FOREST LAKE

2022 Lake Management Study

Prepared for:

Forest Lake Property Owners Association

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February 10th, 2023

Forest Lake Property Owners Association
Attn: Mr. Ron Swagman
6180 Bobcat Trail
Alger, MI 48610

Mr. Ron Swagman,

It was a pleasure assessing Forest Lake for you this past summer. Every year seems to bring a unique set of challenges and we welcome the opportunity to meet these challenges every single year.

While we make the transition and focus our efforts to the 2023 season, we would like to provide you with a full report of the services rendered by Savin Lake Services in 2022. This report will include a brief description of the services rendered and the data that was gathered/generated from services. You will also find included in this report the recommended lakes management approach for 2023.

Please keep in mind that we are a fully integrated lakes management company offering solutions including but not limited to mechanical harvesting, herbicide control, dredging, bio-augmentation, and aeration. Savin Lake Services also offers a complete range of water quality testing, depth contour mapping, individual property solutions, and even aquatic plant density reporting.

We look forward to working with the Forest Lake Property Owners Association this year.

Sincerely,

Matthew Novotny

Matt Novotny – Operations Manager
Savin Lake Services Inc.

Introduction

Savin Lake Services was hired to complete to complete multiple survey methodologies, acquire water quality data, and assess the aquatic vegetation of Forest Lake in 2022. Upon completing these services we would summarize the results and analyze recent yearly trends in conjunction with 2022 results, in order to recommend a lake management plan that is right for Forest Lake both ecologically and recreationally.

Although that was our intent, the spillway remaining damaged throughout 2022 limited our ability to complete some of these strategies. Despite this, we collected data to still provide as much of that information as possible. In this report you will find general vegetation assessment, potential treatment information, water quality data with trending charts, and a lead-in to phosphorus mitigation to improve the health and aesthetics of Forest Lake in the future.

Aquatic Vegetation

The aquatic vegetation observed in Forest Lake in 2022 follows similar to what was observed in recent years. The vegetation is predominantly native with few invasive plants detected. The only observed invasive species was Eurasian Watermilfoil. And although it was detected we only documented a relatively small amount, approximately 1 acre worth. The native vegetation primarily consisted of chara, coontail, thin leaf pondweed, and cattails. Most notably, the northwest end of the lake contained a very dense mixture of coontail, thin leaf pondweed, duckweed, and chara. Other species include bulrush, yellow waterlily, American pondweed, and white stem pondweed. We feel it is improper to classify a vegetation coverage percentage for the 2022 season when the lake is not at its normal level.

Although it was our intent to complete proper survey methodologies such as a complete AVAS Survey and sonar mapping services (Biobase survey), the decreased water levels limited the ability to do so.

Potential Treatment Recommendations

The primary concern with any vegetation management plan are invasive species. In Forest Lake, this means Eurasian Watermilfoil and what was observed in previous years Curly Leaf Pondweed. While systemic control options exist for Eurasian Watermilfoil, none exist for Curly Leaf Pondweed.

For the control of Curly Leaf Pondweed, usually one treatment early in the season (May or June) with aquatic herbicides such as Diquat Dibromide is all that is necessary as the plant will not regrow very well in warmer water temperatures. This will also kill the plant before turion production occurs, limiting future plant growth.

For Eurasian Watermilfoil, because a systemic control option exists, an effort to reduce any large beds of the plant should always be performed. Most systemic control options need to factor herbicide concentration and exposure time for successful treatments. Small beds or individual plants may not allow for systemic control to be viable because of those factors. Therefore, it may be cost beneficial to utilize contact herbicides on smaller beds and reserve any systemic control options to larger beds. However, recent advancements in herbicide technologies have led to the availability certain fast acting systemic herbicides for aquatic use. While the same concentration versus exposure time truths exists for the new products available, the successful systemic control of smaller Eurasian watermilfoil beds has greatly increased. It appears the milfoil population in Forest Lake is minimized, therefore smaller routine (yearly) systemic treatments should be performed to limit its potential regrowth and spread.

Native vegetation and algae should be treated only as needed, if nuisance conditions exist. A healthy ecosystem includes having a wide variety of native plant species present, as well as algae. Native plants and algae provide protection and food sources for juvenile fish and aquatic animals. Additionally, complete removal of native vegetation will open substrate for non-native invasive species to take root. Emergent vegetation such as lily pads and cattails can spread and grow in new areas if it is not managed. However, these plants should be managed similar to other native submerged vegetation and only treated where they may impede recreational use of the lake.

Besides herbicides, mechanical harvesting can sometimes be utilized to manage nuisance vegetation. While removal of vegetation may be beneficial for the lake, for instance due to nutrient release and organic build up once a plant decomposes if treated with herbicides, the harvesting process is slow and more expensive per acre. Additionally, the invasive species starry stonewort and Eurasian watermilfoil can regrow by fragmentation, thus cut stems and fragments of Eurasian watermilfoil and starry stonewort that is not collected (or dropped) by the harvesters may spread and grow in new areas.

When the spillway on Forest Lake is repaired and the water raises to ‘normal’ levels, it will be crucial to perform frequent vegetation surveys to observe the growth of Eurasian watermilfoil and curly leaf pondweed. As these species can outcompete native vegetation, the reintroduction of lake water to previously exposed bottomlands my promote its spread. There is no guarantee that the vegetation distribution in the lake will be the same as it was in 2019.

Water Quality

Forest Lake had water samples taken on September 29h, 2022. Water samples were taken from sites 1, 2, and 3 for water quality testing (refer to Figure 3). Fourteen parameters were analyzed from the water samples at these three sites for this report. Of the parameters tested, Temperature, Dissolved Oxygen, Secchi Disk, and pH were sampled while on the lake. Chlorophyll α, Nitrate-N, Phosphorus, Alkalinity, Conductivity, Total Kjeldahl Nitrogen, Orthophospate, Total Dissolved Solids, Total Suspended Solids, and Turbidity were sampled by sending the water in sample bottles to an independent laboratory, White Water Associates located in Amasa, MI, where the analysis was ran. A complete lake profile for temperature and dissolved oxygen only was taken from site 3, which is the deepest part of the lake.

