Photo courtesy of the Portage Lake Association. Photographer, Al Taylor.

Portage Lake

Lake Management Plan 2021

Prepared for Onekama Township and the Invasive Species Committee

PLM LAKE & LAND MANAGEMENT CORP

Submitted By:
BreAnne Grabill, Environmental Scientist

PO Box 424 · Evart, Michigan 49631
phone 800.382.4434 · fax 231.372.5900
www.plmcorp.net

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Executive Summary

Portage Lake has been managed for well over a decade with goals of identifying and reducing the presence of aquatic invasive species (AIS) throughout the Portage Lake watershed, tracking plant trends, improving water quality and protecting Portage Lake into the future. The following report breaks down the specifics of the previous, current and future management needs.

In 2021, just over 50 acres of nonnative aquatic plants were chemically controlled while just a small area of Phragmites (Phrag), less than a tenth of an acre was controlled via chemical control methods. In the past, beetles were planted as a biological control method for Purple loosestrife but the beetles were unavailable for purchase in 2021. Unfortunately, a new nonnative species, Starry Stonewort (SSW) was found in Portage Lake in both 2020 and 2021. This is highly concerning as this aggressively growing macroalgae grows along the bottom of the lake and can wreak havoc on native plant communities, the fishery as well as recreational uses of the lake. In total, 4.25 acres were targeted for control, down from the 8 acres treated in 2020. SSW adds to both Eurasian watermilfoil (EWM) and Phragmites as the main focus of management within Portage Lake.

When reviewing the management area for the last decade, at no time has more than nine percent of the lake received herbicide management and, in most years, it is under four percent. In 2021, less than 2.5%. This shows that the program has successfully removed and managed the exotic infestation population, while preserving much of the lake from exotic plant disturbance. Further, with over 92% of the lake not receiving any herbicide treatment, the native plant community has been left as natural as a lake will allow with adjusting water levels/depths, a constant changing environment and exotic species introductions. Extensive vegetation surveys and water quality testing is included in the management program annually, to allow a checks and balance over the program and ensure the long-term protection of the lake. The abundance of healthy native plants in Portage Lake increases the long-term stability of the lake, which has been continually found in the extensive surveys performed on Portage Lake. While some water quality parameters have maintained themselves with little change over the years, other parameters have shown some fluctuations. One of the most important parameters to test is Total Phosphorus (TP). After finding a decrease in TP in 2015 and 2016, and a general downward trend; in 2017 TP concentrations increased. Although levels were only considered enriched, not highly enriched, it was concerning. However, in the last few years including 2021, testing has shown a decrease in the overall nutrient levels in Portage Lake, indicating the slight rise in 2017 was short lived. Additionally, no signs of internal loading with TP were found in this year's sampling. Over the years, a few samplings have shown small peaks or elevated levels, but generally speaking; the lake trends are all positive. The Tributaries and Storm Drains around Portage Lake continue to show elevated nutrient levels and prove to be a point source for bringing excess nutrients into the lake. However, the 2021 sampling showed the smallest TP input in recent years, which is an excellent sign. This information is vital in determining the areas within Portage Lake that need to be focused on to reduce nutrient loading to help reduce the productivity in Portage Lake. The ability of Portage Lake to produce algae and aquatic plants is directly related to the overall health (nutrient base) of Portage Lake and its surrounding watershed. While the main goal of the management program is to protect the long-term ecological health of the lake, it is also important to protect the recreational, aesthetical and financial aspects of the lake as well. All of these factors play into the management efforts on Portage Lake, which need to be continued into next season.

Note: Portage Lake has been sampled numerous times in the past to review the genetic makeup of the milfoil or hybrid milfoil within the waterbody. All testing has continued to prove that the aggressive hybrid milfoil has outcompeted any Eurasian strand and will continue to require more rigorous management, when found. Additional research data will be provided as part of this LMP, if and when available from the Universities reviewing genetic data.

Introduction

This management plan documents management activities during 2021, examines current conditions in the lake, and provides management recommendations for 2021. The plan will detail an integrated approach to lake management including but not limited to exotic weed control, water quality monitoring and aquatic vegetation surveying.

Characteristics of the Lake

Portage Lake is a 2110-acre lake located in Onekama Township and the Village of Onekama, Manistee County, Michigan. Public access to the lake is provided by multiple access sties. A large portion of the shoreline has been developed and of that, a majority for single-family year-round homes. A formal lake-use survey was not included in this study, but observations made while working on the lake indicate that the lake is used for fishing, boating (power & non-power), and swimming. Portage Lake makes up 13.6% of the overall Portage Lake Watershed, which drains into Lake Michigan. Numerous other lakes and tributaries flow into Portage Lake, which has a man-made channel into Lake Michigan on the west end. Portage Lake is a natural lake with two deep holes approximately 60' deep.

A few problems necessitating management of Portage Lake are: (1) exotic and invasive species, and (2) water quality concerns. The presence of multiple exotic species has required annual management of the aquatic and terrestrial plants within and around Portage Lake.

Establishment of weedy exotic aquatic plants, including Eurasian watermilfoil and curly leaf pondweed, exacerbates problems caused by aquatic vegetation in the lake. These weedy exotic plants grow to the surface and cause substantially more interference with recreation than native plants.

Management Goals for Portage Lake

- The primary goal of management in Portage Lake is to control and manage nonnative plants, to allow recreational use of the lake and promote a healthy fishery. The nonnative or exotic plant species, Eurasian watermilfoil, Starry stonewort, Curlyleaf pondweed and Phragmites, should be controlled throughout Portage Lake to the maximum extent possible. Native plants should be encouraged throughout the lake to promote an overall heahlty ecosystem. Genetic testing in Portage Lake has found that the Eurasian watermilfoil is hybrid, a new genetic strand of milfoil. In reference to Portage Lake, Eurasian milfoil or EWM will be referring to both EWM and Hyrbid milfoil as it all needs to be managed as a nonnative or exotic, invasive species.
- Aquatic plant management should preserve species diversity and cover of native plants sufficient to provide habitat for fish and other aquatic organisms. Native plants should be managed to encourage the growth of plants that support the Portage Lake fishery (by creating structure and habitat) provided that they do not excessively interfere with recreational uses of the lake (e.g., swimming and fishing) in high-use areas. Where they must be managed, management techniques that reduce the stature of native plants without killing them (e.g., harvesting, contact herbicides) should be used whenever possible. Specific areas should be set aside where native plants will not be managed, to provide habitat for fish and other aquatic organisms. Muskgrass (*Chara*) should be allowed to grow throughout the lake, except in where it grows so tall as to interfere with boating and swimming.
- Water quality efforts in Portage Lake should continue to be made to reduce external loading of nutrients. Proper watershed management techniques should be applied where possible and lake

residents should be encouraged to practice "lake friendly" lawn maintenance.

- Outreach/education of the Portage Lake residents should continue in an attempt to communicate lake activities and management goals. The Portage Lake website should be maintained as a way to directly relay pertinent information along with annual meetings and newsletters.
- Based on currently survey results, the following species are recommended for specific management on Portage Lake.
  - EWM, an exotic species, is an extremely aggressive submerged aquatic plant that has the abilities to form a monoculture among vegetation. EWM spreads by fragmentation (every inch of plant can sprout new growth) and has a very strong root system. EWM forms a canopy above native plants, choking out the competition. EWM also has the ability to overwinter underneath the ice, allowing it to be present throughout the winter. This gives the plant a head start in growing during the spring and chokes out native plants very quickly. EWM should be controlled as soon as it is found within a waterbody to prevent further infestation and loss of native plant diversity. NOTE: Once a native plant is lost in a lake, there is no guarantee it will return.

  - The macroalgae species, Starry stonewort (SSW), should be actively controlled and managed. Starry stonewort is in the same family as Muskgrass (Chara) but is considered an exotic invasive species. Starry stonewort, which looks very similar to the beneficial species Chara, is appearing in more and more lakes. Chara is a highly desired plant because it is typically low growing, keeps the water clear and can slow down the invasion of exotic weed species. Starry stonewort also forms dense mats, but unlike chara, it can grow from 5 to 7 feet tall. Starry stonewort can be very detrimental to a lake's ecosystem and has the ability to kill off native plants and have a negative impact on a lake's fisheries.

  - The aquatic invasive terrestrial plants, Purple loosestrife and Phragmities should be controlled along the shoreline and adjacent wetlands where present. Both species are exotic and have the ability to displace beneficial native vegetation. Purple loosestrife grows 2 -4 feet tall and is a vibrant magenta color. It is very aggressive and can quickly become the dominant wetland vegetaion. Phragmites (common reed) is a wetland grass that ranges in height from 6 to 15 feet tall. "Phrag" quickly becomes the dominant feature in aquatic ecosystems, aggressively invading shorelines, wetlands, and ditches. This plant creates dense "strands" - walls of weeds crowding out beneficial native wetland vegetation and indigenous waterfowl habitats. Spreading by fragmentation and an extensive root system, Phragmites ultimately out-competes native plant life for sun, water and nutrients. As Portage Lake also hosts a healthy native Phrag community, it is vital to identify each strand for proper management and promote native Phragmites, when present.

- The terrestrial invasive plant, Japanese knotweed should be controlled throughout the Portage Lake Watershed. Japanese knotweed is a large, herbaceous perennial plant native to Eastern Asia. In North America, the species has been classified as an invasive species. Japanese knotweed has hollow stems with distinct raised nodes that give it the appearance of bamboo, though it is not closely related. Reaching a maximum height of about 12' each growing season, it is typical to see much smaller plants in places where they sprout through cracks in the pavement or are repeatedly cut down. The invasive root system and strong growth can damage concrete foundations, buildings, roads, paving, retaining walls and architectural sites. It can also reduce the capacity of channels to carry water. It forms thick, dense colonies that completely crowd out any other herbaceous species. The success of the species has been partially attributed to its tolerance of a very wide range of soil types, pH and salinity. The plant is also resilient to cutting, vigorously resprouting from the roots. The most effective method of control is by herbicide application close to the flowering stage in late summer or autumn.

- Narrow-leaf cattails, another terrestrial invasive species, which can often be confused with the Common cattail, are often found growing in marches, lakeshores, ponds, ditches, etc. Similar to other invasive species, Narrow-leaf cattails often form monocultures and outcompete other native species, leading to a concern for species habitat and often affecting recreational use of the area. Narrow-leaf cattail's leaves are about ½ inch wide, roughly half the width of the native broadleaf cattail. The stem is roughly 3-6' tall. The two species also hybridize, producing a cross that can exhibit characteristics of both species, though is often taller and more aggressive than either parent species and can be more difficult to identify. Management options include mowing, digging, grazing, water level manipulation, and chemical control.

Lake Management Overview

Integrated Pest Management (IPM)

IPM approaches to aquatic plant control emphasize spending more effort evaluating the problem, so that exactly the right control can be applied at just the right time to control the pest. IPM approaches minimize treatment costs and the use of chemicals. Lake Management planning ensures the most appropriate, cost-effective treatment for your lake. Planning is an essential phase of Integrated Pest Management and includes lake vegetation surveys, water quality evaluation and a detailed, written lake management plan. Having the plan in place helps lake users know what to expect from lake management. Survey results provide a permanent record of conditions in the lake and the impact of management practices.

Prevention

Early detection and rapid response are key to a successful program. As part of any community education and outreach program, preventing introductions is key. More often than not, nonnative aquatic plants (exotic species) were possibly introduced to Portage Lake by plant fragments carried on boats and/or boat trailers. A variety of other troublesome exotic plants and animals that have been introduced to Portage Lake are also transported this way. Preventing their inadvertent introduction to Portage Lake can significantly lower the cost of future lake management. Education can be an effective preventative measure. Newsletter articles should alert lake residents to the threat from exotic nuisance plants and animals. Warning signs should be erected at any public boat access sites, if applicable, that encourage boaters to clean boats and trailers when launching or removing watercraft from the lake.

Monitoring

It is important to maintain a record of lake conditions and management activities. Vegetation surveys monitor types and locations of plants in the lake, providing information that is essential to the administration of efficient, cost-effective control measures. Vegetation surveys also document the success or failure of management actions and the amount of native vegetation being maintained in the lake. Water quality monitoring can identify trends in water quality before conditions deteriorate to the point where remediation is prohibitively expensive or impossible. Records of past conditions and management activities also help to keep management consistent despite changes in the membership of the organization. Records should include (at a minimum):

- Temperature, dissolved oxygen and Secchi disk depth should be measured in the lake at both deep hole basins. Temperature and dissolved oxygen profiles should be obtained in the deep hole, so as to monitor the timing and extent of oxygen depletion in the hypolimnion (i.e., bottom water).
- Total phosphorus, nitrates, and ammonia should be measured in the surface and bottom water at least two times per season (spring and late summer) to monitor nutrient accumulation in the hypolimnion.
- Chlorophyll a sampling
- Tributary testing including flow and nutrient sampling
- Lake vegetation should be surveyed on an annual basis (late spring and/or late summer/early fall) to document the results of plant management efforts and provide information necessary for planning future management.

Fishery

Portage Lake has a diverse fishery including both cool and warm water species. Many of the fish species rely on vegetated areas to spawn, forage and seek refuge. A healthy native aquatic plant community offers favorable habitat for many species that benefit from the complexity of architectural diversity. Exotic invasive aquatic plant species, such as Eurasian watermilfoil and Starry Stonewort are known to displace native plant communities, reduce architectural diversity and have negative effects on fish populations. Managing exotic aquatic plant species while maintaining native plant communities promotes a healthy and stable fish community.

Submersed Nonnative Plant Management

Areas of nonnative plant growth need to be identified and mapped for management. Utilizing latest technologies available, such as GIS software, precise management maps can be created for implementation. Nonnative infestations, such as Eurasian watermilfoil, require prompt control. Methods of management are provided in this lake management plan. Although a variety of options are available and should be weighed out for each lake, the most common management method is treatment using herbicides.

Starry stonewort should be aggressively controlled to reduce biomass as soon as it is detected. Treatments are most effective when controlled early using algaecides such as SeClear G, Copper Sulfate, and/or Chelated Copper.

When management strategies are applicable and used correctly, control is achievable. Although one management strategy may have been successful for one waterbody, many factors impact success from lake to lake and each unique ecosystem and infestation requires evaluation.

Emergent Nonnative Plant Management

Emergent species such as Purple loosestrife and Phragmites need to be actively monitored and control around the lake.

Purple loosestrife is an exotic species, which is out competing native vegetation, destroying valuable wetlands and animal habitat and expanding in density along Portage Lake. Purple loosestrife can be managed through a variety of techniques including hand pulling, digging, spot treatments or biological control. Selective control through the use of triclopyr (Renovate) is a feasible option for large or small infestations. Hand pulling/digging is more viable for small infestations or in response to an early detection and rapid response. The biological control effort, beetles, have shown positive control measures and this method. Portage Lake has utilized all three management efforts in the past.

Both native and nonnative Phragmites is present in the Portage Lake watershed. Nonnative Phrag, which can out compete native vegetation, destroys valuable wetlands and animal habitat. Research has proven that the BMP for Phragmites is to selectively control the plant through the use of glyphosate or imazapyr herbicides. Treatment techniques often include both hand swiping of plants as well as foliar spray. After treatment, controlled burns, cutting, mowing, etc. can be done with success to remove biomass. Burning or mowing prior to application can further the spread of this highly invasive species. Chemical treatment on Portage Lake has successful remove much of this biomass and allowed native plants to naturally recover.

Narrowleaf cattails, another exotic species, can outcompete native cattails and wetland vegetation. Management options are limited and spot treatments can be effective.

Native Plant Management

Native plants should be controlled primarily by harvesting if required. Unlike Eurasian watermilfoil, most native plants do not regrow rapidly after harvesting, and a single harvest is often sufficient to control them for the entire summer. Normally low-growing species should not be controlled unless unusually fertile growing conditions allow them to grow tall in areas of high recreational use. Contact herbicides applied at higher rates can be effective at controlling native plants that are causing a nuisance close to shore, in between docks.

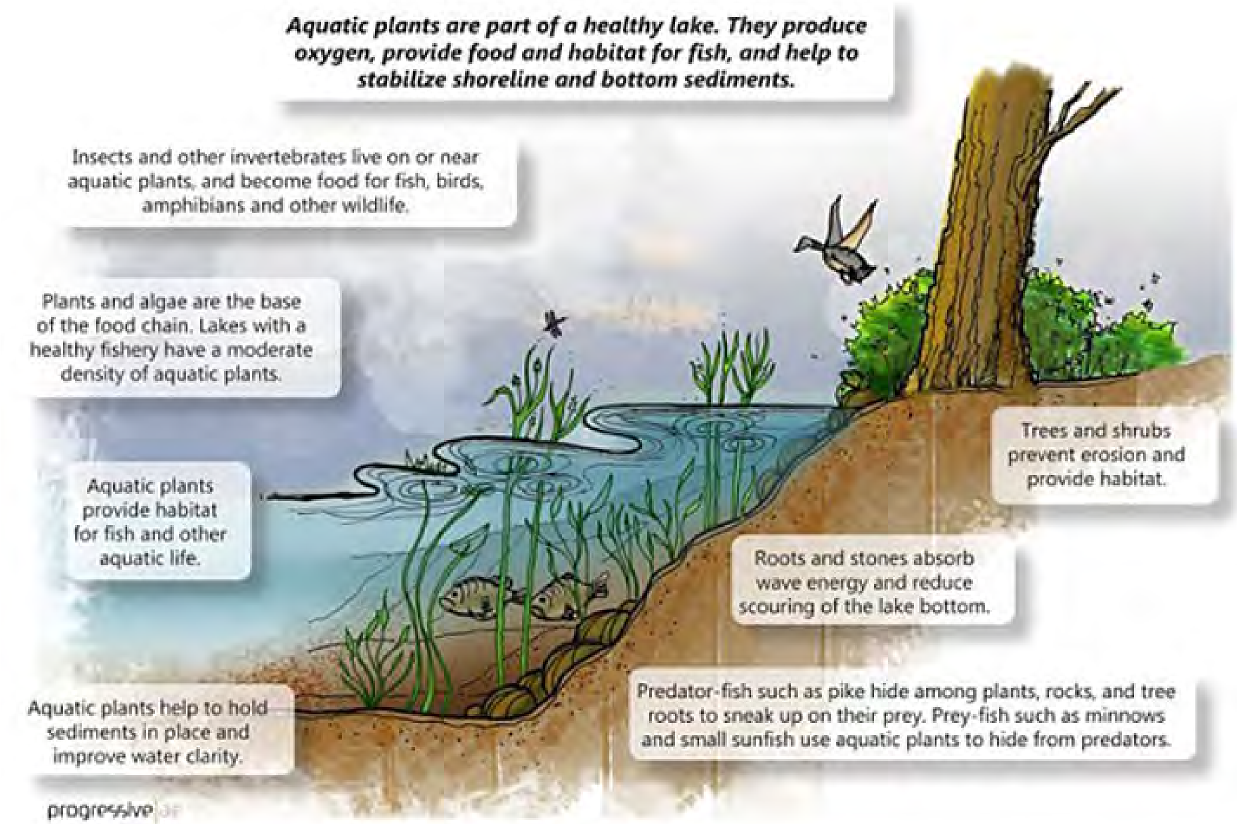


Photo curiosity Progressive AE

Algae Management

Algae are divided into planktonic, filamentous, and macroalgae forms. Planktonic algae are microscopic, free floating plants, often referred to as "water bloom". In large number, the algae can cause water to appear green, brown, yellow, or even red. Cyanobacteria are planktonic algae and can produce a toxin called cyanotoxins. This doesn't mean that if you see any planktonic algae it will have a toxin, but it is wise to be cautious. These algae blooms can last from days to months if conditions are right. Filamentous algae, commonly called "pond scum" can form raft-like masses over the water surface. Since they are vulnerable to winds and currents, they are generally restricted to bays, bayous, and sheltered shorelines. Filamentous algae can grow attached to the lake bottom, weeds and docks. The filamentous algae will frequently detach from the lake bottom and form floating mats. The macroalgae includes three types, Chara, Starry stonewort and Nitella. Chara grows like a carpet on the bottom of the lake. It is nature's water filter and is excellent for fish bedding. Chara grows approximately one inch a week during the summer months.

An overabundance of algae is an indicator that there is an excess amount of nutrients within the water column/lake, causing the waterbody to become overly productive. Algae are very beneficial in a lake ecosystem and can be thought of as the base of the food chain. Therefore, some alga is required.

However, when an alga reaches the point of hindering the use of the lake, control measures are available. Firstly, actions should be taken within the watershed to promote a healthy lake ecosystem and decrease nutrient loading, etc. However, no immediate change will be seen with these actions. Therefore, many lakes opt to include limited algae control within their management program.

Filamentous algae control is not required at this time. Whenever possible reducing nutrient loading entering the lake and watershed is recommended to help reduce future growth. A natural shoreline can also help buffer out nutrients, Chara, a macroalgae should be encouraged lake wide and is one of the most vital species within the waterbody as it is a natural filter for clarity and is very beneficial for sediment stabilization and the fishery.

Starry stonewort, another macroalgae species, is nonnative and needs to be aggressively managed to prevent ecological damage and the loss of Chara. Although these species look similar, SSW requires immediate management, which can be done through chemical application as well as harvesting (mechanical and suction). This species can spread by fragmentation as well, so harvesting practices need to be very specific to avoid spread. Early detection and rapid response with chemical treatments have proven high effective. Established infestation management practices may differ.

Natural Shoreline/Nutrient Loading Abatement

Lakeshore property owners should be encouraged to use phosphorus-free fertilizers on lawns and other areas that drain into Portage Lake or the adjacent wetlands. Lakeshore residents should also be encouraged to manage their waterside landscapes according to the recommendations outlined in publications on this topic available from the MSU Extension.

It is also important to remember that rooted plants derive most of their key nutrients from the sediments; thus, they respond slowly, if at all, to reductions in nutrient loading. In fact, if reductions in nutrient loading lead to improved water clarity, the growth of rooted plants will probably increase.

If organic material (muck) accumulates to undesirable levels in shoreline areas, bacterial treatments should be considered as a way to alleviate the buildup.

Shoreline development has led to habitat degradation and as lakes continue to become more and more developed, the impacts continue to be damaging to the lake ecosystem. From mowed grass and sandy beaches, to seawalls and riprap to wake boat waves and fertilizer, development has negatively impacted a lake in all ecological aspects. By working to reduce the human footprint around the lake, the health of the lake will be improved. Natural shoreline restoration is helpful from reducing nutrient loading and runoff to providing habitat for frogs and fish to naturally defending against Canadian geese congregating in your yard, it is important that action is taken to minimize development impact and restore natural features. Maintaining a natural shoreline can greatly aid in the overall health of the lake.

The implementation of natural shorelines should be encouraged around Portage Lake. Converting seawall shorelines back to natural vegetation; plants, trees and shrubs along the water's edge has many benefits for the lake. Some of benefits of having a natural shoreline are erosion control, nutrient and pollution absorption, increase in wildlife and fish habitat and reduction of nuisance geese on lawns. If seawall removal is not feasible there are other options residents can do to improve and protect the lake. Placing rip rap in front of a seawall will help reduce wave action thus reducing lake scour. Rip rap can also create a suitable shoreline for animals to access the land and provide places for aquatic insects and plants to grow. Also, native vegetation can be planted within the rip rap, creating a more natural shoreline. Adding rip rap is an easy, affordable and effective way to help the lake.

Picture courtesy of MI Natural Shoreline Partnership

Restoration

Pending the level of a waterbody's impairment, specific activities such as phosphorus mitigation, native plantings, fish plantings, etc. can be recommended. As this varies tremendous on a site by site basis, it is generally best to work with healthy lake front living practices, early detection rapid response and education/outreach to prevent infestations and make improvements in the overall ecosystem.

In regards to nonnative plant infestations, it is best to control early. Controlling nonnative plants early is key to lowering the impact to the native plant communities. If and when a monoculture is formed, there is no guarantee that a native species will return. In most cases, once a nonnative plant has been controlled, native plants will naturally flourish in that area. If and when a planting is considered, it is important to only use native species as well as species that have a historical presence within that system. Even native species, once introduced into a new environment can cause negative impacts and have consequences (i.e. Wild Celery (*Vallisneria americana*)).

Lake Management Approaches

Areas of the lake that support vegetation will grow plants, despite intense efforts to remove them. Aquatic vegetation provides important benefits to a lake, including stabilizing sediments, providing habitat for fish and other aquatic organisms, and slowing the spread of exotic plant species. In general, native plants interfere less with recreation and other human activities than exotic species. Non-native plant species, Eurasian watermilfoil and curly leaf pondweed concentrate their biomass at the water surface where they strongly interfere with boating, swimming and other human activities. This growth form also allows exotic plants to displace native plants and form a monospecific (i.e., single species) plant community. The dense surface canopies of Eurasian watermilfoil and Curly leaf pondweed provide a lower quality habitat than that provided by a diverse community of native plants. Control of exotic plant species minimizes interference of plant growth with human activities and protects the native vegetation of the lake. The goal of environmentally responsible aquatic plant management, therefore, is not to remove all vegetation, but to control the types of plants that grow in the lake and the height of plants, to minimize interference with human activities. All activities performed should be do so using best management practices (BMP) and an integrated pest management (IPM) approach using environmental sound technologies and finically feasible options.

