WATER QUALITY AND AQUATIC PLANT ASSESSMENT
FREMONT LAKE FINAL REPORT

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1.0 Introduction

As land use and human activities change through time, it is important to understand how these changes might affect Fremont Lake and its tributaries. Water quality studies and assessments are conducted to track the ecological state of Fremont Lake so management plans can be developed using the most up-to-date and accurate information. The City of Fremont and Sheridan Township have supported monitoring efforts for Fremont Lake for several non-sequential years since 2009. This monitoring has been conducted by local citizen scientists enrolled in the MiCorps Cooperative Lakes Monitoring Program (CLMP). The "Baseline Study on Fremont Lake and its Connecting Waterways" was conducted in 2009 by the Annis Water Resources Institute of Grand Valley State University (GVSU). The present water quality and aquatic plant assessment was conducted by researchers at Michigan State University (MSU) in the Department of Fisheries and Wildlife, MSU Extension, and the Institute of Water Research. Researchers at MSU also accessed several historical reports to compare present and past water quality data.

The goal of this study was to investigate and respond to the recommendations provided in the 2009 baseline study prepared by GVSU (GVSU 2010) (see Recommendations in Section 6.0). In addition, by request from the City of Fremont and Sheridan Township, an outreach component was included by holding three educational town hall-style forums to better inform residents about the current status of Fremont Lake, background information on lake ecosystems, and the importance of conserving the aquatic ecosystem of Fremont Lake for future generations to enjoy.

Objectives of Study

The objectives of our study and project as outlined in the April 2016 proposal (Appendix 1.0) are as follows:

1. Evaluate the current chemical, physical, and biological status of Fremont Lake during the summer of 2016.
2. Reflect the 2016 status of Fremont Lake based on recommendations from the 2010 GVSU report.
3. Provide new recommendations or maintain previous recommendations based on data from the 2010 GVSU report and 2016 MSU data and results.
4. Design and offer three evening public workshops and presentation events for residents to learn about lake ecosystems, aquatic plants, and lake management. The final event will cover a review, results, and recommendations of our study.

5. Distribute a survey with questions about participants' interests, perceptions about the lake, and comments and concerns. Information gathered from the sessions would be collected and integrated into the final report and attached appendices.
6. Provide additional sampling to characterize three connecting tributaries (Brooks Creek, Fremont Drain, and Daisy Creek) that flow into Fremont Lake. The results of the physical and chemical samples will be compared to 2010 data for each creek and within each reach, from upstream of the city limits to a site near the inlet into the lake.

At the outreach event held at the Sheridan Township Hall on June 23, 2016, we distributed a short questionnaire to gather major questions and concerns regarding Fremont Lake. The questionnaire included the following two questions:

1. "What are you most concerned about regarding the current state of Fremont Lake?"
2. "Do you have concerns about how Fremont Lake is being managed? If so, please describe."

The most common responses to these two questions (listed below) were grouped and summarized as follows:

1. What are the trends? Is the lake improving [in quality]?
2. Concerns about weeds, specifically Eurasian watermilfoil (EWM) and algae.
3. Costs are too expensive, and residents are not contributing equally to costs.
4. Concerns with sewer.
5. Are the treatments too aggressive/harming native plants?
6. How should we address different opinions from stakeholders?
7. Why is fishing declining?

In addition to the original study objectives, we attempted to address as many of the above seven concerns as possible. Some concerns (e.g., sewage or addressing different opinions from stakeholders) cannot be directly addressed with results from our study; however, the information and data that our study does provides may be helpful when addressing these concerns. Other concerns (e.g., trends in water quality and concerns about weeds) can be directly addressed with results gathered from our study.

1.1 Lake Ecology

Lake ecology is defined as the study of the chemical, physical, and biological processes that occur within slow or non-moving bodies of water. A lake is divided into physical zones, each containing specific chemical and biological properties and processes. Zones are distinctive based on their location with respect to depth and to physical characteristics of the water within the zone. These zones (Fig. 1.1) are summarized below.

- The **littoral zone** refers to the shallow areas where light penetrates to the bottom of the lake. This zone supports rooted aquatic plants.
- The **limnetic zone** is the area of open water.
- The **euphotic zone** is the layer of open water through which light can penetrate.
- The **profundal zone** is the layer of open water where light is unable to penetrate.
- The **benthic zone** refers to the lake bottom, which spans across shallow and deep areas. It supports bottom-dwelling invertebrates such as clams, snails, and some forms of aquatic insects.

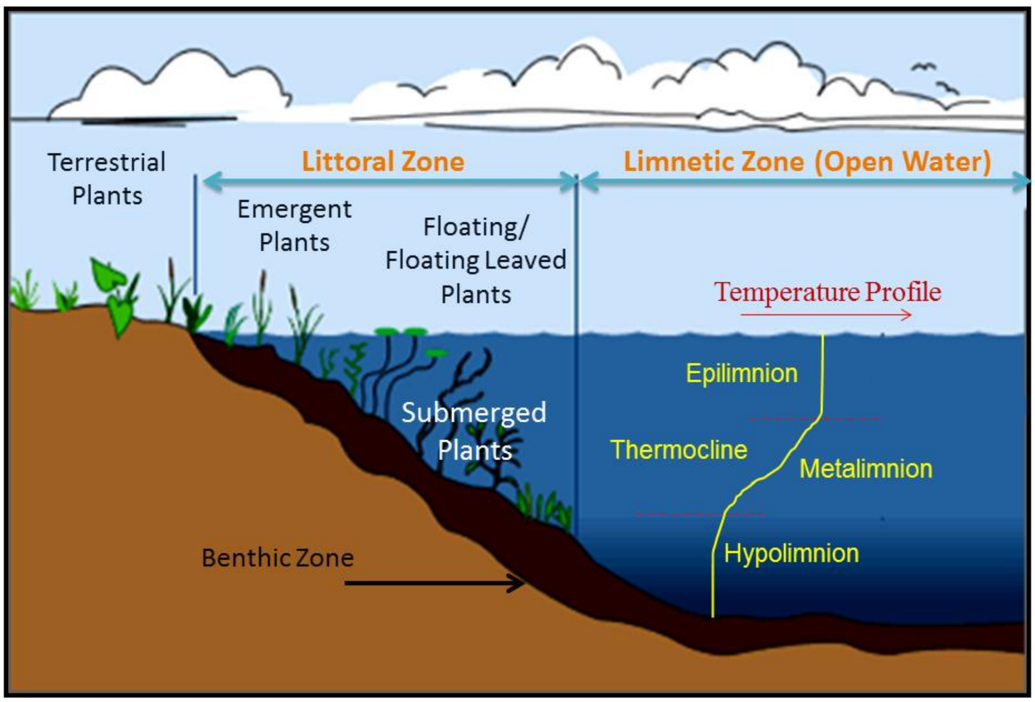


Figure 1.1: A diagram of the various zones within a lake based on light and temperature. Image adapted from: http://www.lakeaccess.org/ecology/lakeecologyprim9.html.

Different biotic and abiotic processes occur in different parts of the lake depending on the depth zone. For example, as depth increases, the availability of light decreases, changing the amount of suitable environment for algal production, different types of bacterial growth, and other biological processes.

Lakes undergo seasonal changes, and these are partially dependent on climate and temperature. Fremont Lake (a relatively deep lake reaching 88 ft.) is a dimictic lake, which means that it mixes two times per year− during mid-spring and mid-fall (Fig. 1.2). Between these periods, the lake forms three distinct layers due to density differences in the water. This is called thermal stratification.

As summer approaches, the lake becomes stratified. This occurs because the surface water is heated by the sun and begins to float on top of the cooler, denser water in the deep parts of the lake. This upper layer, called the epilimnion, floats on top of the denser, colder water below, creating a thermocline. The middle layer, called the metalimnion, is a zone of rapid transition. Below the metalimnion is the hypolimnion, or bottom layer. During thermal stratification, the density differences between the stratified layers keep them from mixing with each other. As a result, nutrients and gases in different layers of the lake do not mix, which greatly impacts the biota and chemical processes in the entire lake.

In the early fall, when the air temperature drops, the epilimnion cools, reducing the density difference between it and the hypolimnion. The winds serve to mix the water to greater depths, and the epilimnion gradually deepens. As this process occurs, the thermocline erodes and the surface water and bottom water approach the same temperature and density, causing the fall overturn. At this time, nutrients and gases from the different layers become mixed throughout the water column.

In winter, stratification still occurs, but the differences in temperature from the top of the lake to the bottom are small. Here the warmer 4^{o}C (39^{o}F) water, which is most dense, is on the bottom and the colder water is layered on top. In some cases, the lake is sealed off from winds by ice, further stratifying the lake.

In spring, after the ice melts, the water temperature increases. With the help of wind, the water temperature becomes the same throughout the water column. This time period is called spring turnover. During spring turnover, oxygen is plentiful and nutrients are circulated throughout the lake. Circulated nutrients, combined with increasing temperature and daylight hours, feed the growth of plants and algae.

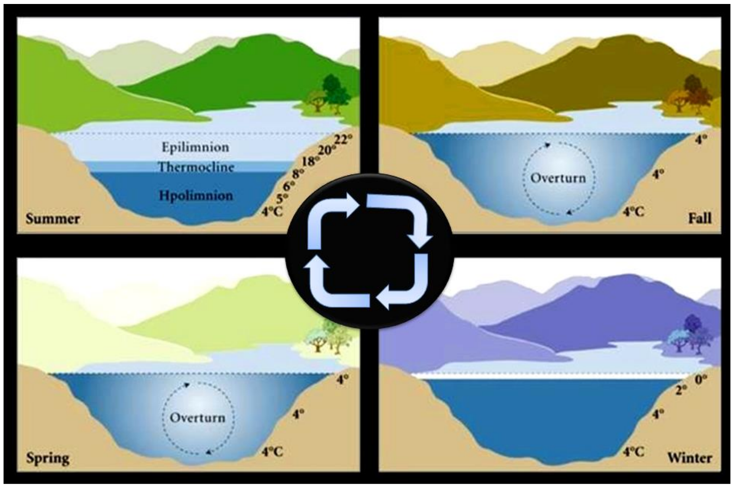


Figure 1.2: Dimictic lake seasonal mixing process. This cycle is important as it will determine what chemical, biological, and physical processes occur in the water column throughout the year. The presence of mixing can be measured by taking temperature and oxygen profiles from the surface to the sediment at the deepest point of the lake. This cycle is typical for Fremont Lake. (*Image source: Young, M. 2004. Thermal Stratification in Lakes. Baylor College of Medicine, Center for Educational Outreach.*)

The mixing process in dimictic lakes is important because any nutrient or biological processes (such as nutrient cycling or aquatic plant die-off in summer) that occur at any given layer are predominantly isolated during the time of stratification and will only mix during the spring and fall. This is important when considering nutrient inputs and storage. For example, phosphorus (which causes increases in algal populations) can enter lakes from urban and agricultural runoff. Once in the lake, the phosphorus can bind to chemicals and sediments or be readily used up by free-floating algae and rooted aquatic plants. However, during mixing periods, phosphorus that has built up in the hypolimnion during the stratification period becomes mixed with the entire water column. This additional phosphorus provides a high nutrient base, which can cause excessive algal blooms in both the spring and fall.

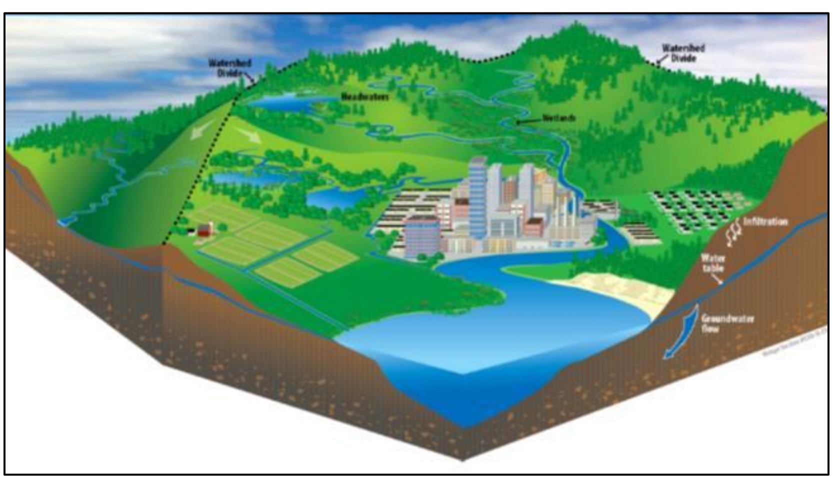


Figure 1.3: A lake and its watershed. Watershed characteristics influence the amount of nutrients and other materials that will flow into a lake from the surrounding landscape. The activities of the surrounding landscape, such as agriculture or urban land, can determine the amount of nutrients flowing off the watershed and directly into a lake. (*Image source: Michigan Sea Grant at University of Michigan* [*http://www.miseagrant.umich.edu/*](http://www.miseagrant.umich.edu/))

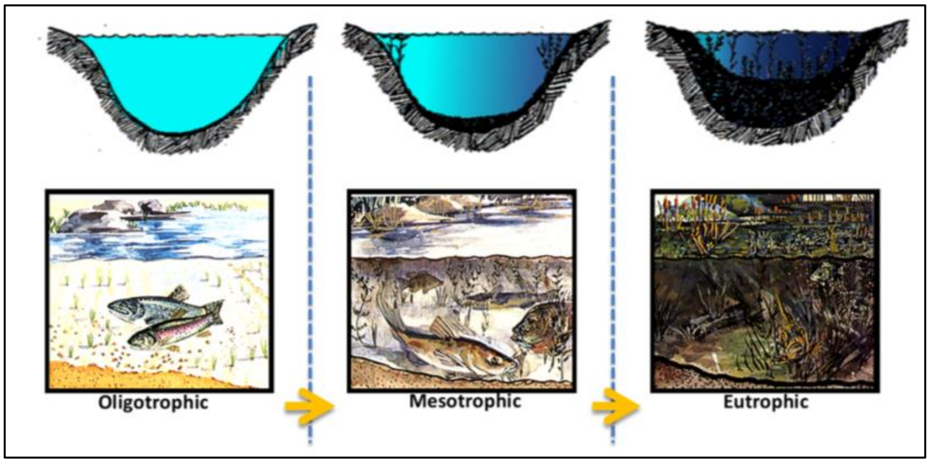


Figure 1.4: The three lake trophic states. Lakes are often grouped into three categories of productivity, or trophic states: oligotrophic, mesotrophic and eutrophic. (*Image source (upper): Understanding Lake Data, UWEX 2004; (lower): An Introduction to Michigan's Water Resources, 2nd Edition. Institute of Water Research, Michigan State University, 1991*)

Lake mixing and nutrient input can affect the algal production occurring in a lake. Lake production can be defined as the amount of mass being produced by the conversion of carbon dioxide and sunlight into carbohydrates and oxygen through the process of photosynthesis. While this process produces valuable oxygen for the lake, too much production can cause excessive algae and plant growth. Sometimes excessive algae growth can lead to nuisance algal blooms and unsafe levels of cyanobacteria, a blue-green type of bacteria (formerly called blue-green algae) that can create toxic conditions in lakes. While overall algal production was measured using chlorophyll *a* (e.g., algae content) (details and results in Section 3.0), this study did not sample or quantify the amount of cyanobacteria in Fremont Lake.

Lakes are influenced by more than just the water within the lake basin. They are influenced by the surrounding landscape and the water that drains it, referred to as the watershed (Fig. 1.3). Understanding the watershed's influence on a lake's chemical and biological condition is vital in order to prepare a comprehensive lake management plan. Understanding the lake's current trophic status (i.e., trophic state) in combination with characteristics of the surrounding watershed (GVSU 2010) is important when planning both short- and long-term lake management plans.

Since the beginning of the 20th century, the classification system assigned to lakes (called trophic state) includes three distinctions: eutrophic, mesotrophic and oligotrophic (Fig. 1.4). Measuring a lake's trophic state and those parameters that influence it is a standard method to track overall water quality through time. "Trophic" means nutrition or growth, and this classification system combines the measurements of water clarity, chlorophyll *a*, and phosphorus concentration into one easily comparable index. A eutrophic lake has high nutrients and high plant growth while an oligotrophic lake has low nutrient concentrations and low plant growth. Mesotrophic lakes fall in-between eutrophic and oligotrophic lakes. While many lakes in one area might be lumped into these few trophic classes, each individual lake has a distinct and unique collection of attributes that determine its trophic state. Overall, trophic state monitoring is a common utility when setting water quality goals and is valuable when constructing both short- and long-term lake management plans. More details about trophic state are provided in Section 3.0: Water Quality.

Trophic status can be influenced by many things spatially (across the landscape) and temporally (through time), making it increasingly important to monitor the environmental changes occurring within the lake and within the environment surrounding the lake. The 2010 report from GVSU provided a detailed review of the land use surrounding Fremont Lake, and this 2016 study aims to provide insight to the current status of the lake that can then be compared to past and future studies. Understanding past influences on a lake can also provide insight into its current and future status. We have constructed a timeline of important events in local history that have potentially influenced the environment, quality, and trophic status of Fremont Lake (Fig. 1.5). This timeline, in conjunction with the results of this study, can provide managers with the most valuable information possible.

1.2 Fremont Lake History

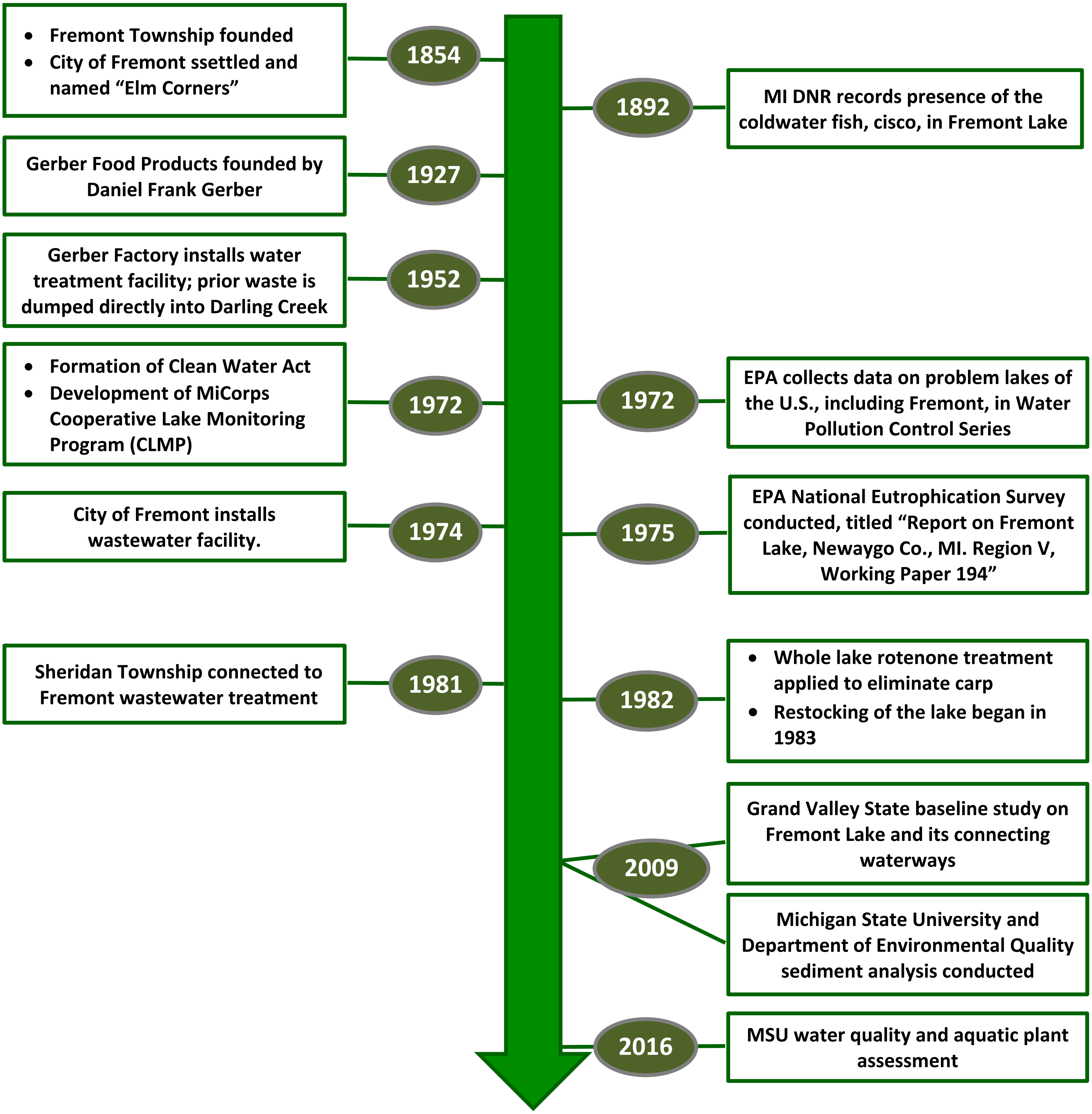


Figure 1.5: Timeline History of Fremont Lake. General national, state, or city events are presented on the left side of the timeline and lake or aquatic-specific events are listed on the right hand side.

2.0 Stream Tributaries

2.1 Introduction to Stream Ecology

Streams are sometimes referred to as the arteries of the earth because they carry materials from upstream to downstream areas. They are common throughout the landscape and provide a variety of functions that are essential for biological processes and human activities. Streams can receive their water from overland or surface flow, subsurface flow and/or groundwater. Both organic and inorganic substances in streams are transported as either dissolved or suspended material. Materials on the bottom of the stream, such as large rocks and boulders, are referred to as bed load and are often too large to be carried in the flowing waters of the stream.

The amount of materials carried from upstream water to downstream water is dependent on several factors, including the channel morphology, gradient, stream discharge, erosion, and the load of materials. The channel morphology includes size, shape, depth, and whether the channel is straight or meandering (sinuous). Straight channels tend to have higher gradients or slope, allowing water to move quickly downstream. Lower gradient streams tend to have more of a meandering channel, which helps slow the overall stream velocity. Stream discharge, often referred to as streamflow, is the total volume of water passing through a cross-sectional area of the stream in a specific amount of time (Fig. 2.1 A). It is determined by multiplying the width of the section by depth of the section by the average stream velocity, and is important in determining the overall load of a pollutant entering and flowing through a stream, the type of substrate, the overall water quality, and numerous other factors.

Figure 2.1: Researchers measuring streamflow (discharge) in Fremont Drain (A) and collecting water samples from Brooks Creek (B).

Phosphorus (P) and nitrogen (N) are important nutrients for plants, but in excess, can lead to increased growth of larger aquatic plants, free-floating and attached algae, and deteriorating water conditions. The major sources of nutrient concentration to streams come from a variety of sources, including agricultural runoff, animal waste, leaky septic system, lawn fertilization, and atmospheric deposition. Phosphorus in streams is often measured as either total phosphorus (TP) or dissolved/soluble reactive phosphorus (SRP), although other forms are present. Nitrogen can be found in the form of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), ammonium (NH_4^+), and organic nitrogen. Because nitrite is typically insignificant relative to nitrate, the two are often combined and referred to as nitrate.

When a stream or drain empties into a lake, some of the materials carried in the water, such as nitrogen, phosphorus, or sediments, end up in the lake. Fremont Lake has seven stream tributaries that empty into it, including Daisy Creek, Brooks Creek, Fremont Drain, Lorden Lake Creek, McDonald Drain, Pell Drain, and an unnamed drain. The majority of both base and peak flows comes from Daisy Creek (AWRI 2010). Base flow is that part of streamflow that comes from groundwater or subsurface flow, while peak flow refers to the maximum flow reached during a precipitation event. For this study, we monitored Daisy Creek and Brooks Creek, since previous studies had shown them to be the largest contributors of phosphorus and suspended solids during peak flows (AWRI 2010). Fremont Drain was also included at the request of the city and township.

For this portion of the study, we were interested in determining 1) changes that have occurred since the last study was done in 2009 and the overall concentration and load of phosphorus, nitrogen, and suspended solids (SS) from the three tributaries; 2) whether the City of Fremont was a large contributor of these chemicals to the downstream reaches of the three tributaries that flow into Fremont Lake; and 3) the concentration of phosphorus stored in the sediments of each tributary.

2.2 Methods

Two location sites, one upstream of the city and one near the mouth of the stream, were selected on each of the three tributaries (Fig. 2.2) for measurements of discharge, total phosphorus, ammonia, nitrate and nitrite, suspended solids, and sediment phosphorus. For Daisy Creek, the upstream site was in Branstrom Park (43.477383, -85.9431) and the downstream site was near Fremont Lake Park off of Cottage Grove St. (43.45765, -85.96158). Brook Creek sites were located off of Dewitt Dr. for upstream (43.470933, -85.972916) and east of Chamberlain Dr. for the downstream site (43.45891, -85.96958). For Fremont Drain, the

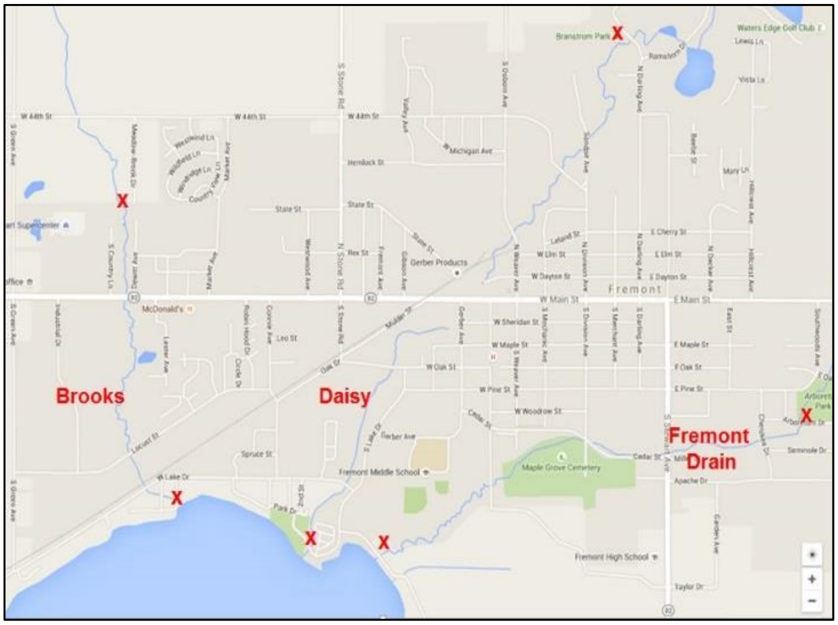


Figure 2.2: Tributaries to Fremont Lake and Sampling Points.

sites selected were in Arboretum Park (43.46230, -85.93195) for upstream and just north of Lakeview Dr. (43.45715, -85.95685) for the downstream site. Data were collected on May 6, 2016 for Daisy Creek and Brooks Creek and on May 11, 2016 for Fremont Drain and again on August 23, 2016 for all sites.

Stream discharge and flow measurements followed USGS protocols (Turnipseed and Sauer 2010). Discharge was measured at each of the upstream and downstream sites using a Pygmy Gurley current meter and wading rod. A relatively straight run within the stream was selected with as few obstructions as possible. In some cases, the stream was extremely narrow, and boulders and smaller rocks could not be avoided. The stream was divided into 1-1.5 ft. subsections where depth and water velocity were determined. Depth was always less than 2.5 ft., so water velocity measurements were taken at 0.6 times the depth to obtain an average mean velocity. Total discharge was then calculated by multiplying the depth times the width times the mean water column velocity for each subsection using the midsection method and adding them together.

Prior to the discharge measurement, two replicate water samples were collected 10 cm below the stream surface in 500 ml bottles and labeled (Fig. 2.1B). This procedure was done first to make sure that disturbed sediments did not contaminate the grab sample. A sample of sediment water was also collected by extracting pore water from below the bottom substrate using a PVC sediment core tube with an attached air stone. The core tube was pushed into the sediment to a depth of six inches and a vacuum was created at the other end using a syringe. The syringe was then retracted and filled with water. The initial sample was discarded to expel any water that may have entered the tube when placed in the water column. A second sample of water was withdrawn and transferred to a 500 ml bottle and labeled (Winger and Lasier 1991).

All bottles were placed in an ice-packed cooler and transported to the MSU limnology laboratory for processing according to Michigan Clean Water Corps standards (Bednarz et al. 2015). Samples were then sent to the MDEQ state laboratory for analysis.

2.3 Results and Discussion

Discharge

For both May and August samples, discharge was greatest in Daisy Creek at 13 cubic feet per second (cfs) and 4.9 cfs, respectively. Discharge was slightly higher downstream than upstream, but the differences were always less than 1 cfs. Both Brooks Creek and Fremont Drain showed similar patterns, with downstream sites having slightly more discharge; however, discharge was less than 1 cfs for both of these tributaries (Table 2.1).

Stream discharge in Daisy Creek was nearly 2.5 times higher in May than in August. Precipitation was approximately twice as much the week of the sampling date in May (slightly less than 1 inch (0.98”)) compared with the August sampling (0.42”) (Enviro-weather 2016).

These data were comparable to the 2009 data collected by Grand Valley State University. During flow in May 2009, discharge was 7.2 cfs in Daisy Creek, 0.9 cfs in Brooks Creek, and 0.2 cfs in Fremont Drain. During low flow conditions in August 2009, discharge was 3.8 cfs for Daisy Creek, 0.5 cfs for Brooks Creek, and 0.06 cfs for Fremont Drain, all considered very low flows. After a storm in April 2009, discharge in Daisy Creek averaged 18.7 cfs. The majority of the discharge from the three tributaries came from Daisy Creek for both the 2016 and 2009 data (Fig. 2.3).

Table 2.1: Discharge for three tributaries during high and low flows.

Tributary Discharge (cfs)	May 6 Upstream	May 6 Downstream	August 23 Upstream	August 23 Downstream
Daisy Creek	12.24	13.1	4.55	4.9
Brooks Creek	0.69	1.58	0.26	0.49
Fremont Drain	0.19	0.64	0.05	0.104

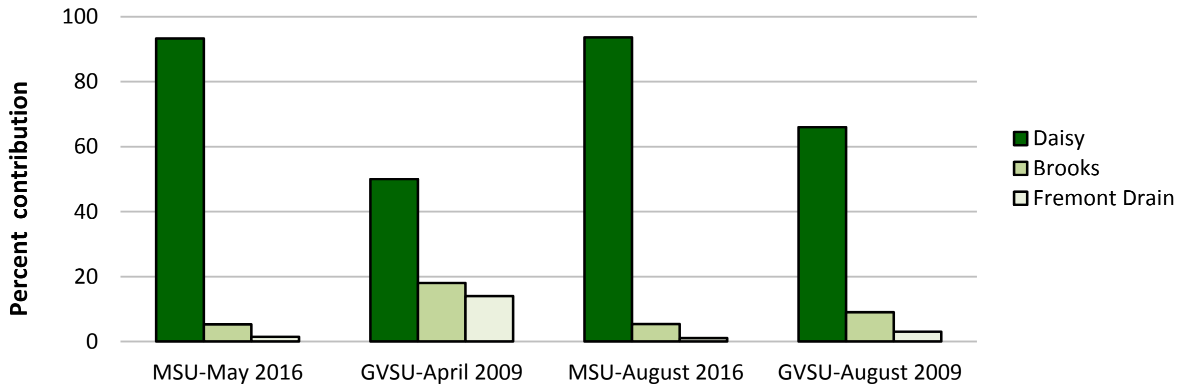


Figure 2.3: Discharge contribution from three tributaries to Fremont Lake during April/May and August in 2009 and 2016.