A well known limnologist named Wally Fusilier developed a grading scale for various parameters of water quality. Data collected in 2022 is shown below and nine of the parameters analyzed were given a grade based on Fusilier's scale. Additionally, the trophic state index is quantified. This index is used to generalize the biological productivity of a waterbody. The 3 main trophic states for a lake are oligotrophic (low productivity), mesotrophic (medium productivity), and eutrophic (high productivity). The index is calculated based on only chlorophyll α, total phosphorus, and secchi disk values.

(Water Quality Sampling Sites)

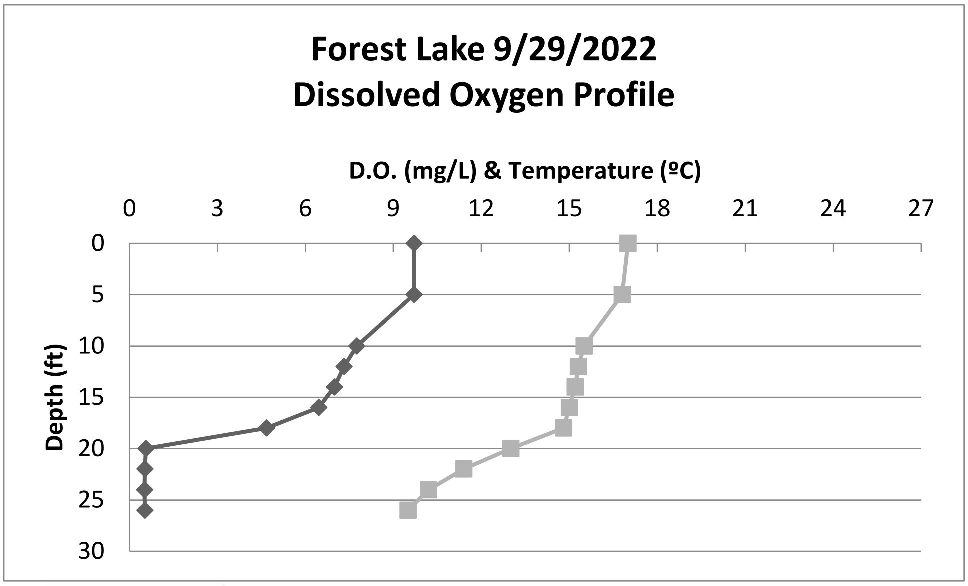
Date: 9/29/2022

Site Number:	**1**	**2**	**3**	**Average**	**Grade**
Chlorophyll α (ug/L)	3.2	3.2	7.7	4.70	D
Total Phosphorus (ug/L)	12	22	20	18.00	A
Nitrate-N	<130	<130	<130	<130	A
Alkalinity (mg/L)	130	120	120	123	A
pH	8.02	7.78	8.22	8.01	A
Conductivity (umho/cm)	350	340	340	343	A
Secchi Disk Depth (meters)	1.83	2.13	2.13	2.0	D
Surface Temp (ºC)	16.3	17	17	16.77	A
Surface D.O. (mg/L)	12.29	10.26	9.7	10.75	A

Trophic State Index	**TSI Value**	**Trophic State**
Secchi Disk	49.8	Mesotrophic
Chlorophyll α	45.8	Mesotrophic
Total Phosphorus	45.8	Mesotrophic

Additional Parameters

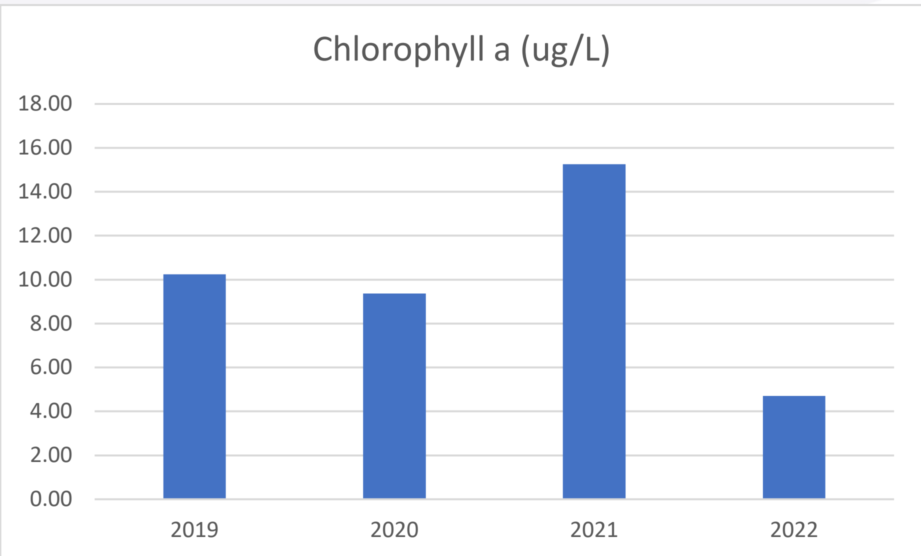
Site Number:	**1**	**2**	**3**	**Average**
Orthophosphate-P (ug/L)	11	<10	<10	11
Total Kjeldahl Nitrogen (mg/L)	0.74	0.85	0.88	0.82
Total Dissolved Solids (mg/L)	210	200	200	<130
Total Suspended Solids (mg/L)	4	3	3	3.3
Turbidity (NTU's)	3	2.7	2.2	2.63

