INTRODUCTION

Photo 1. Silver Lake, Forest County.

Silver Lake, Forest County, is a 320-acre spring lake with a maximum depth of 21 feet (Photo 1). Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first located in Silver Lake in 2010. The EWM population has been managed through hand-harvesting (annually) and herbicide spot treatments (2012 and 2014) since first being located.

In 2015, the Silver Lake Preservation Association, Inc. (SLPA; formerly Forest County Silver Lake Association) hired a professional firm to assist in their hand-harvesting control strategy. Based upon the pre-determined success criteria, professional hand-harvesting of EWM in 2015 was deemed successful with EWM being maintained at low densities within the hand-harvesting areas. While EWM was still present within the areas harvested, the efforts likely slowed the overall expansion and spread of EWM within the lake. The level of EWM in 2015 did not warrant herbicide application in 2016 (Map 1), and it was recommended that professional hand-harvesting of EWM occur again in 2016.

WDNR LONG-TERM EWM TRENDS MONITORING RESEARCH PROJECT

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. Because the state of Wisconsin's waters are managed for multiple uses (Statue 281.11), the WDNR wanted to understand if EWM populations would increase and cause either 1) ecological impacts to the lake and/or 2) reductions in ecosystem services (i.e. navigation, recreation, aesthetics, etc.) to lake users. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes is not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 1). Some lakes, such as Handcock Lake, maintained low EWM populations over the study averaging 2.3% between 2008 and 2015. At these low levels, there are likely no observable ecological impacts to the lake and are no reductions in ecosystem services to lake users. The EWM population of Handcock Lake has increased in recent years to 5.2% in 2015 and over 10% in 2016 (preliminary data not shown in Figure 1).

Eurasian water milfoil populations in other lakes, such as Bear Paw Lake and Little Bearskin Lake trended to almost 25% only to decline to approximately 5% by the end of the study period. There are many factors that could contribute to the decline in the EWM population of these lakes, including climactic conditions and water quality parameters. Little Bearskin is known to contain a robust population of milfoil weevils, and this native insect may be having an impact on the EWM population

within the lake. Boot Lake is a eutrophic system with low water clarity (approx. 3-ft Secchi depth) due to naturally high phosphorus concentrations. It is hypothesized that water clarity conditions in some years may favor EWM growth whereas in other years it may keep the population suppressed. Extreme changes in EWM populations like those observed on Weber Lake have also been documented. The EWM population in 2010-2011 was approximately 20% before spiking above 50% in 2012. Then the population declined back to approximately 15% in 2014 and 2015.

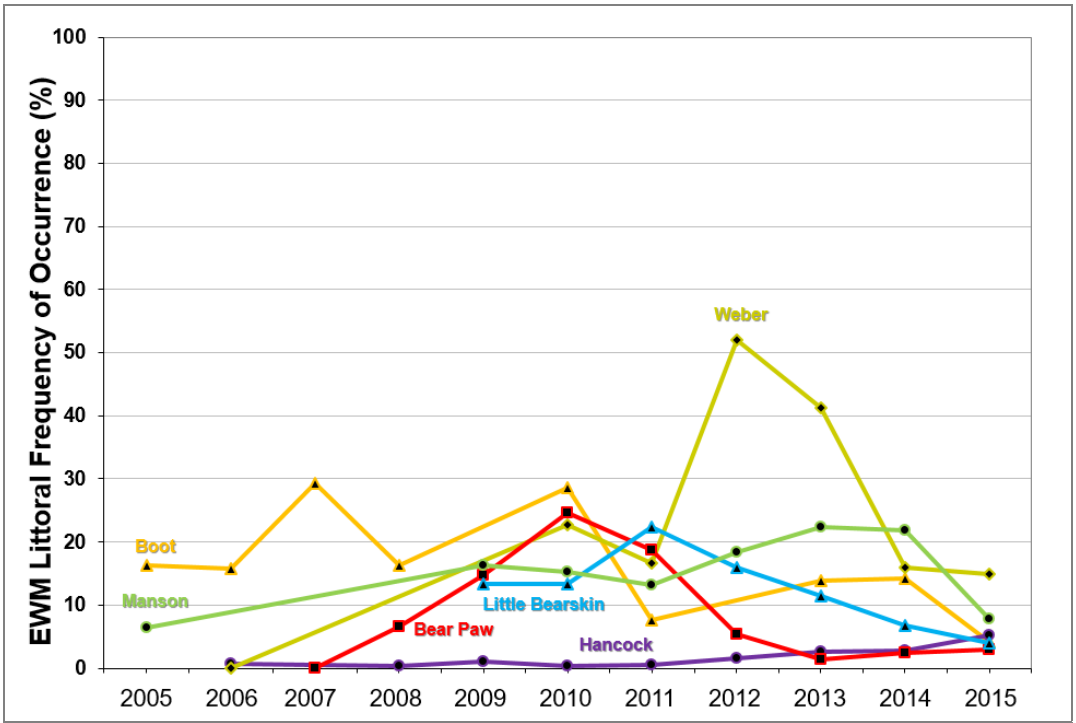


Figure 1. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Some lake managers interpret these data to suggest that in some circumstances, it is not appropriate to manage the EWM population as in some years the population may become less. However, even a lowered EWM population of approximately 10% exceeds the comfort level of many riparians because it is potentially approaching a level than may be impactful to the function of the lake as well as not allowing the lake to be enjoyed by riparians as it had been historically. For reference, it is suspected that the EWM population in Silver Lake is currently < 3%.

