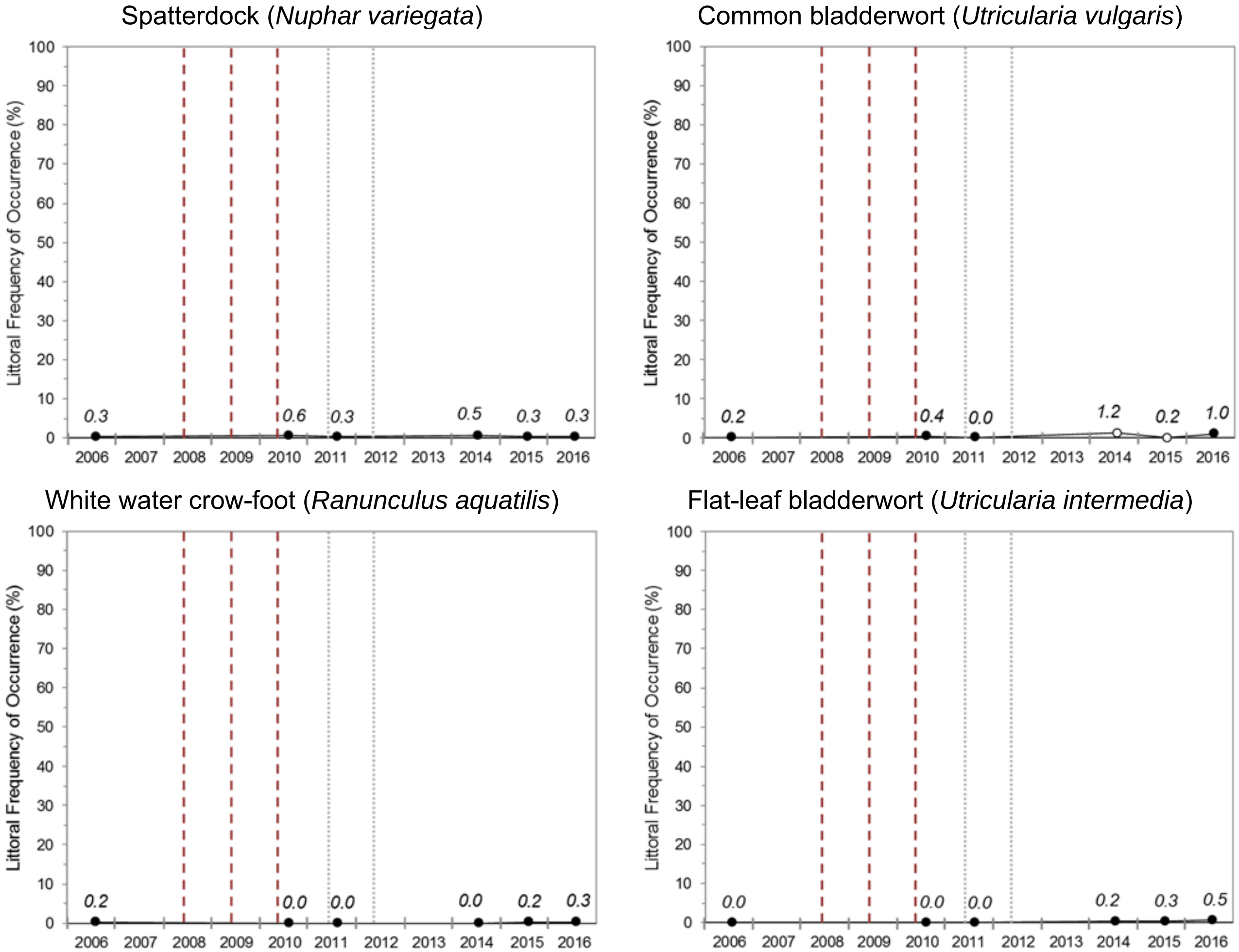


Figure 3.4-5 continued. Littoral frequency of occurrence of native dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

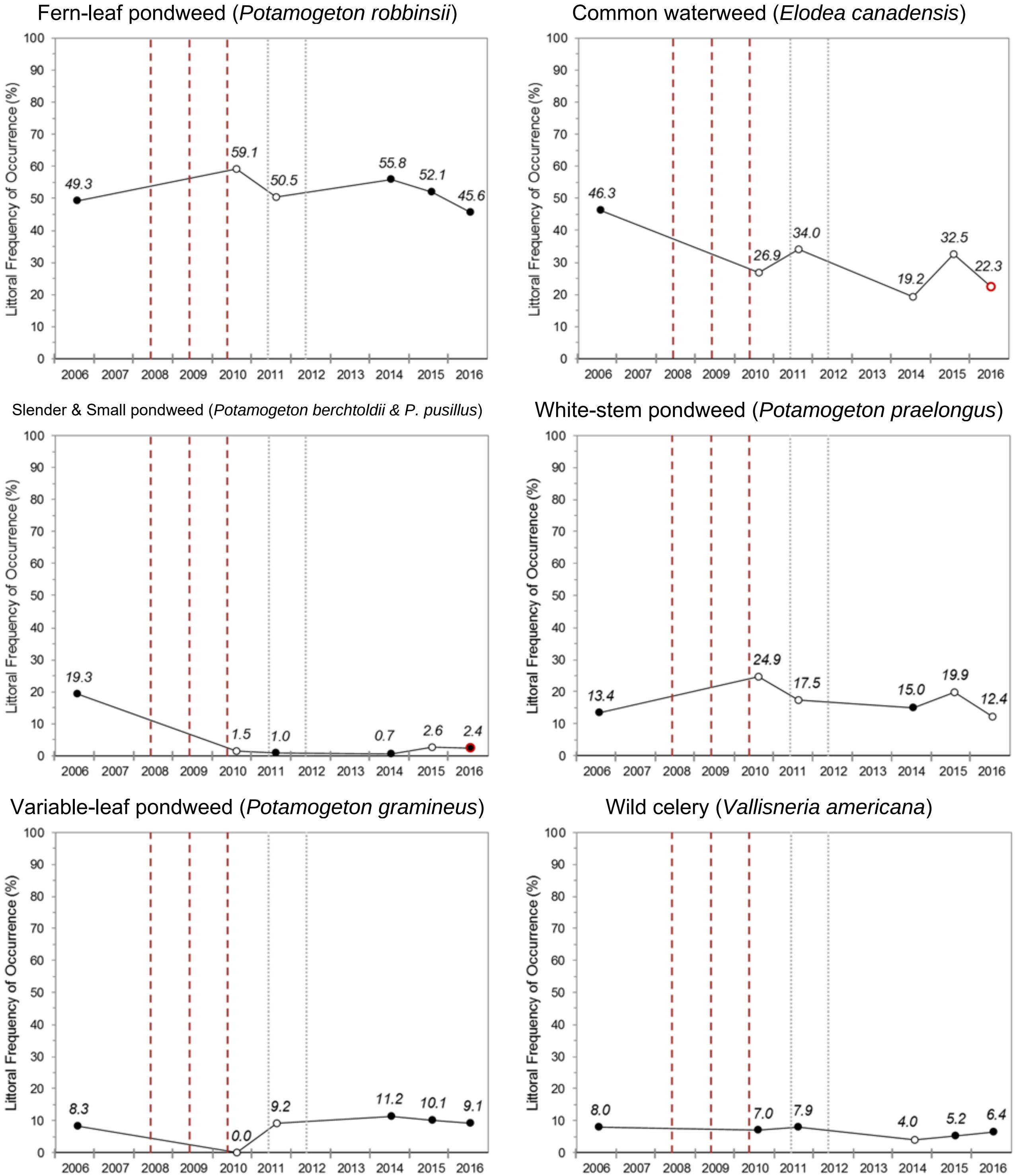


Figure 3.4-6. Littoral frequency of occurrence of native non-dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

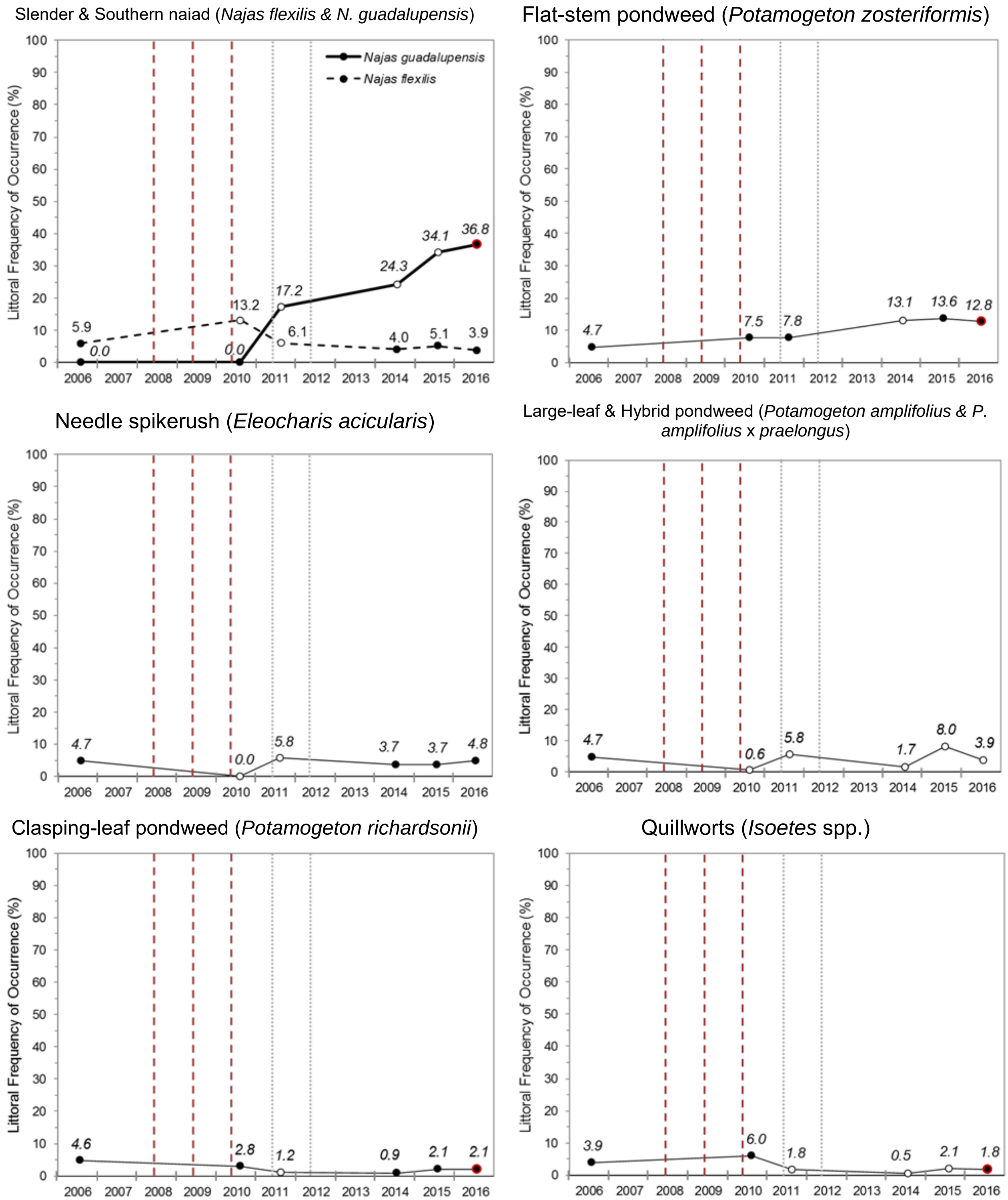


Figure 3.4-6 continued. Littoral frequency of occurrence of native non-dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

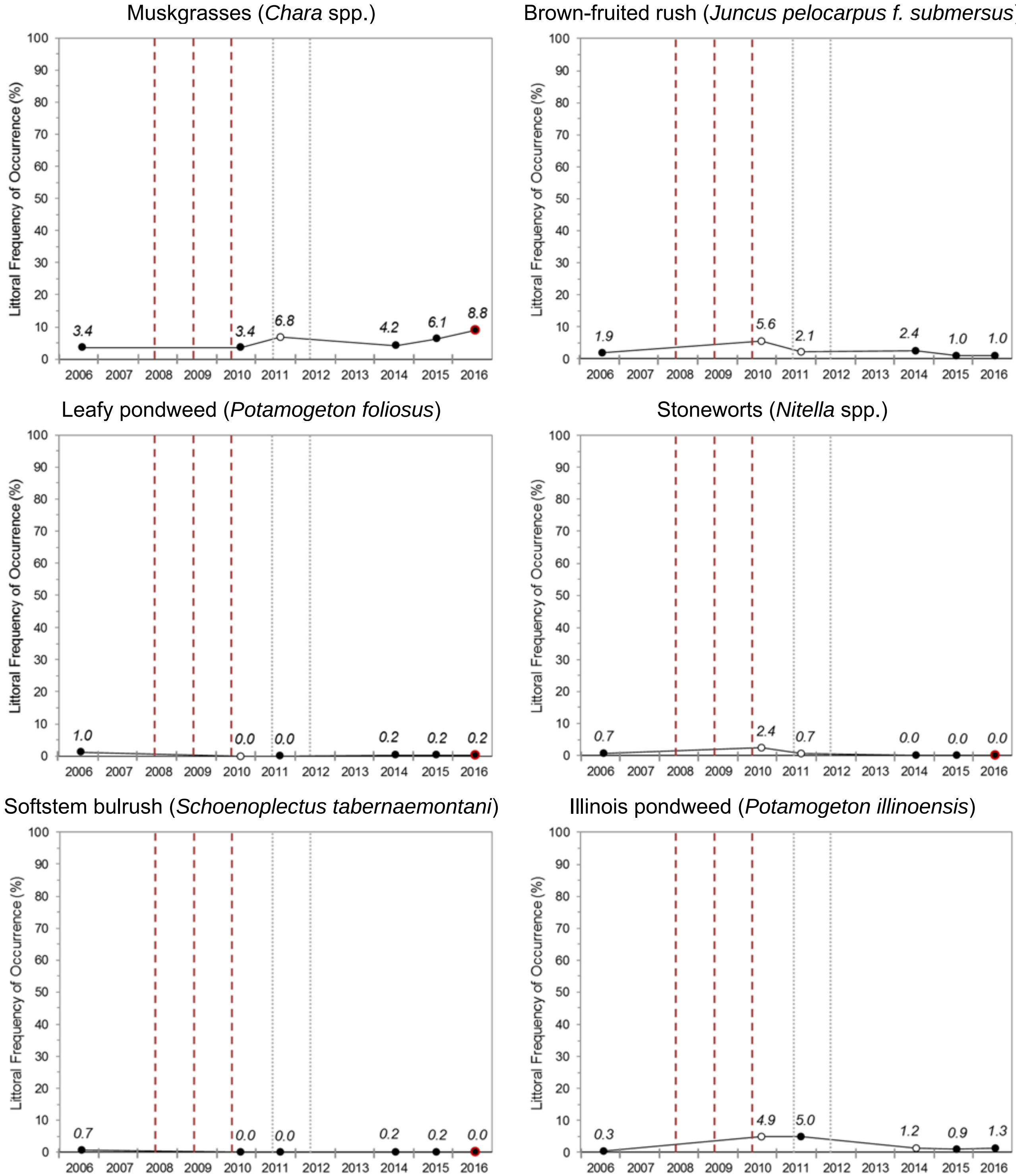


Figure 3.4-6 continued. Littoral frequency of occurrence of native non-dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

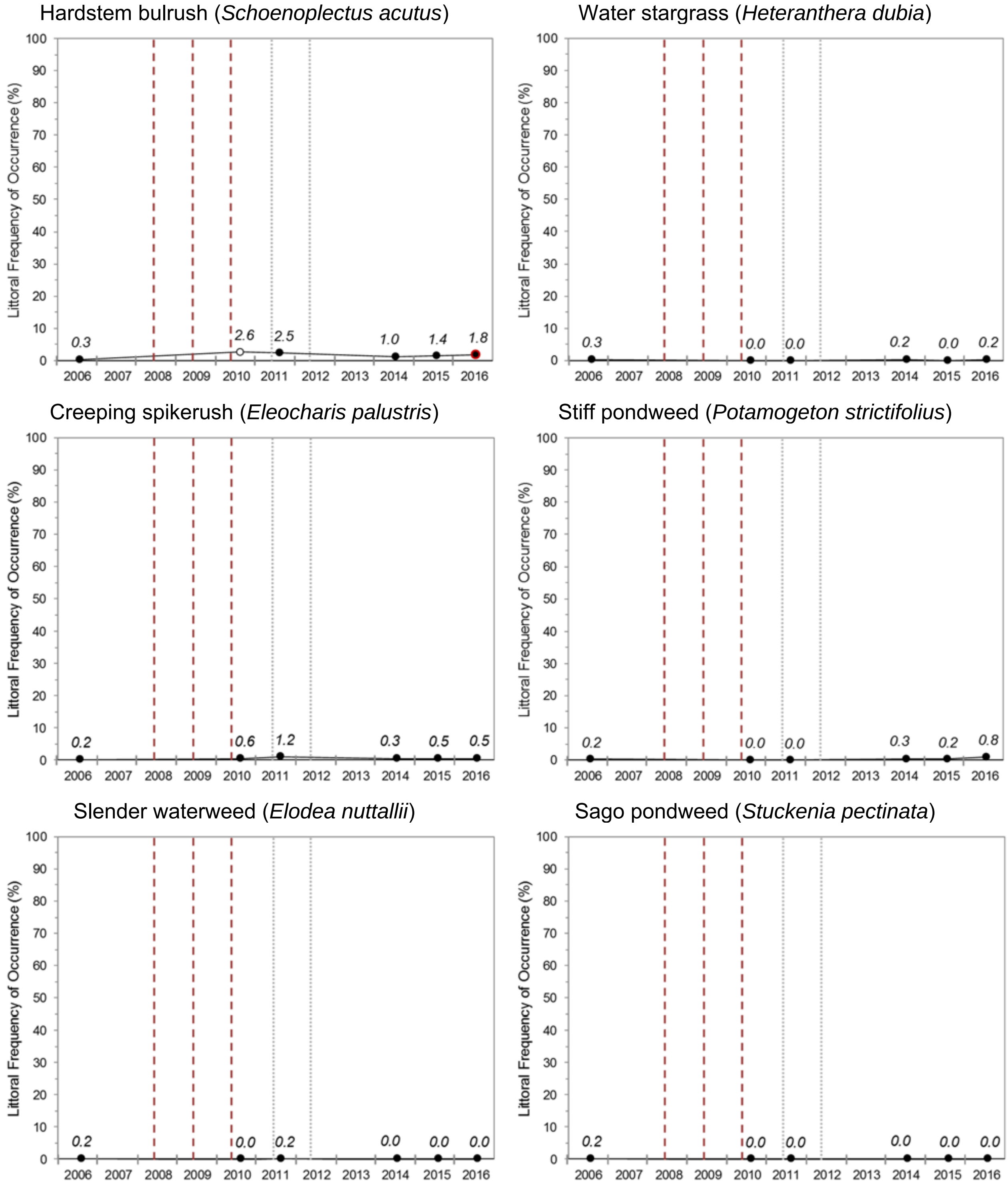


Figure 3.4-6 continued. Littoral frequency of occurrence of native non-dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