Nutrients

Nutrient loading, calculated by multiplying the stream's discharge by the nutrient concentration, was determined for total phosphorus, nitrate and nitrite, and ammonia for each tributary. A stream with a high nutrient concentration and a low flow rate could have a smaller load than a stream with lower nutrient concentrations but a higher flow rate. Based on water quality data from various sources, the EPA suggests that appropriate levels of total nitrogen range between 0.12 and 2.2 milligrams per liter (mg/L) (EPA 2002). In a study of 133 streams in agricultural watersheds across the U.S., approximately 43% had total nitrogen concentrations ranging from 2 to 6 mg/L and 21% had concentrations between 6 and 10 mg/L (Mueller and Spahr 2006). About 22% were under 2 mg/L. For phosphorus, the data is highly variable, and no national water quality standard exists. However, the reference level suggested by EPA for total phosphorus should range from 0.01 to 0.075 mg/L, depending on the region (EPA 2002). In the same study referenced above, 129 streams were assessed for total phosphorus. About 45% had total phosphorus concentrations ranging from 0.1mg/L to less than 0.3 mg/L.

Tables 2.2 and 2.3 provide a summary of concentration (mg/L) and load in pounds per day (lbs/d), respectively, for the previously mentioned chemicals from the 2009 and 2016 studies during May and August. Both Daisy Creek and Fremont Drain had total inorganic nitrogen concentrations below the 2.2 mg/L threshold; however, these concentrations did not include organic nitrogen, a part of total nitrogen. Brooks Creek, however, exceeded these levels in August. This same pattern was found in the 2009 study, but the inorganic nitrogen concentrations were lower (6.2 mg/L for 2016 versus 2.8 mg/L for 2009). Nitrite-nitrate load for Brooks Creek was not as high (17.7 lbs/d) as that from Daisy Creek (26.2 lbs/d) in May. However, in August the load of nitrite-nitrate from Brooks Creek (11.3 lbs/d) exceeded that of Daisy Creek (6.02 lbs/d). Overall, the total discharge from Daisy Creek accounted for 89% of the streamflow among the three tributaries. Brooks Creek accounted for 9%, indicating that the nitrogen load to Fremont Lake would be relatively small.

Table 2.2: Concentrations of chemical parameters during May and August of 2016 and 2009

	Daisy Creek			Brooks Creek			Fremont Drain		
Units: **mg/L**	NO_2 - and NO_3	NH_3	Total P	NO_2 - and NO_3	NH_3	Total P	NO_2 - and NO_3	NH_3	Total P
2016 – May	0.38	0.02	0.04	0.32	0.01	0.06	0.075	0.02	0.06
2016 - August	0.23	0.02	0.05	6.2	0.01	0.04	0.52	0.32	0.17
2009 - May	0.23	0.03	0.04	2.05	.046	0.03	0.18	0.04	0.03
2009 - August	0.6	0.08	0.04	2.8	0.05	0.116	0.74	.067	0.09

Table 2.3. Loading data during May and August of 2016 and 2009

	Daisy Creek			Brooks Creek			Fremont Drain		
Units: **lbs/day**	NO_2 - and NO_3	NH_3	Total P	NO_2 - and NO_3	NH_3	Total P	NO_2 - and NO_3	NH_3	Total P
2016 - May	26.2	1.04	2.91	17.7	.074	0.32	.233	0.045	0.10
2016 - August	6.02	0.49	1.38	11.3	0.01	0.08	0.247	0.098	0.058
2009 - May	8.9	1.4	1.5	9.5	.2	.14	0.2	0.0	0.03
2009 - August	12.4	1.7	0.87	7.6	0.1	0.31	0.2	0.0	0.03

Total phosphorus concentrations from all three tributaries were substantially less in May than the upper range of 0.075 mg/L as suggested by EPA for both the 2009 and 2016 (EPA no date) data. For August data, the total phosphorus concentration in Fremont Drain exceeded the reference level and was 0.17 mg/L in 2016. For the 2009 data, Brooks Creek was above the reference concentration at 0.116 mg/L (Table 2.2). The highest load of total phosphorus in both 2009 and 2016 was from Daisy Creek, with a concentration of 2.91 in May 2016 and 1.5 in

May 2009 (Table 2.3). Neither Brooks Creek nor Fremont Drain had high loads in comparison with Daisy Creek for any of the dates.

Total Suspended Solids

Total suspended solids (TSS), or the small particles that don't sink to the bottom substrate, are one indicator of water quality. TSS can consist of sediment, silt, sand, plankton, and algae. When suspended solids are high, the clarity of water is reduced, making it difficult for organisms to see their prey. These particles can also clog fish gills and destroy fish habitats, leading to a decline in the fisheries resource, causing aesthetic problems, and possibly requiring higher costs for water treatment. Eventually, the particles will settle, resulting in the suffocation of bottom-dwelling organisms and burial of fish eggs. All three tributaries had suspended concentrations less than 20 mg/L (Fig. 2.4). Brooks Creek and Daisy Creek had the highest TSS concentrations in May at 13 mg/L and 8 mg/L, respectively. Concentrations of TSS from 2009 differed from the 2016 data. For those data, Brooks Creek in August had a concentration of 105 mg/L, although values for May were only at 4 mg/L. For 2016, Fremont Drain had no detectable concentrations. In the 2009 study, Fremont Drain concentrations in May were only at 2 mg/L, but in August TSS was reported at 47 mg/L. Total suspended solid concentrations less than 20 mg/L are usually associated with clear water. Wastewater treatment plants must meet standards limits of 30 mg/L for a monthly average (MDEQ no date).

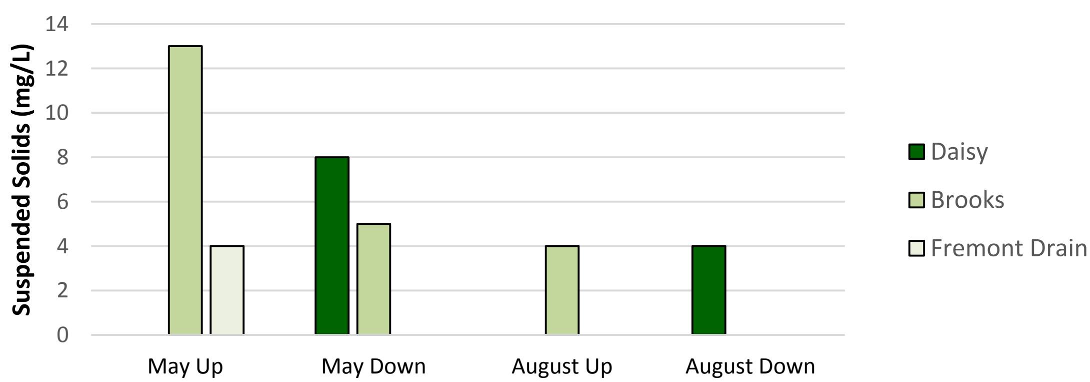


Figure 2.4: Suspended solids in three tributaries to Fremont Lake in May and August of 2016 from upstream (Up) and downstream (Down) sites. Concentrations less than 1 mg/L are too low to appear on the graph.

Upstream versus Downstream

Phosphorus concentrations in sites upstream and downstream of the City of Fremont for both May and August showed either little difference or a decrease in concentration, except for Daisy Creek, which showed a very slight increase in total phosphorus at the downstream site (Fig. 2.5 and Table 2.4). Several factors may account for the lower concentration downstream in the other two tributaries, including adsorption of phosphorus to soil and substrate particles or uptake by attached algae. Only in Fremont Drain was there any substantial decrease, from 0.28 mg/L to 0.06 mg/L. For these data, it appears that the City of Fremont is not a significant contributor of total phosphorus to the tributaries, although as previously mentioned total phosphorus concentrations were above the EPA suggested level in Fremont Drain in August.

Table 2.4: Phosphorus concentrations upstream and downstream of the City of Fremont.

Tributary	Upstream – May (mg/L)	Downstream — May (mg/L)	Upstream – August (mg/L)	Downstream — August (mg/L)
Daisy	0.04	0.04	0.047	0.066
Brooks	0.08	0.04	0.041	0.039
Fremont	0.08	0.035	0.28	0.064

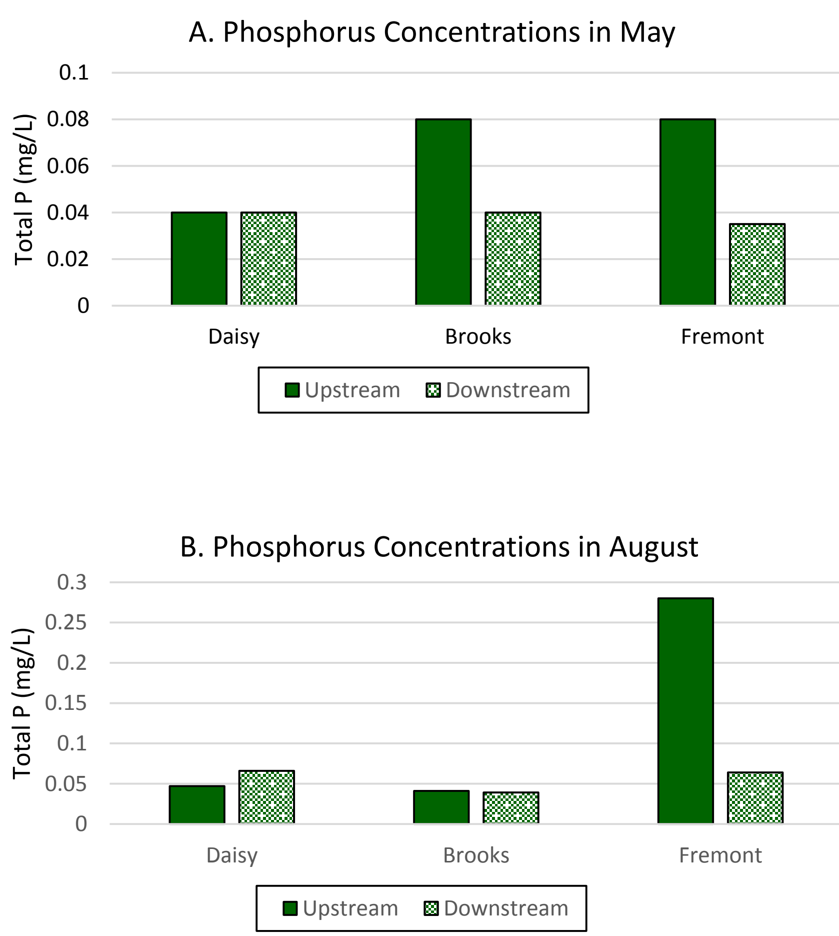


Figure 2.5: Phosphorus concentrations in three tributaries to Fremont Lake in May (A) and August (B).

For nitrogen, a small increase in nitrite-nitrate was detected in Daisy Creek and Fremont Drain. While the increase may be attributed to further input of nitrogen sources above the city versus at the tributary's mouth, the overall addition and final concentration was less than 0.5 mg/L, which is within the suggested range for nitrogen concentrations in streams (Fig. 2.6 A). However, in Brooks Creek the concentration was doubled from May to August (4 mg/L to 8 mg/L). Both of these concentrations are above the EPA suggested appropriate concentrations for total nitrogen. At the downstream site for Brooks Creek, although the concentrations were half of those upstream, they still exceeded the suggested levels, particularly for the August samples (Fig. 2.6).

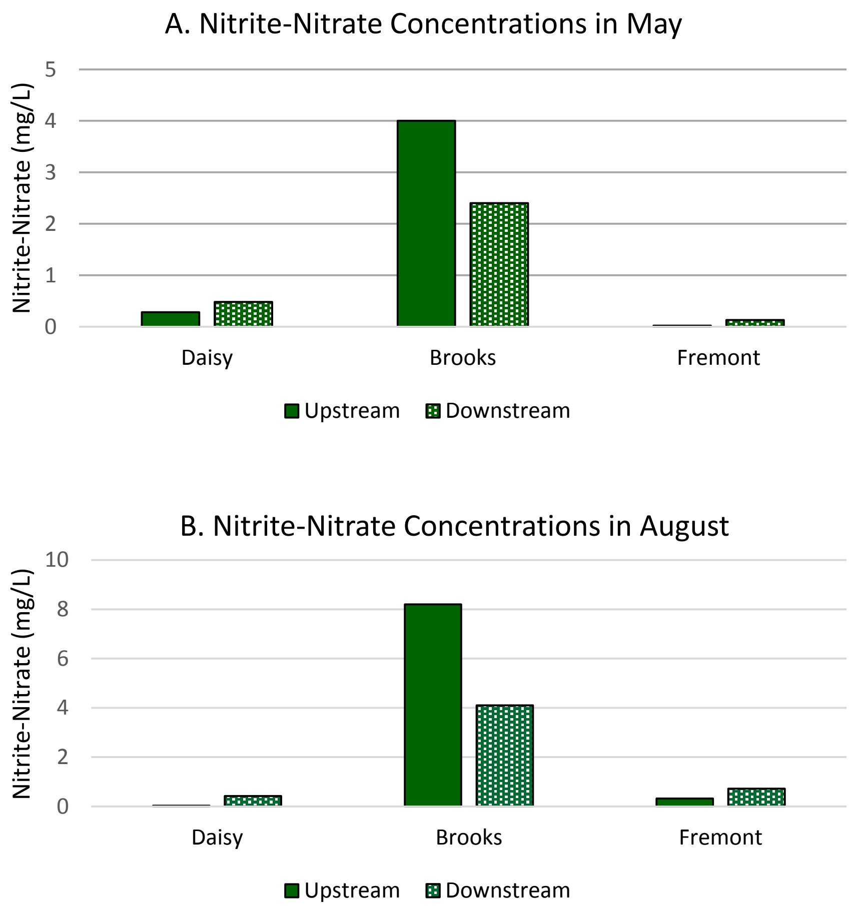
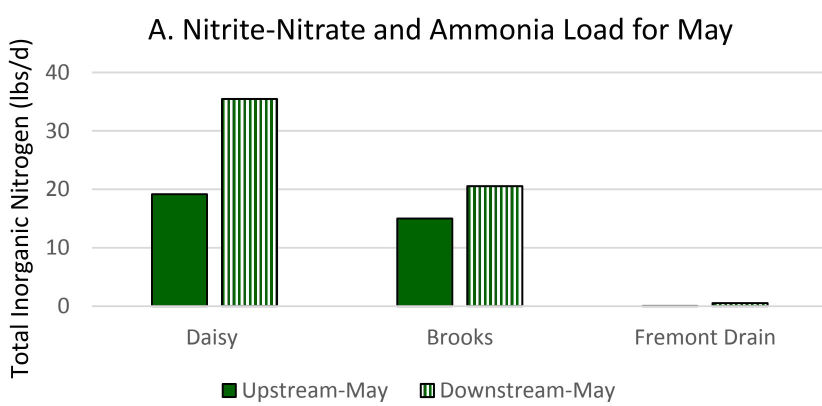


Figure 2.6: Nitrite-nitrate concentrations in three tributaries to Fremont Lake in May (A) and August (B).

High nitrogen concentrations can occur from human and animal waste, urban storm water runoff, septic systems, animal feed lots, agricultural fertilizers, and industrial wastewaters. While the concentrations were higher downstream, the overall load of nitrogen from Brooks Creek was only slightly higher downstream in May compared to upstream and actually lower downstream in August (Fig. 2.7). During the August sampling, flow was minimal, and thus any nitrogen contribution at that time would also be very low. However, if a rain storm occurred and increased the streamflow, Brooks Creek could be a substantial source of nitrogen to the lake as it was in May. The highest total inorganic nitrogen load of 35 lbs/d came from Daisy Creek in May in the downstream sampling area. Upstream load was 19 lbs/d. Since Daisy Creek contributes the highest discharge of the three tributaries, its higher load is expected. Although phosphorus is often more limiting in lakes than is nitrogen, nitrogen is an important nutrient in cultural eutrophication. The amount of nitrogen to phosphorus is often considered an important factor as to how a system responds to nutrient addition (Dodd and Smith 2016).



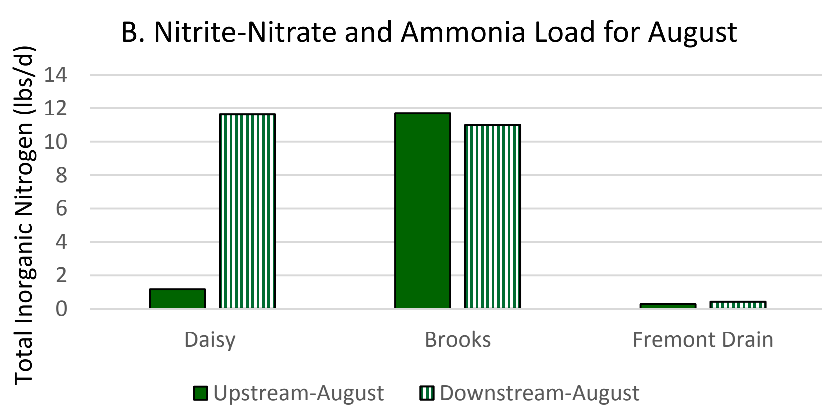


Figure 2.7: Nitrite-nitrate and ammonia load in three tributaries to Fremont Lake in May (A) and August (B).

Sediment Phosphorus

In most streams and lakes, the total phosphorus found in the sediments has a higher concentration than that of the open water. Sediment phosphorus concentration ranges are variable. Howell (2010) found mean sediment TP concentrations of 39.79 mg/L in October in a tributary downstream of a sewage treatment plant. For the three tributaries to Fremont Lake, total phosphorus was always higher in the sediment than in the open water. It was also higher downstream compared to upstream. Brooks Creek showed the largest difference between its upstream (0.25 mg/L) and downstream (3.2 mg/L) site in May. In August, values were substantially lower both upstream and downstream. However, all concentrations were relatively low for sediment phosphorus concentrations (Table 2.5). Sediment phosphorus and its release to the water column can be affected spatially and temporally by sediment type, size of particles, and abiotic and biotic processes.

Table 2.5: Total phosphorus in sediments and open water.

Tributary	Total P in open water (mg/L)	Total P in sediments (mg/L)
May		
Daisy	0.043	0.465
Brooks	0.060	1.725
Fremont Drain	0.059	0.585
August		
Daisy	0.054	0.303
Brooks	0.040	0.077
Fremont Drain	0.172	0.800

3.0 Lake Water Quality

Fremont Lake is a large and well-utilized inland lake that supports a variety of recreational activities, bringing ecological value and economic profit to the local community. The many benefits that people enjoy from lakes are influenced by water quality. When water quality is compromised, so too is the value of the services that the lake provides. In order to maintain and improve Fremont Lake for all uses, it is important to understand the current water quality status of the lake and how it has changed over time. By integrating the physical, chemical, and biological components of a lake with the surrounding watershed and nearby human activities we can begin to understand the underlying influences that drive the water quality of a lake.

The following section will cover our water quality sampling and analysis methods, results, and a discussion of the results. We integrated data from a baseline study conducted in 2009/2010 and historical data from multiple sources. The data in this section has been summarized into a variety of figures and tables. Additional data is available in Appendix 3.0.

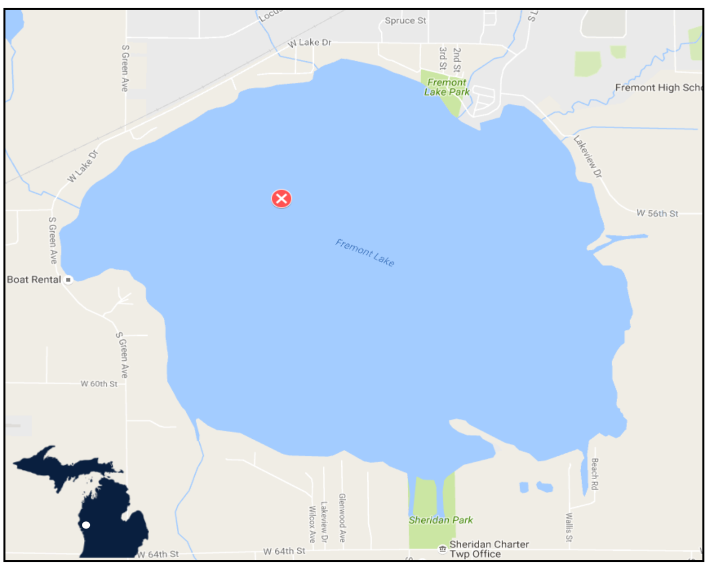


Figure 3.1: Fremont Lake sampling location. The red and white "X" indicates our approximate sampling location.

3.1 Methods

To evaluate the current chemical, physical, and biological status of Fremont Lake, we sampled the lake once a month from May to October in 2016. In May, July, and September, we sampled total phosphorus, soluble reactive phosphorus (SRP), ammonia, nitrite-nitrate, alkalinity, dissolved organic carbon (DOC), pH, conductivity, water clarity, water color, light concentration, dissolved oxygen, temperature, and chlorophyll *a*. In June, August, and October, chlorophyll *a*, water transparency, dissolved oxygen (throughout the water column), and temperature (throughout the water column) were measured.

We collected water samples using a grab sample taken 2 ft. below the surface near the deepest point of the lake, except for hypolimnetic (bottom) phosphorus samples, which were taken with a 2-L Kemmerer sampler at a 25-meter depth (Fig. 3.1). A replicate sample was taken for each parameter. We acidified the phosphorus and nitrogen samples after collection with sulfuric acid. Water samples were kept on ice and in the dark until returned to the laboratory. For chlorophyll *a*, we preserved the samples with magnesium carbonate ($MgCO_3$) soon after collection and then filtered the water through 0.45-µm glass fiber filters within 24 hours of collection and froze the filters for later analysis. We filtered the DOC samples through 0.45-µm glass fiber filters within 24 hours of collection. All chemical and nutrient samples were kept refrigerated until analysis. Analyses were conducted by the State of Michigan Department of Environmental Quality (MDEQ) Laboratory Services except for soluble reactive phosphorus (SRP). SRP was analyzed at Michigan State University's Soil and Plant Nutrient Laboratory by standard methods (Eaton et al. 1998).

Dissolved oxygen and temperature profiles were sampled every meter through the water column with a Professional Plus YSI probe. We measured Secchi disk depth with a standard 20-cm Secchi disk. We measured surface water color with a Hach color test kit CO-1. Surface conductivity and pH were measured immediately on-site with an Orion Star™ A222 Portable Conductivity Meter and an Orion STAR™ A121 Portable pH Meter, respectively.

To quantify the trophic status of Fremont Lake we used Carlson's Trophic Status Index (Carlson 1977). Carlson's Trophic Status Index (TSI) determines the trophic state of a water body using Secchi disk transparency, chlorophyll *a* concentrations, and total phosphorus concentrations. The trophic state of a lake reflects its productivity. We calculated the monthly trophic state of Fremont Lake using all three variables in order to see how Fremont Lake varies throughout the growing season. The formulas we used for calculating TSI values are below.

$TSI = 9.81 \ln \text{Chl } a\ (\mu g/L) + 30.6$
$TSI = 60 – 14.41 \ln (\text{ft. of Secchi disk transparency} * 0.3048)$
$TSI = 14.41 \ln TP\ (\mu g/L) + 4.15$

To evaluate the progress toward the recommendations outlined in the 2010 baseline report, we compared our 2016 lake data to data sampled from the deepest location in the 2010 baseline report (Station FL-1). We could only compare chlorophyll *a* results from August because data from the 2010 baseline report only existed for August. The 2010 baseline report also did not collect data from September and October; therefore, we could not compare our late summer data.

To evaluate the historical water quality trends in Fremont Lake, we searched the EPA and MiCorps database for past data. We also contacted the Michigan Department of Natural Resources (DNR) Fisheries Division to assemble historical fisheries reports. Secchi disk depth, phosphorus, and chlorophyll *a* data were gathered from these reports.

To assess the trend in Secchi disk depth, phosphorus, and chlorophyll *a*, we separated the historical data into two seasonal periods: early stratification (May and June) and summer (July-September). These periods were chosen based on the seasonal differences that may occur in dimictic lakes. For each of the two periods, we calculated the average and standard error for each year if more than two measurements were available.

3.2 Results and Discussion

Fremont Lake has changed considerably through the years. The first Michigan DNR fisheries report for Fremont Lake in 1892 indicated that cisco (a fish also known as lake herring) were present (O'Neal 2009). Although water quality data were not collected for the 1892 report, the presence of cisco indicates that Fremont Lake likely had high water clarity, low nutrients, and high dissolved oxygen throughout the water column. This is assumed because cisco can only live in excellent water quality conditions. As the land in the watershed changed from forest to agriculture and as the local human population increased, the lake began to change. In 1971, the U.S. Environmental Protection Agency (EPA) reported Fremont Lake as one of the "problem lakes" of the United States (Ketelle 1971). They reported that Fremont Lake had a long history of algal blooms and shallow thermoclines. In a thorough 1975 water quality report, the EPA concluded that Fremont Lake was "hyper" eutrophic (hypereutrophic) with depleted oxygen in the lower parts of the lake starting as early as June (EPA 1975). Installed wastewater treatment facilities for the surrounding communities and for the Gerber Baby Food Company greatly reduced nutrient inputs into Fremont Lake as evident from the 1970s and 2000s data. Today, Fremont Lake has considerably lower nutrients, algae (as measured from chlorophyll *a*), and higher water clarity than in the 1970s. However, Fremont Lake continues to be mildly eutrophic, which is likely due to relics of the past and from present activities on the lake and in the watershed.

Trophic Status

Trophic state is a measurement that classifies lakes based on primary productivity (also known as algae production). Lakes are classified in one of three categories: oligotrophic, mesotrophic, or eutrophic. Oligotrophic lakes have low nutrients and therefore low primary productivity. Eutrophic lakes have an abundance of nutrients and high primary productivity. Mesotrophic lakes fall in between. Ultra-oligotrophic and hypereutrophic are sometimes used when a lake is either extremely pristine or excessively enriched (Table 3.1). Evaluating trophic status through time is a useful method to track eutrophication and to see if human activities are accelerating it. See Section 1.1 for more information on trophic state.

According to the total phosphorus and Secchi disk depth data, Fremont Lake was mesotrophic in 2016 (Fig. 3.2). However, in August, September, and October, chlorophyll *a* reached eutrophic conditions. Because chlorophyll *a* is the best indicator of trophic status (Carlson 1983), Fremont Lake is best classified as a mesotrophic lake with eutrophic characteristics in late summer. This result is very similar to what was measured in 2009 (Fig. 3.2), but is a considerable change from the 1970s when the lake was hypereutrophic (Fig. 3.3). Mesotrophic lakes can be great fishing lakes with moderately deep water clarity. However, algal blooms can be common and oxygen may become depleted in the hypolimnion later in the summer causing organisms to move to shallower depths.

Table 3.1: Values and characteristics of each trophic state using the Carlson's Trophic Status Index. (Table based on Fuller and Taricska 2012.)

Lake Trophic Status	Carlson's TSI Value	Chlorophyll *a* (µg/L)	Secchi Disk Depth (m)	Total Phosphorus (µg/L)	Attributes
Oligotrophic	< 38	< 2.2	> 4.6	< 10	Clear water, low amount of aquatic plants, oxygen present year round
Mesotrophic	38-48	2.2 - 6	2.3 - 4.6	10 - 20	Moderately clear water, increasing aquatic plant biomass, potential oxygen problem in hypolimnion
Eutrophic	49-61	6.1 – 22	0.9 – 2.2	21 - 50	Algae and aquatic plant problem, anoxic in hypolimnion
Hypereutrophic	> 61	> 22	< 0.9	> 50	Low water clarity, dense algae, anoxic conditions in metalimnion and hypolimnion

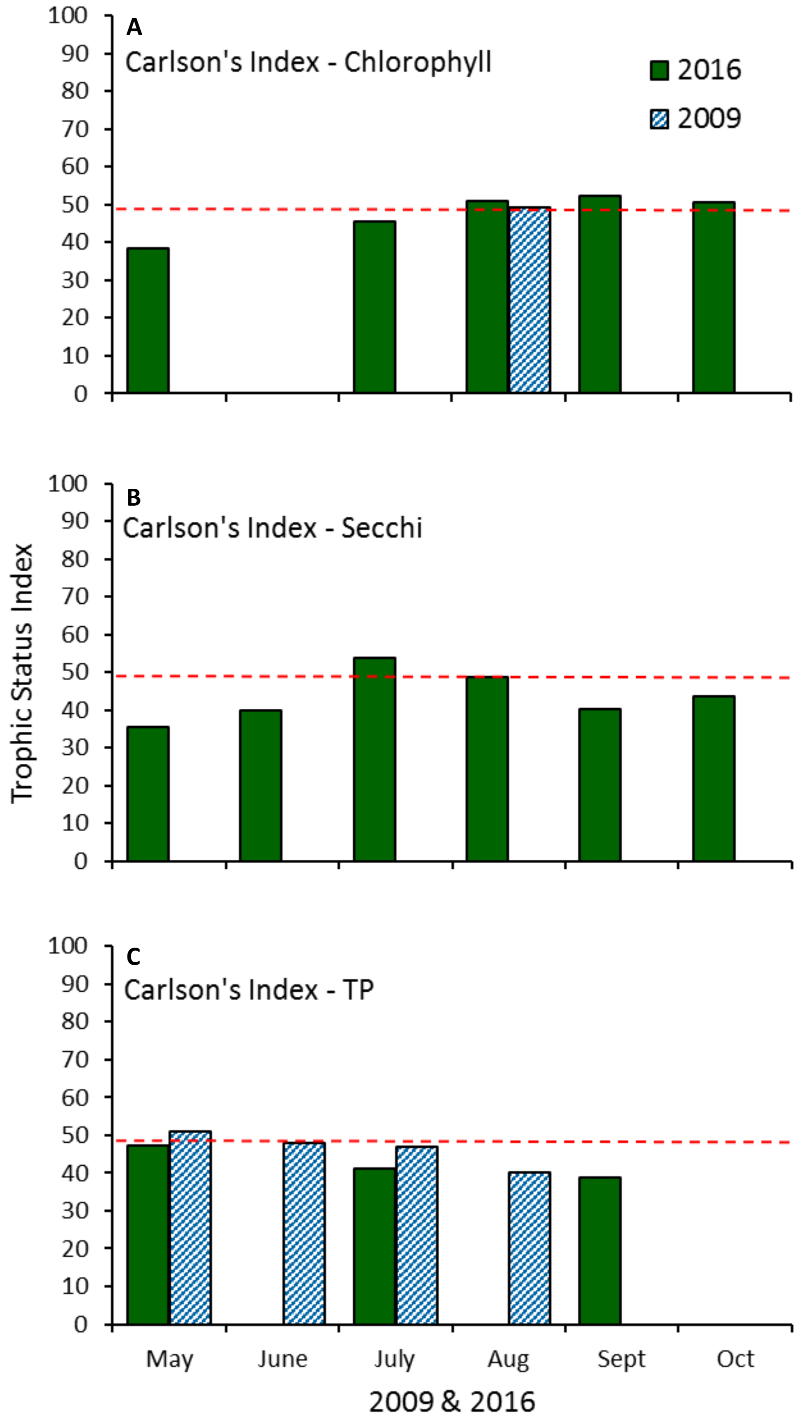


Figure 3.2: Seasonal 2009 and 2016 trophic status using chlorophyll *a* (A), Secchi disk depth (B), and total phosphorus (C). The green bars are 2016 data and the blue bars are the 2009 data. Secchi disk depth was not collected in 2009. Bars above the red slashed line indicate a eutrophic classification.

