# Shawano Lake

**Shawano County, Wisconsin**

# Aquatic Plant Management Plan Update

**April 2014**

Sponsored by:

**Shawano Area Waterways Management Inc.**

WDNR Grant Program

AEPP-387-13

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Onterra LLC
Lake Management Planning

# Shawano Lake
# Aquatic Plant Management Plan Update

Shawano County, Wisconsin

April 2014

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Funded by: Shawano Area Waterways Management, Inc.
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## Acknowledgements

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

### Shawano Lake Planning Committee

| | |
|---|---|
| Ray Zuelke | David Kranjac |
| Gary DeFere | Todd Dobberstein |
| Tim Day | Bill Monfre |

### Wisconsin Dept. of Natural Resources

Brenda Nordin

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# 1.0 INTRODUCTION

**Photo 1. Shawano Lake, Shawano County.**

According to the WDNR 1974 Lake Survey Map, Shawano Lake, Shawano County, is an approximate 6,060-acre drainage lake with a mean depth of 9 feet and a maximum depth of 42 feet. Information collected during this project found that the lake was 6,258 acres with a mean depth of 9.8 feet and maximum depth of 38 feet (Map 1). The differences between these measurements are due to the methodologies and do not suggest a change in morphology has occurred between 1974 and 2013. Shawano Lake's watershed encompasses approximately 74-square miles, and is comprised of mixed agriculture, rural residential areas, forested lands, and urbanized areas. Water drains from Shawano Lake through the Shawano Lake Outlet, through the City of Shawano, into the Wolf River.

Shawano Area Waterways Management, Inc. (SAWM) was created over a decade ago by members of the Shawano Lake Property Owners Association (SLPOA). Shawano Lake and its watershed have been studied since 1991 when the SLPOA was awarded the first of many Wisconsin Department of Natural Resources (WDNR) Grants. This was the first phase in a three-phase management planning project to assess the lake's water quality, watershed, aquatic plant community, and stakeholder perceptions. In 2003, the second of the lake's multi-phase assessment projects began with watershed tributary and in-lake water quality monitoring, aquatic plant assessments, and capacity building and management planning exercises. These studies were completed in 2006.

More intense studies of the lake's nutrient budget were led by the University of Wisconsin-Stevens Point Center for Watershed Science and Education, the results of which were presented in a final report produced in 2008. In 2009, results of the studies described above were used to create the Shawano Lake Watershed Strategic Management Plan and the Shawano Lake Aquatic Plant Management Plan.

The aquatic plant management plan contains 16 recommendations, including further studies, implementation of watershed best management practices, potential funding sources, and the control of native and non-native aquatic plants. Aquatic plant management activities include a combination of herbicide use, mechanical harvesting, and hand-removal to control both native and non-native plants.

The strategic plan contains 22 goals/objectives within eight categories, including monitoring, harvesting, chemical treatment, property owner participation, funding, education, research, and governance. Many of these goals/objectives directly overlap with the recommendations contained within the aquatic plant management plan. Most applicable to this proposed project is the creation of an updated aquatic plant management plan by 2015.

SAWM has been conducting aquatic plant control on Shawano Lake as outlined in the 2009 Aquatic Plant Management Plan, including limited use of an association-owned harvester and nuisance herbicide applications by an association-employed applicator. After three years of implementing the plan's recommendations, the WDNR requested a more precise plan that gives comprehensive guidance on controlling exotics, in addition to the natives, using both chemical and harvesting techniques. SAWM would also like to discover ways to protecting the native aquatic plant community by controlling exotics on a lake-wide scale.

During the winter of 2012-2103, SAWM contracted with Onterra to develop an updated Aquatic Plant Management Plan that addresses the following issues:

1. Updated actions for the control of nuisance levels of native and non-native aquatic plants. These actions would likely include the use of hand-harvesting, mechanical harvesting, and herbicide applications aimed at assuring recreational accessibility of the lake while minimizing impacts to native habitat.
2. Management alternatives for reducing non-native plant species within Shawano Lake on a lake-wide basis with the intention of restoring native aquatic plant habitat. These actions may include mechanical harvesting of specific species, early-season herbicide treatments, and/or water level drawdown. Likely, in tandem with this outcome, nuisance aquatic plant control would be completed as described above.

# 2.0 RESULTS & DISCUSSION

## 2.1 Primer on Data Analysis & Data Interpretation

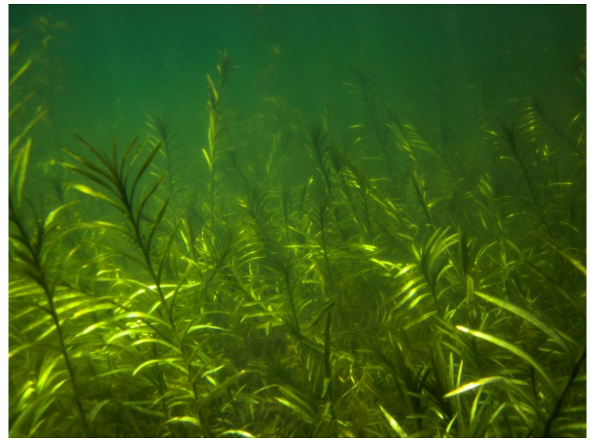

**Photo 2. Native aquatic plants are an important component in maintaining a healthy aquatic ecosystem.**

Native aquatic plants are an important element in every healthy aquatic ecosystem, providing food and habitat to wildlife, improving water quality, and stabilizing bottom sediments (Photo 2). Because most aquatic plants are rooted in place and are unable to relocate in wake of environmental alterations, they are often the first community to indicate that changes may be occurring within the system. Aquatic plant communities can respond in variety of ways; there may be increases or declines in the occurrences of some species, or a complete loss. Or, certain growth forms, such as emergent and floating-leaf communities may disappear from certain areas of the waterbody. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide relevant information for making management decisions.

The **Littoral Zone** is the area of the lake where sunlight is able to penetrate to the sediment providing aquatic plants with sufficient light to carry out photosynthesis.

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was conducted in Shawano Lake by Onterra in July 2013. Based upon guidance from the WDNR, a point spacing (resolution) of 165 meters was used resulting in 925 sampling points being evenly distributed across the lake (Map 1). At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (muck, sand, or rock), and the plant species sampled along with their relative abundance (Figure 1) on the sampling rake was recorded.

A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 13 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 13 feet. Depth information was collected using graduated marks on the pole of the rake or using an onboard sonar unit at depths greater than 13 feet. Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately feel the bottom with this sampling device. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

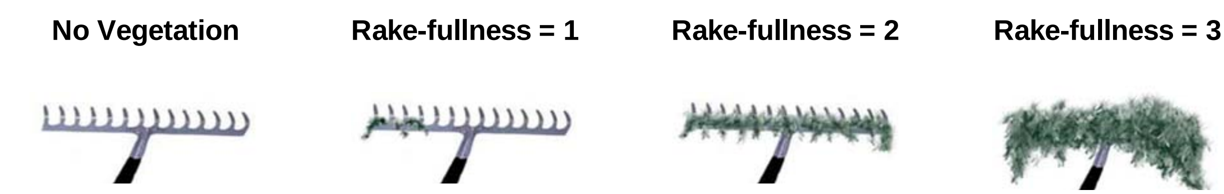


**Figure 1. Aquatic plant rake-fullness ratings.** Adapted from Hauxwell et al (2010).

### Species List

The species list is simply a list of all of the species, both native and non-native, that were located during the 2013 surveys on Shawano Lake. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

### Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey conducted on Shawano Lake in 2013, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, the occurrences of aquatic plant species are displayed as their *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are equal to or less than the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

### Floristic Quality Assessment

The floristic quality of a lake is calculated using its native aquatic plant species richness and those species' average conservatism values. Species richness is simply the number of aquatic plant species that occur in the lake, and for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values (C-value) for each of those species in its calculation. A species coefficient of conservatism value indicates that species' likelihood of being found in an undisturbed system. The values range from 1 to 10. Species that can tolerate environmental disturbance and can be located in disturbed systems have lower coefficients, while species that are less tolerant to environmental disturbance and are restricted to high quality systems have higher values. For example, coontail (*Ceratophyllum demersum*), a submergent native aquatic plant species with a C-value of 3, has a higher tolerance to disturbed conditions, often thriving in lakes with higher nutrient levels and low water clarity, while other species like algal-leaf pondweed (*Potamogeton confervoides*) with a C-value of 10, are intolerant of environmental disturbance and require high quality environments to survive.

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. Shawano Lake falls within the North Central Hardwood Forest Ecoregion (Figure 2), and the floristic quality of its aquatic plant community will be compared to other lakes within this ecoregion as well as the entire State of Wisconsin.

**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.

### Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. As defined previously, 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 species diversity also takes into account how evenly the species are distributed within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

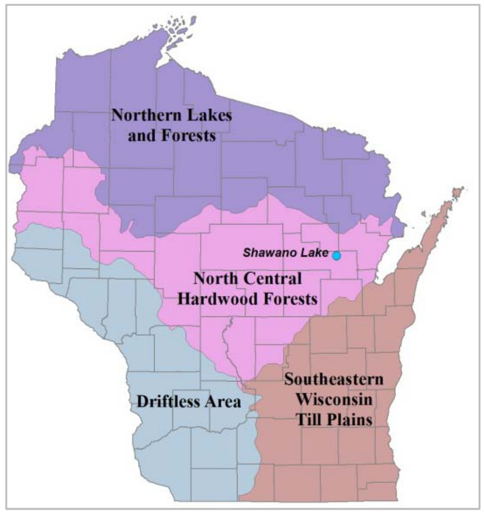


**Figure 2. Location of Shawano Lake within the ecoregions of Wisconsin.** After Nichols (1999).

An aquatic system with high species diversity is much more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. 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 Shawano Lake. Comparisons will be displayed using *boxplots* that showing median values and upper/lower quartiles of lakes in the same ecoregion and in the state. Please note for this parameter, the North Central Hardwood Forest data includes both natural and flowage lakes.

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

## 2.2 Aquatic Plant Survey Results

On June 6, 7, and 10, 2013, Onterra ecologist conducted the Early-season Aquatic Invasive Species (AIS) Survey on Shawano Lake. The goal of this meander-based survey is to locate and map all potential occurrences of aquatic invasive plants within the lake. While the main focus of the survey is to locate occurrences of curly-leaf pondweed (CLP), as this is when this plant is at or near its peak growth, areas of Eurasian water milfoil (EWM) were also located and mapped at this time. Because EWM is at or near its peak growth in late summer, Onterra ecologists returned to Shawano Lake on September 25, 2013 to refine the areas of EWM mapped in June. Large areas of EWM and CLP were located during the 2013 surveys, and because of their importance, they will be discussed separately in the next section.

**Please Note:** Shawano Lake contains a confirmed population of both EWM and hybrid water milfoil (HWM), which is discussed in detail within a separate section. It is impossible to differentiate between HWM and EWM in the field, therefore the following analysis refers to this population as "EWM."

The whole-lake point-intercept survey was completed on Shawano Lake by Onterra on July 12, 15, and 16, 2013 (Appendix A), while the aquatic plant community mapping was completed on July 16, 17, and 18, 2013. During these surveys, a total of 51 aquatic plant species were located, three of which are considered to be non-native, invasive species: the aforementioned EWM and CLP, and the emergent wetland plant purple loosestrife (Table 1). One native emergent species located during the 2013 surveys, square-stem spike-rush, is listed as endangered, or critically imperiled in Wisconsin due to its extreme rarity and vulnerability to extirpation from the state (WDNR PUBL-ER-001 2011). Table 1 also displays the aquatic plant species that were located during a point-intercept survey conducted by the United States Army Corps of Engineers (USACE) in 2005 to determine the location and abundance of EWM and CLP (Appendix B).

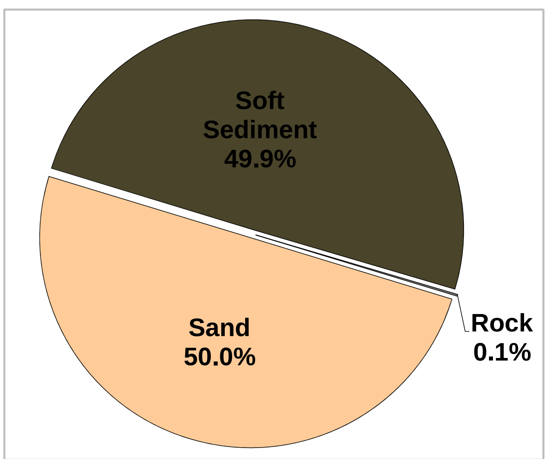


**Figure 3. Shawano Lake proportion of substrate types in areas less than 14 feet.** Created using data from 2013 point-intercept survey.

During the 2012 whole-lake point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 14 feet). These data indicate that 50.0% of the point-intercept locations less than 14 feet deep contained sand, 49.9% contained soft sediments (muck), and 0.1% contained rock (Figure 3).

Map 2 displays the distribution of substrate types in Shawano Lake as determined from the 2013 point-intercept survey. As illustrated, the majority of near-shore areas along the northern and southern shoreline are comprised of sand, while the western and eastern portions of the lake are comprised of soft sediments. 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 areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

**Table 1. Aquatic plant species located in Shawano Lake during USACE 2005 and Onterra 2013 surveys.**

| Growth Form | Scientific Name | Common Name | Coefficient of Conservatism (C) | 2005 (USACE) | 2013 (Onterra) |
|---|---|---|---|---|---|
| Emergent | *Decodon verticillatus* | Water-willow | 7 | | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | | X |
| | *Eleocharis quadrangulata** | Square-stem spike-rush | 10 | I | X |
| | *Lythrum salicaria* | Purple loosestrife | Exotic | X | I |
| | *Phragmites australis subsp. americanus* | Giant reed | 5 | | X |
| | *Pontederia cordata* | Pickerelweed | 9 | I | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | | I |
| | *Sagittaria rigida* | Stiff arrowhead | 8 | | I |
| | *Sagittaria sp. (sterile)* | Arrowhead sp. (sterile) | N/A | | I |
| | *Schoenoplectus acutus* | Hardstem bulrush | 5 | | X |
| | *Schoenoplectus pungens* | Three-square rush | 5 | | X |
| | *Schoenoplectus spp.* | Bulrush spp. | N/A | I | |
| | *Schoenoplectus tabernaemontani* | Softstem bulrush | 4 | | I |
| | *Typha spp.* | Cattail spp. | 1 | | I |
| | *Zizania sp.* | Wild rice Species | 8 | | X |
| FL | *Brasenia schreberi* | Watershield | 7 | | X |
| | *Nuphar variegata* | Spatterdock | 6 | X | X |
| | *Nymphaea odorata* | White water lily | 6 | X | X |
| | *Polygonum amphibium* | Water smartweed | 5 | | I |
| FL/E | *Sparganium eurycarpum* | Common bur-reed | 5 | | I |
| | *Sparganium spp.* | Bur-reed spp. | N/A | I | |
| Submergent | *Bidens beckii* | Water marigold | 8 | I | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X | X |
| | *Chara spp.* | Muskgrasses | 7 | X | X |
| | *Elodea canadensis* | Common waterweed | 3 | X | X |
| | *Heteranthera dubia* | Water stargrass | 6 | | X |
| | *Myriophyllum alterniflorum* | Alternate-flowered water milfoil | 10 | I | |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X | X |
| | *Myriophyllum spicatum* | Eurasian water milfoil | Exotic | X | X |
| | *Myriophyllum tenellum* | Dwarf water milfoil | 10 | I | X |
| | *Najas flexilis* | Slender naiad | 6 | X | X |
| | *Najas guadalupensis* | Southern naiad | 7 | X | X |
| | *Nitella spp.* | Stoneworts | 7 | | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X | X |
| | *Potamogeton amplifolius x illinoensis* | Large-leaf x Illinois pondweed | N/A | | X |
| | *Potamogeton crispus* | Curly-leaf pondweed | Exotic | X | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | | X |
| | *Potamogeton foliosus* | Leafy pondweed | 6 | X | |
| | *Potamogeton friesii* | Fries' pondweed | 8 | | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X | X |
| | *Potamogeton illinoensis* | Illinois pondweed | 6 | X | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | I | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | I | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X | X |
| | *Potamogeton strictifolius* | Stiff pondweed | 8 | X | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X | X |
| | *Ranunculus aquatilis* | White water-crowfoot | 8 | | X |
| | *Sagittaria sp. (rosette)* | Arrowhead rosette | N/A | X | X |
| | *Stuckenia pectinata* | Sago pondweed | 3 | | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X | X |
| | *Vallisneria americana* | Wild celery | 6 | X | X |
| | *Zannichellia palustris* | Horned pondweed | 7 | X | |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | | X |
| FF | *Lemna trisulca* | Forked duckweed | 6 | I | X |
| | *Spirodela polyrhiza* | Greater duckweed | 5 | | X |

*FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floatin*
*X = Located on rake during point-intercept survey; I = Incidental Species*
** = Species listed as 'endangered' in Wisconsin*

During the 2013 point-intercept survey, aquatic plants were found growing to a maximum depth of 22 feet, indicating Shawano Lake has relatively high water clarity which allows sunlight to penetrate to deeper depths and sustain aquatic plant growth. Of the 879 point-intercept locations that fell at or below 22 feet, 73% contained aquatic vegetation, indicating Shawano Lake's littoral zone is highly vegetated. Map 3 illustrates that the majority of the lake supports aquatic plant growth, and only the deepest areas of the lake lack vegetation.