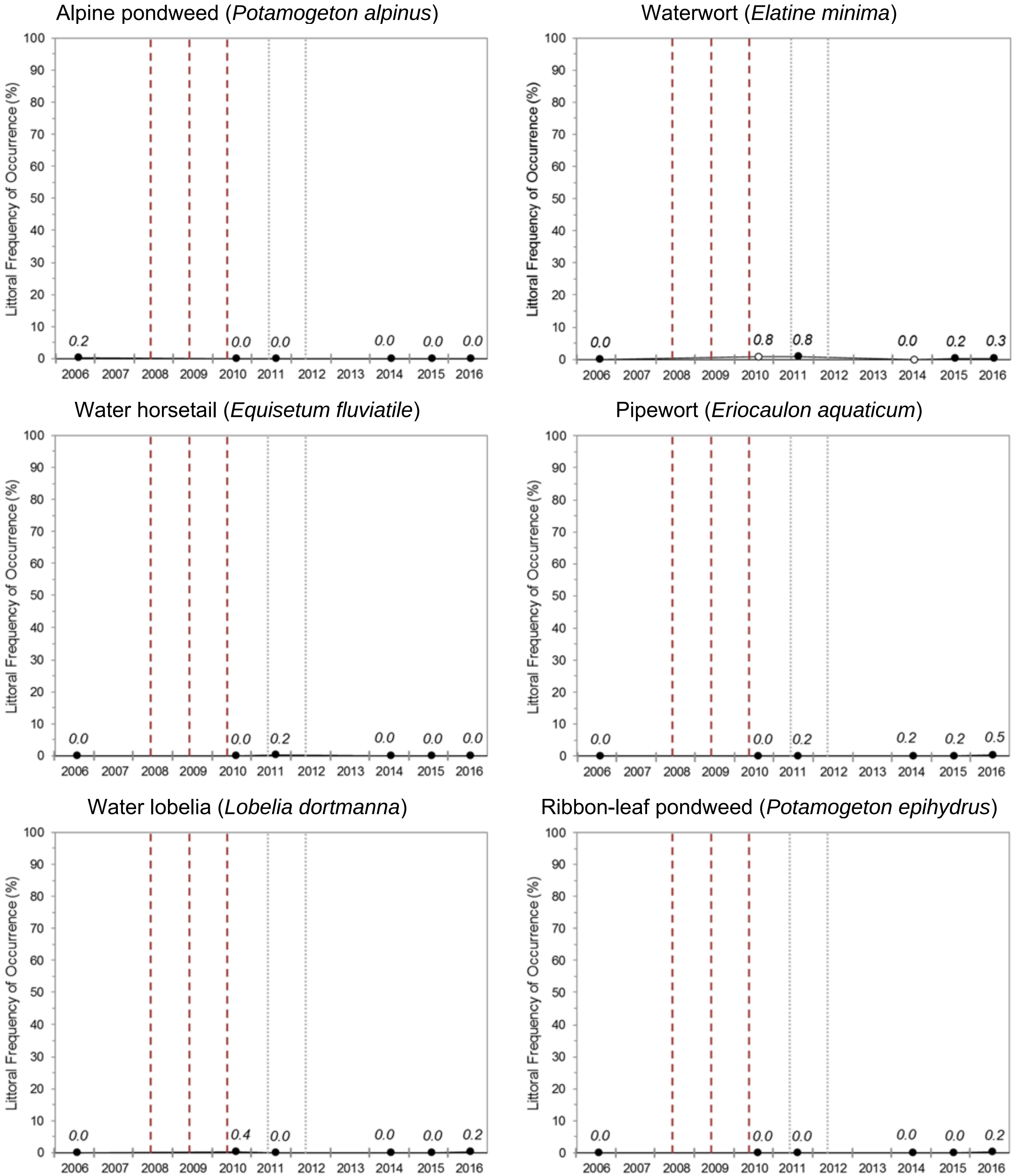


Figure 3.4-6 continued. Littoral frequency of occurrence of native non-dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

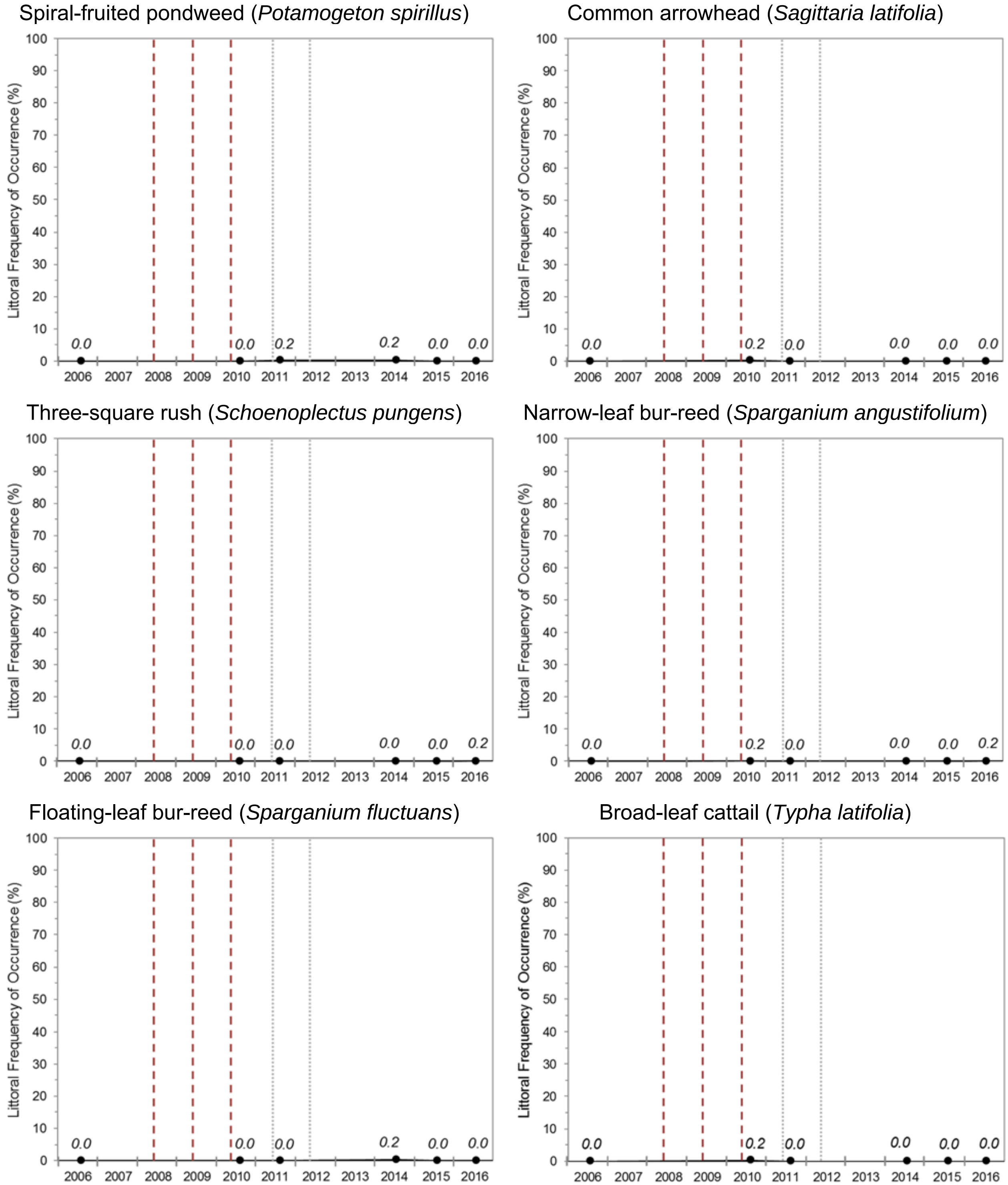


Figure 3.4-6 continued. Littoral frequency of occurrence of native non-dicot aquatic plant species in Big Sand Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2006 (Chi-Square α = 0.05). Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment.

The littoral frequency of occurrence analysis allows for an understanding of how often each plant species is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while fern pondweed was found at 46% of the littoral sampling locations in Big Sand Lake in 2016, its relative frequency of occurrence was 22%. Explained another way, if 100 plants were randomly sampled from Big Sand Lake in 2016, 22 of them would be fern pondweed. Figure 3.4-7 displays the relative occurrence of aquatic plant species from Big Sand Lake from the 2006, 2010, 2011, 2014, 2015, and 2016 surveys.

Prior to the implementation of herbicide control strategies, the littoral frequency of occurrence of all vegetation (native and non-native) in Big Sand Lake was 88.5% (Figure 3.4-8). Of the sampling locations which contained aquatic vegetation, 59.3% contained native aquatic vegetation only, 21.7% contained both native species and EWM, and 7.5% contained EWM only. In 2010, the littoral frequency of occurrence of all vegetation of 86.8% was not statistically different from 2006. However, the proportion of sampling locations with native species increased by 7.5% while the proportion of sampling locations with EWM only decreased to 0%.

The littoral frequency of occurrence of all vegetation in Big Sand Lake saw a statistically valid decline from 86.8% in 2010 to 74.9% in 2011 (Figure 3.4-8). The number of sampling locations containing native aquatic species declined by 12.6%. Between 2011 and 2014, the littoral frequency of occurrence of all vegetation increased to 84.3%, and in 2015 and 2016 remained similar at 84.1% and 81.2%, respectively. The decline in the littoral frequency of occurrence of vegetation in Big Sand Lake from 2006 to 2016 represents a statistically valid reduction of 4.6%. However, the littoral frequency of occurrence of sampling locations with native aquatic plant species were not statistically different between 2006 and 2016 indicating that the reduction in overall vegetation occurrence can be attributed to sampling locations with EWM only.

As discussed in the primer section, the calculations used to create 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 each point-intercept survey and does not include incidentally-located species. The native species encountered on the rake during the 2006, 2010, 2011, 2014, 2015, and 2016 point-intercept surveys and their conservatism values were used to calculate the FQI of Big Sand Lake's aquatic plant community (equation shown below).

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

Figure 3.4-9 compares Big Sand Lake's FQI components to median values of lakes within the Northern Lakes and Forests – Lakes (NLFL) ecoregion and lakes throughout Wisconsin. Native aquatic plant species richness was 34 in 2006 prior to herbicide applications. Following the implementation of large-scale herbicide treatments, native species richness has ranged from 30 in 2010 to 41 in 2016, with an average of 35.2. The native species richness values from Big Sand Lake fall above the upper quartile values for both lakes within the NLFL ecoregion and lakes throughout Wisconsin. While the abundance of certain native aquatic plants has changed since the implementation of large-scale herbicide applications in Big Sand Lake (discussed previously), the overall number of native aquatic plant species has not declined.

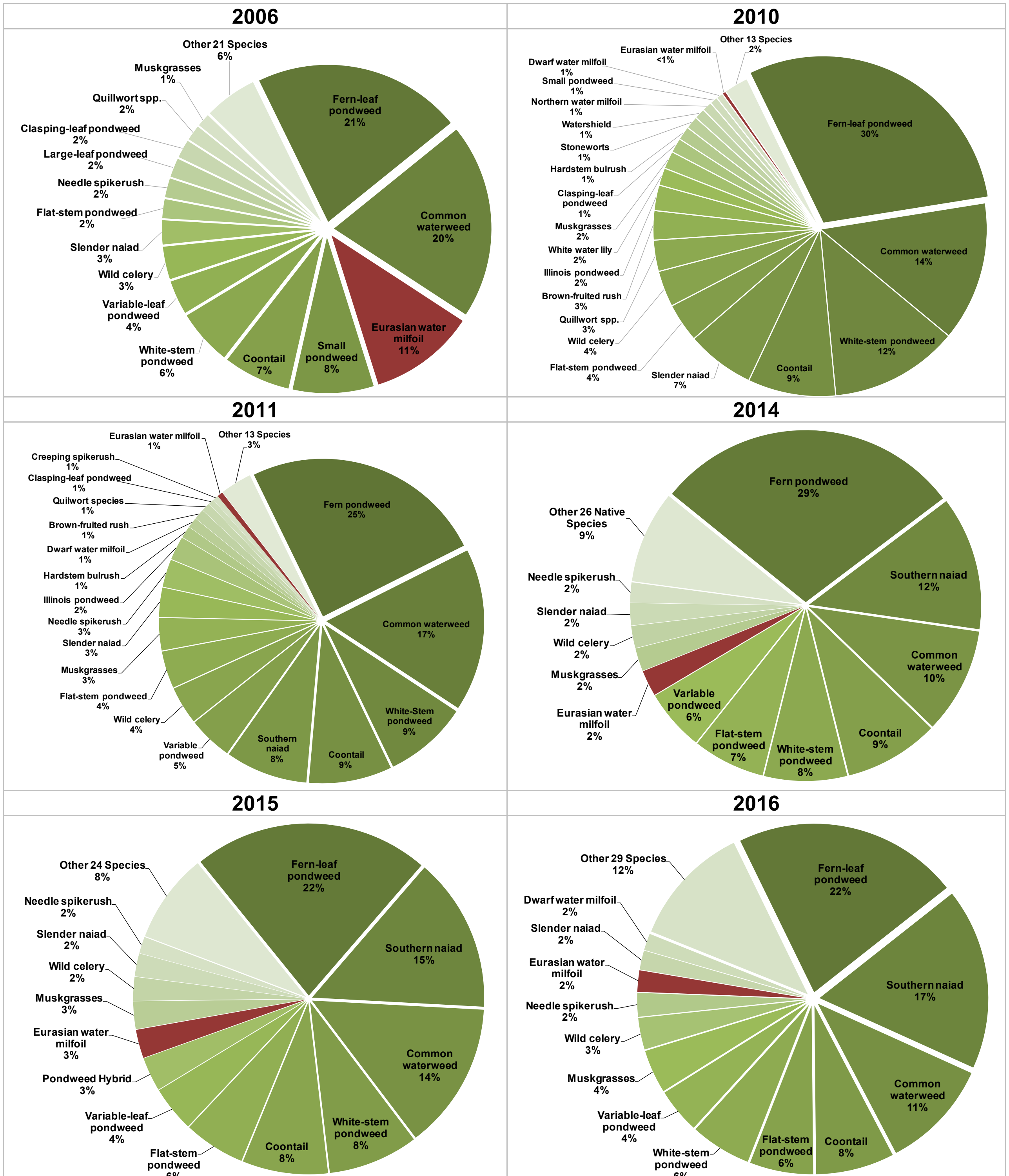


Figure 3.4-7. Big Sand Lake relative frequency of occurrence of aquatic plant species from 2006 to 2016. Exotic species indicated with red. Created using data from WDNR 2006 and Onterra 2010, 2011, 2014, 2015, and 2016 point-intercept surveys.

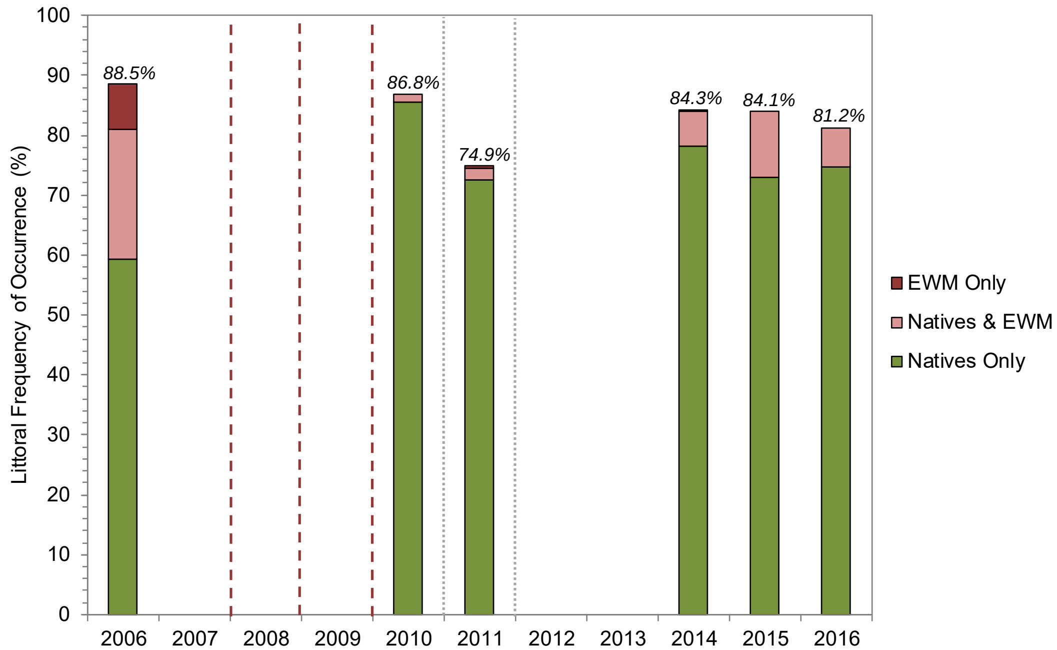


Figure 3.4-8. Big Sand Lake littoral frequency of occurrence of vegetation from 2006-2016. Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment. Created using data from WDNR 2006 and Onterra, 2010, 2011, 2014, 2015, and 2016 point-intercept surveys.

The average coefficient of conservatism of native aquatic plant species in Big Sand Lake was 6.5 in 2006 prior to large-scale herbicide applications (Figure 3.4-9). Following the large-scale herbicide applications, the average conservatism value has ranged from 6.2 in 2014 to 6.5 in 2010 and 2015, with an average of 6.4. Big Sand Lake's conservatism values fall slightly below the median value for lakes within the NLFL ecoregion and slightly above the median value for lakes throughout Wisconsin.

Using Big Sand Lake's native aquatic plant species richness and average conservatism values to calculate floristic quality indicates a floristic quality index value of 37.7 in 2006 (Figure 3.4-9). Following the large-scale herbicide treatments, floristic quality index values ranged from 35.8 in 2010 to 41.1 in 2016 with an average of 37.9. While Big Sand Lake's floristic quality declined slightly in the years immediately following the large-scale herbicide treatments, surveys from 2014-2016 indicate the lake's floristic quality is similar to floristic quality in 2006. Overall, Big Sand Lake's floristic quality is higher than the upper quartile values for lakes within the NLFL ecoregion and throughout the state.