Some lake groups, like the SLPA, choose to manage the EWM population to keep it at a lowered level. Following detection of an EWM population within a lake, it is common for a lake group to initiate management activities and not wait to see if the EWM population will become a problem in their lake. Following EWM detection in Silver Lake, herbicide applications were determined to be the appropriate initial control strategy. Following a subsequent reduction in the EWM population, a combination of

volunteer and professional hand-harvesting was deemed the most appropriate strategy for maintaining a small EWM population. But in other lakes, the EWM population progression is too great for hand-harvesting to provide effective lake-wide control. Continuing the hand-harvesting efforts on these lakes may be able to provide localized EWM reductions where the control strategy is applied and reduce that specific colony from contributing to the overall population increase to the lake. These efforts may also reduce recreational impediments that are caused by dense EWM colonies.

2016 EWM CONTROL STRATEGY

The objective of EWM management in Silver Lake is not to eradicate EWM from the lake, as that is nearly impossible with current tools and techniques. The objective is to maintain an EWM population that exerts little to no detectable impacts on the lake's native aquatic plant community and overall ecology, recreation, and aesthetics. In an effort to prevent the expansion of the Silver Lake EWM population into larger, monotypic colonies, the SLPA again contracted with a professional hand-harvesting firm, Aquatic Plant Management, LLC (APM), in 2016 to conduct hand-removal of all areas of EWM located in Silver Lake (Map 1). By utilizing professional divers, it is believed that larger areas of EWM can be targeted for hand-removal and be done more efficiently than using volunteer efforts alone. The development of the Silver Lake Comprehensive Management Plan, finalized in January of 2016, found that 78% of Silver Lake stakeholder respondents are supportive of utilizing hand-removal efforts to control EWM.

MONITORING METHODOLOGIES

Typically, EWM control programs (mainly with herbicides) incorporate both established qualitative (EWM mapping) and quantitative (sub-sample point-intercept survey) evaluation methodologies. However, quantitative monitoring of hand-removal areas using sub-sample point-intercept methodology was not applicable at this time as there were no areas of EWM large enough to attain the number of sampling locations required to meet the assumptions of statistical analysis. Therefore, each hand-removal site was monitored using comparative GPS-guided pre- and post-hand-harvesting qualitative EWM mapping surveys.

Using sub-meter GPS technology, EWM locations were 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*.

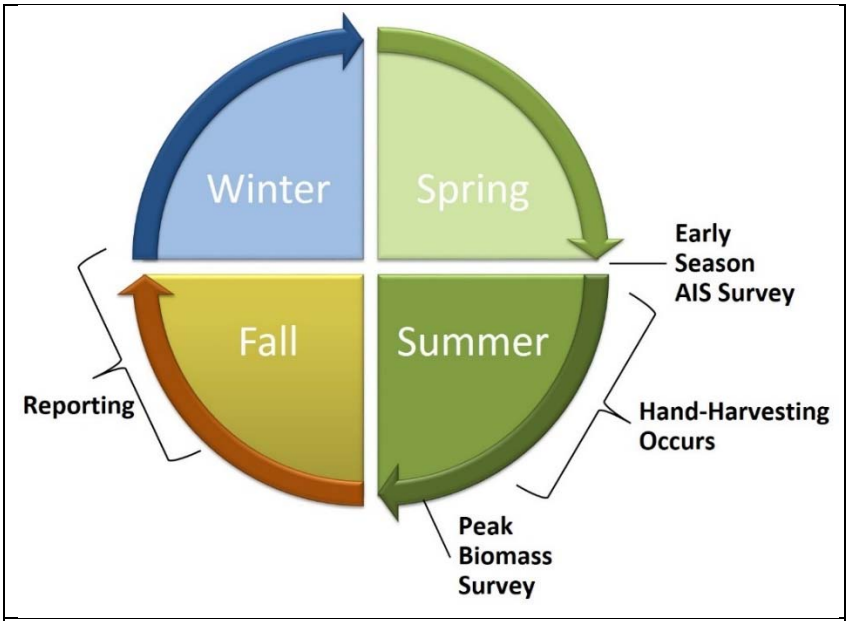


Figure 2. Project timeline diagram.

To assess the 2016 hand-harvesting activities on Silver Lake, qualitative assessments were completed by comparing pre-hand-harvesting data collected during the June 2016 Early-Season AIS (ESAIS) Survey with post-hand-harvesting EWM mapping data collected during the September 2016 Late-Summer EWM Peak-Biomass Survey (Figure 2). If areas containing EWM mapped at the point-based level prior to hand-harvesting were maintained at the point-based mapping level following hand-harvesting, these sites would be deemed successful. If a hand-harvest site expanded from point-based EWM mapping to polygon-based mapping (large EWM colonies) following hand-harvesting, the site would be deemed unsuccessful. For sites containing larger EWM colonies (polygons) prior to hand-harvesting, they would be deemed successful if the density rating of the colony was reduced by at least one density rating (e.g. scattered to highly scattered, or highly scattered to point-based EWM mapping). It must be noted that hand-removal methodology is still experimental, and success criteria for assessing the efficacy of hand-removal are difficult to define.

