Mount Morris Lake

Waushara County, Wisconsin

Final 2021-2023 Water Level Drawdown Report

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1.0 INTRODUCTION

Mount Morris Lake, Waushara County, is a lowland drainage lake with a maximum depth of 40 feet with five main basins. Mount Morris Lake has three tributary inlets and is drained by Rattlesnake Creek, which leads to Little Lake prior to merging with the Willow Creek (Figure 1.0-1 and Map 1).

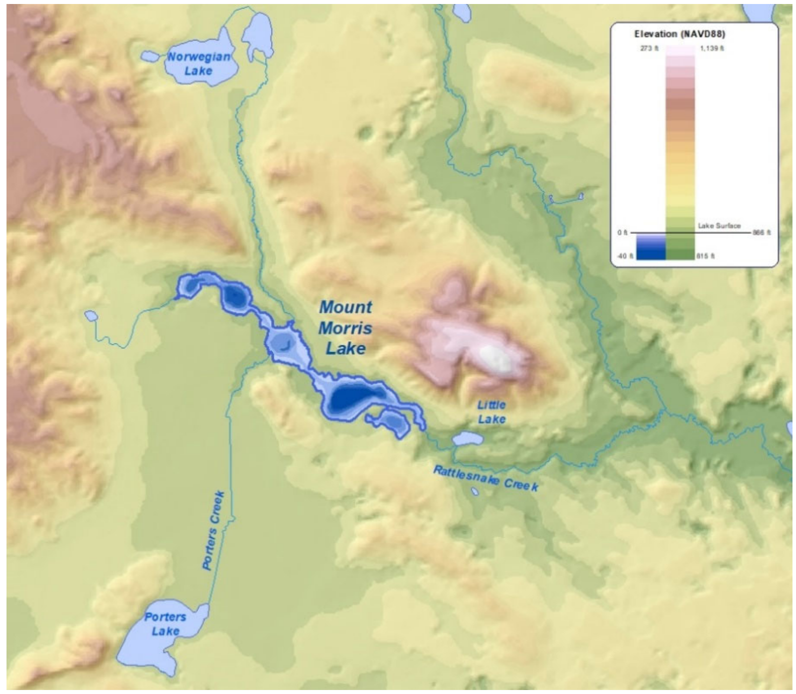


Figure 1.0-1. Mount Morris Lake, Waushara County.

The Mount Morris Lake Management District (MMLMD) is the local citizen-based organization leading the management of Mount Morris Lake (Map 1). The group has worked for years to protect and enhance the lake and has utilized Wisconsin Department of Natural Resources (WDNR) grant funds to conduct lake management planning activities and control invasive aquatic plant species (AIS).

Mount Morris Lake's water level is maintained by a dam at the outlet on the east side of the lake. The dam was first constructed in 1861, impounding waters to operate a grist mill. In the 1920s, the mill was modified to also generate electricity. The mill ceased operations in the early 1970s. The dam was reauthorized by the WDNR in 1977. In order to pass flows in excess of a 100-year storm event, per the Wisconsin Department of Transportation, the dam was modified in 1995. The State Highway 152 bridge and dam spillway were also upgraded in 1995. The dam is inspected annually, with the latest inspection occurring in June, 2021.

The dam is currently owned and operated by the MMLMD. The water levels are maintained within a 1-foot operating range (866.1 – 865ft) through two vertical slide gates. To provide for emergency repair, removal of debris from the flume, or for large water level changes, 12-inch notched stop logs can be individually removed.

1.1 Water level Management Planning Discussions

Mount Morris Lake has been able to manage curly-leaf pondweed (CLP) populations with strategic herbicide applications, but the flow of the system has not allowed sufficient herbicide concentrations and exposure times for Eurasian watermilfoil (EWM) control. It was later confirmed in 2011 through DNA analysis that the Mount Morris system also contained a hybrid (HWM) variety of EWM, which is a cross between EWM and the native, northern watermilfoil (*Myriophyllum sibiricum*). Emerging research is indicating that HWM may be more tolerant to herbicides than pure-strain EWM. The terms EWM and HWM may be used interchangeably throughout this report.

As outlined in the MMLMD's 2013 *Comprehensive Management Plan for Mount Morris Lake*, water level management can be used for AIS control and to rectify sedimentation. Extended drawdowns (winter-summer-winter) are the best technique to achieve increases in water depth through sediment compaction and consolidation. EWM/HWM and CLP have been shown to be negatively impacted by winter drawdowns when the system can be dewatered to a sufficient depth to desiccate (i.e. dry out) and freeze the plant.

In 2019, the MMLMD engaged Onterra to conduct a lake-wide bathymetric modeling study to give preliminary insight into drawdown scenarios and feasibility considering the dam operations. The additional studies were integral to investigating drawdown options more specifically related to Mount Morris Lake; particularly, can the lake feasibly be dewatered six feet (Map 2). In prior years, the majority of the EWM was located in 6 feet of water or less and therefore was thought to be a sufficient depth to impact the system-wide EWM population. The findings of the 2019 bathymetric survey indicate that Lake D is likely to achieve a full 6-foot drawdown. The upstream basins of Lake A-C will likely achieve at least a 4-foot drawdown. If sufficient flows exist to head-cut a channel between the upstream basins, they will also observe up to a 6-foot water level reduction. The Lake E to Lake D channel is only 2 feet deep, consequently dewatering of that basin will not exceed two feet. There is insufficient flow between Lake E and D to facilitate any channel cutting.

The MMLMD was awarded a WDNR AIS-Education, Prevention, and Planning Grant (AEPP-596-20) to assist with additional scoping components during 2020, which some of the surveys would serve as a pre-drawdown dataset if this management strategy is implemented. This included the collection of surface sediment cores from 18 locations around Mount Morris Lake during the summer of 2020 in an effort to understand the percent organic matter at these key locations within the lake (Map 3). The higher the organic content, the more depth would be gained if the sediments are oxidized during a summer drawdown. Said another way, if the organic content was low, a summer drawdown would not likely cause significant increase in depth from consolidation. Using the acoustic data collected during early-spring of 2019, a sediment hardness model was also created. The acoustic data collected in waters less than 2 feet deep can be problematic due to interference, but the data look fairly sound. While these data continue to be investigated, harder and sandy sediments are more prolific than soft and organic sediments. This suggests that some areas may not see large water level changes from decomposition. Based upon these data, in combination with district concerns about the loss of recreation during an extended drawdown, the MMLMD decided to only peruse a winter drawdown for AIS management at this time.

During a March 2, 2019 MMLMD meeting, Ted Johnson (WDNR lakes biologist) and Tim Hoyman (Onterra) educated attendees on the general pros and cons of water level management as it applies to Mount Morris Lake. A recorded presentation was constructed and placed on the MMLMD's website during 2020 with the intent of making decisions on water level management during the July 2020 annual meeting. Ultimately this vote was postponed due to Covid-19 and the timeline for when a drawdown would commence was pushed back a year.

The MMLMD held an advisory referendum vote by mail to determine support or opposition for a winter drawdown during spring 2021. All district members were sent a ballot by USPS to cast their vote, using the official County Tax role as the mail list. The ballot was returned by May 1, 2021. 70% of the returned ballots were in support of the 2021-2022 winter drawdown. The results of the referendum vote were discussed at the Regular Commissioners' meeting on May 8, 2021, and the data was used to compile a budget for presentation at the annual meeting. The MMLD confirmed, through vote at their July 2021 annual meeting, support for a winter drawdown during 2021/2022.

The MMLMD successfully applied for a WDNR Grant to monitor the impacts of the aquatic plants and water quality for two years following the drawdown (AEPP-651-22). The project would have two report deliverables, the first interim report following the *year of refill* (2022) and the final following the *year after refill* (2023). These reports were designed to be progressive, with the 2023 report building off of the contents of the 2022 interim report. This is the final report deliverable for AEPP-651-22.

Eddie Heath of Onterra presented the *year of refill* results at a MMLMD annual meeting one June 24, 2023. The meeting also included information about the use and risks of aquatic herbicides for EWM control, as well as the need for future lake management planning. The presentation handout is included as Appendix B.

1.2 Drawdown Implementation

The temporary winter drawdown was designed to start soon after Labor Day 2021, a high-use recreation weekend. The Mount Morris dam can be manipulated to reduce the water level by 6 feet at the dam by removing 12-inch stop logs. Upon removing each stop-log, it was anticipated to take a few days for the water level to go down by that increment, with a target of 4-6 inches of water level reduction per day. This slow change in water level allows reptiles (e.g. turtles) and amphibians (e.g. frogs, salamanders) a chance to migrate with the water level, as they would soon be burrowing into the muddy shoreline for winter hibernation.

The Mount Morris Lake drawdown started on September 15, 2021, removing the first stop log as described above. The lake was down the full six feet on September 27, 2021. The lake was approximately maintained down the full six feet for the duration of the winter. Some extended rains during spring of 2022 occurred, but the water level at the dam remained roughly constant.

The de-watered period was anticipated to end on roughly May 1, 2022 with the goal of increasing water levels at a pace of 4-6 inches per day. However, the refill process was slightly postponed to start on May 5. One reason for the delay was to allow more time for the new concrete pad at the Town of Mount Morris Landing to dry. Another reason was to allow more time for the reptiles and amphibians to emerge from winter dormancy. The cool spring may have delayed the timing of these activities, and concerns exist that these species would drown if the water level is elevated before they evacuate their hibernation burrows. The water level of the lake was brought back to full pool by May 17, 2022.

Both EWM and HWM have been shown to be impacted greatly by winter drawdowns when the system can be dewatered to a sufficient depth to desiccate (i.e. dry out) and freeze the EWM/HWM's root crown. In order to achieve sediment desiccation and freezing, the drawdown must be implemented during a cold and dry winter. If the exposed sediment is kept hydrated by deep snow, winter rains, or hydrologic springs; the impacts to EWM will likely not meet expectations. The Midwestern Regional Climate Center (MRCC) collects data from federal atmospheric observational sites which provides data to users in the public and private sector. Snowfall depth data collected from the MRCC from Labor Day 2021 to May 1, 2022 is displayed in Figure 3.0-1. The data show that there was zero or only a trace of snow on the ground for 69% of the days within this range.

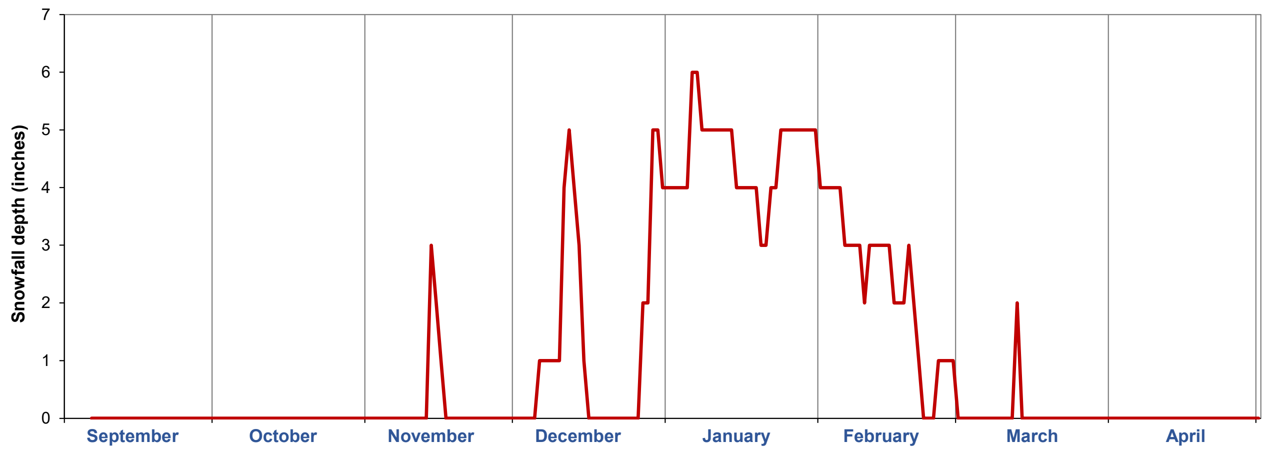


Figure 1.2-1. Snowfall depth collected during the winter drawdown period. Sept 1, 2021 to May 1, 2022.

In Mid-March, Onterra volunteered to collect photos and videos of the dewatered condition, some with the assistance of an aerial drone. The site visit confirms areas of exposed lakebed and channel cutting between basins (Photo 1.2-1). More videos and pictures were compiled into an approximately 4-minute YouTube video: https://youtu.be/kaheIT87g80

Photograph 1.2-1. Aerial photo of Mount Morris Lake during winter drawdown. Photo credit: Onterra, LLC March 16, 2022.

2.0 PRIMER ON AQUATIC PLANT DATA ANALYSIS & INTERPRETATION

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. 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 a 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.

Point-Intercept Survey

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) have been conducted on Mount Morris Lake in 2010, 2013, 2014, 2015, 2016, 2017, 2021, 2022 and 2023. The point-intercept survey spacing and total number of sampling points for Mount Morris Lake is 38 meters and 327 points, respectively. The point-intercept method has been conducted on Emerald Lake in 2010, 2014, 2021, 2022, and 2023. The point-intercept survey spacing and total number of sampling points for Emerald Lake is 38 meters and 32 points, respectively. At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance on the sampling rake was recorded.

Onterra visited the lake on June 22, 30, 2004 to conduct one of the first point-intercept surveys in Wisconsin using the survey methods as described in the Wisconsin Department of Natural Resource document, *Aquatic Plant Management in Wisconsin - Draft*, (April 25, 2005). This protocol was finalized and accepted as the WDNR standard point-intercept survey in 2010 (Hauxwell et al. 2010). Based upon advice from the WDNR at the time, approximately 98 points were evenly distributed for sampling on Mount Morris Lake. This survey was completed very similar to the current day methodologies, however, this distribution of points or meter-spacing between them was adjusted after the WDNR standard point-intercept survey was finalized in 2010. The 2010 survey and there after point intercept grid contains 327 points versus the 98 points in 2004. Due to these differing methodologies, the 2004 data was not used as a direct comparison to the 2010 - current data sets. While methodologies were slightly different, it can be inferred that the aquatic plant community at the time consisted of high biomass as well as curly-leaf pondweed presence at low densities throughout most areas of the lake.

A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 15 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 15 feet. Depth information was collected using graduated marks on the pole of the rake (at depths < 15 ft) or using an onboard sonar unit (at depths > 15 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. At each point that is sampled the surveyor records a total rake fullness (TRF) value ranging from 0-3 as a somewhat subjective indication of plant biomass. 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.

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys on Mount Morris Lake and Emerald Lake. The list also contains each species' scientific name, common name, status in Wisconsin, and 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 aquatic plant species is found within a lake from the point-intercept survey. 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 surveys that have been completed; 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. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism* from the point-intercept survey data of a given year. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

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 surveys (equation shown below). This assessment allows the aquatic plant community of the Mount Morris Lake to be compared to other lakes within the region and state.

Mount Morris Lake falls within the North Central Hardwood Forests (NCHF) *ecoregion* (Figure 2.0-1), 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 within the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Ecoregional and state-wide medians were calculated from whole-lake point-intercept surveys conducted on 392 lakes throughout Wisconsin by Onterra and WDNR ecologists.

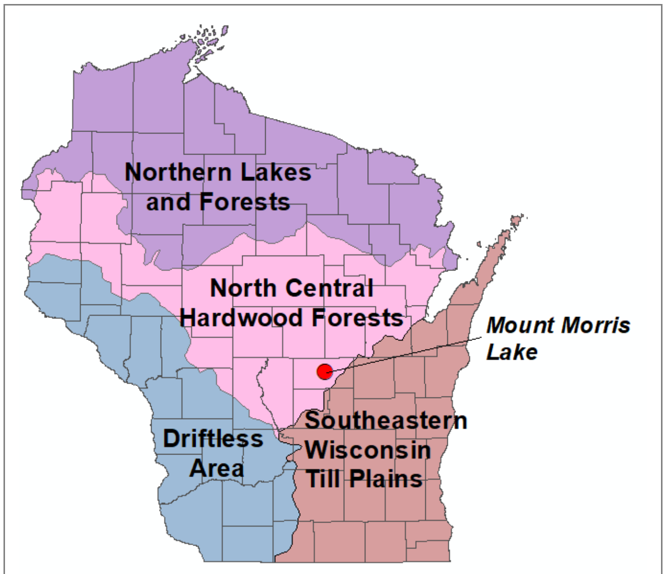


Figure 2.0-1. Location of Mount Morris Lake within the ecoregions of Wisconsin. After (Nichols 1999).

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is 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. Some managers believe a lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan et al. 2018).

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. The Simpson's Diversity Index value from the Mount Morris Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forests (lakes only, does not include flowages) Ecoregion and on 392 lakes throughout Wisconsin.

2.1 Mount Morris Lake Aquatic Plant Monitoring

Aquatic plants are the base of the lake ecosystem; therefore, a complete assessment of the community is vital when considering any management strategy. Aquatic plant surveys occurred during the *year before drawdown* (2021), *year of refill* (2022), and *year after refill* (2023) A full matrix of aquatic plant frequencies can be found in Appendix A.

Table 2.1-1. Aquatic plant species located on Mount Morris Lake.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2004	2010	2013	2014	2015	2016	2017	2021	2022	2023
Emergent	*Bolboschoenus fluviatilis*	River bulrush	Native	5		I								
	Calla palustris	Water arum	Native	9	I	I						I		
	Carex comosa	Bristly sedge	Native	5		I						I	I	I
	Carex hystericina	Porcupine sedge	Native	3									I	
	Carex stricta	Common tussock sedge	Native	7	I									
	Decodon verticillatus	Water-willow	Native	7								I	I	
	Eleocharis erythropoda	Bald spikerush	Native	3	X	X								
	Eleocharis palustris	Creeping spikerush	Native	6									I	
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A		I						I	I	I
	Iris spp. (sterile)	Iris spp. (sterile)	Unknown (Sterile)	N/A								I		
	Iris versicolor	Northern blue flag	Native	5	I							I	I	I
	Iris virginica	Southern blue flag	Native	5		I								
	Juncus effusus	Soft rush	Native	4		I						I	I	
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	I	I						I	I	
	Phalaris arundinacea	Reed canary grass	Non-Native - Invasive	N/A	I	I								
	Pontederia cordata	Pickerelweed	Native	9	I	I			X	X		I	I	
	Sagittaria latifolia	Common arrowhead	Native	3	I	I						I	I	
	Schoenoplectus acutus	Hardstem bulrush	Native	5	X	X		X	X	X		I	I	
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4		I						I	I	
	Sparganium eurycarpum	Common bur-reed	Native	5		I			X	X				
	Typha latifolia	Broad-leaved cattail	Native	1								I	I	
	Typha spp.	Cattail spp.	Unknown (Sterile)	N/A		I						I		
FL	*Nuphar variegata*	Spatterdock	Native	6	X	X	X	X	X	X	X	X	X	X
	Nuphar X rubrodisca	Intermediate pondlily	Native	9				I						
	Nymphaea odorata	White water lily	Native	6	X	X	X	X	X	X		X	X	X
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9								I		
Submergent	*Ceratophyllum demersum*	Coontail	Native	3	X	X	X	X	X	X	X	X	X	X
	Chara & Nitella spp.	Charophytes	Native	7	X	X	X	X	X	X	X	X	X	X
	Chara spp.	Muskgrasses	Native	7	X	X	X	X	X	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X		X	X	X	X	X	X	X
	Elodea canadensis & E. nuttallii	Common & Slender waterweeds	Native	N/A	X	X		X	X	X	X	X	X	X
	Elodea nuttallii	Slender waterweed	Native	7								X		
	Heteranthera dubia	Water stargrass	Native	6	X	X	X	X	X			X	X	X
	Lychnothamnus barbatus	Bearded stonewort	Native	7						X	X		X	
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X	X	X	X	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X	X	X	X	X	X	X	X
	Myriophyllum verticillatum	Whorled watermilfoil	Native	8	X	X	X	X	X	X				
	Najas flexilis	Slender naiad	Native	6	X	X		X			X	X	X	X
	Najas guadalupensis	Southern naiad	Native	7			X	X	X	X	X	X	X	X
	Najas guadalupensis & N. flexilis	Southern naiad & Slender naiad	Native	N/A	X	X	X	X	X	X	X	X	X	X
	Nitella spp.	Stoneworts	Native	7	X	X		X	X	X	X	X	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7									X	X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X	X	X				X	X	X	X
	Potamogeton foliosus	Leafy pondweed	Native	6										X
	Potamogeton friesii	Fries' pondweed	Native	8			X	X	X			X		X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7				X	X	X	X	X	X	X
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	X						X		X
	Potamogeton praelongus	White-stem pondweed	Native	8	X	X		X	X	X		X	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X	X	X	X	X	X	X	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8									X	
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6								X	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8				X		X	X	X	X	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A										X
	Stuckenia pectinata	Sago pondweed	Native	3	X	X	X	X	X	X	X	X	X	X
	Utricularia vulgaris	Common bladderwort	Native	7	X	X	X	X	X	X	X	X	X	
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X	X	X	X	X	X
	Zannichellia palustris	Horned pondweed	Native	7		I								X
S/E	*Eleocharis acicularis*	Needle spikerush	Native	5			X			X		X		
	Sagittaria cuneata	Arum-leaved arrowhead	Native	7		I						X		I
FF	*Lemna minor*	Lesser duckweed	Native	5					X	X	X			X
	Lemna trisulca	Forked duckweed	Native	6	X	X	X	X	X	X		X	X	X
	Lemna turionifera	Turion duckweed	Native	2	X	X	X	X				X		X
	Spirodela polyrhiza	Greater duckweed	Native	5	X	X	X	X	X			X	X	X
	Wolffia spp.	Watermeal spp.	Native	N/A				X	X	X		X		X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; F/L = Floating-leaf & Emergent; S/E = Submergent and/or Emergent; FF = Free-floating

Four aquatic plant species encountered are considered to be non-native, invasive species: Eurasian watermilfoil, curly-leaf pondweed, pale-yellow iris, and purple loosestrife. From all ten point-intercept surveys and four community mapping surveys, the total number of aquatic plant species located in and along the margins of Mount Morris Lake is approximately 65.

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

Comparing pre and post drawdown acoustic surveys aimed to shed light on where channel cutting occurred, sedimentation was scoured or deposited, and if overall water depth was increased in any area. However, the limitations of this methodology would require changes to be at least 6 inches to a foot to discern differences. While sediments may become dehydrated and channel cutting may occur during winter water level drawdowns, the decomposition of organic sediments does not occur to a significant extent with this type of water level management. As a result, winter water level drawdowns do not typically facilitate significant increases in water depth but will be investigated in the subsequent discussion.

Acoustic surveys were conducted on May 7, 2019 and May 25, 2022. These surveys were completed early in the season to help in avoiding issues with dense vegetation interfering with bathymetric outputs. The comparison of results between these surveys can be viewed in Map 4. Overall, very little increase in depth was observed in Mount Morris Lake as a result of the 2021/22 drawdown. It is likely that a little more channel cutting was observed than this model reports.

The maximum depth of aquatic plants found from the point-intercept surveys has varied from 16 feet (2010) to as deep as 21 feet (2023). In recent years the maximum depth has increased (Figure 2.1-1). Changes in Mount Morris Lake's water clarity around are believed to be the driving factor influencing the maximum depth of plant growth. Zebra mussels were verified within the lake in 2014 and may be a contributing factor in water clarity. This is discussed further in the subsequent *3.0 Water Quality Summary* section.

