Comprehensive Lake Management Plan

for

Big and Little Twin Lakes and Spring Lake, Green Lake County, Wisconsin

Prepared for:

The Twin Lakes Association

and

The Green Lake County Land Conservation Department

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Introduction

Project Area

Twin Lakes (Big Twin Lake and Little Twin Lake) and Spring Lake are glacial pothole lakes located in the rolling hills of east-central Green Lake County, just south of Green Lake (**Figures 1-3**). The lakes lie within an area of the county generally dominated by agriculture. Twin Lakes are drainage lakes receiving surface water from an unnamed creek which enters along the east shore of Big Twin Lake. The outlet to Twin Lakes is Hill Creek which drains from the northeast end of Little Twin Lake and flows to Green Lake. Both Twin Lakes and Spring Lake have public accesses with boat ramps. Public access to Little Twin Lake is through a narrow channel from Big Twin Lake. The wetlands surrounding Twin Lakes, which are largely dominated by cattails provide important habitat for waterfowl and other wildlife.

Twin Lakes and Spring Lake are popular with boaters coming from Big Green Lake, which contains many invasive species. The lakes are also highly prized by local anglers year-round for their quality fisheries. Big and Little Twin and Spring Lakes support fisheries of, northern pike (*Esox lucius*), walleye (*Sander vitreus*), largemouth bass (*Micropterus salmoides*), and panfish (WNDR 2005). Waterfowl frequent these lakes during nesting and migration seasons. As a result, the lakes receive moderate waterfowl hunting pressure in the fall.

Two invasive plant species, Eurasian watermilfoil (*Myriophyllum spicatum*) (EWM) and curly leaf pondweed (*Potamogeton crispus*) (CLP) are found in all three lakes.

Big Twin Lake is 74 acres in size with a maximum depth of 46 feet and a mean depth of 17 feet. The shores of Big Twin Lake are predominantly upland. The north and southwest shorelines which represent about a third of the lake shoreline, are moderately developed with cottages and year-round homes. The remaining shoreline is largely undeveloped.

In 2014, Big Twin Lake was categorized as an impaired water (303(d)) by the Wisconsin Department of Natural Resources (WDNR). According to the WDNR, this lake *"is impaired due to one or more pollutants (*total phosphorus*) and associated quality impacts (*excess algae growth*). This water was assessed during the 2014 listing cycle; total phosphorus and chlorophyll sample data exceed 2014 WisCALM listing thresholds for the Recreation use. Total phosphorus and chlorophyll data do not exceed Fish and Aquatic Life thresholds. This water was assessed during the 2016 listing cycle; total phosphorus and chlorophyll sample data exceeded 2016 WisCALM listing thresholds for the Recreation use. Total phosphorus and chlorophyll data do not exceed Fish and Aquatic Life thresholds."*

Little Twin Lake is 21 acres in size with a maximum depth of 10 feet and a mean depth of 4 feet. Big Twin and Little Twin Lakes are connected by a narrow, yet navigable channel. The shores of Little Twin Lake are mostly undeveloped and predominantly a cattail bog. Little Twin Lake provides important spawning habitat for the fish from Big Twin. The lake receives light fishing pressure and moderate duck hunting pressure.

Figure 1. Spring, Big Twin and Little Twin Lakes in Green Lake County, Wisconsin.

Hill Creek drains Twin Lakes. During periods of low precipitation, the creek may dry up. In 2015, Hill Creek was also categorized as an impaired water (303(d)) by the WDNR. *"Water is impaired due to one or more pollutants (*total phosphorus*) and associated quality impacts (*Degraded Biological Community*). Hill Creek is on the 303(d) list for degraded habitat caused by total suspended solids in the water. This water was assessed during the 2016 listing cycle; total phosphorus sample data exceed 2016 WisCALM listing criteria for the Fish and Aquatic Life use and biological impairment was observed (i.e. at least one macroinvertebrate or fish Index of Biotic Integrity (IBI) scored in the poor condition category).* In the case of Hill Creek, the stream contains high nutrients and is often polluted with agricultural runoff. Bank erosion is responsible for serious fish and game habitat destruction. A small dam and fish barrier is constructed on the outlet to prevent carp from entering from Green Lake.

Figure 2. Big and Little Twin Lakes, Green Lake County, Wisconsin.

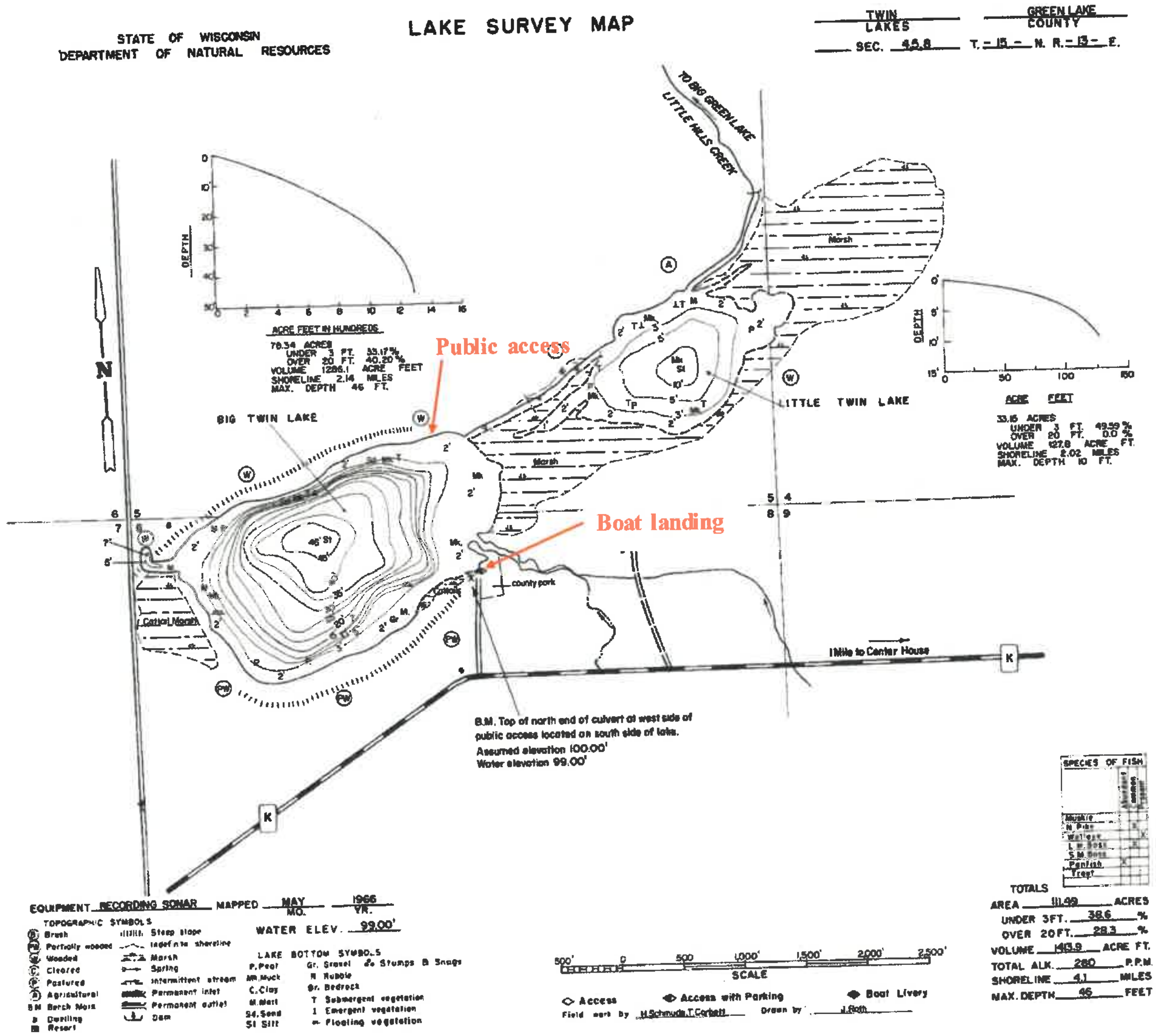
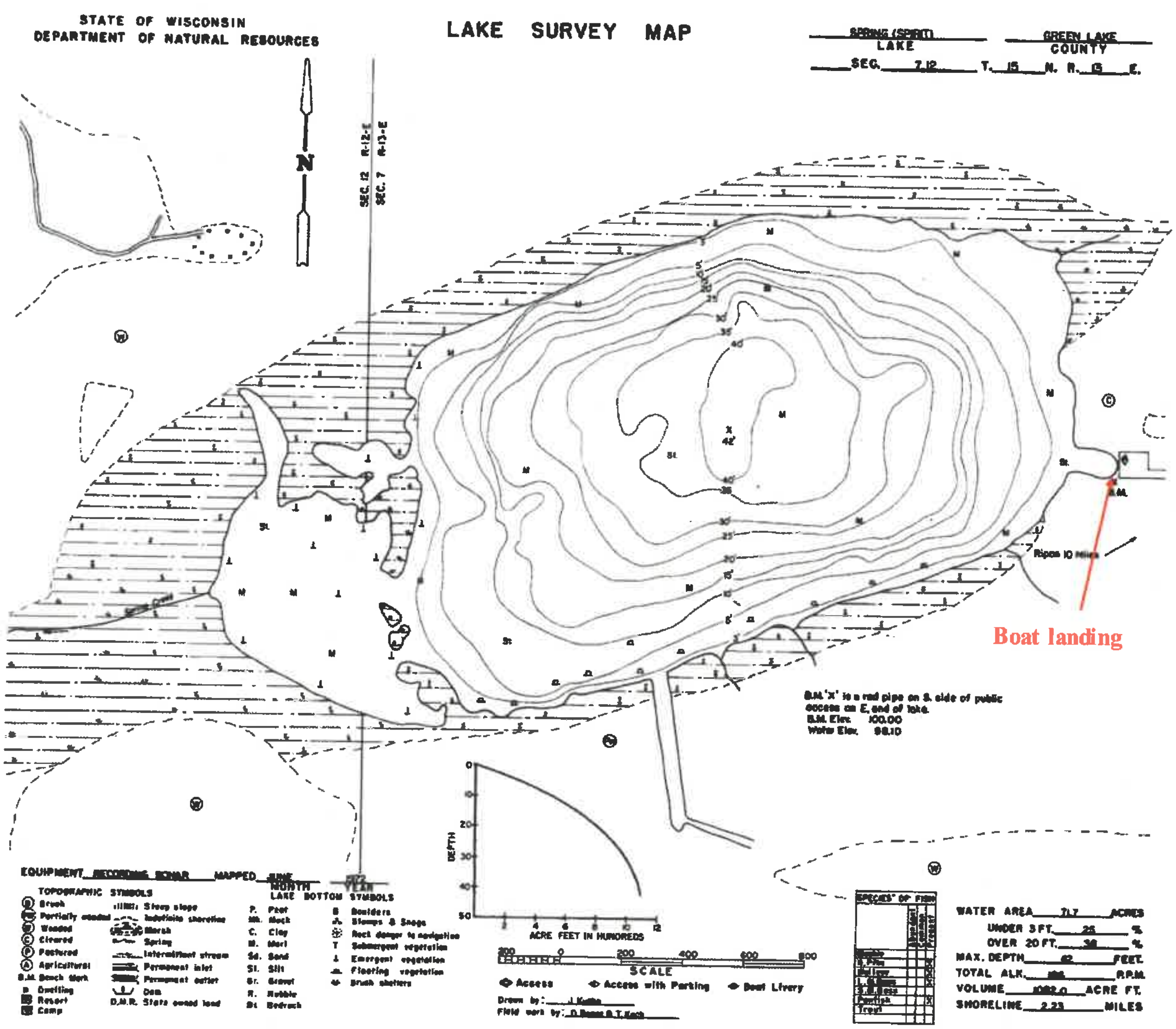


Figure 3. Spring Lake, Green Lake County, Wisconsin.



Spring Lake is located west of Twin Lakes and is 62 acres in size with a maximum depth of 54 feet and an average depth of 16 feet. Spring Lake is a seepage lake which also drains to Green Lake through Spring Creek. The shoreline is mostly undeveloped and has a marl bottom.

The Twin Lakes Association represents the interests of approximately 50 lakeshore property owners and other lake users. There are a small number of property owners on Spring Lake, but no formal lake organization. A majority of the riparian property owners on Twin Lakes are long-term, seasonal residents. Recreation (primarily fishing and boating) and relaxation are very important to the residents. They are concerned about possible declines to the fishery, excessive weed growth and other impacts from aquatic invasive species (AIS). Excessive weed growth has been a major issue for a number of years. In recent years, Twin Lakes has also experienced poor water quality. The lakes have suffered from severe summer algae blooms, poor water clarity, and low dissolved oxygen levels. High levels of nutrients have contributed to the poor water quality found in Twin Lakes. Spring Lake has not suffered the same declines in water quality.

The Twin Lakes Association sponsored a Lake Management Plan in 2006 with grant money from the WDNR. Faced with increasing threats from invasive exotic plants, the Association partnered with the Green Lake County Land Conservation Department (LCD) in 2007 to undertake additional lake management efforts. Under the plan, the association developed an AIS control plan, and received a grant in 2008 for the control and containment of EWM and CLP. The association continued chemical treatment and containment efforts for 6 years, with good results.

The following are the summaries of three grants Twin Lakes have received from 2004 to 2010.

TWIN LAKES ASSN INC.: Twin Lakes Comprehensive Lake Management Plan

The Twin Lakes Association proposes to conduct a lake study which will include lake monitoring and plant appraisals, specifically: 1. Conduct an submergent aquatic plant appraisal via line-transect methodology including an assessment of invasive species, esp. Eurasian water milfoil 2. Conduct a emergent plant appraisal via line transect -transect methodology 3. Conduct an appraisal of trophic conditions within each of 2 lake basins including oxygen and temperature profiling, TSI determinations 4. All findings will be presented in a final report with management recommendations. Specific actions are identified within the original planning grant proposal.

Project Type	LAKE_GRANT - Large Scale Lake Planning
Project ID	LPL-960-04
Year Started	2004
Status	COMPLETE

Activities

Monitor Invasive Species
Comprehensive Planning Studies
Aquatic Plant Monitoring or Survey

TWIN LAKES ASSN INC.: Twin Lakes Comprehensive Appraisal Phase 2

The Twin Lakes Association proposes to continue their efforts toward a comprehensive appraisal of their lake. This project will include the development of a hydrologic budget, trophic appraisal with modeling, and lake nutrient budget model, watershed assessment.

Project Type LAKE_GRANT - Large Scale Lake Planning
Project ID LPL-1016-05
Year Started 2005
Status COMPLETE

Activities

WQ Modeling
Nutrient Budget Development
Hydrologic Budget Development

GREEN LAKE COUNTY: Big & Little Twin Lakes AIS Management Project

Amended 9.28.10: The Green Lake County Department of Land Conservation proposes to control curly-leaf pondweed (CLP) and Eurasian water-milfoil (EWM) through chemical treatment and preventative measures in Big and Little Twin Lakes during the period 2008 - 2012. The project elements and deliverables are specified in Green Lake County's Department of Land Conservation Aquatic Invasive Species Control Grant Application, dated January 29, 2008. The project includes conducting annual pre-treatment and post-treatment surveys to monitor the extent of CLP and EWM and efficacy of treatments; treating CLP and EWM infested areas with aquatic herbicides; reconfiguring the boat launch and installing a carp gate to deter free-floating aquatic invasive plants and carp migration; hiring a county intern to conduct education and prevention activities to prevent further AIS infestations, including training local residents in "Clean Boats Clean Waters", placing signs at boat landings, and plan public outreach materials.

Project Type AIS_GRANT - Aquatic Invasives Control
Project ID ACEI-040-08
Year Started 2008
Status COMPLETE

Activities

Watercraft Inspections - Clean Boats, Clean Waters
Install Kiosk or Sign
Control Invasive Species
Aquatic Plant Monitoring or Survey
Monitor Pre and Post Treatment
Monitor Invasive Species

The Twin Lakes Association has previously taken part in the Clean Boats, Clean Waters program to monitor boat activity at the landing on Big Twin Lake to prevent the movement of AIS into and out of Twin Lakes. Currently, a county AIS coordinator conducts this activity. The boat landing also has a large sign alerting lake users to the risk of invasive species.

The current study has been partially funded through a Lake Planning Grant from the WDNR. It is intended to enhance the ability of the Green Lake County Land Conservation Department and the Twin Lakes Association to develop, promote, and implement an effective long-range plan to protect the water quality and plant and animal communities
The primary goals of this study are:

1) to gather baseline information on the physical, chemical and biological health of Big & Little Twin Lakes and Spring Lake,
2) to gather data on the current and historic water quality of these lakes,
3) to assess the distribution and density of nuisance exotic and beneficial native aquatic plant species through lake surveys,
4) to assess the watersheds and shoreline habitats on each lake and
5) to provide information needed to make informed decisions regarding the future management of the lakes both ecologically and sociologically.

Methods for Field Studies

Aquatic Plant Assessment

On July 21st and 25th, 2016, submergent aquatic plant surveys were conducted on Twin Lakes and Spring Lake utilizing methods developed by the WDNR. The Department's Bureau of Research developed plant survey maps for each of the three waterbodies. Within each waterbody, a series of grid points were mapped **(Figures 4-6, Table 1)**. At each of these locations, aquatic plant samples were collected from a boat with a single rake tow. All plant samples collected were identified to *genus* and *species* whenever possible, and recorded. An abundance rating was given for each species collected using the criteria established by the WDNR (Hauxwell, et al., 2010) **(Figure 7)**. Data collected was used to determine species composition and diversity, percent frequency and floristic quality.

Table 1. Details of the point-intercept plant survey grids for Big and Little Twin and Spring Lakes, Green Lake County, Wisconsin.

Waterbody	Size (acre)	Number of sample points	Grid spacing (m)	Year map created
Big Twin Lake	74	283	32	2006
Little Twin Lake	20.6	96	30	2015
Spring Lake	62	180	37	2008

Two datasets from previous point-intercept surveys were obtained from the WDNR. There are from Big Twin Lake on August 29, 2006 and Spring Lake on June 30, 2008. These data were compared to the 2016 data. Results show where statistically significant changes took place for individual plant species.

Figure 4. Aquatic plant survey map provided by the Wisconsin DNR for Big Twin Lake, Green Lake County, Wisconsin.

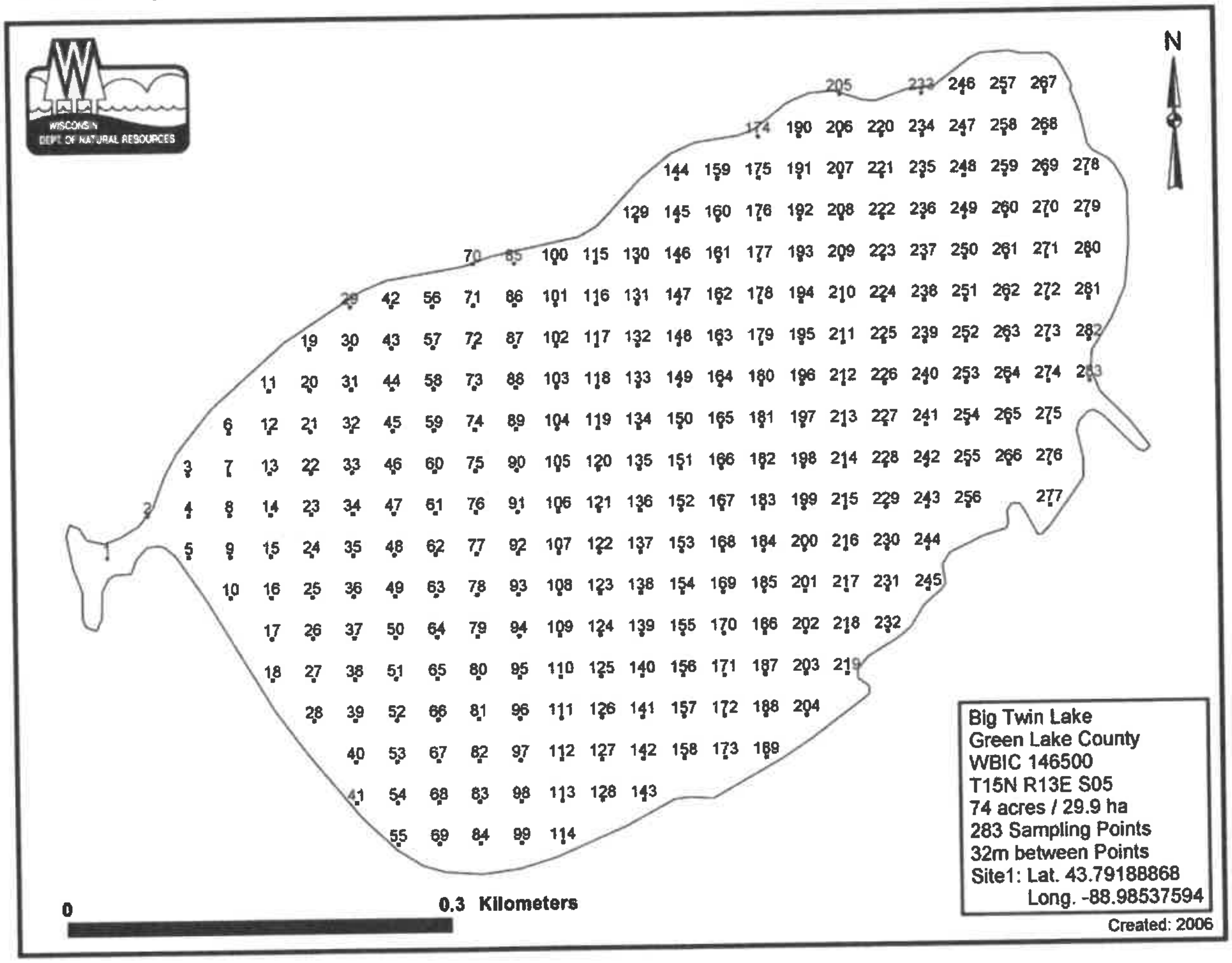


Figure 5. Aquatic plant survey map provided by the Wisconsin DNR for Little Twin Lake, Green Lake County, Wisconsin.