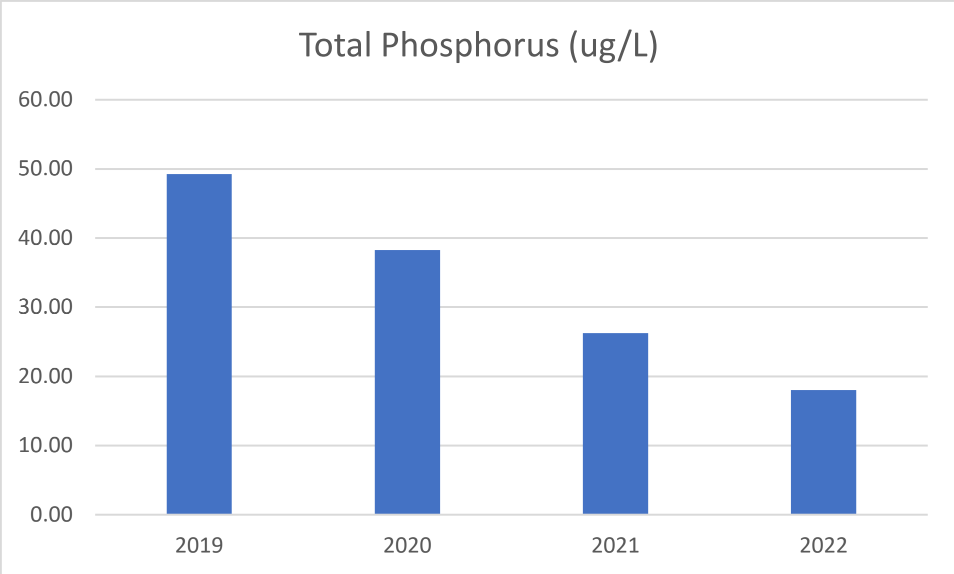


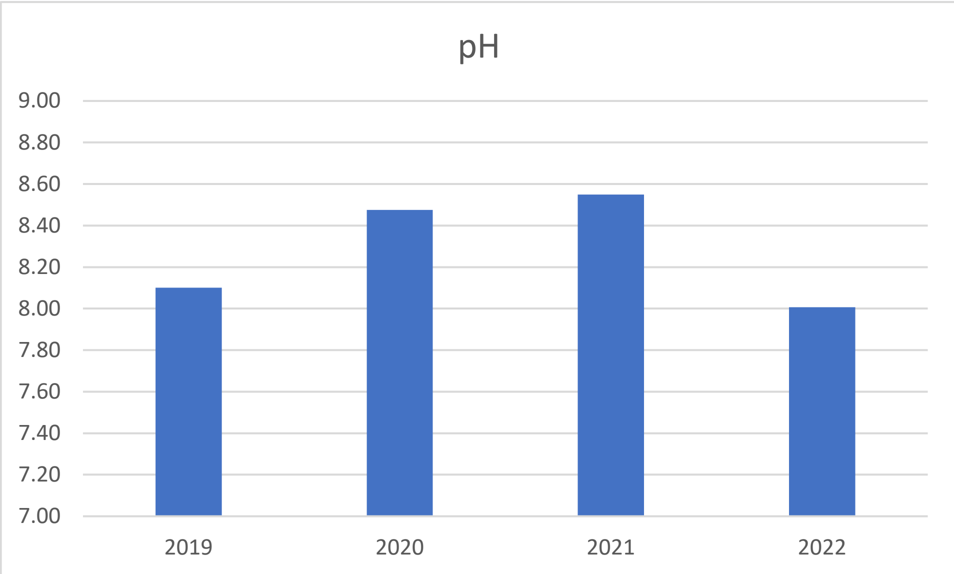
Temp (ºC)	D.O. (mg/L)	Depth (ft)
17	9.7	0
16.8	9.7	5
15.5	7.75	10
15.3	7.31	12
15.2	6.99	14
15	6.45	16
14.8	4.67	18
13	0.56	20
11.4	0.52	22
10.2	0.51	24
9.5	0.52	26

