Portage Lake

Lake Management Plan 2013

Prepared for Onekama Township, Portage Lake Watershed Forever & Invasive Species Committee

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Lake Management Plan

Executive Summary

Portage Lake has been managed over the past six years with goals of indentifying and reducing the presence of exotic species throughout the Portage Lake watershed, tracking plant trends, improving water quality readings and protecting Portage Lake into the future. The following report breaks down the specifics of the previous management, the management of the 2013 season and the need for future management.

In 2013, nearly 140 acres of EWM, Phragmites and Purple Loosestrife were controlled via chemical and biological control methods. Extensive lake mapping, vegetation mapping and water quality testing was performed. The vegetation mapping allowed for detailed description of what is occurring within the water column with the new BioBase technology as well AVAS Survey mapping showing numerous native and non native plants present throughout the lake. The abundance of healthy native plants in Portage Lake increases the long term stability of the lake. While some water quality parameters have maintained themselves with little change over the years, other parameters have shown fluctuations. Some of these fluctuations include showing that the tributaries around Portage Lake are bringing excess nutrients into the lake. This information is vital in determining the areas within Portage Lake that need to be focused on reducing 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 and use of Portage Lake. While the main goal of the management 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.

Introduction

Purpose of the Plan

This management plan documents management activities during 2013, examines current conditions in the lake, and provides management recommendations for 2014. 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 2165-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 exotic plants, to allow recreational use of the lake and promote a healthy fishery. The exotic plant species, Eurasian watermilfoil 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 and Northern watermilfoil species have bred, forming a new genetic strand of milfoil commonly referred to as Hybrid milfoil. In reference to Portage Lake, Eurasian milfoil will be now referring to both EWM and Hyrbid milfoil as it all needs to be managed as an 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.
- The species Starry stonewort, if found on the Portage Lake should be actively controlled and managed. Starry stonewort is in the same family as Muskgrass (Chara) but is considered to be 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.

Starry stonewort

- The 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"

Phragmites

- 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.

- 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.

Strategies for Achieving Lake Management Goals

Aquatic Plant Control Techniques

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. The non-native plant species, Eurasian watermilfoil and curly leaf pondweed concentrate their biomass at the water surface where it strongly interferes 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.

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.

Chemical control, or use of aquatic herbicides, is the most common strategy for controlling exotic plant species. Aquatic herbicides provide predictable results and there is a great deal of research and data regarding theses products. Many of the aquatic herbicides available can be used to selectively control exotic species with minimal or no impact on native species.

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.

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.

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.

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.

Integrated Pest Management (IPM) approaches to aquatic plant control IPM 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.

Exotic Plant Management

Aquatic herbicides currently represent the most reliable, effective, selective means for controlling Eurasian watermilfoil. There are currently five systemic herbicides, 2,4-D (Navigate), 2,4-D amine (Sculpin G), triclopyr (Renovate 3 & OTF), 2,4-D/Triclopyr combination (Renovate Max G) and fluridone (Sonar or Avast), which can be used to achieve long-term, selective control of Eurasian watermilfoil. Systemic herbicides are capable of killing the entire plant. Several contact herbicides, including diquat (Reward or Solera) can also provide short-term control of Eurasian watermilfoil. These herbicides kill only the shoots of the plant, and plants regrow relatively rapidly from their unaffected below ground parts.

Systemic herbicides control Eurasian watermilfoil 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.

Harvesting of Eurasian watermilfoil is **not** recommended. This plant spreads by fragmentation and regrows significantly more rapidly than most native plant species; thus continued harvesting of mixed plant beds typically leads to nearly complete domination of the aquatic vegetation by Eurasian watermilfoil.

Purple loosestrife can be selectively controlled through the use of triclopyr (Renovate). 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. In past years our options to manage this nuisance weed has been extremely limited to prevention, manual removal or broad spectrum herbicide treatments, which not only killed the Purple Loosestrife but also the native vegetation remaining in the treatment areas. The biological control effort, beetles, have shown positive control measures and this method is also encouraged to continue into the future.

Phragmites, can be selectively controlled through the use of glyphosate or imazapyr (Habitat) herbicides. Phragmites is an exotic species, which can out compete native vegetation, destroying valuable wetlands and animal habitat.

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.

Algae Management

Not required at this time.

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 and 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.

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. PLM MD (Muck Digestion) Pellets are a combination of natural beneficial bacteria, enzymes, and vitamins that stimulate the biological activity of the lake bottom. This stimulation allows the bacteria to feed on the organic sediment, therefore reducing the muck levels over time.

Prevention

Eurasian watermilfoil and curly leaf pondweed 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.

Lake Management Activities Conducted in 2013

Water Quality

Water quality was evaluated on May 10, June 4, July 24 and September 16, 2013. The May sampling included Storm Drain and tributary testing. In June, deep hole testing and shoreline testing of Portage lake occurred. The July testing was for Ecoli. During September, tributaries as well as the deep hole basins and shoreline areas 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 were 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 Storm Drain sampling the following occurred at 4 designated drains, (1) Flow testing, (2) surface reading of temperature and dissolved oxygen (3) samples for LakeCheck™ analysis were collected. During the tributary testing, the following occurred at 7 designated tributaries, (1) surface reading for temperature and dissolved oxygen, (2) samples for LakeCheck™ analysis were 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, and Total Kjeldahl Nitrogen.

Weather Challenges of 2013

The spring of 2013 was wet. Increased rainfall can cause a substantial amount of nutrients, debris, sediment and other unknown, potentially harmful, substances into the lake. Each year the weather will causes changes within Portage Lake. Some years it may lower plant production while other years may lead to increase plant growth and elevated water quality numbers.

Aquatic Plant/Algae Control

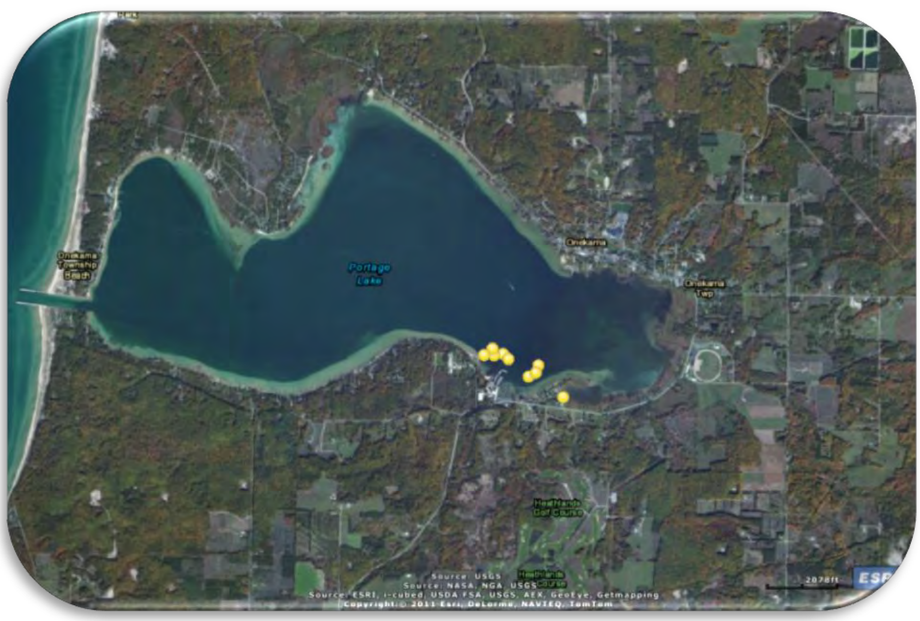
Weed and algae treatments were conducted in June and August to control Eurasian watermilfoil (EWM) and Phragmites. The lake was closely monitored this year for any areas of Eurasian watermilfoil growth and treated as soon as found.