EARLY SEASON AIS SURVEY RESULTS (PRE-HAND-HARVESTING)

On June 16, 2016, Onterra ecologists conducted the Early-Season AIS (ESAIS) Survey on Silver Lake. While EWM surveys are typically conducted later in the summer to coincide with its peak growth, this early-summer meander-based survey was conducted to locate and map areas of EWM so these data could be relayed the hand-harvesters at APM. This provides the hand-harvesters with the most up-to-date and accurate information regarding locations of EWM within the lake. As discussed, the ESAIS Survey also serves as a pre-hand-harvesting survey where the data gathered prior to the implementation of hand-harvesting can be compared to data collected after hand-harvesting during the Late-Summer EWM Peak-Biomass Survey.

During this survey, Onterra ecologists located more EWM than had been located during the Late-Summer EWM Peak-Biomass Survey conducted in September 2015 (Map 1 and 2). In addition to more single plants, clumps, and small plant colonies, a small (0.2 acres) area of scattered EWM was located in the southwestern portion of the lake in June 2016. In the northwestern portion of the lake, more single plants and clumps of plants were located when compared to 2015. Following this survey, eight hand-harvest areas were created totaling 3.6 acres (Map 2) and the spatial data were provided to APM. Onterra recommended that APM give priority to sites A-16 and B-16 as these sites contained the largest and densest areas of EWM.

HAND-HARVESTING MANAGEMENT ACTIONS

Aquatic Plant Management (APM) conducted their hand-harvesting of EWM in Silver Lake on June 30, July 29, August 1, and August 23, 2016. The divers spent a total of 18.6 hours underwater harvesting a total of 845 cubic feet of EWM (Table 1). A total of 495 cubic feet of EWM (58%) was removed from site A-16, 100 cubic feet (12%) from site H-16, 75 cubic feet (9%) from F-16, 5 cubic feet (1%) from G-16, and 170 cubic feet (20%) from areas outside of the previously delineated hand-harvest areas. The APM divers deviated from the delineated hand-harvest areas based on requests from the SLA to target EWM colonies matted on the surface in the northeast portion of lake and near the public boat landing. Based on the hand-harvesting data, approximately 45 cubic feet of EWM were harvested for every one hour spent underwater. Additional details of the hand-harvesting efforts as reported by APM are included as an appendix to this report (Appendix A).

Table 1. Silver Lake 2016 Hand-Harvesting Activities. Adapted from Aquatic Plant Management Silver Lake EWM Removal Report 2016 (Appendix A.)

2016 Hand-Harvest Site	Time Underwater (hours)	EWM Removed (ft^3)
A-16	10.4	495
B-16	0.0	0
C-16	0.0	0
D-16	0.0	0
E-16	0.0	0
F-16	2.3	75
G-16	0.8	5
H-16	1.6	100
Outside 2016 HH Area	3.5	170
Total	**18.6**	**845**

LATE-SUMMER EWM PEAK-BIOMASS SURVEY RESULTS (POST-HAND-HARVESTING)

Onterra ecologists returned to Silver Lake on September 27 and 28, 2016 to conduct the Late-Summer EWM Peak-Biomass Survey to assess the 2016 hand-removal areas and to map EWM throughout the lake (Map 3 and Figure 3). During this survey, EWM was located within the all of the 2016 hand-harvest areas, and additional occurrences outside of these areas were also located. A *highly scattered* area of EWM was located within shallow bay on the southwest side of the lake, while a number of single plants, clumps of plants, and two small plant colonies were located outside of hand-harvest areas in the northern portion of the lake. A few occurrences of EWM were also located in the southeastern portion of the lake.

Professional hand-harvesting occurred within four of the eight hand-harvesting sites in 2016. While the majority of the hand-harvesting (10.4 hours) took place within site A-16 and a total of 495 cubic feet of EWM was removed, this site failed to meet the predetermined criterion (reduction of at least one density rating) for successful control (Table 2). Prior to hand-harvesting during the June 2016 ESAIS Survey, site A-16 contained a 0.2-acre colony of *scattered* EWM surrounded by single plants and clumps of plants (Figure 3). Following hand-harvesting, site A-16 was found to contain a 0.4-acre colony of *dominant* EWM, indicating the EWM within this site increased in size and density. This indicates that

the level effort spent hand-harvesting within this area was not enough to overcome the growth and spread of EWM. However, hand-harvesting likely prevented this area from becoming *highly dominant*.