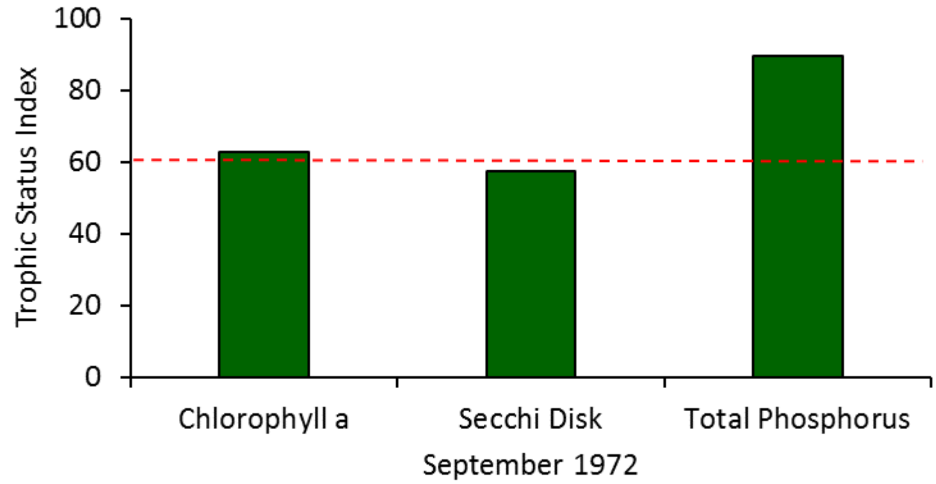


Figure 3.3: Fremont Lake trophic status in September 1972. The bars at or above the red dashed line indicate a hypereutrophic classification.

Dissolved Oxygen

In 2016, Fremont Lake had low to no oxygen (< 4.5 mg/L) in the hypolimnion (deeper zone of the lake) during the majority of the summer. In August and September, concentrations even neared zero in the metalimnion (middle zone of the lake) (Fig. 3.4). Data from 1972 and 2009 confirm that this is a long-time occurrence in Fremont Lake (Fig. 3.5). Low oxygen is likely due to the bacterial decomposition of organic matter. When a lake is thermally stratified and has abundant nutrients, as is the case with Fremont Lake, algae and aquatic plants flourish in the upper portion of the lake where sunlight is available. When algae and plants die, they sink and are decomposed by bacteria, a process that uses oxygen. Furthermore, plant matter does not all decompose immediately and therefore can build up over the years on the bottom of the lake. This buildup and subsequent decomposition can then increase the rate of oxygen depletion. The hypolimnion is not able to become replenished with oxygen because it is too dark for photosynthesis to occur, and oxygen is unable to diffuse from the surface of the lake into the hypolimnion.

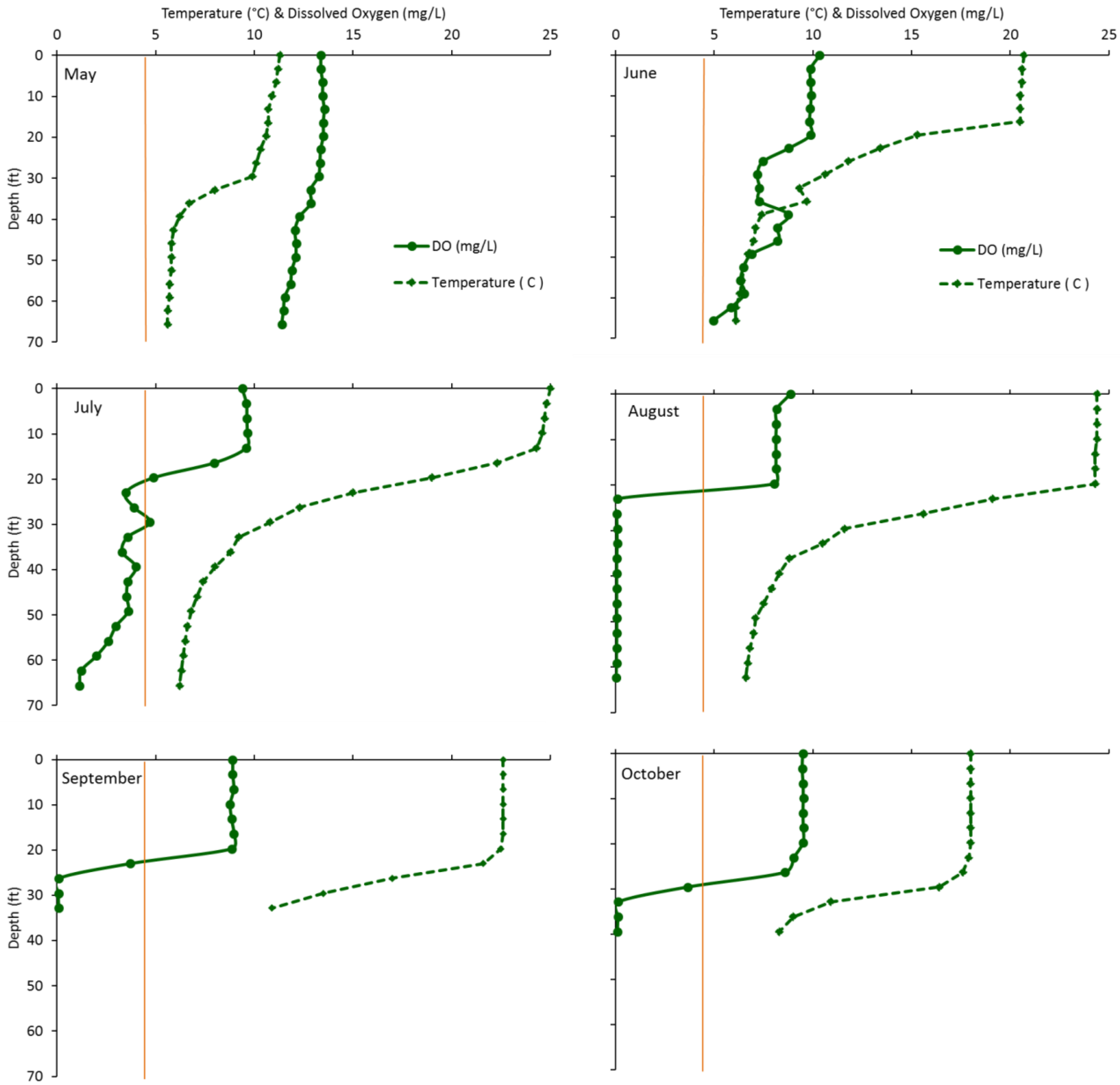


Figure 3.4: 2016 monthly temperature and dissolved oxygen profiles. Dissolved oxygen is the solid line and temperature is the dashed line. The orange vertical line indicates the oxygen concentration where some organisms become stressed (4.5 mg/L). The temperature measurements show that Fremont Lake was thermally stratified throughout our entire sampling period.

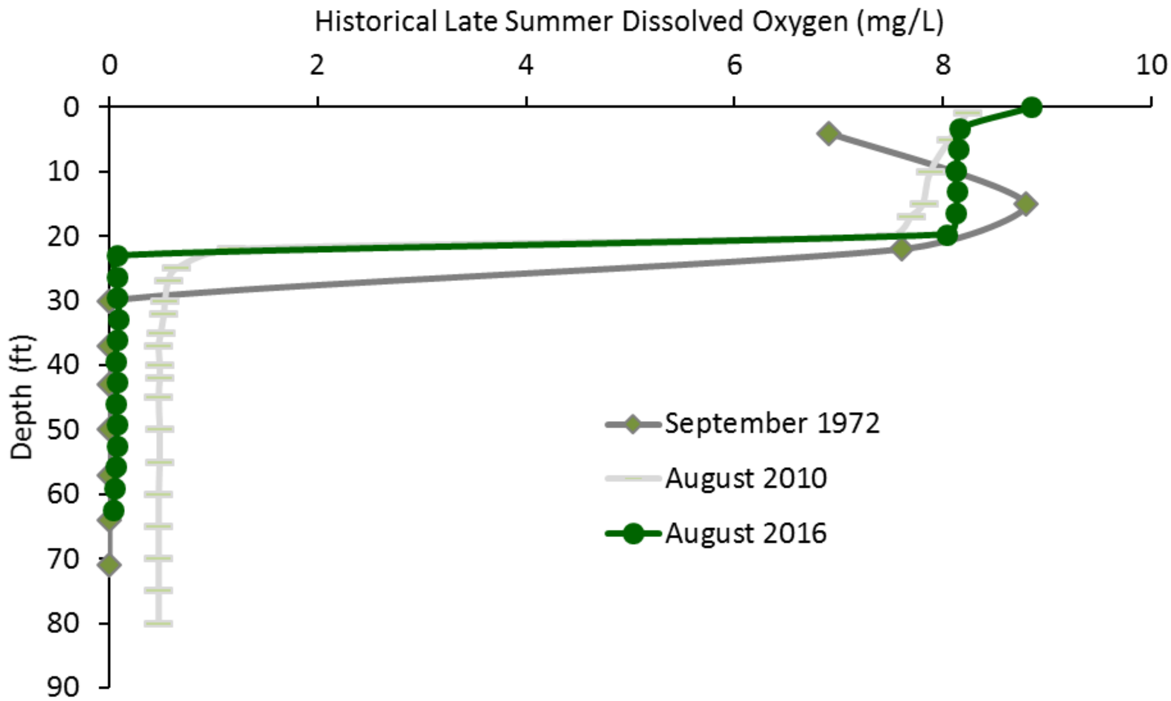


Figure 3.5: Dissolved oxygen profiles from September 1972, August 2010, and August 2016. Note that in all three years, oxygen concentrations become very low around 20 ft.

Low oxygen concentrations can have a considerable impact on a lake because low concentrations can limit the habitat for many organisms. Numerous organisms become stressed below 4.5 mg/L (Hrycik et al. 2016). When this occurs, bottom-dwelling organisms that are unable to easily move to better conditions will either die or have compromised health. More mobile organisms, such as fish, may be able to move into oxygenated water, which is typically found at the top layer of the lake where it is warmer. However, if the water temperature is above the optimal threshold for a fish, it may become stressed or die. Examples of this include summer fish kills where coldwater fish (e.g., cisco) cannot survive in the deep oxygen-poor zones of a lake or in the warmer, shallow oxygen-rich zones (Frey 1955). Some coolwater fish (e.g., walleye) can also be affected in this way. In 2016, the deep and middle zones of Fremont Lake had insufficient oxygen (Fig. 3.4), thus restricting available habitat for fish and other organisms.

If oxygen concentrations reach zero (termed anoxia), the chemistry of the lake changes and triggers a process that can intensify the depletion of low oxygen. When concentrations reach zero, the phosphorus and nitrogen that were trapped in the lake sediments are released and become readily available for plant and algal use. This process is called internal loading. The released nutrients can then fuel new algal growth, which in turn can increase bacterial activity that will reduce oxygen levels further. We did not assess if internal loading occurs in Fremont Lake. However, the 2016 phosphorus trends indicate that internal loading is likely occurring (see the “Nutrients” subsection on page 31 for more details on the 2016 phosphorus trends).

Water Clarity

Fremont Lake had high water clarity (> 10 ft.) in May and June of 2016 (Fig. 3.6), which is common for many lakes (Sommer et al. 1986). During spring, free-floating microscopic crustaceans called *Daphnia* increase in numbers and consume large quantities of algae. If conditions are right the *Daphnia* can remove so much algae that the water becomes clear. This was likely the case in 2016 because we observed a high number of *Daphnia* in Fremont Lake during our spring sampling (Fig. 3.7).

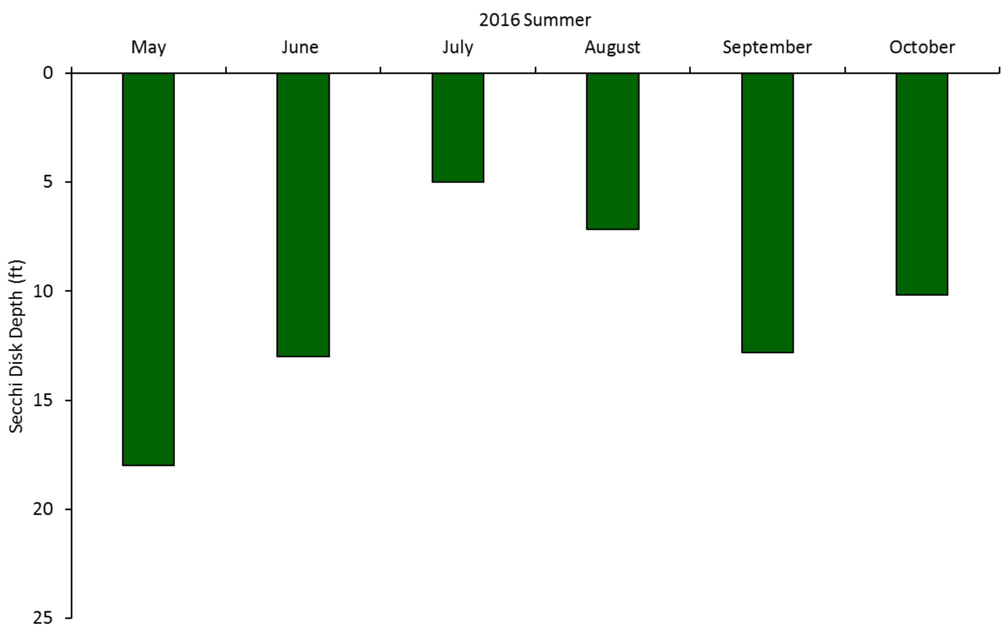


Figure 3.6: 2016 Secchi disk depth (water clarity). The longer the bars the higher the water clarity. Note the higher water clarity in the spring in comparison to the rest of the summer. Secchi disk depth was not compared to the baseline report because it was not collected.

The historical dataset also showed greater water clarity in the spring as compared to the summer months (Fig. 3.8), especially after common carp were removed and predator fish were added by the Michigan DNR in 1980s (Trimburger 1982). The removal of common carp can increase water clarity because carp rummage around the bottom of lakes thereby resuspending lake sediments. The addition of predatory fish can also increase water clarity by shifting the food web so that it favors high populations of *Daphnia,* the organism that filters and removes algae.

Water clarity was more variable for the remainder of summer in Fremont Lake (Fig. 3.8). In July, water clarity fell to 5 ft., but slowly rebounded in the latter half of the summer. This could be from a combination of events. During warm periods of summer, algae can grow quickly and cause the water to look green. Also, July experiences a high level of recreational activity. High boat traffic can erode the shoreline and stir up sediments on the lake bottom. The dislodged sediments can turn the water brownish and also release nutrients that promote more algae growth. Higher water clarity later in the summer may have occurred because of reduced boat traffic and therefore reduced amounts of sediments and nutrients released into the water. However, we cannot conclusively say that this is what occurred because suspended sediment data were not collected in the lake in this study.

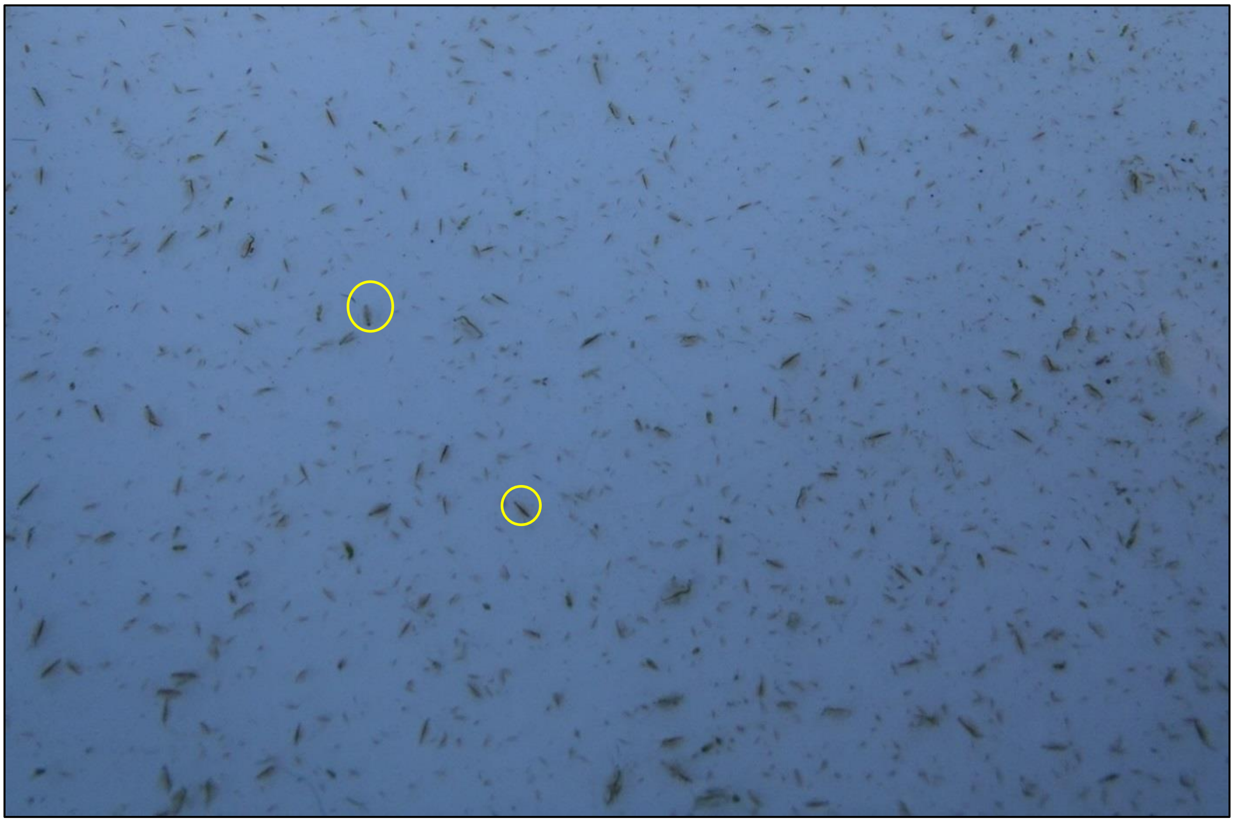


Figure 3.7: Picture showing the results of an informal horizontal plankton tow in Fremont Lake during our May sampling. Note the prevalence of the filter feeding *Daphnia* (a few circled here for emphasis).

Nutrients

Phosphorus is typically the most limiting nutrient to algae growth in lakes. When abundant, algae can proliferate and become a nuisance. In the 1970s, phosphorus was very high (0.16 mg/L), but has since declined (Figs. 3.9 and 3.10). The decline was likely due to the creation of a wastewater treatment facility for the City of Fremont that diverted the city's waste from Fremont Lake. In more recent data the phosphorus concentrations have leveled off. The 2016 data indicates that 1) Fremont Lake is mesotrophic according to surface total phosphorus (TP) concentrations (Fig. 3.2); 2) hypolimnetic TP (Fig. 3.11) and SRP (Fig. 3.12) were substantially greater than the surface water; and 3) surface TP samples declined throughout the summer while hypolimnetic TP and SRP increased throughout the summer (Figs. 3.11 and 3.12). The seasonal phosphorus trends are likely driven by the severe anoxia in the hypolimnion where due to the lack of oxygen, phosphorus is released into the water from the lake sediments (Nurnberg 2009).

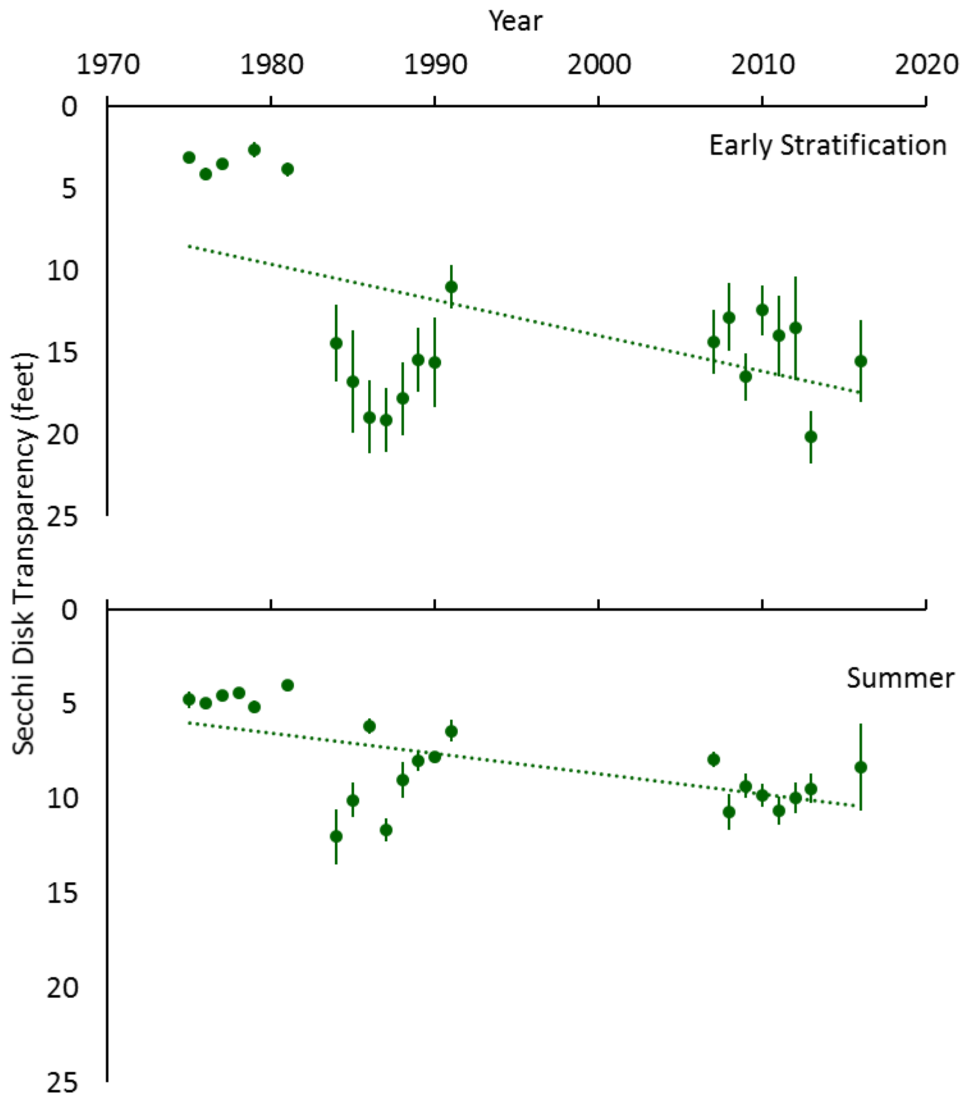


Figure 3.8: Averaged historical Secchi disk measurements from two different time periods for Fremont Lake. Early stratification = May and June; Summer = July, August, and September. A trend line (dotted line) was fit using linear regression to demonstrate the trend of increasing water clarity over time. Note the low water clarity in the 1970s and sudden water clarity increase in the 1980s.

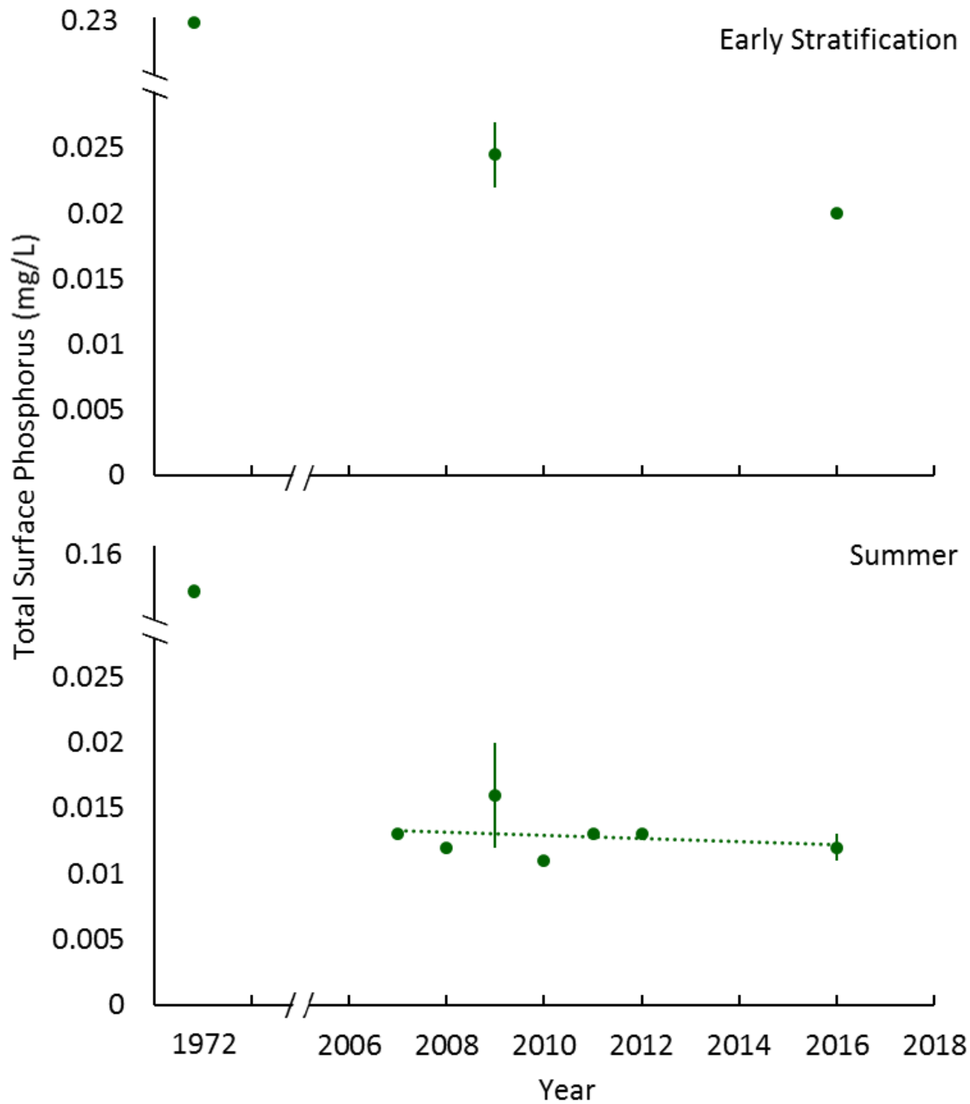


Figure 3.9: Historical surface phosphorus from two different time periods for Fremont Lake. Early stratification = May and June; Summer = July, August, and September. A trend line (dotted line) was fit using linear regression to demonstrate the trend of the newest data. Data from 1972 was excluded from the regressions due to the lack of data between 1972 and 2007. Note the significantly higher 1972 measurement from the 2000s data. Data during the 2000s show little change.

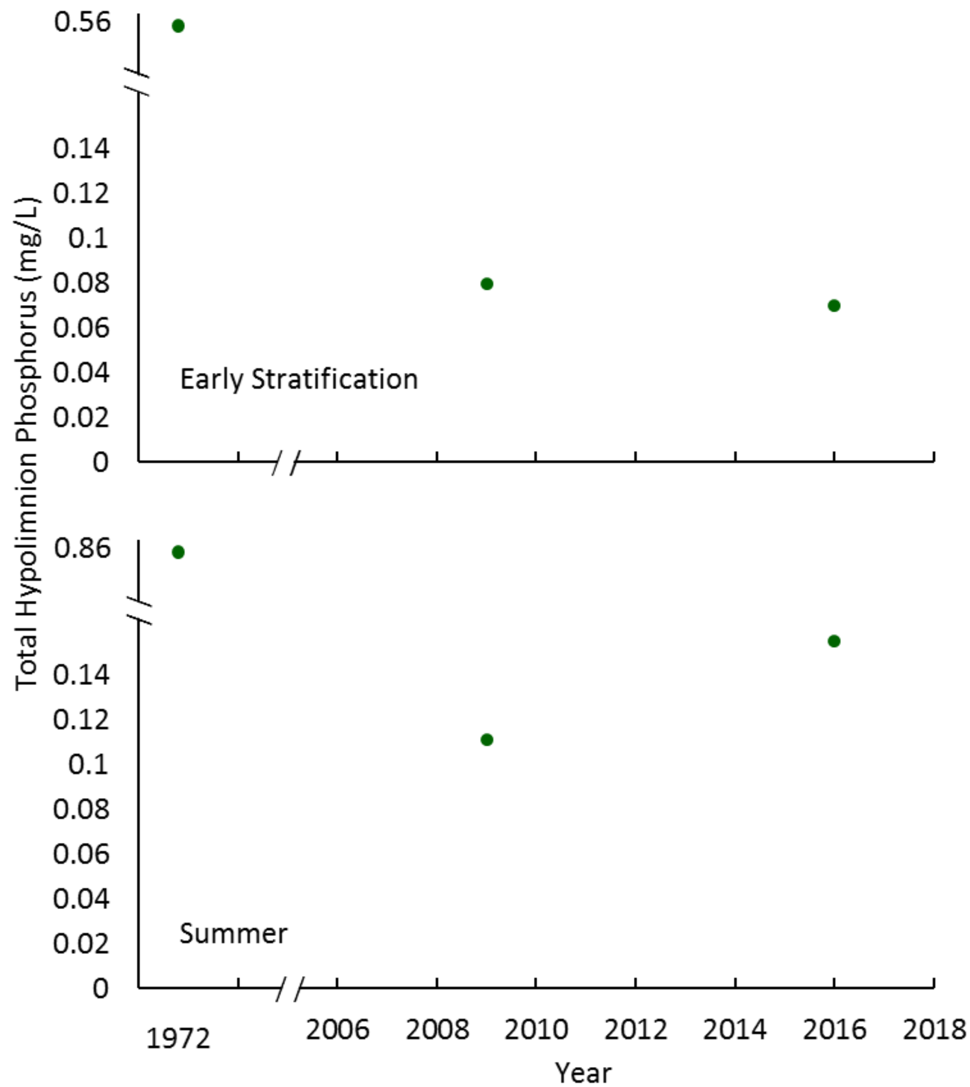


Figure 3.10: Historical hypolimnetic (bottom) phosphorus from two different time periods for Fremont Lake. Early stratification = May and June; Summer = July, August, and September. Very little historical data was available, but note the lower values in the 2000s data compared to 1972.

Nitrogen is usually the other most limiting nutrient to algal growth in lakes. Surface nitrogen measurements declined in Fremont Lake's surface water from May to July. The same happened in 2009 (Fig. 3.13). The reduction of nitrogen in surface waters may indicate the rapid uptake of nitrogen by algae. The low summer concentrations may favor cyanobacteria (formerly called blue-green algae) species that are able to uptake and utilize nitrogen from the atmosphere that is unusable to other algae species. It is important to monitor cyanobacteria in lakes because if phosphorus is high, they can become a nuisance and even become harmful to humans.

