INTRODUCTION

Photo 1. Long Lake, Fond du Lac County.

Long Lake, Fond du Lac County, is an approximately 454-acre drainage lake (including the northwest basin known as Tittle Lake) with a maximum depth of 47 feet and a mean depth of 22 feet (Photo 1). In 2010, the Long Lake Preservation Association, Inc. (LLPA) contracted with Onterra, LLC to conduct a three-year aquatic invasive species (AIS) monitoring and control project. The objective of this project was to monitor and assess herbicide treatments aimed at controlling the non-native invasive plants curly-leaf pondweed (*Potamogeton crispus*; CLP) and Eurasian water milfoil (*Myriophyllum spicatum*; EWM) from 2011-2013. At the end of the three-year AIS monitoring and control project, the LLPA had remaining funds within the Wisconsin Department of Natural Resources (WDNR)-funded AIS-Established Population Control Grant, and along with additional funds requested from the WDNR through an amendment, they were able to extend the project into a fourth year to fund AIS monitoring and control through 2014.

The LLPA completed an update of their management plan in 2015 (*Long Lake Comprehensive Management Plan, Onterra, March 2015*). The updated plan created new thresholds and triggers for the continued control of CLP and EWM within Long Lake. The LLPA has outlined an aggressive approach to CLP management within their *Comprehensive Management Plan* whereas:

- All areas targeted the previous year would be considered for treatment. Based upon the pretreatment survey, these areas may be reduced or removed.
- All areas of colonized CLP will be considered for treatment during the following spring. The LLPA's treatment threshold (trigger) would also extend to immediately adjacent areas of CLP with point-based techniques, with areas mapped as *small plant colonies* being targeted if possible.
- Areas containing AIS but not targeted for herbicide control will be considered for hand-removal. The LLPA has just begun initiating this aspect of their control program.

The goal of CLP management in Long Lake is to reduce the treatable acreage of CLP. This is accomplished through repeat treatments aimed at depleting the base of turions (vegetative reproductive structures) that have built up in the sediments over time. It is unknown exactly how long turions can remain viable in the sediment, but it is believed to be at least 3-5 years. For this reason, all of the areas that were treated in 2015 were proposed to be retreated in 2016 (Map 1). Multiple years of treatment over these same areas will likely need to occur to kill CLP sprouting from previously deposited turions. In total, 30.5 acres were initially proposed for treatment in 2016 (Map 1). No areas of EWM warranted herbicide control in 2016. The LLPA outlined an EWM control strategy within the management plan which involved targeting EWM with spot-treatments or hand-harvesting as appropriate. The EWM population in Long Lake was monitored in 2016 through surveys conducted in June and in August.

One of the objectives of this project is to monitor the treatment effectiveness and 'tune' or refine the treatment strategy in order for the most effective results to be achieved. The mixed results observed in previous spot treatments in Long Lake indicate that the herbicide may not have reached an adequate concentration-exposure time to cause plant mortality. With this knowledge, proposed 2016 treatment areas that were less than 5 acres were proposed to be treated with liquid endothall at an increased rate of 3.0 – 3.5 ppm ai, while treatments of greater than five acres would be treated at a rate of 2.0-2.5 ppm ai.

PRETREATMENT CONFIRMATION AND REFINEMENT SURVEY

On May 5, 2016, Onterra ecologists conducted the Pretreatment Confirmation and Refinement Survey on Long Lake. During this survey, the presence of CLP within the proposed treatment sites was confirmed and the treatment area extents were verified both from the surface and via a submersed video camera in deeper water. The near surface water temperature was found to be 52°F.

Following this survey, Site B-16 was removed due to insufficient levels of CLP warranting treatment being observed within the site. The extents of Site D-16 were slightly modified and resulted in an increase in size from 5.0 to 5.5 acres. Within Site C-16, CLP was observed to be growing within only the shoreward, eastern half of the proposed site and the treatment area was reduced in size from 18.0 acres to 8.0 acres. In total, the final 2016 CLP treatment was reduced from the proposed 30.5 acres to 16.3 acres (Map 1).

The treatment was conducted by Aquatic Biologists, Inc on May 17, 2016. The applicator reported a near-surface water temperature of approximately 11.6°C (52.9°F) and northeast winds of 5 mph at the time of application. Wind speed and direction data obtained from a weather station in nearby Campbellsport, WI, approximately 15 miles from Long Lake (Figure 1). These data indicate that winds were predominantly easterly at the time of treatment and averaged between 6 and 8 mph during the treatment and for approximately 6 hours after the treatment, the anticipated exposure time of the herbicide to the target areas.