Eurasian watermilfoil

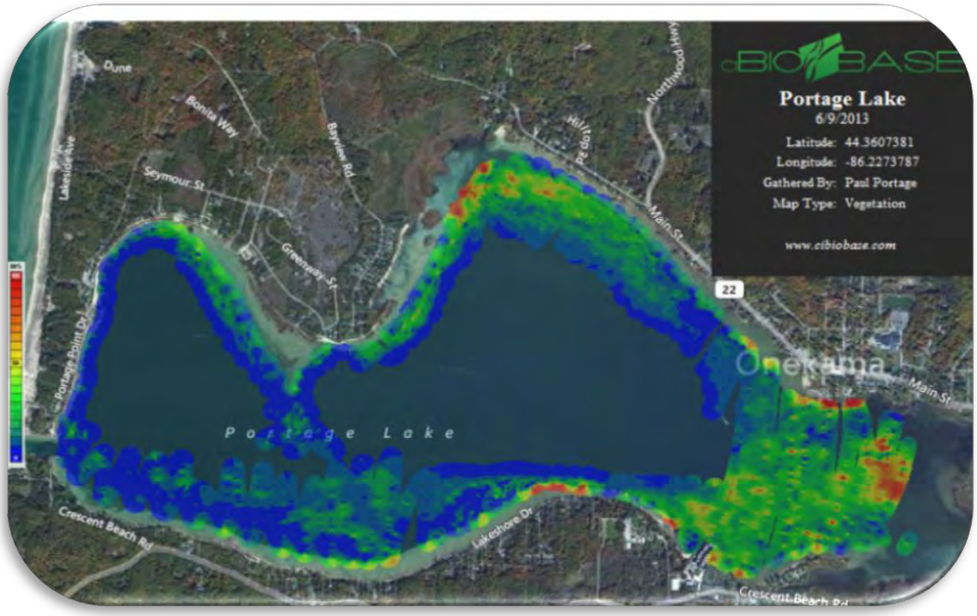
The management strategy for the control of Eurasian watermilfoil has been working. However, despite our efforts, EWM control is a constant battle. Further, the presence of hybrid milfoil supports the conclusion that milfoil treatments will continue to be required annually. A reflection of proper/successful management is a good fishery, which has been verified through the terrific fishing reports on the lake. The Phragmites Treatment Program was been very effective. After the initial treatment of 83 acres, the follow up years have required just a small treatment in proportion to the initial application, The below maps and table show a breakdown of the treatments in Portage Lake in 2013, as well as previous years for both EWM and Phragmites Control.

Map 1: Portage Lake June 2013 Treatment Map

Map 2: Portage Lake July 2013 Treatment Map



Map 3: Portage Lake June Vegetation Composition Map 2013 (pre treatment)



Map 4: Portage Lake July Vegetation Composition Map 2013 (post treatment)

Map 5: Portage Lake Phragmites Treatment Map 2013

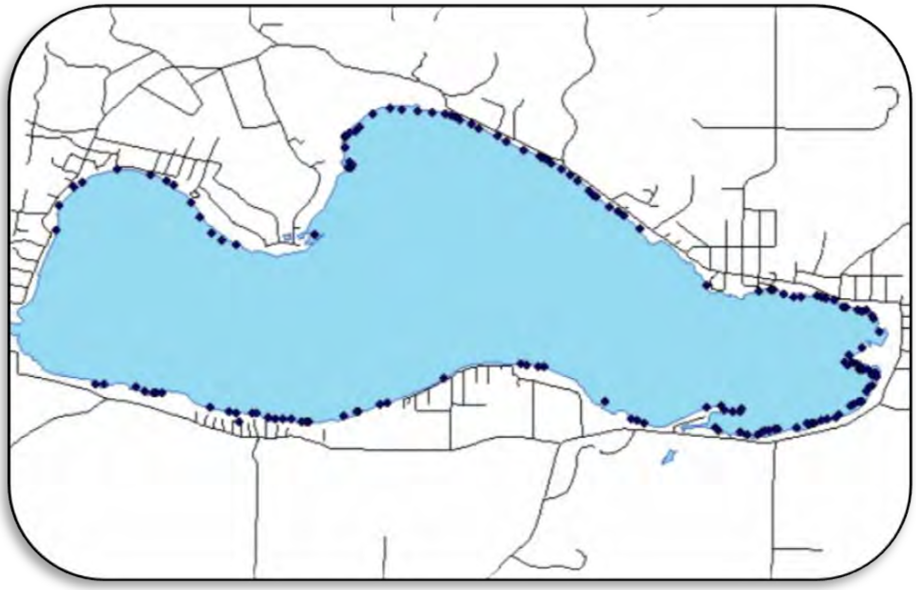


Table 1: Submersed Plant Treatment Quantities (2013-2009)

		Product	Rate #/Acre	Acres	Total Acres
2013	24,27 -Jun	Renovate OTF	160#	5	129.75
		Renovate Max G	160#	39	
		Sculpin G	160#	74.5	
	8-Aug	Sculpin G	160#	10	
		Clipper	200ppb	1.25	
2012	9-Jul	Renovate OTF	120#	10	145
		Renovate Max G	160#	55	
	24-Jul	Renovate OTF	120#	5	
		Renovate Max G	120#	40	
		Sculpin G (2,4-D)	160#	35	
2011	27-Jul	Renovate OTF	120#	22	22
2010	29-Jun	Renovate OTF	120#	5	86
		Navigate 2,4-D	100#	17	
	27-Sep	Renovate OTF	120#	14	
		Navigate 2,4-D	120#	50	
2009	15-Sep	Renovate OTF	120#	~41.5	161.5
		Navigate 2,4-D	100#	120	

Table 2: Phragmites Treatment Summary (2013-2009)

Year	Product	Rate	Acres
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

Planning/Evaluation

Complete surveys of the aquatic vegetation of the lake were conducted on June 4 and September 16, 2013. Additional surveys of the lake were made frequently throughout the summer months for pre or post treatment evaluation, to collect water quality parameters, as well 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 takes into account 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 through the use of 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 and is used to determine areas that will require treatment or management. The second survey is conducted in late summer or fall and is used to determine management success.

Table 3: Plant Species Found In Portage Lake –2013

AVAS Code	Common Name	Scientific Name	% Cumulative Cover June 2013	% Cumulative Cover September 2013
	Submerged- Exotic			
1	Eurasian watermilfoil	*Myriophyllum spicatum*	3.74	1.70
2	Curlyleaf pondweed	*Potomageton crispus*	3.21	0.00
	Submerged- Native			
3	Muskgrass	*Chara*	29.14	26.01
4	Thinleaf pondweed	*Potomageton spp.*	6.01	4.24
5	Flatstem pondweed	*Potomageton zosteriformis*	0.68	0.44
7	Variable leaf pondweed	*Potomageton gramineus*	0.40	1.23
8	White stem pondweed	*Potomageton praelongus*	2.29	0.84
9	Richardsons pondweed	*Potomageton richardsonii*	4.39	7.01
10	Illinois pondweed	*Potomageton illinoensis*	0.00	0.58
11	Largeleaf pondweed	*Potomageton amplifolius*	0.49	0.81
14	Water stargrass	*Zosterella dubia*	0.00	0.23
15	Wild Celery	*Vallisneria Americana*	0.00	19.52
17	Northern milfoil	*Myriophyllum sibiricum*	0.47	1.30
20	Coontail	*Ceratophyllum demersum*	0.79	2.36
21	Elodea	*Elodea Canadensis*	0.59	1.26
25	Naiad	*Najas flexilis*	1.36	4.16
27	Sago pondweed	*Potomageton pectinatus*	0.11	7.31
46	Nitella	*Nitella flexiliis*	0.00	0.13
	Emergent- Native			
30	Water lily	*Nymphaea odorata*	0.02	0.14
39	Cattail	*Typha spp.*	5.64	12.63
40	Bulrush	*Scirpus spp.*	2.54	7.98
	Emergent - Exotic			
43	Purple Loosestrife	*Lythrum salicaria*	0.00	0.01*
44	Common reed	*Phragmites*	0.03	2.30*
	Total		**61.91**	**102.20**

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

Current Conditions in the Lake

Aquatic Vegetation

Over the years the presence of Eurasian watermilfoil and curly leaf 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. Native plants currently have a good diversity and density in the lake.

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 2 are native North American species except Eurasian watermilfoil, Curlyleaf pondweed, Purple loosestrife, and Phragmites. These plants are non-indigenous aquatic nuisance species, i.e., plants from other places. These exotic plants cause considerably more problems than most native species. Eurasian watermilfoil 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 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. Three species commonly found in Portage Lake are Coontail, Sago pondweed and Wild Celery.

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 table break down the parameters tested in the different locations in Portage Lake including the Deep Hole Basins, shoreline sites, Tributaries and Storm Drains.

Table 4: Tributary Water Quality Portage Lake –2013

5/10/2013	Temp (F)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (mg/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Flow (Ft/sec)	Weather
Glenn	48	14.88	414	269	6.88	376	404	4.8	1.52	1	Rain, calm
McCormick	48.9	12.3	395	257	6.75	63	475	12	2.76	2.5	40°F
Onekama	48	14.06	385	250	8.07	18	475	26	1.68	0.8	
Schimke	487	14.23	349	227	7.84	44	378	22	1.51	1.4	
Dunham	48.2	11.13	365	237	7.89	10	470	2.1	1.56	1.6	
Hansen	49.2	12.49	434	282	8.06	62	474	18	1.24	1.9	
9/16/2013	**Temp (F)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (mg/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Flow (Ft/sec)**	**Weather**
Glenn	50.1	12.1	431	280	8.33	<10		2.6	2.86	0.6	Sunny,
McCormick	51.9	8.91	426	277	8.19	17		0.5	2.24	1.2	70°F
Onekama	52.5	10.3	421	273	8.36	16		1.4	2.27	1.4	
Schimke	54.8	10.19	406	263	8.31	35		2.6	2.2	1.6	
Dunham	53.1	10.12	390	253	8.23	<10		2	2.1	1	
Hansen	64.6	9.88	451	293	8.19	27		8.4	2.13	1.2	

Table 5: Deep Hole Basin 1 Portage Lake –2013

Basin 1 June 4 2013		Temp (F)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (mg/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	ALK (mg/L)	Chlor. A (ug/L)	Secchi
	s.	63.3	9.54	307	200	8.57	<10	352	0.71	<.10	127	3.26	14'
	10'	62.4	9.35	305	199	8.47			0.96				
	20'	57.4	10.84	303	197	8.44			0.72				
	30'	52.2	12.24	302	196	8.29	<10	366	0.85	<.10	124	3.31	
	40'	53.06	12.12	302	196	8.33			0.73				
	50'	49.9	9.77	313	203	7.86			0.76				
	60'	49.2	9.45	313	204	7.77	11	369	1.9	<.10	126	3.56	
Basin 1 Sept 16 2013		**Temp (F)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (mg/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**	**Secchi**
	s.	64.6	9.01	296	192	8.55	<10	374	1.2	2.83	116	3.4	14'
	10'	64.6	8.7	296	192	8.66			1.2				
	20'	59	9.15	299	194	8.41			0.69				
	30'	56.4	6.75	309	201	7.92	11	380	1.8	2.8	116	4.2	
	40'	54.6	3.48	322	209	7.59			3				
	50'	53.5	1.61	331	215	7.48			1.8				
	60'	51.7	1.4	332	215	7.47	<10	389	2.9	2.97	135	2.7	

Table 6: Deep Hole Basin 2 Portage Lake –2013

Basin 2 June 4 2013	Temp (F)	D.O. (mg/L)	Conduc-ivity (uS/cm)	TDS (mg/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	ALK (mg/L)	Chlor. A (ug/L)	Secchi
s.	64	10.18	310	201	8.56	<10		0.71	<.10	123	6.41	13'
10'	63.8	9.31	309	201	8.58			0.7				
20'	63.5	8.99	310	201	8.54			0.68				
30'	60.3	9.4	309	201	8.44	<10		0.85	<.10	127	- 0.854	
40'	54.3	8.32	316	205	8.02			0.66				
50'	53.8	8.39	319	207	7.84			0.54				
60'	53.3	7.47	323	210	7.67	<10		1.9	2.15	126	3.2	
Basin 2 Sept 16 2013	**Temp (F)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (mg/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**	**Secchi**
s.	66.8	8.34	298	194	8.59	10		1.2	3.32	113	5.8	13.5'
10'	66.8	8.14	298	194	8.62			1.5				
20'	66.7	8.07	298	194	8.6			0.86				
30'	66.4	7.89	299	194	8.54	<10		1.5	2.7	126	4.2	
40'	61.5	2.42	331	215	7.63			2.9				
50'	58.1	2.38	336	219	7.56			4.6				
60'	58	2.34	337	219	7.54	12		10	2.09	142	0.961	

Table 7: Shoreline Sampling Portage Lake –2013

June 4 2013	Temp (F)	D.O. (mg/L)	Cond. (uS/cm)	TDS (mg/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Chlor. A (ug/L)	Secchi
S. 3a	63.8	11.63	323	210	8.69	13		0.7	<.10	1.07	3.5'
S. 3b	65.4	12.02	315	205	8.81	17		0.9	<.10	0.819	1.5'
S. 3d	65.6	10.61	318	207	8.7	13		0.69	<.10	2.4	3'
Sept 16 2013	**Temp (F)**	**D.O. (mg/L)**	**Cond. (uS/cm)**	**TDS (mg/L)**	**pH (S.U.)**	**TP (ug/L)**	**ORP (mV)**	**Turb. (NTU)**	**TKN (mg/L)**	**Chlor. A (ug/L)**	**Secchi**
S. 3a	65.9	8.52	298	193	8.59	<10		1.3	3.58	7.2	3.5
S. 3b	65.1	9.81	298	193	8.55	<10		1	2.57	5.4	2'
S. 3d	62.4	10.8	310	202	8.42	<10		2.1	2.94	3.7	3'

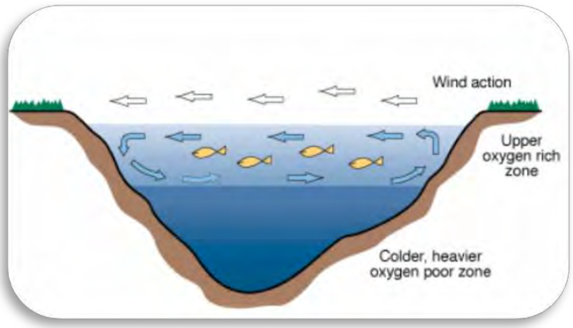
Table 8: Storm Drain Sampling Portage Lake – May 10, 2013

	Temp (F)	D.O. (mg/L)	Cond. (uS/cm)	TDS (mg/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Flow (Ft/sec)	Weather
#2 Zosel Park	54.2	9.93	403	262	7.31	36	391	4.2	2.09	Slow, murky	slight rain
#5 Fourth St	51.3	10.6	553	359	7.52	36	346	3	1.81	quick, clear	slight rain
#6 Third St	50.4	12.48	331	216	7.72	34	353	3.3	1.73	slow, clear	slight rain
#7 First St.	52	7.12	357	232	7.78	40	321	2.1	2.28	slow, clear	slight rain

Temperature and Dissolved Oxygen Profiles

Depth profiles of temperature and dissolved oxygen indicate that on June 4 the lake was already stratified. The surface levels were above saturation, 9.54 mg/L at Basin 1 and 10.18 mg/L at Basin 2 with shoreline ranged from 10.61 to 12.02 mg/L. At this time, Portage Lake had adequate dissolved oxygen all the way down to 60' in depth (9.45 mg/L in Basin 1 and 7.47 mg/L in Basin 2).

On June 4 the lake was thermally stratified, with a thermocline at approximately 20'. 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 well oxygenated.



On May 10, four storm drains and six tributaries were tested coming into Portage Lake. All sites were well oxygenated ranging from 7.12 to 14.23 mg/L.

In September, the lake was still stratified and was anoxic below the thermocline (void of oxygen). The thermocline was in Basin 1 was 20' and at that point the oxygen levels started a quick drop to 1.4 mg/L at the bottom; anoxic water. In Basin 2, the surface waters had already mixed slightly (high winds were reported during the sampling) and it pushed the thermocline deeper to 40'. Below the thermocline, the oxygen levels again dropped off, showing very anoxic waters at the bottom of the lake.

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.

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 and September as well as in the tributaries and shoreline sites. The pH in June ranged 7.67-8.57 (bottom waters having slightly lower pH than surface) and in September from 7.54-8.66 (bottom waters having slightly lower pH than surface waters). The shoreline sampling was similar to the deep hole basins as was the tributary and storm drain sampling.

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 and September in both Basin 1 and Basin 2. The average sampling between both basins in June was 125 mg/L with a range of 123-127 mg/L. The September samples were similar with an average of 124 mg/L with a range of 113-142 mg/L. All sampling show the lake to be considered "soft" with readings under 150 mg/L, a typical threshold of a hardwater 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 readings of TDS on Portage Lake ranged from June readings averaging 201 mg/L to September readings averaging 203 mg/L. (Shoreline samplings were very similar to deep basins). The tributary sampling in September was only slightly higher. 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 and overall the spring readings (average 310 uS/cm) were slightly lower than the September readings (average 313 uS/cm), likely due to runoff which is also supported by the higher conductivity readings from the Tributaries (May average Conductivity reading is 390 uS/cm while September average is 420 uS/cm). The tributary Conductivity readings are almost considered high dissolved salts (material). All of these numbers are similar to past data collected.

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 of 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. Of the 2013 sampling data that was analyzed (additional testing will take place in 2014) all the sampling appeared to be oxidized.

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 participles can capture heat from the sun raising water temperature as well (often witnessed in shallow waters). Turbidity readings on Portage Lake averaged 0.9NTU's in June to 2.5NTU's in September with higher readings near the bottom of the lake. Shoreline sampling averaged annually was 1.1 NTU's while the tributaries average was overall higher, which would be expected in a shallow, flowing system (14.15 NTU's in May while lowered to 2.9 NTU's in September). 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 14 feet while Basin 2 was 13'. Basin 2 is likely more impacted by the fetch of the lake, therefore would likely have a lower Secchi disk reading. Clarity remained consistent all summer with the

Secchi disk depth of 14' in September in Basin 1 and 13.5' in Basin 2. Water clarity can fluctuate from week to week depending on several environmental factors such as rain fall & algal production. These clarity readings show that sunlight will be available for plant and algae throughout much of the lake.

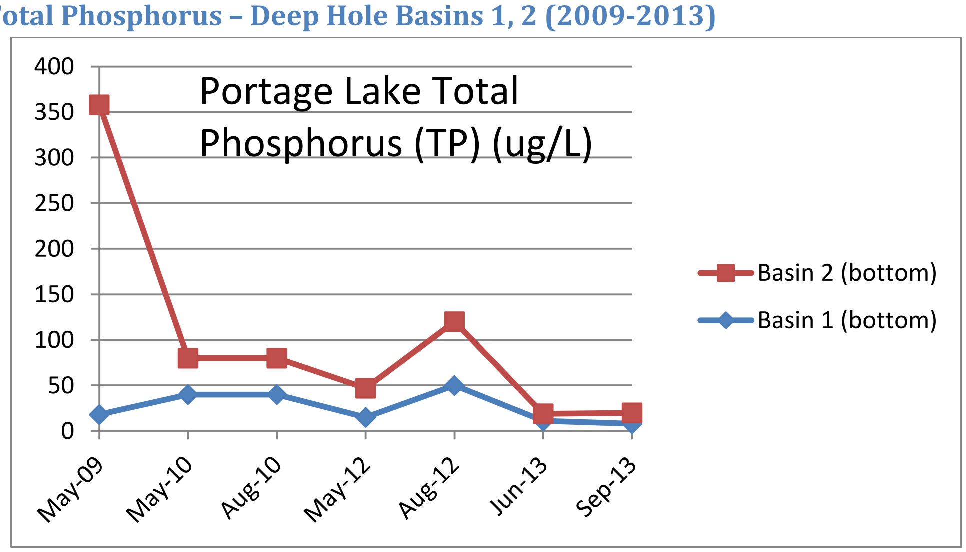
Total Phosphorus

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. Total phosphorus concentrations in June in Basin 1 were <10 μg/L at the lake surface, and <10 μg/L at thermocline depth and 11 μg/L in the bottom water. In Basin 2, <10 μg/L at the lake surface, and <10 μg/L at thermocline depth and <10 μg/L in the bottom water. The June Shoreline readings from sites 3A, 3B and 3D ranged from 13-17μg/L. The tributary TP readings in May ranged from 10-63μg/L with an outlier of 376μg/L in Glenn Creek, which could be due to a bad sample as fall levels were much lower. Storm Drain TP May readings were from 34-40μg/L. Readings above 10μg/L are considered slightly enriched while readings over 30μg/L are considered enriched. It is not surprising that the higher TP readings are coming from the tributaries and storm drains. The lower overall lake concentrations are an excellent sign.

September Total Phosphorus concentrations were: Basin 1 <10μg/L at the surface, 11μg/L in the thermocline and <10μg/L at bottom while Basin 2 10μg/L at the surface, <10μg/L in the thermocline and 12μg/L at bottom. The shoreline readings from sites 3A, 3B and 3D were all <10μg/L while the tributaries overall range lowered greatly from <10μg/L to 35μg/L. The high May reading in Glenn Creek was reduced to Phosphorus concentrations of <10μg/L and the higher September reading was in Schimke Creek. The September readings show that the higher phosphorus concentrations are found in the tributaries and that internal loading was not a large contributing factor to TP in 2013. The 2013 data shows the TP has declined greatly in both Basins in 2013. Additional data to see if this drop is unique to 2013 or on a decline is required. Basin 2 is routinely higher in concentrations than Basin 1, which is expected due to the fetch of Portage Lake.

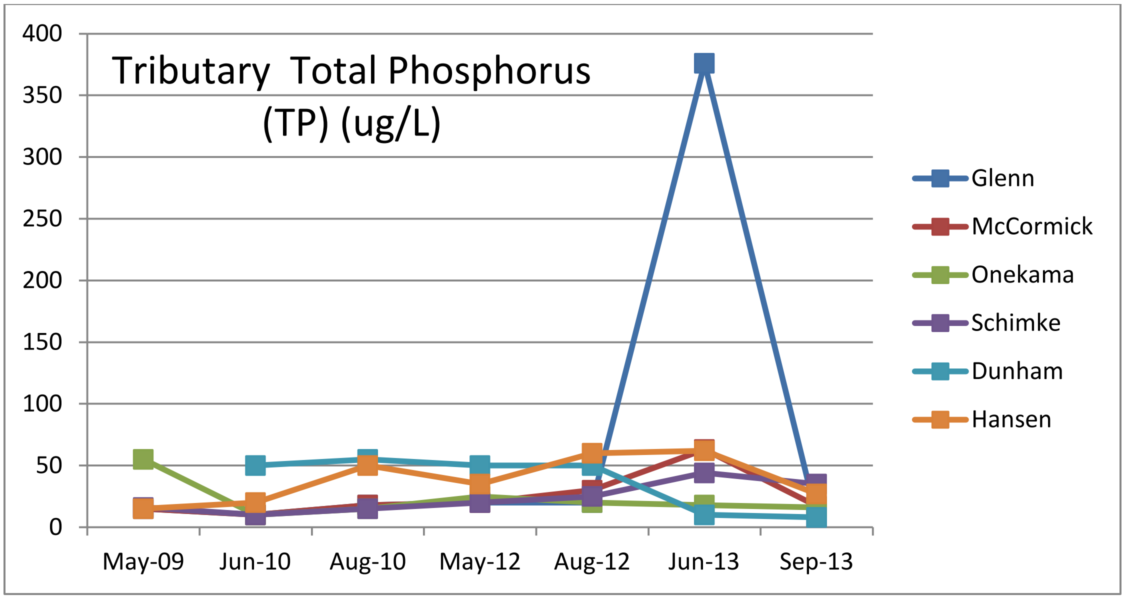
See below graphs of TP concentrations from 2013. Basin 1 and 2 are graphed using data previously collected on Portage Lake (via various sources, provided to PLM via the Portage Lake Watershed Forever website).

Graph 1: Total Phosphorus – Deep Hole Basins 1, 2 (2009-2013)



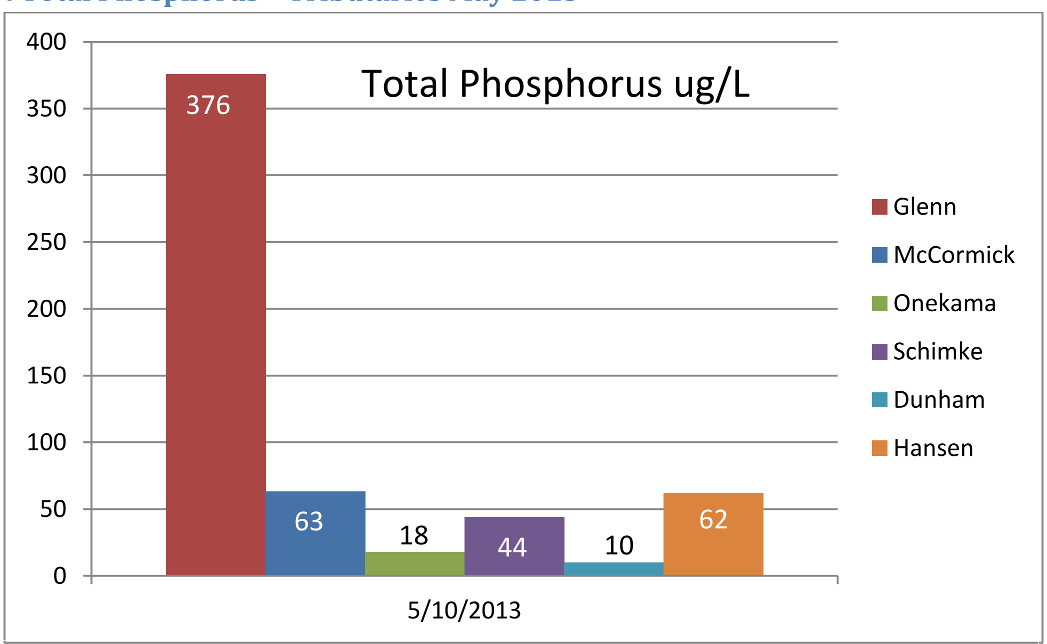
As the graph illustrates, there have been a few spikes in the TP concentrations over time and an overall decrease in 2013. Basin 2 is routinely higher in TP than Basin 1.

Graph 2: Total Phosphorus – Tributaries 2009-2013



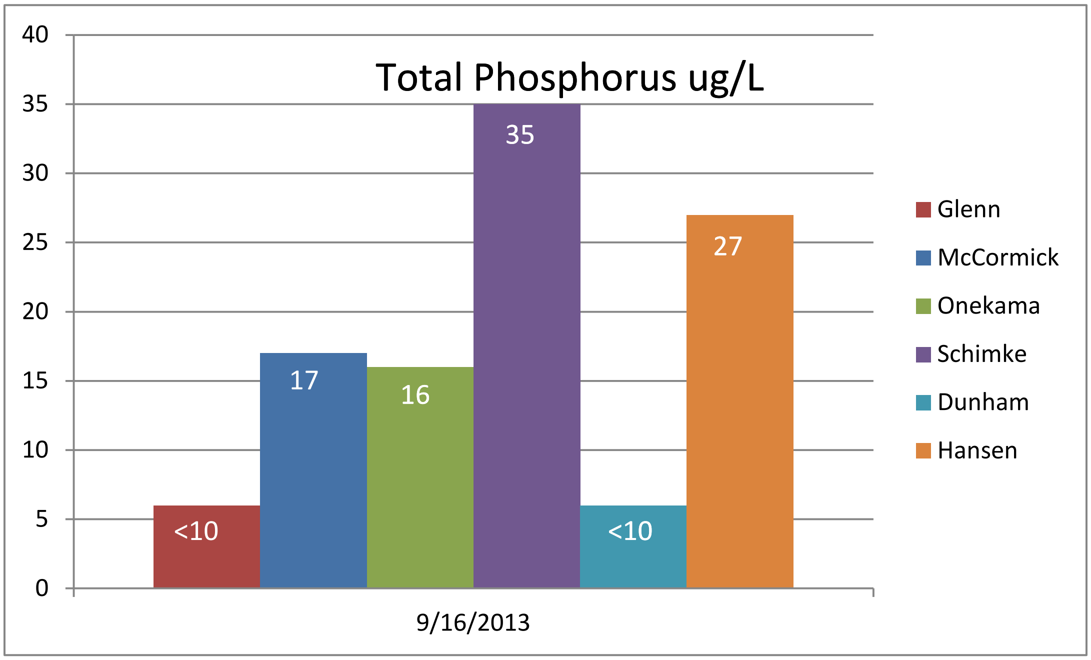
As the graph illustrates, there is consistency between the creeks on an annual basis. See below graphs to show the 2013 comparisons between the creeks.

Graph 3: Total Phosphorus – Tributaries May 2013



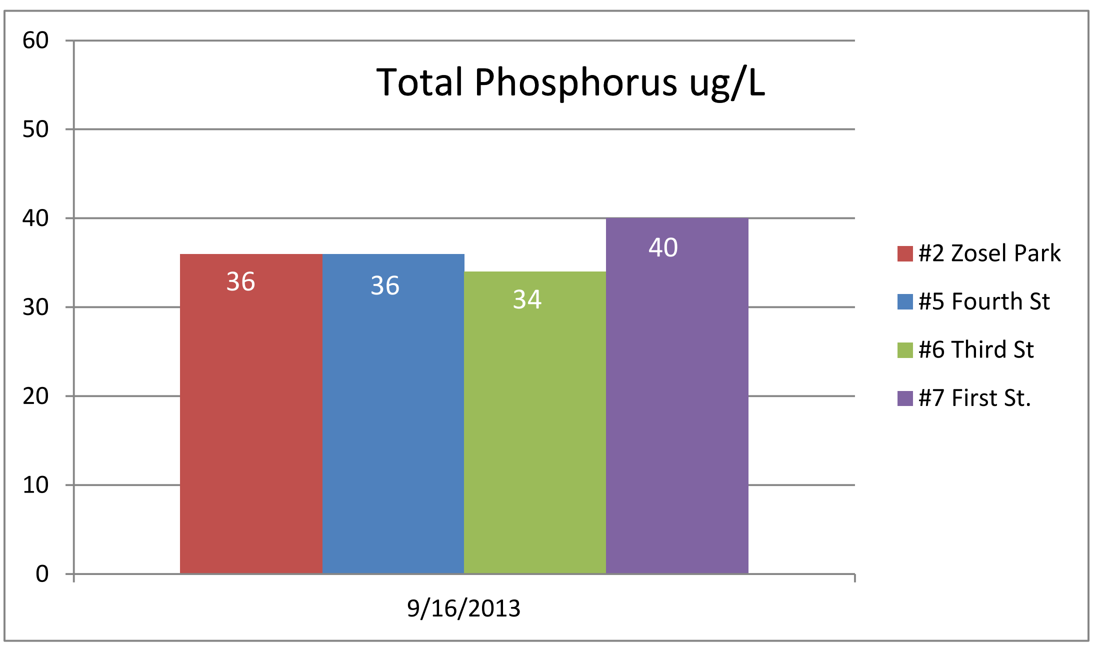
As the graph illustrates, there is a large fluctuation between the TP in the different creeks entering Portage Lake. The highly elevated Glenn Creek could be due to a contaminated sample or evidence of a large Phosphorus loading site into Portage Lake.

Graph 4: Total Phosphorus – Tributaries September 2013



As the graph illustrates, there is a large fluctuation between the TP in the different creeks entering Portage Lake, and their TP concentrations shifted greatly from the May readings. Note: TP <10 are graphed above at an estimated level below 10 to show on the graph. Lab analysis is limited to >10 concentrations. Further concentrations <10 are considered very low, not enriched.

Graph 5: Total Phosphorus – Storm Drains May 2013

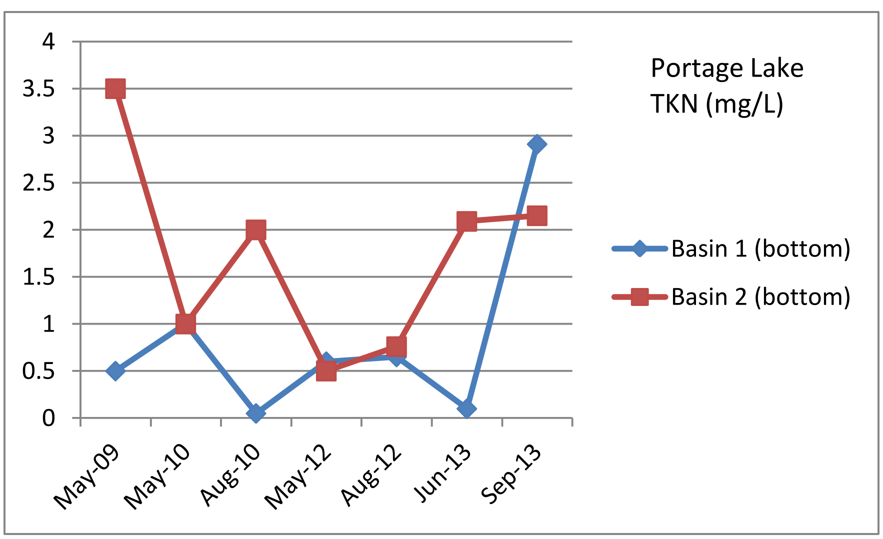


As the graph illustrates, there is similarity between the TP in the different storm drains entering Portage Lake, and their TP concentrations are much enriched. These sites are a key introduction point of Phosphorus into Portage Lake.

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). Nitrate Nitrogen was not specifically tested in Portage Lake, but the overall TKN was. Lakes with a TKN value of .66mg/L are typically classified as oligotrophic lakes (having fewer nutrients, less productivity). Lakes will TKN values above 1.88mg/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. 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 can be 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 1000 ug/L are considered suitable for healthy fisheries. Ammonia concentrations usually do not become elevated until water is void of oxygen and the nitrates are converted. Ammonia testing was not done in Portage Lake in 2013, but it is recommended in the future. The TKN readings on Portage Lake at Basins 1 and 2 in the June were very low, <.10mg/L however the September samples showed much higher elevated numbers ranging from 2.09mg/L – 2.91mg/L. The tributaries and storm drains showed elevated TKN numbers in the May, June and September samples ranging from 1.24 mg/L- 3.58 mg/L. TKN readings have increased in 2013 and additional testing is recommended to tell whether the trend is slowing increasing. These increases show that the lake (at the time of sampling) is Phosphorus limited.

Graph 6: TKN – Portage Lake Basins 1, 2 (2009-2013)



As the graph illustrates, the TKN concentrations on Portage Lake have fluctuated greatly over the last few years, with a large spike in September 2013. Again, Basin 2 is routinely higher in Basin 1, which would be expected based on the location and the fetch of the lake.

Chlorophyll

Chlorophyll measures the amount of algae (green plant) in the water. Some 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 in June (1 to 6.41 μg/L) averaged at 2.89ug/L indicate low to moderate algal populations. Shoreline samplings sites (3A, 3B, 3D) averaged 1.4ugl/L, very low. Chlorophyll increased slightly overall in September to an average 3.62 μg/L at the Deep Hole Basins (.9-5.8ug/L) while the shoreline sites averaged 5.4ug/L. This higher level, in shallow, warmer waters is common as the warmer water can be a breeding ground for algae. Overall, chlorophyll levels are on average low to moderate overall and appear to be less than past years on Portage Lake.

Algae Composition

Algal composition testing was performed at both deep Basins as well as the shoreline testing sites in June and September. The June testing showed the majority genera present included (presented as must abundant to least abundant); Bacillariophyta (diatoms): *Asterionella sp., Stauronesis sp., Stephanodiscus sp., Cyclotella sp.,* Chlorophyta (green algae): *Chlamydomonas sp., Pediastrum sp., Micrasterias sp., Scenedesmus sp.,* Cyanophyta (blue green algae): *Gomphosphaeria sp., Lyngbya sp.* The September sampling showed that the similar species in the genera were present however, Cyanophyta (blue green algae), specifically *Microcystis sp*., was more abundant than other species and genera of phytoplankton. Some blue green algae, including *Microcystis sp*., can produce toxins. These toxins are normally released when the algae nears 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., Rotifer sp.,* and *Copepods sp*. Diverse and present phytoplankton is required to have a healthy zooplankton community as the base of the food chain. The diversity in Portage Lake is evidence of a healthy water quality structure and a healthy, robust fishery.

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. E. Coli was tested in Portage Lake in July of 2013. Three locations of concern were tested in the lake including Schimke Creek and the Camp Area. All samples came back very low.

Table 9:E. Coli Results In Portage Lake –2013

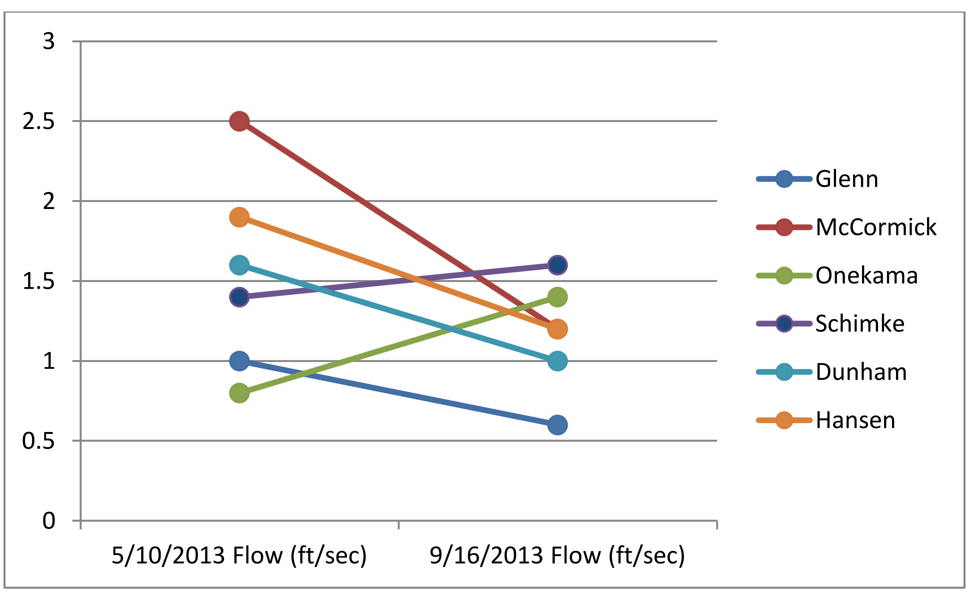
Ecoli	E. Coli (CFU/100mL)	Total Coliforms (CFU/100mL)	Notes
Sample 1 Schimke Creek	4	28	Water meets bacteriological standards for safe swimming
Sample 2 Camp	4	4	Water meets bacteriological standards for safe swimming
Sample 3 Camp	4	20	Water meets bacteriological standards for safe swimming

Bacterial counts are expressed as the number of Colony Forming Units per 100 milliliters (CFU/100mL). For full body contact recreation (including swimming) counts of E. coli should not exceed 130 (CFU/100mL)as a monthly geometric mean of at least five samples per the State of Michigan standard, or single samples should not exceed 298 (CFU/100mL) [235 CFU/100mL in a designated bathing beach area] per Federal (EPA) guidelines. Current recreational water quality standards do not rely on Total Coliform counts.

Tributary Flow

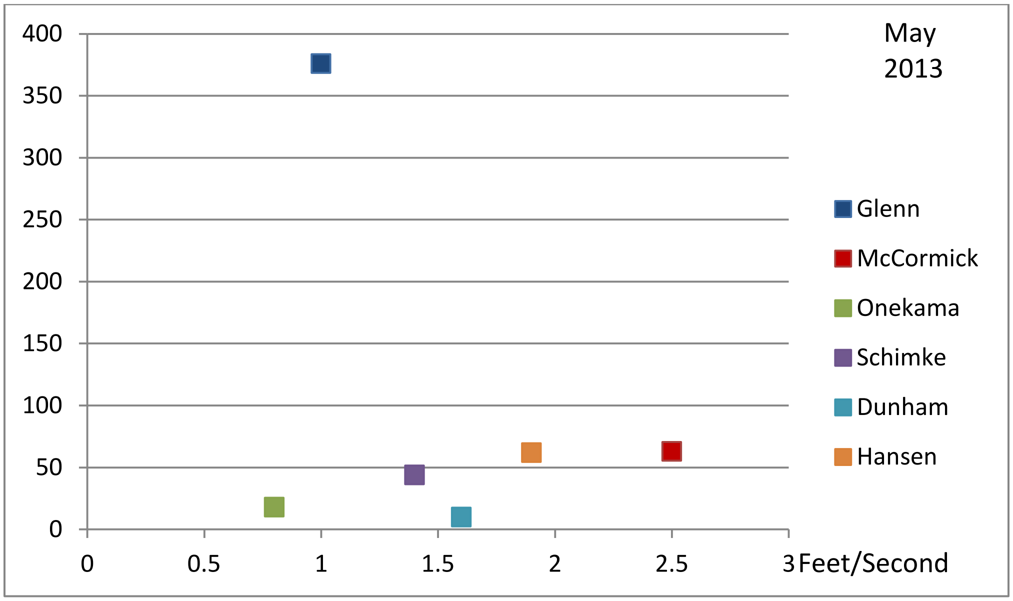
Flow rate data was determined, using a digital flow meter, at the six tributaries studied in 2013 in May and September. Flow ranged from 0.8 -2.5 feet/second in the May sampling and from 0.6-1.6 feet/second in September. The rates of flow varied from each creek and the basic chemistry varied as well. 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 7: Tributary Flow Rates –May and September 2013