Of the 48 native aquatic plant species located during 2013 surveys on Shawano Lake, 40 were physically encountered on the rake during the whole-lake point-intercept survey. The remaining 8 species were located incidentally. Of the 40 species encountered on the rake, forked duckweed, wild celery, coontail, muskgrasses, flat-stem pondweed, and common waterweed were the six-most frequently encountered (Figure 4).

Forked duckweed is a small, free-floating aquatic plant species with oar-shaped fronds. Unlike other duckweeds found in Wisconsin, forked duckweed generally grows submersed, forming large mats along the bottom or becoming entangled in rooted aquatic plants, and they obtain all of their nutrients directly from the water. Because of this, they aid in maintaining good water quality by acquiring nutrients that would otherwise be available to free-floating algae. In addition, when growing in large mats, forked duckweed provides a valuable source of structural habitat and food for wildlife. In 2013, forked duckweed was most abundant between 6 and 12 feet and was mostly found in areas containing soft sediments.

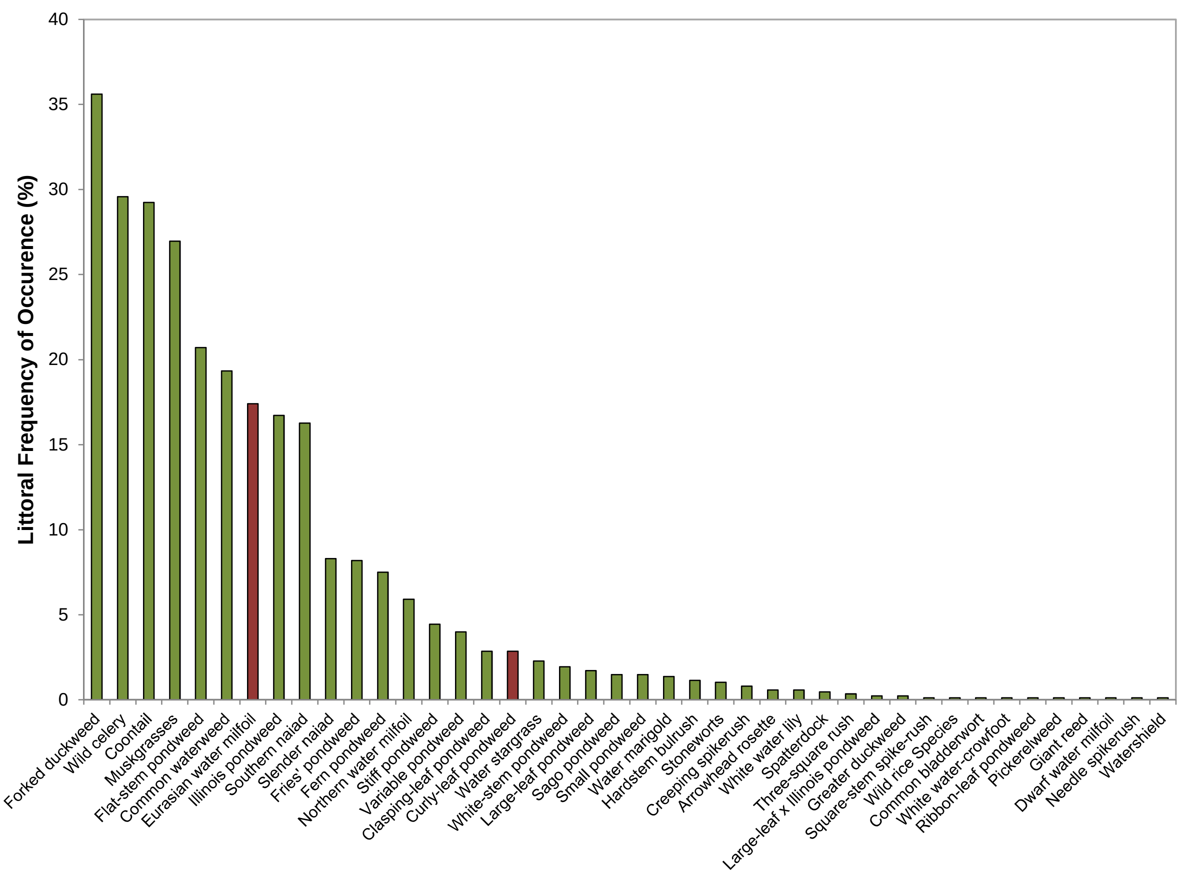


**Figure 4. 2013 littoral frequency of occurrence of aquatic plant species in Shawano Lake.** Created using data from July 2013 aquatic plant point-intercept survey. Exotic species indicated in red.

Wild celery, also known as tape or eel grass, was the second-most abundant plant in Shawano Lake in 2013 (Figure 4), and was most abundant between 3 and 9 feet over areas dominated by sandy substrates. The long leaves of wild celery provide excellent habitat for aquatic organisms, while its extensive root systems stabilize bottom sediments. Additionally, the leaves, fruits, and winter buds are food sources for numerous species of waterfowl and other wildlife.

Coontail, arguably the most common aquatic plant species in Wisconsin, was the third-most frequently encountered aquatic plant in 2013 (Figure 4). It possesses bushy whorls of stiff leaves that resemble the shape of a raccoon’s tail. Lacking roots, this species obtains the majority of its nutrients directly from the water and can grow prolifically in nutrient-rich water, often attaining nuisance levels and forming dense mats at the surface. Also able to tolerate low-light conditions, coontail is usually one of the most dominant species found in eutrophic lakes. The dense foliage of coontail provides excellent habitat for aquatic invertebrates and fish, especially in deeper water where other native aquatic plants cannot grow. While coontail has the capacity to grow to nuisance levels, no surface-matted areas of coontail were observed on Shawano Lake during the 2013 surveys. The point-intercept data indicate that coontail was most prevalent between 6 and 12 feet over areas containing soft sediments.

The fourth-most frequently encountered aquatic plants in 2013 were the muskgrasses, a genus of macroalgae. Several species of muskgrasses occur in Wisconsin, though this study did not identify this group to the species level. As their name suggests, many muskgrasses exude a strong, skunk-like odor. They are usually found in lakes with higher alkalinity and can be found growing in sandy or mucky substrates. Muskgrasses often grow in large beds providing both structural habitat and sources of food for both aquatic and terrestrial organisms. In Shawano Lake, muskgrasses were most abundant between 1 and 9 feet of water, and were mainly located over areas of sand.

Flat-stem pondweed, the fifth-most abundant plant in Shawano Lake, is one of many pondweed species found in Wisconsin, and as its name indicates, has a conspicuously flattened stem. It possesses long, linear leaves, and when growing in large beds, provides excellent structural habitat for aquatic organisms. Its foliage and fruit also provide food to waterfowl, mammals, and other wildlife (Borman et al. 1997). In Shawano Lake, flat-stem pondweed was most frequent between 5 and 11 feet of water, and was usually found growing in soft sediments.

The sixth-most frequently-encountered aquatic plant in Shawano Lake, common waterweed, is abundant in Wisconsin and throughout North America. Like coontail, common waterweed can tolerate low-light conditions, and thrives in lakes with nutrient-rich water. Under certain conditions, common waterweed can grow prolifically and create large mats at the water’s surface which can hinder recreation. Common waterweed was abundant in the western portion of Shawano Lake in 2013, and this plant was observed creating large mats on the surface in some areas (Photo 3). In 2013, common waterweed was most abundant between 6 and 11 feet over areas of soft sediments.

**Photo 3. Common waterweed, a native aquatic plant, matting on the surface of western Shawano Lake.** Photos taken during July 2013 point-intercept survey.

It is unrealistic to quantitatively define the term "nuisance," as this designation is subjective by nature. At one point in time, WDNR Science Services researchers hypothesized that nuisance levels of certain plant species may occur when their littoral frequency of occurrences exceed 35%. While this standard has gone out of favor by WDNR researchers, it is utilized below to provide perspective.

Plants that can potentially cause nuisance conditions are those that can grow dense and grow to and/or near the water surface. In Shawano Lake, forked duckweed was the only plant that exceeded this arbitrary benchmark (Figure 4); however, as discussed, forked duckweed grows submersed and does not create mats on the water's surface. In 2013, common waterweed had a littoral frequency of occurrence of approximately 19%, indicating that this species is not creating nuisance conditions on a lake-wide level, but can grow to nuisance levels in localized areas like what was observed in 2013. The nuisance levels of aquatic plants experienced by recreationalists on Shawano Lake is likely due to a combination of species, mainly CLP, EWM, and common waterweed.

As mentioned previously, the state-endangered square-stem spike-rush (*Eleocharis quadrangulata*) was located in a few locations around Shawano Lake in 2013 (Photo 4). Square-stem spike-rush is listed as uncommon globally and can only be found in a handful of locations in Wisconsin. Because of the threat of extirpation from Wisconsin, this species is listed as critically imperiled in the state, and removal of this plant without an endangered species permit is illegal in Wisconsin. This species was observed forming relatively large contiguous stands, which provide structural habitat for wildlife, stabilize bottom sediments, and buffer the shoreline from wave action.

**Photo 4. State-endangered square-stem spike-rush (*Eleocharis quadrangulata*) on Shawano Lake.**

In the summer of 2005, the USACE conducted a whole-lake point-intercept survey similar to the one conducted in 2013 to assess the distribution and abundance of EWM and CLP within Shawano Lake (Owens et al. 2007). The point-intercept resolution (space between points) was 175 meters and resulted in 838 point-intercept sampling locations (Appendix B). While this was not the same methodology that was utilized in 2013, the littoral frequency data of aquatic plants in 2005 can be compared to the data that were collected in 2013. Figure 5 displays the littoral occurrence of aquatic plant species with at least a littoral occurrence of 5% in one of the surveys. The change in occurrence of each species from 2005 to 2013 was statistically valid (Chi-square $\alpha = 0.05$). A number of species saw large changes in their occurrence from 2005 to 2013, such as forked duckweed, muskgrasses, Illinois pondweed, southern naiad, EWM, and CLP. Aquatic plant communities are dynamic, but it is unclear why such large reductions and increases were observed in some species. The occurrence of CLP was likely lower in 2013 due to the timing of the survey; the 2013 survey was conducted in July when CLP had already naturally senesced, while the June 2005 likely capture the occurrence of CLP when it was at its peak growth.

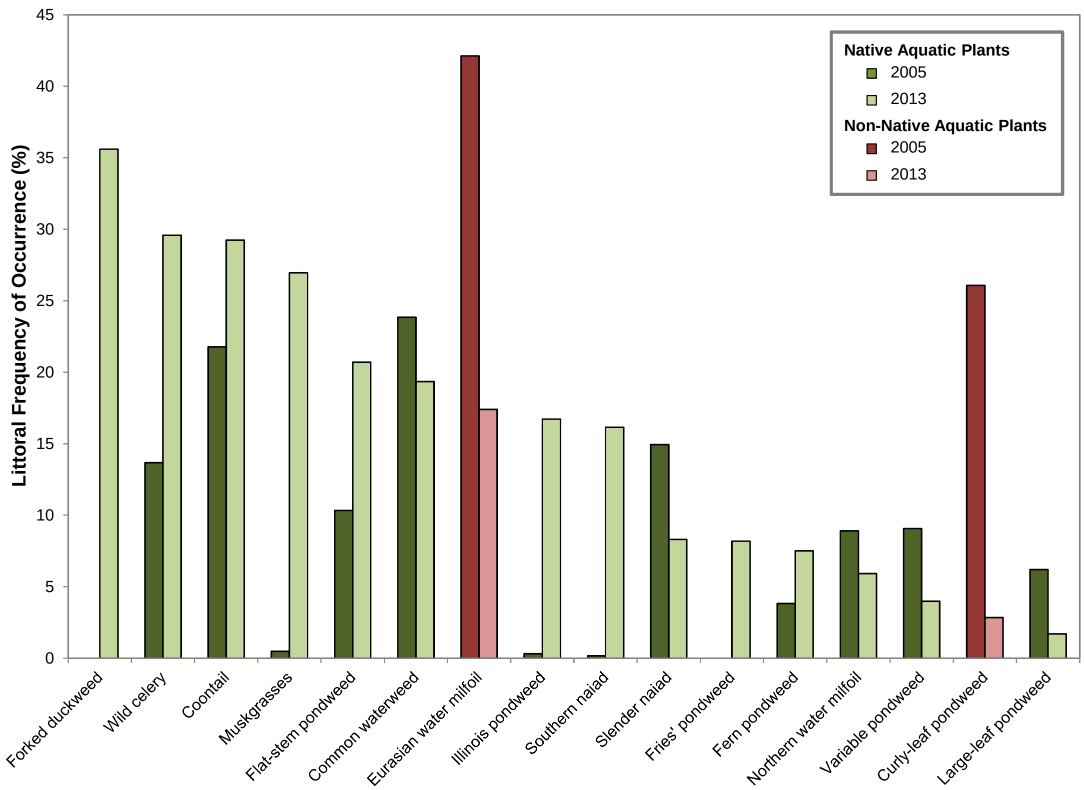


**Figure 5. Littoral frequency of occurrence of select aquatic plant species from USACE 2005 and Onterra 2013 point-intercept surveys.** Note: Only those species with an occurrence of at least 5% in either survey are displayed. Created using data from USACE 2005 and Onterra 2013 point-intercept surveys.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total 48 native aquatic plant species were located in Shawano Lake during the 2013 surveys, 40 were encountered on the rake during the point-intercept survey. These 40 native species and their conservatism values were used to calculate the FQI of Shawano Lake's aquatic plant community in 2013 (equation shown below).

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

Figure 6 compares the FQI components of Shawano Lake from the 2005 and 2013 point-intercept surveys to median values of lakes within the North Central Hardwoods and Southeastern Till Plains Lakes and Flowages (NCSE) Ecoregion as well as the entire State of Wisconsin. Shawano Lake is species-rich, as indicated by the native aquatic plant species richness values of 40 from the 2013 point-intercept survey. While the number of native species was only 21 in 2005, this is likely due to the larger resolution of the sampling locations, identification abilities of the surveyors, or a combination of both. The 2013 species richness value greatly exceeds the upper quartile values for lakes in the NCSE Ecoregion and for lakes throughout Wisconsin.