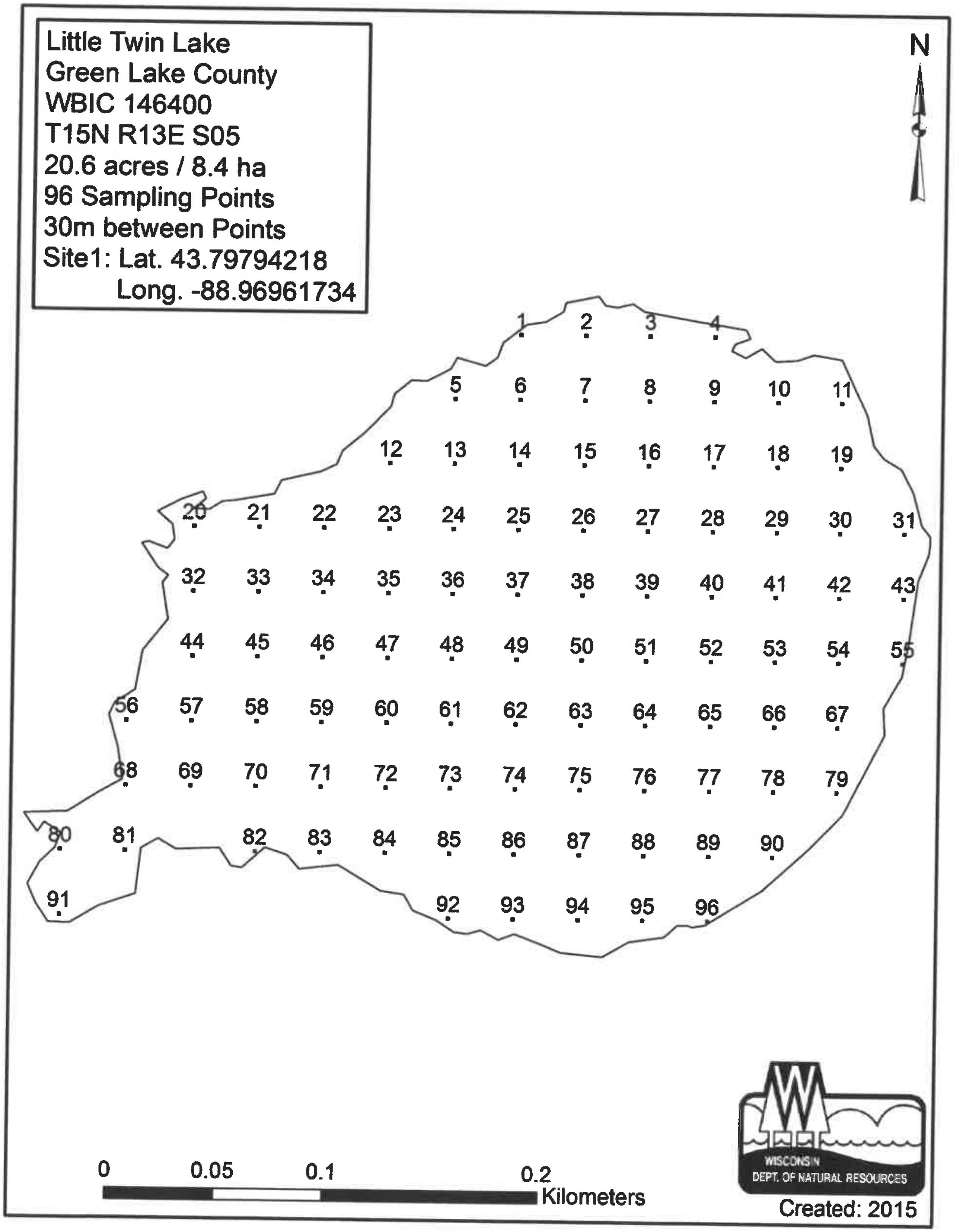


Figure 6. Aquatic plant survey map provided by the Wisconsin DNR for Spring Lake, Green Lake County, Wisconsin.

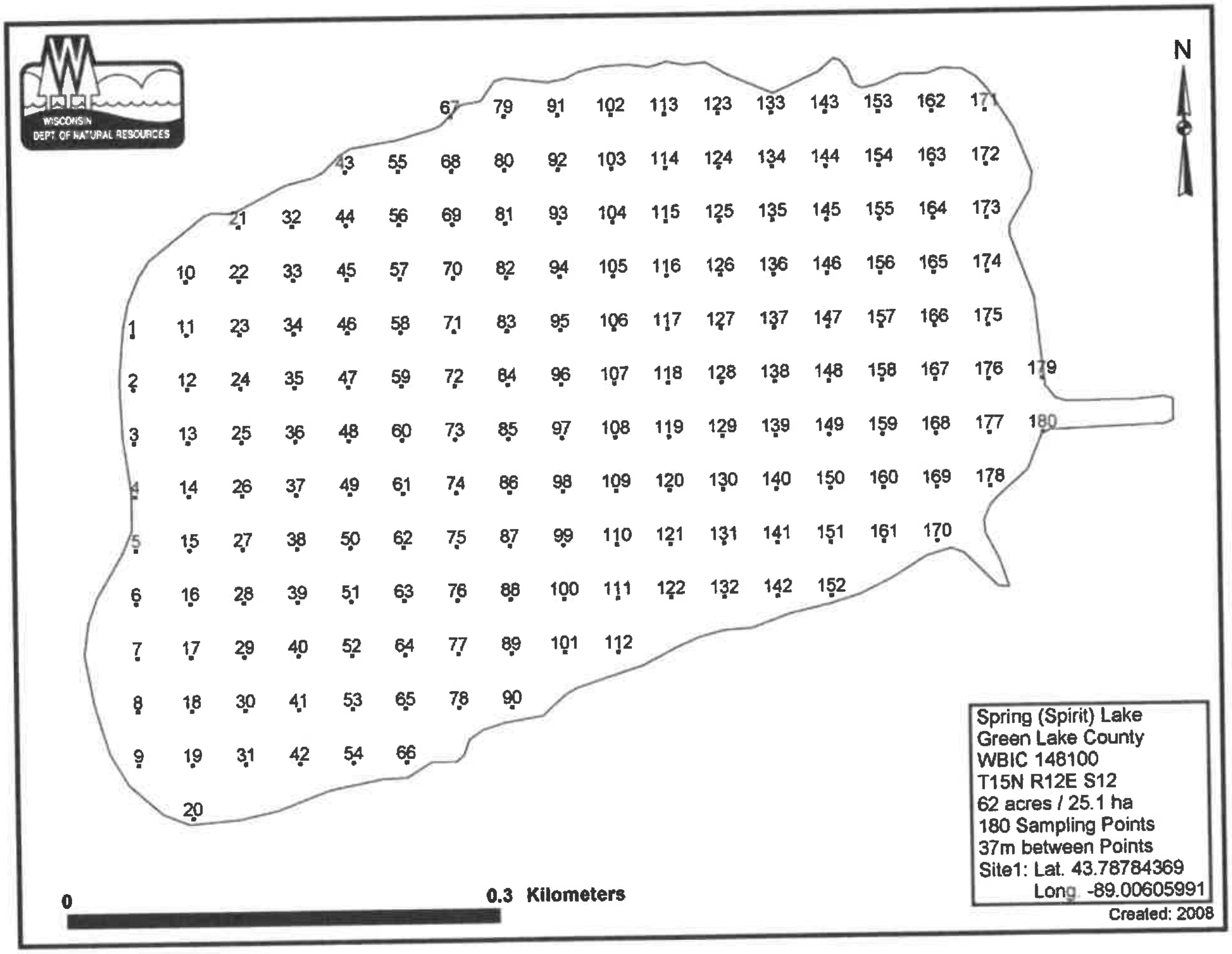


Figure 7. Plant abundance rating criteria used in submergent aquatic plant surveys.

Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

Aquatic Invasive Species (AIS) Distribution Mapping

In order to best manage AIS in the lakes, detailed mapping surveys were conducted on June 2nd and October 17th, 2016 by Cason & Associates staff. The purpose of these surveys was to accurately document the distribution and abundance of EWM and CLP. CLP has a unique life-cycle. It is a cold-water species that begins growing early in the year, just after ice out. Late in the spring, it produces vegetative reproductive structures called turions. When the water temperatures rise in the summer, the CLP plants die back and the turions fall to the bottom of the lake. The following spring, these turions sprout into new plants. CLP management is complicated by the fact these turions can remain viable in the sediment for a number of years. Because of the nature of CLP, spring surveys are the best time of the year to locate and map this species. EWM, on the other hand, is best surveyed in the late summer or fall when the plants are at their largest.

The AIS distribution mapping surveys were performed using surface observations, sonar and rake tows to verify locations. The locations of the beds were drawn on a lake map. Waypoints with GPS coordinates were recorded at each bed to accurately map their locations and size using ArcMap mapping software.

Water Quality Assessment

As part of this study, water quality samples were collected from each lake four times; in the spring following turnover (May 23rd), July 21st, September 19th and October 25th, 2017. Due to a scheduling mishap, the planned August sampling did not take place and an October date was added. Samples were collected from six locations: the deepest point of each lake basin, the Twin Lakes inlet, Twin Lakes outlet and the Spring Lake outlet (**Figure 8**). During these sampling events the following parameters were measured:

- pH, conductivity, alkalinity (spring only)
- Nitrates & nitrites (spring only)
- Kjeldahl Nitrogen (spring only)
- Total phosphorus
- Chlorophyll *a*
- Water transparency (Secchi depth)
- Dissolved oxygen profile
- Temperature profile

Table 2 contains a sampling schedule for water quality monitoring. Water samples were sent to the State Laboratory of Hygiene for analysis. Measurements of water transparency, dissolved oxygen and temperature were collected on-site during each sampling event. Dissolved oxygen and temperature data were collected at regular depth intervals with the use of a dissolved oxygen meter. Transparency data were collected with a Secchi disk. A Secchi disk is a black and white disk approximately eight inches in diameter that is lowered into the water to a depth where it is no longer visible from the surface.

In addition, the inflow and outflow of these lakes were measured. During each sampling event, a flow meter was used to determine the speed and volume of water entering and leaving the lakes. Nutrient data collected during these events are important for tracking the movement of nutrients into and out of these lakes.

Chlorophyll *a*, total phosphorus and Secchi depth data collected was used to quantify the productivity of the lakes (Trophic State Index). Software available from the Wisconsin Department of Natural Resources (WDNR) entitled Wisconsin Lake Modeling Suite (WiLMS) was used to predict the trophic state of each waterbody given its size, watershed area, mean depth and eco-region. Comparisons were made between the predicted phosphorus and TSI values and those calculated from the phosphorus, chlorophyll and Secchi data collected during the study. The WiLMS program was also used to estimate the nutrient loading occurring in the lakes by incorporating nutrient and dissolved oxygen data. These analyses allow for a more in-depth view of the nutrient budget within the lakes.

Table 2. Sampling schedule for water quality monitoring of Spring, Big Twin and Little Twin Lakes, Green Lake County, Wisconsin.

	Date/Sampling Locations			
	2016			
Parameter	May	July	September	October
Total phosphorus	A B C D E F	A B C D E F	A B C D E F	A B C D E F
Dissolved phosphorus	A B C D E F	A B C D E F	A B C D E F	A B C D E F
Total Suspended Solids	B C D E	B C D E	B C D E	B C D E
Chlorophyll *a*	A B C	A B C	A B C	A B C
Secchi depth	A B C	A B C	A B C	A B C
Dissolved oxygen profile	A B C	A B C	A B C	A B C
Temperature profile	A B C	A B C	A B C	A B C
Conductivity, Alkalinity, pH	A B C D E F	--	--	--
Total nitrogen (Kjeldahl)	A B C D E F	--	--	--
Nitrate and Nitrite as N	A B C D E F	--	--	--

A = Spring Lake (site ID = 243019)
B = Big Twin Lake (site ID = 243018)
C= Little Twin Lake(site ID = 243023)
D = Twin Lakes inlet (site ID = 10033607)
E = Twin Lakes outlet (site ID = 10015830)
F = Spring Lake outlet (site ID = 243026)

Figure 8. Sampling locations in and around Spring, Big Twin and Little Twin Lakes in Green Lake County, Wisconsin in 2016.

A = Spring Lake (site ID = 243019)
B = Big Twin Lake (site ID = 243018)
C= Little Twin Lake(site ID = 243023)
D = Twin Lakes inlet (site ID = 10033607)
E = Twin Lakes outlet (site ID = 10015830)
F = Spring Lake outlet (site ID = 243026)

Watershed Assessment

Because much of what happens in the watershed surrounding a lake can impact the overall water quality and health of a lake, it is important to investigate and document aspects of the watershed which can have such an impact.

An Erosion Vulnerability Assessment for Agricultural Lands (EVAAL) watershed model was developed by Green Lake County LCD Staff to aid in further identifying and prioritizing locations for best management practices throughout the basin. EVAAL and Stream Power Index (SPI) modeling were implemented using LiDAR to locate and identify medium-high priority areas for non-point pollution potential.

The boundaries of Big and Little Twin Lakes' and Spring Lake's watersheds were delineated using topographic maps. Data obtained from WDNR's Bureau of Technology Services was used to quantify the land-use and vegetative cover types within the watersheds. The percent cover for each of these categories was determined. Information from the WDNR's website was be used to determine if environmentally sensitive areas have been designated within the watersheds. Land-use patterns, vegetative cover, potential nutrient loading sources, and environmentally sensitive areas were identified and mapped. Green Lake County LCD staff conducted field by field assessments of lands identified as medium-high erosion vulnerability in the EVAAL model. Areas of concern were identified and documented. Areas of concern include active soil erosion, livestock operations, tillage operations, and other indicators of non-point sources beyond tolerable levels (5 t/ac). Potential BMPs locations were also be identified, such as grassed waterways, sediment basins, and rock lined chutes. This documentation includes recording GPS coordinates and collecting photos to identify areas of interest or concern.

Soil nutrient testing was made available to all cropland acres within the watershed. Soil sample collection, lab testing, and results were made available to all willing landowners within the watershed at no charge. The results provide a snapshot of soil fertility within the watershed, and provide data to the landowners for nutrient management planning.

The WiLMS software was also used to estimate the external loading of nutrients, namely phosphorus, into Big & Little Twin Lakes and Spring Lake. The software uses export coefficients for various land-use and cover types to represent phosphorus loading into a lake from external sources. This software also takes in account lake morphology, watershed drainage area, septic systems and net precipitation. This analysis helps determine the source of nutrients, namely phosphorus, into the lakes.

Results and Discussion

Aquatic Plant Communities

Results of the data for the point-intercept aquatic plant surveys conducted on Big and Little Twin and Spring Lakes in 2016 are found in **Tables 3-6**. Eight native aquatic plant species were identified during the point-intercept survey on Little Twin Lake. Ten species were identified on Spring Lake and 15 species were identified on Big Twin Lake. The state-wide average for lakes is 13 species (Nichols, 1999). Twin Lakes and Spring Lake lie at the edge of the Northern Lakes and Forests and Southeastern Wisconsin Till Plain ecoregions of Wisconsin (**Figure 9**). Natural lakes in these regions have an average of 13 and 14 species, respectively (Nichols, 1999).

Figure 9. Ecoregions of Wisconsin (after Omernik and Gallant, 1988).

Figure 10 - 12 show the distribution of EWM and the three most abundant native species in each lake basin.

Tables 4 – 6 include summary tables showing the frequency of occurrence for plant species in the three lakes. Percent frequency values reflect the occurrence of a particular plant species within sites shallower than maximum depth of plants. Relative frequency values reflect the occurrence of a particular species in relation to all other species found.

In addition, **Tables 7 and 8** show comparisons between data collected on Big Twin Lake in 2006 and 2016 and on Spring Lake in 2008 and 2016. A point-intercept survey of Little Twin Lake was not conducted prior to 2016. Chi-square statistical analysis has been conducted for each plant species in Big Twin Lake and Spring Lake to determine if statistically significant changes in species abundance have occurred between the two surveys. The summary tables identify which species experienced significant change, the extent of the change and whether the change represents an increase or decrease in a species' abundance. In Big Twin Lake, EWM, seven native species and filamentous algae showed significant declines over the past decade. Similarly, in Spring Lake EWM, five native species and filamentous algae showed significant declines since 2008. Over the past ten years, Big Twin Lake has been chemically treated for invasive species on a number of occasions. Spring Lake has not. It is likely these management efforts have contributed to the decline in the abundance of these native species in Big Twin Lake, however, the Spring Lake data would suggest there are some natural factors that have affected plant abundance in these lakes over this time period.

Table 3. Summary of aquatic plant survey data collected on Spring, Big Twin and Little Twin Lakes in Green Lake County, Wisconsin in 2016.

Waterbody	Number points mapped	Number points sampled	Number points w/ veg.	Max depth of plants	Number of species	Simpson Diversity Index	Mean Coefficient of Conservatism	Floristic Quality Index
Big Twin Lake	283	259	107	18.6	15	0.85	5.5	19.1
Little Twin Lake	96	94	33	5	8	0.59	4.2	10.2
Spring Lake	180	180	59	22.5	10	0.60	5.1	15.3

Table 4. Results of aquatic plant survey conducted on July 25, 2016 on Big Twin Lake, Green Lake County, Wisconsin.

Common name	Scientific name	Percent Frequency (%)	Relative Frequency (%)
Eurasian watermilfoil	*Myriophyllum spicatum*	16.4	8.2
Curly-leaf pondweed	*Potamogeton crispus*	3.3	1.6
Coontail	*Ceratophyllum demersum*	53.3	26.7
Northern watermilfoil	*Myriophyllum sibiricum*	32.0	16.0
Sago pondweed	*Stuckenia pectinata*	29.5	14.8
Fries' pondweed	*Potamogeton friesii*	20.5	10.3
Muskgrasses	*Chara* sp.	17.2	8.6
Filamentous algae	--	13.1	--
Forked duckweed	*Lemna trisulca*	12.3	6.2
White water crowfoot	*Ranunculus aquatilis*	7.4	3.7
Spatterdock	*Nuphar variegata*	2.5	1.2
Small pondweed	*Potamogeton pusillus*	2.5	1.2
Clasping-leaf pondweed	*Potamogeton richardsonii*	1.6	0.8
Water star-grass	*Heteranthera dubia*	0.8	0.4

Table 5. Results of aquatic plant survey conducted on July 25, 2016 on Little Twin Lake, Green Lake County, Wisconsin.

Common name	Scientific name	Percent Frequency (%)	Relative Frequency (%)
Eurasian watermilfoil	*Myriophyllum spicatum*	21.8	26.7
Curly-leaf pondweed	*Potamogeton crispus*	1.8	2.2
Coontail	*Ceratophyllum demersum*	47.3	57.8
Filamentous algae	--	29.1	--
Sago pondweed	*Stuckenia pectinata*	7.3	8.9
Forked duckweed	*Lemna trisulca*	1.8	2.2
Fries' pondweed	*Potamogeton friesii*	1.8	2.2
Small duckweed	*Lemna minor*	visual	--
Cattails	*Typha* spp.	visual	--

Table 6. Results of aquatic plant survey conducted on July 21, 2016 on Spring Lake, Green Lake County, Wisconsin.

Common name	Scientific name	Percent Frequency (%)	Relative Frequency (%)
Eurasian water milfoil	*Myriophyllum spicatum*	2.7	4.4
Muskgrasses	*Chara* sp.	32.7	53.8
Slender naiad	*Najas flexilis*	20.0	33.0
Filamentous algae	--	8.7	--
Spatterdock	*Nuphar variegata*	2.0	3.3
Coontail	*Ceratophyllum demersum*	1.3	2.2
Illinois pondweed	*Potamogeton illinoensis*	1.3	2.2
Common bladderwort	*Utricularia vulgaris*	0.7	1.1
Aquatic moss	--	0.7	--

Figure 10. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) and the three most abundant native plant species sampled on July 25, 2017 in Big Twin Lake, Green Lake County, Wisconsin.

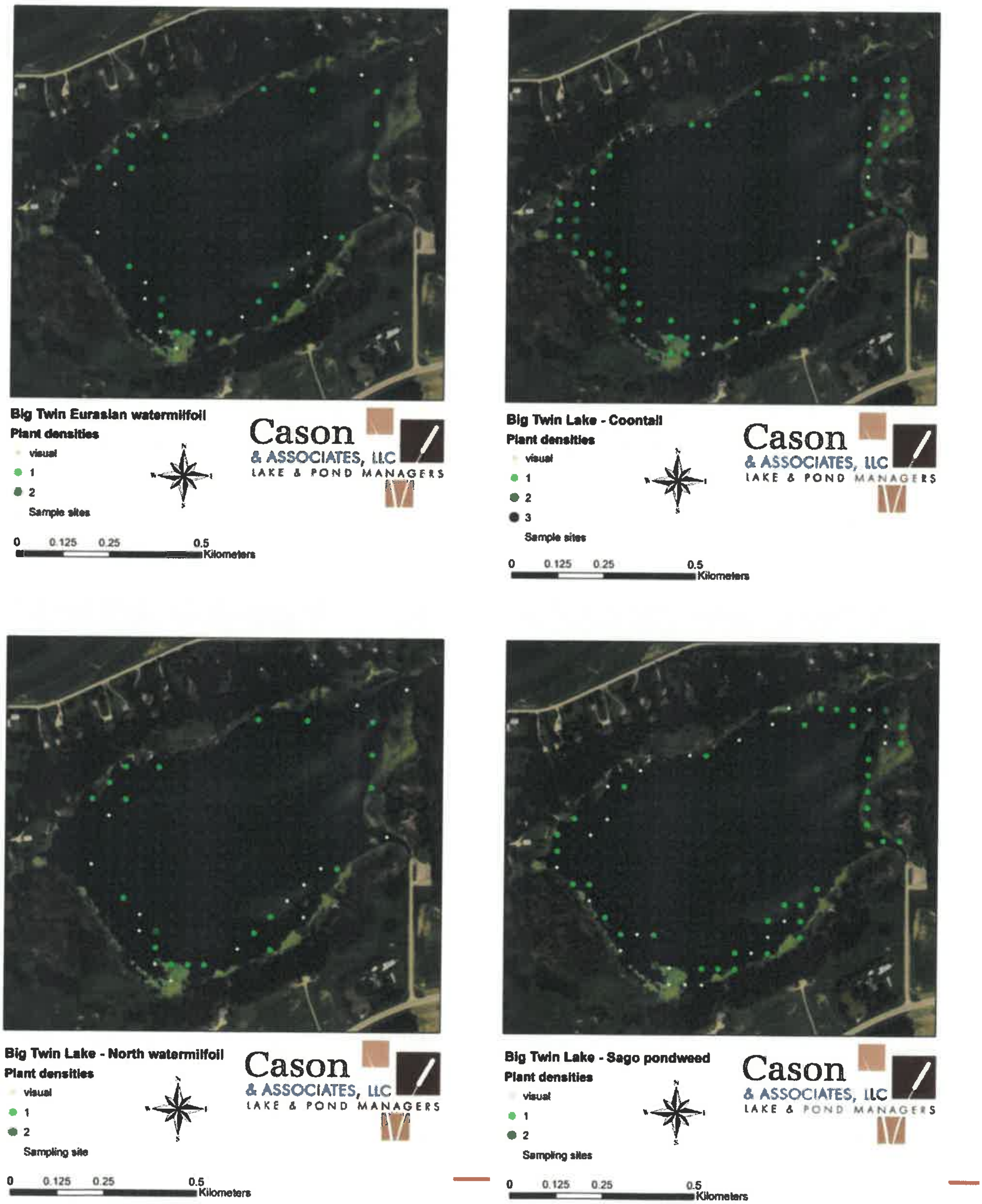


Figure 11. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) and the three most abundant native plant species sampled on July 25, 2017 in Little Twin Lake, Green Lake County, Wisconsin.