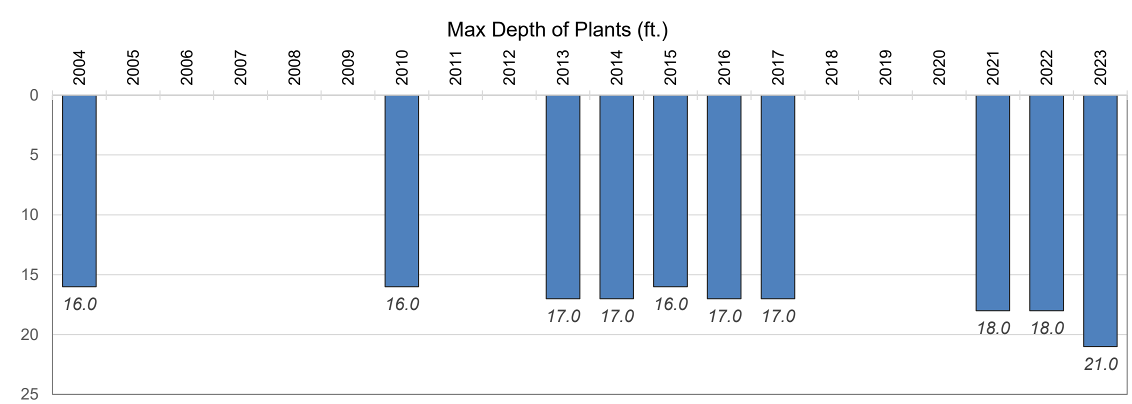


Figure 2.1-1. Maximum depth of plants from point-intercept surveys in Mount Morris Lake.

Figure 2.1-2 investigates the depths at which vegetation, and specifically EWM, are growing at in Mount Morris Lake based upon the point-intercept survey. Plants growing in 6 feet of less would be anticipated to be impacted by the drawdown, whereas plants growing out deeper would not. During 2021 before the winter drawdown, more than half of all the EWM was growing in waters under 6 feet. During the year of refill (2022), slightly more than half the EWM was growing in waters greater than 6 feet. EWM recolonized back in waters less than 6 feet deep during the *year after refill* (2023).

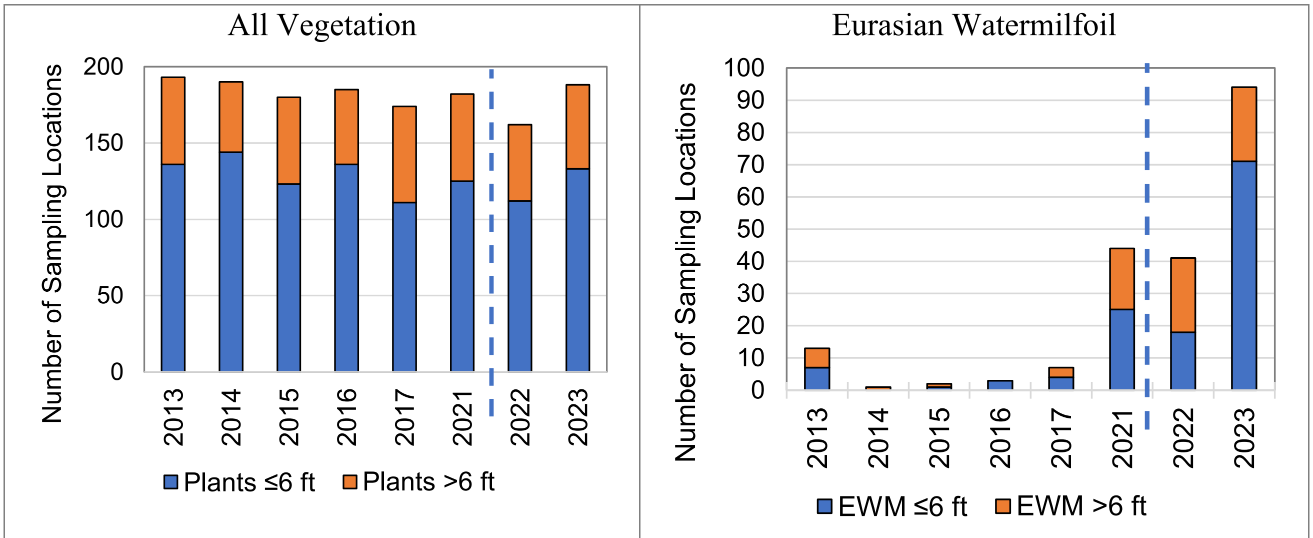


Figure 2.1-2. Vegetation growing in waters 6 feet and less vs greater than 6 feet.

Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 214 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (i.e. littoral zone) in Mount Morris Lake in 2023, approximately 87% contained aquatic vegetation. The total rake fullness (TRF) data indicates that where aquatic plants are present in Mount Morris Lake, they are at a moderate to high abundance. Total rake fullness levels have historically been very similar with a high abundance of plant biomass (Figure 2.1-3).

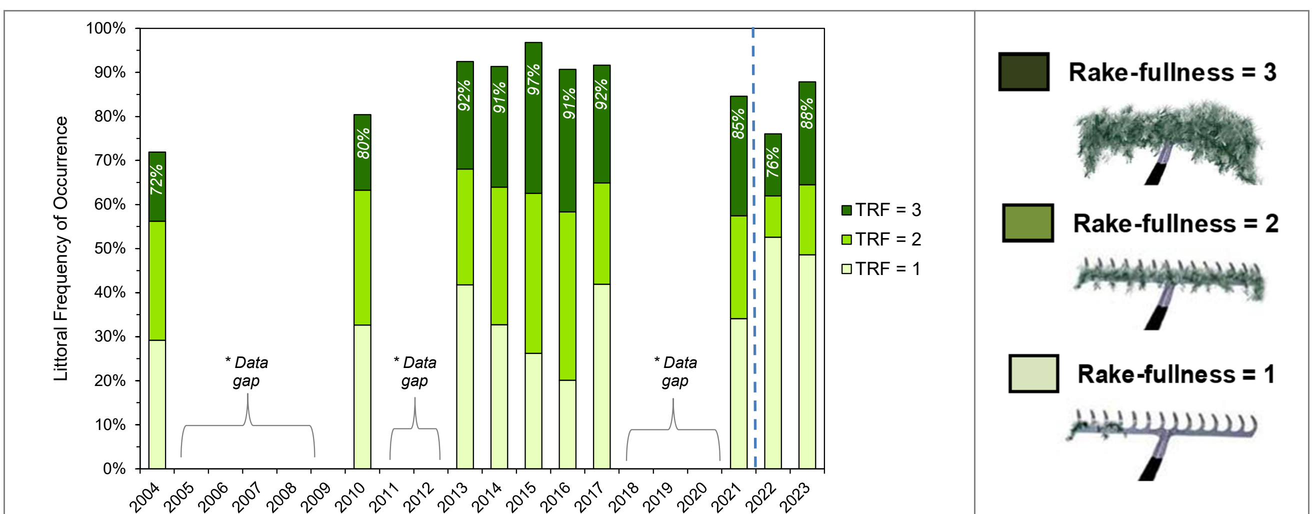


Figure 2.1-3. Mount Morris Lake aquatic vegetation total rake fullness ratings. The dashed blue line signifies the winter 2021-22 drawdown event.

Figure 2.1-4 shows the littoral frequency of occurrence (LFOO) of aquatic plants from the 2021 (Pre-drawdown), 2022 (post-drawdown), and 2023 (a *year after refill*) point-intercept surveys. Of the 12 species investigated on this figure, four had statistically valid increases following the drawdown and one had a statistically valid reduction. Charophytes, wild celery, and common and slender waterweeds were the most frequent native aquatic plant species on average found in Mount Morris Lake in 2021, 2022, and 2023 (Photograph 2.1-1).

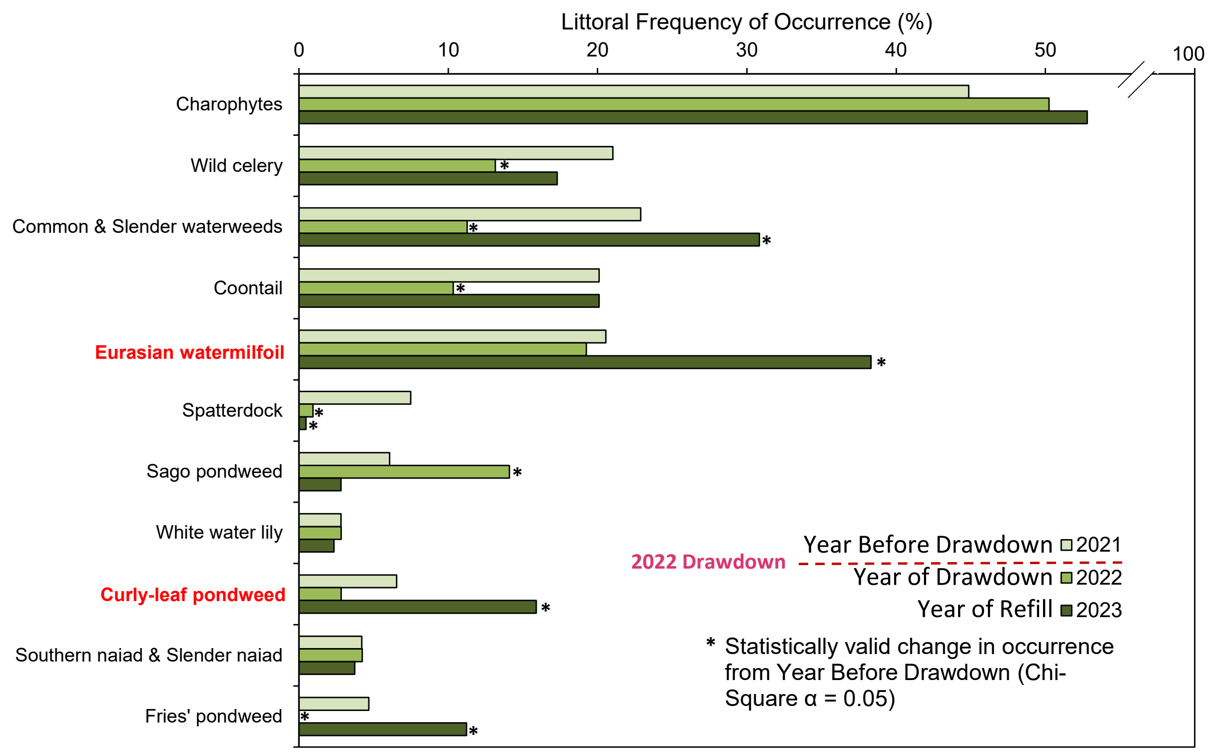
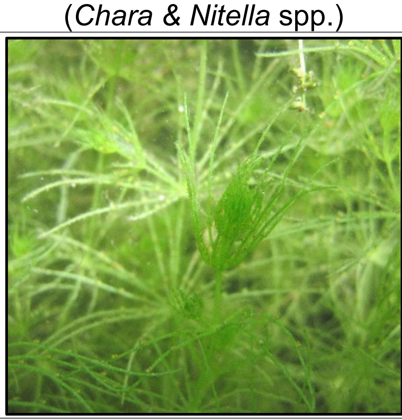
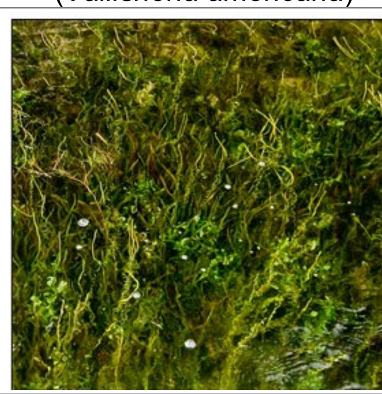
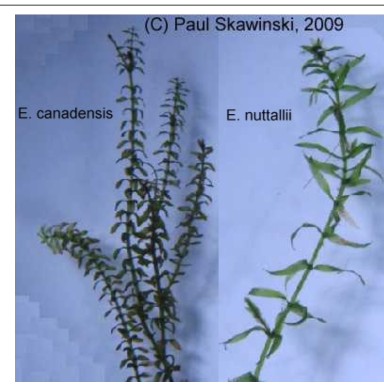


Figure 2.1-4. Mount Morris Lake 2021, 2022, and 2023 LFOO. LFOO = littoral frequency of occurrence of plants with an occurrence of 4% or more. Asterisk symbols (*) represent a statistically valid change from 2022 to 2023.

Charophytes (*Chara & Nitella* spp.)	Wild celery (*Vallisneria americana*)	Common and Slender waterweeds (Elodea canadensis & E. nuttallii)
		

Photograph 2.1-1. Three-most frequently encountered aquatic plants in Mount Morris Lake in 2023. Photo credit Onterra.

In the field, it is often difficult to distinguish between certain species of aquatic plants that are very similar morphologically, especially when flowering/fruiting material is not present. Because of this, the littoral occurrences of the following morphologically-similar species were combined for this analysis: muskgrasses (*Chara* spp.) and stoneworts (*Nitella* spp.), slender naiad (*Najas flexilis*) and southern naiad (*N. guadalupensis*), common waterweed (*Elodea canadensis*) and slender waterweed (*E. nuttallii*), as well as small pondweed (*Potamogeton pusillus*) and slender pondweed (*P. berchtoldii*).

Charophytes were the most frequently encountered aquatic plant species in the 2023 point-intercept survey with an occurrence of 52.8% (Figure 2.1-5). Muskgrasses, a genus of macroalgae, are not true vascular plants, and are often abundant in waterbodies that are clear with higher alkalinity. Often growing in dense beds, muskgrasses stabilize bottom sediments, provide excellent structural habitat for aquatic organisms, and are sources of food for fish, waterfowl, and other wildlife (Borman et al. 2007). *Nitella* species, or stoneworts as they may be called, are actually a type of macro-algae rather than a vascular plant. Whorls of forked branches are attached to the "stems" of the plant, which are long, slender, smooth-textured algae. Because they lack roots, stoneworts remove nutrients directly from the water. In Mount Morris Lake, charophytes were prevalent between 1 and 21 feet of water. The occurrence of charophytes has been variable over time with statistically valid changes in occurrence in 2010 and 2021 (Figure 2.1-5). Recent surveys, charophytes has been stable at about 45-50% between 2021 and 2023.

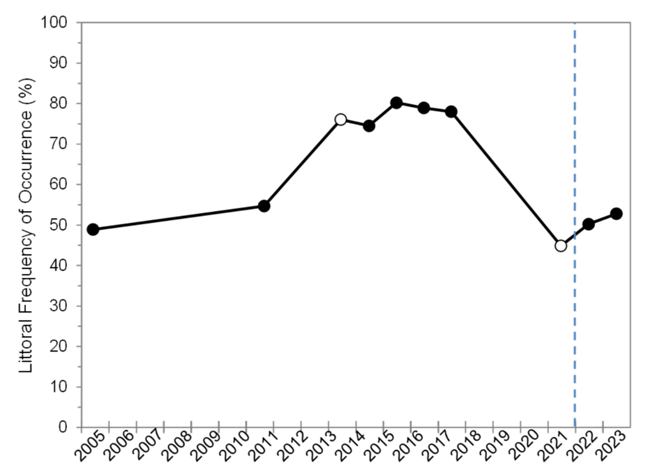


Figure 2.1-5. Charophytes LFOO in Mount Morris Lake from 2010-2023. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05).

Common and slender waterweeds were the third most frequently encountered native aquatic plant species in Mount Morris Lake in 2023 with a littoral frequency of occurrence of 30.8% (Figure 2.1-7). Common waterweed can be found in waterbodies across Wisconsin, is tolerant of high-nutrient, low-light conditions, and can grow to nuisance levels under ideal conditions. Common waterweed has blade-like leaves in whorls of three produced on long, slender stems. Like other submersed aquatic plants, common waterweed helps to stabilize bottom sediments and provides structural habitat and food for wildlife. In 2023, common waterweed was abundant throughout most

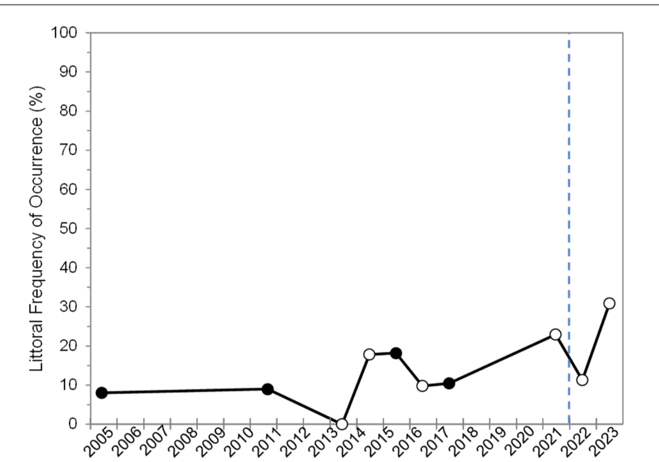


Figure 2.1-7. Waterweeds LFOO in Mount Morris Lake from 2010-2023. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05).

littoral areas of Mount Morris Lake, being found at depths ranging from 1 and 12 feet of water.

Coontail was one of the most common species in the 2021-2023 surveys with occurrences as high as 20.1% (2023). Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives most of its nutrients directly from the water (Gross, Erhard and Ivanyi 2003). The occurrence of coontail exhibited statistically valid decreases after the 2021-22 drawdown event. The occurrence of coontail at 20.1% in 2023 returned the population of coontail to pre-drawdown occurrences. In 2023, coontail was found at depths ranging from 1 and 17 feet of water.

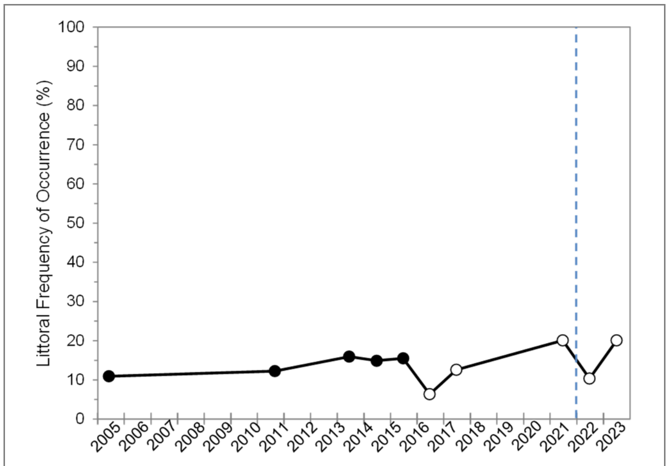


Figure 2.1-6. Coontail LFOO in Mount Morris Lake from 2010-2023. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05).

Figure 2.1-8 investigates the littoral frequency of occurrence of several other native aquatic plant species that have been commonly encountered in point-intercept surveys in Mount Morris Lake.

Wild celery was a frequently found species in Mount Morris Lake in 2023 with a littoral frequency of occurrence of 17.3% (Figure 2.1-8). Wild celery produces long, ribbon-like leaves which emerge from a basal rosette, and it prefers to grow over harder substrates and is tolerant of low-light conditions. Its long leaves provide valuable structural habitat for the aquatic community while its network of roots and rhizomes help to stabilize bottom sediments. In mid- to late-summer, wild celery often produces abundant fruit which are important food sources for wildlife including migratory waterfowl. Animals may eat the entire plant, including the tubers that reside within the sediment.

Fries' pondweed populations were the highest on record in 2023 with a littoral frequency of occurrence of 11.2% (Figure 2.1-8). A common species in calcareous waters (hard water), Fries' pondweed is one of Wisconsin's several narrow-leaved pondweed species. Fries' pondweed plays a large role in aquatic ecosystems by providing structural habitat and sources of food to invertebrates, fish, and other wildlife. Often growing in deeper water, this species likely supplies oxygen to the deeper, colder layer of water that is sealed off from atmospheric oxygen during the summer.

Sago pondweed was another common plant found in Mount Morris Lake. It is highly tolerant of low-light conditions, and is often the last rooted plant able to survive in waterbodies with extremely turbid water (Borman, Korth and Temte 1997). To survive in these conditions, it produces numerous needle-like leaves that spread out near or at the water's surface in a fan-shape to gather light. Sago pondweed has been found to be one of the most valuable food resources for waterfowl, producing numerous seeds and tubers. As a disturbance-tolerant species, sago pondweed populations peaked during the *year after refill* (2022) ad declined in 2023 as the lake has had more time to stabilize following the drawdown.

White water crowfoot is a native aquatic plant with finely-dissected leaves that arrange in a fan shape and alternate along the stem. This plant grows in lakes or slow-moving shallow water, with white flowers being noticeable in approximately June. This plant is poisonous to most animals when ingested and can cause irritation if it comes in contact with bare skin (Simpson 2024). White water crowfoot populations have been extremely stable over time.

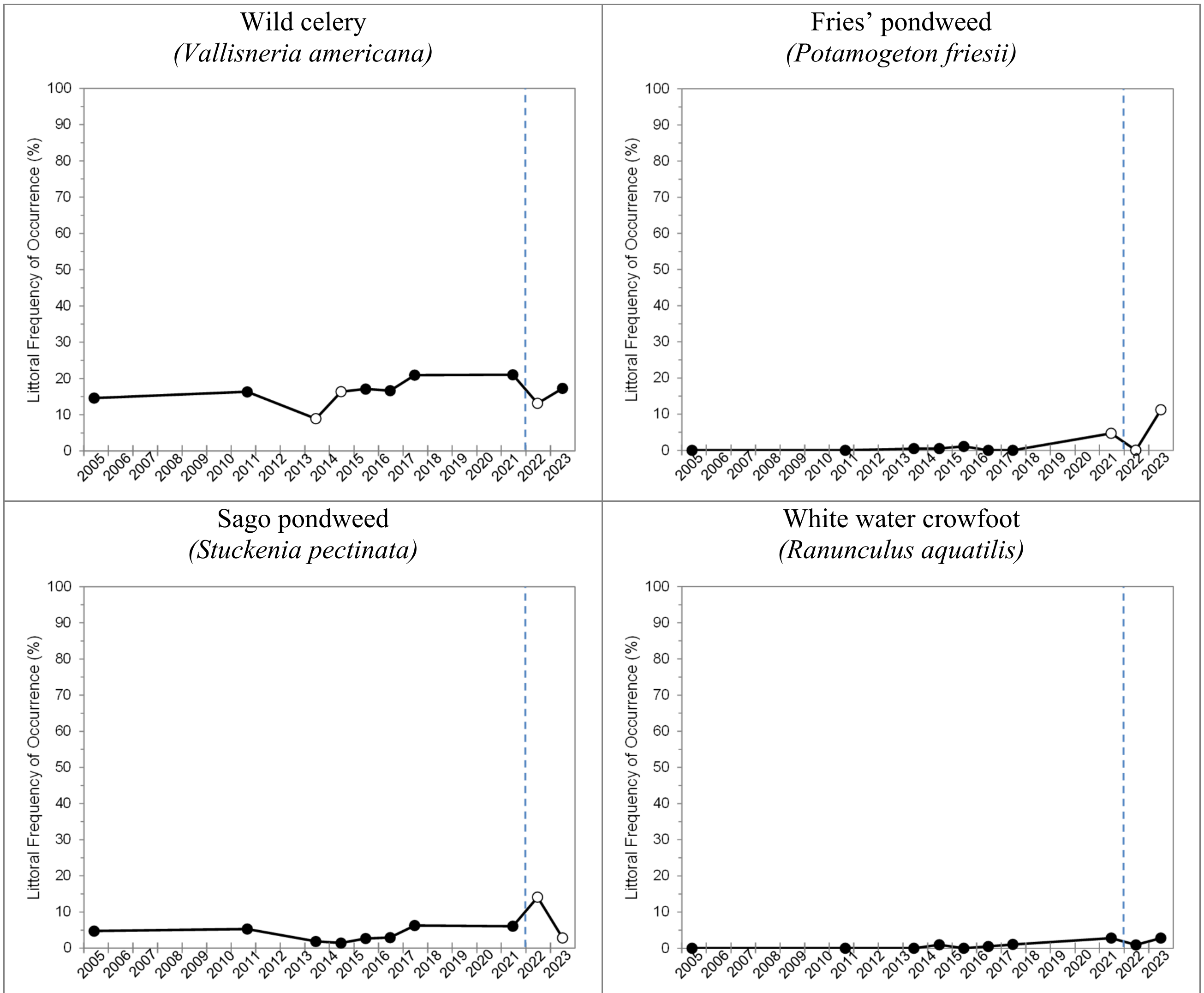


Figure 2.1-8. Common species LFOO in Mount Morris Lake. Open circle represents statistically valid change in occurrence from previous survey (Chi-Square α = 0.05). The dashed blue line signifies a lake wide drawdown event.