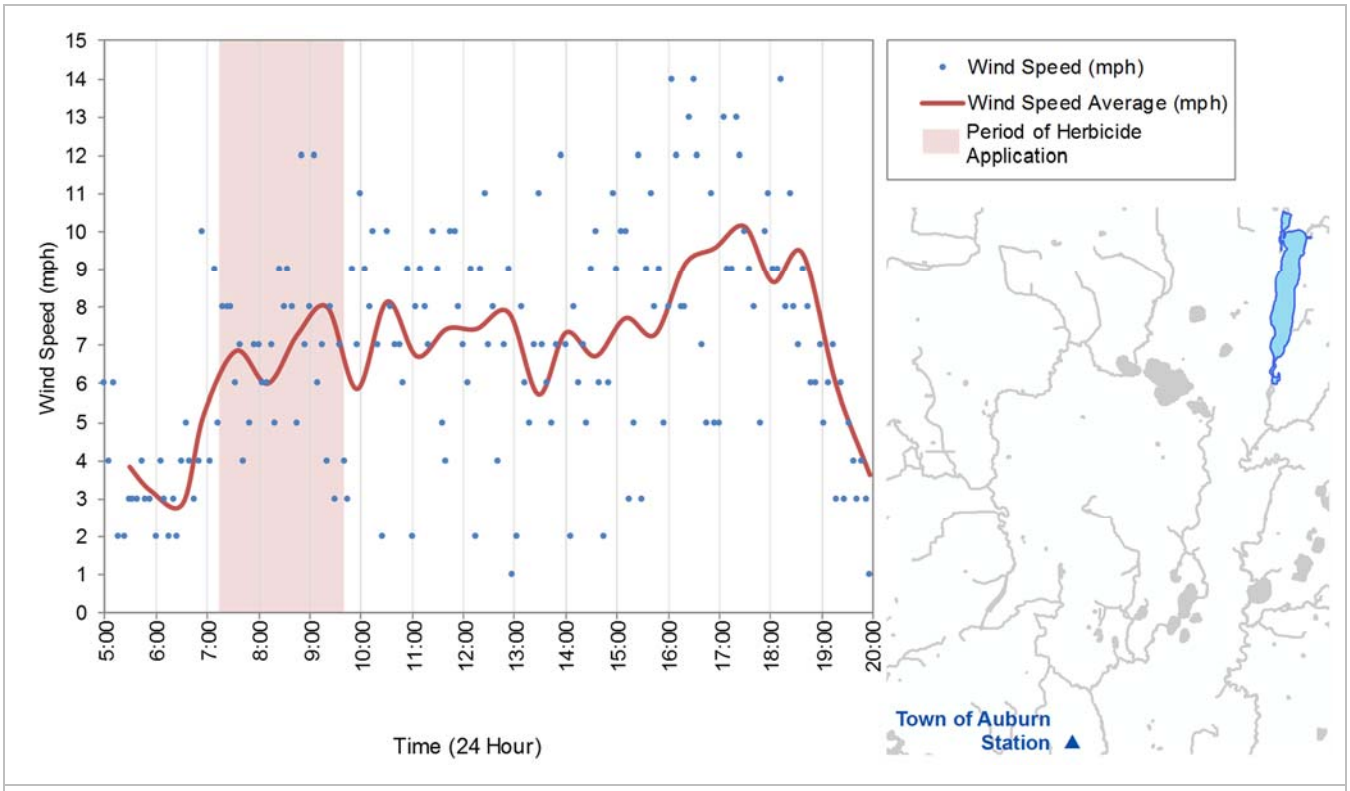


Figure 1. Wind speed and direction approximately 3 hours before and 10 hours after herbicide was applied to the Long Lake 2016 treatment areas on May 5, 2016. Created using data from Weather Underground Station in Cambellsport WI. Average wind speeds calculated in 30-minute increments.

AQUATIC PLANT MONITORING RESULTS

The objective of an herbicide treatment strategy is to maximize target species (CLP) 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 AIS colony density ratings before and after the treatments.

CLP Monitoring Results

It is difficult to assess the efficacy of a single year of treatment on a lake's CLP population. Curly-leaf pondweed naturally senesces (dies back) in early summer, making it is difficult to determine if a reduction in CLP following a spring treatment was caused by the treatment, natural senescence, or both. However, quantitative sub-sample point-intercept data collected annually in the spring prior to treatment within treatment areas allows for a determination if the CLP population is being reduced over time. The goal of CLP management is to annually kill the plants before they are able to produce and deposit new turions, and thus, overtime, deplete the existing turion bank within the sediment. Over the course of multiple annual CLP treatments, these annual sub-sample point-intercept surveys should quantitatively document a reduction in CLP occurrence as the turion base is depleted.

In Long Lake, quantitative evaluation was made through the collection of data at point-intercept sub-sample locations located within CLP treatment areas (Figure 2). Data was collected in the spring prior to the herbicide treatment where at each of these locations, the presence (or absence) of CLP was recorded. The survey was replicated during June of 2016 to correspond with the peak growth stage of CLP. Comparing the spring pretreatment point-intercept survey data with the June post treatment data is difficult to determine CLP control due to factors of natural die off (senescence) discussed above. But certainly, if CLP exist within the treatment areas following treatment, a failed treatment is likely to have occurred.

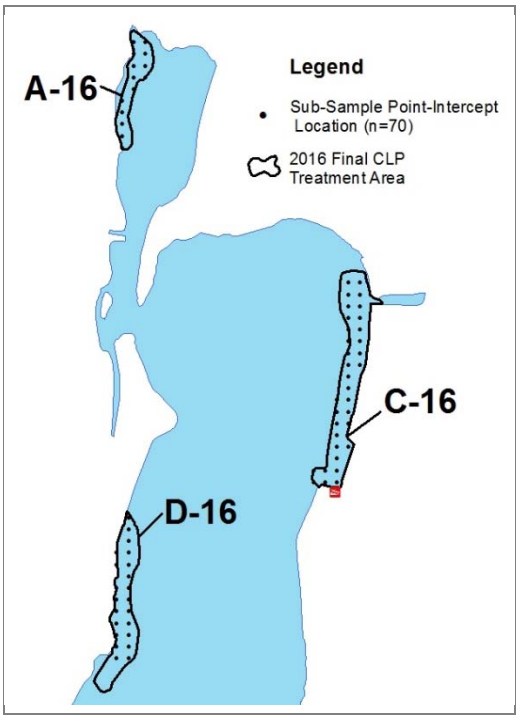


Figure 2. Sub-sample point-intercept survey locations within three 2016 CLP treatment sites

During the May 2016 pretreatment sub-sample point-intercept survey, seven (10.0%) of the 70 sampling locations contained CLP (Figure 3). Following the treatment, CLP was found on two sampling locations (2.9%) during the June 2016 survey. The reduction in CLP LFOO between the spring and June 2016 surveys suggest that the CLP population was at least somewhat controlled by the spring 2016 treatment.

The presence of native aquatic plant species was also recorded during the June 2016 surveys and can be compared to future potential surveys conducted in 2017 and beyond in the same sites. Comparing these data from year to year allows for a statistical comparison of native aquatic plant occurrence.

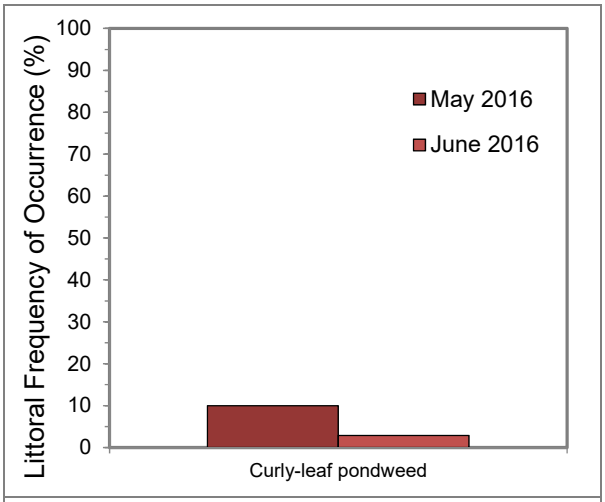


Figure 3. Frequency of occurrence of CLP from sub-sample point-intercept locations within Long Lake treatment areas.

Curly-leaf pondweed was mapped during a June 22 Early Season AIS Survey (ESAIS). During the June survey, the 2016 herbicide treatment areas were visited to conduct quantitative monitoring (sub point-intercept survey points) and to qualitatively map CLP in the sites to assess the spring 2016 treatment. Within site A-16, a combination of point-based CLP occurrences consisting of *single or few plants* and *clumps of plants* were located in the northern end of the site, and no colonized CLP was mapped in the site (Map 2). This suggests that CLP control was achieved in the southern part of the site, but not in the northern part near the inlet from the Watercress Creek where water dilution was likely higher.

Within site C-16, only one *single or few* CLP occurrence was located in the site suggesting successful control in 2016 (Map 2). Some additional *single or few plants* or *clumps of plants* were located just outside the northern end of treatment site near another inlet. One *single or few* CLP occurrence was located within Site D-16 during the June survey, suggesting successful control in 2016 (Map 2).

Curly-leaf pondweed was located widely scattered in other areas the lake during the June 2016 survey (Map 2). A relatively small *scattered* colony was located along the eastern shore between the State Park access and public beach and a combination of *scattered* or *highly scattered* colonized CLP was mapped in the channelized area at the far southern end of the lake (Map 2).

EWM Monitoring Results

The EWM population in Long Lake was monitored in 2016 through mapping surveys conducted during June and August. The first monitoring event on Long Lake in 2016 was the Early Season Aquatic Invasive Species Survey (ESAIS). This late-spring/early-summer survey provides an early look at the lake and in addition to mapping CLP, provides a good opportunity to locate EWM occurrences in the lake while the growth stage of most of the native plant population is relatively low. The EWM locations identified during the June survey are refined during the late summer survey when the plants have grown to their peak biomass level. On June 22, 2016, Onterra ecologists conducted the ESAIS Survey on Long Lake. This survey indicated that EWM population was at relatively low levels in the lake and no large continuous colonies were present (Map 3).

The EWM was re-evaluated during the EWM Peak-biomass Survey conducted on September 26, 2016. A similar amount of EWM was found during the September 2016 survey as in June (Map 3).

2016 Mechanical Harvesting Activities

In 2016, the LLPA hired a mechanical harvesting contractor to harvest areas of dense aquatic vegetative growth in order to maintain navigability in portions of the lake. The final mechanical harvesting areas were determined following the June ESAIS survey as to ensure that harvesting activities in areas known to contain EWM or CLP were minimized. Maps 4 & 5 show the final harvesting lanes as they related to the AIS occurrences mapped during the June survey. Harvesting activities occurred from July 18 to 25 and resulted in the harvest of approximately 500 cubic yards of plant material over the course of 57 hours. The majority of the harvested plant biomass was of a native watermilfoil (85%), with approximately another 10% composed of bladderwort species and lesser amounts of common waterweed, coontail, muskgrasses, pondweeds, and water lilies.

CONCLUSIONS AND DISCUSSION

The 2016 CLP herbicide treatment on Long Lake appears to have been successful in controlling the CLP population within the targeted areas. No colonized areas of CLP were located within the 2016 treatment areas and quantitative data indicate that the occurrence of CLP remains low within areas that have been targeted for control. Curly-leaf pondweed was found in many areas throughout the littoral zone during the June 2015 survey but at low densities that are not causing impact to the ecosystem nor recreational impediments to lake users.

Consistent with the strategy outlined within *Long Lake Comprehensive Management Plan, Onterra, March 2015*, each of the three 2016 final treatment areas is proposed to be part of the preliminary strategy in 2017. The results of the 2016 Pretreatment Confirmation and Refinement Survey will ultimately determine the final treatment acreage, particularly if insufficient CLP warranting treatment is observed in parts (or all) of the treatment sites. Because these sites have been targeted for a number of years, it is anticipated that the final treatment acreage will be much less than originally proposed on Map 6.

It is recommended to forgo treatment of the scattered and highly scattered CLP colonies within the channelized area on the southern end of the lake in 2017 since herbicide dissipation is likely to be increased in this portion of the lake making successful control through an herbicide treatment more difficult. If these colonies of CLP are found to expand in density to a rating of *dominant* or greater in 2017, considerations for herbicide control will be made for 2018.

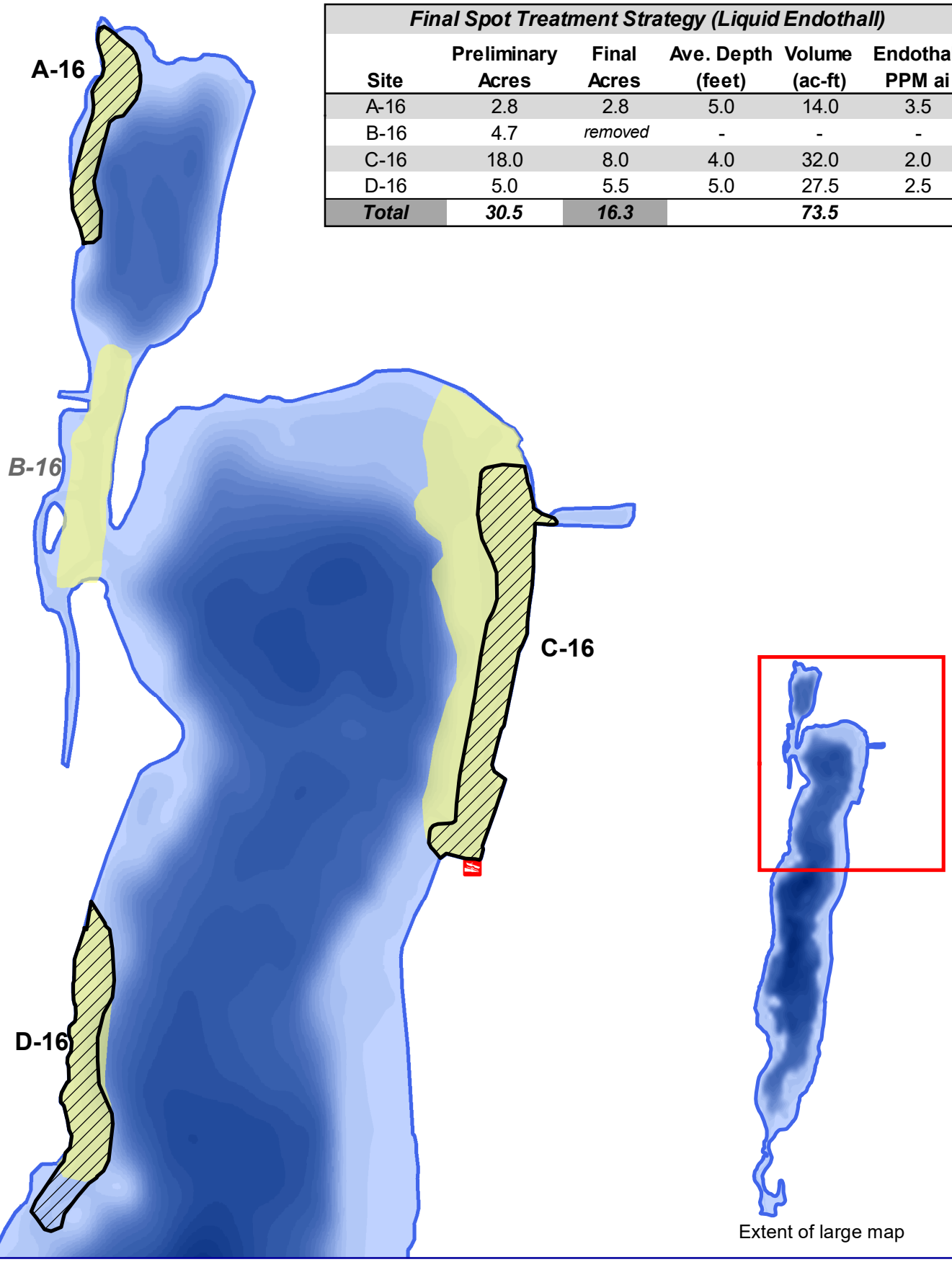
Given the low density of EWM once again within Long Lake in 2016, no herbicide treatment targeting EWM is proposed for 2017. The LLPA will pilot a professional-based hand-harvesting program in 2017 and evaluate what role this management technique may have in its integrated approach moving forward. Hand-harvesting control methods may pose a challenge on the chain due to the plethora of native plants in the targeted areas.

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

An Early Summer AIS Survey (ESAIS) will be conducted in June 2017 from which a final hand-harvesting strategy would derive. Onterra's initial recommendations are to target areas in Tittle Lake for this pilot program (Map 7). The EWM colonies are relatively small and low-density, ideal for this control strategy. These locations are also within one of the higher areas of flow in the system and may be less applicable to future herbicide control strategies. Onterra will provide the hand-harvesting firm with the spatial data from the June survey to aid the removal efforts. Following the hand removal efforts, a Late-Summer EWM Peak Biomass Survey will qualitatively assess the hand harvesting efforts.

Onterra recommends that hand-harvesting occur from approximately mid-June to early-September for two primary reasons: 1) it allows for the control action to occur between the professional pre- and post-monitoring surveys for planning (prioritization of sites) and evaluation of efficacy (pre- to post-monitoring), and 2) hand-pulling of EWM too early or too late in the season can make complete extraction (including the roots) more difficult as the plants tend to be brittle when less actively growing at these early and late parts of the growing season.

Final Spot Treatment Strategy (Liquid Endothall)					
Site	Preliminary Acres	Final Acres	Ave. Depth (feet)	Volume (ac-ft)	Endothall PPM ai
A-16	2.8	2.8	5.0	14.0	3.5
B-16	4.7	*removed*	-	-	-
C-16	18.0	8.0	4.0	32.0	2.0
D-16	5.0	5.5	5.0	27.5	2.5
Total	***30.5***	***16.3***		***73.5***	



Extent of large map

650
Feet

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

Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, June 2015
Map Date: May 6, 2016
Filename: LongFDL_CLP_T2016_Cond1.mxd

Project Location in Wisconsin

Legend

2016 Final CLP Treatment Area

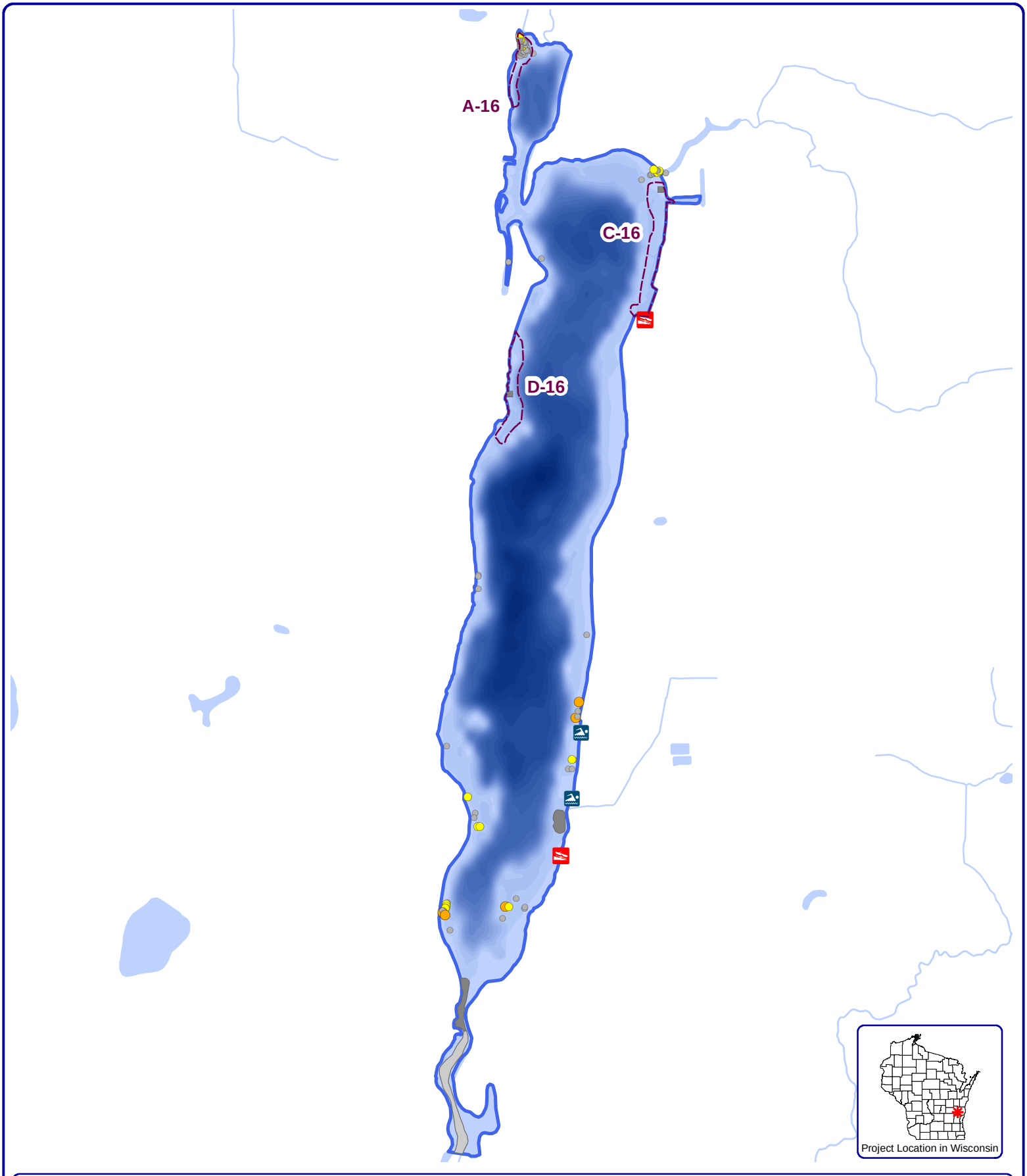
2016 Preliminary CLP Treatment Area

Map 1

Long Lake

Fond du Lac County, Wisconsin

2016 Final CLP Treatment Strategy



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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Map Date: June 23, 2016
Filename: Long_FDL_CLP_June16.mxd

Legend

Curly-leaf pondweed (June 2016)

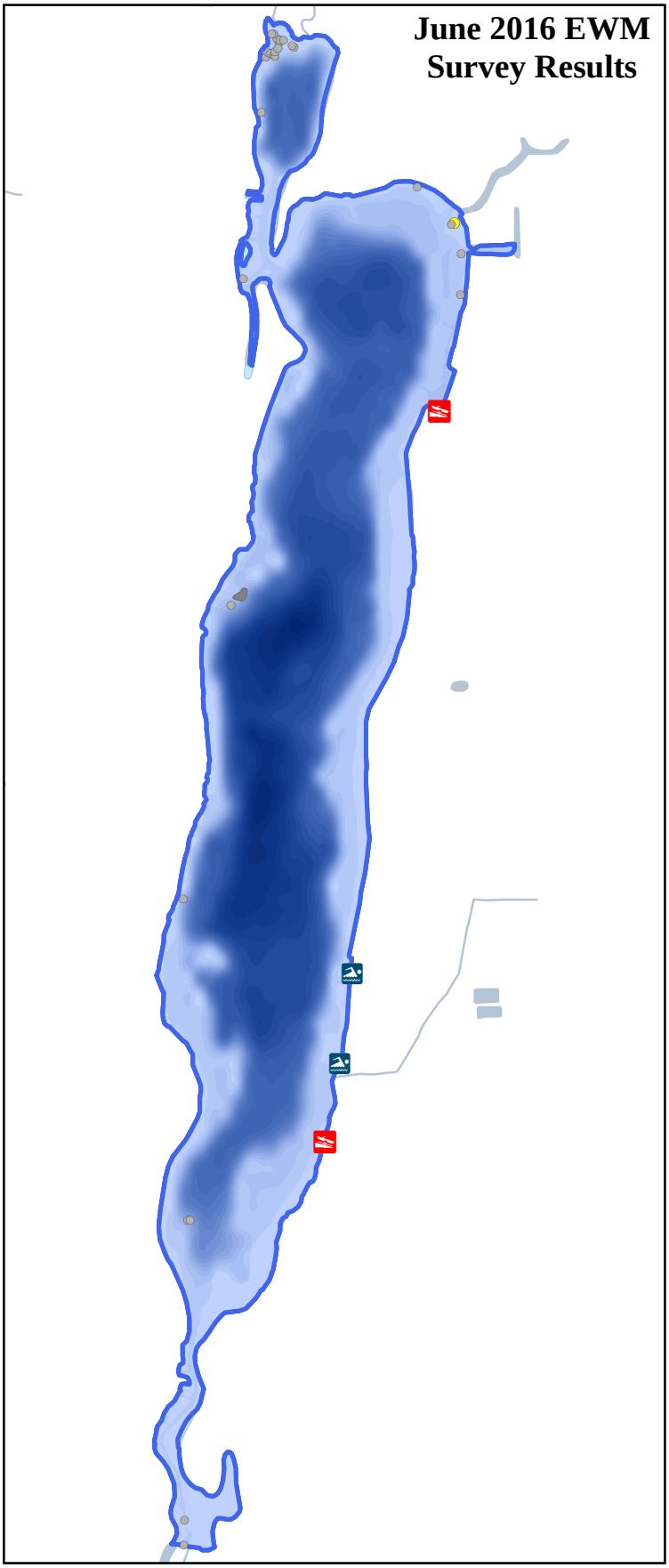
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Point-Intercept Survey CLP occurrence *June 2016)*
- 2016 CLP Herbicide Treatment Area

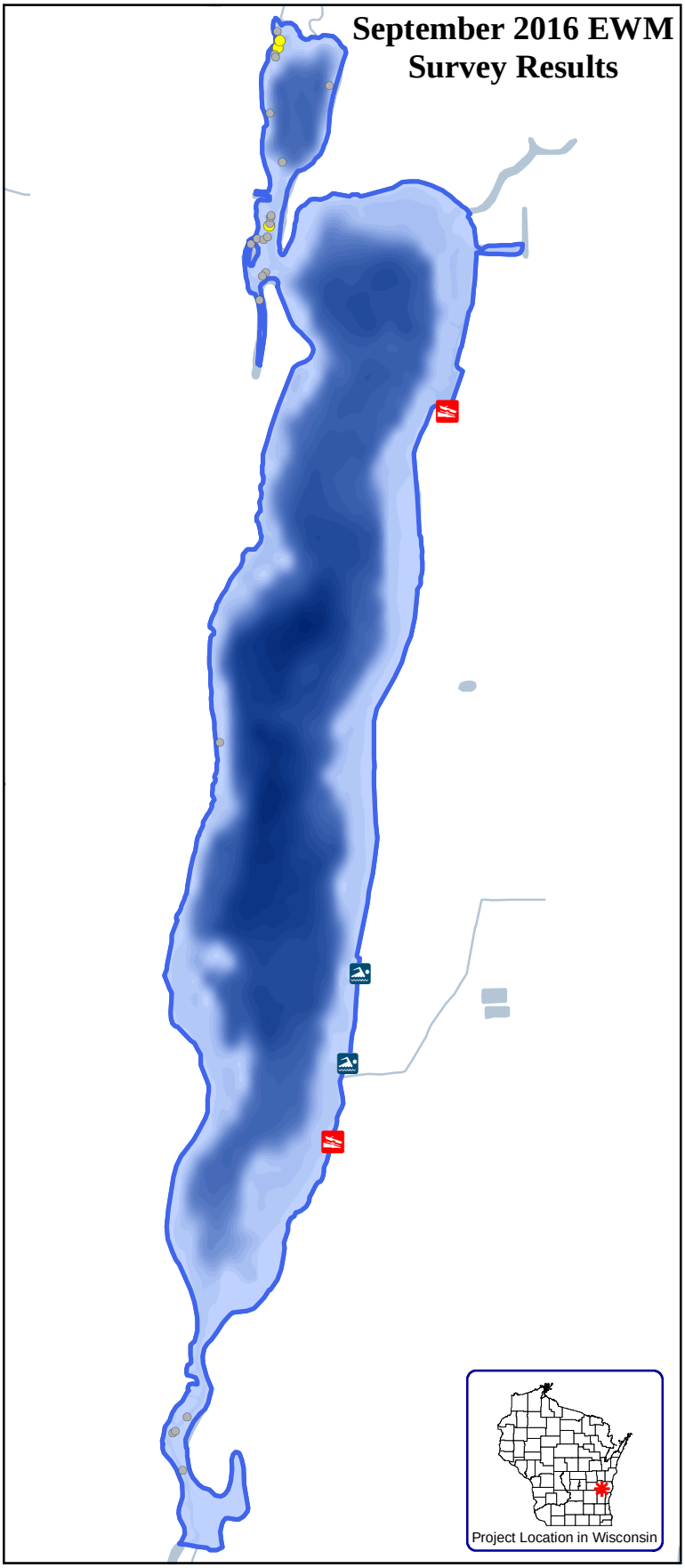
Map 2

Long Lake

Fond du Lac County, Wisconsin

June 2016 CLP Survey Results





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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Map Date: January 16, 2017
Filename: Long_FDL_EWM_June16.mxd

Legend

Eurasian Water Milfoil

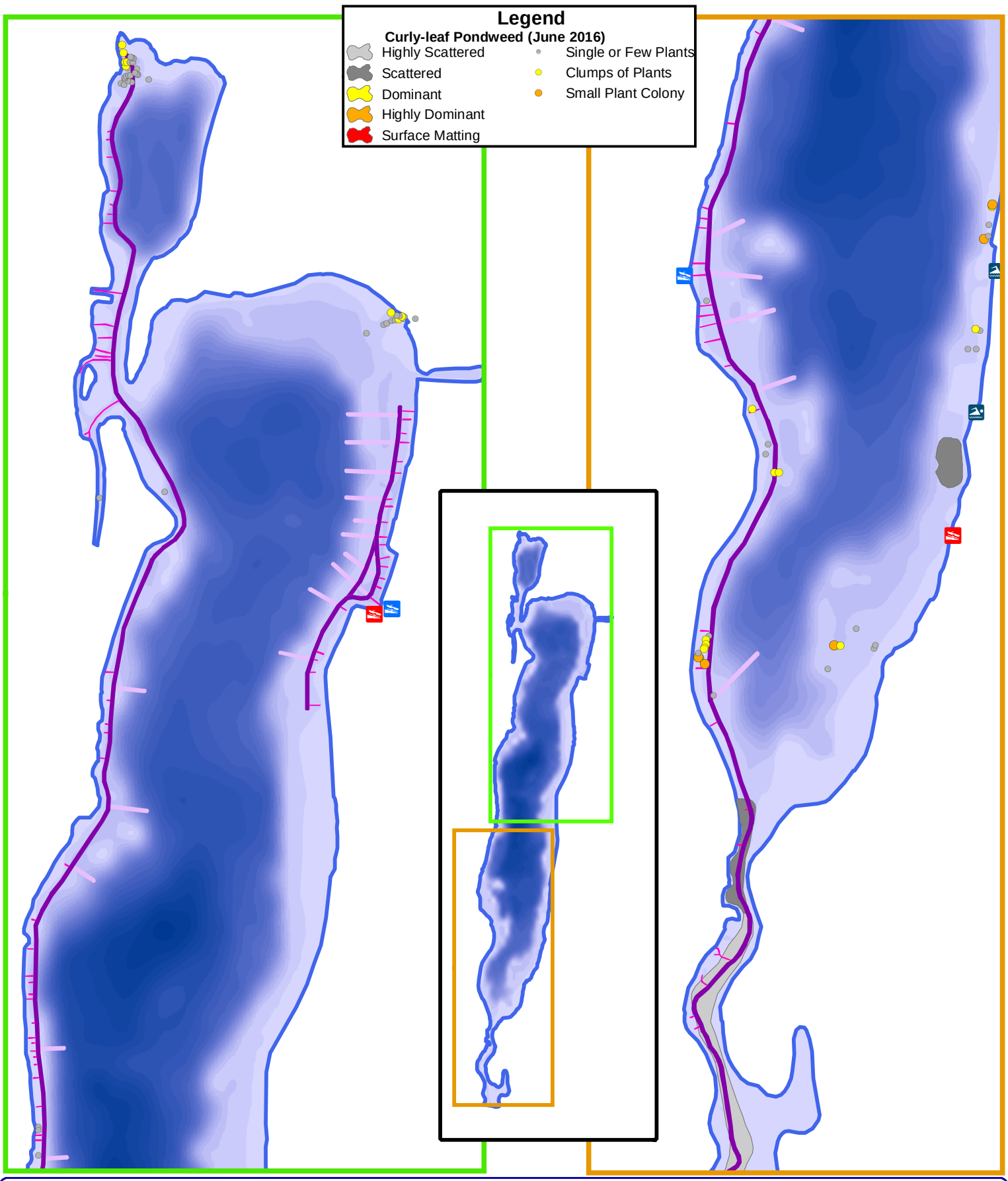
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

Map 3

Long Lake

Fond du Lac County, Wisconsin

2016 EWM Survey Results



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Sources:
Roads and Hyrdo: WDNR
Bathymetry: WDNR 197, Digitized by Onterra
Aquatic Plants: Onterra, 2016
Map Date: March 2, 2016
Filename: LongFDL_MechHarvest_2016_v2.mxd

Project Location in Wisconsin

Legend

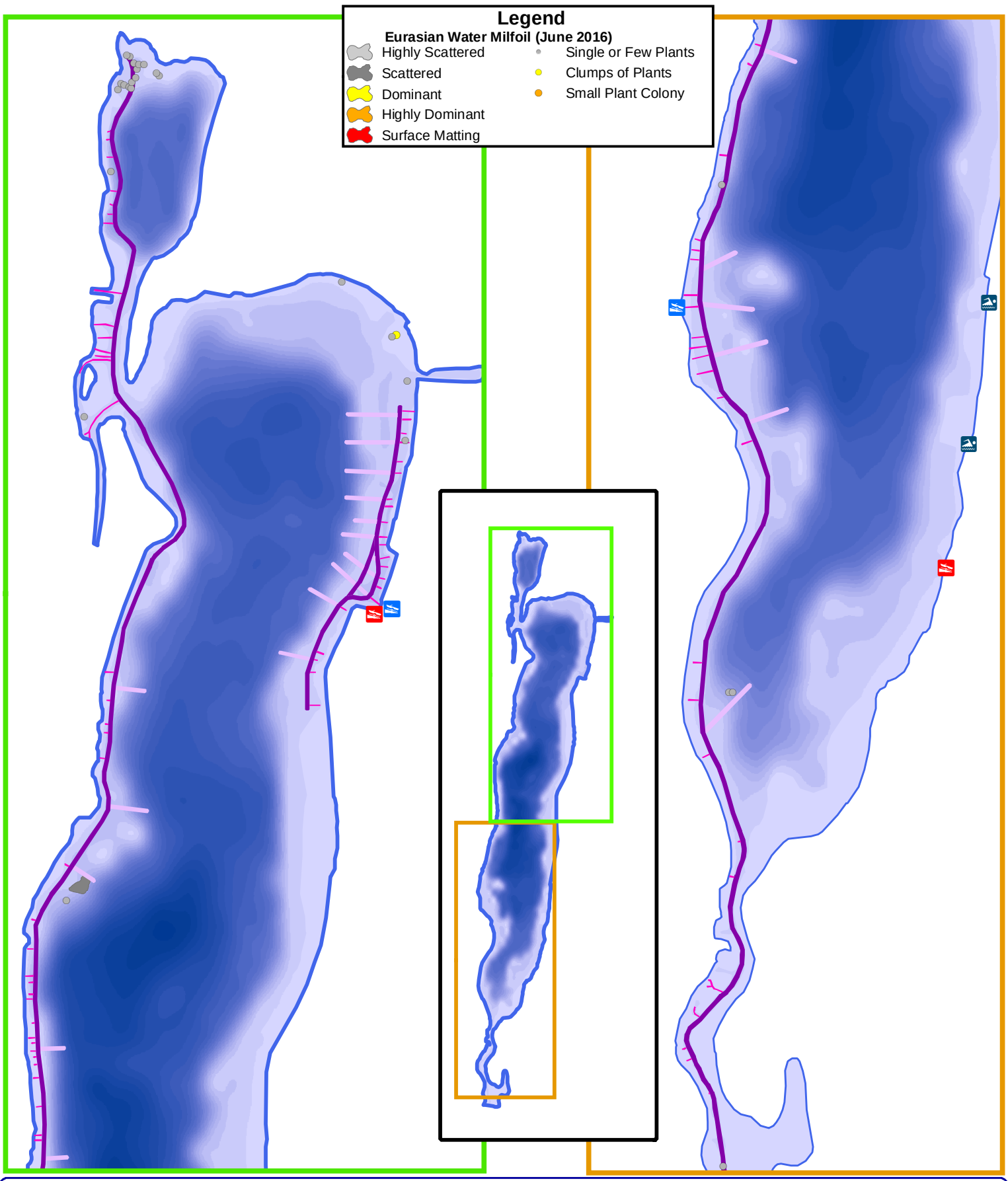
- Common Use Center Lane (30-ft wide, 13.0 acres)
- Common Use Lakeward Spoke (30-ft wide, 3.7 acres)
- Riparian Access Spoke (10-ft wide, 1.2 acres)

Map 4

Long Lake

Fond du Lac County, Wisconsin

2016 Mechanical Harvest Plan - CLP



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Sources:
Roads and Hyrdo: WDNR
Bathymetry: WDNR 197, Digitized by Onterra
Aquatic Plants: Onterra, 2016
Map Date: March 2, 2016
Filename: LongFDL_MechHarvest_2016_v2.mxd

Project Location in Wisconsin

Legend

- Common Use Center Lane (30-ft wide, 13.0 acres)
- Common Use Lakeward Spoke (30-ft wide, 3.7 acres)
- Riparian Access Spoke (10-ft wide, 1.2 acres)

Map 5

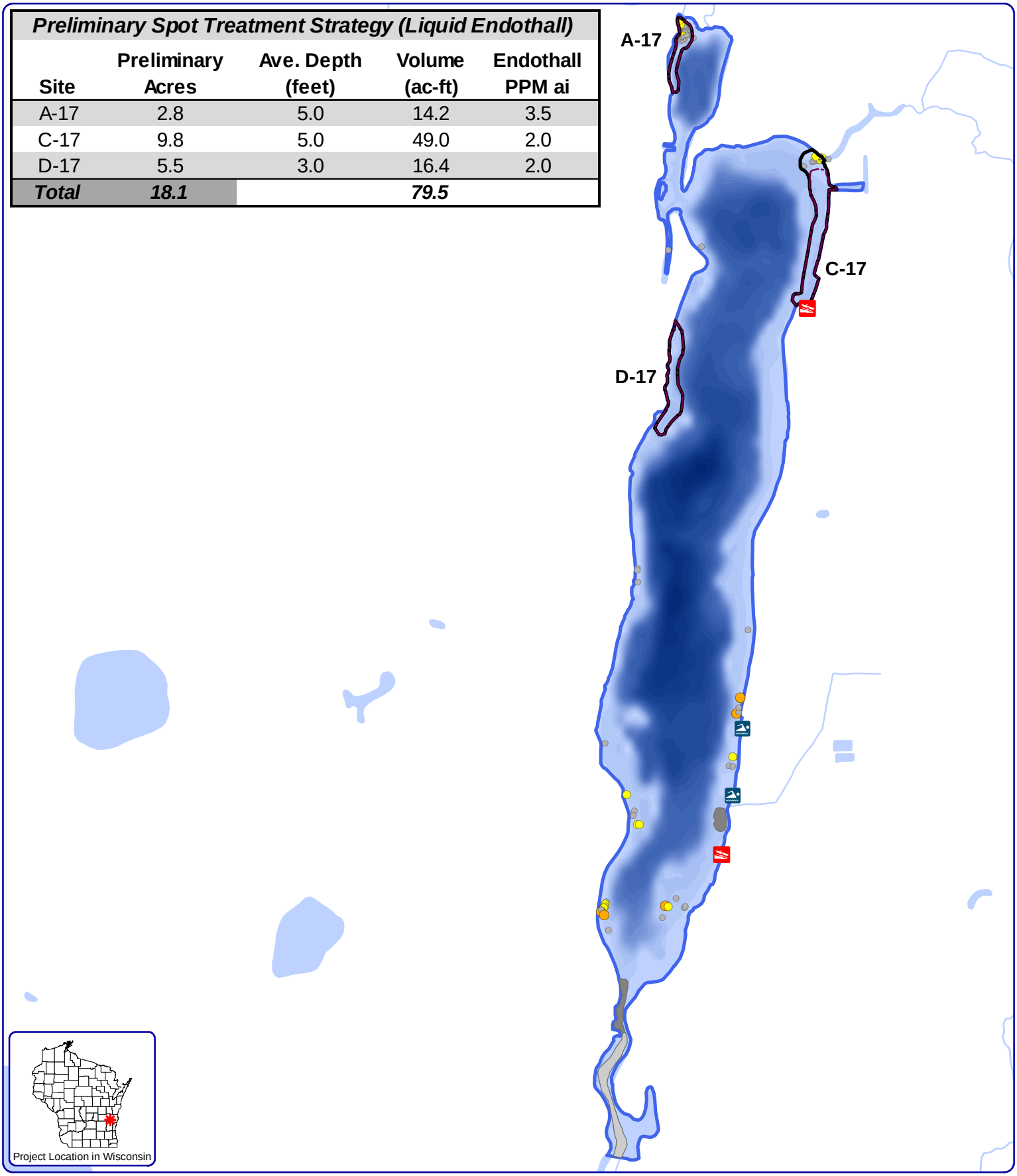
Long Lake

Fond du Lac County, Wisconsin

2016 Mechanical Harvest Plan - EWM

Preliminary Spot Treatment Strategy (Liquid Endothall)