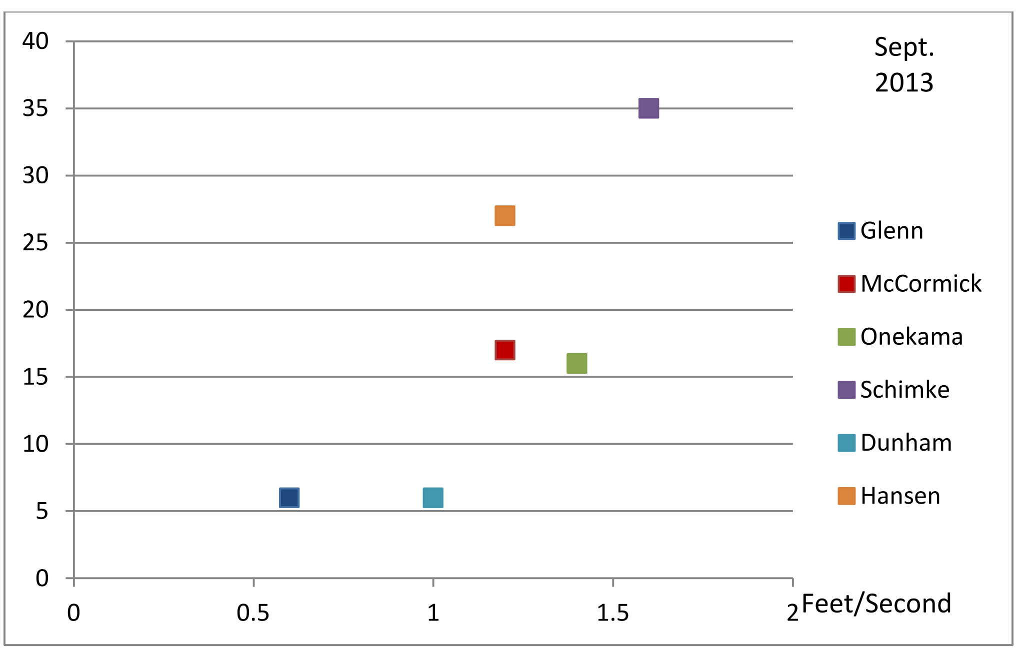
As the graph illustrates, there was a decline in flow rate at the end of the summer versus the beginning of the summer. Rain is often greater in the spring, causing increased flow from the Tributaries into the lake.

Graph 8: Tributary Flow Rates and Phosphorus (ug/L) comparisons –May 2013



As the graph illustrates, for the most part, the greater the flow, the higher the Total Phosphorus. Again, the outlier shown in Glenn Creek, mentioned earlier in discussion of the TP concentrations could be from a bad sample, as overall a strong correlation is shown.

Graph 9: Tributary Flow Rates and Phosphorus (ug/L) comparisons –September 2013



As the graph illustrates, for the most part, the greater the flow, the higher the Total Phosphorus. Overall a strong correlation is shown between flow and TP in the Creek sampled.

Evaluation of Trophic Status

Carlson's Trophic State Index (TSI) calculated from June data yielded values between 28 and 43 and from September data yielded values between 28 and 40 (see Table 10). In general, these values rate Portage Lake as meso-oligotrophic to mesotrophic. Characteristics associated with 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.

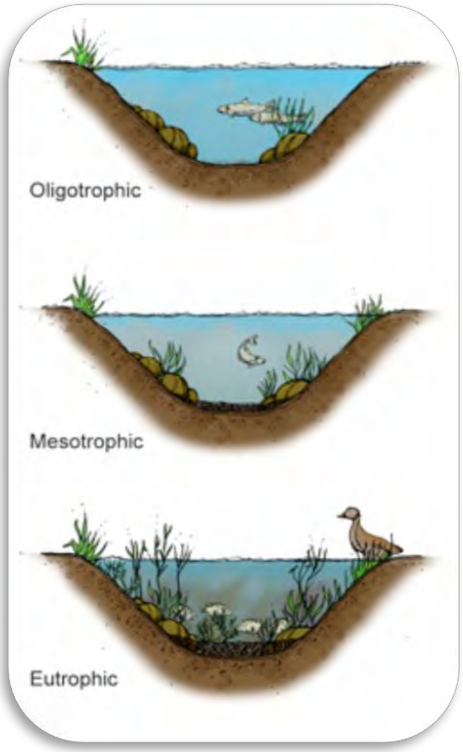


Table 10: June Trophic State Index (TSI) Values

Site	TSI from Secchi Depth	TSI from Total Phosphorus	TSI from Chlorophyll
Basin 1 – June	39	28	42
Basin 2 - June	40	28	43
Basin 1	39	28	40
Basin 2	40	36	30

2013 Water Quality Concerns/Recommendations

Current water quality problems in Portage Lake 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.

Management Recommendations for 2014

Management options are dependent on many factors, including but not limited too, 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 2014 aquatic plant management program should detect and treat any areas where Eurasian watermilfoil or hybrid watermilfoil is present.

Any areas of Eurasian watermilfoil should be promptly treated using herbicides. Treatments with the herbicides, Triclopyr and/or 2,4-D, in localized treatment areas to slow the spread of Eurasian watermilfoil, when found should be conducted. The herbicides Triclopyr and 2,4-D, control Eurasian watermilfoil with little or no impact on most native plant species. Since they are selective, systemic herbicides, they can actually kill Eurasian watermilfoil plants. Under ideal conditions, several consecutive annual applications of Renovate or 2,4-D can reduce Eurasian watermilfoil to a maintenance (low) abundance. For this strategy to succeed, it is necessary to treat all the Eurasian watermilfoil in the lake each time they are applied. Michigan regulation restricting 2,4-D use in the vicinity of drinking water wells may result in the inability to apply 2,4-D near the shoreline of the lake.

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, can also provide short-term control of Eurasian watermilfoil. These herbicides kill only the shoots of the plant, and plants regrow relatively rapidly from their unaffected belowground parts.

Nuisance native plant management can also be incorporated into a lake management program with conventional herbicide treatments if needed. Native plant treatments are completed using only contact herbicides in beach areas. Contact herbicides will not target the root system of the plant.

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. The systemic herbicides, Glyphosate and Imazapyr, are effective at controlling Phragmites while Renovate 3 is effective in controlling Purple Loosestrife. Since they are systemic herbicide, the root system of the plant will be killed not just the foliage. Further, Purple Loosestrife should continue biological control measures as well.

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 formation of the SAD or from outside factors, they may not be included in this budget.

Table 11: Proposed 2014 Budget Portage Lake

Proposed/ Estimated Budget	2014
Emergent Control	7,000
EWM Control	55,000
Permit	1,500
Lake Management	12,500
Contingency Funds	7,600
Total	**83,600**

The Recommended Management Schedule for 2014:

- A spring vegetation survey (to evaluate conditions in the lake).
- Herbicide Treatment for milfoil as required
- Extensive water quality monitoring throughout season
- A fall vegetation survey
- Late summer/fall Phragmites treatment