Littoral area, water clarity, depth and sediment variation, shoreline complexity, and water chemistry are all factors that influence aquatic plant species richness. Shawano Lake, having relatively high water clarity, has a large littoral zone, supporting aquatic vegetation throughout most of the lake. As discussed earlier, Shawano Lake contains areas comprised of sand and areas comprised of soft sediments, and in addition, have many bays sheltered from wind and waves that provide protection for more sensitive species. These differing habitats support aquatic plant communities of varying species composition, and create a species-rich environment.

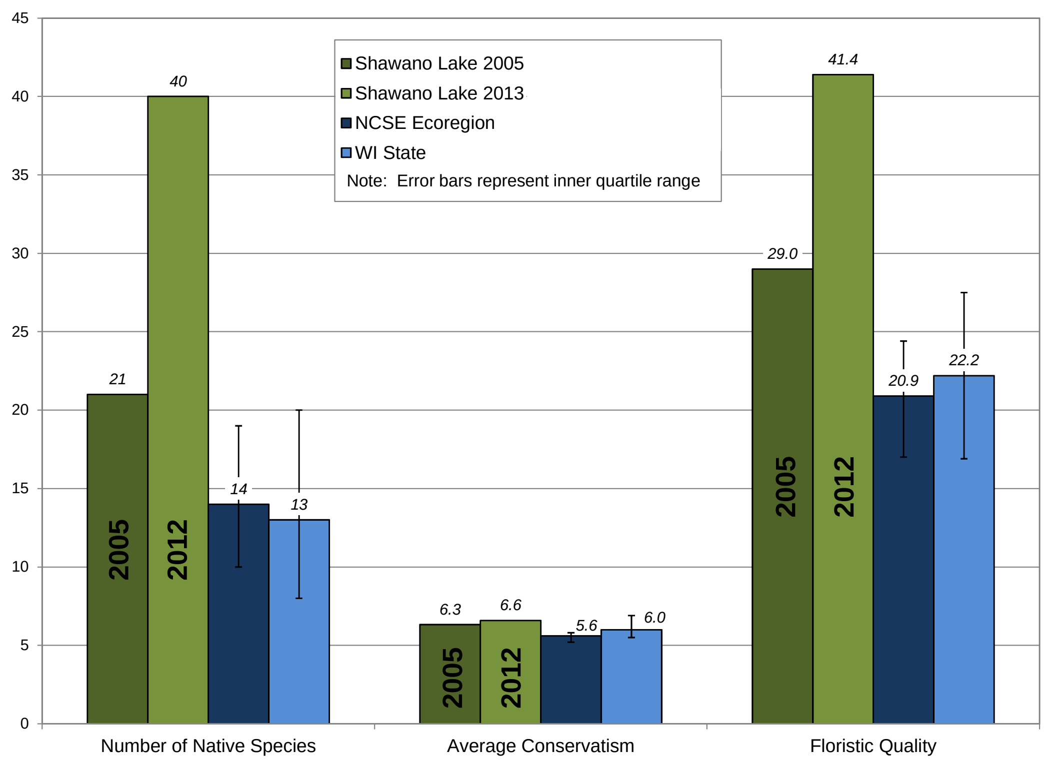


**Figure 6. Shawano Lake Floristic Quality Analysis.** Created using data from USACE, 2005 & Onterra, 2013 point-intercept surveys. Analysis follows Nichols (1999) where NCSE = North Central Hardwoods and Southeastern Till Plains Lakes and Flowages Ecoregion.

The average conservatism value for Shawano Lake's aquatic plant community was 6.3 and 6.6 in in 2005 and 2013, respectively, indicating that Shawano Lake contains a higher number of aquatic plant species that are more sensitive to environmental degradation than most lakes within the NSCE Ecoregion and Wisconsin. Combining the native species richness and average conservatism values yields a value of 29.0 for 2005 and an exceptionally high value of 41.4 for 2013. The FQI value for 2013 greatly exceeds upper quartile values for lakes in the NCSE Ecoregion and for lakes throughout Wisconsin, indicating the native aquatic plant community of Shawano Lake is of very high quality.

As explained earlier, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Shawano 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.

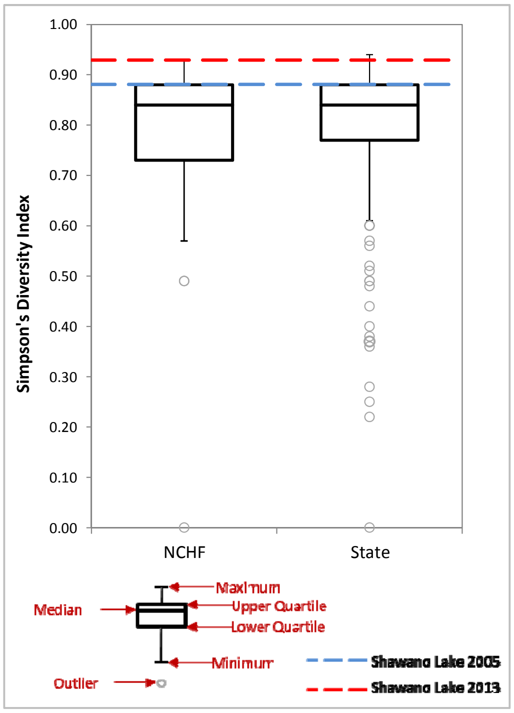


**Figure 7. Shawano Lake Simpson's Diversity Index.** Created using data from USACE 2005 and Onterra 2013 point-intercept surveys. Ecoregion and state data provided by WDNR Science Services.

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 Shawano Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 71 lakes within the North Central Hardwood Forests (NCHW) Ecoregion (Figure 6). Using the data collected from the 2005 and 2013 point-intercept surveys, Shawano Lake's aquatic plant community was shown to have high species diversity with a Simpson's diversity values of 0.88 and 0.93, respectively. The 2005 value falls on the upper quartile value for lakes in the ecoregion and the state, while the value from 2013 matches the maximum value calculated for the ecoregion and just below the maximum value calculated for the state. In other words, if two individual aquatic plants were randomly sampled from Shawano Lake in 2013, there would be a 93% probability that they would be different species.

As explained earlier, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while forked duckweed was found at approximately 36% of the littoral sampling locations in Shawano Lake in 2013, its relative frequency of occurrence is 13%.

Explained another way, if 100 plants were randomly sampled from Shawano Lake, 13 of them would be forked duckweed. Figure 8 displays the relative occurrence of aquatic plant species from Shawano Lake in 2013, and illustrates that the aquatic plant community is not overly-dominated by one or few species, leading to high species diversity.

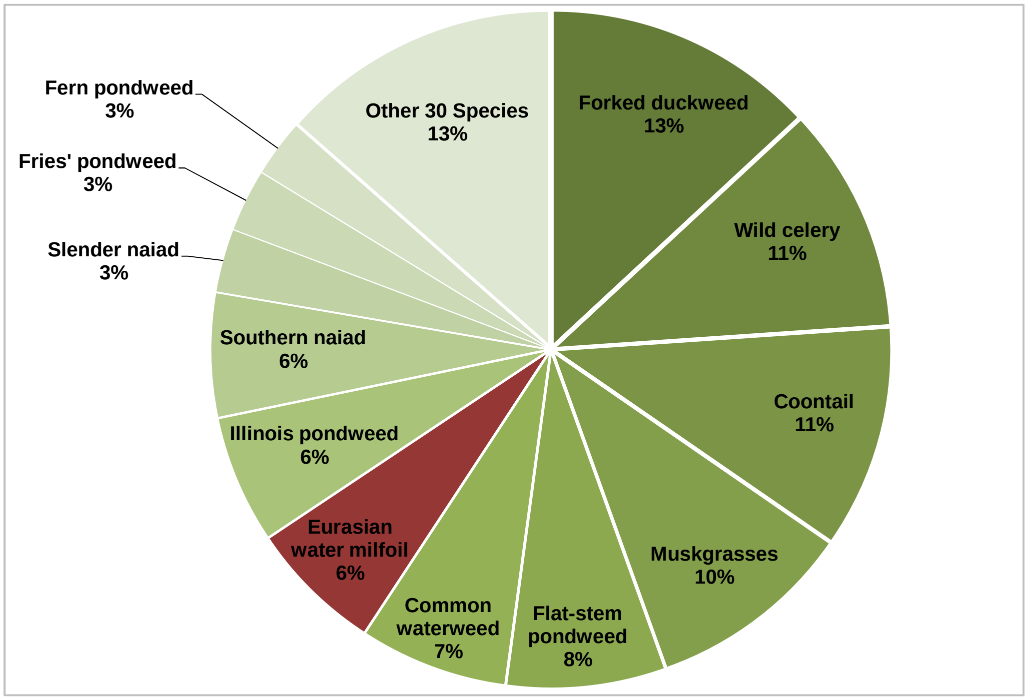


**Figure 8. Relative frequency of occurrence of aquatic plant species in Shawano Lake.** Created using data from Onterra 2013 point-intercept survey.

The 2013 aquatic plant community mapping survey revealed that Shawano Lake contains approximately 226 acres of emergent and floating-leaf aquatic plant communities (Maps 4 & 5). Nineteen emergent and floating-leaf aquatic plant species were located in the lake in 2013 (Table 1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Shawano Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Most of the emergent and floating-leaf aquatic plant communities in Shawano Lake fall within WDNR-designated Critical Habitat Areas (WDNR 2003, Map 8). These areas were given this designation in 2006 because they play an integral role in in the Shawano Lake ecosystem, and their conservation is vital to the overall health of Shawano Lake. More specifically, these areas in Shawano Lake are defined by the WDNR as Sensitive Areas, or "areas of aquatic vegetation identified by the department as offering critical or unique fish and wildlife habitat to the body of water" (WDNR 2003). The designation of these sensitive areas in Shawano Lake may change the permitting process for construction projects and other activities on nearby shorelines, and ensures that any proposed projects will not have any negative impacts on these important habitats.

## 2.3 Non-native Aquatic Plants

### *Curly-leaf pondweed (Potamogeton crispus)*

It is not known when CLP was first introduced to Shawano Lake, but studies conducted in 1993 documented its presence indicating it has been present in Shawano Lake for at least 20 years. Onterra ecologists conducted the Early-Season Aquatic Invasive Species Survey on June 6, 7, and 10, 2013. During this meander-based survey of Shawano Lake's littoral zone, areas of CLP were located and mapped (Map 6). In 2013, CLP was located in areas of the littoral zone that were comprised of soft sediments to a maximum depth of 14 feet, mainly the western and extreme eastern portions of the lake.

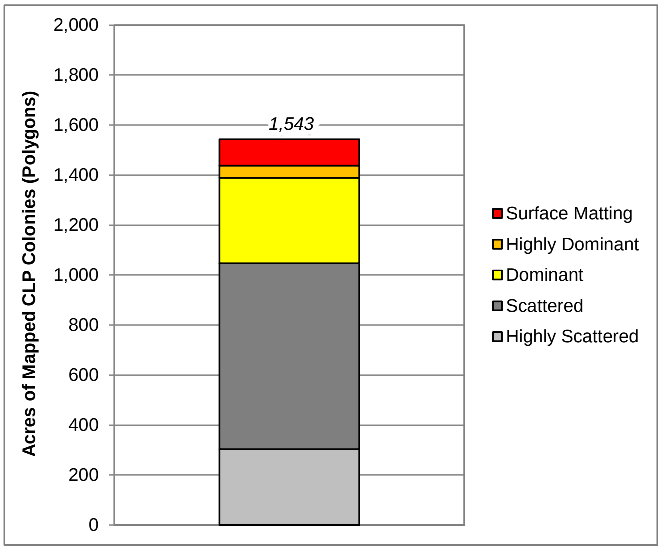


**Figure 9. Acres of CLP colonies (polygons) mapped in June 2013 in Shawano Lake.**

In total, approximately 1,543 acres of colonized CLP were mapped in Shawano Lake in June 2013, of which approximately 496 acres (32%) were classified as *dominant* or greater (Figure 9). The largest surface-matted CLP colony was located off shore from the Swan Acre Drive boat landing, along the south shore in the eastern portion of the lake (Photo 5). The CLP within this area was extremely dense, making navigation through this area nearly impossible. Another large surface-matted area of CLP was located off the southern shore in the western portion of the lake, along with a number of *highly dominant* and *dominant* colonies. While large, dense colonies of CLP were located in 2013, the majority of the CLP located was comprised of *scattered* or *highly scattered* colonies.

**Photo 5. Surface-matted CLP in Eastern Shawano Lake.** Photo taken during June 2013 EASAIS Survey.

### EWM (Myriophyllum spicatum)

EWM was officially documented in Shawano Lake in 1994, though studies conducted prior to 1994 indicated its presence in the lake. Onterra ecologists mapped areas of EWM in Shawano Lake during the Early-Season Aquatic Invasive Species Survey, and later revisited these areas in September 2013 to refine them as necessary (Map 7). From these surveys, approximately 1,761 acres of colonized EWM were mapped (Figure 10). Unlike CLP, the majority of the acreage mapped (909 acres or 52%) were comprised of *dominant* or *highly dominant* EWM. However, only 4.8 acres of *surface matting* EWM were located in 2013.

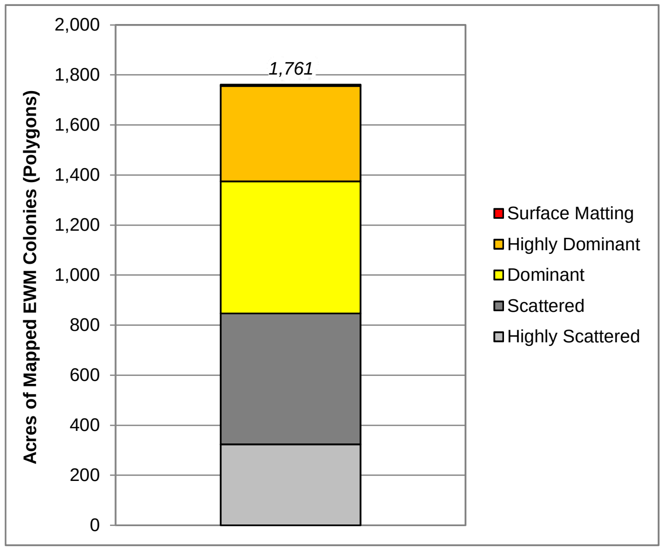


**Figure 10. Acres of EWM colonies (polygons) mapped in June and September 2013 in Shawano Lake.**

Like CLP, most of the EWM was located over areas of the littoral zone that were comprised of soft sediments, except for one colony located along the northern shore in shallower water over sand. The 2013 whole-lake point-intercept survey indicated that EWM was most abundant between 6 and 11 feet of water, and is similar to what was observed during the USACE's 2005 point-intercept survey.

In 2010, samples of EWM were sent to the Annis Water Resources Institute at Grand Valley State University in Michigan to determine if the EWM in Shawano Lake was of hybrid origin; a cross between EWM and the indigenous northern water milfoil (*M. sibiricum*). Hybrid water milfoil presents some complications for management as research is indicating that certain strains may have higher tolerance to aquatic herbicides. The specimens processed in 2010 from Shawano Lake were confirmed as hybrid water milfoil. In 2013, another milfoil specimen from Shawano Lake was sent in for DNA analysis, and the results indicated it was pure-strain EWM. These results indicate that there are likely populations of both hybrid water milfoil and pure-strain EWM in Shawano Lake.