It is important that control techniques meet the needs and expectations of lake users. Each technique has advantages and disadvantages. Many aquatic plants are relatively susceptible to some control measures but resistant to others. Too often, lake groups select a control technique before determining what their needs are.

Aeration

Aeration can be a beneficial tool to sustain ecological balance within an aquatic ecosystem. By maintaining sufficient oxygen levels throughout a waterbody, the entire eutrophication process can be slowed down, the health of the fishery can be maintained and overall water quality can be improved. The implementation of an aeration system to control rooted aquatic plant growth is not recommended. Rooted plants, such as Eurasian watermilfoil, will not be affected by aeration. Similar to the use of biological control, the impact of aeration on improving water quality and reducing organic sediment will vary greatly from site to site. Therefore, it is extremely important to thoroughly evaluate each site's conditions and expectations before implementing an aeration system. Aeration systems are regulated by EGLE with an extensive and costly monitoring program.

Bacteria augmentation

The use of bacteria product formulations and application techiques has greatly improved in recent years. Granular bacteria products can be applied to specific shoreline areas to reduce organic muck that has acumulated over the years. As waterbodies age, organic sediment can build up due to excessive plant and algae growth. This process is called eutrohpication. Increasing native populations of bacteria can slow this process down. Reductions in the depth of muck may depend on many variables. Most importantly, the percent of sediment that is organic. The more organics in the sediment, the greater the potential for muck reduction via bacteria augmentation. Bacteria use is performed under a Rule 97 permit, overseen by EGLE and is a nonrestrive, all natural product.

Benthic barriers

The use of benthic barriers dates back quite far as a form of pest or weed control. Mats can be placed on bottom sediments to stop light penetration and control places in small areas. This method is not selective and should be used with caution in areas of spawning. Securely placing mats and avoiding navigational hazards is highly important as well. This management technique does require a permit through EGLE and should be used in smaller areas to avoid negative impacts to the native plant community.

Biological control

Biological control options for nuisance aquatic vegetation are limited. Grass carp, which indiscriminately devour aquatic vegetation, have been restricted in many states because of their nonselective grazing and fear they may escape into nonintended waters. The use of the milfoil weevil (Euhrychipsis lecontei) to control Eurasian watermilfoil has been implemented in many Michigan lakes. PLM Lake & Land Management Corp has many years of experience particapating in weevil stocking, evaluations and longterm observations related to their performance and sustainability. Although the milfoil weevils may impact EWM populations in certain situations, the use of this tool remains unpredictable. In recent years, the production of milfoil weevils has ceased. The use of Purple loosetrife beetles (Galerucella beetle) has shown some success on dense infestations of Purple loosetrife with less impact on sparse populations.

Chemical control

Michigan Department of Environment, Great Lakes and Energy (EGLE) regulates the use of chemical control in lakes and ponds across Michigan. This highly restrictive practice uses federal and state approved herbicides and/or algaecides under permits for conrtrolling plants or algae. Dosage, timing, product, and location and among some factors restricted by the permit. The use of aquatic herbicides, is the most common strategy for controlling nonnaitve or exotic plant species. Aquatic herbicides provide predictable results and there is a great deal of research and data regarding theses products. There are two types of herbicides, systemic or contact. Many of the aquatic herbicides available can be used to selectively control exotic species with minimal or no impact on native species.

Systemic herbicides are capable of killing the entire Eurasian watermilfoil plant with little or no impact on most native plant species. Under ideal conditions, several consecutive annual applications of these herbicides can reduce Eurasian watermilfoil to maintenance (low) abundance, such that only relatively small spot treatments are required to keep it under control. For this strategy to succeed, it is necessary to treat most of the Eurasian watermilfoil in the lake each time. There are currently five systemic herbicides, 2,4-D (Navigate), 2,4-D amine (Sculpin G), triclopyr (Renovate 3 & OTF), fluridone (Sonar or Avast), and ProcellaCOR which can be used to achieve long-term, selective control of Eurasian watermilfoil. ProcellaCOR has systemic like capabilities, while using low application rates and potentially allowing for multiple season control. Triclopyr is a systemic herbicide with selectivity very similar to 2,4-D. Triclopyr is not subject to the well setback restrictions that currently affect 2,4-D. Therefore, triclopyr can be used to control Eurasian watermilfoil in near shore areas. A combination of both systemic herbicides in Portage Lake could greatly reduce the growing Eurasian watermilfoil problem.

Several contact herbicides, including diquat (Reward) can also provide short-term control of Eurasian watermilfoil and other nonnative species. These herbicides kill only the shoots of the plant, and plants regrow relatively rapidly from their unaffected below ground parts.

Diver assisted suction harvesting (DASH)

DASH utilizes a suction hose and a diver that hand removes individual plants in selected areas (similar to a vacuum). On land, the collection of material is removed to an offsite location. This management option is also permitted through EGLE. Although very costly on a per acre basis, it is more commonly used on very small infestations. Bottom sediment type is a consideration with this management type as the area can become very stirred up and make visibility extremely difficult, impacting the end results. As fragmentation is a concern, prevention of spreading plants needs to be a consideration. This tool can be used specifically for both nonnative and native species.

EutroSORB – Phosphorus Filtration Technology

Reducing the phosphorus loading coming into the waterbody, specifically from the numerous creeks and storm drains entering Portage Lake would directly improve the waterbody. Through new technology, SePRO (a leader in water quality enhancement technology) has developed a phosphorus filtration product, EutroSORB, that rapidly binds nutrients in flowing water. This proactive water management technique is a critical need for most waterbodies large and small. This ecologically benign product can be used to offset the need for responsive algae management. EutroSORB bags filter phosphorus from entering a waterbody for a safe, efficient and environmental sound alternative for nutrient control.

Mechanical harvesting

Mechanical harvesting is best suited for native plant species. Most native plant species have a higher tolerance to aquatic herbicides and require higher dosage rates (higher cost and reduced selectivity). Mechanical harvesting can be used to provide relief from native plant species if they are causing a recreational nuisance. Harvesting does not kill the plants, but simply reduces it's stature, leaving lower growth for fish habitat and sedimnet stabilization. Mechanical harvesting of Eurasain watermilfoil is not recommended as it will expedite its spread throughout a lake through fragmentation.

Swimmers itch

Swimmers itch, caused by a parasite that travels through waterfowl (i.e. Mergansers) after eating snails and is present in the water column. This parasite can cause an allergic reaction on the skin of lake users, resulting in a rash. Although managing a lake for swimmers itch is difficult, there are prevetions that swimmers can use to reduce the impact. Applying sunscreen prior to water entry to create a barrier on your skin, toweling dry immeidately upon leaving the water and swimming in deeper water are reccomended. Michigan Department of Environment, Great Lakes and Energy (EGLE) no longer permits the control of Swimmers Itch using copper sulfate, which was historically done. Reducing the presence of the parasite by limitin the presence of the hosts (Mergansers) is promising. Much research is being done on this front currently across the State of Michigan and additional management reccomendations may become available in the future.

Lake Management Activities Conducted in 2021

Water Quality

Water quality was evaluated on May 3, June 8, July 29, and September 28, 2021. The May sampling included storm drain and tributary testing. In June, deep hole testing and shoreline testing of Portage Lake occurred. The later July sampling for deep hole testing occurred (this was an additional sampling added into the program in 2015). During the last sampling; tributaries, shoreline and the deep hole basins were sampled. During the deep hole sampling the following occurred, (1) a depth profile of water temperature and dissolved oxygen concentrations were measured at ten feet intervals at both Deep Hole Basins and the Secchi disk depth was measured, (2) samples for LakeCheck™ analysis was collected from the deep holes of the lake (surface, bottom and every 10' between) for numerous parameters, (3) chlorophyll and algal composition analysis was collected from surface, mid thermocline and bottom samples. During the shoreline sampling, the following occurred, (1) depth profile for water temperature and dissolved oxygen concentrations were measured at the surface, (2) samples for LakeCheck™ analysis was collected at the surface for numerous parameters, (3) chlorophyll and algae composition analysis was collected at the surface. During the Storm Drain sampling the following occurred at four designated drains, (1) Flow testing, (2) surface reading of temperature and dissolved oxygen (3) samples for LakeCheck™ analysis was collected. During the tributary testing, the following occurred at seven designated tributaries, (1) surface reading for temperature and dissolved oxygen, (2) samples for LakeCheck™ analysis was collected and (3) flow was determined. LakeCheck measures at the various sites included some or all of the following parameters: Conductivity, Total Dissolved Solids, pH, Conductivity, Total Phosphorus, Oxidative Reduction Potential (ORP), Alkalinity, Ammonia, Nitrates and Total Kjeldahl Nitrogen. The additional tributary testing included sampling at one tributary and including testing multiple locations from the entrance at the lake, upstream. Parameters tested included Total Phosphorus, Nitrates and Alkalinity.

Eurasian watermilfoil

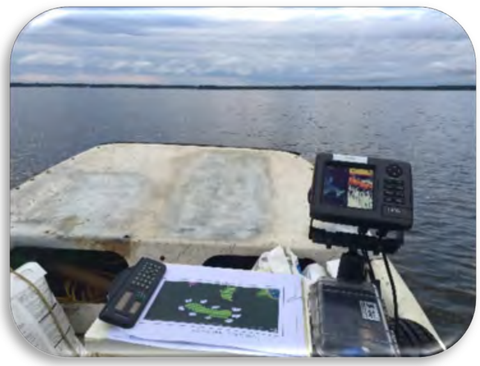
Weather Challenges of 2021

Michigan winters are usually quite different from year to year. While some are very cold and have high snowfall amounts, others are the opposite. The winter of 2020/2021 was relatively mild. When looking at the previous few winters, which were also rather mild, it brings some concern with how the lakes, specifically the plants, will respond the following summer. Weather patterns can have impacts well into the next few seasons, so when we have a mild Michigan winter, it is not helpful with controlling exotic species. Further, ice coverage came late and was not as thick as normal; leading to more sunlight penetration and ability for EWM to overwinter. Weather patterns throughout the summer also have impacts. Each lake responds differently from the weather impact and as Portage Lake tends to be slow to grow in the spring, the longer, warmer falls may impact growth differently than smaller, inland lakes. Finally, weather patterns have brought unusually high-water levels to the Great Lakes, which in turn have had large impacts on Portage Lake. Changes in water levels will have impacts on a waterbody, both short and long term and do need to be taken into consideration when managing aquatic plants.

Exotic species tend to benefit from changes in weather conditions. In Portage Lake, little plant growth is evident early on into the growing season and it is not until mid-summer that diverse plant coverage is found. Weather patterns can have impacts on lakes and individual plant trends that may not be evident right way.

Aquatic Plant Control

Weed treatments were conducted in June and August to control Eurasian watermilfoil (EWM) and Starry Stonewort in Portage Lake. Phragmites was also treated in 2021. The lake was closely monitored this year for any areas of exotic plant growth and treated accordingly.



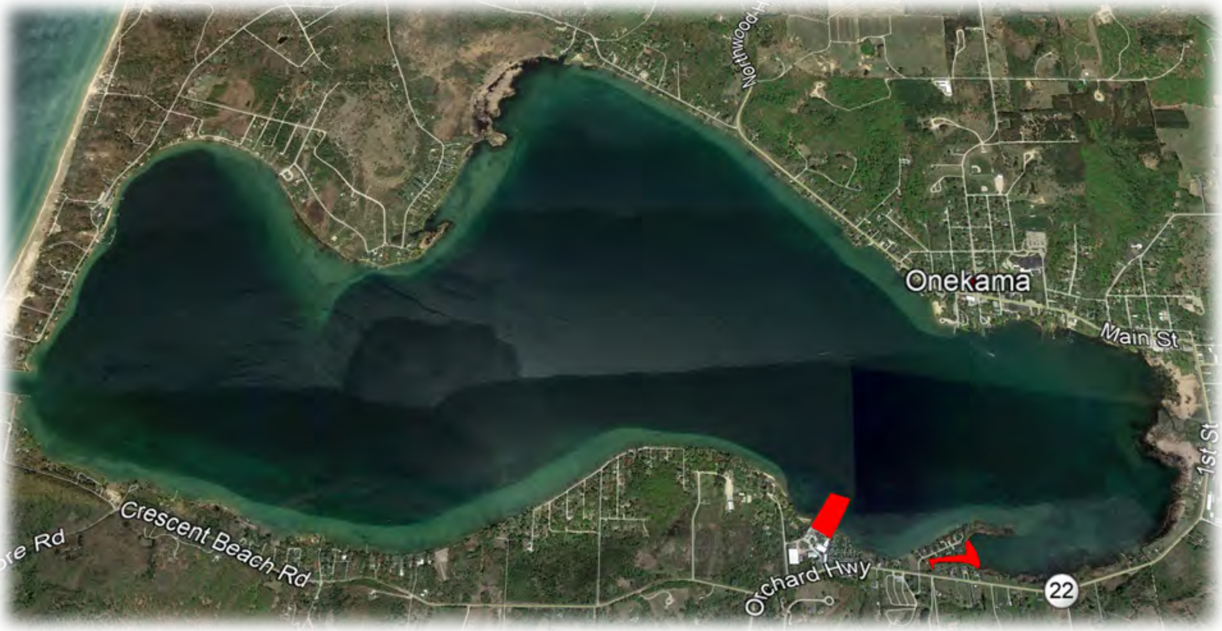
The management strategy for the control of Eurasian watermilfoil has been working, with substantial reductions in EWM treatments from when the initial treatments began. Although some years see some fluctuation, overall there is a downward trend. However, despite our efforts, EWM control is a constant battle that is heightened with hybrid watermilfoil. The presence of Hybrid watermilfoil supports the conclusion that milfoil treatments will continue to be required annually. Although fewer acres of milfoil management have been required in recent years, the recommended application rates have increased, which uses up the budget more quickly. It is important to plan according for increasing costs from the economy as well as from an evolving plant community. In 2020, through early detection and rapid response, Starry stonewort was identified and treated quickly, in hopes of limiting the spread lake wide. 2021 surveys found the previous year's actions to be very successful, with very little regrowth and no new areas of infestation found. Having a management program in place allowed for the SSW to be detected and treated within a matter of days versus months. Post survey results in both 2020 and 2021 showed a highly effective treatment and time will tell on future impact from this species.

A reflection of proper/successful management is a good fishery, which has been verified through Michigan DNR surveys (separate reports available) as well as the fishing reports on the lake. An independent fish survey of Portage Lake may be beneficial to further research the species, size and fishery habitat within the lake. Additionally, a fish study may help to alleviate some concern about the management program's impacts on the native plant community.

The Phragmites Treatment Program has been very effective as well. After the initial treatment of 83 acres, the follow up years have required just small treatments in proportion to the initial application. In certain years, Purple loosestrife beetles have been planted as a biological control method in the Portage Lake Plan. Access to beetles in 2020 and 2021 was been limited, due to a global pandemic, and has prevented new plantings.

The below maps and table show a breakdown of the treatments in Portage Lake in 2021.

Map 1: Portage Lake June 2021 Treatment Map



June 17, 2021 EWM and CLP Treatment, 6.5 acres Aquathol K marked in Red.

Map 2: Portage Lake August 2021 Treatment Map

August 12, 2021 EWM Treatment- 17.5 acres ProcellaCOR/Diquat, 22.4 acres Sculpin G SSW Treatment – 4.25 acres

The color codes on this map are specified for committee approval of specific products in certain areas as well as for the applicator to implement site specific rates/products/avg. depths.

Blue/Green/Purple are ProcellaCOR/Diquat, Yellow is SeClear G, Orange is Sculpin G. More detail provided is Table 1. Treatment polygons are based on GPS points/data collected in the field based on nonnative plant beds found and mapped during surveys.

Map 3: Portage Lake Terrestrial Treatment Map 2021

2021 Phragmites Treatment-0.03 acres

Map 4: Portage Lake 2009 EWM Infestation Treatment Map

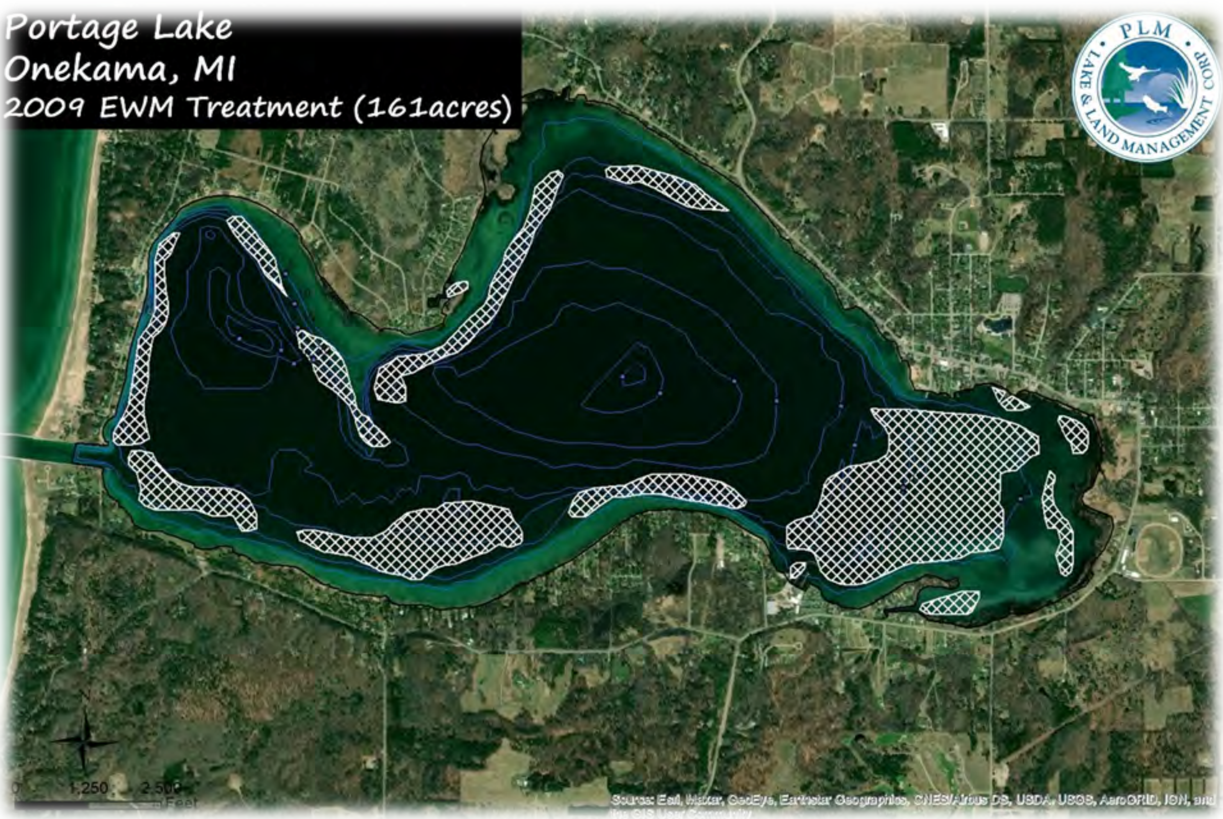


Table 1: Submersed Plant Treatment Quantities 2021-2009

		Product	Rate#/Acre	Acres	Total Acres
2021	17-Jun	Aquathal K	1gal	6.5	50.65
	12-Aug	ProcellaCOR/Diquat	4pdu/1gal	1.5	
		ProcellaCOR/Diquat	5pdu/1gal	16	
		Sculpin G	300#	22.4	
		SeClear G	50#	4.25	

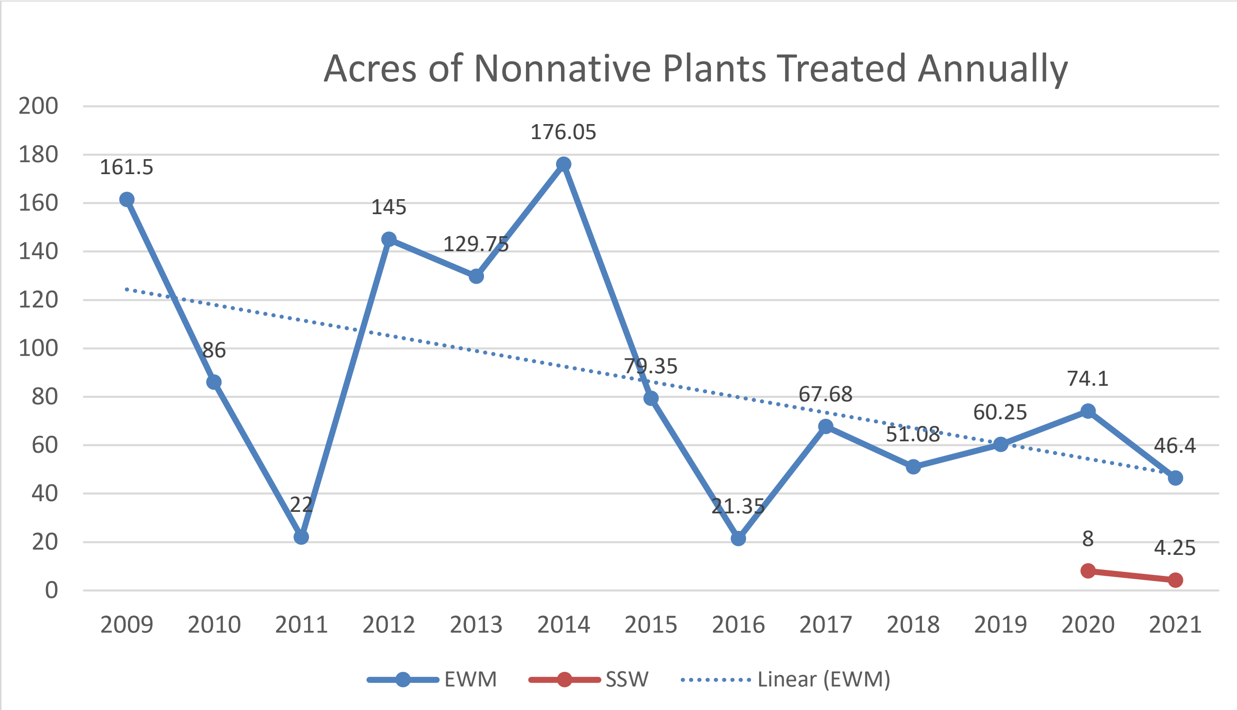
For a complete, historical overview of product usage, treatment dates, acres, etc., please see addendum 2.

Table 2: Terrestrial Treatment Summary 2021-2009

(Phragmites, Narrow leaf cattails, Yellow iris, Purple loosestrife, Japanese knotweed)

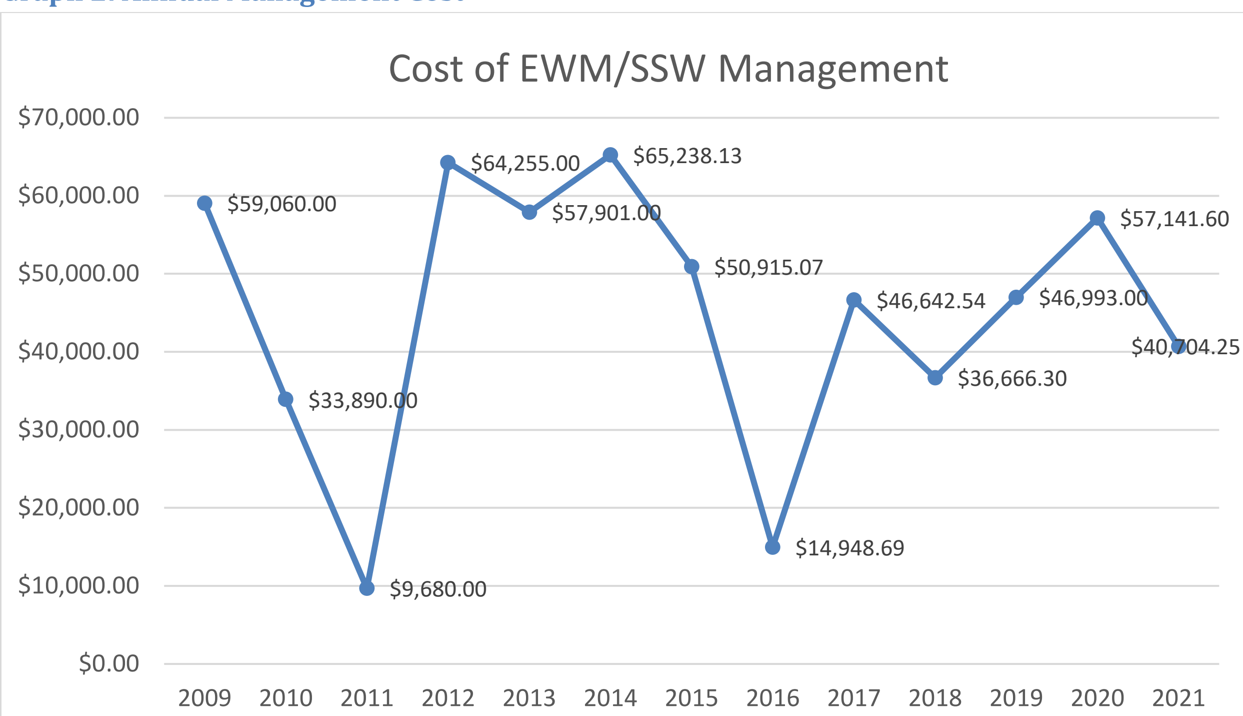
Year	Product	Rate	Acres
2021	Glyphosate	5%	0.03
2020	Glyphosate	5%	0.25
2019	Glyphosate/Imazapyr	3%	6.6
2018	Glyphosate/Imazapyr	1.5,3%	0.2
2017	Glyphosate/Imazapyr	1-3%	0.15
2016	Glyphosate/Imazapyr	1-3%	0.48
2015	Glyphosate/Imazapyr; Triclopyr	1-3%	4
2014	Glyphosate/Imazapyr	4%	6.2
2013	Glyphosate/Imazapyr	2%	7.9
2012	Glyphosate/Imazapyr	2%	13.5
2011	Glyphosate/Imazapyr	2%	7
2010	Glyphosate/Imazapyr	2%	10
2009	Glyphosate/Imazapyr	2%	83

Graph 1: Annual Management Acres



This graph shows acres of EWM and SSW treated since the start of the program. There is a clear trend down, showing success with reducing the coverage of EWM through proper management techniques.

Graph 2: Annual Management Cost



This graph shows cost of EWM and SSW treated since the start of the program. The overall trendline here is decreasing as well, an excellent sign. Although unit costs have increased with application rates and economic impacts, the program has been able to keep a similar budget and minimize cost increases whenever possible.

Planning/Evaluation

Surveys of the aquatic vegetation of the lake were conducted on June 8, 17; July 29; August 12, 16; September 29; and October 4, 2021. Surveys of the lake were made frequently throughout the summer months for pre or post treatment evaluation, to collect water quality parameters, as well as to have additional survey data available for management purposes. Vegetation surveys determine the locations of target and non-target plant species. The results of the surveys are used to determine the most appropriate management strategy. The vegetation surveys also document the success of the prescribed management program. An AVAS survey is the State of Michigan's method for conducting a complete aquatic vegetation survey. The Aquatic Vegetation Assessment Site (AVAS) survey divides the parts of the lake capable of growing plants (littoral zone) into subareas and records the cover of each aquatic plant found in each "site". This method of surveying considers not only the types of plant species present in the lake but also the densities of those species. AVAS surveys are also an excellent way to track plant species trends over time. A goal of invasive plant management is to have native plants increase while exotic plants decrease over time. The success of this goal can be illustrated using the AVAS data collected over several years. Since different native plants grow at varying times throughout the season, it is important to evaluate the lake multiple times to account for *all* species in the lake. The first evaluation is conducted in the spring/early summer while the second is conducted in late summer or fall.

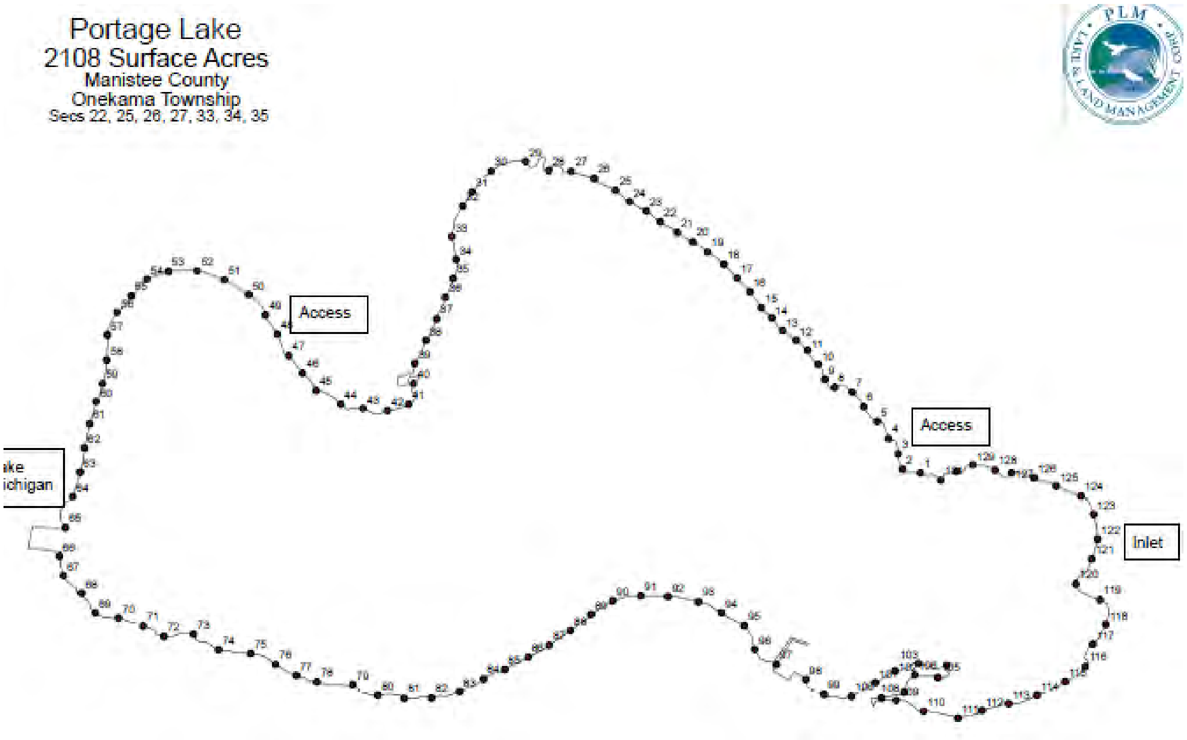
Table 3: Plant Species Found in Portage Lake –2021

*** Based from boat survey, not as precise as a walking shoreline survey**

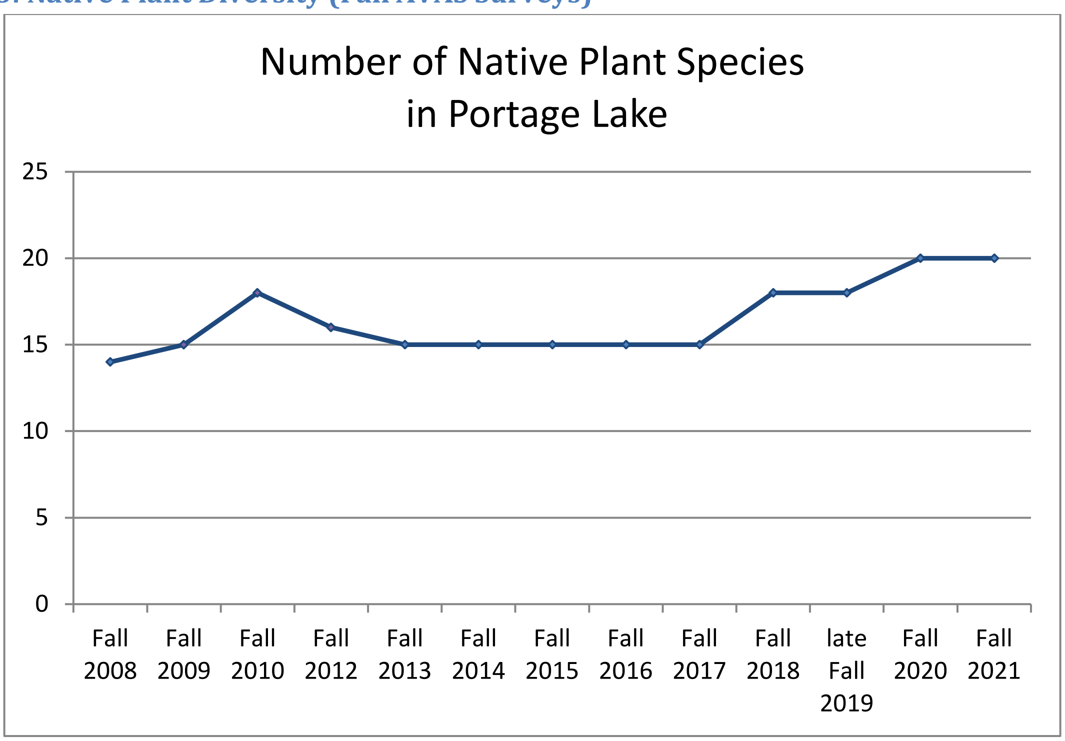
AVAS Code	Common Name	Scientific Name	% Cumulative Cover June 2021	% Cumulative Cover October 2021
	Submerged- Exotic			
1	Eurasian watermilfoil	*Myriophyllum spicatum*	2.74	1.98
2	Curlyleaf pondweed	*Potamogeton crispus*	2.41	0.08
29	Starry stonewort	*Nitellopsis obtusa*	0.00	0.08
	Submerged- Native			
3	Muskgrass	*Chara*	24.46	36.08
4	Thinleaf pondweed	*Potamogeton spp.*	2.74	7.46
5	Flatstem pondweed	*Potamogeton zosteriformis*	1.55	2.93
6	Robbins pondweed	*Potamogeton robbinsil*	0.00	0.00
7	Variable leaf pondweed	*Potamogeton gramineus*	2.29	4.54
8	White stem pondweed	*Potamogeton praelongus*	1.26	4.08
9	Richardsons pondweed	*Potamogeton richardsonii*	3.05	7.95
10	Illinois pondweed	*Potamogeton illinoensis*	5.35	13.62
11	Largeleaf pondweed	*Potamogeton amplifolius*	2.31	1.62
14	Water stargrass	*Zosterlia dubia*	0.00	0.23
15	Wild Celery	*Vallisneria Americana*	0.56	19.57
17	Northern milfoil	*Myriophyllum sibiricum*	0.09	0.08
20	Coontail	*Ceratophyllum demersum*	1.17	7.25
21	Elodea	*Elodea Canadensis*	0.31	2.88
22	Bladderwort	*Utricularia valgaris*	0.55	0.67
24	Buttercup	*Ranunculus longirostris*	0.77	0.23
25	Naiad	*Najas flexilis*	3.95	7.12
27	Sago pondweed	*Potamogeton pectinatus*	0.32	9.75
45	Variable leaf watermilfoil	*Myriophyllum heterophyllum*	0.03	0.69
48	Water marigold	*Megalodenta beckii*	0.00	0.00
	Emergent- Native			
30	Water lily	*Nymphaea odorata*	0.00	0.00
37	Pickerelweed	*Pontederia cordata*	0.00	0.31
39	Cattail	*Typha spp.*	11.88	15.37
40	Bulrush	*Scirpus spp.*	10.47	15.65
42	Swamp loosestrife	*Dianthera americana*	0.00	0.00
	Emergent - Exotic			

43	Purple loosestrife	*Lythrum salicaria*	0.00	0.00
44	Common reed	*Phragmites*	0.00	0.08*
	Total		**79.21**	**161.21**

Map 5: Portage Lake AVAS Map

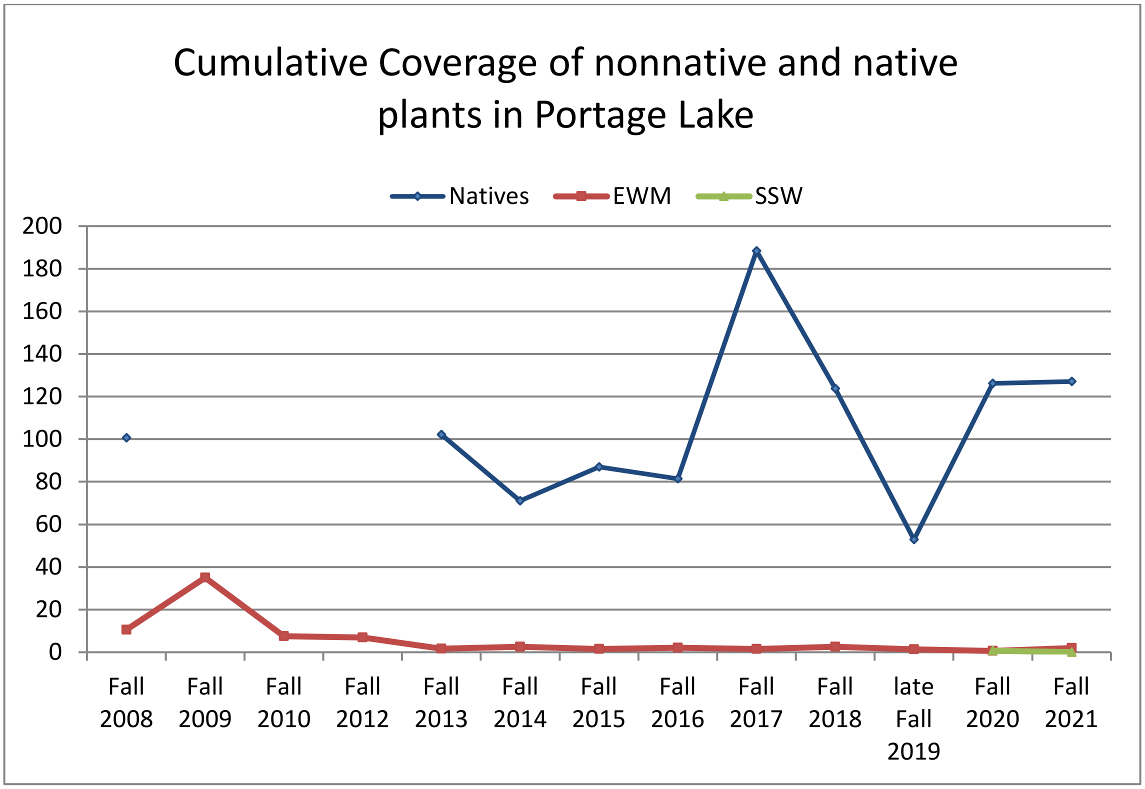


Graph 3: Native Plant Diversity (Fall AVAS Surveys)



This graph shows the diversity of native plants in Portage Lake. Portage Lake has excellent native plant diversity and this has been maintained throughout managing the nonnative plant species.

Graph 4: EWM, SSW & Native Plant Cumulative Cover (Fall AVAS Surveys. EWM data marked with purple dots was not collected by PLM. It was taken from data collected in Portage Lake LMP's, 2009-2012.)



This graph shows the cumulative coverage of EWM, SSW & Native plants from 2008-2021. The overall decline in the presence of EWM from the start of the management program shows the success of the program and that the population is currently being maintained at very low levels. The 2019 survey found great diversity but lower density, likely contributed to the weather patterns and a cooler September than the previous few years when increases in plant growth were found. As thought in 2019, the 2020 densities increased, with a warmer fall and earlier survey. The native plant population will naturally vary from year to year based on weather, water depth and many other factors; but has been maintained during the management of EWM.

Current Conditions in the Lake

Aquatic Vegetation

Over the years, the presence of Eurasian watermilfoil and Curlyleaf pondweed undoubtedly reduced native plant diversity in the lake. Curlyleaf pondweed, although aggressive, naturally dies out mid-season and the increase in native plants after that die off is evident when looking at the early and late season surveys. With the new introduction of Starry stonewort, potential impact to native plant communities is increased with this aggressive species. Native plants currently have good diversity and density in the lake and though proper management, they can be maintained.

Native plant diversity will continue to be promoted in the lake. The native plant species in Portage Lake benefit the lake, performing such functions as stabilizing sediments and providing habitat for fish and other aquatic organisms. In general, native species cause few problems, compared with those caused by exotic plants. Plant diversity is key to maintaining and improving the overall ecological balance of Portage Lake.

All of the plants listed in Table 3 are native North American species except Eurasian watermilfoil, Curlyleaf pondweed, Starry stonewort Purple loosestrife and Phragmites. These plants are nonindigenous aquatic nuisance species, i.e., plants from other places. These exotic plants cause considerably more problems than most native species. Eurasian watermilfoil and Starry stonewort can attain nuisance levels of growth at almost any time of year, whereas curly leaf pondweed completes its lifecycle and drops out of the water column by approximately the Fourth of July.

The native plant species benefit the lake, performing such functions as stabilizing sediments and providing habitat for fish and aquatic organisms. In general, native species cause few problems, compared with those caused by exotic plants. Three species commonly found in Portage Lake:

Coontail

Sago pondweed

Wild Celery

Water Quality Monitoring

Water quality monitoring is a critical part of lake management. Water quality monitoring provides an ongoing record of conditions in a waterbody. Changes in water quality can indicate threats from sources such as failed or inadequate septic systems, agricultural and lawn runoff, burgeoning development and erosion from construction site. Prompt identification of threats to water quality makes it possible to remedy them before irreversible harm has been done. Riparian's enjoyment of the water resource and the value of their property depend on maintaining water quality. The following tables break down the parameters tested in the different locations in Portage Lake including the Deep Hole Basins (Basin 1 and Basin 2), Shoreline Sites (3A, 3B, 3D), Tributaries (Glen Creek, McCormick Creek, Onekama Creek, Schimke Creek, Dunham Creek, Stream #9, Hansen Creek) and Storm Drains (#2, #5, #6, #7).

The graphs and tables below contain historical water quality data on Portage Lake that has been collected from numerous parties other than PLM. All information was made available to PLM via the Invasive Species Committee, on behalf of the Portage Lake Watershed Forever and Onekama Township and used with permission.

Map 6: Portage Lake Water Quality Testing Locations

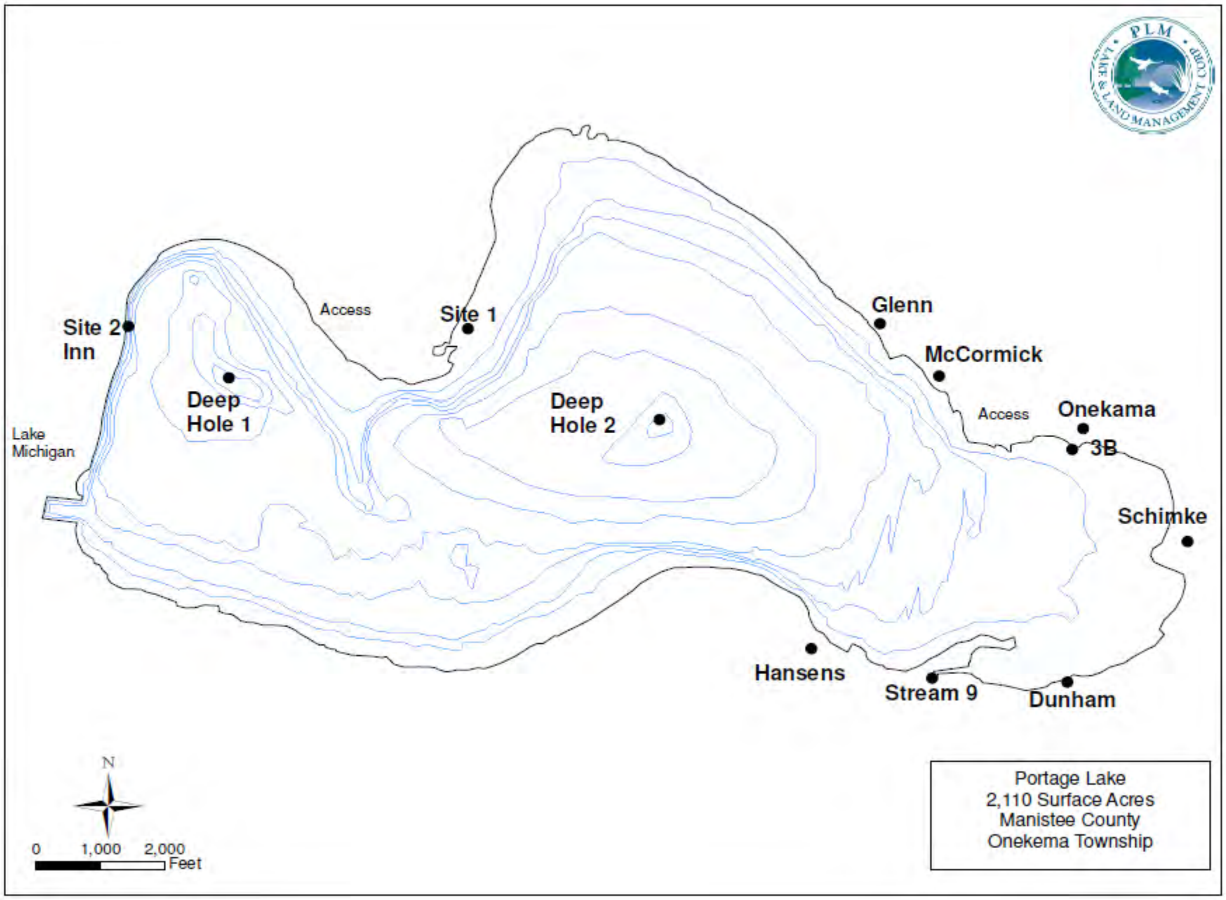


Table 4: Tributary Water Quality Portage Lake –2021

5/3/2021 Sunny Wind 5-10	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (mg/L)	Flow (Ft/sec)
Glenn	49.1	10.8	388.8	253	8.38	7	0.797	1420	0.083	0.6
McCormick	49.2	9.17	390.3	254	8.21	9	0.296	790	0.027	0.4
Onekama*	50	10.56	376.1	244	8.44	8	1.07	1180	0.074	0.4
Schimke	50.7	10.56	369	240	8.36	7	0.7	940	0.015	1.8
Dunham	50.9	10.59	362.8	236	8.36	9	0.443	760	0.028	1.4
Hansen	51.8	10.02	396.3	257	8.24	8	0.365	770	0.017	1.2
Stream #9	53.9	9.75	338.6	220	8.16	8	0.515	470	0.041	0.8
9/28/2021	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**Flow (Ft/sec)**
Glenn	51.26	10.65	387.5	197.6	8.49	7	0.006	1450	0.07	1
McCormick	51.62	9.49	387.5	81.4	8.37	9	0.134	936	0.012	0.8
Onekama	51.8	10.65	375.6	154.5	8.61	8	0.03	1350	0.05	1.8
Schimke	52.5	10.55	378.5	189.4	8.56	8	0.134	1040	0.02	1.4
Dunham	53.06	10.37	356.1	207.7	8.6	9	0.52	853	0.051	1.6
Hansen	55.9	9.69	191.6	210.4	8.47	7	0.085	859	0.03	1
Stream #9	57.02	9.84	356.7	190.5	8.35	20	0.008	639	0.052	1.2

Table 5: Deep Hole Basin 1 Portage Lake –2021

(Secchi Disc: June 16, July 15’, Sept.12.5’)

Basin 1 June 8 2021	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	71.6	9.47	280.3	182	8.63	7	201.2	0.77	4.04	230	0.015	124	3.36
10'	67.6	9.78	278.6	181	8.62	-	208	0.81	-	-	-	-	-
20'	58.6	11.81	266.9	173	8.57	-	221.2	0.67	-	-	-	-	-
30'	53.2	12.02	268	174	8.43	8	231.4	0.7	1.81	230	0.01	126	5.3
40'	51.8	11.43	271.2	176	8.54	-	221	0.57	-	-	-	-	-
50'	51.5	10.89	272.4	177	8.43	-	229.2	0.32	-	-	-	-	-
60'	50.9	10.18	269.1	177	8.41	7	227.4	0.41	7.6	230	0.01	124	1.52
Basin1 Jul 29 2021	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
s.	74.12	9.97	255.7	166	9	8	145.2	0.65	2.25	230	0.01	108	7.49
10'	71.78	10.06	258.7	168	8.86	-	157.5	0.73	-	-	-	-	-
20'	61.3	11.46	261	170	8.76	-	168.9	0.58	-	-	-	-	-
30'	57.2	10.55	267.7	174	8.58	8	178.2	0.46	1.92	230	0.01	109	13.7
40'	54.8	4.36	286.6	186	7.91	-	199	0.17	-	-	-	-	-
50'	54.5	3.19	288.3	187	7.76	-	202.1	0.17	-	-	-	-	-
60'	54.5	2.52	289.5	188	7.73	8	153.7	1.67	1.93	230	0.01	120	11.6
Basin1 Sep29 2021	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
s.	62.7	9.2	264.1	172	8.58	56	127.9	0.18	1.1	230	0.215	126	12.6
10'	62.4	9.21	263.9	172	8.58	-	139.8	0.25	-	-	-	-	-
20'	57.3	7.94	269.1	175	8.21	-	156.6	0.15	-	-	-	-	-
30'	56.1	7.64	269.9	175	8.16	7	163.7	0.5	0.68	230	0.018	133	5.29
40'	55.2	6.7	271	176	7.92	-	175.7	1.01	-	-	-	-	-
50'	55.04	6.3	271.5	176	7.87	-	179.8	1.2	-	-	-	-	-
60'	54.8	5.7	272	177	7.8	8	178.3	11.81	0.55	230	0.329	124	14.9

Table 6: Deep Hole Basin 2 Portage Lake –2021

(Secchi Disc: June 14’, July 10.5’, Sept. 9’)

Basin 2 June 8 2021	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	72.4	9.61	280.7	182	8.61	8	208.2	0.77	6.33	230	0.029	121	16.7
10'	67.4	9.93	279.1	181	8.62	-	213.5	0.75	-	-	-	-	-
20'	64	10.29	277.3	180	8.4	-	229.8	0.7	-	-	-	-	-
30'	59	10.75	276.2	179	8.37	8	234.1	0.7	0.45	230	0.017	125	2.32
40'	55.7	10.34	280.5	182	8.24	-	241.6	0.56	-	-	-	-	-
50'	54.5	9.14	284.6	185	8.11	-	247	0.28	-	-	-	-	-
60'	53.9	8.79	281.1	183	8.09	7	244.2	0.72	2	230	0.01	124	0.807
Basin2 Jul 29 2021	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
s.	74.6	9.94	256.3	167	8.93	8	167.6	0.49	1.1	230	0.01	111	8.13
10'	76.3	10.58	256.5	167	8.89	-	175	0.67	-	-	-	-	-
20'	65.8	10.9	2563.4	171	8.7	-	182.5	0.49	-	-	-	-	-
30'	61.88	6.43	281.9	183	8.1	8	203.3	0.4	1.11	230	0.01	105	3.42
40'	60.2	2.94	290.4	189	7.67	-	219.8	0.24	-	-	-	-	-
50'	59.3	1.05	294.6	192	7.53	-	163.5	0.49	-	-	-	-	-
60'	59.1	0.86	295.5	192	7.48	8	124.8	0.049	1.43	230	0.01	130	3.74
Basin2 Sep28 2021	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
s.	63.5	8.83	264.5	172	8.48	8	197.6	0.13	0.451	230	0.03	119	51.8
10'	63.5	8.53	264.5	172	8.44	-	28.2	0.33	-	-	-	-	-
20'	63.5	8.67	264.7	172	8.44	-	56.1	0.1	-	-	-	-	-
30'	63	8.16	265.6	173	8.36	8	70.9	0.38	0.214	230	0.032	114	14.5
40'	62.6	7.64	267	174	8.27	-	81.8	0.51	-	-	-	-	-
50'	61.8	6.49	271.6	177	8.05	-	91.9	1.72	-	-	-	-	-
60'	60.2	0.44	300.3	195	7.62	8	108.8	8.75	0.562	230	0.219	121	19.4

Table 7: Shoreline Sampling Portage Lake –2021

Jun8 Secchi	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
Cove 7'	71.06	9.7	280.3	182	8.64	8	192.6	0.72	8.64	230	0.053	122	7.05
3B 7'	73.9	9.43	283.6	184	8.54	8	201.9	0.53	3.3	230	0.04	123	1.86
Inn 9'	70.16	9.51	278.6	181	8.66	8	201	0.75	1.17	230	0.019	118	1.71
Jul 29 Secchi	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
Cove 5'	74.6	9.96	254	165	8.99	8	147.7	0.71	0.641	230	-	109	6.09
3B 5'	76.8	10.3	255.5	166	9.01	8	143.2	0.27	1.86	230	-	106	7.38
Inn 10'	74.4	10.04	255.8	166	9.01	8	149.4	0.66	0.79	230	-	100	5.34
Sep28 Secchi	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
Cove 3'	62.9	9.19	266.1	173	8.54		124.1	0.1	-	-	-		40.4
3B 5'	63.8	10.14	266.9	174	8.78	8	180.2	0.27	0.251	230	-	115	17.8
Inn 4'	62.6	9.42	263.7	171	8.65	8	177.9	0.29	0.212	230	-	115	28.30

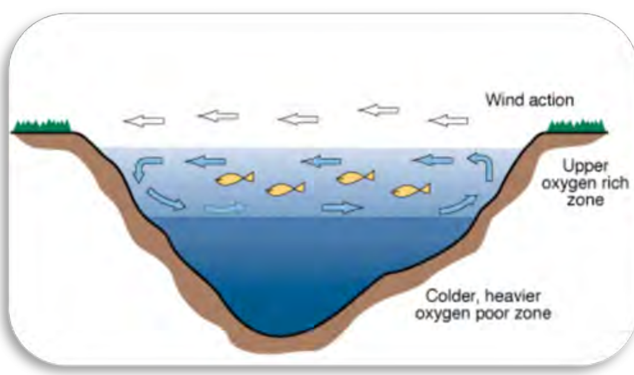
In 2019, samplings were moved to new shoreline sites. 3B remained the same standard site 3B, but 3A was moved to the small cove and 3D was moved to Portage Point Inn.

Table 8: Storm Drain Sampling Portage Lake –2021

May 5, 2021	Temp (C)	D.O. (mg/L)	Cond. (uS/cm)	TDS (mg/L)	pH (S.U)	TP (ug/L)	Nitrate (ug/L)	Flow (Ft/sec)	Weather Sunny
#2 Zosel Park	-	-	-	-	-	-	-	-	No water/flow present
#5 Fourth St	54.1	6.4	2.2	1	7.77	9	230	0.3	Slow, clear
#6 Third St	51.4	9.35	386	251	7.98	15	470	0.1	Clear, low flow
#7 First St.	54.8	6.07	1401	913	7.44	63	230	0	No flow, stagnant

Temperature and Dissolved Oxygen Profiles

Depth profiles of temperature and dissolved oxygen indicate that on June 8 the lake was already stratified. The surface levels were above saturation, 9.47 mg/L at Basin 1 and 9.61 mg/L at Basin 2 with shoreline ranging from 9.19 to 10.30 mg/L. At this time, Portage Lake had adequate dissolved oxygen all the way down to 60' in depth (10.18 mg/L in Basin 1 and 8.71 mg/L in Basin 2). On June 8, the lake was thermally stratified, with a thermocline at approximately 10' in Basin 1 and 10' in Basin 2 – slightly higher than in 2019 and 2020. The epilimnion (i.e., water above the thermocline) was well oxygenated, with oxygen concentrations at adequate levels to support a healthy fishery. Conditions in the hypolimnion (i.e., water below the thermocline) were also oxygenated.



On May 6, four storm drains (table 9) and seven tributaries (table 4) were tested coming into Portage Lake. The storm drains had similar DO levels to past years, expect for Drain #2 Zosel Park which couldn't be sampled due to water levels. All of the tributaries were well oxygenated ranging from 9.14 to 10.59 mg/L, similar to previous years.

In late July, the lake was still strongly divided. The late July sampling was added into the program in 2015 and has been sampled since. Basin 1 was stratified and was almost anoxic at the bottom of the lake (void of oxygen). The thermocline in Basin 1 was 20', similar to most recent years. Oxygen levels stayed more consistent and didn't start declining until 40' and at that point the oxygen levels started a quick drop from 10.55 mg/L to 2.52 mg/L. These levels are lower (more concerning) than 2021 sampling. 3.0 mg/L is generally considered anoxic. In Basin 2, the surface waters had oxygen levels at 9.94 mg/L (similar to past years) and a thermocline at 30'. Oxygen levels the last few years have been better in the July sampling, but in 2021, levels were concerning again. Basin 2 deep sample had a reading of 0.86 mg/L compared to 4.83 mg/L in 2020, 3.45 mg/L in 2019 and to 0.93 mg/L in 2018. In 2021, oxygen levels below 30' were concerning, showing signs of anoxic water.

During the fall, the lake was still stratified strongly in Basin 1 and slightly in Basin 2 during the sampling period. In years past, both mixing and no mixing has been found during this sampling period. The warmer Michigan Fall seasons witness the last few years will impact this greatly. Basin 1 was stratified and it was NOT anoxic below the thermocline (void of oxygen), which is excellent. DO levels ranged from 9.2 mg/L at the surface to 5.7 mg/L at the bottom, much higher than in 2020. In Basin 2, which in many years has already mixed, had a thermocline during the sampling at 50', which is very deep. Further, the oxygen was saturated from top to the thermocline and then was void of oxygen to the bottom. 8.83 mg/L at the surface, 6.49 mg/L in the thermocline and 0.44 mg/L at the bottom.

Substantial oxygen demand leads to rapid deoxygenation of the hypolimnion upon thermal stratification in the spring and oxygen concentrations are frequently decreased in bottom waters during the summer. Depletion of oxygen beneath the thermocline during the summer is a common symptom of eutrophication, and often leads to elevated internal nutrient loading as the result of the release of phosphorus from hypolimnetic sediments. The 2019 sampling showed good oxygen levels present in the hypolimnion, compared to previous years, as did some of the 2020 readings. The 2021 sampling wasn't as positive.

pH

pH describes the balance between acids and bases in the water. Neutral values of pH are desirable. Low pH values typically result either from the growth of bog vegetation (such as peat moss), acid precipitation ("acid rain"), or acid runoff (as in acid mine drainage). Excessive growth of certain plants and algae can raise pH values. A majority of Michigan lakes have pH values in the 7-9 range. Portage Lake pH was recorded in Basin 1 and Basin 2 in the June, July and September as well as in the tributaries and shoreline sites. The pH in June ranged 8.09 - 8.63, in July from 7.48 -9.00 and in September from 7.62 - 8.58. The shoreline sampling was similar to the deep hole basins as was the tributary and storm drain sampling. This data is consistent with previous samplings.

Total Alkalinity

Alkalinity, in addition to pH, measures the amount of dissolved bases and the balance of acids and bases in the water. Alkalinity specifically measures the concentration of carbonates and bicarbonates in the water. These compounds and other ions associated with them can make water "hard". High alkalinity lakes are hardwater lakes, while low alkalinity lakes are softwater lakes. Different kinds of plants, algae and other aquatic organisms live in hardwater versus softwater. Alkalinity is a basic characteristic of water and is neither inherently good nor bad. Total Alkalinity was measured in June, July and September in both Basin 1 and Basin 2. The average sampling between both basins in June was 124 mg/L with a range of 121-126 mg/L. The July samples were similar with an average of 113 mg/L with a range of 105 - 130 mg/L. The September samples were similar with an average of 122 mg/L with a range of 119 - 133 mg/L. All samplings show the lake to be considered "soft" with readings under 150 mg/L, a typical threshold of a hardwater lake. Overall, the 2021 readings on the lake are slighter higher than previous readings, but overall show consistent softwater data for Portage Lake.

Conductivity and Total Dissolved Solids

Conductivity and Total Dissolved Solids (TDS) measure the total amount of material dissolved in the water. Higher values indicate potentially rich, more productive water, whereas lower values indicate potentially clean, less productive water. (If nutrient pollution is occurring, the total phosphorus concentration is a much better indicator of potential productivity.) The combined readings of TDS on Portage Lake ranged from June readings averaging 179 ug/L, July averages of 178 ug/L to September readings averaging 175 ug/L. (Shoreline samplings were very similar to deep basins). The tributary sampling was slightly higher, averaging 243 ug/L in May and 175 ug/L in September. Overall, these averages classify the overall TDS of Portage Lake as Low Dissolved material. The conductivity readings on Portage Lake are slightly higher than the TDS readings with the basin average of 276 uS/cm in June, 274 uS/cm in late July and 269 uS/cm in September. (uS/cm=microsiemens per centimeter). Higher levels can likely be due to runoff, which is also supported by the slightly higher conductivity readings from the tributaries (May average Conductivity reading is 374 uS/cm while September average is 347 uS/cm). Tributary readings are similar to past readings.

Oxidative Reduction Potential (ORP)

The oxidative reduction potential of a lake measures the ability of the water to serve as potential oxidizers and indicates the degree of reductants present within the water (the ability to gain or lose electrons). The reduction potential measurement has proven useful as an analytical tool in monitoring changes in a system rather than determining their absolute value. Like pH, the redox potential represents an intensity factor. It does not characterize the capacity of the system for oxidation or reduction; in much the same way that pH does not characterize the buffering capacity. Generally speaking, higher ORP values, the healthier the lake. As a lake stratifies and oxygen levels decrease towards the bottom of the lake, ORP values will decrease even in a healthy lake due to the lack of oxygen. This is because there are many bacteria working in the sediments to decompose the material and they use up the available oxygen. ORP is measured in addition to pH and dissolved oxygen as it can provide additional information of the water quality and degree of pollution, if present. High ORP values indicate high levels of oxygen in the water and that bacteria that decompose the dead matter can work more effectively. The deep basins ranged from 201 - 247 mV in June sampling to 124 - 219 mV in the late July sampling to 28 - 197 mV in the end of summer/fall sampling, indicating oxidized conditions. Tributaries and shoreline samples had similar results to past years.

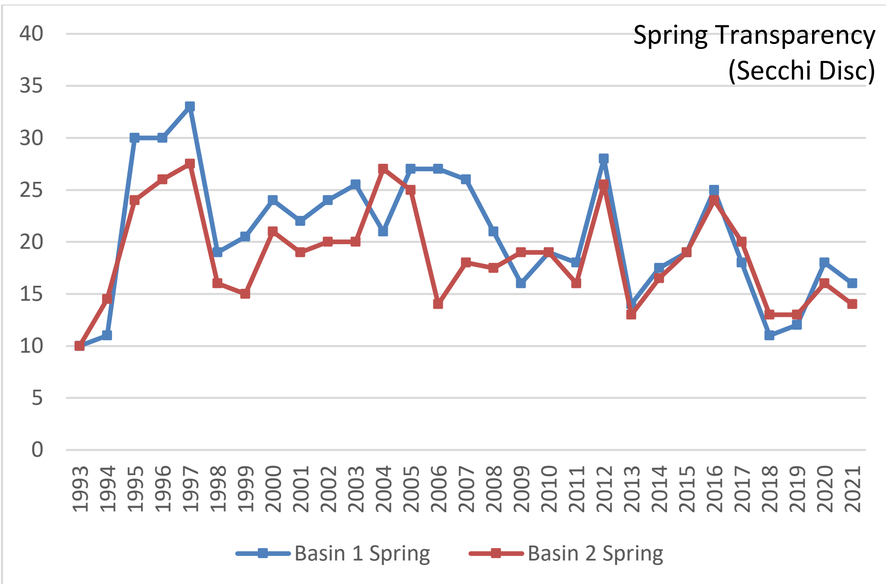
Turbidity

Turbidity is a measure of the clarity of the water, specifically from the presence of suspended particles in the water. Turbidity will typically increase as the suspended particles in the water increase, lowering clarity of the water. Turbidity may be caused by a variety of factors from the bottom sediments, erosion, algae production, and runoff and possibly from fish species such as carp. Suspended particles can capture heat from the sun raising water temperature as well (often witnessed in shallow waters). Turbidity readings on Portage Lake ranged from 0.28 – 0.81 NTU's in June to 0.17 –1.67 (at the bottom) NTU's in late July to 0.18 – 11.81 NTU's in October. This outlier result is likely due to the bottom sediments getting disrupted during sampling and should be thrown out based on historical data. Shoreline sampling ranged from 0.53 - 0.75 NTU's in June, 0.27 - 0.71 NTU's in late July and 0.1 – 0.29 NTU's in September. The World Health Organization (WHO) requires drinking water be less than 5 NTU's, but recreational water can be significantly higher. Overall, the turbidity readings on Portage Lake are within safe drinking water standards and overall show that clarity should be very good on the lake.

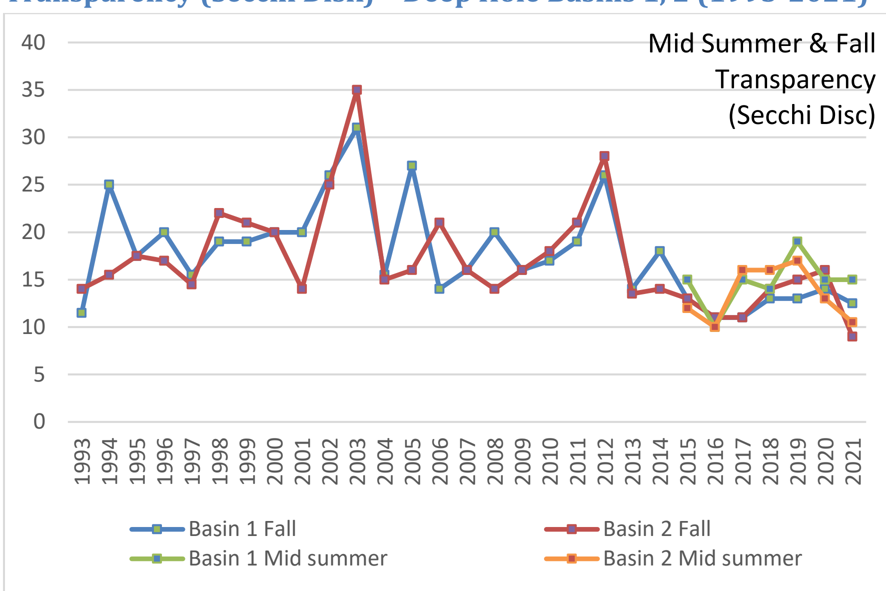
Secchi Disk Depth

The Secchi disk depth is another measure of water clarity, determined by measuring the depth to which a black and white disk can be seen from the surface. (Larger numbers represent greater water clarity.) In June, Basin 1 was 16' while Basin 2 was 14'. Clarity decreased with the Secchi disk depth of 15' in late July in Basin 1 and 10.5' in Basin 2 and was at 12.5' in Basin 1 and Basin 2 was at 9' in September, which is lower than normal. Water clarity can fluctuate from week to week depending on several environmental factors such as rain fall & algal production. Basin 2 may likely be more affected by the fetch of the lake, therefore would likely have a lower Secchi disk reading, which is not evident each year. These clarity readings show that sunlight is available for plant and algae throughout a good portion of the lake. The shoreline sampling sites had very good clarity.

Graph 5: Spring Transparency (Secchi Disk) – Deep Hole Basins 1, 2 (1993-2021)



Graph 6: Fall Transparency (Secchi Disk) – Deep Hole Basins 1, 2 (1993-2021)



Total Phosphorus

Total phosphorus measures the total amount of phosphorus in the water. Phosphorus is an important plant nutrient (i.e., fertilizer) and the nutrient most likely to limit algal growth. Phosphorus levels are not only related to internal loading of nutrients but also from external sources. Elevated phosphorus inputs to lakes caused by human activities are a major cause of cultural eutrophication. Readings above 10 μg/L are considered slightly enriched while readings over 30 μg/L are considered enriched.

Total phosphorus concentrations in June in Basin 1 were 7 μg/L at the lake surface, and 8 μg/L at thermocline depth and 7 μg/L in the bottom water. In Basin 2, 8 μg/L at the lake surface, and 8 μg/L at thermocline depth and 7 μg/L in the bottom water. The June shoreline readings from sites Cove was 8 μg/L, 3B was 8 μg/L and the Inn was 8 μg/L.

The tributary TP readings in May ranged from 7 - 9 μg/L (one of the lowest results on record). Storm Drain TP May readings were from 9 - 63 μg/L. In the past, higher TP readings have been found coming from the tributaries and storm drains. Overall, the spring samplings on the lake have stayed similar to past years, showing a slight trend down. The tributaries were down from the past while the storm drains were similar to the past, both of which are standardly more elevated than the basins.

Late July Total Phosphorus concentrations were: Basin 1: 8 μg/L at the surface, 8 μg/L in the thermocline and 8 μg/L at bottom while Basin 2: 8 μg/L at the surface, 8 μg/L in the thermocline and 8 μg/L at bottom. No increases from the June testing and readings are still well below levels of concern and similar to 2020 results.

End of summer Total Phosphorus concentrations were: Basin 1 56 μg/L at the surface, 7 μg/L at 30' and 8 μg/L at bottom while Basin 2; 8 μg/L at the surface, 8 μg/L in the thermocline and 8 μg/L at bottom. All of these results are similar or to 2020 except for the Basin 1 sample, which is an outlier compared to recent data.

In 2017, levels were increased from 2016, but in 2018, levels had decreased and were back similarly to 2016 concentrations. Overall, the sampling in 2019, 2020 and 2021 are all similar, which very few fluctuations overall.

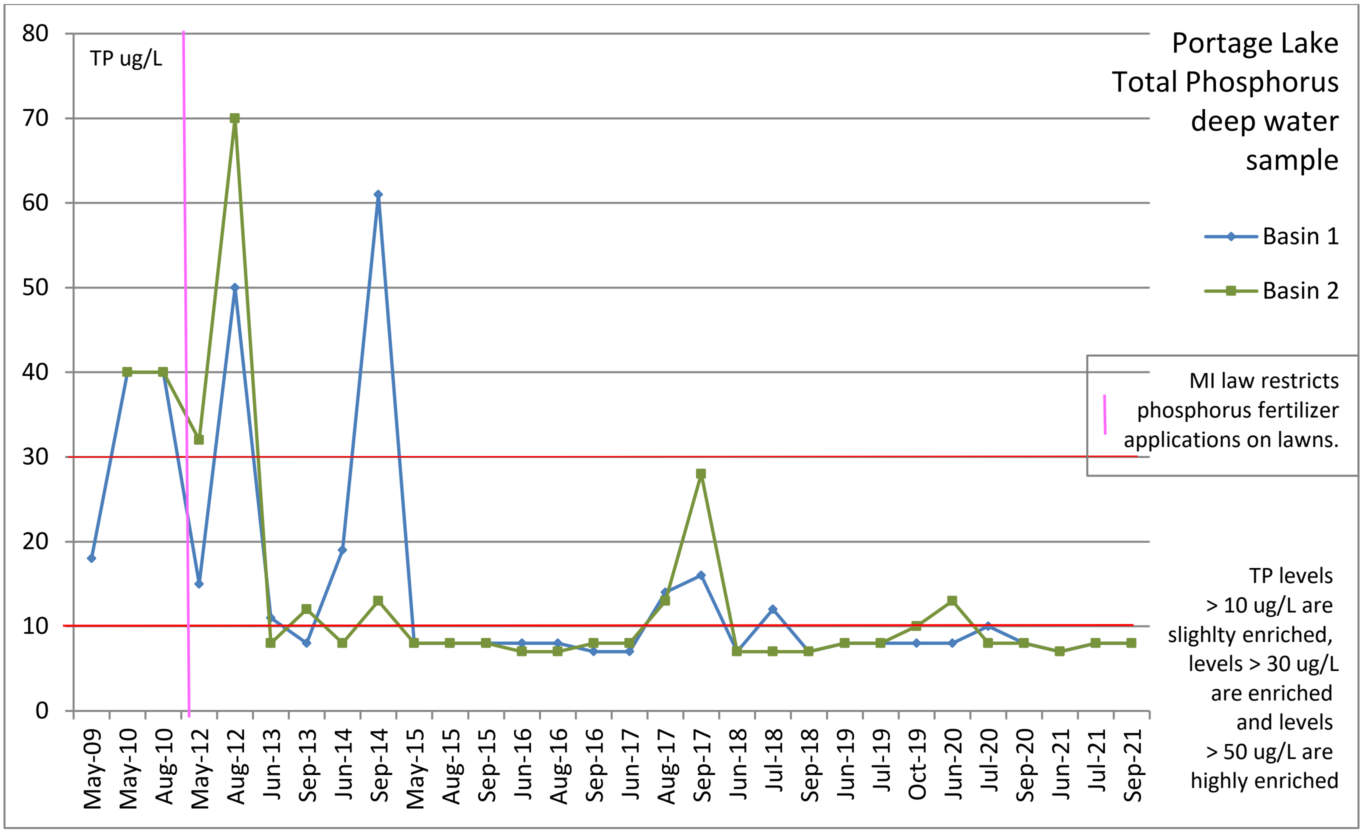
In years past, Tributary sampling showed Stream #9 was generally the highest of the reading; however, in recent years, this is not always been the case. In 2021, the tributaries were similar in the spring and fall and were overall less polluted than years past. Historically, the tributary samplings show higher levels of TP compared to the basins, with numerous results considered slightly elevated-to-elevated. Stream #9, which as additional tributary upstream testing completed, did not have enough flow or water present in the creek, to collect adequate samples in 2021.

Overall readings show that higher phosphorus concentrations are found in the tributaries and that internal loading was not a large contributing factor to TP in 2021. The 2021 data shows the TP had stayed low in both Basins, similar to what was found in 2019 and 2020, and still well below historical data. Past data has shown that Basin 2 is routinely higher in concentrations than Basin 1, which is expected due to the fetch and potential lack of oxygen of Portage Lake; however, the last few years of data has shown a declining trend.

See below graphs of TP concentrations from 2021. Basin 1 and 2 are graphed using data previously collected on Portage Lake (via various sources, provided to PLM via the Portage Lake Watershed Forever website with permission from the committee).

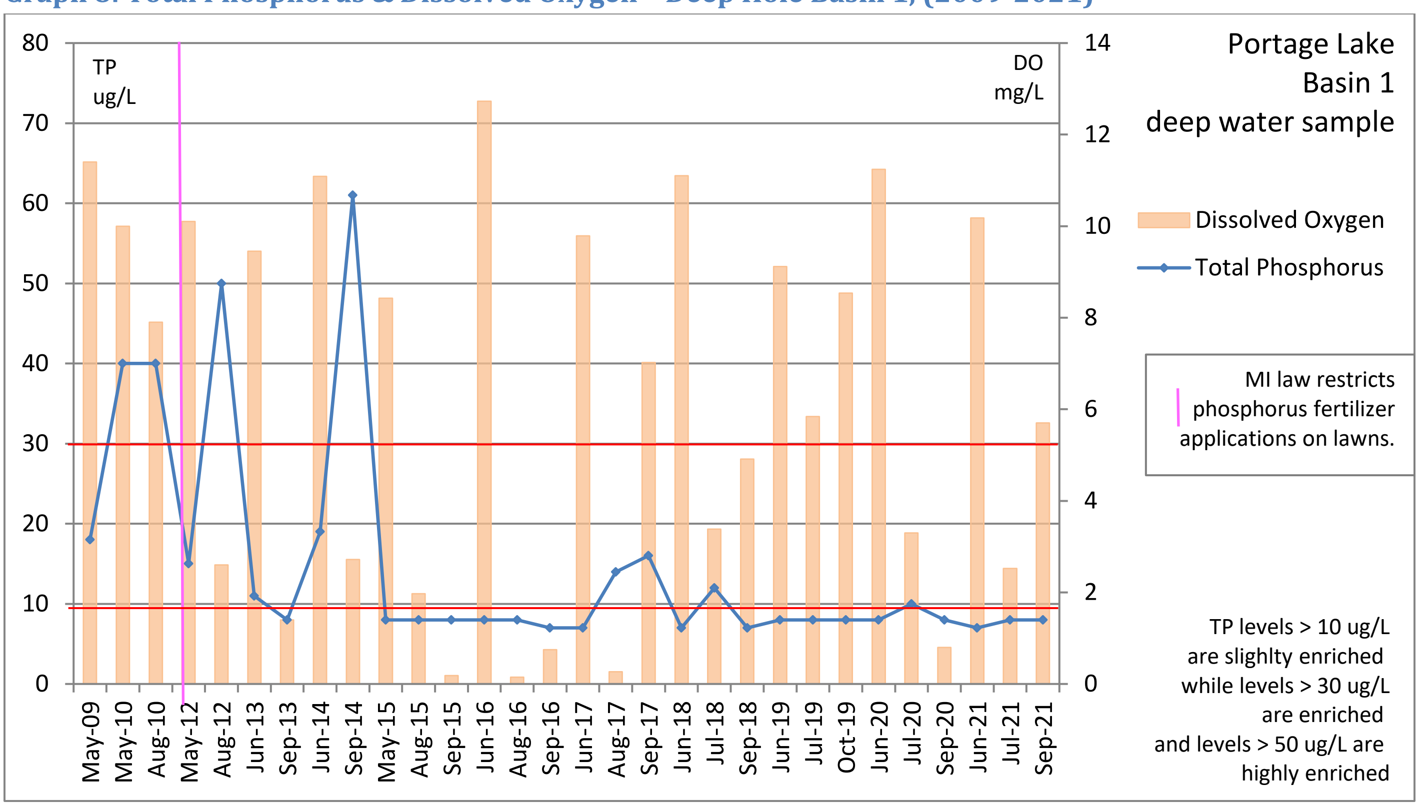
Beginning January 1, 2012, Michigan law restricts phosphorus fertilizer applications on lawns. This is noted in graphs as an event to track Phosphorus trends post ban.

Graph 7: Total Phosphorus – Deep Hole Basins 1, 2 (2009-2021)



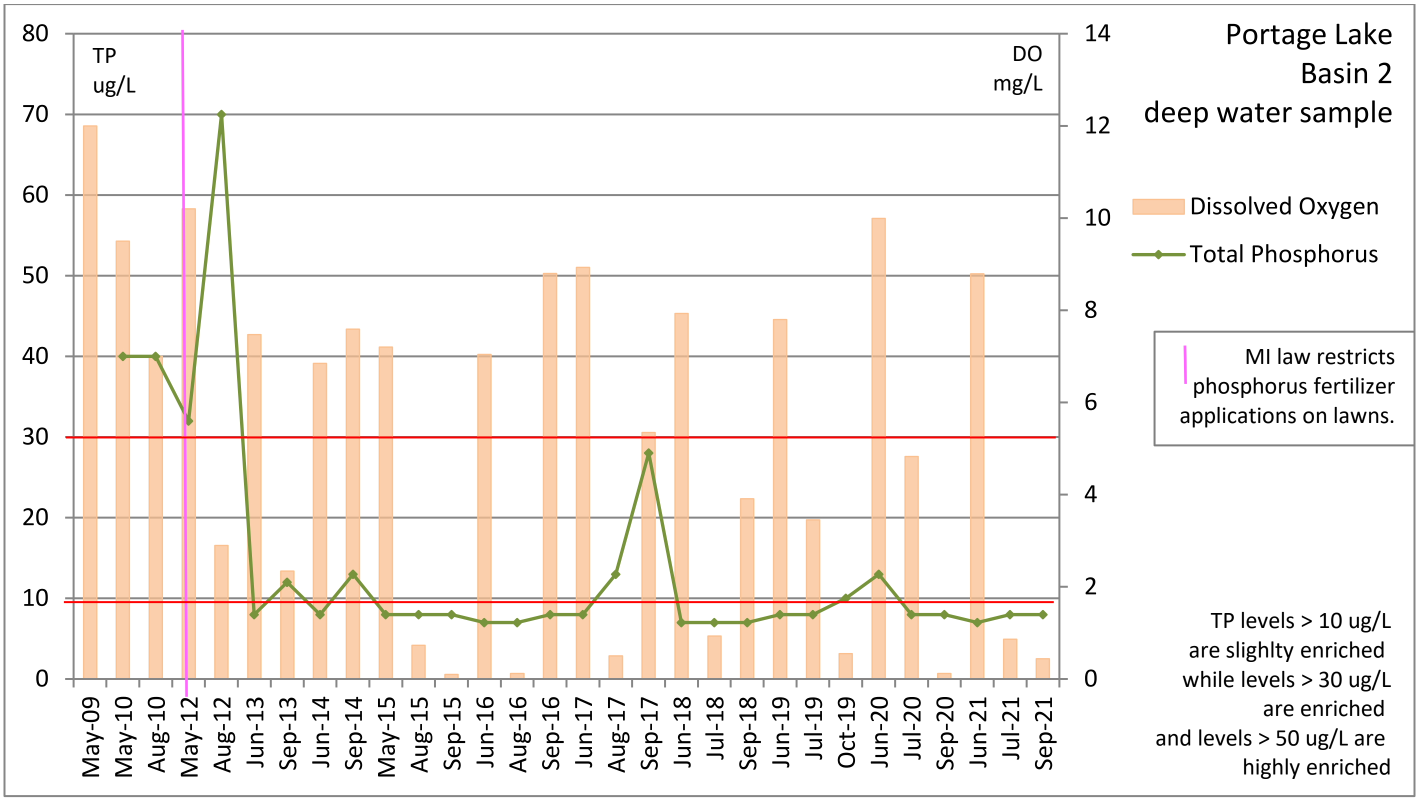
There have been a few spikes in TP over time but generally speaking, the bottom waters of Portage Lake are not classified enriched based on the sampling in recent years. Note: Basin 2 May 2009 sample is not graphed as the reading of 340 ug/L is an extreme outlier and not reflective of the overall lake results.

Graph 8: Total Phosphorus & Dissolved Oxygen – Deep Hole Basin 1, (2009-2021)



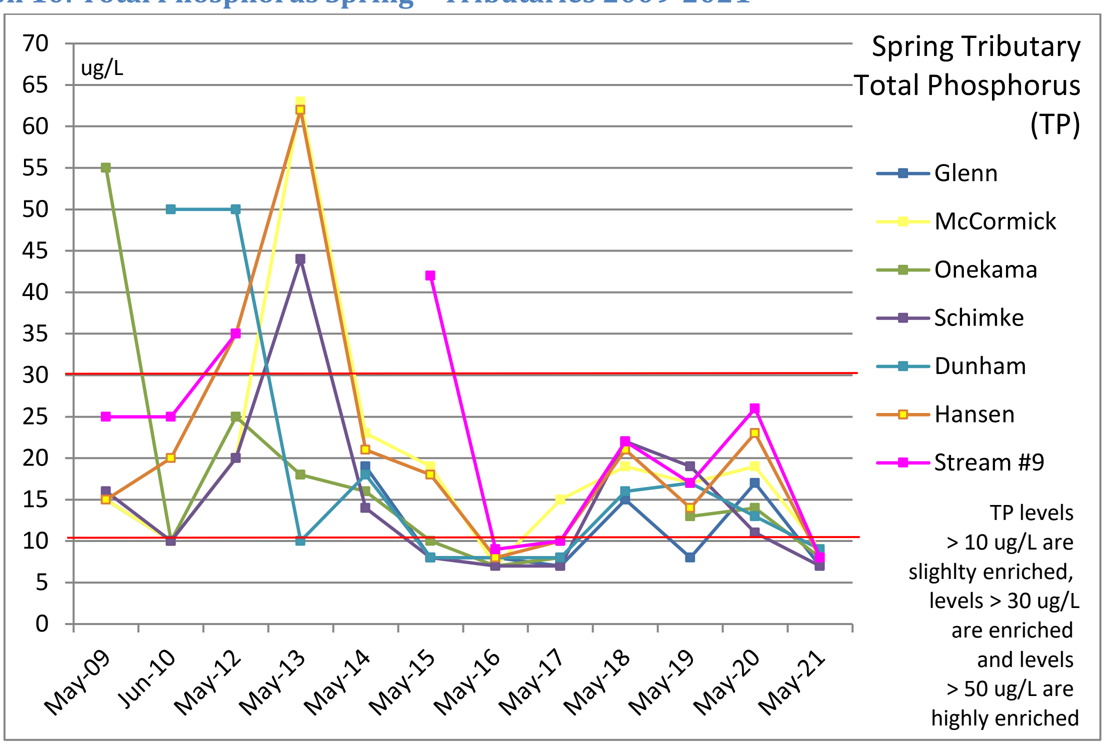
Looking at the trend line, Basin 1 has higher DO levels during mid to late summer months than Basin 2. Higher DO levels are better. Internal loading (spikes in TP) can take place when DO levels decrease. There is no indication of internal loading taking

Graph 9: Total Phosphorus & Dissolved Oxygen – Deep Hole Basin 2, (2009-2019)

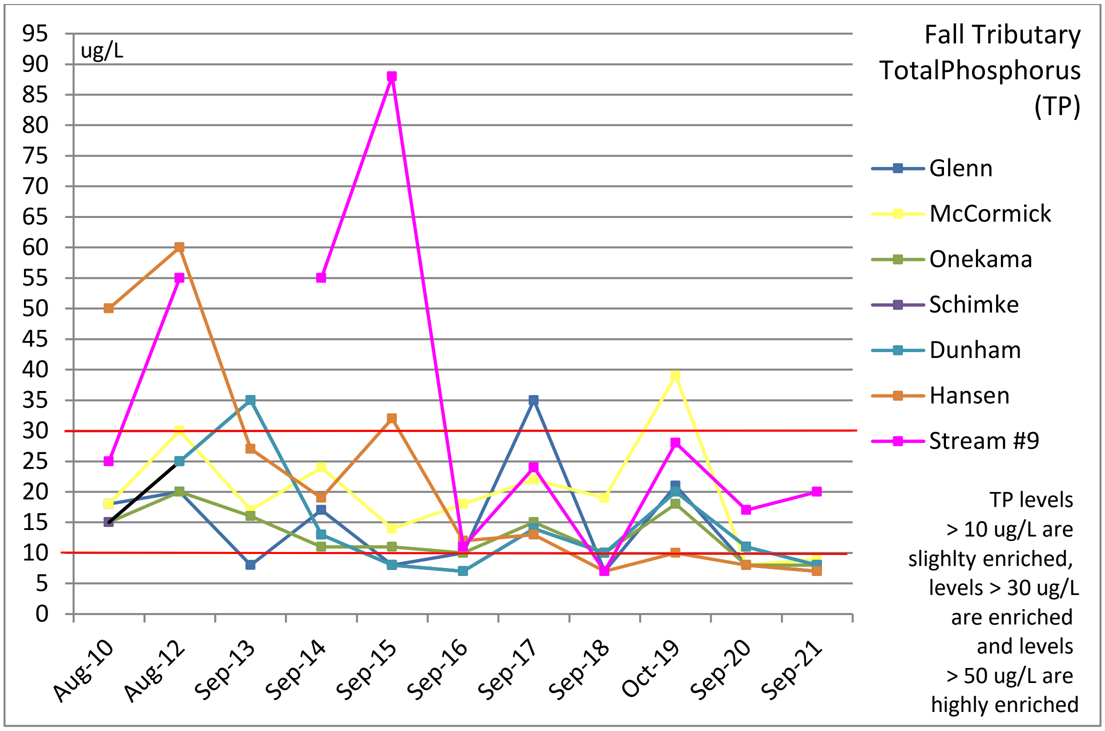


Looking at the trend lines, DO has consistency declined in the mid to late summer months, leading to anoxic conditions. However, TP levels have stayed low; which is an excellent sign. There is no indication of internal loading in Basin 2.

Graph 10: Total Phosphorus Spring – Tributaries 2009-2021

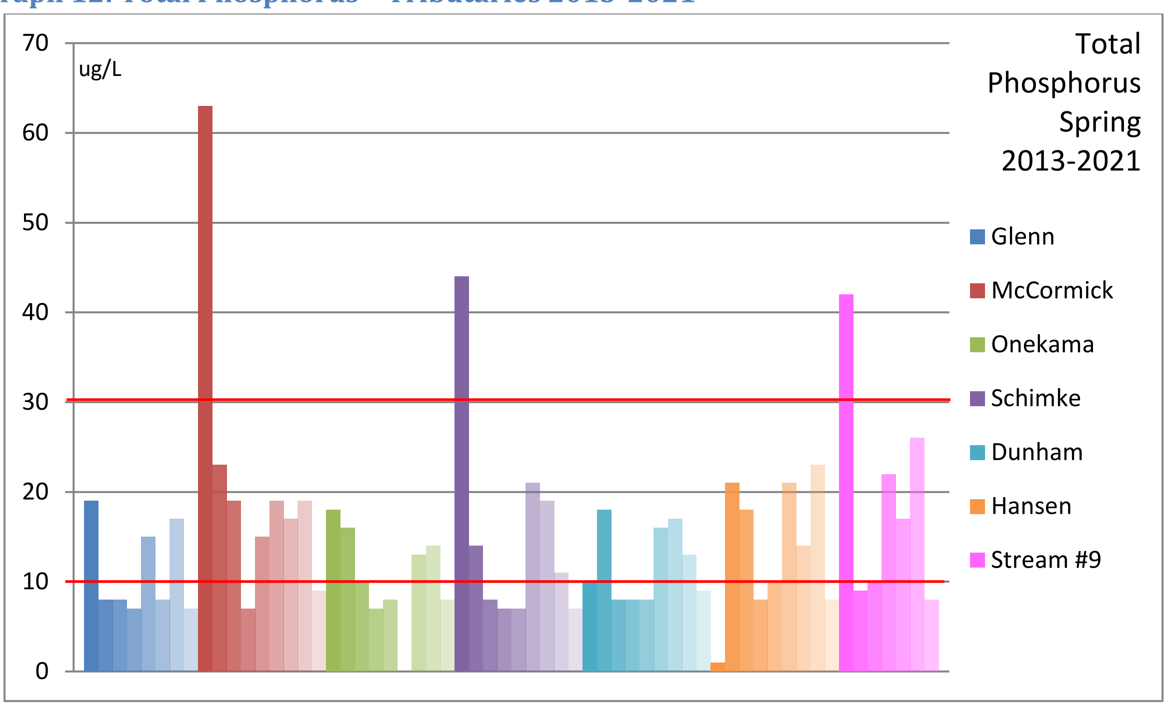


Graph 11: Total Phosphorus Fall – Tributaries 2009-2021



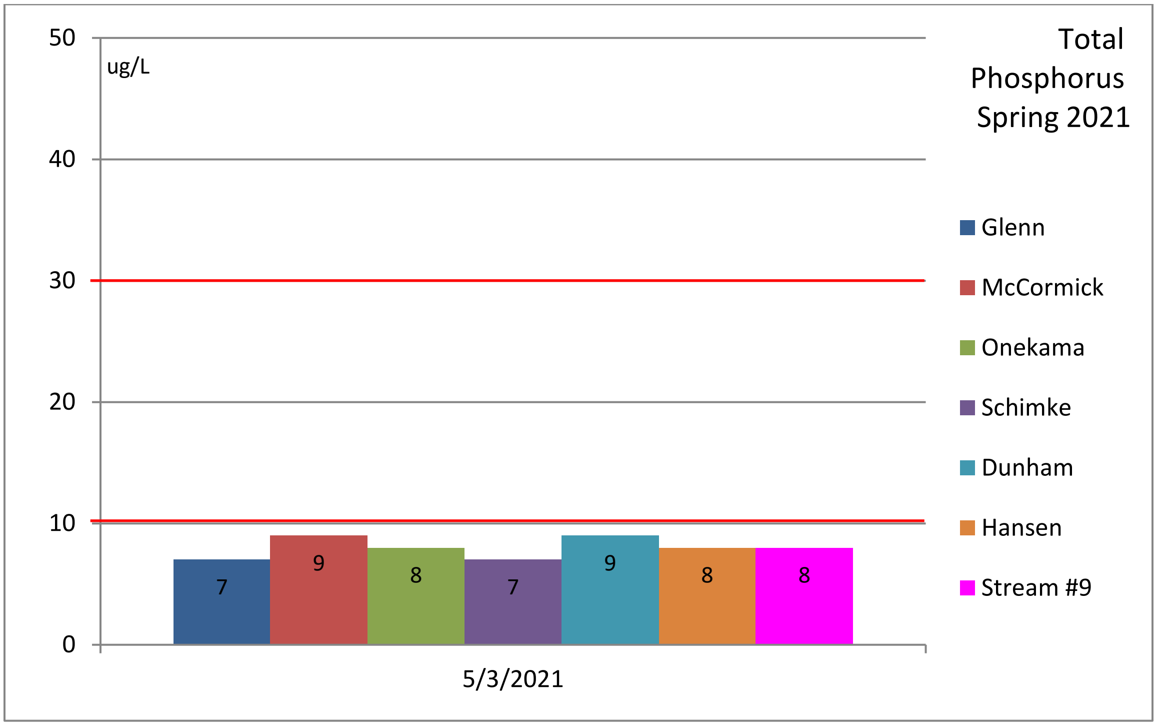
As these graphs illustrate, there are fluctuations between the creeks over time. See below graphs to show the 2021 comparisons between the creeks. Glenn Creek May 2013 sample was removed from this graph as an extreme outlier, likely from a contaminated sample. Stream #9 was not sampled in 2013.

Graph 12: Total Phosphorus – Tributaries 2013-2021



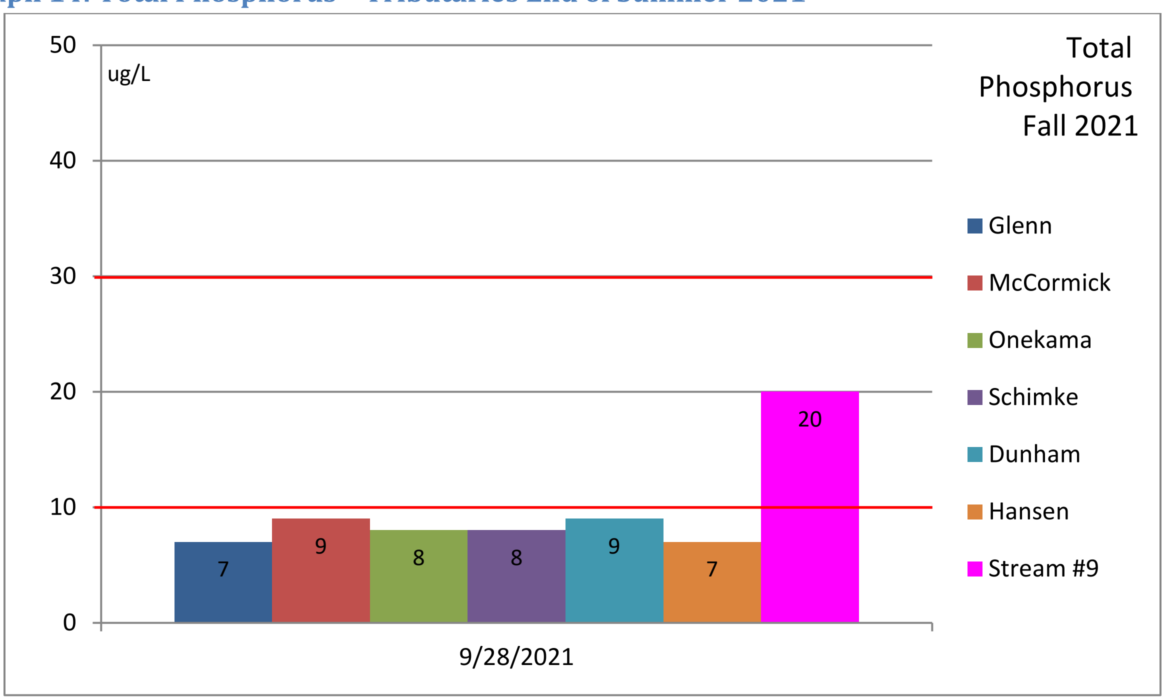
This graph illustrates the fluctuation in TP in each Tributary over time.

Graph 13: Total Phosphorus – Tributaries May 2021



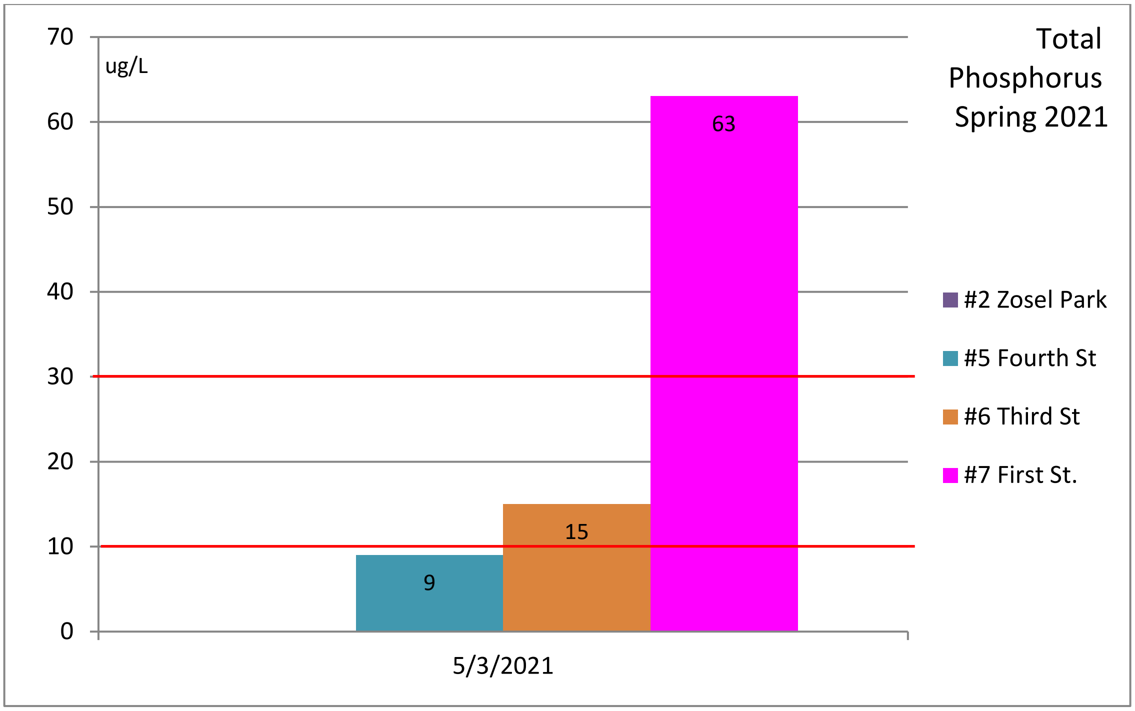
Total Phosphorus in 2021 were all classified as slightly enriched, which is decreased from years past.

Graph 14: Total Phosphorus – Tributaries End of Summer 2021



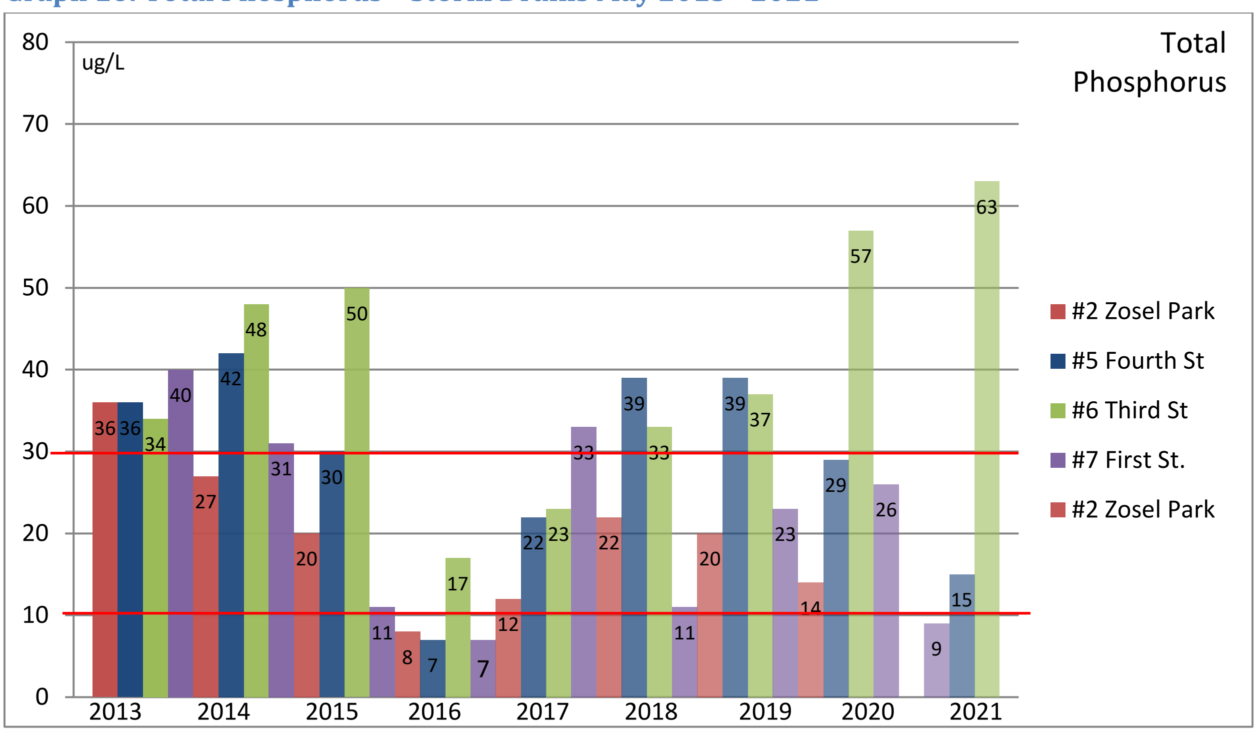
As the graph illustrates, the TP in the fall sampling was also lower than years past. The overall results in 2021 shown above, are a positive sign for the Portage Lake watershed.

Graph 15: Total Phosphorus – Storm Drains May 2021



As the graph illustrates, there is a fluctuation between the TP in the different storm drains around Portage Lake and overall, the samples are mostly enriched with #7 highly enriched in 2021. No water was present for sampling of #2.

Graph 16: Total Phosphorus – Storm Drains May 2013 - 2021

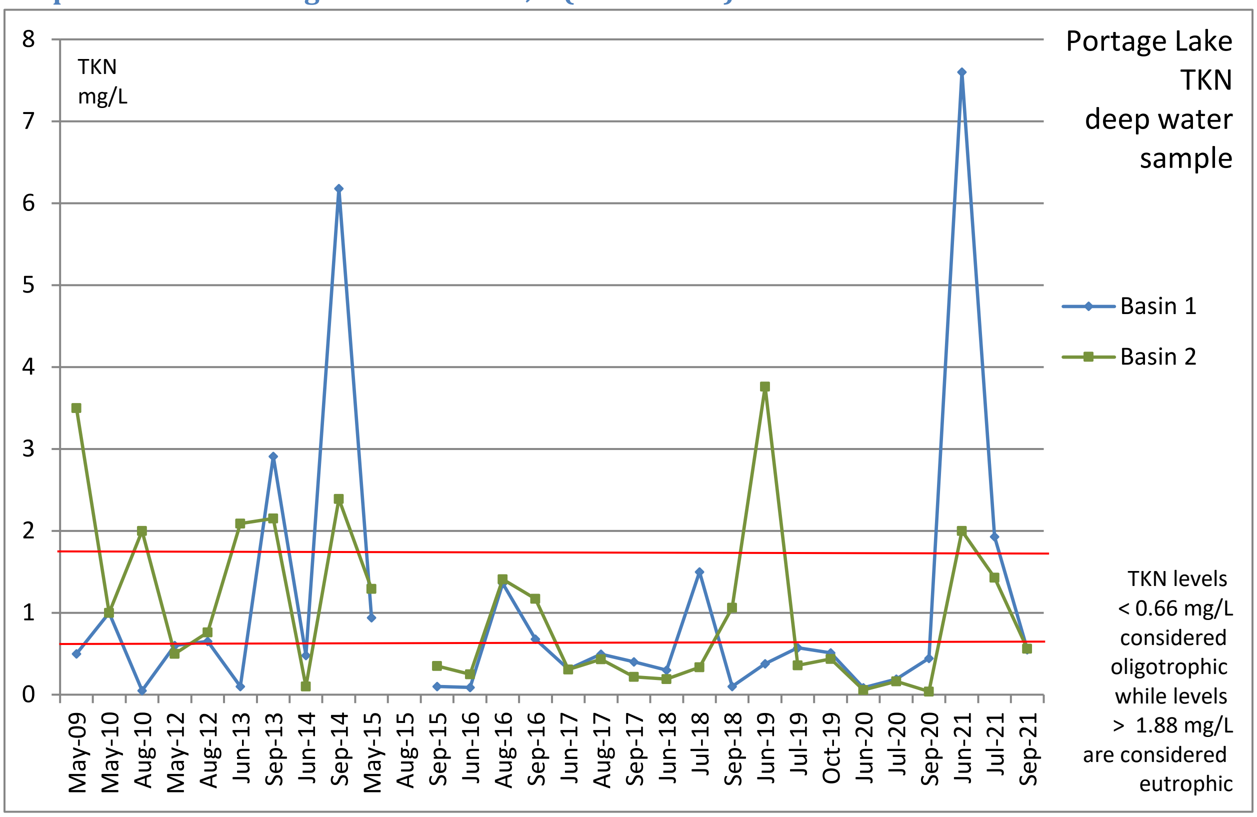


As the graph illustrates, there is variance between the TP in the different storm drains entering Portage Lake and most of the TP concentrations are considered enriched. These sites are a key introduction point of Phosphorus into Portage Lake.

Total Kjeldahl Nitrogen (TKN)

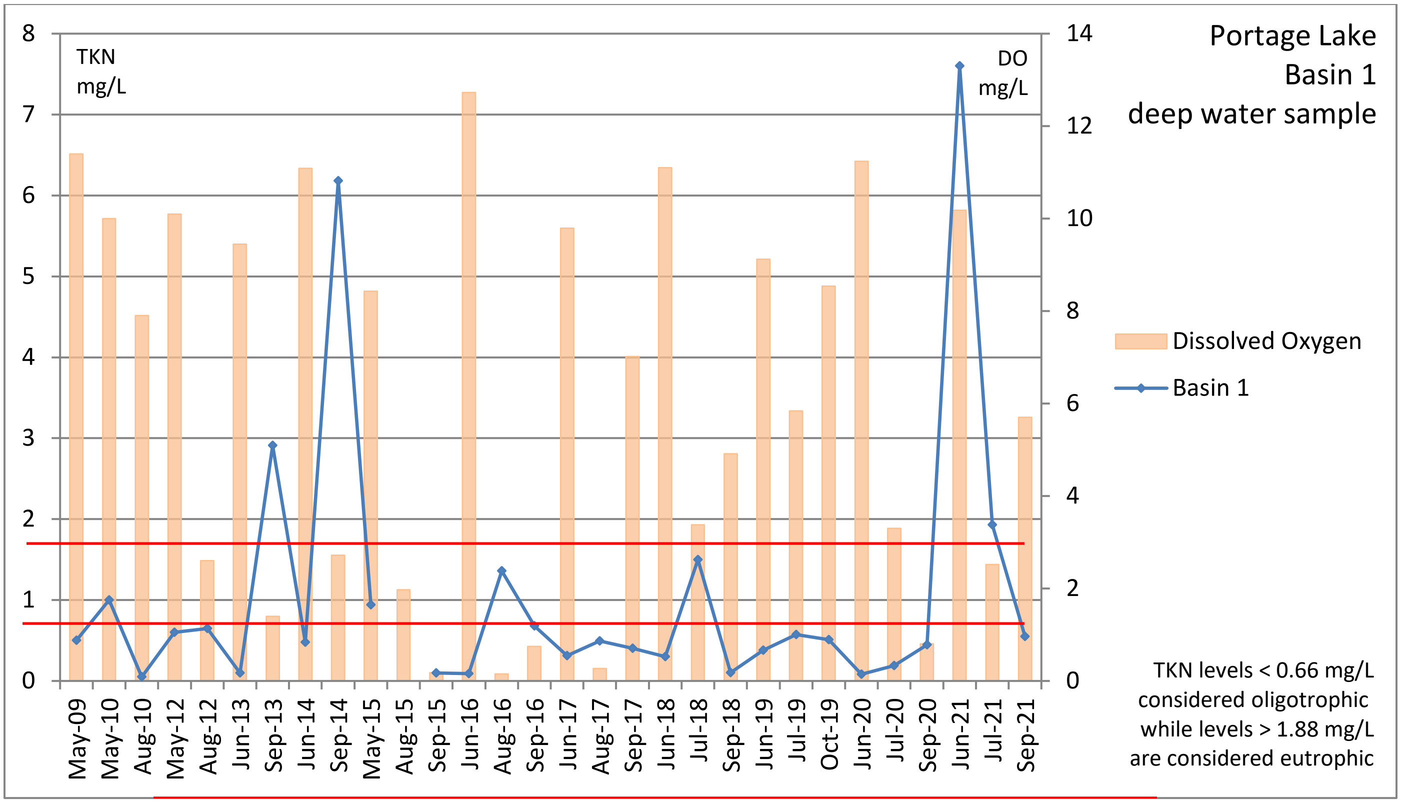
TKN measures the total organic amount of nitrogen (nitrate and nitrite) and ammonia in the water. Nitrogen is the plant nutrient (i.e. fertilizer) most likely to control the amount of rooted plant growth in lakes and ponds. Most Midwestern lakes have more nitrogen and more rooted plant growth than is desirable, so lower values are generally considered better. The major sources of nitrogen in lakes are from agriculture (animal waste, fertilizer) and atmospheric emissions (fossil fuel). Lakes with a TKN value of 0.66 mg/L or less are typically classified as oligotrophic lakes (having fewer nutrients, less productivity). Lakes with TKN values above 1.88 mg/L may be classified as eutrophic (highly productive and nutrient rich). Nitrates do not accumulate very much in the bottom waters during the summer because when nitrate is void of oxygen it turns into ammonia. Therefore, ammonia testing is an excellent way to determine internal loading of nitrogen. The TKN readings on Portage Lake at Basins 1 and 2 in June ranged from 0.03 mg/L to 6.33 mg/L, in late July from 1.1 mg/L to 2.25 mg/L and in September from 0.03 mg/L – 0.445 mg/L between both basins. The tributaries and storm drains showed lower levels than past years as well. The tributaries samples ranged from 0.08 mg/L- 0.553 mg/L in May and from 0.214 mg/L – 1.10 mg/L in September.

Graph 17: TKN – Portage Lake Basins 1, 2 (2009-2021)

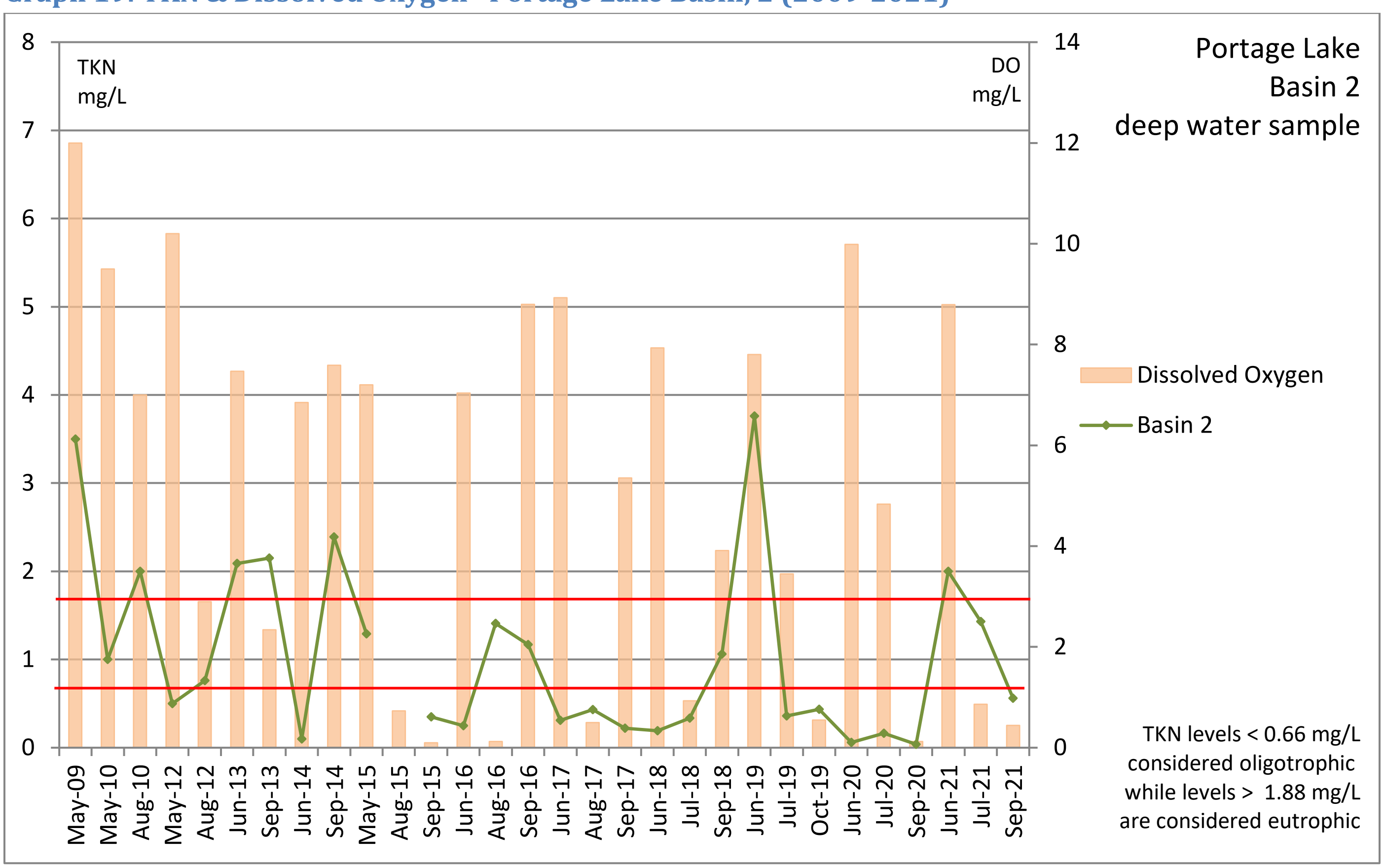


As the above graph illustrates, the TKN concentrations on Portage Lake have fluctuated some in recent years and spiked in 2014, 2019 and 2021. A large spike (or outlier) in August 2015 is not graphed. 2021 sampling show elevated levels and additional sampling in 2022 is highly recommended. The below graph illustrates Basin 1 in more detail and that the spike in 2021 is not correlated to DO levels.

Graph 18: TKN & Dissolved Oxygen– Portage Lake Basin 1 (2009-2019)



Graph 19: TKN & Dissolved Oxygen– Portage Lake Basin, 2 (2009-2021)



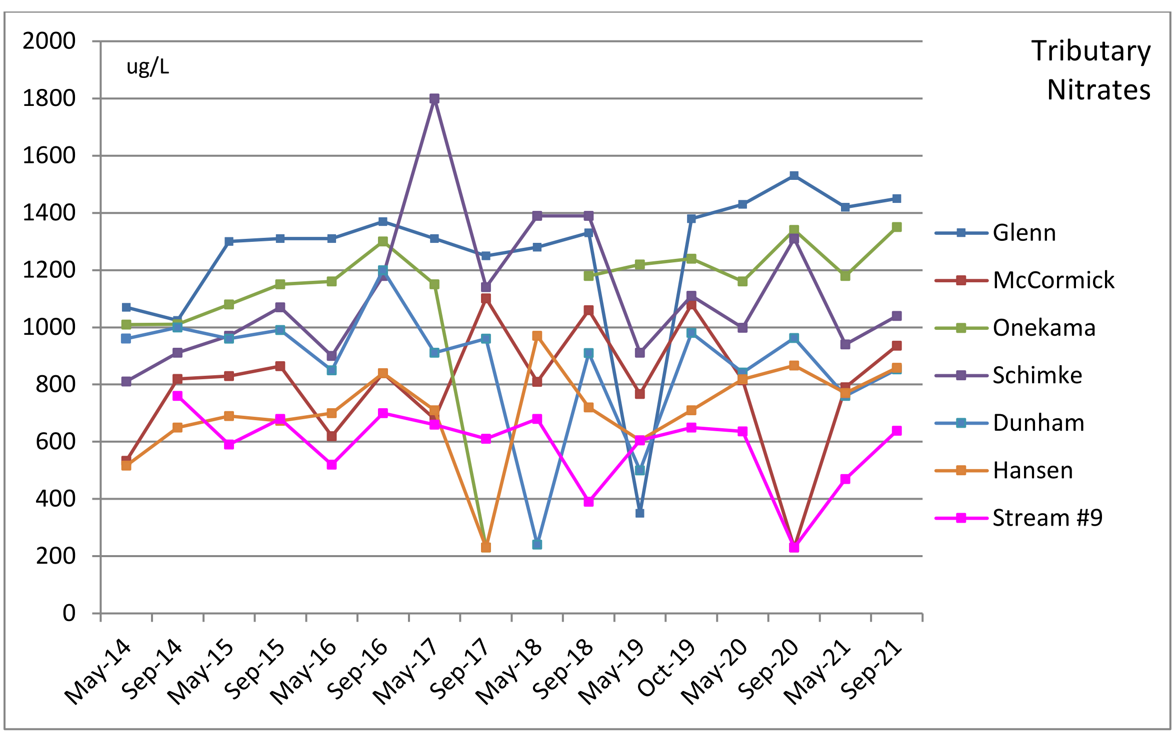
Basin 2 has followed a similar pattern to Basin 1 but the spikes in 2021 were not as great, despite low DO levels.

Nitrates

Nitrates measure the total amount of in-organic nitrogen in the water. Again, nitrogen is an important plant nutrient (i.e., fertilizer) and the nutrient most likely to limit the growth of rooted plants. Most Midwestern lakes have more nitrogen and more rooted plant growth than is desirable, so lower values are generally considered better. Nitrate levels under 250 µg N/L are considered not enriched while readings between 250-750 µg N/L are slightly enriched, readings from 750-1250 µg N/L are enriched and readings over 1250 µg N/L are highly enriched. The sampling in both Basins were consistent this year. The June concentrations of nitrates in Basin 1 and 2 were 230 µg N/L. The late July readings were 230 µg N/L and September concentrations of nitrates were 230 µg N/L throughout the water column. Nitrates in the tributaries ranged from 470 µg N/ to 1420 µg N/L in the spring and from 639 µg N/ to 1450 µg N/L in September, which were similar to last season. Nitrates are typically higher in the spring when the water is colder because the bacteria needed to digest the nitrates are not as productive in cooler temperatures. Nitrates will often decrease over the spring and be slightly less in the lake by the end of the summer. Based on the higher levels of nitrates observed in inlets (Tributaries and Storm Drains) in May and September, loading of the lake appears to be mainly from external sources. External sources for nitrate pollution are agricultural practices (manure, fertilizer), animal feedlots, urban runoff and municipal wastewater runoff. Based on the location of Portage Lake and the makeup of the surrounding watershed, nitrate enrichment is most likely coming from agricultural practices that have leached into the groundwater and animal feedlots. Nitrates did not accumulate very much in the bottom waters during the summer. The nitrates did not accumulate because when nitrate is void of oxygen it turns into ammonia. Therefore, ammonia testing is a better way to determine internal loading of nitrogen.

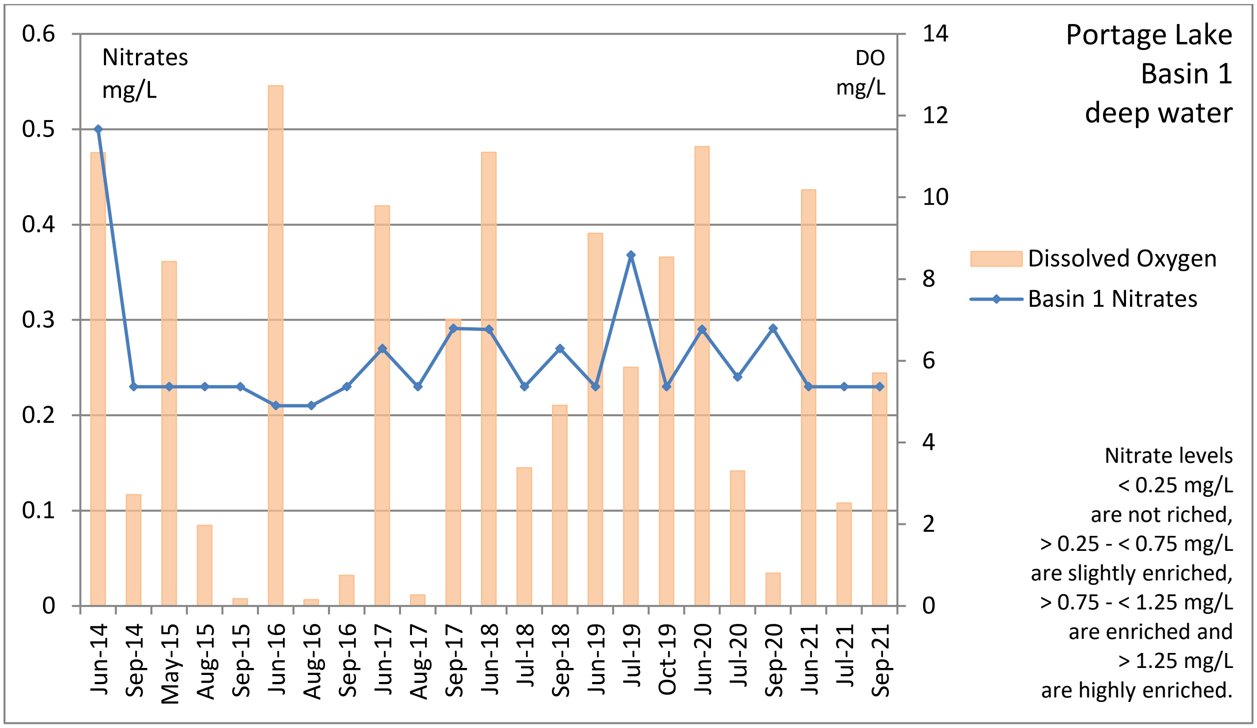
These samples show that the lake (at the time of sampling) may be Phosphorus limited. Phosphorus limited lakes tend to have a TN:TP >15. In 2021, the average TN was 230 ug/L in the basins and the TP 10.4 ug/L, giving a TN:TP of 22. This reading indicates Phosphorus may be the limiting nutrient. This is common in most lakes in this geographical area.

Graph 20: Nitrates– Portage Lake Tributaries

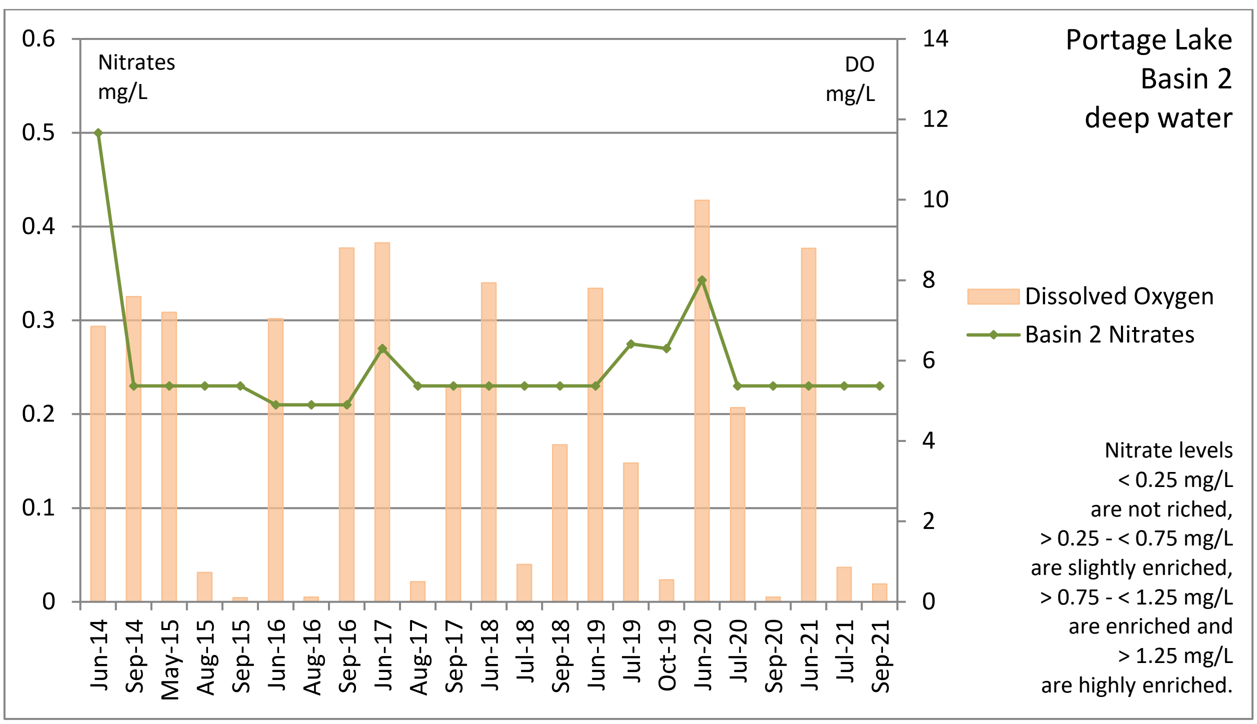


As the graph illustrates, the nitrate concentrations in the Portage Lake Tributaries range from slightly enriched to enriched to highly enriched. It is recommended to continue testing.

Graph 21: Portage Lake Nitrates Basin 1 (2014-2021)



Graph 22: Portage Lake Nitrates Basin 2 (2014-2021)

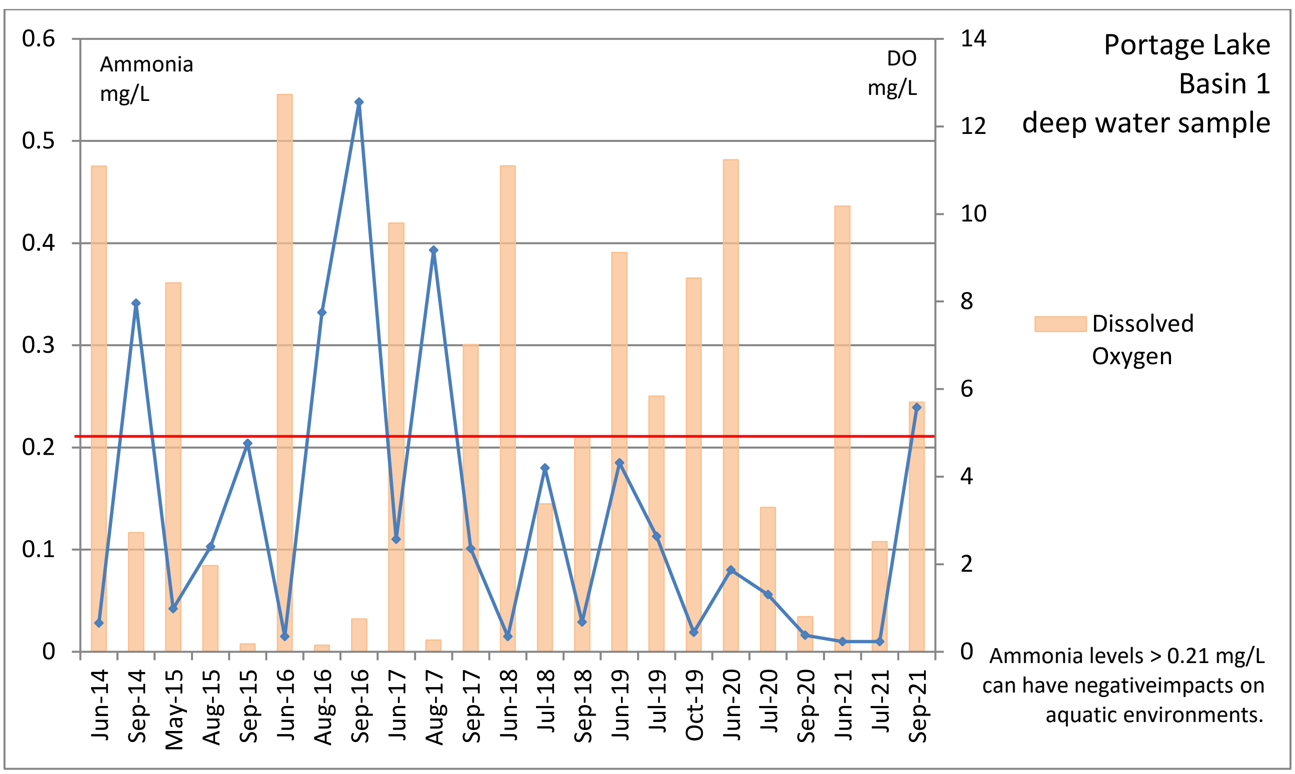


Graphs 21 and 22 show the DO levels with the nitrates in both Basins. Nitrate levels do not increase with decreased DO levels.

Ammonia

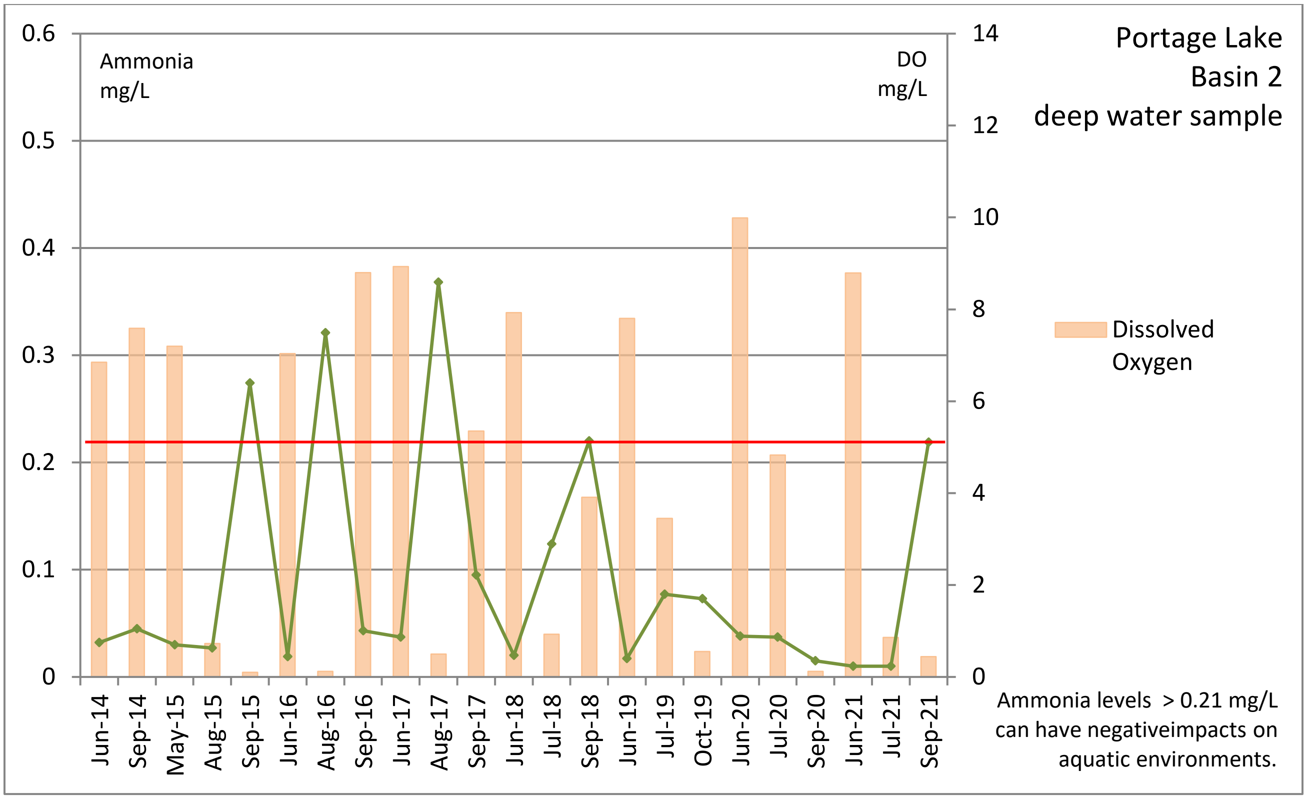
Ammonia is a form of nitrogen found in organic materials, sewage, and many fertilizers. It is the first form of nitrogen released when organic matter decays. Also, when ammonia degrades it consumes oxygen, which worsens already existing anaerobic conditions. However, ammonia can be used by most aquatic plants and is therefore an important nutrient. When oxygen is present in a lake ecosystem, ammonia will convert to nitrates. Ammonia is toxic to fish at relatively low concentrations in pH-neutral or alkaline water. In fish, ammonia affects hatching and growth rates, and can cause changes in tissues of gills, the liver and the kidneys. Ammonia concentrations below 1 mg/L (or 1000 ug/L) are generally considered suitable for healthy fisheries; however, Ammonia concentrations can have impacts on aquatic organisms at lower levels. It is important to review all ammonia concentrations based on the specific lake type, temperature, pH and dissolved oxygen. Michigan EGLE includes standards in part 4 (Water Resources Protection, Water Quality Standards) that ammonia shouldn't exceeded the Aquatic Maximum Value (AMV) threshold of 0.21 mg/L (210 ug/L) in which they feel negative impacts can occur in aquatic communities. Further, the Final Acute Value (FAV) shouldn't exceed a concentration of 0.42 mg/L (or 420 ug/L) where short term exposure can lead to negative impacts on aquatic organisms. Ammonia concentrations usually do not become elevated until water is void of oxygen and the nitrates are converted. Therefore, concentrations of Ammonia do not become elevated until anaerobic conditions are present, typically mid-summer. The concentration of ammonia at the Basin 1 in June was 0.015 mg/L (or 15 ug/L) at the surface and 0.01 mg/L (10 ug/L) at the bottom while in Basin 2 it was 0.029 mg/L (or 29 ug/L) at the surface and 0.01 mg/L (or 10 ug/L) at the bottom. In late July, the concentrations were 0.01 mg/L at the surface and 0.01 mg/L at the bottom in Basin 1 and 0.01 mg/L at the surface and 0.01 mg/L at the bottom in Basin 2. The September concentrations were 0.015 mg/L at the surface and 0.0239 mg/L at the bottom in Basin 1 and 0.03 mg/L at the surface and 0.219 mg/L at the bottom in Basin 2. All readings are well within range for a healthy fishery. The shoreline areas ranged from 0.04 mg/L – 0.053 mg/L throughout the summer, all considered very low. As oxygen is not an issue here, this is expected. The tributaries had similar levels of ammonia as the lake throughout the season. Ammonia concentrations ranged from 0.015 mg/L to 0.083 mg/L (with an average of 0.04 mg/L) in the tributaries.

Graph 23: Ammonia– Portage Lake Basin 1 (2014-2021)



As the graph illustrates, the ammonia concentrations in the Basin 1 are elevated when DO levels decline (i.e. in 2016); which is expected in anaerobic conditions. Although some thresholds have concentration spikes elevated on Portage Lake, the general review of the Ammonia trend is low. When spikes have been seen, internal loading of ammonia was likely and the 2021 sampling showed no concerns.

Graph 24: Ammonia– Portage Lake Basin 2 (2014-2021)

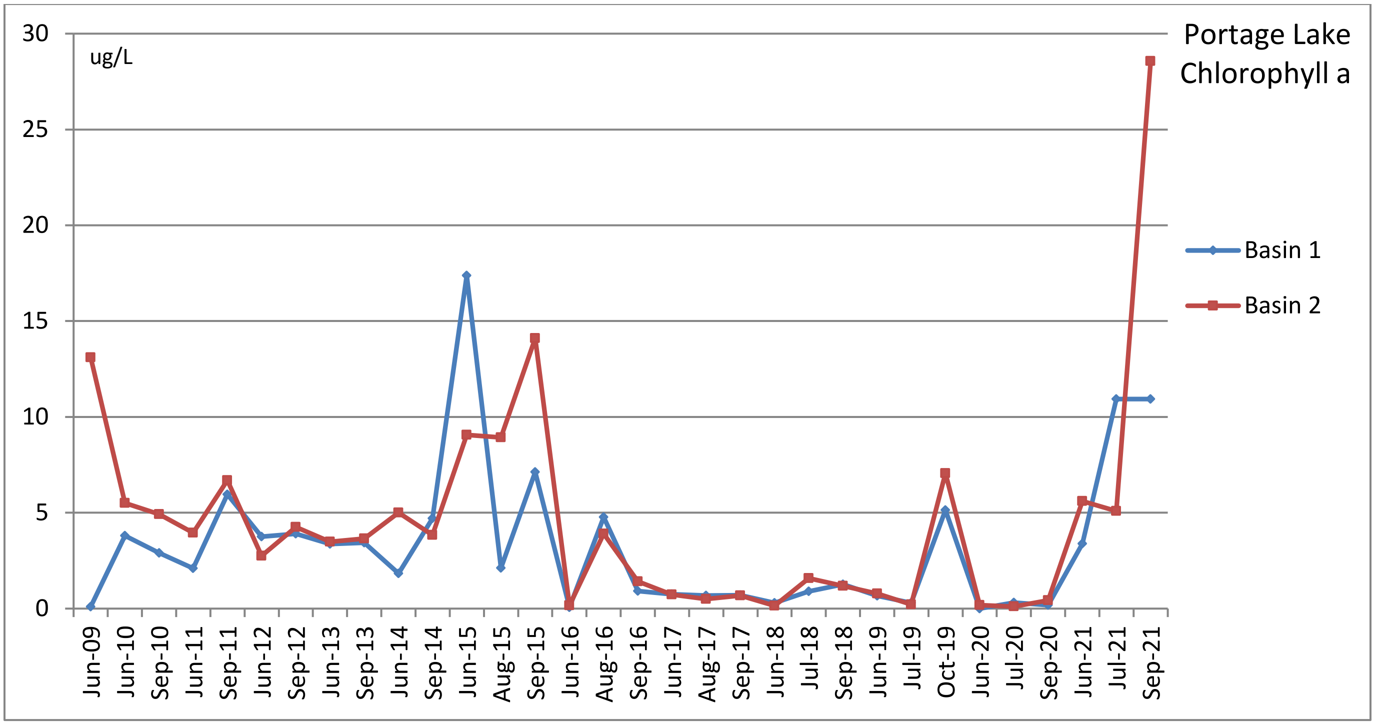


Basin 2 follows Basin 1 with spikes in Ammonia concentrations when DO levels drop.

Chlorophyll

Chlorophyll measures the amount of plankton (green algae) in the water. Some plankton or algal growth is essential to support the growth of other organisms (e.g., fish) in the lake, but human activities and natural eutrophication often lead to excessive algal growth; thus, lower concentrations of chlorophyll are usually considered desirable. Chlorophyll concentrations in Portage Lake Deep Basins in June ranged from 0.807 ug/L to 16.7 µg/L indicating higher plankton populations than previous years. Shoreline samplings sites averaged 10.62 ug/L in June. Chlorophyll in the Deep Basins ranged from 3.74 ug/L – 13.7 ug/L in late July, while shoreline sites averaged 6.27 ug/L. In September, Chlorophyll ranged from 5.29 ug/L to 51.8 ug/L, the highest on record for Portage Lake. The average in September was 19.74 ug/L. The shoreline sites averaged 28.33 ug/L in September. A higher level, in shallow, warmer waters is common as the warmer water can be a breeding ground for plankton. Overall, chlorophyll levels have varied some in recent years and were much higher in 2021. Additional sampling is recommended and over time, sampling technology has improved as well.

Graph 25: Chlorophyll a– Portage Lake Deep Basins



Chlorophyll a sampling has declined over the last few years with some spikes, likely weather related and 2021 sampling showed large increases. Additional sampling is recommended.

Algae and Zooplankton Composition

Algal composition testing was performed at both deep Basins as well as the shoreline testing sites in June, late July and September. The June testing showed the majority genera present included (presented as most abundant to least abundant); Cyanophyta (blue green algae)*: Microcystis sp.,* Bacillariophyta (diatoms): *Cyclotella sp., Asterionella sp., Fragilaria sp., Tabellaria sp.;* Chlorophyta (green algae): *Chlamydomonas sp., Scendesmus sp., Spirogyra sp., Pediastrum sp.* The July sampling found Bacillariophyta (diatoms): *Fragilaria sp., Cyclotella sp.;* Chlorophyta (green algae): *Pediastrum sp., Chlorella sp., Gloecystis sp., Ulothrix sp.;* Euglenophyta, specifically *Trachelomonas sp.;* Cyanophyta (blue green algae), specifically *Microcystis sp*., The September sampling found Cyanophyta (blue green algae), specifically *Microcystis sp*., *Gloeotrichia sp*., the most abundant species and genera of phytoplankton followed by Chlorophyta (green algae): *Pediastrum sp., Chlorella sp.;* Bacillariophyta (diatoms): *Fragilaria sp.* Some blue green algae, including *Microcystis sp*., can produce toxins. These toxins are normally released when the algae near the end of the life cycle and often occur for short phases during a growing season, often times towards the end of the season after the water temperatures and nutrient loading have reached a high. Further, blue green algae are not consumed by Zebra mussels, so if Zebra mussels are present in a lake ecosystem, it is likely to have lower green algae populations and higher blue green algae, as the Zebra Mussels will filter the green algae out of the water column and leave the blue green algae alone. The levels of blue green algae are not high enough to warrant a concern at this time. The blue green algae "scum" that forms on the lake surface when densities are extremely high should be avoided if that were to occur, but the densities in Portage Lake are not high enough to cause a bloom at this point.

The zooplankton communities were also identified while looking at the phytoplankton and numerous species of zooplankton were documented including; *Cladocera sp. (Daphnia)., Rotifer sp., Brachiopoda sp.,* and *Copepods sp*. Diverse and present phytoplankton is required to have a healthy zooplankton community as the base of the food chain.

Fecal Indicator Bacteria (E. Coli)

Fecal Indicator Bacteria (E. Coli) measurements count the number of live fecal indicator bacteria in the sample. These bacteria are considered reliable indicators of fecal contamination when they are found in a pond or lake; it is very likely that the water is being contaminated by animal feces. Contamination can potentially be derived from a number of sources, including failed septic systems, agriculture runoff, or waterfowl or wildlife droppings.

In the last decade, E.Coli monitoring has become a priority for the watershed in order to ensure healthy, clean water for the area's residents and visitors. E.Coli data has been collected throughout the watershed by various entities including District 10 Heath Department, Onekama Village, Onekama Township and PLM Lake & Land Management. Between 2009 and 2021, over 280 composite samples were collected around Portage Lake and its tributaries. Only two of these samples exceeded partial body contact and four exceeded total body contact criteria. All samples that exceeded these water quality standards were collected in Schimke Creek and Stream #9.

In the year 2018, the scope of the E.Coli monitoring expanded to include road end beaches and tributary streams. A total of three samples at 10 sites were collected six times between June and August, five of which were dry weather events and one which took place during a rain event. As previously mentioned, Schimke Creek and Stream #9 had elevated E.Coli levels over the total body contact criteria and are under further inspection.

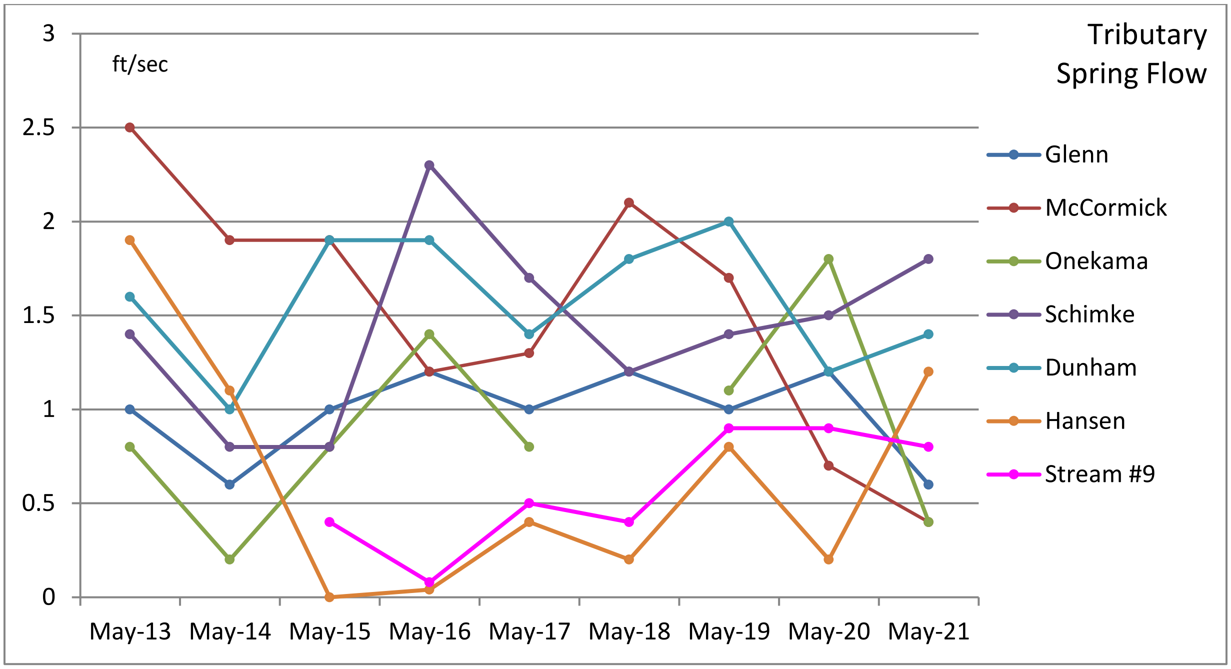
The majority of the sample sites in the Portage Lake watershed that have been monitored for E.Coli have had consistently low concentrations meaning that in the context of E.Coli, water quality is high and public health risk is low.

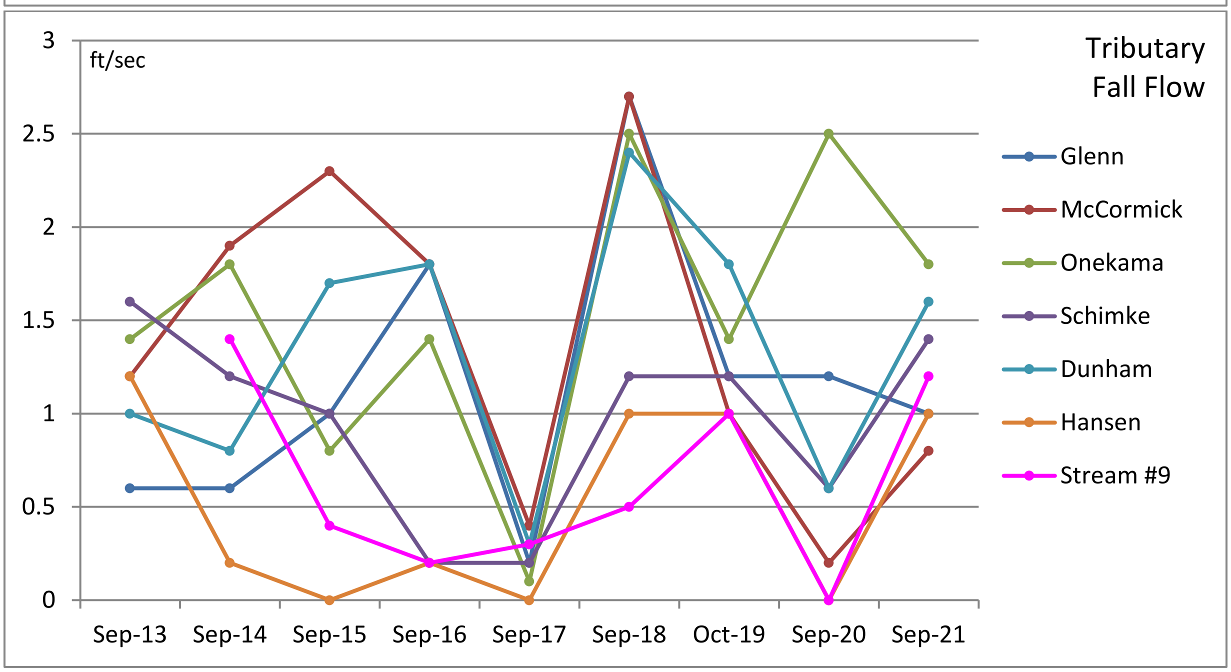
2021 monitoring found no elevated sampling in the July sampling, which tested numerous locations including Portage Point Inn, Swimming beaches, Camps, and inlet areas.

Tributary Flow and Phosphorus

Flow rate data was determined, using a digital flow meter, at the seven tributaries studied in May and in September. Flow ranged from 0.4 feet/second – 1.8 feet/second in the May sampling and from 0.8 feet/second – 1.8 feet/second in September. Unlike some previous years, Onekama Creek was the fastest flowing in 2020 and 2021. The rates of flow varied from each creek and the basic chemistry varied as well. Nutrients coming in from the creeks are a concern, as it is a transport from the watershed into Portage Lake. Total Phosphorus is graphed below along with flow to see how the flow and TP are connected.

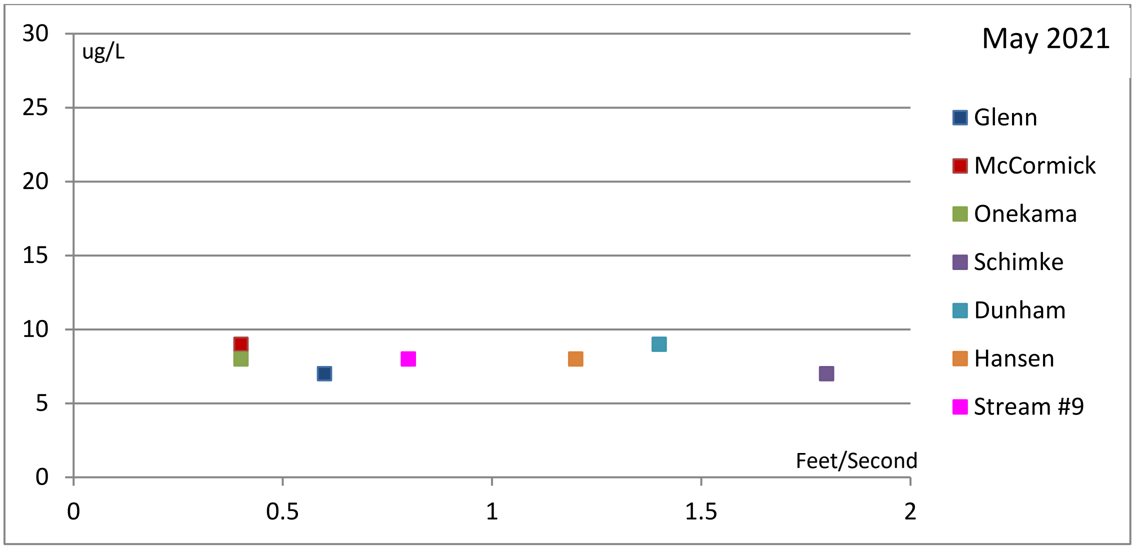
Graph 26 and 27: Tributary Flow Rates with Total Phosphorus (ug/L) –May (top); September (bottom) 2013-2021

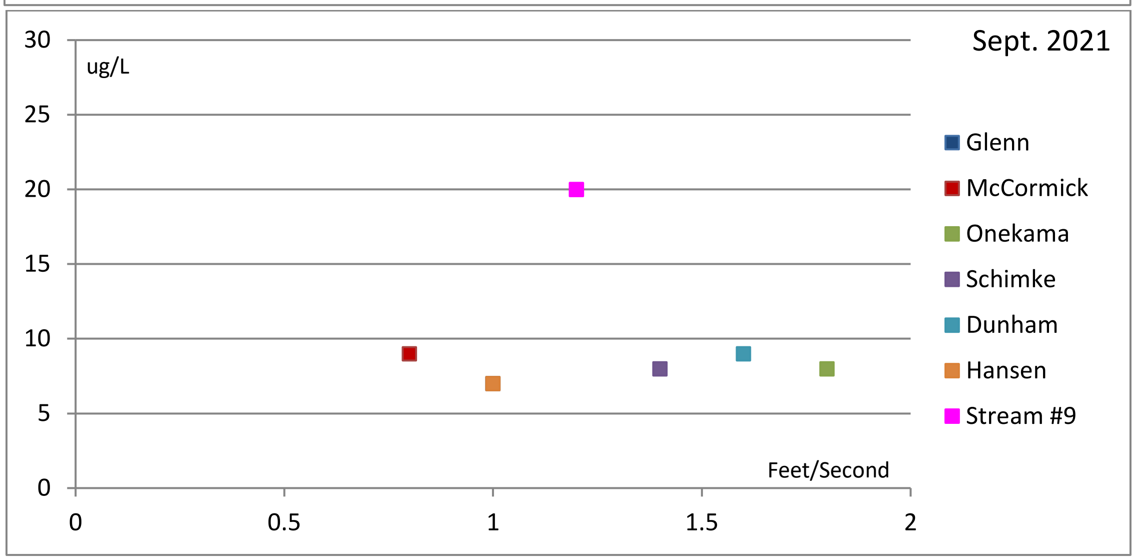




Historically, these graphs illustrate that there is a decline in flow rate at the end of the summer versus the beginning of the summer. Typically, higher flows in spring will increase nutrient inputs in the spring and they decrease in the fall. This is standardly due to snow melt and spring rain. Generally speaking, the flow in 2022 and 2021 had a higher range and overall higher average. This likely correlated with high water levels in the watershed. High water levels in the watershed could be having impacts on other parameters including nutrient levels as well as plant growth.

Graph 28 and 29: Tributary Flow Rates and Phosphorus (ug/L) comparisons – May 2021 (top) – September 2021 (bottom)





In years past, the graph has illustrated a correlation between flow and TP. The greater the flow, the higher the Total Phosphorus. (This correlation has historically been strong.) In 2021, the TP concentrations were all very similar, down from recent years, regardless to flow.

Additional Tributary/Upstream testing

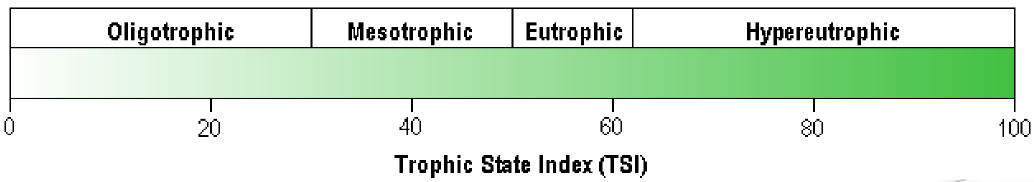
Tributary testing was expanded in 2016 to include testing four creeks upstream to determine if there were any point source locations determined or pinpointed. Determining any area of concern would allow future work to reduce nutrient loading into the lake be done. Using best management practices throughout the entire watershed, but especially on the creeks leading directly into the lake are essential. Determining if there is a location within the first few miles of the creek off of the lake that has elevated nutrient levels would allow future focus to be determined.

Based on historical data of nutrient levels from the tributaries, four creeks were selected to have additional testing done. Those creeks include: McCormick, Schimke, Hansen and Stream #9. During this test, each creek was also tested upstream at locations that were determined upon walking up the creek. Upon walking upstream, visual observations were made for any concerns including but not limited to drain tiles, erosions, buffers, invasive, flow issues, sources of nutrient inputs, etc. Based on observations the following locations were selected as potential sources of nutrient inputs: culverts, wetlands, location of golf course, farming field, houses, roads, etc.

Of the data collected, most locations came up somewhat enriched, with the largest concern being Stream #9. Because Stream #9 was the largest concern in 2016, it was selected for upstream testing in 2017 and all the years since. The last few years have shown lower TP than prior testing, which is a positive sign. The water depth and flow going into the lake in 2021 was too low for sampling. Evaluating conditions in 2022 is recommended to determine if additional sampling is needed.

Evaluation of Trophic Status

Carlson's Trophic State Index (TSI) is used to measure the trophic state of individual lakes. Lakes are ranked from 1 to 100 based on Secchi disc depth, Total phosphorus concentrations and/or Chlorophyll a levels. Based on that ranking, the TSI is determined. This chart gives the approximate classification for each category.



Portage Lake's June data yielded values between 28 and 39, in late July between 30 and 43 and in September between 30 and 48 (Table 12). All of these values are considerable higher than 2020 results. In general, these values rate Portage Lake as mesotrophic. Characteristics associated with oligotrophic to meso- oligotrophic lakes are low nutrient levels, clear water and low productivity. High dissolved oxygen levels typically occur and survival of cold water fish is possible. Mesotrophic lakes tend to have moderate nutrient levels, clear water and moderate productivity. Rooted plants are abundant and the lake can still support a cold water fishery. As the picture to the right shows, eutrophic lakes (not Portage Lake at this time, but given for comparison) have high nutrient levels, turbid water, algae blooms are likely and sometimes severe. Plants are abundant and dissolved oxygen is often depleted from bottom waters, restricting fish populations to warm water species.

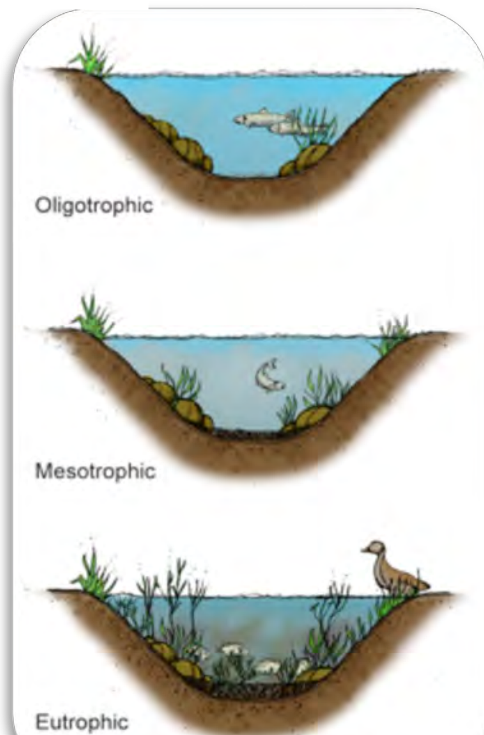


Photo curiosity Progressive AE

Table 10: 2021 Trophic State Index (TSI) Values

Site	Secchi Depth	Total Phosphorus	Chlorophyll a
Basin 1 – June	37	28	28
Basin 2 – June	39	30	30
Basin 1- July	38	30	30
Basin 2- July	43	30	30
Basin 1 – Sept.	41	58	58
Basin 2 – Sept.	45	30	30

2021 Water Quality Concerns/Recommendations

Current water quality problems in Portage Lake can result from nutrient loading from the watershed and nutrient rich bottom sediments in the lake. Please note that the overall nutrient levels in Portage Lake are still relativity low compared to most Michigan waterbodies. Reductions in external nutrient loads may eventually reduce internally generated water quality problems, though improvements will require that dramatic reductions in external loading be sustained for long periods of time. Even if sufficient loading reductions are achieved, many years will be required before improvement is evident. In order to manage external nutrient inputs, it would be necessary to develop and implement a watershed management plan for the Portage Lake watershed. Watershed activities and public awareness using good management practices in the watershed will have long term positive improvements in the lake. This could be one cause of the decrease in nutrient levels in the lake.

Management Recommendations for 2022

Management options are dependent on many factors, including but not limited to, species abundance (density), species richness, species location and many lake characteristics. Whenever an exotic species is found within an aquatic environment, action needs to be taken to prevent long term ecological damage as well as recreational and aesthetic loss that will take place.

Submersed Aquatic Plants

The 2021 aquatic plant management program should detect and manage/treat any areas where Eurasian watermilfoil or hybrid watermilfoil and Starry stonewort are present in addition to any other invasive, exotic species.

Emergent Vegetation Management

Purple loosestrife and Phragmites should continue to be addressed around the perimeter of the lake to prevent the further spread of these exotic species. Continuing biological control of Purple Loosestrife with beetles, if available, is recommended to continue. In addition, any other invasive terrestrial plants including but not limited to Japanese knotweed, honey suckle, garlic mustard and autumn olive should be targeted for control.

Monitoring

Aquatic vegetation and water quality should continue to be monitored to document the condition of the lake and to provide warning of any changes in the condition of the lake that need to be addressed by additional lake management activities.

Proposed Budget

The following budget is proposed based on previous requirement on Portage Lake and the budget is limited to the management and treatment of Portage Lake. If additional costs are required in the maintenance of the SAD or from outside factors, they may not be included in this budget. Please also note that as additional data becomes available from the Grant Study and application rates increase, the budget may have to be adjusted long term to account for genetically changing plants.

Table 11: Proposed 2022 Budget Portage Lake

Proposed/ Estimated Budget	2022
Emergent Control	2,000
EWM/SSW Control	47,400
Permit	1,600
Lake Management/Fish Survey	25,000
Contingency Funds	7,600
Total	83,600

The Recommended Management Schedule for 2022:

- A spring and fall vegetation survey (to evaluate conditions in the lake).
- Exotic plant management/treatment, as required
- Pre and post implementation surveys as required, in addition to a mid-summer survey
- Extensive water quality monitoring throughout season
- Late summer/fall Phragmites Control
- Community Education/outreach activities
- Fish Study

Addendum 1 Product Explanation guide

Aquathol K

Active ingredient- Dipotassium Endothall 40.3%
Use- Contact herbicide
Half-life- 5-8days
Target Species- Curlyleaf pondweed
Mode of action- Respiration is inhibited, during which, oxygen consumption is also inhibited. Effects are greater in the dark, due to the fact that the results are non-photosynthesis-based.

ProcellaCOR

Active ingredient- Florpyrauxifen-benzyl 2.7%
Use- Systemic herbicide
Half-life- 1-6days (pH and temp. dependent)
Target Species- Eurasian watermilfoil
Mode of action- Idoleacetic acid (IAA) is the main auxin in plants, regulating growth and development which is triggered to disrupt growth by binding to it. Roots are most sensitive to fluctuations in IAA level. This product mimics the plant growth hormone auxin that causes excessive elongation of plant cells that ultimately kills the plant.

Navigate (2,4-d)

Active ingredient- 2,4-dichlorophenoxy acetic acid 27.6%
Use- Systemic herbicide
Half-life- 15days
Target Species- Eurasian watermilfoil
Mode of action- Acts as a plant growth hormone (auxin) which stimulates rapid excessive growth which interferes with cell division, food utilization, and other vital processes of the plant. Systemic effects are more specific to dicots as opposed to monocots.

Renovate 3

Active ingredient- Triclopyr 44.4%
Use- Systemic herbicide
Half-life- 1 day with light
Target Species- Eurasian watermilfoil
Mode of action- Acts as a plant growth hormone (auxin) which stimulates rapid excessive growth which interferes with cell division, food utilization, and other vital processes of the plant. Systemic effects are more specific to dicots as opposed to monocots.

Renovate OTF

Active ingredient- Triclopyr 14.0%
Use- Systemic herbicide
Half-life- 1 day with light
Target Species- Eurasian watermilfoil
Mode of action- Acts as a plant growth hormone (auxin) which stimulates rapid excessive growth which interferes with cell division, food utilization, and other vital processes of the plant. Systemic effects are more specific to dicots as opposed to monocots.

SeClear G

Active ingredient- Copper Sulfate Pentahydrate 58.9%
Use- Algaecide
Target Species- Starry stonewort

Mode of action- Copper is regulated by plants/algae because it is an essential mineral. Too much copper can be toxic to plants as it inhibits photosynthesis. Copper naturally occurs in the environment and is highly soluble in water and it can bind with sediments.

Sculpin G

Active ingredient- 2,4-dichlorophenoxyacetic acid, dimethylamine salt 20%

Use- Systemic herbicide

Half-life- 14days

Target Species- Eurasian watermilfoil

Mode of action- Acts as a plant growth hormone (auxin) which stimulates rapid excessive growth which interferes with cell division, food utilization, and other vital processes of the plant. Systemic effects are more specific to dicots as opposed to monocots.

Tribune

Active ingredient- Diquat dibromide 37.3%

Use- Contact herbicide

Half-life- 48hours

Target Species- Eurasian watermilfoil, Curlyleaf pondweed

Mode of action- Reduction of a free radical through the natural processes of respiration and photosynthesis. The salts formed can bond and release with electrons in the plant over and over again, virtually "short circuiting" the plants ability to use photosynthesis.

Addendum 2 Product Terminology

Active ingredient: An active ingredient are the chemicals in the pesticide that kills, controls or repels pests. Often, the active ingredient makes up a small portion of the whole product.

Inert ingredient: An inert or other ingredient are combined with active ingredients to make a pesticide product. Inert ingredients are used to stabilize the product, help it stick, sink, dissolve, improve ease of application, drift among other factors.

Half-life: The half-life of an herbicide is the length of time it takes for 50% of the herbicide to beak down to secondary compounds. "The half-life can help estimate whether or not a pesticide tends to build up in the environment. Pesticides with shorter half-lives tend to build up less because they are much less likely to persist in the environment." National Pesticide Information Center

Systemic herbicide: Systemic herbicides are absorbed and transported through the plant's vascular system, killing the entire plant.

Contact herbicide: Contact herbicides kill the part of the plant in contact with the chemical but the roots may survive.

Selective herbicide: A selective herbicide is formulated to control specific weeds. It is a material that is toxic is some plant species but not all.

Addendum 3 Portage Lake Product Use Overview

Year	Date	Product	Rate lbs/Acre	Acres	Total Acres	Total Product	% active ingredient	Total active ingredient used
2021	17-Jun	Aquathal K	1gal	6.5	50.65	6.5gal	40.30%	2.6195gal
	12-Aug	ProcellaCOR/Diquat	4pdu/1gal	1.5		6pdu/1.5g	2.7%/37.3%	0.51ou/0.55gal
		ProcellaCOR/Diquat	5pdu/1gal	16		80pdu/16g	2.7%/37.3%	6.84ou/5.96gal
		Sculpin G	300lbs	22.4		6720lbs	20%	1344lbs
		SeClear G	50lbs	4.25		212.5lbs	58.90%	125.16lbs
2020	17-Jun	Clipper	200ppb	6.3	82.1	19.8lbs	51%	10lbs
	2-Aug	ProcellaCOR/Ren3	4pdu/3.5g	13.5		47.25pdu/54g	22.7%/44.4%	4ou/23.9gal
		Sculpin G	240lbs	4.15		1000lbs	20%	200lbs
		ProcellaCOR/Diquat	4pdu/1gal	19.65		78.6pdu/19.65g	2.7%/37.3%	6.7ou/7.3gal
		ProcellaCOR	9pdu	30.5		247.5pdu	2.70%	21.18ou
		SeClear G	50lbs	8		400lbs	58.90%	235.6lbs
2019	17-Jun	Clipper	200ppb	6.3	60.25	19.8lbs	51%	8.5lbs
	15-Aug	Renovate 3	4g	4.5		18gal	44.40%	7.99gal
		Renovate OTF	240lbs	25.25		6312.5lbs	14%	883.75lbs
		Sculpin G	240lbs	20		4800lbs	20%	960lbs
		ProcellaCOR	11pdu	4.2		45.6pdu	2.70%	3.9ou
2018	17-Jun	Clipper	200ppb	1.58	51.08	5lbs	51%	2.55lbs
	15-Aug	Renovate 3	4gal	4.5		18gal	44.40%	7.99gal
		Renovate OTF	200ppb	8		1600lbs	14%	224lbs
		ProcellaCOR	11.43pdu	3.5		40.4pdu	2.70%	3.45ou
		Sculpin G	240lbs	33.5		8040lbs	20%	1608lbs
2017	14-Jun	Clipper	200ppb	1.58	67.68	5.53lbs	51%	2.82lbs
	15-Aug	Renovate OTF	240lbs	13		3120lbs	14%	436.8lbs
		Renovate OTF	200lbs	14		2800lbs	14%	392lbs
		Renovate 3	4gal	5.6		22.4gal	44.40%	9.94gal
		Sculpin G	240lbs	29.5		7080lbs	20%	1416lbs
		Sculpin G	200lbs	4		800lbs	20%	160lbs
2016	27-Jun	Clipper	200ppb	1.25	21.35	3.9lbs	51%	1.98lbs
	2-Aug	Renovate OTF	200lbs	6.6		1320lbs	14%	184.8lbs
		Renovate OTF	240lbs	3.5		840lbs	14%	117.6lbs
	3-Aug	Renovate OTF	200lbs	3		600lbs	14%	8.4lbs
		Renovate 3	4gals	2		8gal	44.40%	3.55gal
		Sculpin G	240lbs	5		1200lbs	20%	240lbs
2015	19-Jun	Clipper	200ppb	1.25	79.35	4lbs	51%	2.04lbs
	28-Jul	Renovate OTF	200lbs	4		800lbs	14%	112lbs
	28-Jul	Renovate OTF	240lbs	3.8		920lbs	14%	128.8lbs
	28-Jul	Sculpin G	200lbs	4		800lbs	20%	160lbs
	28-Jul	Sculpin G	240lbs	66.3		15920lbs	20%	3184lbs
2014	26-Jun	Renovate OTF	200lbs	1.5	176.05	300lbs	14%	42lbs
	29-Jul	Renovate OTF	200lbs	0.8		160lbs	14%	22.4lbs
		Renovate LZR Max	120lbs	95		11360lbs	18%	2044.8lbs
		Sculpin G	200lbs	10		2000lbs	20%	400lbs
		Clipper	200ppb	1.25		4lbs	51%	2lbs
	8-Sep	Sculpin G	160lbs	23		3680lbs	20%	736lbs
		Sculpin G	200lbs	12.5		2500lbs	20%	500lbs
		Sculpin G	240lbs	6		1440lbs	20%	288lbs
		Renovate LZR Max	160lbs	26		4160lbs	18%	748.8lbs

Year	Date	Product	Rate lbs/Acre	Acres	Total Acres	Total Product	% active ingredient	Total active ingredient used
2013	24,27 - Jun	Renovate OTF	160lbs	5	129.75	800lbs	14%	112lbs
		Renovate Max G	160lbs	39		6240lbs	18%	1123.2lbs
		Sculpin G	160lbs	74.5		11920lbs	20%	2384lbs
	8-Aug	Sculpin G	160lbs	10		1600lbs	20%	320lbs
		Clipper	200ppb	1.25		4lbs	51%	2.04lbs
2012	9-Jul	Renovate OTF	120lbs	10	145	1200lbs	14%	168lbs
		Renovate Max G	160lbs	55		8800lbs	18%	1584lbs
	24-Jul	Renovate OTF	120lbs	5		600lbs	14%	84lbs
		Renovate Max G	120lbs	40		4800lbs	18%	864lbs
		Sculpin G (2,4-D)	160lbs	35		5600lbs	20%	1120lbs
2011	27-Jul	Renovate OTF	120lbs	22	22	2640lbs	14%	369.6lbs
2010	29-Jun	Renovate OTF	120lbs	5	86	600lbs	14%	84lbs
		Navigate 2,4-D	100lbs	17		1700lbs	27.60%	469.2lbs
	27-Sep	Renovate OTF	120lbs	14		1680lbs	14%	235.2lbs
		Navigate 2,4-D	120lbs	50		6000lbs	27.60%	1656lbs
2009	15-Sep	Renovate OTF	120lbs	~41.5	161.5	5000lbs	14%	700lbs
		Navigate 2,4-D	100lbs	120		12000lbs	27.60%	3312lbs
Total					**1132.76**			

Addendum 3 Portage Lake Treatment Cost Overview

Year	Date	Product	Price	Total Price
2021	17-Jun	Aquathal K	$9,286.75	
	12-Aug	ProcellaCOR/Diquat	$862.50	
		ProcellaCOR/Diquat	$10,800.00	
		Sculpin G	$18,480.00	
		SeClear G	$1,275.00	$40,704.25
2020	17-Jun	Clipper	$4,000.35	
	2-Aug	ProcellaCOR/Ren3	$9,450.00	
		Sculpin G	$2,739.00	
		ProcellaCOR/Diquat	$11,102.25	
		ProcellaCOR	$27,450.00	
		SeClear G	$2,400.00	$57,141.60
2019	17-Jun	Clipper	$4,000.50	
	15-Aug	Renovate 3	$1,620.00	
		Renovate OTF	$22,472.50	
		Sculpin G	$13,200.00	
		ProcellaCOR	$5,700.00	$46,993.00
2018	17-Jun	Clipper	$1,003.50	
	15-Aug	Renovate 3	$1,620.00	
		Renovate OTF	$5,932.80	
		ProcellaCOR	$6,000.00	
		Sculpin G	$22,110.00	$36,666.30
2017	14-Jun	Clipper	$1,003.30	
	15-Aug	Renovate OTF	$11,570.00	
		Renovate OTF	$10,383.24	

		Renovate 3	$2,016.00	
		Sculpin G	$19,470.00	
		Sculpin G	$2,200.00	$46,642.54
2016	27-Jun	Clipper	$793.75	
	2-Aug	Renovate OTF	$4,894.96	
		Renovate OTF	$3,115.00	
	3-Aug	Renovate OTF	$2,224.98	
		Renovate 3	$720.00	
		Sculpin G	$3,200.00	$14,948.69
2015	19-Jun	Clipper	$768.75	
	28-Jul	Renovate OTF	$2,933.32	
	28-Jul	Renovate OTF	$3,344.00	
	28-Jul	Sculpin G	$2,100.00	
	28-Jul	Sculpin G	$41,769.00	$50,915.07
2014	26-Jun	Renovate OTF	$1,031.25	
	29-Jul	Renovate OTF	$550.00	
		Renovate LZR Max	$47,500.00	
		Sculpin G	$5,187.50	
		Clipper	$750.00	
	8-Sep	Sculpin G	$0.00	
		Sculpin G	$6,484.38	
		Sculpin G	$3,735.00	
		Renovate LZR Max	$0.00	$65,238.13
2013	24,27 -Jun	Renovate OTF	$2,800.00	
		Renovate Max G	$19,500.00	
		Sculpin G	$32,258.50	
	8-Aug	Sculpin G	$4,330.00	
		Clipper	$812.50	$59,701.00
2012	9-Jul	Renovate OTF	$4,400.00	
		Renovate Max G	$27,500.00	
	24-Jul	Renovate OTF	$2,200.00	
		Renovate Max G	$15,000.00	
		Sculpin G (2,4-D)	$15,155.00	$64,255.00
2011	27-Jul	Renovate OTF	$9,680.00	$9,680.00
2010	29-Jun	Renovate OTF	$2,200.00	
		Navigate 2,4-D	$5,780.00	
	27-Sep	Renovate OTF	$6,160.00	
		Navigate 2,4-D	$19,750.00	$33,890.00
2009	15-Sep	Renovate OTF	$18,260.00	
		Navigate 2,4-D	$40,800.00	$59,060.00
Total Price				$404,330.43