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 example, while charophytes were found at about 53 % of the littoral sampling locations in Mount Morris Lake in 2022, its relative frequency of occurrence is approximately 17% (Figure 2.1-10). Explained another way, if 100 plants were randomly sampled from Mount Morris Lake, 17 of them would be charophytes. Figure 2.1-10 displays the relative frequency of occurrence of aquatic plant species from each of the point-intercept surveys in Mount Morris Lake.

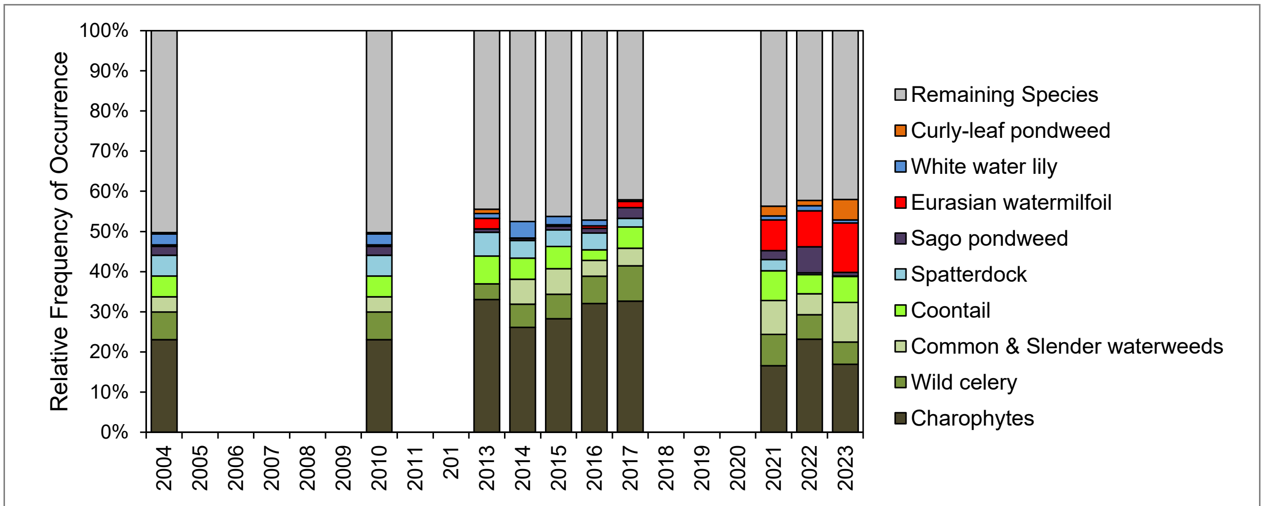


Figure 2.1-10. Relative frequency of occurrence of aquatic plants in Mount Morris Lake.

The native aquatic plant species located on the rake during the point-intercept surveys from 2010-2023 and their conservatism values were used to calculate the Floristic Quality Index (FQI) for each year (Figure 2.1-11). Native species richness, or the number of native plant species recorded on the rake has varied over time in Mount Morris Lake with the lowest values in 2017 (16) and 2013 (18) (Figure 2.1-11). In most years, the species richness has been above the ecoregion and state median values. For instance, in 2023, species richness has been at its highest ever recorded, at a value of 29. Which is well above the ecoregion (15) and state (19) median values.

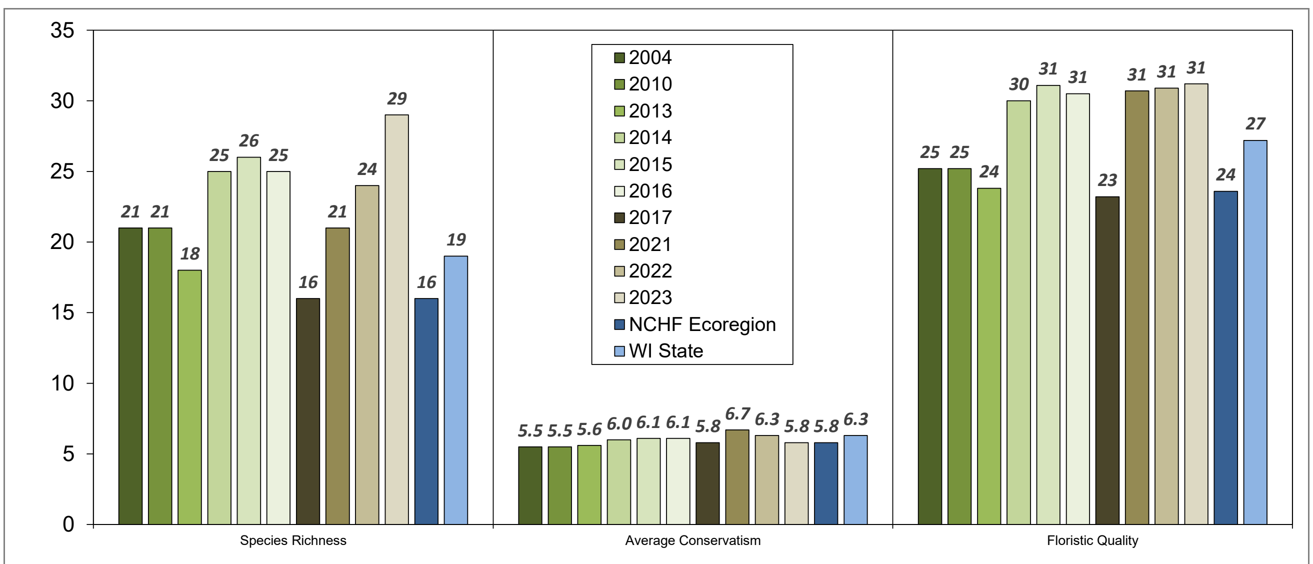


Figure 2.1-11. Native aquatic plant species richness, average conservationism, and floristic quality.

Average conservatism values have been consistently between 5.5-6.7 in surveys conducted between the monitoring years. In 2023, the value was 5.8, which is the same as the median ecoregion value and slightly below the median value for Wisconsin state.

The 2023 floristic quality value is also well above state and ecoregion median. FQI is calculated from values associated with the species richness and average conservatism which were both fairly high in

2023 compared to past surveys; therefore, the FQI value of 31.2 in 2023 which is the highest value recorded in Mount Morris Lake and is well above the state and ecoregion median values.

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 Mount Morris Lake's diversity values rank. Using data collected by Onterra, quartiles were calculated for lakes within the NLFL Ecoregion (Figure 2.1-12). Using the data collected from the whole-lake point-intercept surveys, Mount Morris Lake's aquatic plant species diversity has varied over time. In 2023, Simpson's diversity was the second highest it's ever been recorded at 0.88.

Figure 2.1-13 investigates the average number of native plant species at each littoral point-intercept sampling location. These data show closely follows the same trend as the Simpson's Diversity Index. The 2023 survey indicated 1.70 native species per littoral sampling site. This is near the average value recorded since monitoring began in 2010.

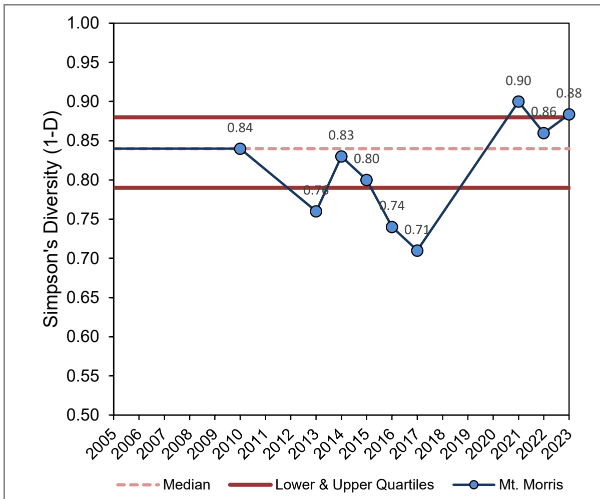


Figure 2.1-12. Mount Morris Lake Simpson's Diversity Index. The dashed blue line indicates a lake wide drawdown event.

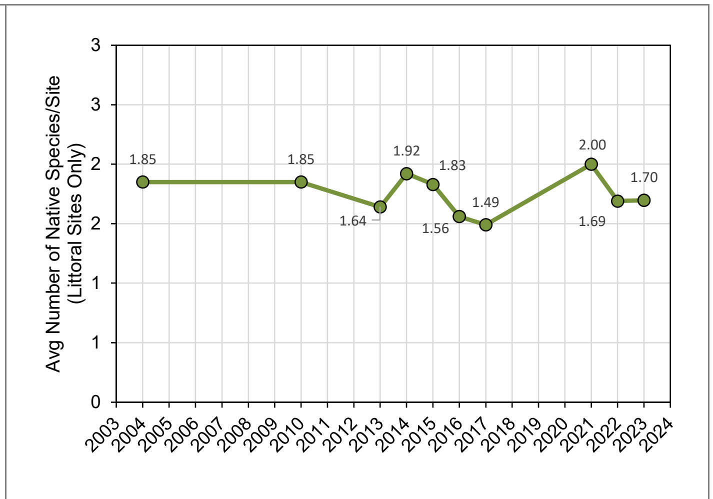


Figure 2.1-13. Average number of native aquatic plant species per littoral sampling site. The dashed blue line indicates a lake wide drawdown event.

In 2022, Onterra ecologists conducted a survey aimed at re-mapping emergent and floating-leaved plant communities in Mount Morris Lake (post-drawdown) to be compared with the 2021 data (pre-drawdown). In 2021, approximately 21.5 acres of emergent and floating-leaf aquatic plant communities were delineated in Mount Morris Lake compared to 8.7 in 2022 (Figure 2.1-14). This decline in acreage of approximately 13.1 appears to have primarily effected communities that were dominated by spatterdock (*Nuphar variegata*) and white-water lily (*Nymphaea odorata*), both being floating-leaf species. Examination of the 2021 and 2022 data together shows that many of the emergent and floating- leaf communities retracted shoreward between the two surveys (Figure 2.1-14 and Map 8).

Emergent and floating-leaf plant communities often recede or expand in response to changes in water levels. As water levels rise, these communities retract as water at their lakeward extent becomes too deep. In contrast, these communities often expand during periods of lower water levels. The 2021/22 winter drawdown appears to have had a large negative impact on the floating-leaf and emergent communities on Mount Morris Lake. While the 2022 data showed a large decrease in these communities, it is expected in the coming years for these plant species to rebound to their previously mapped locations in 2021.

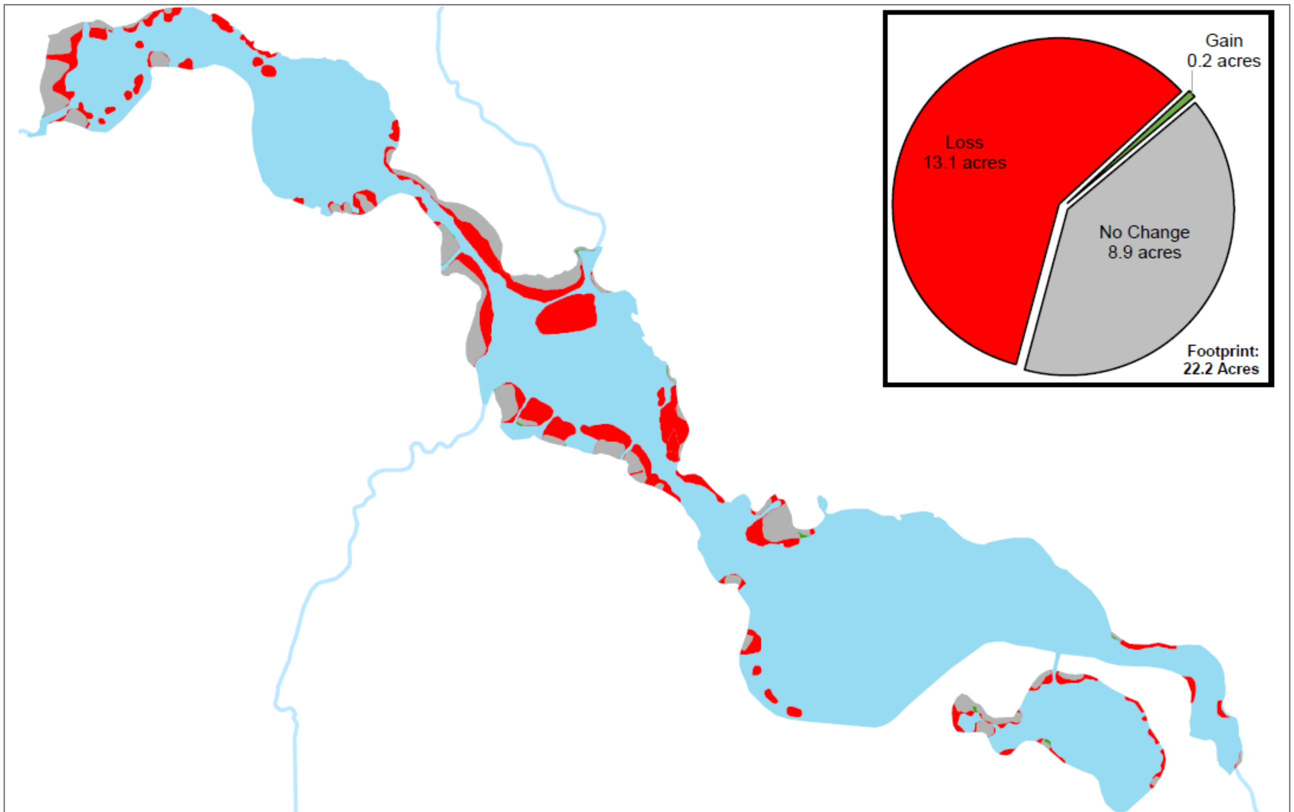


Figure 2.1-14. Mount Morris Lake community mapping 2021 and 2022 compare.

2.2 Emerald Lake Aquatic Plant Monitoring

While many property owners and lake users refer the entire system as Mount Morris Lakes, the WDNR considers Mount Morris Lake as the four main basins, and Emerald Lake as a sperate lake. Therefore, the point-intercept survey data are presented in this manner.

During the winter 2021/2022 drawdown, Emerald Lake received a 2-foot decline in water depth. Preliminary drawdown modeling indicated, it was not expected for Emerald Lake to have much, if any, aquatic plant impacts because of the inability for the lake to be lowered by more than 2 feet. Aquatic plant surveys occurred during the *year before drawdown* (2021), *year of refill* (2022), and *year after refill* (2023). A full matrix of aquatic plant frequencies can be found in Appendix A.

Two aquatic plant species encountered are considered to be non-native, invasive species: Eurasian watermilfoil and curly-leaf pondweed. From all five point-intercept surveys and four community mapping surveys, the total number of aquatic plant species located in and along the margins of Emerald Lake is 34.

Table 2.2-1. Aquatic plant species located on Emerald Lake.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010	2014	2021	2022	2023
Emergent	*Eleocharis palustris*	Creeping spikerush	Native	6				I	
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A			I		
	Iris spp. (sterile)	Iris spp. (sterile)	Unknown (Sterile)	N/A			I	I	
	Iris versicolor	Northern blue flag	Native	5				I	
	Typha latifolia	Broad-leaved cattail	Native	1				I	
FL	*Nuphar variegata*	Spatterdock	Native	6	X	X			
	Nymphaea odorata	White water lily	Native	6	X	X	X	X	
Submergent	*Ceratophyllum demersum*	Coontail	Native	3				X	
	Chara & Nitella spp.	Charophytes	Native	7	X	X	X	X	X
	Chara spp.	Muskgrasses	Native	7	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3			X	X	X
	Elodea canadensis & E. nuttallii	Common & Slender waterweeds	Native	N/A			X	X	X
	Elodea nuttallii	Slender waterweed	Native	7			X		
	Heteranthera dubia	Water stargrass	Native	6			X		X
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A			X	X	X
	Najas flexilis	Slender naiad	Native	6	X	X	X	X	X
	Najas guadalupensis	Southern naiad	Native	7		X	X	X	X
	Najas guadalupensis & N. flexilis	Southern naiad & Slender naiad	Native	N/A	X	X	X	X	X
	Nitella spp.	Stoneworts	Native	7			X		X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A			X	X	X
	Potamogeton foliosus	Leafy pondweed	Native	6					X
	Potamogeton friesii	Fries' pondweed	Native	8			X		X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7		X	X		
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	X	X		X
	Potamogeton praelongus	White-stem pondweed	Native	8					X
	Potamogeton pusillus	Small pondweed	Native	7					X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X			X	X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6			X	X	
	Stuckenia pectinata	Sago pondweed	Native	3			X	X	
	Utricularia vulgaris	Common bladderwort	Native	7	X				
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X
FF	*Lemna trisulca*	Forked duckweed	Native	6			X		
	Spirodela polyrhiza	Greater duckweed	Native	5			X		

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; F/L = Floating-leaf & Emergent; S/E = Submergent and/or Emergent; FF = Free-floating

During the 2023 point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicates that 100% of the point-intercept locations contained soft organic sediments, and 0% contained rock or sand. The soft organic sediment throughout the majority of Emerald Lake is very conducive for supporting lush aquatic plant growth.

The maximum depth of aquatic plants found from the point-intercept surveys has varied from 15 feet (2010/2021) to 17 feet (2022/2023) . Plants in 2022 and 2023 were found growing throughout the entirety of the lake so for each point intercept survey every point was sampled and no areas were recorded as too deep for plant growth.

Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 32 point-intercept sampling locations that were sampled in Emerald Lake in 2023, approximately 97% contained aquatic vegetation. This level of vegetation is the highest since surveys began.

Aquatic plant rake fullness data collected in 2023 indicates that 31% of the 32 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 44% had a TRF rating of 2, 22% had a TRF rating of 3, and 3% had no vegetation. The TRF data indicates that where aquatic plants are present in Emerald Lake, they are at a moderate to high abundance. Total rake fullness levels up have historically been fairly similar with a high abundance of plant biomass in most years (Figure 2.2-1).

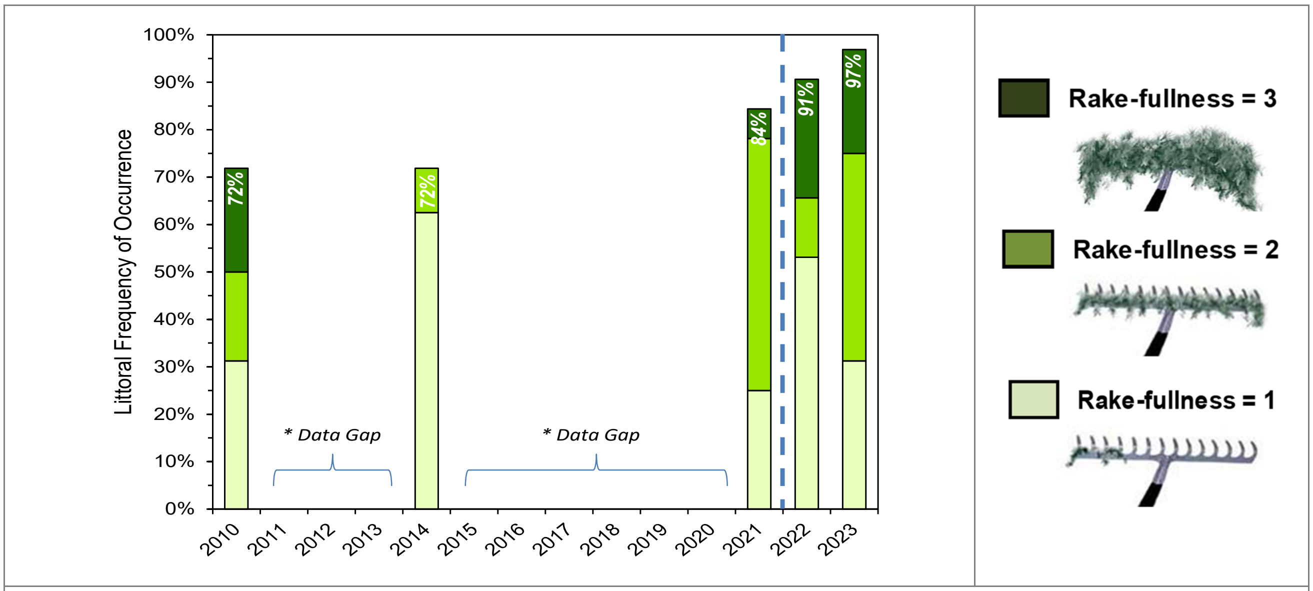


Figure 2.2-1. Emerald Lake aquatic vegetation total rake fullness ratings. The dashed blue line signifies the winter 2021-22 drawdown event.

Figure 2.2-2 shows the littoral frequency of occurrence (LFOO) of aquatic plants from the 2021 (Pre-drawdown), 2022 (*year after refill*) point-intercept surveys, and 2023 (*year after refill*). In the field, it is often difficult to distinguish between certain species of aquatic plants that are very similar morphologically, especially when flowering/fruiting material is not present. Because of this, the littoral occurrences of the following morphologically-similar species were combined for this analysis: muskgrasses (*Chara* spp.) and stoneworts (*Nitella* spp.), slender naiad (*Najas flexilis*) and southern naiad (*N. guadalupensis*), as well as common waterweed (*Elodea canadensis*) and slender waterweed (*E. nuttalii*).

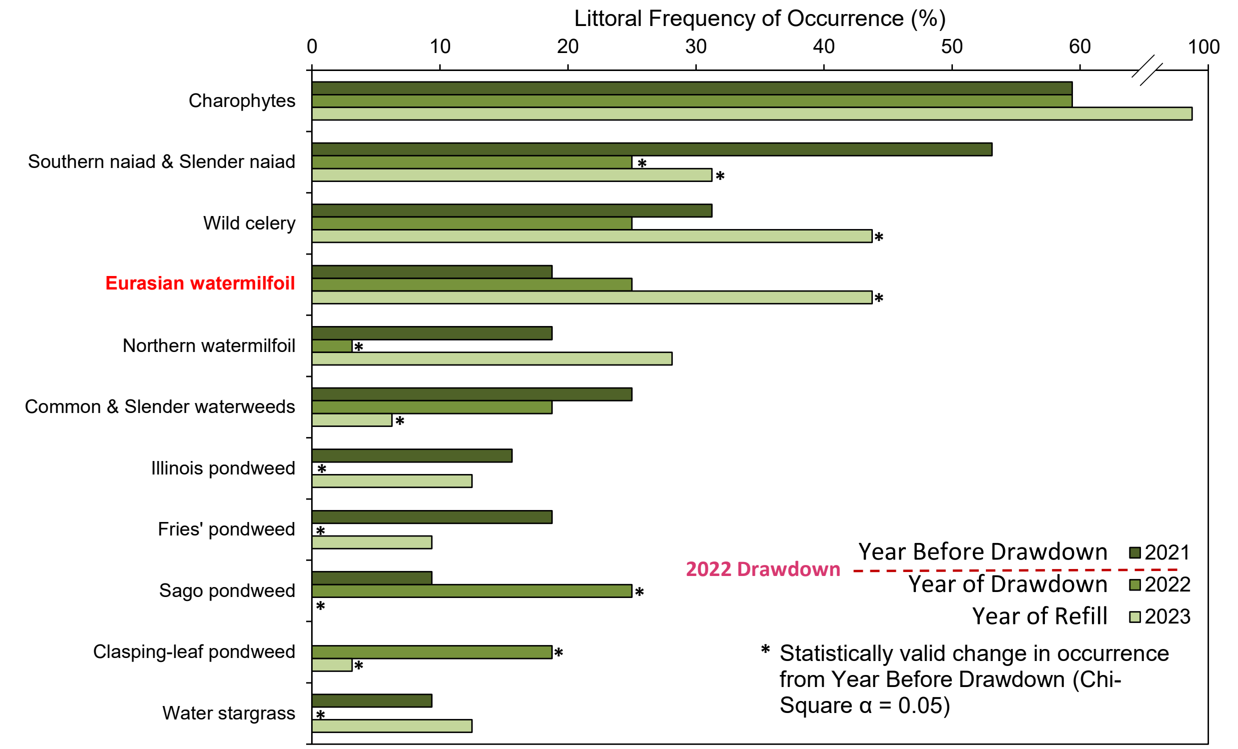
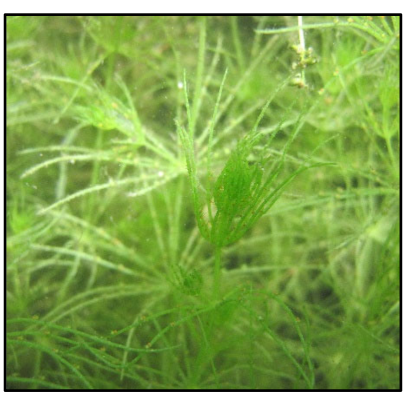


Figure 2.2-2. Emerald Lake 2021, 2022, and 2023 LFOO. LFOO = littoral frequency of occurrence of plants with an occurrence of 6% or more.