### Purple loosestrife (Lythrum salicaria)

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

Isolated, scattered populations of purple loosestrife were located along the shorelines of Shawano Lake in 2013 (Maps 5 & 6). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by non-native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the removal of the plant from the shorelines around Shawano Lake.

# 3.0 SUMMARY & CONCLUSIONS

The results of the aquatic plant surveys conducted in 2013 indicate that the native aquatic plant population of Shawano Lake is exceptional by most standard analyses. The lake contains a high number of species, none of which are overly dominating the system. Also, the species present are of high quality. However, these species are sensitive to environmental disturbances, including out-competition by aquatic invasive species.

While data reflecting the plant community of Shawano Lake prior to EWM and CLP infestation does not exist, the available data indicate that the native plant community has remained resilient between 2005 and 2013. The studies also indicate that EWM and CLP have a considerable presence in the lake, likely becoming firmly established over the past few decades. The dense monocultures of these species that exist in many parts of Shawano Lake greatly affect the function of the ecosystem within that area. These are also the areas that have the greatest impact and stakeholder enjoyment and use patterns.

Following the completion of data analysis in November 2013, a series of meetings were held between Onterra ecologists/planners and a sub-committee (Planning Committee) of the SAWM (Appendix C). Due to their importance, the SAWM Planning Committee discussed three main management goals: 1) CLP Control Strategy, 2) EWM Control Strategy, and 3) Nuisance Aquatic Plant Control Strategy.

## CLP Control Strategy

At this time, the SAWM Planning Committee has decided to focus their management attention away from attempting to control the population of CLP within Shawano Lake. During the meetings with this group, several CLP control strategies were discussed, all of which were cost prohibitive and unclear as to whether control objectives would be met. An overview of these discussions are included in the bulleted list below:

- **Early-Season Herbicide Treatment of CLP** Traditionally, CLP control consists of numerous annual herbicide treatments conducted in May of each year. This will kill each year’s plants before they are able to produce reproductive turions (asexual seed-like structures). After multiple years of treatment, the turion supply in the sediment becomes exhausted and the CLP population decreases significantly. Normally a control strategy such as this includes 5 or more years of repetitive treatments to the same areas.

  As discussed above, CLP has likely been present within Shawano Lake for many decades which has resulted in a robust bank of turions within the sediments of Shawano Lake. While the research remains unclear, it is likely that the turion base within Shawano Lake could sustain a hearty CLP population for 5-7 years. If all 1,543 acres of colonized CLP were targeted with liquid endothall at a standard use pattern (spot treatment applied at 1.5 ppm ai), the cost of a single year of treatment would exceed one million dollars. Since repeating that treatment for 5 or more years would likely be required, this strategy was determined cost prohibitive before additional conversations about potential collateral treatment effects to the native plant community occurred.

Additional discussions took place regarding the applicability of targeting only those colonies that were causing the greatest ecological impacts and recreational nuisance. The cost of targeting only the *Dominant, Highly Dominant*, and *Surface Matted* CLP colonies would be approximately one-third less than targeting all CLP colonies within Shawano Lake. While an effective implementation of this strategy would kill a vast majority of a single year's CLP population before it was able to produce turions, there would still be numerous acres of lower-density CLP that would be contributing to the amount of turions within the lake sediments.

- **Early-season Mechanical Harvesting of CLP** Until recently, many lake managers believed that harvesting the above ground CLP biomass early in the season, before turions are produced, would act in a similar manner to herbicides, such that the amount of CLP turion production in mechanically harvested areas would be significantly reduced. However, based upon the research and experience of John Skogerboe, scientist at the USACE Research and Development Center, any management strategy that fails to kill the entire CLP plant (including rhizomes and root crowns) does not prevent new turion formation. It appears that stressed pants may tend to produce turions at internodes, and may be extremely numerous. Turion production has also been shown to occur on the rhizome itself, which would not be removed or killed during mechanical harvesting activities.

  While an early-season mechanical harvesting program may not be a viable measure to reduce the amount of CLP within the lake over time, this program would provide the benefit of removing CLP biomass to increase navigation and recreational activities during June and early July. Mechanically harvesting CLP may also benefit the water quality of the system. In lakes with dense CLP occurrences, the water quality of the lake can also be impacted by increased phosphorus levels following the CLP's mid-summer die-off. In shallow lakes such as Shawano Lake, this surge of phosphorus can often lead to severe algae blooms. These factors may justify an early-season harvesting program not for ecological restoration of the aquatic plant community, but from nuisance navigation and water quality perspectives.

## EWM Control Strategy

Surveys conducted by Onterra in 2013 indicate that Shawano Lake contains 1,761 acres of colonized EWM spread throughout the entire lake. At this time, the most feasible control strategy for targeting widespread EWM populations on a system like Shawano Lake is with herbicide treatments.

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 is an important concept in understanding how aquatic herbicides function. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of a joint research project between the WDNR, USACE, and private consultants. 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 effects outside of that area. Ongoing research indicates that herbicide quickly dissipates and dilutes from spot treatments, especially small spot treatments (less than 5 acres). In order for mortality of the target plants to occur, the short exposure time (often hours) needs to be offset by the plants being exposed to a high herbicide concentration. Like terrestrial herbicide applications, spot treatments are used by lake managers to strategically target a specific colony o a target plant. However, obtaining effective herbicide concentration and exposure times has proven difficult in many instances. This results in seasonal control such that the target plants are greatly injured by the treatment, but fully rebound by the end of the summer or the following year.

Herbicide application rates for spot treatment are formulated volumetrically, typically targeting 2,4-D at 3.0-4.0 ppm 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 3.0-4.0 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 11). While lake managers may propose that a particular volumetric dose be used, such as 3-4.0 ppm ae, it is understood that actually achieving 3-4.0 ppm ae within the water column is not likely due to dissipation and other factors.

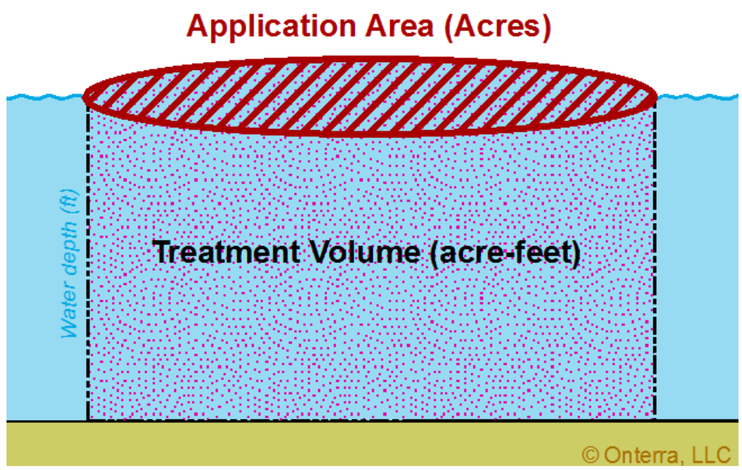

**Figure 11. Herbicide Spot Treatment diagram**.

Whole-lake treatments are those where the herbicide is applied to specific sites, but the goal of the strategy is for the herbicide to reach a target concentration when it equally distributes throughout the entire volume of the lake (or lake basin, or within the epilimnion of the lake or lake basin). The application rate of whole-lake treatments is dictated by the volume of water in with which the herbicide will reach equilibrium. Because exposure time is so much longer, effective herbicide concentrations for whole-lake treatments are significantly less than required for spot treatments. Whole-lake treatments are typically conducted when the target plant is spread throughout much of the lake, as is the case for Shawano Lake.

At this time, it appears that a whole-lake herbicide treatment would be appropriate for Shawano Lake. While implemented on many lakes throughout the state, whole-lake treatments remain experimental in nature and have not been conducted on a lake in Wisconsin the size of Shawano Lake. Lake managers and SAWM Planning Committee members discussed several aspects of a whole-lake treatment that require information before implementation of a whole-lake strategy is warranted: logistical feasibility, efficacy concerns, uncertainty in ecological response, financial constraints, and ability to gain sociological backing (i.e. stakeholder support) (Figure 12). Each one of these implementation challenges is addressed below:

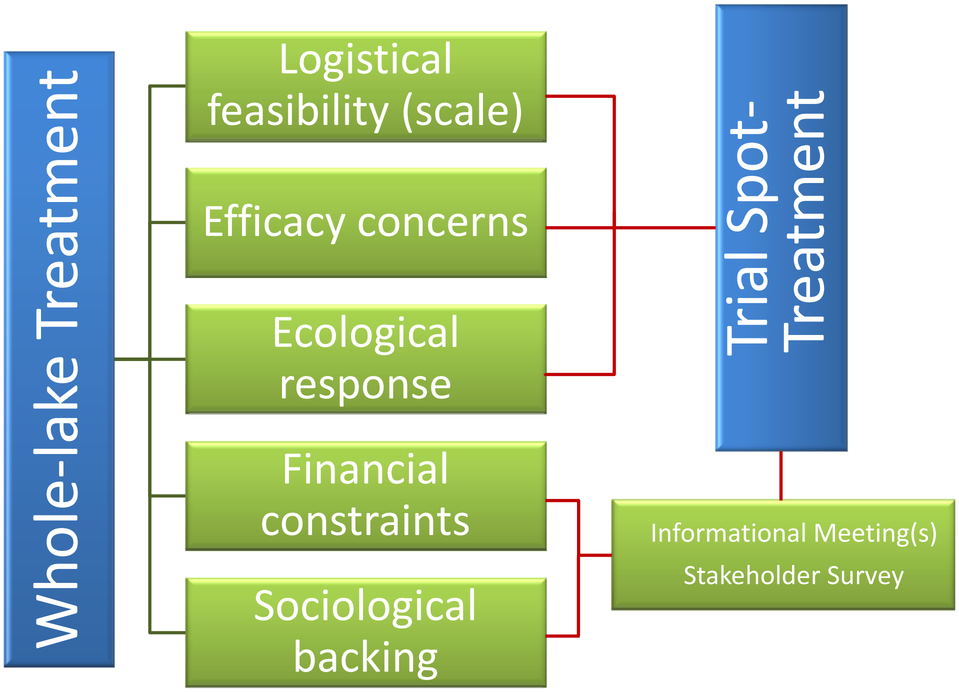


**Figure 12. Flow chart addressing concerns of implementing a whole-lake treatment on Shawano Lake.**

- **Logistical Feasibility** The scale of both Shawano Lake and its EWM population are at the foundation of all aspects requiring attention. Completing a whole-lake herbicide treatment relies on the mixing volume of the system to reach a uniform target herbicide concentration. Depending on the specifics of a developed whole-lake treatment strategy, many hundreds of acres and a large amount of product would be required; therefore, additional information would need to be gathered to determine if firms exist that could apply the herbicide to such a large area in a timely manner. The application would need to be conducted such that the herbicide applied on the first day of the treatment has not significantly degraded by the final day of the treatment. Subsequent conversations may discover that alternate application methods or a different herbicide type (e.g. fluridone) may be more applicable to a treatment of this scale.

- **Efficacy Concerns** Shawano Lake contains a confirmed population of both EWM and hybrid water milfoil (HWM). The concept of heterosis, or hybrid vigor, is important in regards to HWM management. The foundation of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. HWM typically has thicker stems than EWM, is a prolific flowerer, and grows faster than EWM. These conditions likely contribute to this plant being particularly less susceptible to biological and chemical control strategies. Some whole-lake treatments targeting HWM with 2,4-D at concentrations of 0.35 – 0.4 ppm ae had better rates of success than lower rates typically employed for pure-strain EWM control (0.3 – 0.35 ppm ae), but some hybrid populations continue to be difficult to control even at those higher concentrations. Upstream HWM populations on Washington and Loon Lakes have shown to be difficult populations to control at standard dosing patterns.

- **Ecological Response** The higher use rates required to target HWM may have increased collateral effects on the native aquatic plant community compared with more-typical use rates employed for pure-strain EWM control projects. Ongoing research indicates that some native plants have been shown to recover quickly the year following an herbicide treatment, whereas others take more time.

- **Financial Constraints** Implementation of a whole-lake 2,4-D treatment for control of EWM/HWM on Shawano Lake would cost between $400,000 and $600,000. Even with the possibility of receiving a maximum of $200,000 in grant funds from the WDNR, the cost of implementing this strategy remains out of reach at this point in time. Alternative herbicide treatment options will also be reviewed as appropriate for Shawano Lake during this process that may be more cost effective.

- **Sociological Backing (Stakeholder Support)** The use of herbicides, even for an ecologically-driven cause, is not without general objection by lake stakeholders. While all herbicides are registered by the Environmental Protection Agency (EPA) and are approved for use by the WDNR, they are not entirely without risk. Technically, registration by the EPA means that the product has been fully evaluated and the risks that have been determined are outweighed by the benefits the proper use of the herbicide poses. It is important for lake stakeholders to be educated about the benefits and risks of conducting a control strategy on the lake in order to make an educated decision about the lake's future management and condition.

It has been proposed that conducting a smaller scale trial 2,4-D treatment on Shawano Lake would directly address aspects of the logistical feasibility, efficacy concerns, and ecological response. Proper monitoring of a trial treatment would produce sound data on the management action that can be presented to the general public through a distributed written report and potentially several informational meetings. Along with conveying this information to the public, additional awareness campaigns, including an anonymous, written stakeholder survey, could be conducted to understand the broader wishes of the Shawano Lake user group. If the trial treatment satisfactorily addresses the first three implementation challenges listed above, a positive feedback loop of sociological backing (stakeholder support) resulting in additional financial contributions (e.g. individual, municipal, business, agency, etc.) for implementation of a whole-lake treatment strategy may occur. If the trial treatment does not adequately address these implementation challenges, a modified experimental approach may be warranted until the desired goals are met.

Figure 13 provides an approximate timeline for completion of the tasks. The schedule needs to be flexible to accommodate for weather, scheduling conflicts, etc., but it provides a general indication of the dates for completing the proposed components. With Onterra's assistance, SAWM successfully received a WDNR AIS-Established Population Control Grant to cover the costs of implementing project components up to, but not including, the implementation of a whole-lake treatment (up to dashed line on Figure 13).

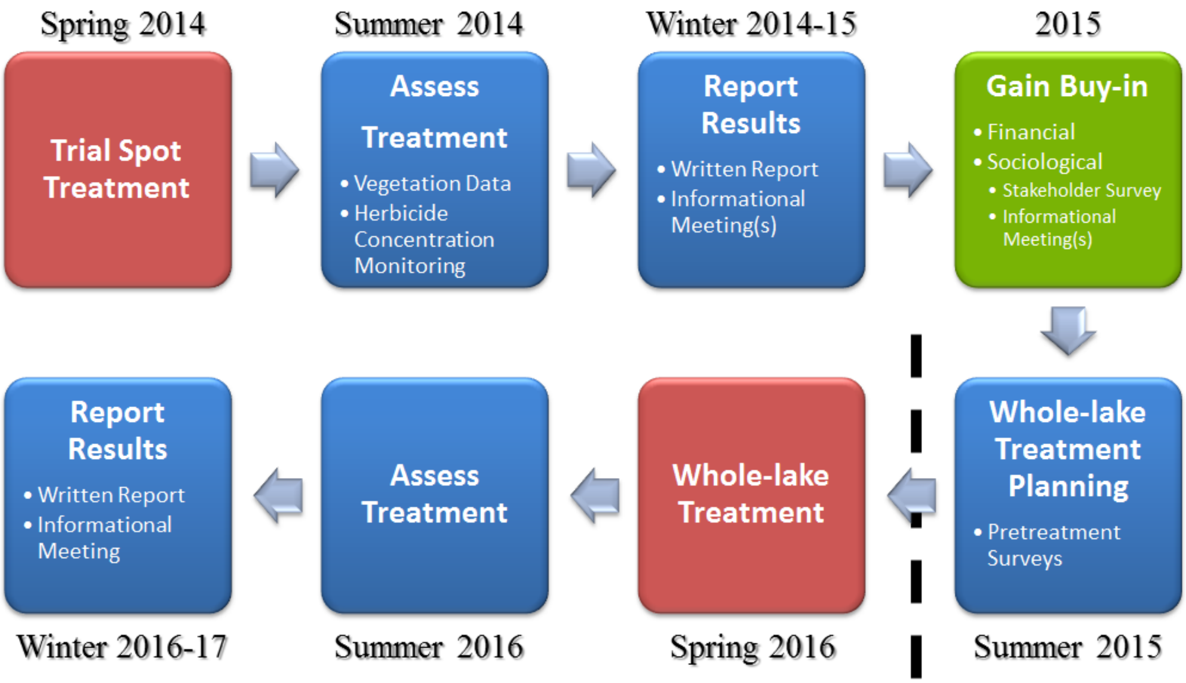


**Figure 13. Flow chart outlining tentative project timeline.**

As discussed above, the herbicide applied to the trial spot treatment area will dissipate out of the application area an dilute with the volume of water within Shawano Lake. Figure 14 shows a hypothetical example of 2,4-D concentrations assuming that the herbicide would mix uniformly only within the volume of water depicted within the scenario. This over-simplified set of calculations is a good exercise to understand potential herbicide concentrations in non-targeted areas.