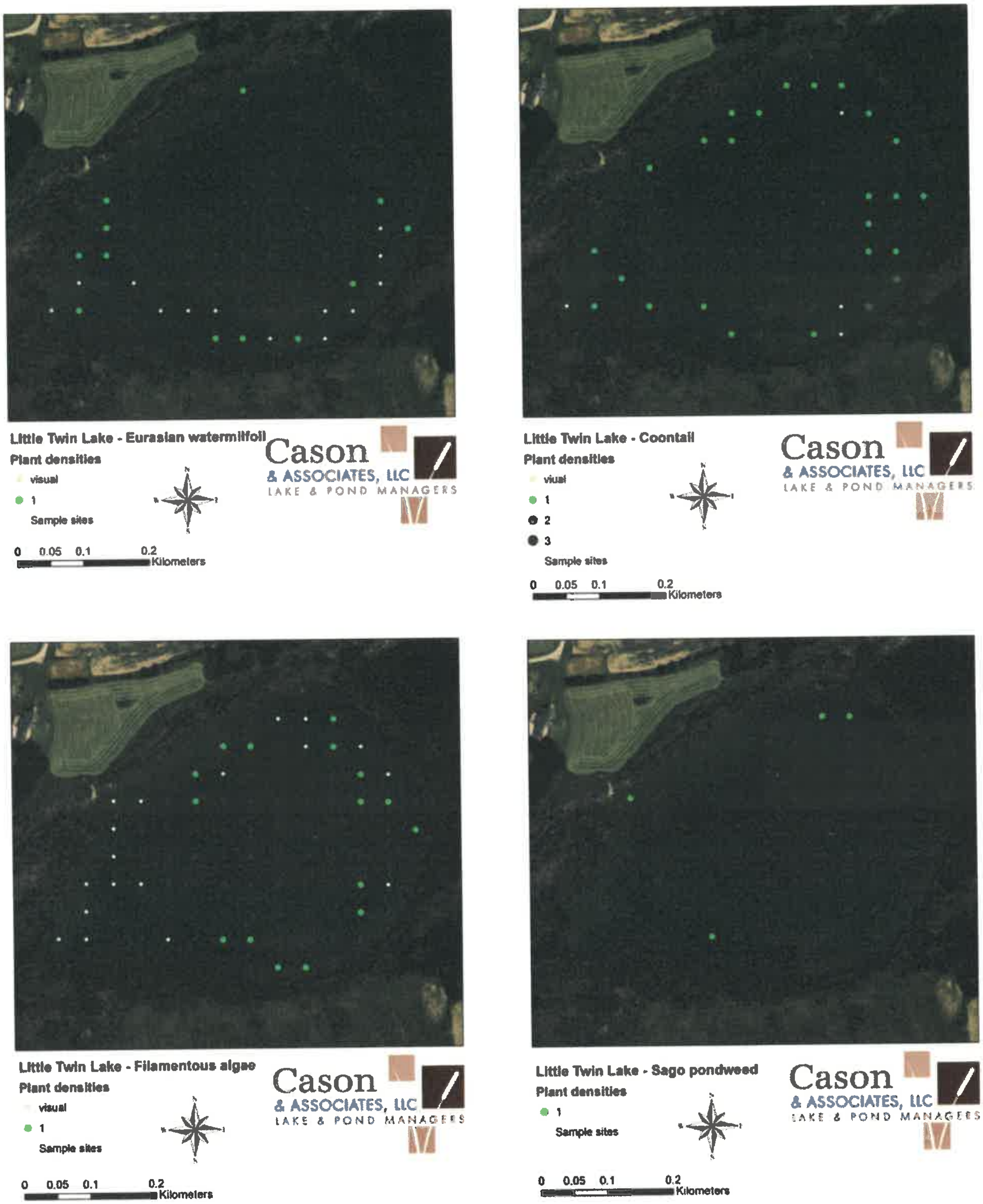


Figure 12. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) and the three most abundant native plant species sampled on July 21, 2017 in Spring Lake, Green Lake County, Wisconsin.

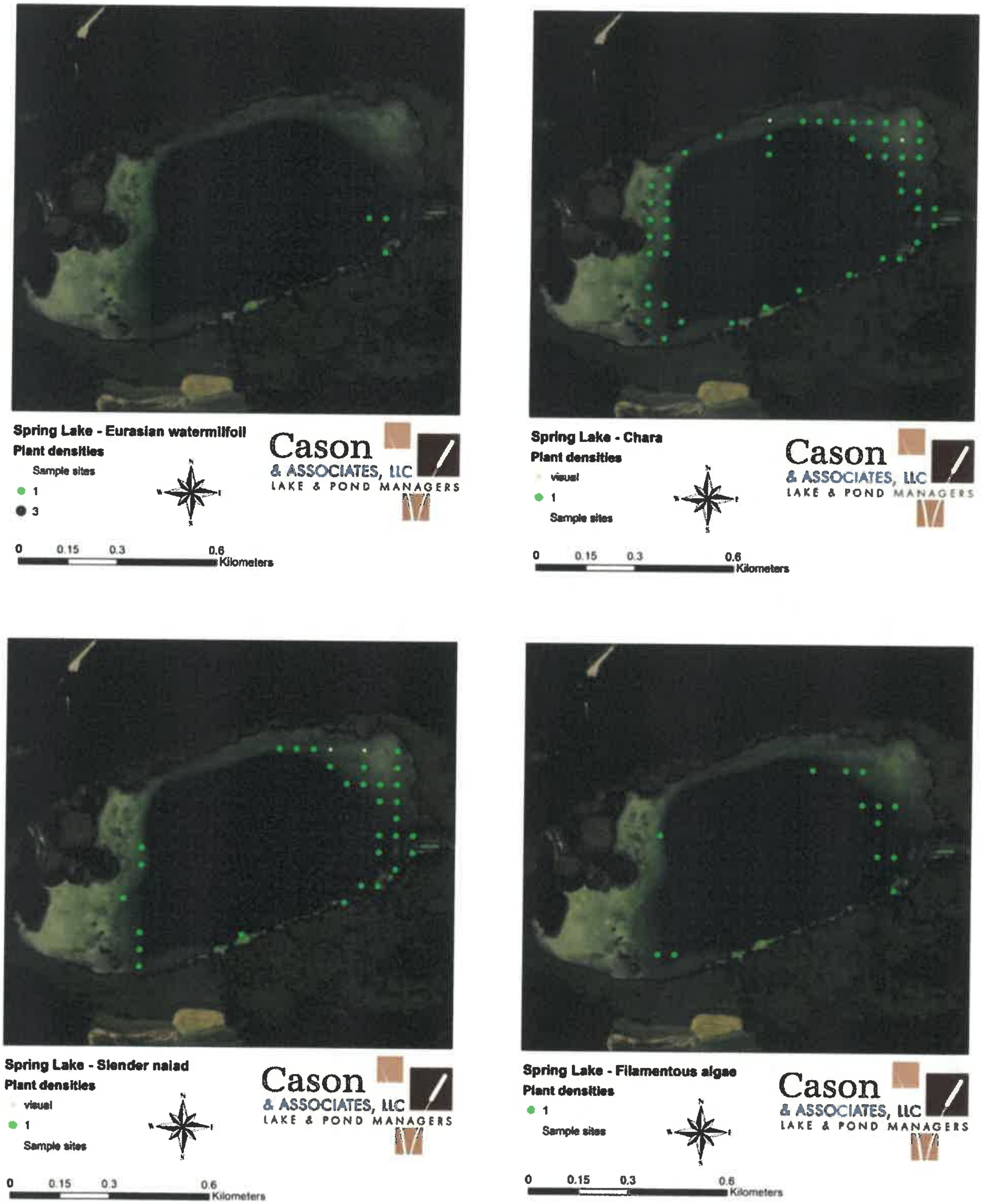


Table 7. Comparison of aquatic plant survey data from June 2008 and July 2016 on Spring Lake, Green Lake County, Wisconsin.

		Jun. 2008	Jul. 2016		
Common Name	Scientific Name	Percent Frequency	Percent Frequency	Significant Change?	Increase (I) or Decrease (D)
Eurasian water milfoil	*Myriophyllum spicatum*	18.5	2.7	***	D
Curly-leaf pondweed	*Potamogeton crispus*	1.2	--		
Muskgrasses	*Chara* sp.	59.3	32.7	***	D
Slender naiad	*Najas flexilis*	43.2	20.0	***	D
Filamentous algae	--	22.2	8.7	**	D
Spatterdock	*Nuphar variegata*	--	2.0		
Coontail	*Ceratophyllum demersum*	2.5	1.3		
Illinois pondweed	*Potamogeton illinoensis*	9.9	1.3	**	D
Common bladderwort	*Utricularia vulgaris*	--	0.7		
Aquatic moss	--	--	0.7		
Water stargrass	*Heteranthera dubia*	1.2	--		
White water lily	*Nymphaea odorata*	1.2	--		
Softstem bulrush	*Schoenoplectus tabernaemontani*	7.4	--	***	D
Sago pondweed	*Stuckenia pectinata*	13.6	--	***	D

* significant change (a = 0.05), ** more significant change (a = 0.01), *** most significant change (a = 0.001)

Table 8. Comparison of aquatic plant survey data from August 2006 and July 2016 on Big Twin Lake, Green Lake County, Wisconsin.

Common Name	Scientific Name	Aug. 2006 Percent Frequency	Jul. 2016 Percent Frequency	Significant Change?	Increase (I) or Decrease (D)
Eurasian watermilfoil	*Myriophyllum spicatum*	47.0	16.4	***	D
Curly-leaf pondweed	*Potamogeton crispus*	3.5	3.3		
Coontail	*Ceratophyllum demersum*	69.6	53.3	***	D
Northern watermilfoil	*Myriophyllum sibiricum*	40.0	32.0	***	D
Sago pondweed	*Stuckenia pectinata*	33.9	29.5	***	D
Fries' pondweed	*Potamogeton friesii*	5.2	20.5		
Muskgrasses	*Chara* sp.	28.7	17.2	***	D
Filamentous algae	--	41.7	13.1	***	D
Forked duckweed	*Lemna trisulca*	20.0	12.3	***	D
White water crowfoot	*Ranunculus aquatilis*	0.9	7.4		
Spatterdock	*Nuphar variegata*	3.5	2.5		
Small pondweed	*Potamogeton pusillus*	--	2.5		
Clasping-leaf pondweed	*Potamogeton richardsonii*	10.4	1.6	***	D
Water star-grass	*Heteranthera dubia*	2.6	0.8		
Small duckweed	*Lemna minor*	4.4	--	**	D
Common waterweed	*Elodea canadensis*	2.6	--		

* significant change (a = 0.05), ** more significant change (a = 0.01), *** most significant change (a = 0.001)

Simpson Diversity Index

The plant data collected were used to calculate Simpson Diversity Index (**Table 3**). In order to estimate the diversity of the aquatic plant community, this index takes in account both the number of species identified (richness) and the distribution or relative abundance of each species. As these parameters increase, so does the overall diversity. With the Simpson Diversity Index (D), 1 represents infinite diversity and 0, no diversity. That is, the bigger the value of D, the higher the diversity. The value of D calculated for this study's waterbodies ranged from 0.59 to 0.85. Little Twin Lake had the lowest value at 0.59. **Table 3** also shows that at the time of the survey, plants were only found growing to 5.0 feet. Little Twin Lake has also had a history of poor water quality. Only the most tolerant plant species can survive in these conditions. The value for D in Spring Lake was also quite low and the number of species found were also below average. Unlike Little Twin Lake, Spring Lake has good water quality. However, it appears to naturally be a lake with low aquatic plant growth. The sediment is largely marl, meaning it has high levels of lime. Sediment of this type are typically lower in nutrients and do not often support abundant plant growth.

Assessment of Floristic Quality

These plant data were also used to assess the "floristic quality" of each water body (**Table 3**). The method used assigns a value to each *native* plant species called a Coefficient of Conservatism (C). It does not take in account the presence of exotic species, mosses, sponges, or filamentous algae. Coefficient values range from 0 - 10 and reflect a particular species' likelihood of occurring in a relatively undisturbed landscape. Species with low coefficient values, such as coontail (C = 3), are likely to be found in a variety of habitat types and can tolerate high levels of human disturbance. On the other hand, species with higher coefficient values, such as Fries' pondweed (*Potamogeton friesii*) (C = 8), are much more likely to be restricted to high quality, natural areas. By averaging the coefficient values available for the submergent and emergent species found in 2016, values ranging from 4.2 to 5.5 (**Table 3**) were calculated. The average value for lakes in Wisconsin is 6.0. The average for lakes in the Northern Lakes and Forests ecoregion is 6.7, while the average for lakes in the Southeastern Wisconsin Till Plain ecoregion is 5.6 (Nichols, 1999).

By utilizing the Coefficients of Conservatism for the plant species for each water body, further assessment of floristic quality can be made. By multiplying the average coefficient values by the square root of the number of plant species found, a Floristic Quality Index (FQI) was calculated (**Table 3**). Values from 2016 ranged from 10.2 to 19.1. In general, higher FQI values reflect higher lake quality. The average for Wisconsin lakes is 22.2. The average for lakes in the Northern Lakes and Forests ecoregion is 24.3. The average for lakes in the Southeastern Wisconsin Till Plain ecoregion is 20.9 (Nichols, 1999). Both Coefficient of Conservatism and the Floristic Quality Index values suggest the quality of the lakes, specifically in terms of the plant community, is below average for the region.

Aquatic plants serve an important purpose in the aquatic environment. They play an instrumental role in maintaining ecological balance in ponds, lakes, wetlands, rivers, and streams. Native aquatic plants have many values. They serve as buffers against nutrient loading and toxic chemicals, act as filters that capture runoff-borne sediments, stabilize lakebed sediments, protect shorelines from erosion, and provide critical fish and wildlife habitat. Therefore, it is essential that the native aquatic plant community within these lakes be protected. **Appendix A** provides a list of the more abundant native aquatic plant species that were found during the 2016 surveys. Ecological values and a description are given for each species

Aquatic Invasive Species Management

Eurasian watermilfoil and curly-leaf pondweed have been the main aquatic invasive species of concern in Twin and Spring Lakes. According to the WDNR website, the invasive species narrow-leaf cattail (*Typha angustifolia*) and zebra mussel (*Dreissena polymorpha*) are also present in Spring Lake. During the aquatic plant surveys conducted in 2016, zebra mussels were not identified in Spring Lake.

Results of the spring and fall surveys were used to develop the maps shown in **Figures 13-20**. In addition, results of the June 2 and October 17, 2016 aquatic invasive species surveys are found in **Table 9**. Note, EWM was not identified in Little Twin Lake in the spring (no map) but was found in the fall.

Table 9. Acreages of curly-leaf pondweed and Eurasian watermilfoil identified on June 2 (Spring) and October 17, 2016 (Fall) on Big and Little Twin Lakes and Spring Lake, Green Lake County, WI.

Curly-leaf Pondweed - Spring 2016			
Lake	CLP acreage	Lake acreage	% cover
Big Twin Lake	17.8	74.0	24.1%
Little Twin Lake	19.0	20.6	92.2%
Spring Lake	0.5	62.0	0.8%

Eurasian watermilfoil - Spring 2016			
Lake	EWM acreage	Lake acreage	% cover
Big Twin Lake	11.5	74.0	15.5%
Little Twin Lake	0.0	20.6	0.0%
Spring Lake	1.0	62.0	1.6%

Eurasian watermilfoil - Fall 2016			
Lake	EWM acreage	Lake acreage	% cover
Big Twin Lake	23.2	74.0	31.4%
Little Twin Lake	11.6	20.6	56.3%
Spring Lake	3.2	62.0	5.2%

Figure 13. Distribution of curly-leaf pondweed (*Potamogeton crispus*) identified on June 2, 2016 on Big Twin Lake, Green Lake County, Wisconsin.

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Figure 14. Distribution of curly-leaf pondweed (*Potamogeton crispus*) identified on June 2, 2016 on Little Twin Lake, Green Lake County, Wisconsin.

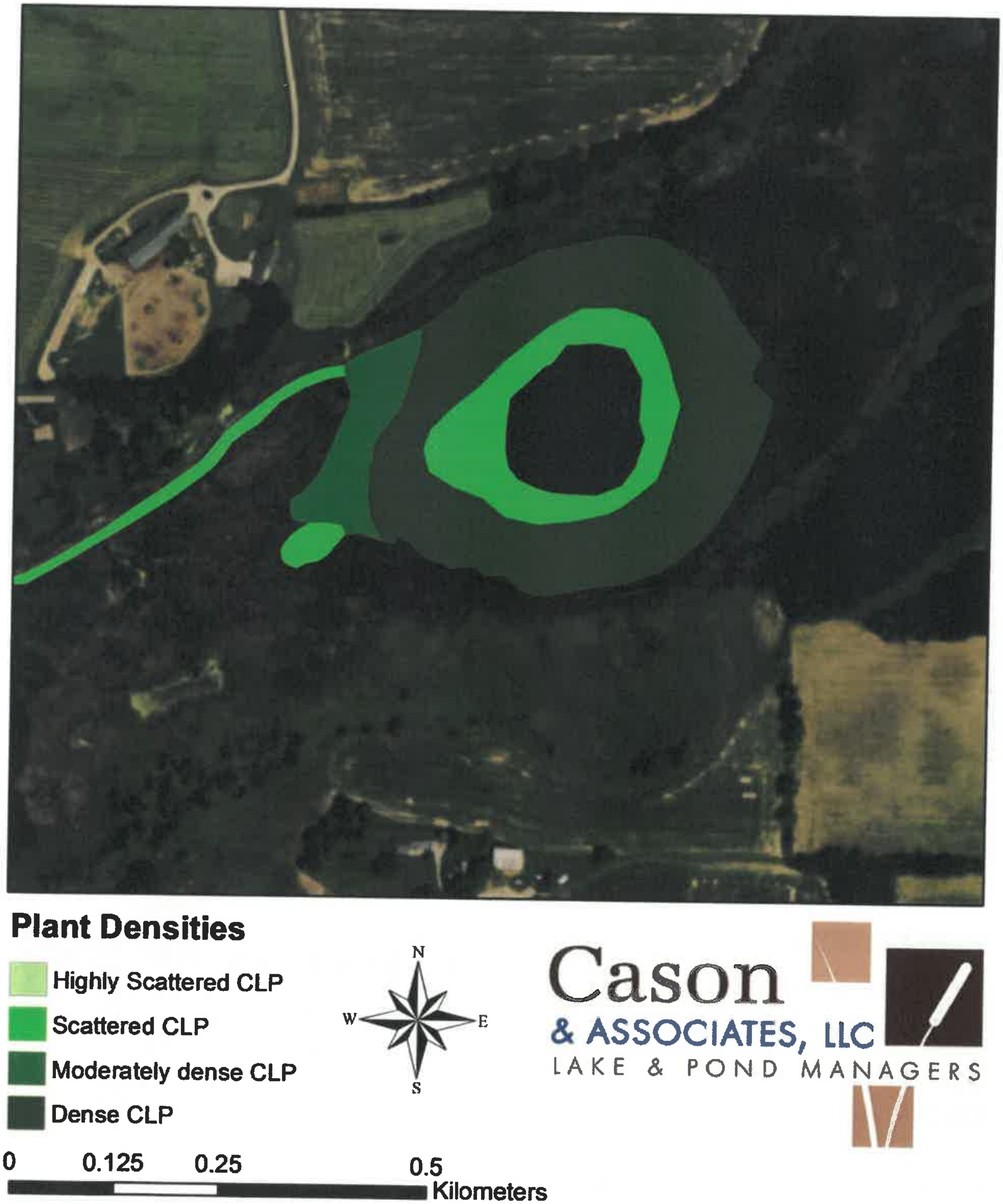

Figure 15. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) identified on June 2, 2016 on Big Twin Lake, Green Lake County, Wisconsin.

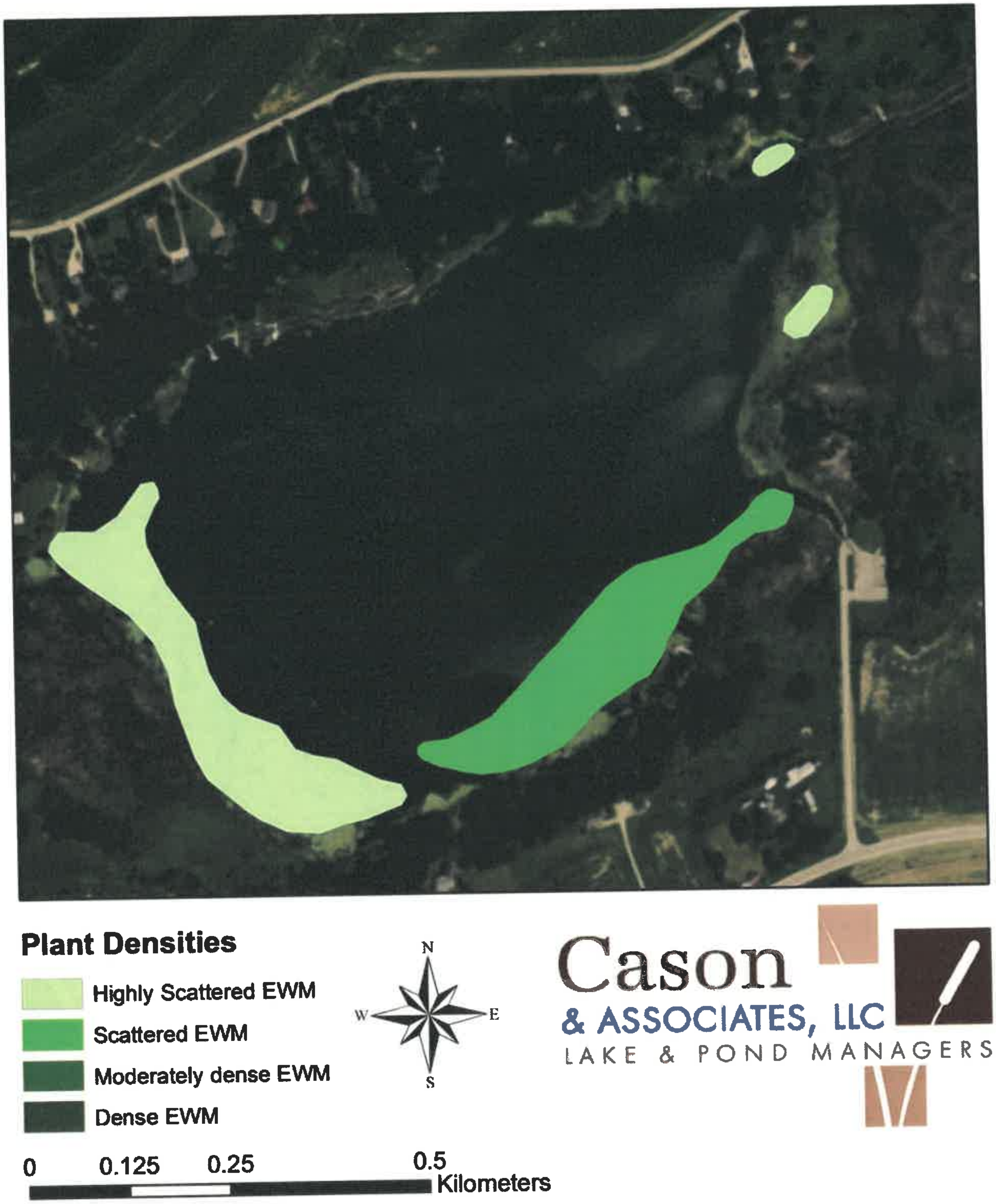

Figure 16. Distribution of curly-leaf pondweed (*Potamogeton crispus*) identified on June 2, 2016 on Little Twin Lake, Green Lake County, Wisconsin.