Site	Preliminary Acres	Ave. Depth (feet)	Volume (ac-ft)	Endothall PPM ai
A-17	2.8	5.0	14.2	3.5
C-17	9.8	5.0	49.0	2.0
D-17	5.5	3.0	16.4	2.0
Total	***18.1***		***79.5***	



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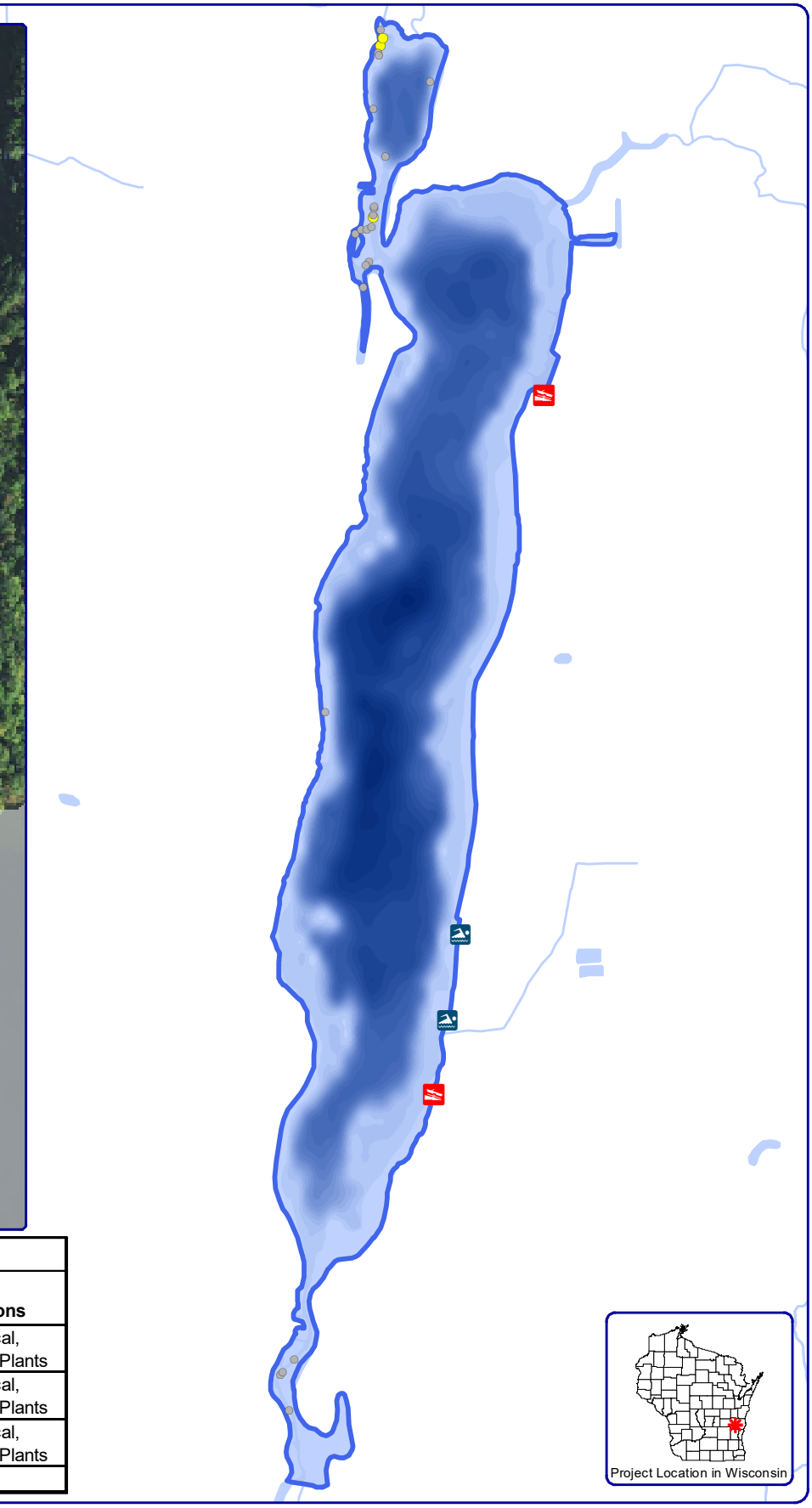
Sources:
Roads and Hyrdo: WDNR
Bathymetry: Onterra 2015
Aquatic Plants: Onterra, June 2016
Map Date: January 11, 2017
Filename: LongFDL_CLP_T2017_Prelim1.mxd

Legend

Curly-leaf pondweed (June 2016)

- Highly Scattered
- Scattered
- Dominant *(None)*
- Highly Dominant *(None)*
- Surface Matting *(None)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2016 Final CLP Treatment Area
- 2017 Preliminary CLP Treatment Area

Map 6
Long Lake
Fond du Lac County, Wisconsin
2017 Preliminary CLP Treatment Strategy



2016 Preliminary Hand-Harvest Areas				
Site	Conditional Acres	Ave Depth (feet)	Sediment	Obstructions
R-17	0.36	3 (2-4)	Marly Mucky	No Physical, Heavy Native Plants
S-17	0.14	3 (2-4)	Marly Mucky	No Physical, Heavy Native Plants
T-17	0.33	3 (2-5)	Marly Mucky	No Physical, Heavy Native Plants
Total	**0.83**			

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Sources:
Roads and Hyrdo: WDNR
Bathymetry: Onterra 2015
Aquatic Plants: Onterra, September 2016
Map Date: February 23, 2017

Legend

Eurasian Water Milfoil (September 2016)

- Highly Scattered *(None)*
- Scattered *(None)*
- Dominant *(None)*
- Highly Dominant *(None)*
- Surface Matting *(None)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2017 Preliminary EWM Hand-Harvest Site

Map 7
Long Lake
Fond du Lac County, Wisconsin
2017 Preliminary EWM Hand-Harvest Control Strategy