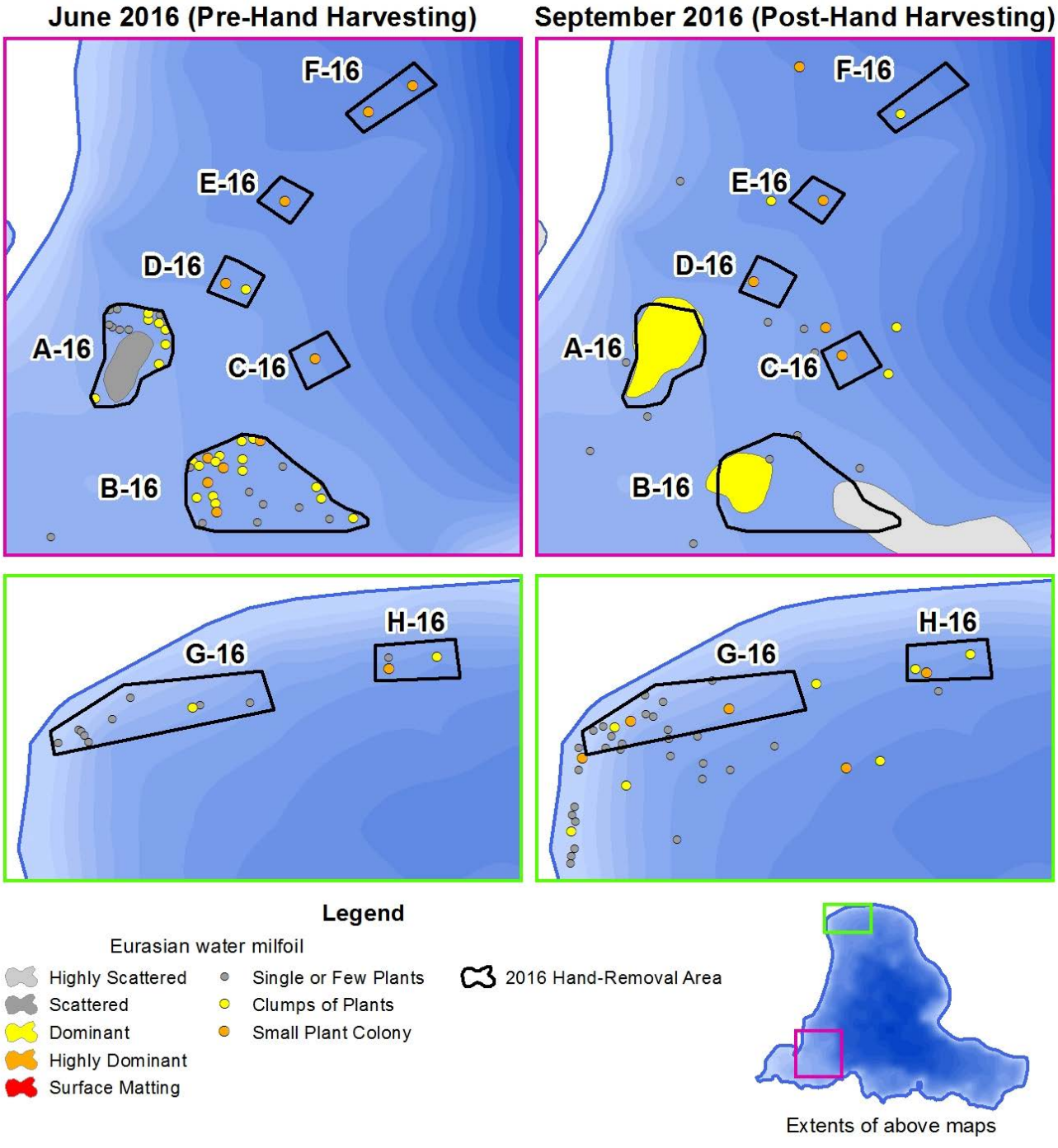


Figure 3. Silver Lake June 2016 pre- and September 2016 post-hand-harvesting EWM survey results within 2016 hand-harvest areas.

Prior to hand-harvesting, sites F-16, G-16, and H-16 contained EWM mapped with point-based techniques (single or few plants, clumps of plants, small plant colonies) (Figure 3 and Table 2).

Following hand-harvesting, these areas were still found contain EWM at the point-based mapping level, and therefore, all three met the pre-determined success criterion of maintaining low-density EWM. While B-16 was designated as a priority site by Onterra, no harvesting occurred within this area. Additionally, no harvesting occurred within sites C-16, D-16, or E-16. As mentioned earlier, APM deviated from these areas based on the request of the SLA. In June 2016, site B-16 contained numerous single plants, clumps of plants, and small plant colonies (Figure 3 and Table 2). By September 2016, this area contained a 0.3-acre colony of *dominant* EWM and a portion of a 0.9-acre *highly scattered* colony of EWM. The EWM within C-16, D-16, and E-16 was mapped using point-based techniques in June 2016, and the EWM remained at the point-based mapping level in September 2016. Overall, of the four sites which were harvested, three met the pre-determined success criterion for successful control.

Table 2. Silver Lake June 2016 pre- and September 2016 post-hand-harvesting results.

Site	June 2016 EWM (Pre-Hand-Harvest)	September 2016 EWM (Pre-Hand-Harvest)	Success Criteria Met
A-16	Colonized (scattered)	Colonized (dominant)	No
B-16	Point-based (SPC, C, S)	Colonized (dominant & scattered)	NA
C-16	Point-based (SPC)	Point-based (SPC)	NA
D-16	Point-based (SPC, C)	Point-based (SPC)	NA
E-16	Point-based (SPC)	Point-based (SPC)	NA
F-16	Point-based (SPC)	Point-based (C)	Yes
G-16	Point-based (C, S)	Point-based (SPC, C, S)	Yes
H-16	Point-based (SPC, C, S)	Point-based (SPC, C)	Yes

S = Single or Few Plants; C = Clumps of Plants; SPC = Small Plant Colony
NA = Not Applicable; no harvesting occurred

2016 CONCLUSIONS & DISCUSSION

The 2016 post-hand-harvesting survey on Silver Lake indicated the hand-harvesting efforts were met with mixed results. Of the eight hand-harvesting sites delineated by Onterra in June 2016, four saw hand-harvesting by professional harvesters. Of the four sites harvested, three met the pre-determined success criterion. Following the June 2016 pre-hand-harvesting survey, Onterra gave priority to sites A-16 and B-16 as these areas were found to contain the largest and densest areas of EWM. Of these two areas, A-16 was the only area where hand-harvesting was implemented. And while the majority of the hand-harvesting took place within site A-16, it was not enough to reduce the EWM within this area by at least one density rating. The post-hand-harvesting survey found that the area of EWM within A-16 had increased in size and density. However, a significant amount of EWM was removed from this area and likely prevented this area from becoming even larger and denser.

Unfortunately, EWM was located outside of the hand-harvesting areas during the September 2016 survey, most notably within the northern and southwestern portions of the lake. Overall, there was a greater occurrence of EWM within the lake in September 2016 than when compared to the survey completed in September 2015. While the professional hand-harvesters removed a significant amount of EWM which likely slowed the expansion and spread of EWM, it was not enough to prevent EWM from increasing at the lake-wide level.

During the Silver Lake Management Planning Project Wrap-Up Meeting held in August of 2016, concern was raised about the high number of EWM fragments observed, particularly along the southern shoreline. Some of these fragments were likely the result of hand-harvesting activities, and while the hand-harvesters take great care to capture fragments, it is not possible to contain all of them. Much of the EWM in Silver Lake grows in relatively shallow water and close to the surface, and motorboat traffic likely also causes EWM fragmentation. One of the primary concerns at the meeting was if hand-harvesting was causing more harm than good by generating EWM fragments. Onterra ecologist Brenton Butterfield explained that EWM auto-fragments a couple times of year, and that hand-harvesting likely has an overall positive effect by removing plants before they have the chance to fragment. While EWM occurrence has increased from 2015 to 2016, it is believed that the hand-harvesting in Silver Lake is preventing more rapid expansion and spread.

Within the Silver Lake Management Plan that was finalized in 2016, a threshold was developed to determine when the use of herbicides should be considered for EWM control. This threshold includes the presence of colonized areas of EWM (polygons) of a *dominant* density rating or greater where at least a five-acre application area could be delineated. As is discussed within the Lake Management Plan, ongoing studies are indicating that in spot treatments of less than 5.0 acres the herbicide dissipates too rapidly to cause EWM mortality if systemic herbicides like 2,4-D are used. Ongoing field trials are accessing the efficacy (EWM control) and selectivity (collateral native plant impacts) of herbicides that may be effective with a shorter exposure time.

Two small areas of *dominant* EWM were located in Silver Lake in 2016, and an herbicide application area placed over these sites would be approximately 2.6 acres, falling short of the pre-determined trigger of at least 5.0 acres for considering the use of an herbicide treatment (Figure 4). Because an herbicide treatment targeting current areas of dominant EWM in Silver Lake would likely not lead to successful long-term control, it is recommended that the SLPA continue with a professional hand-harvesting strategy in 2017.

To continue EWM monitoring and control strategy development, the SLPA has applied for a WDNR AIS-Education, Planning and Prevention Grant to aid in funding these activities in 2017 and 2018. However, the cost of implementing the control strategy (i.e. professional hand-harvesting or herbicide treatments) are not eligible expenses. Therefore, the SLPA needs to develop a realistic hand-harvesting budget for 2017. Unfortunately, the exact amount of effort that would be required to meet the SLPA's control expectations are difficult to quantify. The fault of many hand-harvesting efforts is that the amount of effort (time) put forth is nowhere near what is be needed to keep the population in check or reduce it.

Some professional hand-harvesting firms use basic snorkeling or SCUBA based divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) system which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process. In Squash Lake in Oneida County, the DASH system has proven to be effective at removing larger, denser colonies of EWM. In developing a hand-harvesting budget for 2017, the SLPA should consider if the additional costs associated with hiring a firm with DASH technology is worth implementing on Silver Lake.

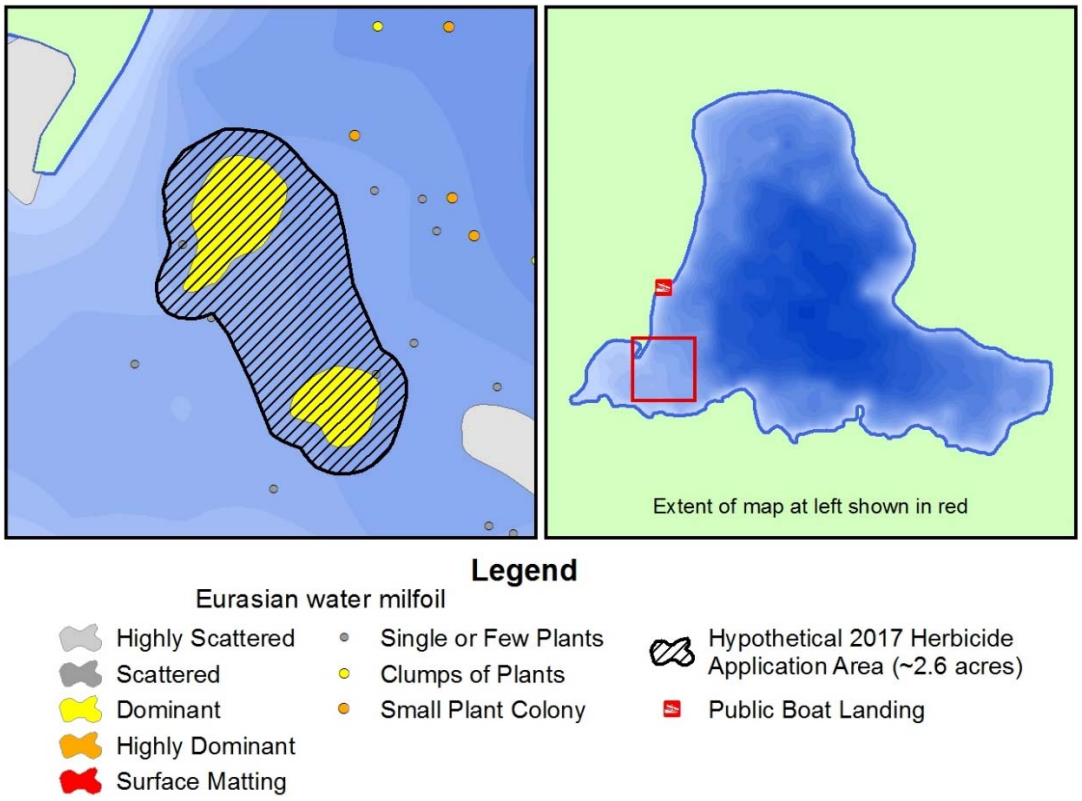
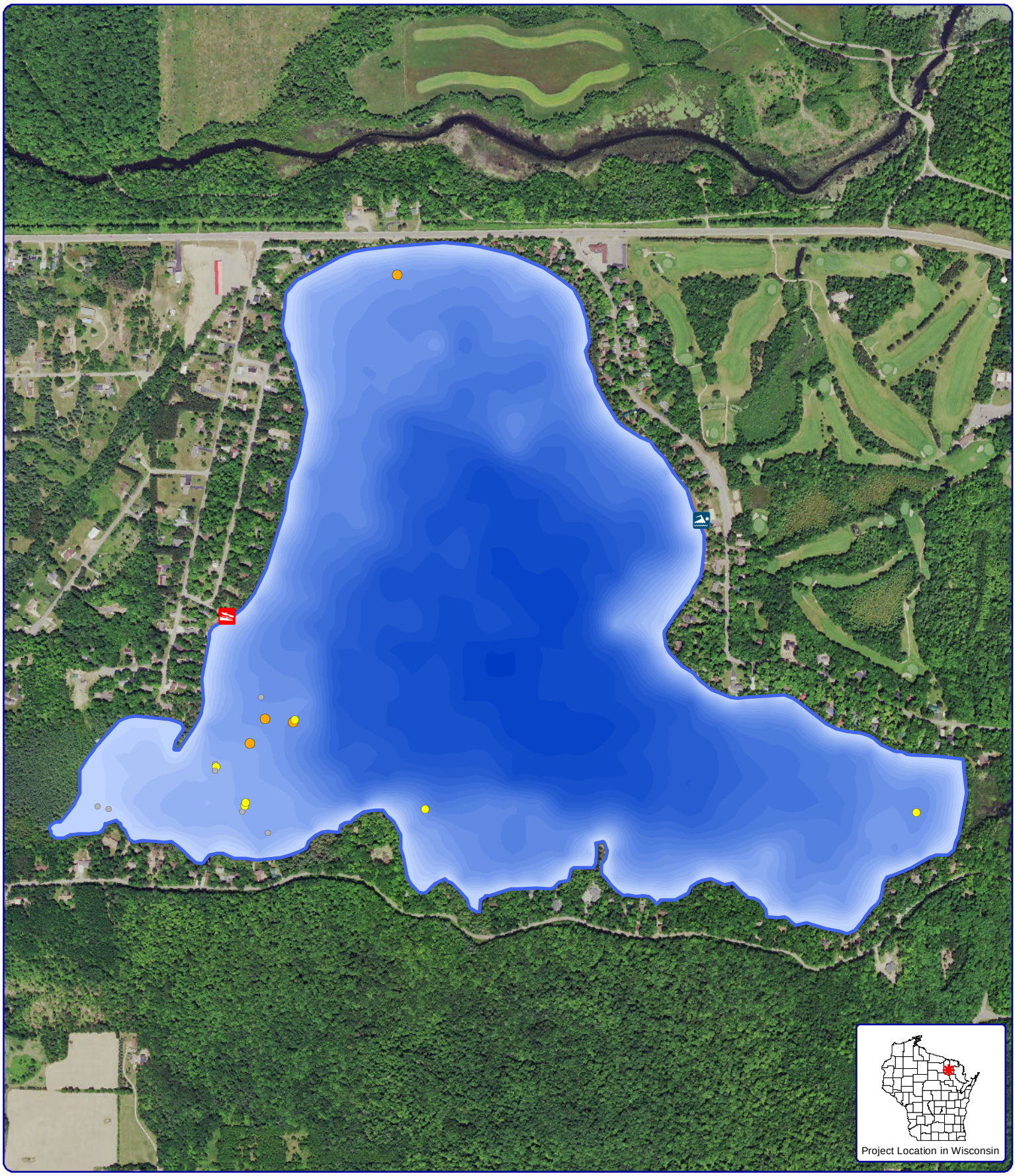


Figure 4. Silver Lake September 2016 EWM and hypothetical herbicide application area (~2.6 acres) targeting two colonies of *dominant* EWM.