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Figure 17. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) identified on October 17, 2016 on Big Twin Lake, Green Lake County, Wisconsin.

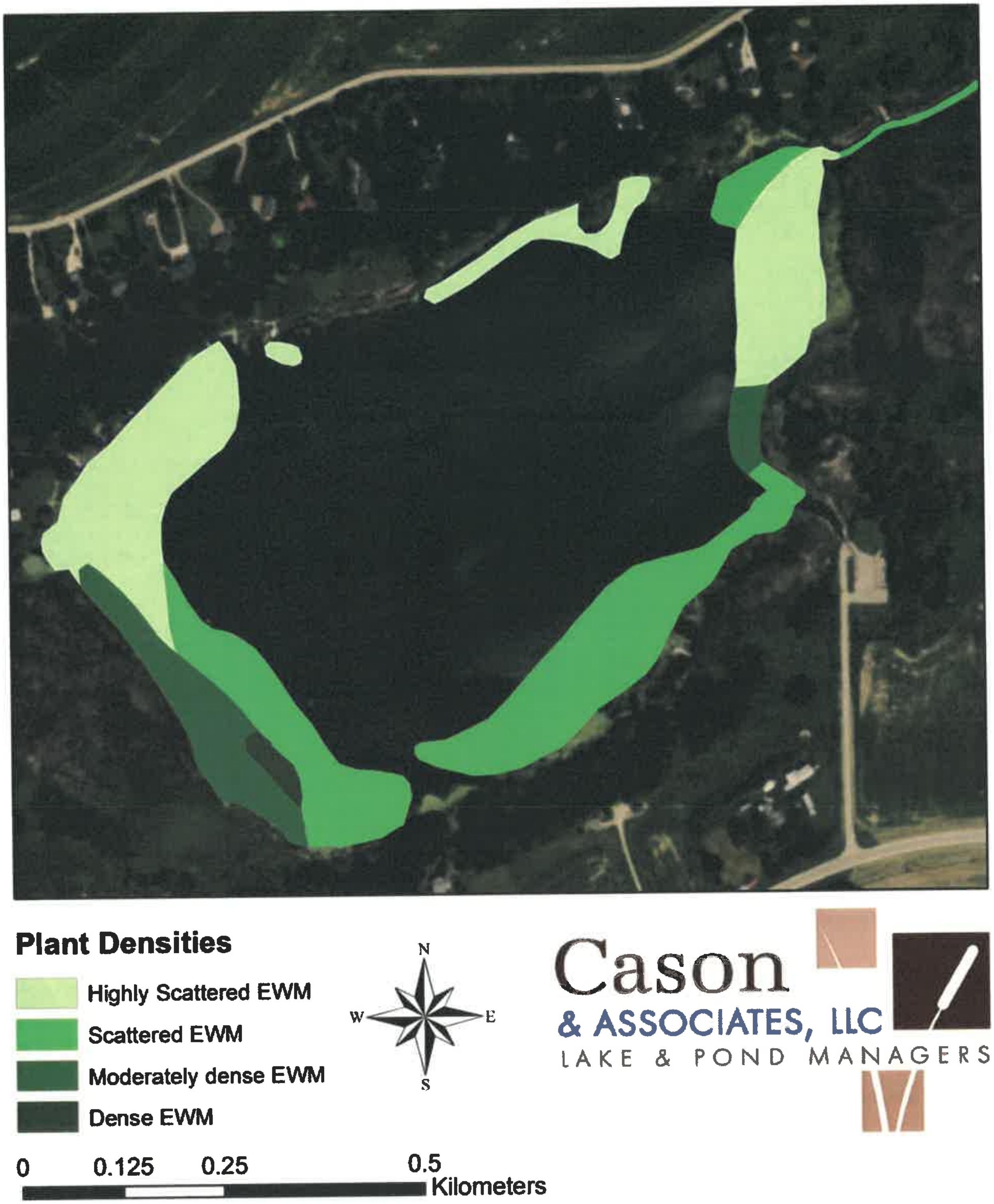


Figure 18. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) identified on October 17, 2016 on Little Twin Lake, Green Lake County, Wisconsin.

Figure 19. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) identified on June 2, 2016 Spring Lake, Green Lake County, Wisconsin.

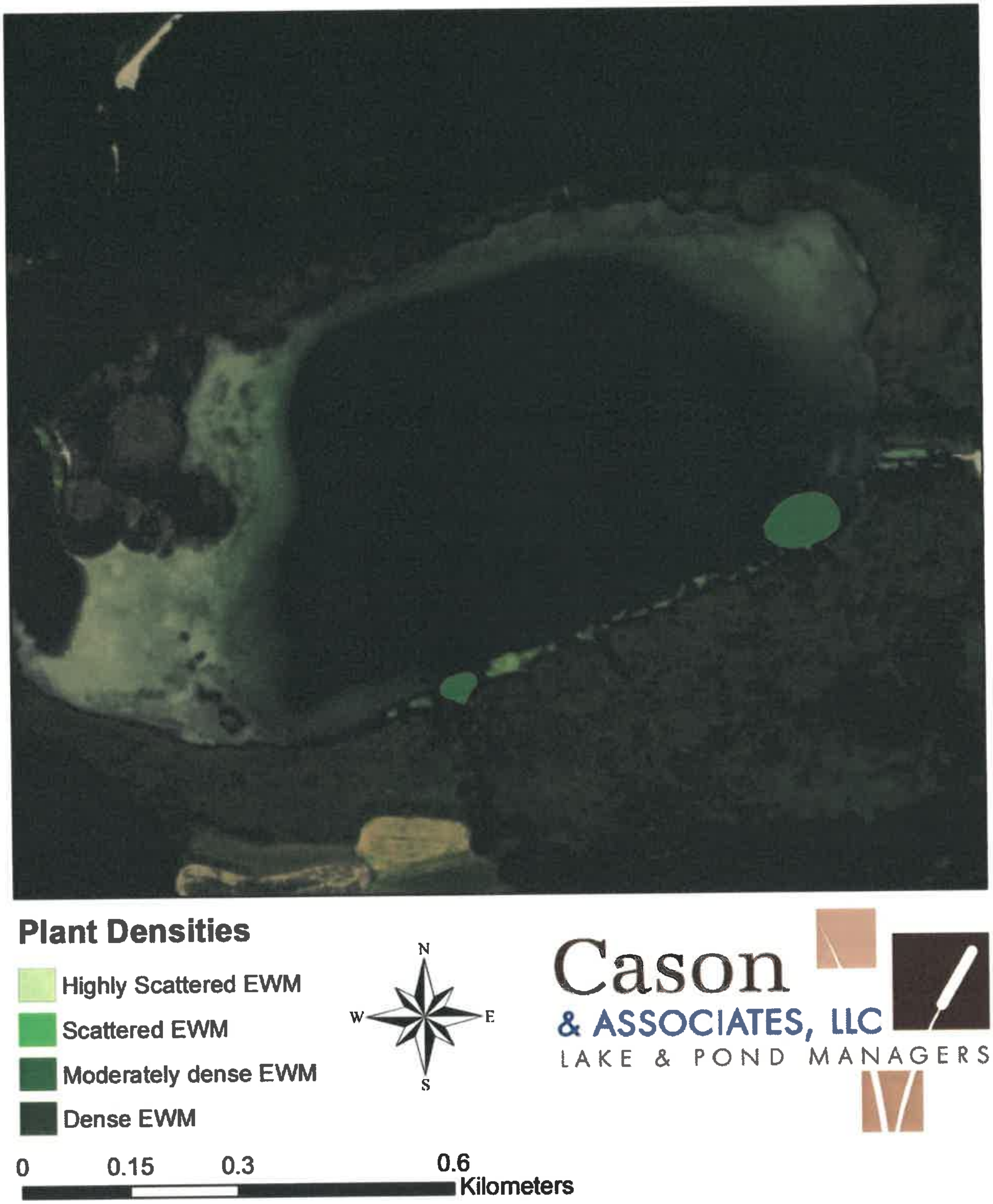


Figure 20. Distribution of Eurasian watermilfoil (*Myriophyllum spicatum*) identified on October 17, 2016 on Spring Lake, Green Lake County, Wisconsin.

Water Quality Analysis

Water quality data available from 2004-2016 for Big Twin, Little Twin and Spring Lakes were collected and compiled in **Table 10**. Little water quality data is available historically for these lakes. **Table 11** contains the stream flow data for the Twin Lakes inlet and outlet and Spring Lake outlet. Daily precipitation data for 2016 was gathered from the National Oceanic & Atmospheric Administration (NOAA) in an attempt to correlate water quality data with precipitation in the days leading up to a sampling event. Total precipitation for the ten days prior to each sampling date in 2016 is as follows: 0.24 inch prior to May 23, 2016, 0.59 inch prior to July 21, 2016, 0.90 inch prior to September 19, 2016 and 0.04 inch prior to October 25, 2016. With the exception of perhaps the October 25th sampling date, there does not appear to be significant rainfall prior to the remaining dates. Interestingly, the highest rate of flow measured at the Twin Lakes inlet (as part of this study) was on July 21, 2016.

Phosphorus

Phosphorus is one of the most important water quality indicators. Phosphorus levels can determine the amount of algae growth in a lake. Phosphorus can come from external sources within the watershed (fertilizers, livestock, septic systems) or to a lesser extent, from groundwater. Phosphorus can also come from within the lake through a process called internal loading. Internal loading occurs when plants and chemical reactions release phosphorus from the lake sediments into the water column.

The average phosphorus concentration for natural lakes in Wisconsin is 0.025 mg/L or 25 ppb (Shaw, et al, 2004). Wisconsin Administrative Code NR 102.06 establishes total phosphorus criteria for lakes and rivers based on a number of criteria. For lakes that are both drainage and stratified (Big Twin and Spring Lakes), the criterion is 0.03 mg/L. For lakes that are drainage lakes, but are not stratified (Little Twin Lake), the criterion is 0.04 mg/L. Values at or below these levels are preferred. Data for Big Twin Lake ranged from 0.0032 mg/L to 0.0358 mg/L phosphorus (**Table 10**). The spring and fall data were below the 0.030 mg/L criterion while the summer samples were just over it. With one exception, the total phosphorus levels from 2004 to 2006 were consistently higher than the 2016 range of values; peaking at 1.080 mg/L on August 3, 2005. In Little Twin Lake, the data ranged from 0.0319 mg/L to 0.199 mg/L phosphorus. The highest levels were measured in the summer months. This is likely largely due to the high levels of curly-leaf pondweed in Little Twin Lake, and to a certain extent Big Twin Lake as well. As the water temps rise and curly-leaf pondweed plants die back, they decompose releasing nutrients into the water column. The range for values collected from 2004 to 2006 was 0.052 to 1.31 mg/L. Similarly, levels peaked in summer months after the expected die-off of curly-leaf pondweed.

Similar trends were seen with the inlet and outlet data for Twin Lakes. Inlet samples ranged from 0.0376 mg/L to 0.351 mg/L phosphorus. As lakes with high concentration of agriculture in the watershed, it is known that erosion is taking place outside the lakes and inflowing water would contain elevated nutrients. The highest inlet values were measured in the summer months. Data collected from 2004 to 2006 fell within the 2016 range of data.

Table 10. Water quality data from 2016 for Big and Little Twin Lakes and Spring Lake, Green Lake County, Wisconsin.

Big Twin Lake

Date	Secchi depth feet	pH SU	Conductivity umhos/cm	Alkalinity mg/L	Chlorophyll mg/L	Total Phosphorus mg/L	Dissolved Phosphorus mg/L	Nitrates & Nitrites mg/L	Total Kjeldahl Nitrogen mg/L	Total Nitrogen mg/L	Total Dissolved Solids mg/L
5/27/2004	5.5	8.5	--	--	4.33	0.135	--	2.3	--	--	--
6/23/2004	9	8.5	--	--	7.18	0.076	--	5.97	--	--	--
7/19/2004	8	8.5	--	--	20.5	0.030	--	6.28	--	--	--
7/22/2004	5.25	--	--	--	--	--	--	--	--	--	--
8/12/2004	4.5	--	--	--	--	--	--	--	--	--	--
8/16/2004	3.1	8.7	--	--	35	0.039	--	5	--	--	--
8/27/2004	3.1	--	--	--	--	--	--	--	--	--	--
10/31/2004	6	--	--	--	--	--	--	--	--	--	--
11/15/2004	7.5	8	--	--	9.24	0.116	--	--	--	--	--
1/31/2005	7	8	--	--	7.74	0.054	--	2.02	--	--	--
4/14/2005	2.5	8	--	--	70.9	0.125	--	1.51	--	--	--
6/13/2005	5.5	9.29	--	--	41.7	0.054	--	0.359	--	--	--
6/29/2005	3.75	--	--	--	--	--	--	--	--	--	--
7/27/2005	3.5	--	--	--	--	--	--	--	--	--	--
8/3/2005	3.5	9.17	--	--	30.7	1.080	--	ND	--	--	--
8/23/2005	3.1	9.2	427	167	--	0.049	0.008	ND	1.57	1.57	256
8/31/2005	3	--	--	--	--	--	--	--	--	--	--
10/27/2005	4	--	--	--	--	--	--	--	--	--	--
11/10/2005	3.4	8.44	--	--	31.7	0.076	--	0.11	--	--	--
1/11/2006	2.4	8.27	--	--	13.3	0.281	--	0.197	--	--	--
5/20/2006	6	--	--	--	--	--	--	--	--	--	--
6/27/2006	5.1	--	--	--	15.0	0.041	--	--	--	--	--
7/15/2006	3.5	--	--	--	--	--	--	--	--	--	--
7/18/2006	2.5	--	--	--	44.9	0.054	--	--	--	--	--
8/28/2006	3	--	--	--	28.8	0.037	--	--	--	--	--
10/15/2006	5	--	--	--	7.65	0.110	--	--	--	--	--
6/24/2009	11	--	--	--	2.71	0.023	--	2.21	0.76	2.97	--
7/31/2009	5.5	8.7	469	--	26.8	0.036	--	0.945	0.90	1.845	--
9/3/2009	5.5	8.7	468	--	6.91	0.043	--	0.671	1.08	1.751	--

Yellow cells indicate phosphorus data exceeding total phosphorus criteria established by Wisconsin Administrative Code NR.102.06 for lakes.

Table 10. Water quality data from 2016 for Big and Little Twin Lakes and Spring Lake, Green Lake County, Wisconsin (continued).

Big Twin Lake

Date	Secchi depth feet	pH SU	Conductivity umhos/cm	Alkalinity mg/L	Chlorophyll mg/L	Total Phosphorus mg/L	Dissolved Phosphorus mg/L	Nitrates & Nitrites mg/L	Total Kjeldahl Nitrogen mg/L	Total Nitrogen mg/L	Total Dissolved Solids mg/L
9/23/2009	4	--	--	--	22.5	0.039	--	--	--	--	--
5/23/2016	25.5	8.64	540	205	ND	0.0142	0.0021	4.77	0.866	5.636	ND
7/21/2016	4.2	--	--	--	18.9	0.0358	0.0019	--	--	--	4.4
9/19/2016	6.2	--	--	--	20.5	0.0319	0.0053	--	--	--	4.0
10/25/2016	7.5	--	--	--	10.2	0.0326	0.0032	--	--	--	3.0

Little Twin Lake

Date	Secchi depth feet	pH SU	Conductivity umhos/cm	Alkalinity mg/L	Chlorophyll mg/L	Total Phosphorus mg/L	Dissolved Phosphorus mg/L	Nitrates & Nitrites mg/L	Total Kjeldahl Nitrogen mg/L	Total Nitrogen mg/L	Total Dissolved Solids mg/L
5/27/2004	3.1	8	--	--	2.34	1.31	--	1.42	--	--	--
6/23/2004	6	8.5	--	--	22.1	0.111	--	2.02	--	--	--
7/19/2004	6	8.5	--	--	56.5	0.066	--	1.37	--	--	--
8/16/2004	1.5	8.7	--	--	109	0.233	--	ND	--	--	--
11/15/2004	8	8.5	--	--	21.2	0.052	--		--	--	--
1/31/2005	5.8	8	--	--	22.2	0.062	--	1.66	--	--	--
4/14/2005	2.4	8.5	--	--	45.8	0.146	--	ND	--	--	--
6/13/2005	8.2	8.94	--	--	7.69	0.194	--	ND	--	--	--
8/3/2005	1.5	8.84	--	--	131	0.347	--	ND	--	--	--
8/23/2005	1.1	8.68	446	195	--	0.323	0.01	ND	3.48	3.48	264
11/10/2005	2.9	9.01	--	--	16.3	0.14	--	0.054	--	--	--
1/11/2006	5.9	7.7	--	--	12.8	0.095	--	0.174	--	--	--
5/23/2016	1.8	8.89	465	187	2.16	0.0319	0.0020	1.78	1.01	2.79	12.5
7/21/2016	1.1	--	--	--	130	0.199	0.0022	--	--	--	25.0
9/19/2016	2.2	--	--	--	135	0.147	0.0069	--	--	--	16.3
10/25/2016	3.7	--	--	--	38.8	0.0713	0.0034	--	--	--	7.0

Yellow cells indicate phosphorus data exceeding total phosphorus criteria established by Wisconsin Administrative Code NR.102.06 for lakes.

Table 10. Water quality data from 2016 for Big and Little Twin Lakes and Spring Lake, Green Lake County, Wisconsin (continued).

Twin Lakes inlet

Date	Secchi depth feet	pH SU	Conductivity umhos/cm	Alkalinity mg/L	Chlorophyll mg/L	Total Phosphorus mg/L	Dissolved Phosphorus mg/L	Nitrates & Nitrites mg/L	Total Kjeldahl Nitrogen mg/L	Total Nitrogen mg/L	Total Dissolved Solids mg/L
5/27/2004	--	--	--	--	--	0.098	--	11.7	--	--	--
6/23/2004	--	--	--	--	--	0.078	--	15.3	--	--	--
7/19/2004	--	--	--	--	--	0.082	--	16.5	--	--	--
8/16/2004	--	--	--	--	--	0.082	--	16.3	--	--	--
11/15/2004	--	--	--	--	--	0.072	--	--	--	--	--
4/14/2005	--	8.5	--	--	--	0.109	--	7.36	--	--	--
6/13/2005	--	8.74	--	--	--	0.182	--	6.78	--	--	--
8/3/2005	--	8.7	--	--	--	0.181	--	5.13	--	--	--
11/10/2005	--	8.08	--	--	--	0.294	--	2.28	--	--	--
1/11/2006	--	--	--	--	--	0.046	--	6.34	--	--	--
5/23/2016	--	8.34	7.5	271	--	0.0715	0.0343	12.4	0.259	12.659	9.0
7/21/2016	--	--	--	--	--	0.351	0.0795	--	--	--	121.0
9/19/2016	--	--	--	--	--	0.136	0.0960	--	--	--	3.8
10/25/2016	--	--	--	--	--	0.0376	0.0376	--	--	--	6.0

Table 10. Water quality data from 2016 for Big and Little Twin Lakes and Spring Lake, Green Lake County, Wisconsin (continued).

Twin Lakes outlet

Date	Secchi depth	pH	Conductivity	Alkalinity	Chlorophyll	Total Phosphorus	Dissolved Phosphorus	Nitrates & Nitrites	Total Kjeldahl Nitrogen	Total Nitrogen	Total Dissolved Solids
	feet	SU	umhos/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/27/2004	--	8	--	--	--	0.132	--	1.26	--	--	--
6/23/2004	--	--	--	--	--	0.105	--	1.31	--	--	--
7/19/2004	--	--	--	--	--	0.121	--	0.579	--	--	--
8/16/2004	--	--	--	--	--	0.199	--	0.03	--	--	--
11/15/2004	--	--	--	--	--	0.14	--	--	--	--	--
1/31/2005	--	7.1	--	--	--	--	--	--	--	--	--
4/14/2005	--	8	--	--	--	0.288	--	0.186	--	--	--
6/13/2005	--	9.13	--	--	--	0.586	--	0.462	--	--	--
5/23/2016	--	8.72	460	221	--	0.146	0.0732	1.33	0.827	2.157	--
7/21/2016	--	--	--	--	--	0.236	0.1010	--	--	--	12.6
9/19/2016	--	--	--	--	--	0.145	0.0717	--	--	--	12.0
10/25/2016	--	--	--	--	--	0.107	0.0694	--	--	--	14.6

Spring Lake

Date	Secchi depth	pH	Conductivity	Alkalinity	Chlorophyll	Total Phosphorus	Dissolved Phosphorus	Nitrates & Nitrites	Total Kjeldahl Nitrogen	Total Nitrogen	Total Dissolved Solids
	feet	SU	umhos/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/23/2016	8.9	8.52	529	243	2.17	0.013	0.0022	1.59	0.794	2.384	--
7/21/2016	5.4	--	--	--	2.38	0.0144	0.0026	--	--	--	--
9/19/2016	13.8	--	--	--	1.17	0.0193	0.0047	--	--	--	--
10/25/2016	14.5	--	--	--	0.525	0.0176	0.0034	--	--	--	--

Table 10. Water quality data from 2016 for Big and Little Twin Lakes and Spring Lake, Green Lake County, Wisconsin (continued).

