INTRODUCTION


Photo 1. Crooked Lake, Oconto County.

Crooked Lake, Oconto County, is an approximate 143-acre drainage lake with a reported maximum depth of 37 feet. Gilkey and Bass Lakes, 20 and 12 acres, respectively, are smaller seepage lakes directly connected and flowing into to Crooked Lake. Gilkey Lake has a reported maximum depth of six feet and flows into Crooked Lake's northeast side, while Bass Lake has a reported maximum depth of 11 feet and is connected to Crooked Lake via a small channel on the lake's southeast side. Eurasian water milfoil (*Myriophyllum spicatum;* EWM) was first documented from Crooked, Gilkey, and Bass Lakes in 2002. Since 2008, the Crooked Lake Protection & Rehabilitation District (CLPRD) has been actively managing the EWM population through strategically targeted herbicide applications and volunteer based hand harvesting removal efforts.

Following effective control of EWM in 2013, Onterra ecologists only located low-density occurrences of EWM during the late summer of 2013 within the Crooked Lake system. Within Bass Lake, many EWM clumps and single plant occurrences were located in the summer of 2013 (Map 1). After discussions with the CLPRD, an herbicide control strategy was proposed for Bass Lake in 2014 to target the largest remaining known area of EWM in the system.

2014 EWM CONTROL STRATEGY

Understanding concentration-exposure times are important considerations for implementing successful control strategies utilizing aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of a joint research project between the WDNR, U.S. Army Engineer Research and Development Center (USAERDC), and private consultants. Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) whole-lake treatments and 2) spot treatments.

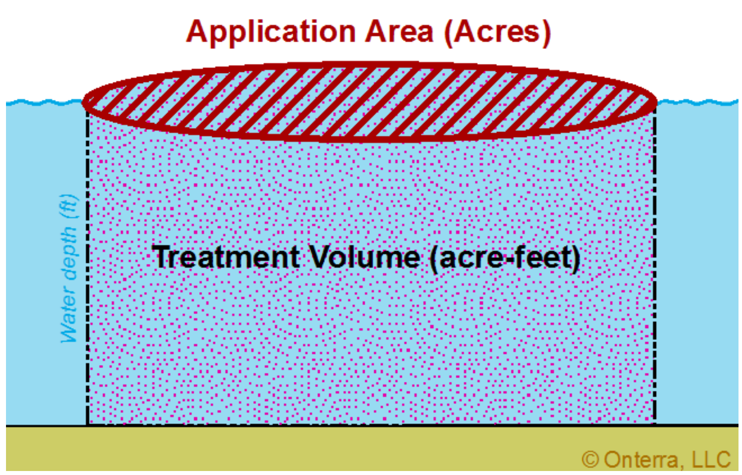


Figure 1. Herbicide Spot Treatment diagram.

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant effects outside of that area. Herbicide application rates for spot treatment are formulated volumetrically, typically targeting EWM with 2,4-D at 3-4.0 ppm acid equivalent (ae). This means that sufficient 2,4-D is applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal 3-4.0 ppm ae. This standard method for determining spot treatment use rates is not without flaw, as no physical barrier keeps the herbicide within the *Treatment Volume* and herbicide dissipates horizontally out of the area before reaching equilibrium (Figure 1). 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. This strategy was implemented in 2012 and 2013 within parts of the Crooked Lake system.

Whole-lake, or whole-basin, 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 which the herbicide will reach equilibrium with. Because exposure time is so much greater, effective herbicide concentrations for whole-lake treatments are significantly less than required for spot treatments.

Due to Bass Lake's relatively small water volume, almost any spot-treatment that would be conducted in this basin would have whole-lake implications. Therefore, Onterra recommended that a whole-lake treatment would be the most appropriate way to target the EWM within Bass Lake (Map 1). Unlike spot treatments that rely on a short exposure (hours) of a high concentration of herbicide, this strategy involves applying a low dose of 2,4-D to the entire lake understanding that the effective exposure time of the herbicide would be 14-28 days. To compensate for the anticipated migration of herbicide from Bass Lake into Crooked Lake through water flow, the target lake-wide concentration of 2,4-D was proposed to be on the higher-end of standard dosage rates at 0.400 ppm ae (Map 1). No herbicide treatments were proposed for Gilkey Lake or Crooked Lake during 2014.

PRETREATMENT CONFIRMATION AND REFINEMENT SURVEY

On May 15, 2014, Onterra conducted the EWM Spring Pretreatment Confirmation and Refinement Survey on the Crooked Lake system. During this survey, the proposed treatment site within Bass Lake was visited. A temperature and dissolved oxygen profile collected in Bass Lake indicated the lake was weakly stratified with near-surface water temperatures in the mid-50s°F and near-bottom temperatures in the low-50s°F (Figure 2). Sufficient EWM warranting treatment was confirmed in the originally proposed treatment area. The EWM was visible from the surface and was observed to be green and actively growing. Native plant growth was observed to be minimal, being mostly comprised of fern-leaf pondweed. No alterations of the treatment area were made. Given the water temperature and growth stage of EWM, Onterra recommended that the treatment occur as soon as logistically possible.

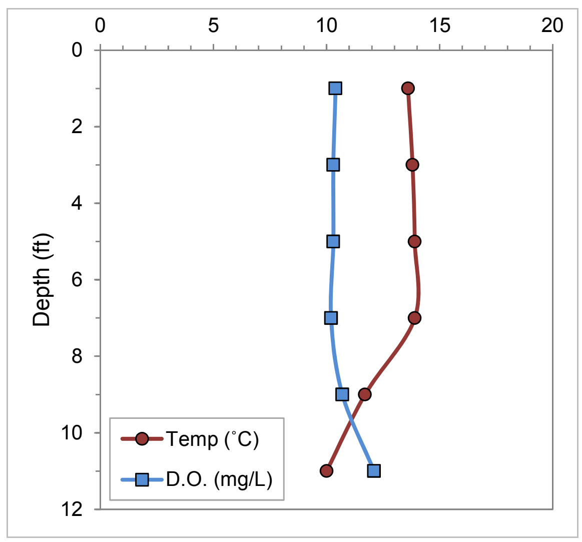


Figure 2. Bass Lake Pretreatment temperature and dissolved oxygen profile. Data collected on May 15, 2014.

Prior to the Pretreatment Confirmation and Refinement Survey, an acoustic survey was also conducted on Bass Lake approximately one week after ice out to obtain accurate bathymetric data. The updated bathymetric data allow for the most accurate estimate of the water volume within the lake. This volume is then used to accurately determine the correct amount of herbicide that needs to be applied to achieve the desired target concentration. The acoustic survey data indicated Bass Lake contains approximately 72.4 acre-feet of water, only slightly higher than previous estimates of 69.4 acre-feet. During the acoustic survey, several water velocity measurements at the channel between Bass Lake and Crooked Lake were also collected. These data revealed that water at that time was actually flowing from Crooked Lake into Bass Lake. Because of this, it was believed that herbicide migration out of Bass Lake would be lower than originally anticipated, and the lake-wide target concentration of 2,4-D was lowered slightly to 0.375 ppm ae.

The low-concentration, whole-lake 2,4-D treatment was conducted by Schmidt's Aquatic Plant Control on May 27, 2014. The applicator reported 0-5 mph winds out of the north during the application and a near surface water temperature of 68°F.

MONITORING METHODOLOGIES

The objective of any herbicide treatment strategy is to maximize target species (EWM) mortality while minimizing impacts to valuable native aquatic plant species. Monitoring herbicide treatments and defining their success incorporates both quantitative and qualitative methods. As the name suggests, quantitative monitoring involves comparing number data (or quantities) such as plant frequency of occurrence before and after the control strategy is implemented. Qualitative monitoring is completed by comparing visual data such as EWM colony density ratings before and after the treatments.