Of the 11 species investigated on this figure, three had statistically valid reductions following the after drawdown point intercept survey (2022) and three had statistically valid increases. Charophytes, slender and southern naiads, and wild celery were the most frequent native aquatic plant species found in Emerald Lake in 2021, 2022, and 2023 (Photograph 2.2-1).

Charophytes (*Charra & Nitella* spp.)	Southern and slender naiad (*Najas gualalupensis & N. flexilis*)	Wild celery (*Vallisneria americana*)
	 	

Photograph 2.2-1. Three-most frequently encountered aquatic plants in Emerald Lake in 2023. Photo credit Onterra.

Most populations in Emerald Lake mirrored the results from the four main lakes of Mount Morris Lake. Wild celery populations increased on Emerald Lake of greater magnitude than Mount Morris Lake. Populations of Illinois pondweed and fries' pondweed were absent in 20223, but have rebound in 2023. Similar to Mount Morris Lake, sago pondweed populations crashed during 2023.

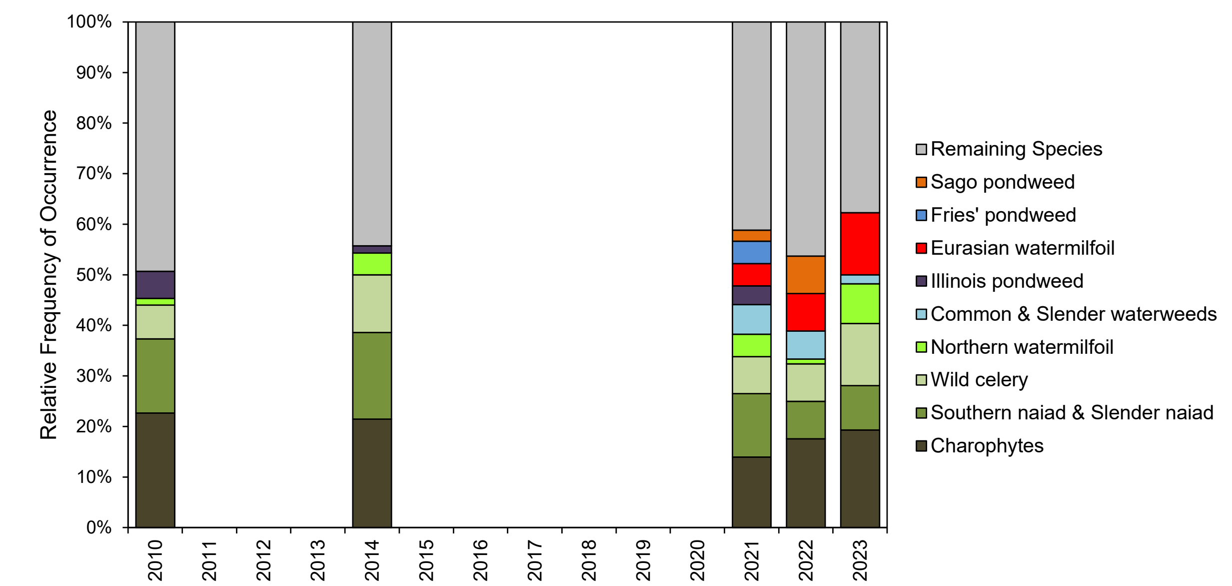


Figure 2.2-6. Relative frequency of occurrence of aquatic plants in Emerald Lake.

The native aquatic plant species located on the rake during the point-intercept surveys from 2010-2023 and their conservatism values were used to calculate the Floristic Quality Index (FQI) for each year (Figure 2.2-7). Native species richness, or the number of native plant species recorded on the rake has varied over time in Emerald Lake with the lowest values in 2010/2014 (9) (Figure 2.2-7). In all years, the species richness has been below the state median values and in 2021 was above the ecoregion median value.

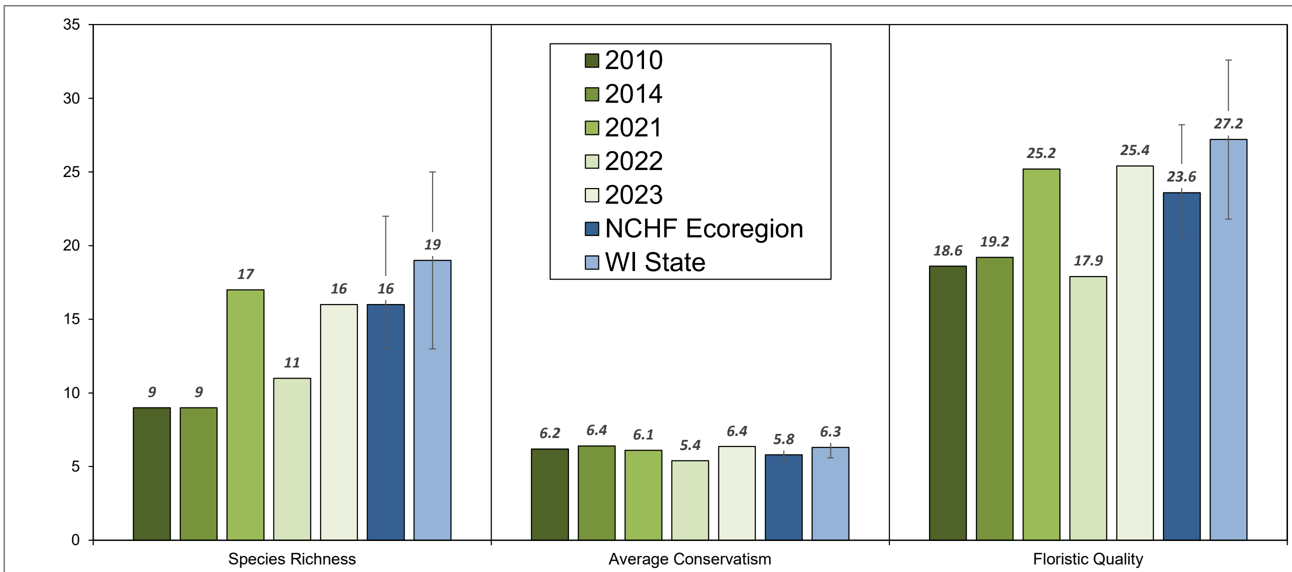


Figure 2.2-7. Native aquatic plant species richness, average conservationism, and floristic quality.

Average conservatism values have been consistently between 5.4-6.4 in surveys conducted between the monitoring years. 2023 survey yielded a high conservatism value of 6.4. The floristic quality value was above the ecoregion median for 2023, with a value of 25.4, but still below the median for the state of Wisconsin. FQI is calculated from values associated with the species richness and average conservatism which were both high in 2023 compared to past surveys.

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 Emerald Lake's diversity values rank. Using data collected by Onterra, quartiles were calculated for lakes within the NCHF Ecoregion (Figure 2.2-8). Using the data collected from the whole-lake point-intercept surveys, Emerald Lake's aquatic plant species diversity has varied over time. In 2023, Simpson's diversity was the third highest it's ever been recorded at 0.86.

Community mapping was also completed on Emerald Lake in 2021 and 2022. This discussion is located within the *Mount Morris Lake Aquatic Plant Monitoring* section.

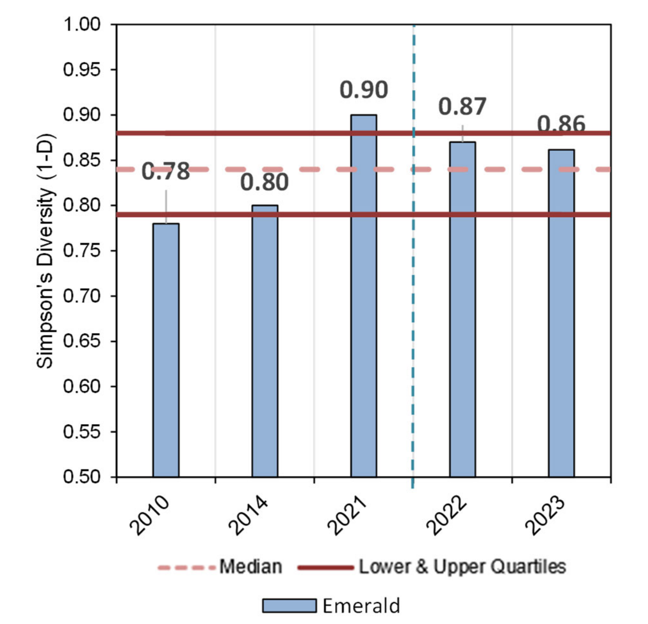


Figure 2.2-8. Emerald Lake Simpson's Diversity Index. The dashed blue line indicates a lake wide drawdown event.

2.3 Non-native Aquatic Plants in Mount Morris Lake

All the aquatic plant data discussed so far was collected as part of point-intercept surveys. The subsequent materials will also incorporate data from AIS mapping surveys. Additional explanation about how these two surveys differ is discussed below.

The point-intercept survey provides a standardized way to gain quantitative information about a lake's aquatic plant population through visiting predetermined locations (Map 1) and using a rake sampler to identify all the plants at each location (Photograph 2.3-1). The survey methodology allows comparisons to be made over time, as well as between lakes. The point-intercept survey is most often applied at the whole-lake scale as has been presented above.

Photograph 2.3-1. Point-intercept survey on a WI lake. Photo credit Onterra.

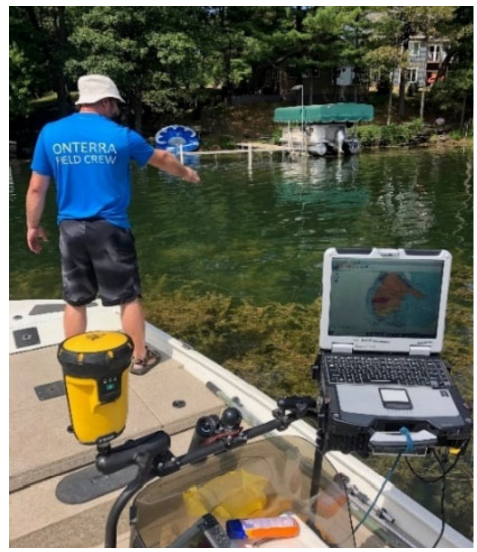


Photo 2.3-2. EWM mapping survey on a Wisconsin lake. Photo credit Onterra.

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake. EWM grows high in the water column, which can cause recreation and navigation impediments. This factor allows it to typically be mapped through surface observation. During an EWM mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat (Photograph 2.3-2). Field crews may supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The EWM population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.

Eurasian watermilfoil (Myriophyllum spicatum)

Eurasian watermilfoil (EWM is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 2.3-1). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating. However, in some lakes, EWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

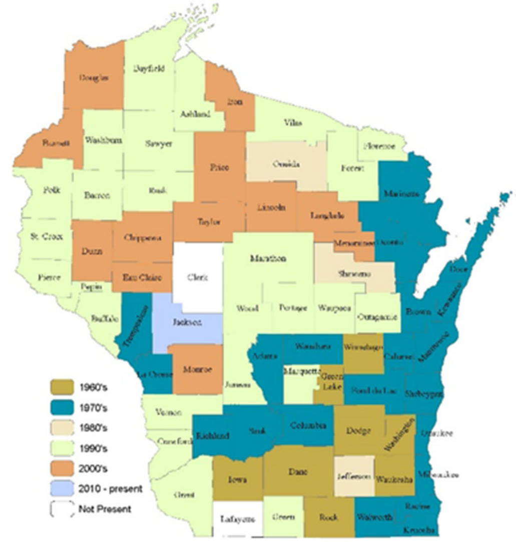


Figure 2.3-1. Spread of EWM within WI counties.

At least a portion of Mount Morris Lake's invasive watermilfoil population is comprised of hybrid EWM (HWM), a cross between EWM and native northern watermilfoil. Studies have shown that most strains of HWM are less responsive to commonly used herbicides compared to pure-strain EWM. Unless specifically indicated, this report will use "EWM" when discussing the invasive milfoil (EWM and HWM) population of Mount Morris Lake.

The concept of heterosis, or hybrid vigor, is important in regards to EWM management in Mount Morris Lake. The root of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. In general, hybrid watermilfoil (*M. spicatum* x *sibiricum*) typically has thicker stems, is a prolific flowerer, and grows much faster than pure-strain EWM (LaRue et al. 2012). These conditions may likely contribute to this plant being particularly less susceptible to chemical control strategies (Glomski and Nehterland 2010), (Poovey et al. 2007), (Nault et al. 2018). In lakes that contain both EWM and hybrid watermilfoil (HWM), concern exists that the more-easily controlled EWM component of a lake's invasive milfoil population may be controlled by herbicide treatment, but the slightly less-susceptible HWM component will survive, rebound in a short period of time, and then comprise a larger proportion of the invasive milfoil population.

EWM population of Mount Morris Lake

Following detection of EWM within Mount Morris Lake in 2004, numerous spot-treatments and basin-wide control strategies have been implemented towards EWM. Unfortunately, many of these treatments have fallen short of expectations. Season reductions in EWM populations were often observed, only to rebound the following year. Ongoing studies are indicating that in small spot treatments (working definition is less than 5 acres) the herbicide dissipates too rapidly to cause EWM mortality if systemic herbicides like 2,4-D are used. On Mount Morris Lake, water flow also acts to reduce concentrations and exposure times of the herbicide.

Onterra ecologists completed a series of Late-Season EWM Mapping Survey during the *year before drawdown* (2021), *year of refill* (2022), and *year after refill* (2023) to access the EWM population (Maps 5 & 6, Figure 2.3-2).

It is important to note that the acreages reflected on Figure 2.3-3 only account for EWM mapped with area-based methodologies (polygons) and any point-based mapping occurrences (points) do not contribute to the acreage totals. Much of the EWM population in the lake was approaching the water's surface making for easy identification or low growing and difficult to observe visually from the surface for both surveys. Multiple dense, *dominant* and *scattered* colonies were mapped throughout the lake in both years. The 2022 Late-Summer EWM Mapping Survey indicated 13.3 acres of EWM within Mount Morris Lake, representing a decrease in population from the 2021 survey by about 4.3 acres (Figure 2.3-3). Some areas experienced an increase in EWM growth while other areas experienced a decrease in the 2022 *year after refill* results (Figure 2.3-3). Continued EWM population increased was documented during 2023. The winter 2021/22 drawdown was insufficient to fully dry or freeze the root crowns of the EWM population, falling short of success expectations.

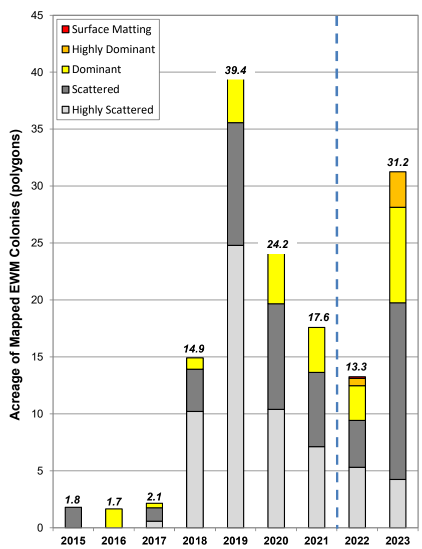


Figure 2.3-2. Acres of EWM colonies in Mount Morris Lake from 2015-2023. Data from annual Onterra Late-Season EWM Mapping Surveys.

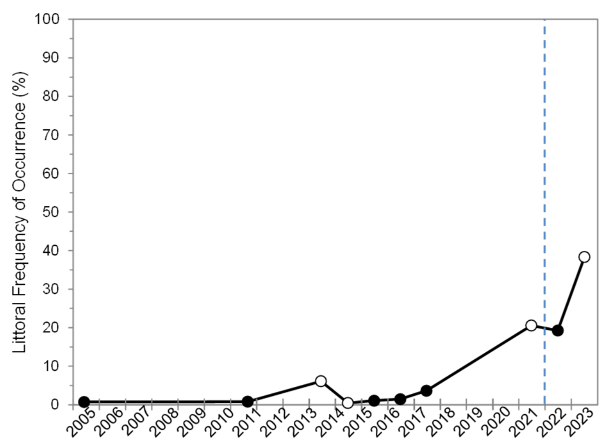


Figure 2.3-3. Littoral frequency of occurrence of EWM in Mount Morris Lake. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05). The dashed blue line signifies the winter 2021-22 drawdown event.

Curly-leaf Pondweed (Potamogeton crispus)

Curly-leaf pondweed (CLP) is a non-native, invasive submersed aquatic plant native to Eurasia. Like our native pondweeds, CLP produces alternating leaves along a long, slender stem. The leaves are linear in shape with a blunt tip, and the margins are wavy and conspicuously serrated (saw-like). The plants are often brownish/green in color. Mount Morris Lake has a number of native pondweed species, some of which are similar in appearance to and may be mistaken for CLP (Photograph 2.3-3).

Photograph 2.3-3. Curly-leaf pondweed and native pondweed 'look-a-likes.' Featured species found in found in Mount Morris Lake. Photo credit Onterra.

It is unknown when CLP was first introduced to Mount Morris Lake, but dense, widespread distribution was documented in 2004. Total phosphorus spikes were documented surrounding the early-summer die-off of this species. The nuisance conditions and water quality impairments prompted the MMLMD to initiate approximately a decade of repetitive early-season endothall herbicide treatments. Herbicide concentration monitoring occurred from 2010-2016, allowing the MMLMD to adjust application rates to meet control goals. The project goals were met, with only low-density CLP occurrences being documented since 2016 when herbicide management ceased.

Like some of Wisconsin's native pondweeds, CLP's primary method of propagation is through the production of numerous asexual reproductive structures called turions. Once mature, these turions break free from the parent plant and may float for some time before settling and overwintering on the lake bottom. Once favorable growing conditions return (i.e., spring), new plants emerge and grow from these turions (Photograph 2.3-4). Many of the turions produced by CLP begin to sprout in the fall and overwinter as small plants under the ice. Immediately following ice-out, these plants grow rapidly giving them a competitive advantage over native vegetation. Curly-leaf pondweed typically reaches its peak biomass by mid-June, and following the production of turions, most of the CLP will naturally senesce (die back) by mid-July.

Photograph 2.3-4. Single CLP turion sprouting several new plants. Photo credit Onterra.

The senescence of curly-leaf pondweed populations has been shown to release a significant amount of phosphorus into the water from decomposing plant tissues ((Leoni et al. 2016). Modeled using the quantities and densities of curly-leaf pondweed from the 2016 survey, an estimated 51 pounds of phosphorus could be added to the water column. However, since Mount Morris Lake is a flowage the amount of phosphorus curly-leaf pondweed releases likely does not remain in the lake for an extended period of time.

In some lakes, CLP can reach growth levels which interfere with navigation and recreational activities. However, in other lakes, CLP appears to integrate itself into the plant community and does not grow to levels which inhibit recreation or have apparent negative impacts to the lake's ecology or plant community without becoming a nuisance or causing measurable impacts to the lake ecosystem.

CLP population of Mount Morris Lake

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced in one year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Traditionally a control strategy for an established CLP population includes 5-7 years of treatments of the same area to deplete the existing turion bank within the sediment (Johnson et al. 2012) (Skogerboe et al. 2008). In practice, it is unclear how many years CLP turions can remain viable and therefore the number of consecutive years treatments are required is unknown.

The 2012 WDNR grant-funded CLP project was designed such that roughly 36 acres of Mount Morris Lake would be targeted for four straight years with liquid endothall, modifying the dosing strategy along the way in response to data reflecting measured herbicide concentrations, efficacy, and selectivity. This CLP control program on Mount Morris Lake showed positive signs of control and management strategies may shift more towards maintaining the lowered CLP population within the lake. Further discussions of these data are presented in the *2017 AIS Monitoring & Control Strategy Assessment Report.*

CLP populations declined during the *year after refill* (2022) on the system, but significantly increased during the *year after refill* (2023) (Maps 7 & 8). While the footprint of CLP has increased, the density largely consists of *highly scattered* or *scattered* densities, which are those not likely to impact navigation, recreation, or how the ecosystem functions.

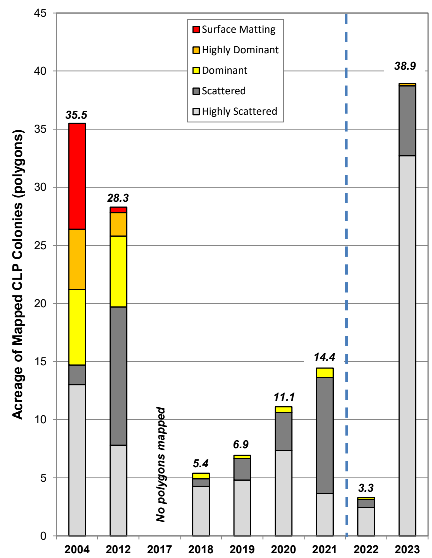


Figure 2.3-4. Acres of CLP colonies in Mount Morris Lake from 2004-2022. Data from annual Onterra Early-Season CLP Mapping Surveys.

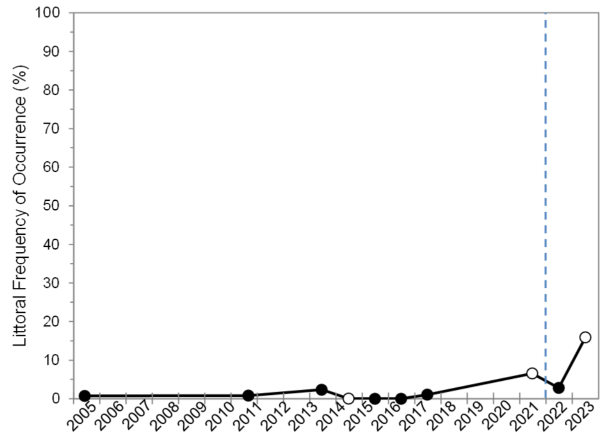


Figure 2.3-5. Littoral frequency of occurrence of CLP in Mount Morris Lake. Open circle represents statistically valid change from previous survey (Chi-Square α = 0.05). The dashed blue line signifies the winter 2021-22 drawdown event.

3.0 WATER QUALITY SUMMARY

In addition to aquatic plant surveys, basic water quality data were collected in 2021, 2022, and 2023 to understand any potential changes in water quality that may be linked to the winter drawdown. While not anticipated on Mount Morris Lakes, some drawdowns have resulted in decreased water clarity and depressed dissolved oxygen rates, as well as serve cyanobacteria (blue-green algae) blooms during the *year after refill* (Personal comm. Scott Provost).

Trophic Parameters in Mount Morris Lake

The *2013 Comprehensive Management Plan* discussed the water quality of Mount Morris Lake in as much detail as possible considering the inconsistency of the dataset and each lake (A – E) individually. At the time, the water quality data from Mount Morris Lake indicated that the lake is, on average, in good to excellent condition. The data did not reveal any trends over time, but did indicate fluctuation in values thought to be related to increased precipitation in 2010. Additional information regarding water quality analysis and the relationship between the trophic parameters (phosphorus, chlorophyll-*a*, and Secchi disk transparency) can be found in the 2013 management plan.

Since the *2013 Comprehensive Management Plan*, Mount Morris Lake was included in the CLMN program which that collected valuable water quality data (phosphorus, chlorophyll-*a*, and Secchi disk transparency). The general relationship between Mount Morris Lake water quality, especially water clarity, and Mount Morris Lake aquatic plants, are expanded on later in this section.

Mount Morris Lake total phosphorus data are displayed in Figure 3.0-1. The July 2022 phosphorus reading from the deep-hole site was 15.2 µg/L, the weighted summer average from 1988 – 2022 is 19.5 µg/L. The 2022 phosphorus concentration is similar to recent growing season mean years and is only slightly lower than the weighted summer average for all years. The 2022 and 2023 phosphorus data are considered to be *Good* to *Excellent* for a deep lowland drainage lake and the pattern of *Good* to *Excellent* total phosphorus concentrations continue since the 2013 plan was completed.

A near-bottom water sample was also collected during the July 2022 visit to Mount Morris Lake. During the July 2022 sampling, the lake was stratified with anoxic conditions being recorded at depths 20-feet and below. The near-bottom water sample was collected at a depth of 38-feet and contained a phosphorus concentration of 65.3 µg/L. As discussed in the 2013 management plan, deep lakes, like Mount Morris Lake, can go through longer stratification periods and lead to an anoxic bottom layer (hypolimnion) with elevated phosphorus concentrations due to the release of phosphorus that is bound in the sediment during anoxic conditions. In Lake D, bottom phosphorus concentrations vary widely with the highest concentration of 578 µg/L being found in late-August 2010 and values below 49 µg/L being recorded during the entire summer of 2007. As discussed in the 2013 plan, while some amount of internal loading is occurring in Mount Morris Lake D, as happens in most stratified lakes, it is likely negligible compared to the amount of phosphorus entering the lake through its watershed, and therefore does not make up a large portion of the lake's overall nutrient budget.

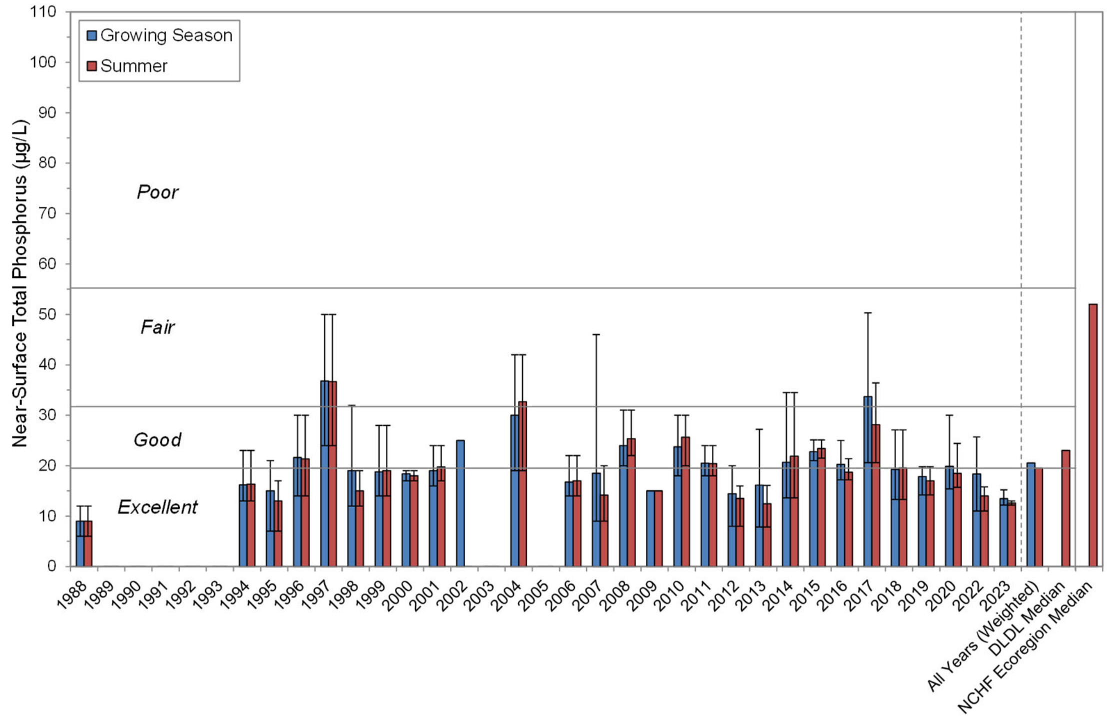


Figure 3.0-1. Mount Morris Lake surface water total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Mount Morris Lake chlorophyll-*a* data are shown in Figure 3.0-2. The chlorophyll-*a* concentrations have remained fairly stable within the dataset and within recent sampling years. The average values range from *Good* to *Excellent* for deep lowland drainage lakes but primarily fall within the *Excellent* category. Mount Morris Lake's mean value for the full dataset is in the *Excellent* category and lower than median values from lakes of the same type and all lakes found in the North Central Hardwood Forests ecoregion.

The July 2022 chlorophyll-a reading from the deep hole site was 1.67 µg/L, one of the lowest results in the lake's dataset. The weighted summer average from 1988 – 2022 is 4.6 µg/L. Nuisance algal blooms typically occur when chlorophyll-a concentrations exceed 20 µg/L. All values collected from Mount Morris Lake have been below that level since the start of the dataset.

Similar to phosphorus and chlorophyll-*a* data, a wide range of Secchi disk data (Figure 3.0-3) has been collected from 1986 to 2022. Water clarity in 2022 was *Excellent* for Mount Morris Lake and summer average was 14.4 feet, while summer weighted mean Secchi disk depth is 11.8 feet for the entire dataset. Mount Morris Lake's weighted summer mean is deeper than the median value from other deep lowland drainage lakes, and lakes of all types within the ecoregion. Overall, the average is considered *Excellent* for deep lowland drainage lakes.

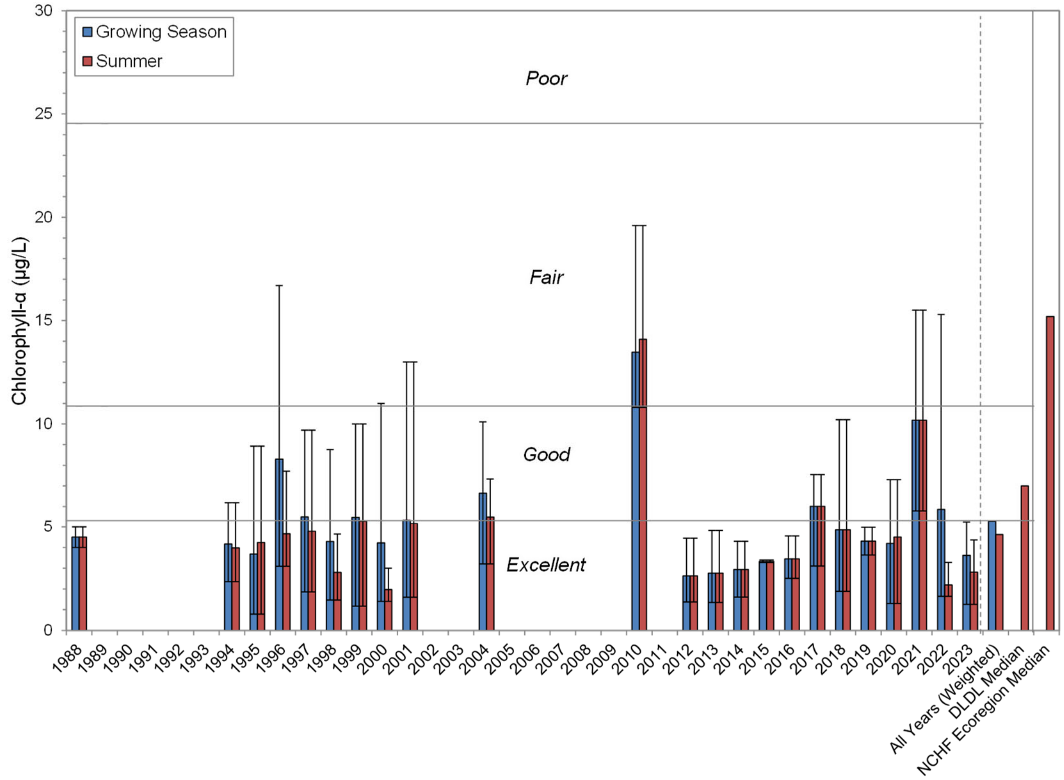


Figure 3.0-2. Mount Morris Lake surface water chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

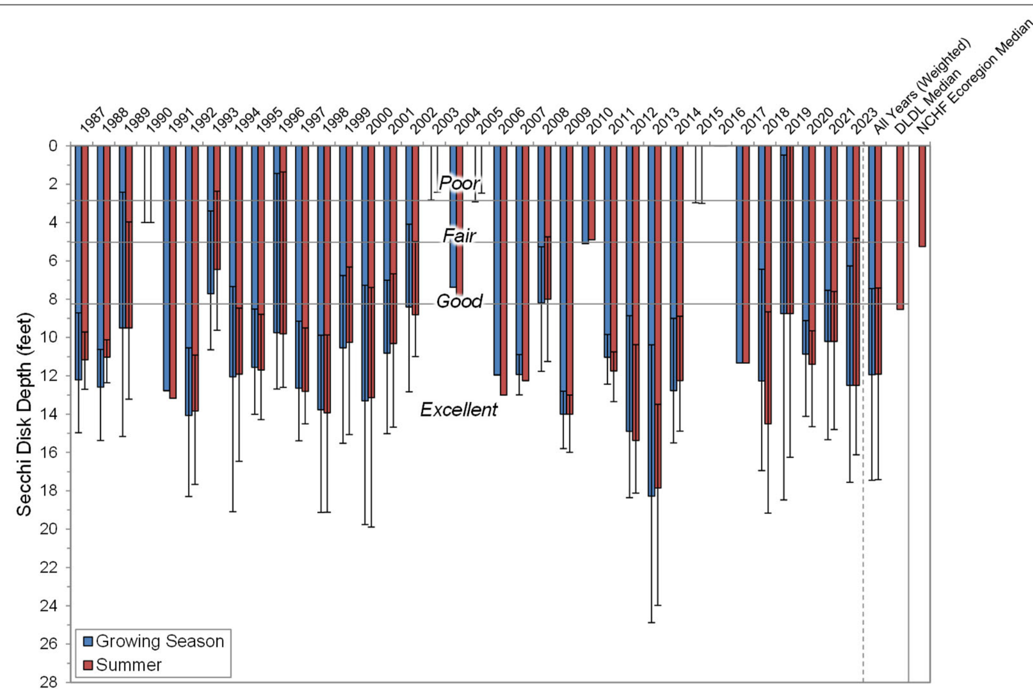


Figure 3.0-3. Mount Morris Lake Secchi disk depths. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Monthly Secchi disk data available from 2022 can be found on Figure 3.0-4 along with average historical Secchi disk readings from Mount Morris Lake. The 2022 Secchi disk measurements show lower clarity throughout the months of May and June, with measurements becoming deeper in the summer months of July and August. During 2022, clarity was greater than average in the summer but was below average in May, June, and fall. As previously discussed, some increases in aquatic plant biomass, especially deeper waters, was documented in 2022.

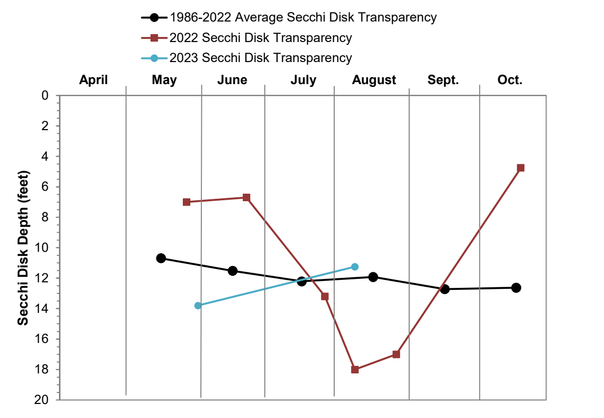


Figure 3.0-4. Secchi disk transparency values by month in Mount Morris Lake.

Considering the entire Secchi disk transparency dataset, there is a very slight trend in increasing water clarity utilizing summer month means (Figure 3.0-5). However, when only mean Secchi data since the discovery of the invasive zebra mussel (*Dreissena polymorpha*) (2014-2022) are considered, that trend flattens considerably (Figure 3.0-6). It must be noted that data are limited during this timeframe due to the missing 2015 and 2016 data. Considering these data cannot be said if there has been an increasing trend in clarity since 2014. Studies have shown that zebra mussels usually do not have detectable effects on the lake's ecosystem until their population rapidly expands about five to 10 years after their introduction (Karatayev et al. 1997). Zebra mussels were discovered in Mount Morris Lake about a decade ago, so the lake would likely already be experiencing the effects of this species ecologically, but the transparency data do not seem to support an increase in clarity. This may be due to the fact that Mount Morris Lake has always had clear water and the impact of zebra mussels is not detectable.

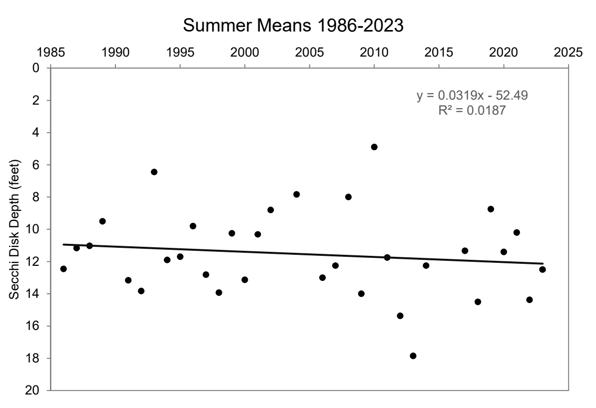


Figure 3.0-5. Summer mean Secchi disk values from 1986 to 2023. Trendline shows slight increase in transparency values over the dataset.

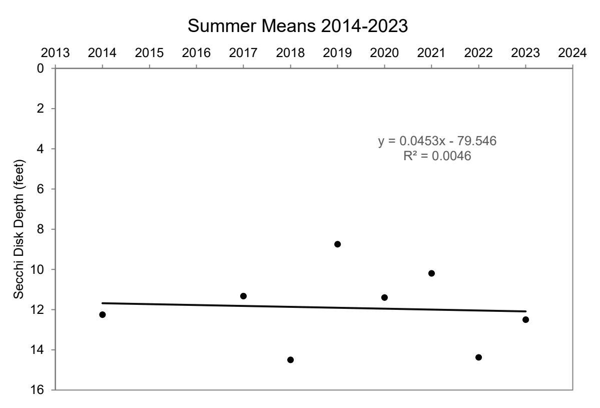


Figure 3.0-6. Summer mean Secchi disk values from 2014 to 2023. Trendline is nearly flat over timeframe in which zebra mussel were known to exist in Mount Morris Lake.

Dissolved Oxygen and Temperature in Mount Morris Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Mount Morris Lake in 2020-2023 by Onterra staff. Profiles depicting these data are displayed in Figure 3.0-7. The data indicate that Mount Morris Lake is a typical dimictic lake showing summer stratification with anoxic conditions developing in the hypolimnion.

During some times of stratification, especially during July 2020 and May 2022, the phenomenon known as *dissolved oxygen maxima* is apparent by the increased dissolved oxygen levels at depth. This phenomenon occurs in lakes with clear water that support an algae population that control their depth. During daylight hours, the algae move deeper into the water column to depths with more desirable light levels, and as a result, the oxygen they produce during photosynthesis is higher than the depths below and above the algal mass.

Data were collected twice through winter ice cover during 2021 and 2023. During both samplings, oxygen levels were well above minimum values to support the fishery in the lake.

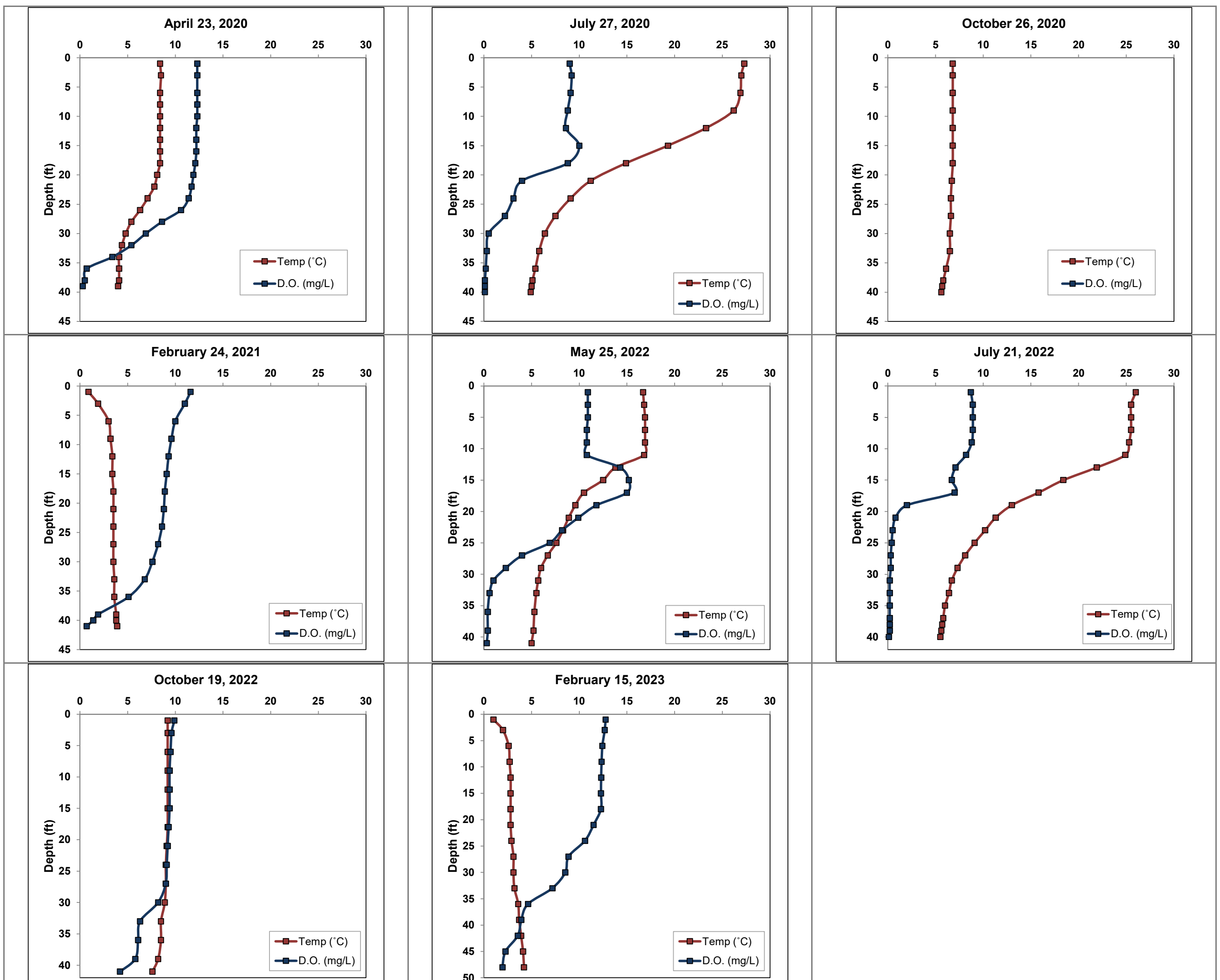


Figure 3.0-7. Mount Morris Lake dissolved oxygen and temperature profiles. Please note the October 2020 profile does not include D.O. readings.

Additional Water Quality Data Collected at Mount Morris Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic, meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in Mount Morris Lake was found to be slightly alkaline with a value of 8.5 in both years and falls within the normal range for Wisconsin Lakes (Figure 3.0-8).

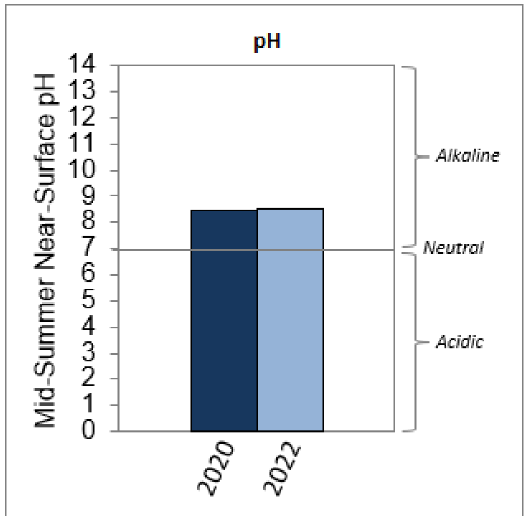


Figure 3.0-8. Mount Morris Lake mid-summer near-surface pH value.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3)_2$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Mount Morris Lake was measured at 172 (mg/L as $CaCO_3$) in 2020 and 177.5 in 2022, indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain (Figure 3.0-9).

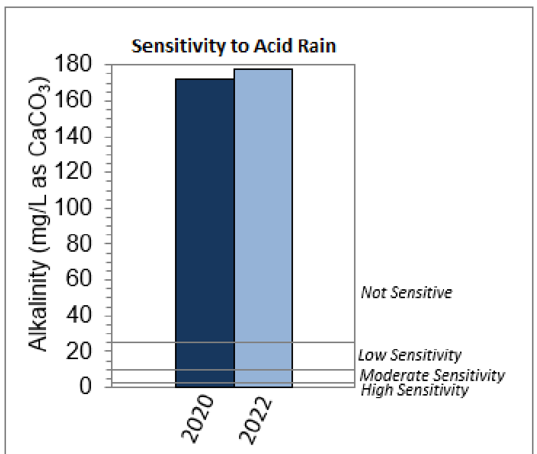


Figure 3.0-9. Mount Morris Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from near-surface.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Mount Morris Lake's pH of 8.5 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Mount Morris Lake was found to be 38.9 and 42.4 mg/L in 2020 and 2022, respectively, falling well within the optimal range for zebra mussels (Figure 3.0-10).

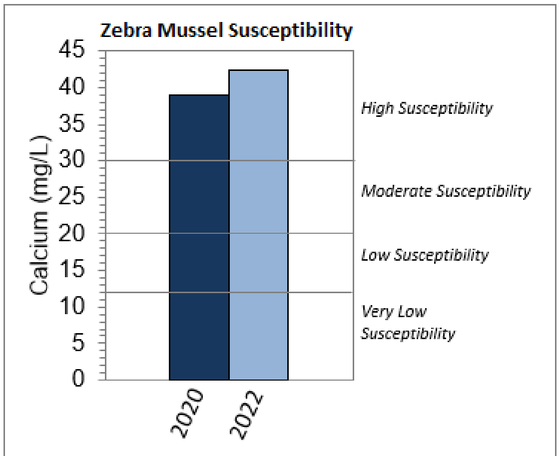


Figure 3.0-10. Mount Morris Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

Zebra mussels (*Dreissena polymorpha*) are small bottom-dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. Zebra mussels can attach themselves to boats, boat lifts, and docks, and can live for up to five days after being taken out of the water. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring. Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Best practice methods for cleaning boats that have been in zebra mussel infested waters is inspecting and removing any attached mussels, spraying your boat down with diluted bleach, power-washing, and letting the watercraft dry for at least five days.

A measure of water clarity once all of the suspended material (i.e., phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color was measured at 17.5 SU (standard units) in 2020 and 22.5 in 2022, indicating the lake's water was *slightly colored* in these years (Figure 3.0-11).

Overall, water quality remained relatively stable before the drawdown (2020) and after the drawdown (2022) signifying the drawdown did not have any significant measurable impacts to the water quality of Mount Morris Lake.

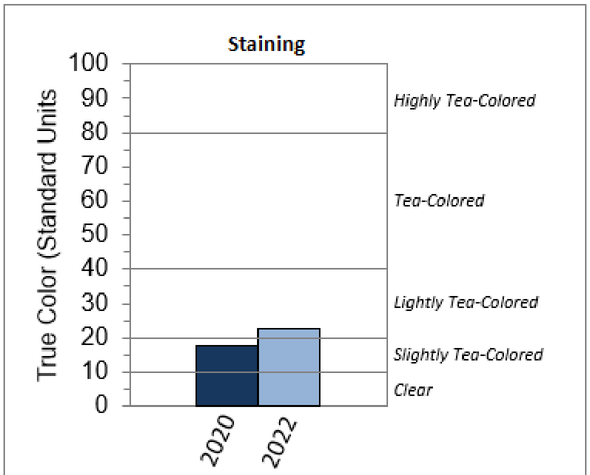


Figure 3.0-11. Mount Morris Lake 2022 near-surface true color value.

4.0 SUMMARY & DISCUSSION

The 2021/2022 winter drawdown of Mount Morris Lake was implemented largely as planned. Much of the lake experienced an approximately 6-foot water level reduction, except approximately 2 feet in Emerald Lake. Both EWM and HWM have been shown to be impacted greatly by winter drawdowns when the system can be dewatered to a sufficient depth to desiccate (i.e. dry out) and freeze the EWM/HWM's root crown. EWM reductions did not meet expectations from the 2021/2022 drawdown, meaning the plants remained hydrated during the winter. Most of the rebounding EWM was found in waters deeper than 6 feet, meaning the drawdown was not sufficiently deep enough to effectively control the EWM population. During planning stages of the drawdown, it was estimated that 90% of the EWM would be impacted by a 6-foot drawdown. While investigations into water clarity do not show strong evidence of increases following zebra mussel infestation, aquatic plants are growing to deeper waters in recent years and may have contributed to the drawdown being less effective than anticipated.

The impact of drawdowns on CLP is variable. CLP populations remained low during the *year after* drawdown (2022), but increased in footprint considerably in the *year after drawdown* (2023). However, CLP populations continue to exist at low densities that are not likely having much impact on human uses or ecological function.

Native plant response was variable as predicted; some plants decreased and others increased. The most surprising drawdown response was related to declines in floating-leaf species (spatterdock and white water lily) in the system. In many drawdowns Onterra has monitored, these species increased following the drawdown and even caused some navigation and recreational issues during the first few years after drawdown. It is anticipated that these communities will rebound in the upcoming years, so continued monitoring is warranted.

The pretreatment sediment surveys indicated relatively low proportions of soft sediments in Mount Morris Lake. Fine sediment particles comprise soft sediments, which are more easily moved than larger sand and marl sediments. During the drawdown, soft sediment may have been redistributed into different parts of Mount Morris Lake or continued downstream. The acoustic modeling survey did not yield major increases in water depth, although likely underestimated the amount of channel cutting that occurred between basins.

Overall, it is clear that a 6-foot drawdown is not an effective tool for EWM control on Mount Morris Lake. The EWM is growing too deep for a significant-enough portion of the population to be impacted. Native plant impacts were observed following the drawdown, with rebound of many occurring during the *year after refill* (2023). However, the reduction of the floating-leaf community will take longer to rebound.

The MMLMD is aligning themselves to update their Aquatic Plant Management Plan, learning about the evolution of aquatic plant *Best Management Practices* since their previous management planning efforts.

5.0 LITERATURE CITED

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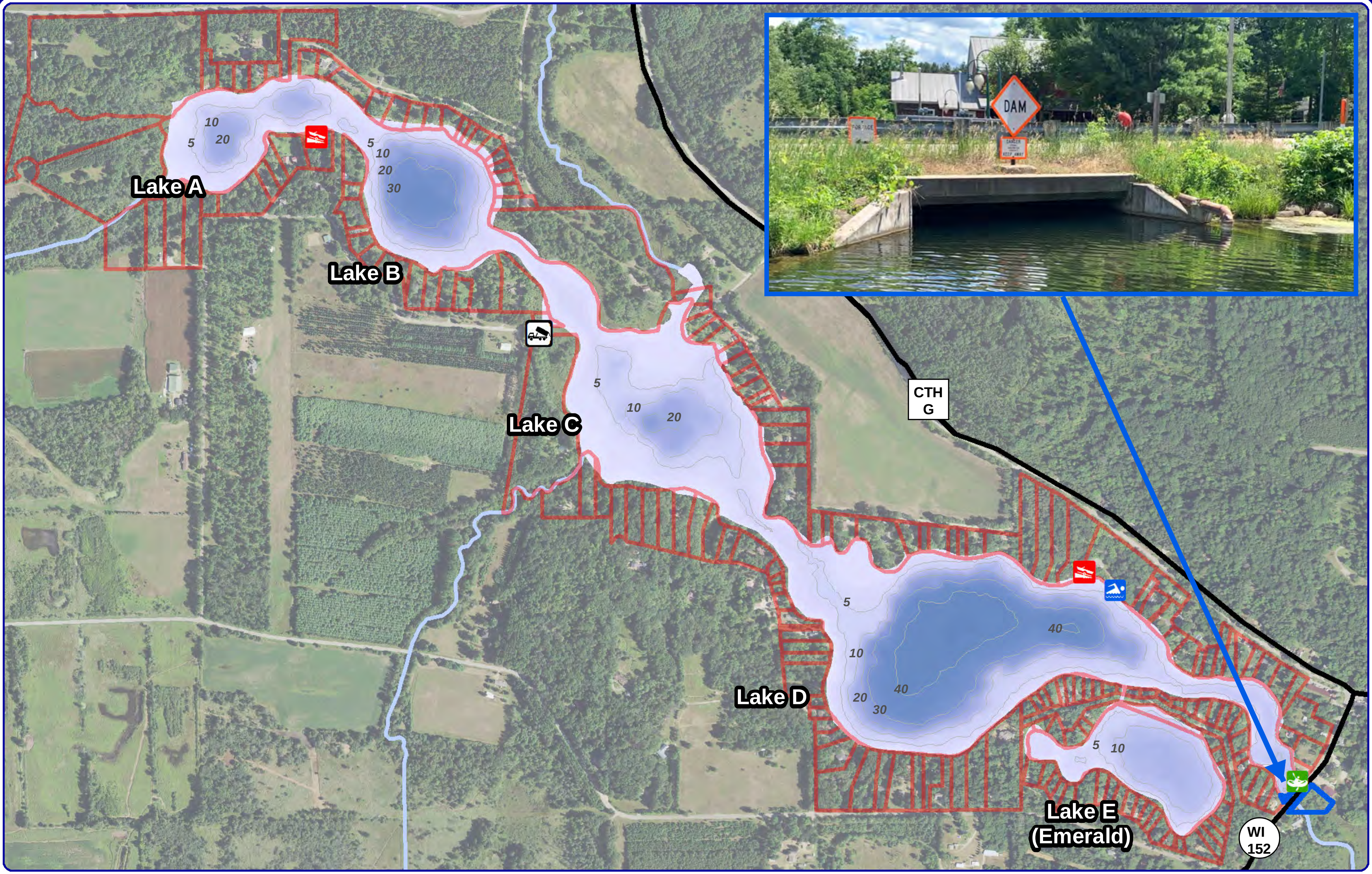

N
W E
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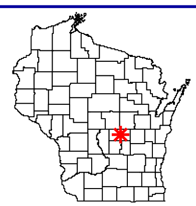
830
Feet

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

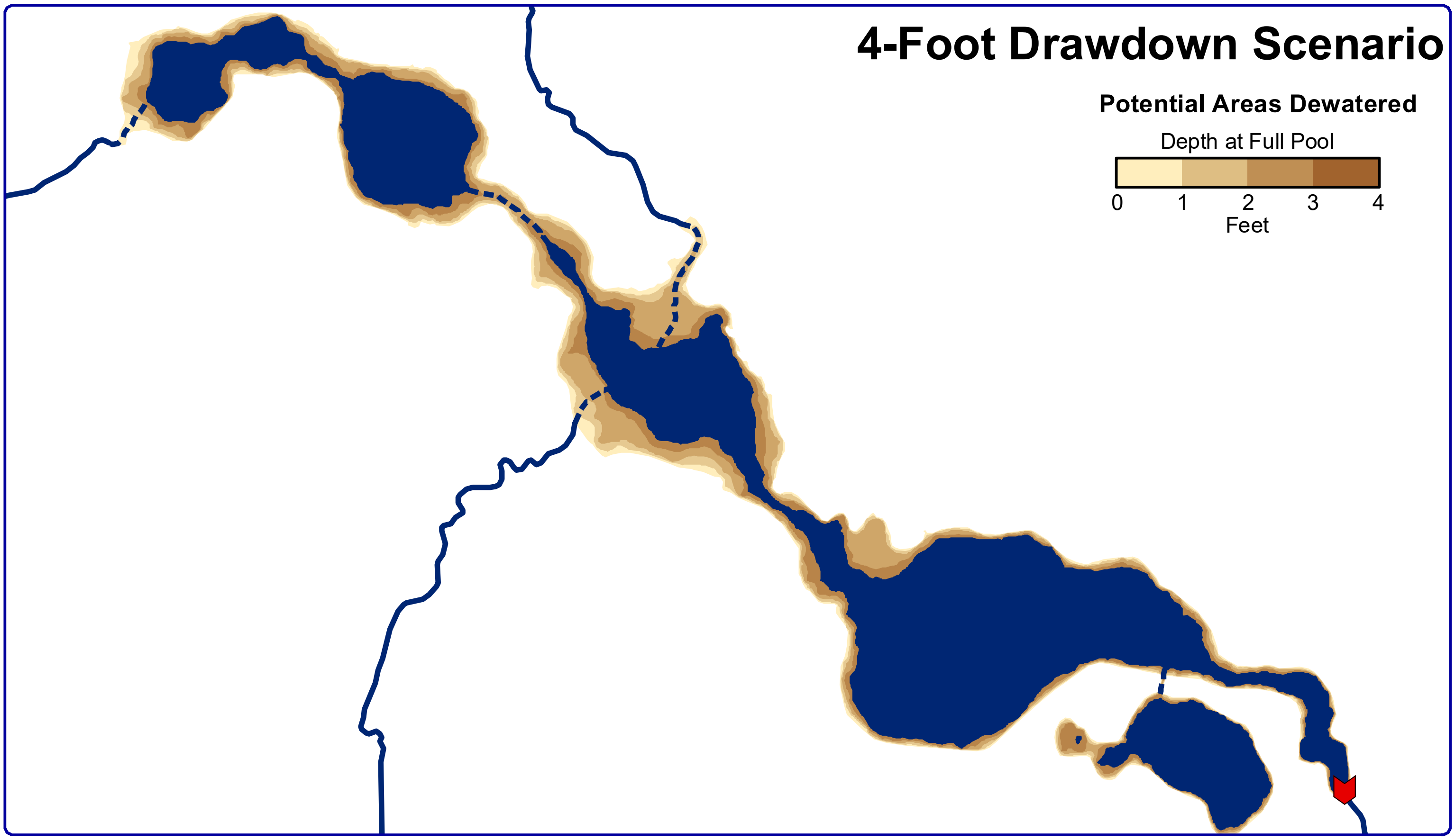
Sources:
Orthophotography: NAIP, 2020
Bathymetric Survey: Onterra, 2019
Map Date: July 13, 2021 - EJH
Filename: MM_2019Bathy.mxd

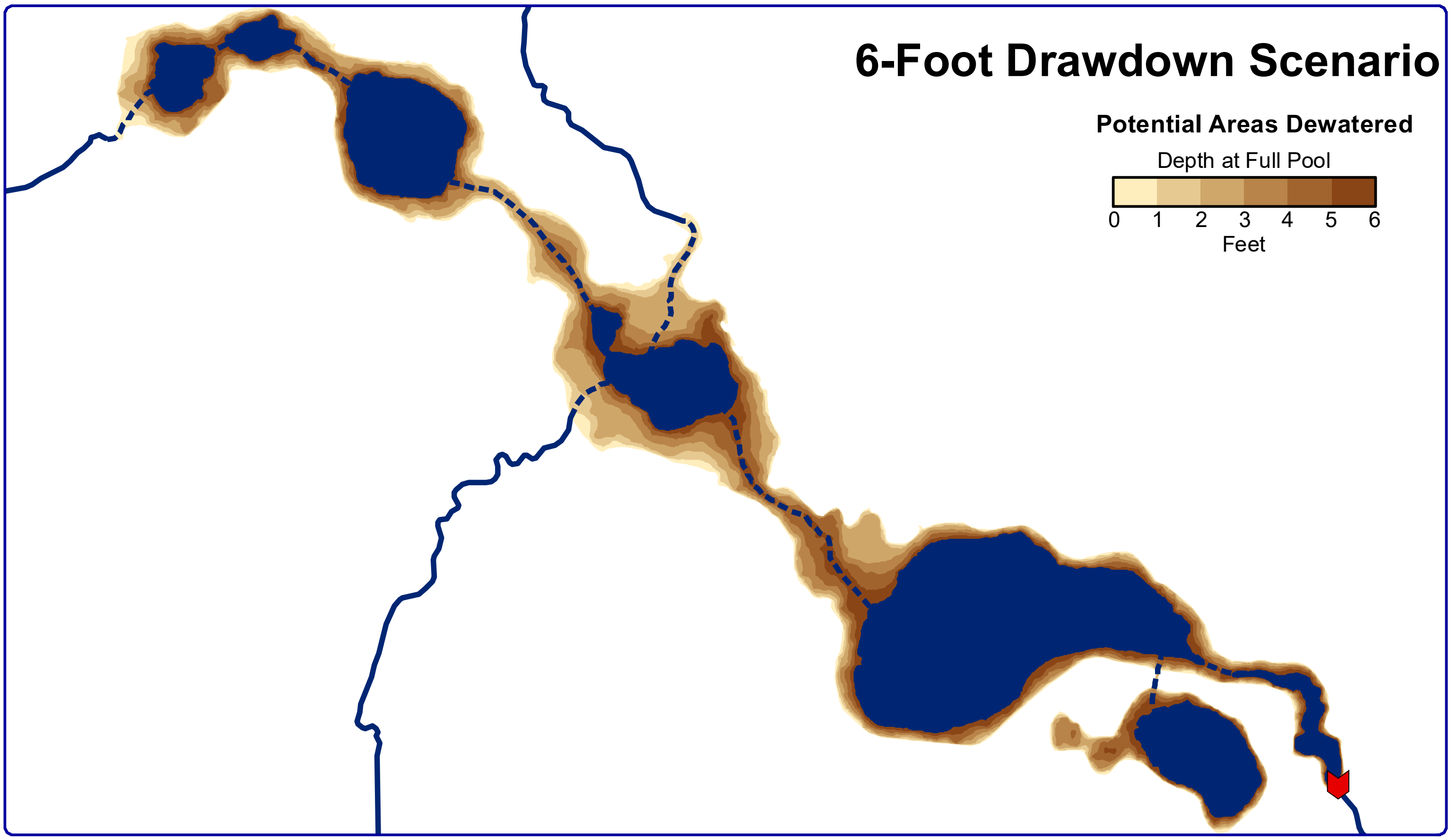

Project Location in Wisconsin

Legend

- Canoe Portage
- Public Landing
- Town Beach
- Mechanical Harvester Parking Location
- Mount Morris Lakes Management District Boundaries
- Dam Property

Map 1
Mount Morris Lake
Waushara County, Wisconsin
Project Location & District Boundaries





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Feet

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Lake Management Planning

815 Prosper Road
De Pere, WI 54115
920.338.8860
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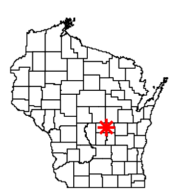
Sources:
Hyrdro: WDNR
Bathymetric Survey: Onterra, 2019
Map Date: July 13, 2021 - EJH



Project Location in Wisconsin

Legend

Open Water During Drawdown

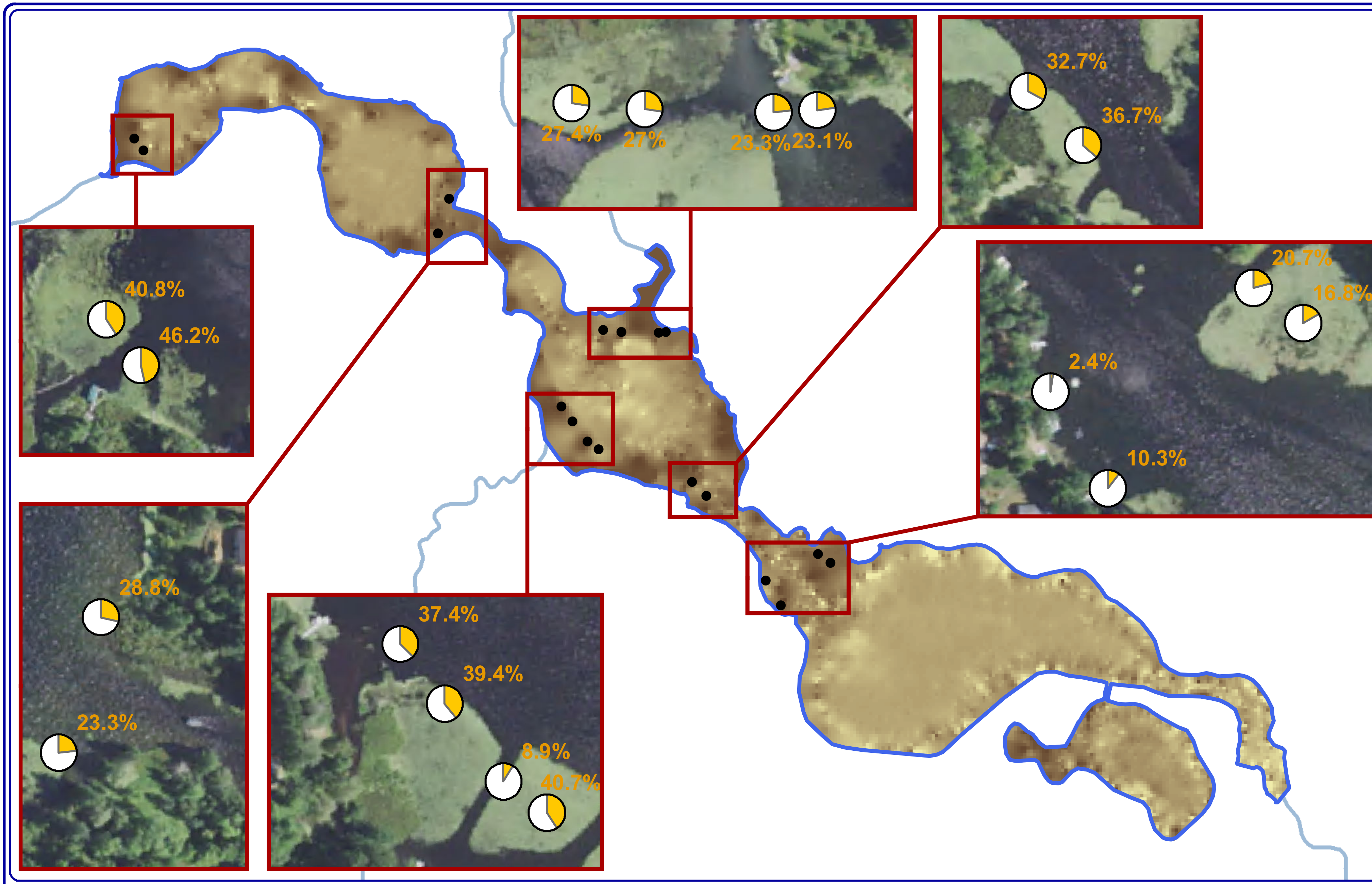
Potential Basin Connection During Drawdown

Map 2

Mount Morris Lake

Waushara County, Wisconsin

Potential Area Dewatered



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Feet

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Lake Management Planning
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920.338.8860
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Sources:
Roads and Hydro: WDNR
Orthophotography: NAIP, 2018
Acoustic Model: Onterra, 2019
Sediment Survey: Onterra, 2020

Map Date: November 25, 2020

Project Location in Wisconsin

Legend

Sediment Core Analysis

Percent Organic Matter

Acoustic Model

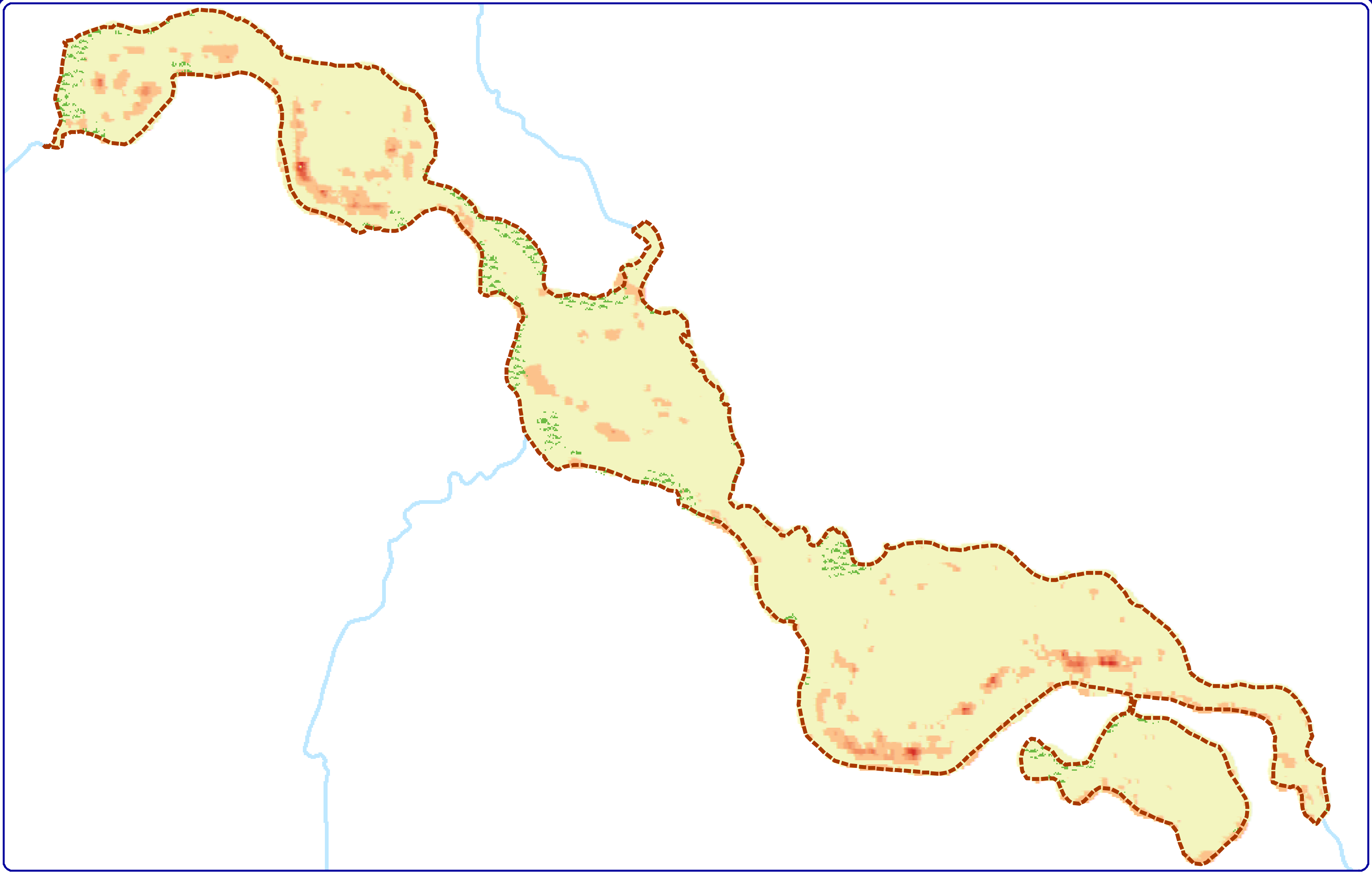
Hard — Soft

Substrate Hardness

Map 3

Mount Morris Lake
Waushara County, Wisconsin

Sediment Surveys: Acoustic Model & Core Analysis



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Feet

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920.338.8860
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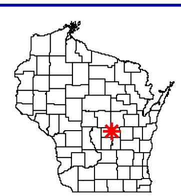
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2021-22
Map date: December 5, 2022 - EJH