As explained earlier, lakes with diverse aquatic plant communities are believed to 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 Big Sand Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

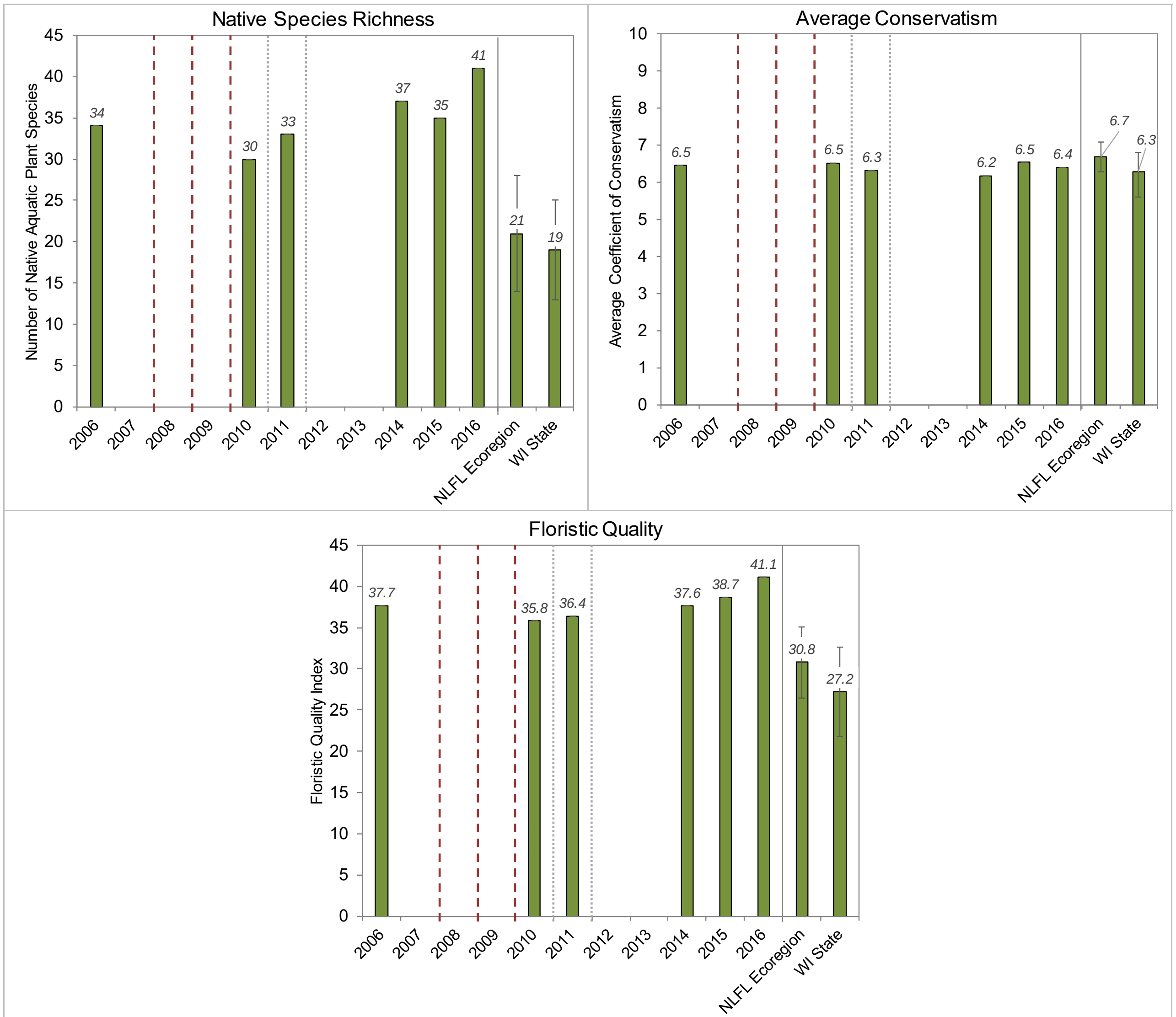


Figure 3.4-9. Big Sand Lake Floristic Quality Assessment. Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment. Created using data from WDNR 2006 and Onterra 2010, 2011, 2014, 2015, and 2016 whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data. Analysis follows Nichols 1999.

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 Big Sand Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.4-10). Using the data collected from the 2006, 2010, 2011, 2014, 2015 and 2016 point-intercept surveys, Big Sand Lake's aquatic plant community is shown to have similar species diversity to other lakes within the NLFL ecoregion (median = 0.88). In 2006, Big Sand Lake had a Simpson's Diversity Index value of 0.88. From 2010 to 2016 Simpson's Diversity Index values ranged from 0.87 to 0.89, with an average of 0.88. No change in species diversity was observed following the large-scale herbicide treatments.

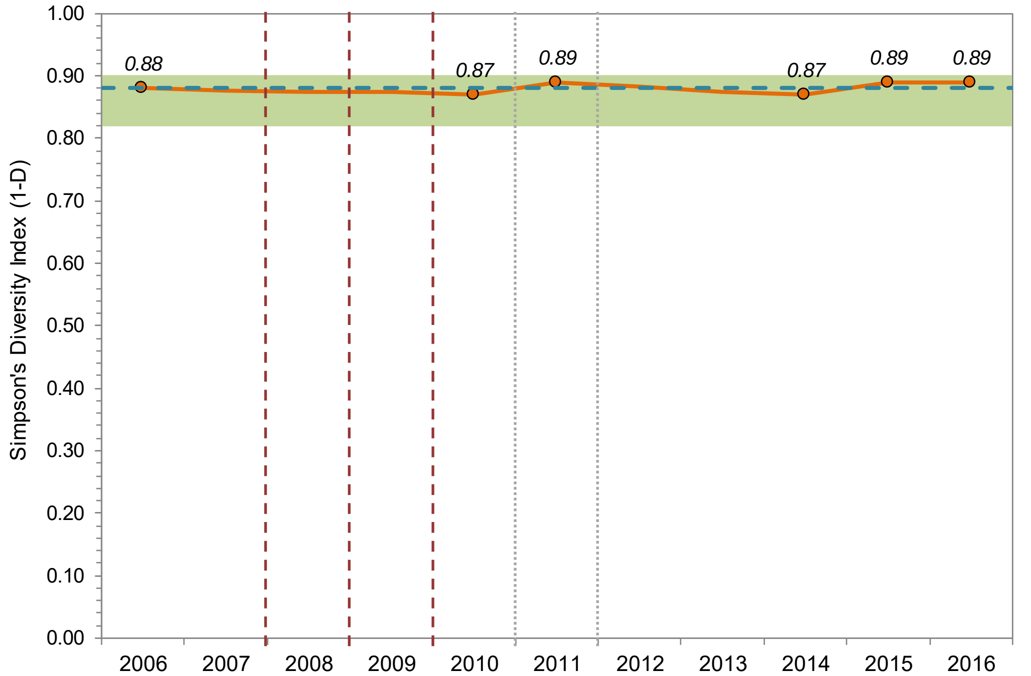


Figure 3.4-10. Big Sand Lake Simpson's Diversity Index. Red dashed lines indicate large-scale 2,4-D treatment and grey dashed lines indicate small-scale 2,4-D treatment. Created using data from WDNR 2006 and Onterra 2010, 2011, 2014, 2015, and 2016 whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data.

Onterra ecologists also conducted an aquatic plant community mapping survey in 2014 aimed at mapping communities of emergent and floating-leaf vegetation. During this survey, approximately 95.5 acres of emergent and floating-leaf aquatic plant communities comprised of 19 species were delineated (Table 3.4-1, Table 3.4-2, Map 5). Most of the communities in Big Sand Lake comprised of emergent vegetation are dominated by hardstem bulrush (Photo 3.4-8), while floating-leaf communities are dominated by white water lily and watershield. On the southern shore of the lake, a colony of giant reed was located growing amongst hardstem bulrush (Photo 3.4-8). While there is a non-native and highly invasive subspecies of giant reed present in Wisconsin, the morphology of the plants located on Big Sand Lake indicate that this population is comprised of the native subspecies.

Table 3.4-2. Acres of emergent and floating-leaf aquatic plant communities on Big Sand Lake in 2014. Created using data from 2014 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	28.9
Floating-Leaf	44.2
Mixed Emergent & Floating-Leaf	22.1
Total	**95.2**

Photo 3.4-8. Expansive hardstem bulrush community along the northern shore of Big Sand Lake (left), and an Onterra staff member inspects a giant reed (native subspecies) colony located on the southern shore (right). Photo credit Onterra.

Continuing the analogy that the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Big Sand Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Non-native Aquatic Plants in Big Sand Lake

Eurasian water milfoil

Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first discovered in Big Sand Lake in 1990, and was the first lake in Vilas County to record the presence of this non-native plant. It was already widespread throughout the lake in 1990, indicating it had likely been present within the lake for some time prior to its discovery. From 1996-1997, a study was conducted on Big Sand Lake to determine if the native milfoil weevil (*Euhrychiopsis lecontei*) could prove to be a viable biological control method for EWM. The study concluded that there were indications of short-term impacts to EWM, but the high cost of weevil applications and the variability in efficacy selected against the use of this option.

During the 2006 point-intercept survey conducted by the WDNR, EWM was found to be widespread throughout the littoral areas of the lake and was the third-most frequently encountered aquatic plant species with a littoral frequency of occurrence of 25.3%. Since 2008, the BSLPOA has been actively managing EWM within the lake utilizing herbicide applications. During the winter of 2009-2010, the BSLPOA contracted with Onterra to aid in the development of an EWM control and monitoring strategy.

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. Because the state of Wisconsin's waters are managed for multiple uses (Statue 281.11), the WDNR wanted to understand if EWM populations would increase and cause either 1) ecological impacts to the lake and/or 2) reductions in ecosystem services (i.e. navigation, recreation, aesthetics, etc.) to lake users. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes is 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 3.4-11). Some lakes, such as Handcock Lake, maintained low EWM populations over the study averaging 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 Handcock Lake has increased in recent years to 5.2% in 2015 and over 10% in 2016 (preliminary data not shown in Figure 3.4-11).

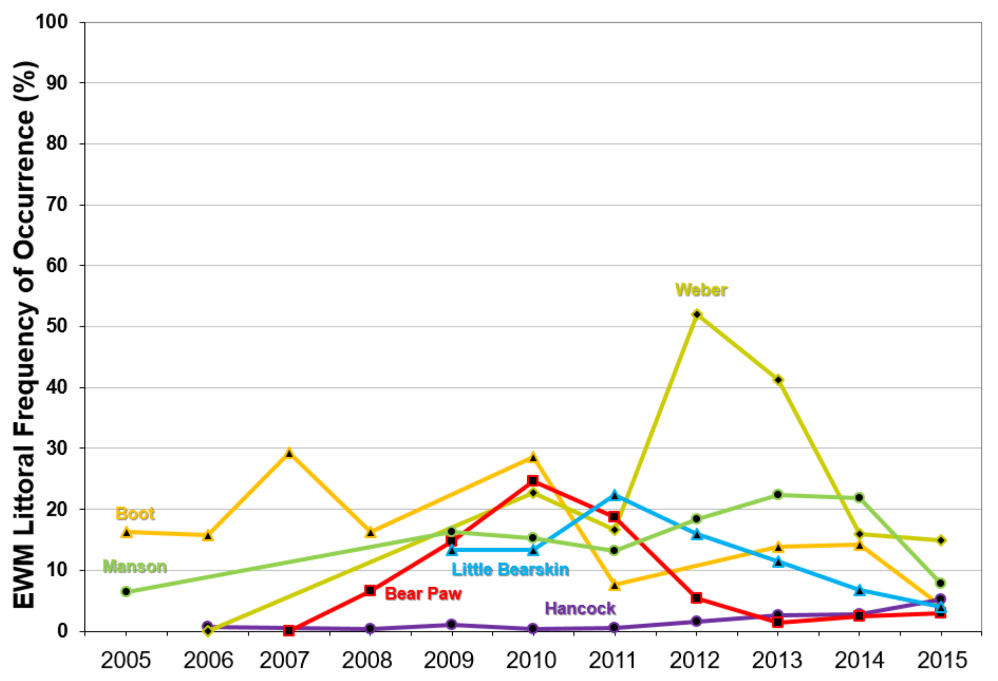


Figure 3.4-11. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

EWM populations in other lakes, such as Bear Paw Lake and Little Bearskin Lake trended to almost 25% only to decline to approximately 5% by the end of the study period. There are many factors that could contribute to the decline in the EWM population of these lakes, including climactic conditions and water quality parameters. Little Bearskin is known to contain a robust population of milfoil weevils and this native insect may be having an impact on the EWM population within the lake. 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 keep the population suppressed in other years. Extreme changes in EWM populations like those observed on Weber Lake have also been documented. The EWM population in 2010-2011 was approximately 20% before spiking above 50% in 2012. Then the population declined back to approximately 15% in 2014 and 2015.

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. Some lake managers interpret these data to suggest that in some circumstances, it is not appropriate to manage the EWM population as in some years the population may become less. However, even a lowered EWM population of approximately 10% exceeds the comfort level of many riparians because it is approaching a level than may be impactful to the function of the lake as well as not allowing the lake to be enjoyed by riparians as it had been historically.

Some lake groups chose to manage the EWM population to keep it at an artificially lowered level. Following detection of an EWM population within a lake, it is common for a lake group to initiate management activities and not wait to see if the EWM population will become a problem in their lake. In other instances, the management strategy is simply to maintain a lower level population of EWM for the purposes of allowing the ecosystem to function as it had before the exotic was introduced to the lake. And yet other lakes are managed simply to alleviate the lost ecosystem services, most notably to manage for multiple human uses. As discussed within the Primer sub-section, there are a number of different management techniques used for controlling EWM with the most commonly implemented being hand-harvesting and herbicide control.

Background on Herbicide Application Strategy

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to dilute herbicide concentration within aquatic systems. Understanding Concentration-Exposure Times (often referred to as CETs) is an important consideration for the use of 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.

A Cooperative Research and Development Agreement between the Wisconsin Department of Natural Resources and U.S. Army Corps of Engineers Research and Development Center in conjunction with significant participation by private lake management consultants have coupled quantitative aquatic plant monitoring with in-lake herbicide concentration data to evaluate efficacy, selectivity, and longevity of chemical control strategies implemented on a subset of Wisconsin waterbodies. Based on the preliminary findings from this research, lake managers have adopted two main treatment strategies: 1) spot treatments, and 2) large-scale (whole-lake) treatments.

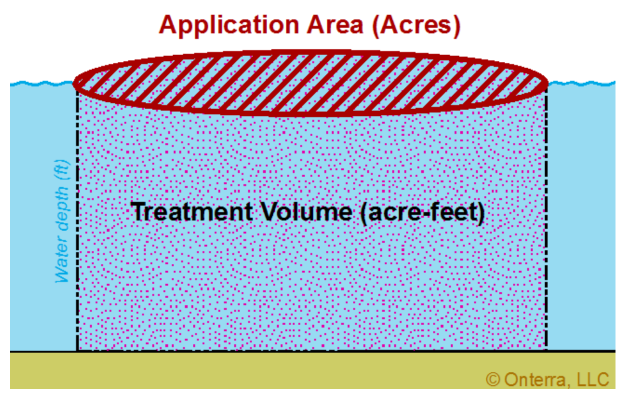


Figure 3.4-12. Herbicide Spot Treatment diagram.

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 effects outside of that area. Herbicide application rates for spot treatment are formulated volumetrically, typically targeting EWM with 2,4-D at 3.0-4.0 ppm acid equivalent (ae). This means that sufficient 2,4-D is applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal 3-4.0 ppm ae. 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 3.4-12). While lake managers may propose that a particular volumetric dose be used, such as 3.0-4.0 ppm ae, it is understood that actually achieving 3.0-4.0 ppm ae within the water column is not likely due to dissipation and other factors.

Ongoing research clearly indicates 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). 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.

WDNR administrative code defines large-scale treatments as those that exceed 10% of the littoral zone (NR 107.04[3]). From an ecological perspective, large-scale (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 (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. In regards to the WDNR's 10% littoral frequency of occurrence threshold discussed above, there is ecological basis in this standard. In general, if 10% of a lake was targeted with 2,4-D at 4.0 ppm ae, the whole-lake equilibrium concentration would be approximately 10% of that rate or 0.4 ppm ae. The target 2,4-D concentration for large-scale EWM treatments is typically between 0.250 and 0.400 ppm ae understanding that the exposure time would be dictated by herbicide degradation and be maintained for 7-14 days or longer. Therefore, spot treatments that approach 10% of a lake's area will become large-scale treatments.

Large-scale treatments have become more widely utilized by many lake managers (and public sector regulatory partners) as they impact the entire EWM population at once. This minimizes the repeated need for exposing the lake to herbicides as is required when engaged in an annual spot treatment program. 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 3.4-13). Some large-scale treatments have been effective at reducing EWM populations for 5-6 years following the application.

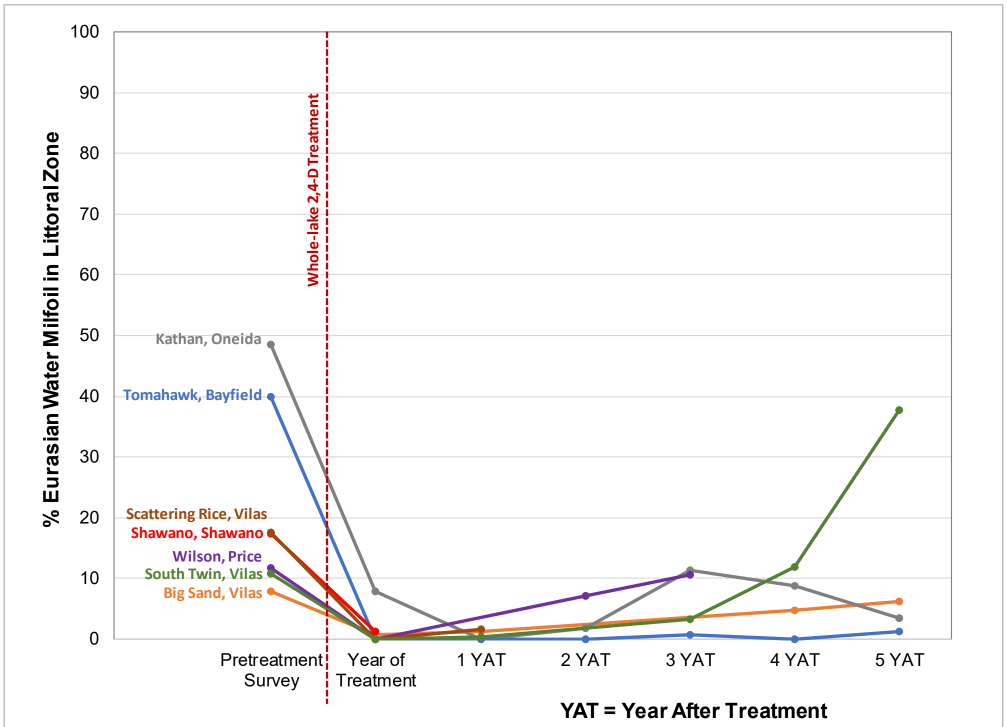


Figure 3.4-13. Littoral frequency of occurrence of EWM in lakes managed with large-scale 2,4-D treatments.

Predicting success (EWM control) and native plant impacts from whole-lake treatments may also be better understood than for spot treatments. Some native plants are quite resilient to this herbicide use pattern, either because they are inherently tolerant of the herbicide or they emerge later in the year than when the herbicide was 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.

It is also important to note that US EPA registration of aquatic herbicides typically requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with 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).

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 0.5 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). While the herbicide concentrations and exposure times that caused the larval fathead minnow survival rates to decline in the study are much higher and longer than would be targeted for large-scale treatments, some 2,4-D treatments that accidentally exceeded the target rates could have approached the target concentrations tested by DeQuattro and Karasov (2015).