As is discussed earlier in this report, long-term research being completed by the WDNR is showing that EWM has the capacity to fluctuate in its occurrence naturally over time in the absence of any active management strategy. However, the SLPA has elected to actively manage EWM within Silver Lake as they want to prevent EWM from reaching higher abundances (i.e. littoral frequency of 10%). Given the expansion of EWM in Silver Lake in 2016 despite the hand-harvesting efforts, Onterra ecologists believe the EWM population will continue to progress unless a larger hand-harvesting effort is implemented in 2017. If surveys in 2017 find that the EWM continues to expand, the triggers outlined within the Silver Lake Management Plan will likely be reached for implementing an herbicide treatment in the spring of 2018.



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920.338.8860
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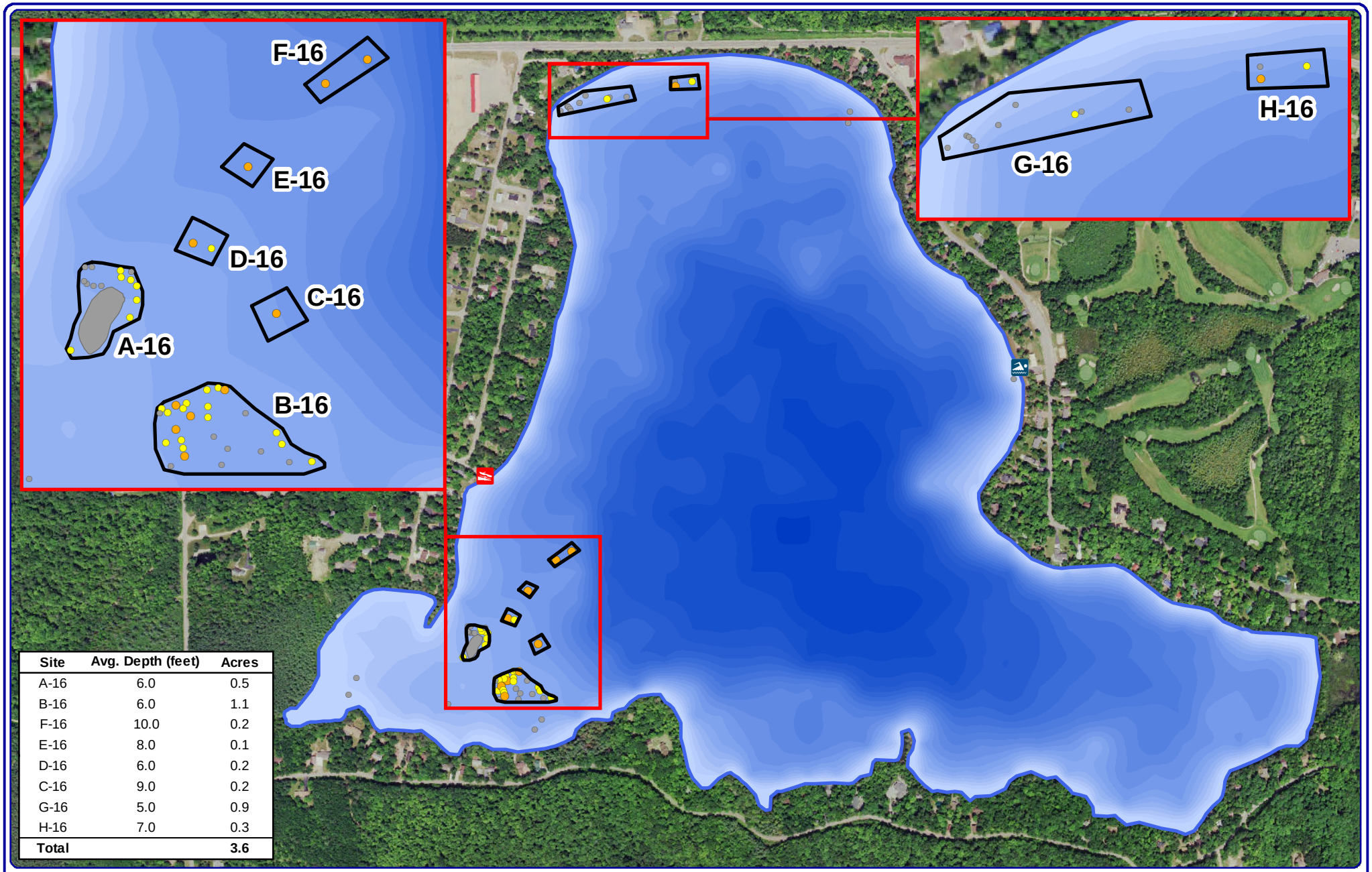
Sources:
Bathymetry: Onterra, 2014
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2015
Map Date: November 14, 2016
Filename: Map1_SilverF_EWM_Sept15.mxd

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony
- Public Boat Landing
- Public Beach