Project Location in Wisconsin

Legend

Bathymetry Model Comparsion
2019 Pre- to 2022 Post Drawdown

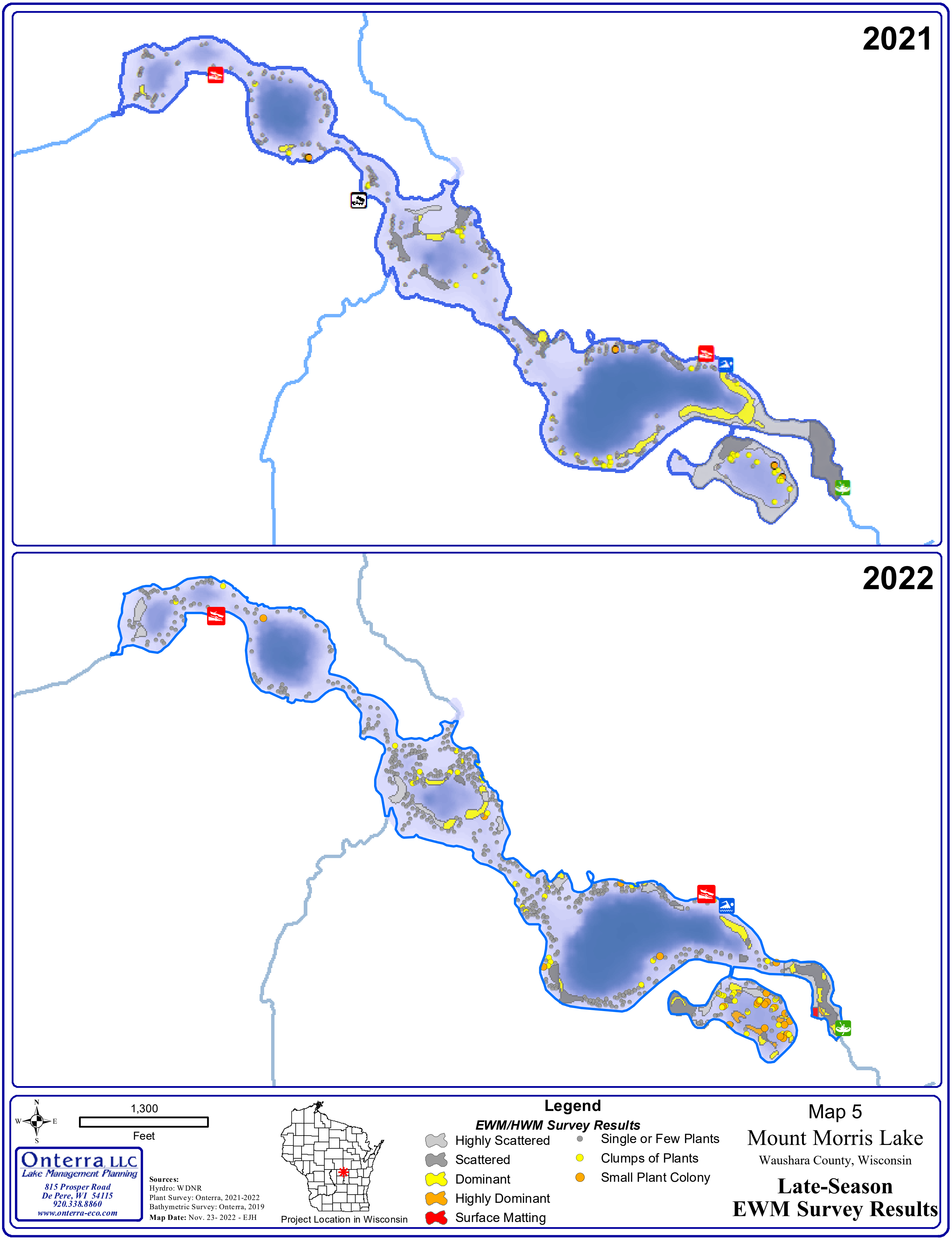
Depth Increase Potential

More ← Less

2022 Floating-Leaf &/or Emergent Community

Map 4
Mt. Morris
Waushara County, Wisconsin

Confirmation Model of Depth Increase



2021
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1,300
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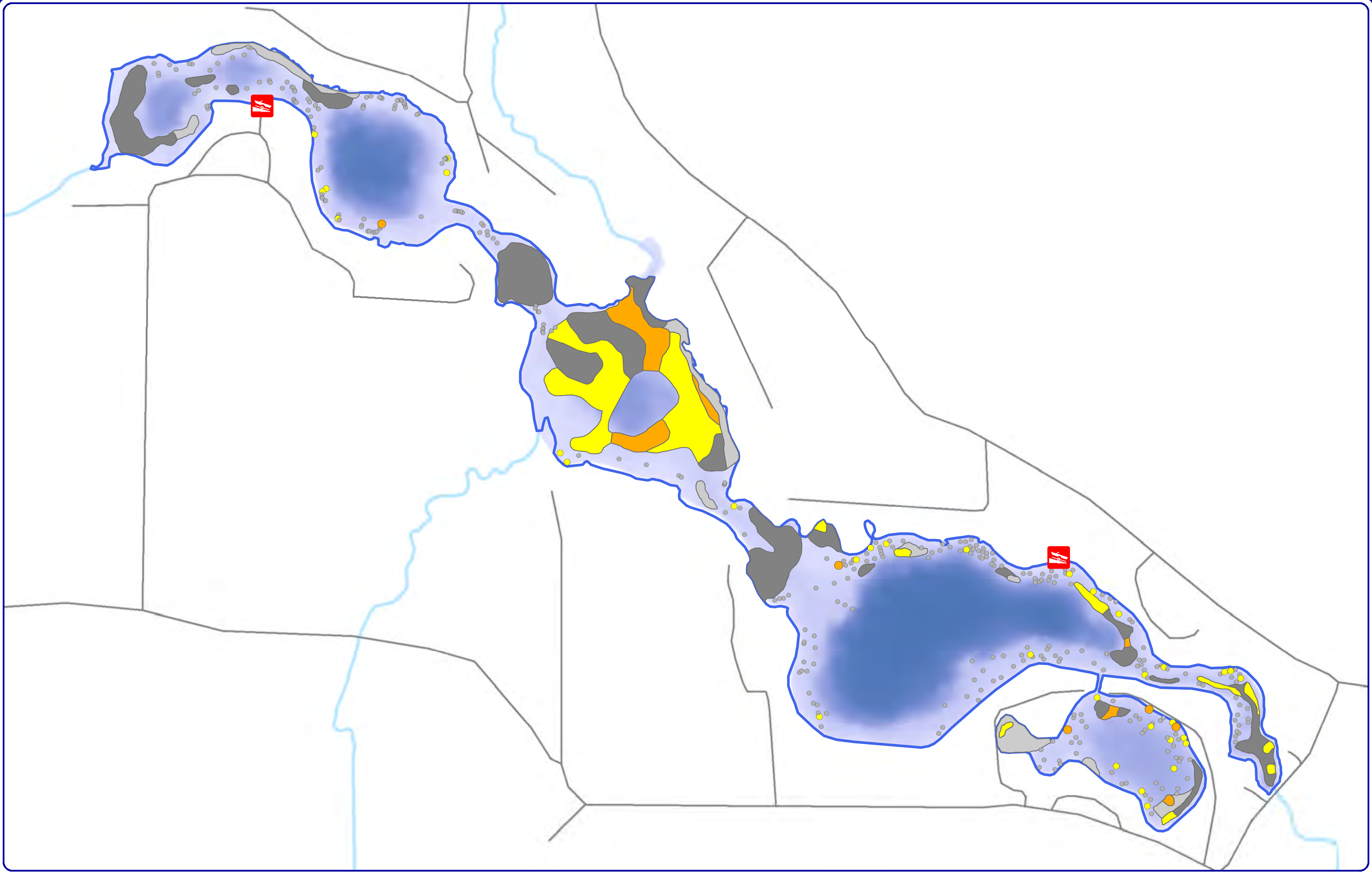
W
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Hyrdro: WDNR
Plant Survey: Onterra, 2021-2022
Bathymetric Survey: Onterra, 2019
Map Date: Nov. 23- 2022 - EJH
Project Location in Wisconsin
Legend
EWM/HWM Survey Results
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony
Map 5
Mount Morris Lake
Waushara County, Wisconsin
Late-Season
EWM Survey Results



Legend

Eurasian watermilfoil (Sept. 26, 2023)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting *(None)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Public Boat Landing

825

Feet

Project Location in Wisconsin

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

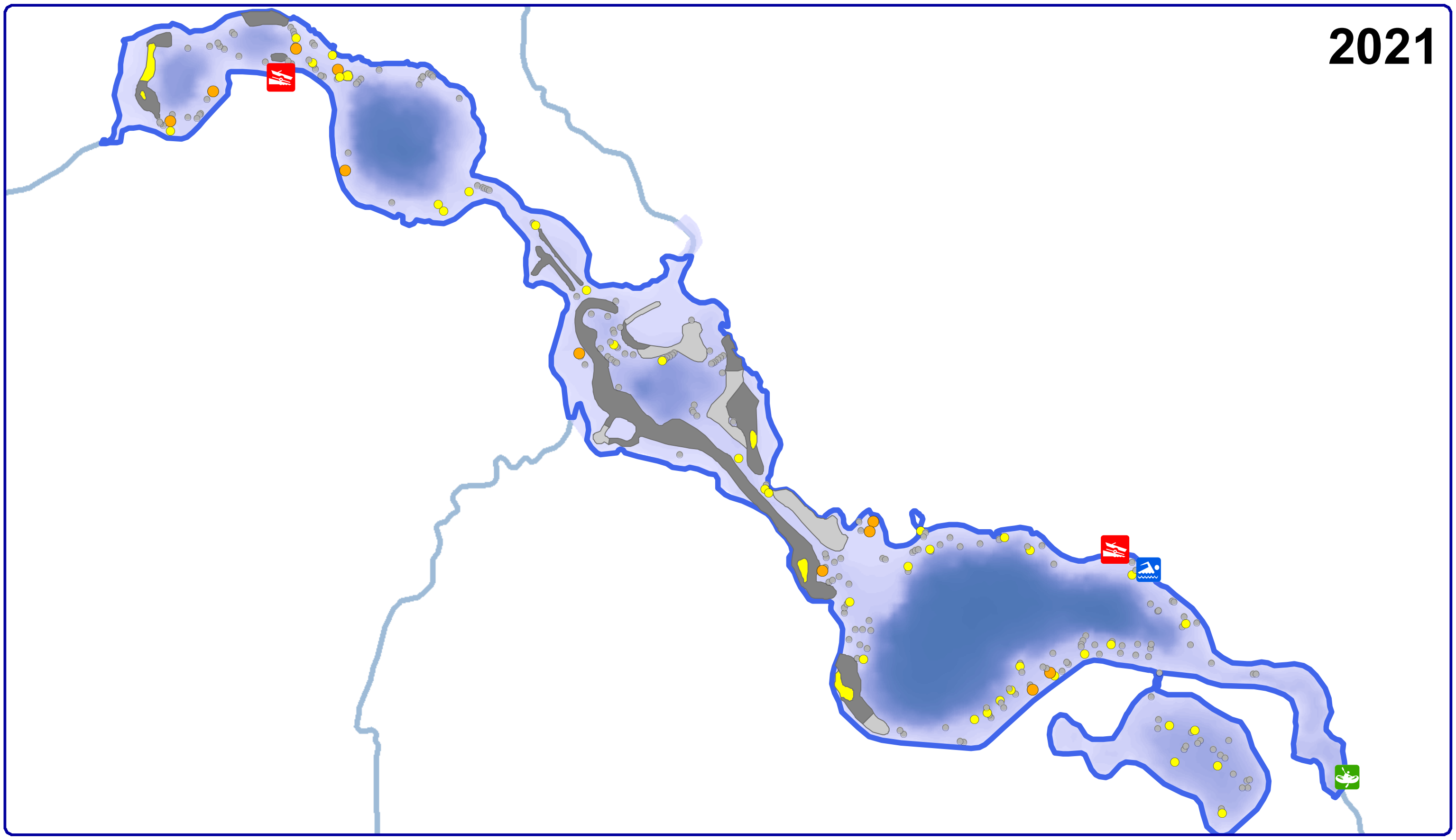
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2019
Aquatic Plants: Onterra, 2023
Orthophotography: NAIP, 2022
Map Date: October 16th, 2023 KLW
Filename: MM_EWM_PB_Oct23.mxd

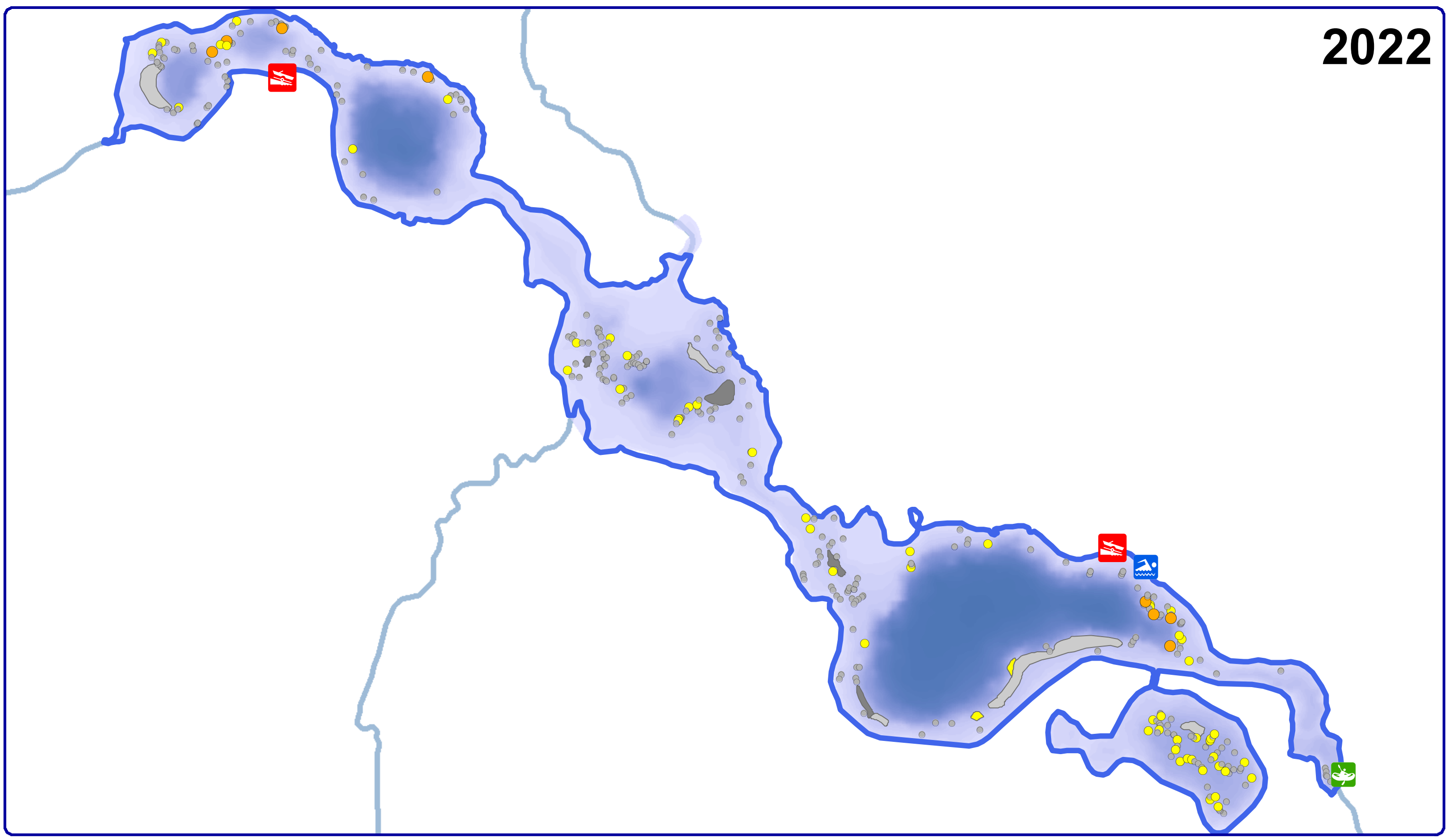
Map 6

Mt. Morris Lake

Waushara County, Wisconsin

2023 Late-Season EWM Survey Results





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Feet

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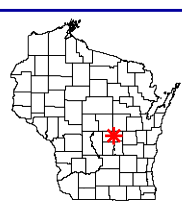
www.onterra-eco.com

Sources:
Hyrdro: WDNR
Plant Survey: Onterra, 2019-2020
Bathymetric Survey: Onterra, 2019
Orthophoto: NAIP, 2018
Map Date: July 1- 2022 - EJH


Project Location in Wisconsin

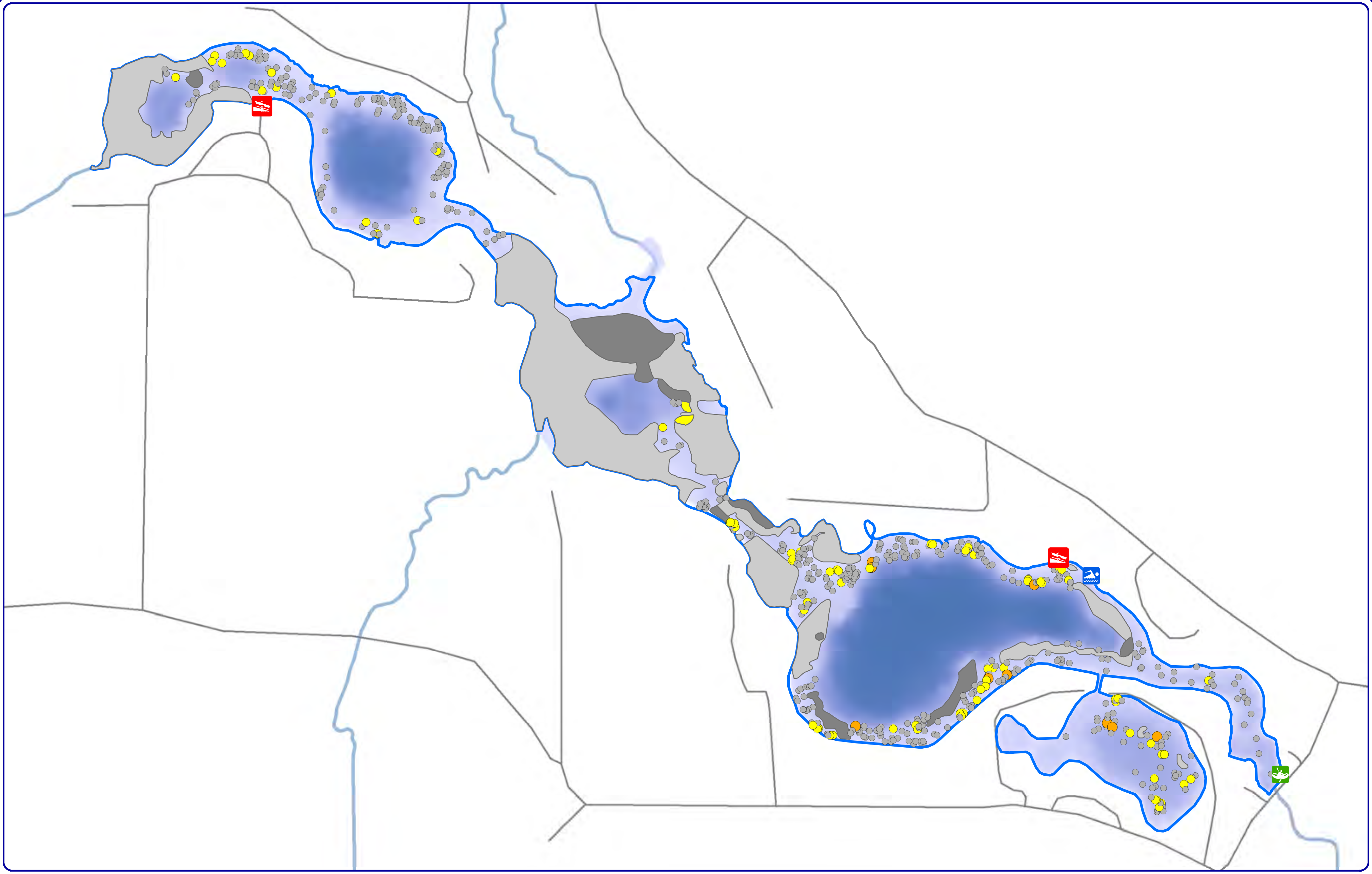
Legend

CLP Survey Results

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

Map 7
Mount Morris Lake
Waushara County, Wisconsin

Early-Season CLP Survey Results



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Feet

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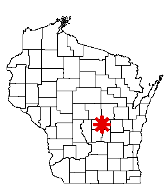
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2019
Aquatic Plants: Onterra, 2023

Map Date: June 21, 2023 AMS



Project Location in Wisconsin

Legend

Curly-leaf Pondweed (June 16, 2023)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(None)*
- Surface Matting *(None)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Public Boat Landing
- Beach Area
- Carry-In Access

Map 8

Mt. Morris Lake

Waushara County, Wisconsin

June 2023 CLP Survey Results

A

APPENDIX A

Littoral Frequency of Occurrence of Aquatic Plants from available Point-Intercept Surveys

- **Mount Morris Lake**
- **Emerald Lake**

Mount Morris Lake

Point-Intercept Aquatic Plant Survey Data Matrix

Scientific Name	Common Name	LFOO (%)									
		2004	2010	2013	2014	2015	2016	2017	2021	2022	2023
Chara & Nitella spp.	Charophytes	48.9	54.7	76.1	74.5	80.2	78.9	78.0	44.9	50.2	52.8
Chara spp.	Muskgrasses	52.6	58.8	76.1	70.7	75.9	76.0	74.9	43.0	43.7	46.7
Vallisneria americana	Wild celery	14.6	16.3	8.9	16.3	17.1	16.7	20.9	21.0	13.1	17.3
Elodea canadensis & E. nuttallii	Common & Slender waterweeds	8.0	9.0	0.0	17.8	18.2	9.8	10.5	22.9	11.3	30.8
Elodea canadensis	Common waterweed	8.0	9.0	0.0	17.8	18.2	9.8	10.5	22.4	11.3	30.8
Ceratophyllum demersum	Coontail	10.9	12.2	16.0	14.9	15.5	6.4	12.6	20.1	10.3	20.1
Myriophyllum spicatum	Eurasian watermilfoil	0.7	0.8	6.1	0.5	1.1	1.5	3.7	20.6	19.2	38.3
Nuphar variegata	Spatterdock	10.9	12.2	13.6	12.5	11.8	10.3	5.2	7.5	0.9	0.5
Stuckenia pectinata	Sago pondweed	4.7	5.3	1.9	1.4	2.7	2.9	6.3	6.1	14.1	2.8
Nitella spp.	Stoneworts	2.2	2.4	0.0	4.8	5.9	7.8	3.1	2.3	7.0	7.5
Nymphaea odorata	White water lily	5.8	6.5	2.8	11.5	5.9	3.4	0.0	2.8	2.8	2.3
Potamogeton crispus	Curly-leaf pondweed	0.7	0.8	2.3	0.0	0.0	0.0	1.0	6.5	2.8	15.9
Najas guadalupensis & N. flexilis	Southern naiad & Slender naiad	6.2	6.9	4.2	1.9	2.1	2.0	1.6	4.2	4.2	3.7
Myriophyllum verticillatum	Whorled watermilfoil	4.7	5.3	1.4	11.1	7.5	2.9	0.0	0.0	0.0	0.0
Potamogeton richardsonii	Clasping-leaf pondweed	4.0	4.5	2.3	3.4	1.6	5.4	1.6	1.9	0.5	2.3
Myriophyllum sibiricum	Northern watermilfoil	2.2	2.4	3.8	4.3	2.7	2.0	2.1	3.7	2.8	2.3
Potamogeton friesii	Fries' pondweed	0.0	0.0	0.5	0.5	1.1	0.0	0.0	4.7	0.0	11.2
Utricularia vulgaris	Common bladderwort	6.9	7.8	1.9	1.9	3.2	1.0	0.5	1.4	0.5	0.0
Najas flexilis	Slender naiad	6.2	6.9	0.0	1.0	0.0	0.0	0.5	0.9	3.8	1.9
Heteranthera dubia	Water stargrass	4.0	4.5	3.8	3.4	0.5	0.0	0.0	1.4	0.5	2.8
Lemna turionifera	Turion duckweed	2.2	2.4	2.8	3.4	0.0	0.0	0.0	7.9	0.0	1.9
Spirodela polyrhiza	Greater duckweed	2.2	2.4	0.5	4.3	3.2	0.0	0.0	4.7	0.5	1.9
Lemna trisulca	Forked duckweed	2.2	2.4	0.5	1.4	1.1	1.0	0.0	5.1	0.9	2.3
Najas guadalupensis	Southern naiad	0.0	0.0	4.2	1.0	2.1	2.0	1.0	3.3	0.5	1.9
Ranunculus aquatilis	White water crowfoot	0.0	0.0	0.0	1.0	0.0	0.5	1.0	2.8	0.9	2.8
Potamogeton zosteriformis	Flat-stem pondweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	5.6	2.3
Lemna minor	Lesser duckweed	0.0	0.0	0.0	0.0	2.7	1.5	1.6	0.0	0.0	1.4
Wolffia spp.	Watermeal spp.	0.0	0.0	0.0	2.4	0.5	0.5	0.0	2.3	0.0	0.9
Potamogeton illinoensis	Illinois pondweed	1.5	1.6	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.5
Potamogeton gramineus	Variable-leaf pondweed	0.0	0.0	0.0	0.5	0.5	0.5	1.6	0.9	0.9	0.9
Potamogeton berchtoldii & P. pusillus	Slender and small pondweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.9
Potamogeton berchtoldii	Slender pondweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.9
Potamogeton praelongus	White-stem pondweed	0.7	0.8	0.0	0.5	0.5	0.5	0.0	0.5	0.5	0.0
Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Schoenoplectus acutus	Hardstem bulrush	0.4	0.4	0.0	0.5	0.5	1.0	0.0	0.0	0.0	0.0
Potamogeton foliosus	Leafy pondweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Lychnothamnus barbatus	Bearded stonewort	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.9	0.0
Eleocharis acicularis	Needle spikerush	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.9	0.0	0.0
Zannichellia palustris	Horned pondweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Sparganium eurycarpum	Common bur-reed	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0
Potamogeton strictifolius	Stiff pondweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0
Pontederia cordata	Pickerelweed	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0
Eleocharis erythropoda	Bald spikerush	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sagittaria cuneata	Arum-leaved arrowhead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Elodea nuttallii	Slender waterweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0

Emeral Lake

Point-Intercept Aquatic Plant Survey Data Matrix

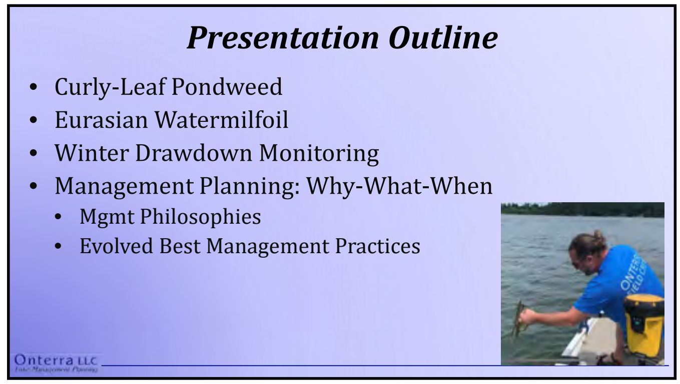
Scientific Name	Common Name	LFOO (%)				
		2010	2014	2021	2022	2023
Chara & Nitella spp.	Charophytes	53.1	46.9	59.4	59.4	68.8
Chara spp.	Muskgrasses	53.1	46.9	56.3	59.4	65.6
Najas guadalupensis & N. flexilis	Southern naiad & Slender naiad	34.4	37.5	53.1	25.0	31.3
Vallisneria americana	Wild celery	15.6	25.0	31.3	25.0	43.8
Najas guadalupensis	Southern naiad	0.0	21.9	50.0	18.8	28.1
Myriophyllum spicatum	Eurasian watermilfoil	0.0	0.0	18.8	25.0	43.8
Myriophyllum sibiricum	Northern watermilfoil	3.1	9.4	18.8	3.1	28.1
Najas flexilis	Slender naiad	34.4	15.6	3.1	6.3	3.1
Elodea canadensis & E. nuttallii	Common & Slender waterweeds	0.0	0.0	25.0	18.8	6.3
Potamogeton illinoensis	Illinois pondweed	12.5	3.1	15.6	0.0	12.5
Elodea canadensis	Common waterweed	0.0	0.0	15.6	18.8	6.3
Potamogeton friesii	Fries' pondweed	0.0	0.0	18.8	0.0	9.4
Stuckenia pectinata	Sago pondweed	0.0	0.0	9.4	25.0	0.0
Potamogeton richardsonii	Clasping-leaf pondweed	9.4	0.0	0.0	18.8	3.1
Heteranthera dubia	Water stargrass	0.0	0.0	9.4	0.0	12.5
Nymphaea odorata	White water lily	12.5	6.3	3.1	3.1	0.0
Potamogeton zosteriformis	Flat-stem pondweed	0.0	0.0	3.1	18.8	0.0
Potamogeton crispus	Curly-leaf pondweed	0.0	0.0	3.1	6.3	3.1
Potamogeton gramineus	Variable-leaf pondweed	0.0	3.1	9.4	0.0	0.0
Nitella spp.	Stoneworts	0.0	0.0	6.3	0.0	3.1
Elodea nuttallii	Slender waterweed	0.0	0.0	9.4	0.0	0.0
Potamogeton pusillus	Small pondweed	0.0	0.0	0.0	0.0	3.1
Potamogeton praelongus	White-stem pondweed	0.0	0.0	0.0	0.0	3.1
Potamogeton foliosus	Leafy pondweed	0.0	0.0	0.0	0.0	3.1
Nuphar variegata	Spatterdock	3.1	3.1	0.0	0.0	0.0
Ceratophyllum demersum	Coontail	0.0	0.0	0.0	6.3	0.0
Utricularia vulgaris	Common bladderwort	3.1	0.0	0.0	0.0	0.0
Spirodela polyrhiza	Greater duckweed	0.0	0.0	3.1	0.0	0.0
Lemna trisulca	Forked duckweed	0.0	0.0	3.1	0.0	0.0

B

APPENDIX B

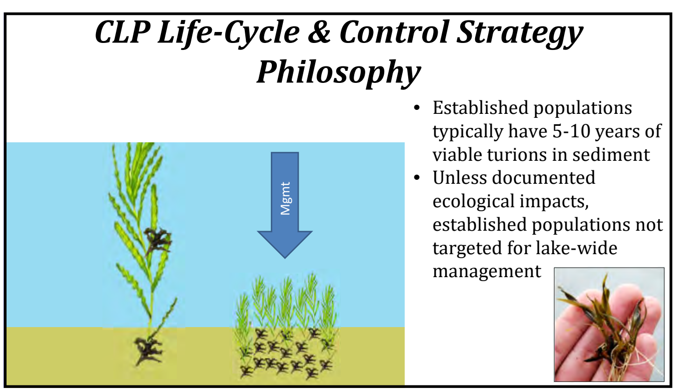
Mount Morris Drawdown Results Meeting Presentation Handout

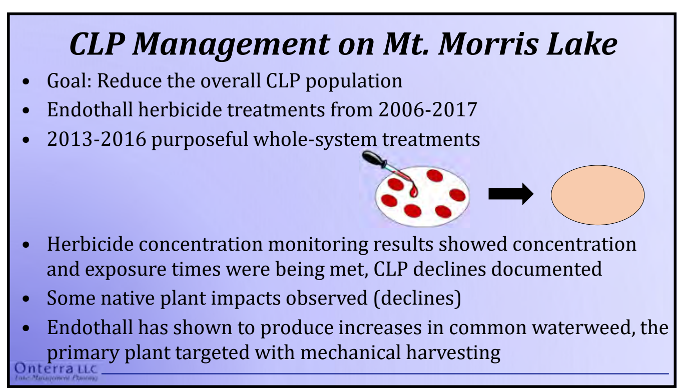

Mount Morris Lake
Management District
Winter Drawdown Mentoring
Year of Refill Info Mtg
June 24, 2023
Eddie Heath
Onterra LLC
Lake Management Planning
AEPP-651-22


Presentation Outline
• Curly-Leaf Pondweed
• Eurasian Watermilfoil
• Winter Drawdown Monitoring
• Management Planning: Why-What-When
• Mgmt Philosophies
• Evolved Best Management Practices
Onterra LLC


EWM
Biology & Management


Non-Native Aquatic Plants
Curly-Leaf Pondweed
• Established population, present in 2004 when Onterra first worked on the lake
• CLP senescence largely occurs by July 4th Weekend in many years


CLP Life-Cycle & Control Strategy Philosophy
Mgmt
• Established populations typically have 5-10 years of viable turions in sediment
• Unless documented ecological impacts, established populations not targeted for lake-wide management


CLP Management on Mt. Morris Lake
• Goal: Reduce the overall CLP population
• Endothall herbicide treatments from 2006-2017
• 2013-2016 purposeful whole-system treatments
• Herbicide concentration monitoring results showed concentration and exposure times were being met, CLP declines documented
• Some native plant impacts observed (declines)
• Endothall has shown to produce increases in common waterweed, the primary plant targeted with mechanical harvesting
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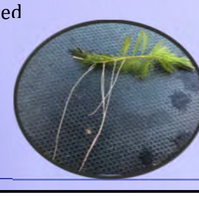
Non-Native Aquatic Plants
Eurasian Watermilfoil

- **Established population, present in 2004 when Onterra first worked on the lake**
- **Confirmed pure-strain and hybrid population in system**

EWM Propagation

- **Produces seed, but low viability**
- **Spread primarily through fragments, a vegetative clone**

Auto-fragment
- Purposefully produced
- High energy storage
- Higher viability



Allo-fragment
- Mechanical breakage
- Low energy storage
- Lower viability

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EWM Management on Mt. Morris Lake

- Goal: Reduce the overall EWM/HWM population
- Herbicide treatments from 2008-2017
- Some treatments designed as spot treatments, some as whole-basin treatments
- Herbicide concentration monitoring results showed concentration and exposure times were NOT being met
- Some native plant impacts observed (declines)
- Many different herbicides and combinations attempted, all only produced seasonal suppression with complete rebound
- Considered winter drawdown as an EWM management tool

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Water Level Management

Drawdown as a Lake Management Tool

Why do lake groups utilize drawdowns?

Aquatic Invasive Plant Management →	*If the lake can be lowered far enough, winter drawdowns typically work well (roughly Labor Day – Memorial Day)*
Native Plant Restoration/Enhancement Sediment Decomposition/Consolidation }	*Must include significant sediment exposure over much of the growing season (winter-summer-winter)*
Shoreline Modification/Dredging →	*Two-week water level reduction nearly anytime of year*

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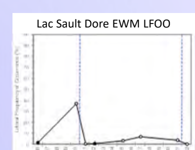
Reduce AIS Populations



- EWM/HWM have been shown to be impacted greatly by drawdowns
  - Winter drawdown has shown to be sufficient
  - Needs to desiccate and freeze the root crown
  - Cold and dry winter conditions are the best
  - Will not be effective if sediment remains hydrated by snow, winter rains, or hydraulic springs

- CLP response to drawdown is variable
  - Winter drawdowns have reduced CLP populations for a few years following event
  - Turions in sediment may be protected from desiccation and freezing

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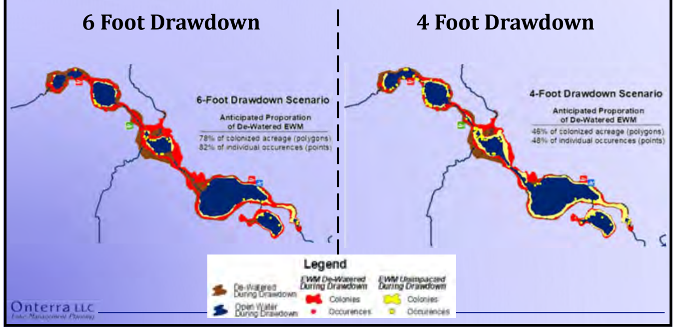
Reduce EWM Populations



Winter 2021-2022 Drawdown

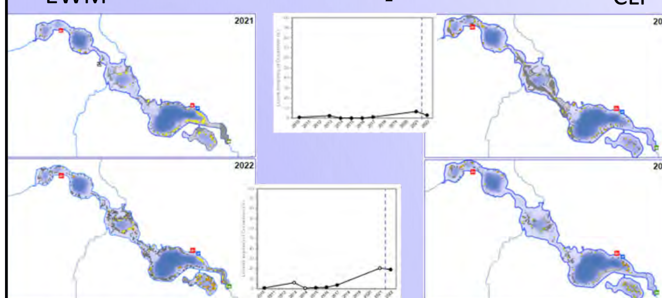
- 2021 District advisory referendum passed (70% favor)
- WDNR permit approved, and 2-yr monitoring grant awarded
- 6 ft dewatered at dam from Sept 15, 2021 to May 5, 2022
- Good channel cutting, so lakes A, B, C probably received between 4-6 ft drawdown (Emerald only 2 ft)
- Moderate insulating snowfall coverage in Jan-Feb

Winter 2021-2022 Drawdown

Results: AIS Population

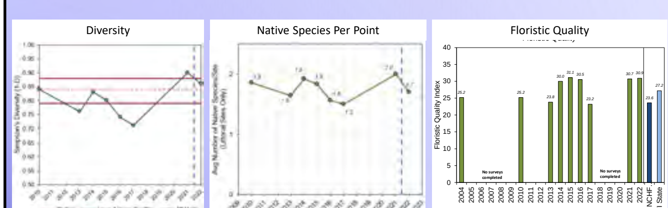
EWM

CLP



Results: Floating-Leaf Community

Results: Submergent Plant Community



Winter 2021-2022 Drawdown Summary

- *Year of refill* results indicate EWM control goals were not met
- CLP population may have dipped in 2022, but expansion in 2023
- Submergent plant community is healthy, potentially causing user impacts
- Floating-leaf community impacted greater than predictions
- Not much depth gained aside from channel cutting
- Recommendation: district to update their APM Plan accordingly

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Why Create a Lake Management Plan?

- Preserve/restore ecological function
- To create a better understanding of lake's positive and negative attributes.
- To discover ways to minimize the negative attributes and maximize the positive attributes.
- Snapshot of lake's current status or health.
- Foster realistic expectations and dispel any misconceptions.

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What is a Lake Management Plan?

- Many organizations have "plans" for managing Mount Morris and it's watershed
- This is the Mount Morris Lake Management District's *Plan* for managing Mount Morris Lakes
  - Based upon the district's capacity
  - Addressing the district's concerns
  - Complimentary to other *Plans*
  - Acknowledging the Public Trust Doctrine

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Management Plan and Grants

- WDNR recommends ***Comprehensive Management Plans*** generally get updated every 10 years
  - Particularly for grants/permits related to water quality improvements (implementation grants)
- WDNR recommends lakes conducting active management update aspects of the plan every 5 years (***APM Plan***)
  - Particularly for grants/permits related to aquatic plant management (AIS control grants, NR107, NR109)
  - Whole-lake PI survey needs to be within 5 years
  - Management action in AIS Grant needs to be supported by Plan

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AIS Management Perspectives

1. **Reduce AIS Population on a lake-wide level (Population "Control")**
   Will not "eradicate" EWM or CLP
   - Would likely rely on herbicide treatment (risk assessment)
   - Set triggers (thresholds) of implementation and tolerance
   - Sometimes is not consistent with regulatory framework
   - Not achievable on some systems

2. **No Coordinated Active Management (Let Nature Take its Course)**
   - If desired, manual removal efforts directed by property owners
3. **Minimize navigation and recreation impediment (Nuisance Mgmt)**
   - Target areas with herbicide spot treatments and/or mechanical harvester to restore navigation & recreation capacity

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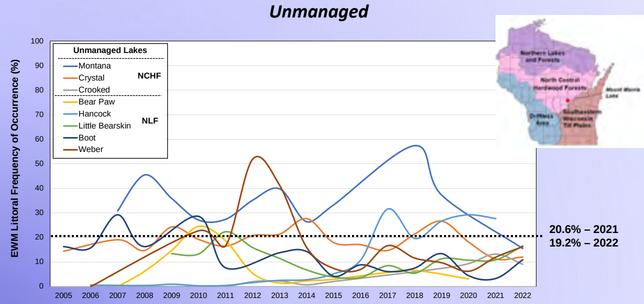
WDNR EWM Long-Term Monitoring Trends

Unmanaged



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NR107 (Herbicide) & NR109 (Mechanical)

Purpose

- Management of *nuisance-causing* aquatic plants in a manner consistent with sound ecosystem management and where the loss of ecological values is minimized

Interpretation

- Discourage herbicide use for native plants, even if nuisance causing
- Best if action is outlined in a Management Plan
- Encourages the management technique with the least ecological impact, which is often inferred as drawdown>mechanical>herbicide
- Protection of native habitats

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Best Management Practices (BMPs)

- **A "placeholder" term to represent the management option that is currently supported by that latest science and policy**
- **Definition evolves over time**
  - ***Pre 2010*** - small spot treatments, granular 2,4-D for EWM
  - ***Early 2010s*** - larger spot treatments, liquid 2,4-D (amine) for EWM
  - ***Mid 2010s*** – whole-lake/basin treatments, spot treatments with herbicide combos, hand-harvesting/DASH for small sites
  - ***Current***– new herbicides, continued whole-lake/basin approaches, nuisance maintenance vs population management, mechanical harvesting, increasing human tolerance, allow nature to take its course

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Florpyrauxifen-benzyl (ProcellaCOR™)

- New class of synthetic auxin hormone mimics
  - Different binding affinity than other auxins (2,4-D/Triclopyr)
  - Use at PPB rate vs PPM
- Shorter contact exposure time (CET) requirement
- Short environmental fate of active ingredient, acid metabolite longer environmental fate (activity on plants)
- Detailed information on field applications is limited (first in 2019 in WI)
- *Reduced Risk Status* granted by EPA
- Safer ≠ Safe

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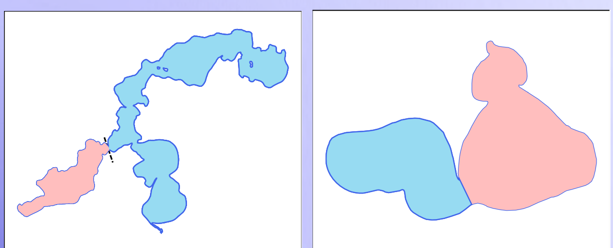
Area of Potential Impact (AOPI)

- Mixing area, reaches equilibrium - basin or bay of a lake



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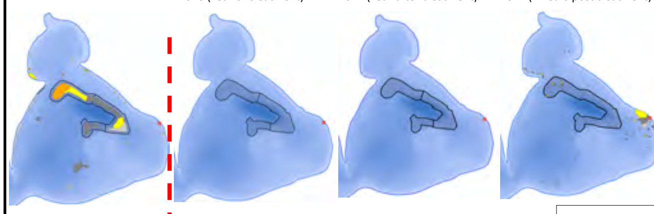
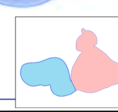
HWM

Berry Lake (Oconto Co.)

2019 (Year before treatment)
2020 (Year of treatment)
2021 (Year after treatment)
2022 (2-Years post treatment)



Application Area: 10.0 acres
Application Rate: 4.0 PDU
Basin-wide (131 acres) Calculation: 0.67 ppb



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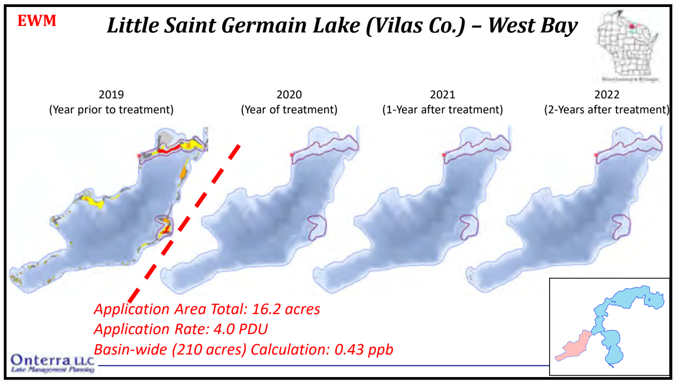

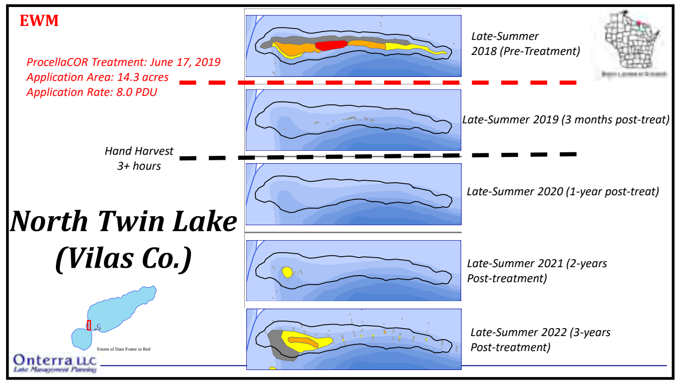

ProcellaCOR impacts on Aquatic Plants

- EWM control for 3-4 years, potentially longer particularly if follow-up hand-harvesting is conducted
- Northern watermilfoil is greatly impacted and may not come back as quickly as EWM
- Some other native plants impacted (reduced by 50%): coontail, water marigold, possibly water stargrass
- Water lilies will be stressed but typically rebound
- Pondweeds and most other native plants are largely unimpacted

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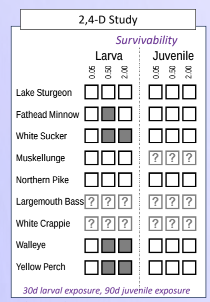
Herbicide impacts on Fish

- Baseline screening of ProcellaCOR for EPA at spot-treatment use patterns (high & short) indicated *Practically nontoxic* to freshwater fish
- At whole-lake concentrations and exposure times (low & long), some fish species have been proven to be impacted by 2,4-D
  - When exposed to egg (deformities) and larval stage (survivability)
  - First 14 days post hatch is most sensitive period
- ProcellaCOR is a similar "type" of herbicide (auxin hormone mimic), so similar impacts to fish at long & low exposures are likely



Dehnert et al. 2021

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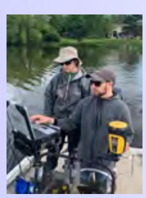
APM Planning Summary

- MMLMD needs to revisit AIS management goals
  - Long- and short-term
  - Cost-benefit of various mgmt. actions
- Sufficient aquatic plant data exists, unless want to wait until drawdown impacts stabalize
- Understand perceptions and perceived needs of district members – stakeholder survey
- Core committee needs to learn how APM BMPs and regulatory philosophy have evolved



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Thank You

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Lake Management Planning

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