Big Sand Lake Treatment History

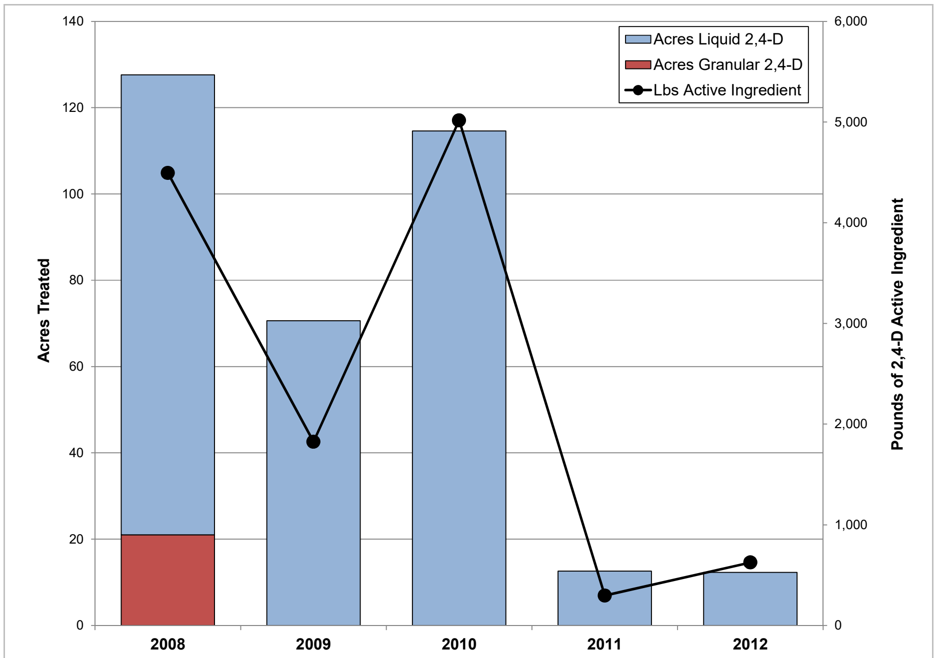


Figure 3.4-14. Big Sand Lake historical EWM treatment acreage and herbicide quantity.

The 2008, 2009, 2011, and 2012 treatments that occurred on Big Sand Lake were designed using the spot-treatment strategy where specific areas of EWM were targeted for control. However, in 2008, the idea of whole-lake treatments was not yet on the radar of lake managers. As will be discussed, approximately 130 acres of Big Sand Lake were applied with either liquid or granular 2,4-D in 2008, and with the knowledge gained since then, it is believed this treatment functioned as a whole-lake treatment, with herbicide dissipating throughout the entire epilimnion of the water body. The 2010 treatment was designed using the whole-lake treatment strategy. In 2008, 21 acres were applied with the ester formulation of granular 2,4-D (Navigate®), while the remaining 106.6 acres were applied with the amine formulation of liquid 2,4-D (Weedar®) (Figure 3.4-14). From 2009-2012, the treatment areas were applied with the amine liquid formulation of liquid 2,4-D (DMA IV® or Weedestroy®). Using the definition for large-scale treatments discussed previously, the 2008, 2009, and 2010 treatments in Big Sand Lake would be considered large-scale, while the 2011 and 2012 were considered small-scale.

Prior to 2010, formal monitoring of these treatments was not completed, but the 2008 treatment appeared to be highly successful at reducing EWM. A smaller 70-acre treatment was completed in 2009; however, a survey by Barb Gajeweski revealed considerable amounts of EWM throughout the lake, indicating it had quickly rebounded following the 2008 and 2009 treatments (Map 6). Over the winter of 2009-2010, Onterra designed a treatment strategy for 2010 where approximately 115 acres would be targeted with a 2,4-D at 2.1 ppm acid equivalent (ae), a standard spot-treatment use rate at the time. The application of 2.1 ppm over the treatment areas was hypothesized to only result in 0.073 ppm ae lake-wide. This would be too low to have whole-lake implication and the success of the 2010 treatment on Big Sand Lake was theorized to be reliant on the first few days of higher concentration within the treatment areas.

Herbicide monitoring following the 2010 found that the mean 0-7 days after treatment (DAT) 2,4-D concentration was 0.169 ppm acid equivalent (ae) and the initial concentration was closer to 0.205 ppm ae based on y-intercept of half-life analysis (Figure 3.4-15). The average 1 day after treatment 2,4-D concentration was 0.23 ppm ae, however some of the sites were in the areas where herbicide was applied (approx. 0.8 ppm ae) and other were in the center of the lake where herbicide levels were undetectable.

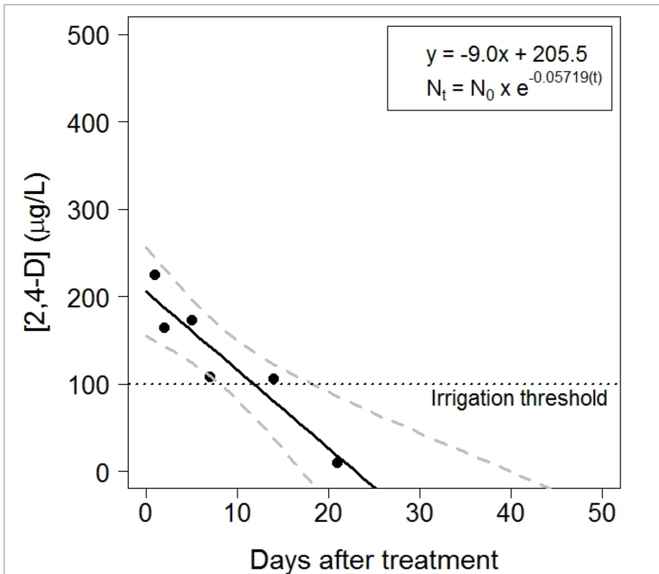


Figure 3.4-15. 2010 Big Sand Lake 2-4,D half-life analysis Data provided by and used with permission from the WDNR Bureau of Science Services.

While all the factors that resulted in this higher herbicide concentration are unknown, it is suspected that a weak thermocline at approximately 12-13 feet may have been present which limited the vertical dissipation of the herbicide only within this layer. Perhaps related to the high primary production within Big Sand Lake, the 2,4-D half-life of the 2010 treatment was only 11.5 days.

Post-treatment surveys found this treatment to be highly effective at reducing EWM, with the occurrence of EWM decreasing by 96% when compared to 2006, and 91% when compared to the spring of 2010 prior to the treatment (Map 7). To continue the success of reducing EWM on Big Sand Lake, spot-treatments of remaining EWM colonies were conducted in 2011 and 2012. Up until late-2010, 2,4-D treatments were conducted based upon surface acreage of the treatment area, 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 2,4-D to be formulated based upon the volume of water in which the herbicide application would occur.

Approximately 12.6 acres of EWM were treated with the liquid formulation of 2,4-D at a concentration of 2.5 ppm ae in 2011, and this treatment was successful as no EWM could be located within these areas following the treatment (Map 8). In addition, the 2011 whole-lake point-intercept survey found the lake-wide occurrence of EWM to still be very low. In 2012, approximately 12.3 acres were also applied with the liquid formulation of 2,4-D, but at an increased concentration of 3.0 ppm ae (Map 9). Because the 2012 treatment areas were smaller than those treated in the past, the application rate was increased. While the 2011 treatment saw success, the 2012 treatment, to the surprise of those involved, did not meet expectations (Map 9 and Map 10). In addition, EWM increased in occurrence around the lake in 2012, though not to levels seen prior to the 2010 treatment.

In 2014, the littoral occurrence of EWM had increased, but to a relatively low littoral occurrence of 4.7% (Map 11). The littoral occurrence of EWM in 2015 and 2016 was 6.3 and 4.3%, respectively, and is not statistically different from its occurrence in 2014. These data indicate that the EWM population in Big Sand Lake has remained stable over the period from 2014-2016. Eurasian water milfoil mapping surveys were not completed in 2015 and 2016; however, given its littoral frequency was not statistically different from 2014, the acreage of colonized EWM was likely similar as well.

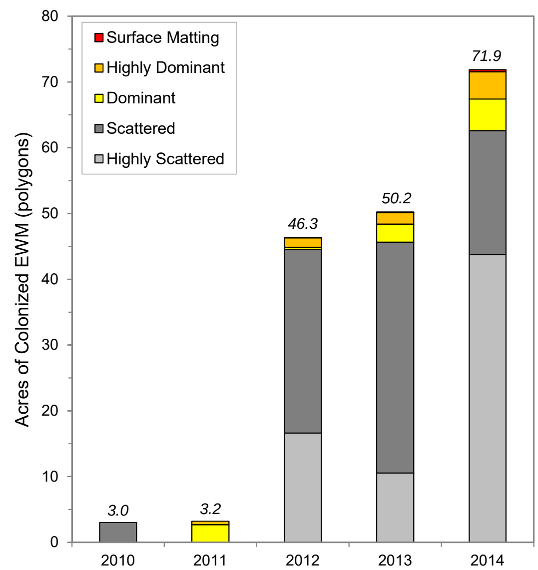


Figure 3.4-16. Big Sand Lake acreage of colonized EWM from 2010-2014. Created using data from Onterra Late-Summer Peak-Biomass Surveys.

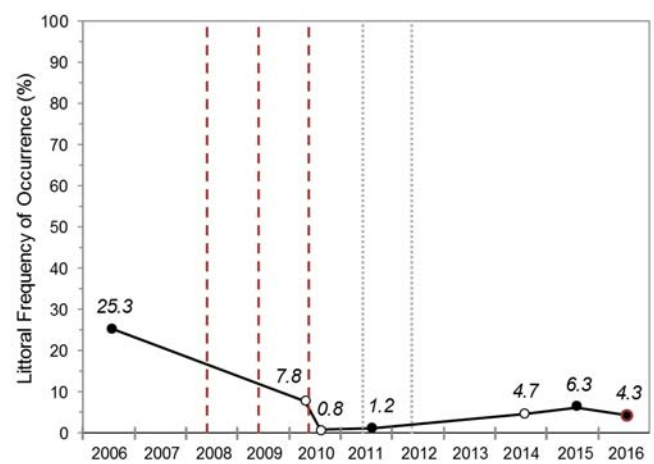


Figure 3.4-17. Big Sand Lake EWM littoral frequency of occurrence from 2006-2016. Open circles represent a statistically valid change in occurrence from previous survey (Chi-Square $\alpha = 0.05$). Red-dashed lines indicate large-scale herbicide management and grey lines indicate small-scale herbicide management.

Curly-leaf pondweed

As discussed in the previous section, curly-leaf pondweed (*Potamogeton crispus*; CLP) was recorded during the WDNR's 2006 whole-lake point-intercept survey. However, a CLP specimen was never collected/vouchered and it is likely that the presence of CLP was recorded in error on the field data sheet. Curly-leaf pondweed has not been observed in Big Sand Lake during any of the subsequent surveys since 2006, including a survey completed by Onterra in June of 2014 with a specific goal of locating potential occurrences of CLP.

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Big Sand Lake. The goal of this section is to provide an overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc.) that were brought forth by the BSLPOA stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2015 & GLIFWC 2014A and 2014B).

Big Sand Lake Fishery

Big Sand Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was ranked as the second highest important or enjoyable activity on Big Sand Lake (Question #14). Approximately 59% of these same respondents believed that the quality of fishing on the lake was "Good" to "Excellent" (Question #11); however, 41% of these respondents believed that the fishing had gotten "Much worse" or "Somewhat worse" in the lake, while 28% believe the fishing has "Remained the same" (Question #12). Respondents selected crappie, bluegill/sunfish and yellow perch as the most popular species they pursue, though largemouth bass, walleye and smallmouth bass were also popular options, as was "All fish species" (Question #10).

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 Big Sand Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

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

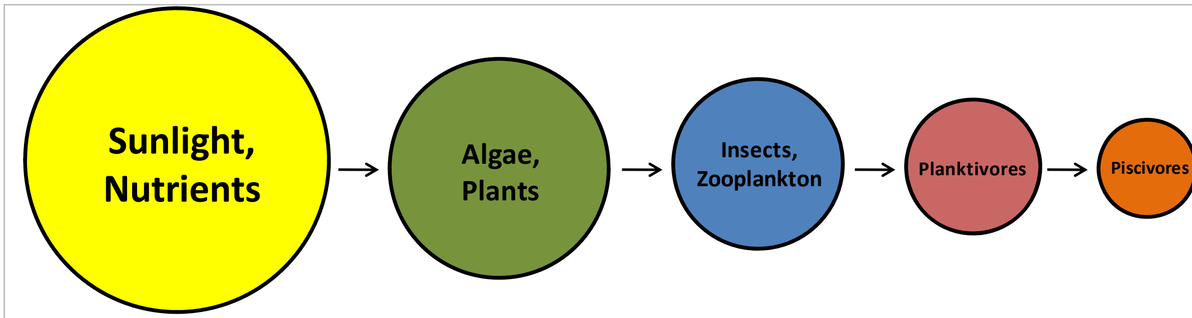


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Big Sand Lake 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 Big Sand 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 popular game fish that are present in the system.

Table 3.5-1. Gamefish present in the Big Sand Lake with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
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
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
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass	*Micropterus dolomieu*	13	Mid-May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye	*Sander vitreus*	18	Mid-April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Big Sand Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-2). Big Sand 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" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish).

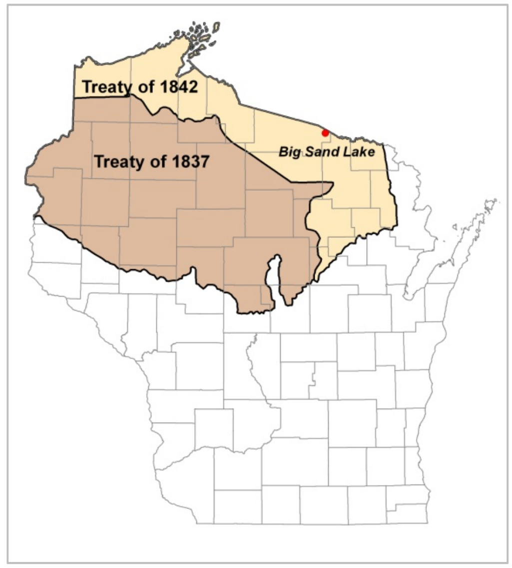


Figure 3.5-2. Location of Big Sand Lake within the Native American Ceded Territory (GLIFWC 2014A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level". Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

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 2014B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly 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. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye and muskellunge comprise the vast majority of the open water spear fish harvest. Records indicate that members of the Mole Lake tribe have harvested walleye since 1990 through this open water spearing season. (Figure 3.5-3). One common misconception is that the spear harvest targets the large spawning females. Tribal spearers may only take two walleyes over 20 inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2014B). This regulation limits the harvest of the larger, spawning female walleye.

The relationship between the safe harvest number, declaration and actual harvest is displayed for walleye (Figure 3.5-3) and muskellunge (Figure 3.5-4). Once a safe harvest number is set for a given lake, tribal leaders may declare a quota of fish they may spear in the upcoming season. From 1990 to 2014, tribal spearers have claimed a walleye declaration (quota) that is between 40% and 95% of the safe harvest value, averaging 73% during this time period. On average, Native American spear fishermen have harvested 68% of the declared quota on Big Sand Lake with respect to walleye.

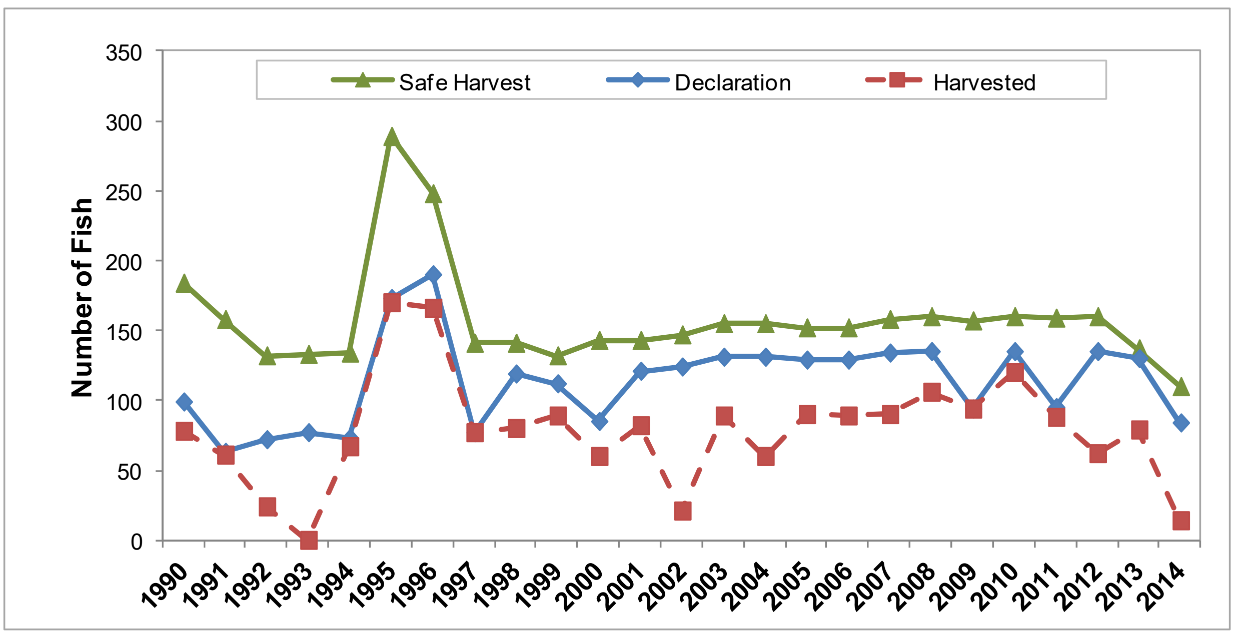


Figure 3.5-3. Native American walleye spear fishery statistics. Annual Native American walleye spear harvest statistics are summarized for 1990-2014. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

While between 9 and 15 muskellunge have been declared on Big Sand Lake since 1990, only four fish (1 in 2001, 2 in 2009, 1 in 2014) have been harvested during the open water spear fishery.

Big Sand Lake Substrate and Near Shore Habitat

Just as forest wildlife require proper trees and understory growth to flourish, fish prefer certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Indeed, lakes with primarily a silty/soft substrate and much 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.

According to the point-intercept survey conducted by Onterra in 2014 on Big Sand Lake, 37% of the point-intercept locations in the littoral zone contained sand, 57% were classified as muck and 6% were classified as rock. Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

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.