Map 1
Silver Lake
Forest County, Wisconsin
September 2015 EWM Locations



Site	Avg. Depth (feet)	Acres
A-16	6.0	0.5
B-16	6.0	1.1
F-16	10.0	0.2
E-16	8.0	0.1
D-16	6.0	0.2
C-16	9.0	0.2
G-16	5.0	0.9
H-16	7.0	0.3
Total		**3.6**

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Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2014
Aquatic Plants: Onterra, 2016
Map Date: November 14, 2016
Filename: Map2_SilverF_EWM_June16.mxd


Project Location in Wisconsin

Legend

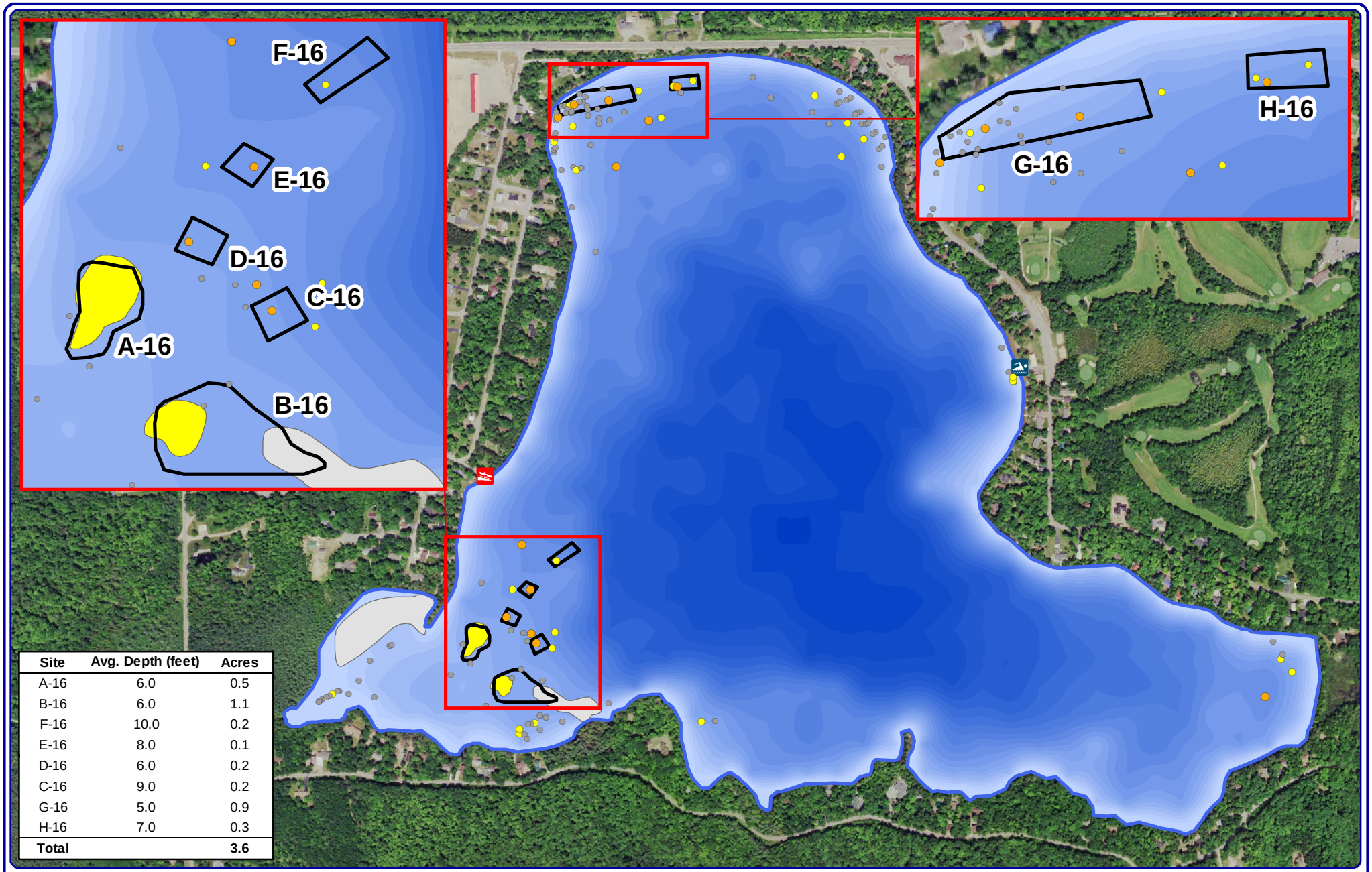
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2016 Hand-Removal Area
- Public Boat Landing
- Public Beach

Map 2

Silver Lake

Forest County, Wisconsin

June 2016 EWM Locations & 2016 Hand-Harvest Areas



Site	Avg. Depth (feet)	Acres
A-16	6.0	0.5
B-16	6.0	1.1
F-16	10.0	0.2
E-16	8.0	0.1
D-16	6.0	0.2
C-16	9.0	0.2
G-16	5.0	0.9
H-16	7.0	0.3
Total		**3.6**

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Feet

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Sources:
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Bathymetry: Onterra, 2014
Aquatic Plants: Onterra, 2016
Map Date: November 14, 2016
Filename: Map3_SilverF_EWM_Sept16.mxd


Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2016 Hand-Removal Area
- Public Boat Landing
- Public Beach

Map 3

Silver Lake

Forest County, Wisconsin

Sept. 2016 EWM Locations & 2016 Hand-Harvest Areas