Each zone is approximately 1 mile away from the trial treatment site. If the herbicide from A-14 mixes within Zone 1, the theoretical 2,4-D concentrations are at levels that may impact some plant species. Based on ongoing research being conducted by the WDNR, U.S. Army Corps of Engineers (USACE), and private consultants, this 2,4-D concentration has not been moderately effective in controlling EWM/HWM when exposed to the target plants for 20-30 days. Since it is understood that the herbicide will continually dilute and mix outside of this arbitrary zone, the theoretical concentrations are not likely to be met and would likely experience a significantly shorter exposure time than needed to cause native or non-native plant impacts within this area.

Additional calculations demonstrating the herbicide from A-14 mixing east within the lake show that 2,4-D concentrations would be far insufficient to cause native or non-native plant impacts at anticipated exposure times.

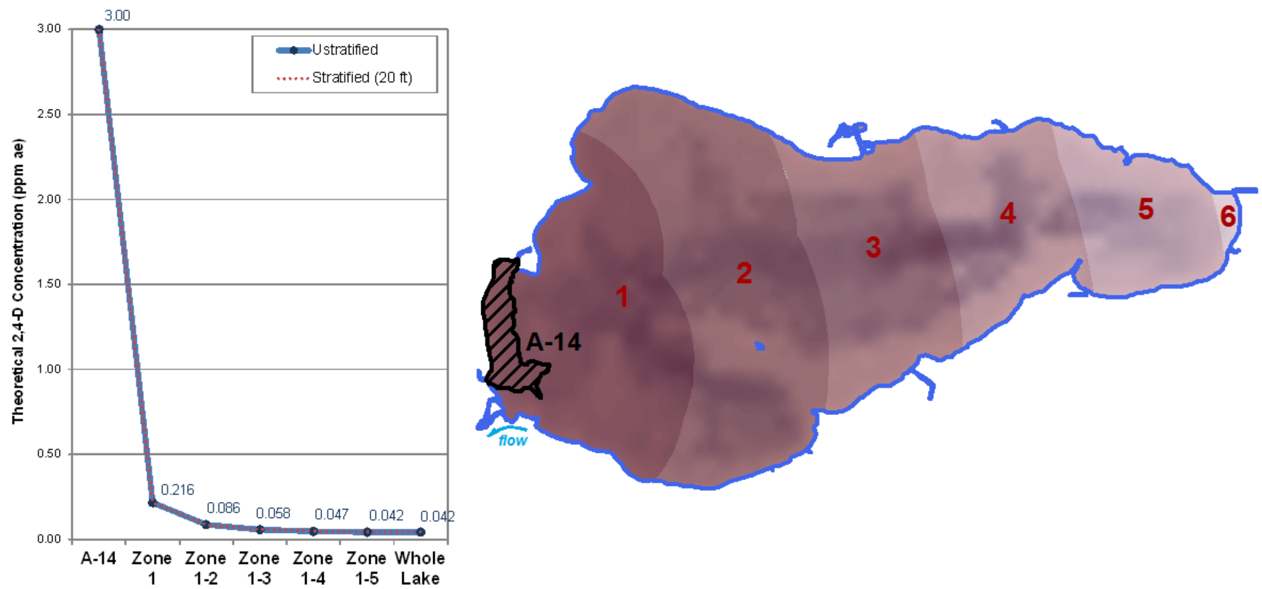


**Figure 14. Potential 2,4-D concentrations assuming herbicide mixing within multiple zones.** Zones are 1 mile concentric buffers from the lakeward edge of A-14. Labels are for calculations assuming the lake is unstratified at the time of application. Assuming an epilimnion extending to 20 feet, the stratified calculations are within 0.002 ppm ae of unstratified conditions in all examples.

## Nuisance Aquatic Plant Control Strategy

As discussed within the introduction strategy, SAWM has been conducting a nuisance control strategy utilizing aquatic herbicides and mechanical harvesting form many years. The goal of these activities has been solely to provide increased navigational abilities within particular areas. As a part of this program, herbicides are applied in the form of 100-ft wide lanes in which watercraft can travel through areas of dense aquatic plant growth (Map 8). Applied in early-summer, the control actions are likely targeting CLP that has not died back yet, as well as EWM, common waterweed, southern naiad, and miscellaneous pondweeds. Even if a whole-lake 2,4-D treatment is conducted in the relatively near future and effectively controls the EWM/HWM for a multi-year time period, the lush aquatic plant conditions of the lake would continue to require control actions to take place to alleviate the recreational impairments in some areas.

Map 8 shows the seven navigation lanes that SAWM has maintained over the past few years, primarily through the use of herbicide application (but also with mechanical harvesting). Successful implementation of this strategy would result in the greatest control (plant mortality) within the lanes where the herbicide was directly applied. Secondary impacts (plant injury) may also occur in nearby areas to the treatment lanes, but these plants typically fully recover in 4-6 weeks following the treatment. If plant regrowth occurs within the treatment lanes, adequate herbicide concentration and exposure times were not met resulting in plant injury vs plant mortality.

In late-June 2013, lanes 1-6 were targeted for control with diquat (2 gallons/acre) and 2,4-D (5 gallons/acre = approx. 1.2 ppm ae). Due to the exposure times required for plant control with 2,4-D, even at its maximum application rate (4.0 ppm ae), it is not a proper herbicide choice in this situation. Diquat requires a much shorter exposure time than other aquatic herbicides and if applied at its maximum application rate (2 gallons/surface acre), it will likely yield the desired outcomes. However, diquat may not fully impact native and non-native pondweeds within these lanes. Discussion about adding liquid endothall to the navigation lanes have occurred. Like 2,4-D, endothall would likely need to be applied towards it maximum application rate (5.0 ppm ai) to overcome the anticipated short exposure times associated with this treatment scenario. However, diquat alone may provide the desired results. In prior years, copper was also used to aid in algae control. Because this herbicide contains copper, it is often disfavored by regulatory agencies.

Advantages of herbicide use in this situation include the immediacy and longevity of results. Disadvantages include, the plant biomass is not removed from the waterbody, but instead the plant tissue is left to decay; high per acre cost; and the use of herbicides is often controversial among stakeholders.

The abundance of largely non-rooted plants such as common waterweed and southern naiad produce large floating mats of these species in many areas of the lake. In the past, SAWM would use its mechanical harvesting equipment to pick up these *floaters* using the mechanical harvester in its shallowest setting. Aside from targeting the floating plant fragments, the only mechanical harvesting that occurred in 2013 was for individual land owners. These management activities are supported by the current management planning effort. Some disgruntled landowners incorrectly blamed the mechanical harvesting activities for the large quantities of plant fragments that washed up on their shorelines. These fragments most likely consist of common waterweed and southern naiad that became dislodged during high wind/wave action; or EWM that has auto-fragmented as a natural part of its lifecycle.

As with all aquatic plant management techniques, harvesting has its advantages and disadvantages. Advantages include the removal of plants and associated nutrients from the waterbody, immediate relief of nuisance plants, harvesting is less controversial than chemical use, and specific areas can be targeted accurately. Disadvantages include sediment re-suspension, fragmentation of plants, and need for repeated cuttings within a single year. Mechanical harvesting in areas that contain pioneering aquatic invasive species populations may increase the rate of spread of these species as it ‘drags’ cut fragments to other parts of the system. This is not applicable to Shawano Lake, as the EWM and CLP populations of Shawano Lake have been well established for many years and already occur in all areas of the lake that contain suitable habitat.

# 4.0 IMPLEMENTATION PLAN

During the planning meetings that took place during November 2013, the SAWM Planning Committee discussed the results of the 2013 studies with ecologists/planners from Onterra. The Planning Committee discussed the strengths and weaknesses of Shawano Lake and its stakeholders, as well as the opportunities and threats they face. These issues were discussed in terms of 1) feasibility of addressing the issue, and 2) level of the issue's importance. As a result of the discussion, SAWM was able to identify goals for protection and Shawano Lake's aquatic vegetation, as well as communicating and education individuals who use the lake.

The implementation plan presented below represents the path the SAWM will follow in order to meet their aquatic plant management goals. The goals detailed within the plan are realistic and achievable, as are the action steps required to reach those goals. The implementation plan is a living document that will be under frequent review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the lake's stakeholders.

### Management Goal 1: Control current Eurasian water milfoil population within Shawano Lake

**Management Action:** Conduct trial treatment on Shawano Lake

**Timeframe:** Early-spring 2014

**Facilitator:** Planning Committee

**Description:** During 2013, EWM was located in 17.4% of the littoral point-intercept sample locations, and was found covering approximately 30% of the lake's littoral zone (≤ 20 ft) through qualitative mapping surveys (Map 7). Of the EWM population, over 900 acres consist of *Surface Matted*, *Highly Dominant,* or *Dominant* colonies. These are the colonies likely contributing to the acute ecological impacts to the system, as well as causing the greatest interference to recreation and navigation by lake users.

When the EWM population within a lake expands to levels as observed in Shawano Lake, they are most feasibly controlled through whole-lake herbicide treatment strategies. As detailed within the Summary & Conclusions Section, this strategy relies on the herbicide reaching equilibrium with a mixing volume of the lake, exposing the entire lake to a low-concentration of herbicide (typically 2,4-D for EWM) that will have multiple weeks of exposure time before degrading into inert chemical compounds.

Due to the awesome size of Shawano Lake, implementing a whole-lake treatment strategy at this time is not a realistic or responsible first step. During the planning process, five primary implementation challenges have been identified: logistical feasibility, efficacy concerns, questionable ecological response, financial constraints, and ability to achieve stakeholder support (Figure 12). The first step to address these challenges will be a trial herbicide treatment, to be conducted on Shawano Lake during the spring of 2013. The first three implementation challenges can be directly addressed through a trial spot-treatment.

**Trial Spot-Treatment Strategy Specifics**

Implemented at a higher target concentration than a whole-lake treatment strategy due to a much shorter anticipated exposure time (hours to days vs weeks), a trial spot-treatment has been devised for Shawano Lake. The target area (Figure 15), was chosen because it met the following conditions:

- It is a large, contiguous area of high density EWM.
- It is located within an area where greater herbicide exposure time is anticipated as opposed to the center of lake where it would be more exposed to wind/wave action. Therefore an increased likelihood of a successful treatment is brought about.
- There is separation between the EWM that is targeted by the treatment and adjacent colonies. Dense areas of EWM adjacent to the treatment area jeopardize the success of the treatment (re-colonization) as well as cloud the stakeholder perception of the treatment (lake users do not know exactly where the treatment took place and will see lots of EWM and think the treatment did not work).
- No WDNR Sensitive Areas are located within the treatment area
- Target areas is within a high use and high visibility location

The 145-acre proposed treatment site is proposed to be targeted with liquid 2,4-D at 3.0 ppm ae during the spring when surface water temperatures are between 50-60°F. The average depth of this site is approximately 6 feet deep. If the amount of herbicide applied to the treatment area distributed evenly within the whole lake, the concentration (0.042 ppm ae) would be far insufficient to cause native or non-native plant impacts at anticipated exposure times.

The partial success of any herbicide treatment strategy relies upon accurate dosing. One component of accurately determining how much herbicide is required requires and understanding of the water depth within the treatment site. During the 2014 Spring Pretreatment Confirmation & Refinement Survey, Onterra would systematically collect continuous, advanced sonar data within the proposed trial treatment site, of which the data would be sent to a Minnesota-based firm for processing. The resulting data would produce an updated bathymetric map for this area to allow for a more-accurate and updated dosing strategy to be developed for this treatment.

Along with providing updated depth information, the acoustic mapping survey would also indicate the percent biomass of aquatic plants within the areas the data was collected at. While the map output would not differentiate between aquatic plant species, it would indicate where high bio-volumes of vegetation exist in the lake. This information may be important for fisheries and lake managers to understand the structural impacts of the macrophyte communities in association with the trial treatment. Pairing this data with additional quantitative plant data (discussed below) may provide indication of the plant species/type contributing to the bio-volume present following the treatment.

**Monitoring Strategy & Success Criteria**

Efficacy: Two types of aquatic plant monitoring would be completed to determine treatment effectiveness; 1) qualitative monitoring comparing pre- and post treatment EWM mapping data, and 2) quantitative monitoring using point-intercept data (utilizing locations from whole-lake grid that are within and adjacent to the spot-treatment application area) and point-intercept sub-sample data (new grid of points placed over treatment area, much closer together than whole-lake point-intercept grid [50 meters vs 165 meters]).

1. Qualitatively, a successful treatment would include a reduction of EWM density as demonstrated by a decrease in two density ratings (e.g. *Highly Dominant* to *Scattered)* when comparing the 2013 EWM mapping data with data to be collected during 2014.
2. Quantitatively, a successful treatment would include a significant reduction in EWM frequency following the treatments as exhibited by at least a 75% decrease in exotic frequency from the pre- and post-treatment point-intercept sub-sampling. The 2014 trial treatment monitoring strategy will implement quantitative methods using a modified point-intercept methodology consistent with the Appendix D of the WDNR Guidance Document, Aquatic Plant Management in Wisconsin (WDNR 2010). In general, a sub-sample point-intercept grid will be placed over the treatment site to yield approximately 200 sampling locations.

   These sub-sample locations would be sampled the spring (April-May) before the treatment (pretreatment) and the late-summer following the treatment (post treatment). Data collected at these locations would be analyzed in terms of EWM treatment efficacy (statistical difference in pre and post EWM presence).