Quantitative Aquatic Plant Monitoring

Whole-Lake Point-Intercept Survey

The whole-lake point-intercept method, as described by the WDNR Bureau of Science Services (Hauxwell et al. 2010), was used to complete quantitative evaluations of the occurrences of EWM and native aquatic plant species in Bass Lake. In Bass Lake, quantitative evaluation was made through the collection of data at 59 point-intercept sampling locations evenly spaced across the lake at a resolution of 30 meters (Figure 3). Comparing data collected before and after the treatment allows for a statistical comparison of aquatic plant occurrences and a quantitative determination of treatment efficacy on a lake-wide scale. Based upon pre-determined success criterion, the 2014 herbicide treatment strategy would be deemed effective if the point-intercept data show that the EWM frequency of occurrence following the treatment is reduced by at least a statistically valid 50% (Chi-square $\alpha = 0.05$).

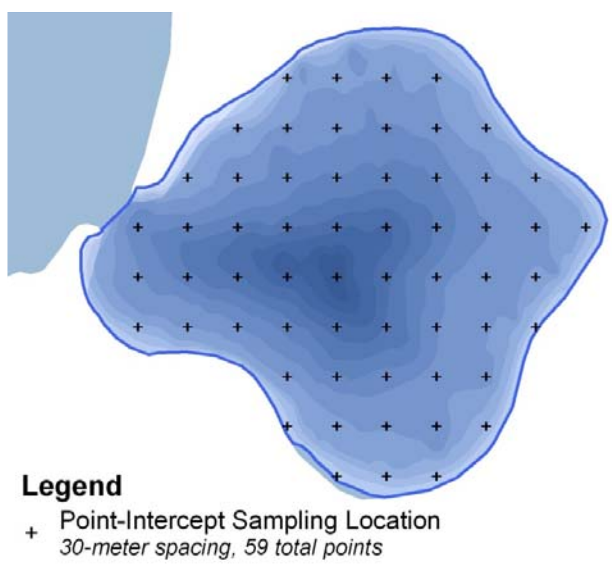


Figure 3. Whole-lake point-intercept survey sampling locations on Bass Lake.

Bio-Acoustic Survey

Approximately one week following ice-out on May 7, 2014 prior to treatment and on August 22, 2014 following the treatment, Onterra ecologists conducted acoustic surveys. While one of the goals of the spring acoustic survey was to obtain accurate bathymetric data, these surveys also measured the *bio-volume* of aquatic plants within Bass Lake. The bio-volume of aquatic plants is the percentage of the water column that is occupied by aquatic vegetation. Numerous tight transects were made across the entirety Bass Lake while collecting continuous advanced sonar-based information. The data collected during this survey are then uploaded to a Minnesota-based company (BioBase, a division of Navico) for processing. Unlike the point-intercept survey, these bio-acoustic data do not differentiate between aquatic plant species. However, lake managers use these data to gain an understanding of the level of aquatic plant growth present within the lake before and after treatment.

Qualitative EWM Monitoring

Using sub-meter GPS technology, EWM locations were mapped the year prior to treatment (2013) in late-summer when EWM is at or near its peak growth, and in the late summer immediately following the treatment (2014). The EWM population was mapped by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *Highly Scattered* to *Surface Matting*. Point-based techniques were applied to EWM locations that were considered as *Small Plant Colonies* (<40 feet in diameter), *Clumps of Plants*, or *Single or Few Plants*. Qualitative monitoring of herbicide treatments includes comparing spatial data reflecting EWM locations and densities during the peak-growth stages the summer before the treatment and the summer immediately following the treatment. Based upon a pre-determined success criterion, an effective treatment would include a 75% reduction of EWM as demonstrated by a decrease in density rating (e.g. *Highly Dominant* to *Dominant*).

Herbicide Concentration Monitoring

In-lake herbicide concentrations are also monitored as a part of some treatment strategies, especially those involving anticipated whole-lake impacts. In Bass Lake, 2,4-D concentrations were monitored to determine if the target concentrations had been met. With this type of monitoring, water samples are collected by trained volunteers from multiple locations over the course of numerous days following treatment. Water samples were collected at four sites (Figure 4) at time intervals of approximately 1, 3, 5, 7, 14, 21 and 28 days after treatment (DAT) using an integrated sampler. The samples were fixed (preserved) with acid and shipped to the Wisconsin State Lab of Hygiene (SLOH) where the herbicide analysis is completed.

TREATMENT MONITORING RESULTS

Herbicide Concentration Monitoring Results

Typical whole-lake treatment EWM strategies target whole-lake concentrations between 0.300 and 0.400 ppm acid equivalent (ae). In most instances, the initial concentrations are maintained for 5-7 DAT before observable herbicide degradation occurs. For this reason, the average 1-7 DAT concentration is often used by lake managers as predictor of EWM efficacy and associated native plant impacts. The target lake-wide 2,4-D concentration for the 2014 treatment on Bass Lake was 0.375 ppm ae and the 2014 herbicide concentration monitoring data indicate that Bass Lake had an initial mean 2,4-D concentration of 0.377 ppm ae at 1 DAT (Table 1). A combination of herbicide migration to Crooked Lake and herbicide degradation caused the average 1-7 DAT concentration to be 0.296 ppm ae (Table 1, Figure 4 & 5). From 1-5 DAT, the concentration of 2,4-D remained the highest at sampling locations Bas1 and Bas2, while concentrations fell more rapidly at sites Bas3 and Bas4. By 7 DAT, concentrations at all four locations were around 0.200 ppm ae, and by 14 DAT, concentrations had fallen to near the irrigation restriction limit of 0.100 ppm ae. Sometime between 14 and 21 DAT, concentrations of 2,4-D had fallen below detectable limits.

Table 1. Average 2,4-D concentrations from Bass Lake, 2014.

	2,4-D ppm ae
1 DAT ave	377.5
1-3 DAT ave	355.0
1-5 DAT ave	335.0
1-7 DAT ave	296.3

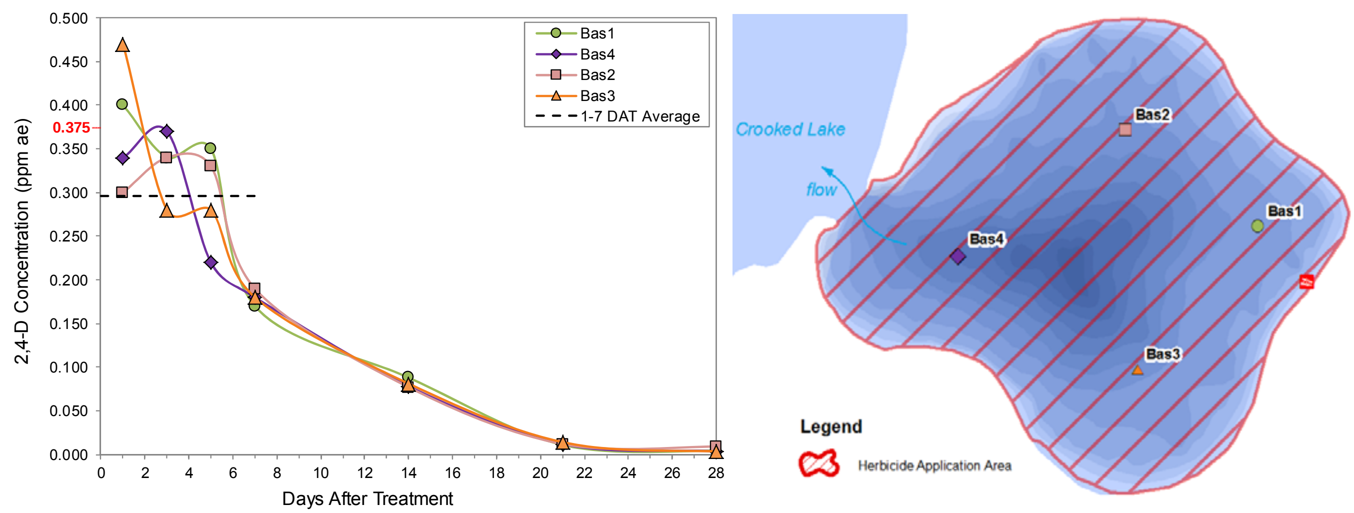


Figure 4. Bass Lake 2014 2,4-D concentrations from 1-28 DAT (left) and herbicide concentration monitoring locations (right).