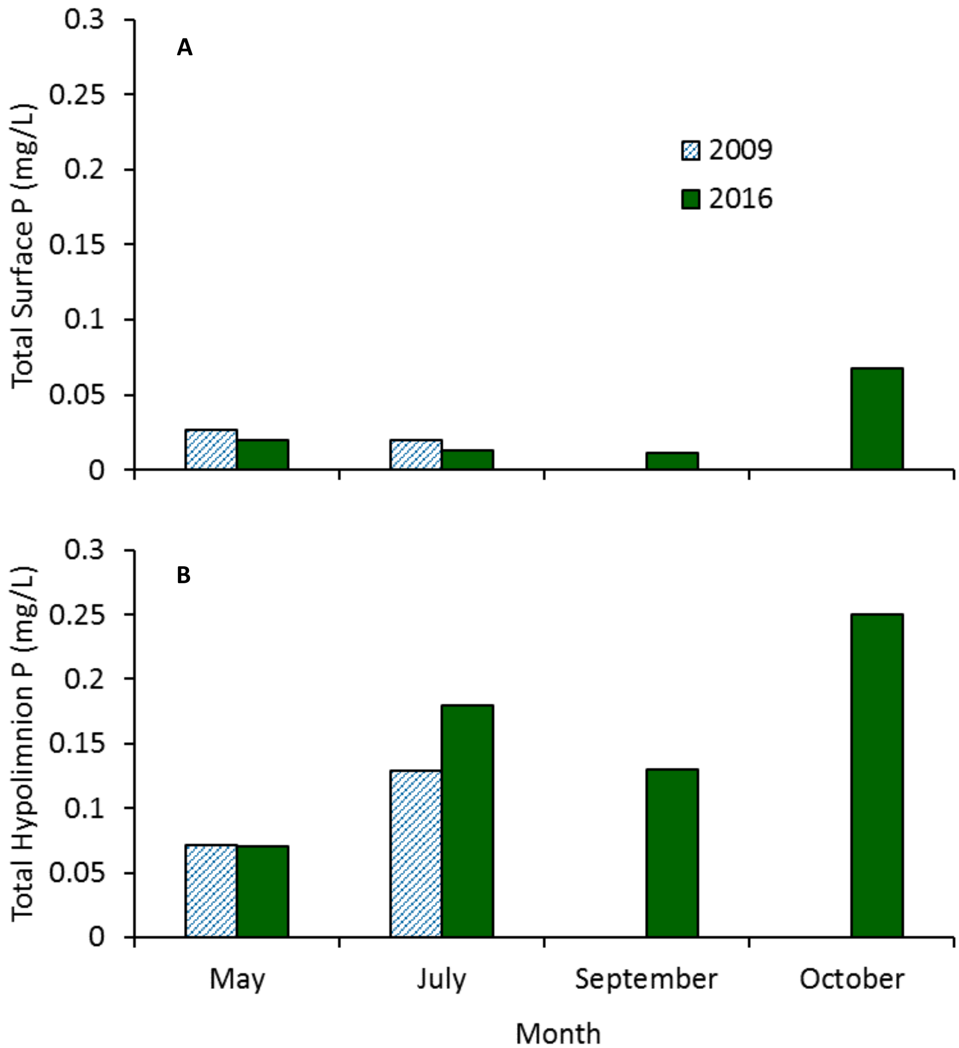


Figure 3.11: Total surface phosphorus (A) and total bottom phosphorus (B) for 2009 and 2016.

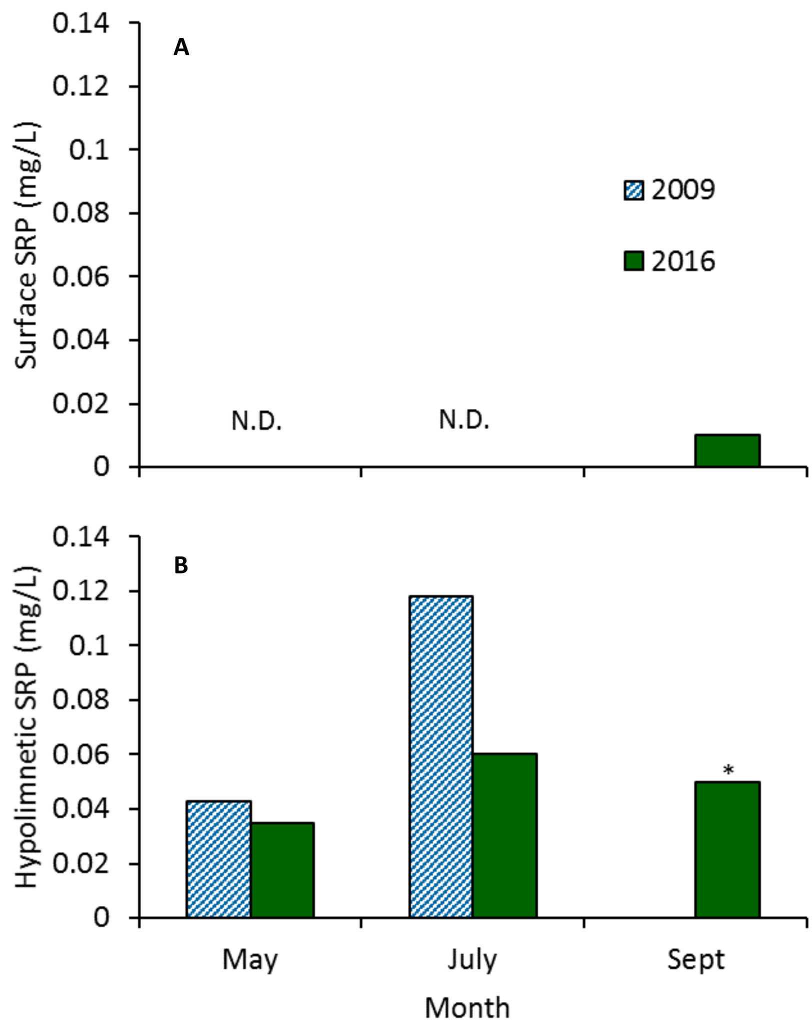


Figure 3.12: Surface soluble reactive phosphorus (A) and bottom soluble reactive phosphorus (B) for 2009 and 2016. N.D. means "Not Detected". * September data reflects the average of two values.

Chlorophyll a

Chlorophyll *a* is a proxy measurement for the amount of suspended algae in lakes. Therefore, the higher the chlorophyll *a* concentrations, the more green the lake water will appear. Chlorophyll *a* measurements were high enough in 1972 to classify Fremont Lake as hypereutrophic (Fig. 3.3). Chlorophyll *a* levels have dramatically dropped since then (Fig. 3.14), but later summer concentrations still fall within a eutrophic status (Fig. 3.15). Algae are largely driven by available nutrients, although other factors may also drive concentrations (see Water Clarity subsection for details on zooplankton). However, a simple rule of thumb is the lower the nutrients (especially phosphorus), the lower the amount of algae.

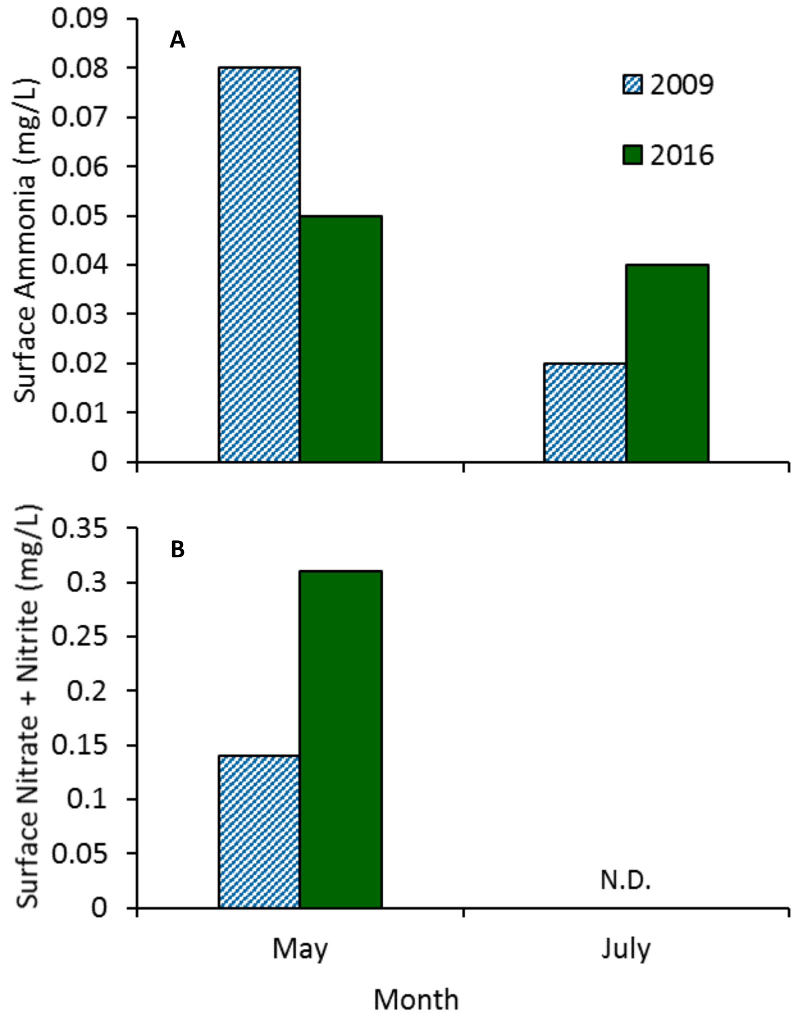


Figure 3.13: Nitrogen data from 2009 and 2016. Surface ammonia (A) and surface nitrate + nitrite (B).

Table 3.2: Select chemical attributes measured in Fremont Lake in 2016. pH, conductivity, and alkalinity are in the high range in comparison to other lakes in Michigan.

Variable	2016		
	May	July	Sept
Water Color (Co/Pt)	15	15	20
pH	8.17	8.5	8.6
Conductivity (µS/cm)	533.7	237.5	470.7
Alkalinity (mg/L)	180	140	140
Dissolved Organic Carbon (mg/L)	4.6	9.9	7

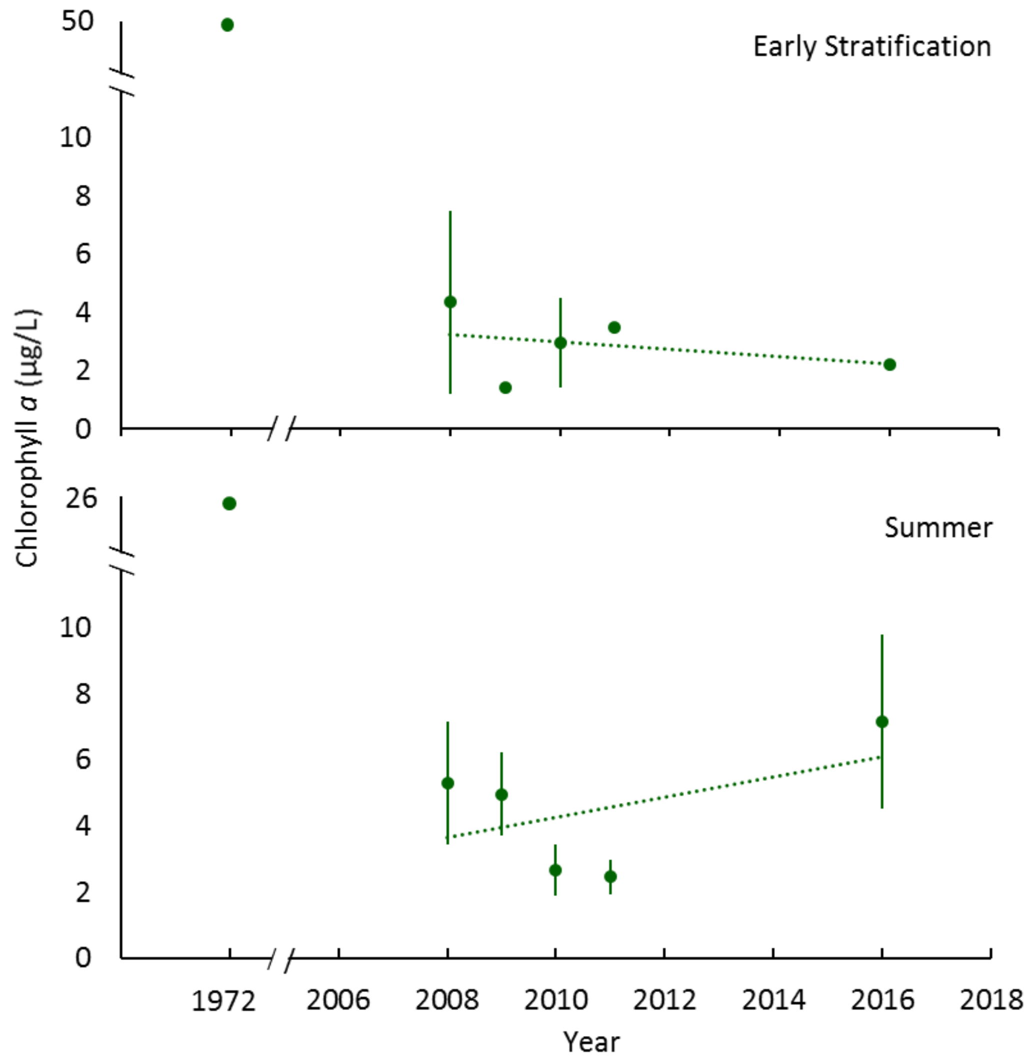


Figure 3.14: Historical chlorophyll *a* from two time periods for Fremont Lake. Early stratification = May and June; Summer = July, August, and September. A trend line (dotted line) was fit using linear regression to demonstrate the trend of the newest data. Data from 1972 were excluded from the regressions due to the lack of data between 1972 and 2007.

Other Chemical Characteristics of Fremont Lake

Fremont Lake has a medium/high alkalinity and a fairly high pH (Table 3.2) compared to other Michigan lakes (Fuller and Taricska 2012). The higher alkalinity is likely due to the surrounding geology and is a sign of good buffering capacity, which can help protect the lake from acid rain. The pH is also likely driven by the surrounding geology. A higher pH and alkalinity will also partially dictate what aquatic plant species will be present (Hutchinson 1975).

Conductivity is the measure of the ability of water to conduct an electric current. The more dissolved substances in the water, the higher the conductivity. Conductivity in Fremont Lake (Table 3.2) is higher than average for Michigan lakes (Fuller and Taricska 2012). This is likely also due to the surrounding geology.

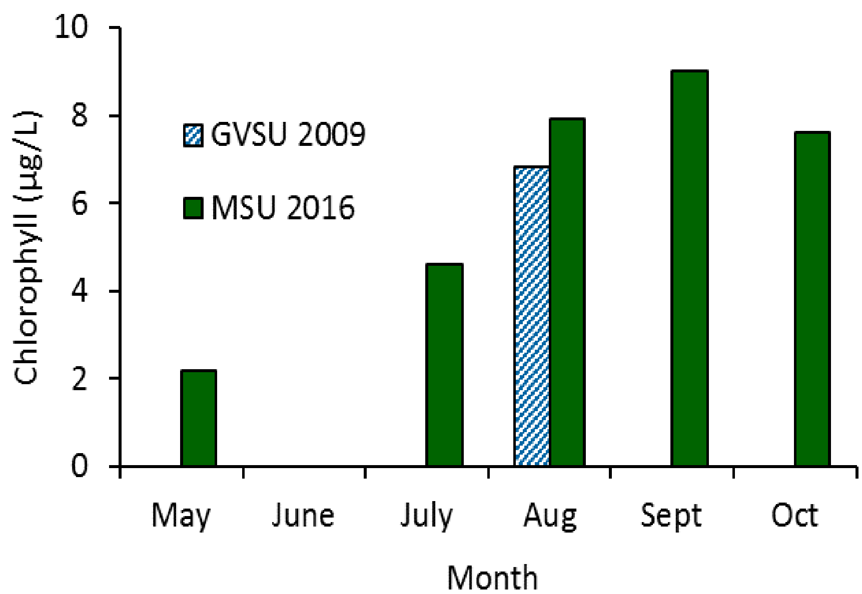


Figure 3.15: Chlorophyll *a* for Fremont Lake for 2009 (blue bars) and 2016 (green bars). Note the monthly increase in 2016.

Summary

Fremont Lake has not changed substantially from the GVSU Baseline Report in 2010; however, the lake has changed considerably in the last several decades. Since the diversion of wastewater from the City of Fremont and the removal of common carp in the 1980s, the water quality in Fremont Lake has greatly improved. Data available from the 2000s indicate that the lake is consistently in the mesotrophic and lower eutrophic spectrum − a positive divergence from what Fremont Lake once was.

A concern for Fremont Lake is low oxygen levels, which begin in the lower portion of the lake in early summer and eventually reach the middle portion of the lake later in the summer. In late summer there was little oxygen present at depths greater than 20 ft. This confines most organisms, including fish and their food sources, to the upper portion of the lake. A secondary consequence of oxygen depletion is the release of nutrients from the sediments, which may be contributing to higher algae concentrations later in summer and fall.

3.3 Additional Information

Copper Sulfate Treatments

Copper sulfate is an effective tool for the temporary reduction of algae in lakes. However, effects are only temporary (varying from 1 to 3 weeks) and reapplication is necessary throughout the summer for desirable results. Because continual treatments are necessary, copper-resistant algae can develop within the lake and more copper may be required for similar results.

Copper sulfate applications can also cause oxygen concentrations to temporarily decline due to the influx of dead algae cells to a lake. Care should be taken to avoid this in Fremont Lake, especially in later summer when the metalimnion (middle section of lake) has low oxygen concentrations. More information can be found in recommendations, Section 6.0.

4.0 Aquatic Plants

4.1 Introduction to Aquatic Plant Ecology

Aquatic plants play an important role in the functioning of lake ecosystems. A diverse and structurally complex aquatic plant community provides habitat and food resources for a variety of species such as fish, turtles, waterfowl, and invertebrates (Carpenter and Lodge 1986; Scheffer 1998). In addition, aquatic plants reduce shoreline erosion, prevent resuspension of sediments, and increase water clarity. When abundant, aquatic plants can also reduce algae by outcompeting the algae for nutrients and light. In any given lake, aquatic plant cover and diversity can be influenced by a number of environmental conditions such as alkalinity, pH, conductivity, water clarity, lake shape and size, nutrients, and dissolved carbon (Capers et al. 2009; Cheruvelil and Soranno 2008). Studying aquatic plant communities in lakes involves investigations of not only the plants themselves, but the environmental conditions of the lake and landscape that could be influencing what type and how many plant species are growing in the lake. When designing the 2016 limnological study of Fremont Lake, the parameters measured were chosen because of their importance for characterizing water quality, and because they have been shown to have strong relationships with aquatic plant communities.

In this section, we will define aquatic plants as any plants that are found to be growing in, out of, within, on, or floating in the water of Fremont Lake. The common growth types of aquatic plants are: emergent, submersed, free-floating or floating-leaf (Fig. 4.1). Emergent species contain a portion of stem or leaf structure that emerges from the surface of the water while maintaining a submersed root zone in the sediment. Submersed species are found growing entirely under the surface of the water, either rooted or floating unattached. Floating-leaved species are rooted in the sediment and grow leaves that sit on or are slightly elevated from the surface of the water. Free-floating species are usually smaller plant species that float on the surface of the water and do not have roots anchored in the sediment. Most lakes contain all four categories, which creates a complex habitat that is beneficial to a lake ecosystem. Although in our sampling we did not classify each species within these categories, we did record presence and abundance for any species that we observed or collected that are included in these growth type categories.

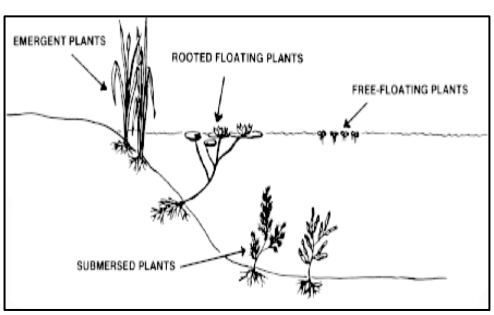


Figure 4.1: Categories of plant growth types. *Image credit: http://www.uky.edu/Ag/PAT/cat5/cat5.htm*

4.2 Native Versus Invasive Plants in Your Lake

Not all aquatic plants are the same, especially when comparing between native and invasive plant species, the role different species play in aquatic plant communities, and their effects on lake ecosystems. While invasive aquatic plants can provide some benefits, it is more likely that invasive plants are a detriment to a lake. Invasive plant species can outcompete native species for space and resources, eliminating suitable habitat for juvenile fish, macroinvertebrates, and other aquatic organisms. Some especially troublesome aquatic invasive plants, like Eurasian watermilfoil, can easily spread through fragmentation. They can clog municipal pipes and canals, obstruct fishing gear and outboard motors, and drastically change the littoral zone landscape of a lake – sometimes changing the physical lake structure permanently. According to the United States Environmental Protection Agency, the definition of invasive is "a species that is not native and whose introduction causes, or is likely to cause, economic or environmental harm or harm to human health." Within the state of Michigan invasive plant species are categorized as either prohibited or restricted, with the most threatening and high-risk species being in the former category; the more widespread and commonly observed, yet invasive species are in the latter.

In Michigan, between 2009 and 2010, over five million dollars from state, federal and Great Lakes Restoration Initiative funding sources were spent on managing, monitoring, and researching invasive species. Invasive species can also inflict local economic costs as lakeside properties are sometimes valued as much as 19% less when aquatic invasive species are present (such as Eurasian watermilfoil). More information on invasive species in Michigan can be found online at the State of Michigan website, http://www.michigan.gov/invasives/.

While the overall goal of aquatic plant management is to restrict – or hopefully eliminate − the growth and spread of the invasive or nuisance species in the lake, an important objective remains to concurrently maintain or sometimes promote the growth of native plant species. A healthy and diverse native aquatic plant community benefits overall water quality, assists in managing detrimental algae, promotes productive fish populations, and overall provides the environment needed for a healthy and sustainable lake ecosystem.

4.3 Methods

To evaluate the historical aquatic plant trends in Fremont Lake, we searched the State of Michigan Department of Environmental Quality Aquatic Nuisance Control (DEQ ANC) MiWaters Database for historical plant surveys and aquatic plant treatment information (https://miwaters.deq.state.mi.us). All permit history can be found by searching for "Fremont

Lake, Newaygo Co." in the "Water Resource Information and Forms" tab. Fremont Lake has had herbicide permits issued since 2009, meaning that it has been under official aquatic plant management since that time. In 2016 the aquatic plant management company, PLM Lake and Land Management Corp. (www.plmcorp.net/), conducted aquatic plant and algae treatments using a variety of chemical compounds and formulations. All information about the chemicals used and their concentrations, amounts, areas applied, and times of application are governed by Michigan Law Part 33, Aquatic Nuisance Control, of the Natural Resources and Environmental Protection Act, 1994 PA 451. More information on chemical control and management of aquatic plants in Michigan inland lakes can be found online at www.michigan.gov/deqinlandlakes.

To inventory the plant species present in Fremont Lake and the relative abundance of each species, we conducted two plant sampling surveys: the first in mid-May prior to herbicide treatments and the second in mid-July after herbicide treatments and when plants are at maximum seasonal growth.

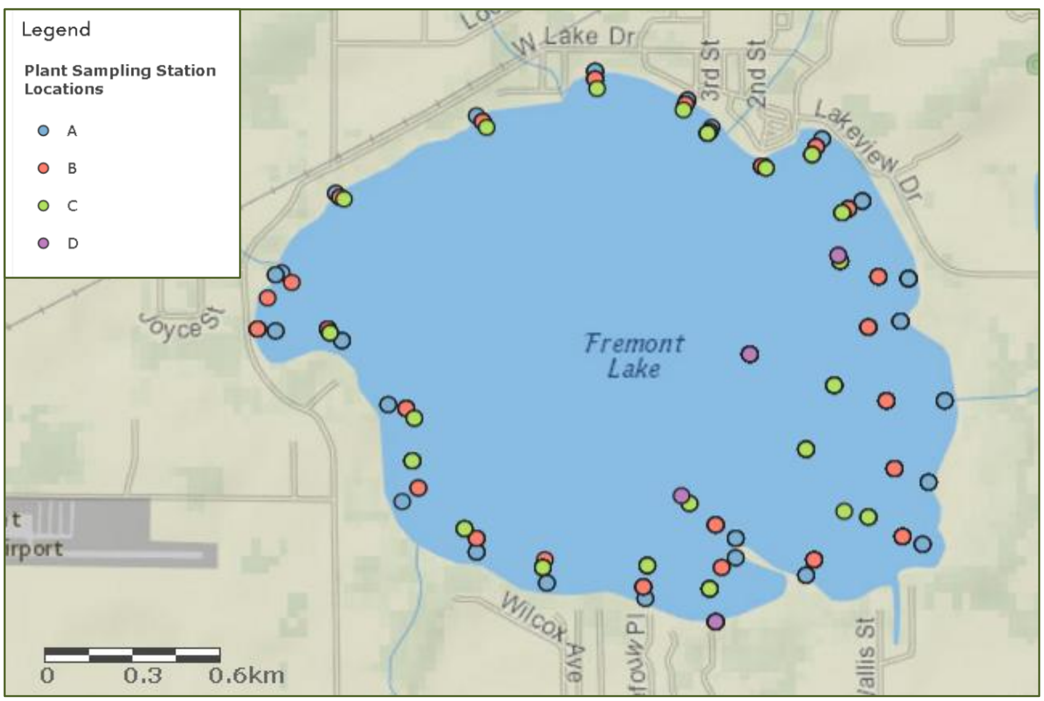


Figure 4.2: Sampling locations of the aquatic plant assessment completed by MSU researchers in May and July 2016. Each dot represents a sampling station along one transect. Each transect runs from the shoreline and extends perpendicularly into the lake until the photic zone ends (at approximately 17-20 ft. deep). Each dot represents a sample station where a rake was thrown four times, once in each quarter-clock direction (12, 3, 6, and 9 o'clock). After each rake toss, the number of species found and the relative density (0-100%) were recorded on a data sheet.

Aquatic plants were sampled using a stratified design modified from the MiCorps CLMP aquatic plant identification and mapping protocols (Wandell and Wolfson 2007), where we sampled 25 transects consisting of 12-16 rake tosses each (Fig. 4.2). This sampling design is appropriate for Fremont Lake as it follows a non-harvest, whole-lake approach that accounts for depth variation and is easy to replicate. This protocol collects information on what species are found growing in the lake as well as their locations and relative abundances (or densities).

At each sample station, four rake tosses are completed to determine the relative density of each plant species observed at all sample stations in all transects (Fig. 4.3). To calculate the relative amount of each species in the lake, two density ratings were calculated.

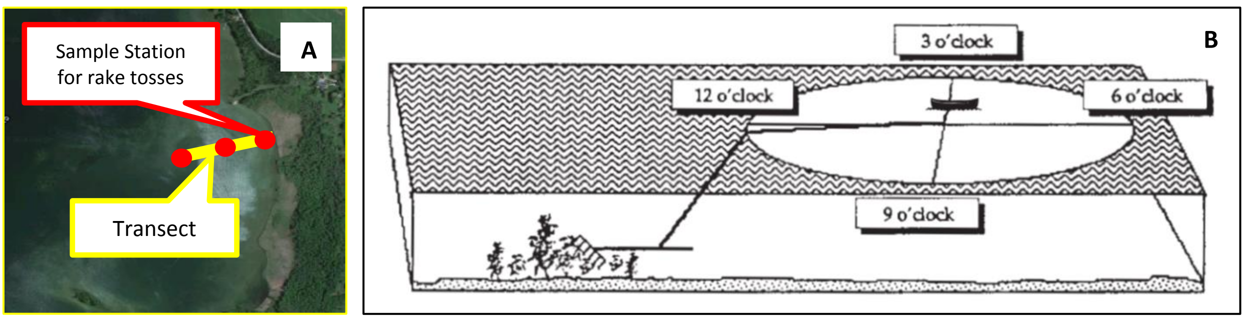


Figure 4.3: Aquatic plant sample design including transect and sampling station layout (A) and the protocol for how rake tosses were thrown at each sample station (B). At each sample station, a double-sided rake attached to a 30 ft. - long synthetic line is pitched at each clock position and then dragged along the lake bottom. The rake is then hauled back into the boat. The collected vegetation is identified and the density of each species is estimated. Adapted from: Simpson, J.T. 1991.

The first density rating, provided by the MiCorps aquatic plant identification and mapping protocol, attributes density ratings for each species based on the number of times the plant was collected during the four rake tosses at each sampling station. This method results in a number that includes not only the amount of times a species is found within the lake but also the relative amount. Specific methods can be found in Chapter 5 of Citizen's Guide for the Identification, Mapping and Management of the Common Rooted Aquatic Plants of Michigan Lakes (Wandell and Wolfson 2007), which can be accessed at:

https://micorps.net/wp-content/uploads/CommonRootedAqPlants-MSUE-WQ-55.pdf.

The second density rating is a direct calculation of the frequency of each species. Frequency is a reflection of the probability of sampling a particular species based on the sampling effort in the area of interest. Unlike the above CLMP method, frequency represents the presence of the species found in the lake irrelevant of density at each sampling. Frequency was calculated by dividing the total number of times that the species was found by the total number of sampling rake tosses (n=310). For example, if Eurasian watermilfoil was pulled up in a total of 140 rake tosses and a total of 310 rake tosses were thrown, then the frequency of Eurasian watermilfoil

(EWM) is 140 ÷ 310 = 0.45. We then multiply by 100 to obtain a frequency of 45% for EWM. This metric can be compared to frequencies of plants collected during submerged aquatic vegetation (SAV) surveys, which are required by permit-holding lake management companies that are applying chemicals to open water.

We enrolled Fremont Lake in the MiCorps Aquatic Plant Identification and Mapping parameter as well as the Exotic Aquatic Plant Watch parameter. For more information on these MiCorps CLMP plant parameters, visit https://micorps.net/lake-monitoring/ and click on the "Monitoring Programs" section.

4.4 Results and Discussion

Summarized and interpreted results of the plant sampling completed on Fremont Lake during 2016 by MSU can be found within this section; raw data can be found in the Appendix (4.0). In 2016, species richness (or the total number of plant species) observed in Fremont Lake was 22 and 21 for May and July, respectively. The total list of species observed from the most recent aquatic plant sampling efforts and the species richness for each of these years can be found in Table 4.1.

An interesting commonality across all surveys in Table 4.1 is the presence of several restricted aquatic invasive plant species: EWM (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*). Curly-leaf pondweed (Fig. 4.4) is the only invasive pondweed species found in Michigan and can be easily identified by the presence of its crinkly leaves and little teeth along the leaf margins. EWM can be identified by counting the leaflets on one side of the leaf; the invasive milfoil species will have 12 or more leaflets while all the native milfoil species will have less than 12 leaflets on one side. However, the native and invasive species can hybridize, making it more difficult to identify which is the EWM. An important life history trait of EWM is its strong ability to spread through fragmentation, a process where some plants can reproduce vegetative when a portion of a plant is cut (i.e., fragmented) and then carried to other parts of the lake by waves or winds. For EWM, a fragment as small as two inches can regrow and add to the invasive biomass in the lake. Plant fragments can also become attached to fishing equipment, boat motors, birds or animals, and make spread among water bodies more likely. In addition, some plant fragments can survive for hours or days out of water making it imperative that boats and motors be inspected for hitch-hiking plant fragments.