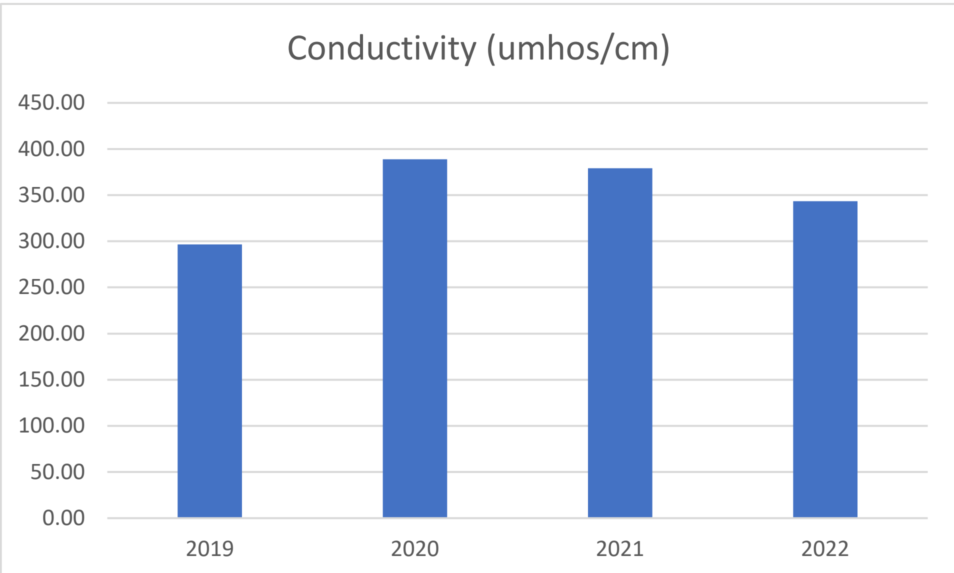
Water Quality Trend Graphs

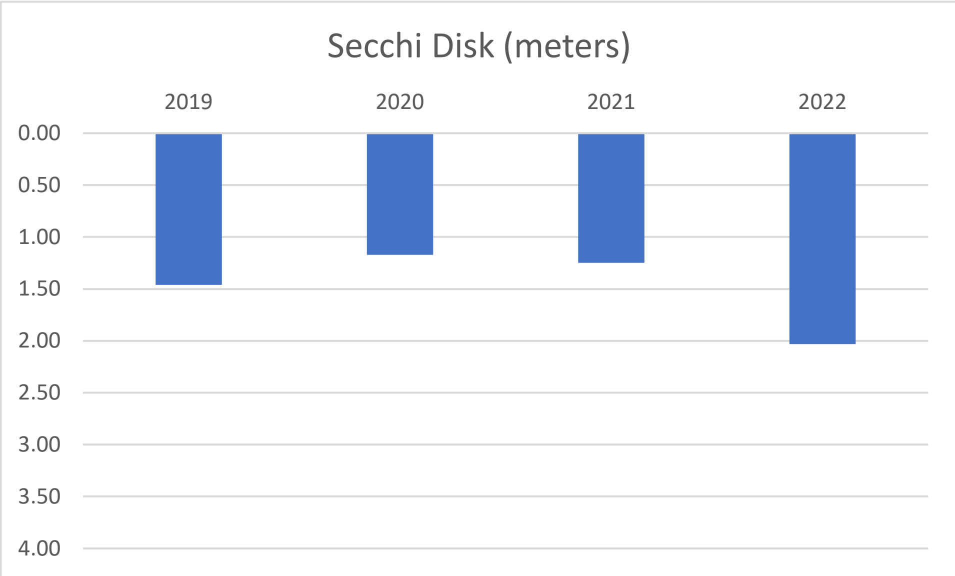
The following are graphs showing recent trending for some of the previously tested water quality data. Data provided is an average of all values obtained in a particular year. Not all parameters have graphs provided. This is due to either having one or two years with data available, or having a majority of the data being unquantified. The most common reason for this is if the values were below the detection limit for the tests being run. For instance, Nitrate-N values are all below the detection limit of 130 ug/L in 2022.

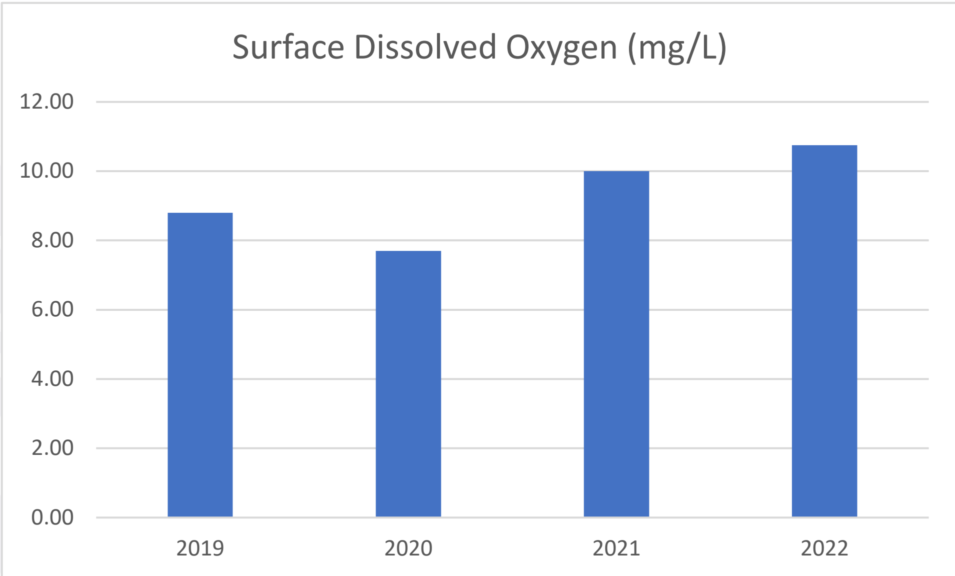


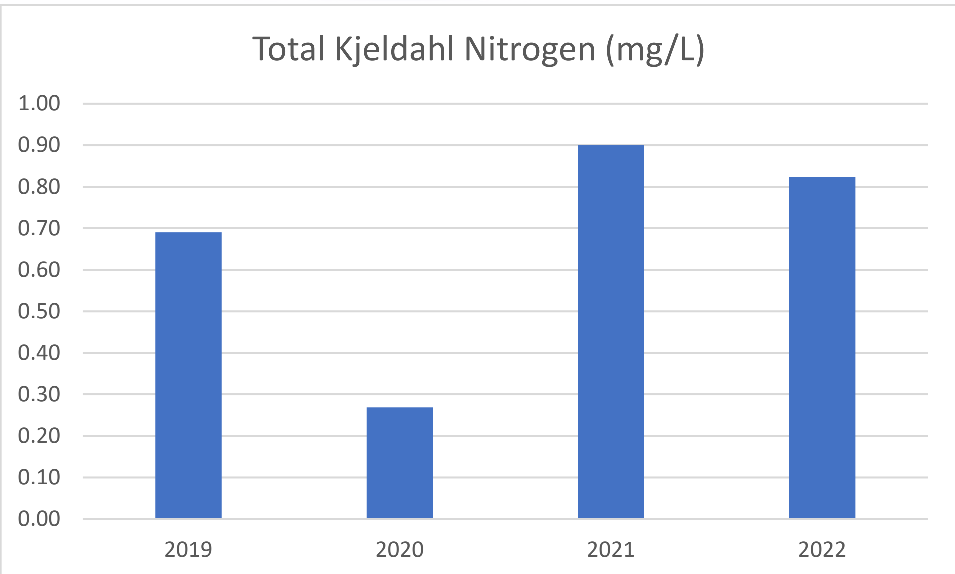

Total Phosphorus (ug/L)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2019
2020
2021
2022

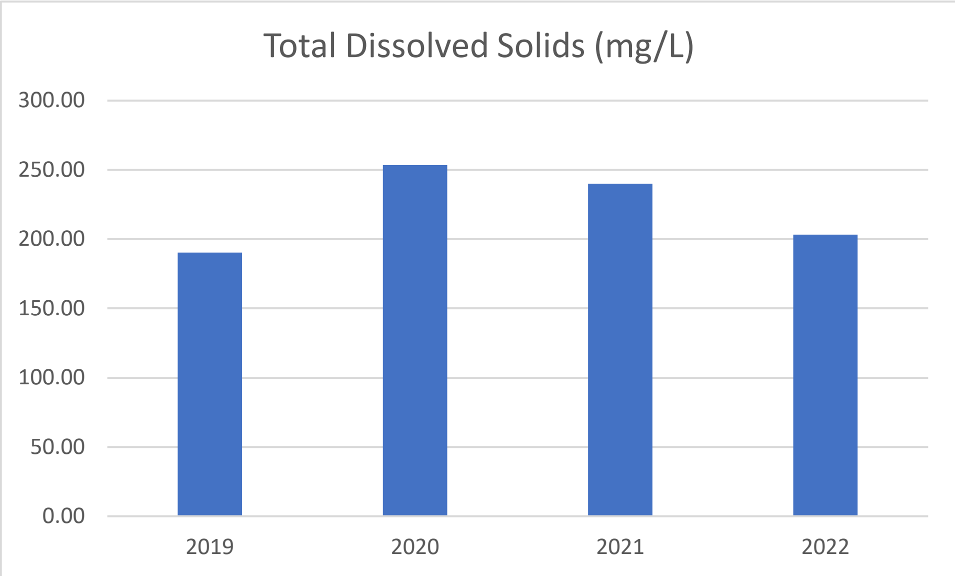

pH
9.00
8.80
8.60
8.40
8.20
8.00
7.80
7.60
7.40
7.20
7.00
2019
2020
2021
2022


Conductivity (umhos/cm)
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
2019
2020
2021
2022