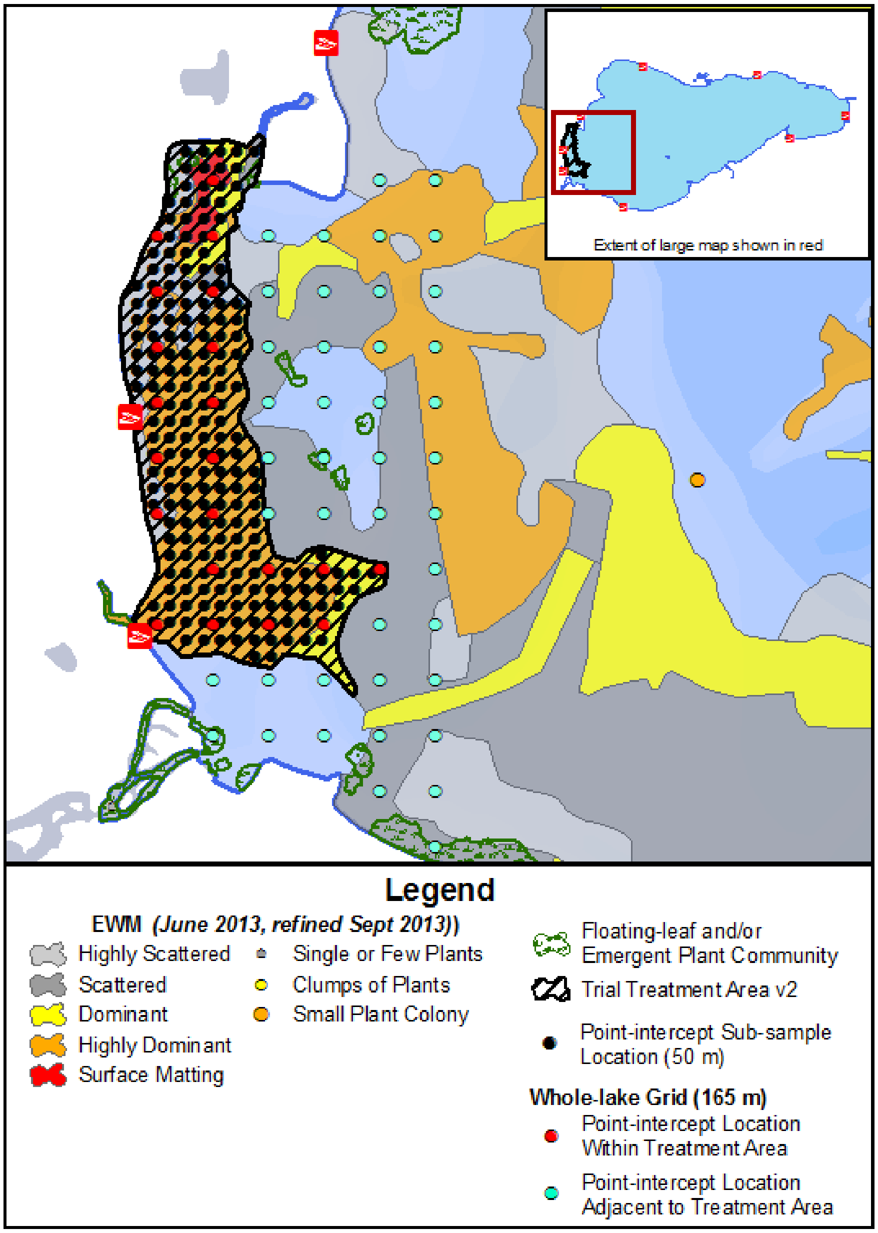


**Figure 15. Trial herbicide treatment proposed for Shawano Lake during the spring of 2014.**

Selectivity:
Successful herbicide treatments entail maximizing efficacy against target species while minimizing impacts to the native (non-target) plant community. Many actions are taken to reduce the chance of herbicide impacts on native aquatic species, including the selection of the herbicide type/concentration and the time of year that the herbicide is applied. By conducting the herbicide treatment early in the growing season, when many native plants have not yet begun growing, the herbicide is more selective towards EWM. While 2,4-D was traditionally thought to be selective towards broad-leaf (dicot) species, emerging data from the WDNR and USACE indicate that some

narrow-leaf (monocot) species are impacted by this herbicide.

Native plant frequency of occurrence monitoring will occur at point-intercept locations contained within and adjacent to the 2014 application area (Figure 15). Statistical comparisons of native plant occurrence before and after the treatment will be conducted. Please note that it is not appropriate to use native plant frequency of occurrence data during the early-spring pretreatment survey to compare against surveys completed later in the summer due to phenologic differences in these plants' life cycles.

In-lake Herbicide Concentration Monitoring:
In conjunction with the WDNR and US Army Corps of Engineers, herbicide concentration monitoring at strategic locations throughout the system would take place to understand the concentration/exposure time of the herbicide at different time periods and locations following the treatment. This information would indicate whether or not the amount of herbicide applied is sufficient for causing EWM mortality and if any adjustments in treatment strategy need to be made.

Water samples would be collected by trained volunteers from the lake. The properly preserved samples would be sent to the USACE for laboratory analysis. Under the current program, there would be no analysis costs for the USACE to run the samples. However, it is uncertain if this will hold true in 2014. Coupling the herbicide concentration data with the point-intercept data will be valuable for assessing the trial treatment.

**Action Steps:**

See description above.

**Management Action:** Gain stakeholder input regarding a whole-lake EWM treatment on Shawano Lake

**Timeframe:** 2015 (potentially beyond)

**Facilitator:** Planning Committee *or* Education and Communication Committee.

**Description:** The monitoring results of the 2014 trial spot-treatment will be made available through a written report during the winter months of 2014-2015. The information contained within the report will also be presented by Onterra at various public meetings and distributed to the public through a coordinated educational campaign. Public education of how the trial spot-treatment addressed particular implementation challenges will be important to allow stakeholders to have an educated opinion about the benefits and risks of moving forward with a whole-lake treatment.

Once the educational campaign has had sufficient time to operate, comments and opinions would be solicited from Shawano Lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. The information would be collected through a written survey/comment form supplied to each member household by mail. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. Prior to distribution, the survey would be officially approved by a survey expert from the WDNR.

The results of the stakeholder survey coupled with comments received during the educational campaign will be integrated into a proposed control strategy moving forward. If this management action results in achieving sociological backing, this may provide a positive feedback loop for gaining financial support for conducting a whole-lake treatment on Shawano Lake. If sufficient sociological or financial support does not exist, SAWM may investigate enhancing the nuisance aquatic plant control strategy outlined within Management Goal #3.

**Action Steps:**

1. SAWM Planning Committee determines if it is necessary to create an Education and Communication Committee to carry on the tasks of this management action.
2. Onterra report and present on trail spot-treatment.
3. Through help from Onterra, Committee creates educational materials based upon the results of the trial spot-treatment.
4. Committee distributes educational material through various communication mediums.
5. Committee distributes written stakeholder survey to property owners around Shawano Lake.
6. Stakeholder survey results are compiled by the SAWM Planning Committee or third-party contractor and provided to Onterra for analysis.
7. Onterra create a written report outlining a proposed control strategy that incorporates the sociological opinions documented during the stakeholder survey and educational campaign.
8. Committee conducts an effort to gain financial support for implementing the proposed control strategy. If sufficient private funds are accumulated, the Committee (with help from Onterra) would seek available grant funds from the WDNR.

**Management Action:** Conduct whole-lake herbicide treatment on Shawano Lake

**Timeframe:** 2016 (or later)

**Facilitator:** Board of Directors

**Description:** If the two management goals outlined above are able to satisfactorily address all 5 of the implementation challenges outlined (Figure 11), a whole-lake herbicide treatment will be planned for Shawano Lake.

**Whole-Lake Treatment Strategy Specifics**

At this time, the most likely herbicide candidate for this treatment would be liquid 2,4-D, applied over *Dominant, Highly Dominant,* and *Surface Matting* EWM colonies that would result in a whole-lake concentration of 0.35 to 0.40 ppm ae. However, the whole-lake control strategy would also reflect additional information gained between the creation of this document and the implementation of the treatment strategy, potentially resulting in a modified herbicide or use rate. The herbicide treatment would be conducted during the early-spring when surface water temperatures are between 50-60°F.

**Monitoring Strategy & Success Criteria**

Two types of aquatic plant monitoring would be completed to determine treatment effectiveness; 1) qualitative monitoring comparing pre- and post treatment EWM mapping data, and 2) quantitative monitoring using point-intercept data (utilizing locations from whole-lake grid).

1. Qualitatively, a successful whole-lake treatment would include a 50% reduction of colonized EWM acreage within the lake, and the majority of the remaining densities being comprised of low-density (*Highly Scattered* and *Scattered*) EWM colonies.
2. Quantitatively, a successful whole-lake treatment would include a significant reduction in EWM frequency following the treatments as exhibited by at least a 75% decrease in exotic frequency from the pre- and post-treatment point-intercept sampling. This analysis will utilize data from the whole-lake point-intercept grid, collected during the summer before and the summer immediately following the treatment. An additional whole-lake point-intercept survey would be conducted during the following summer (2 years post) to ensure that considerable EWM regrowth did not occur.

   Native plant frequency of occurrence would also be collected during the point-intercept surveys conducted the summer prior to the treatment and the 2 summers following the treatment. This will allow an understanding of how the control strategy impacted the non-target native aquatic plants of the system.

In-lake Herbicide Concentration Monitoring:

In conjunction with the WDNR and US Army Corps of Engineers, herbicide concentration monitoring at strategic locations throughout the system would take place to understand the concentration/exposure time of the herbicide at different time periods and locations following the treatment. This information would indicate whether or not the amount of herbicide applied is sufficient for causing EWM mortality and if any adjustments in treatment strategy need to be made.

Water samples would be collected by trained volunteers from the lake.

The properly preserved samples would be sent to the USACE for laboratory analysis. Under the current program, there would be no analysis costs for the USACE to run the samples. However, it is uncertain if this will hold true at the time when a whole-lake strategy is implemented. Coupling the herbicide concentration data with the point-intercept data will be valuable for assessing the whole-lake treatment.

**Action Steps:**

See description above.

## Management Goal 2: Prevent additional AIS from entering Shawano Lake, and prevent AIS from Shawano Lake from infecting other lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Shawano Lake public access locations.

**Timeframe:** Continuation of current effort

**Facilitator:** SAWM Planning Committee

**Description:** Currently public boat landing on Shawano Lake are monitored through training provided by the Clean Boats Clean Waters program. The majority of this effort is conducted by paid limited term employees through Oconto County (Table 2). SAWM continues to support the efforts of the county.

**Table 2. Watercraft inspections conducted on Shawano Lake.** WDNR 2013.

| | Boats Inspected | | |
|---|---|---|---|
| **Landing** | **2010** | **2011** | **2012** |
| Access at Shawano Lake Outlet (CTH HHH) | 2 | 2 | 0 |
| Access Nr Cattau Beach Dr | 0 | 6 | 5 |
| Access Nr County HHH And Lake Dr | 0 | 7 | 0 |
| Access Nr Stark Rd And Washington Lake | 0 | 13 | 372 |
| Access Nr Swan Acre Dr | 0 | 116 | 327 |
| Access Off Hwy H Nr Sunset Circle | 0 | 205 | 114 |
| Boat Ramp By Cecil | 26 | 82 | 212 |
| Shawano County Park Access | 0 | 8 | 274 |
| Shawano Lake Outlet Channel | 0 | 144 | 238 |
| **Total** | **28** | **583** | **1542** |

Shawano 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 invasives from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasives that originated in Shawano Lake. The goal would be to cover the landings 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.

Dovetailing with the watercraft inspections, the Shawano County Park recently installed and currently maintains two boat washing stations, offered to lake visitors free of charge. Boat owners are encouraged to power wash their watercrafts prior to entering the lake, limiting Shawano Lake's exposure to new AIS. Boats should also be power washed after visiting Shawano Lake, to ensure the AIS from Shawano Lake are not exposed to other lakes.


**Photo 6. Boat wash station on Shawano Lake**

**Action Steps:**

See description above as this is an established program.

## Management Goal 3: Maintain Navigability on Shawano Lake

**<u>Management Action:</u>** Support responsible actions to gain reasonable navigational access to open water areas of Shawano Lake

**Timeframe:** Ongoing

**Facilitator:** Planning Committee

**Description:** SAWM understands the importance of native aquatic vegetation on Shawano Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, caused by both non-native and native vegetation. In order to alleviate navigation impediments caused by the vegetation, herbicide applications by an association-employed applicator have been conducted in 2012 and prior within these areas.

SAWM supports the reasonable and environmentally sound actions to facilitate navigability on Shawano Lake. These actions target nuisance levels of aquatic plants in order to restore watercraft navigation patterns.

Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area required to permit the access or use.

The lanes displayed on Map 8 were digitized by Onterra using a collective of information provided by SAWM, the herbicide applicator that conducted the 2013 treatment, the WDNR, and the USACE. However, the position of the lanes may not be completely spatially accurate since GPS data had not been collected in association with past control activities. Moving forward, an onboard hand-held GPS (grant-funded) will be used by the association-employed applicator during the herbicide application to ensure proper dosing and herbicide coverage, provide proper records of where the activities took place, and to allow lake managers and stakeholders to create and modify treatment lanes prior to implementation. Basemaps of the application areas shown on Map 8 will be loaded onto the GPS unit prior to the herbicide application. This will also allow fisheries and resource managers to update the position of the navigation lanes prior to the treatment if conflicts arise.

**Action Steps:**

See description above

# 5.0 METHODS

## Aquatic Invasive Species Surveys

Early-season AIS surveys were completed on Shawano Lake during a June 6, 7, and 10, 2013 field visit, in order to correspond with the anticipated peak growth of CLP. EWM populations were also mapped during this timeframe. The extents and densities of the EWM colonies were refined as appropriate based upon a September 25, 2013 site visit. Visual inspections were completed throughout the lake by completing a meander survey by boat. Point, polyline, and polygon data were recorded directly in ArcPad (ESRI) on a Microsoft Windows-based ruggedized Panasonic Toughbook computer, blue-toothed Global Positioning System (GPS) data through a Trimble GeoXT data collector with sub-meter accuracy.

## Comprehensive Macrophyte Survey

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

### *Point-intercept Survey*

The point-intercept method as described by the WDNR Bureau of Science Services (PUB-SS-1068 2010) was used to complete this study on July 12, 15, and 16, 2013. A point spacing of 165 meters was used resulting in approximately 925 points. Data were recorded using the computer/GPS methodology described above.

### *Floating-leaf and Emergent Plant Community Mapping Survey*

On July 16, 17, and 18, 2013, the aquatic vegetation community types within Shawano Lake (emergent and floating-leaved vegetation) were mapped. Point, polyline, and polygon data were recorded using the computer/GPS methodology described above.

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.

# 6.0 LITERATURE CITED

Borman, S., R. Korth., J. Temte. Through the looking glass. PUB-FH-207-97.

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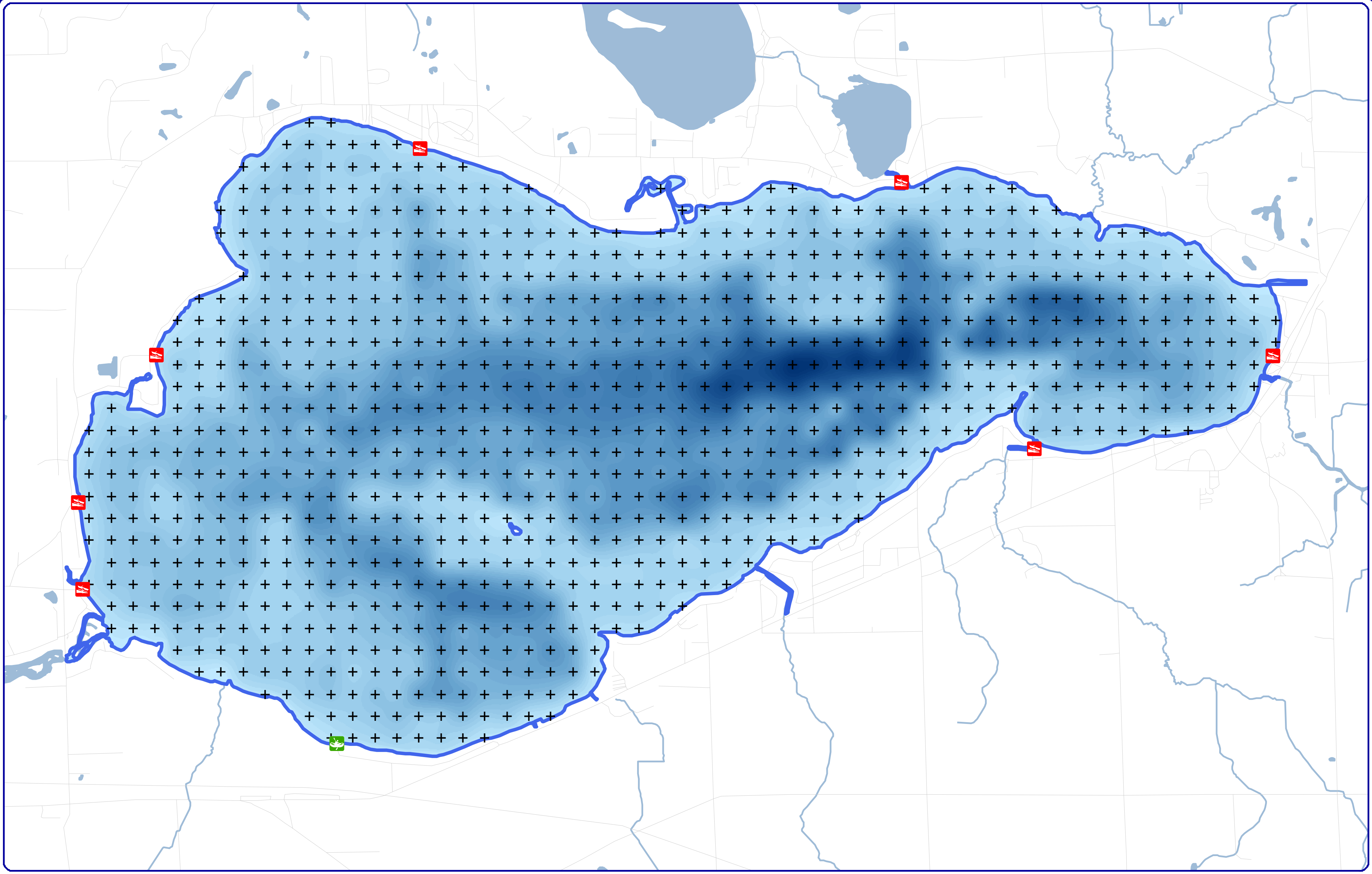
Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2): 133-141

Owens, C.S., W.F. James, J.G., Skogerboe, R.M. Smart. 2007. Distribution and Abundance of Eurasian Watermilfoil (*Myriophyllum spciatum* L.) and Curly-Leaf Pondweed (*Potamogeton crispus* L.) in Shawano Lake, Wisconsin. Engineer Research and Development Center Vicksburg MS Environmental Lab

WDNR, 2003. Shawano Lake Sensitive Area Survey Report and Management Guidelines.

Wisconsin Department of Natural Resources – Bureau of Endangered Resources. 2011. Wisconsin Endangered and Threatened Species Laws and List. PUBL-ER-001.



3,250

Feet

Onterra LLC
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815 Prosper Road
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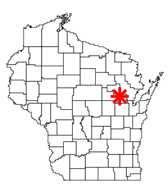
920.338.8860
www.onterra-eco.com

**Sources:**
Roads and Hydro: WDNR
Bathymetry: Onterra, 2013
**Map Date:** November 1, 2013
*Filename: Map1_Shawano_Location.mxd*



Project Location in Wisconsin

## Legend

Shawano Lake ~6,063 acres
*WDNR Definition*

\+ Point-Intercept Survey Location
*165-meter spacing, 925 total points*

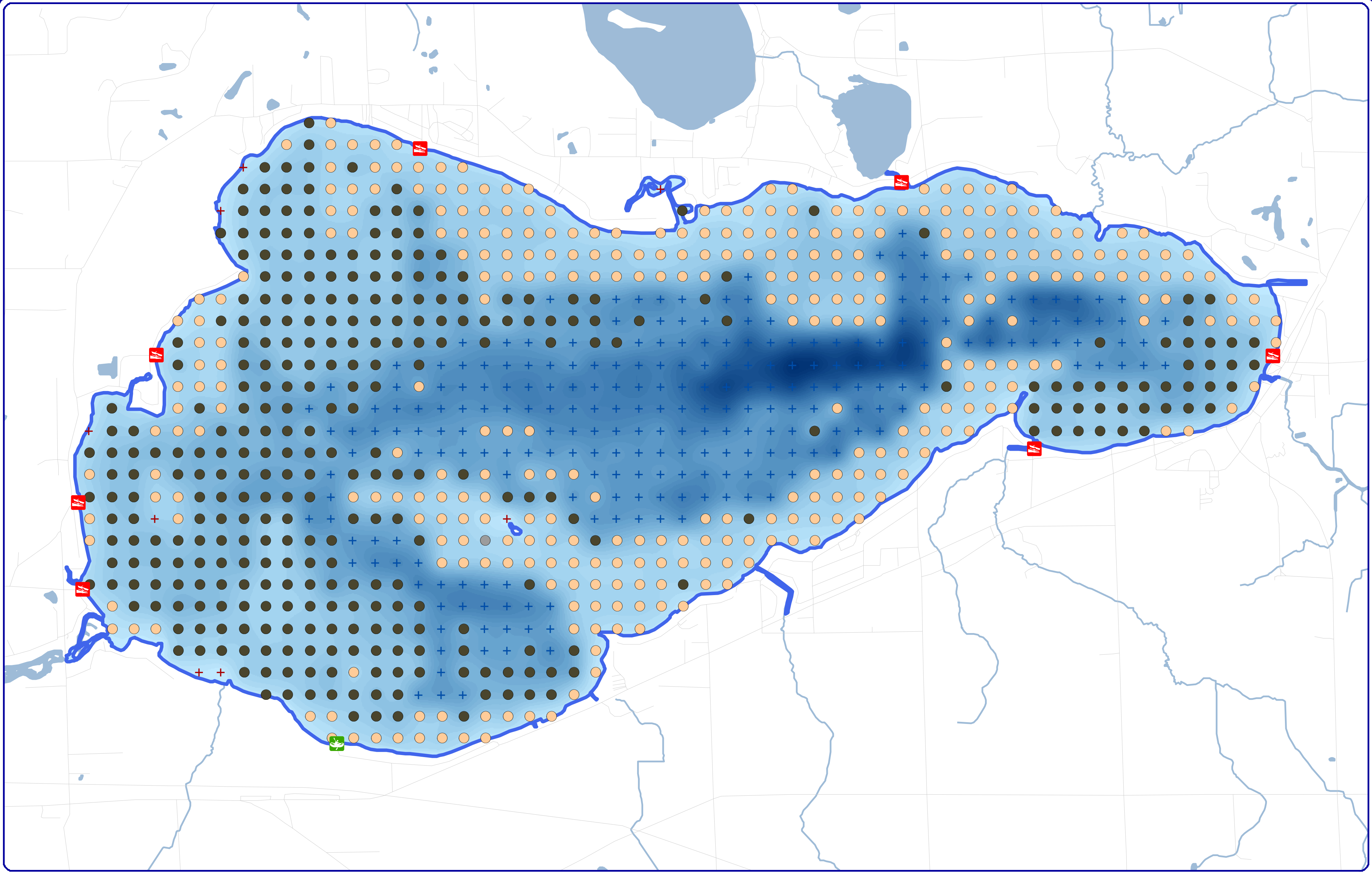
Public Boat Landing

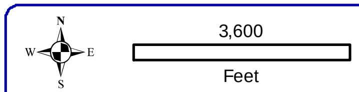
Carry-in Access

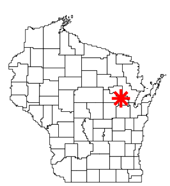
Map 1

Shawano Lake
Shawano County, Wisconsin

**Project Location & Lake Boundaries**





Project Location in Wisconsin

**Legend**

- Soft/Organic Sediments
- Rock
- Sand
- Too Deep - No Data
- Non-navigable/Temporary Obstacle

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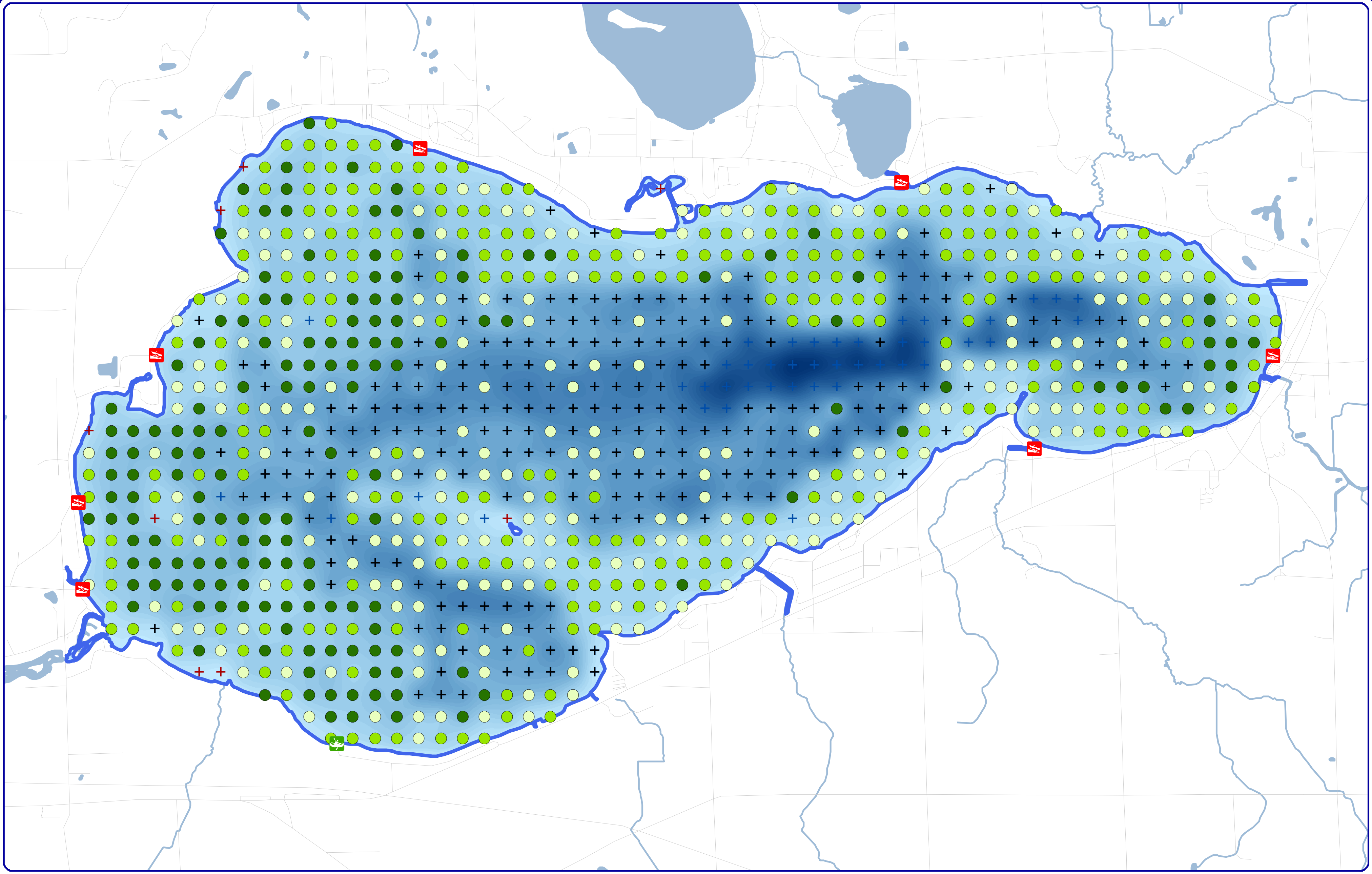
**Sources:**
Roads and Hydro: WDNR
Bathymetry: Onterra, 2013
**Map Date:** November 1, 2013
*Filename: Map2_Shawano_SubstratePI.mxd*

Map 2
Shawano Lake
Shawano County, Wisconsin

**2013 PI Survey: Substrate Types**



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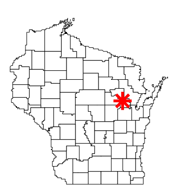
**Sources:**
Roads and Hydro: WDNR
Bathymetry: Onterra, 2013
**Map Date:** November 1, 2013
*Filename: Map3_Shawano_TRFPI.mxd*



Project Location in Wisconsin

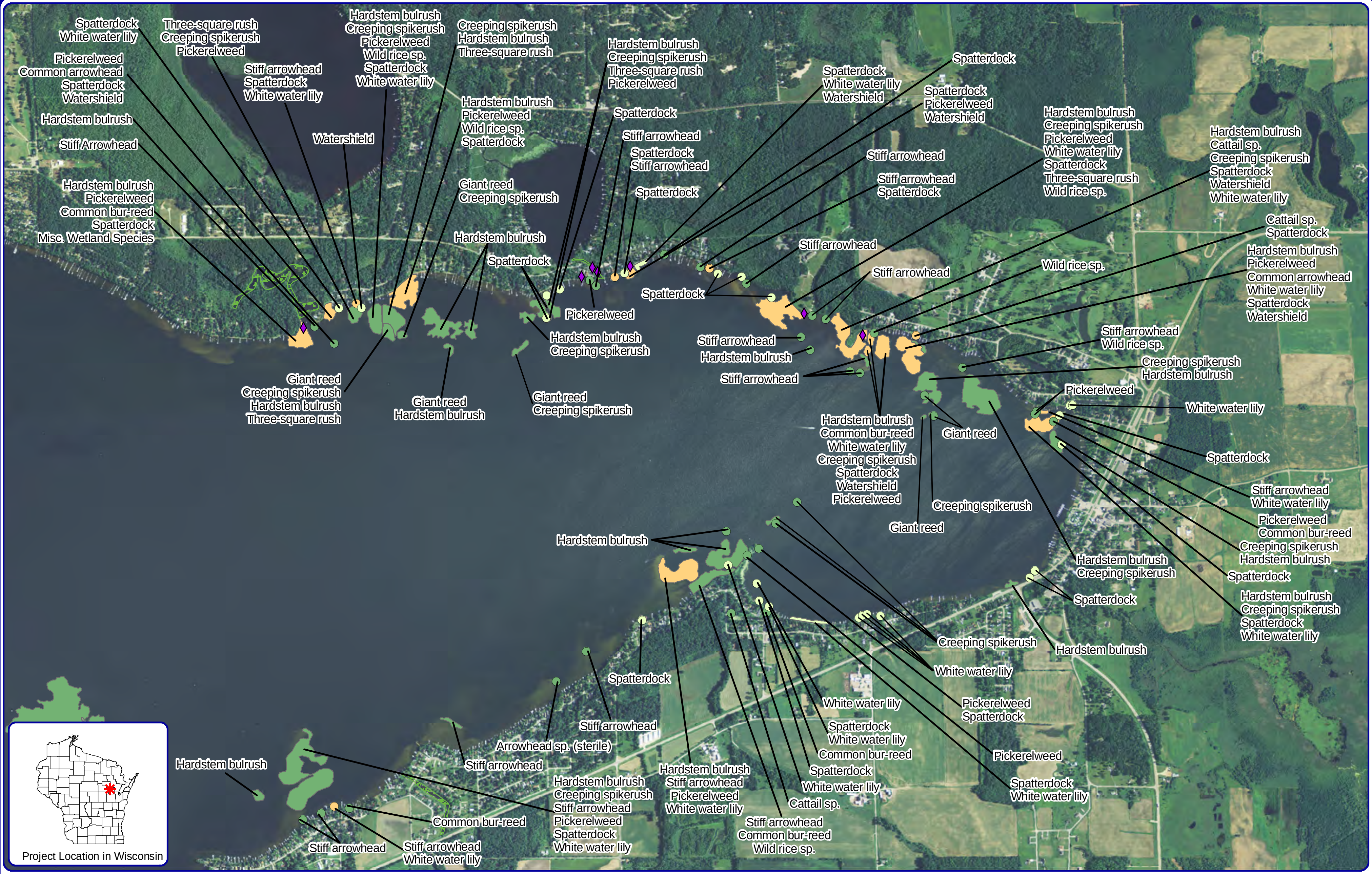
## Legend

### 2012 Total Rake Fullness

- \+ No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- \+ Too Deep
- \+ Non-navigable/Temporary Obstacle