Table 4.1: List of aquatic plant species observed in Fremont Lake during 2009, 2013, and 2016. Species that are considered invasive or have invasive varieties are indicated in **red bold.**

Scientific name	Common Name	PLM 2009 June	Progressive AE 2013 June	Progressive AE 2013 August	MSU 2016 May	MSU 2016 July
Ceratophyllum demersum	Coontail	X	X	X	X	X
Chara sp.	Muskgrass	X	X	X	X	X
Cladophora / Hydrodictyon	Filamentous algae				X	X
Decodon verticillatus	Swamp Loosestrife		X	X	X	X
Elodea canadensis	Elodea / water weed	X	X	X	X	X
Lemna minor	Small Duckweed		X	X		
Lythrum salicaria	**Purple loosestrife**			X	X	X
Myriophyllum spicatum	**Eurasian watermilfoil**	X	X	X	X	X
Myriophyllum sibiricum	Northern watermilfoil			X	X	X
Myriophyllum sp.	Water milfoil				X	X
Najas flexilis	Bushy pondweed			X	X	X
Nitellopsis obtusa	**Starry Stonewort**				*	
Nuphar variegata	Yellow water lily / Spadderdock	X	X	X	X	X
Nymphaea odorata	White water lily	X		X	X	X
Phragmites sp.	Common Reed		X		X	X
Pontedaria cordata	Pickeral weed		X		X	X
Potamogeton crispus	Curly-leaf pondweed	X	X		X	X
Potamogeton nodosus	American / long-leaf pondweed			X		X
Potamogeton richardsonii	Richard's pondweed		X			
Potamogeton sp.	Pondweed	X			X	X
Ranunculus sp.	Water Buttercup					
Sagittaria sp.	Arrowhead		X		X	X
Schoenoplectus sp.**	Bulrush		X	X	X	
Spirodella sp.	Greater / large duckweed			X		
*Stukenia pectinata***	Sago pondweed	X		X	X	X
Typha latifolia	**Cat-tail**	X		X	X	X
Vallisineria americana	Water Celery / Eel grass	X	X	X		X
Zosterella dubia	Water Star-grass	X		X	X	
	Total number of species	**12**	**14**	**18**	**22**	**21**

*DNA analysis run by the Environmental Engineering lab at MSU revealed trace amount of Starry Stonewort in Fremont Lake.
** *Schoenoplectus sp.* is the updated classification of *Scirpus spp.* (bulrush). *Stukenia pectinata* is the updated classification of *Potamogeton pectinatus* (sago pondweed).

Both EMW and curly-leaf pondweed are fairly common in Lower Peninsula inland lakes and eradication is unlikely. However, with comprehensive chemical and/or removal treatments, the prevention of future introductions, and the concurrent promotion of native aquatic plant species, invasive aquatic plant populations can be controlled to levels that have a lesser effect on recreation and ecosystem and water quality health.

An additional invasive species was possibly detected during the MSU 2016 spring sampling. A few fragments of potential starry stonewort (*Nitellopsis obtusa,* Fig. 4.5) were found in the northwest side of the lake, but the positive identifying features (small, white, star-shaped bulbils) were absent. Because the fragments were small and lacked certain positive identifying features, we sent the fragments to the environmental genomics laboratory in the Department of Civil and Environmental Engineering at MSU.   The fragments were analyzed using loop-mediated isothermal amplification (LAMP). LAMP is a DNA amplification procedure similar to the more widely-used quantitative polymerase chain reaction (qPCR), but uses 4-6 primers instead of 2 and is conducted under isothermal conditions at 63°C. While the fragments themselves did not yield a positive result for starry stonewort, there were some delayed positive amplifications from the sample, indicating that traces of starry stonewort could potentially exist in Fremont Lake. Further monitoring is encouraged in order to best manage this aggressive invasive species.

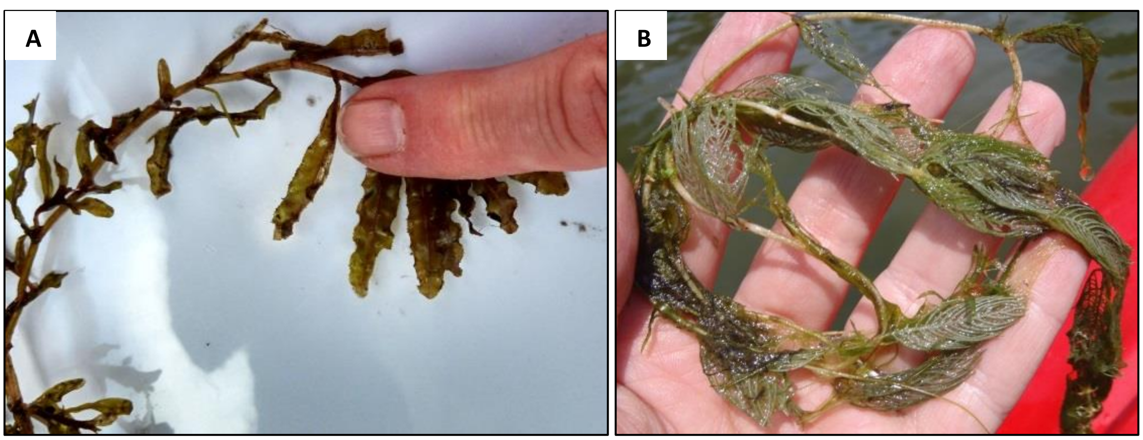


Figure 4.4: Curly-leaf pondweed (A) and Eurasian watermilfoil (B) were two of the invasive aquatic plant species found in Fremont Lake, Newaygo Co., during 2016 plant sampling. (*Photos by Angela De Palma-Dow*)

The variation in total number of species observed in Fremont Lake when comparing between 2009, 2013, and 2016 can be attributed to several different factors such as seasonal growth patterns, survey methods, new species introductions, and overall variation in sampling protocol and effort. To accommodate the variation observed in species richness, annual plant surveys and monitoring (much like what Fremont Lake has historically employed) are extremely useful and are continuously encouraged as part of any sound lake management plan.

Figure 4.5: Starry stonewort (*Nitellopsis obtusa*) is an aggressive, invasive macro-alga that grows along the bottom of hardwater lakes creating thick, dense carpets that exclude native plants and drastically change lake ecosystems. Starry stonewort can be identified by the presence of white, star-shaped bulbils, which are the plant's reproductive structures that fall into the sediment during fall, and sprout in spring. There currently are no successful treatments that have been shown to eradicate this species from inland lakes of Michigan; therefore, prevention and early detection are the most important methods to control this invasive plant. *(Photo by Angela De Palma-Dow, White Lake, Oakland Co., MI*)

Results of the 2013 and 2016 MSU plant sampling results can be compared in Fig. 4.6. These bar graphs show the relative frequency of sampled species (i.e., how many times each species was sampled on a rake toss divided by the total number of rake tosses). For both years, the amount of Eurasian watermilfoil and curly-leaf pondweed were lower in the summer months compared to the spring months. This is likely due to several factors: 1) chemical herbicide treatments targeting these species have been successful in limiting the abundance of these two species; 2) curly-leaf pondweed, which reaches maximum growth during spring to early summer, starts to die-back during the mid-summer months, and can be almost completely gone by August or September; and 3) there is more growth of native species during the summer than the spring, allowing some increased competition between native and invasive plant communities. Regardless of the reason behind these observed trends regarding these troublesome invasive species, the pattern is important to note. It is also important to make annual efforts to manage, control, and possibly eliminate these species from Fremont Lake.

Spatial distribution of the aquatic plant surveys for both the spring and summer sampling can be seen in Figs. 4.7 and 4.8. The aquatic plant that most commonly causes concerns for Fremont Lake residents and inland lake associations in Michigan is the presence and impacts of Eurasian watermilfoil. We visually plotted the locations and relative abundances of EWM (and all other native aquatic plants) sampled for both the spring and summer sampling periods. Comparing the locations and abundance of EWM between spring and summer is important because after the spring sampling, the population had been aggressively chemically treated throughout the season. When comparing the amount and locations of EWM between these two figures, the decrease in EWM can be observed indicating that the current herbicide treatment plan is successful and should be continued in some form to provide continued maintenance and management of the troublesome EWM. In addition to continued management of this species, monitoring and surveys that take into account the location and density of all species should be continued in order to best follow trends over time in the aquatic plant community in Fremont Lake.

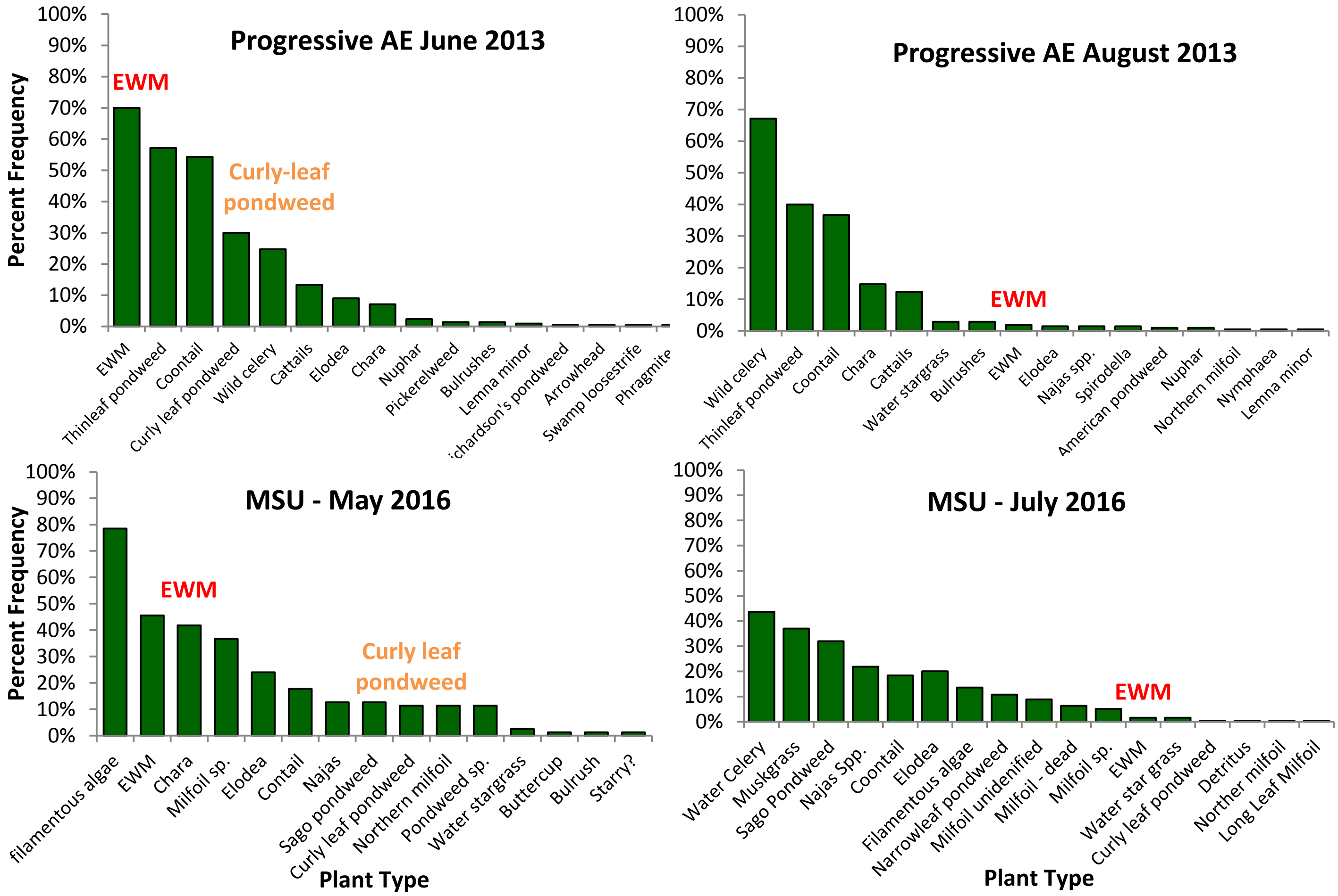


Figure 4.6: The frequency of aquatic plants sampled using rake tosses during spring and summer months in 2013 (Progressive AE, A and B) and 2016 (MSU, C and D).

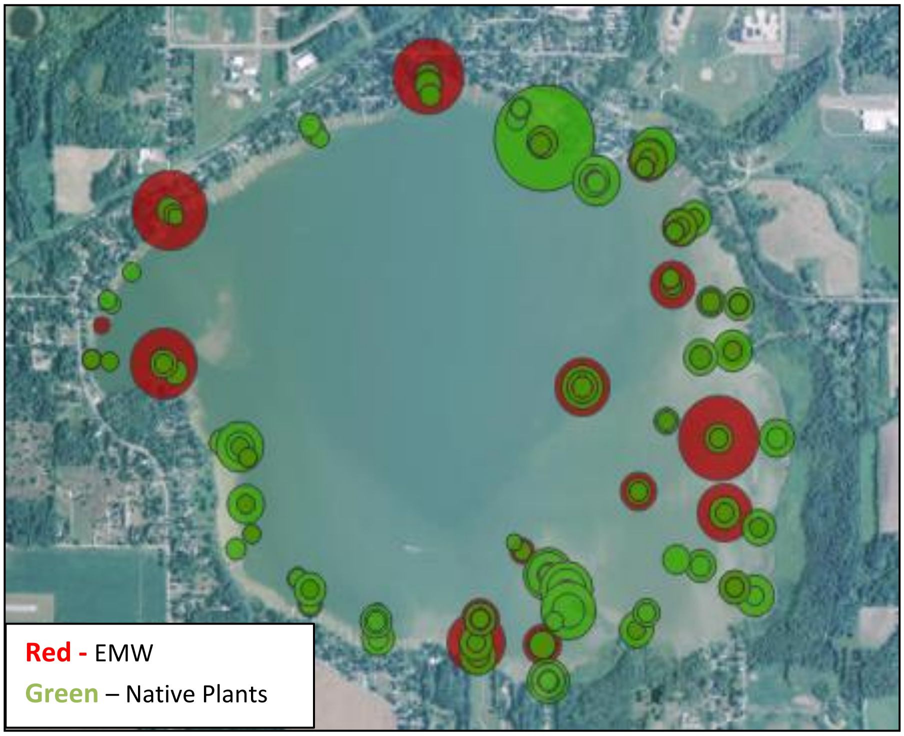


Figure 4.7: Locations and relative abundances of Eurasian watermilfoil and all other native aquatic plants during the May 2016 sampling by MSU researchers. This figure reflects the aquatic plant community including Eurasian watermilfoil (EMW) prior to any chemical herbicide treatments in 2016. The larger the circle, the higher the relative abundance of EWM.

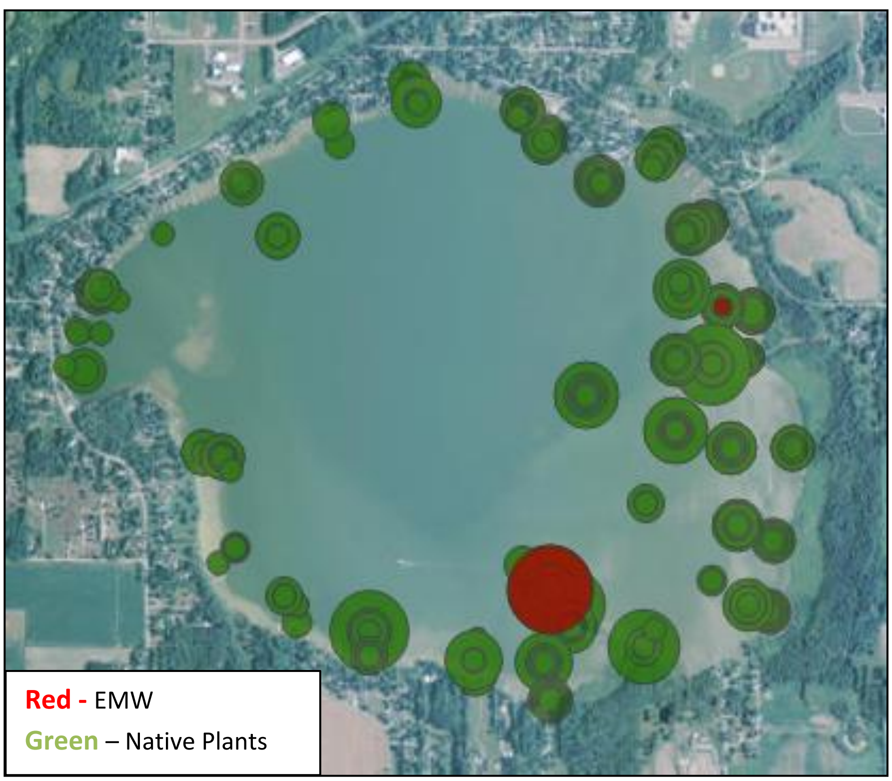


Figure 4.8: Locations and relative abundances of EWM and all native plants during the July 2016 sampling event by MSU researchers. This distribution reflects the aquatic plant community including EWM distribution after several chemical herbicide treatment events. The reduction in overall EWM from spring to summer indicates successful treatment efforts. The one area of concern near the southern boat launch area indicates that this might be a population that was recently introduced or was not targeted by the herbicide treatments and should be a priority site for future treatments and monitoring.

4.5 Plant-Related Outreach Events

In addition to plant sampling, MSU researchers scheduled and implemented several important invasive species outreach and prevention measures. In late July, the MSU mobile boat unit was stationed at the two public boat launches at Fremont Lake (Fig. 4.9). The mobile boat unit is a self-contained gas-powered pressure washer unit that enables users to wash boats with heated, high-pressure water before and after they launch a boat into Fremont Lake. The washed runoff water, potentially containing fragments, propagules, larvae, or seeds of invasive species, is collected in a ground mat that is later vacuumed, collected into a sealed container, and disposed of off-site into a proper water treatment-bound receptacle. In addition to the mobile boat wash unit, the City of Fremont and Sheridan Township erected two "Help Stop Aquatic Hitchhikers" metal signs, provided by the Michigan DEQ and DNR via MSU. These signs, guarding the north and south boat launches, can help to educate the public about removing plant fragments from their boats prior to and after entering the lake as described by the "Clean, Drain, Dry" campaign. In addition, an invasive species-specific outreach event, also held in late July, presented information and examples of the effects of invasive species on lake ecosystems.

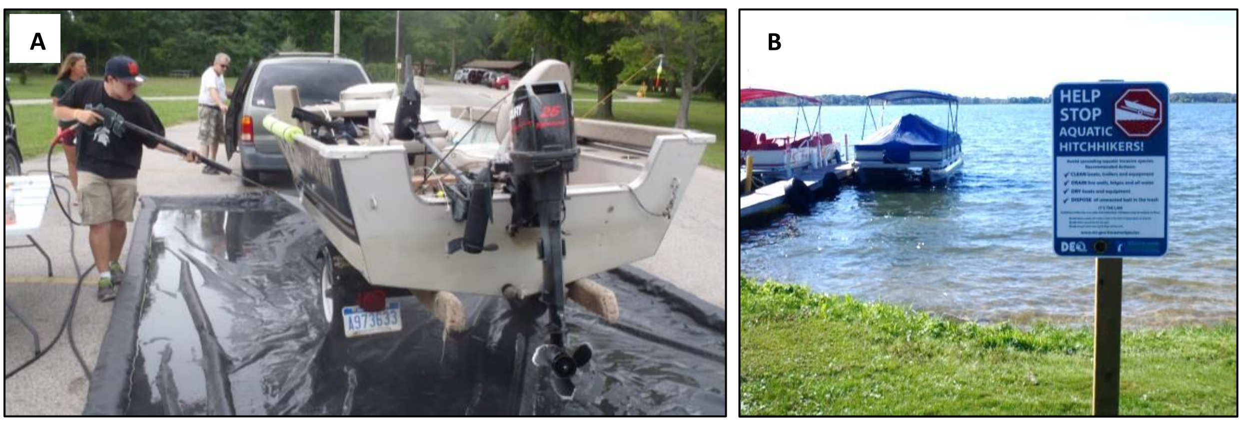


Figure 4.9: Fremont Lake hosted the MSU mobile boat wash unit (A) and posted "Help Stop Aquatic Hitchhikers" signs (B), provided by the Michigan DEQ and DNR, at both the north and south boat launches at Fremont Lake. Outreach and education efforts are important components in any successful aquatic invasive species management plan as these are two of the main methods to prevent the introduction of new invasive species.

5.0 Score the Shore

5.1 Background and Ecology

An additional element of assessing a lake ecosystem is determining the status of the shoreline. Healthy shorelines are essential for healthy lakes. Shorelines are a natural transition zone between land and water, providing habitat for many types of fish and wildlife. Bluegill, bass, and pike use these areas for spawning, protection, and food, while countless species of birds, amphibians, reptiles, and insects require this land-water interface for survival. In addition, healthy shorelines contain an ample vegetation buffer with deep-rooted plants that slow runoff and serve as crucial erosion control.

Unfortunately, the removal and modification of original natural shoreline has become a major stressor to many Michigan Lakes. If a majority of aquatic and marginal plants are removed and the gradual transition between land and water disappears, habitat is lost and many species will decline. Also, the water quality of a lake is impacted because without the vegetated buffer, runoff, erosion, and sediment inputs increase, more phosphorus is carried into the lake, and toxic pollution runoff from yards and homes increases. Many efforts to reduce shoreline erosion by hardscaping (i.e., adding seawalls) can actually cause more harm because wave action near seawall structures can cause scouring of the bottom lake sediment, which increases turbidity and harms spawning habitat for fish (Fig. 5.1). In addition, the resulting disturbed habitat may allow opportunistic invasive aquatic plants to thrive.

The MiCorps Cooperative Lakes Monitoring Program (CLMP) implemented the "Score the Shore" monitoring program as an interactive way for people to assess the quality of their shoreline habitat, so that they can maintain existing healthy areas and take steps to improve degraded areas (MiCorps 2016).

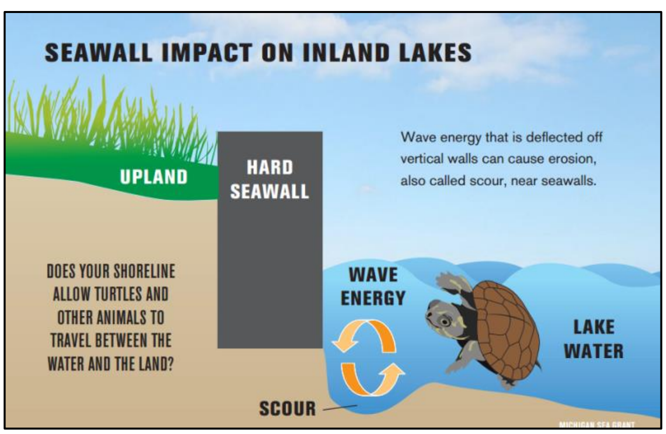


Figure 5.1: Graphic of wave energy when encountering a vertical artificial structure. With no shoreline space to absorb the energy, waves will deflect downward, scouring out bottom sediment causing increased turbidity, release of nutrients, disruption of fish spawning areas and destabilizing shoreline structures. (*Image credit: Michigan Sea Grant, (http://www.miseagrant.umich.edu/downloads/coastal/11-501-Natural-Shoreline-booklet-DEQ-LR.pdf*)

The Score the Shore tool is designed to help individuals and lake associations delineate areas of the shoreline that should be protected or improved. It serves as an integral element for lake management plans and for educating lakefront property owners about the importance of healthy shorelines.

5.2 Methods

We evaluated Fremont Lake's shoreline using the Michigan Clean Water Corps' Score the Shore protocol (https://micorps.net/wp-content/uploads/CLMP-Score-the-Shore-Procedures-2016.pdf). We completed the survey across three dates during the summer of 2016: June 14, July 7, and September 30. To create survey sections for estimating quantities of natural and artificial shoreline features, we created 25 1000-ft. survey sections in advance of the survey using Google My Maps (https://support.google.com/mymaps/answer/3024396?hl=en). Coordinates (latitude and longitude) for the beginning and end points of each 1000-ft. section were determined with a handheld Garmin GPS. The coordinates can be found in Appendix 5.0. We conducted the survey by kayak.

The survey consisted of estimating four shoreline components: structural, littoral, riparian, and erosion control practices. See Appendix 5.0 for an example data form.

For the structural characteristics, the number of physical structures were counted in each section, including homes, major buildings, docks, and boatlifts.

The littoral zone (or the aquatic area near the shore) was characterized by estimating the percentage of emergent or floating vegetation and submerged vegetation. The presence of current aquatic plant management activities was noted, as well as the amount of downed trees or woody debris and erosion along the shoreline.

To characterize the riparian zone (or the land near the shore), the percentage of maintained lawn, maintained or artificial beach, or impervious surface was determined, in addition to percentage of unmowed vegetation and the average belt depth of any unmowed vegetation.

Lastly, erosion control was characterized by determining the percentage and type of vertical artificial structures (e.g., seawall, boulders, and rock walls), sloped artificial structures (e.g., concrete, rock, and riprap), and bioengineering structures (e.g., coir logs and branch bundles).

Each of the parameters discussed above were ranked on a point system. Points were added up for each section, and specific equations were used to calculate the final score for each section.

These equations can be found on the scoring sheet (Appendix 5.1). Final scores were ranked on a scale of 0 to 100.

After the 25 section scores were calculated, the overall development density (average number of structures per section) and the overall shore score (sum of section scores divided by total number of sections) were calculated. The health of the lakeshore habitat is assigned one of four classifications, depending on the score received for each section and for the overall lake. These classifications are described as “good” (76-100), “fair” (51-75), “poor” (26-50), and “extremely impacted” (0-25) (MiCorps 2016).

5.3 Results and Discussion

Fremont Lake received an overall shore score of 54 out of 100, meaning that the shoreline is in fair health. The number of all buildings and docks totaled 426, resulting in a development density of 17 structures per 1000-ft. section.

Across all 1000-ft. sections, six were classified as “good”, six as “fair”, 12 as “poor”, and only one as “extremely impacted”. Figure 5.2 displays the distribution of shoreline health scores across all sections. Figure 5.3 displays a map of Fremont Lake with the score and health classification of each section.

Approximately 25% of the shoreline of Fremont Lake is classified as having “good” health, and an equal amount is classified as having “fair” health. The large wetland area surrounding the southeast portion of Fremont Lake is the main contributor to these high scores. The wetland area, as well as the “fair” sections on the western and northeast sides of the lake, should be protected from new shoreline hardening as much as possible to ensure that their shoreline habitats do not lose their integrity over time (DEQ 2016).

Approximately half of Fremont Lake’s shoreline is classified as having “poor” health. This result is likely due to several factors. We observed a high amount of vertical artificial structures (mainly seawall) along much of the shoreline, as well as several maintained lawns with little to no unmowed vegetation buffer. In addition, there was a relatively high development density.

Since vertical artificial structures are intended to control erosion yet often result in increased erosion due to bottom scour, it would be ideal to continue erosion control by adding rip-rap (DEQ 2016). Other bioengineered structures for a natural shoreline include coir logs and brush bundles, which are made of natural, biodegradable materials that help to stabilize sediment and encourage plant growth for continued erosion control after the materials biodegrade (Fig. 5.4).

There was only one 1000-ft. section that was “extremely impacted”. This section had a high amount of maintained lawn, maintained or artificial beach, or impervious surface. We also observed a high amount of vertical artificial structures and a moderate amount of sloped artificial structures.

Rectifying the shoreline of Fremont Lake with careful planning will not only help to control erosion in a natural way, but will enhance the ecological functioning of the shoreline and result in improved water quality and habitat for fish and wildlife. Please see Section 5.4 for additional information on shoreline restoration.

Since shoreline conditions generally do not change significantly from year to year, the Score the Shore method is a tool that can be conducted every 3-5 years to monitor observable change. It is intended to serve as a useful educational tool for property owners and lake managers, and not as a regulatory measure.

Figure 5.2: Distribution of shoreline health scores in Fremont Lake across all sections.

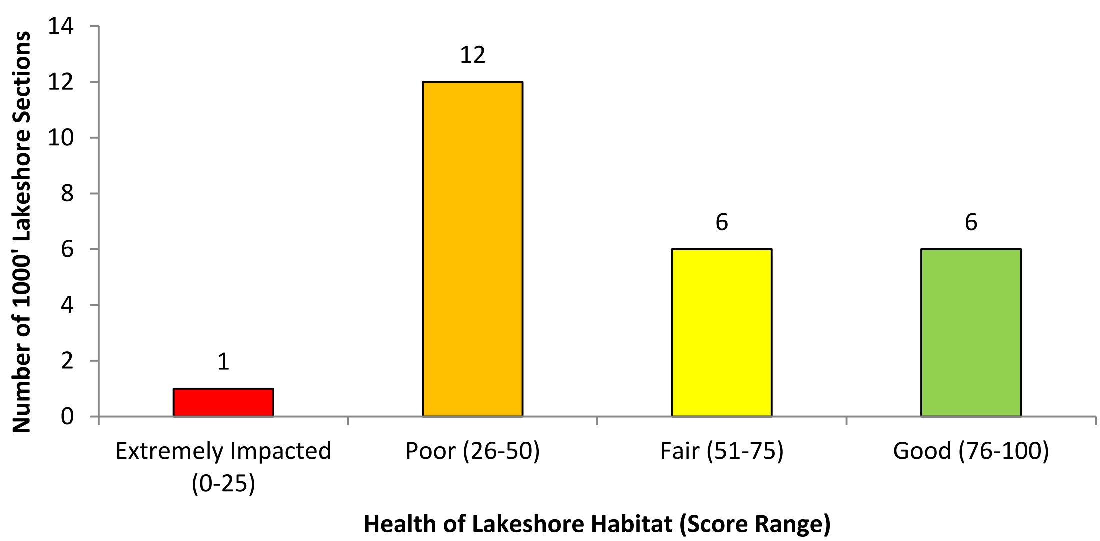


Figure 5.3: Health scores of the shoreline sections of Fremont Lake. Sections were 1000 ft. in length and there were a total of 25 sections. Colors with their corresponding score ranges and health classifications are as follows: green (76-100) = good; yellow (51-75) = fair; orange (26-50) = poor; and red (0-25) = extremely impacted.

Figure 5.4: Installation of coir logs on Kent Lake, Oakland Co. (A), and a few weeks after installation of erosion blanket and brush bundle (B) on Gull Lake, Kalamazoo Co.

6.0 Reflections and Recommendations

6.1 Reflections

In this last section we will review and provide updates on the current status of the recommendations provided in the GVSU 2010 report in Table 5.1. Table 5.2 provides recommendations based on the water quality and plant assessment study completed by MSU in 2016.

Data available from the 2000s through 2016 indicate that Fremont lake is consistently in the mesotrophic and lower eutrophic spectrum, which is an improvement from its status as a highly eutrophic “problem” lake, according to 1971 EPA data. During the summer of 2016, MSU researchers made several important observations that were the basis for many of the recommendations provided in Table 6.2. One of the more noteworthy observations included relatively low oxygen levels in the deep zones of the lake during the summer (Fig. 3.5). Oxygen is needed by many of the living organisms in the lake such as fish and insects and therefore, these low oxygen concentrations are of concern. The oxygen and nutrient data also suggests that internal loading may be occurring, which may contribute to excessive algae growth. Water clarity, an important factor in overall health and production in a lake, has steadily improved over the years since initial sampling in 1974, suggesting again that water quality is improving (Fig. 3.8). Water clarity is a fairly easy measurement and, regardless of any other research occurring on the lake, should be collected every year from spring to fall in order to best monitor important changes through time.

For nutrient contributions from the three tributaries, nitrogen concentrations from Brooks Creek were above EPA-suggested thresholds in August for both the 2016 and 2009 studies. Only Fremont Drain exceeded EPA-suggested phosphorus thresholds in the 2016 study. However, the suggested phosphorus threshold was exceeded in Brooks Creek for the 2009 study (Table 2.2). The contribution of nutrients through stream tributaries is just one factor in the contribution of non-point pollution sources entering Fremont Lake.

Fremont Lake has an abundance of aquatic native plant species, however, there are also several concerning invasive aquatic and wetland plants present in Fremont Lake such as Eurasian watermilfoil and curly-leaf pondweed (Fig. 4.4). These troublesome species will need continuous monitoring and treatments because left unchecked; they can drastically reduce the ecological and economical value of a lake. It is important to track the relative amounts of these species, in addition to preventing and monitoring the introduction or presence of new invaders, to identify if management strategies are being effective and where to prioritize future efforts.