Secchi Disk (meters)
2019
2020
2021
2022
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00


Surface Dissolved Oxygen (mg/L)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
2019
2020
2021
2022


Total Kjeldahl Nitrogen (mg/L)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2019
2020
2021
2022


Total Dissolved Solids (mg/L)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
2019
2020
2021
2022

Parameter Descriptions:

TEMPERATURE AND DISSOLVED OXYGEN

Temperature exerts a wide variety of influences on most lakes, such as the separation of layers of water (stratification), solubility of gases, and biological activity.

Dissolved oxygen is the parameter most often selected by lake water quality scientists as being important. Besides providing oxygen for aquatic organisms in natural lakes, dissolved oxygen is involved in phenomena such as phosphorus precipitation to, and release from, the lake bottom sediments and decomposition of organic material in the lake.

Low dissolved oxygen concentrations (below 4 milligrams per liter) are generally insufficient to support fish life. In most Michigan lakes, there is no dissolved oxygen below the thermocline in late summer. Some experts like to see some dissolved oxygen in the bottom water of a lake, even if it is almost zero. This is because as long as there is some dissolved oxygen in the water at the bottom of the lake, phosphorus precipitated by iron to the bottom sediments will remain there. Once a lake runs out of dissolved oxygen in the water at the bottom iron comes back into solution. When that happens, it releases the phosphorus back into the water. This can cause additional algae to grow when the lake mixes.

DISSOLVED OXYGEN, PERCENT SATURATION

Because the amount of dissolved oxygen a water can hold is temperature dependent with cold water holding more than warm water, dissolved oxygen saturation is often a better way to determine if oxygen supplies are adequate. The best is between 90 and 110 percent.

CHLOROPHYLL α

Chlorophyll α is used by lake scientists as a measure of the biological productivity of the water. Generally, the lower the chlorophyll α, the better. High concentrations of chlorophyll α are indicative of an algal bloom in the lake, an indication of poor lake water quality. The highest surface chlorophyll α concentration found by Wallace Fusilier (Water Quality Investigators, WQI) in a Michigan lake was 216 micrograms per liter. Best is below one microgram per liter.

SECCHI DISK TRANSPARENCY (originally Secchi's disk)

In 1865, Angelo Secchi, the Pope's astronomer in Rome, Italy devised a 20-centimeter (8 inch) white disk for studying the transparency of the water in the Mediterranean Sea. Later an American limnologist (lake scientist) named Whipple divided the disk into black and white quadrants which many are familiar with today.

The Secchi disk transparency is a lake test widely used and accepted by limnologists. The experts generally felt the greater the Secchi disk depth, the better quality the water. However, one Canadian scientist pointed out acid lakes have very deep Secchi disk readings. (Would you consider a very clear lake a good quality lake, even if it had no fish in it? It would be almost like a swimming pool.) Most lakes in southeast Michigan have Secchi disk transparencies of less than ten feet. On the other hand, Elizabeth Lake in Oakland County had 34 foot Secchi disk readings in summer 1996, evidently caused by a zebra mussel invasion a couple of years earlier.

Most limnology texts recommend the following: to take a Secchi disk transparency reading, lower the disk into the water on the shaded side of an anchored boat to a point where it disappears. Then raise it to a point where it's visible. The average of these two readings is the Secchi disk transparency depth.

Secchi disk measurements should be taken between 10 AM and 4 PM. Rough water will give slightly shallower readings than smooth water. Sunny days will give slightly deeper readings than cloudy days. However, roughness influences the visibility of the disk more than sunny or cloudy days.

TOTAL PHOSPHORUS

Although there are several forms of phosphorus found in lakes, the experts selected total phosphorus as being most important. This is probably because all forms of phosphorus can be converted to the other forms. Currently, most lake scientists feel phosphorus, which is measured in parts per billion (1 part per billion is one second in 31 years) or micrograms per liter (ug/L), is the one nutrient which might be controlled. If its addition to lake water could be limited, the lake might not become covered with the algal communities so often found in eutrophic lakes.

Based on WQI's studies of many Michigan inland lakes, they've found many lakes were phosphorus limited in spring (so don't add phosphorus) and nitrate limited in summer (so don't add nitrogen).

10 parts per billion is considered a low concentration of phosphorus in a lake and 50 parts per billion is considered a high value in a lake by many limnologists.

NITRATE NITROGEN

Nitrate, also measured in the parts per billion range, has traditionally been considered by lake scientists to be a limiting nutrient. The experts felt any concentration below 200 parts per billion was excellent in terms of lake water quality. The highest value found by Fusilier was 48,000 parts per billion in an Ottawa County River which flowed into Lake Macatawa in Holland, Michigan

On the other hand, WQI has studied hundreds of Michigan inland lakes, and many times they find them nitrate limited (very low nitrate nitrogen concentrations), especially in summer.

WQI was finding many lakes have lower nitrate nitrogen concentrations in summer than in spring. This is probably due to two factors. First, plants and algae growing in lakes as water warms can remove nitrates from the water column. And second, bacterial denitrification (where nitrates are converted to nitrogen gas by bacteria) also occurs at a much faster rate in summer when the water is warmer.