Map 3
Shawano Lake
Shawano County, Wisconsin

**2013 PI Survey:**
**Vegetation Distribution**

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**Sources:**
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2010
**Map date:** October 24, 2013
Filename: Map4_Shawano_Comm_2013_East.mxd

## Legend

**Small Plant Communities**
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

**Large Plant Communities**
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

**Exotic Plant Communities**
- Purple loosestrife

Map 4
Shawano Lake - East
Shawano County, Wisconsin

**Floating-leaf & Emergent Aquatic Plant Communities**


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Feet

## Legend

**Small Plant Communities**
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

**Large Plant Communities**
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

**Exotic Plant Communities**
- Purple loosestrife

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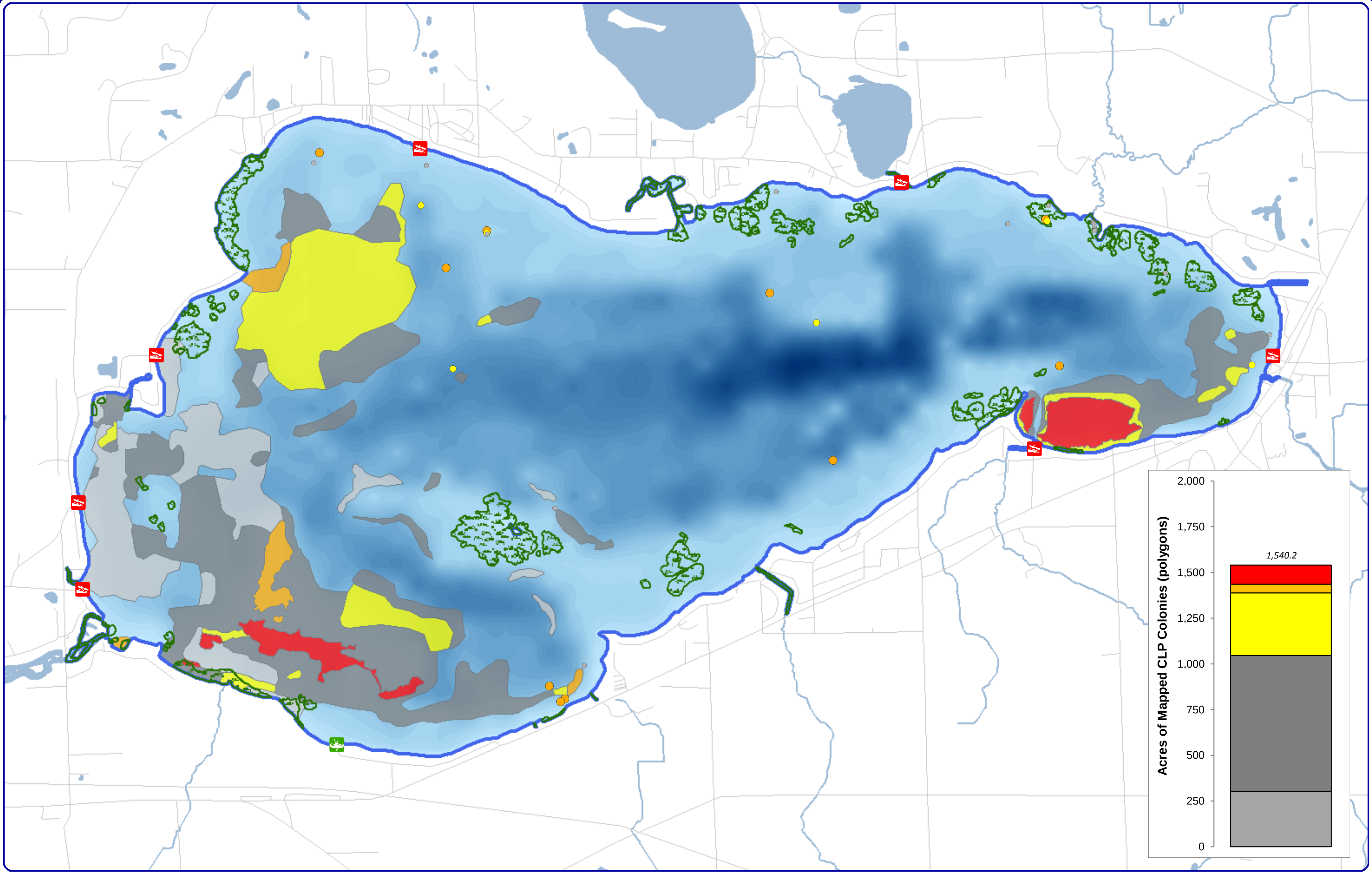
**Sources:**
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2010
**Map date:** October 24, 2013
Filename: Map5_Shawano_Comm_2013_West.mxd

Map 5
Shawano Lake - West
Shawano County, Wisconsin

**Floating-leaf & Emergent Aquatic Plant Communities**

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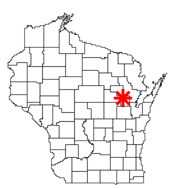
**Sources:**
Roads and Hydro: WDNR
Bathymetry: Onterra, 2013
**Map Date:** November 1, 2013
*Filename: Map6_Shawano_CLPPB_June13.mxd*



Project Location in Wisconsin

## Legend

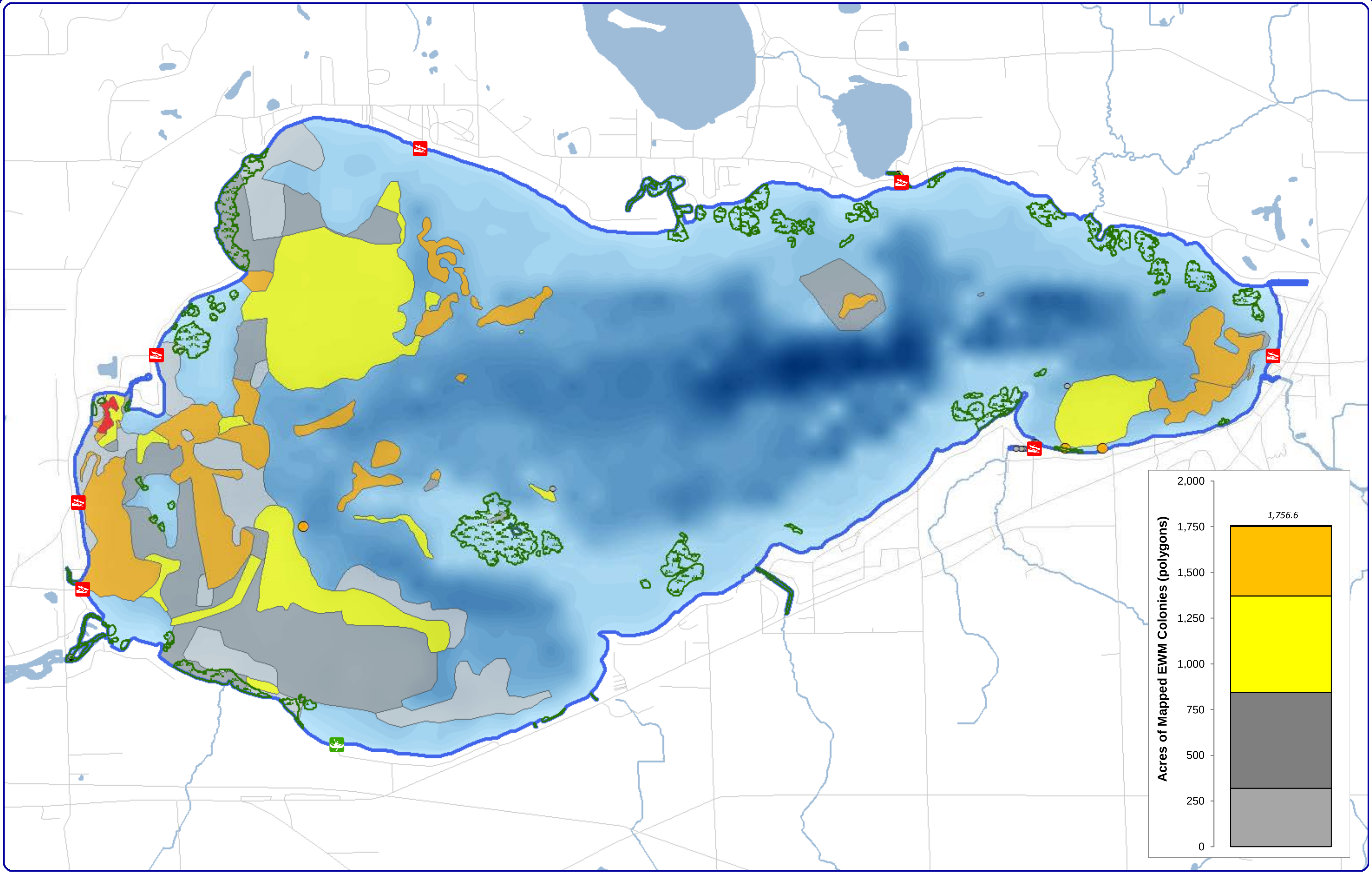
**Curly-leaf pondweed (June 2013)**

**Large CLP Community**
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting

**Small CLP Community**
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

Floating-leaf and/or Emergent Plant Community

Map 6
# Shawano Lake
Shawano County, Wisconsin
# 2013 Curly-leaf Pondweed Locations

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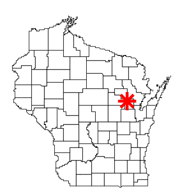
**Sources:**
Roads and Hydro: WDNR
Bathymetry: Onterra, 2013
**Map Date:** November 1, 2013
*Filename: Map7_Shawano_EWMPB_June13.mxd*


Project Location in Wisconsin

## Legend

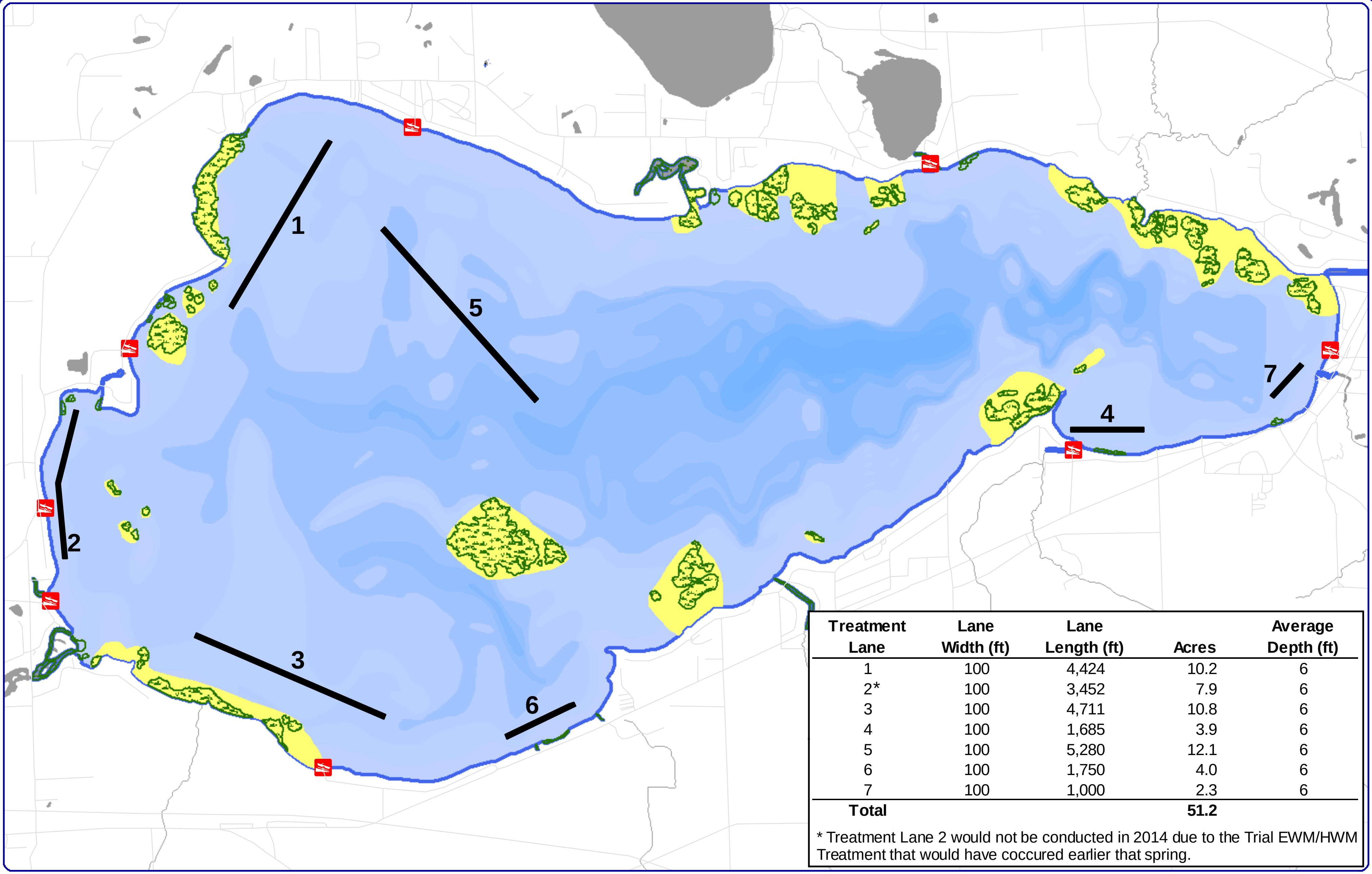
**Eurasian water milfoil (June 2013, refined Sept 2013)**

**Large EWM Community**
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting

**Small EWM Community**
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

Floating-leaf and/or Emergent Plant Community

Map 7
# Shawano Lake
Shawano County, Wisconsin
# 2013 Eurasian water milfoil Locations




| Treatment Lane | Lane Width (ft) | Lane Length (ft) | Acres | Average Depth (ft) |
|---|---|---|---|---|
| 1 | 100 | 4,424 | 10.2 | 6 |
| 2* | 100 | 3,452 | 7.9 | 6 |
| 3 | 100 | 4,711 | 10.8 | 6 |
| 4 | 100 | 1,685 | 3.9 | 6 |
| 5 | 100 | 5,280 | 12.1 | 6 |
| 6 | 100 | 1,750 | 4.0 | 6 |
| 7 | 100 | 1,000 | 2.3 | 6 |
| **Total** | | | **51.2** | |

* Treatment Lane 2 would not be conducted in 2014 due to the Trial EWM/HWM Treatment that would have coccured earlier that spring.

N W E S

3,100
Feet

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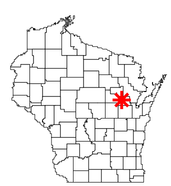
**Sources:**
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2013
Sensitive Areas: WDNR, 2003
Nusiance Lanes: Digitized by Onterra from WDNR permit records
**Map Date:** December 2, 2013
*Filename: Map8_Shawano_NusianceControl.mxd*


Project Location in Wisconsin

## Legend

Nusiance Navigation Treatment Lane
Floating-leaf and/or Emergent Plant Community
Public Access
WDNR Sensitive Area

Map 8

# Shawano Lake

Shawano County, Wisconsin

## Nuisance Navigation Herbicide Lanes