Shoreline health in Freemont Lake is mostly stable due to the large wetland shoreline along the east and south side of the lake; however, some heavier development and artificial shorelines along the north shore of the lake, in combination with heavy boat activity, are contributing to a degraded shoreline in those areas (Fig. 5.3).

The purpose of these recommendations is to provide Fremont Lake managers and stakeholders a more thorough understanding when developing short-term and long-term lake management plans. There are no simple solutions or tools that will quickly maintain or improve water quality in Fremont Lake. Improving the water quality in Fremont Lake should include a multi-faceted, multi-year (or multi-decade), comprehensive and holistic approach. A desired outcome for Fremont Lake is attainable, and the following recommendations are provided to assist in accomplishing that outcome.

6.2 Recommendations

Table 6.1: Reflection on recommendations from the 2010 GVSU report based on 2016 water quality and aquatic plant assessment by MSU, as part of Objective 2.

GVSU 2010 Recommendation – Short Term	Status, updates & comments from MSU 2016
Further investigation of the Daisy Creek, Brooks Creek, and Fremont Drain basins to determine the magnitude of nutrient sources and determine the best locations for best management practices.	In order to reduce nutrient flows in Fremont Lake, this suggestion still remains a priority for future investigations and management.
Further investigation of Fremont Lake to determine if internal loading (release of phosphorous from sediments) is a factor.	This is an important recommendation, especially with the knowledge from the DO profiles revealing the large amount of hypoxia during August. Low / no oxygen levels increase the probability of internal loading.
Creation of a social marketing campaign to promote storm water education in the watershed.	This kind of education and outreach is always encouraged, however monitoring within the watershed beyond the three tributaries described in this report were beyond the original direction of this study. In addition to storm water awareness, general education targeted towards the community about improving water quality in Fremont Lake through limits in fertilizer runoff, proper septic tank maintenance, and prevention of invasive species into Fremont Lake is also encouraged.
Work with communities in the watershed to implement Low Impact Development techniques into site design processes.	We continue support of this recommendation with collaborations with MSU Extension, watershed groups, other non-profit community organizations, and state agencies. Some information can be found at: https://www.michigan.gov/documents/deq/Online_Resources_for_GI_C

	onference_455011_7.pdf
Encourage inspection and maintenance of individual septic systems located throughout the watershed, but even more importantly around the perimeter of Fremont Lake.	This recommendation is still supported and will be a constant goal as long as septic systems exist on and around Fremont Lake. We also recommend education and outreach for proper septic maintenance and management, including distribution of educational materials such as the "Managing Waste Household Septic Systems" by MSU Extension, available at: http://msue.anr.msu.edu/news/managing_waste_household_septic_systems_part_one http://msue.anr.msu.edu/news/household_septic_system_-_part_two http://msue.anr.msu.edu/news/managing_waste_household_septic_system_-_part_three
Conduct septic dye testing to ascertain the need to maintain or replace existing septic systems.	This recommendation is a sound method for addressing the above recommendation. Leaky septic systems can add nutrients into Fremont Lake, contributing to excess growth of algae and aquatic plants. Constant monitoring of septic systems in the Fremont Lake watershed is an important step towards monitoring the overall health of the lake.
Create evaluation techniques to determine if pollutant loading reductions are being achieved over time.	By enrolling in an annual lake monitoring program, such as the MiCorps Cooperative Lakes & Stream Monitoring Program, or by hiring a lake management company that is contracted to measure water quality parameters, trends on nutrient loading in Fremont Lake and its tributaries can be monitored and evaluated over time.
GVSU 2010 Recommendation – Long Term	**Status, updates & comments from MSU 2016**
Install buffer and filter strips along stream corridor and lake front to reduce the inputs of nutrients.	This recommendation is still an important goal to accomplish. In addition, we suggest maintaining floodplains. Also, by decreasing impervious channelization, water will have more time to infiltrate into the soil during storm events, instead of being funneled at high velocities into Fremont Lake.
Create more opportunities for runoff infiltration and detention in developed areas to reduce direct nonpoint source pollution inputs. Examples of infiltration and detention best management practices include bio-retention (rain gardens), constructed wetlands, capturing storm water (rain barrels, cisterns), vegetated swales, and vegetated or green roofs.	We support these recommendations, with additional efforts towards enhancing and increasing the areas of natural shorelines and/or reducing the impervious, artificial materials being used/constructed around the lake. Monitoring and record-keeping of the efforts completed towards this recommendation are also encouraged to monitor landscape improvements that can be compared when monitoring water quality trends over time. There are several state-run incentive programs in which property owners can participate, such as the Shoreline Steward Program http://www.mishorelandstewards.org/. Creation of local education and incentive programs is encouraged to increase participation in these types of programs.
Returning some of the natural	This recommendation is supported; however, it is costly to

sinuosity back to the stream channels to help slow the transport of sediment and nutrients to the lake.	implement. Until it can be accomplished, deterring nutrients from entering the stream tributaries, by methods listed previously, will reduce nutrient input into the lake.
Using phosphate free fertilizer for lawn maintenance.	It is encouraged that all lakeside property owners, and residents living within the Fremont watershed, follow the State of Michigan phosphorous limit regulations, which were updated in 2012, after the GVSU report. Additional information can be found online at MDARD http://www.michigan.gov/mdard/0,4610,7-125-1569_16993_19405---,00.html It is our further recommendation that the City of Fremont and Sheridan Township print and distribute information about proper fertilizer use, such as the brochure created by MSU Extension titled "Help Protect and Preserve Water Quality in Michigan: Using Phosphorous Free Fertilizer" available at: http://www.michigan.gov/documents/mdard/phosphorus_flyer_2-9-11_376295_7.pdf
Implement social marketing campaign to inform watershed stakeholders of their impact on water quality and steps they can take to improve and protect their water resources.	Outreach events aimed at specific stakeholders within the watershed is encouraged. We recommend building relationships with MSU Extension, local conservation districts and other watershed groups to accomplish this goal.
Consider sewer system extension, water conservation practices, and alternative septic treatment techniques as a way to minimize the associated impacts from individual septic systems on lake water quality.	We also support this recommendation and, according to town-hall evaluations, sewer system extension is also a priority to residents of Fremont. Long-term planning might include a goal of extending sewer systems, perhaps through state, county or community grant acquisition.
Implement evaluation techniques to determine the best management practices are improving water quality in the watershed.	By enrolling in an annual lake monitoring program, such the MiCorps Cooperative Lakes Monitoring Program (CLMP) and Volunteer Stream Monitoring Program (VSMP, http://www.michigan.gov/deq/0,4561,7-135-3313_3681_3686_3728-32396--,00.html), or a lake management company that is contracted to measure water quality parameters, trends on nutrient loading in Fremont Lake and its tributaries can be monitored and evaluated over time.
Lake management efforts implemented if internal loading of phosphorous is determined to be a problem in Fremont Lake.	We support lake management activities like reducing external nutrient additions that will begin to address internal loading in Fremont Lake. For example, this can include further study of water quality of Fremont Lake and tributaries, along with implementation of some or all of the following recommendations we provided based on the 2016 study.

Table 6.2: Recommendations based on 2016 water quality and aquatic plant assessment by MSU.

MSU 2016 recommendation	Further information & examples
Create short- and long-term lake management plans with clear goals and input from all stakeholders.	According to the North America Lake Management Society: "*A lake and/or watershed management plan is a dynamic document that identifies goals and action items for the purpose of creating, protecting and/or maintaining desired conditions in a lake and its watershed for a given period of time. Each lake management plan is different, depending on the conditions of the lake (watershed) and the interests of the stakeholders involved. A lake management plan also provides a framework for future lake boards and users as to what issues have been addressed and how successful previous efforts were.*" More information on developing a lake management plan and examples of plans from other lakes and states and be found at the NALMS website: https://www.nalms.org/home/lake-management-planning/
Keep record of lake water quality trends and patterns through continued lake and stream monitoring.	This recommendation, in conjunction with several by GVSU, to monitor trends in lake water quality can be met several ways: 1) Through annual enrollment in the Michigan's state-wide volunteer monitoring program, MiCorps Cooperative Lakes Monitoring Program (CLMP). MiCorps also includes a volunteer stream monitoring program (VSMP), which can supplement the lake monitoring. The MiCorps program is affordable, includes training, materials and staff assistance and includes sampling of parameters such as total phosphorus, chlorophyll *a*, dissolved oxygen (DO)/temperature, water clarity (Secchi), exotic plants, and score the shore (completed by the MSU team). Enrollment in MiCorps CLMP and VSMP is available online at: https://micorps.net/ 2) Utilization of a private contractor, such as a lake management company, to measure the same water quality parameters that are described within this report. Some companies and organizations are available through the Michigan Aquatic Managers Association http://mamagroup.org/ or by contacting other lake associations/managers in the Michigan Lakes and Streams Association: http://www.mymlsa.org/
Low dissolved oxygen levels need to be addressed. These lower levels are likely due to excess decomposition of organic matter. Because organic	There are several steps involved in meeting this recommendation: 1) Continue monitoring of DO/temperature and nutrient levels in Fremont Lake as listed in the previous recommendation.

matter comes from many sources, further investigation might provide insights into the causes of low DO.	2) Prioritize future funds for sediment testing to compare with sediment analysis done by Michigan DEQ and MSU in 2009 to establish contribution from sedimentation layers to low DO levels. 3) Complete DO lake profiles before and after algal herbicide treatments. 4) Generally, continue to decrease organic matter and nutrient inputs to Fremont Lake by implementing other recommendations such as fixing leaky septic systems, reducing nutrient runoff, and increasing natural shorelines and landscapes around the lake. 5) Obtain more information from knowledgable non-biased personnel about the positive and negative effects of temporary aeration, including if it would be sufficient to reduce hypoxia, what type of system would work best, where it should be located for maximum benefit, and if the positives outweigh the negatives.
Reduce organic and nutrient inputs (i.e., septic system maintenance, shoreline vegetation improvement).	This will always be an important and ongoing recommendation that can be attainable in Fremont Lake. Following the items in the above recommendation will help in accomplishing this recommendation, working with the local NRCS and Conservation District office can be an avenue of further direction, assistance, and resources. The Newaygo Conservation District can be contacted here: http://newaygocd.org/
Stormwater management will help address nutrient concentrations in tributaries.	From our informal observations of the tributaries after rain we recommend that stormwater management practices that reduce the rate of water flow and pollutants into Fremont Lake be implemented within Fremont Lake's watershed. Practices include, but are not limited to: rain gardens, water retention ponds, wetland protection, wetland creation, vegetated buffer strips, and drainage tile outlet control structures. Michigan Department of Transportation (MDOT) has multiple educational and outreach materials to help landowners learn about smart storm water strategies. http://www.michigan.gov/stormwatermgt/0,1607,7-205-30103---,00.html
Continue active treatment for invasive plants, particularly targeted Eurasian watermilfoil (EWM) & curly-leaf pondweed treatments.	Based on analysis from 2009, 2013, and 2016 aquatic plant treatment surveys, there is evidence of a decline in Eurasian watermilfoil in Fremont Lake, but there is still a sizeable population that, without proper management and annual treatments, can spread throughout the lake. There are some specific actions that the City of Fremont, Sheridan Township, and the Fremont Lake Association can implement to assist in the monitoring and management of aquatic invasive species:

	1) Continue chemical treatments of aquatic invasive plant species using a licensed application company. 2) Continue aquatic plant community monitoring either through enrollment in MiCorps Aquatic Plant Identification and Mapping Program or by hiring a third party to complete plant surveys (different then the aquatic plant treatment company). 3) Follow and incorporate Integrated Pest Management (IPM) strategies into lake management plans. A useful IPM document by MSU Extension is available here: http://www.deq.state.mi.us/documents/deq-water-great-lakes-aquatics-exotic4.pdf
Continue no-treatment zones of the lake where native aquatic plant communities can flourish.	Vigilant monitoring is needed in these areas to prevent rebounding populations of Eurasian watermilfoil and curly-leaf pondweed. Consider carefully removing patches in this zone following hand removal protocols: https://www.uwsp.edu/cnr-ap/UWEXLakes/Documents/programs/CBCW/publications/EWMhandpullingbrochure.pdf
Prevent new invasions and further spread of aquatic invasive species (AIS) such as: • Eurasian watermilfoil (present in Fremont Lake) • Curly-leaf pondweed (present in Fremont Lake) • Starry stonewort (fragments and DNA found in Fremont Lake 2016) • European Frog-bit (found in Grand Rapids August 2016) • New Zealand mud snails (found in Au Sable River summer 2016) • *Phragmites* (found all along east side of the state) • Parrot Feather (found in Jackson and Wayne counties)	Some methods to assist in meeting these recommendation can include: 1) Increase outreach and social marketing efforts to educate those living and visiting Fremont Lake to wash their boats, kayaks, canoes, fishing and swimming gear before entering Fremont Lake. (Campaign/social marketing materials and information is provided at the Protect Your Waters and Stop Aquatic Hitchhikers website http://protectyourwaters.net/ and State of Michigan Take Action against Aquatic Invasive Species webpage) http://www.michigan.gov/invasives/0,5664,7-324-74328---,00.html 2) Enroll and participate in Clean Boats, Clean Waters program. Information is available at: http://www.mymlsa.org/cbcw & http://msue.anr.msu.edu/program/info/clean_boats_clean_waters 3) Continue educational programs and displaying signage to encourage residents and visitors to clean their boats prior to entering Fremont Lake. 3) Invest in a boat washing station, mobile or permanent, to provide boat washes and water treatment of boats being launched and leaving Fremont Lake. a) During summer months, MSU has a mobile boat wash unit that can visit Fremont Lake and provide outreach and demonstrations to raise awareness for preventing AIS introduction. https://www.stewardshipnetwork.org/sites/default/files/boat_wash_flyer_2016_final.pdf b) Muskegon River Watershed Assembly also has a mobile boat wash unit that can visit Fremont Lake during busy summer days http://mrwa.org/

	c) Examples of various Michigan lakes that have installed permanent boat wash units *(the following are embedded links)*: Paradise Lake, Grand Traverse County Crystal Lake, Benzie County Hagerman Lake, Iron County (and http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5400155.pdf) Higgins Lake, Roscommon County 4) Sponsor local invasive species prevention outreach events
Install a no wake zone 300 ft. from the shore. Create additional no wake zones in sensitive areas (shallow areas of the lake). For areas of the lake where invasive aquatic plants are being managed, install temporary no-motor-boat zones to prevent AIS spread and promote growth of native communities that can assist in preventing EWM spread and create fish habitat.	Installation of no-wake/no-motor boat zones can accomplish several goals such as: 1) Decreasing shoreline erosion and resuspension of sediments caused by reduced wave action near the shore. Reduced resuspension will also reduce the amount of nutrients that can be re-released back into the water. 2) Reducing mediated fragmentation of fast-growing invasive and nuisance species such as Eurasian watermilfoil or the native wild celery/eelgrass/tape grass (*Vallisineria americana*) 3) Encourage the growth of native aquatic plant species that can be beneficial to the lake's fishery, absorb nutrients from the water column and sediment, and improve water clarity. Examples can be found in Section 1 (Pages 5-20) of the "Maine Citizen Guide to Aquatic Invasive Plant Management" available at: http://www.mainevlmp.org/wp-content/uploads/2014/03/MMI-Citizens-Guide-For-Web.pdf
Moderate and monitor copper-based treatments 1) "Side effects of 58 years of copper sulfate treatment of the Fairmont lakes, Minnesota" http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.1984.tb04797.x/abstract	Copper-based algaecides are used for reducing both free-floating and branched algae in Fremont Lake and many other inland lakes in Michigan. While they provide an immediate, inexpensive, and short-term remedy to "green-water" by reducing the growth of algae, continual use of copper-based algaecides has been shown to lead to many negative impacts to lake health. Some states, like Washington and Minnesota, have instituted laws to limit or prevent the use of copper-based algaecides in inland lakes. Some negative effects of using copper-based algaecides for short or long periods in lakes include: 1) Increased toxicity to invertebrates such as water fleas, crayfish, and other crustaceans, and snails. Some of these animals serve as primary food for fish. http://dnr.wi.gov/lakes/plants/factsheets/CopperFactsheet.pdf 2) Copper build up in lake bottom sediments 3) Possible increase in oxygen demand at the lake bottom – changes nutrient cycles and briefly depletes DO in water column Alternative non-copper algae treatments can be found at:

	http://www.ecy.wa.gov/programs/wq/plants/algae/lakes/ControlOptions.html
Utilize resources aimed at improving shoreline health.	There are ample resources that provide more information on healthy shorelines and how to properly manage for them. Listed below are the major groups and organizations involved in maintaining healthy shorelines in Michigan. 1) Michigan Natural Shoreline Partnership (MNSP): *The mission of MNSP is to use bioengineered erosion control and green landscaping technologies to promote natural shorelines. MNSP would be an excellent resource for understanding how to restore the natural shoreline of Fremont Lake.* 2) Property owners in Fremont Lake can also learn about how to become a "Michigan Shoreline Steward", designed to provide recognition to those who implement best management practices for healthy shorelines (www.mishorelinepartnership.org). 2) "Natural Shorelines for Inland Lakes" – Michigan Sea Grant and Michigan Department of Environmental Quality. This publication provides a great overview about healthy shorelines and how to restore them (http://www.michigan.gov/documents/deq/wrd-natural-shorelines-inland-lakes_366530_7.pdf).

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GLOSSARY

Adapted from New Hampshire departmental Services Volunteer Lake Assessment Program (http://des.nh.gov/organization/divisions/water/wmb/vlap/glossary.htm)

Acidic: The condition of water or soil in which substances lowers the pH below 7.0.

Acidification: A process by which the acidity of the water is raised (pH is lowered).

Aerobic: Requiring oxygen to live or occurring in the presence of oxygen.

Anaerobic: The absence of oxygen (also *anoxic*).

Algae: Simple single-celled (phytoplankton), colonial, or multi-celled, mostly aquatic plants, containing chlorophyll and lacking roots, stems and leaves. Aquatic algae are microscopic plants that grow in sunlit water that contains phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain. Algae is either suspended in water or attached to rocks and other substrates. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations (algae of the open water) vary widely from day to day, as life cycles are short. (*Refer to Phytoplankton and Periphyton*)

Algal Bloom: A heavy growth of algae in and on a body of water. This usually is a result of high nitrates and phosphate concentrations entering water bodies.

Alkalinity or Acid Neutralizing Capacity (ANC): Describes the ability of the water to buffer any acidic inputs.

Bedload: The larger rocks and boulders in a stream that roll along the stream floor

Bedrock: The solid rock beneath the soil or loose sediments.

Benthic: Located on the bottom of a body of water or in the bottom sediments.

Bioaccumulation: The process by which the concentration of a substance is increased through successive links in a food chain which may result in toxic concentrations at the top of the chain.

Best Management Practices (BMPs): An engineered structure or management activity that eliminates or reduces adverse environmental effects of pollutants.

Biological Production or Biomass: Total amount or weight of living plants and animals that an ecosystem yields.

Buffer Strip: Grass or other vegetation planted between a waterway and an area of intensive land use in order to reduce erosion.

Channel morphology: Describes the shape of the river channel.

Chlorophyll *a*: The green pigment found in plants that is essential for photosynthesis. It is sometimes used to measure the amount of algae in the lake.

Chlorides: Sodium chloride (table salt) is often used in to de-ice roadways during winter months. The salt (chloride) may then be washed into nearby lakes and streams resulting in elevated chloride levels in the water body. Elevated chloride levels can have an adverse effect on aquatic plants and animals. In public water supplies the EPA has set a standard that requires chloride levels not to exceed 250 mg/L due to possible health concerns.

Conductivity: A measure of the electrolytes in the water, which may be elevated by the presence of salts resulting from soil composition, faulty septic systems, or road salts.

Cultural Eutrophication: An increased input of nutrient and sediment materials usually due to the activities of the people in the watershed, resulting in declining water quality and premature aging of a lake or pond.

Cyanobacteria (blue-green algae): Bacteria, formerly known as blue-green algae, that photosynthesize (use sunlight to produce food) and are blue-green in color. While cyanobacteria occur naturally in all lakes and ponds, elevated nutrient levels may cause cyanobacteria to "bloom" or grow out of control and cover the lake surface. The concern associated with cyanobacteria is that some species produce toxins that may affect domestic animals or humans through skin contact or ingestion. These toxins may cause a variety of symptoms, including nausea, vomiting, diarrhea, fever, skin rashes, eye and nose irritations. If you see a cyanobacteria bloom do not go in the water, do not drink the water, and do not let pets or livestock go in or drink the water.

Dimitic: A lake that mixes freely twice a year (once in the spring and once in the fall), and is thermally stratified in the summer and winter.

Dissolved Oxygen: The amount of oxygen in the water. Dissolved oxygen may be produced by algae and aquatic plants or mixed into the water from the air. It is used by fish, aquatic insects, crayfish and other aquatic animals. Dissolved oxygen is usually measured in milligrams per liter or parts per million.

Dredging: Removing solid matter from the bottom of a water body to make a deeper channel.

Ecology: The study of the interactions between organisms and their environments.

Epilimnion: The upper, well-circulated, warm layer of a thermally stratified lake. (*Refer to Hypolimnion and Metalimnion*)

Erosion: The gradual wearing away of land surface materials, especially rocks, sediments, and soils, by the action of water, wind, or a glacier. Usually erosion also involves the transport of eroded material from one place to another.

Eutrophic: Nutrient-rich waters, generally characterized by high levels of biological production. (*Refer to Mesotrophic and Oligotrophic*)

Exotic Species: A plant or animal species introduced to an area from another country or state that is not native to the area.

Food Chain: A succession of organisms in an ecological community that constitutes a continuation of food energy from one organism to another as each consumes a lower member and in turn is preyed upon by a higher member.

Gradient: The steepness or drop in elevation of a channel over its horizontal distance.

Groundwater: (1) Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturated zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.

Headwater: The source and upper reaches of a stream; also the upper reaches of a reservoir.

Hypolimnion: The deep, cold, relatively undisturbed bottom waters of a thermally stratified lake. (*Refer to Epilimnion and Metalimnion*)

Internal Loading: The release of phosphorus from the lake bottom sediments into the bottom layer of the water, enhanced by oxygen levels on the bottom of the lake that are less than 0.5 milligrams per liter.

Kemmerer Bottle: A piece of equipment used to collect water samples from a specific depth in a lake or pond.

Lake Association: A voluntary organization made up of people who own land on or near a lake. The organization usually works towards preventing or solving any water quality concerns of the lake. A formal lake association should understand legal and tax issues, as well as keep financial records, and determine where funding will come from.

Lake Production: The amount of mass being produced by the conversion of carbon dioxide and sunlight into carbohydrates and oxygen through the process of photosynthesis.

Leaching: The process by which soluble materials in the soil, such as salts, nutrients, pesticide chemicals, or contaminants, are washed into a lower layer of soil or are dissolved and carried away by water.

Lentic: Referring to standing waters such as ponds and lakes.

Limiting Nutrient: An essential nutrient for plant growth, which is in the least abundance in the environment relative to the needs of the plant. Phosphorus is usually the limiting nutrient in freshwater lakes and rivers.

Limnology: The study of the biology, chemistry, and physics of freshwater lakes, ponds, streams, and rivers and inland saline waters.

Littoral: The shoreline zone of a lake where sunlight penetrates to the bottom and is sufficient to support rooted plant growth.

Lotic: Refers to running waters such as streams and rivers.

Low-Impact Development: A type of site development and design in which runoff water is allowed to infiltrate into the soil rather than flowing directly into a lake or stream. Low-impact development allows the lake or stream to function in a more natural way, with less human impact. (*Refer to Runoff*)

Metalimnion: The middle layer of water in a thermally stratified lake, between the epilimnion and hypolimnion, where the change in temperature with depth is at its greatest. (*Refer to Epilimnion and Hypolimnion*)

Non-Point Pollution: Pollution originating from a diffuse area (not a single point) in the watershed, often entering the water body via surface runoff or groundwater.

Nutrients: Inorganic substances required by plants to manufacture food by photosynthesis. Phosphorus is the nutrient that usually limits the amount of aquatic plant growth in many temperate lakes.

Oligotrophic: Nutrient-poor waters, generally characterized by low biological production. (*Refer to Eutrophic and Mesotrophic*)

Periphyton: An assemblage of microorganisms (plants and animals) firmly attached to and growing upon solid surfaces, such as the bottom of a stream, rocks, logs, pilings, and other structures.

pH: The measure of how acidic the water is, on a scale of 1-14; 1 is very acidic, and 14 is very basic.

Phosphorus: The nutrient most necessary for plant and algae growth in many lakes, which comes from many sources including faulty septic systems, lawn fertilizers, agricultural runoff, and decaying plant matter.

Phytoplankton: Microscopic plants that float within or on top of lake water. (*Refer to Algae*)

Plankton Net: A fine mesh net used to collect microscopic plants and animals.

Point Source Pollution: Pollution into a water body from a specific and identifiable source, such as industrial waste or municipal sewers.

Riprap: Large rocks placed along the bank of a waterway to prevent erosion.

Run: The portion of water in a stream that moves smoothly downstream, without interferences from rocks or bottom substrate.

Runoff: Precipitation that enters surface waters from overland flow and from groundwater.

Secchi Disk: An instrument used for measuring the transparency of lakes. It is a 20-cm diameter disk with black and white quadrants.

Sedimentation: The transport and deposition of sediment particles by flowing water.

Silt Screen: A sheet of fabric placed like a fence around a construction site to trap sediments and prevent them from entering a water body.

Stream Load: Solid matter carried by a stream.

Stream Discharge: The volume of water moving down a stream per unit area over a discrete amount of time, usually expressed as cubic feet per second (cfs), cubic meters per second (cms), or gallons per day (gpd).

Thermal Stratification: A process by which a deep lake becomes layered by temperature in the summer months. The layers will separate because colder water sinks to the bottom, leaving warmer water at the surface. In winter, the upper layers are coldest, and the warmest water is on the bottom (since water is heaviest at 4˚C). Because these layers form chemical and biological barriers, limnologists sample at each layer of the lake.

Thermocline: The point of maximum temperature change with depth in a thermally stratified lake.

Transparency: A measure of water clarity often determined by the depth at which a Secchi disk can be seen below the surface of the water. Transparency may be reduced by the presence of algae and suspended materials such as silt and soil particles.

Tributary: A stream that flows to a larger stream or other body of water.

Trophic Classification: Biologically ranking the quality of lakes using a model that incorporates several parameters. These parameters often include: chlorophyll-a, Secchi disk transparency, nutrient concentration, aquatic plant abundance, and dissolved oxygen.

Trophic State: In general, trophic state refers to the biological production, both plant and animal life, that occurs in a lake. The level of production that occurs is defined by several factors, but primarily by the phosphorus supply to the lake and the volume and residence time of the water in the lake. (Refer to O*ligotrophic, Mesotrophic, Eutrophic*)

Turbidity: A measure of the particles suspended in the water column, which affect the clarity and transparency of the water. These particles may include silt, clay, and algae.

Water Residence Time: The number of years required to completely replace the water volume of a lake by incoming water, assuming complete mixing.

Watershed: The land area draining to a particular water body. A watershed is often described as a funnel, where the lake or river is the bottom of the basin, collecting all the water that falls inside the funnel.

Watershed Management: Implementing practices within a watershed designed to protect or restore the water quality of the receiving water body. Such practices may include the implementation of *Best Management Practices*.

Zooplankton: Microscopic animals that live in lakes.

APPENDICES

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A Proposal for Water Quality and Aquatic Plant Assessment of Fremont Lake, Newaygo County, Michigan.

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Introduction

At the request of MSU Extension Educator Ryan Coffee, the City of Fremont and Sheridan Township, we have prepared a proposal to describe our intended activities in order to assess the general water quality and aquatic plant status of Fremont Lake, MI. This proposal outlines the sampling needs and timeframe expected to determine the physical, chemical and biological status of Fremont Lake during the 2016 year. The goal of this project is to investigate and respond to the recommendations provided in the original 2010 *Baseline Study on Fremont Lake and its Connecting Waterways* report prepared by the Annis Water Resources Institute of Grand Valley State University. In addition, by request, an outreach component and timeline will be proposed with the goal of providing educational programs to better inform Fremont Lake users and residents about the importance of conserving the aquatic ecosystem of Fremont Lake for future generations to enjoy.

This proposal contains what we consider an excellent way to evaluate the progress towards the recommendations outlined in the original 2010 report. This is a flexible document and can be revised or adjusted based on the needs and desires of the City of Fremont and Sheridan Township. In addition to this proposal, the authors strongly recommend that the City of Fremont, with collaboration of the Fremont Lake Association, enroll and monitor their lake in the MiCorps Cooperative Lake Monitoring Program (CLMP), not only to be financially savvy going into the future but to maintain consistency with measured water quality parameters over time in order to best observe changes occurring in the lake. Simultaneous enrollment in the CLMP program during 2016 will allow us, as staff working on this project, to assist in training the citizen monitors – something that is not always available to the other 250 Michigan lakes enrolled in this program but highly coveted. It is strongly encouraged that the Sheridan Township take advantage of this opportunity.

Objectives of Study

Below we outline the proposed objectives of our study to be completed according to the timeline provided in Table 2.

1) Evaluate the current chemical, physical, and biological status of Fremont during 2016.

2) Reflect 2016 status of Fremont Lake based on recommendations from 2010 study and report.

3) Provide new recommendations or maintain previous recommendations based on 2010 and 2016 data and results.

4) Design and offer several public workshops and presentation events where residents can learn about lake ecosystems including the role of aquatic plants. We propose 2-3 evening "open sessions" each with a theme. For example, one would be Aquatic Plant Ecology and Identification, one would be general lake and watershed management or aquatic invasive species or a topic chosen by the Board. At each of these meeting we would also distribute a survey with questions about participants' interests, perceptions about the lake, comments and concerns. Information gathered from the sessions would be collected and integrated into the final report. **As amended**, the last session would be a review of our findings along with recommendations.

5) As amended, additional sampling will occur to characterize two connecting tributaries, Brooks and Daisy Creeks that flow into Fremont Lake. The physical and chemical results collected will be compared to 2010 data for each creek and within each reach, from upstream of city limits to a site near the inlet into the lake.

Methods and materials

To assess the physical, chemical and biological status of Fremont Lake, a suite of water quality parameters and thorough aquatic plant sampling study will be conducted during the spring and summer of 2016. All chemical and nutrient analysis will be sampled according to standard limnological methods and procedures, preserved according to and analyzed by the State of Michigan (SOM) Department of Environmental Quality Laboratory Services. Plant sampling will include a quantitative assessment of presence and relative abundance and will include descriptions of the native aquatic plant community as well as the extent of invasive plant species presence and distribution. The parameters to be sampled and the associated unit of measurement and method are listed in Table 1. Trophic Lake status, using the Carlson Index of clarity, total phosphorus and chlorophyll *a*, will be determined for Fremont Lake, placing it in one of the following categories of Oligotrophic, Mesotrophic, or Eutrophic. Stream measurements will follow standard methods and, as closely as possible, follow site location and data sample collection as described in the original 2010 report by GVSU.

Table 1. List of Parameters and method of measurements categorized by sample type.