Generally, limnologists feel optimal nitrate nitrogen concentrations (which encourage maximum plant and algal growth) are about 10-20 times higher than phosphorus concentrations. The reason more nitrogen than phosphorus is needed is because nitrogen is one of the chemicals used in the production of plant proteins, while phosphorus is used in the transfer of energy, but is not used to create plant material. If the nitrate concentration is less than 10-20 times the phosphorus concentration, the lake is considered nitrogen limited. If the nitrate concentration is higher than 10-20 times the phosphorus concentration, the lake is considered phosphorus limited.

TOTAL ALKALINITY

Alkalinity is a measure of the ability of the water to absorb acids (or bases) without changing the hydrogen ion concentration (pH). It is, in effect, a chemical sponge. In most Michigan lakes, alkalinity is due to the presence of carbonates and bicarbonates which were introduced into the lake from ground water or streams which flow into the lake. In lower Michigan, acidification of most lakes should not be a problem because of the high alkalinity concentrations.

HYDROGEN ION CONCENTRATION (pH)

pH has traditionally been a measure of water quality. Today it is an excellent indicator of the effects of acid rain on lakes. About 99% of the rain events in southeastern Michigan are below a pH of 5.6 and are thus considered acid. However, there seems to be no lakes in southern Michigan which are being affected by acid rain. Most lakes have pH values between 7.5 and 9.0.

SPECIFIC CONDUCTIVITY

Conductivity, measured with a meter, detects the capacity of a water to conduct an electric current. More importantly however, it measures the amount of materials dissolved in the water, since only dissolved materials will permit an electric current to flow. Theoretically, pure water will not conduct an electric current. It is the perception of the experts that poor quality water has more dissolved materials than does good quality water

Orthophosphate

Another common name for orthophosphate is “reactive phosphorus”. Orthophosphate is the form of phosphate available to living organisms. For example, orthophosphate is the phosphorus form that is directly taken up by algae. Thus, the amount of orthophosphate in the amount available for potential algal growth.

Total Kjeldahl Nitrogen (TKN)

TKN is the amount of nitrogen in the water in the form of ammonia and in all biological forms. The higher the value, the more likely a problem exists such as algae blooms and less oxygen.

Total Dissolved Solids (TDS)

Total dissolved solids is the amount of dissolved organic and inorganic material in the water. Generally higher TDS results in poorer water quality.

Total Suspended Solids (TSS)

Total suspended solids is the amount of suspended material in the water. Higher levels of TSS will increase water temperatures and decrease dissolved oxygen levels. Suspended particles will absorb more heat from the sun than water will.

Turbidity

Turbidity is the measure of the clarity of water. It is the measurement of the light scattered by material in the water. Turbidity readings can be used to indicate the potential pollution in the water.

Phosphorus Mitigation

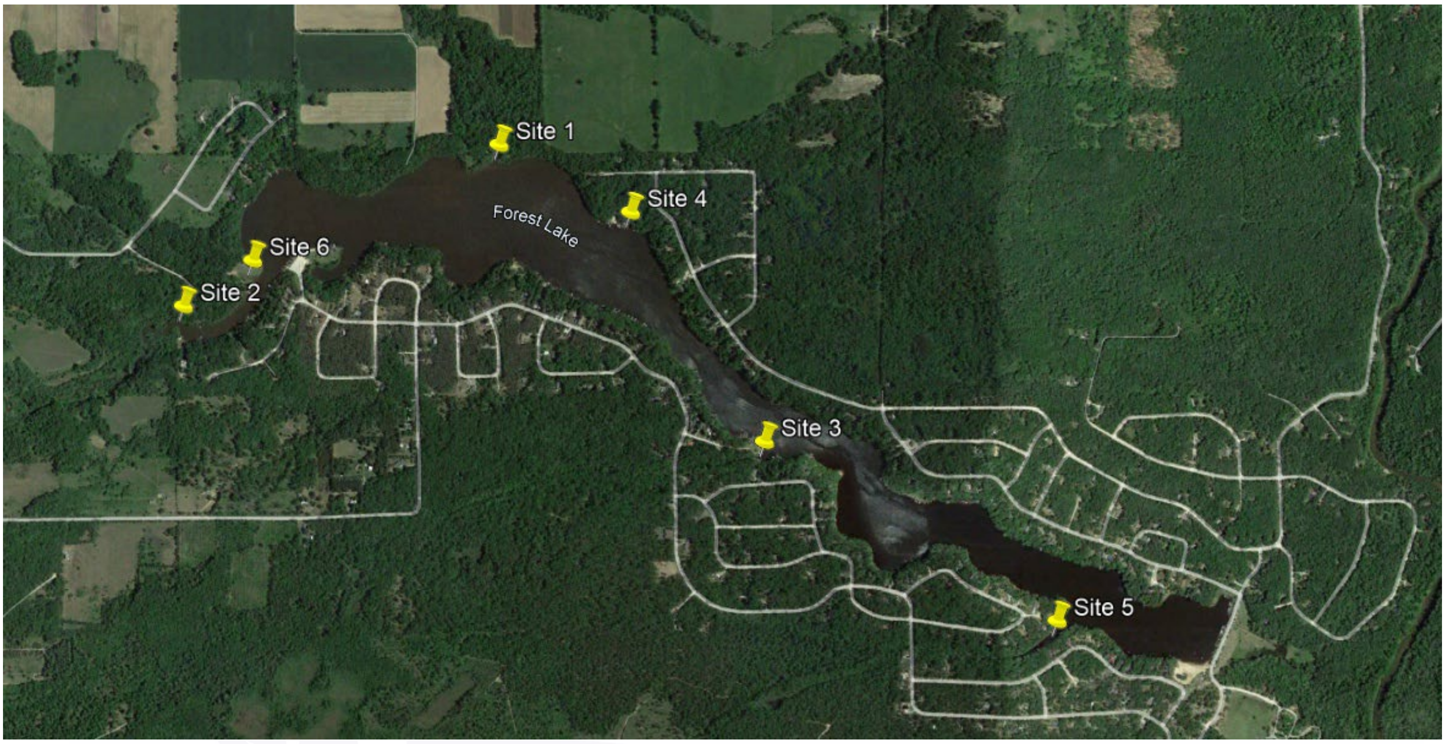
There exists a couple of products that directly capture and remove phosphorus from a waterbody. One set of products will strip the phosphorus from the water column and cap the sediments from internal releasing phosphorus back into the water. A couple examples of this are Allum and Phoslock. Another product that accomplishes a similar strategy is EutroSORB. EutroSORB is a line of multiple products that is designed to capture soluble reactive phosphorus. Each product in the EutroSORB line accomplishes the capture of phosphorus through different means. For instance one product is a large bag filled with the ingredient that is designed capture phosphorus. Water flows through the bag, and phosphorus in the water will bind with the ingredient and settle inside the bag. Once the binding capacity is near its limit, you remove the bag, thus removing the bound phosphorus, and replace a new bag to start the process over. Because of this process, the water entering the lake contains much less available phosphorus for algae to use. Other products help bind phosphorus already in the water column, and another blocks internal loading of phosphorus from sediments.