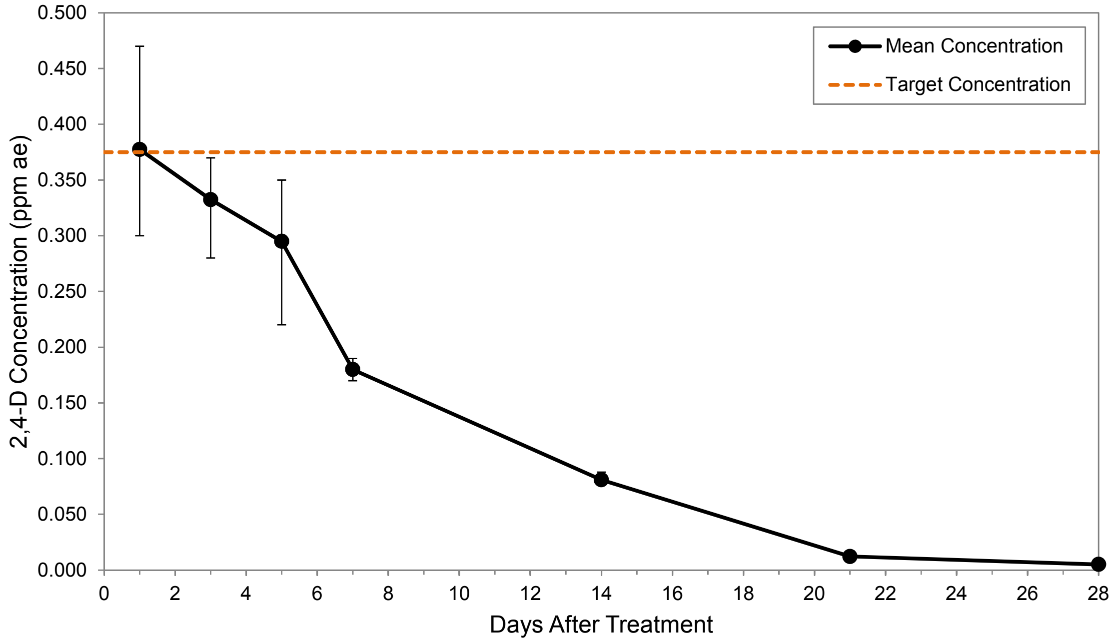


Figure 5. Bass Lake 2014 mean 2,4-D concentrations from four sampling locations from 1-28 DAT. Error bars represent maximum and minimum values.

Figure 6 shows the precipitation that was observed at a weather station approximately seven miles away in Mountain WI around the date of the application. A rainfall event of 1.18 inches was recorded the day before the treatment which could have impacted the water flow within the Crooked Lake system over the following days; however the rate of water flow out of Bass Lake was not expected to be a major component affecting herbicide dissipation. Some rainfall in the days following the treatment may have had a small effect on the flow rate within the Crooked Lake system as well.

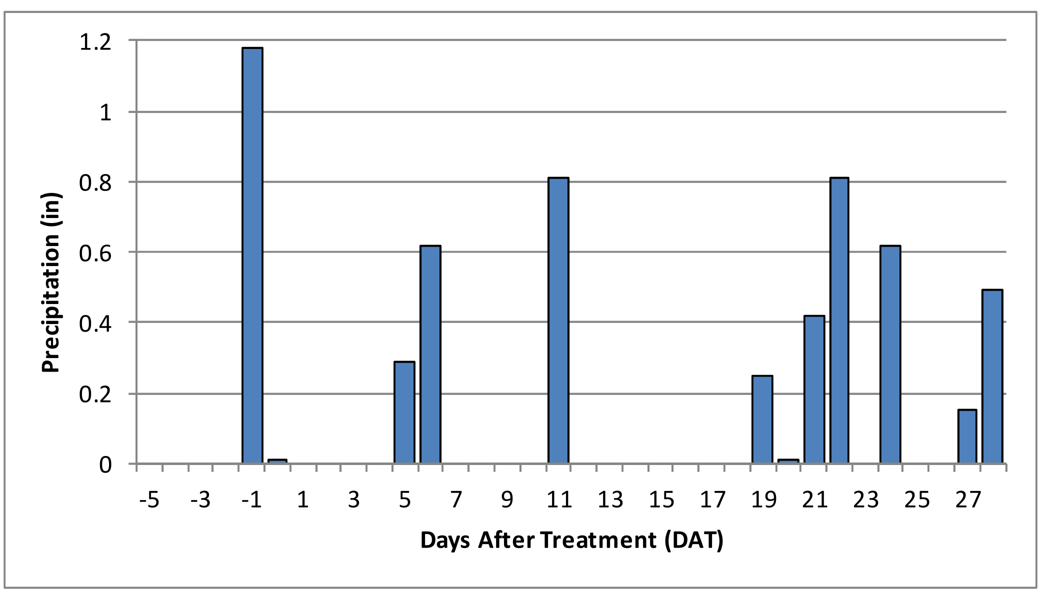


Figure 6. Daily rainfall totals recorded in Mountain WI five days before and 28 days after treatment of Bass Lake. Data from weatherunderground.com**.**

Near-surface water temperatures were recorded at all four locations by the herbicide concentration monitoring volunteer. These data indicate that temperatures increased from the upper-60s°F at the time of treatment to the low-70s°F by 28 DAT. Higher water temperatures typically cause higher biological activity. Because 2,4-D degradation occurs from biological activity, higher water temps may cause faster herbicide degradation.

Aquatic Plant Monitoring Results

Efficacy

During the pre-treatment point intercept survey of Bass Lake in the spring of 2014, EWM was not encountered on the rake as levels were low enough to be below the detection limit for this type of survey. Due to this, a quantitative comparison of pre- and post-treatment EWM levels cannot be made. EWM was not recorded on the post treatment point intercept survey as well, indicating EWM populations remain at a low level in Bass Lake. The post treatment mapping survey conducted during the late-summer of 2014 indicated that the EWM population was reduced following the treatment with no colonized acreage being located and only a small number of *Single or Few Plants* being observed (Figure 7). This indicates that the 2014 treatment was successful at causing EWM mortality in Bass Lake.