Big Sand Lake Regulations and Management

Because Big Sand Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. As of 2015, there is a three fish bag limit for walleye for lakes in the ceded territory. Additional regulations for harvesting walleye from Big Sand Lake are listed in Table 3.5-2. Because Big Sand Lake is located within the northern region of Wisconsin, special regulations may occur that differ from those in other areas of the state. For example, Big Sand Lake is in the northern large and smallmouth bass management zone; the northern zone has a catch and release only season occurring through May and part of June. Table 3.5-2 displays the 2016-2017 regulations for species that may be found in Big Sand Lake. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.5-2. WDNR fishing regulations for Big Sand Lake, 2016-2017.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25, however only 5 or fewer can be bluegill/pumpkinseed over 7”
Largemouth bass	May 7 to March 5	The minimum length limit is 14" and the daily bag limit is 5 (in combination with smallmouth bass).
Smallmouth bass	May 7 to June 17	Catch and release only
	June 18 to March 5	The minimum length limit is 14" and the daily bag limit is 5 (in combination with largemouth bass).
Northern pike	May 7 to March 5	No minimum length limit and the daily bag limit is 5.
Muskellunge	May 28 – November 30	The minimum length limit is 50” and the daily bag limit is 1.
Walleye, sauger, and hybrids	May 7 to March 5	The minimum length is 15”, but fish between 20”-24” may not be kept, and only one fish over 24” is allowed. Daily bag limit is 3 fish.
Bullheads	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.

Big Sand Lake is currently managed by the WDNR as a panfish, largemouth bass and muskellunge fishery. The lake is well known for its panfishing. The WDNR is examining several bag/size limit panfishing regulation changes, in hopes of providing better quality panfishing on Wisconsin lakes. During a three year social study, fisheries biologists and social scientists with the WDNR examined angler feedback regarding panfish harvest and angling goals. The results of this study indicate that Wisconsin panfish anglers are not interested in sweeping changes to regulations, but are interested in addressing specific lakes with overharvest issues. Fisheries biologists have proposed various regulation options which would seek to increase panfish size on 95 lakes across the state. Regional WDNR Fisheries Biologist, Steve Gilbert, indicated to the BSLPOA that the following regulation was being considered for Big Sand Lake:

> *“A total of 25 panfish but no more than five of the sunfish (bluegill and pumpkinseed) may be over 7” (25/5 over 7”).”*

The BSLPOA supported the potential rule change. While Big Sand Lake was identified as a potential candidate for the Panfish Study, it was not included in the final listing of lakes that would be included. During the Panfish Study regulation development process, WDNR staff raised some concerns about having anglers measure panfish. As a result, the committee modified the proposed regulations to the following three options

1. *“A total of 25 panfish but no more than 10 of any one species (25/10)”*
2. *“A total of 15 panfish but no more than 5 of any one species during May and June (15/5 seasonal) – 25 panfish the rest of the year”*
3. *“A total of 15 panfish but no more than 5 of any one species (15/5)”*

Although Big Sand Lake is not included in the Panfish Study, Mr. Gilbert believed that a panfish regulation change would be good for Big Sand Lake. And with the BSLPOA already supporting the originally proposed rule change, it was put into effect starting in 2016. The WDNR would like to evaluate this regulation though fisheries surveys in approximately 6 to 8 years.

The WDNR stocked the lake with walleye periodically in the 1970's, 80's 90's and 00's, first as fingerlings, then fry, then as small fingerlings (Table 3.5-3). The WDNR discontinued stocking in the lake after determining that the lake lacked the spawning habitat to produce recruiting walleye population of any kind. The BSLPOA continues to stock large fingerling walleye through a private permit to provide this angling opportunity. In 2012, the WDNR estimated the adult walleye population to be roughly 953 fish, or 0.7 fish per acre, which is considered low. A 1994 study estimated the walleye population at 1.7 fish per acre. Steve Gilbert, WDNR fisheries biologist, believes that lack of adequate spawning habitat and unsuccessful recruitment (natural or from stocked fish) has kept this population from sustaining itself (personal communication, 2015). As stated earlier, walleye prefer gravel/rock substrate for spawning. The lake does hold some spawning habitat on the southeast side (Steve Gilbert – personal communication and Map 5) however this habitat type has not been able to produce recruitment to a detectable level.

Muskellunge stocking has taken place in Big Sand Lake, primarily in the 1970's, mid 1980's and 1990's (Table 3.5-3). Recently (2013 and 2015), the WDNR began stocking large fingerling muskellunge at 0.25 fish per acre to bolster this population. The lake has minimal natural recruitment for this species as well, but WDNR biologist believe stocking can produce a quality fishery for this species.

Table 3.5-3. WDNR fish stocking data for Big Sand Lake (WDNR 2015). 2012-2014 were privately stocked by BSLPOA.

Year	Species	Age Class	# Stocked	Avg. Length (inches)
1974	Muskellunge	Fingerling	1,500	7
1977	Muskellunge	Fingerling	2,777	7
1984	Muskellunge	Fingerling	1,500	11
1985	Muskellunge	Fingerling	1,000	12
1990	Muskellunge	Fingerling	1,400	11
1991	Muskellunge	Fingerling	560	11
1992	Muskellunge	Fingerling	700	11
1993	Muskellunge	Fingerling	700	10
1996	Muskellunge	Fingerling	1,400	10.7
1998	Muskellunge	Large fingerling	1,400	12.3
2000	Muskellunge	Large fingerling	1,400	9.9
2013	Muskellunge	Large fingerling	352	9.2
2015	Muskellunge	Large fingerling	356	11.8
1974	Walleye	Small fingerling	13,500	3
1976	Walleye	Small fingerling	15,000	3
1985	Walleye	Small fingerling	72,380	2.33
1987	Walleye	Small fingerling	210,000	2
1989	Walleye	Small fingerling	90,075	2.33
1991	Walleye	Small fingerling	35,152	2.2
1992	Walleye	Fry	37,284	2
1994	Walleye	Fry	400,000	0.2
1995	Walleye	Small fingerling	70,944	2.38
1999	Walleye	Small fingerling	70,021	1.7
2001	Walleye	Small fingerling	70,044	1.85
2003	Walleye	Small fingerling	70,902	1.6
2005	Walleye	Small fingerling	35,200	1.6
2012	Walleye	6-7 inches	1,350	n/a
2013	Walleye	6-7 inches	2,750	n/a
2014	Walleye	6-7 inches	3,000	n/a

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Big Sand Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian water milfoil.
3) Collect sociological information from Big Sand Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

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

Big Sand Lakes water quality is excellent, with low measured phosphorus, low free-floating algae (measured as chlorophyll-a), and high water clarity. These favorable conditions are a result of Big Sand Lake's overall watershed and the condition of near-shore properties. The watershed is relatively small, being only three times the size of Big Sand Lake. Also, the land cover types of the watershed are those that contribute the least amount of phosphorus to the lake. Almost 80% of Big Sand Lake's shoreland is in a natural/undeveloped, or developed-natural condition. These are the shoreland types that provide the largest nutrient buffering capabilities, as well as providing the greatest habitat for aquatic and terrestrial wildlife. While Big Sand Lake contains less coarse woody habitat than pre-European settlement, it did contain approximately 9 coarse woody habitat pieces per shoreland mile. This is not dissimilar from other lakes in the area, many of which have even more severely reduced coarse woody habitat present within them.

Even with Big Sand Lake's excellent water quality and fairly undeveloped shoreline, the BSLPOA are attempting to start a positive trend to further improve some of the more-urbanized shorelands around the lake. This will start by finding approximately three landowners and may have interest in conducting shoreland restoration activities. Once these people have been identified, restoration design plans will be worked up for the properties so that storm water will be maximally retained on the property and native plants will be planted and encouraged to thrive. The designs will be shared with the BSLPOA members so they have better expectations of what a shoreland restoration project may look like on their property. And if the property owners conduct the restoration projects as designed, they can further serve as a demonstration site for other lake residents.

Because Big Sand Lake has a relatively small watershed, the impact of low precipitation can have large impacts on Big Sand Lake's water levels. On average, WVIC is able to stay within their water level management's operation range. However, years with low precipitation pose a challenge to keep water levels above the minimum level and still have sufficient discharge as mandated to sustain the trout fishery and habitat below the dam. WVIC is in the process of reviewing their water level operation plan and may have minor impacts of the water levels on Big Sand Lake.

The BSLPOA hopes to improve the walleye fishery of the lake. Because the lake contains little prime walleye spawning habitat, the WDNR fisheries biologist believes that unsuccessful recruitment has kept the walleye population from being able to sustain itself and therefore they do not recommend stocking. However, through a private permit, they have allowed the BSLPOA to stock approximately 7,000 large fingerling walleye from 2012-2014. The BSLPOA has put its stocking program on hold until it can determine if this large effort is making a difference or not through studies that are hope to occur during the fall of 2016,

As for many lake groups in this region of Wisconsin, Eurasian water milfoil weighs heavy on their minds. Big Sand Lake was one of the first lakes in the area to contain EWM and at one point, had one of the largest populations of EWM in the area. After a series of herbicide controls, the population was driven down to a level where small herbicide spot treatments are not likely to be effective. At the low EWM population level, the Big Sand Lake ecosystem is likely not being heavily impacted by EWM, nor are the lake users being hampered of their activities. The BSLPOA has taken an approach many area lakes have also taken; tolerate the EWM population until it reaches levels that are more likely impacting the integrity of the ecosystem and interfering with lake user's ability to recreate and enjoy the lake. Once it reaches that threshold, initiate a whole-lake herbicide treatment strategy to reset the EWM population. Whole-lake treatments may only be necessary every 7-10 years to keep a maintained EWM population within the lake. This allows time for the BSLPOA to raise funds for the future treatment, as well as the Big Sand Lake ecosystem time to rebound from any secondary impacts the herbicide treatment may have imposed.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the BSLPOA Planning Committee and ecologist/planners from Onterra. It represents the path the BSLPOA will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Big Sand 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 BSLPOA 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 (e.g. Education and Communication Committee, Water Quality Director/Committee, Invasive Species Committee, Shoreland Improvement Director/Committee). The BSLPOA 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: Increase BSLPOA'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:	BSLPOA Board of Directors – possibly formation of an Education and Communication Committee
Description:	Education represents an effective tool to address many lake issues. The BSLPOA regularly distributes quarterly newsletters and maintains a website (http://www.bigsandlakepoa.org/). 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 BSLPOA will also give consideration to the use of social media by having a Facebook® group page. This would further increase the association's ability to communicate with interested stakeholders by allowing them to post information and social messages, as well as building a sense of community. The BSLPOA will continue to make the education of lake-related issues a priority. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support.

	Example Educational Topics • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology • Zebra mussels and their role of increasing filamentous algae • Sedimentation • Boating safety (promote existing guidelines, recommendations, water patrol) • Noise, air, and light pollution • Shoreline habitat restoration and protection • Fireworks • Fishing regulations and overfishing • Minimizing disturbance to spawning fish
Action Steps:	
	See description above as this is an established program.

Management Action:	Continue BSLPOA's involvement with other entities that have responsibilities in managing (management units) Big Sand Lake
Timeframe:	Continuation of current efforts
Facilitator:	BSLPOA Board of Directors – possibly formation of an Education and Communication Committee
Description:	As outlined on the BSLPOA's website: "The Big Sand Lake Property Owners Association has been created to maintain and improve the environmental quality of Big Sand Lake. We strive to address issues that concern lake shore property owners and businesses that reside on or near our lake. As an association, we take pride in our lake and are dedicated to make the necessary efforts to preserve and promote the natural resources of Big Sand Lake." 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 BSLPOA 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 Phelps Chamber of Commerce	President (Renee Snook - phelpschamber @gmail.com	Provides information and networking related to the advancement of the Big Sand Lake community.	Once a year, or more as needed. May check website (http://www.phelpscofc.org/ for updates.	The Chamber of Commerce serves a valuable role in promoting local businesses, tourism, and community within the Big Sand Lake area.
Town of Phelps Lakes Committee	Chairman (Dave Roberts 715 545-2829)	Big Sand Lake falls within the Town of Phelps.	Once a year, or more as needed. May check website (http://townofphelps.com/town-lakes-committee-) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Vilas County Lakes & Rivers Association	President (Rollie Alger– president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	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 (Steve Gilbert – 715.358.9229)	Manages the fishery of Big Sand 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.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	BSLPOA 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 Long Lake.	Once a year, or more as issues arise.	General water-level communications.

Management Goal 2: Maintain Current Water Quality Conditions

<u>Management Action:</u>	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	BSLPOA Board of Directors – possibly formation of a Water Quality Director or Committee
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Water quality data is currently been collected by the Wisconsin Valley Improvement Corporation (WVIC) for a 3-year period, once every 10 years. The next sampling period will be conducted in 2020-2023. In addition to the WVIC's efforts, volunteer water quality monitoring has been completed annually by Big Sand Lake riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. Data has been collected through the advanced CLMN program in the past on Big Sand Lake. The Secchi disk readings and water chemistry 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. It is the responsibility of the current CLMN volunteer in conjunction with the BSLPOA Commissioners to coordinate new volunteers as needed. When a change in the collection volunteer occurs, Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
2.	CLMN volunteer and/or BSLPOA Commissioners would facilitate new volunteer(s) as needed
3.	Coordinator contacts Sandra Wickman (715.365.8951) to acquire necessary materials and training for new volunteer (s)

Management Goal 3: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Big Sand Lake

Management Action:	Manage EWM Population on Big Sand Lake with Herbicide Control Strategies
Timeframe:	Continuation of current effort
Facilitator:	BSLPOA Board of Directors – possibly formation of an AIS Committee
Description:	One of the most feasible methods of control Eurasian water milfoil on a lake-wide basis is through the use of herbicide applications - specifically, early-spring treatments. A stakeholder survey was sent to Big Sand Lake riparians during October-November 2014. The response rate was moderately low (35%), therefore the results *may* follow public opinion but cannot be interpreted as being a statistical representation of the population. Approximately 77.5% of stakeholder respondents indicated they believe aquatic plant control is need on Big Sand Lake by answering either *Definitely Yes* or *Probably Yes*, whereas approximately 6.5% of respondents did not feel aquatic plant control was needed by answering either *Definitely No* or *Probably No* (Appendix B, Question #23). Figure 5.0-1 shows the level of stakeholder respondent support for the responsible use of herbicide (chemical) control of aquatic plants on Big Sand Lake. The majority (64%) of respondents were supportive (pooled *Highly Support* and *Moderately Supportive*) of this technique, whereas just 19% were not supportive (pooled *Not Supportive* and *Moderately Unsupportive*). Approximately 17% of stakeholder respondents indicated they were *Neutral* or *Unsure* regarding the responsible use of herbicide methods to manage aquatic plants in Big Sand Lake. Figure 5.0-2 outlines the level of stakeholder respondent support for the previous phase of Eurasian water milfoil control on Big Sand Lake (2008-12) and well as future herbicide use to target the invasive plant moving forward. The stakeholder respondent data indicate a similar level of support for past and future herbicide use to control Eurasian water milfoil

Question 24: What is your level of support for the responsible use of Herbicide (chemical) Control on Big Sand Lake?

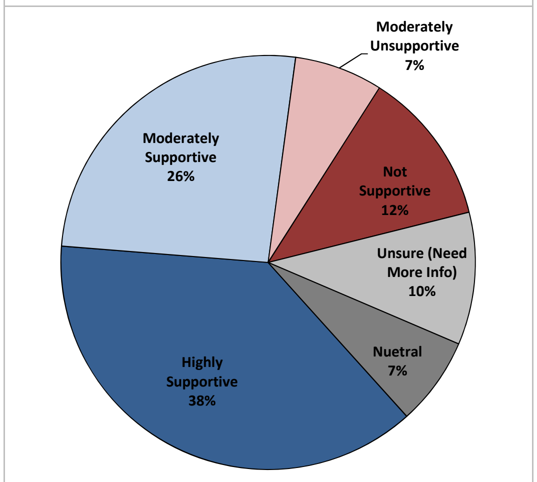


Figure 5.0-1. Select survey responses from the Big Sand Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

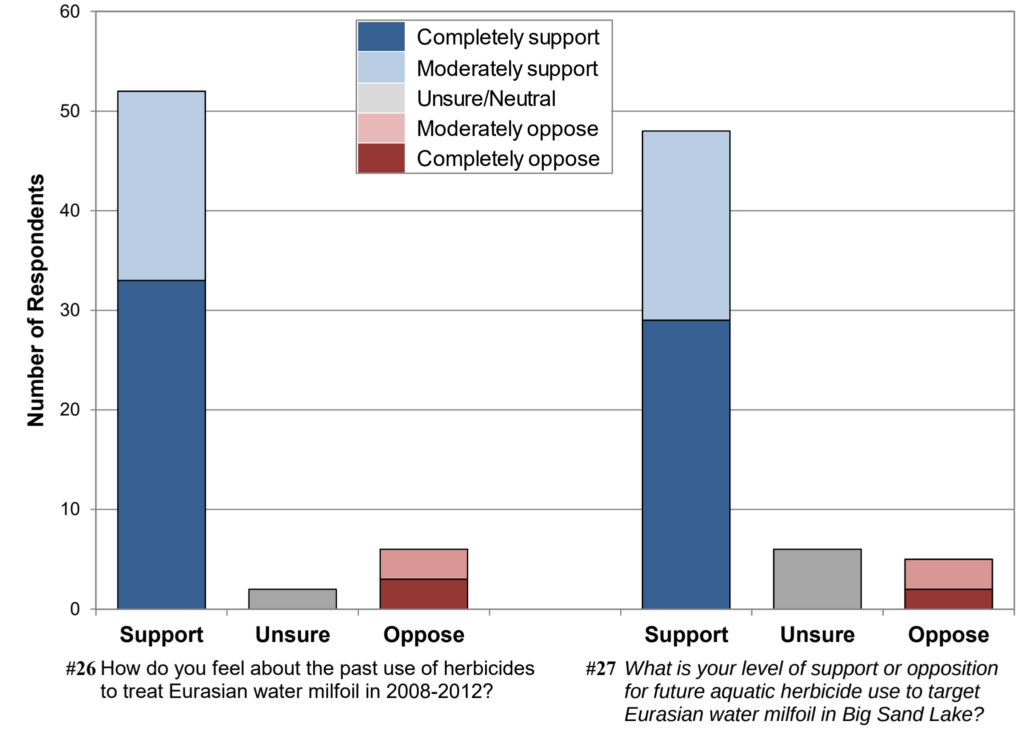


Figure 5.0-2. Select survey responses from the Big Sand Lake Stakeholder Survey – Question #26 & #27. Additional questions and response charts may be found in Appendix E.

Active Management Implementation Strategy: Due to the large and broad size of Big Sand Lake, past attempts at conducting spatially targeted "spot" treatments have been only marginally effective. The BSLPOA agree that use of herbicides to control EWM need to have more favorable and predictable results for the control action to be worth the risk of using herbicides. It is also understood that targeting the EWM on a lake-wide basis, similar to conducted in 2008 and 2010, will produce more predictable results. Prior to these efforts, EWM was observed in 25.3% of the lake's littoral zone. The 2014, 2015, and 2016 point-intercept surveys documented EWM in 4.7%, 6.8%, and 4.3% of the littoral zone, respectively.

As discussed within the *Background on Herbicide Application Strategy Subsection* of this report, EWM littoral frequency of occurrence of 10% is often used as a trigger to initiate a large-scale treatment. This is based in WDNR administrative code as well as treating 10% of a lake's littoral zone will have large-scale impacts. The BSLPOA had many discussions regarding the EWM Long Term Trends data and how even in unmanaged EWM populations, EWM frequencies can vary up and down from year to year. Because of that knowledge and the risk assessment of herbicide use, the BSLPOA chose to tolerate the reduced ecosystem services the lake provides (areas of reduced navigation and aesthetics) and select a higher threshold for when a whole-lake treatment will take place.

The BSLPOA will have annual point-intercept surveys conducted on Big Sand Lake to track the EWM population over time. Once the EWM population exceeds 15% littoral frequency of occurrence, the BSLPOA will initiate the planning and pretreatment steps necessary to conduct a whole-lake treatment on Big Sand Lake, likely utilizing 2,4-D at a standard epilimnetic dosing strategy (0.275 – 0.375 ppm ae). For reference, the 2010 whole-lake 2,4-D treatment likely started out at 0.205 ppm ae and had a 0-7 day after treatment average of 0.169 ppm ae. Continued investigations of whole-lake 2,4-D treatments prior to initiation of one on Big Sand may alter the accepted dosing range.

<u>Active Management Monitoring Strategy</u>:
A cyclic series of steps will be used to plan and implement the control efforts. The series includes conducting the following surveys during the *year prior to the treatment*, *year of the treatment*, and *year following the treatment*:

- A lake-wide mapping assessment of EWM completed while the plant is at peak growth stage (peak biomass).
- A detailed assessment of bathymetric data from the lake, potentially augmenting with an acoustic survey of the lake.
- Quantitative assessments of the native and non-native aquatic plant community of the lake utilizing point-intercept survey methodology.

During the *year of the treatment*, the project would include verification and refinement of the treatment plan immediately before control strategies are implemented. This potentially would include refinements of herbicide application areas, assessments of growth stage of aquatic plants, and documentation of thermal stratification parameters that influence the final dosing strategy.

Volunteer-based monitoring of temperature profiles would also be coordinated surrounding the treatment, as well as collection of post treatment herbicide concentration sample at multiple locations and sampling intervals.

The success criteria of a whole-lake treatment would be a 70% reduction in EWM littoral frequency of occurrence comparing point-intercept surveys from the *year prior to the treatment* to the *year after the treatment.* This means if the treatment occurs in 2020, the *year before treatment* would be 2019 and the *year after treatment* would be 2021. Regardless of treatment efficacy, a whole-lake treatment would not be conducted during the *year following the treatment*.

As shown in Figure 3.4-13 the EWM population is often greatly impacted the year of large-scale treatment and low EWM levels are maintained for 4-5 years following the control action. Many lake groups initiate a whole-lake herbicide strategy with the intention of implementing smaller-scale control measures (herbicide spot treatments, hand-removal) when EWM begins rebounding. Occasionally, the EWM rebounds in a fashion that does not lend well to these methods and the lake groups then tolerates the EWM to until it again exceeds the

	predefined threshold to trigger another whole-lake treatment. If the BSLPOA initiates a large-scale treatment that does not meet the success criteria, they will consider alternative chemical control use patterns for ecosystem restoration or possibly chemical or non-chemical control techniques for restoring localized areas to deliver higher ecosystem services. Appropriate implementation triggers and success criteria for these actions would need to be developed through an updated lake management planning effort. Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program will be sought to partially fund this control program. Specifically, funds would be applied for under the Established Population Control classification, currently on February 1st of each year. Based on the data collected over the three-year project, the BLPOA would revisit their management plan as it applies to EWM control and monitoring. Based upon the information gained during the multi-year control project, the BLPOA would update their management plan as appropriate. This may include targeting low-level EWM populations through coordinated volunteer and professional hand-harvesting efforts.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3.	Initiate control and monitoring plan.
4.	Update management plan to reflect changes in control needs and those of the lake ecosystem.

<u>Management Action:</u>	Continue Clean Boats Clean Waters watercraft inspections at Big Sand Lake public access location
Timeframe:	Continuation of current effort
Facilitator:	BSLPOA Board of Directors – possibly formation of an AIS Committee
Description:	Currently the BSLPOA monitors the public boat landing using training provided by the Clean Boats Clean Waters program. Big Sand Lake is an extremely popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional 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 Big Sand 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 Big Sand Lake (AIS monitoring, stakeholder education, etc.), paid watercraft inspectors would be sought to monitor the Big Sand Lake's single public boat landing. In 2014, the BSLPOA utilized approximately 200 hours of paid watercraft inspections through Vilas County's student intern program and plans to continue that level of commitment.
Action Steps:	
	See description above as this is an established program.

Management Goal 4: Enhance the Walleye Fishery on Big Sand Lake

Management Action:	Continue to work with WDNR fisheries managers to enhance the walleye population on Big Sand Lake
Timeframe:	Ongoing
Facilitator:	BSLPOA Board of Directors
Description:	Big Sand Lake is a popular fishing destination for panfish, muskellunge, and walleye. Typically, anglers target lakes that have walleye densities above 3 adult fish per acre. The most recent walleye population estimate (2012) found only 0.7 adult walleye per acre in Big Sand Lake. As discussed within the Fisheries Data Integration Section (3.5), the regional WDNR Fisheries Biologist (Steve Gilbert) attributes the low walleye population to the lack of spawning habitat and walleye recruitment. Mr. Gilbert also notes that previous stocking efforts of small fingerlings have not been successful. The BSLPOA hoped that stocking larger fingerlings (6-7 inches) would be more successful. The BSLPOA have funded private stocking of large fingerling walleyes between 2012 and 2014 at a rate of 1-2 fish per acre. In order to evaluate whether the large fingerling walleye stocking is effective, a fall electrofishing survey can be used to understand the amount of fish reaching certain age/size thresholds, particularly how many stocked fish make it to their second fall. While tentatively planned for 2015, the WDNR unfortunately ran out of time and resources to conduct a fall electrofishing survey. The WDNR attempted to conduct the survey in 2016 as well, but were unable due to unforeseen circumstances. The BSLPOA has put their *Adopt a Walleye* program on hold until they are able to assess their earlier stocking efforts through a fall electrofishing survey, potentially in fall 2017.

	A BSLPOA Director has recently been in contact with the Mole Lake Sokaogon Chippewa Tribe, whose community exercises their open water spearing rights of walleye on Big Sand Lake. While it appears that the walleye that are raised at Mole Lake's hatchery are not compatible for stocking into Big Sand Lake, the tribe may be able to provide other grant opportunities for stocking as well as assist the WDNR with electrofishing and walleye surveys.
Action Steps:	
	See description above as this is an established program.

Management Goal 5: Improve Lake and Fishery Resource by protecting and restoring the shoreland condition of Big Sand Lake

Management Action:	Investigate restoring highly developed shoreland areas around Big Sand Lake
Timeframe:	Initiate 2015.
Facilitator:	BSLPOA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
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. In 2014, the shoreland assessment survey indicated that 0.9 miles, or 9% of Big Sand Lake's 9.0-mile shoreline, consists of *urbanized* or *developed-unnatural* areas (Map 3). Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, the BSLPOA has decided to take the following steps to increase shoreland restoration on Big Sand Lake: 1. Educate riparians about the importance of healthy and natural shorelands. 2. Solicit 3-5 riparians to allow shoreland restoration and storm water runoff designs for their property. 3. The BSLPOA work with Vilas County (Quita Sheehan) or private entity to create design work. Small-scale WDNR grants may be sought to offset design costs. 4. Designs be shared with BSLPOA members to provide further education of shoreland restoration projects. 5. Move forward with implementing shoreland restoration per the designs that were developed for those riparians that wish to.

	Project funding would partially be available through the WDNR's Healthy Lakes Implementation Plan (see below). 6. Shoreland restoration sites will serve as demonstrations sites to encourage other riparians to follow same path of 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:	
1.	Recruit facilitator from Planning Committee
2.	Facilitator contacts the Vilas County Land and Water Conservation department to gather information on initiating and conducting shoreland restoration projects. If able, the County Conservationist would be asked to speak to BSLPOA members about shoreland restoration at their annual meeting.
3.	The BSLPOA would encourage property owners that have restored their shorelines to serve as demonstration sites.

Management Action:	Protect natural shoreland zones around Big Sand Lake
Timeframe:	Initiate 2015
Facilitator:	BSLPOA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	Approximately 6.4 miles (71%) of Big Sand 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 Big Sand Lake, and that these shorelands remain in a natural state.

	Map 3 indicates the locations of Natural and Developed-Natural shorelands on Big Sand Lake. Only about 12% of the lake's shoreland is part of the Chequamegon -Nicolet National Forest (11%) or the State of Wisconsin (1%). 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 BSLPOA in preserving the Big Sand 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. Properties along the western shoreline of Big Sand Lake and within the Thoroughfare Creek between Big Sand Lake and Long Lake are already protected by restrictive environmentally-conscious covenants as a part of the Poh-Wah-Gom Passage Association. 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.

<u>Management Action :</u>	Coordinate with WDNR and private landowners to expand coarse woody habitat in Big Sand Lake
Timeframe:	Initiate 2016
Facilitator:	BSLPOA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	BSLPOA stakeholders must realize the complexities and capabilities of the Big Sand 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 (3.3) and Fisheries Data Integration Section (3.5) discuss the benefits of coarse woody habitat in detail.
	
	The BSLPOA 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 Steve Gilbert (WDNR Fisheries Biologist) to gather information on initiating and conducting coarse woody habitat

	projects.
3.	The BSLPOA would encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

6.0 METHODS

Lake Water Quality

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

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

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

♦ indicates samples collected as a part of the Citizen Lake Monitoring Network.
■ indicates samples collected by volunteers under proposed project.
● indicates samples collected by consultant under proposed project.

Watershed Analysis

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

Aquatic Vegetation

Early Season Aquatic Invasive Species Survey

Surveys of curly-leaf pondweed were completed on Big Sand Lake during a June 18, 2014 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Big Sand Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on August 3 and 4, 2015. A point spacing of 80 meters was used resulting in 902 points.

Community Mapping

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

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium.

Treatment Monitoring

The methodology used to monitor the previous EWM herbicide treatments is included within the Non-Native Aquatic Plant Section.

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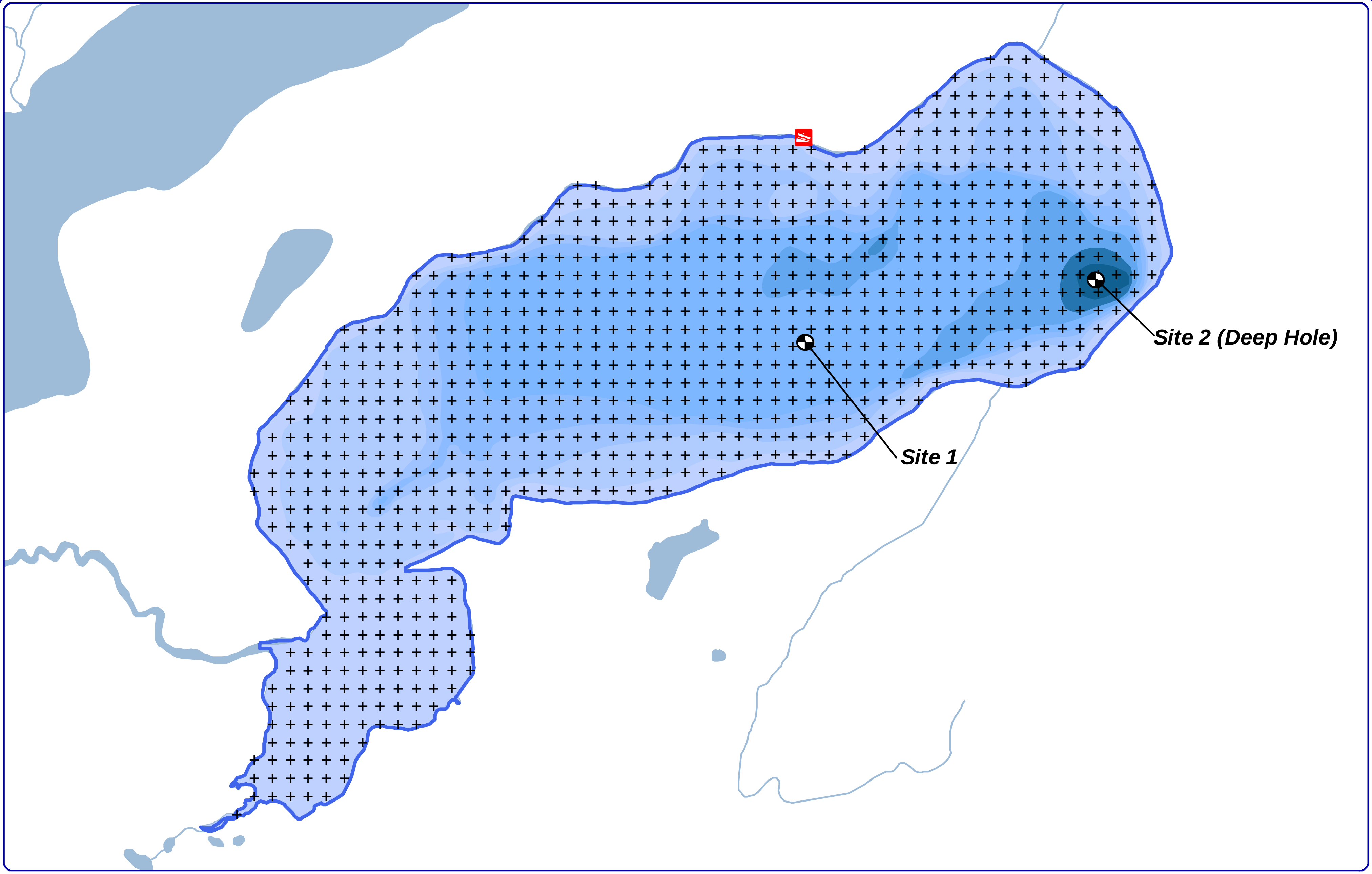

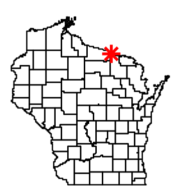

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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR. digitized by Onterra
Map Date: July 31, 2014
Filename: Map1_BigSand_Location.mxd

Legend

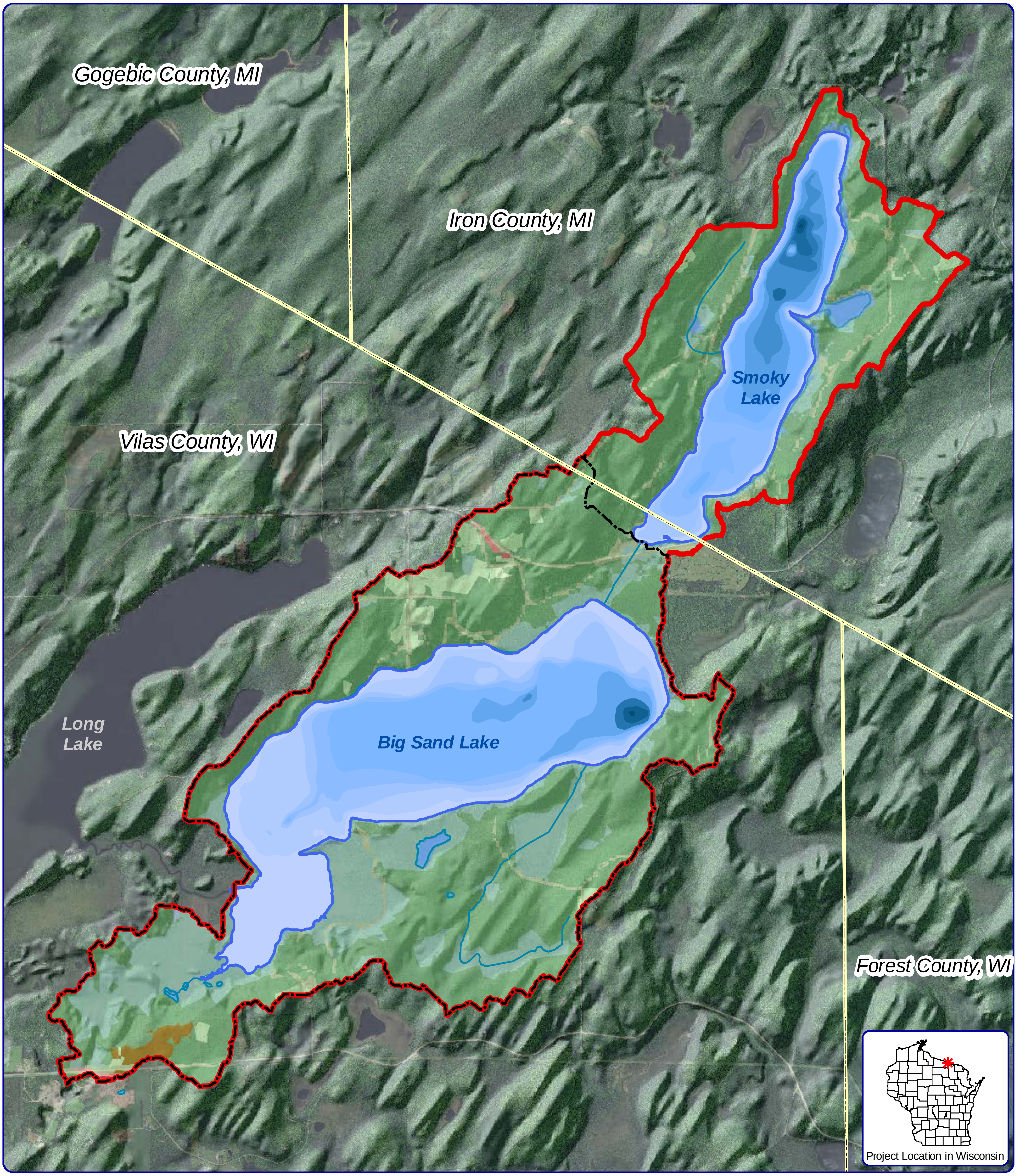
Big Sand Lake ~1,427 acres
WDNR Definition

Point-Intercept Survey Location
80-meter spacing, 902 total points

Water Quality Sampling Location

Public Access

Map 1
Big Sand Lake
Vilas County, Wisconsin
Project Location & Lake Boundaries



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Big Sand Lake Watershed Boundary
Big Sand Lake Direct Watershed Boundary

Land Cover Types

- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Rural Open Space
- Pasture/Grass
- Row Crops
- Rural Residential
- Urban - Medium Density
- Urban - High Density

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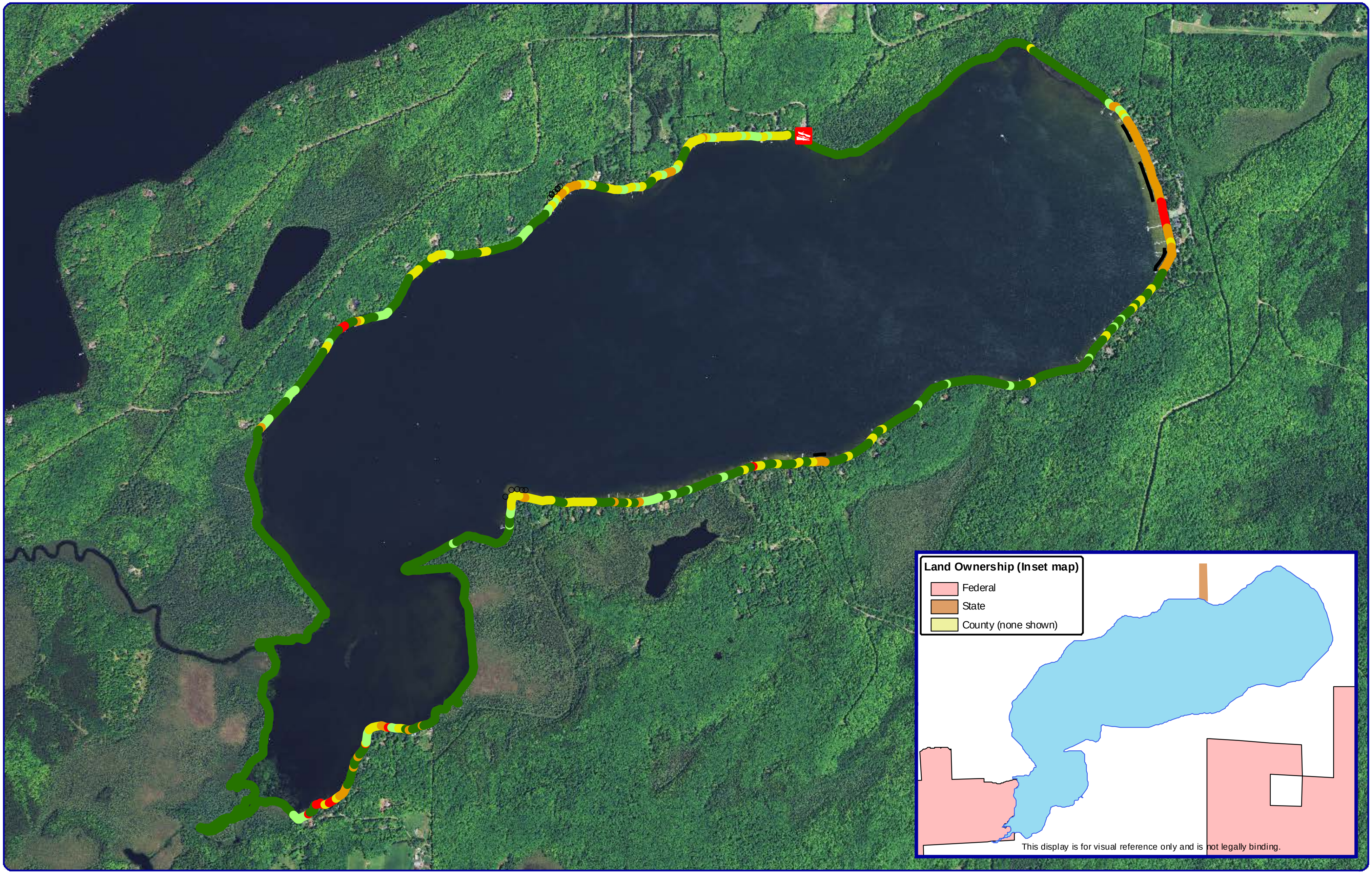
Sources:
Hydro: WDNR
Land Cover: NLCD, 2006
Orthophotography: NAIP, 2013
Map Date: July 31, 2014
Filename: Map2_BigSand_WS.mxd

Map 2
Big Sand Lake
Vilas County, Wisconsin

Watershed Boundaries & Land Cover Types



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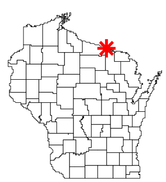
Sources:
Federal Lands: USDA Forest Service
Hydro, State Land and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2014
Map Date: October 7, 2014
Filename: Map3_BigSand_SCA.mxd



Project Location in Wisconsin

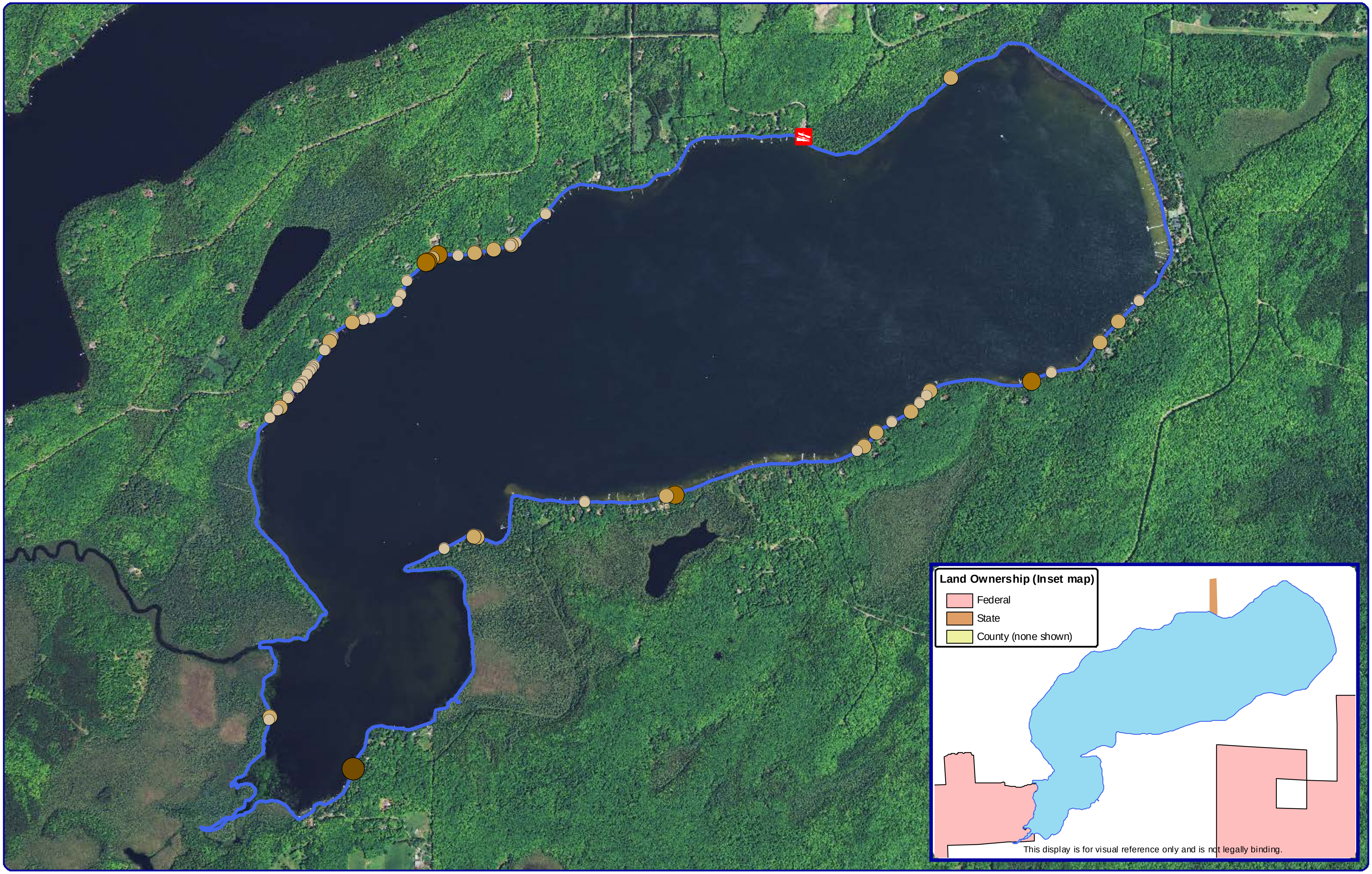
Legend

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall

- Masonry/Wood
- Rip-Rap

Map 3
Big Sand Lake
Vilas County, Wisconsin
2014 Shoreland Condition



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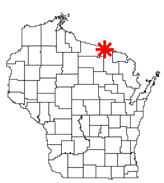
Sources:
Federal Lands: USDA Forest Service
Hydro, State Land and Roads: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plant Survey: Onterra, 2014

Map Date: October 3, 2014
Filename: Map4_BigSand_CWH.mxd

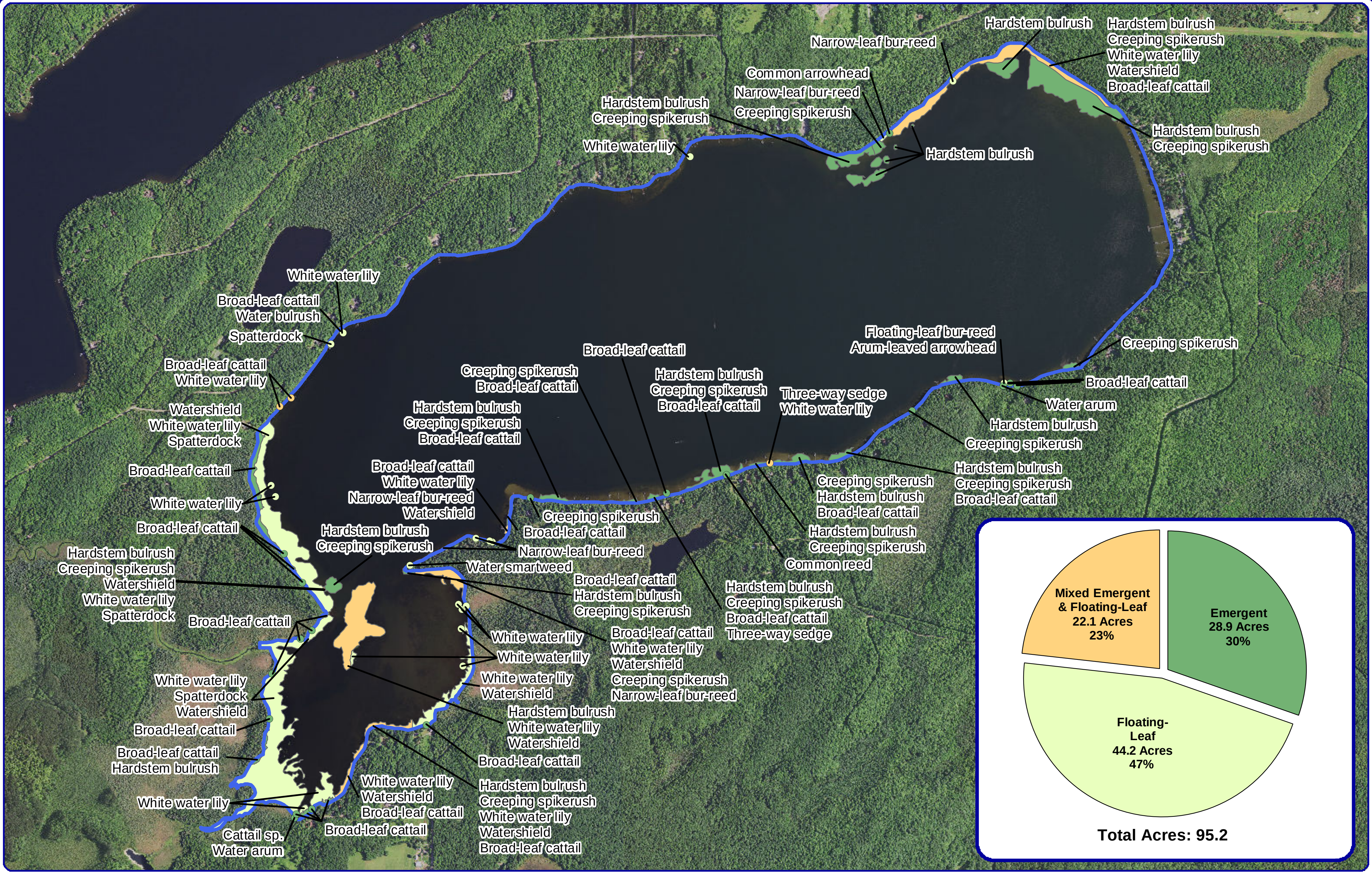


Project Location in Wisconsin

Legend

2-8 Inches	>8 Inches
No Branches	No Branches
Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches *(None)*
Full Canopy	Full Canopy *(None)*

Map 4
Big Sand Lake
Vilas County, Wisconsin
2014 Coarse Woody Habitat Survey Results



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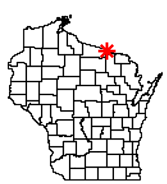
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR. digitized by Onterra
Map Date: July 31, 2014
Filename: Map5_BigSand_Comm.mxd



Project Location in Wisconsin

Legend

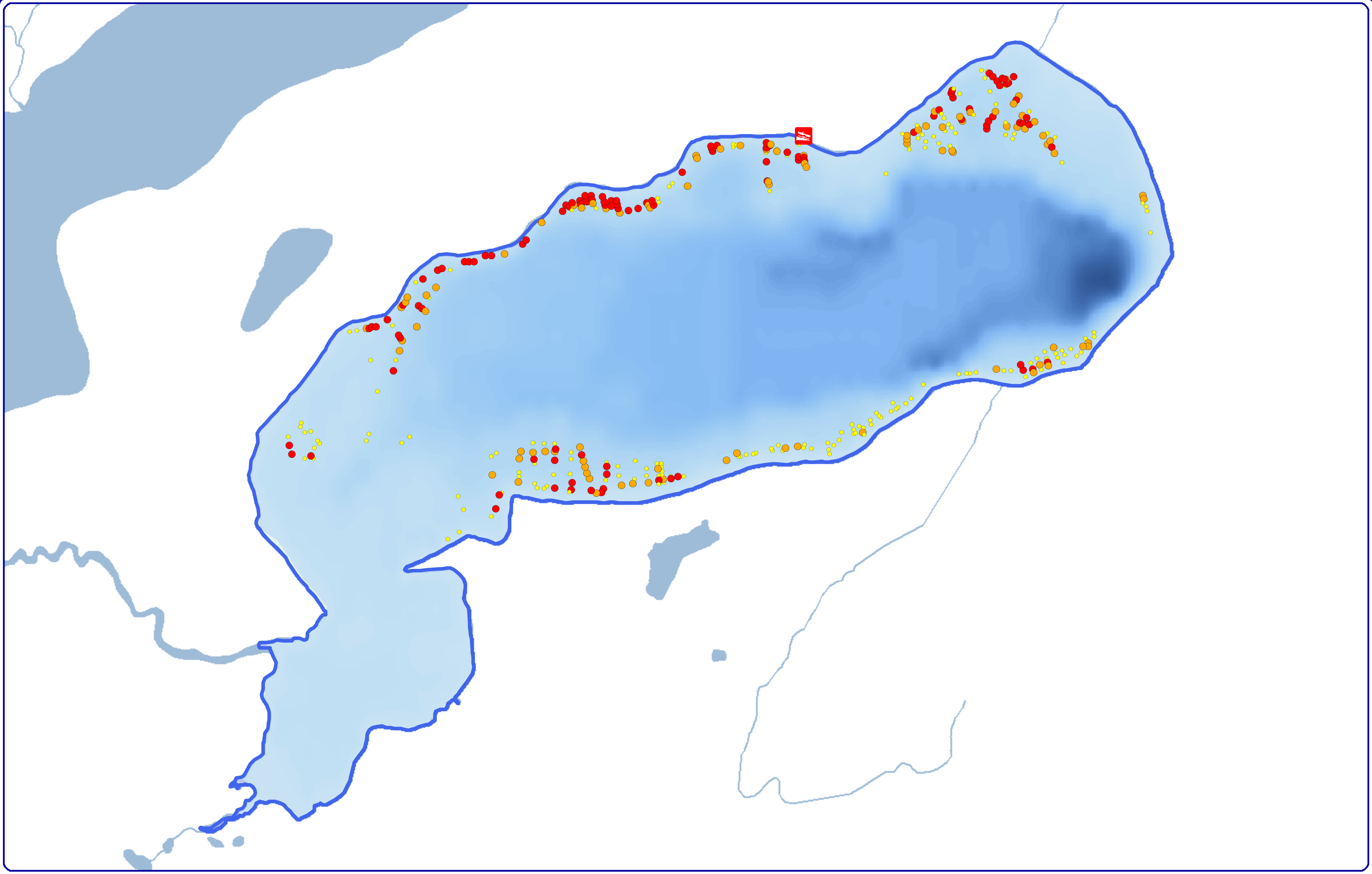
Small Plant Community	Large Plant Community
Emergent	Emergent
Floating-Leaf	Floating-Leaf
Mixed Emergent & Floating-Leaf	Mixed Emergent & Floating-Leaf

Map 5

Big Sand Lake

Vilas County, Wisconsin

2014 Emergent & Floating-leaf Aquatic Plant Communities



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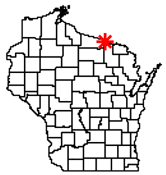
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR. digitized by Onterra
EWM Mapping: Barb Gajeweski, 2009
Map Date: July 31, 2014
Filename: Map6_BigSand_EWM_Sept09.mxd



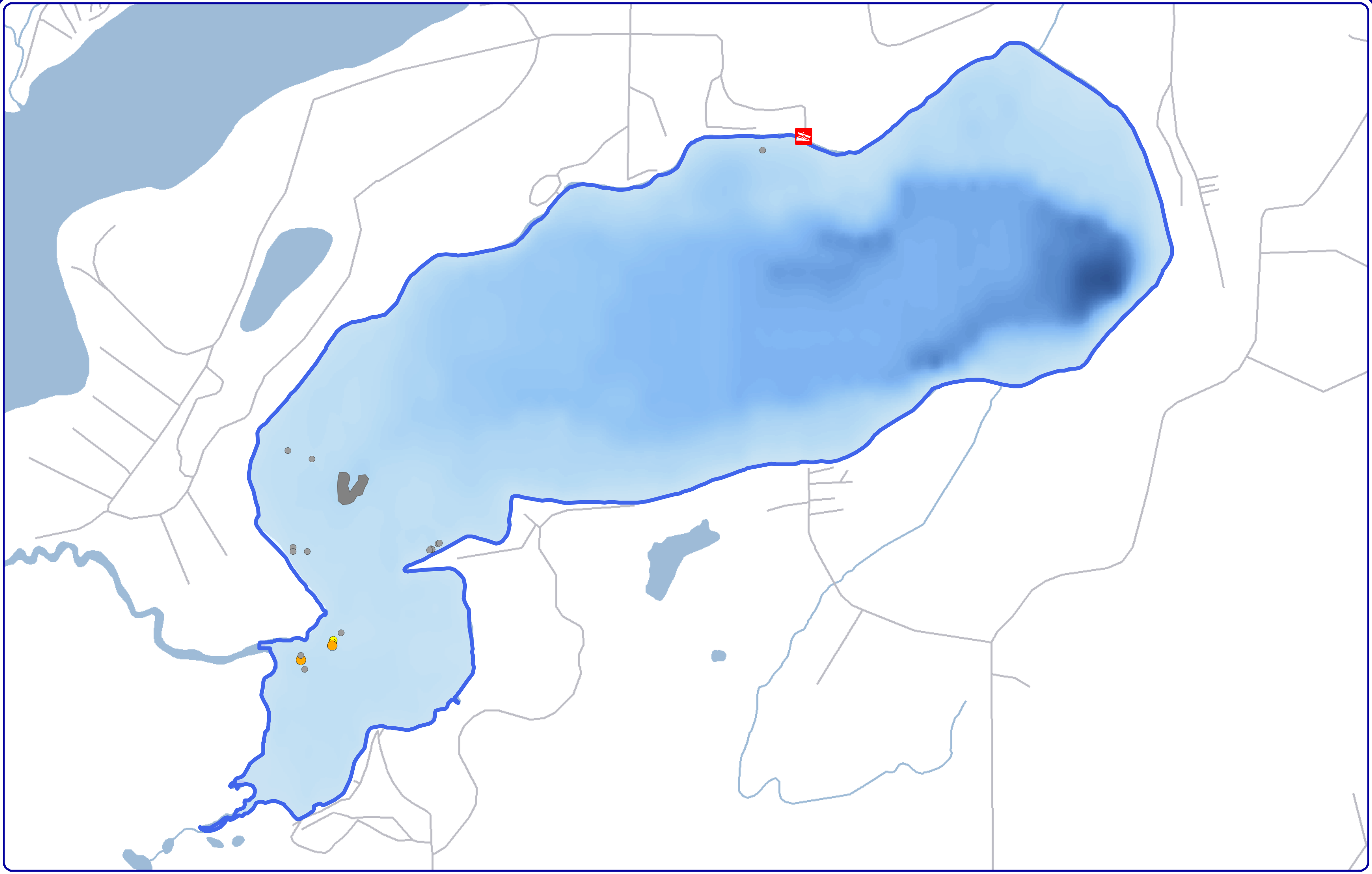
Project Location in Wisconsin

Legend

Eurasian Water Milfoil Locations
Surveyed by B.Gajewski, 09/06-07/09

- Density Rank 1 (1-10 plants)
- Density Rank 2 (10-20 plants)
- Density Rank 3 (20+ plants)

Map 6
Big Sand Lake
Vilas County, Wisconsin
2009 EWM Locations



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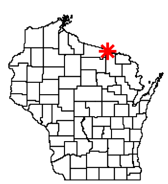

Project Location in Wisconsin

Legend

EWM (August 2010)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 7
Big Sand Lake
Vilas County, Wisconsin
2010 EWM Locations

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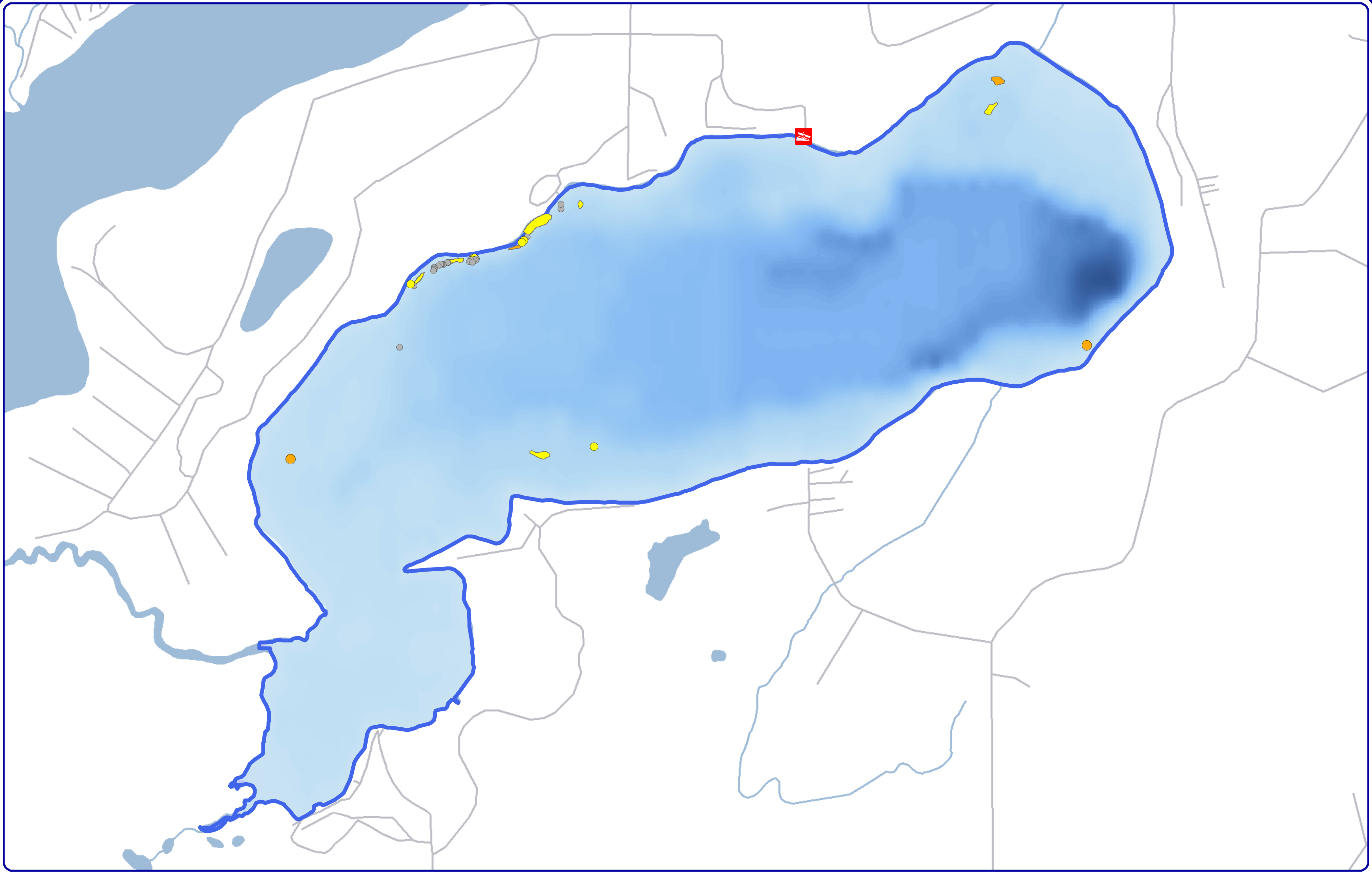
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR. digitized by Onterra
EWM Mapping: Onterra, 2010
Map Date: July 31, 2014
Filename: Map7_BigSand_EWM_Aug10.mxd



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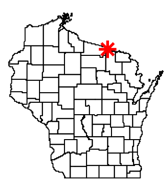
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Mapping: Onterra, 2011
Map Date: July 31, 2014
Filename: Map8_BigSand_EWM_Aug11.mxd



Project Location in Wisconsin

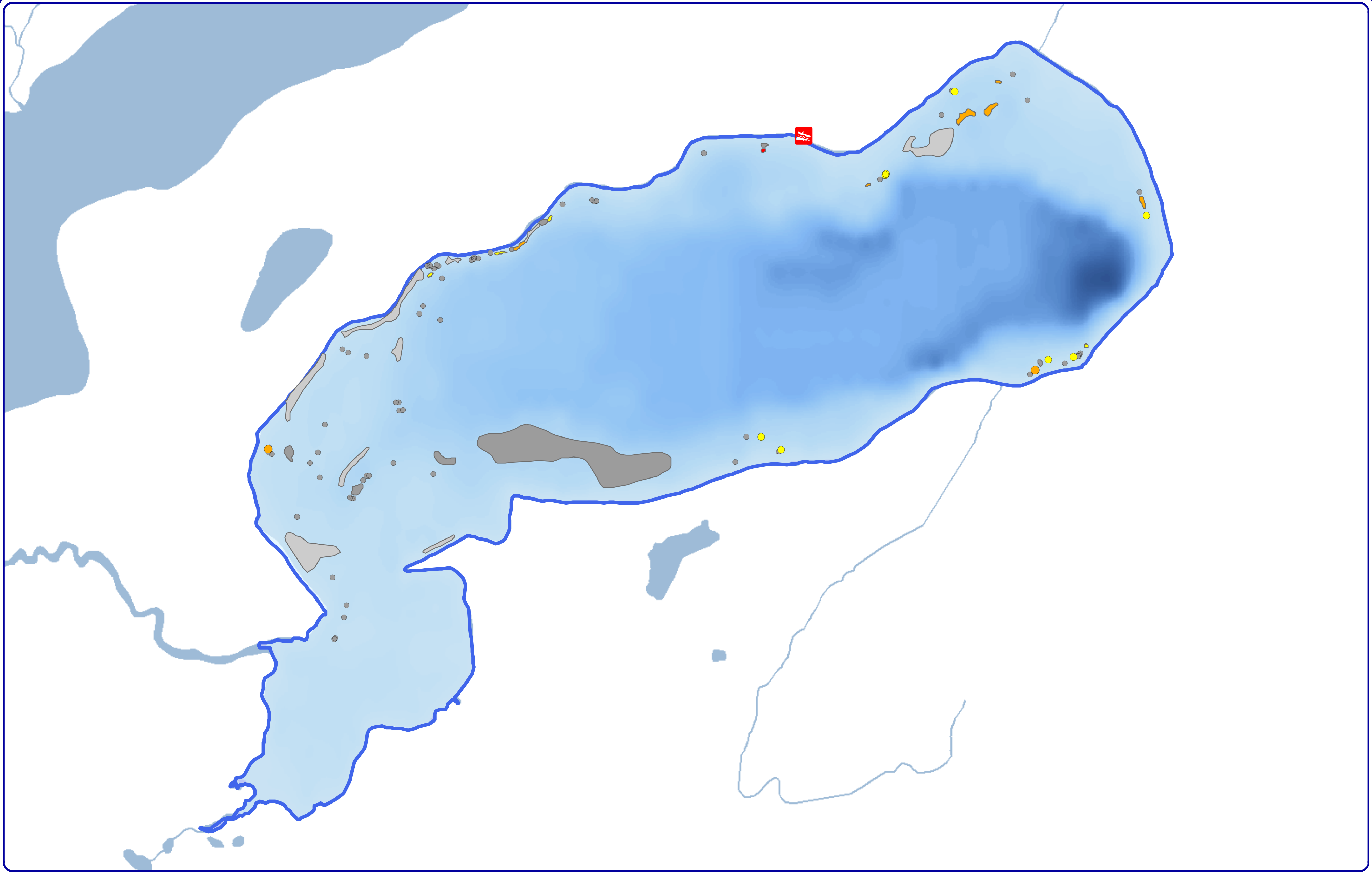
Legend

EWM (August 2011)

Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting

Single or Few Plants
Clump of Plants
Small Plant Colony

Map 8
Big Sand Lake
Vilas County, Wisconsin
2011 EWM Locations



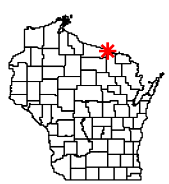
N W E S

1,800

Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Mapping: Onterra, 2012
Map Date: July 31, 2014
Filename: Map9_BigSand_EWM_Aug12.mxd



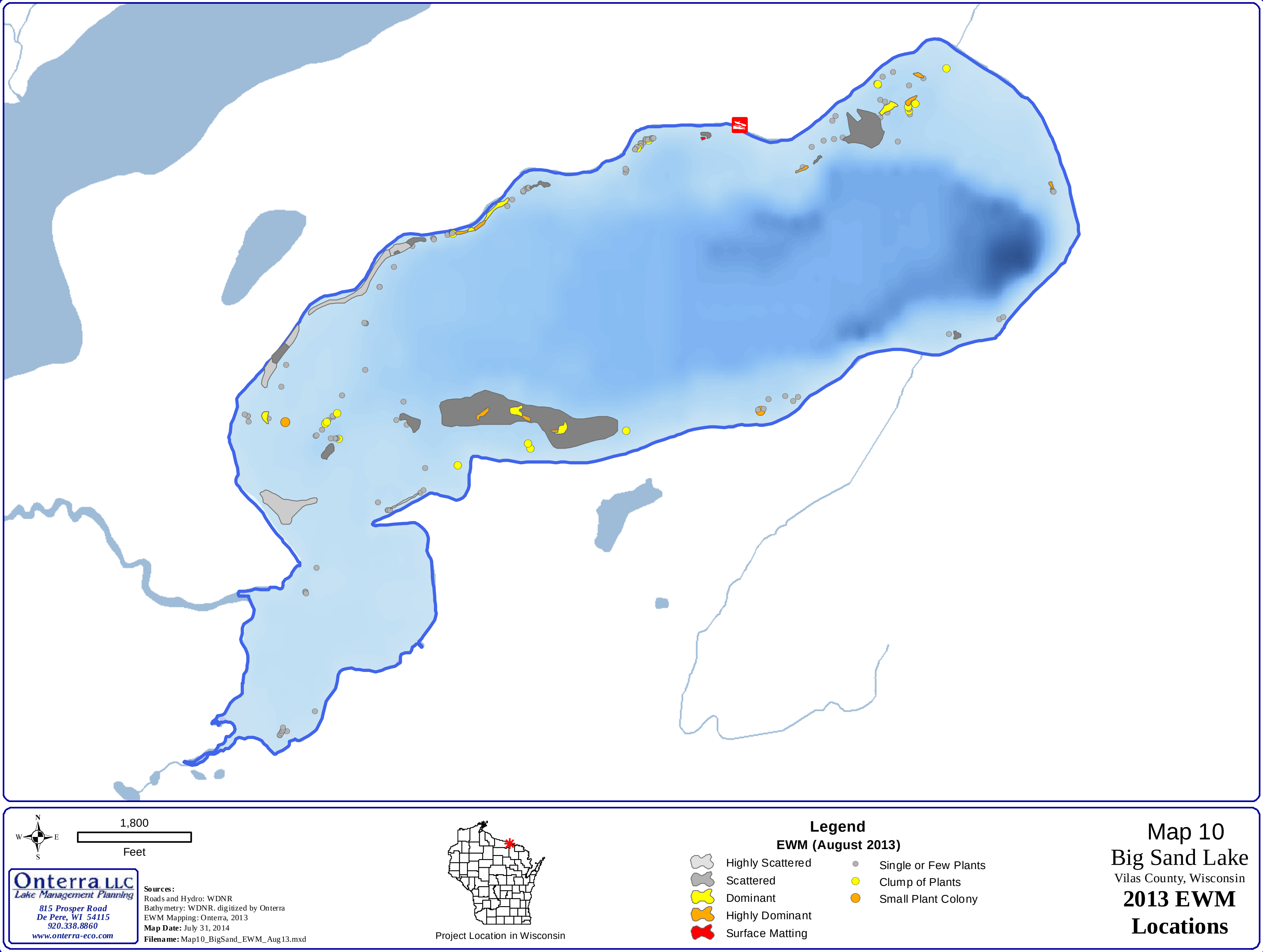
Project Location in Wisconsin

Legend

EWM (August 2012)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 9
Big Sand Lake
Vilas County, Wisconsin
2012 EWM Locations



Onterra LLC
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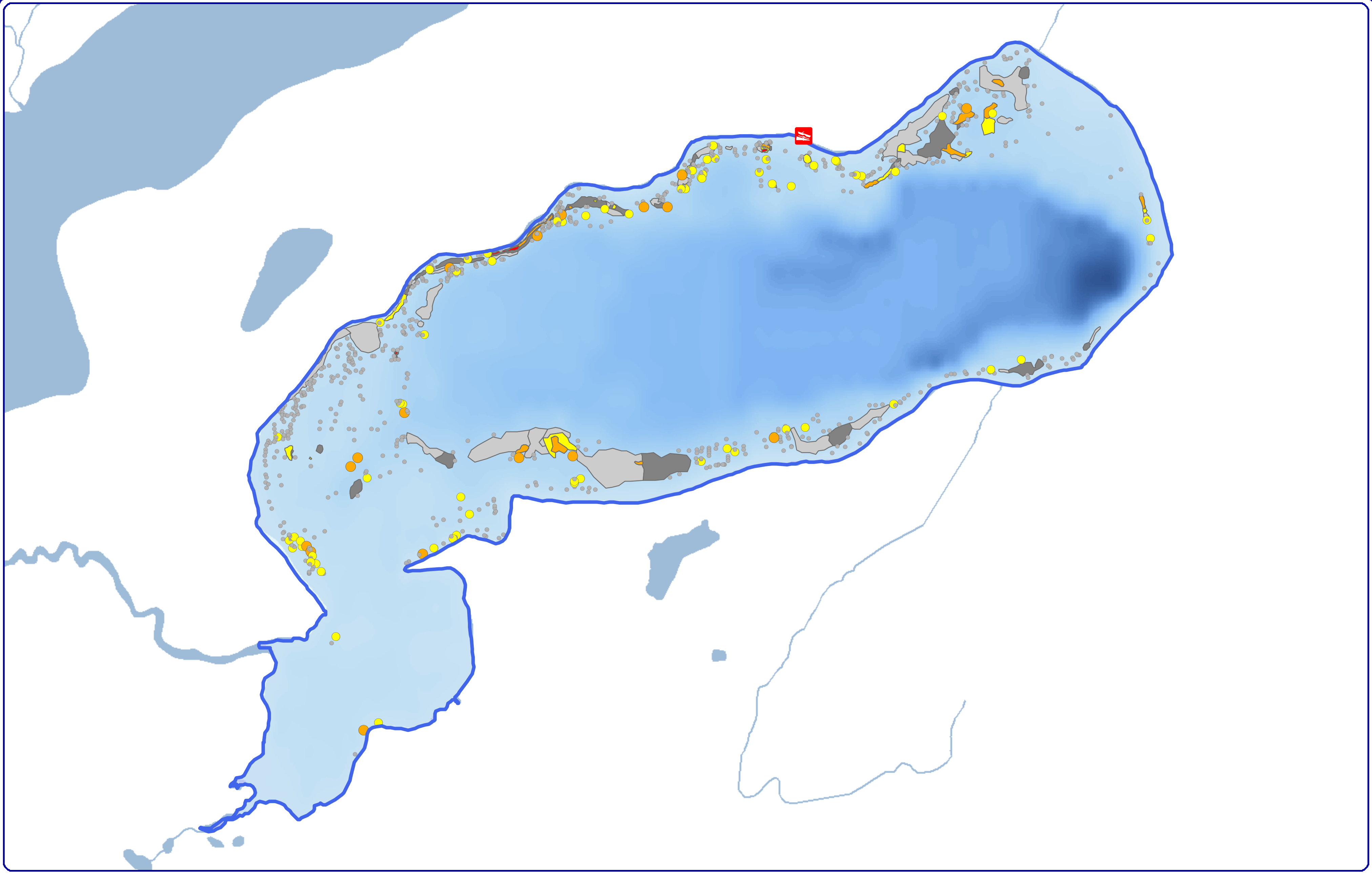
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
EWM Mapping: Onterra, 2013
Map Date: July 31, 2014
Filename: Map10_BigSand_EWM_Aug13.mxd

Map 10
Big Sand Lake
Vilas County, Wisconsin
2013 EWM Locations



N
W
E
S
1,800
Feet

Legend
EWM (August 2014)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Onterra LLC
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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR. digitized by Onterra
EWM Mapping: Onterra, 2014
Map Date: July 31, 2014
Filename: Map11_BigSand_EWM_Aug14.mxd

Map 11
Big Sand Lake
Vilas County, Wisconsin
2014 EWM Locations