Spring Lake outlet

Date	Secchi depth	pH	Conductivity	Alkalinity	Chlorophyll	Total Phosphorus	Dissolved Phosphorus	Nitrates & Nitrites	Total Kjeldahl Nitrogen	Total Nitrogen	Total Dissolved Solids
	feet	SU	umhos/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/23/2016	--	--	--	--	--	0.032	0.0027	2.94	1.02	3.96	--
7/21/2016	--	--	--	--	--	0.0239	0.0026	--	--	--	--
9/19/2016	--	--	--	--	--	0.0214	0.0059	--	--	--	--
10/25/2016	--	--	--	--	--	0.0259	0.0078	--	--	--	--

Total phosphorus data from the outlet ranges from 0.107 mg/L to 0.236 mg/L. These values are similar to magnitude to the values measured in Little Twin Lake where the outlet stream is found. The outlet data from 2004 fall within this range while the two data points available for 2005 were above 0.288 and 0.586 mg/L measured on April 14 and June 13, 2005, respectively.

On Spring Lake phosphorus levels ranged from 0.0130 mg/L to 0.0193 mg/L while the outlet values ranged from 0.0214 mg/L to 0.032 mg/L. These values are largely below the criterion of 0.030 mg/L phosphorus. Spring Lake is a less developed lake in a smaller watershed with a lower concentration of agriculture. These factors alone can largely explain the lower phosphorus concentrations. No water quality data could be found for Spring Lake prior to 2016.

Table 11. Stream flow data for the Twin Lakes inlet and outlet and Spring Lake outlet, Green Lake County, Wisconsin.

Twin Lakes inlet			
	area	speed	flow
Date	ft^2	ft/sec	ft^3/sec
5/23/2016	10	0.43	4.25
7/21/2016	19.5	1.66	32.33
9/19/2016	11	0.62	6.78
10/25/2016	9	0.29	2.64
Twin Lakes outlet			
	area	speed	flow
Date	ft^2	ft/sec	ft^3/sec
5/23/2016	2.8	3.96	11.09
7/21/2016	2.8	1.07	3.00
9/19/2016	2.3	1.00	2.29
10/25/2016	2.72	1.09	2.95
Spring Lake outlet			
	area	speed	flow
Date	ft^2	ft/sec	ft^3/sec
5/23/2016	2.44	0.53	1.29
7/21/2016	5.76	0.81	4.65
9/19/2016	5.74	0.89	5.14
10/25/2016	6.3	0.98	6.19

Dissolved (Ortho) Phosphorus

Dissolved or ortho-phosphorus represents the phosphorus within a water sample that is biologically available to plants and algae at the time of sampling. It does not take into account other forms of phosphorus that are chemically unavailable or tied up in living or dead biomass, etc. Through processes such as decomposition, other forms of phosphorus can be made available as dissolved phosphorus. Values for dissolved phosphorus in most cases are magnitudes lower than the corresponding results for total phosphorus. Some of the Twin Lakes inlet and outlet data show dissolved phosphorus data at levels higher than the State's *total* phosphorus criteria.

Nitrogen

Excess nitrogen can also be a threat to overall water quality. Nitrogen is an important nutrient for plants and algae. It can enter lakes from groundwater, surface runoff (livestock manure and agricultural fertilizers) and precipitation. In addition, decomposing organic matter releases nitrogen.

Nitrogen can exist in a number of forms in aquatic systems. Samples collected in Big Twin, Little Twin and Spring Lakes in 2016 were tested for nitrates and nitrites and Kjeldahl nitrogen (**Table 10**). Nitrates and nitrites are inorganic forms of nitrogen which can be readily used by plants and algae. Kjeldahl nitrogen is the sum of organic and ammonia forms of nitrogen. By adding the results of these two tests, the total amount of nitrogen in all forms can be determined. As with total phosphorus, nitrate and nitrite data are available from 2004-2006 from Big Twin, Little Twin, the inlet and outlet. Water naturally contains less than 1 mg/L of nitrogen. If the inorganic forms of nitrogen exceed 0.3 mg/L, there is sufficient nitrogen to support summer algae blooms and negatively affect water quality. Samples from all sampling locations in 2016 were analyzed for these parameters during the spring sampling event only. Results show inorganic nitrogen (nitrates and nitrites) levels well above 0.3 mg/L with the highest concentration measured in Twin Lakes inlet. This is also the case for nitrate and nitrite levels measured from 2004 to 2006 from all sample sites. Total nitrogen (nitrates and nitrites plus Kjeldahl nitrogen) levels were consistently above 1 mg/L. The highest levels were found in Big Twin Lake and the Twin Lakes inlet that enters into Big Twin Lake. These levels are again likely attributable to the large percentage of agriculture in the watershed.

Chlorophyll

Chlorophyll is the pigment found in all green plants, including algae, that give them their green color. It is the site in plants where photosynthesis occurs. Chlorophyll absorbs sunlight to convert carbon dioxide and water to oxygen and sugars. Chlorophyll data is collected to estimate how much phytoplankton (algae) there is in a lake. Generally, the more nutrients there are in the water and the warmer the water, the higher the production of algae and consequently chlorophyll.

Chlorophyll concentrations below 10 µg/L are most desirable for lakes. Surprisingly, chlorophyll levels were undetectable in the spring sample on Big Twin Lake. Chlorophyll concentrations in the summer months were 18.9 mg/L and 20.5 µg/L and 10.2 µg/L in the fall **(Table 10)**. Summer months in particular were approximately twice the desired criterion. This trend was also seen in data collected from 2004-2006. This too is related to nutrients in the lakes. In particular, increased phosphorus in a lake will contribute to increases in algae production reflected in measured chlorophyll concentrations. This very apparent when the Little Twin Lake data is considered. As expected, chlorophyll levels in this basin were low in the spring 2016 at 2.16 µg/l. By the summer months, levels were very high at 130 µg/L and 135 µg/L. By the fall, levels dropped to 38.8 µg/L. Again, as curly-leaf pondweed decomposition occurs and watershed inputs of nutrients increase, chlorophyll production also increases. Again, this same trend can be seen in the 2004-2006 data.

Chlorophyll values in Spring Lake were consistently well below the 10 µg/l threshold.

Secchi Transparency

Water clarity is often used as a quick and easy test for a lake's overall water quality, especially in relation to the amount of algae present. There is an inverse relationship between Secchi depth and the amount of suspended matter, including algae, in the water column. The less suspended matter, the deeper the Secchi disc is visible and the higher water quality present. Secchi depths greater than six feet are generally indicative of good water quality. Water clarity in Big Twin Lake in the spring was uncharacteristically high (25.5 feet). In July, clarity had dropped to 4.2 feet, reached 6.2 feet in September and was 7.5 feet in October **(Table 10)**. In Little Twin Lake, clarity was consistently low ranging from 1.1 feet to 3.7 feet. It was noted in the spring, Little Twin Lake has a whitish, cloudy appearance, the cause of which is unclear.

Spring Lake water clarity ranged from 5.4 feet in July to 14.5 feet in October.

Trophic State

There is a strong relationship between levels of phosphorus, chlorophyll and water clarity in lakes. As a response to rising levels of phosphorus, chlorophyll levels increase and transparency values often decrease. The effect of this is viewed as an increase in the productivity of a lake.

Lakes can be categorized by their productivity or trophic state. When productivity is discussed, it is normally a reflection of the amount of plant and animal biomass a lake produces or has the potential to produce. The most significant and often detrimental result is elevated levels of algae and nuisance aquatic plants.
Lakes can be categorized into three trophic levels:

- oligotrophic - low productivity, high water quality
- mesotrophic - medium productivity and water quality
- eutrophic - high productivity, low water quality

These trophic levels form a spectrum of water quality conditions. Oligotrophic lakes are typically deep and clear with exposed rock bottoms and limited plant growth. Eutrophic lakes are often shallow and marsh-like, typically having heavy layers of organic silt and abundant plant growth. Mesotrophic lakes are typically deeper than eutrophic lakes with significant plant growth, and areas of exposed sand, gravel or cobble-bottom substrates.

Lakes can naturally become more eutrophic with time, however the trophic state of a lake is more influenced by nutrient inputs than by time. When humans negatively influence the trophic state of a lake the process is called *cultural eutrophication*. A sudden influx of available nutrients may cause a rapid change in a lake's ecology. Opportunistic plants such as algae and nuisance plant species are able to out-compete other more desirable species of macrophytes. The result is often poorer water quality.

Total phosphorus, chlorophyll and Secchi depth are often used as indicators of the water quality and productivity (trophic state) in lakes. Values measured for these parameters can be used to calculate Trophic State Index (TSI) values (Carlson 1977). The formulas for calculating the TSI values for Secchi disk, chlorophyll, and total phosphorus are as follows:

- Secchi TSI = 60 - 14.41 ln Secchi disk (meters)
- Chlorophyll TSI = 9.81 ln Chlorophyll (µg/L) + 30.6
- Phosphorus TSI = 14.42 ln Total phosphorus (µg/L) + 4.15

The higher the TSI calculated for a lake, the more eutrophic it is (**Figure 21**). Classic eutrophic lakes have TSI values starting around 50. TSI values calculated from the Big Twin Lake water quality data from 2004 to 2016 were largely between 35 and 80 (**Figure 22**). TSI values often peak in the summer months when biological activity and productivity correspondingly peak. These data indicate Big Twin Lake, in terms of water quality, exhibits characteristics of a eutrophic lake. However, based on the available date, since 2004 the average TSI value for Big Twin Lake has declined suggesting water quality has improved slightly over that time period. TSI values calculated for Little Twin Lake in 2016 were between 50 and 80 (**Figure 23**). These values clearly indicate Little Twin Lake is a eutrophic lake. TSI values calculated for Spring Lake in 2016 were between 35 and 45 (**Figure 24**), placing it with the boundaries of a mesotrophic lake. TSI values are not calculated for flowing waterbodies such as the inlet or outlets to these lakes.

Figure 21. Relationship between trophic state in lakes and parameters including Secchi transparency, chlorophyll, and total phosphorus.

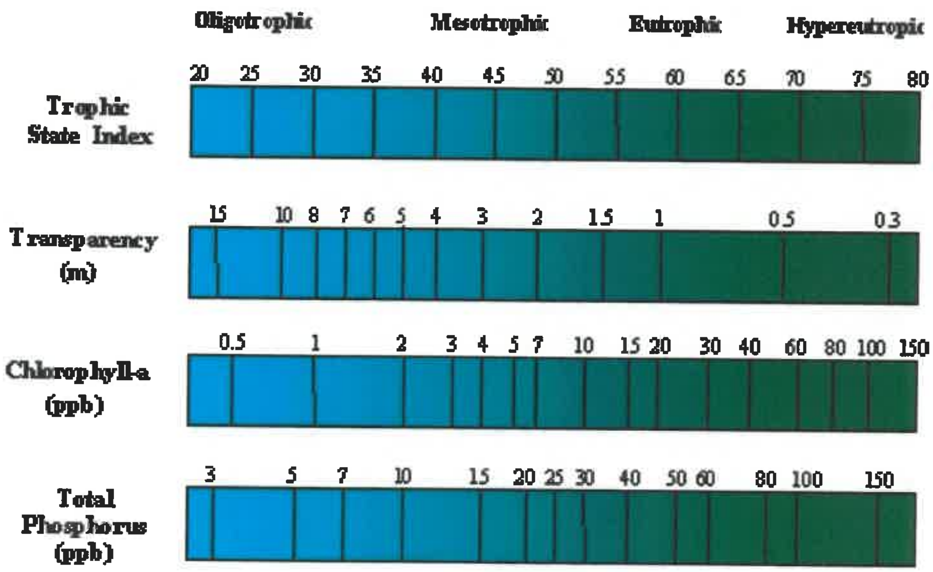


Figure 22. Trophic State Index values from 2004 - 2016 for Big Twin Lake, Green Lake County, Wisconsin.

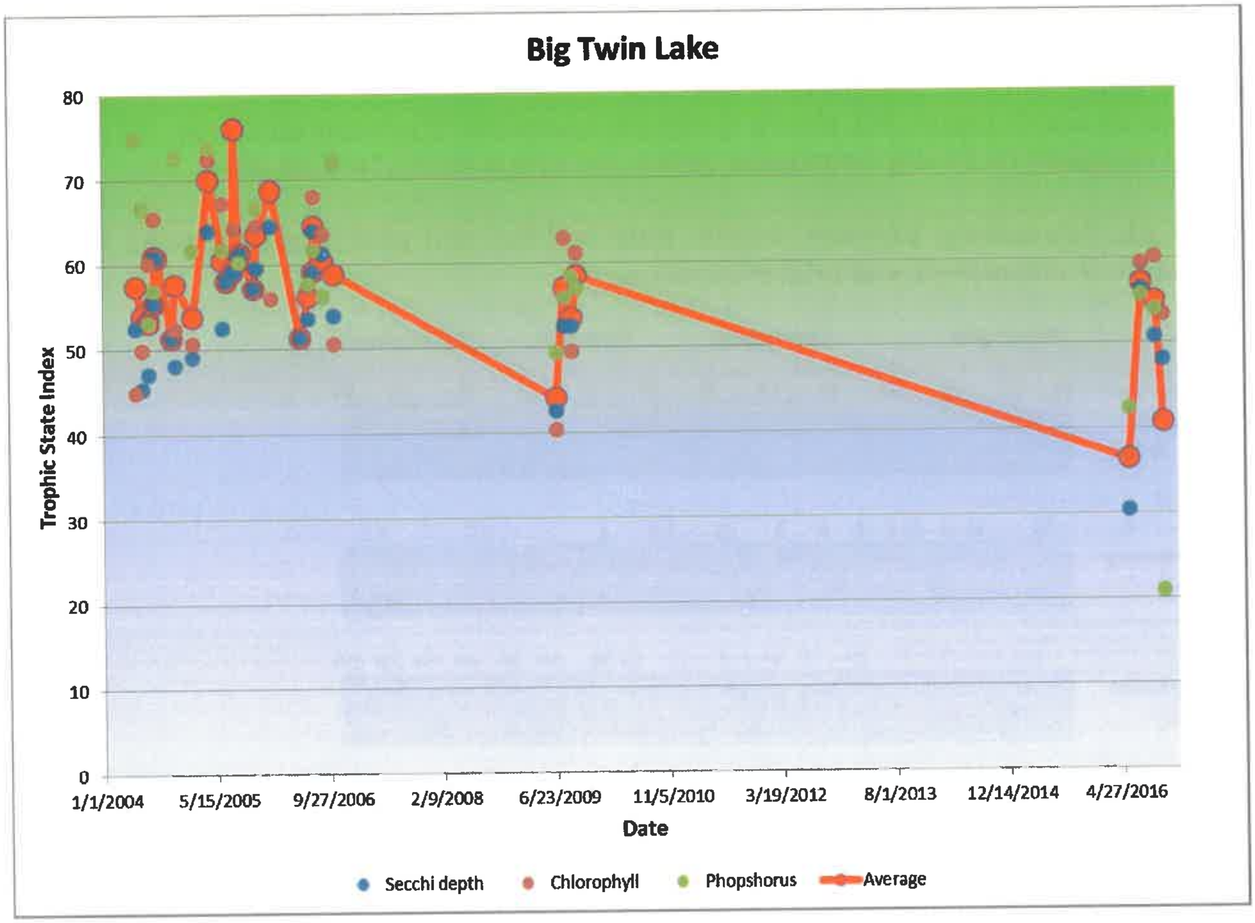


Figure 23. Trophic State Index values from 2016 for Little Twin Lake, Green Lake County, Wisconsin.

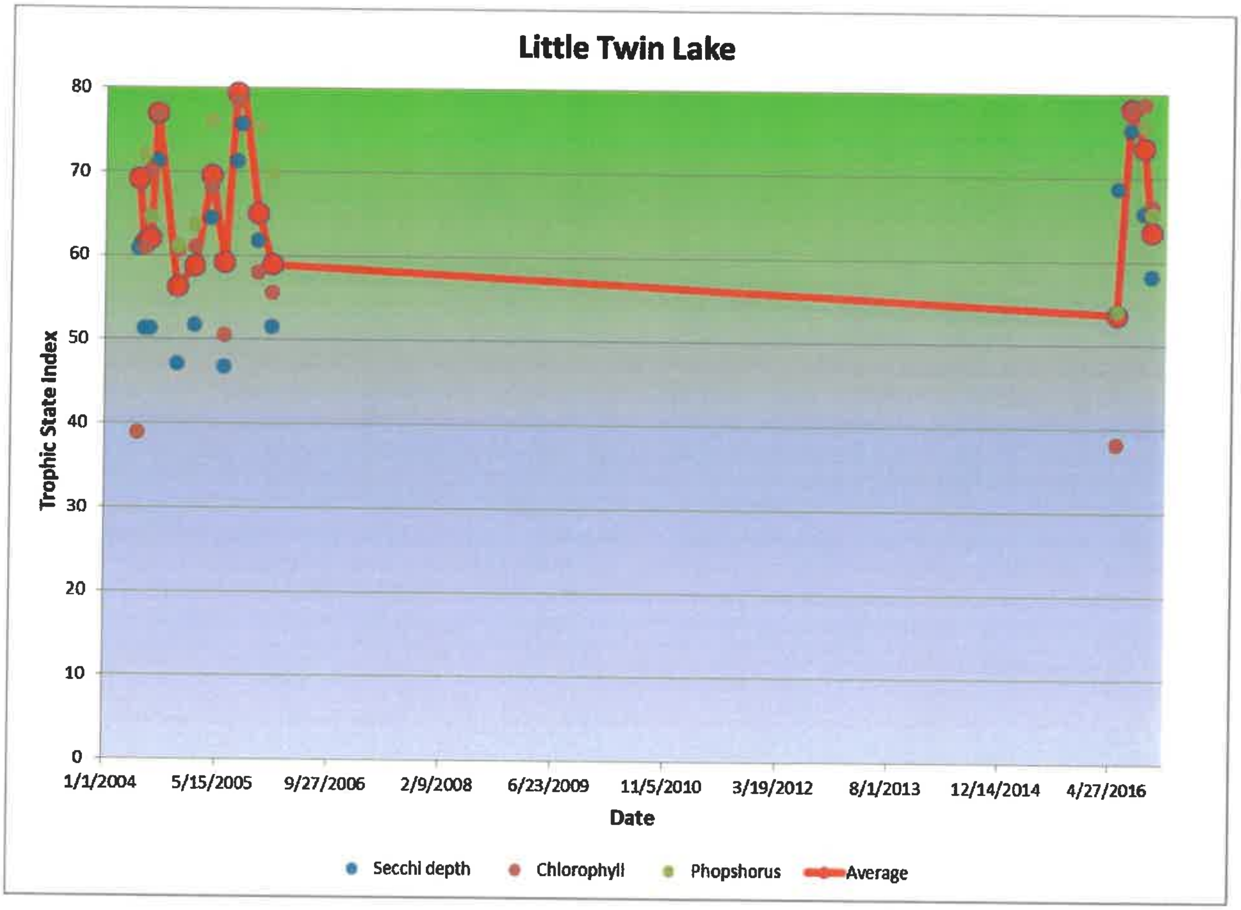
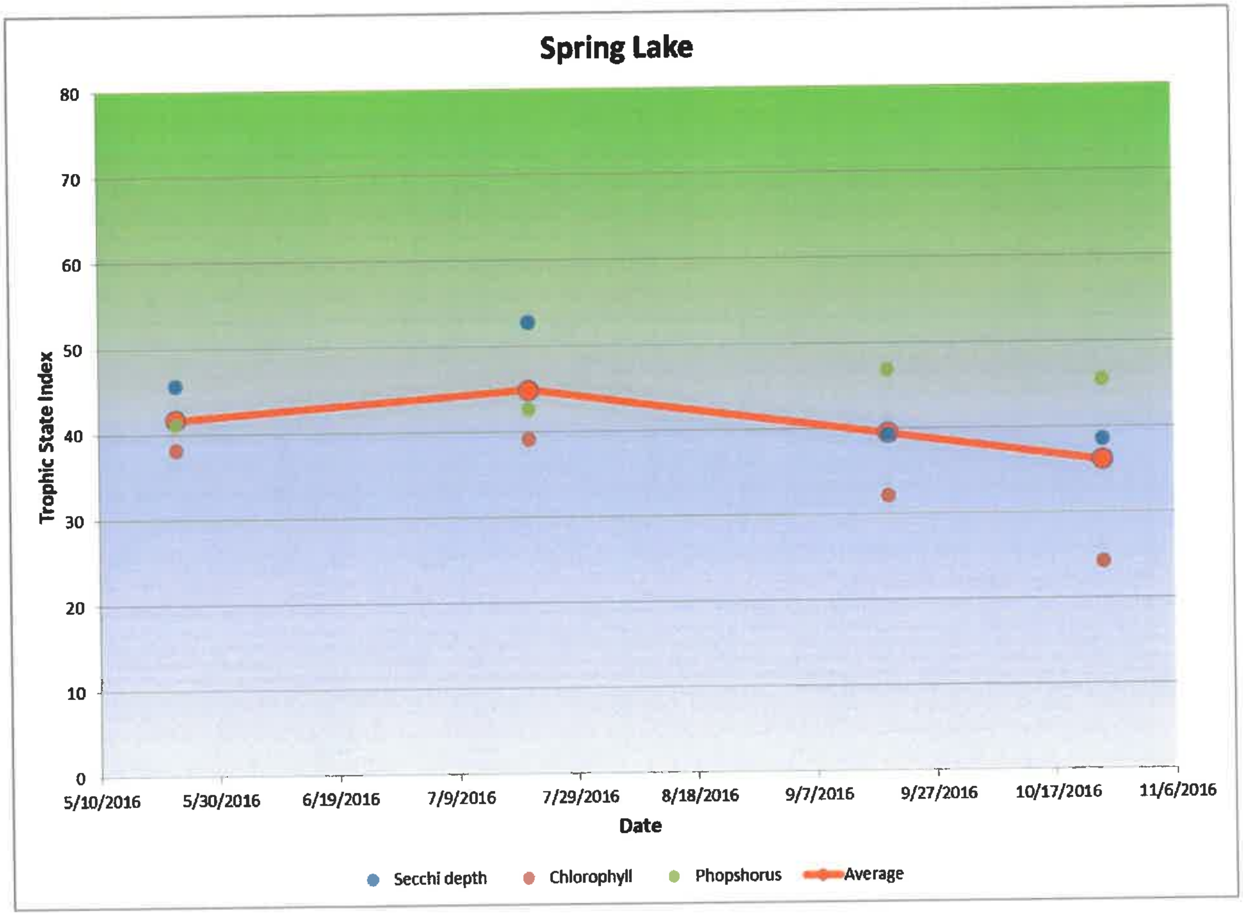
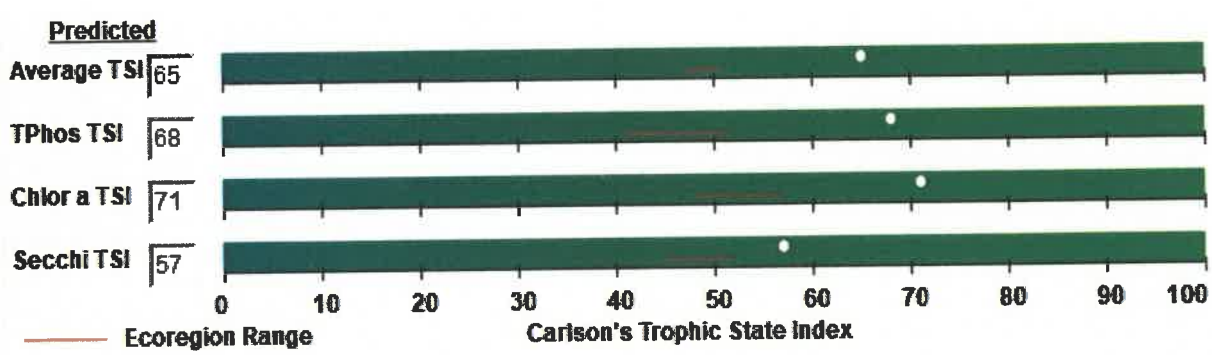


Figure 24. Trophic State Index values from 2016 for Spring Lake, Green Lake County, Wisconsin.



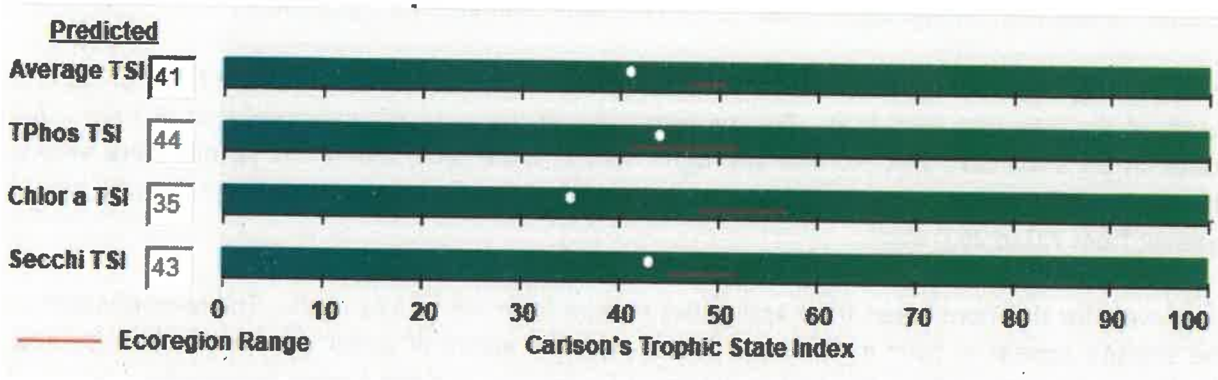
Results of the WiLMS modeling found that the observed trophic state index values for Twin Lakes fell above the predicted range of TSI values for the average TSI, phosphorus, chlorophyll and Secchi TSI values (**Figure 25**). In other words, the water quality of Twin Lakes based on these parameters was significantly lower than expected for lakes of this type in this region of Wisconsin.

Figure 25. Results of Wisconsin Lake Modeling Suite (WiLMS) analysis in 2016 for Twin Lakes, Green Lake County, Wisconsin.



Results of the WiLMS modeling for Spring Lake found that the observed trophic state index values fell above the predicted range of TSI values for the average TSI, chlorophyll and Secchi TSI values and fell within the predicted range for phosphorus TSI values (**Figure 26**). This suggests, the water quality of Spring Lake is slightly higher than expected for a lake of this type in this region of Wisconsin.

Figure 26. Results of Wisconsin Lake Modeling Suite (WiLMS) analysis in 2016 for Spring Lake, Green Lake County, Wisconsin.



pH

pH is a measure of a lake's acidity or alkalinity. It is the negative log of the hydrogen ion concentration in the water. Many factors influence pH including geology, productivity, pollution, etc. pH levels between seven and nine are not uncommon for lakes in Wisconsin. The spring 2016 data for this study show pH values between 8.34 and 8.89. These data are not cause for concern.

Conductivity

Conductivity is the measure of the inorganic compounds in a body of water as determined by how well an electrical current is carried through a water sample. Conductivity is dependent upon the concentration of inorganic compounds suspended in the water column. High conductivity values may indicate contamination from septic systems, fertilizers, animal wastes or road salts. As a result, conductivity can be used to determine if human activities are influencing water quality. The recommended value for conductivity in lake samples is below 300 µmhos/cm. The data from Big Twin Lake (540 µmhos/cm), Little Twin Lake (465 µmhos/cm) and their inlet (715 µmhos/cm) and outlet (460 µmhos/cm) on May 23, 2106 were consistently higher than the 300 µmhos/cm threshold. On the same date, the value for Spring Lake was 529 µmhos/cm. This suggests all the waterbodies being studied are affected by outside contamination.

Alkalinity

Alkalinity is a measure of the amount of carbonates, bicarbonates and hydroxide present in water. Alkalinity is predominantly determined by soil and bedrock characteristics. Lakes and ponds fed by groundwater from limestone aquifers tend to have high alkalinity. High alkalinity can also be a result of high algae and aquatic plant production. Low alkalinity (< 25 mg/L) waters are susceptible to acid rain. Alkalinity levels were well above 25 mg/L (ranging from 187 to 271 mg/L).

in all of the waterbodies tested in 2016. This indicates these are hard water systems able to withstand acid rain conditions. These levels do not warrant concern.

Total Suspended Solids

The levels of total suspended solids can be influenced by a number of factors including the transport of pollutants and sediments into a lake, growth and abundance of microscopic organisms such as planktonic algae, and disturbances within a lake from human activities or wind and wave action. Specific thresholds do not exist for suspended solids in lakes. As a result a relative comparison should shed some light on the data available for Twin Lakes.

In the spring, Big Twin Lake had undetectable levels of suspended solids. At the time, the Secchi depth of the lake was 25.5 feet. For the remainder of the year, the concentration of suspended solids in Big Twin Lake was 3.0 and 4.4 mg/L. At the same time, the Secchi depths were around the 6.0 foot threshold. Concentrations of solids for Little Twin Lake were significantly higher ranging from 7.0 to 25.0 mg/L.

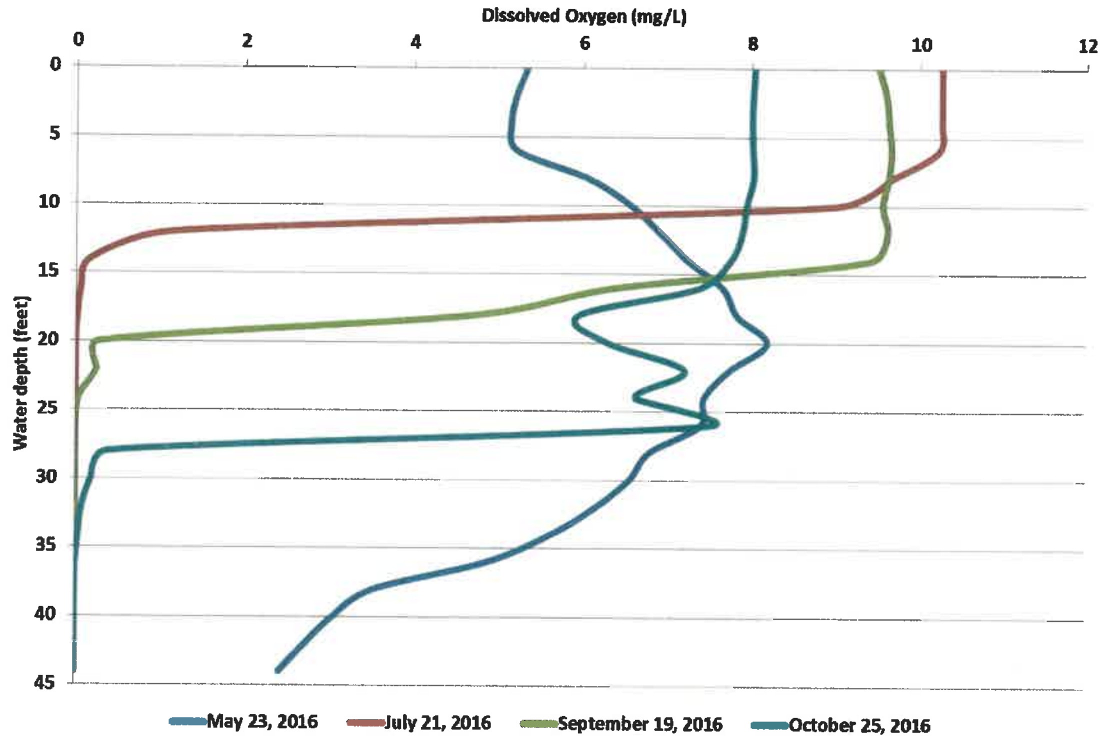
The levels for the Twin Lakes inlet and outlet ranged from 3.8 to 121 mg/L. The level of solids in the streams appear to have a direct correlation with the speed of water measured. As expected, the higher the rate of flow, the higher potential for erosion and the higher the resulting levels of suspended solids transported in the water.

Dissolved oxygen and temperature

The threshold level of oxygen needed for fish such as largemouth bass, yellow perch, and sunfish to grow and thrive is 5 mg/L. **Figures 25 – 27** show the dissolved oxygen and temperature data for Twin and Spring Lakes from 2016. Surface dissolved oxygen data were generally above this 5 mg/L threshold in all three lakes. However, in July, dissolved oxygen levels in Big and Little Twin Lakes dropped quickly forming an oxycline, or sharp change in oxygen concentrations. This is often associated with a lake's thermocline (sharp change in water temperature) where there is a similar change in water temperatures. This limits the volume of the lakes that can support a healthy fishery. Later in the year, the oxycline drops deeper in the lakes opening more lake volume to fish and other aquatic organisms. Little Twin Lake did not appear to develop a strong thermocline. This is largely due to the shallowness of this lake. In

Spring Lake data show a healthier profile in terms of dissolved oxygen and temperature. The oxycline and thermocline during much of the year were at depths of 20 to 25 feet.

Figure 25. Dissolved Oxygen and temperature data collected in 2016 on Big Twin Lake, Green Lake County, Wisconsin.



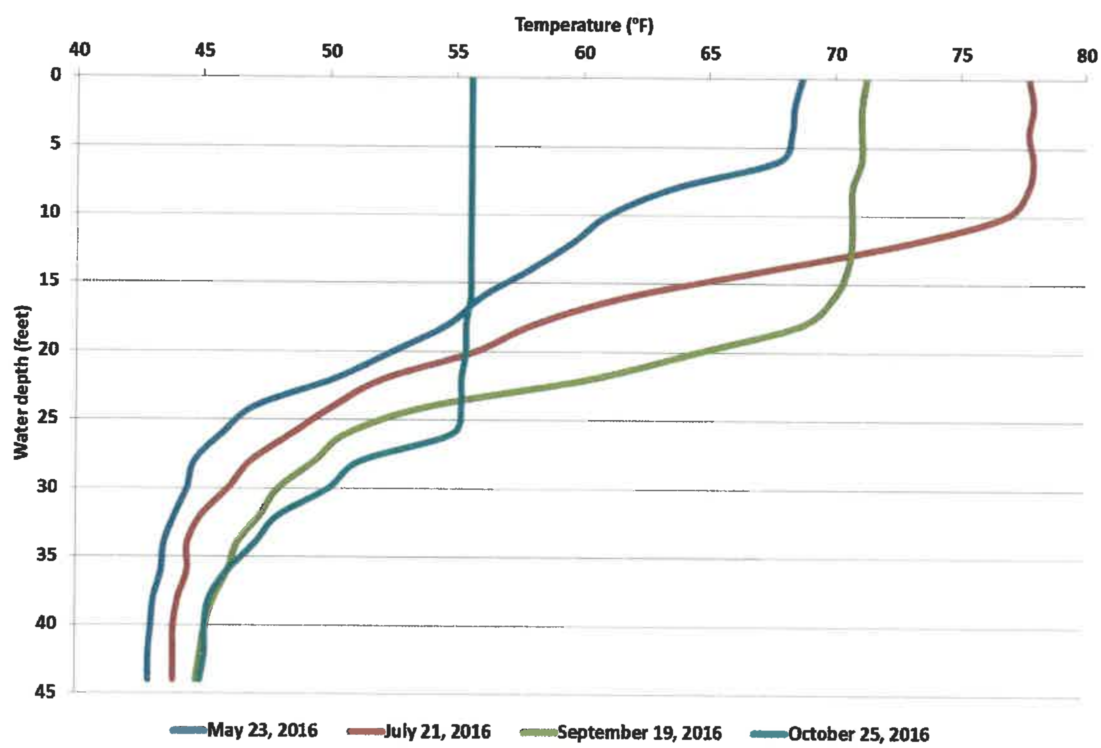
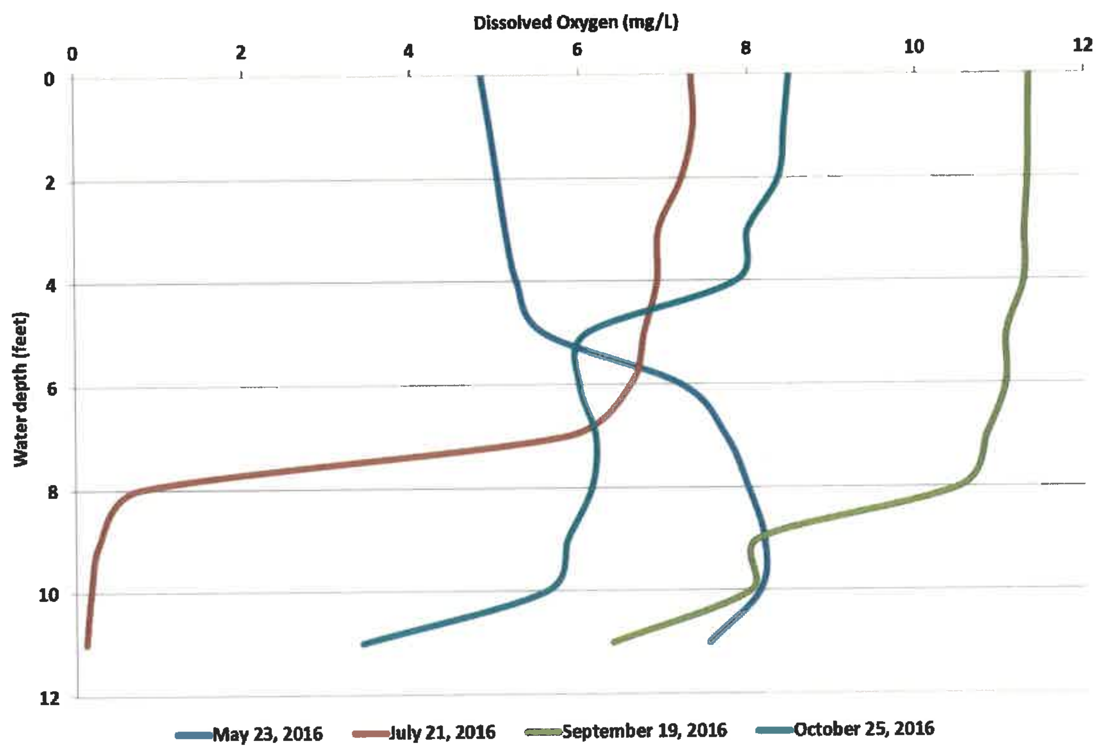


Figure 26. Dissolved Oxygen and temperature data collected in 2016 on Little Twin Lake, Green Lake County, Wisconsin.



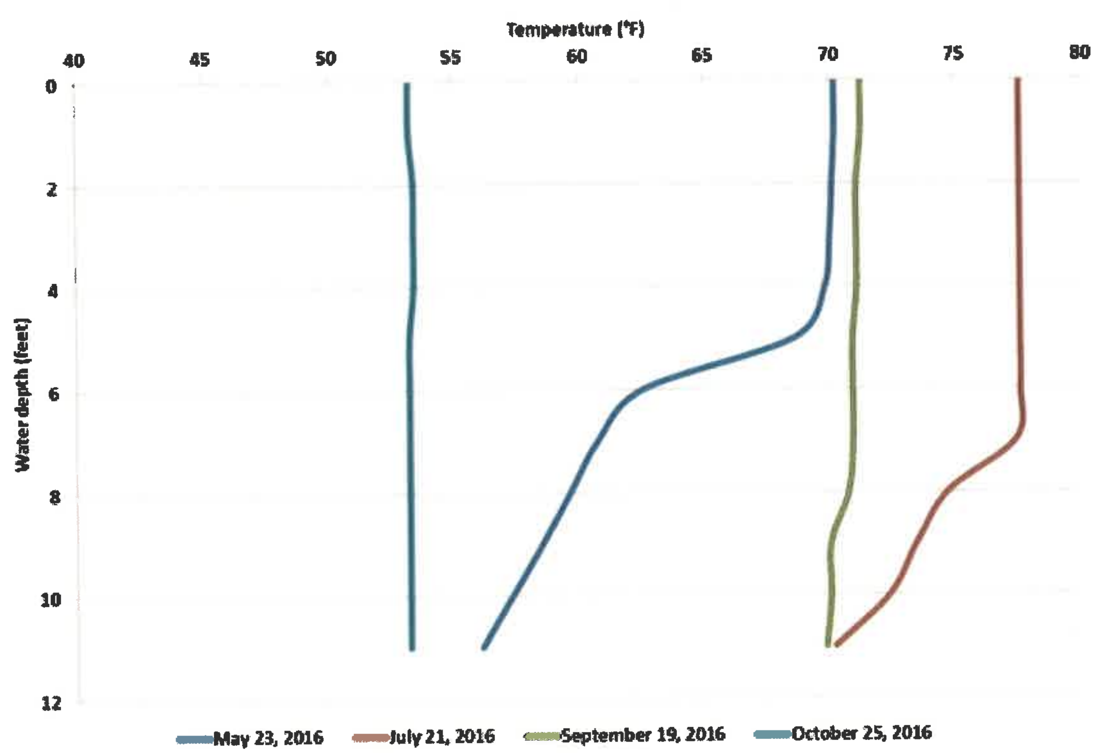
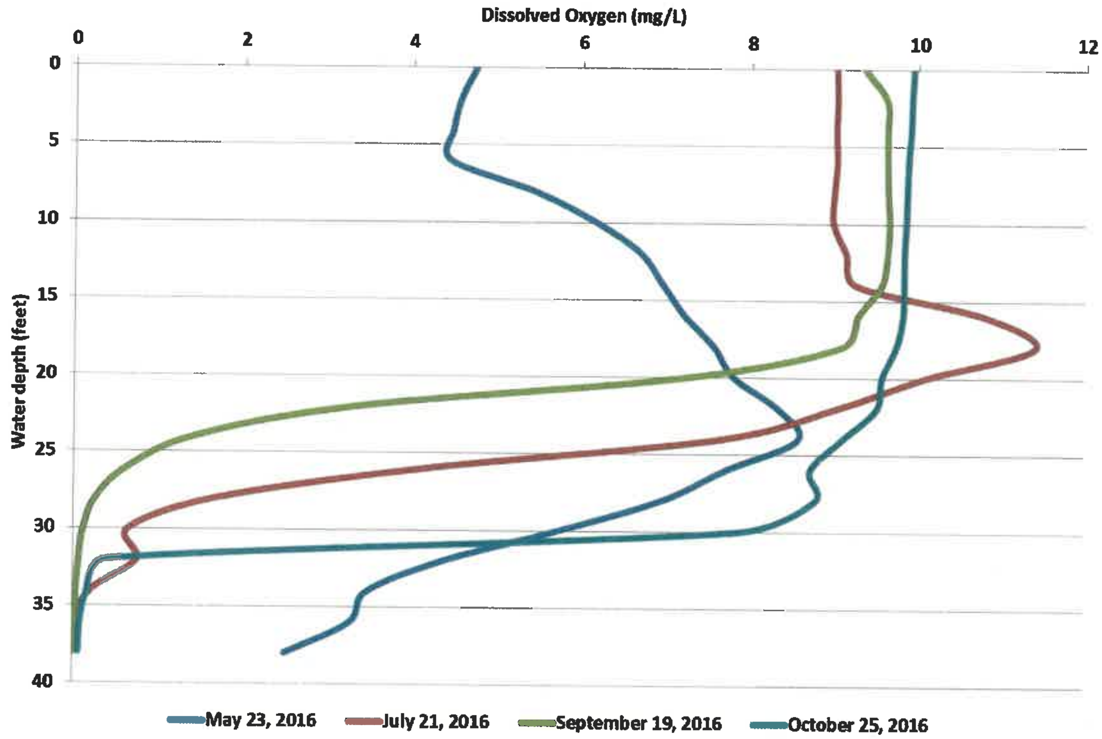
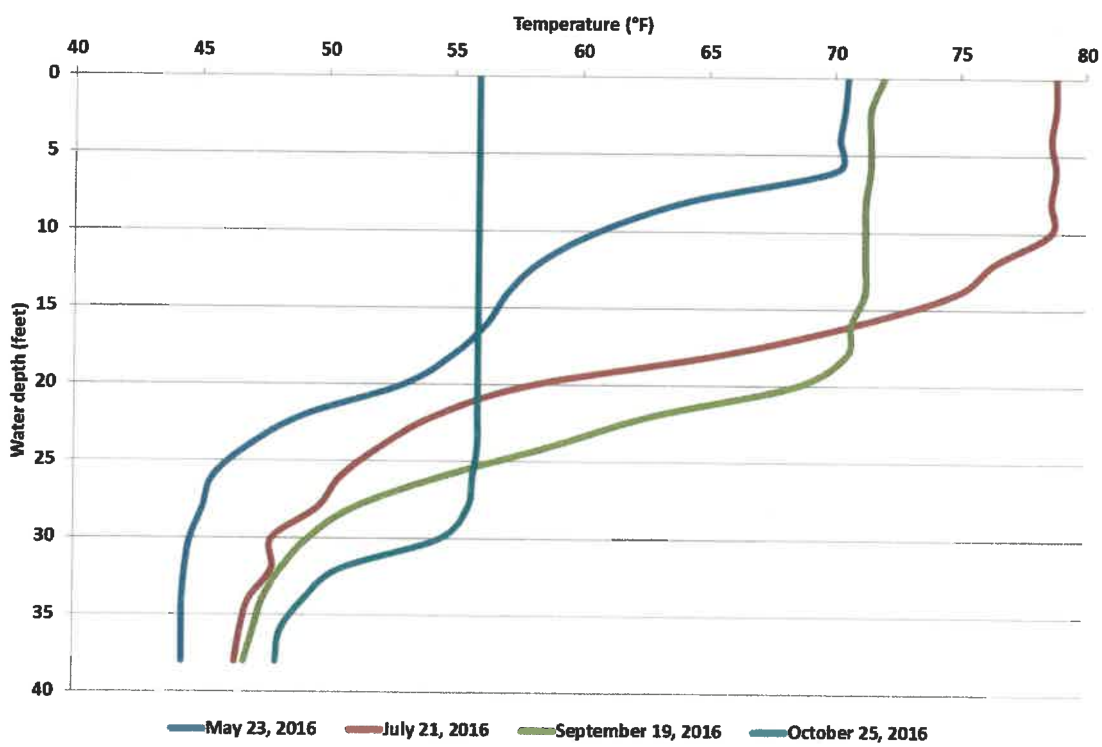


Figure 27. Dissolved Oxygen and temperature data collected in 2016 on Spring Lake, Green Lake County, Wisconsin.





Watershed Analysis

Figures 28 and 29 show the delineation of the watersheds of Twin Lakes and Spring Lake and the land use types present, respectively. The data for the land use map (**Figure 29**) was provided by the WDNR's Bureau of Technology Services. The watershed for Twin Lakes is approximately 2,772 acres while the Spring Lake watershed is approximately 658 acres.

Tables 12 and 13 contain a breakdown of land use and cover types within the watersheds of Twin Lakes and Spring Lake, respectively.

The survey and resulting analysis found that the watershed of Twin Lakes is heavily dominated (78.6%) by general agriculture and herbaceous/field crops. The agricultural areas of the watershed are mostly crop fields dominated by corn, alfalfa, wheat and soybeans. This includes fallow areas that appear to have been in crop production at some point in the past. By taking land out of production, farmers help reduce soil erosion, improve water quality and increase wildlife habitat. An additional 16.2% is forested, 4.9% is wetlands and 0.3% barren. Similarly, the Spring Lake watershed contains 57.1% agriculture, 31.1% forest and 11.8% wetlands.

The steepest slopes in the Twin Lakes watershed are found along the north shore of Big Twin Lake. In the past, it was noted during high rain events or spring snow melt, a large volume of water can pass under the road and flows directly into Big Twin Lake. Depending upon land use practices, this can cause direct runoff of pollutants directly into Twin Lake.

Table 12. Land use and cover types found within the watershed of Twin Lakes, Green Lake County, WI.

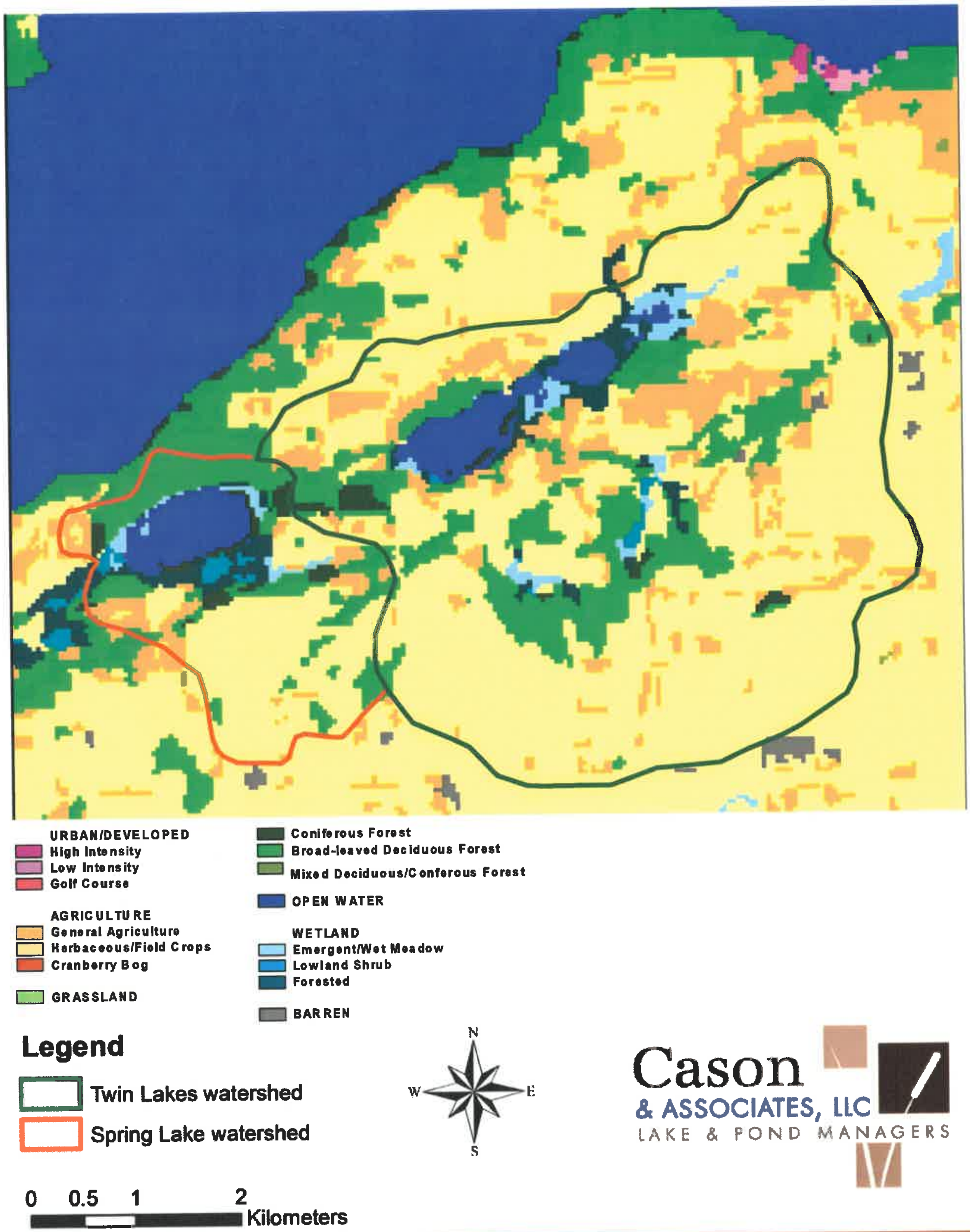
Cover Type	Percent
Agriculture:	
Herbaceous/Field Crops	62.9%
General Agriculture	15.7%
Forest:	
Broad-Leaved Deciduous Forest	14.8%
Coniferous Forest	1.4%
Wetland:	
Forested Wetland	2.7%
Emergent/Wet Meadow	1.8%
Lowland Shrub	0.4%
Barren	0.3%
	100.0%

Table 13. Land use and cover types found within the watershed of Spring Lake, Green Lake County, WI.

Cover Type	Percent
Agriculture	
Herbaceous/Field Crops	46.9%
General Agriculture	10.2%
Forest	
Broad-Leaved Deciduous Forest	25.1%
Coniferous Forest	6.0%
Wetland	
Forested Wetland	5.7%
Emergent/Wet Meadow	3.6%
Lowland Shrub	2.5%
	100.0%

Figure 28. Watershed delineation for Twin Lakes and Spring Lake, Green Lake County, Wisconsin.

Figure 29. Land cover types and watershed delineation for Twin Lakes and Spring Lake, Green Lake County, Wisconsin.



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Nutrient loading

The external loading of runoff pollutants, namely phosphorus, into Twin Lakes and Spring Lake were approximated with the WiLMS modeling software which utilizes general export coefficients for a number of land use types. Loading is expressed as kilograms (or pounds) of pollutant/nutrient per hectare per year. WiLMS also takes into account a number of other factors including lake morphology, watershed drainage area, oxygen stratification, measured phosphorus concentrations during turnover and the growing season, and estimated area of anoxia (oxygen depletion). By inputting data for a number of these factors, the WiLMS software was able to predict the estimated total annual phosphorus load into the lakes.

By utilizing the data available for land use types in the watershed, it was estimated that the total input of phosphorus from direct runoff annually into Twin Lakes is approximately 882 kg (1,944 lbs). Of this, a large portion is from non-point sources. The WiLMS software also estimated only 1.0 kg (2.2 lbs) of phosphorus enter the lakes through septic systems because approximately 90% of the phosphorus from septic systems is retained by the soil.

By utilizing the phosphorus and flow data for the Twin Lakes inlet and outlet, a rough nutrient budget can be made. Calculations estimate the total phosphorus load entering the lake from the inlet is 1,174 kg (2,588 lbs) annually. This is likely a more accurate estimation since it is based on actual data and not export coefficients for land-use types in the watershed. The estimated load leaving Twin Lakes through the outlet is 2,100 kg (4,627 lbs) annually. As a result, approximately 923 kg (2,031 lbs) of phosphorus originate from other areas including internal loading, septic systems and areal (atmospheric) deposition.

Internal loading likely comes from two main sources in Twin Lakes, direct release from sediment and from plant decomposition. Under oxygen-depleted conditions (anoxia), phosphorus is readily released from the sediments of a lake. The dissolved oxygen and temperature data show that Big Twin Lake becomes stratified and by the July sampling event, the lower portion of the lake had become anoxic. This happens to a lesser extent on Little Twin Lake. These conditions persisted through the October sampling event. Secondly, when plants die and decompose in a lake, large amounts of nutrients can be released into the water column. This can be particularly problematic in lakes like Twin Lakes that historically have had a large population of curly-leaf pondweed. As previously explained, curly-leaf pondweed plants die off and decompose during the warm months of summer. In many lakes, a large spike in nutrient levels are seen in the weeks following this die-off.

More detailed watershed assessments were conducted by the Green Lake County LCD. Results of these assessments as well as management recommendations for future management of the lakes' watersheds will be added to this report at a later date.

Fish and Wildlife Assessment

Twin Lakes and Spring Lake are well-known fishing destinations in Green Lake County. Some of the most commonly found species in these lakes include largemouth bass, northern pike and panfish (WNDR 2005).

In 2014, the WDNR conducted late-spring electrofishing surveys focused on bass/panfish on Twin Lakes and Spring Lake. The Twin Lakes survey took place on May 20, 2014 and covered approximately 1.5 miles of shoreline. The Spring Lake survey took place on June 3, 2014 and covered approximately 1.2 miles of shoreline. Results of these surveys are found in **Appendix B**. **Tables 14 and 15** show the types on numbers of fish caught during the surveys of Twin Lakes and Spring Lake, respectively. During both surveys, bluegills and largemouth bass were the most abundant species found.

Table 14. Abundance of fish species found by the WDNR on May 20, 2014 in Twin Lakes, Green Lake County, Wisconsin

Fish Species	Total Catch
Bluegill	130
Largemouth Bass	69
Pumpkinseed	17
Northern Pike	12
Black Crappie	4
Yellow Perch	3

Table 15. Abundance of fish species found by the WDNR on June 3, 2014 in Spring Lake, Green Lake County, Wisconsin

Fish Species	Total Catch
Bluegill	164
Largemouth Bass	76
Yellow Perch	11
Pumpkinseed	7
Green Sunfish	2
Walleye	1

In Twin Lakes, there were a fair number of bluegills, 20 of which were "quality-sized". Largemouth bass exhibited a strong upcoming year class with some large fish present. The average size was a little small, but not bad. The northern pike were very small/stunted with moderate numbers. Few yellow perch and black crappies were caught. It is possible the survey took place after the crappies' spawn which resulted in low numbers. In Spring Lake, there were strong numbers of bluegills, 35 of which were "quality-sized". Largemouth bass exhibited small average size with some trophy-sized fish. Yellow perch numbers were low, but good sized. The WDNR lists Twin Lakes as having walleyes, however, none were identified during the 2014 survey.

Table 16 includes habitat requirements and improvements information regarding fish species commonly found in these waters. This information was gathered from George C. Becker's *Fishes of Wisconsin*.

Table 16. Description of fish habitat requirements and improvements for fish species found in the Twin Lakes and Spring Lakes, Green Lake County, Wisconsin.

Species	Habitat Requirements			Habitat Improvements	Important Water Quality Parameters
	Spawning	Rearing	Foraging		
Large-Mouth Bass (*Micropterus salmoides*)	* Shallow protected areas containing emergent vegetation with sandy to gravely substrate * Soft bottoms with woody debris present	* Shallow edges	* Waters less than 18 ft. deep containing aquatic macrophytes * Shallow open areas	* Leave woody debris in lake including small limbs *Control dense stands of nuisance vegetation to improve foraging efforts	* Water temperature is a very important factor * L-M Bass prefer warm water (27-30°C)
Northern Pike (*Esox lucius*)	* Shallow flooded marshes associated with a lake or any flooded area containing emergent vegetation	* Shallow spawning areas with vegetation	* Site feeders, prefer vegetation for camouflage which allows them to ambush their prey	* Control dense stands of nuisance vegetation * Plant native macrophytes	* Do best in cool to moderately warm water temperatures. (21-27°C)
Walleye (*Sander vitreus*)	* Rocky Shorelines with wave washed shallows * Areas where inlet streams enter lake and contain a gravel substrate	* After hatching migrate out to open waters of lake * After 1-2 months return to inshore habitats	* Utilize hard bottom areas including bars, shoals, and emergent vegetation	* Construction of artificial spawning areas (rocks, gravel) * Addition of woody debris (logs) for habitat/foraging	* Do well in both clear and turbid waters
Black Crappie (*Pomoxis nigromaculatus*)	* Shallows containing sand or fine gravel substrate * Spawn near chara and other submerged vegetation	* Young live in shallow protected areas	* Midwater feeders associated to abundant stands of aquatic vegetation and open areas * School around large submerged trees	* Plant chara which is associated with spawning sites * Submerge woody structures	* Prefer clear, warm waters

Table 16 (continued). Description of fish habitat requirements and improvements for fish species found in the Twin Lakes and Spring Lakes, Green Lake County, Wisconsin.

Species	Habitat Requirements: Spawning	Habitat Requirements: Rearing	Habitat Requirements: Foraging	Habitat Improvements	Important Water Quality Parameters
Bluegill *(Lepomis macrochirus)*	* Shallows consisting of sand or gravel substrate	* Young stick to shallow cover (emergent and submerged vegetation)	* Tend to remain in or near cover during the day and at night enter the shallows * Utilize all sources of vegetation	* Control dense stands of exotic vegetation *Add woody cover if habitat is limited	* Found more frequently in clear water verses turbid * Very susceptible to winter kill due to low oxygen levels
Pumpkinseed *(Lepomis gibbosus)*	* Spawn in shallow warm bays with sand or gravel substrates	* Young tend to live on or near shallow water spawning areas in emergent vegetation	* Feed in deeper waters with rocky or plant covered substrates	* Control dense stands of exotic macrophytes * Restore native emergents	* Most frequently found in cool to moderately warm waters * Prefer clear to moderately turbid water
Green Sunfish *(Lepomis cyanellus.)*	* Spawn in shallow water, Nests built in shelter of rocks, logs and clumps of grass	* Young seek warm, shallow waters in the vicinity of weed beds.	* Feed in quiet pools in warm, shallow waters	* Control dense stands of exotic macrophytes * Restore native emergents	* Can survive in clear to turbid waters in temperatures over 90°F
Yellow Perch *(Perca flavescens)*	* Spawn in slow-moving or static waters where emergent and submerged vegetation is present * Also spawn on submerged brush	* Shallows among vegetation	* Feed mainly near the bottom in offshore open water habitats lacking dense vegetation	* Control dense stands of nuisance vegetation * Protect native macrophytes	* Do well in turbid, nutrient rich waters

Results of the fish and wildlife habitat survey are found in **Figures 30-42**. These maps identified areas of woody debris and tree falls as well as emergent and floating-leaf plant locations within Big and Little Twin Lakes and Spring Lake. Collectively, a large portion of these lakes is littoral and exhibit abundant plant growth. A majority of the emergent plant growth on Big and Little twin Lakes is from cattails (*Typha* spp.), but to a far lesser extent bulrushes (*Schoenoplectus* spp.) and burreed (*Sparganium* spp.). Bulrushes and cattails are both abundant on Spring Lake. Floating-leaf plants such as the waterlilies are moderately abundant along the south and west shores of Big Twin Lake and the south shore of Spring Lake. Little Twin Lake does not have a community of floating-leaf plants. Very little woody debris exists in these lakes. Two areas of woody debris were identified on Big Twin Lake. None were found on Little Twin or Spring Lakes.

Figure 30. Fish and wildlife habitats in and around Big Twin Lake, Green Lake County, Wisconsin.

Figure 31. Fish and wildlife habitats in and around Little Twin Lake, Green Lake County, Wisconsin.

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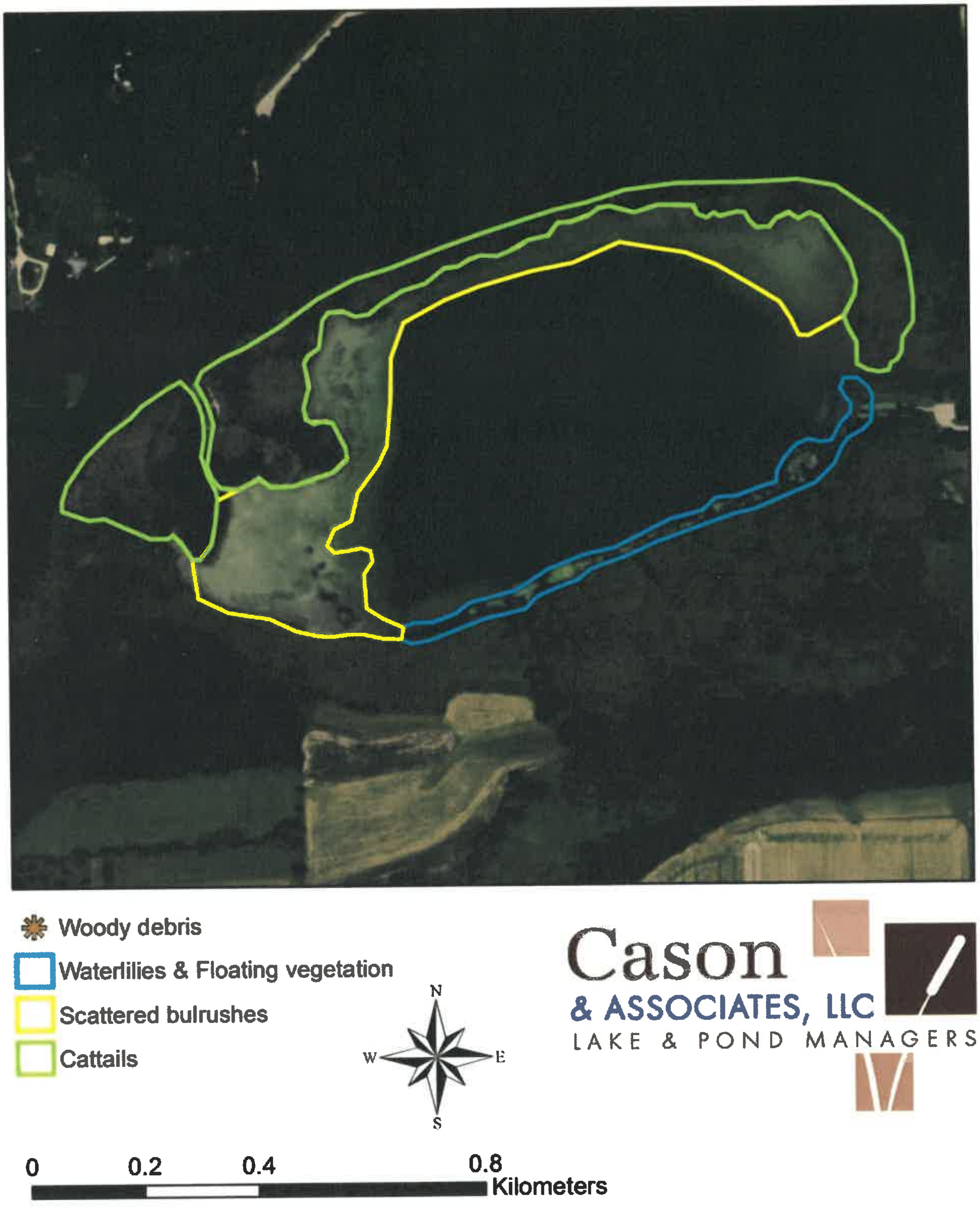
Figure 32. Fish and wildlife habitats in and around Spring Lake, Green Lake County, Wisconsin.



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Lake Management Alternatives

Aquatic Invasive Species Management

AIS management continues to be one of the primary lake management concerns for Twin Lakes and Spring Lake. As of 2016, there is approximately 23.2 acres of EWM in Big Twin Lake, 11.6 acres in Little Twin Lake and 1.0 acre in Spring Lake. In addition, in the spring of 2016, 17.8 acres of CLP were identified in Big Twin Lake, 19.0 acres in Little Twin Lake and 0.5 acre in Spring Lake. Twin Lakes, in particular, are re high-use recreational lakes in Green Lake County.

Control options for this species should be revisited. AIS have interfered with recreational activities including swimming, boating and fishing in numerous lakes throughout Wisconsin including Twin Lakes. Communities of native aquatic plants, as well as fish and wildlife, have also suffered as a result of these aquatic invaders.

Herbicide treatment of invasive species

Herbicides have been the most widely used and often most successful tools for controlling EWM and CLP in the State. The most commonly employed herbicide used to manage EWM in numerous of Wisconsin lakes is 2,4-D (e.g. Navigate®, DMA4®, Sculpin®). 2,4-D is a systemic herbicide. When applied at labeled rates, 2,4-D has been shown to be an effective tool at managing EWM. There are other aquatic plant species that are sensitive to 2,4-D as well. As a result, some non-target species may experience statistically significant declines following a herbicide treatment. Based on published research, a 2,4-D concentration of 2.0 mg/L is required for good control at an exposure time of 24 hours after treatment (HAT). In addition, 1.0 mg/L is required for good control at 48 HAT and 0.5 mg/L is required for 72 HAT (Green and Westerdahl 1990). When large-scale (whole-lake) treatments take place, often a low-dose of herbicide is applied with a target concentration often between 0.3 and 0.4 mg/L.

The herbicide most often used to control CLP is endothall (e.g. Aquathol®, Aquathol Super K®). Endothall is a contact herbicide when applied at low concentrations acts as a systemic herbicide. While endothall herbicides are effective on a broad range of aquatic monocots, early season applications made at low rates are able to select for CLP. Endothall herbicides effectively kill the parent plant, but the turions are resistant to herbicides, allowing CLP to regenerate annually.

Studies conducted by the Army Corps of Engineers have found that conducting treatments of CLP using endothall when water temperatures are in the 50-60° F range will kill plants before turions (vegetative reproductive structures) form, thus providing long-term control. Researchers found that conducting treatments for five consecutive seasons or more for established curly-leaf pondweed populations will target both the standing crop of the pondweed as well as the resulting regrowth from the turions (Skogerboe and Poovey, 2002).

Endothall and 2,4-D are herbicides which break down microbially and do not persist in the environment. When applied at the labeled rates, herbicides are an effective management tool for control of many aquatic plant species. While no control method could be considered cheap, when large areas of aquatic plants require management, herbicide treatments are among the least costly of methods. This is in part due to the relatively low labor costs in comparison to measures such as hand-pulling, mechanical harvesting, etc. When properly executed, herbicide treatments have produced long-term control of invasive species (below nuisance levels). The greatest disadvantage of herbicide treatments is that they rarely produce 100% control. In order to effectively manage an exotic species with herbicides, the chemical has to be present at a high enough concentration for a long enough period of time to cause plant mortality. A number of factors can influence this. All herbicides in an aquatic environment will become diluted by the surrounding water. This makes it particularly difficult to achieve success in smaller, spot treatments. Flowing systems have increased risk of lowered exposure time. Microbes break down the chemicals at varying rates. Certain plants are more resilient than others. Factors such as plant maturity may also reduce treatment efficacy. Several follow-up management activities (e.g. treatments, mechanical harvesting, manual removal, etc.) whether in-season or in subsequent years, may be needed to reduce AIS to target levels.

The distribution and density of plant growth is the main factor that determines the appropriate treatment approach to chemically manage AIS. Due to high dilution rates of herbicides, the WDNR discourages the use of systemic herbicides on small spot treatments where the appropriate contact/exposure time is difficult to achieve. Contact/exposure time is the time required for a herbicide to be in contact with a plant to be effective. When small, spot areas are targeted, a fast-acting contact herbicide like diquat (e.g. Reward®, Tribune®) should be considered as an alternative. Diquat can effectively control aquatic plant growth with as little as six hours of contact time. If a large enough portion of a lake contains AIS, a large-scale, whole-lake treatment with a low target concentration of herbicides may be warranted. By conducting a whole-lake treatment, the exposure time can be extended since dilution is generally mitigated. In addition, not only are the known locations of invasive species targeted with whole-lake treatments, the unknown locations are as well.

As with any herbicide treatment, collateral damage is always a concern. The *desired* result of herbicide treatment of invasive species is to effectively eliminate the target species while minimizing the impact to non-target species and to water quality. This can be difficult in situations where native species sensitive to herbicide treatments are present or where large amounts of plant biomass may remain after treatment. To offset this risk, early-season treatments with semi-selective herbicides at low concentrations, target AIS when the plants are small and when cooler temperatures slow the microbial decomposition of herbicides.

With large-scale treatments, it is important to include monitoring of the residual herbicide concentrations after treatment. For greatest success, it is important the target concentrations are reached. If the concentrations are not achieved, then the treatment can be ineffective and could add to plant tolerance of the chemical. Collecting this information is the only way to assure dosage and contact/exposure time is achieved.

With any chemical treatment on a public lake, a Chapter 109 permit (Wisconsin Administrative Code - NR 109) through the WDNR is required prior to treatment. In addition, many of the herbicides used to manage AIS require the applicator be licensed and certified through the State.

Biological control - milfoil weevils

There has been considerable research on biological vectors, such as insects, and their ability to affect a decline in EWM populations. Of these, the milfoil weevil (*Euhrychiopsis lecontei*) has received the most attention. Native milfoil weevil populations have been associated with declines in EWM in natural lakes in Vermont (Creed and Sheldon, 1995), New York (Johnson et al., 2000) and Wisconsin (Lilie, 2000). While numerous lakes have attempted stocking milfoil weevils in hopes of controlling milfoil in a more natural manner, this method has not proven successful in Wisconsin. A twelve-lake study called "The Wisconsin Milfoil Weevil Project" (Jester et al. 1999) conducted by the University of Wisconsin, Stevens Point in conjunction with the WDNR researched the efficacy of weevil stocking. This report concluded that milfoil weevil densities were not elevated, and that EWM was unaffected by weevil stocking in any of the study lakes. Recently, however, work carried out on a number of Portage County lakes has shown some promise at enhancing milfoil weevil populations. In order for weevils to be successful in reducing the extent of EWM, a number of environmental criteria are needed, including the availability of proper year-round habitat. This study did not include an assessment of shoreline habitat specifically in terms of weevil survival.

Manual removal of vegetation

Manual removal options include raking or hand-pulling aquatic plants and diver-assisted suction harvesting (DASH). Individuals can remove aquatic vegetation in front of their homes, however, there are limitations as to where plants can be hand-pulled and how much can be removed. In most instances, control of native aquatic plants is discouraged and is limited to areas next to piers and docks. When aquatic vegetation is manually removed it is restricted to an area that is 30 feet or less in width along the shore. Invasive species (EWM, CLP, etc.) may be manually removed beyond 30 feet without a permit, as long as native plants are not harmed. Manual removal of native plants beyond the 30 foot area would require an NR 109 permit. Benefits of manual removal include low cost compared to other control methods. However, raking or hand-pulling aquatic plants can be labor intensive.

Similar to hand-pulling, suction harvesters physically remove plants from the lake bed. A diver or snorkeler is needed to remove the plants from the sediment and feed it into the harvester. As with other similar activities, removal of the entire plant, including the stems and roots is important to eliminate the possibility of further spread. This method should increase manual invasive species harvesting efficiency and reduce the amount of fragmentation during the harvesting operations. There are firms in the State that specialize in DASH. As an alternative, a number of lake organizations in the State have built their own DASH units and operate them throughout the season. There are a lot of variables to consider when it comes to planning DASH activities and selecting areas to harvest. These include plant bed size and density, water clarity, sediment type, native plant abundance, obstructions such as docks or fallen trees, financial resources and time restraints. These factors also determine the speed at which progress is made. DASH is a small-scale tool and should not be expected to greatly reduce EWM densities in areas of widespread growth. DASH operations should primarily focus on areas scattered EWM locations not slated for chemical treatment. It would be wise to focus first on areas of high boat traffic.

This approach may be most useful in Spring Lake where the distributions of EWM and CLP are relatively low.

Aquatic plant harvesting

Mechanical harvesting involves the removal of aquatic plants from a lake using a machine that cuts and collects the plants for transport to an off-shore disposal site. Generally, harvesting equipment can be adjusted to cut to a desired depth up to approximately five feet. Harvesting operations often include equipment, such as a barge, to transport plant materials from a harvester to the shore where a conveyor is used to transfer the materials to a waiting truck. Harvesting is often used for areas where dense, sometimes monotypic, aquatic plant growth significantly interferes with navigation. It is also used to collect floating mats of vegetation that interfere with recreational use of the lakes. Harvesting produces fast results on a small scale, and the removal of plant biomass from a lake. In recent years, a number of lodge and resort owners have reported a decline in business due to the increase in aquatic plant growth. In addition, the benefits of harvesting include nutrient removal, and few if any seasonal restrictions. However, this method is limited to water deep enough for navigation. In addition, harvesting is not generally used to restore aquatic plant communities. It is a maintenance approach used primarily for navigational issues. Harvesting can complicate the management of AIS, particularly EWM. Because milfoil spreads efficiently through fragmentation, and harvesting results in a large number of fragments, the two are generally considered incompatible. However, research has shown harvesting over the long-term can have the ability to keep EWM populations in check, as well as promote native plant growth (Barton et al., 2013). Harvesting also comes with high initial equipment costs, as well as relatively high maintenance, labor, and insurance costs, disposal site requirements, and a need for trained staff. Many of these issues are avoided with contract harvesting. Other negatives include impacts to fish, invertebrates and amphibians.

An NR109 permit is required for aquatic plant harvesting.

Conclusions and Recommendations

Aquatic Invasive Species

Management of aquatic plants in Big and Little Twin Lakes will continue to be a challenge. The Twin Lakes Association will have to contend with nuisance levels of invasive and native aquatic plant species for the foreseeable future. Although the quality of the lakes, specifically in terms of the plant community, is below average for the region, in many ways, Twin Lakes have ideal conditions for the growth and spread of aquatic plants which may continue to be a threat to the lake's ecosystem.

Multiple treatment approaches should be considered for treatment of AIS in Twin Lakes and Spring Lake. The distributions of EWM and CLP in Big Twin Lake are highly enough that either spot treatments or whole-lake treatments could be employed to manage these species. In Little Twin Lake, both species take up a large portion of the lake. As a result, whole-lake treatments are likely the best treatment option. In Spring Lake, the distribution of AIS is much lower. As a result, spot treating with a contact herbicide is likely the best treatment approach. Given the low occurrence of AIS in Spring Lake, further monitoring may be warranted to determine if these species continue to spread. However, this approach runs the risk of delaying management while AIS expand and become more costly to manage. It is recommended the Association work with the WDNR and the applicator to develop a herbicide monitoring plan with a schedule of sampling frequency and locations as well as instructions for the preservation and submission of the water samples.

The Association should understand that management of AIS will need to be adaptive. If one approach is unable to provide continued progress in the coming years, a modified treatment approach or other non-chemical management approach should be considered. On a limited basis, harvesting can be used to supplement EWM and CLP management. It should be understood that this approach can encourage the spread of certain aquatic plant species.

It is recommended that annual AIS surveys be performed for the foreseeable future. These surveys will serve to monitor the effects of previous management activities while preparing for additional efforts. With the wide-spread distribution of AIS particularly in Big and Little Twin Lakes, it is recommended that monitoring utilizing current WDNR protocols be employed to accurately locate and map aquatic invasive species in the lakes. Specifically, a "focused" point-intercept approach would allow for qualitative mapping of the EWM beds as well as quantitative data collection that can be used in statistical analyses. It is recommended spring and fall invasive species surveys take place annually. CLP is best identified in the spring, while EWM is best identified in late-summer and fall.

It is also recommended that annual winter stakeholder meetings take place to assess the results of the previous year's AIS management activities. Attendees should include representatives from the Twin Lakes Association Board, Green Lake County, WDNR and Cason & Associates. These meetings should provide consensus on annual invasive species management activities. It is recommended a goal of reducing EWM growth to 10% littoral frequency of occurrence based on point-intercept survey data goal be established. This approach provides a standardized, repeatable, and quantitative approach. If and when this goal is reached in any particular basin, management should integrate other pest management techniques such as spot treatments using a contact herbicide, hand pulling, DASH or mechanical harvesting. Stakeholders should collectively decide on how best to proceed when this initial goal is met. Management actions may vary from lake to lake and from year to year.

Genetic testing

Genetic testing of the lakes' milfoil is recommended. This testing has been used throughout the State and has found that much of the milfoil that lakes are managing are hybrid strains; crosses between Eurasian watermilfoil and northern watermilfoil. Research has found some hybrid strains are more difficult to manage through chemical treatments. Since both of these parent species are present in Big Twin Lake, it is possible the plants identified as Eurasian watermilfoil are, in fact, hybrid watermilfoil. It is also possible all three strains exist. It is generally recommended this type of analysis be repeated approximately everyone five years. It would be wise to collect samples prior to any chemical management from all three lakes to better determine what types of milfoil are present and where.

Cattails

Annually, the Twin Lakes Association has sponsored treatment of select areas of cattail growth for nuisance relief. Often the channel between Big and Little Twin Lakes require chemical treatment of cattails maintain navigability between the two lakes and access for nearby riparian property owners. This approach should continue for the foreseeable future. The habitat maps in this report (Figures 30 – 32) show the locations of cattails in Twin Lakes. If additional areas of cattails begin to become a nuisance, they two should be proposed for treatment. Annually, recreational use of the lake and the abundance of cattails should be revisited to determine if changes in the locations or approach to cattail treatments should be made.

Aquatic Invasive Species grant

Green Lake County and the Twin Lakes Association are eligible to apply for a grant through the WDNR to assist in the management of AIS in the lakes. The Aquatic Invasive Species – Established Population grant program provides funding on a cost-sharing basis to assist with planning, implementing and monitoring efforts related to, in this case, large-scale management of EWM and CLP. It is recommended a proposal be submitted to the WNDR (February 1st deadline) to cover three years of management activities from 2018 through 2020.

Clean Boats, Clean Waters

Green Lake County has an existing Clean Boats, Clean Water (CBCW) program that includes monitoring at the Twin Lakes landing. The WDNR in cooperation with the UW-Extension Lakes Program has developed this volunteer watercraft inspection program designed to educate motivated lake organizations in preventing the spread of exotic plant and animal species among Wisconsin lakes. This program is particularly useful to Twin Lakes due to the large number of visitors to the lakes. Through the Clean Boats, Clean Waters program, volunteers are trained to monitor and stop the spread of invasive plants and animals. Not only does this program help reduce the likelihood of new invasive species being introduced to lakes, it also help prevent the spread of invasive species out of these lakes to other lakes in the region. More information can be found at the WDNR's website.

It is recommended members of the Twin Lakes Association play a bigger role in the Clean Boats, Clean Waters program. All individuals willing to participate should be taught to identify invasive species. The Association should make it a priority to include such measures during all normally scheduled meetings whenever possible. In addition, special meetings should be sponsored to train volunteers for this program.

The native plant, northern watermilfoil, grows in the lakes. Because it superficially looks much like EWM, care should be taken to specifically learn to differentiate between the two species. In addition to EWM and curly-leaf pondweed, it would behoove members of the Association to become familiar with the identification of other invasive species that pose a threat to Wisconsin lakes (see **Appendix C**). Additional information and education materials are available through the WDNR and the local UW-Extension office. **Appendix C** also contains information regarding management options for the invasive species previously mentioned. As always, education should be a key component of any exotic species management effort.

Water Quality Management

Data from 2016 show during the warmest times of the year, the Big and Little Twin Lakes experience relatively poor water quality. For the most part, little data are available for the past decade or more. There are a number of practices that individual property owners can undertake to improve or maintain water quality in their lakes. It is recommended the Association encourage these activities through presentations at meeting and in newsletters.

Nutrient management options

Elevated nutrient inputs from human activities around a lake can adversely affect both water clarity and water quality. A number of practices can be carried out to improve water quality. The Green Lake County Land Conservation Department has worked hard to improve land use practices and identify and manage areas of erosion within the watershed to minimize excessive nutrient and sediment inputs. Significant contributions of nutrients to the lake can come from direct runoff from areas closest to the lake. The following are options for water quality enhancement which both the Association, as a whole, and individual lakefront property owners can undertake in an effort to maintain water quality.

The first step in managing nutrients in a lake is to control external sources of nutrients. These can include: encouraging proper lawn care, restoring vegetation buffers around waterways, encouraging beneficial agricultural practices, and reducing run-off.

Lawn care practices

Individuals can play a large part in reducing sedimentation from local sources. Mowed grass up to the water's edge is a poor choice for the well-being of a lake. Studies show that a mowed lawn can cause seven times the amount of phosphorus and 18 times the amount of sediment to enter a waterbody (Korth and Dudiak, 2003). Lawn grasses also tend to have shallow root systems that cannot protect the shoreline as well as deeper-rooted native vegetation (Henderson et al., 1998).

Property owners should take care to keep leaves and grass clippings out of the lake whenever possible, as they contain nitrogen and phosphorus. The best disposal for organic matter, like leaves and grass clippings, is to compost them.

Fertilizers that enter the lake will encourage an increase in plant and algae biomass. Fertilizers contain nutrients that can wash directly into the lake. While elevated levels of phosphorus can cause unsightly algae blooms, nitrogen inputs have been shown to increase weed growth. Increases in plant biomass will lead to further sedimentation and navigational issues. Landowners are encouraged to perform a soil test before fertilizing. A soil test will help determine if a yard needs to be fertilized. For assistance in having soil tested, contact the local county UW-Extension office. Since April 1, 2010, fertilizers containing phosphorus cannot be applied to lawns or turf in Wisconsin. This change in the State's statutes is intended to provide protection to Wisconsin's lakes, rivers, streams and other water resources from phosphorus run-off. The fact is most lawns in Wisconsin don't need additional phosphorus. The numbers on a bag of fertilizer are the percentages of available nitrogen, phosphorus and potassium found in the bag. Phosphorus free fertilizers will have a 0 for the middle number (e.g. 10-0-3).

Vegetative buffer zones

There are beneficial alternatives to the traditional mowed lawn. It is best to leave the natural shoreline undisturbed. If clearing is necessary to access and view the lake, consider very selective removal of vegetation.

If the natural shoreline has been disturbed or removed it would be ideal to restore it. Restoring a vegetative buffer zone is an important alternative. Ideally, a buffer zone consists of native vegetation that may extend from 25 – 100 feet or more from the water's edge onto land, and 25 – 50 feet into the water. Often a buffer to this extent is not feasible, either physically or economically. In these cases, a smaller or narrower buffer can still provide the same benefits of a more extensive buffer, just on a smaller scale. A buffer should cover between 50% and 75% of the shoreline frontage (Henderson et al., 1998). In most cases this still allows plenty of room for a dock, swimming area, and lawn. Buffer zones are made up of a mixture of native trees, shrubs, and other upland and aquatic plants. Studies have also shown that providing complex habitats through shoreline features, such as plants and erosion control devices, can result in significant increases in fish diversity and numbers (Jennings et al., 1999).

Shoreline vegetation serves as an important filter against nutrient loading and traps loose sediment. A buffer provides excellent fish and wildlife habitat, including nesting sites for birds, and spawning habitat for fish. Properly vegetated shorelines also play a key role in bank stabilization. A number of resources are available to assist property owners in creating beneficial buffer zones. These include the WDNR, local UW-Extension office, and Green Lake County. These organizations can provide descriptions of beneficial native plant species and listings of aquatic nurseries in the State. The WDNR have grant programs that can be utilized for funding sources.

Erosion control

Erosion is a natural process, but it is for the benefit of the landowner and health of the lake that erosion control practices be carried out to slow the process as much as possible. Sedimentation into the lake causes nutrient pollution, turbid water conditions, eliminates fish spawning habitat, and increases eutrophication. Shoreline owners are encouraged to leave existing vegetation undisturbed, as it is a great shore stabilizer. The placement of logs, brush mats, and rock riprap are also options against erosion. When riprap is used it is recommended that desirable shrubs and aquatic plants be planted within the riprap. The plantings serve as nutrient filters and habitat. Before any shoreline stabilization project is initiated, it is advised that property owners contact the local WDNR office for project approval and to obtain any necessary permits.

Reduced impacts from boating

Boat traffic can cause an increase in suspended solids, especially in shallow areas of lakes (Hill, 2004). Studies have shown that maximum increases in turbidity occur between two and 24 hours following boating activities. The full effects of heavy boating depend upon a number of factors including propeller size, boat speed, draft, and sediment characteristics (Asplund, 1996). Silty sediments tend to have the highest susceptibility to resuspension and the highest potential for the reintroduction of nutrients into the water column. Studies have also focused on algae (chlorophyll a) concentrations but found no significant changes following boating activity. This is due primarily to an indeterminate time lag which occurs between the release of nutrients and the subsequent increase in algal growth. It has also been suggested that disturbances to the native plant communities due to watercraft use can accelerate the spread of opportunistic exotic plant species such as EWM and curly leaf pondweed (Asplund and Cook, 1997).

Wisconsin statutes require boaters to maintain no-wake speeds within 100 feet of shorelines, other boats, or fixed structures, including boat docks and swimming platforms. However, it is difficult to enforce such regulations, and even slow boat traffic can have a negative impact on sediments and plant communities in shallow areas. This not only has a negative impact to the lake but shallow conditions can also damage boat propellers and motors. It is recommended that the Association take the opportunity to educate members and lake users alike of the impacts boating can have on a lake.

Septic system maintenance

Septic systems are known to contribute nutrients to a lake. It is the responsibility of lakeshore property owners to ensure that septic systems are properly functioning. A failing septic system can contaminate both surface and ground water. Many Counties in Wisconsin have taken inventory of septic systems and enrolled them in a three-year maintenance program. Property owners should avoid flushing toxic chemicals into septic systems. This can harm important bacteria that live in the tank and naturally break down wastes. Owners should also avoid planting trees, compacting soil, or directing additional surface runoff on top of the drain field.

Fish habitat

Although there is an abundance of emergent and floating-leaf vegetation in Big and Little Twin Lakes, little woody habitat is generally absent. It would benefit all three lakes to have cribs or large woody habitat structures called fish sticks installed. Fish cribs are bundles of trees that are weighted and sunk in relatively shallow areas of a lake. Fish sticks are downed trees that are tied or grouped together and are anchored to the shore and are partially or fully submerged. Fish sticks are not "tree drops" per se, since the trees are moved out from shore often around a distance of 30 feet or more. Both fish cribs and fish sticks provide habitat which creates food, shelter, and breeding areas for all sorts of creatures both aquatic and terrestrial. It is recommended the Association work with the WDNR and the Green Lake LCD to plan for the placement of these structures in the three lakes.

Wisconsin Citizen Lake Monitoring Network

Very little historic water quality data is available for Big and Little Twin Lakes and Spring Lake. Volunteers should consider increasing the frequency of data collection following WDNR guidelines. This includes regular collection of water clarity (Secchi depth) data and three sampling events each summer where samples are collected for chlorophyll and phosphorus analysis as well as monitoring dissolved oxygen and temperature profiles. This can be done through the Wisconsin Citizen Lake Monitoring Network. This program provides an opportunity for volunteers from lake organizations to assist in state-wide water quality monitoring. Through a database managed by the WDNR, information gathered is shared by volunteers and archived. The importance of long-term data is crucial in assessing changes to the lake environment. In addition, participating in projects of this type can help the Association secure additional grant money from the WDNR. Funds are awarded to organizations that demonstrate a commitment to the health and wellbeing of their lakes.

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