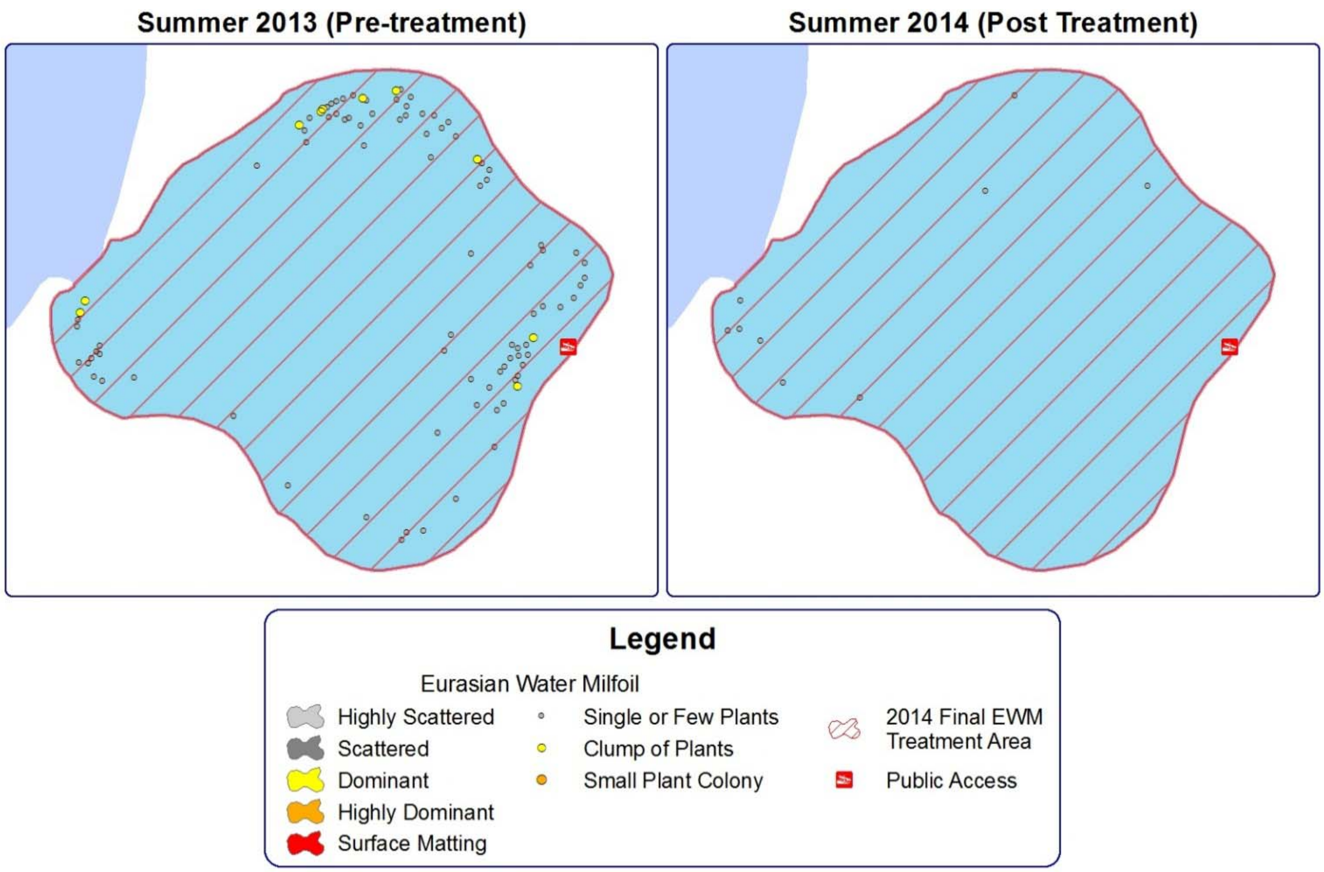


Figure 7. Bass Lake 2013 pre- and 2014 post-treatment EWM locations.

Selectivity

The littoral frequencies of occurrence of native aquatic plant species available from the August 2011 pretreatment and August 2014 post treatment surveys are shown in Figure 8. Overall, four native aquatic plant species exhibited statistically valid changes in their occurrence from before and after treatment. Creeping bladderwort, common waterweed, and variable pondweed all exhibited statistically valid reductions in their occurrences from 2011 to 2014, declining by 76%, 43%, and 70%, respectively. Like EWM, creeping bladderwort is a dicot and thought to be particularly sensitive to 2,4-D treatments. Common waterweed and variable pondweed, unlike EWM, are monocots and were not historically believed to be susceptible to dicot-selective herbicides likes 2,4-D. However, emerging research by the USACE, WDNR, and consultants is indicating that some of these species may be prone to decline following 2,4-D treatments, especially, long-exposure, low-concentration use patterns. However, their declines may also have been a result of environmental factors outside of the treatment, such as a late ice-out and cooler-than-average summer temperatures. While these species declined in their occurrence, they are still present in Bass Lake and it is believed these populations will make a full recovery.

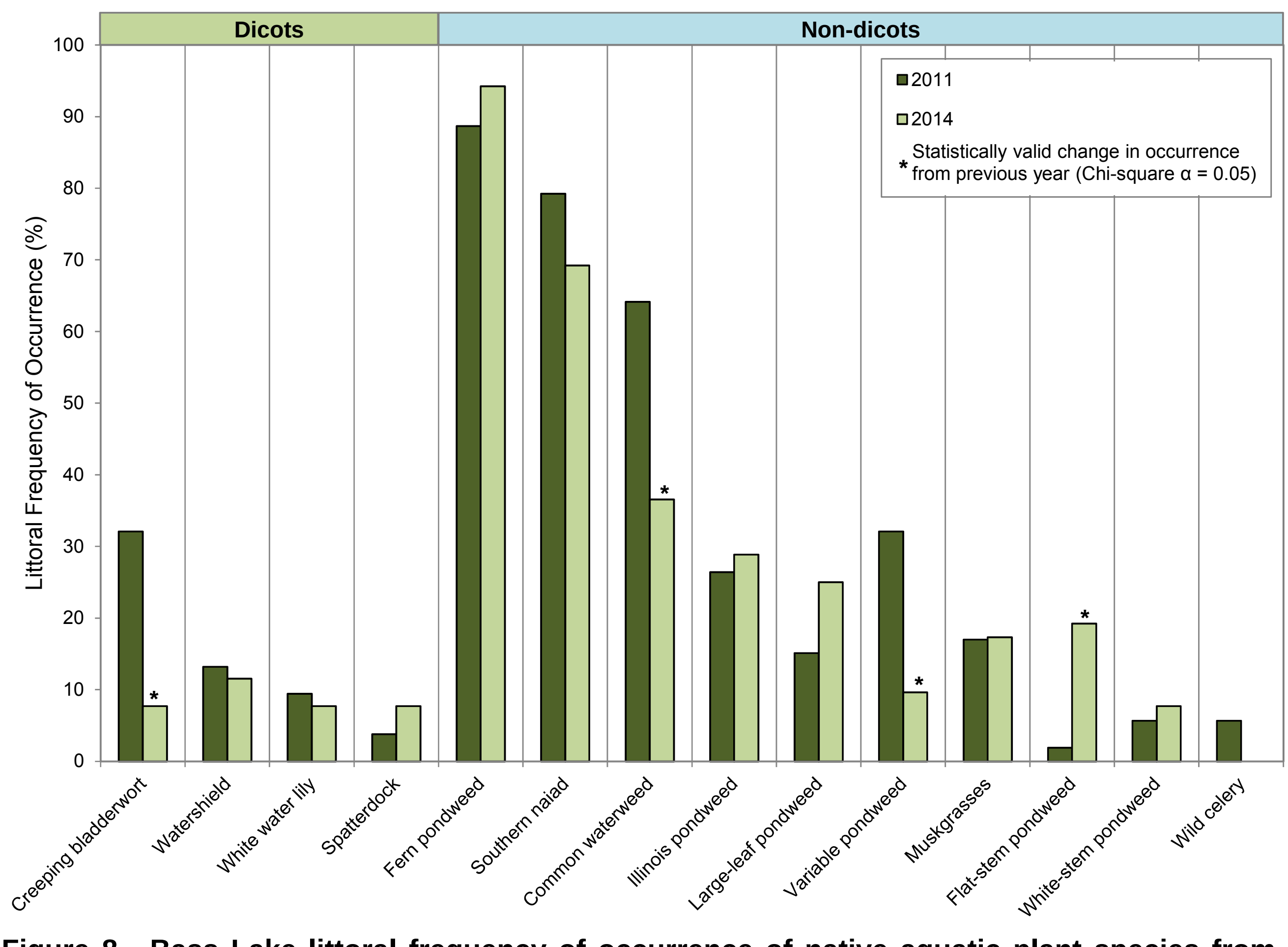


Figure 8. Bass Lake littoral frequency of occurrence of native aquatic plant species from a 2011 pre-treatment and a 2014 post-treatment survey. Note: Only aquatic plant species with a littoral frequency of occurrence of at least 5% in either year is used for statistical analysis. 2011 N=53, 2014 N=52.

One native aquatic plant species, flat-stem pondweed, displayed a statistically valid increase over this time period, increasing in occurrence nine-fold (Figure 8). The occurrences of the other ten native aquatic plant species displayed in Figure 6 were not found to be statistically different from 2011 to 2014. Overall, while three species saw statistically valid reductions in their occurrence following the treatment, there were no declines that would cause immediate concern.