These products will soon be available for use in Michigan. We believe when they are, it will be a key component of lake management strategies. We will be able to treat algal problems from the source, nutrients. Because of this, we collected water samples from creeks entering the lake, as well as collected sediment samples from the lake bottom, to help start some of the data collection that would be necessary to implement a phosphorus mitigation strategy.

Sediment samples were acquired at the same 3 water quality sampling sites. Creeks were numerically labeled the same as previous studies for comparisons.

- Site 1: Seder Creek.
- Site 2: Wells Creek.
- Site 3: Whippoorwill Creek.
- Site 4: Ringneck Creek.
- Site 5: Bobcat Creek.
- Site 6: Park Road Drain.

Preserving Our Lakes Today For Our Generations Tomorrow
3088 HOTTIS ROAD HALE, MI 48739 877-SAV-LAKE (877-728-5253) LakeAndPond.com



(*Stream Sampling Sites*)

Stream Data:

FRP (ug/L)

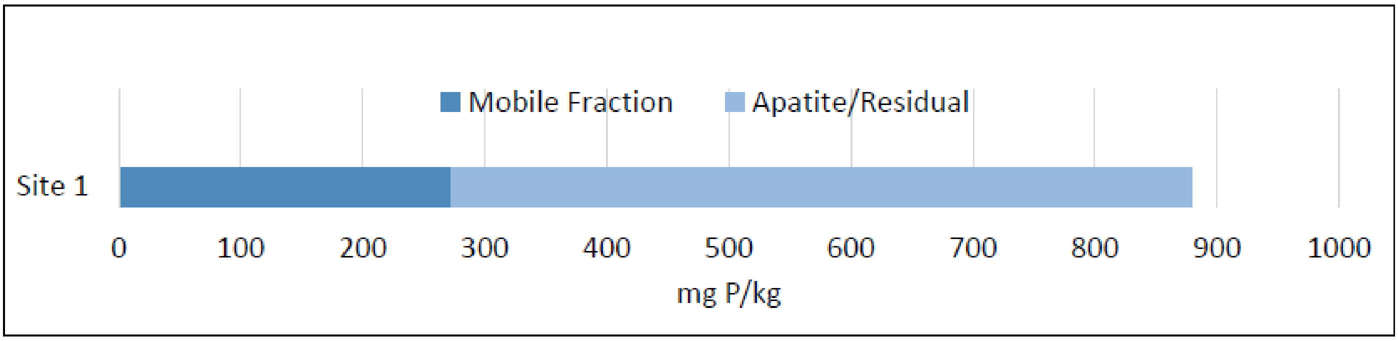
Stream Data	Sampling Dates Early Summer	Sampling Dates Late Summer
Site 1	151.4	No Flow
Site 2	9.5	5
Site 3	8	<5
Site 4	11.4	No Flow
Site 5	30.4	21.8
Site 6	N/A	No Flow

TP (ug/L)

Stream Data	Sampling Dates Early Summer	Sampling Dates Late Summer
Site 1	385.1	No Flow
Site 2	33.4	21
Site 3	19	10.7
Site 4	91.3	No Flow
Site 5	38.8	38.4
Site 6	N/A	No Flow

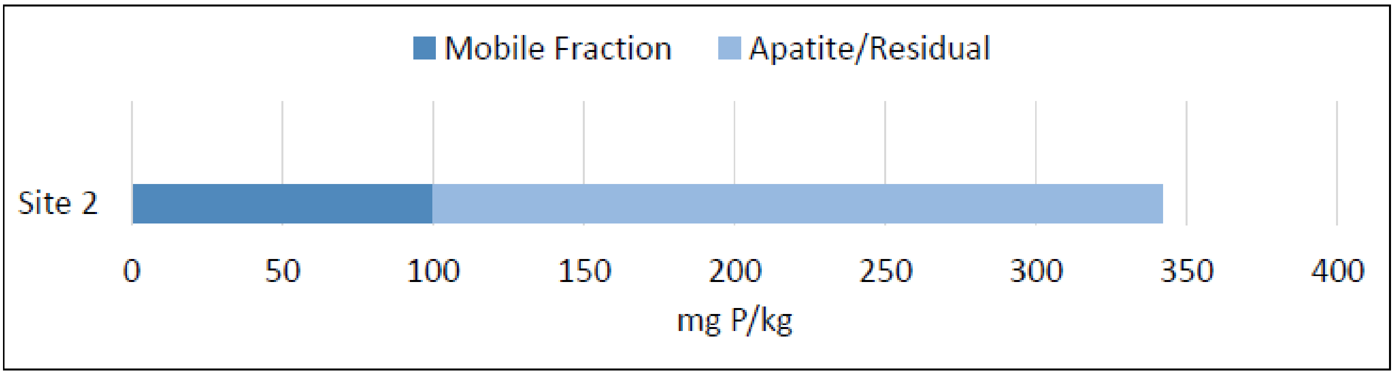
Sediment Data:

Sample ID	Sample Name	Apatite and Residual (mg P/kg)	Mobile Phosphorus† Fraction (mg P/kg)	TP (mg P/kg)	% Solids (% Dry Wt.)
CTM40965	Site 1	607	272	879	23