Category	Parameter	Method / units
Physical	Water Clarity	Secchi Disk Depth / meters
	Water Color	HACH Color Wheel / Cobalt Platinum units
	Light Concentration	Li-Cor Quantum Light Meter
	Sediment type	Categorized during plant sampling as sand, silt/muck/peat, marl, or gravel/cobble/rocks.
	Total Suspended Solids (TSS)*	Grab sample / mg/L
	Stream Flow*	Wading Rod & Flow Meter / cubic feet/sec
Chemical	Phosphorus: Total Phosphorus (TP) Soluble Inorganic Phosphorus (SRP)	Integrated Tube Sampler / ug/L
	Nitrogen: Total Nitrogen (TN) Ammonium (NH^{4+}) Nitrate (NO^{3-}) Nitrite (NO^{2-})	Integrated Tube Sampler / ug/L
	Dissolved Oxygen (DO)	YSI Performance Plus Sonde /Depth Profile (mg/L)
	Temperature	YSI Performance Plus Sonde /Depth Profile (C^{o}/F^{O})
	pH	Hydrolab Multi parameter probe & meter
	Conductivity (Con.)	Hydrolab Multi parameter probe & meter (µS / cm)
	Alkalinity (Alk)	Titration (CaCO3)
	Dissolved Organic Carbon (DOC)	Integrated Tube Sampler / ug/L
Biological	Chlorophyll *a*	Integrated Tube Sampler ug/L
	Aquatic Plants	Rake and / or snorkel survey

*These measurements will be conducted in streams only.

Proposed Timeline

We will follow the following timeline, provided in Table 2, as closely as possible in order to complete all sampling necessary for the completion of this study.

Table 2. Expected timeline to complete field work, reporting, and outreach components.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Pre-Season Administrative												
Project Planning			x	x								
Purchasing Materials				x								
Technician Search and Hire				x								
Physical												
Water Clarity (Secchi)					x	x	x	x	x			
Water Color (Color Wheel)					x	x	x	x	x			
Light Penetrance					x	x	x	x	x			
Sediment type							x					
Chemical - Nutrients												
Phosphorus(Total and SRP)					x		x		x			
Nitrogen Measurements					x		x		x			
Dissolved Oxygen (DO Profile)					x	x	x	x	x			
Temperature (Profile)					x	x	x	x	x			
pH					x		x		x			
Conductivity (Con.)					x		x		x			
Alkalinity (Alk)					x		x		x			
Dissolved Organic Carbon (DOC)					x		x		x			
Biological												
Chlorophyll *a* (Chl *a*)					x	x	x	x	x			
Aquatic Plant Survey					x		x					
Stream Sampling												
Flow (cfs)					x			x				
Total Suspended Solids(TSS)					x			x				
Total Phosphorous (TP)					x			x				
Nitrogen (N)					x			x				
Outreach Component												
Outreach Workshops / Educational meetings					x		x			x		
Post-Season Administrative												
Analyze Data and Results									x	x		
Report Preparation										x	x	
Report submission & presentation											x	x
Project and Report reflection & evaluation (Optional)												x

Proposed Topic Schedule and Dates for Outreach events and Educational Meetings

To complete Objective 5 and to satisfy the desires of the Fremont Lake board, three outreach and educational meetings, or 'workshops' are proposed. These meetings will be hosted by the City of Fremont and Sheridan Township, at a suitable public location and presentations will be made by Angela De Palma-Dow, Lois Wolfson, and additional speakers, if warranted. The following presents the proposed dates for each workshop and accompanying topic and related materials. It is the responsibility of the City of Fremont and Sheridan Township to promote these workshops to the public and to provide the appropriate venue, any concessions specified in the 'Materials needed' section, and refreshments if desired for the audience. For all three workshops, the first hour will be dedicated to presentation of materials, and the remaining half hour can be open for Q&A or discussion from the audience or the board.

Table 4. Proposed outreach workshops/ educational meetings dates, times and topics.

Date	Time	Workshop topic	Materials Needed
Thursday May 19th	7-8:30 PM	General Lake Ecology and the role of Aquatic Plants*	Projector & screen, At least two display tables
Thursday July 28th	7-8:30 PM	Lake and Watershed management and Aquatic Invasive Species OR The board can pick a relevant topic	Projector & screen, At least two display tables
Thursday October 6th	7-8:30PM	Results presentation and current lake status	Projector & Screen

* The free Michigan State University Boat Wash unit can visit Fremont Lake boat launch to provide stewardship and education on preventing the spread of invasive species as well as provide free boat washes. It's recommended that the boat wash visit within two weeks after this workshop.

APPENDIX 2.0 STREAM DATA

Stream data for 2016. Dashes indicate samples were not collected. N.D. indicate "Not Detected".

Site	Sample Date	Field ID	Stream location	Replicate	Geographic Location		Discharge (CFS)	TP water (mg/L)	TP sediment (mg/L)	NH3 (mg/L)	NO2+NO3 (mg/L)	TSS (mg/L)
					latitude	longitude						
Daisy Creek	5/6/2016	S Daisy UP	up	A	43.47738	-85.9431	12.24	0.04	0.26	0.01	0.28	N.D.
Daisy Creek	5/6/2016	S Daisy UP	up	B	43.47738	-85.9431		0.04	-	0.01	0.28	N.D.
Daisy Creek	5/6/2016	S Daisy DOWN	down	A	43.45765	-85.9616	13.14	0.04	0.67	0.02	0.48	8
Daisy Creek	5/6/2016	S Daisy DOWN	down	B	43.45765	-85.9616		0.05	-	0.02	0.48	6
Brooks Creek	5/6/2016	S Brooks UP	up	A	43.47093	-85.9729	0.691	0.08	0.25	0.02	4	13
Brooks Creek	5/6/2016	S Brooks UP	up	B	43.47093	-85.9729		0.08	-	0.02	4	12
Brooks Creek	5/6/2016	S Brooks DOWN	down	A	43.45877	-85.9698	1.58	0.04	3.2	N.D.	2.4	5
Brooks Creek	5/6/2016	S Brooks DOWN	down	B	43.45877	-85.9698		0.04	-	N.D.	2.4	5
Fremont Drain	5/11/2016	S Fremont Drain UP	up	A	43.4623	-85.932	0.19	0.083	0.4	0.02	0.021	4
Fremont Drain	5/11/2016	S Fremont Drain UP	up	B	43.4623	-85.932		0.084	-	0.02	0.02	5
Fremont Drain	5/11/2016	S Fremont Drain Down	down	A	43.45715	-85.9569	0.637	0.035	0.77	0.02	0.13	N.D.
Fremont Drain	5/11/2016	S Fremont Drain Down	down	B	43.45715	-85.9569		0.034	-	0.02	0.13	N.D.
Daisy Creek	8/23/2016	S Daisy UP	up	A	43.47738	-85.9431	4.55	0.047	0.21	0.02	0.028	N.D.
Daisy Creek	8/23/2016	S Daisy UP	up	B	43.47738	-85.9431		0.041	0.36	0.02	0.027	N.D.
Daisy Creek	8/23/2016	S Daisy DOWN	down	A	43.45765	-85.9616	4.9	0.066	0.32	N.D.	0.43	4
Daisy Creek	8/23/2016	S Daisy DOWN	down	B	43.45765	-85.9616		0.062	0.32	N.D.	0.43	N.D.
Brooks Creek	8/23/2016	S Brooks UP	up	A	43.47093	-85.9729	0.261	0.041	0.055	0.01	8.2	4
Brooks Creek	8/23/2016	S Brooks UP	up	B	43.47093	-85.9729		0.037	0.081	0.01	8.4	4
Brooks Creek	8/23/2016	S Brooks DOWN	down	A	43.45877	-85.9698	0.49	0.039	0.075	N.D.	4.1	N.D.
Brooks Creek	8/23/2016	S Brooks DOWN	down	B	43.45877	-85.9698		0.042	0.096	0.01	4.2	5
Fremont Drain	8/23/2016	S Fremont Drain UP	up	A	43.4623	-85.932	0.054	0.28	0.37	0.61	0.32	N.D.
Fremont Drain	8/23/2016	S Fremont Drain UP	up	B	43.4623	-85.932		0.28	0.92	0.61	0.32	N.D.
Fremont Drain	8/23/2016	S Fremont Drain Down	down	A	43.45715	-85.9569	0.104	0.064	1.1	0.04	0.72	N.D.
Fremont Drain	8/23/2016	S Fremont Drain Down	down	B	43.45715	-85.9569		0.062	0.81	0.03	0.71	N.D.

APPENDIX 3.0 WATER QUALITY

Water quality data for Fremont Lake (2016). Dashes indicate samples were not collected. N.D. means “Not Detected”.

Date	Replicate	Geographic Location		TP (mg/L) Epilimnion	TP (mg/L) Hypolimnion	Sediment TP (mg/L)	SRP (mg/L) Epilimnion	SRP (mg/L) Hypolimnion	NH3 (mg/L)	NO2+NO3 (mg/L)	DOC (mg/L)	Alkalinity (mg/L)	Conductivity (µS/cm)	pH	Chlorophyll *a* (µg/L)	Secchi Depth (m)
		Latitude	Longitude													
May 6, 2016	A	43.45338	85.97146	0.02	0.07	-	N.D.	0.035	0.05	0.31	4.6	180	533.7	8.17	2.2	5.5
May 6, 2016	B	43.45338	85.97146	0.02	0.06	-	N.D.	0.035	0.05	0.31	4.6	180	-	-	1.9	5.5
June 14, 2016	A	43.45338	85.97146	-	-	0.73	-	-	-	-	-	-	-	-	-	4.05
June 14, 2016	B	43.45338	85.97146	-	-	0.94	-	-	-	-	-	-	-	-	-	4.05
July 7, 2016	A	43.45338	85.97146	0.013	0.18	0.27	N.D.	0.06	0.04	N.D.	9.9	140	237.5	8.5	4.6	1.55
July 7, 2016	B	43.45338	85.97146	0.013	0.17	0.22	N.D.	0.07	0.04	N.D.	9	140	-	-	4.2	1.55
August 23, 2016	A	43.45338	85.97146	-	-	-	-	-	-	-	-	-	-	-	7.9	2.18
August 23, 2016	B	43.45338	85.97146	-	-	-	-	-	-	-	-	-	-	-	7.8	2.18
September 15, 2016	A	43.45338	85.97146	0.011	0.13	0.44	0.01	0.01	-	-	7	140	470.7	8.6	9	3.9
September 15, 2016	B	43.45338	85.97146	.012	0.051	0.59	0.02	0.09	-	-	6.8	140	-	-	9.4	3.9
October 6, 2016	A	43.45338	85.97146	0.068	0.25	-	-	-	-	-	-	-	-	-	7.6	3.1
October 6, 2016	B	43.45338	85.97146	.037	0.24	-	-	-	-	-	-	-	-	-	5.3	3.1

Monthly dissolved oxygen and temperature profile data for Fremont Lake (2016). Dashes indicate samples were not collected.

Depth (m)	May		June		July		August		September		October	
	Temp. (°C)	D.O. (mg/L)	Temp. (°C)	D.O. (mg/L)	Temp. (°C)	D.O. (mg/L)	Temp. (°C)	D.O. (mg/L)	Temp. (°C)	D.O. (mg/L)	Temp. (°C)	D.O. (mg/L)
Surface	11.3	13.38	20.7	10.33	25	9.38	24.4	8.85	22.6	8.9	18	9.49
1	11.2	13.38	20.6	9.87	24.8	9.6	24.4	8.16	22.6	8.9	18	9.46
2	11.1	13.47	20.6	9.87	24.7	9.62	24.4	8.15	22.6	8.95	18	9.51
3	10.9	13.47	20.5	9.9	24.6	9.64	24.4	8.12	22.6	8.77	18	9.52
4	10.7	13.55	20.5	9.86	24.3	9.58	24.3	8.13	22.6	8.84	18	9.5
5	10.7	13.5	20.5	9.81	22.3	7.97	24.3	8.12	22.6	8.96	18	9.52
6	10.6	13.5	15.3	9.88	19	4.89	24.3	8.03	22.5	8.85	18	9.51
7	10.3	13.37	13.4	8.78	15	3.47	19.1	0.08	21.6	3.7	17.9	9.04
8	10.1	13.33	11.8	7.47	12.3	3.9	15.6	0.07	17	0.07	17.6	8.59
9	9.9	13.26	10.6	7.17	10.8	4.7	11.6	0.08	13.5	0.07	16.4	3.64
10	8	12.85	9.3	7.29	9.2	3.57	10.5	0.09	10.9	0.08	10.9	0.14
11	6.7	12.87	9.7	7.29	8.8	3.3	8.8	0.07	-	-	9	0.12
12	6.2	12.3	7.4	8.75	8	3.99	8.3	0.06	-	-	8.3	0.09
13	5.9	12.07	7.1	8.21	7.4	3.59	7.9	0.07	-	-	-	-
14	5.8	12.12	7	8.2	7.1	3.52	7.5	0.06	-	-	-	-
15	5.8	12.1	6.7	6.89	6.8	3.6	7.1	0.07	-	-	-	-
16	5.8	11.9	6.5	6.48	6.6	2.98	7	0.07	-	-	-	-
17	5.7	11.83	6.4	6.32	6.5	2.6	6.8	0.06	-	-	-	-
18	5.7	11.54	6.3	6.52	6.4	2	6.7	0.05	-	-	-	-
19	5.6	11.48	6.1	5.85	6.3	1.22	6.6	0.04	-	-	-	-
20	5.6	11.39	6.1	4.96	6.2	1.14	-	-	-	-	-	-

APPENDIX 4.0 PLANT SECTION - MAY

transect	station	depth	WP	LAT	LONG	species	abundance	density number
1	A	2		43.45743333	-85.9634167	filamentous	100	5
1	B	11		43.45731667	-85.96345	filamentous	17.5	3
1	B	11		43.45731667	-85.96345	ewm	12.5	1
1	C	21		43.45725	-85.9636	najas	5	2
1	C	21		43.45725	-85.9636	filamentous	2.5	1
1	C	21		43.45725	-85.9636	ewm	2.5	1
1	C	21		43.45725	-85.9636	chara	6.25	1
2	A	3	410	43.45620167	-85.9611667	filamentous	37.5	3
2	A	3	410	43.45620167	-85.9611667	najas	2.5	1
2	A	3	410	43.45620167	-85.9611667	sago	2.5	1
2	B	12	411	43.45616667	-85.9612833	sago	5	2
2	B	12	411	43.45616667	-85.9612833	filamentous	17.5	3
2	B	12	411	43.45616667	-85.9612833	elodea	5	2
2	B	12	411	43.45616667	-85.9612833	milfoil sp	2.5	1
2	C	25	412	43.4561	-85.9611167	sago	2.5	1
2	C	25	412	43.4561	-85.9611167	filamentous	5	2
3	A	3	413	43.45705	-85.9586667	filamentous	33.75	3
3	A	3	413	43.45705	-85.9586667	n milfoil	5	2
3	B	6	414	43.45678333	-85.9589667	ewm	21.25	3
3	B	6	414	43.45678333	-85.9589667	coontail	6.25	1
3	B	6	414	43.45678333	-85.9589667	n milfoil	25	2
3	B	6	414	43.45678333	-85.9589667	elodea	2.5	1
3	C	14	415	43.45656667	-85.9591	filamentous	5	2
3	C	14	415	43.45656667	-85.9591	ewm	2.5	1
3	C	14	415	43.45656667	-85.9591	n milfoil	2.5	1
4	A	3	416	43.45503333	-85.9569833	filamentous	15	3
4	A	3	416	43.45503333	-85.9569833	milfoil sp	21.25	3
4	A	3	416	43.45503333	-85.9569833	sago	2.5	1
4	A	3	416	43.45503333	-85.9569833	ewm	6.25	1
4	B	7	417	43.45483333	-85.9575833	elodea	7.5	3
4	B	7	417	43.45483333	-85.9575833	filamentous	15	3
4	B	7	417	43.45483333	-85.9575833	ewm	17.5	4
4	B	7	417	43.45483333	-85.9575833	coontail	21.25	3
4	B	7	417	43.45483333	-85.9575833	n milfoil	2.5	1
4	C	17	418	43.45466667	-85.9578	milfoil sp	5	2
4	C	17	418	43.45466667	-85.9578	ewm	2.5	1
4	C	17	418	43.45466667	-85.9578	filamentous	2.5	1
5	A	3	419	43.45253333	-85.9550167	sago	2.5	1
5	A	3	419	43.45253333	-85.9550167	filamentous	17.5	4
5	A	3	419	43.45253333	-85.9550167	n milfoil	5	2
5	A	3	419	43.45253333	-85.9550167	chara	2.5	1
5	A	3	419	43.45253333	-85.9550167	elodea	2.5	1

transect	station	depth	WP	LAT	LONG	species	abundance	density number
5	A	3	419	43.45253333	-85.9550167	ewm	6.25	1
5	B	4	420	43.45261667	-85.95625	n milfoil	12.5	1
5	B	4	420	43.45261667	-85.95625	filamentous	15	3
5	B	4	420	43.45261667	-85.95625	ewm	7.5	3
5	B	4	420	43.45261667	-85.95625	chara	11.25	3
5	B	4	420	43.45261667	-85.95625	elodea	5	2
5	C	10	421	43.45313333	-85.9578667	elodea	7.5	3
5	C	10	421	43.45313333	-85.9578667	coontail	11.25	3
5	C	10	421	43.45313333	-85.9578667	z dubia	2.5	1
5	C	10	421	43.45313333	-85.9578667	ewm	23.75	4
5	C	10	421	43.45313333	-85.9578667	filamentous	2.5	1
5	C	10	421	43.45313333	-85.9578667	najas	2.5	1
5	D	24	422	43.4533	-85.9579667	najas	5	2
5	D	24	422	43.4533	-85.9579667	filamentous	2.5	1
6	A	3	423	43.45118333	-85.9553	filamentous	27.5	4
6	A	3	423	43.45118333	-85.9553	ewm	11.25	3
6	A	3	423	43.45118333	-85.9553	pota seedling	2.5	1
6	A	3	423	43.45118333	-85.9553	milfoil sp	2.5	1
6	B	4	424	43.451	-85.9567333	ewm	5	2
6	B	4	424	43.451	-85.9567333	filamentous	21.25	4
6	B	4	424	43.451	-85.9567333	chara	7.5	3
6	B	4	424	43.451	-85.9567333	sago	2.5	1
6	B	4	424	43.451	-85.9567333	n milfoil	6.25	1
6	D	14	427	43.45011667	-85.9617333	najas	5	2
6	D	14	427	43.45011667	-85.9617333	elodea	5	2
6	D	14	427	43.45011667	-85.9617333	milfoil sp	31.25	2
6	D	14	427	43.45011667	-85.9617333	ewm	31.25	3
6	D	14	427	43.45011667	-85.9617333	coontail	17.5	4
6	D	14	427	43.45011667	-85.9617333	p crispus	5	2
6	D	14	427	43.45011667	-85.9617333	chara	5	2
7	A	3	428	43.44866667	-85.9534	filamentous	23.75	4
7	A	3	428	43.44866667	-85.9534	coontail	2.5	1
7	A	3	428	43.44866667	-85.9534	chara	2.5	1
7	A	3	428	43.44866667	-85.9534	milfoil sp	5	2
7	B	7	429	43.44861667	-85.9559167	p crispus	12.5	2
7	B	7	429	43.44861667	-85.9559167	filamentous	11.25	3
7	B	7	429	43.44861667	-85.9559167	elodea	7.5	3
7	B	7	429	43.44861667	-85.9559167	milfoil sp	15	2
7	B	7	429	43.44861667	-85.9559167	ewm	50	2
7	B	7	429	43.44861667	-85.9559167	sago	2.5	1
7	B	7	429	43.44861667	-85.9559167	pota seedling	2.5	1
7	C	15	430	43.44915	-85.9581333	coontail	10	4
7	C	15	430	43.44915	-85.9581333	najas	2.5	1

transect	station	depth	WP	LAT	LONG	species	abundance	density number
7	C	15	430	43.44915	-85.9581333	filamentous	8.75	2
7	C	15	430	43.44915	-85.9581333	n milfoil	8.75	2
7	C	15	430	43.44915	-85.9581333	ewm	2.5	1
7	C	15	430	43.44915	-85.9581333	p crispus	2.5	1
8	A	4	431	43.44601667	-85.9541667	filamentous	21.25	4
8	A	4	431	43.44601667	-85.9541667	elodea	2.5	1
8	A	4	431	43.44601667	-85.9541667	ewm	2.5	1
8	A	4	431	43.44601667	-85.9541667	najas	2.5	1
8	B	6	432	43.44646667	-85.9556333	chara	15	2
8	B	6	432	43.44646667	-85.9556333	p crispus	8.75	2
8	B	6	432	43.44646667	-85.9556333	ewm	31.25	2
8	B	6	432	43.44646667	-85.9556333	filamentous	13.75	4
8	B	6	432	43.44646667	-85.9556333	milfoil sp	18.75	2
8	B	6	432	43.44646667	-85.9556333	elodea	2.5	1
8	C	11	433	43.44708333	-85.9593333	chara	2.5	1
8	C	11	433	43.44708333	-85.9593333	elodea	2.5	1
8	C	11	433	43.44708333	-85.9593333	coontail	11.25	3
8	C	11	433	43.44708333	-85.9593333	ewm	17.5	3
8	C	11	433	43.44708333	-85.9593333	filamentous	2.5	1
9	A	2	434	43.44401667	-85.9543667	filamentous	27.5	4
9	A	2	434	43.44401667	-85.9543667	milfoil sp	2.5	1
9	A	2	434	43.44401667	-85.9543667	pota seedling	2.5	1
9	B	5	435	43.44425	-85.9552667	filamentous	17.5	4
9	B	5	435	43.44425	-85.9552667	ewm	11.25	3
9	B	5	435	43.44425	-85.9552667	milfoil sp	12.5	2
9	B	5	435	43.44425	-85.9552667	coontail	2.5	1
9	B	5	435	43.44425	-85.9552667	chara	18.75	2
9	B	5	435	43.44425	-85.9552667	elodea	2.5	1
9	B	5	435	43.44425	-85.9552667	najas	2.5	1
9	B	5	435	43.44425	-85.9552667	z dubia	2.5	1
9	C	10	436	43.44491667	-85.9566667	filamentous	17.5	4
9	C	10	436	43.44491667	-85.9566667	p crispus	2.5	1
9	C	10	436	43.44491667	-85.9566667	n milfoil	5	2
10	A	3	439	43.44305	-85.9594	chara	17.5	4
10	A	3	439	43.44305	-85.9594	filamentous	21.25	4
10	A	3	439	43.44305	-85.9594	ewm	2.5	1
10	A	3	439	43.44305	-85.9594	pota seedling	2.5	1
10	B	13	438	43.44351667	-85.95905	filamentous	11.25	3
10	B	13	438	43.44351667	-85.95905	chara	8.75	2
10	B	13	438	43.44351667	-85.95905	pota seedling	5	2
10	B	13	438	43.44351667	-85.95905	milfoil sp	12.5	2
10	B	13	438	43.44351667	-85.95905	sago	2.5	1
10	B	13	438	43.44351667	-85.95905	najas	2.5	1

transect	station	depth	WP	LAT	LONG	species	abundance	density number
10	C	20	437	43.4451	-85.9577333	filamentous	13.75	4
11	A	3	440	43.4442	-85.9624	filamentous	43.75	4
11	A	3	440	43.4442	-85.9624	chara	27.5	4
11	A	3	440	43.4442	-85.9624	milfoil sp	2.5	1
11	A	3	440	43.4442	-85.9624	najas	2.5	1
11	B	6	441	43.44466667	-85.9632333	chara	40	4
11	B	6	441	43.44466667	-85.9632333	filamentous	31.25	4
11	B	6	441	43.44466667	-85.9632333	milfoil sp	7.5	3
11	B	6	441	43.44466667	-85.9632333	elodea	2.5	1
11	C	15	443	43.44531667	-85.9643167	ewm	8.75	2
11	C	15	443	43.44531667	-85.9643167	milfoil sp	2.5	1
11	D	24	442	43.44556667	-85.9647	No plants	0	0
12	A	2.5	444	43.44361667	-85.96235	filamentous	46.25	4
12	A	2.5	444	43.44361667	-85.96235	chara	20	4
12	B	19	445	43.4433	-85.9629667	milfoil sp	2.5	1
12	B	19	445	43.4433	-85.9629667	pota seedling	2.5	1
12	C	11	446	43.4426	-85.96345	ewm	18.75	2
12	C	11	446	43.4426	-85.96345	filamentous	15	2
12	C	11	446	43.4426	-85.96345	elodea	5	2
12	C	11	446	43.4426	-85.96345	milfoil sp	15	2
12	C	11	446	43.4426	-85.96345	coontail	2.5	1
12	C	11	446	43.4426	-85.96345	p crispus	12.5	1
12	D	3	447	43.44151667	-85.9631833	chara	31.25	3
12	D	3	447	43.44151667	-85.9631833	filamentous	18.75	3
12	D	3	447	43.44151667	-85.9631833	milfoil sp	21.25	3
12	D	3	447	43.44151667	-85.9631833	p crispus	6.25	1
12	D	3	447	43.44151667	-85.9631833	elodea	2.5	1
12	D	3	447	43.44151667	-85.9631833	ranunculus	2.5	1
13	A	3	448	43.4423	-85.9662167	filamentous	25	4
13	A	3	448	43.4423	-85.9662167	chara	7.5	3
13	B	5	449	43.44268333	-85.9663	filamentous	13.75	4
13	B	5	449	43.44268333	-85.9663	ewm	33.75	4
13	B	5	449	43.44268333	-85.9663	chara	21.25	3
13	B	5	449	43.44268333	-85.9663	elodea	2.5	1
13	C	10	450	43.44335	-85.9661333	ewm	18.75	2
13	C	10	450	43.44335	-85.9661333	chara	18.75	2
13	C	10	450	43.44335	-85.9661333	milfoil sp	5	2
13	C	10	450	43.44335	-85.9661333	elodea	5	2
13	C	10	450	43.44335	-85.9661333	filamentous	2.5	1
14	A	3	451	43.4428	-85.9704667	filamentous	20	4
14	A	3	451	43.4428	-85.9704667	chara	5	2
14	B	15	452	43.4435	-85.97055	sago	2.5	1
14	C	10	453	43.4433	-85.9705667	filamentous	5	2

transect	station	depth	WP	LAT	LONG	species	abundance	density number
14	C	10	453	43.4433	-85.9705667	chara	18.75	2
14	C	10	453	43.4433	-85.9705667	elodea	2.5	1
14	C	10	453	43.4433	-85.9705667	milfoil sp	8.75	2
14	C	10	453	43.4433	-85.9705667	coontail	2.5	1
15	A	3	454	43.44375	-85.9734667	filamentous	10	4
15	A	3	454	43.44375	-85.9734667	chara	7.5	3
15	A	3	454	43.44375	-85.9734667	pota seedling	2.5	1
15	B	8	455	43.44423333	-85.97345	chara	18.75	2
15	B	8	455	43.44423333	-85.97345	milfoil sp	2.5	1
15	B	8	455	43.44423333	-85.97345	ewm	2.5	1
15	C	16	456	43.4445	-85.9739333	coontail	6.25	1
15	C	16	456	43.4445	-85.9739333	milfoil sp	2.5	1
15	C	16	456	43.4445	-85.9739333	chara	2.5	1
16	A	2	457	43.44538333	-85.9766333	filamentous	5	2
16	B	20	458	43.44585	-85.97595	ewm	2.5	1
16	B	20	458	43.44585	-85.97595	filamentous	2.5	1
16	C	5.5	NA	43.446695	-85.976155	chara	7.5	3
16	C	5.5	NA	43.446695	-85.976155	filamentous	25	4
16	C	5.5	NA	43.446695	-85.976155	ewm	2.5	1
16	C	5.5	NA	43.446695	-85.976155	milfoil sp	2.5	1
17	A	2.5	461	43.4485	-85.9772333	filamentous	10	4
17	A	2.5	461	43.4485	-85.9772333	chara	10	4
17	B	8	460	43.44836667	-85.97645	chara	37.5	4
17	B	8	460	43.44836667	-85.97645	milfoil sp	11.25	4
17	B	8	460	43.44836667	-85.97645	filamentous	15	3
17	B	8	460	43.44836667	-85.97645	coontail	2.5	1
17	B	8	460	43.44836667	-85.97645	ewm	2.5	1
17	C	14	459	43.44805	-85.9760833	ewm	6.25	1
17	C	14	459	43.44805	-85.9760833	chara	2.5	1
18	A	3	461	43.45056667	-85.9791667	chara	10	4
18	A	3	461	43.45056667	-85.9791667	milfoil sp	5	2
18	A	3	461	43.45056667	-85.9791667	filamentous	10	4
18	B	NA	462	43.45096667	-85.9797833	filamentous	5	2
18	B	NA	462	43.45096667	-85.9797833	coontail	2.5	1
18	B	NA	462	43.45096667	-85.9797833	elodea	2.5	1
18	B	NA	462	43.45096667	-85.9797833	Starry????	6.25	1
18	B	NA	462	43.45096667	-85.9797833	chara	2.5	1
18	C	12	463	43.4508	-85.9797167	ewm	40	3
18	C	12	463	43.4508	-85.9797167	filamentous	13.75	4
18	C	12	463	43.4508	-85.9797167	chara	2.5	1
19	A	27	464	43.45085	-85.9820333	milfoil sp	2.5	1
19	A	27	464	43.45085	-85.9820333	ewm	2.5	1
19	B	12	NA	43.45096667	-85.9828	ewm	5	2

transect	station	depth	WP	LAT	LONG	species	abundance	density number
19	B	12	NA	43.45096667	-85.9828	milfoil sp	2.5	1
19	B	12	NA	43.45096667	-85.9828	filamentous	2.5	1
19	B	12	NA	43.45096667	-85.9828	pota seedling	2.5	1
20	A	19	466	43.450054	-85.966915	filamentous	2.5	1
20	B	4	467	43.451968	-85.982382	ewm	2.5	1
21	A	24	468	43.452692	-85.98206	filamentous	2.5	1
21	A	24	468	43.452692	-85.98206	chara	2.5	1
21	B	4	469	43.450086	-85.966875	filamentous	2.5	1
22	A	14	470	43.455288	-85.979445	filamentous	11.25	3
22	A	14	470	43.455288	-85.979445	ewm	46.25	4
22	B	3	471	43.45521	-85.979295	p crispus	2.5	1
22	B	3	471	43.45521	-85.979295	sago	2.5	1
22	B	3	471	43.45521	-85.979295	filamentous	5	2
22	C	2	472	43.4551	-85.979146	No plants	0	0
23	A	16	473	43.457796	-85.973432	filamentous	7.5	3
23	B		474	43.4576	-85.973217	filamentous	10	4
23	B		474	43.4576	-85.973217	chara	2.5	1
23	B		474	43.4576	-85.973217	milfoil sp	2.5	1
23	C	2	475	43.457428	-85.973002	filamentous	2.5	1
24	A	11	476	43.45921	-85.968365	coontail	12.5	1
24	A	11	476	43.45921	-85.968365	ewm	43.75	4
24	A	11	476	43.45921	-85.968365	filamentous	10	4
24	B	4.5	478	43.458976	-85.96835	ewm	2.5	1
24	B	4.5	478	43.458976	-85.96835	milfoil sp	15	3
24	B	4.5	478	43.458976	-85.96835	filamentous	11.25	3
24	C	2	477	43.458664	-85.96825	bulrush	6.25	1
25	A	20	479	43.458321	-85.964432	filamentous	5	2
25	A	20	479	43.458321	-85.964432	p crispus	2.5	1
25	A	20	479	43.458321	-85.964432	milfoil sp	2.5	1
25	B	4	480	43.45816	-85.964476	chara	2.5	1
25	B	4	480	43.45816	-85.964476	filamentous	5	1
25	B	4	480	43.45816	-85.964476	pota seedling	2.5	1
25	C	2	481	43.457996	-85.964595	filamentous	6.25	1