Bioacoustics Survey Results

As mentioned previously, an acoustic survey was conducted on Bass Lake approximately one week after ice out (pre-treatment) as well as during the late summer of 2014 (post treatment). The main purpose of the early spring survey was to refine the bathymetry data for calculating accurate volume measurements of Bass Lake; however, aquatic plant bio-volume data were also collected at this time as well. Percent bio-volume in this survey refers to the percent of the water column that is taken up by vegetation. For example a 10% bio-volume would mean approximately 10% of the water column depth is filled with vegetation, whereas a 100% bio-volume would mean aquatic plants fill the water column from the bottom of the lake to the surface of the water (or 100% of the water column). These data collected in May show that aquatic plant growth prior to treatment was low and likely comprised of EWM and some low-growing, evergreen plants like fern pondweed (Figure 9). The acoustic survey was conducted again in August 2014 in order to quantify aquatic plant growth after treatment (Figure 9). The bio-volume in Bass Lake showed that the native plant community was still present in levels that will provide structural habitat for the variety of fish and aquatic organisms that depend on it. The aquatic plant community in terms of overall biomass did not seem to be greatly affected by the early 2014 whole-lake 2,4-D treatment in Bass Lake.

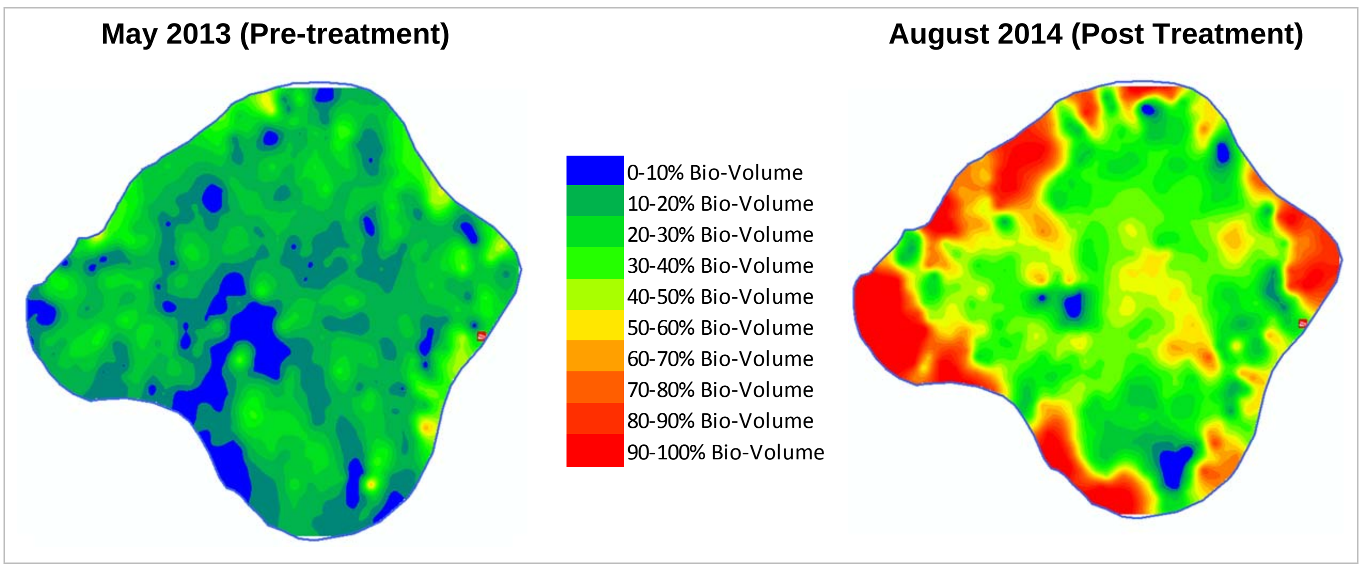


Figure 9. Bass Lake spring 2014 pre- and summer 2014 post-treatment aquatic plant bio-volume.

It is important to note that aquatic plant bio-volume is relative to water depth. For example, an area in 3 feet of water with a bio-volume of 90% has the same level of aquatic plant growth as an area of 8 feet of water with a bio-volume of 34%; plants in both of these areas are approximately 2.7 feet tall. To illustrate this, Figure 10 displays the average bio-volume of aquatic plants across water depth in Bass Lake from the August 2014 survey. Bio-volume values are highest in 1-3 feet of water, where approximately 70% of the water column in these areas is occupied by aquatic plants. Beyond 3 feet, bio-volume rapidly declines with increasing water depth; however, this is not an indication that the biomass or level of aquatic plant growth declines as well. Figure 10 also displays the average height of aquatic plants across water depths calculated by multiplying the average bio-volume values with water depth. This shows that from 0-9.5 feet, aquatic plants get taller as water depth increases where they reach a maximum average height of around 4 feet. Beyond 9.5 feet, aquatic plant height declines to approximately 2 feet. Aquatic plants grow across all water depths in Bass Lake, from less than a foot of water near shore to the maximum depth of the lake of 14 feet. Future acoustic surveys in Bass Lake may be used for comparison as a way to monitor changes in plant volume over time.

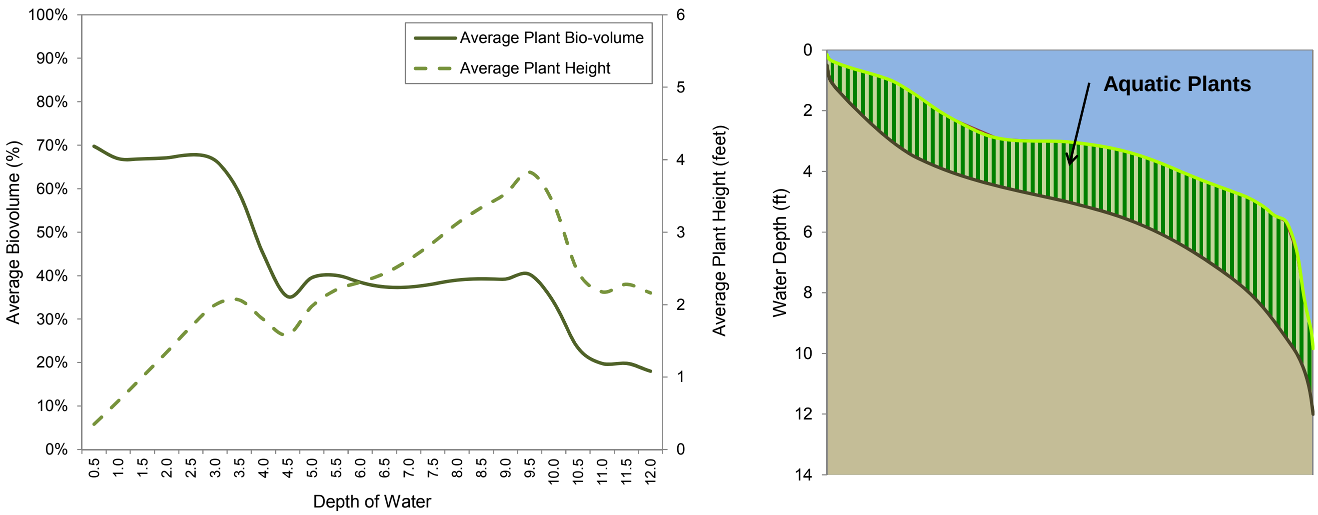


Figure 10. August 2014 average aquatic plant bio-volume and aquatic plant height across water depth in Bass Lake.

LAKE-WIDE EWM SURVEY RESULTS

On August 22, 2014, Onterra ecologists conducted the Late-Summer EWM Peak-Biomass Survey on the Crooked Lake system. This is a visual-based survey where tight transects are made throughout littoral areas of the lakes to locate and map occurrences of EWM. As discussed earlier, the lake-wide treatment of Bass Lake was successful, and only a handful of single EWM plants were located in the lake following the treatment (Map 2). No EWM could be located in Gilkey Lake and only small amounts comprised of single plants, clumps of plants, and two small plant colonies were located in the northern and southern portions of Crooked Lake (Map 2). Overall, the 2014 EWM population within this system was at a very low level. The 2015 control strategy for the areas of EWM located in 2014 is discussed within the Conclusions and Discussion Section.

CURLY-LEAF PONDWEED

On July 10, 2014, Onterra ecologists completed the Early-Season AIS Survey on the Crooked Lake system. Like the Late-Summer EWM Peak-Biomass Survey, this is a meander-based survey of the lakes littoral areas designed to locate and map occurrences of non-native plants. While EWM is usually not at its peak growth at this time of year, the water is typically clearer during the early summer allowing for more effective viewing of submersed plants, and EWM is often growing higher in the water column than many of the native aquatic plants at that time of year. The EWM mapped during the Early-Season AIS Survey is refined during the Late-Summer Peak-Biomass survey. In addition, the locations of EWM occurrences located during early summer are provided to volunteers to aid in their hand-removal efforts.

In addition to mapping EWM during the Early-Season AIS Survey, ecologists are also looking for potential occurrences of other non-native aquatic plants. One in particular, curly-leaf pondweed (*Potamogeton crispus*; CLP) is at or near its peak growth in early summer before naturally senescing (dying back) in early July, making early summer the most probable time to locate this species. Unfortunately, Onterra ecologists located a few single plant occurrences of CLP in the eastern portion of Crooked Lake during the June 2014 survey (Map 3). This is the first recorded occurrence of CLP within Crooked Lake, and given the small number of plants located, it is believed that it was likely introduced to the lake relatively recently. Specimens were collected and sent to the UW-Stevens Point Herbarium where they were positively identified as CLP.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants (Photo 2). The plants begin growing almost immediately after, if not immediately before, ice-out and by early-summer they reach their peak growth. As they are growing, each plant produces numerous turions (asexual reproductive structures) which break away from the plant and settle to the bottom following the plant's senescence. The deposited turions lie dormant until autumn when they sprout to produce small winter foliage, and they remain in this state until spring foliage is produced. The advanced growth in spring gives the plant a significant jump on native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition. However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance. While it is not known how CLP will react in Crooked Lake, it is recommended that these single plant occurrences be targeted for hand-removal in 2015.

More information on CLP can be found on the WDNR's website:

http://dnr.wi.gov/topic/Invasives/fact/CurlyLeafPondweed.html.


Photo 2. Close-up of CLP (left) and population (right) of surface-matted CLP on Shawano Lake, Shawano County, Wisconsin.

CONCLUSIONS & DISCUSSION

Overall, the 2014 EWM low-concentration, whole-lake 2,4-D treatment on Bass Lake was successful. The herbicide concentration monitoring data indicate that the lake-wide target 2,4-D concentration was met and that the concentration-exposure time was sufficient to control EWM with only minimal regrowth observed following the treatment. Additionally, adverse impacts to the native aquatic plant community were isolated to three species. The summer 2014 surveys indicated that EWM currently exists at low levels throughout the system, with no EWM being located in Gilkey Lake. Because of this, no herbicide treatments are proposed for Bass and Gilkey Lakes in 2015; however, it is believed volunteer-based hand-harvesting efforts would be beneficial in Bass Lake in 2015.

While herbicide control of EWM is not proposed to occur in Bass or Gilkey Lakes in 2015, a small area totaling 2.4 acres in Crooked Lake is proposed to be targeted with herbicides in 2015 (Figure 11, Map 2). This area is comprised of a small plant colony with surrounding single plant and clump occurrences of EWM, and is believed to be too large to be controlled via volunteer hand-harvesters. This spot treatment site is proposed to be targeted with a combination of liquid 2,4-D at the maximum application rate of 4.00 ppm ae and liquid endothall at a rate of 1.50 ppm ae. Emerging research is indicating that when these spot treatment areas fall below five acres, the treatment effectiveness is hard to predict and often unsuccessful due to rapid herbicide dissipation. In addition, herbicide dissipation will likely be more rapid in this area as the proposed 2015 treatment site is located in the northern portion of Crooked Lake in close proximity to the lake's tributary inlet and outlet where water exchange is believed to be higher. It is believed that conducting a treatment using a combination of these herbicides has an additive or synergistic effect. This strategy has been shown to be effective in whole-lake treatment scenarios, but until 2014, its effectiveness in spot treatment scenarios had not been fully tested. A trial area of approximately 15 acres in Lake Metonga, Forest County was applied with a combination of liquid 2,4-D and endothall in 2014. This area was mainly comprised of *Highly Dominant* EWM prior to treatment, and preliminary results indicate that this treatment was highly effective at reducing EWM within this area. However, the treatment site on Lake Metonga was much larger than are being proposed for Crooked Lake; therefore treatment expectations may not be directly transferable.

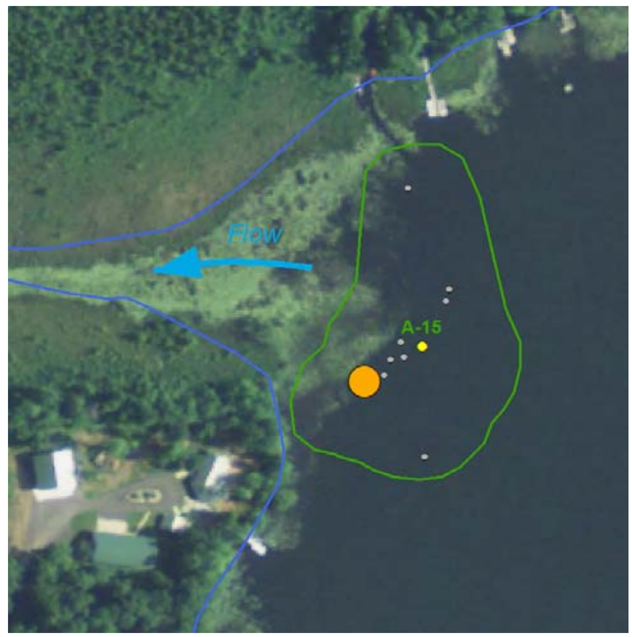


Figure 11. Proposed 2015 Spot-Treatment Strategy. *Grey dot = Single or Few, Yellow dot = Clumps of Plants, Orange dot = Small Plant Colony (note indicate approx. 25 ft in diam).*

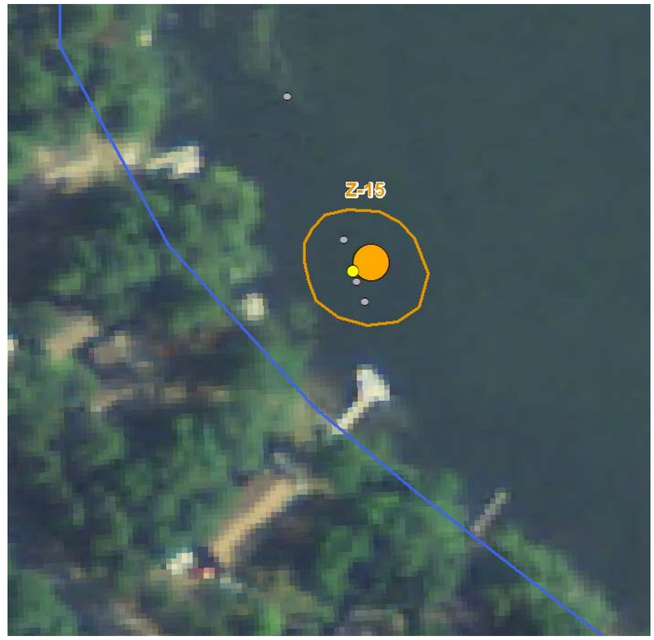
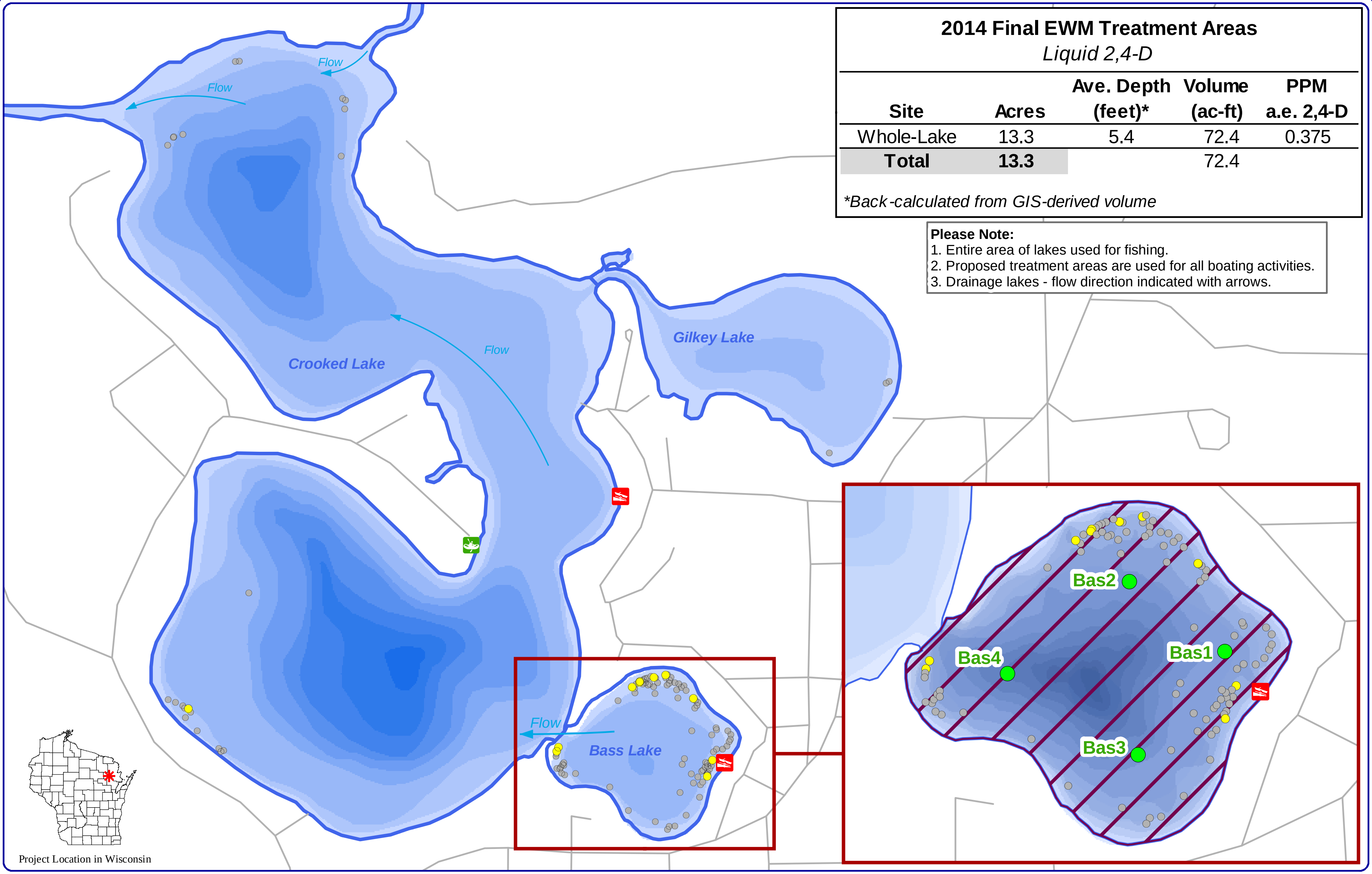


Figure 12. Proposed 2015 Hand-Harvesting Strategy. *Grey dot = Single or Few, Yellow dot = Clumps of Plants, Orange dot = Small Plant Colony (note indicate approx. 20 ft in diam).*

In addition to the 2.4-acre herbicide application area, an approximate 0.1-acre area of EWM in the southern portion of Crooked Lake is proposed to be targeted with professional hand-harvesters (Figure 12, Map 2). While volunteer hand-harvesting has occurred on these lakes in the past and it is believed that this hand-harvesting was having a positive effect, EWM expansion was occurring despite this hand-removal effort. Because of this, it is recommended that professional hand-harvesting methods be utilized in the future to control smaller AIS communities. There are a few firms specializing in hand harvesting methods in Wisconsin of which may be a good option going forward in the ongoing control of AIS population control in the Crooked Lake system. An emerging harvesting method uses a Diver-Assisted Suction Harvester (DASH). The DASH system involves divers hand-removing the EWM plants and then inserting the removed biomass into a suction hose to be delivered up to the deck of a boat. Because this technique utilizes a mechanical device, a WDNR Mechanical Harvesting Permit would be required.

The discovery of CLP in Crooked Lake in 2014 is unfortunate; however, the population consisted of only a few plants making eradication a realistic goal if actions are taken quickly. It is believed that volunteer hand-removal would be an effective strategy to remove this early infestation of CLP. In June 2015, Onterra ecologists will map the occurrences of the CLP and relay their locations to the volunteer hand-harvesters. The hand-harvesting should occur as early as possible so that the plants can be removed before they are able to produce and deposit their turions. Continued monitoring of these areas following hand-removal will be required to determine if these efforts were effective and if CLP has since spread to other areas of these lakes.



2014 Final EWM Treatment Areas

Liquid 2,4-D

Site	Acres	Ave. Depth (feet)*	Volume (ac-ft)	PPM a.e. 2,4-D
Whole-Lake	13.3	5.4	72.4	0.375
Total	**13.3**		72.4	

*Back-calculated from GIS-derived volume

Please Note:
1. Entire area of lakes used for fishing.
2. Proposed treatment areas are used for all boating activities.
3. Drainage lakes - flow direction indicated with arrows.

N W E S

700

Feet

Legend

Highly Scattered (none found)
Scattered (none found)
Dominant (none found)
Highly Dominant (none found)
Surface Matting (none found)
Single or Few Plants
Clump of Plants
Small Plant Colony (none found)
Herbicide Concentration Sampling Location
2014 Proposed & Final Treatment Area

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

Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2013
Bathymetry: WDNR 1968 - digitized by Onterra
Orthophotography: NAIP, 2010
Map Date: October 10, 2013
File Name: Map1_Crooked_EWMPB_Sept13.mxd

Map 1

Crooked Lake

Oconto County, Wisconsin

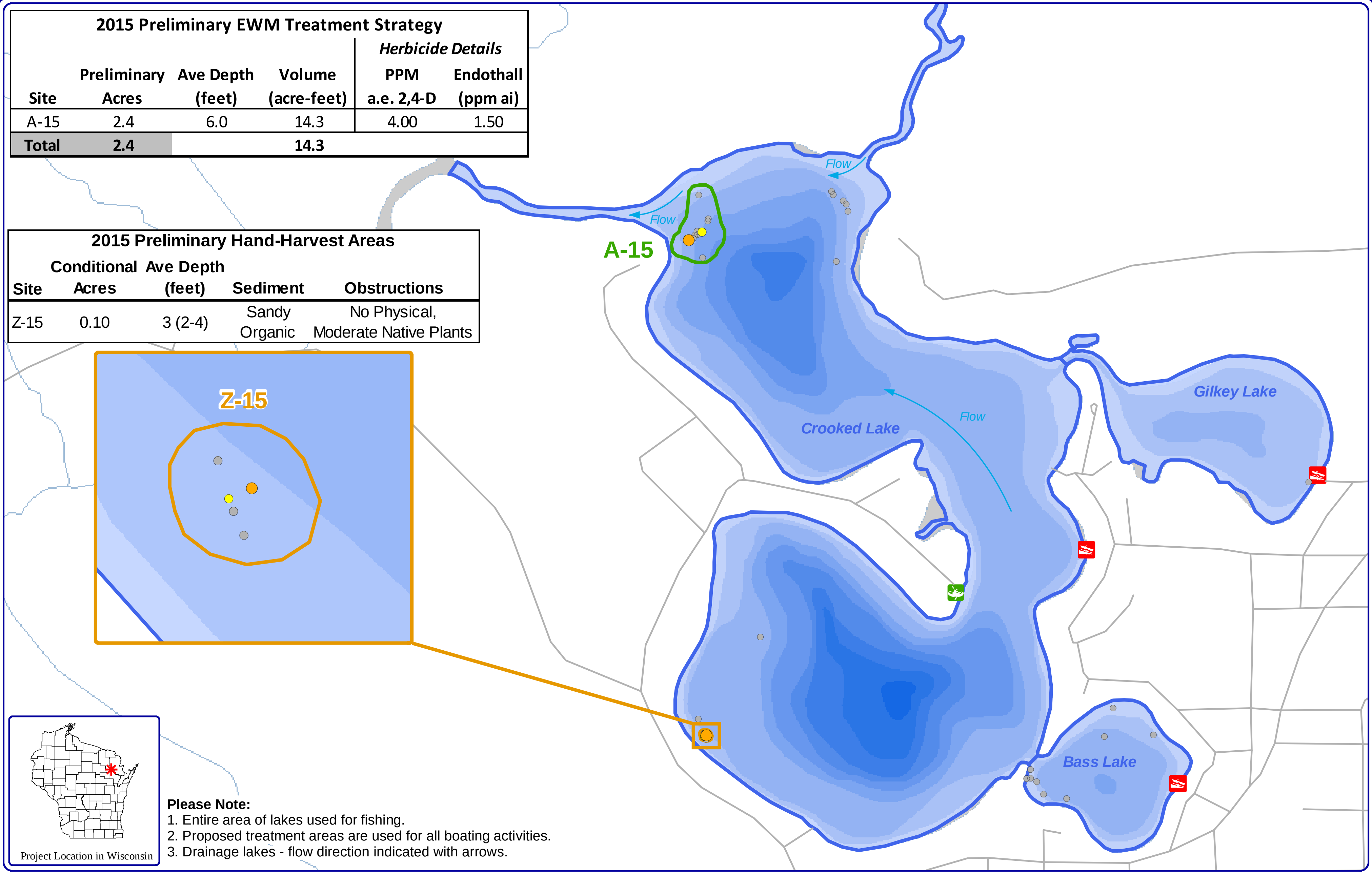
2014 EWM Control Strategy

2015 Preliminary EWM Treatment Strategy

Site	Preliminary Acres	Ave Depth (feet)	Volume (acre-feet)	Herbicide Details: PPM a.e. 2,4-D	Herbicide Details: Endothall (ppm ai)
A-15	2.4	6.0	14.3	4.00	1.50
Total	**2.4**		**14.3**		

2015 Preliminary Hand-Harvest Areas

Site	Conditional Acres	Ave Depth (feet)	Sediment	Obstructions
Z-15	0.10	3 (2-4)	Sandy Organic	No Physical, Moderate Native Plants



Please Note:
1. Entire area of lakes used for fishing.
2. Proposed treatment areas are used for all boating activities.
3. Drainage lakes - flow direction indicated with arrows.

N, E, S, W

800

Feet

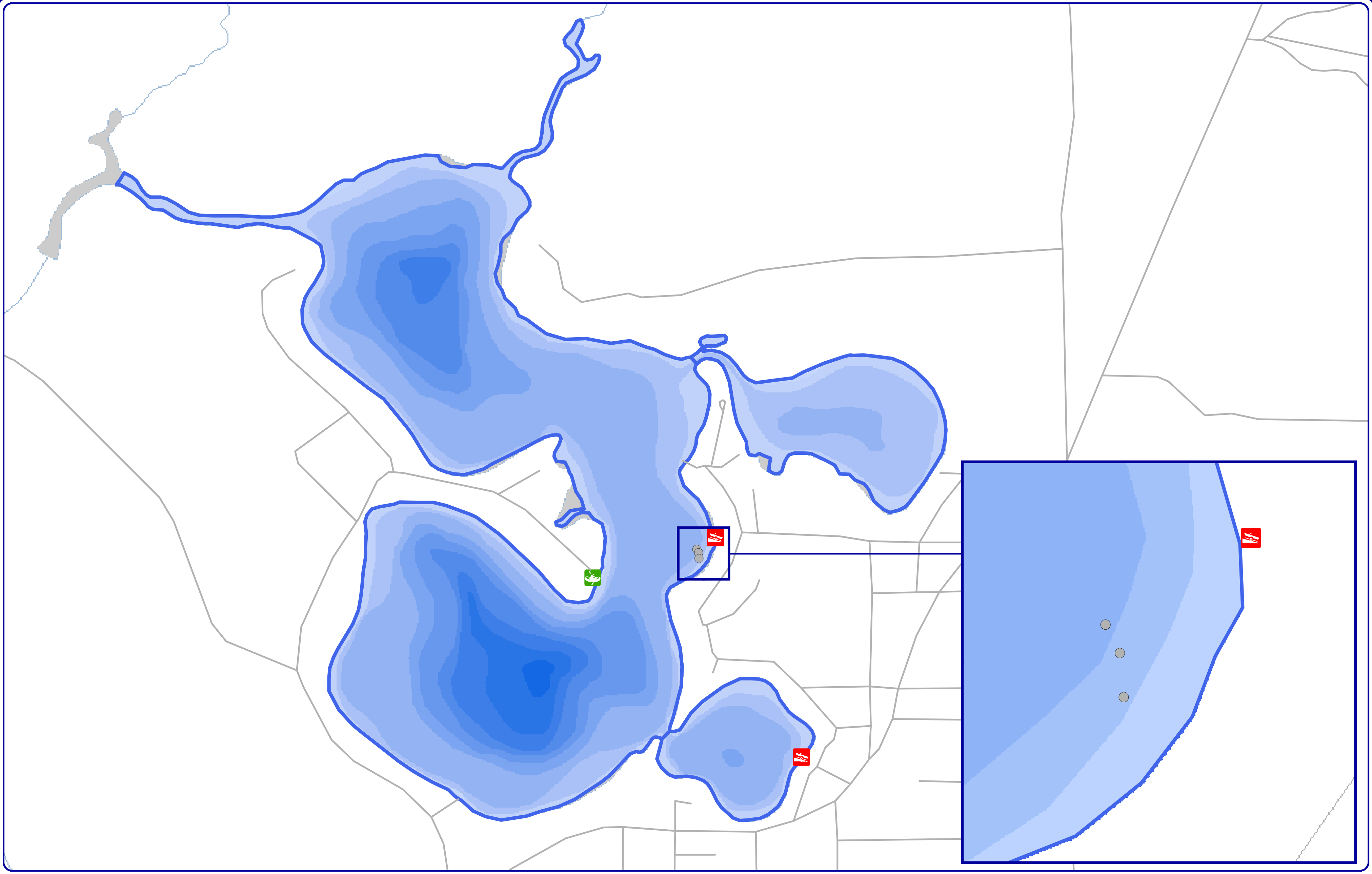
Legend

- Highly Scattered (none found)
- Scattered (none found)
- Dominant (none found)
- Highly Dominant (none found)
- Surface Matting (none found)
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2015 Proposed Herbicide Treatment Area
- 2015 Proposed Hand Harvest Area

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Aquatic Plants: Onterra, 2014
Map Date: December 19, 2014
File Name: Map2_Crooked_EWM_T2015Prelim1.mxd

Map 2
Crooked, Bass & Gilkey Lakes
Oconto County, Wisconsin
2015 Proposed EWM Treatment Areas

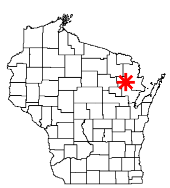


N
W E
S

850
Feet

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

Sources:
Hydro: WDNR
Orthophotography: NAIP, 2013
Aquatic Plant Survey: Onterra, 2014
Map Date: December 18, 2014



Project Location in Wisconsin

Legend

- Highly Scattered *(none found)*
- Scattered *(none found)*
- Dominant *(none found)*
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clump of Plants *(none found)*
- Small Plant Colony *(none found)*

Map 3
Crooked Lake
Oconto County, Wisconsin

2014 Curly-leaf Pondweed Locations