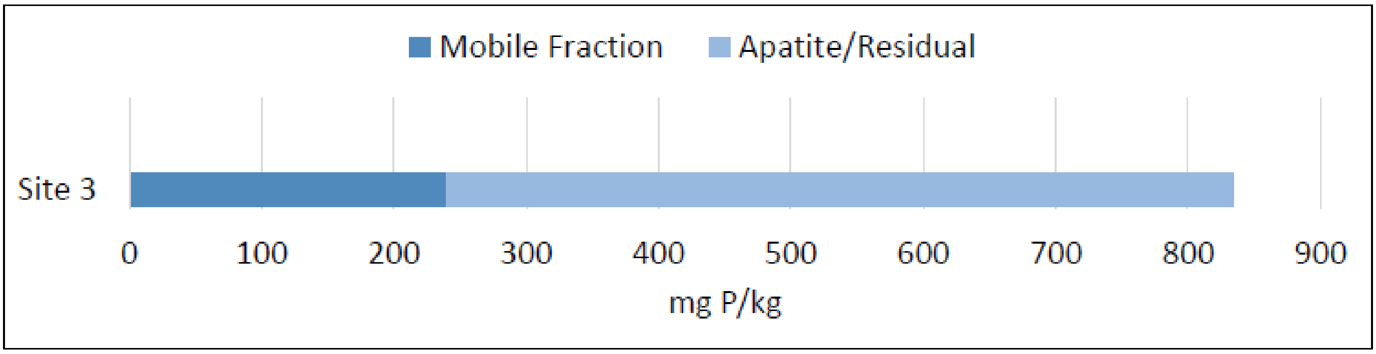
†Mobile phosphorus represents fractions of sediment phosphorus that are potentially bio-available in typical aquatic environments. All concentrations are reported based on dry weight

Sample ID	Sample Name	Apatite and Residual (mg P/kg)	Mobile Phosphorus† Fraction (mg P/kg)	TP (mg P/kg)	% Solids (% Dry Wt.)
CTM40966	Site 2	241	100	342	47



†Mobile phosphorus represents fractions of sediment phosphorus that are potentially bio-available in typical aquatic environments. All concentrations are reported based on dry weight

Sample ID	Sample Name	Apatite and Residual (mg P/kg)	Mobile Phosphorus† Fraction (mg P/kg)	TP (mg P/kg)	% Solids (% Dry Wt.)
CTM40967	Site 3	594	240	834	24

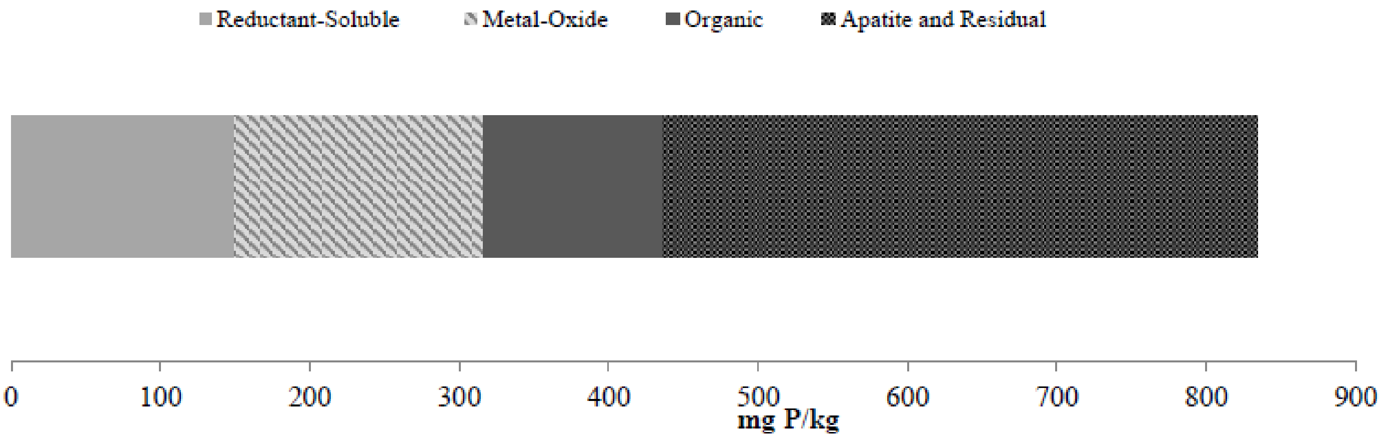


† Mobile phosphorus represents fractions of sediment phosphorus that are potentially bio-available in typical aquatic environments. All concentrations are reported based on dry weight

Name	Sample ID	% Solids (% Dry Wt.)	Labile (mg P/kg)	Reductant-Soluble (mg P/kg)	Metal-Oxide (mg P/kg)	Organic (mg P/kg)	Apatite and Residual (mg P/kg)
Site 3	CTM40967	24	*	150	166	120	397

* Concentration was less than reportable limits with 99% confidence

All concentrations are reported based on dry weight



2023 Forest Lake Management Recommendations

Forest Lake will soon undergo many changes between the repairing of the spillway, the water levels returning to normal, and the dredging project that will begin as well. Monitoring of the water quality and vegetative growth will be important upon their completion. As previously stated, the vegetative response to the lake filling could potentially allow invasive species to spread rapidly. Should this be the case in 2023, systemic treatments of Eurasian watermilfoil would be recommended. Native species treatments should be discouraged to allow their propagation, with the exception of treatments that are necessary for allowing recreational use of the lake if their coverage and density mimic what has been observed in the northwest portion of the lake.

In general, Savin Lake Services does not believe herbicide treatment of aquatic vegetation will be necessary in 2023. However, should the Property Owners Association request herbicide treatment of Forest Lake at its current water level to benefit recreational uses like kayaking and canoeing please let us know as soon as possible so the permit application process with Michigan EGLE can begin in a timely manner.

An updated sonar survey is recommended when water levels return to normal. The bathymetric (depth contour), biovolume (vegetation density), and bottom hardness maps will be informative and complement other survey methodologies to evaluate any changes that may have occurred to the lake over the last few years. Water quality monitoring should be completed in a similar manner to previous years in order to document changes that may occur when the lake returns to normal water levels.