APPENDIX 4.1 PLANT SECTION – JULY

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
1	B	3	1B	43.45732	-85.9635	Chara	25	4
1	B	3	1B	43.45732	-85.9635	Najas spp.	12.5	2
1	B	3	1B	43.45732	-85.9635	narrowleaf PW	6.25	1
1	B	3	1B	43.45732	-85.9635	milfoil	18.75	4
1	B	3	1B	43.45732	-85.9635	elodea	6.25	1
2	A	3	410	43.4562	-85.9612	Elodea	25	4
2	A	3	410	43.4562	-85.9612	narrowleaf PW	18.75	3
2	A	3	410	43.4562	-85.9612	Sago	25	4
2	A	3	410	43.4562	-85.9612	Vallisineria	12.5	2
2	A	3	410	43.4562	-85.9612	Chara	12.5	2
2	A	3	410	43.4562	-85.9612	filamentous	6.25	1
2	A	3	410	43.4562	-85.9612	dead filamentous	6.25	1
2	B	12	411	43.45617	-85.9613	elodea	31.25	4
2	B	12	411	43.45617	-85.9613	Vallisineria	25	4
2	B	12	411	43.45617	-85.9613	narrowleaf PW	25	4
2	B	12	411	43.45617	-85.9613	Najas spp.	6.25	1
2	B	12	411	43.45617	-85.9613	Sago	18.75	3
2	B	12	411	43.45617	-85.9613	coontail	6.25	1
2	C	25	412	43.4561	-85.9611	filamentous	6.25	1
2	C	25	412	43.4561	-85.9611	coontail	6.25	1
2	C	25	412	43.4561	-85.9611	elodea	12.5	2
2	C	25	412	43.4561	-85.9611	Sago	6.25	1
2	C	25	412	43.4561	-85.9611	narrowleaf PW	6.25	1
3	A	3	413	43.45705	-85.9587	Sago	25	4
3	A	3	413	43.45705	-85.9587	elodea	6.25	1
3	A	3	413	43.45705	-85.9587	Vallisineria	25	4
3	A	3	413	43.45705	-85.9587	narrowleaf PW	6.25	1
3	A	3	413	43.45705	-85.9587	filamentous	12.5	2
3	B	6	414	43.45678	-85.959	coontail	25	4
3	B	6	414	43.45678	-85.959	Najas spp.	6.25	1
3	B	6	414	43.45678	-85.959	filamentous	12.5	2
3	B	6	414	43.45678	-85.959	narrowleaf PW	6.25	1
3	B	6	414	43.45678	-85.959	Sago	6.25	1
3	C	14	415	43.45657	-85.9591	detritus	6.25	1
4	A	3	416	43.45503	-85.957	milfoil	6.25	1

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
4	A	3	416	43.45503	-85.957	Chara	25	4
4	A	3	416	43.45503	-85.957	Najas spp.	25	4
4	A	3	416	43.45503	-85.957	Sago	25	4
4	A	3	416	43.45503	-85.957	Vallisineria	18.75	3
4	A	3	416	43.45503	-85.957	elodea	12.5	2
4	B	8	417	43.45483	-85.9576	coontail	12.5	2
4	B	8	417	43.45483	-85.9576	elodea	31.25	4
4	B	8	417	43.45483	-85.9576	Vallisineria	25	4
4	B	8	417	43.45483	-85.9576	Najas spp.	18.75	3
4	B	8	417	43.45483	-85.9576	zosterella dubia	6.25	1
4	B	8	417	43.45483	-85.9576	milfoil	25	4
4	B	8	417	43.45483	-85.9576	filamentous	12.5	2
4	B	8	417	43.45483	-85.9576	Sago	12.5	2
4	C	15	418	43.45467	-85.9578	coontail	12.5	2
4	C	15	418	43.45467	-85.9578	zosterella dubia	6.25	1
4	C	15	418	43.45467	-85.9578	narrowleaf PW	6.25	1
5	A	2	419	43.45253	-85.955	Sago	25	4
5	A	2	419	43.45253	-85.955	Najas spp.	25	4
5	A	2	419	43.45253	-85.955	Chara	25	4
5	A	2	419	43.45253	-85.955	Vallisineria	25	4
5	A	2	419	43.45253	-85.955	Elodea	18.75	3
5	A	2	419	43.45253	-85.955	milfoil native	6.25	1
5	A	2	419	43.45253	-85.955	narrowleaf PW	6.25	1
5	A	2	419	43.45253	-85.955	milfoil	12.5	2
5	B	4	420	43.45262	-85.9563	Chara	25	4
5	B	4	420	43.45262	-85.9563	Najas spp.	18.75	3
5	B	4	420	43.45262	-85.9563	Vallisineria	25	4
5	B	4	420	43.45262	-85.9563	milfoil freak	18.75	3
5	B	4	420	43.45262	-85.9563	EWM	6.25	1
5	B	4	420	43.45262	-85.9563	elodea	25	4
5	B	4	420	43.45262	-85.9563	Sago	18.75	3
5	B	4	420	43.45262	-85.9563	filamentous	6.25	1
5	C	9	421	43.45313	-85.9579	coontail	37.5	4
5	C	9	421	43.45313	-85.9579	Vallisineria	18.75	3
5	C	9	421	43.45313	-85.9579	filamentous	18.75	3
5	C	9	421	43.45313	-85.9579	Sago	6.25	1
5	C	9	421	43.45313	-85.9579	Chara	12.5	2

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
5	C	9	421	43.45313	-85.9579	elodea	18.75	3
5	C	9	421	43.45313	-85.9579	zosterella dubia	12.5	2
5	C	9	421	43.45313	-85.9579	Najas spp.	25	4
5	C	9	421	43.45313	-85.9579	milfoil	6.25	1
5	C	9	421	43.45313	-85.9579	milfoil freak	6.25	1
5	D	20	422	43.4533	-85.958	Najas spp.	6.25	1
5	D	20	422	43.4533	-85.958	filamentous	6.25	1
6	A	3	423	43.45118	-85.9553	Chara	18.75	3
6	A	3	423	43.45118	-85.9553	Vallisineria	12.5	2
6	A	3	423	43.45118	-85.9553	Sago	18.75	3
6	A	3	423	43.45118	-85.9553	Najas spp.	12.5	2
6	A	3	423	43.45118	-85.9553	coontail	6.25	1
6	B	4	424	43.451	-85.9567	Chara	56.25	5
6	B	4	424	43.451	-85.9567	Vallisineria	25	4
6	B	4	424	43.451	-85.9567	Najas spp.	18.75	3
6	B	4	424	43.451	-85.9567	Najas spp.	18.75	3
6	B	4	424	43.451	-85.9567	Sago	25	4
6	B	4	424	43.451	-85.9567	Elodea	6.25	1
6	B	4	424	43.451	-85.9567	coontail	6.25	1
6	B	4	424	43.451	-85.9567	narrowleaf PW	6.25	1
6	C	4.5	425	43.45112	-85.9582	Chara	31.25	4
6	C	4.5	425	43.45112	-85.9582	Najas spp.	25	4
6	C	4.5	425	43.45112	-85.9582	Vallisineria	31.25	4
6	C	4.5	425	43.45112	-85.9582	elodea	25	4
6	C	4.5	425	43.45112	-85.9582	coontail	6.25	1
6	C	4.5	425	43.45112	-85.9582	narrowleaf PW	12.5	2
6	C	4.5	425	43.45112	-85.9582	milfoil	6.25	1
6	D	14	427	43.45012	-85.9617	Chara	43.75	4
6	D	14	427	43.45012	-85.9617	Vallisineria	25	4
6	D	14	427	43.45012	-85.9617	Sago	18.75	3
6	D	14	427	43.45012	-85.9617	narrowleaf PW	6.25	1
6	D	14	427	43.45012	-85.9617	elodea	12.5	2
6	D	14	427	43.45012	-85.9617	milfoil	6.25	1
6	D	14	427	43.45012	-85.9617	filamentous	12.5	2
6	D	14	427	43.45012	-85.9617	coontail	6.25	1
7	A	3	428	43.44867	-85.9534	Vallisineria	25	4
7	A	3	428	43.44867	-85.9534	Sago	18.75	2

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
7	A	3	428	43.44867	-85.9534	filamentous	25	4
7	A	3	428	43.44867	-85.9534	narrowleaf PW	12.5	2
7	A	3	428	43.44867	-85.9534	Chara	12.5	2
7	A	3	428	43.44867	-85.9534	Najas spp.	6.25	1
7	B	7	429	43.44862	-85.9559	Elodea	25	4
7	B	7	429	43.44862	-85.9559	Chara	31.25	3
7	B	7	429	43.44862	-85.9559	milfoil freak	18.75	3
7	B	7	429	43.44862	-85.9559	Najas spp.	31.25	4
7	B	7	429	43.44862	-85.9559	Vallisineria	18.75	3
7	B	7	429	43.44862	-85.9559	Sago	12.5	2
7	B	7	429	43.44862	-85.9559	narrowleaf PW	12.5	2
7	B	7	429	43.44862	-85.9559	milfoil	6.25	1
7	C	15	430	43.44915	-85.9581	coontail	43.75	4
7	C	15	430	43.44915	-85.9581	filamentous	6.25	1
7	C	15	430	43.44915	-85.9581	elodea	18.75	3
7	C	15	430	43.44915	-85.9581	milfoil freak	12.5	2
7	C	15	430	43.44915	-85.9581	Najas spp.	12.5	2
7	C	15	430	43.44915	-85.9581	narrowleaf PW	6.25	1
7	C	15	430	43.44915	-85.9581	milfoil	6.25	1
7	C	15	430	43.44915	-85.9581	filamentous	6.25	1
8	A	4	431	43.44602	-85.9542	Vallisineria	25	4
8	A	4	431	43.44602	-85.9542	narrowleaf PW	6.25	1
8	A	4	431	43.44602	-85.9542	filamentous	6.25	0
8	A	4	431	43.44602	-85.9542	Sago	6.25	1
8	A	4	431	43.44602	-85.9542	Chara	18.75	3
8	A	4	431	43.44602	-85.9542	Najas spp.	6.25	1
8	A	4	431	43.44602	-85.9542	elodea	12.5	2
8	A	4	431	43.44602	-85.9542	milfoil freak	6.25	1
8	B	5	432	43.44647	-85.9556	coontail	6.25	1
8	B	5	432	43.44647	-85.9556	Vallisineria	31.25	4
8	B	5	432	43.44647	-85.9556	milfoil freak	18.75	3
8	B	5	432	43.44647	-85.9556	Najas spp.	12.5	2
8	B	5	432	43.44647	-85.9556	filamentous	25	4
8	B	5	432	43.44647	-85.9556	milfoil dead	25	3
8	B	5	432	43.44647	-85.9556	elodea	12.5	2
8	B	5	432	43.44647	-85.9556	Sago	6.25	1
8	C	11	433	43.44708	-85.9593	filamentous	18.75	4

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
8	C	11	433	43.44708	-85.9593	coontail	6.25	1
8	C	11	433	43.44708	-85.9593	Vallisineria	6.25	1
8	C	11	433	43.44708	-85.9593	milfoil freak	6.25	1
9	A	2	434	43.44402	-85.9544	Najas spp.	6.25	1
9	A	2	434	43.44402	-85.9544	Chara	25	4
9	A	2	434	43.44402	-85.9544	Vallisineria	18.75	3
9	A	2	434	43.44402	-85.9544	Sago	18.75	3
9	A	2	434	43.44402	-85.9544	elodea	6.25	1
9	A	2	434	43.44402	-85.9544	narrowleaf PW	12.5	3
9	A	2	434	43.44402	-85.9544	zosterella dubia	6.25	1
9	B	5	435	43.44425	-85.9553	Chara	18.75	1
9	B	5	435	43.44425	-85.9553	Vallisineria	31.25	4
9	B	5	435	43.44425	-85.9553	elodea	18.75	3
9	B	5	435	43.44425	-85.9553	Sago	18.75	3
9	B	5	435	43.44425	-85.9553	milfoil freak	18.75	3
9	B	5	435	43.44425	-85.9553	coontail	6.25	1
9	C	10	436	43.44492	-85.9567	filamentous	12.5	2
9	C	10	436	43.44492	-85.9567	Chara	6.25	1
10	A	3	439	43.44305	-85.9594	Najas spp.	12.5	2
10	A	3	439	43.44305	-85.9594	Chara	50	5
10	A	3	439	43.44305	-85.9594	milfoil freak	12.5	2
10	A	3	439	43.44305	-85.9594	Najas spp.	6.25	1
10	A	3	439	43.44305	-85.9594	Vallisineria	18.75	3
10	A	3	439	43.44305	-85.9594	coontail	6.25	1
10	A	3	439	43.44305	-85.9594	Sago	6.25	1
10	B	13	438	43.44352	-85.9591	coontail	6.25	1
11	A	4.4	440	43.4442	-85.9624	Chara	50	5
11	A	4.4	440	43.4442	-85.9624	Vallisineria	25	4
11	A	4.4	440	43.4442	-85.9624	Najas spp.	12.5	2
11	A	4.4	440	43.4442	-85.9624	filamentous	18.75	3
11	B	5	441	43.44467	-85.9632	Chara	62.5	5
11	B	5	441	43.44467	-85.9632	EWM	25	4
11	B	5	441	43.44467	-85.9632	Vallisineria	31.25	4
11	B	5	441	43.44467	-85.9632	coontail	12.5	2
11	C	15	443	43.44532	-85.9643	coontail	18.75	1
12	A	2.5	444	43.44362	-85.9624	Chara	31.25	4
12	A	2.5	444	43.44362	-85.9624	milfoil freak	12.5	2

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
12	A	2.5	444	43.44362	-85.9624	coontail	6.25	1
12	A	2.5	444	43.44362	-85.9624	Sago	12.5	2
12	A	2.5	444	43.44362	-85.9624	filamentous	12.5	2
12	A	2.5	444	43.44362	-85.9624	Vallisineria	6.25	1
12	A	2.5	444	43.44362	-85.9624	Najas spp.	6.25	1
12	C	11	446	43.4426	-85.9635	Chara	37.5	3
12	C	11	446	43.4426	-85.9635	Vallisineria	18.75	3
12	C	11	446	43.4426	-85.9635	Sago	12.5	2
12	C	11	446	43.4426	-85.9635	coontail	6.25	1
12	C	11	446	43.4426	-85.9635	milfoil freak	12.5	2
12	C	11	446	43.4426	-85.9635	elodea	6.25	1
12	D	3	447	43.44152	-85.9632	Vallisineria	25	4
12	D	3	447	43.44152	-85.9632	elodea	25	4
12	D	3	447	43.44152	-85.9632	Najas spp.	6.25	1
12	D	3	447	43.44152	-85.9632	milfoil dead	18.75	3
12	D	3	447	43.44152	-85.9632	Sago	12.5	2
12	D	3	447	43.44152	-85.9632	milfoil freak	12.5	2
12	D	3	447	43.44152	-85.9632	Chara	6.25	1
12	D	3	447	43.44152	-85.9632	curly leaf	6.25	1
13	A	3	448	43.4423	-85.9662	Chara	25	4
13	A	3	448	43.4423	-85.9662	Najas spp.	6.25	1
13	A	3	448	43.4423	-85.9662	milfoil dead	6.25	1
13	A	3	448	43.4423	-85.9662	milfoil freak	6.25	1
13	A	3	448	43.4423	-85.9662	elodea	6.25	0
13	A	3	448	43.4423	-85.9662	coontail	6.25	1
13	B	5	449	43.44268	-85.9663	Vallisineria	18.75	3
13	B	5	449	43.44268	-85.9663	milfoil	6.25	1
13	B	5	449	43.44268	-85.9663	Sago	12.5	2
13	B	5	449	43.44268	-85.9663	Chara	37.5	4
13	B	5	449	43.44268	-85.9663	coontail	6.25	1
13	B	5	449	43.44268	-85.9663	elodea	6.25	1
13	B	5	449	43.44268	-85.9663	filamentous	6.25	1
13	B	5	449	43.44268	-85.9663	Najas spp.	6.25	1
13	C	10	450	43.44335	-85.9661	coontail	1.25	1
14	A	3	451	43.4428	-85.9705	Chara	18.75	0
14	A	3	451	43.4428	-85.9705	Sago	18.75	3
14	A	3	451	43.4428	-85.9705	milfoil dead	12.5	2

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
14	A	3	451	43.4428	-85.9705	Najas spp.	6.25	1
14	A	3	451	43.4428	-85.9705	Vallisineria	6.25	1
14	B	15	452	43.4435	-85.9706	Chara	56.25	4
14	B	15	452	43.4435	-85.9706	coontail	25	4
14	B	15	452	43.4435	-85.9706	Sago	25	4
14	B	15	452	43.4435	-85.9706	Vallisineria	25	4
14	B	15	452	43.4435	-85.9706	elodea	12.5	2
14	B	15	452	43.4435	-85.9706	milfoil dead	18.75	3
14	B	15	452	43.4435	-85.9706	milfoil freak	6.25	1
15	A	3	454	43.44375	-85.9735	milfoil dead	6.25	1
15	A	3	454	43.44375	-85.9735	Vallisineria	6.25	1
15	A	3	454	43.44375	-85.9735	Chara	12.5	2
15	B	8	455	43.44423	-85.9735	Chara	6.25	1
15	B	8	455	43.44423	-85.9735	Vallisineria	6.25	1
15	B	8	455	43.44423	-85.9735	coontail	6.25	1
15	C	16	456	43.4445	-85.9739	coontail	18.75	2
15	C	16	456	43.4445	-85.9739	Najas spp.	6.25	1
15	C	16	456	43.4445	-85.9739	milfoil dead	6.25	1
15	C	16	456	43.4445	-85.9739	Chara	6.25	1
16	A	2	457	43.44538	-85.9766	Chara	6.25	1
16	B	15	505	43.44585	-85.976	Chara	12.5	1
16	B	15	505	43.44585	-85.976	majas brown	6.25	1
16	B	15	505	43.44585	-85.976	Vallisineria	6.25	1
16	B	15	505	43.44585	-85.976	milfoil freak	6.25	1
16	B	15	505	43.44585	-85.976	coontail	6.25	1
16	B	15	505	43.44585	-85.976	elodea	6.25	1
17	A	2.5	461	43.4485	-85.9772	Chara	25	4
17	A	2.5	461	43.4485	-85.9772	Vallisineria	25	4
17	A	2.5	461	43.4485	-85.9772	Sago	6.25	1
17	A	2.5	461	43.4485	-85.9772	milfoil dead	6.25	1
17	B	8	460	43.44837	-85.9765	Chara	25	4
17	B	8	460	43.44837	-85.9765	Vallisineria	25	4
17	B	8	460	43.44837	-85.9765	Najas spp.	6.25	1
17	B	8	460	43.44837	-85.9765	milfoil dead	12.5	2
17	B	8	460	43.44837	-85.9765	elodea	12.5	2
17	B	8	460	43.44837	-85.9765	Sago	6.25	1
17	B	8	460	43.44837	-85.9765	coontail	6.25	1

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
17	C	14	459	43.44805	-85.9761	coontail	6.25	1
19	A	27	464	43.45085	-85.982	Vallisineria	25	4
19	A	27	464	43.45085	-85.982	Chara	6.25	1
19	A	27	464	43.45085	-85.982	Najas spp.	6.25	1
19	A	27	464	43.45085	-85.982	Najas spp.	6.25	1
19	A	27	464	43.45085	-85.982	milfoil dead	6.25	1
19	A	27	464	43.45085	-85.982	Sago	12.5	2
19	B	12	NA	43.45097	-85.9828	Vallisineria	6.25	1
20	A	4	466	43.45212	-85.9829	Vallisineria	6.25	1
20	A	4	466	43.45212	-85.9829	Sago	6.25	1
20	A	4	466	43.45212	-85.9829	filamentous	6.25	1
21	A	3	469	43.45337	-85.9817	Chara	25	4
21	A	3	469	43.45337	-85.9817	Sago	25	4
21	A	3	469	43.45337	-85.9817	Najas spp.	18.75	3
21	A	3	469	43.45337	-85.9817	coontail	12.5	2
21	A	3	469	43.45337	-85.9817	filamentous	12.5	2
21	A	3	469	43.45337	-85.9817	milfoil dead	12.5	2
21	A	3	469	43.45337	-85.9817	Vallisineria	18.75	3
21	A	3	469	43.45337	-85.9817	narrowleaf PW	6.25	1
22	A	3	472	43.45337	-85.9817	Sago	25	4
23	A	3	472	43.45337	-85.9817	vallisineria	12.5	2
22	A	3	472	43.45337	-85.9817	Najas spp.	6.25	1
22	B	5	513	43.45466	-85.9742	vallisineria	25	4
22	B	5	513	43.45466	-85.9742	Sago	12.5	2
22	B	5	513	43.45466	-85.9742	Chara	25	4
22	B	5	513	43.45466	-85.9742	potomogeton nodosus	6.25	1
22	B	5	513	43.45466	-85.9742	Najas spp.	6.25	1
22	B	5	513	43.45466	-85.9742	elodea	6.25	1
20	C	15	514	43.4501	-85.9668	Vallisineria	6.25	1
21	C	15	514	43.4501	-85.9668	Chara	6.25	1
22	C	15	514	43.4501	-85.9668	coontail	6.25	1
23	A	2	475	43.45786	-85.972	Vallisineria	18.75	3
23	B	5	474	43.45724	-85.9717	Vallisineria	12.5	2
24	A	2	476	43.45895	-85.9689	Sago	25	4
24	A	2	476	43.45895	-85.9689	Chara	6.25	1
24	A	2	476	43.45895	-85.9689	Vallisineria	6.25	1
24	B	3	478	43.45851	-85.9687	Sago	18.75	3

transect	station	depth	WP	LAT	LONG	species	relative abundance	density number
1	A	2	1A8	43.45743	-85.9634	Chara	15	3
1	A	2	1A8	43.45743	-85.9634	Sago	25	5
1	A	2	1A8	43.45743	-85.9634	Vallisineria	6.25	1
1	A	2	1A8	43.45743	-85.9634	filamentous	12.5	2
1	A	2	1A8	43.45743	-85.9634	coontail	6.25	1
1	A	2	1A8	43.45743	-85.9634	narrowleaf PW	12.5	2
1	B	3	1B	43.45732	-85.9635	Vallisineria	25	4
1	B	3	1B	43.45732	-85.9635	Sago	25	4
24	B	3	478	43.45851	-85.9687	Vallisineria	18.75	3
24	C	8	477	43.45844	-85.9686	coontail	31.25	4
24	C	8	477	43.45844	-85.9686	vallisineria	6.25	1
24	C	8	477	43.45844	-85.9686	Najas spp.	6.25	1
24	C	8	477	43.45844	-85.9686	Chara	6.25	1
24	C	8	477	43.45844	-85.9686	narrowleaf PW	6.25	1
24	D	15	515	43.45835	-85.9685	narrowleaf PW	6.25	1
25	A	20	479	43.45819	-85.9643	Chara	25	4
25	A	20	479	43.45819	-85.9643	narrowleaf PW	18.75	3
25	A	20	479	43.45819	-85.9643	filamentous	6.25	1
25	A	20	479	43.45819	-85.9643	Sago	25	4
25	A	20	479	43.45819	-85.9643	Vallisineria	12.5	2
25	A	20	479	43.45819	-85.9643	Najas spp.	12.5	2
25	B	4	480	43.45809	-85.9645	Vallisineria	12.5	2
25	B	4	480	43.45809	-85.9645	coontail	6.25	1
25	B	4	480	43.45809	-85.9645	Sago	6.25	1
25	C	2	481	43.45798	-85.9645	elodea	6.25	1
25	C	2	481	43.45798	-85.9645	narrowleaf PW	6.25	1

APPENDIX 4.2 PLANT SECTION – MICORPS EAPW REPORT

EXOTIC AQUATIC PLANT WATCH

Cooperative Lakes Monitoring Program

Michigan Clean Water Corps

Lake Name: Fremont Lake County: Newaygo

Township: Sheridan

Lake Sampling Site (Field ID) Number: 620029

Volunteer Monitor Name(s): Angela DePalma-Dow, Erick Elgin, Lois Wolfson and Liz Throckmorton

Date(s) of Survey : ~~July~~ May 12, 2016 and July 13, 2016 Time: all day

Comments (unusual conditions, recent weed treatments, etc.):

also completed APM this year in this lake

- If *no exotic aquatic plants were found* during the survey, check here: ☐
  Use Page 2 to document the locations you surveyed on your lake.

- If exotic plants were found, check the species found below:
  - ☑ Eurasian milfoil
  - ☑ Curly-leaf pondweed
  - ☐ Hydrilla
  - ☑ Starry Stonewort
  - ☐ Other ______
  - ☐ Other ______

DNA testing Through MSU showed some Starry Stonewort DNA present but didn't I.D. plant fragments w/ stars present.

Include the following items in your report:

- ☑ This completed data form (Pages 1 and 2)
- ☑ Lake map with numbered site locations
- ☑ Any photographs taken of collected plants

Send your complete report to the CLMP contact listed in the project procedures.
Keep a copy of the report for your records.

→ Data was entered into online database Nov 8, 2016

APPENDIX 5.0 SCORE THE SHORE – GPS SAMPLE LOCATIONS

GPS Coordinates of the beginning and end of each Score the Shore section.

Section	Beginning		End	
	Latitude	Longitude	Latitude	Longitude
1	43.45637	-85.9611	43.45659	-85.9584
2	43.45659	-85.9584	43.45455	-85.957
3	43.45455	-85.957	43.45257	-85.9548
4	43.45257	-85.9548	43.45035	-85.9535
5	43.45035	-85.9535	43.44782	-85.953
6	43.44782	-85.953	43.4455	-85.9537
7	43.4455	-85.9537	43.4434	-85.955
8	43.4434	-85.955	43.44292	-85.9594
9	43.44292	-85.9594	43.44454	-85.9624
10	43.44454	-85.9624	43.44271	-85.9607
11	43.44271	-85.9607	43.4419	-85.9647
12	43.4419	-85.9647	43.44286	-85.9686
13	43.44286	-85.9686	43.44313	-85.9722
14	43.44313	-85.9722	43.44463	-85.9763
15	43.44463	-85.9763	43.44662	-85.9766
16	43.44662	-85.9766	43.44929	-85.9782
17	43.44929	-85.9782	43.44992	-85.9821
18	43.44992	-85.9821	43.45224	-85.9825
19	43.45224	-85.9825	43.45384	-85.9805
20	43.45384	-85.9805	43.45579	-85.9774
21	43.45579	-85.9774	43.45737	-85.9737
22	43.45737	-85.9737	43.45795	-85.9709
23	43.45795	-85.9709	43.4588	-85.9686
24	43.4588	-85.9686	43.45808	-85.9647
25	43.45808	-85.9647	43.45637	-85.9611

APPENDIX 5.1 SCORE THE SHORE – SAMPLE DATA SHEET

Survey Cover Sheet

SCORE THE SHORE

Data Form

Cooperative Lakes Monitoring Program

Michigan Clean Water Corps

Lake Name:______________________________ County:_____________________

Township:_______________ Lake Sampling Site (Field ID) Number:___________

Volunteer Monitor Name(s):____

Date(s) of Survey :____

Lake Level during survey was:______ Average/Normal _____ Low _____ High

Does the lake have a legal lake level? ____ Yes ____ No

If yes, indicate level gage reading at time of survey, if possible: __________

Did the lake level impact survey results? If so, how?

____

Total number of 1000' sections surveyed: ________________________

(If the final section was substantially shorter than 1000', note its

approximate length here: ____________________)

Were photographs taken as part of this survey? ____ Yes ____ No

Development Density		**Overall Shore Score**	
A. Total no. of all buildings & docks		A. Add all of the overall section scores:	
B. Total no. of sections:		B. Total no. of sections:	
Divide A by B for the avg. number of structures per 1000 feet		Divide A by B for the Shore Score for your lake: *(It is a 0-100 scale)*	

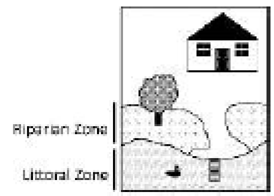
CLMP Score the Shore Data Form Survey Cover Sheet

Score the Shore data form.

Other comments pertinent to the results of the assessment (plant treatments, restoration projects, deviations from standard procedures, weather)

Section #: _____ Lake/County:_________________________________ Date:____________

GPS/Landmark at Start of Section: ____



PASS 1 (Boat is 100 yards from shore):

Number of: Homes/Major Buildings: __________

Docks/Boatlifts:________

PASS 2 (Boat is 20-30 yards from shore):

Littoral (Aquatic) Zone Characteristics and Shoreline Erosion: **Littoral Zone Raw Score:** ☐

% Emergent/Floating Vegetation___ None (0) ____ <10% (1) ___ 10-25% (2) ___ 25-75% (3) ____ >75% (4)

% Submerged Vegetation ___ None (0) ____ <10% (1) ___ 10-25% (2) ___ 25-75% (3) ____ >75% (4)

_____ Unable to see

Is aquatic plant management evident/known? ____ No (0) ____ Minor (at docks, swim areas; -1) ____ Major (-2)

Amount of Downed Trees/Woody Debris: ____ None (0) ____ Few: 1-5 (1) ____ Several: 6-15 (2) ___ Many: 16+ (3)

Erosion along shoreline (check one):___ None observed (0) ____ Minor (-1) ___ Moderate (-2) ___ Severe (-3)

PASS 3 (Boat back out to 100 yards from shore):

Riparian (Land Near Shore) Zone Characteristics: **Riparian Zone Raw Score:** ☐

% Maintained Lawn, Maintained/Artificial Beach, or Impervious (% of total section length):

_____ None (0) _____ <10% (-1) _____ 10-25% (-2) _____ 25-75% (-3) _____ >75% (-4)

% Unmowed Vegetation Belt (any vegetation other than lawn; % of total section length):

_____ None (0) _____ <10% (1) _____ 10-25% (2) _____ 25-75% (3) _____ >75% (4)

Average Unmowed Vegetation Belt Depth:

_____ None (0) _____ < 10 ft. (1) _____ 10-40 ft. (2) _____ > 40 ft. (3)

Shoreline Erosion Control Practices: **Erosion Control Raw Score:** ☐

Vertical Artificial: _____ None (0) ____ <10% (-1) ____ 10-25% (-2) ___ 25-75% (-3) ____ >75% (-4)

Types of Vertical Structure (check all that apply) _____ Seawall _____ Boulders /Rock Walls

_____Other - describe:

Sloped Artificial: _____ None (0) ____ <10% (-1) ____ 10-25% (-2) ___ 25-75% (-3) ____ >75% (-4)

Types of Sloped Artificial (check all that apply) _____ Concrete _____ Rock/Riprap

_____ Other - describe:

Bioengineering (e.g. coir logs, branch bundles):

___ None (0) ___ <10% (-0.5) ___ 10-25% (-1) ___ 25-75%(-1.5) ____ >75% (-2)

GPS/Landmark at End of Section: ___________________________

Go to back for Final Scoring and Comments

Final Scoring

These equations transform your raw scores into a 0-100 scale. You should round to the nearest whole number. Remember to multiply before you add.

Littoral Zone Raw Score (from other side): _____ x 6.2 + 31.3 = [ ] **Littoral Zone Final Score**

If "Unable to see" submerged vegetation use this: x 8.3 + 41.5 =

Riparian Zone Raw Score (from other side): _____ x 9.1 + 36.4 = [ ] **Riparian Zone Final Score**

Erosion Control Raw Score (from other side): _____ x 11.1 + 100 = [ ] **Erosion Control Final Score**

Add the Scores Above = [ ]

Divide the Score Above by 3 = [ ] OVERALL SECTION SCORE

Comments or Concerns for this Section: