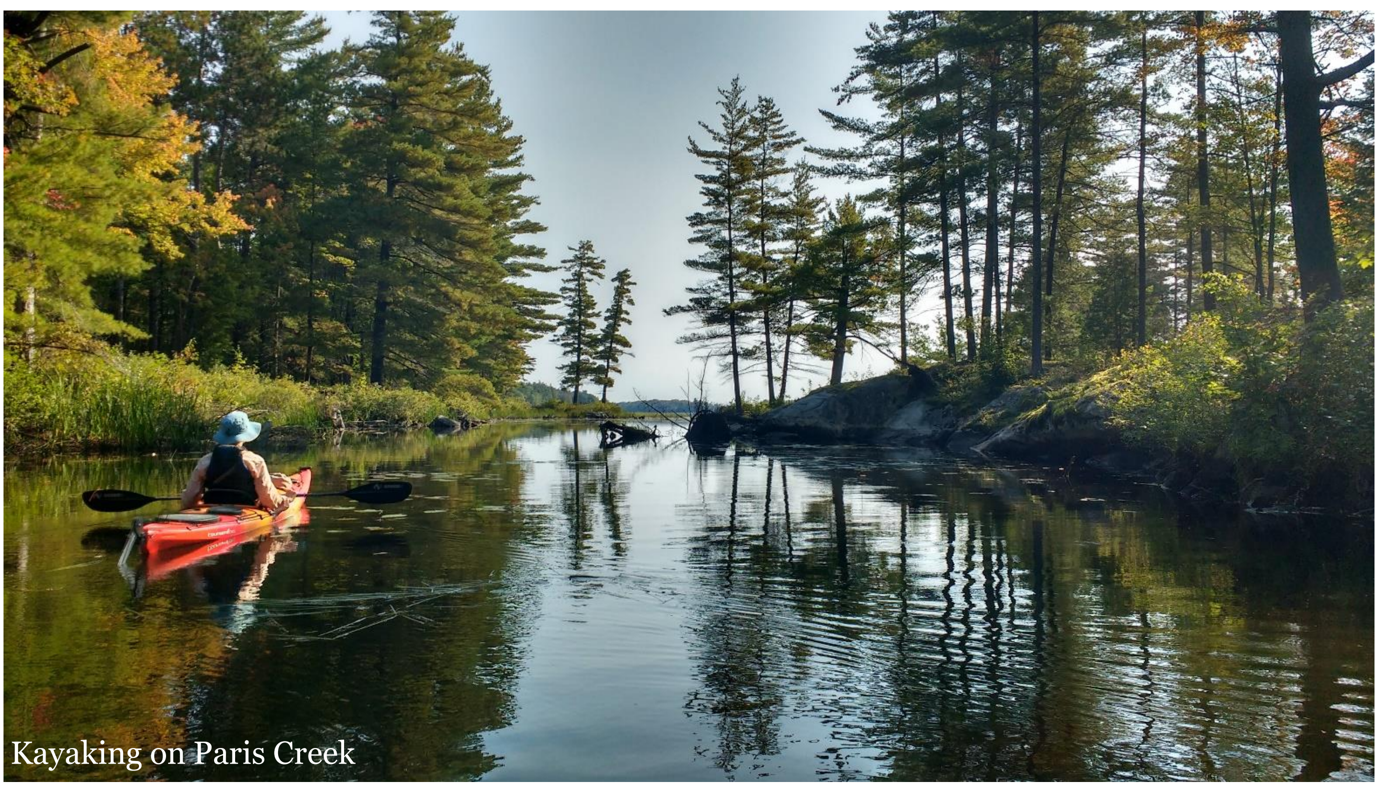
WHITE LAKE PRESERVATION PROJECT

REPORT

Water Quality Monitoring Program 2017


Kayaking on Paris Creek

ABSTRACT

White Lake waters were monitored for 13 physical and chemical parameters as well as for biological factors. Nine sites representing all parts of the lake were sampled every two weeks from May through October. The results show that the presence of zebra mussels has altered the chemistry of the lake. Of particular interest this year is the significant increase in water clarity (even when compared to 2016!) resulting from the filtering effect of zebra mussels. The total phosphorus levels measured in the lake water decreased by about 15 percent when compared to values obtained last year and 60% when compared to 2015 levels. There is no evidence that there was less phosphorus entering the lake in 2017 as compared to previous years. The much lower levels of total phosphorus found in the lake during the 2016/2017 seasons were due to the explosion of zebra mussel populations throughout the lake. Lower phosphorus levels are entirely due to the transfer of phosphorus from lake waters to the sediments (especially near-shore sediments) by zebra mussels, a process which encourages green algal blooms and even toxic blue-green algal blooms to occur. Although there were no toxic algal blooms observed in 2017, there was a lake-wide proliferation of filamentous green algae seen along most of the shoreline of the lake. This algal bloom is expected to return next year.

The detailed chemical and biological data and interpretations contained in this report provide us with basic information about White Lake and also any trends evolving with time. This data is important now and also to future generations of investigators studying White Lake.

The effects of zebra mussels as well as climate change are only two of the multiple stressors affecting White Lake which, taken together, make the lake more susceptible to algal blooms and other undesirable consequences due to human activity. The results contained in this report highlight the importance that we, the caretakers of White Lake, do whatever we can to minimize our impact on White Lake ecosystems.

February, 2018

2.0 Overview

Many people ask us to describe the condition of White Lake in a word. They ask if it is in good condition or in only fair condition. Although it would be expedient to do so, these terms are subjective, have little meaning, and cannot be used to paint a complete picture which is in reality much more complex. Our objective is to collect valid data in a systematic and scientific manner, to interpret these data and in turn inform you of changes taking place over time. We publish all of our raw data and invite anyone to suggest alternate interpretations. This is how science works. The word '*Preservation*' looms large in our organizational name because one of our main objectives is to work to keep the lake in as pristine a condition as possible.

The data collected during the 2015 ice-free season showed that the quality of White Lake waters progressed from Mesotrophic (moderately enriched, some nutrients) to Eutrophic (enriched, higher levels of nutrients) during the summer season. These observations were in general agreement with historical data collected over many years. However, the data we collected was more extensive and systematic than any data collected in the past. Recent toxic algal blooms spurred us to study the lake in more detail than ever so that we could gain insight into the cause and control of these algal blooms, which can be a public health issue.

In 2016, White Lake experienced an explosion in populations of zebra mussels, with numbers estimated to be up to one billion individuals. Zebra mussels have been found in every part of White Lake and are especially prevalent attached to aquatic plants. In 2017, the extent and the intensity of the infestation increased significantly. It will likely take several more years before an equilibrium is reached and zebra mussels numbers become stable.

The most obvious effect of the presence of zebra mussels is the greatly increased clarity of the lake. Looking back at 2015 and years previous, such a finding would have been welcomed as an improvement in water quality. However, attendant effects of zebra mussels are serious and transformative. Zebra mussels are filter feeders and can lead to the wholesale (~90%) transfer of nutrients from lake waters to sediments, especially near the shoreline. White Lake is only 9.1 m deep at the deepest location and has an average depth of 3.0 m. Secchi depth reading which measure water clarity reached over 7 m in 2017. This means that for the first time virtually the entire floor of the lake is illuminated with sunlight.

The concentration of total phosphorus in the lake has declined when compared to levels measured in previous years. Total phosphorus levels are 15% lower than they were just last year and 60% lower than they were during 2015 and in previous years. This trend will likely continue into the future. The reduction in total phosphorus levels in no way indicates that there is less phosphorus entering the lake. There is, in fact, no evidence of any changes in human activity or other factors which would result in lower total phosphorus levels other than those resulting from zebra mussels infesting of the lake.

Another consequence of zebra mussel infestation is the occurrence of blooms of filamentous green algae. These were especially visible this year. Throughout the lake could be seen large green mats of the algae growing on the lake floor or extending its reach and draping itself on aquatic plants reaching almost to the surface of the lake. These are likely to occur again next year.

At present, we do not know what the final state of White Lake will be with respect to zebra mussels and their effect on water quality because every lake is unique with respect to available nutrients, physical and chemical conditions. However, there is ample scientific literature for us to use to predict some of the changes that will take place (see Bibliography at end of report). At best, we will have to become accustomed to the presence of zebra mussels as a common nuisance. Zebra mussels transfer phosphorus to nearshore areas and create what are perceived to be positive impacts in open water areas (lower phytoplankton densities together with higher water clarity) and negative impacts in nearshore areas in the form of fouled sediments and increased green algal biomass. There is scientific literature reporting that zebra mussels have been shown to increase abundance of *microcystis aeruginosa* blue-green algae with associated increases in algal toxins. Only time will tell what the effects of zebra mussels will be on White Lake.

In the meantime, we have become more vigilant and press our politicians to work with our lake associations and other interested parties to ensure that existing bylaws are enforced and that we take measures to protect and preserve the lake. These measures could include septic inspections, shoreline rehabilitation, limits on boat sizes and the control of damaging wakes. There are many things we can do to mitigate the effects of other stressors we cannot control such as already present invasive species and climate change.

We should also become organized as a society to pro-actively work to prevent the infestation of White Lake with other invasive species some of which have effects far worse than zebra mussels. They are just around the corner!!

The report following this introduction details all of the changes we have measured and the interpretations we put forward. Not everyone will want to read and assimilate all of the information detailed in this report.

The Science Committee and the WLPP value your opinions and suggestions and welcome any comments or questions you may have concerning this report, its contents or any of our other activities. There is an anonymous suggestions box setup for your convenience on the WLPP website main page at: www.WLPP.ca or you may contact us directly at WLPPmail@gmail.com.

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Out on a water sampling run!

4.0 <u>WLPP Water Quality Monitoring Program</u>

The water quality monitoring program for 2017 consisted of two parts. The first part was carried out by WLPP volunteers and involved the collection of water samples mid-month for 6 months starting in May. We continued to monitor the Deepest Pickerel Bay site so that we would always have a site at which we can measure the Secchi depth, no matter how clear the water becomes as a result of the presence of zebra mussels. This site is located over the deepest spot on the lake at 9.1 m. Duplicate water samples were collected for phosphorus analysis and a single separate sample was collected for calcium, chloride, sulphate, and dissolved organic carbon determinations. Water samples were filtered through an 80-micron mesh to remove any large biota such as daphnia which would skew analytical results. Note that the total phosphorus data obtained is for both phosphorus available as free phosphorus (there are several phases of phosphorus suspended and in solution) as well as phosphorous contained in small phytoplankton and zooplankton. Secchi depth readings as well as temperature at the Secchi depth were recorded at the same time. Additionally, Secchi depth and temperature readings were taken every two weeks during the summer season providing additional data for these parameters. We also completed extensive field studies of specific conductivity, total hardness, magnesium hardness as well as temperature and depth measurements.

All water samples for the determination of phosphorus content were shipped to the Dorset Environmental Science Centre (Ontario Ministry of the Environment and Climate Change) for analysis under the auspices of the Lake Partners Program. The method used for the determination of phosphorus is described in the publication: B.J. Clark et al, *Assessing variability in total phosphorus measurements in Ontario lakes*, Lake and Reservoir Management, 26:63-72, 2010. The limit of detection for phosphorus using this method is 0.2 parts per billion (ppb).

The second sampling protocol was carried out under contract with Watersheds Canada. Transportation to sampling sites on the lake was provided by WLPP volunteers. Sampling was carried out on three days mid-month in May, July and September. In addition to Secchi depth, readings were taken at metre or half-metre intervals for temperature, dissolved oxygen, specific conductance, and pH. Water samples were also taken for chlorophyll-a and alkalinity measurements.

The results obtained from this study differed considerably from those obtained by the same program in 2015, but were similar to results obtained in 2016. Water clarity was very high with a maximum Secchi depth greater than 7 m being recorded. The pH of the lake indicated that waters were alkaline but increased somewhat in pH as the season progressed. The alkalinity or hardness of the water and the electrical conductivity of the lake did not change appreciably during the season. This trend was in agreement with 2015 results when these parameters were nearly constant throughout the ice-free season. Chlorophyll-a values essentially collapsed to levels which were at or near the limit of detection for the analytical method used. The scientific literature reports that when a zebra mussel infestation occurs, phytoplankton population in the water column can be reduced by more than 90%. Since White Lake is a relatively large but very shallow lake, the surface area on which zebra mussels can thrive is large when compared to the total volume of water contained in White Lake. For this reason, it is more likely that phytoplankton populations were almost totally removed as would not be the case for a much smaller and deeper lake. For all of the sampling sites, dissolved oxygen content was adequate to support the species of fish found in White Lake. However, dissolved oxygen values were lower later in the year and with increasing depth.

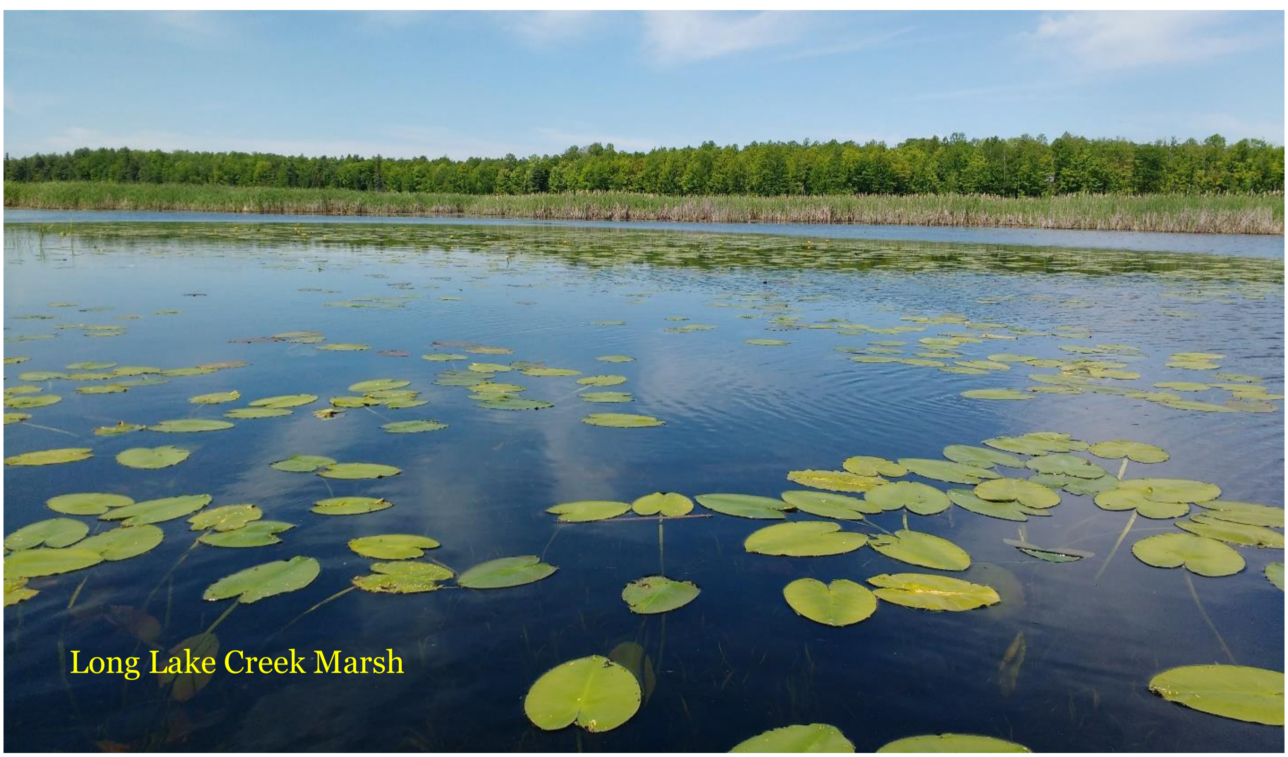
Measurements for specific conductivity, pH, Cl, Ca, and dissolved organic carbon all show high results and that the waters contained in Hayes and Bane Bays are quite different from waters found in the remainder of the lake, especially the Main Water Body (Zone 1, see Section 7.0 of this report). This prompted us to revise the lake zone map we developed last year. More importantly, the physiochemical characteristics of this part of the lake indicate that the area fits the definition of a fen type of marshland. Fens are sensitive marshlands and require protection. For the Hayes B area of White Lake this is especially important since this area hosts one of the two sections of the White Lake Fen which is home to a registered endangered species, the Bogbean Buckmoth.

One important finding we highlighted in both our 2015 and 2016 reports was that an important source of phosphorus entering White Lake during the summer months originates from sediments releasing previously bound phosphorus into the water column. In shallow areas, this could result from wind and wave mixing and boating activities. In deeper areas, anoxia in the upper sediment layers results in the dissolution of bound phosphorus and release via diffusion to the waters above. Released phosphorous is then taken up by phytoplankton and moved up into the water column. This phenomenon is common in lakes such as White Lake and is partly responsible for increasing phosphorus concentrations during the summer to levels above those considered eutrophic. This finding does not in any way diminish the importance of phosphorus coming from septic systems which is known to be a major source of phosphorus.

This year, the major changes occurring in White Lake were caused by the further infestation of zebra mussels in all parts of the lake. White Lake is now in a period of transition lasting several years where the water chemistry is changing, phytoplankton concentrations are diminishing and aquatic plant growth is likely to increase. The possibility of toxic algal blooms is ever present. Another change which we report here is the presence of large quantities of filamentous green algae such as Cladophora. This alga is green and hair-like and found in patches along the shoreline. Continued monitoring of the lake is required as is affirmative action by residents, cottagers, interested parties and the Councils of the four municipalities governing White Lake. Action needs to be taken to re-establish disturbed shorelines, respect setbacks, enforce good and well known environmental practices including septic system inspections. We also need to protect our shorelines from boat wakes which erode shorelines and disturbs near-shore sediments.

The changing climate tending towards warmer and longer summers (and longer ice-free periods) means that everyone using the lake, be they cottagers, permanent residents, campers, or casual users need to increase vigilance and care to preserve and protect White Lake.

Note: The sections that follow below are more technical in nature and form the basis of the conclusions presented above.



5.0 Point Form Summary of Main Findings

1. Zebra mussel populations have greatly expanded and increased during the 2017 season. We expect to see this trend continue for several more years.

2. The clarity of the lake has more than doubled compared to previous years. Maximum Secchi depths of over 7 metres were measured.

3. The total phosphorus concentration in the water column has declined by over 15% when compared to 2016 values and by 60% when compared to 2015 and the years before that.

4. As in previous years, the highest concentrations of total phosphorus were measured at Three Mile Bay and North Hardwood Island sites.

5. All of the changes noted above are not indicative of improvements in lake water quality, but are the changes which have occurred as a result of the presence of zebra mussels.

6. Chemical parameters such as calcium, pH, specific conductance, chlorophyll-a, dissolved oxygen, and total alkalinity have changed when compared to data from 2015, but are similar to 2016 data. We believe that weather conditions including rainfall has an impact on these parameters.

7. Studies of waters entering the lake from the four main streams show that these waters make up a minor fraction of waters entering the lake following the spring freshet. Most of the water entering the lake is from springs or ground water ingress.

8. Waters flowing from streams on the western side of the lake are very low in dissolved solids and are typical of waters flowing off of shield-type rocks. Streams flowing into White Lake from the south, including Boundary Creek, have the chemical signature of waters which have come in contact with high-calcium rocks and are comparable in composition to the composition of White Lake waters.

9. Even though 2017 was a very wet year during which we received more than twice the rainfall of 2016, the warming and cooling patterns of the lake water were very similar and also agreed with the temperature profiles obtained in 2014 and 2015 and 2016.

10. Because of the very wet season, lake levels were not effectively controlled at the White Lake Dam. Water levels were significantly higher. At times, the lake was 0.3 metres higher than target levels.

11. Calcium concentration levels varied somewhat during the summer months. The changes observed were strongly correlated to the amount of rainfall entering the lake.

12. In terms of lake chemistry and physical conditions, the lake can be divided into 5 zones. The southern part of White Lake from Fisher's Point (opposite Fish Creek) south to Sunset Bay (encompassing the main water body of the lake and about 80% of the volume of the lake) acts as a separate lake. The remaining zones of the lake, which include all of the shallow areas, cannot mix with the main water body since there is only a single outlet for waters leaving White Lake at the White Lake dam.

13. There were no dangerous blue-green algal blooms observed in 2017. However, the presence of large beds of filamentous green algae were found along the shoreline in most parts of the lake. The occurrence of this nuisance algae is one of the side effects of the presence of zebra mussels.

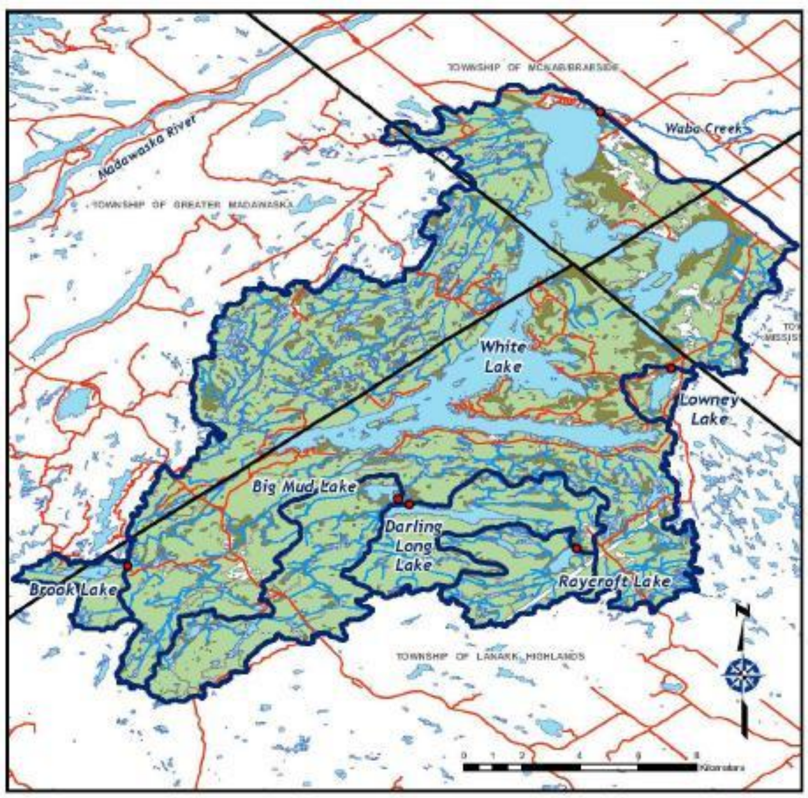
14. The analysis of changes in water chemistry and water clarity resulting from the presence of zebra mussels in White Lake suggest that the popular 'Trophic Levels' published in the *Ontario Handbook for Lake Capacity Studies* no longer can be used to describe the condition of White Lake. A more scientific and studied approach is required.

Sunrise

6.0 Water Quality Monitoring Program, 2017: Results and Discussion

D. Conrad Grégoire, Ph.D.

Introduction and Summary of Results: The quality of the water in White Lake is of great importance to anyone wishing to use the lake for recreational purposes and also for the maintenance of a healthy ecosystem including fisheries. The long-term monitoring of water quality will provide a record of how the lake is changing with time. The effects of climate change, increasing use by humans and the influence of invading species on White Lake need to be recorded so that we can take whatever actions are required to ensure the long-term health of the lake.



White Lake is characterized as a shallow warm water lake. The drainage basin (pictured in the map) is relatively small compared with the total area of the lake. The western part of the lake shore is comprised mainly of pre-Cambrian (acidic) rocks whereas the remainder of the shoreline and the rocks under the lake are calcium rich in nature (basic). It is the calcium rich rocks that give the lake its chemical signature with a basic pH and high calcium content. Both of these factors strongly favour the growth of zebra mussels, an invasive species which has now been observed in great numbers in all parts of White Lake since 2016.

An examination of the drainage basin map in concert with topographical maps reveals that the parts of the lake located near the pre-Cambrian rocks are fed by surface and ground waters emerging from heavily forested and hilly terrain. The remainder of the lake, including areas starting at Hayes Bay and stretching through The Canal, the

Narrows and finally the White Lake Village Basin is surrounded by deforested landscape including some farms.

The forested areas, which include numerous beaver dams and ponds, serve as a buffer storing much of the water falling as rain or melting from snow. Trees also have a significant uptake of water during the growing season. On the other hand, the remainder of drainage basin comprising deforested landscape offers little or no storage of water above the natural water table. In parts of the lake which are surrounded by dense forest, and which also contains the deepest waters, rain and runoff reach the lake at a slower pace relative to the deforested areas. As a consequence of this, the shallowest parts of the lake including parts of The Canal and areas leading to and including parts of the White Lake Village Basin receive rain and snow melt surface waters as well as ground water infiltration (up through the bottom of the lake) at a much higher rate especially after a weather event such as a heavy rain.

White Lake has a modest turnover rate and as such the water in the lake is renewed less than one time per year. Detailed chemical studies of Hayes and Bane Bays have revealed that these waters are considerably more saline (contains more dissolved chemicals like calcium, etc.) than waters from the rest of the lake. Lowney Lake waters are even higher in salinity. This means that water entering the lake at these locations have come into contact with reactive calcareous (calcium-containing) rocks. These very shallow areas are likely also subject to evaporation which would increase salinity even further. Based on earlier measurements taken at The Canal sampling site, (2015/2016) it was thought that this area along with Hayes and Bane Bays have a more rapid turnover than the rest of the lake. We now think that this is the case for The Canal only and not the two Bays, which we believe are essentially backwaters with low turnover rates. If this is correct, then the Hayes and Bane Bays of White Lake are sensitive ecological areas needing of protection. More detailed water chemistry studies scheduled for 2018 may provide more proof in support of these assertions.

One observation not mentioned elsewhere in this report was the observed water current at The Canal sampling site. On two occasions during our routine sampling runs we observed a significant current flowing out of The Canal area towards the main part of the lake. We were surprised that no such current was observed in areas upstream from The Canal site (towards Hayes Bay) suggesting that there was a significant flow of water entering The Canal area not originating from Hayes Bay. As there are no streams at this location, water could only be entering from springs or from general ground water ingress.

One of the more important findings reported in earlier studies was that no single part of the lake can be taken to represent the entire lake. Each sampling site (with the exception of the three shallow sites discussed below) exhibited similar but significantly different behaviour when comparing phosphorus concentrations and other factors. Taken together, the different sampling sites and their relative locations on the lake reveal a pattern showing that much of the phosphorus entering the lake stays in the lake and finds its way into the sediments. The accumulation of phosphorus in sediments increases as one travels on White Lake from North to South from The White Lake Village Basin towards Three Mile Bay. Our studies show that White Lake could be divided into as many as five separate zones with each zone exhibiting different chemical behaviours. These zones would be connected by areas where mixing takes place, for example, at the Jacobs Is. site just south of the narrows leading to the White Lake Village Basin. A map showing these zones is presented in this report.

To the casual observer, there were three major changes in White Lake which affected recreational use. The first is the ever-growing presence of zebra mussels especially under docks and on shoreline rocks. The second was the startling increase in water clarity. The third change is the presence of large masses of green filamentous algae covering large swaths of aquatic plants and also occurring in large beds on the floor of the lake. All of these changes are due to the presence of zebra mussels in White Lake. This report provides evidence for this and also documents the extent to which the lake has clarified and been affected by algal blooms.

An important source of information on White Lake which is currently in draft format is the State of the Lake report produced by the White Lake Steering Committee. We highly recommend reading this report in conjunction with this one in order to obtain a true picture of White Lake. The draft report is posted on the WLPP website at www.WLPP.ca

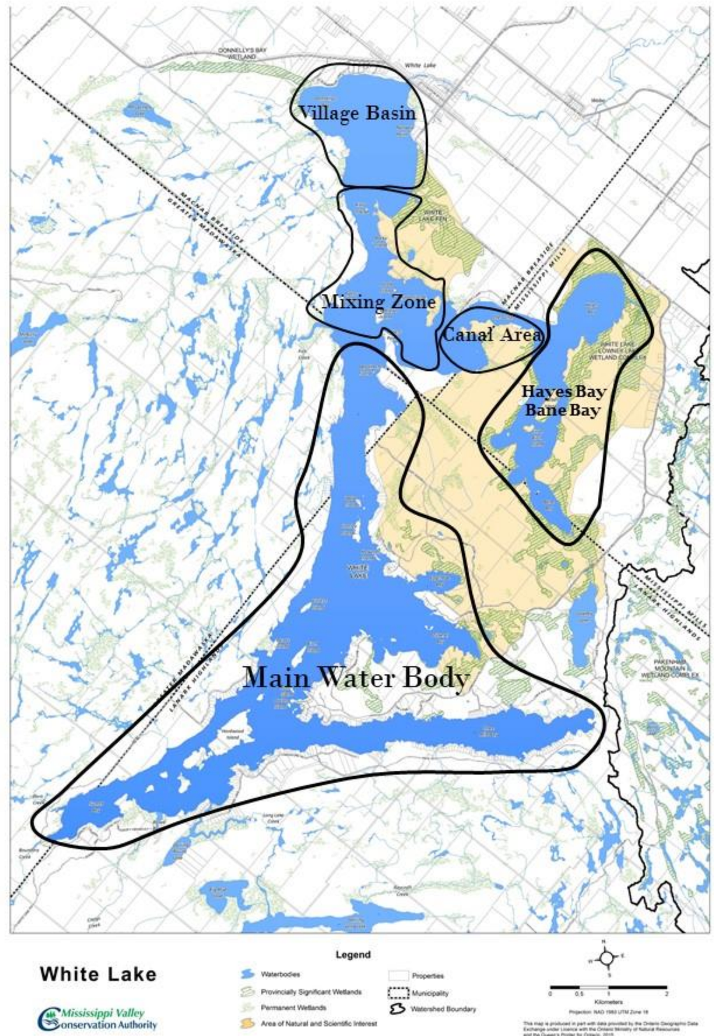
This report and its contents is a collaborative effort of the WLPP Science Committee. Of particular note are the contributions of David Overholt, Jean-Pierre Thonney, Peter Raaphorst and Adam Pugh, Joyce Benham and Robert Carrière.

7.0 Revised White Lake Zone Map

In previous reports, we have suggested that White Lake could be thought of as a collection of almost independent interconnected water bodies rather than a unitary lake.

There are a number of criteria which could be used to divide the lake into different zones based on population density, geology, shoreline coverage, etc. We believe that the different zones of the lake can best be described by their chemistry. While all zones have some characteristic in common, there are enough differences between each zone (shown on the map at right) to justify its classification.

As a result of new chemical data we collected during the past year, we are making some minor changes to the zone map proposed in our 2016 Report. New specific conductivity measurements in addition to temperature measurements in Bane Bay indicate that this water body should be considered as part of the Hayes Bay Zone.



The ***Main Water Body (Zone 1)*** is the part of White Lake which takes in virtually all of the water with a depth greater than four metres. This zone contains Sunset Bay, Three Mile Bay, Pickerel Bay and surrounding areas. This zone existed as a lake before any dam was constructed which raised the level of the lake by about 1.5 metres. Here one finds very deep layers of sediments (up to 6 metres) and very similar water chemistry. The temperature regime, the pH, conductivity, oxygen content, alkalinity and Secchi depths are very nearly the same everywhere. Although the total phosphorus concentrations differ somewhat (with higher levels further South on the lake), the change in phosphorus concentrations over the summer months follows the same pattern with maximum concentrations reached in mid-July.

Hayes Bay/Bane Bay (Zone 2) is a relatively isolated part of the lake and is only 1.6 m in depth at high water in the spring. It is characterized by black gelatinous sediments and is nearly free of aquatic plants in the central basin. The waters there have a slightly higher pH than the rest of the lake and also higher conductivity. The concentration of salt is higher by a factor of three compared to the rest of the lake probably from saline ground water entering through the sediment layer. Because of its dark sediments and shallow depth, this part of the lake heats up the fastest and to the highest temperatures if there had not been a recent rain event. The concentration of total phosphorus is lower here than in the rest of the lake, but slightly higher than concentrations in The Canal area. The waters from Hayes and Bane Bays flow into The Canal Area.

The Canal *Area (Zone 3)* on White Lake is characterized by white marl sediments and a depth of 2.4 metres. For both 2015 and 2016, the lowest concentrations of total phosphorus are found here with levels less than half of those found in the Main Water Body. Our temperature data indicates that in this zone, large quantities of subterranean ground waters are infiltrating into the lake and also leaving the lake relatively more quickly than waters from Hayes Bay or the Main Water Body. This is especially evident immediately after a significant rain event. There are no aquatic plants on the lake bed. These waters have a slightly higher salt content than the rest of the lake due to the mixing of waters originating from Hayes Bay. Note that The Canal Area could be described as a marl area. This could impede the growth of phytoplankton and aquatic plants and exhibit lower phosphorus concentrations due to the coprecipitation of calcium and phosphorus.

The ***Village Basin (Zone 4)*** zone is characterized by white marl sediments and an almost uniform depth of 1.65 m at high water. The floor of the lake is largely free of aquatic plants save some bulrush and patches of wild rice. Total Phosphorus levels are about 30% lower than found in the Main Water Body. The water sampled here is representative of the water which is leaving White Lake over the dam and into the creek. Temperature data from this area also shows, as in the case of The Canal and Hayes Bay that there is significant ingress of subterranean ground waters mixing in with lake water.

Hayes Bay, The Canal and the Village Basin have several things in common. Prior to the building of the dam, these areas existed as open water only during the spring freshet and then quickly turned into marshes or wetlands with water depths of perhaps half a metre or less. Another commonality is the lack of aquatic plants in these areas. It could be that since each of these areas is partially flushed by ground water ingress that plants do not have a chance to take hold. Certainly, the white marl of The Canal and the Village Basin would provide a poor source of nutrients to plant root systems. For Hayes Bay, the sediment there is organic but made up of a very fine particulate not offering much of a foothold for aquatic plants. For all three areas, the effect of wind and waves would also contribute to low plant growth.

The ***Mixing Zone (Zone 5)*** encompasses both sides of the narrows including Rocky Island and extends some distance towards the Village Basin. This area is characterized by shallow dark sediments and ranges from 2.5 m to 4 m in depth at high water. In this area, the lake floor is covered with dense mats of aquatic plants. The temperature of the water in this area is intermediate between the waters coming from The Canal and the Main Water Body. The simple reason for this is that this is where waters from both of these zones mix to give water with special characteristics relative to other parts of the lake. Generally speaking, the water in the Mixing Zone is clearer than would be observed in other parts of the lake for a given total phosphorus concentration. Water leaving this area and entering the Village Basin has lost a significant fraction of its phosphorus content to sedimentation and aquatic plants.

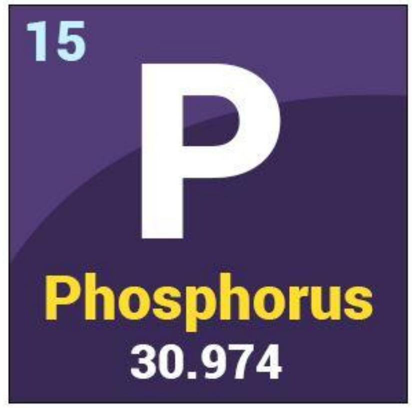
Waters originating from the upper four zones have no opportunity to mix with the much deeper waters of the Main Water Basin which contains by far the greatest share of the volume of White Lake. It could be argued that the most vulnerable part of White Lake is Hayes Bay because there is little opportunity for any nutrients entering this bay to be flushed out at a reasonable rate. With the exception of Three Mile Bay whose waters have access to the remainder of the deeper Main Water Body, the shallow areas at the top of the lake contain the densest populated areas with the likely greatest human impact on lake waters.

Bogbean Buckmoth in White Lake Fen – an endangered species

8.0 **Phosphorus**

What is Total Phosphorus?

Phosphorus is element 15 of the Periodic Table. It is so important because life cannot exist without it. Phosphorus is one of the building blocks of DNA and hence proteins, and is integral to any ecosystem including lakes like White Lake. However, if there is too much of it, then we can have problems such as dangerous or nuisance algal blooms. For this reason, we monitor the levels of phosphorus in the water so that we can assess the health of the lake and hopefully modify our behaviour to prevent excess quantities of phosphorus from entering the lake.



But what are we measuring anyway? We report our results for phosphorus as 'Total Phosphorus' which implies that total phosphorus is not just one thing but the sum of many things. This is the case!

Phosphorus is a very reactive element and can exist in many oxidation states, which is to say that it likes (as much as an element can 'like') to combine with other elements in many different ways.

But where does it come from? Phosphorus occurs in nature mostly as the mineral apatite which is also called calcium phosphate $Ca_5(PO_4)^+$. It can enter lake water by a number of ways including: rain which contains atmospheric dust; pollen which is high in proteins; fertilizers, detergents, septic systems, etc.; surface soil runoff, and ground water containing dissolved phosphorus compounds. It has been estimated that the concentration of total phosphorus in White Lake waters prior to the arrival of Europeans was about 7.5 parts per billion or ng/ml (see Ferris in Bibliography).

When it comes to lakes, we are not really interested in ALL forms of phosphorus, but only the forms which can affect living creatures including fish, plankton (including certain algae, bacteria, protozoans, crustaceans, mollusks) and us!

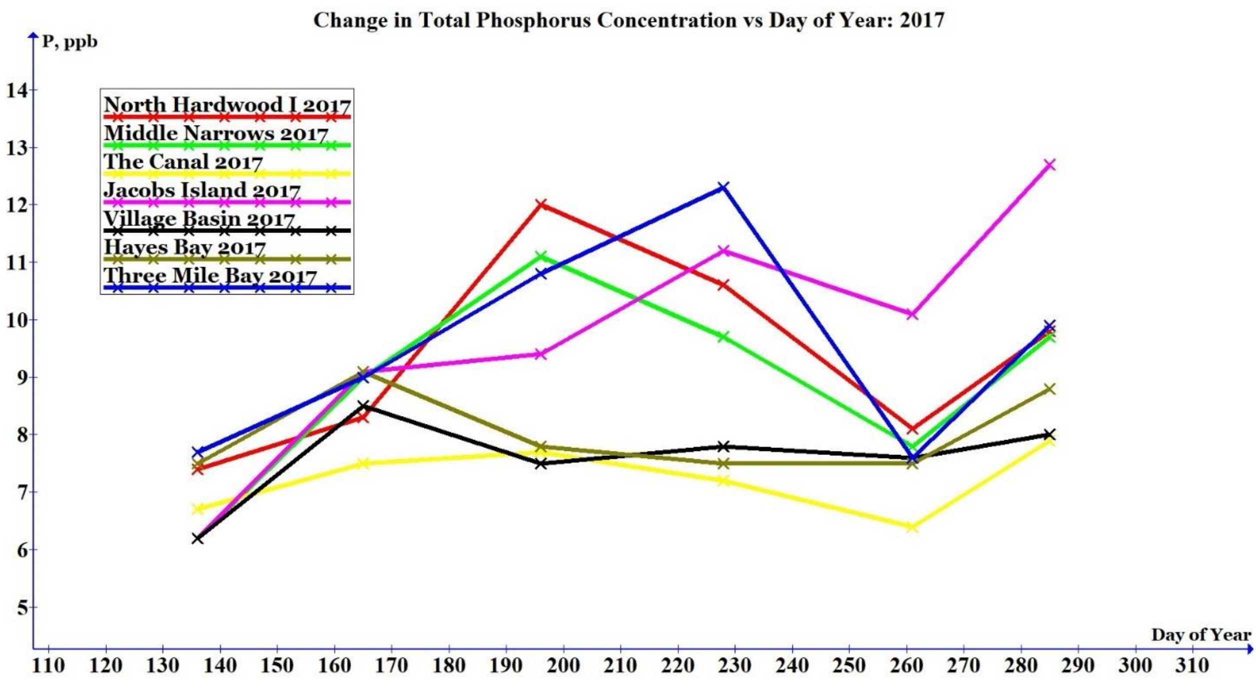
In lake water, the term 'Total Phosphorus' includes all of the phosphorus that can be measured in water which has passed through an 80-micron (micro or millionth of a metre) filter. The 80-micron filter is used only to remove large zooplankton. Everything else including phytoplankton, small zooplankton and suspended material and other materials with adsorbed phosphorus gets through. These are true total phosphorus samples and are not in any way described as filtered and only containing dissolved phosphorus. If you place one 1 mm-sized daphnia in a phosphorus sample tube and analyze it in distilled water, one can get a result of 35 µg/L (ppb). For this reason, these larger organisms must be filtered out prior to analysis.

The dissolved phosphorus-containing fraction is sometimes called the bioavailable phosphorus. This definition is great for most people, but chemists and biologists will want to tell you that the term' Total Phosphorus' includes all forms of organic phosphates, inorganic phosphates and also organic and inorganic soluble reactive phosphates as well as small particulate phosphate-containing materials.

The phosphorus contained in sediments is just as complex if not more so. It is easy to realize that the study of lakes as well as other bodies of water is very challenging and requires the highest levels of science and ingenuity to completely describe the complexity of an aquatic system.

One final note: It is important to realize that the 'Total Phosphorus' we are measuring in White Lake waters only accounts for a small portion of the total amount of phosphorus which enters the lake. Most of the phosphorus entering the lake falls to the bottom of the lake (such as pollen) and once there, eventually decomposes and becomes available to animals and plants. This is why the concentration of phosphorus in lake sediments is literally hundreds of thousands of times greater than in the water just above it! *Now we can discuss the total phosphorus results for White Lake for 2017.*

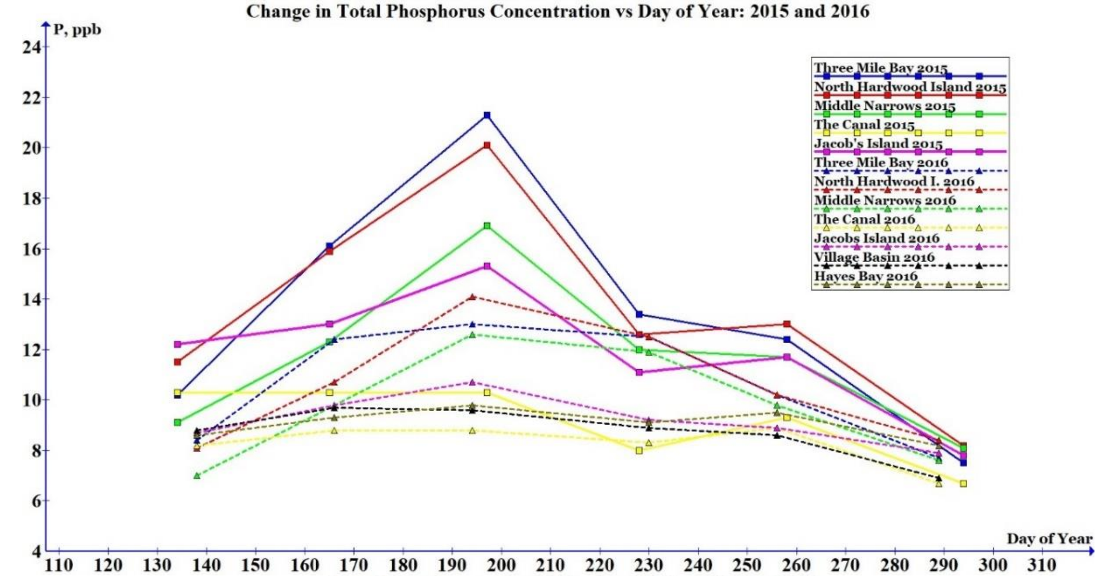
The graph below shows the change in total phosphorus concentrations during the ice-free season for 2017 and the following graphs show results for 2015 and 2016. The 2016 data is shown as triangles connected with a dashed line.



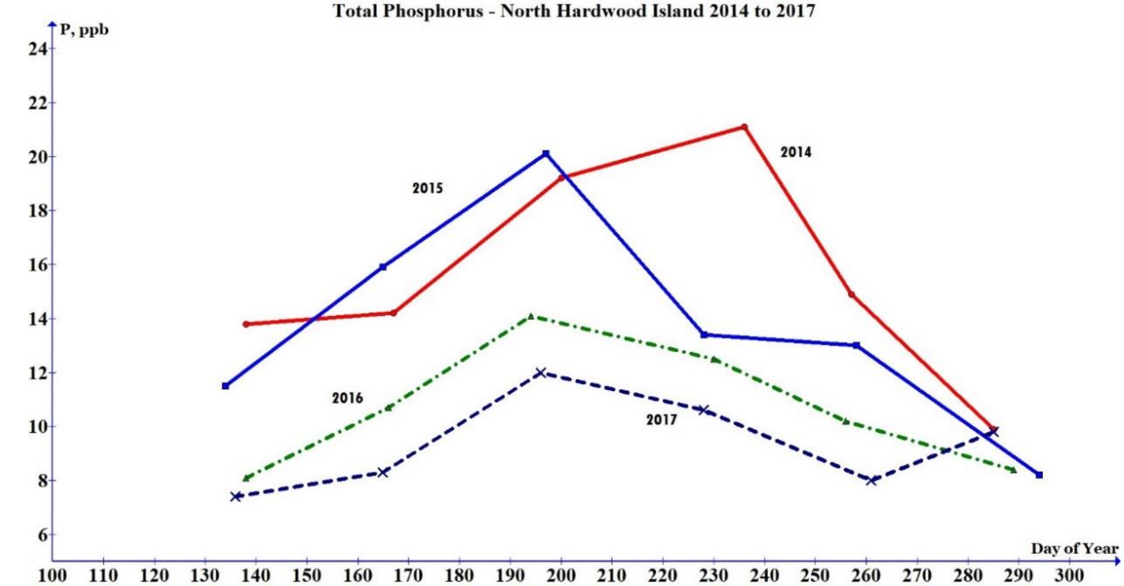
The data for 2015 (below) show an increase in the total phosphorus concentration over the summer months reaching a peak or highest value in mid-July. After this date, the total phosphorus concentration decreases significantly. These data also show that the highest total phosphorus values were obtained at the southern part of the lake nearest Three Mile Bay. These results and trends are in agreement with measurements recorded during the last ten years by government agencies and volunteers.

The data for 2017 show the same trend with waters increasing in total phosphorus concentrations as the sampling date approached mid-July. The main difference when comparing results from 2015 to 2017 is the marked decrease in total phosphorus concentrations. When comparing results for 2017 with those from 2015, total phosphorus concentrations decreased by about 60%. The 2017 results were about 15% lower than those obtained during the previous year. In addition to this, another difference observed in total phosphorus concentrations is the marked increase (compared to a month before)

Change in Total Phosphorus Concentration vs Day of Year: 2015 and 2016



Total Phosphorus - North Hardwood Island 2014 to 2017



which occurred for samples collected on October 12, 2017. This increase may be due to decreased zebra mussel activity because of a low water temperature of 12 °C. If phosphorus was being absorbed from the water column by zebra mussels at a slower rate, and the rate of phosphorus input into the lake was unchanged or increasing, this would result in a higher total phosphorus concentration. It may also be that fall turnover combined with phosphorus back loading gives the same result at such low concentration levels.

North Hardwood Island is the only sampling site for which we have four consecutive years of data. The graph below shows the trend in total phosphorus concentrations over this time period. Note that phosphorus concentration levels for the October sampling are virtually the same for all four years of data (see discussion on 2017 data above).

Clearly, concentrations of phosphorus were similar at the beginning of the year in both 2014 and 2015. Concentrations declined significantly in 2016 and again in 2017, likely because of the zebra mussel infestation which went into high-gear in 2016 and continued in 2017. Phosphorus concentrations declined in 2017 by 60% when compared to 2014 and 2015 levels and by 15% when compared to 2016 levels. We can expect a further decrease in total phosphorus concentrations in 2018, albeit probably smaller than the year before.

Before continuing with the discussion on phosphorus, it is important to discuss at some length the reason and implications for the actual shape of the total phosphorus vs time curves being discussed so far.

At any given time, phosphorus is entering the lake from a variety of sources including the atmosphere, surface runoff, ground water ingress, sediment back loading, septic systems, etc. At the same time, phosphorus is leaving the water column as it is taken up into living organisms, precipitated as part of an insoluble compound, etc. The total phosphorus concentration measured in lake water at any given time is the balance between the rates of phosphorus entering and leaving the water column. Starting in April and continuing until mid-July, the total phosphorus concentration in the lake steadily increases. This, in turn, means that the amount of phosphorus entering the water column *exceeds* the amount of phosphorus leaving the water column. In mid-July, the total phosphorus concentration reaches a maximum and at that point in time the rate of phosphorus entering the lake water is equal to and balanced by the rate of phosphorus leaving the water column. Beyond mid-July, the total phosphorus concentration in the lake water steadily decreases indicating that the rate of phosphorus input into the lake is *less* than the rate of loss of phosphorus from the water column.

Returning now to the results obtained for total phosphorus in 2016 and 2017: One might be tempted to explain the sudden decrease in total phosphorus levels to lower levels (compared to previous years) of phosphorus input into the lake. Unfortunately, there is no evidence to support this assertion. More likely, however, is the introduction of a new pathway by which phosphorus is removed from the water column and it is this phenomenon which results in lower overall total phosphorus measurements.

The explosion of zebra mussel populations in White Lake during the 2016 season explains why total phosphorus levels have decreased significantly over previous years. Zebra mussels reportedly (see bibliography) remove over 90% of the phytoplankton normally found in an unaffected lake. Zebra mussels are efficient at removing phosphorus from the water column and transferring it to sediments via feces and pseudo-feces. It is also reported that the concentration of soluble reactive phosphorus remains unchanged allowing for further phytoplankton production. However, it is known that this type of phosphorus is a primary food for zebra mussel veligers (larvae). The phosphorus transferred to sediments by zebra mussels eventually becomes available for algae growth and may result in an increase in green algal blooms in the future. We have already observed blooms of filamentous green algae in most parts of the lake.

The shape of the phosphorus vs day of year curves shown in the graph above can be explained by the effect of sediment or back loading of phosphorus formerly bound in sediments which are released back into the water column.

Although the concentration of phosphorus in lake water is measured in the low tens of parts per billion (ppb), the concentration of phosphorus in the sediments occurs in the parts per million (ppm) range. This means that the concentration of phosphorus in the sediments is literally hundreds of thousands of times greater than that found in the waters above them. White Lake has a modest turnover or renewal rate, estimated to less than 0.9 times per year. Thus, phosphorus entering the lake by whatever means is efficiently sequestered by living organisms which in turn die and settle to the bottom of the lake. Lake sediments become the phosphorus reservoir for White Lake, with those sediments holding the accumulation of most of the phosphorus entering the lake over many centuries, or even thousands of years.

Oxygen levels in water and sediment contribute greatly to the availability of phosphorus for phytoplankton and algal growth. Phosphorus bound in sediments, organic sediment particles or chemically bonded to inorganic species such as iron oxide only remain chemically bound if there is sufficient dissolved oxygen present. When oxygen becomes depleted due to consumption by rotting vegetation, for example, a change in redox (reduction/oxidation) potential in the sediment takes place which creates chemical conditions favouring the release of phosphorus (chemically reducing conditions) back into the lake water above. When this happens, however, not all of the phosphorus is available for mixing with the water column above. Some of the phosphorus is tightly bound and remains that way. However, a significant portion of the phosphorus can become mobile. For White Lake, sediments will hold their phosphorus unless there is a mechanism in place by which it can be released. The scientific literature suggests that phosphorus in about the first 18 to 20 centimetres of sediment is available for reintroduction into the water column under the right conditions.

The interface between the bottom water of White Lake and the sediment is not as distinct or as sharp as one would imagine for a sandy-bottomed lake. White Lake has a muddy bottom. Organic matter settling out of the water column is generally in a very fine particulate form. When these particulates reach the bottom of the lake, they form an unconsolidated layer of what could be described as dense 'smoke' increasing in density as one moves further down the sediment column. Over time, and with the arrival of more material settling out of the water column, these sediments become more compacted and dense. The nature of White Lake bottom sediments, as described above, was verified by scuba diving during the summer of 2015.

Anoxic (no dissolved oxygen) conditions were not detected in White Lake waters during measurements taken during the ice-free months of 2017. However, during these measurements, if the oxygen measuring probe was lowered into the initial layers of sediment, the oxygen content did drop considerably, especially in Three Mile Bay. This observation may mean that in the unconsolidated layer of sediments, phosphorus could exist in a weakly bound or even free state. Movement of any free phosphorus out of this layer and into the water column could occur by such processes as diffusion within the sediment layers. Displacement of this phosphorus into the water column could also occur as a result of wind and waves and the disturbance of bottom water/sediment by the underwater wake created by boat motors especially in shallow areas. Another mechanism for back loading is discussed in the *next section of this report* and involves the role of micro-algae living in sediments creating anoxic conditions during the night resulting in the release of phosphorus into the water column.

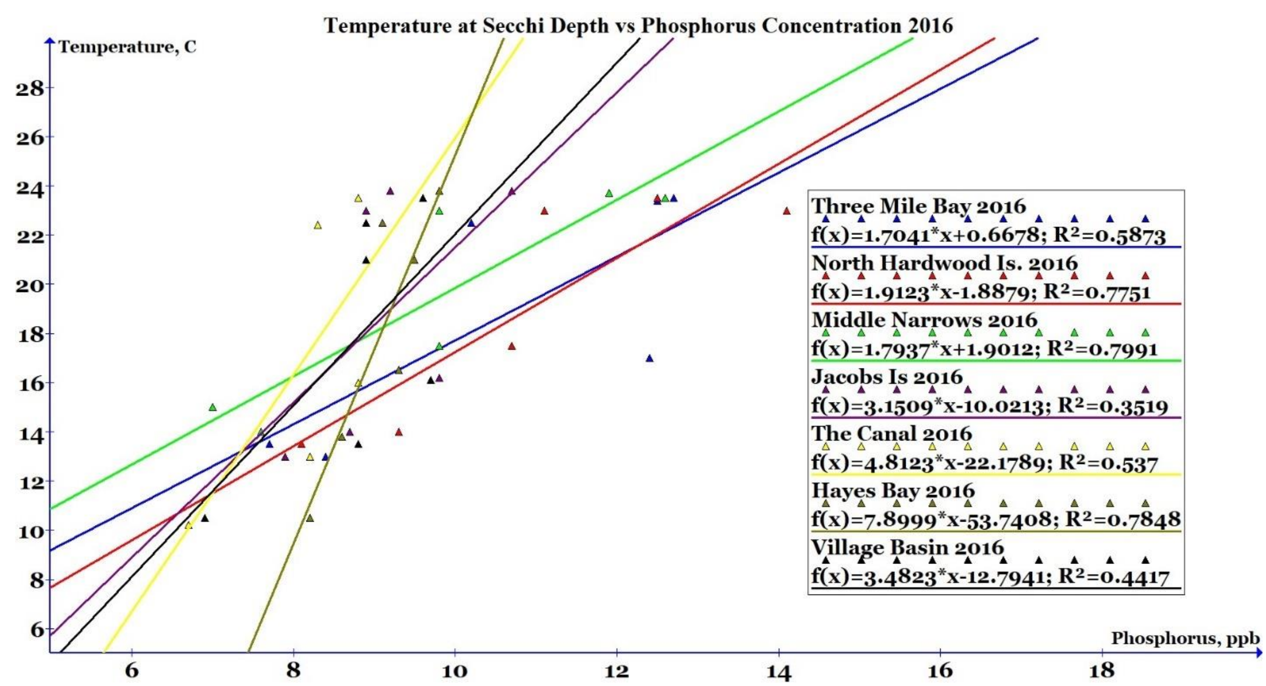
The data reported (see 'Temperature' section of this report) for temperatures measured down the water column shows that in 2015 and 2016, water temperatures were essentially uniform from the surface of the lake to the bottom of the lake at all sampling sites after the first week of June. Temperature uniformity occurred at a slightly later date in 2017 probably because of the large amount of rainfall and cooler weather prevailing during spring and early summer. This efficient mixing of waters to produce uniform temperatures is due to conduction of heat through the water column and diffusion (convection) whereby water molecules can move to equalize temperatures. In short, the same mechanism(s) responsible for efficiently thermally mixing the water column could also be responsible for remobilizing loosely bound or free phosphorus from the unconsolidated lake sediment layer and distributing it into the water column.

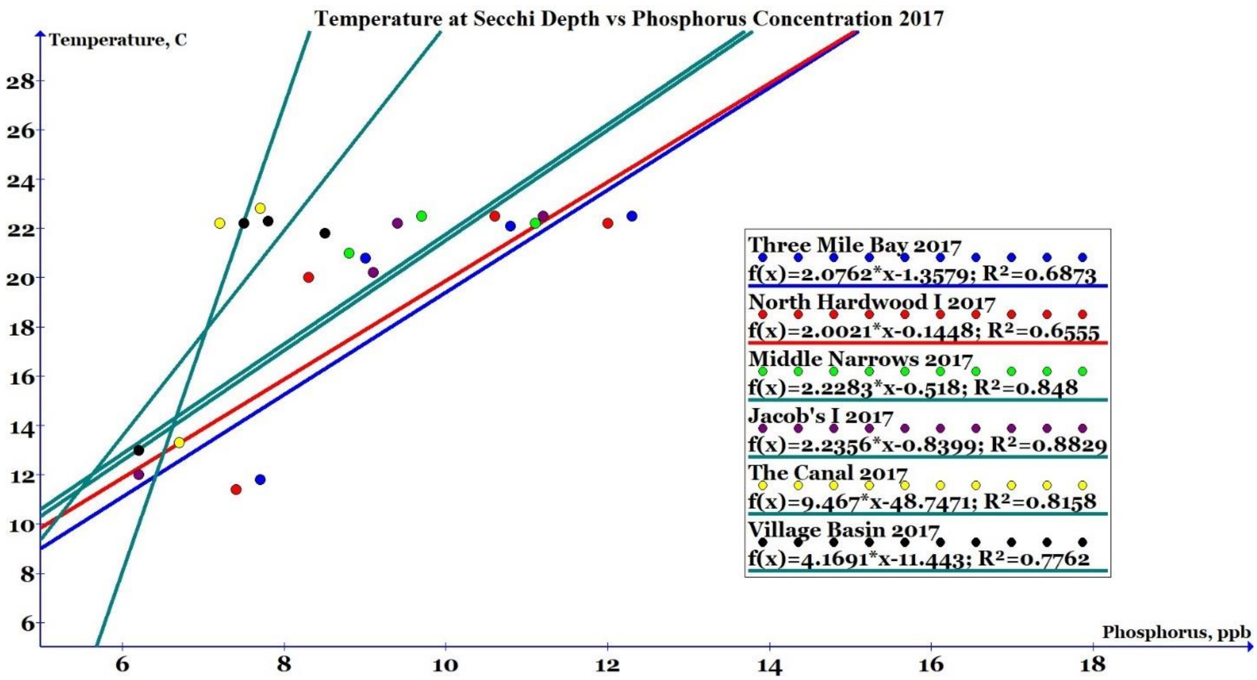
The release of phosphorus from sediments is also accelerated by an increase in water temperature over the summer season. During that time, bottom waters increase in temperature by about twenty degrees. The rate of chemical reactions (such as those releasing phosphorus from sediments) roughly doubles for each 10-degree rise in ambient temperature. So, we can expect that over the course of the summer, the rate of phosphorus released to the water column will also rise significantly further increasing the total amount of free phosphorus available to lake waters. The effects of diffusion, phytoplankton, and microbial action in sediments will also increase accordingly with increases in temperature.

Correlation Plots

One way of determining if a parameter is dependent on another parameter, such as total phosphorus, with temperature or Secchi depth, is to plot these data against one another on a single graph. A linear regression analysis of the data will give a straight line and a correlation coefficient (**R^2**) which is a statistical number expressing the 'rightness of fit'. A very low correlation coefficient (close to zero) means that there is no relation between the two parameters, whereas a high correlation coefficient (approaching 1) means that the two parameters are closely related and could be dependent on one another.

The graphs below show that for 2016 and 2017 a significant correlation existed between water temperature and total phosphorus concentrations for many sampling sites and especially for the deeper Zone 1 sites. Similar and high correlation coefficients were also obtained in 2015 for correlation plots of temperature with total phosphorus. The correlation coefficients (shown in the legend on graphs) was in the range of 0.7 to 0.8 or very high. This indicates that the concentration of total phosphorus in the water column is very dependent on the temperature of the water and hence the temperature of the sediment. This is evidence in support of back-loading as a source of phosphorus and explains the shape of the TP vs Day of Year curves presented above.





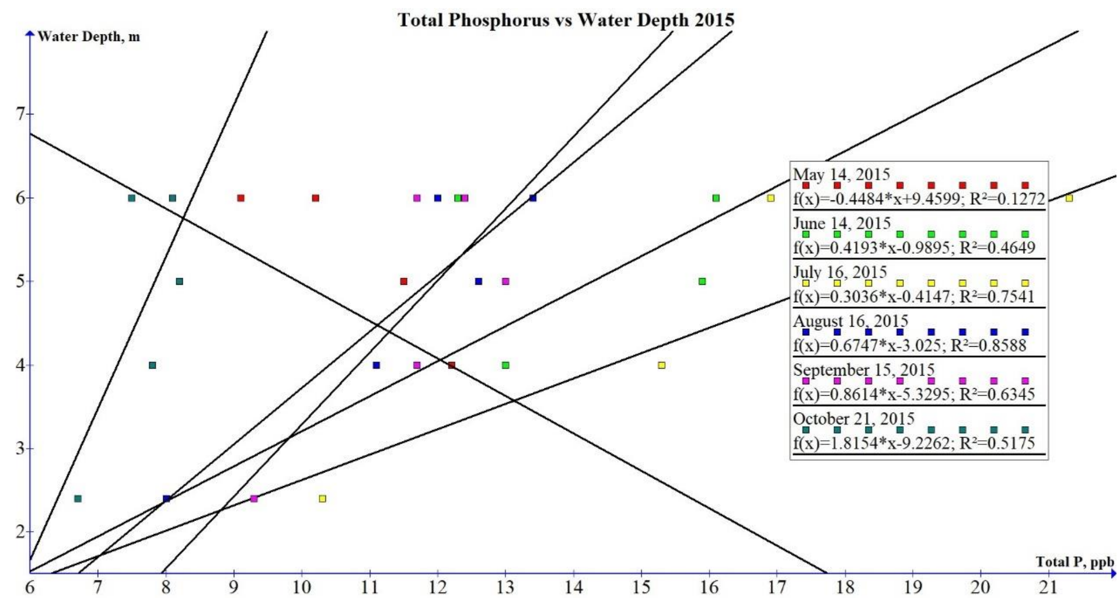
We have also studied the correlation of total phosphorus concentrations with measured Secchi depths. The results are presented below in tabular form.

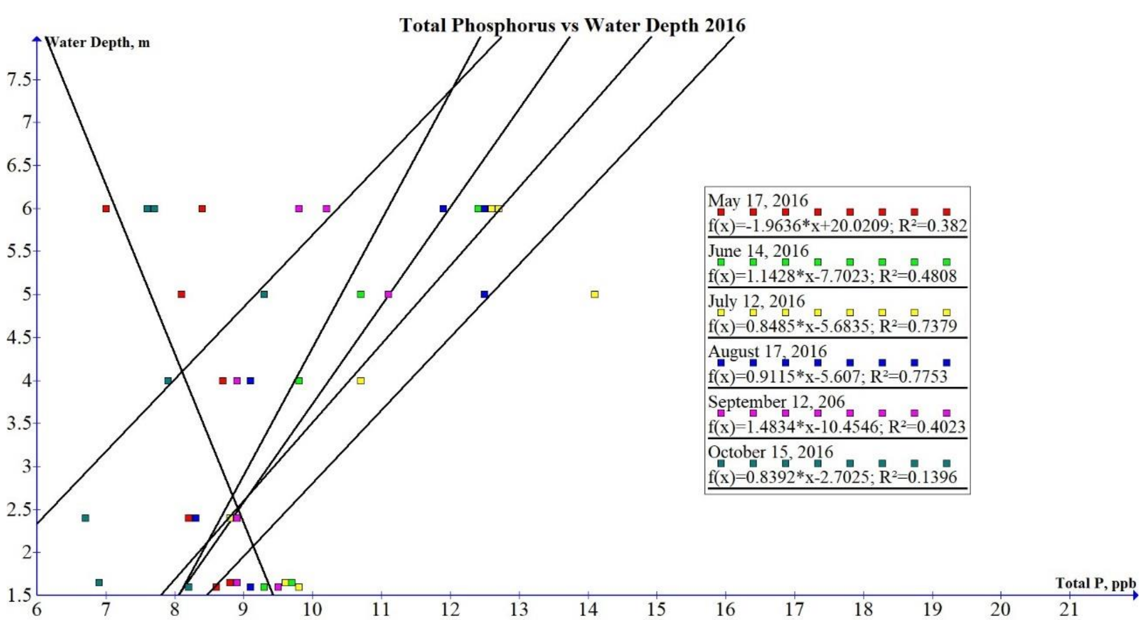
Sampling Site	**Correlation Coefficient (R^2)**			
	2014	*2015*	*2016*	*2017*
Three Mile Bay	.6954	.9077	.0001	.9999
N. Hardwood I.	-	.8725	.3015	.9119
Middle Narrows	-	.7481	.6738	.1527

In both 2015 and 2016, there were relatively high correlations between these two parameters. In 2016, the correlation broke down and in 2017, the correlation appeared to have been re-established. In our previous report we explained the 2016 results as a consequence of the rapid explosion of zebra mussel populations removing phosphorus from the water column. There may have been other factors involved such as the presence of particulates in the water not related to algal growth. In 2017, the correlation for two of the three sites were very high and poor for the Middle Narrows site. At this point, more data is required before we can establish a trend in these correlation coefficients.

8.1 Correlation of Water Depth with Total Phosphorus

The total phosphorus data collected from White Lake in 2015 and 2016 exhibited some correlation with the depth of the water at the sampling site. The effect was first reported in our 2015 WQMP report. The correlation was strongest with sampling sites located within the zone representing the Main Water Body (Zone 1) of White Lake, located in the southern portion of the lake. Correlation plots of total phosphorus concentration with water depth for each of the sampling dates in both 2015 and 2016 are shown below. For the sake of brevity, the corresponding 2017 figure giving similar results is not presented here.



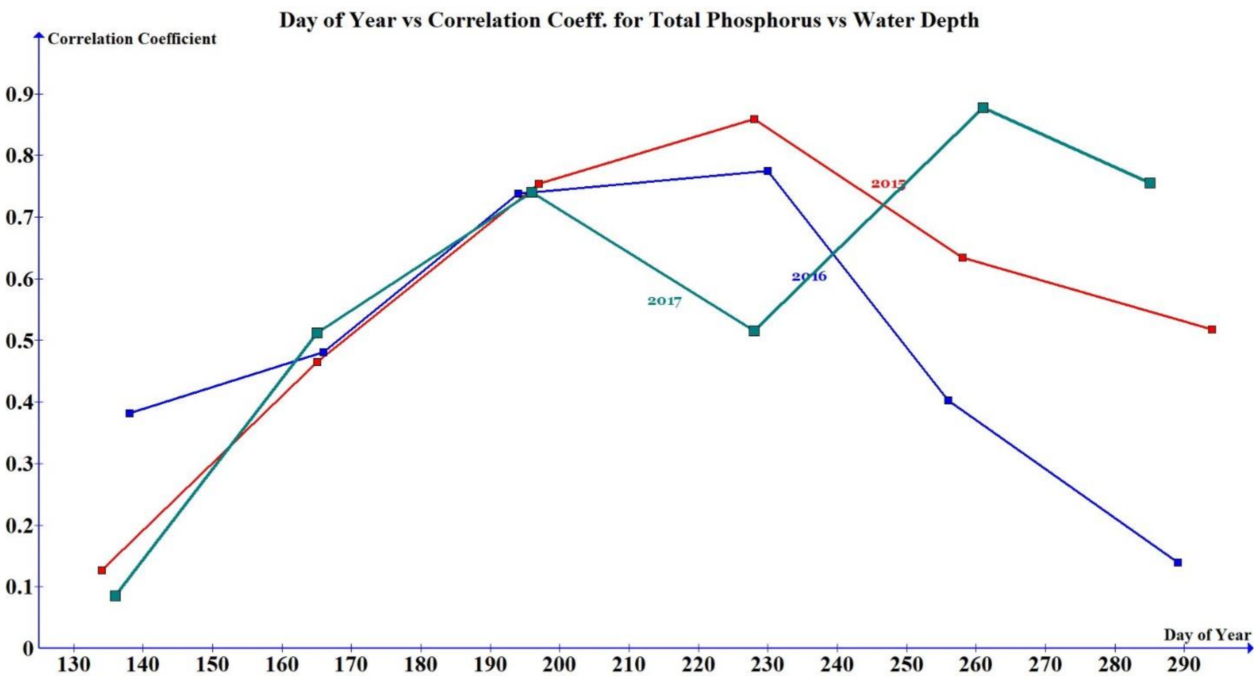


The correlation coefficients (R^2) for each of the plots shown above are given below:

Date, 2015	R^2		Date, 2016	R^2
May 14	.1272		May 17	.3820
June 14	.4649		June 14	.4808
July 16	.7541		July 12	.7379
August 16	.8588		August 17	.7753
September 15	.6345		September 12	.4023
October 21	.5175		October 15	.1396

Date, 2017	R^2
May 16	.0856
June 14	.5120
July 15	.7410
August 16	.5150
September 18	.8780
October 12	.7552

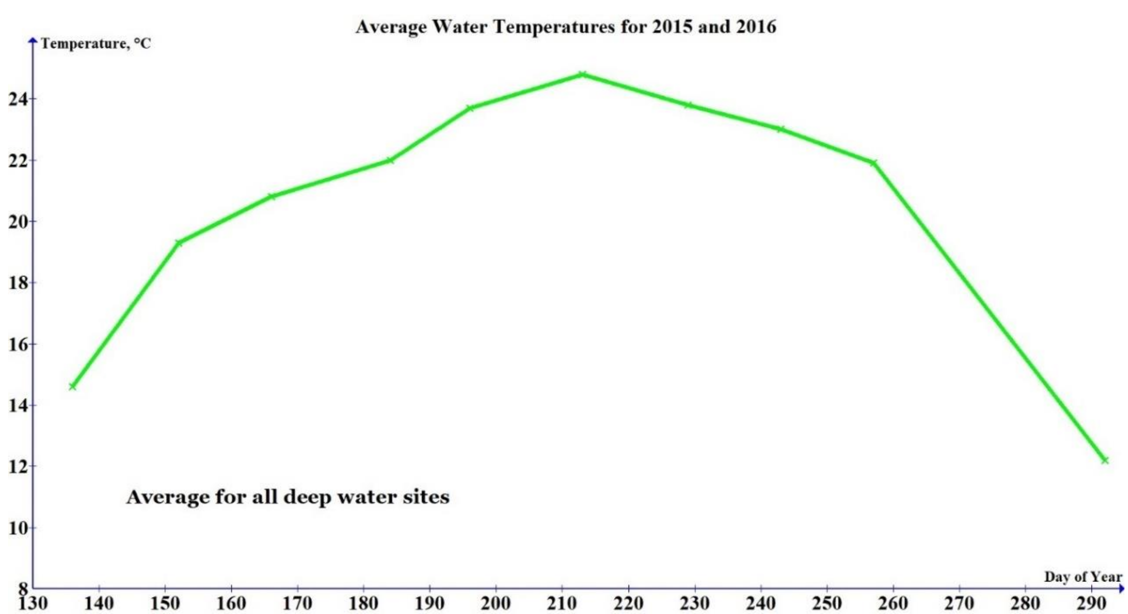
A cursory examination of data for 2015 and 2016 shows that during the beginning and at the end of each ice-free season, the correlation between water depth and total phosphorus concentrations ranges from poor to moderate. During the middle of the season, however, when the lake is at its warmest, the correlation is relatively high reaching above 0.8. For 2017, the correlation coefficients become relatively high by July and remain so for the rest of the year and are comparable to those obtained in previous years. If these data are



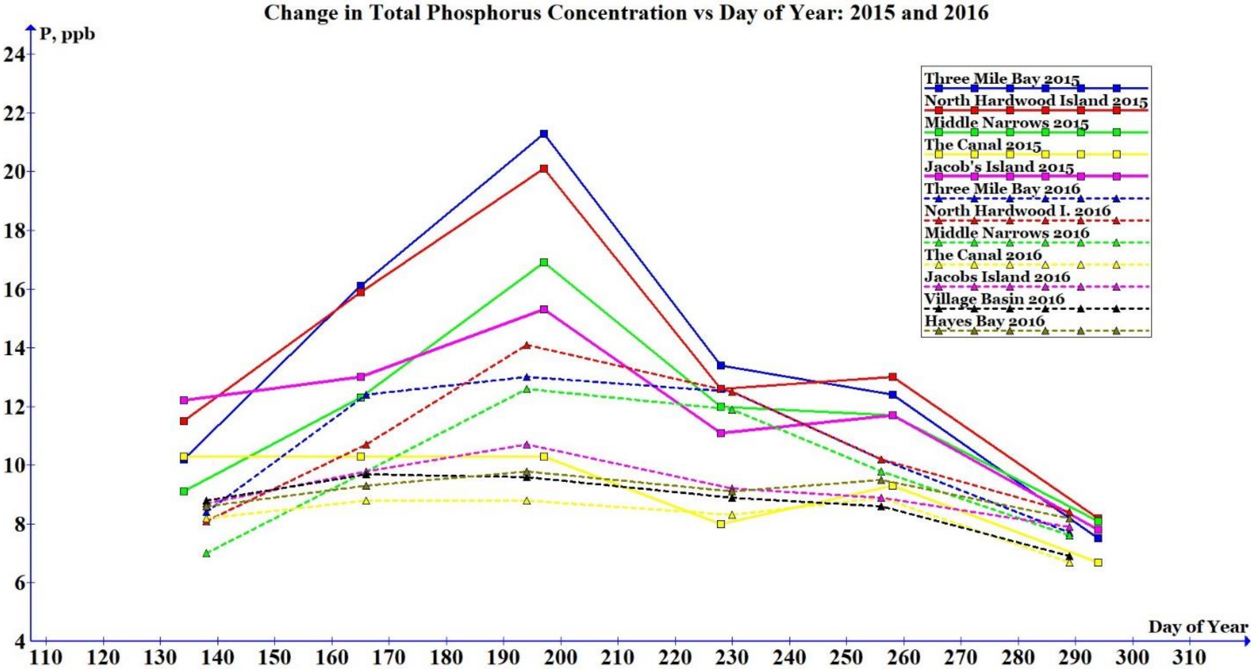
plotted together on a single graph, the curves obtained for both 2015 and 2016 are similar in shape having maxima that appear at about the same time of year – end of July. The results for 2017 do not exactly correspond, however this could be because of the very low phosphorous concentrations obtained for these water samples. For this reason, the discussion below may be more applicable to the 2015/6 data.

As a result of our studies of the chemical and physical properties of White Lake waters carried out during the 2015 to 2017 field seasons, it was observed that parameters such as total phosphorus, Secchi depth, temperature and chlorophyll-a were highly correlated with each other especially in 2015. This was not always the case in 2016 or 2017. The infestation of White Lake with zebra mussels changed the chemistry of the lake significantly. Values for parameters such as those cited above were now always mathematically correlated with one another save total phosphorus and water temperature. This data couple remained highly correlated for the three field seasons 2015 to 2017. Therefore, the phenomenon responsible for the characteristic total phosphorus vs day of year curves is independent of the presence of zebra mussels. This can be interpreted as further evidence of back loading of phosphorus from lake sediments into the water column above. This process is very dependent on the temperature of the water column above the sediments and can also be dependent on available sunlight. The plot for 2017 is slightly offset compared to other years. This is likely an experimental artifact resulting from infrequent (once a month) sampling rate. With so few data points on a plot such as this one, it is very likely that the 'real or actual' maxima for all the curves is missed between sampling periods. The data are nonetheless useful for purposes of this discussion.

Below are figures showing the change in water temperature for White Lake vs day of year as well as the growth and decay of the total phosphorus concentrations vs day of year. The 2017 figure showing the analogous data can be found in the 'phosphorus' section of this report.



Change in Total Phosphorus Concentration vs Day of Year: 2015 and 2016



The shapes of all of the curves shown above indicate that there is a correlation between water depth, total phosphorus concentrations and back loading of phosphorus from sediments into the water column. It is especially interesting that the two plots of correlation coefficients for 2015 and 2016 are very similar, in spite of the fact that the presence of zebra mussels in the lake had made profound changes in water chemistry. Note that the correlation coefficients for the latter months of 2016 are significantly lower than for those obtained in 2015 during the same period. This may be caused by phosphorus loss from the water column to zebra mussel activity. The curve for 2017 shows the same general pattern as the other two data lines.

It is well known that there are many sources of phosphorus which enter the lake during the year and that there are a number of different phosphorus-containing chemicals and living species (including phytoplankton and zooplankton) present in the water column at any given time. The proportions of each of the different chemical and living species contributing to the total amount of phosphorus in the water column very likely changes with time depending on various conditions including weather.

It is possible that at the beginning and the end of the ice-free season, when White Lake waters are cooler, that the contribution of phosphorus from sediments (back loading) is relatively small when compared with back loading occurring during the hottest months of the year (highest water temperatures). This could result in the poorer correlation coefficients for total phosphorus vs water depth observed at the beginning and end of the ice-free season. Another way of saying this is that at the beginning and end of the ice-free season, the total phosphorus in the water column largely originates from sources other than from sediment back loading.

Although we do not have any quantitative results for the concentration of phosphorus in White Lake sediments, one could speculate that the concentration of phosphorus in sediments could be higher in deeper areas of the lake. This is because for any given unit of area on the lake floor, deeper sites will have a much greater volume of water above the unit area of lake floor. This higher volume of water would naturally contain a higher total quantity of phosphorus, when compared to shallow sites, which could potentially settle to the bottom of the lake and become part of the sediments there. This effect would be especially pronounced for a lake like White Lake which has a turnover rate of less than one lake volume per annum.

Thus, sediments from deeper waters would contain higher concentrations of phosphorus which would yield larger quantities of total phosphorus to the water column once back loading occurred. We note that the concentration of phosphorus in lake sediments in nearby lakes such as Calabogie lake have been measured. Concentrations ranging from 2,000 to 3,000 parts per million were reported. Lake sediment concentrations are therefore from 200,000 to 300,000 times HIGHER in sediments than the concentration of phosphorus in the water column above it.

The above arguments can be challenged, mainly because there are other factors which can affect total phosphorus concentrations such as sources of the element from septic fields, etc. The mechanisms of loss of phosphorus from the water column likely also change during the year. Also, higher concentrations of back loaded phosphorus from deeper sites would be released into correspondingly larger volumes of lake water above it (per unit area) thus tending to normalize total phosphorus concentrations from deeper and more shallow sites. This would be true unless the concentration of phosphorus in the sediments were proportionally higher in the first place or more susceptible to back loading (less dissolved oxygen in water column above sediments).

Another factor which could also contribute to a higher RATE of phosphorus release from sediments is the influence of algae living in sediments or at the sediment-water interface. Studies such as the one completed by Carlton and Wetzel (see Bibliography) show that in the first few centimetres of sediment, micro-algae living there can cause oxic conditions to change to anoxic during the night. This effect would result in the release of bound phosphorus from sediments into the water column above. This effect or condition would persist longer or be more effective in the deeper parts of the lake where less sunlight would shine and for shorter periods of time when it does.

In the spring, White Lake is likely very well mixed and greatly influenced by runoff concentrations. In lakes with internal loads, like White Lake, the accumulation of phosphorus may begin early and continue until the fall when dying algae return most of their nutrients to the sediments.

It is important to note that White Lake does not stratify, at least not strongly, such that there is no unmixed layer (hypolimnion) that can accumulate phosphorus. Rather, phosphorus is accumulated in the water column because it is carried there by algal cells that have been in contact with the sediment water interface. Now that there are zebra mussels, there are fewer nutrients in open water but also fewer algal cells in open water so the potential for an internal load to accumulate is diminished. The process in a mixed shallow lake is therefore mostly driven by the phytoplankton community's ability to entrain phosphorus from the sediments. Phosphorus cannot simply be released from sediment into the lake water because it will immediately return to the sediments once it comes in contact with oxygenated water. It could be that a number of factors such as temperature and depth influence the efficiency of the phytoplankton community to move phosphorous away from the sediment interface and into the water column above. There are likely other factors as well.


Marsh – near Wabalac Road

9.0 Water Clarity – Secchi Depth

One of the most dramatic changes in White Lake water quality which we have observed since the arrival of zebra mussels in 2016 is the increase in water clarity. So how much clearer is the water now compared to 2015 when the lake was in its natural state?

It turns out that the water clarity has changed differently in different parts of the lake. In areas close to shorelines (where most zebra mussels are found) like Three Mile Bay, water clarity has doubled! At locations further away from shorelines, the Secchi depth (see box on right) has increased by about 80%. In the middle of the lake, the increase is only about 60%.

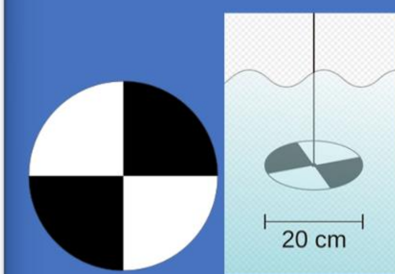
In July of 2015, the Secchi depth in Three Mile Bay was 2.1 metres and by July 2017, the Secchi depth had increased to 4.1 metres. We are now measuring Secchi depths of over 7 metres at some locations. So what?

Water clarity on the surface appears to be a good thing. However, there are some important consequences to consider:

- Aquatic plants will propagate in deeper parts of the lake.
- Aquatic weed beds will thicken in shallow areas where weeds currently exist.
- More zebra mussel habitat will be created on new plant beds.
- Enhanced water clarity means less food for small creatures, including fish.
- The presence of filamentous green algae along shorelines will become more prominent. This 'green angel hair' was visible in nearly all parts of the lake this year.
- Fish will have a harder time hiding from predators.
- Currently, there are no approved ways of reversing any of the changes noted above. We must now prevent the spread of zebra mussels from White Lake to other water bodies.

WHAT IS SECCHI DEPTH AND HOW IS IT MEASURED?

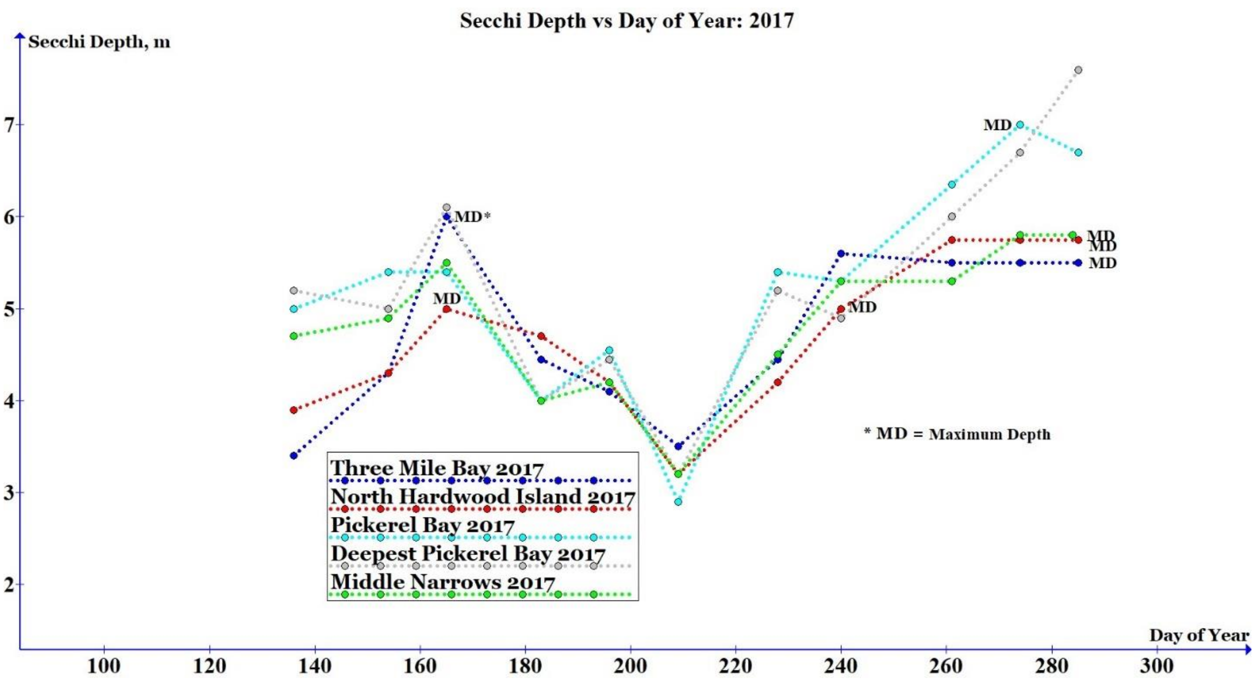
The Secchi depth is a measure of the clarity or transparency of the water. The Secchi disk, named after an Italian scientist, is used to make the measurement. The disk is segmented black and white and 20 cm in diameter:



The disk is lowered into the water until it is no longer visible. The recorded depth, in metres, is one half of the distance that light can travel through the body of water being measured. A Secchi depth of 6 metres, for example, means that light can travel through 12 metres of water. White Lake is a maximum of 9.1 metres deep.

Secchi Depth Data:

Below is a graph containing the Secchi depth readings for White Lake taken during the ice-free season, 2017.



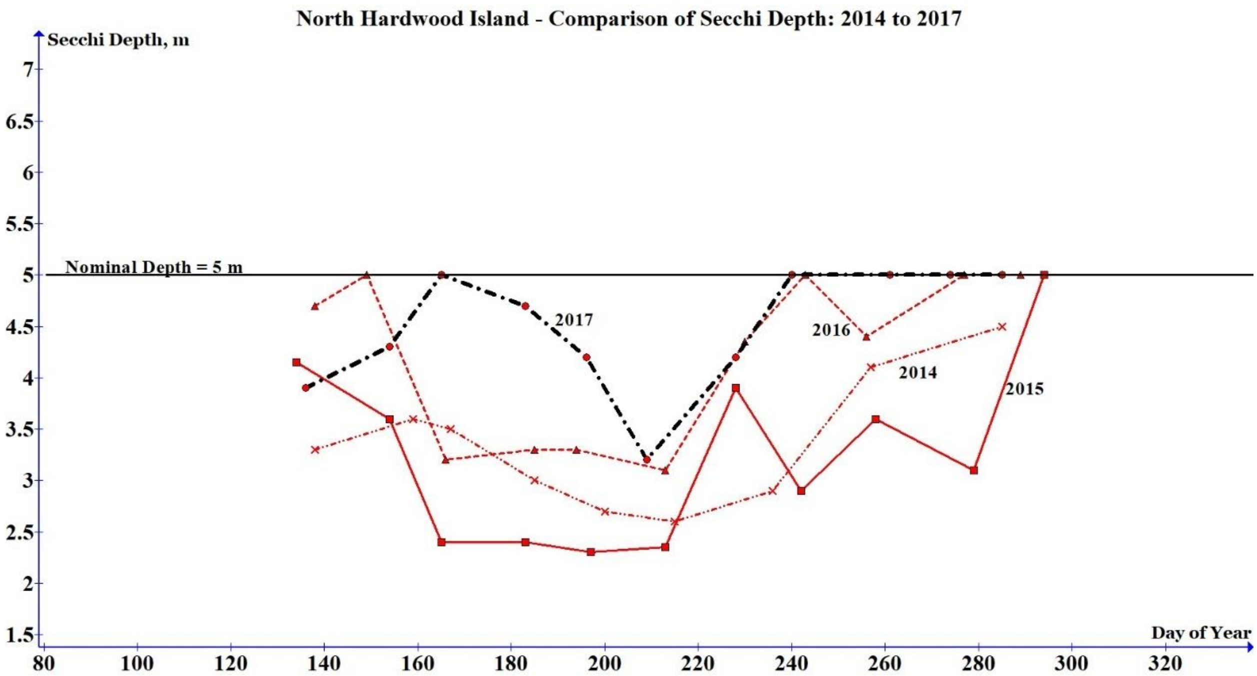
The pattern of Secchi depth readings is similar to those observed during previous years. Secchi depths increase as the lake water column becomes uniform in temperature and then decreases as the temperature of the lake increases. At higher temperatures there is more biological activity as well as supply of nutrients. Minimum Secchi depths (lowest water clarity) were achieved sometime during the last week of July, 2017.

Of the nine sites we sampled, there were only five that had measurable Secchi depths. The remainder of sites were too shallow or the water was too clear at all times. Notably, this year the Jacob's Island sampling site (depth 4 m) was added to this list for the first time. During the previous two years, this site yielded measurable Secchi depths.

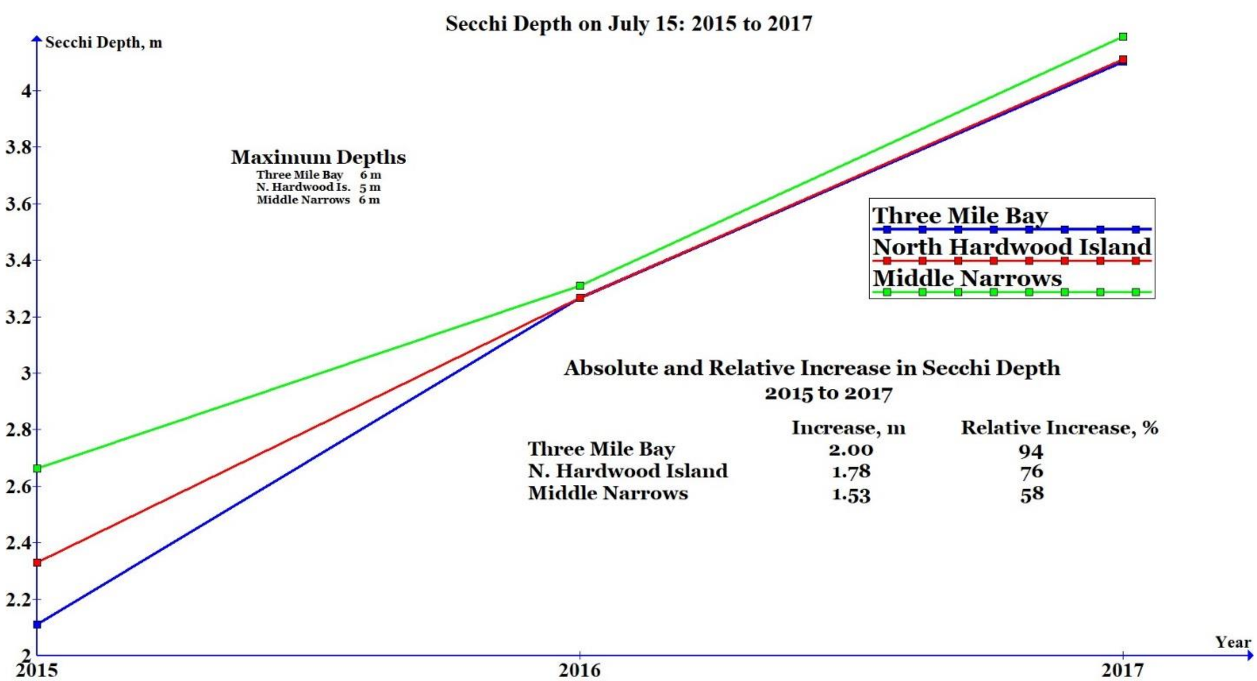
Also, the graph above indicates the frequency of times that a Secchi depth was not read because of the clarity of water. These data points are labeled 'MD' for maximum depth.

The figure below shows Secchi depth data for the North Hardwood Island site taken during four consecutive years: 2014 to 2017. The 2017 data line is highlighted in black.

The data show that from 2014 to 2017 the Secchi depth readings have been steadily increasing such that the last several measurements taken for this site during 2017 did not result in a Secchi depth due to increased water clarity.



One way to look at this data is to plot the Secchi depth readings taken in mid-July for the years 2015 to 2017.



What can be derived from this figure is presented in the table contained within the graph. These results show that for the Middle Narrows site, water clarity has increased 58% since 2015; 76% at the North Hardwood Island site and a whopping 94% at the Three Mile Bay sampling site. As mentioned at the beginning of this section, the reason for the increased water clarity is attributable to the growing presence of zebra mussels in White Lake.

Discussed in another section of this report, we know the number of zebra mussels is still on the rise and will be for the next three or four years.

9.1 Frequency of Secchi Depth Readings Exceeding Sampling Site Depth

Another way of showing how the clarity of White Lake has been increasing in recent years is to consider the number of times we were unable to obtain a Secchi depth at each of the five deep water sites we monitor on a regular basis.

Sampling Site	Max. Depth, m	2015	2016	2017
Jacobs I.	4.0	2	8	11*
N. Hardwood I.	5.0	1	3	5
Middle Narrows	6.0	0	1	2
Three Mile Bay	6.0	1	2	5
Pickerel Bay	7.5	0	0	1
Total		4	14	24

*maximum number of measurements made per year

These data show that for any given sampling site, the number of times the Secchi depth could not be read because of water clarity increases with each year. For example, for Jacobs I., in 2015, there were only two occasions out of a possible 11 that the Secchi depth exceeded the water depth at the site. This increased to 8 times in 2016 and finally 11 in 2017. Looking at the total number of times Secchi depths could not be read for all sites combined, these increased from 4 in 2015 to 24 in 2017.

Finally, we can now consider the number and percent of Secchi depth readings exceeding sampling site depths and calculate the percentage of lake bottom which is now exposed to sunlight. For this calculation, the 'Deepest Pickerel Bay' sampling site was used because it has a depth of 9.1 m, the deepest in the lake.

Deepest Pickerel Bay	2015	2016	2017
#/max #	3/11	7/11	10/11
Percent	27.3%	63.6%	91.0%

One must also consider that the Secchi depth reading, in metres, represents only half of the distance through which light will travel in the lake. So, if there is a Secchi depth reading of 4 m, this means that sunlight will travel 8 m towards the bottom of the lake. Of course, the intensity of sunlight diminishes as it penetrates or travels through the water column, but only 1% of sunlight reaching the bottom of the lake can be enough to promote plant and algal growth.

The results contained in the above table indicates that in 2017, the percentage of time during daylight hours that sunlight could penetrate to the bottom of the deepest part of the lake was 91.0%. Since only about 10% of the lake has a depth of 9 m, this means that only about 1% of the surface of the lake floor was 'dark' during the summer months. Put another way, more than 99% of the lake bottom now receives sunlight and is subject to increased plant and phytoplankton growth.

10.0 Chlorophyll-a

Water clarity is influenced by the amount of phytoplankton or microscopic algae present in the water. Chlorophyll-a is the green pigment in phytoplankton. The lower the chlorophyll-a concentration in the lake, the lower the phytoplankton population, and the clearer the lake becomes. The greater the phosphorus concentration in the water, the greater is the potential for phytoplankton growth to occur.

The evolution of chlorophyll-a levels in White Lake is shown in the series of four tables and graph below. Historical reports (4^{th} table/bar graph) show that the chlorophyll-a concentration in White Lake varied from about 3.5 to 5.5 parts per billion. In 2015, chlorophyll-a results were lower than historical results and ranged from about 1.5 to 4 parts per billion. These results are compatible with measurements taken in 1975 and 2007.

Chlorophyll-a concentrations obtained for both the 2016 and 2017 seasons were a radical departure from historical values. Essentially, chlorophyll-a concentrations have been reduced to below or at the detection level of the analytical methodology used for many of the samples we collected. The chart below would indicate that this result could be used to classify White Lake as oligotrophic or a lake of very low productivity. This is not the case. The reason for the low chlorophyll-a concentrations is the presence of an exploding population of zebra mussels. The published research on this subject indicates that populations of phytoplankton are reduced by 90% or more when zebra mussels invade a lake.

The much greater water clarity of White Lake and the lower phosphorus concentrations measured during both the 2016 and 2017 seasons support this conclusion. Phytoplankton populations may rebound somewhat in coming years once the chemistry of White Lake reaches the new equilibrium imposed on it by the presence of large numbers of zebra mussels. Early signs of this may be visible in the 2017 results. Samples taken during he warmest part of the summer show detectable amounts of chlorophyll-a. It is also at this time of year that phosphorus concentrations are reaching maximum values. In any case, chlorophyll-a concentrations are still at best a factor of five lower than historical norms.

Chlorophyll- a (ug/L or ppb) - 2017

Sampling Site	**May 16 (day 136)**	**July 28 (day 209)**	**September 18 (day 261)**
Three Mile Bay	1.1	0.64	<0.5
N. Hardwood Island	<0.5	0.53	0.64
Deepest Pickerel Bay	≤ 0.5	0.86	<0.5
Middle Narrows	<0.5	0.75	0.53
Jacob's Island	<0.5	0.96	0.75
The Canal	0.86	0.64	<0.5
Hayes Bay	<0.5	0.86	<0.5
Village Basin	0.75	0.96	<0.5

Chlorophyll- a (ug/L or ppb) - 2016

Sampling Site	**June 14 (day 166)**	**July 12 (day 194)**	**August 17 (day 230)**
Three Mile Bay	≤ 0.5	<0.5	<0.5
N. Hardwood Island	<0.5	<0.5	<0.5
Pickerel Bay	≤ 0.5	<0.5	<0.5
Middle Narrows	<0.5	<0.5	<0.5
Jacob's Island	<0.5	<0.5	<0.5
The Canal	<0.5	<0.5	<0.5
Hayes Bay	<0.5	<0.5	<0.5
Village Basin	<0.5	<0.5	-

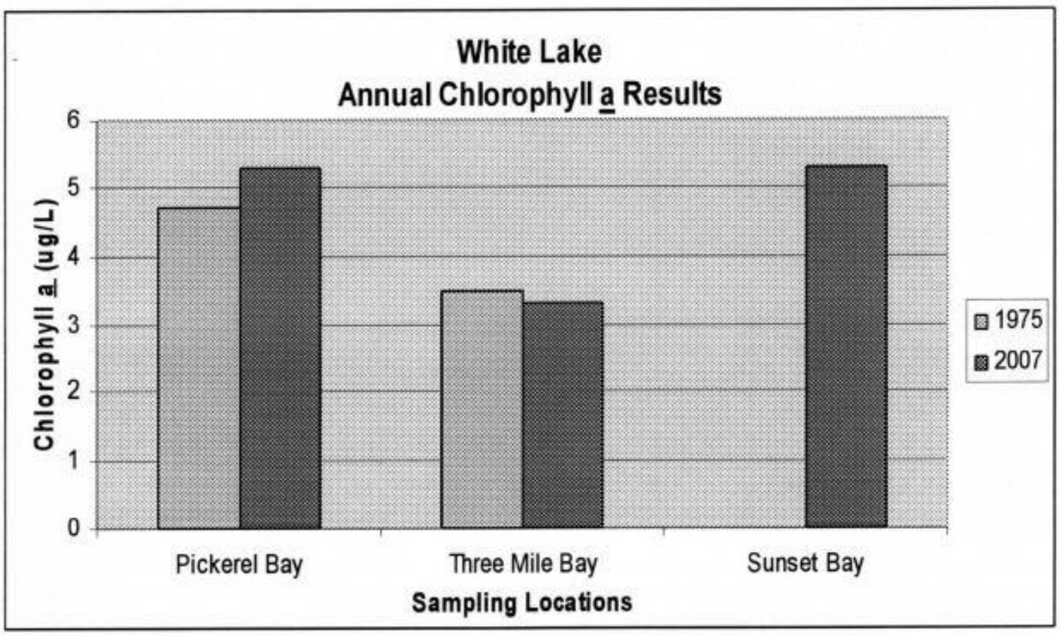
Chlorophyll- a (ug/L or ppb) - 2015

Sampling Site	**May 14 (day 134)**	**July 16 (day 197)**	**Sept. 15 (day 258)**
Three Mile Bay	<0.5	3.0	1.7
N. Hardwood Island	<0.5	2.9	1.7
Pickerel Bay	<0.5	2.3	1.4
Middle Narrows	<0.5	2.1	2.0
Jacob's Island	<0.5	3.9	≤ 0.5
The Canal	<0.5	0.80	≤ 0.5

The lower the Chlorophyll a density, the clearer your lake is!

Nutrient Loading and How to Interpret the Water Quality Result :	
If the Chlorophyll a density is…	Your Lake is…
Up to 2 ug/L (low algal density)	Oligotrophic - unenriched, few nutrients
2 – 4 ug/L (moderate algal density)	Mesotrophic – moderately enriched, some nutrients
More than 4 ug/L (high algal density)	Eutrophic – enriched, higher levels of nutrients

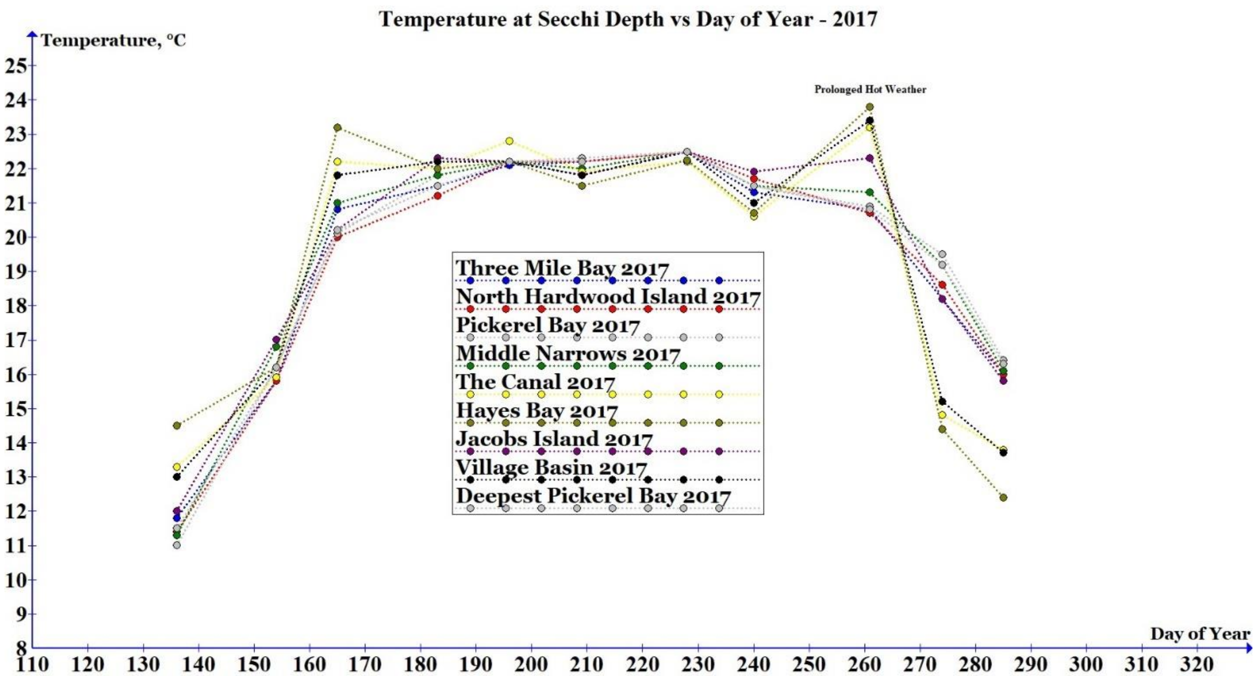
Chlorophyll-a concentrations in White Lake for 1975 and 2007



11.0 Water Temperature

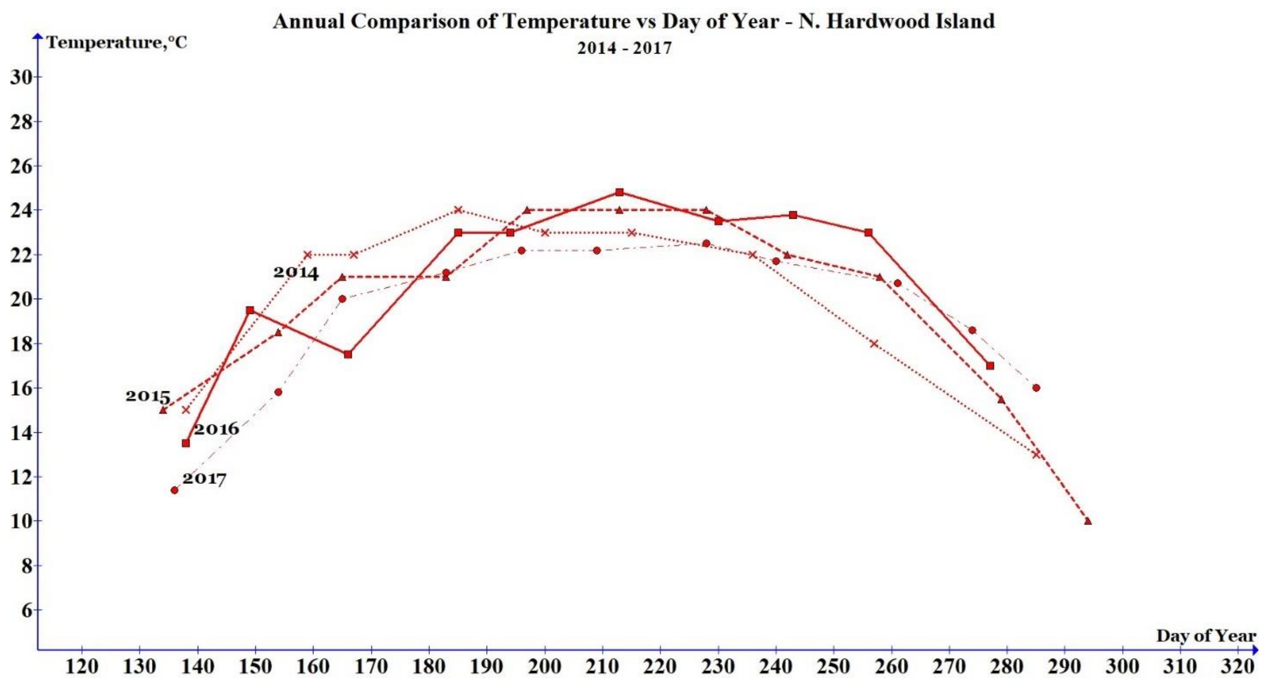
Temperature is one of the most important parameters when discussing water quality parameters. Changes in temperature affect the rates of chemical reactions, pH, and also the equilibrium concentrations of dissolved gases in the water column such as oxygen and carbon dioxide. Temperature also affects the solubility of many chemical compounds and can therefore influence the effect of pollutants on aquatic life. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impacts many species. For White Lake, increased water temperatures would also increase the release of phosphorus (back loading) from sediments into the water column. All temperatures reported in this study were taken at the Secchi depth using a thermometer calibrated against a secondary standard mercury glass thermometer.

The graph below shows the temperature of White Lake water over the course of the ice-free season:



Although there is clearly some variation in measured temperatures depending on the location of the sampling site, the temperature curves follow a trajectory very similar to those observed in previous years (see below). Not evident in the figure above, are differences in temperatures taken at deeper sampling sites relative to those taken at the three very shallow (≤ 2 m) sampling sites. For the most part, water temperatures for all of the deeper sites were almost the same differing by no more than 0.5 °C. However, the temperatures for the shallow sites were at times quite different from those of the deeper sites because they are more susceptible to recent or current weather conditions. A full explanation of this topic can be found in our 2016 report of scientific activities available on our website www.WLPP.ca.

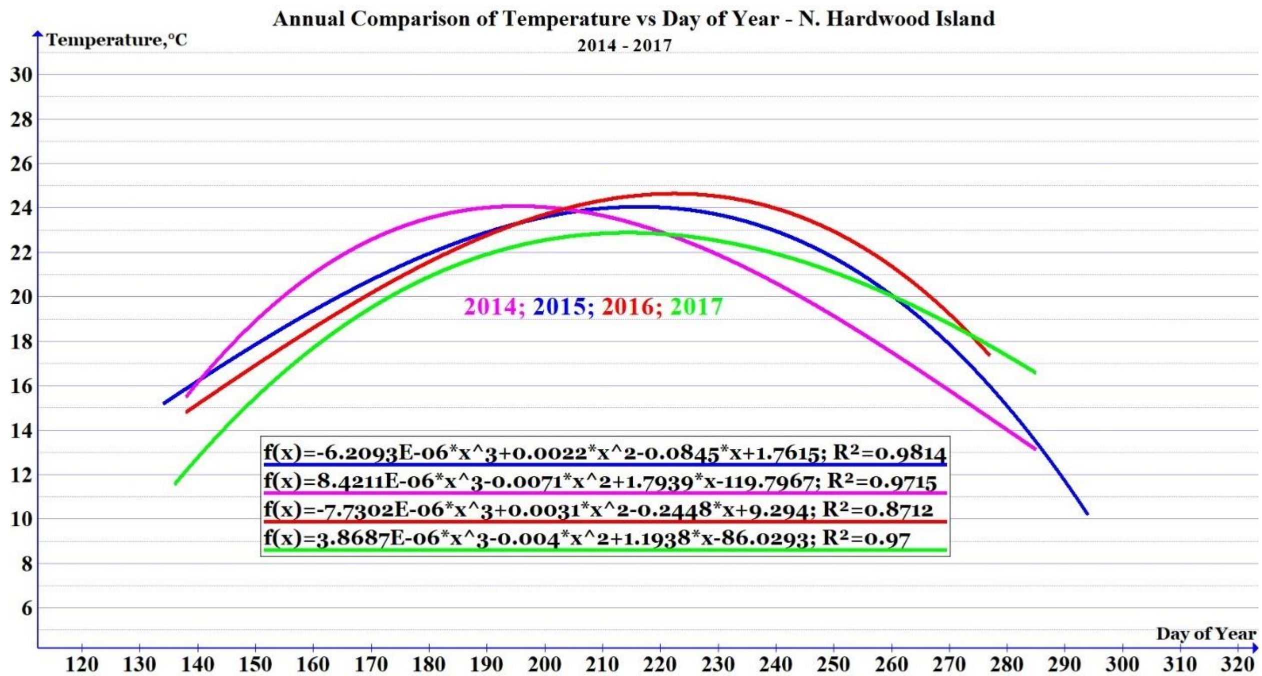
We now have four consecutive years of water temperature measurements for the deeper sites (Main Water Body Zone) on White Lake. The figure below gives temperature measurements obtained at the North Hardwood Island site for the years 2014 to 2017.



Although there is some year to year differences for temperatures recorded on a given date, the same general pattern in water temperatures with day of year is observed. This indicates, along with the other data in this section, that the temperature regime of the lake is quite regular from year to year. Therefore, the heat content of the lake is not changing appreciably from year to year even if there are differences in weather conditions. This may indicate that the floor of the lake has a significant role in buffering the temperature of the lake itself.

However, the 2017 data shows that the lake water was up to two degrees cooler than in previous years and especially so during the beginning of the ice-free season. The very significant rains experienced during the same time period (see Weather Section below) may explain this observation.

The date on which the maximum temperature was reached is not evident from looking at the curves in the above graph. Temperature measurements were taken only every two weeks and so it is almost certain that the maximum temperature is not represented on these curves. To help in obtaining the date on which the maximum temperature was reached, the data can be treated using an algorithm to convert the data to a 3rd order polynomial equation which can be plotted. The results of such a treatment is shown below.



The equations describing each of the derived curves are shown in the data box located in the figure above. In all cases, the correlation coefficient (R^2) is very high and close to unity indicating that the curves are a very good statistical fit for the temperature data.

With the exception of the 2014 data, the remaining data are in general agreement. Using these curves, it is possible to obtain the maximum annual water temperature and the day of the year it was reached. The table below summarizes this data.

Year	Day of Year	Maximum Temperature, ˚C
2014	199	24.1
2015	217	24.0
2016	223	24.7
2017	216	22.9
Average Values	214 ± 10 (219 ± 4)*	23.9 ± .75

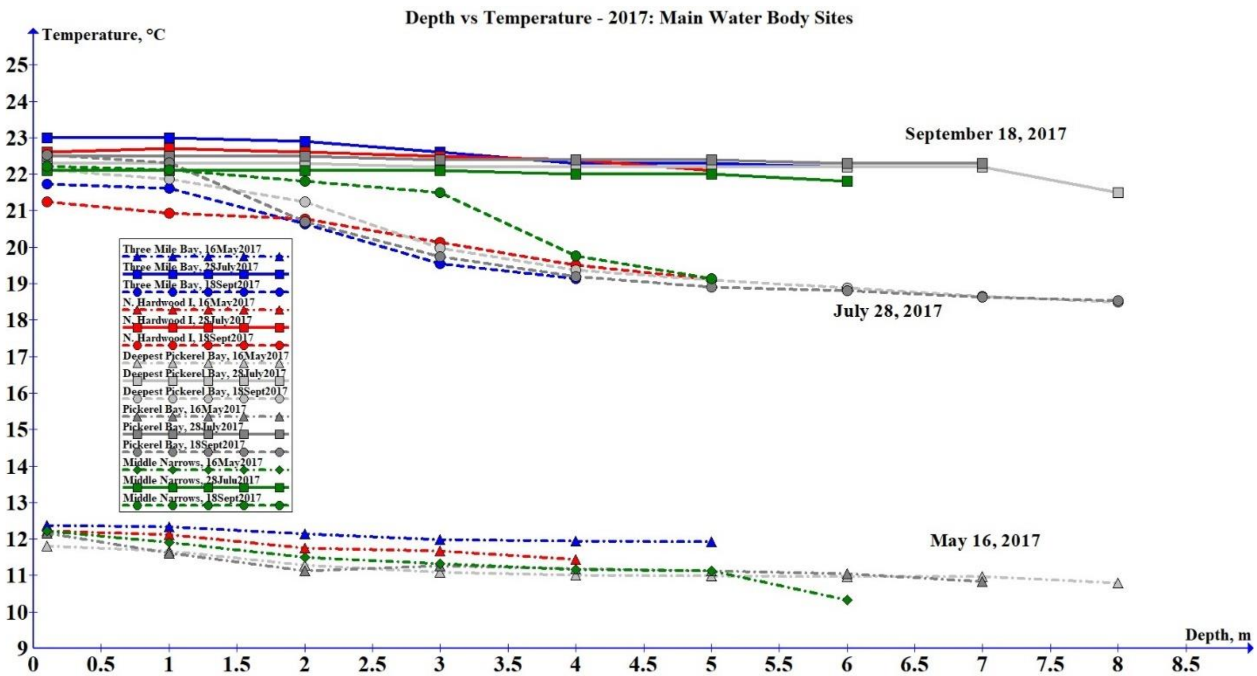
* average calculated without 2014 result.

These data show that whatever the weather pattern for the year, the water temperature reaches its maximum value within an 8-day range. The actual maximum temperature varies by no more than one degree. Even during a relatively cool and wet year (2017) the maximum temperature of the lake was only one degree lower than the four-year average value. For 2017, day 219 (average day of year for maximum temperature) was August 7.

11.1 Temperature as a Function of Depth

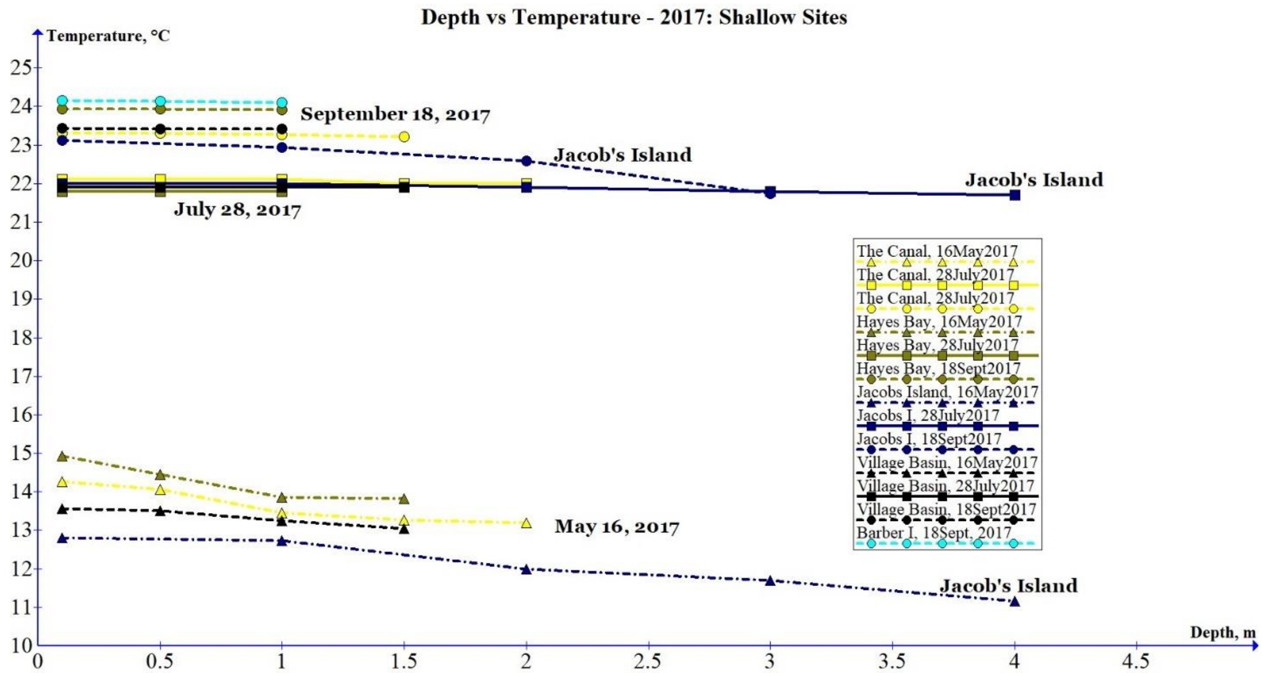
On three separate dates, measurements were taken of the water temperature profile with depth at nine locations on the lake. A YSI multi-probe in-situ measurement system was used.

The graph below shows results for the three sampling dates for the deeper sites (Zone 1) on the lake. These sites are grouped together because they all show similar physiochemical characteristics and as such are distinct from the shallow sites.



The above graph shows that there was only a small change in water temperature with increasing depth. The effect is more pronounced in July than in May which could be the result of large quantities of water entering the lake from ground water ingress (springs) following two months of significant rain. These results are similar to those obtained in 2016 but are different from results obtained in 2015. In 2015 there were significant temperature gradients with depth during the early months of the ice-free season. It could be that the longer ice-free season resulting from global warming is responsible for changing the temperature vs depth profile at a given time.

The figure below contains analogous data for the shallow sites. Data for the Jacob's Island site are included here although this site is intermediary between the deep and shallow sites and is the location where waters from the Main Water Body (Zone 1) mix with waters flowing from The Canal (Zone 3).



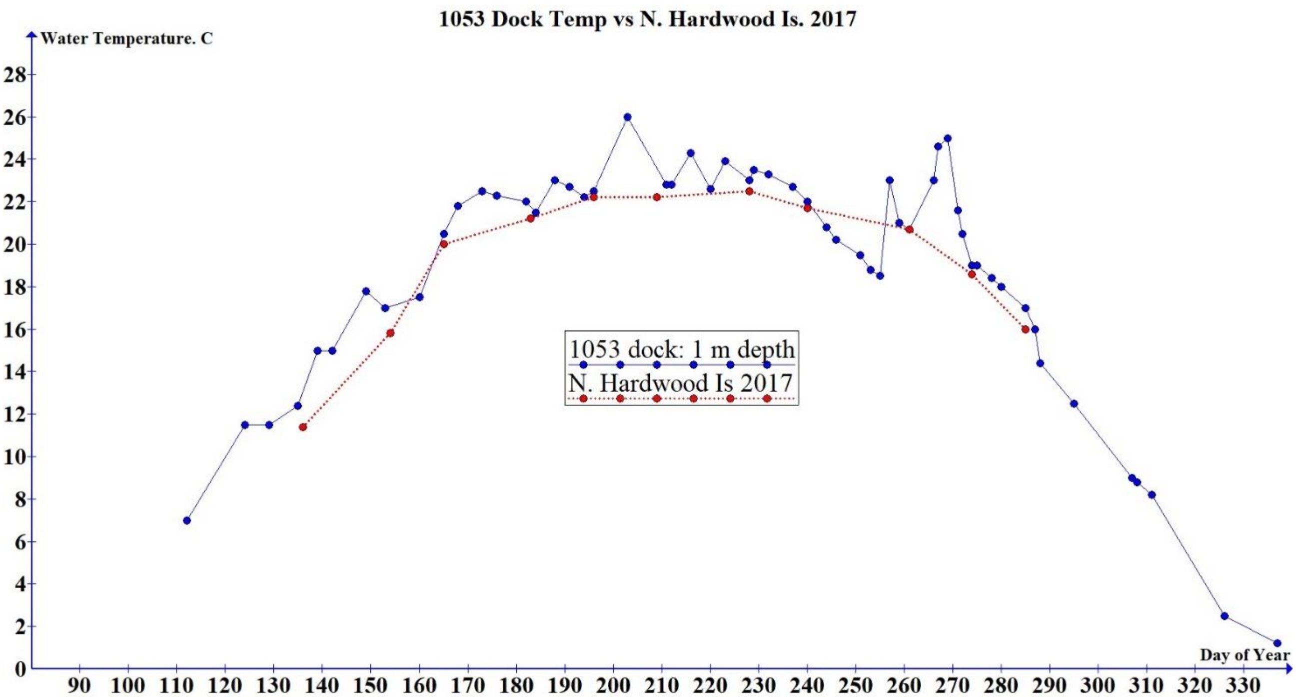
The above graph shows that the temperature of the shallow sites decreases significantly with depth for the May 16 sampling date. We suggest that the temperature of water near the floor of the lake is colder than the water directly above because colder water is entering the lake from below (springs). For other sampling dates, temperatures were approximately two degrees higher than those measured at the deeper sites and did not change with depth. For the September 18 sampling, the water temperature at Jacob's Island decreased with depth. This was likely due to mixing of cooler water from the Main Water Body with water flowing out from The Canal.

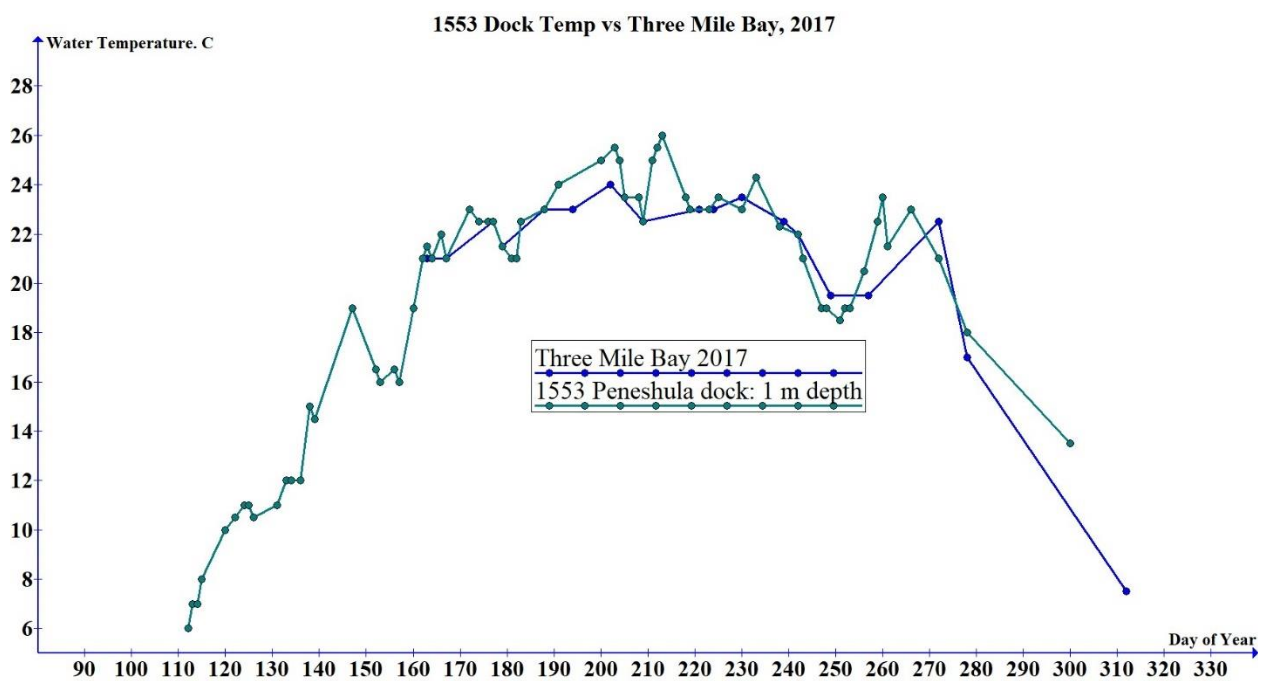
For all three sampling dates, water temperatures varied by no more than two degrees over the entire water column. White Lake is generally a well mixed lake with uniform temperatures throughout a given Zone (see Zone map).

11.2 Comparison of Shoreline with Open Lake Water Temperatures

For this experiment we were interested in determining if water temperatures taken from a dock in shallow water would correspond to the water temperature measured at the nearest sampling site. To do this we measured water temperatures 1 m under docks located on the western shore of the lake (opposite McLaughlin's Island), and on the northern shore of Three Mile Bay. These two sites were within 500 m of two of our sampling sites. The Western shore site (1053 Wabalac Rd.) was near N. Hardwood Island and the second site (1553 Peneshula Rd.) was near the Three Mile Bay sampling site. Temperatures were read nearly every day at the two dock sites and at least every two weeks at the lake sampling sites.

The figures below show the temperature vs day of year data for all four locations.

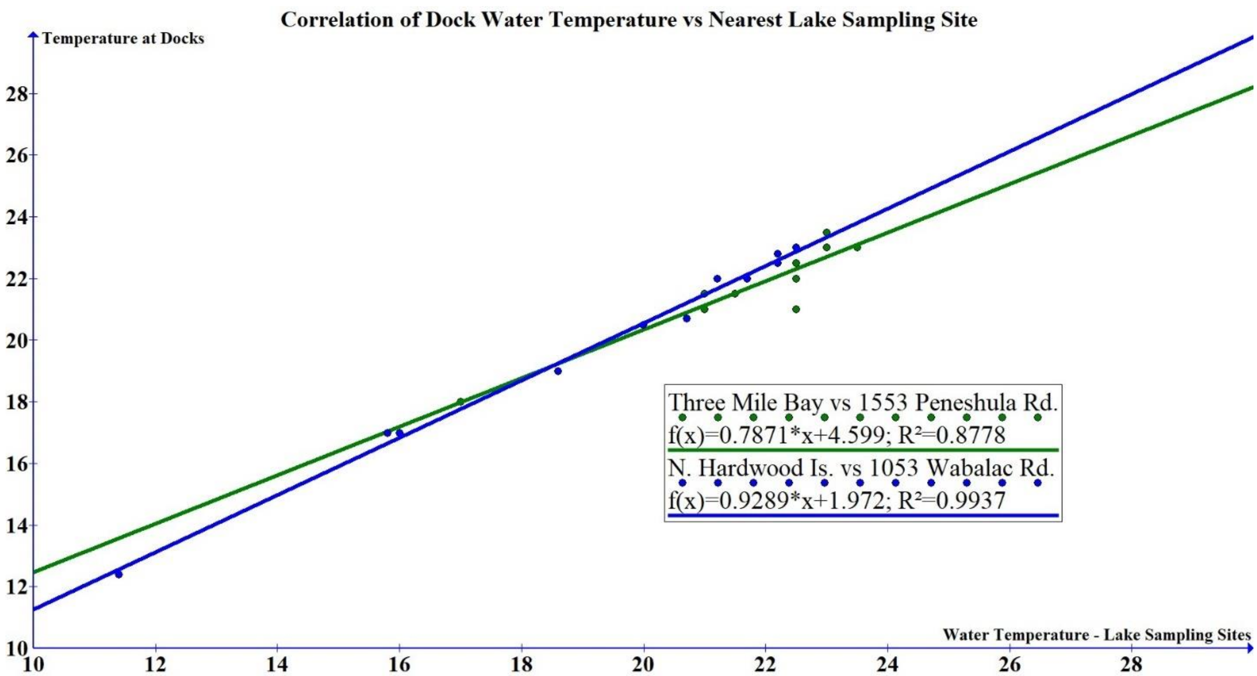




These plots show that the day to day temperatures at the dock sites could both increase or decrease over a few days. However, the general shape of the curves obtained for the dock sites closely follows the curves obtained for the adjacent lake sampling site which was measured less frequently.

Of interest is whether or not shoreline (dock) temperatures can be used as a surrogate for bulk lake water temperatures. We know that White Lake is well mixed during most of the ice-free season making this kind of a comparison worthwhile.

A correlation plot was constructed from temperature data taken on the same dates when lake sampling site temperatures were measured. Sampling site temperatures were read at the corresponding Secchi depth or 1 m above the lake bottom should the Secchi depth exceed the depth of the sampling site.



The calculated correlation coefficients (R^2) are both very high and near unity showing that the temperature data sets (dock and lake site) correspond very well with one another. However, the slope of the two lines are less than one indicating a bias in the data. The temperatures taken at the shoreline were about 1 degree lower than the corresponding temperature taken at the lake sampling site. It is possible that temperatures taken at the docks were lower than lake temperatures because cooler water was entering the lake (ground water ingress/springs) along the shoreline. Swimmers often come across cooler upwelling water near the shoreline.

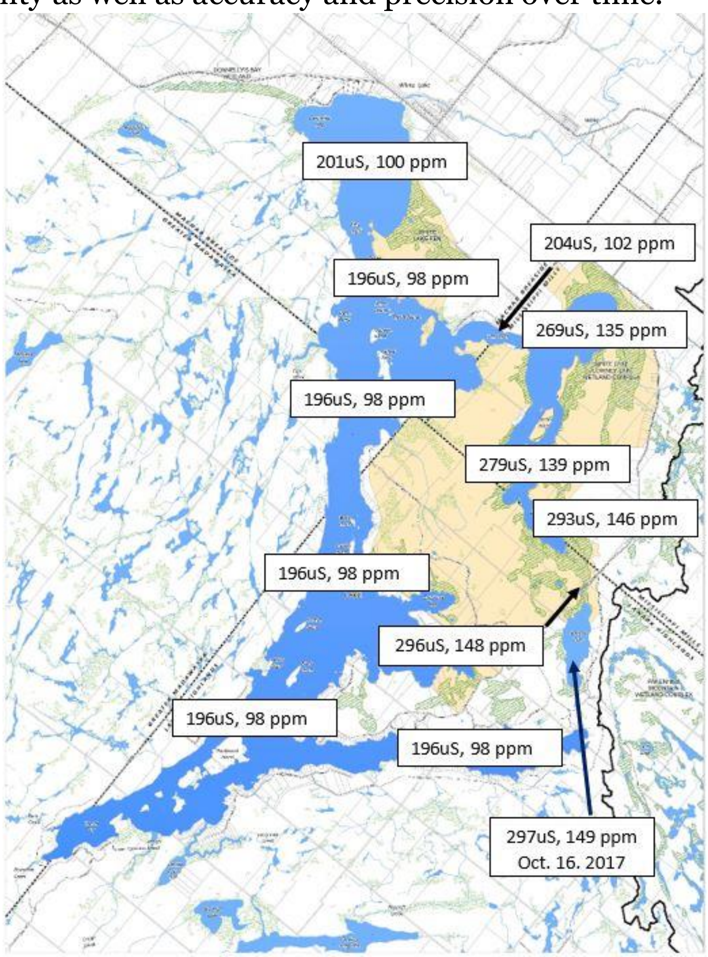
Temperatures were generally measured in the morning before the heat of the day could influence shallow water temperatures close to shore.

12.0 Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electric current. Specific conductance, is also referred to as *conductivity*, *electrical conductivity* or *specific electrical conductance*. In general, the higher the concentration of dissolved salts in the water, the easier it is for electricity to pass through it. Conductivity is reported in *microSiemens* (μS) per centimeter (cm). Conductivity measurements can be converted to *total dissolved solids* measurements which are reported in parts per million (ppm). A rough approximation of the concentration of dissolved solids in a freshwater source in ppm (milligrams/liter) can be obtained by multiplying the μS/cm value by 0.66 (the actual conversion factor may range from 0.55 to 0.80 for water of different sources). Because they are temperature dependent, these measurements are corrected and reported as if they were made at 25 ^{o}C.

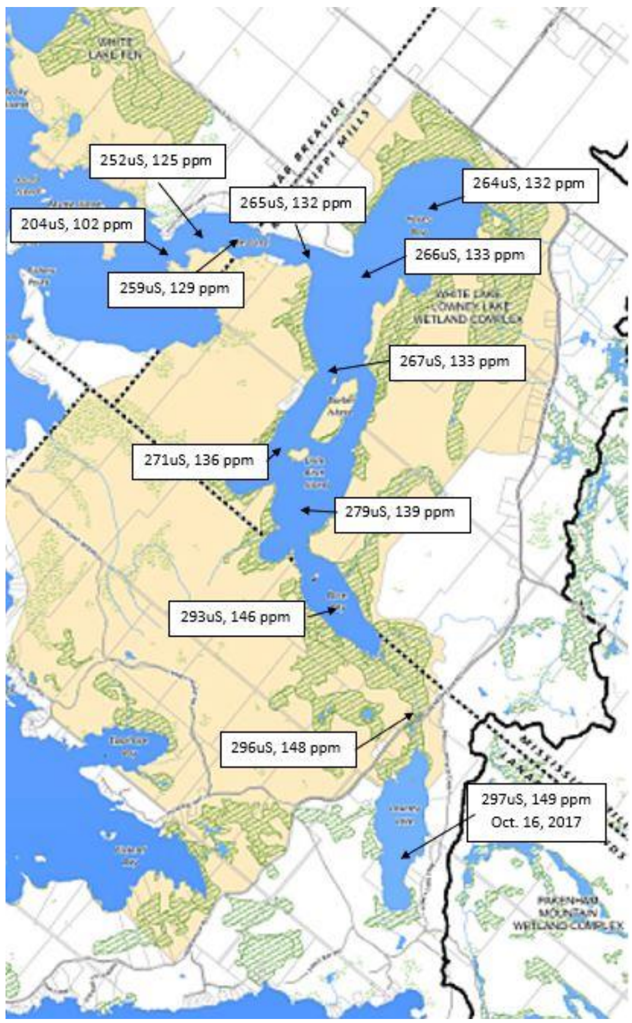
12.1 Lake-Wide Specific Conductivity Measurements

For this study, specific conductance measurements were taken with a Model AZ8361 pen-type conductivity/total dissolved solids meter. This device was calibrated before each use with a standard reference sodium chloride solution. Appendix 4 in this report contains data and statistical considerations for this meter. Results are reported for short, medium and long-term stability as well as accuracy and precision over time.



All samples were collected on August 28, 2017 from all parts of the lake and analyzed the same day in the laboratory or at the sampling site itself. The conductivity meter also provided values for total dissolved solids. These values are not tabulated separately here since these can be calculated from the formula given in the previous paragraph. For information purposes, a specific conductance value of 200 µS corresponded to a total dissolved solids value of 100 µg/ml as read from the instrument.

The map above shows the results obtained for water samples collected from all parts of the lake. A water sample for Lowney lake was also collected and analyzed. The map below shows an expanded view of the map covering Hays and Bane Bay as well as The Canal area and Lowney Lake. The largest variation in conductivity were observed in this part of the lake. Values for total dissolved solids (TDS) were added to both maps for the sake of completeness.



In another section of this report (Section 7), we provide a map of White Lake which divides the lake into 5 separate zones based on lake chemistry and other factors. It is advantageous to take the results for specific conductivity shown on the maps above and study them with respect to these lake zones.

Minimum, Maximum and Average Values for Specific Conductivity (SC) in Different Lake Zones

Location	Min. SC, µS	Max.SC, µS	Range, µS	Average, µS
Main Water Body (Zone 1)				
Three Mile Bay	187	198	11	193.2
North Hardwood Island	191	198	7	195.2
Deepest Pickerel Bay	192	198	6	195.2
Pickerel Bay	193	198	5	195.1
Middle Narrows	192	199	7	195.0
Mixing Zone (Zone 4)				
Jacobs Island	193	206	13	198.2
Village Basin (Zone 5)				
Village Basin	194	210	16	200.5
The Canal Area (Zone 3)				
The Canal	200	225	25	213.0
Hayes Bay, Bane Bay (Zone 2) and Lowney Lake				
Hayes Bay	263	288	25	272.3
Barber Island	267	293	26	281.0
Bane Bay I	279	299	20	287.5
Bane Bay II	2 measurements			293.0
Lowney Lake Outlet	1 measurement			296.0
Lowney Lake	1 measurement			289.0
Active Streams, Western Shore				
Boundary Creek	2 measurements			267.5
Paris Creek	2 measurements			41.0

A number of observations can be made from this data table:

1. Lake-wide, the variability in specific conductivity ranged from 187 to 299 µS, a difference of 112 µS or 60%.
2. Specific conductivity values obtained for the Main Water Body (Zone 1) were relatively uniform throughout the year with an average range in values of about 3.7% of the overall average value.
3. Specific conductivity values obtained for The Canal and Hayes Bay, Bane Bay, Lowney Lake Complex were more variable than for the Main Water Body, with the average range value being about 9.1% of the average value overall.
4. Other locations such as Jacobs Island and Village Basin exhibited variabilities intermediate to those of other locations cited in points 2 and 3 above.
5. Streams flowing into the Main Water Body did not have a significant influence on the conductivity (or total dissolved solids), of the Main Water Body and so likely make up only a small proportion of the water entering White Lake. As well, this result also indicates that the lake itself was well mixed at that time.
6. The larger changes observed in specific conductivity in shallow areas reflect the sensitivity of these locations to factors such as rain and evaporation.

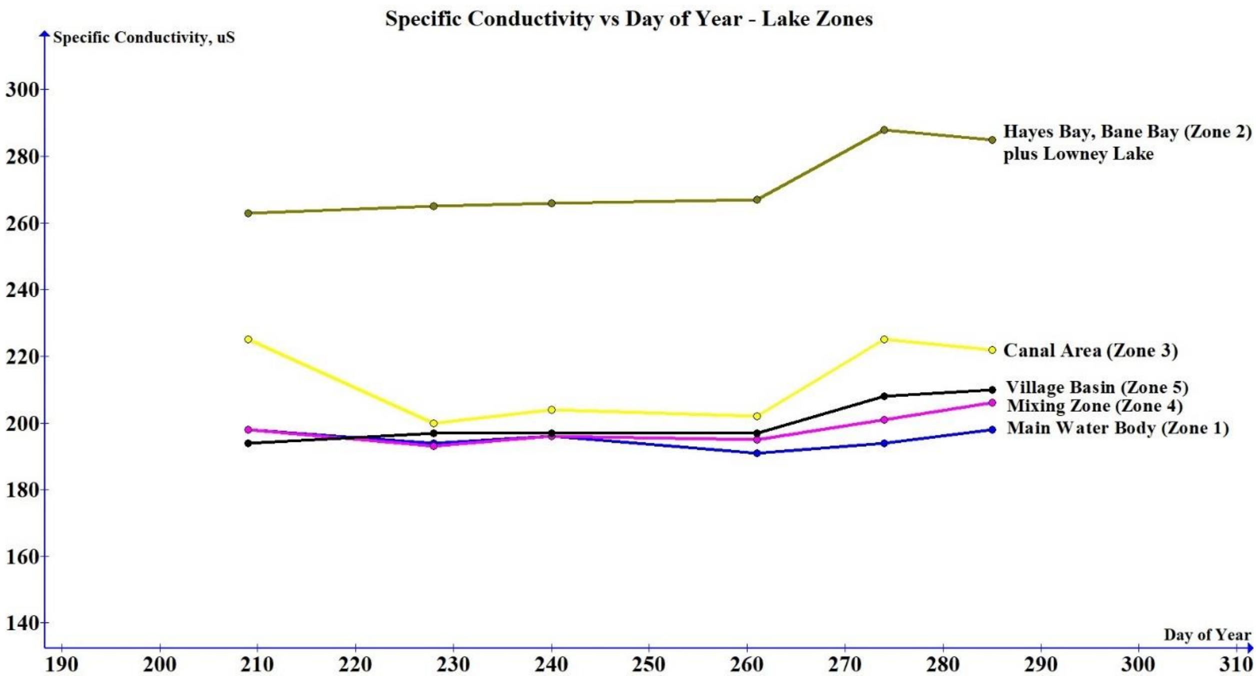
7. For all parts of the lake, the specific conductivity results indicate that White Lake is largely spring fed by ingress of ground waters or springs.
8. The average value for specific conductivity for The Canal site was 213 µS whereas the value at the Hayes Bay site was 272.3 µS. Water flowing from Hayes Bay into The Canal thus experienced a decrease of specific conductivity of 21.8%. For this to have happened, waters at The Canal site would need to have had significant input from another water source of lower Specific Conductivity. This may mean that waters from the adjacent bay to the south was mixing with Canal water or there was a significant flow of water entering The Canal from ground water sources (springs). The latter is more likely since total phosphorus concentrations measured for The Canal are much lower that those of adjacent waters be they from the Main Water Body or Hayes Bay.
9. More detailed measurements of specific conductivity in waters in and adjacent to The Canal are required. This will be the subject of research to be completed during the 2018 field season.

The composition of waters entering the lake reflects the chemical composition of the rocks through which these waters flowed before entering the lake. Calcareous rocks containing minerals such as calcite and dolomite are relatively soluble bringing into solution minerals such as Ca and Mg into waters which come into contact with the rock. The amount of minerals transferred from rock to the aqueous phase will depend on the pH of the water as well as the contact time with the rock as well as temperature. This is what may account for the relatively high specific conductance measured in Lowney Lake and downstream locations such as Bane and Hayes Bays. More study is required to explain the changes in specific conductivity observed in waters downstream from Hayes Bay and especially in the area where waters from The Canal flow into greater White Lake on its way downstream towards the White Lake Creek Dam.

In the figure below, data is presented for specific conductivity measurements taken in different lake zones as a function of time (day of year). Values for Zone 1 were essentially the same at all locations and are given as the average of all of the five sampling sites. These data show that there was relatively little variation in conductivity measurements over the ice-free season. Results are flat until there is a rise in mid-September, followed by a small increase thereafter. Note that the first point for The Canal is high when compared to subsequent measurements. This can only occur if there was some movement of waters from areas with higher conductivity values such as Hays Bay.

It is worth noting that during the first half of the 2017 ice-free season, rainfall was especially heavy which may have contributed to an overall reduction in specific conductivity in all parts of the lake. Water entering the lake from springs later in the year when rainfall was light may have resulted in higher specific conductivity values during this time period. Evaporation could also explain and increase especially in shallow areas.

One interesting observation was in relation to the specific conductivity for the Village Basin (Zone 5). Conductivities were higher there than for the mixing zone (Zone 4) which flows directly into the Village Basin. Higher water conductivity could be due to the introduction of more saline waters into part of the Village Basin from the White Lake Fen. This Fen is located within both Hayes Bay and the Village Basin. Fens are special marshlands which, by definition, receive upwelling mineral rich waters (from springs). Similar results were obtained in 2015 and 2016 (see WLPP reports in www.WLPP.ca).



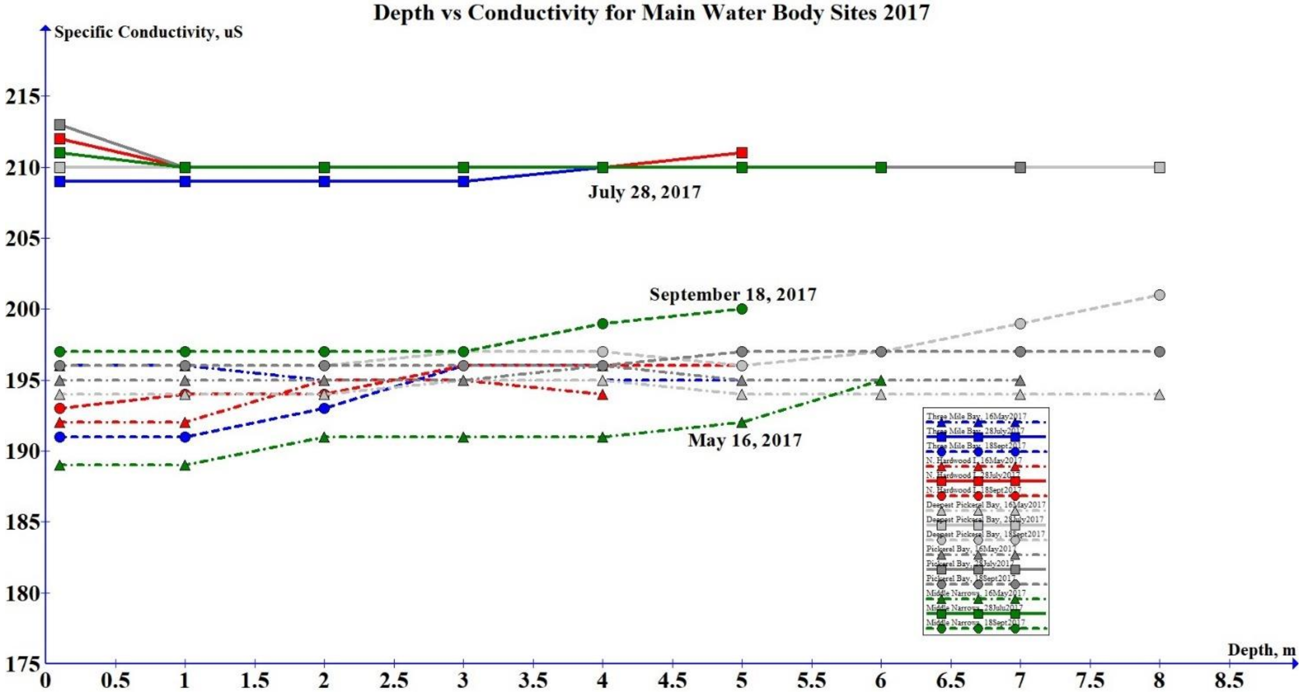
12.2 Variability of Specific Conductance with Depth

Measurements of specific conductance were completed as a function of water depth using a YSI multi-parameter probe. Measurements were done at all sampling sites on May 16, July 28 and September 18, 2017. Results are presented in the two graphs (below) and are divided into two sets of data; one for the deeper sites within the Main Water Body (Zone 1); and the shallower sites on White Lake.

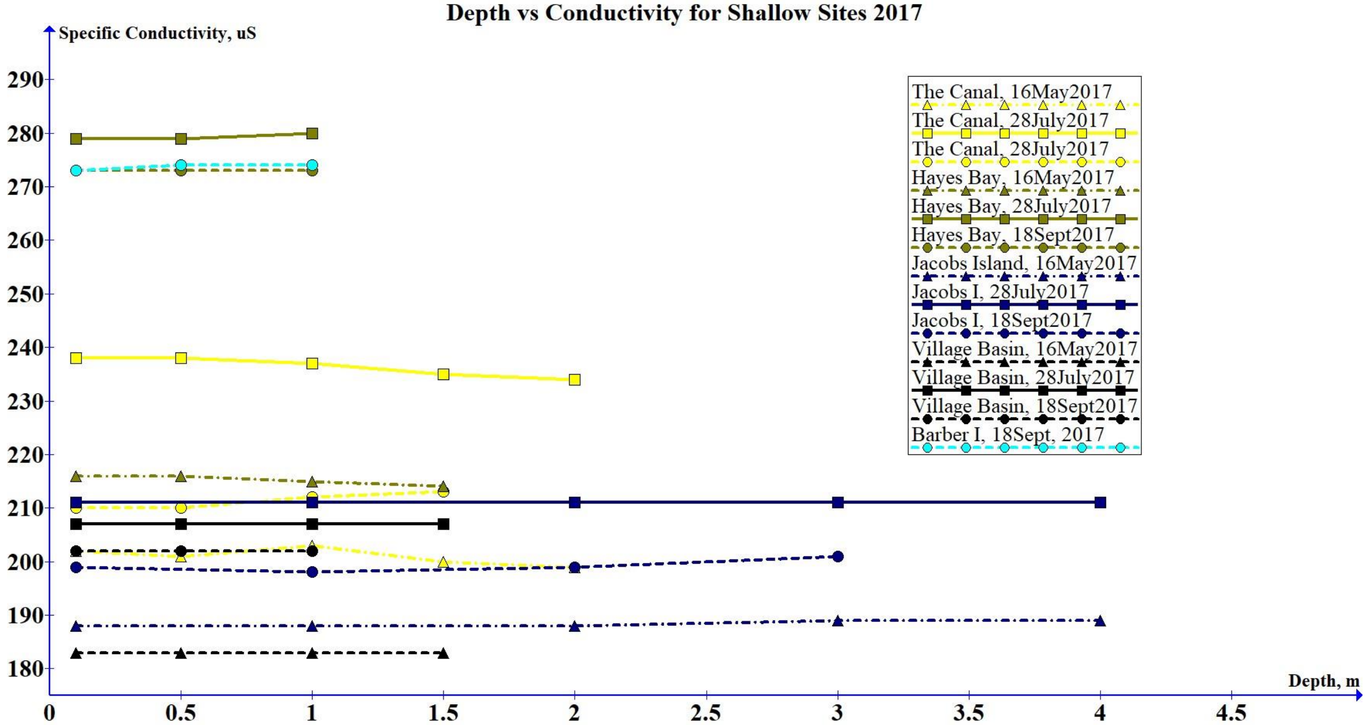
The results indicate that for the deeper sampling sites (Zone 1) there were only moderate increases in conductivity with depth, especially for the May and September sampling dates. These results may be due to more mineralized waters entering the lake at depth (springs) during this time periods.

For the shallow sites, there appears to be very efficient mixing of waters in the water column resulting in uniform conductivity measurements.

Depth vs Conductivity for Main Water Body Sites 2017

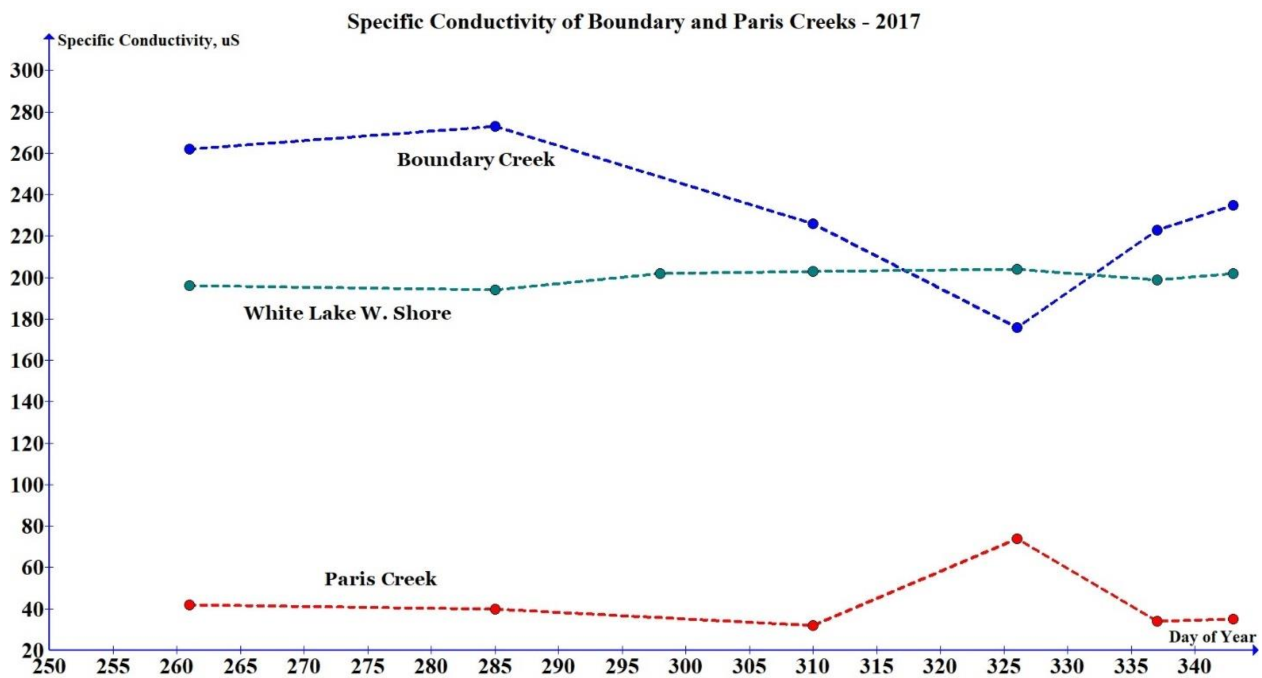


Depth vs Conductivity for Shallow Sites 2017



12.3 Changes in Specific Conductivity with Time for Boundary and Paris Creeks

Although the waters of the Main Water Body (Zone 1) show little change in conductivity over time, this is not the case with two major White Lake feeder streams. The figure below shows the changes in specific conductivity for Boundary and Paris Creeks. These creeks are both located on the western shore of White Lake close to the southern end of the lake on Sunset Bay. For comparison purposes, data for lake water taken along the western shore of the lake (1053 Wabalac Road) is included.



During the time data was collected for this graph, there were several rain events as well as some early winter snow fall with subsequent melting. The conductivity of Boundary Creek water decreased when more heavily mineralized water normally flowing from the creek was mixed with surface runoff of much lower conductivity. For Paris Creek which has a naturally very low specific conductivity, the same circumstances resulted in an increase in conductivity. This could be because runoff waters were more acidic from interactions with decaying organic material which then dissolved calcium from rocks it came into contact with. During this time, the colour of the water from Paris Creek was noticeably darker indicating a higher content of dissolved organic carbon.

Interestingly, the specific conductivity of lake water did not change appreciably during the same time period. This indicates that surface runoff and stream input do not greatly influence bulk lake water chemistry of White Lake.

13.0 Impact of Stream Waters Entering White Lake

There are many sources of water entering the lake all combining to form White Lake. Each of these sources may have different chemical characteristics and in turn could have an effect on the overall composition of lake water.

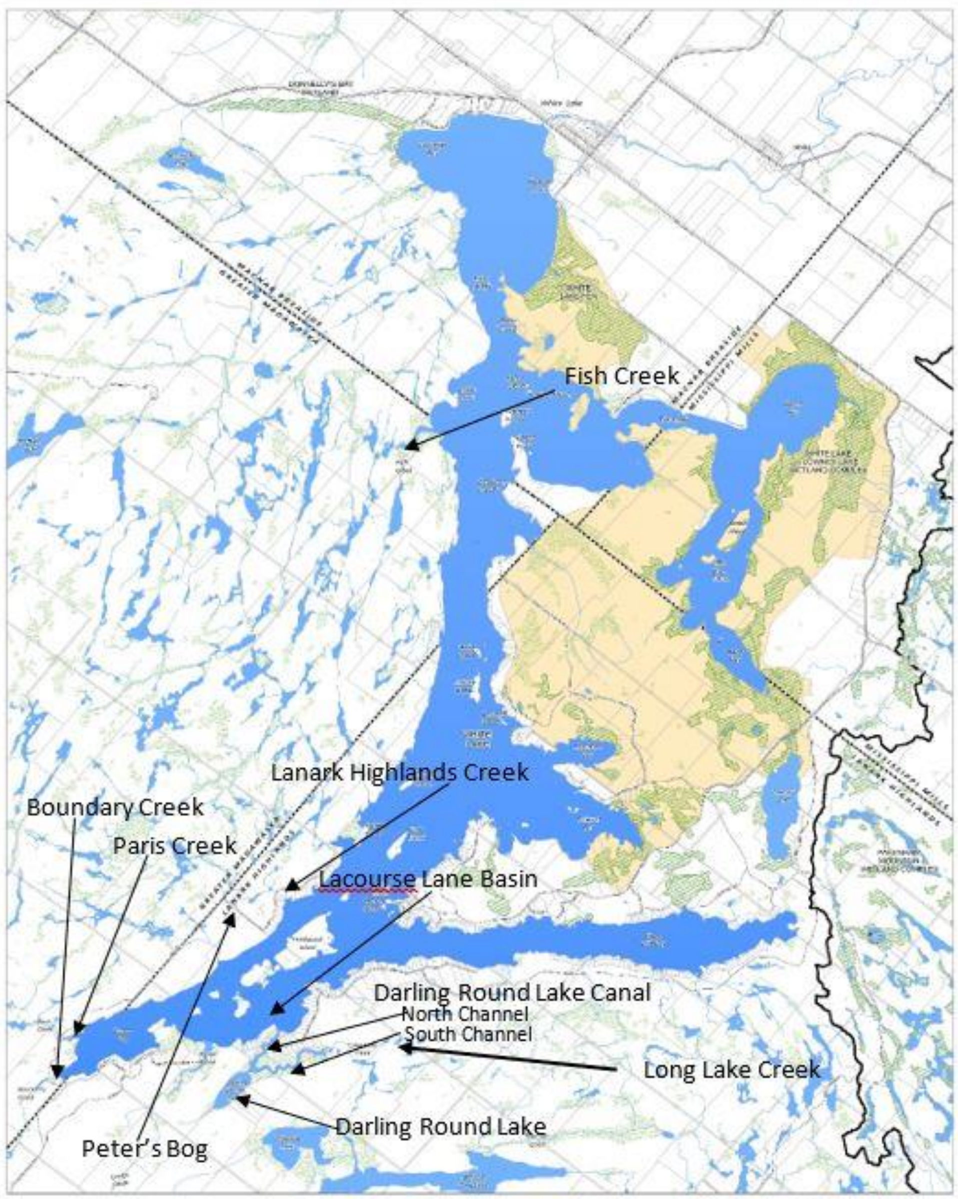
Sources of water entering the lake include rainfall, streams, surface runoff (rain, melting snow, etc.) and water entering from beneath the lake as springs or from ground water ingress. Of course, there are also several mechanisms by which water leaves the lake. For White Lake, water leaves lake primarily by outflow at the White Lake dam and evaporation.

The geology of the rocks surrounding White Lake as well as those underlying the lake can also influence the composition of bulk lake water. For example, the western shore of the lake is mainly comprised of Precambrian shield rocks which are relatively insoluble and acidic. In contrast to this, the rock surrounding the remainder of the lake as well as those underneath the lake are mainly calcium rich or calcareous rocks such as limestone, calcite and dolomite. These rocks are relatively soft, soluble and basic in nature (high pH).

Rainwater can also be an important source of water entering White Lake. Rainwater by its very nature is very soft and contains virtually no dissolved solids and has a neutral pH. In terms of impact on water levels, one only has to consider the amount of rain that fell directly on White Lake during the 2017 ice-free season. Nearly one metre of rain fell on the lake during this time. Since the average depth of White Lake is only three metres, this means that for this year, rainfall alone accounted for 1/3rd of the total volume of the lake at any given time. For shallow parts of the lake such as Hayes and Bane Bays (1.5-2 metres deep), rainfall accounted for nearly 100% of their total volume at any given time. Of course, rainfall entering the lake does so erratically and over many months and so does not immediately displace large volumes of lake water. Also, during this time, surface water runoff, stream waters as well as ground water are also entering the lake as these flows increase during and immediately after rainfall. Some of the rain falling on land anywhere within the watershed of White Lake will eventually find its way into the lake.

13.1 Measurement of Hardness, Ca, Mg and Ca/Mg Ratios in White Lake and Feeder Stream Waters

One approach to studying the impact of stream waters on lake water composition is to measure the total hardness, Ca and Mg concentrations and by calculation, the Ca/Mg ratio. We did this using a HATCH hardness test kit. This kit is comprised of several reagent solutions as well as chemical endpoint indicators. A standard volume of sample is taken, and after the adjustment of pH and the addition of indicator, is titrated with calibrated droppers containing a solution of EDTA complexing agent. In each case, for the determination of total hardness and calcium hardness, the number of drops required to achieve the indicator colour change is counted. Standard calculations (given below) are used to provide total hardness expressed in parts per million (µg/ml) of $CaCO_3$ as well as calcium hardness also expressed as parts per million $CaCO_3$. Magnesium hardness is calculated by difference.



Although there are more than 10 streams flowing into White Lake only 4 of these are active throughout the year and deliver significant amounts of water into the lake. Three of the streams are located on the western shore of the lake. These are Fish Creek, Boundary Creek and Paris Creek. The fourth stream is Long Lake Creek which is located along the southern shore of the lake. The waters of Long Lake Creek flow through a marshland then combine with water flowing out of Darling Round Lake before entering White Lake. Locations of these streams are shown on the map above. Photos of the sampling sites as well as notes pertaining to specific sites are also included at the end of this section of the report.

Hardness is a chemical parameter which refers to the total amount of calcium and magnesium contained in water. By titration and calculation, we have also obtained the concentration of calcium and magnesium in these waters. Waters which are low in calcium and magnesium have not come into contact with calcareous rocks such as limestone and dolomite. Low calcium and magnesium concentrations can also result if water is flowing rapidly over a section of calcareous rocks and does not have sufficient time to interact with these rocks. Also, a mixture of waters high in calcium and magnesium with runoff from rainfall or snow melt could also exhibit low hardness numbers.

One way to better define or describe the interaction of water with its geological setting is to study the ratio of calcium to magnesium. The ratio of calcium to magnesium provides a chemical signature of the rocks with which water has interacted.

The geology of the White Lake watershed is well known from surficial geology maps of the White Lake basin as well as published reports by the Ontario Ministry of the Environment and Climate Change and the Geological Survey of Canada (please see documentation at www.WLPP.ca) There is a very large calcite mine (OMYA Canada Ltd.) located in nearby Clayton, ON, which is just to the southeast of White Lake. The mineral there is approximately 99% calcium carbonate with the remainder being largely magnesium carbonate. However, as one moves away from the mine, the rock contains increasingly higher concentrations of dolomite (Ca/Mg carbonate) [Tom Lalonde, OMYA Canada, personal communication]. This means that we can reasonably expect to see differences in the calcium/magnesium ratios of White Lake source waters flowing through areas of different calcium/magnesium mineral compositions.

The table below contains total hardness, calcium and magnesium concentrations as well as the calcium/magnesium ratios for 22 water samples taken from streams, marshes and all parts of White Lake. The results presented in the table are colour coded in order to simplify interpretation. The yellow highlighted results are for lake water samples obtained from sampling sites which are routinely sampled for a large number of chemical and physical parameters (see map in the initial pages of this report) as well as Long Lake Creek. The green highlighted results are for streams located on the western shore of White Lake and also Darling Round Lake, a small connected lake located just to the south of White Lake. Finally, the red highlighted results are for data arising from the analysis of waters from Darling Round Lake Canal and marshlands through which it drains on the way to White Lake.

As can be seen on the table below, the Ca/Mg ratio for the different colour-highlighted groups are different and are approximately 8, 2 and 5 for the three data groupings. What does this mean?

A number of observations can be made from the data presented in the table below:

1. The Ca/Mg ratios indicate that there are at least three different chemical signatures for the set of water samples analyzed. Therefore, three different mineral sources are apparent.
2. With the exception of Boundary Creek, stream waters entering White Lake from the western shore are very low in minerals compared to all other water samples. These waters have had only limited contact with calcareous rocks and can be associated more with granitic or shield-type rocks.
3. Although Boundary Creek has the same Ca/Mg signature of other creeks on the western side of the lake, the total hardness of this water was somewhat higher (140 vs 120 ppm) than lake water samples. As shown in the photos below, Boundary Creek flows past a large clearly exposed deposit of calcite visible from Rt. 511 near the White Lake Rd. intersection. This is the source of minerals in the creek water.
4. The Ca/Mg ratio of waters moving through the marshlands of the north and south Darling Long Lake canals (see map above) has likely been altered by the uptake of minerals by plants. The results obtained for an inland bog (sample 5) gave similar results.
5. Waters from Long Lake Creek and all sites on the lake have identical Ca/Mg ratio chemical signatures (8.3).

One of the most important observations from this study was that all of the lake samples from all parts of White Lake had the same Ca/Mg ratio signature and that this ratio was significantly higher than all of the stream waters entering the lake, with the exception of Long Lake creek, which drains Darling Long Lake in the same watershed.

If waters entering White Lake via streams and creeks had significant influence on the composition of White Lake waters, one would expect to see some variations in both the total hardness and Ca/Mg ratio for samples taken in different parts of the lake. There should be a significant difference in Ca/Mg ratios for water samples taken near the western shore (e.g. N. Hardwood Island) as compared to those taken closer to the opposite shore (e.g. The Canal). This was not observed.

Conclusion: This study shows that surficial waters (streams, runoff) have only limited influence on the composition of the water contained in White Lake. **We can now suggest that White Lake is a lake primarily fed from springs and sub-terranean/lake sources.** This conclusion is in agreement with published reports from the Ontario Ministry of Natural Resources and Climate Change as mentioned above (see www.WLPP.ca). Also see Section 16 (Ca) of this report which provides evidence that 88% of the water entering White Lake is derived from ground water sources (including some streams) with the remainder coming from rain and surface runoff.

Measurement of Hardness, Ca and Mg Concentrations – White Lake and Feeder Streams

Date	Sample #	Location	Total Hardness Drops EDTA	Total Hardness $[CaCO_3]$, ppm	Ca Hardness Drops EDTA	Ca Hardness $[CaCO_3]$, ppm	Mg Hardness $[CaCO_3]$, ppm	Ca,ppm	Mg,ppm	Ca/Mg
3Jun17	1	Boundary Cr.	7	140	4	80	60	32	14.4	2.2
3Jun17	2	Paris Cr.	2	40	1	20	20	8	4.8	1.7
3Jun17	3	L.H. Cr.[1]	2	40	1	20	20	8	4.8	1.7
3Jun17	4	Shoreline Lake Water[2]	6	120	5	100	20	40	4.8	8.3
3Jun17	5	Peter's Bog	2.5	30	1.2	24	6	9.6	1.4	6.9
10Jun17	6	Darling Round Lake	9	180	6	120	60	48	14.4	3.3
10Jun17	7	Darling Round Lake Canal S[3]	8	160	6	120	40	48	9.6	5.0
10Jun17	8	Long Lake Creek	7.2	144	6	120	24	48	5.8	8.3
10Jun17	9	Mouth of Darling Round Lake Canal N[4]	7.5	150	6	120	30	48	7.2	6.7
10Jun17	10	Shoreline Lake Water[2]	6	120	5	100	20	40	4.8	8.3
12Jun17	11	Fish Creek	2	40	1.0	20	20	8	4.8	1.7
13Jun17	12	Darling Round Lake Canal N[3]	8	160	6	120	40	48	9.6	5.0
13Jun17	13	Lacourse Lane Basin (centre)	6	120	5	100	20	40	4.8	8.3
3Jul17	14	Three Mile Bay	6	120	5	100	20	40	4.8	8.3
3Jul17	15	N. Hardwood Island	6	120	5	100	20	40	4.8	8.3
3Jul17	16	Deepest Pickerel Bay	6	120	5	100	20	40	4.8	8.3
3Jul17	17	Pickerel Bay	6	120	5	100	20	40	4.8	8.3
3Jul17	18	Middle Narrows	6	120	5	100	20	40	4.8	8.3
3Jul17	19	Jacobs Island	6	120	5	100	20	40	4.8	8.3
3Jul17	20	The Canal	6	120	5	100	20	40	4.8	8.3
3Jul17	21	Hayes Bay	7	140	6	120	20	48	4.8	10.0
3Jul17	22	Village Basin	6	120	5	100	20	40	4.8	8.3

[1]Part 16, Lot 26 Concession VIII Darling Township (Western Shore, Wabalac Road) lot owned by Lanark Highlands; [2]Taken 5 m (1.5 m depth) from shoreline @ 1053 Wabalac Road; [3] Samples taken at mid-point. [4] Mouth of Darling Round Lake Canal N. S = South; N = North

Example Calculation: calcium and magnesium

a. Total hardness expressed as $CaCO_3$, obtained using the EDTA titration = 120 mg/L (sample value)
b. Ca hardness expressed as $CaCO_3$, obtained using the EDTA titration = 70 mg/L (sample value)
c. Mg hardness as $CaCO_3$ = total hardness – calcium hardness = 120 – 70 = 50 mg/L
d. Ca^{+2} = (70 mg/L as $CaCO_3$) $\times$ (40 g Ca^{2+} / 100 g $CaCO_3$) = 28 mg/L as Ca^{2+}
e. Mg^{2+} = (50 mg/L as $CaCO_3$) $\times$ (24 g Mg^{2+} / 100 g $CaCO_3$) = 12 mg/L as Mg^{2+}
f. Results obtained using HATCH Total Hardness and Calcium Hardness test kit Cat. No. 1457-01. Magnesium hardness calculated by difference.

NOTES:

1. Error estimated to be approximately 10% for Ca and Mg and 20% for Ca/Mg ratios.
2. When the number of reagent drops is small (2 to 3) Calcium tends to be overestimated and Magnesium underestimated.
3. Lake water values (samples 4, 10 and 13) are for samples taken nearshore (samples 4 and 10). Sample 13 was taken in deep water (4m) at centre of basin opposite Lacourse Lane in Southern part of White Lake and the outlet of Darling Round Lake Canal North.
4. Samples 5 was taken in an isolated marshy location (max .5 m depth) located on km 5 of Wabalac Road. Results may reflect exposure to growing aquatic plants and fish, etc. which take up Ca and Mg from these waters. Therefore, the Ca/Mg ratio likely does not entirely reflect the chemical composition of rock or minerals these waters have been in contact with.
5. Samples 1,2,3,6 and 11 all show similar (same within error) Ca/Mg ratios indicating that these waters have been in contact with the same or very similar rock or mineral formation.
6. Sample 1,2,3, 6 and 11 gave calcium values ranging from 8 to 48 ppm indicating that these waters have had differing contact times with rocks or minerals of similar composition (see point 6 above).
7. Samples 1,2,3,6 and 11 gave magnesium values ranging from about 5 to 14 indicating that these waters have had differing contact times with rocks or minerals of similar composition (see point 6 above).
8. Data shaded in green are for the major sources of stream water entering White Lake. Calcium concentrations range from 8 to 48 ppm. Magnesium concentrations range from 4.8 to 14.4. Higher absolute concentrations may indicate contact time of water with soluble minerals. However, (within error) the Ca/Mg ratio for all the samples are similar (1.7 to 3.3) except for the Long Lake Creek sample which has a ratio of 8.3. This result indicates that all the stream waters on the West side of the lake are exposed to rocks of similar composition whereas water in Long Lake Creek (and associated source drainage basin) is in contact with rocks or minerals with a much higher Ca concentration relative to its Mg content. Long Lake Creek is the water source closest to the Tatlock calcite mine which contains one of the purest calcium carbonate deposit in the world.
9. For the creeks located on the Western side of White Lake (samples 1,2,3 and 11) all had relatively low Ca concentrations in keeping with waters draining shield-type rock or waters having only limited contact with calcium containing rocks.
10. The exception is sample 1 (Boundary Creek) which had a Ca and Mg close to lake water values (samples highlighted in yellow). This creek passes through a zone known to contain calcite mineral outcrops near the intersection of RT 511 and White Lake Road. The outcrop is clearly visible today (see photo below) and is reported in published documents listing mineral showings in the Darling Township area.


Sample #1
Boundary Creek


Sample #2
Paris Creek


Sample #3
Lanark Highlands
Creek


Sample #5
Peter's Bog


Sample #6
Darling Round Lake

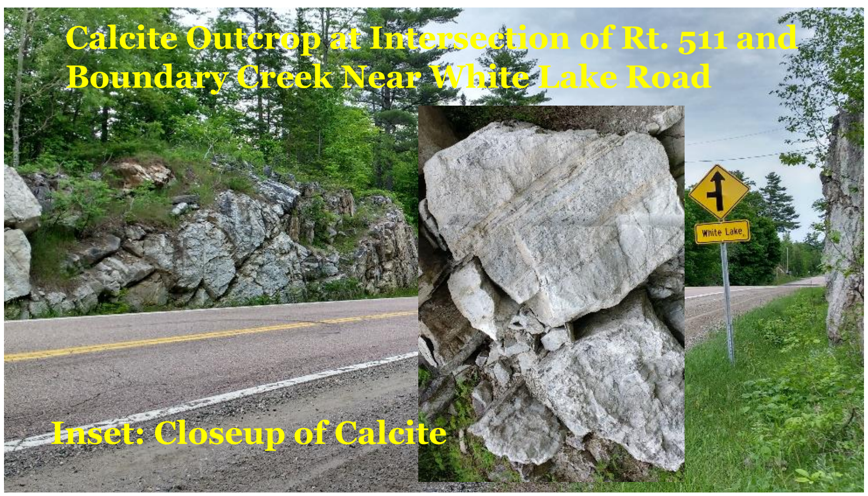

Sample #7
Darling Round Lake Canal South


Sample #8
Long Lake Creek


Sample #9
Mouth of Darling Round Lake Canal North


Sample #11
Fish Creek


Sample #12
Darling Round Lake Canal


Calcite Outcrop at Intersection of Rt. 511 and
Boundary Creek Near White Lake Road
White Lake
Inset: Closeup of Calcite


Darling Round Lake and Canals

14.0 Dissolved Oxygen

Oxygen is an essential element in any aquatic system. Oxygen is needed by all organisms to sustain life. The amount of oxygen dissolved in lake water varies from day to day and even between night and daytime. Most of the dissolved oxygen in lake water comes from the atmosphere and becomes dissolved into the water column by diffusion and the action of wind and waves. Oxygen concentration varies significantly with water temperature with colder waters able to contain more oxygen in solution than warmer waters. Oxygen is also produced during sunlight hours as a result of photosynthesis by phytoplankton and aquatic plants. Oxygen is consumed by these same plants during the night, when no photosynthesis can occur, and also by fish, plankton and the decay of organic materials at the bottom of the lake.

Because of the dependence of oxygen levels on many environmental factors, it is easy to see that the concentration of oxygen in lake water can vary greatly during the ice-free months and can certainly vary from year to year.

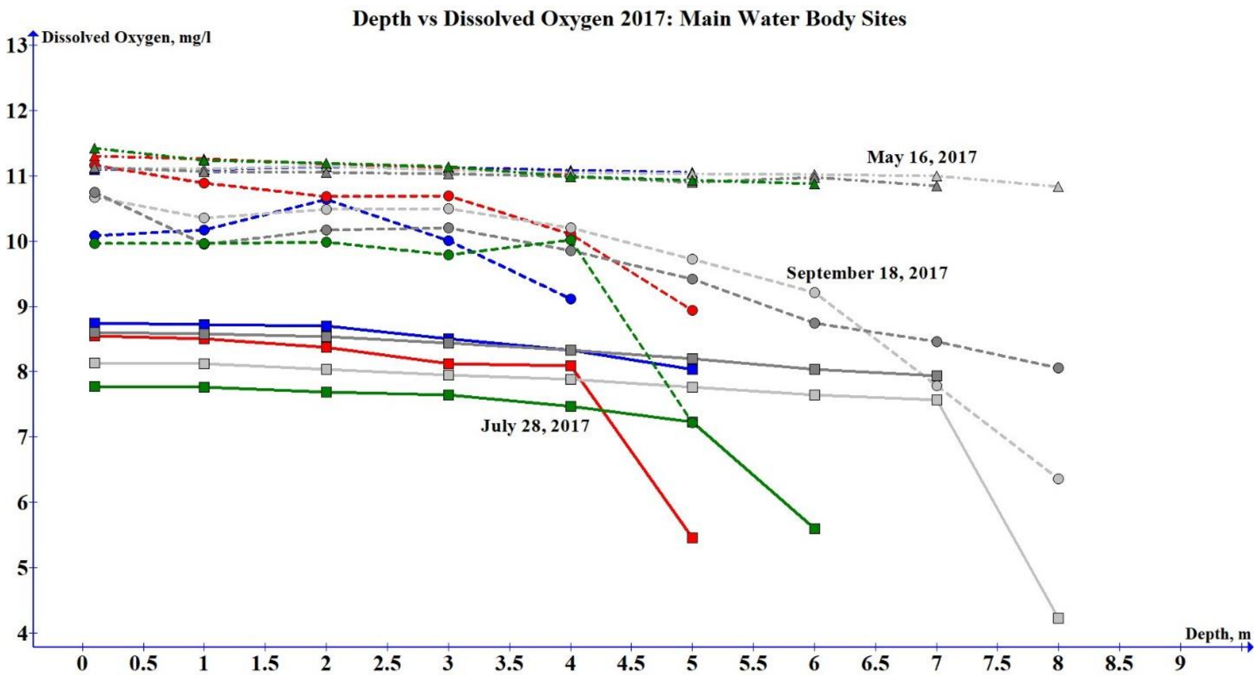
The concentration of oxygen in the water column can seriously effect fish populations and if dissolved oxygen concentrations dip below about 5 mg/L, fish stocks can be severely stressed or even die. Oxygen levels of from 7 to 11 mg/L are very good for most fish and other aquatic organisms.

Oxic conditions are said to exist when there is dissolved oxygen in the water. When there is no oxygen present, anoxic conditions are said to exist. Clearly, where oxygen levels are too low, fish populations can be threatened. Another important consequence of anoxic conditions, especially at the water-sediment interface, is the chemical release of phosphorus back into the water column. Sediments contain phosphorus concentrations hundreds of thousands of times greater than phosphorus concentrations in the water just above it. Phosphorus released from the sediment back into the water column (see 'Phosphorus' section of this report) can promote the occurrence of algal blooms. This effect is called phosphorus back-loading.

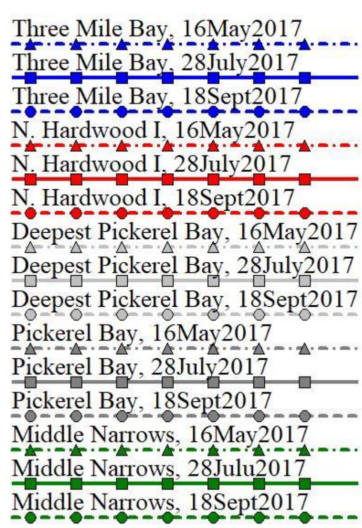
Oxygen concentrations levels as a function of depth have been measured in White Lake for three consecutive years. The results obtained for the first two years are similar. In 2015, dissolved oxygen profiles were measured in May, July and September and in 2016 measurements were made in June, July and August. For both of these years, little variation in dissolved oxygen concentrations with depth were observed during the May/June and August/September sampling dates. For July in both 2015 and 2016, there was a marked decrease in dissolved oxygen concentrations with depth starting at a depth of about 3m. At no times were dissolved oxygen concentrations low enough to affect the survival of fish.

Measurements were made with a YSI multi-parameter probe. The sensors located on this probe are quite sensitive and can easily be damaged. For this reason, the probe is never lowered below about 1 metre from the bottom of the lake. Physical damage can occur by the probe hitting the bottom of the lake as a result of wave action (boat rising and falling with swells). The oxygen sensor itself is subject to fouling by sediment components giving inaccurate results. For these reasons, we do not actually have accurate dissolved oxygen concentrations at the actual water-sediment interface making it difficult to assess whether oxic or anoxic conditions actually exist there.

The two figures below give dissolved oxygen profiles for 2017. For the sake of clarity, data was divided into two sets: one for the sampling sites in the Main Water Body (Zone 1); and one for the remaining sites which are quite shallow.

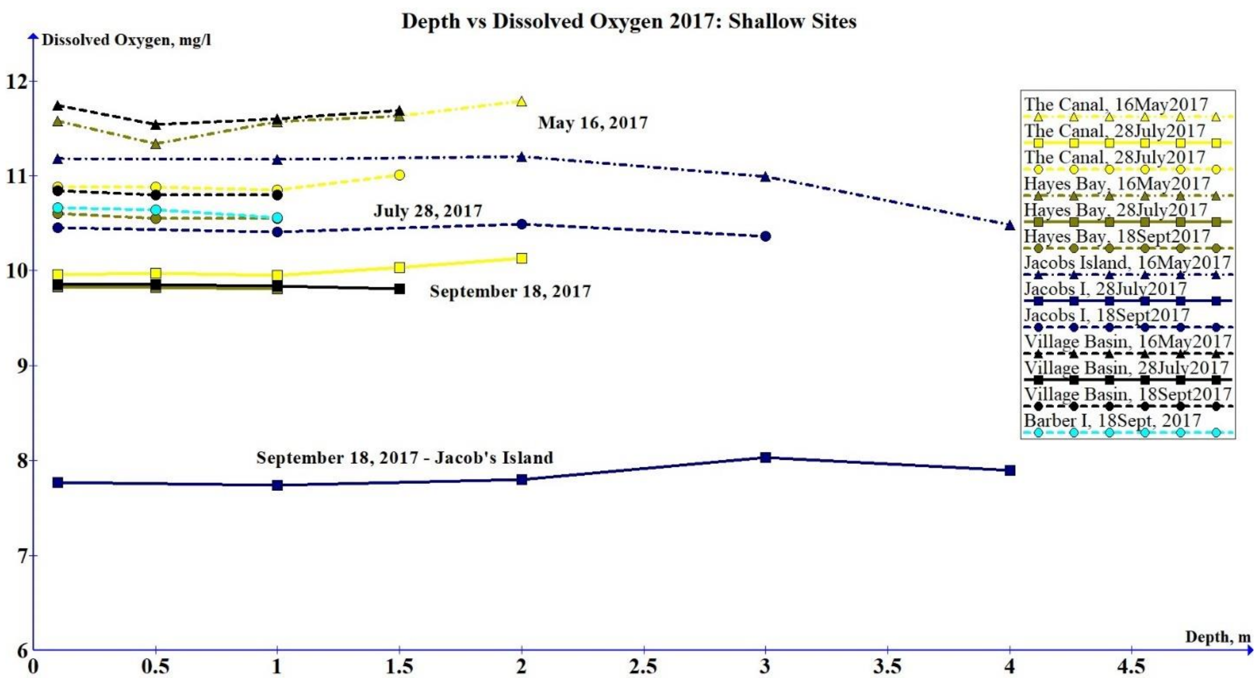


Legend for Dissolved Oxygen vs Depth – Zone 1, 2017



These results show that for the May 16, 2017 sampling date, dissolved oxygen concentrations were high and virtually constant from the top to the bottom of the water column. For both the July 28, 2017 and September 18, 2017 sampling dates, dissolved oxygen levels at the surface decreased with day of year when compared to levels obtained in May. Also, as was observed in both 2015 and 2016, oxygen levels began to decrease starting at a depth of about 3 metres. This is in contrast to previous years when a significant decrease in oxygen levels with depth was only observed in July.

Dissolved oxygen concentrations for the Jacob's Island site (Zone 4) and the remaining sites (all other zones) are shown below.



For all three sampling dates, the dissolved oxygen concentration did not change appreciably with depth. Concentration levels were also higher than for the Zone 1 sites with the exception of Jacob's Island (lowest line on graph) which had levels comparable to the Zone 1 sites. Generally, the concentration of oxygen was lower for the deeper sites than for the much shallower sites such as The Canal, Hayes Bay and the Village Basin where concentrations were uniformly higher. This may be due to the fact that at the shallow sites, there are no aquatic plants on the lake bed and that the effect of wind and wave would be more pronounced than for deeper sites where oxygen could only reach depths greater than about 3 metres by diffusion and convection. Wind and wave action at shallower sites would ensure that oxygen was uniformly distributed throughout the water column.

The changes that we observed in dissolved oxygen water levels from month to month and year to year can be attributed to changes in weather and also climate change. There are so many factors which influence the amount of oxygen dissolved in lake waters that it would be very difficult to attribute any changes to a specific parameter such as air temperature or rainfall. In general, dissolved oxygen levels in White Lake were good for maintaining a healthy aquatic environment.

Oxygen levels reported in this study were measured in areas of open water and not along the shoreline. Shoreline dissolved oxygen levels can be quite different than in areas located closer to the middle of the lake. This is because waters near the shoreline can be warmer than bulk water temperatures and are also more susceptible to the effects of wind and waves.

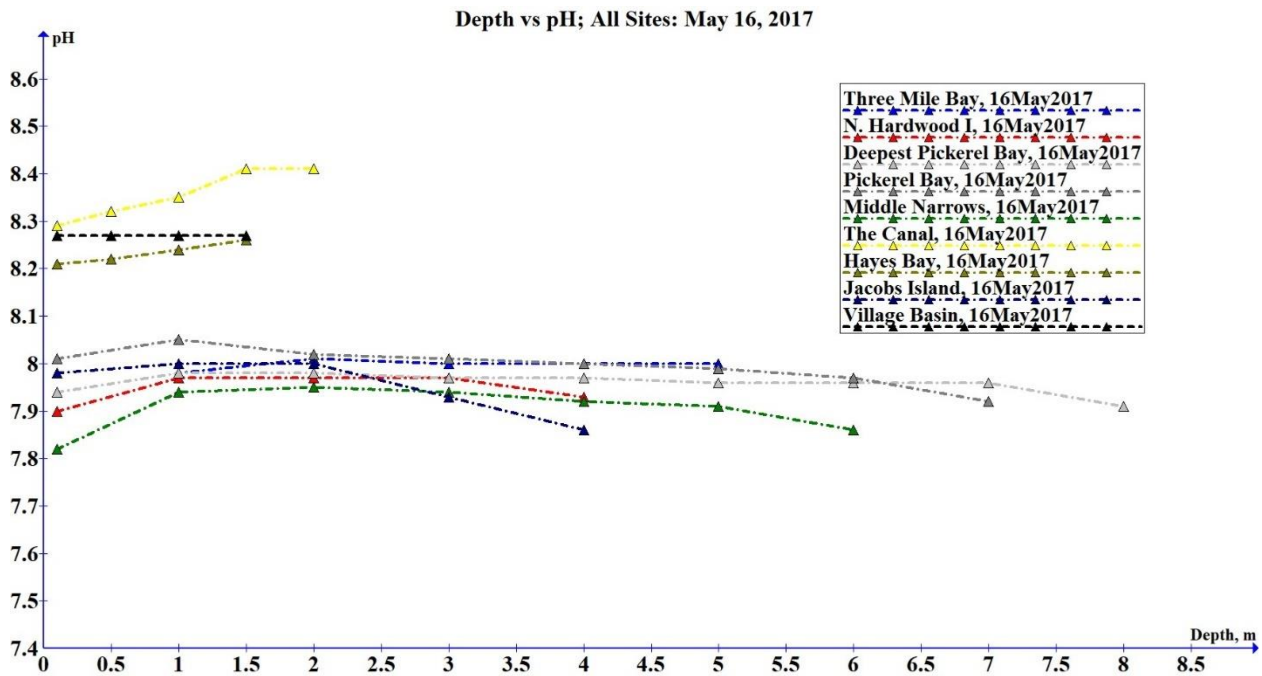
The presence of excessive quantities of algae along shore areas can also have a significant effect, especially at night when these aquatic plants consume oxygen rather than produce it. Local anoxic conditions can result, causing such events as water snail kills due to asphyxiation.

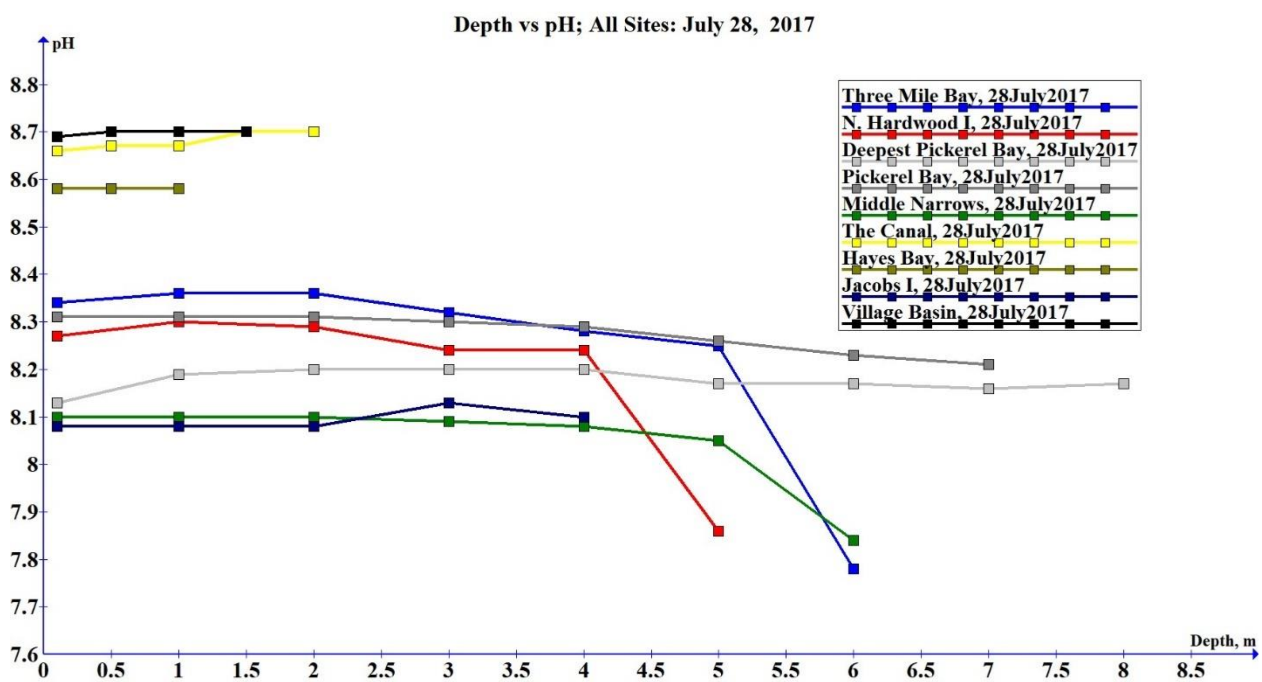
Watersheds Canada and Water Rangers Hard at Work!

Coming in for a Landing

15.0 pH

pH is a measure of the concentration of hydrogen ion in lake water and indicates the intensity of the acidic (pH<7) or basic characteristic (pH>7) of the system as a whole. The pH of lake water is controlled by dissolved chemical compounds in the water and some biochemical processes such as photosynthesis and respiration. In lake waters like those of White Lake, the pH is mainly controlled by the balance between carbon dioxide, carbonate and bicarbonate ions. Because the pH is dependent on the concentration of carbon dioxide, it is therefore linked to lake productivity.





The figures above give pH values as a function of depth for two sampling dates: May 16, 2017 and July 28, 2017. Data for the August 18 sampling data was not obtained due to an instrument malfunction.

A cursory examination of the data in these figures show that the pH of the shallow sites on White Lake was considerably higher than for the deeper sites all located in Zone 1. Secondly, the pH of every site is somewhat different possibly reflecting slightly different environmental conditions at each and every location. The pH at any given location also increased as the summer progressed.

For the May 16 sampling, the pH did vary with depth generally increasingly slightly during the first metre and then decreased slightly with depth. The greatest change was for The Canal site which was approximately 2 metres in depth. The increase in pH with depth could be caused by the flow of higher pH water from under the floor of the lake after passing through calcium-rich sand. The lake floor at The Canal is composed predominately of white marl which indicate an overabundance of calcium carbonate in the water column. Because of this, higher pH values are expected as well as increased sequestration (co-precipitation) of phosphorus.

More dramatic changes in pH with depth were recorded during the July sampling. Three sites in particular showed a decrease in pH at depths greater than 4 metres. These sites were Three Mile Bay, North Hardwood Island and Middle Narrows. The lower pH measurements obtained for these three sites were taken close to the floor of the lake. The increased clarity of the lake (more sunlight reaching the floor) due to the presence of zebra mussels may have resulted in higher biological activity which results in the excretion of acid to the water column. The same decrease in pH was not as pronounced as for the two deepest sites on the lake (Pickerel Bay sites). The depth of these sites may have reduced the total quantity of light reaching the lake floor resulting in less biological activity when compared to the other three shallower sites discussed above.

Below are tables containing averaged pH data for 2015 through to 2017. On the surface, 2017 and 2015 data agree in terms of trends with pH increasing through the summer. For 2016, pH decreased as the summer passed.

It is a challenge to quantitatively explain these results. However, weather may be a factor as well as changes occurring since the infestation of the lake with zebra mussels. In terms of weather, 2016 was a drought year with a total precipitation of only 431 mm of rain whereas in 2015 and 2017, 518 and 990 mm of rain fell, respectively. Almost certainly the amount of sunshine hours and average air and water temperatures would also influence lake water pH.

pH - 2017

Sampling Site	May 16 (day 136)	July 28 (day 209)
Three Mile Bay	7.99 ± .03	8.32 ± .05
N. Hardwood Is.	7.95 ± .03	8.25 ± .04
Deepest Pickerel Bay	7.96 ± .02	8.18 ± .02
Pickerel Bay	8.00 ± .04	8.28 ± .04
Middle Narrows	7.91 ± .05	8.05 ± .09
Jacob's Island	7.95 ± .06	8.09 ± .02
The Canal	8.36 ± .05	8.68 ± .02
Hayes Bay	8.23 ± .02	8.58 ± .00
Village Basin	8.27 ± .00	8.70 ± .01

Results: average ± standard deviation

pH - 2016

Sampling Site	June 14 (day 166)	July 12 (day 194)	August 17 (day 230)
Three Mile Bay	7.92 ± .14	7.54 ± 1.6	7.04 ± .12
N. Hardwood Is.	8.10 ± .03	8.06 ± .08	7.15 ± .09
Pickerel Bay	8.14 ± .04	8.07 ± .11	7.24 ± .12
Middle Narrows	8.02 ± .05	8.05 ± .07	7.25 ± .09
Jacob's Island	8.10 ± .06	8.09 ± .15	7.38 ± .14
The Canal	8.34 ± .03	8.26 ± .03	7.43 ± .03
Hayes Bay	8.23 ± .01	8.28 ± .13	7.55 ± .08
Village Basin	8.22 ± .03	8.41 ± .02	7.56 ± .06

Results: average ± standard deviation

Observations 2016: The shallow sites (last three in table) show anomalous (high) pH values when compared to those measured for the remaining deeper sites with the exception of Three Mile Bay which was slightly more acidic for each of the three sampling dates. The pH of the lake generally decreased (more acidic) with time over the summer.

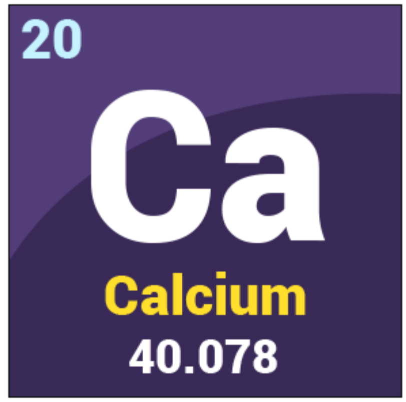
pH - 2015

Sampling Site	May 14 (day 134)	July 16 (day 197)	September 15 (day 258)
Three Mile Bay	7.67 ± .17	8.01 ± .08	8.15 ± .03
N. Hardwood Is.	7.65 ± .15	8.01 ± .04	8.18 ± .02
Pickerel Bay	7.72 ± .13	8.03 ± .10	8.18 ± .03
Middle Narrows	7.42 ± .02	8.04 ± .09	8.28 ± .03
Jacob's Island	7.78 ± .03	8.06 ± .17	8.19 ± .03
The Canal	8.02 ± .03	8.27 ± .04	8.18 ± .07

Results: average ± standard deviation

Observations 2015: The pH of White Lake increased with time over the summer. The Canal site (a shallow site) gave anomalously high (compared to the rest of the lake) pH values for the May and July sampling dates.

16.0 <u>Calcium</u>



The table below contains values for calcium concentrations measure in White Lake for 2017. The average value for the calcium concentrations measured on each of the three dates for 2017 were the same, within experimental error. The average of all values for 2017 was 29.0 µg/ml or ppm. The average value for 2016 was 33.2 ppm and for 2015, 35.3 ppm. Using historical values for calcium obtained by the Lake Partners Program from 2008 to 2012, we calculate an average value of 32.5 ppm. It is possible that the different calcium concentrations measured over the years and during the past two field seasons are natural difference caused by the relative inputs of various water sources entering White Lake.

The graph following the tables is a correlation plot of average calcium concentrations measured monthly from 2015 to 2017 plotted against monthly rainfall. A linear regression analysis of these data indicates that the calcium concentration in White Lake waters is dependent on the amount of rainfall entering the lake. The correlation coefficient (R^2) obtained was 0.783 which is relatively high indicating that the relation between the two parameters is significant.

Calcium (ppm) – 2017

Sampling Site	May 16 (day 136)	June 14 (day 165)	July 15 (day 196)
Three Mile Bay	28.4	30.0	-
N. Hardwood I.	28.5	29.9	28.6
Middle Narrows	28.4	29.4	-
Jacob's Island	27.7	29.4	27.5
The Canal	29.4	30.8	32.5
Hayes Bay	31.0	36.4	-
Village Basin	27.3	29.4	27.2
Average Values:	28.3 ± .74*	29.8 ± .55*	29.0 ± 2.5*

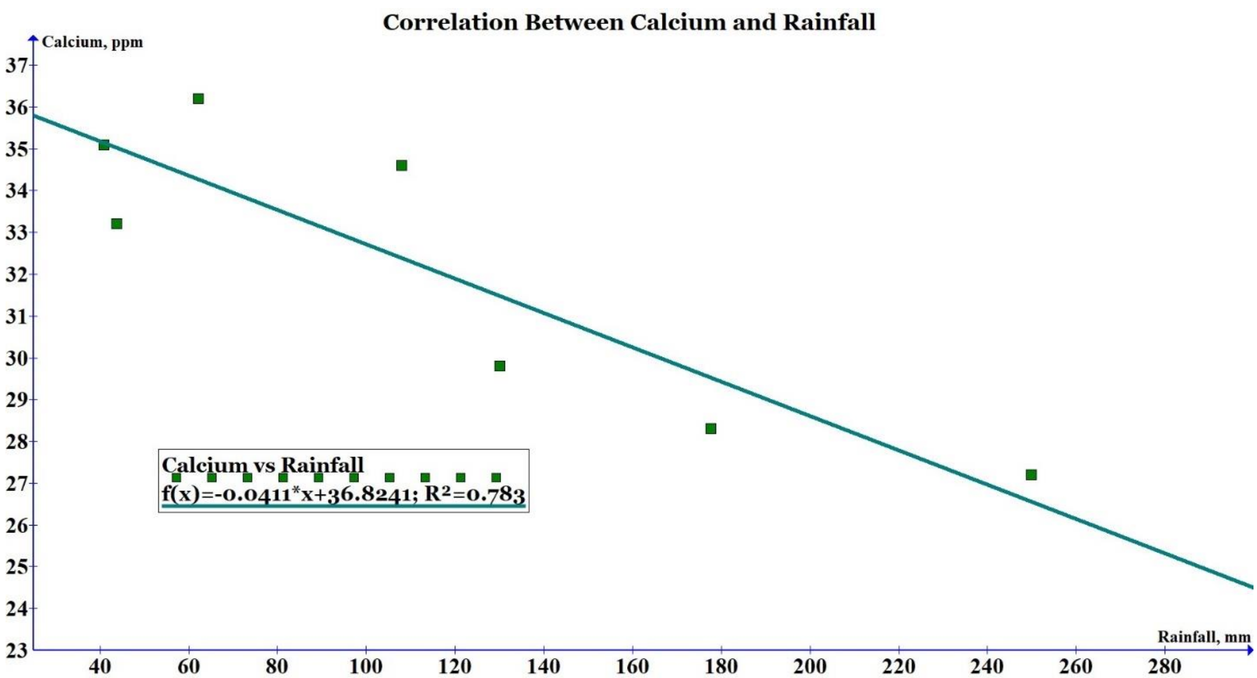
* Hayes Bay Results excluded

Calcium (ppm) - 2016

Sampling Site	May 17 (day 138)	June 14 (day 166)	July 12 (day 194)
Three Mile Bay	36.4	-	-
N. Hardwood Island	31.8	-	-
Middle Narrows	31.1	-	-
Jacob's Island	31.4	-	-
The Canal	34.3	-	-
Hayes Bay	36.6	-	-
Village Basin	31.0	-	-
Average Values:	33.2 ± 2.5		

Calcium (ppm) - 2015

Sampling Site	May 14 (day 134)	June 14 (day 165)	July 16 (day 197)
Three Mile Bay	36.2	37.3	36.7
N. Hardwood Island	37.3	37.2	36.7
Middle Narrows	35.3	33.2	35.8
Jacob's Island	36.2	33.3	35.2
The Canal	35.8	32.2	31.1
Average Values:	36.2 ± .7	34.6 ± 2.4	35.1 ± 2.3



The Y-axis intercept of 36.8 ppm is the concentration of calcium in waters entering White Lake when there is no rainfall whatsoever. This likely is the calcium concentration of waters entering the lake from groundwater ingress or springs. We can therefore expect moderate changes in calcium concentrations from year to year depending on the weather.

Taking into account the average calcium concentration from all of the values given in the tables above (32.3 ± 3.2) and comparing that with the intercept value given above (36.8 ppm), it is possible to calculate that approximately 88% of the water entering White Lake is derived from ground water sources (including some streams) with the remainder coming from rain and surface runoff.

17.0 Chloride

Chloride data for 2015, 2016 and 2017 are given in the tables below. The data collected in 2015 shows that a concentration of about 3.5 ppm chloride was found at all sampling sites with the exception of The Canal, where chloride values were slightly elevated. The 2016 data shows the same pattern with the new sampling site of Hayes Bay giving a chloride concentration of 10 ppm (not sampled in 2015), which was about three times the concentration measured at all other sites on the lake with the exception of The Canal, which gave a value of 5.35 ppm. For 2017, comparable results were obtained. For all of the sites (except The Canal and Hayes Bay) the average values for all three years were the same within error.

In the 'Specific Conductance' section of this report, the Hayes Bay site gave anomalously high specific conductance values for all three sampling dates which spanned the summer months. This indicates that the high conductance value was due to the presence of higher concentrations of sodium chloride, especially since Ca values are only slightly elevated when compared to Ca concentrations at other sites.

The source of the additional chloride is not likely to be from road salt since if this were the case, values for conductance would decline over the course of the summer months. Therefore, chloride is more likely to originate from subterranean brines reaching this part of the lake through the sediment layer. The elevated values for chloride found at The Canal are likely due to the mixing of waters from Hayes bay with those of The Canal or its own weaker (Cl) source of subterranean brine. This is the only part of the lake where this phenomenon has been observed.

In order to completely account for the much higher specific conductance values obtained for Hayes and Bane Bays, it would be necessary to have a complete analysis of waters for all of the major cations and anions in solution. These would include calcium, magnesium, sodium, potassium, chloride, H^+, and bicarbonate

Chloride (ppm) – 2017

Sampling Site	May 16 (day 136)	June 14 (day 165)	July 15 (day 196)
Three Mile Bay	2.8	3.4	-
N. Hardwood Island	3.1	3.5	2.8
Middle Narrows	3.3	3.3	-
Jacob's Island	3.7	3.3	3.2
The Canal	6.2	5.6	7.5
Hayes Bay	9.5	10.2	-
Village Basin	3.8	4.0	3.3
Average Values*:	3.34 ± .42	3.50 ± .29	3.10 ± .27

*excluding The Canal and Hayes Bay

Chloride (ppm) – 2016

Sampling Site	May 17 (day 138)	June 14 (day 166)	July 12 (day 194)
Three Mile Bay	3.4	3.5	3.7
N. Hardwood Island	3.4	3.5	3.6
Middle Narrows	3.5	3.8	3.7
Jacob's Island	3.7	4.1	3.8
The Canal	5.4	5.5	5.1
Hayes Bay	10.0	10.1	10.3
Village Basin	3.7	4.4	4.6
Average Values*:	3.53 ± .16	3.86 ± .39	3.88 ± .41

*excluding The Canal and Hayes Bay

Chloride (ppm) – 2015

Sampling Site	May 14 (day 134)	June 14 (day 165)	July 16 (day 197)
Three Mile Bay	3.49	3.42	3.30
N. Hardwood Island	3.34	3.41	3.14
Middle Narrows	3.48	3.51	3.44
Jacob's Island	3.43	3.58	3.38
The Canal	3.93	3.87	4.20
Average Values*:	3.44 ± .07	3.48 ± .08	3.32 ± .13

*excluding The Canal

18.0 Dissolved Organic Carbon (DOC)

Dissolved organic carbon (DOC) is a generic term for all organic materials dissolved in waters. Dissolved organic matter can be found in both surface waters and ground waters. Once organic matter begins to decompose, a large number of high molecular weight water-soluble compounds are formed. These compounds are sometimes referred to as humic and fulvic acids. These compounds are natural and pose no danger to human or aquatic life. When these compounds occur in sufficiently high concentrations, water takes on a tea-colour. Other substances also contribute to the concentration of DOC. These include low molecular weight acids, low-weight substances (which pass through a 0.45 µ filter) and polysaccharides. Polysaccharides are released when phytoplankton are decaying and are one of the substances responsible for the 'foaming' we see every year on White Lake in late fall. Large quantities of foam can sometimes be seen on some shorelines on windy days.

Dissolved organic carbon is an important complex of substances that affects many physical, chemical and biological processes in aquatic environments. For example, DOC binds many metals and nutrients, affects water transparency and thermal stratification, affects pH and alkalinity and is a substrate for microbial production. Most importantly, it attenuates the penetration of harmful ultraviolet radiation into the water column. Interestingly, it is also known that zebra mussel veligers (larvae) readily ingest DOS as a source of food.

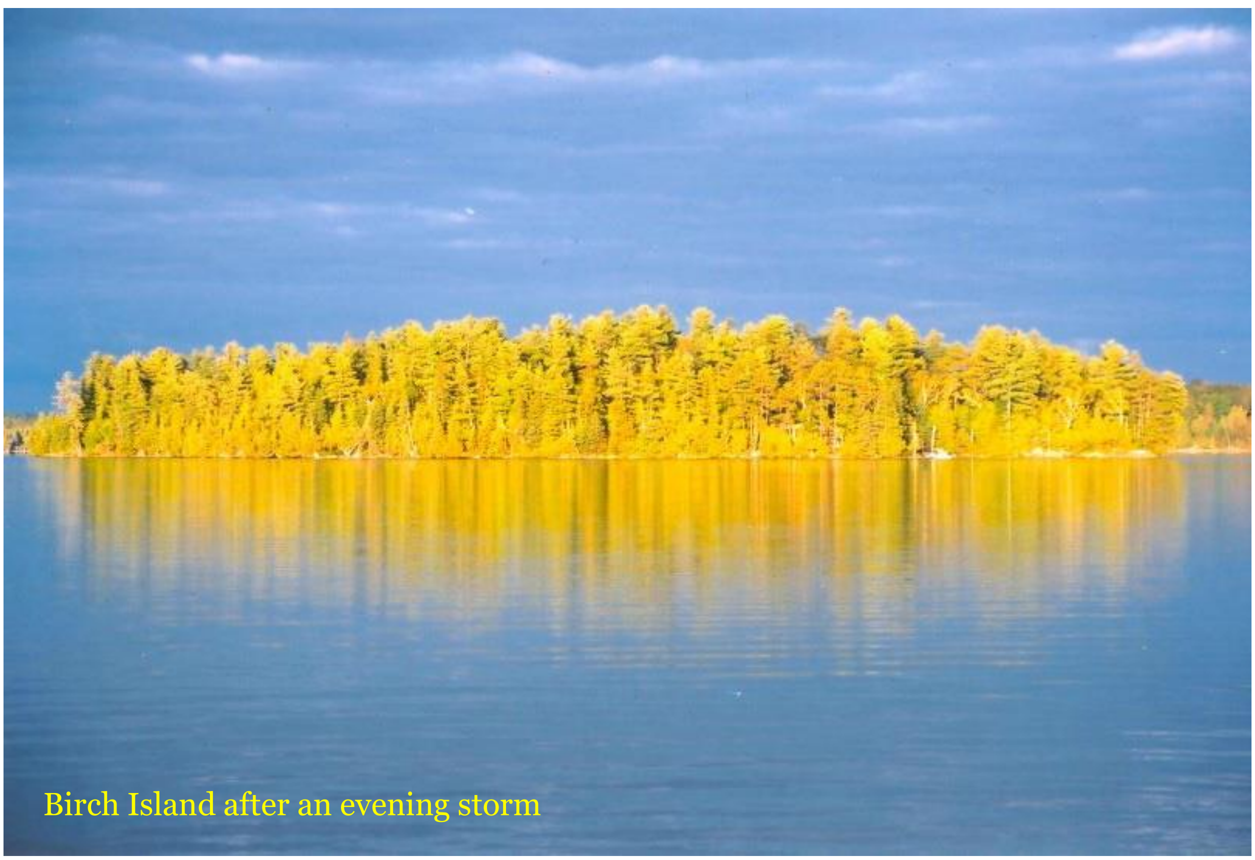
The literature suggests that lakes with an average DOC of 30 ppm and with values greater than 30 ppm are classed as dystrophic (tea-colored). These lakes are dark brown and have a very low pH. At the other end of the trophic scale, lakes with an average DOC of 2 ppm with a range of concentrations from 1 to 3 ppm are considered oligotrophic. Mesotrophic lakes have an average DOC of 3 ppm with a range of concentrations from 2 to 4 ppm. Finally, eutrophic lakes have an average DOC of 10 ppm with a range of concentrations of from 3 to 34 ppm. In some lakes there are substantial amounts of internally generated dissolved organic carbon compounds which are colorless, which can make the use of DOC as a measure of dystrophy difficult.

The DOC concentrations found in White Lake fall between the mesotrophic and eutrophic classifications. Waters from The Canal and especially Hayes Bay are very close to eutrophic in status. The much higher DOC values for Hayes Bay may be the result of the higher residence time of water in this area, the very shallow water levels (1.5 m) and the abundance of decaying organic material in the sediment layer. White Lake (DOC ~ 5 mg/L) is at or below the threshold that would indicate dystrophy.

DOC (ppm) – 2017

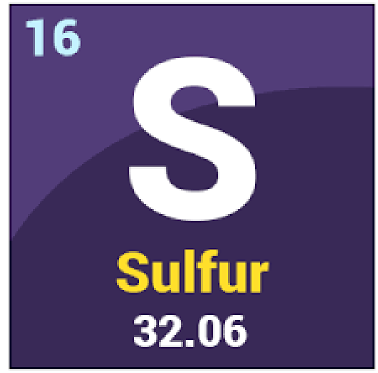
Sampling Site	May 16 (day 136)	June 14 (day 165)	July 15 (day 196)
Three Mile Bay	5.2	5.3	-
N. Hardwood Island	5.0	5.0	4.6
Middle Narrows	5.2	4.8	-
Jacob's Island	5.1	4.7	4.9
The Canal	5.4	5.8	6.4
Hayes Bay	6.8	8.0	-
Village Basin	5.5	5.0	5.3
Average Values*:	5.20 ± .19	4.96 ± .23	4.93 ± .35

*excluding The Canal and Hayes Bay



Birch Island after an evening storm

19.0 Sulphate



Sulphur is a non-metallic element. The three most important sources of sulphur for commercial use are elemental sulphur, hydrogen sulphide (H_2S, found in natural gas and crude oil) and metal sulphides such as iron pyrites. Hexavalent sulphur combines with oxygen to form the divalent sulphate ion (SO_4^{2-}). Sulphates occur naturally in numerous minerals, including barite ($BaSO_4$), epsomite ($MgSO_4 \cdot 7H_2O$) and gypsum ($CaSO_4 \cdot 2H_2O$). The reversible interconversion of sulphate and sulphide in the natural environment is known as the "sulphur cycle." Sulphate enters the lake by a variety of ways including dust in the atmosphere, minerals in the local rocks and from human activity.

Sodium, potassium and magnesium sulphates are all soluble in water, whereas calcium and barium sulphates and the heavy metal sulphates are not. Dissolved sulphate may be reduced to sulphide, volatilized to the air as hydrogen sulphide, precipitated as an insoluble salt or incorporated in living organisms.

Sulphate levels in Canadian lakes typically range from 3 to 30 mg/L. Recent data from Ontario show similar levels in small lakes (12.7 ± 11.3 µg/ml); sulphate concentrations were 7.6 µg/ml in Lake Superior at Thunder Bay and 19 mg/L in Lake Huron at Goderich.

The average daily intake of sulphate from drinking water, air and food is approximately 500 mg, with food being the major source. The objective for sulphate concentrations in drinking water is ≤500 µg/ml, based on taste considerations.

Sulphate (µg/ml or ppm) - 2017

Sampling Site	**May 16 (day 136)**	**June 14 (day 165)**	**July 15 (day 196)**
Three Mile Bay	-	4.8	3.9
N. Hardwood Island	5.0	4.8	4.0
Middle Narrows	4.8	4.6	3.9
Jacob's Island	4.5	4.6	3.8
The Canal	4.2	4.3	3.4
Hayes Bay	4.2	3.9	3.0
Village Basin	4.3	4.3	4.3

The average sulphate concentration in White Lake was 4.5 ± .3 µg/ml in May; 4.6 ± .2 µg/ml in June; and 3.9 ± .3 µg/ml in July. Also, the sulphate concentrations were slightly lower in July than for other months and also lower in The Canal and Hayes Bay sampling sites. The lower concentrations of sulphate later in the year and in two of the shallow sites corresponded to higher calcium concentrations found in the lake at that time and at those locations.

Sulphate concentrations are very low owing to the very high concentration of calcium in the water. Calcium sulphate is very insoluble which means that most of the sulphate entering the lake would precipitate to the lake bottom as solid particles. Sulphate concentrations in White Lake are well below drinking water or even aesthetic concentrations levels and therefore should be of no concern to lake users.

20.0 Zebra Mussels

Zebra mussels are native to Southern Russia and were first documented in 1769. They were believed to have been introduced into the Great Lakes in the late 1980's in ballast water from transoceanic ships carrying veligers (larvae), juvenile or adult mussels. Since then they have spread into the Eastern US and up into Canada through interconnected waterways and by hitchhiking on boat surfaces or in engine cooling systems. Note that they can live up to 7 to 9 days out of the water. Adults average 2 to 3 cm in length, but can grow up to 5 cm. Now they have arrived in White Lake! Last fall, the White Lake Preservation Project's Science committee first documented their presence.

Zebra mussels live for about 4 to 5 years. One female can produce 20 to 40 thousand eggs each reproductive cycle which can be repeated 30 to 40 times a year. During the five-year lifetime, a single zebra mussel will produce about five million eggs, and about 50,000 of these will reach adulthood. The offspring of a single mussel can in turn produce a total of half a billion-adult offspring. It's easy to see why we calculate that there may be over a billion of them right now in White Lake. Zebra mussels feed on small organisms called plankton (which includes algae) that drifts in the water. The zebra mussels blanketing the bottom of our lakes filter water as they eat plankton. White Lake is very rich in plankton and provides an ideal feeding ground for zebra mussels. An adult mussel can filter 1 to 1.5 litres of water a day so just imagine how quickly they could filter the water in White Lake if there are a billion in the lake.

During 2017, zebra mussel populations in White Lake continued to increase. As well, the extent of the infestation continued to spread to new sites. In particular, the rocky lake floor saw new populations exploding. The extent of colonization is far from over and during the coming years, it is likely that we will be finding zebra mussels wherever they can establish a foot hold.

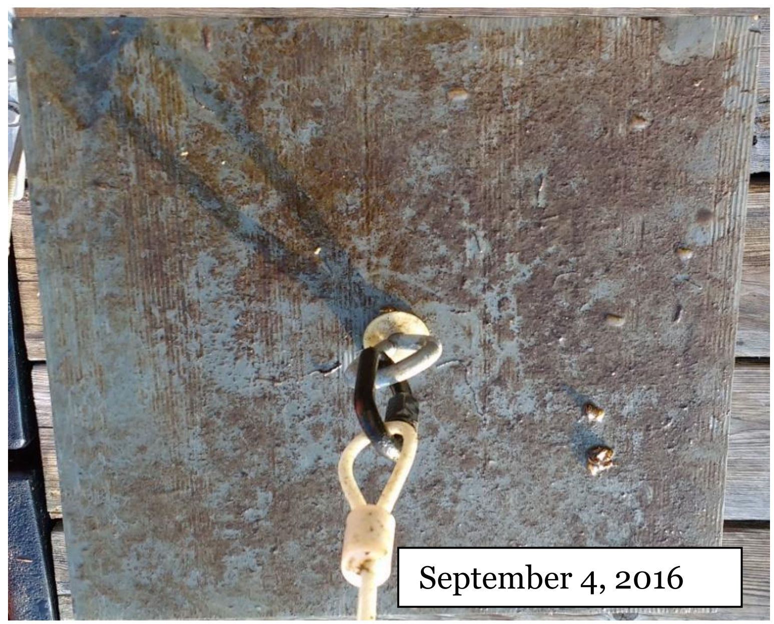
In 2016 we started an experiment to gauge the change in populations of zebra mussels. We made a passive device designed to show how rapidly populations were growing. The device consisted of a 12' x 12' natural slate tile suspended horizontally 1 metre below the surface of a dock. The slate provides a natural rock substrate on which zebra mussels could attach and grow. We stationed several of these at different locations on the lake, but the results and photos shown here are for the station located at 1053 Wabalac Road on the western shore of the lake.

The series of photos below show the growth, over time, of zebra mussels on both the underside and topside surfaces of the slate substrate.


July 12, 2016


August 4, 2016


August 28, 2016


September 4, 2016


July 29, 2017


September 10, 2017


November 4, 2017


November 4, 2017

The slate was installed relatively late in the year on July 12, 2016. However, by the end of the year, some colonization had taken place especially under the slate and also concentrated on one edge of the tile. We have noticed that for rocks on the floor of the lake that zebra mussels prefer the more protected underside of a rock rather than the more exposed (to wind/wave action) surfaces. By July of 2017, mussels attached to the slate had grown considerably in size. By the end of the summer of 2017, it was clear that a second generation of mussels had established themselves on most of the underside of the slate and were now colonizing the upper surface of the slate. A close examination of the zebra mussels show that the most recent generation consider all surfaces fair game and the shell of an existing mussels makes a suitable point for attachment.

Below is a narrative written by one of our Science Committee members reporting on changes occurring in zebra mussel populations in deeper parts of the lake. Jean-Pierre Thonney is a marine and fisheries biologist. He is a snorkeler and scuba diver and thus was able to provide us with this report and attached underwater photos.

20.1 Underwater Observations Around Birch Island on White Lake - *Jean-Pierre Thonney*

Preface: The following text is an anecdotal summary of underwater observations by JP Thonney during a 3-year period around Birch Island on White Lake. These are not quantitative but rather provide a basic comparative description of conditions from the shoreline to ~ 20m from shore (0-5m depth) from snorkeling surveys carried out intermittently between June and Sept of 2015-2017.

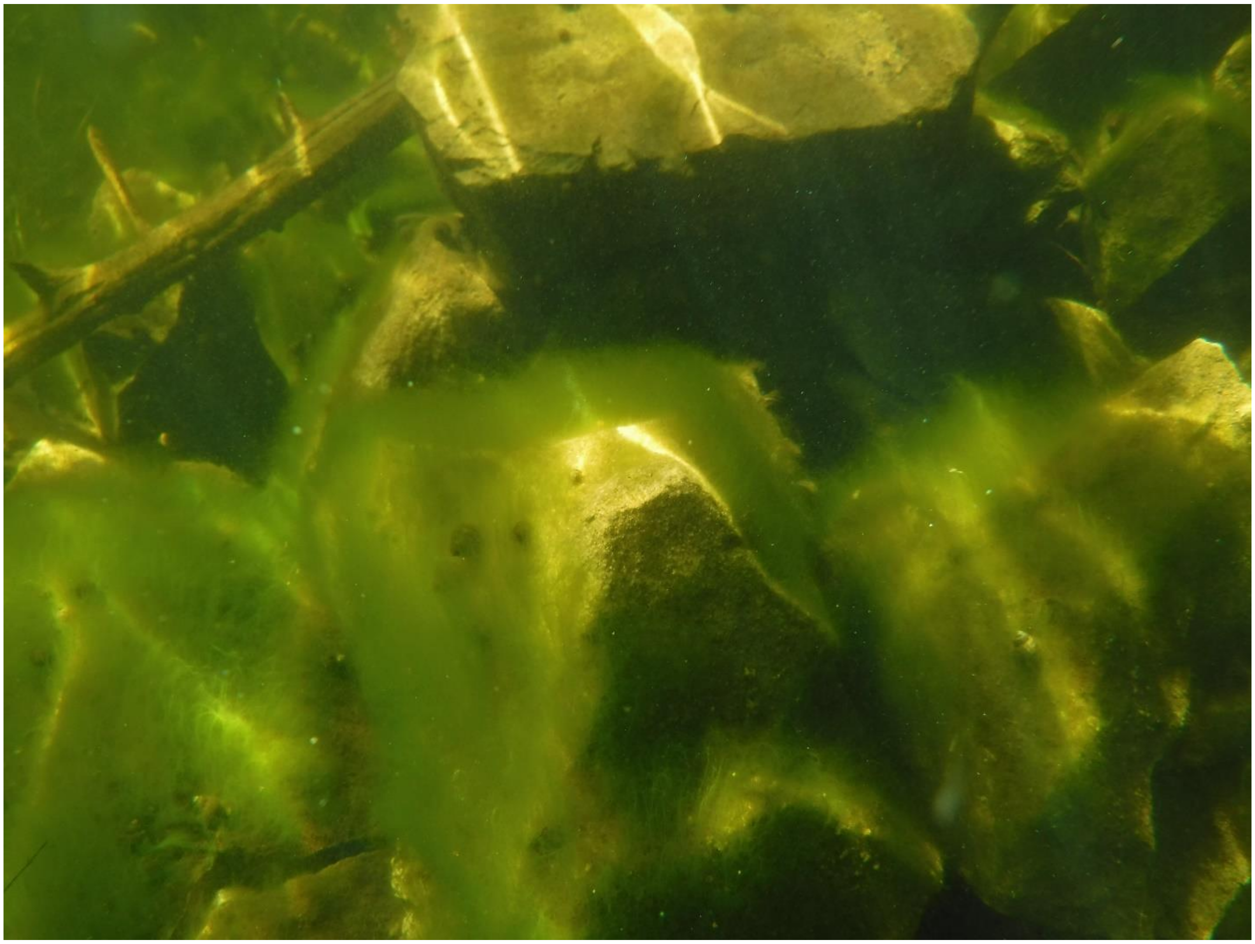
A general description of the survey area reveals a seemingly more exposed and dynamic area at the western and northern side of the island with deeper, rockier and more sloped bottom with barren cobble, boulder substrate predominating. During periods of heavy boat traffic and during periods of high wind and waves, a suspension and/or re-suspension of material (possibly from boat wash hitting exposed shores) occurs along this coast creating more turbidity than on the eastern shoreline. The eastern side of the island is generally shallower and more depositional with a more sedimentary substrate and extensive forests of mixed species macrophyte beds in the sheltered shallow coves. The southern part of the island has both an extended rocky outcrop to the Southeast as well as a depositional environment with moderate macrophyte growth in the sheltered cove in front of the lone cottage on the island.

2015 - As described above there was a preponderance of bare rocky lake bottom from the southwestern tip to the northern end of the island. The photo below depicts typical substrate with little fine sediment. There was scattered macroalgal growth consisting of pondweed and native milfoil with some occasional Eurasian milfoil clusters. There were no zebra mussels observed but Pomacea (Mystery snail) were relatively common. No filamentous or other microalgae colonies were observed.

On the eastern side of the island there was an established extensive mix of macrophytes covering the fine to sandy textured lake bottom. There were 8-9 species of macrophyte identified with some microalgal colonies noted, but no filamentous algae observed on holdfasts.

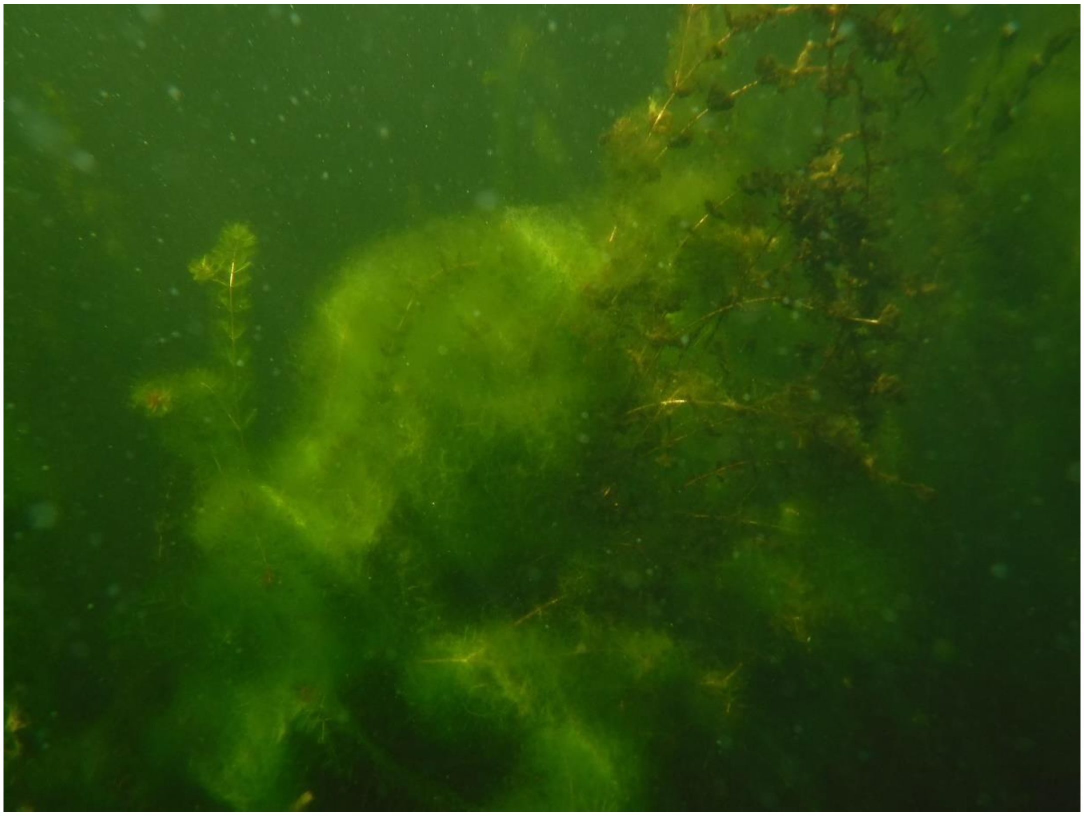
2016 - The first appearance of settled zebra mussels around Birch Island tended to be mostly on artificial holdfasts such as old tires and other human detritus (usually on the underside) although there were some minor groupings on a few rocky substrates. Along the northwestern part of the island there were fewer mussel groupings seen than around the southern point near the cottage (photo below) but a slight increase of Eurasian milfoil which is now (2016) forming some modest but disparate beds.

This year (2016) also represented the advent of filamentous as well as unconsolidated green algae growth (photo below) on some of the rocky outcrops on the hard bottom southern part of the island including off the rocky point near the cottage on Birch Island.



2017 - There was a dramatic increase from the previous year in mussel density, Eurasian milfoil occurrence, and filamentous algae growth. Mussels have become ubiquitous on hard surfaces and occur in a multi-layered formation blanketing rocky surfaces all along the shallows of the island's shore (photos below). Mussels also occur on other holdfasts such as fallen logs and branches and on the underside of floating docks and other artificial structures. The density is thick enough on some of the hard bottom substrate that there is no exposed natural surface left.

The milfoil has established in areas that were previously mostly barren in the northwest part of the island. There are now significant beds of Eurasian milfoil along that part of the lake floor where it less than 10% coverage of any macrophytes in 2015. Along with this greatly increased occurrence of milfoil there is a major increase in filamentous algae growth on at least 50% these and other species of macrophytes along the western shore of the island. This algal growth is at its greatest coverage at the northern tip of the island where it essentially creates a blanket smothering the beds in that area. It is much less prevalent on the eastern side of the island. The quantity of filamentous algae has basically remained unchanged at the southern end of the island.



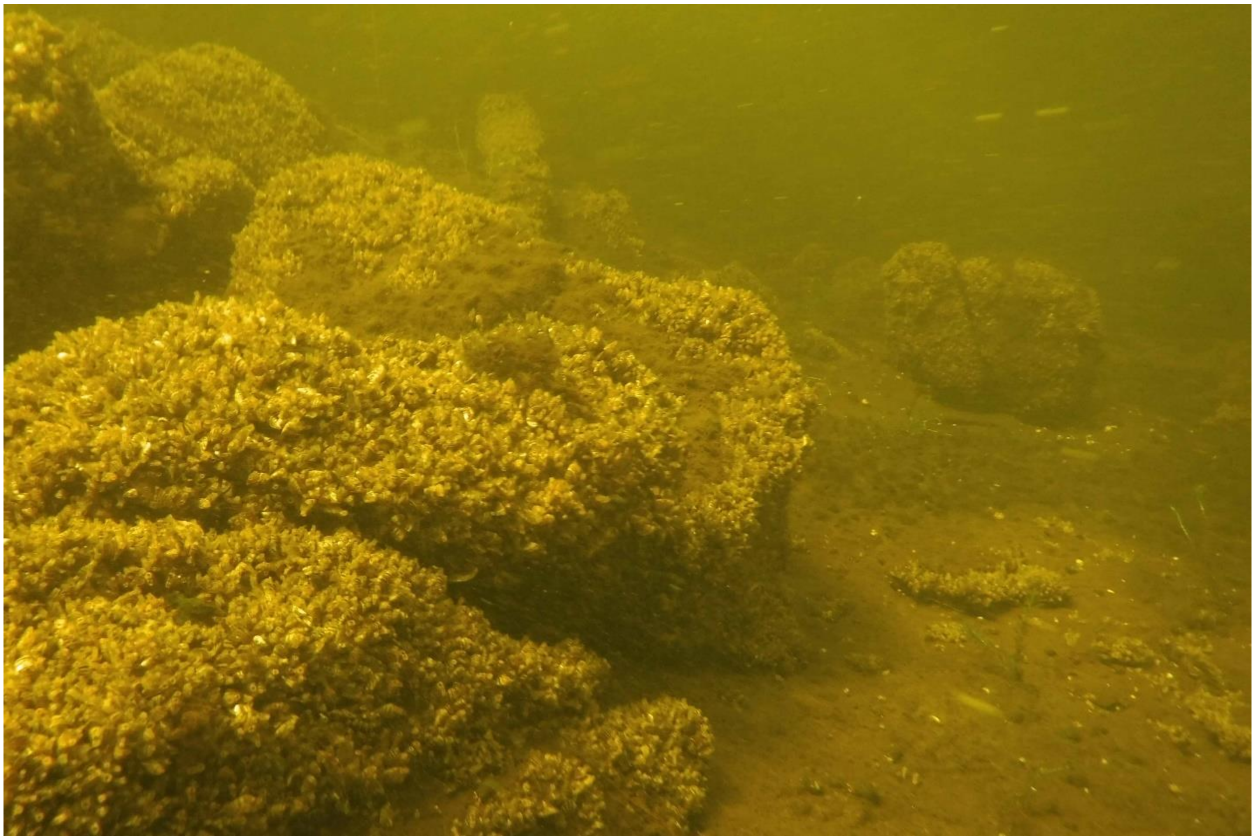
It may be worth noting that, with the exceptionally high water this summer, that there were even more suspended solids in the water than previously noted in 2015-2016 which may be a function of the greater erosional impact on the shoreline from wave action.

[It should be noted that the presence of large quantities of filamentous green algae is a direct consequence of the presence of zebra mussels in the lake. This is because zebra mussels in effect transfer nutrients from the middle of the lake and the entire water column to their locations, mostly in shoreline areas. These nutrients end up in shoreline sediments and in turn promote the growth of a number of species of filamentous green algae. Please refer to the section of this report entitled 'Algal Blooms'.]-DCG

20.2 Underwater Photos of Zebra Mussel Populations – Hardwood Island

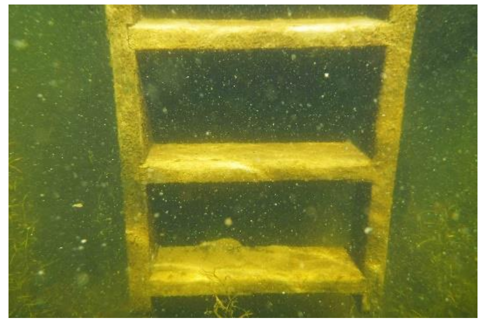
David Overholt

These photos show the density of zebra mussel populations in White Lake as well as the extensive coverage of rocks on the floor of the lake. The final photo is of a fresh water clam (unionid) covered with zebra mussels.



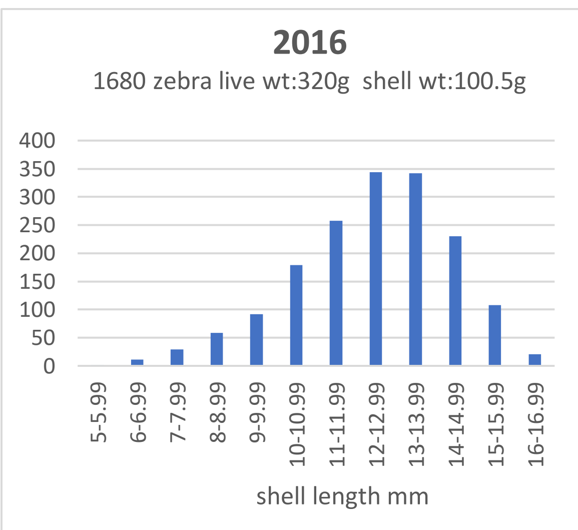
20.3 Zebra Mussel Growth Rates and Size Distribution: 2016-2017

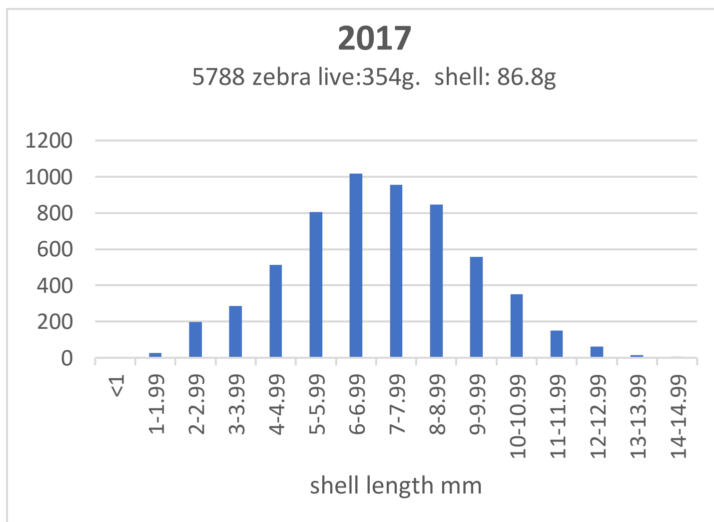
David Overholt



Zebra mussels were harvested from a wooden dock ladder in 2016 and again in 2017. Both samples were retrieved on day 289 (October 10th) of their respective year, and had experienced emersion times of 103 days and 126 days respectively. All zebra mussels present on the under surfaces of the steps were collected and sized. The location of the dock ladder was on the north shore of Three Mile Bay at 1553 Peneshula Dr. The resulting number and size distribution plots are give below.

When compared to the data obtained for 2017, the 2016 results show that there were fewer zebra mussels present, but that they represented larger size classes. A frequency distribution shows a size range of from under 5 to over 17 mm and a mean shell length of 12.4 mm. The 2016 sample was skewed with more individuals present in the larger size classes.





The results for 2017 show a more normal distribution with a size range of from 2 to 15 mm and a mean size of 7.4 mm. This reflects the larger numbers of small size categories under 5 mm. The difference in growth between the two years may indicate that zebra mussels were late in their 2017 breeding season. Water temperature is a key factor in zebra mussel reproduction and 2017 was a relatively cooler year than 2016. Zebra mussels invest more into shell production as they increase in size. This is seen in the 2016 data where almost a third of the overall weight was represented by shell, whereas in 2017 zebra mussels invested ¼ of their weight in shell. In spite of the difference in sample sizes, both years yielded similar total living weights of 320 grams for 2016 and 354.5 grams for 2017.

Studies have shown that growth rates can be estimated from shell length. A 2016 daily growth rate of 0.14 mm/day projected back from the mean value of 12.43 mm may suggest that a major settlement period (when veligers fix onto stable substrate) for zebra mussels occurred around the 88th day previous (day 274 or October 1st). For that date the 2016 record shows a water temperature of 18 °C for Three Mile Bay.
For 2017, the growth rate was calculated to be 0.11mm/day projected back, as before, from a mean size of 7 mm which would be reached after 63 days of growth. This would place the settlement for the mean population at day 226 or august 14th. At that time the water temperature for Three Mile Bay was 23°C. Both of these temperatures bracket the optimum temperature range for zebra mussel growth. The late season occurrence in 2017 also agrees well with our initial observations for late summer water clearing caused by the filtering action of zebra mussels.

Three Mile Bay; July 17 2017

Zebra Mussel Shell Whitening

Zebra mussels taken from weed beds in Three Mile Bay exhibited a distinctive whitening of the shell. In the majority of cases this occurred at the broader hinged apex. This represents a loss of the periostracum which is a thin membrane that covers the zebra mussel and is needed for it to grow new shell. The appearance of whitening is not restricted by mussel size and can be found on juveniles as well. This whitening occurs as a result of zebra mussels forming clusters. Most zebra mussels found on *Najas flexilis,* the common plant cover found in Three Mile Bay exhibit this whitening, yet they do not occur in clusters and instead are evenly dispersed. This may suggest that zebra mussels do form clusters at some point in their lives, but can easily detach and become mobile and move away from their original settlement location.

Zebra Mussel Veligers

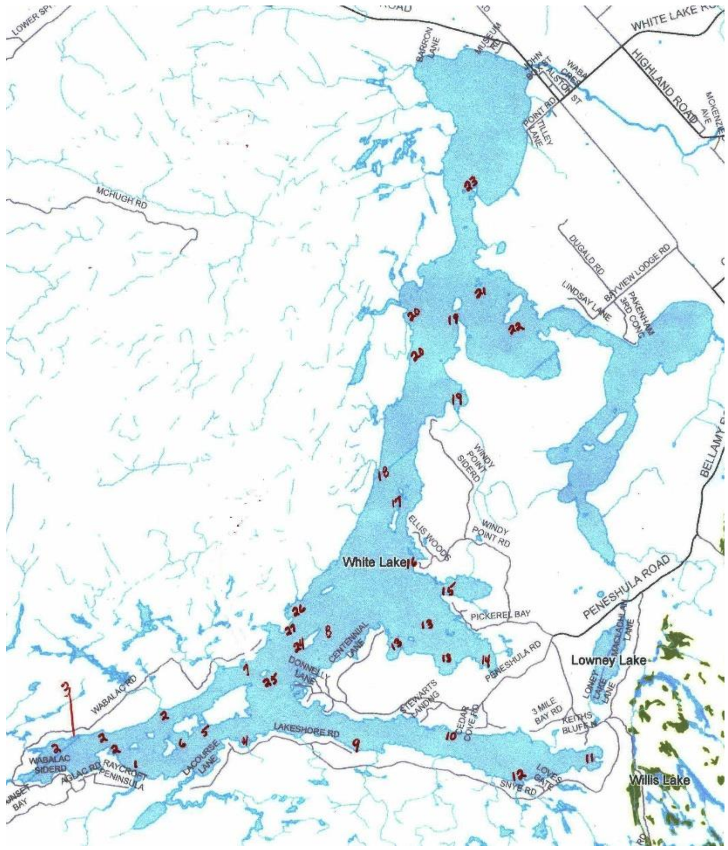
The zebra mussel *veliger* refers to the mobile larval stage of the organism. Their small size (70- 100 µm), and the short duration (2-9 days) of the larval stage, make them difficult to spot. Nevertheless, they do appear in the water column as part of the planktonic community. The image below is a veliger from the surface waters of Three Mile Bay. In this photomicrograph one can just make out the velum fringed with cilia, which it uses for movement and feeding. The velum will soon begin to form a foot at which time the mussel settles out of the water column. It is thought that this is their most vulnerable stage as they become prey to benthic and pelagic feeders.

16 06 2017; Three Mile Bay; 90µm 450x

02 08 2017 What's for lunch?

21.0 Loon Survey and Wildlife Observations

Survey Dates: Saturday, June 24 to July 1, 2017
Joyce Benham and Bob Carrière



This year was an especially wet year with nearly a metre of water falling on White Lake as rain. We were concerned that high water levels could result in nesting failures. This was not the case. All or most of the chicks seen this year were much larger than in previous years and all appeared active and in good health. There appeared to be plenty of food for all water fowl on the lake. Minnows and literally clouds of small fish were easily seen with the increased clarity of the water. For the second year, we have not encountered deer or other large mammals along the shore of the lake.

Observations:

Site 1: Broad Brook shallows always delivers a very co-operative adult couple with two chicks, very tolerant of our presence and very photogenic. This has become our favorite and most predictable area for us to visit. In the past, other couples were seen in the vicinity of the southern part of Hardwood I., but not this year. It is likely that at this location nesting sites may have been affected by high water levels. However, there appeared to be new occupants in the shallows/channel between parts of Harwood Island but we did not dare venturing deeper for fear of grounding our boat.

Site 2: The Northwest shore is always abundant with Blue Herons but some of the rocky outcrops south of Hardwood I. were water-covered which affected the usual traffic of sea gulls and blue herons.

Site 4: The rocks at this location were almost entirely water-covered and no loon activity was noticed.

Site 9: The south shore of Three Mile Bay continues to produce numerous loon couples with chicks, possibly 4 or 5 pairs, seeking refuge from pleasure boats in the many undeveloped bays. Yet, against all odds, we constantly see adults in the main channel dodging speed boats.

Site 10: This site was more flooded than usual and the ospreys from previous years have lost their nesting tree to the weather. Ospreys are definitely still around and seen flying/feeding over the bay, but nesting sites have probably been moved to more protected areas in the interior. Half way up the southeast side of Hardwood Island, the new osprey nest from last year was occupied by adults and two chicks.

Site 11: Once again this site was not occupied by loons. This was disappointing for us as there were always one or two couples present with chicks. Also, conditions were ideal for photography with the late afternoon sun and lack of boating activity.

Site 12: This site was active with 2 adults and 2 chicks of fair size.

Sites 13/14: Pickerel Bay has maintained its large osprey nest with two chicks, although the supporting rocky islands seemed much smaller with the higher water levels. Pairs of loon adults (no chicks) were located in the far reaches of the bay. The rocky alcoves on the south shore of Pickerel Bay were populated with 2 or possibly 3 pairs, some with chicks, but again the high water hiding known rocky areas and dead heads kept us from getting closer.

Site 15: Eggshape bay had a couple of adults with 2 chicks and this year we were able to navigate the bay without grounding the boat on sand bars. There were numerous sightings of Blue Herons on the grassy shoreline.

Site 16: The usual loon couple with 1 chick were seen navigating the rocky shallows between Stanley and Waba Islands. The eagle's nest on Stanley Island was still active but the 2 chicks were already flying from branch to branch. The Southern rocky point of Stanley I., were herons are usually seen fishing, was almost totally submerged.

Site 18: The bay below and east of Deadman's Island was active with the usual Osprey nest where two chicks were seen. A pair of adult loons with one chick was also observed. There were some bald eagles flying in the far back reaches of the same bay. The eagle's nest was once located on the water's edge below the Bay, but now could have been moved to a quieter area inland.

Site 19: Nesting areas on sand were totally flooded with no loons present.

Sites 20, 21, 22: Despite heavy boat traffic, two adults with two chicks were seen north of Richardson's Island. Another couple with two chicks were also seen behind Russell's Island. Reid's Island hosted 2 sets of adults with one fairly large chick each.

Across from the main channel at Site 20, near the opening to Fish Creek, there were at least one nesting pair with two chicks and numerous other fishing bachelors seen on various occasions. We boated past the almost submerged rocks at Ryan's point and the familiar osprey nest which was gone last year has not been rebuilt

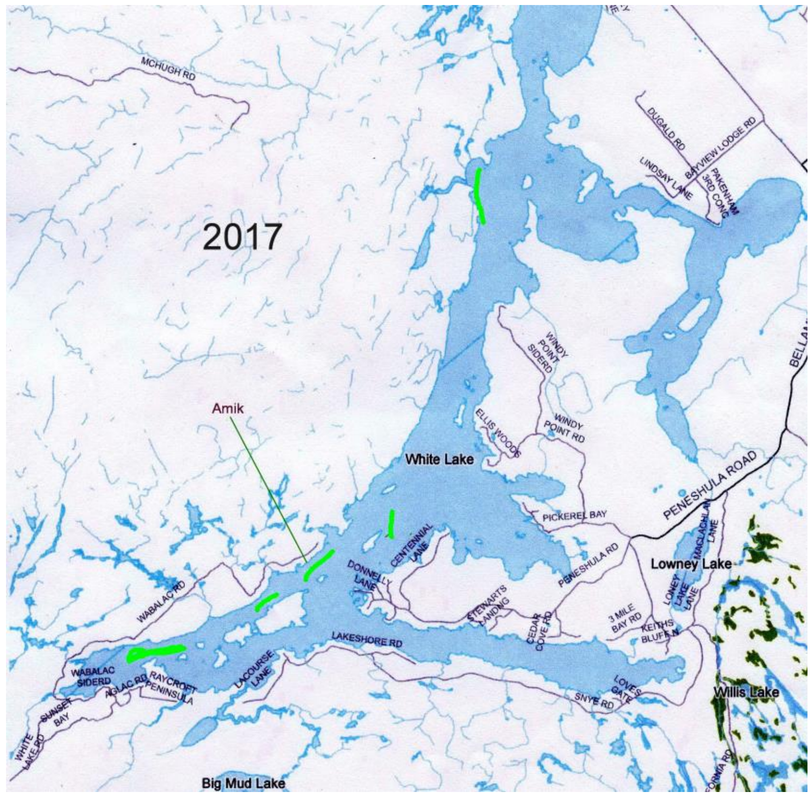
Site 24: Birch Island had an active Osprey nest as in previous years but the chicks had already fledged when we arrived.

Site 25: This co-operative fishing area was still active late in the evening attracting 5 to 6 adult loons.

Site 26: This site had two pairs of adults with one chick each.

Site 27: Unlike previous years, no loons were observed at this site and adjoining marsh.

Cooperative Fishing:



The map to the right shows areas along the shoreline where loons have been observed doing cooperative fishing.

The green highlighted areas are locations where we have seen adult loons gather late in the evening for what appears to be a co-operative line fishing and feeding.

The loons appear to swim in a line formation until one sees prey after which they collectively dive, resurface and repeat the same process. At other times one or two loons will literally fly on the surface of the water beating their wings loudly in the water for 100 metres or so. They then swim around and resume their fishing. We always considered these adults as bachelors without mates but witnessed otherwise this summer. The areas of collective fishing are all located in what we would call deep channels, while at the same locations, we have never seen local nesting couples.

SURVEY RESULTS:

During the 2017 observation period, we counted 45 adult loons on White Lake, producing 19 mating pairs with 21 offspring.

22.0 Algal Blooms – 2017

The summer was only starting, but already we had received quite a few enquiries from cottagers about patches or blobs of algae either on the floor of the lake or free-floating and drifting with the wind. Sometimes, a large mat of algae ended up on the shoreline.

We could attribute this lake-wide bloom to the unusually wet spring and early summer weather we experienced. Alternatively, this algal bloom could be one of the predicted consequences of having zebra mussels in White Lake. This is very likely the case.

The WLPP has had a close look at many of these algal masses and have found through microscopic examination that they were all green filamentous algae. These algae are all naturally occurring and are harmless in the sense that they do not produce dangerous toxins. At worst, they are a nuisance especially when they concentrate on your shoreline and begin to rot. Some cultures harvest this stuff and eat it as a green vegetable added to soup and other dishes. The WLPP does not recommend this!

Time will tell if this is an isolated occurrence or if these algal blooms return each year. Very little can be done about these blooms. However, there are some actions we can take to ensure that these blooms are minimized. This can be done primarily by reducing our impact on the lake. In particular, maintaining a healthy shoreline, respecting setbacks for building projects, maintaining septic systems and reducing boat wakes and other disturbances to the shoreline and near-shoreline sediments. All of these actions will reduce the amount of nutrients entering the lake at the very locations where zebra mussels are active.

If you want to know more, have a look at the photos below which correspond to the three most common filamentous algae we have seen in White Lake. You could also have a look at the algae identification guide we have posted on our website: (http:wlpp.ca/wlppwebsite_018.htm) and especially the guide prepared by the Kawartha Lakes Association which is also available for download at this address: http://wlpp.ca/linked/kawartha_algae_book_web.pdf.

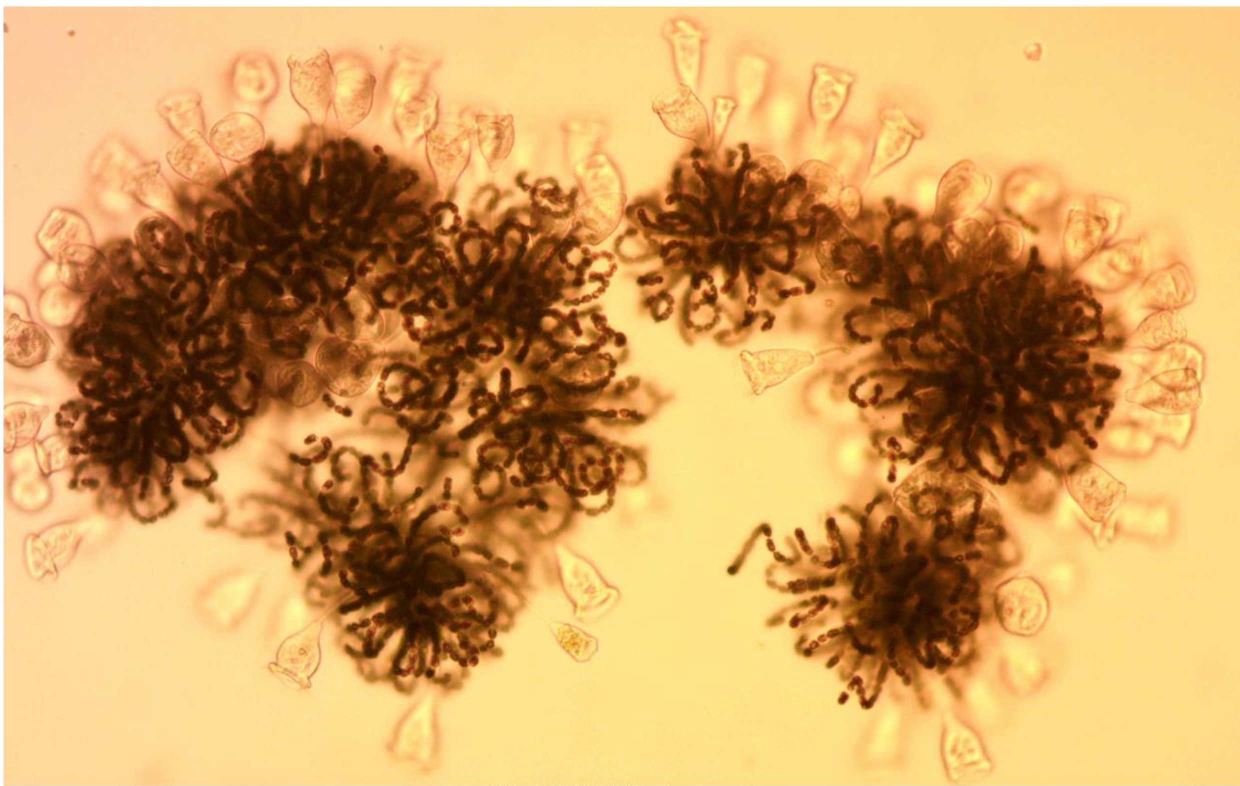
Mougeotia

Sirogonium

Sirogonium is a genus of filamentous charophyte green algae of the order Zygnematales. It is found in freshwater areas on all continents but Antarctica. Spirogyra measures approximately 32–115 μm in width.

It should be noted that on June 29, 2017 a private citizen did alert the Leeds, Grenville and Lanark Health Unit of a possible blue-greed algal bloom located in the Three Mile Bay area. Two samples were taken by officials and sent for analysis. Luckily, this sample did not contain any toxins nor did it contain any blue-green algae. The sample was found to contain diatoms, golden-brown algae and green algae. All of these species are common in White Lake.

It is well known that the presence of zebra mussels in lakes can promote the growth of microcystis and anabaena blue-green algae. Although there were no blooms of these algae in White Lake during the 2017 summer season, they were detected in water everywhere in the lake we sampled. Below is a photo taken by David Overholt on June 3, 2017. The photo shows anabaena blue-green algae with attached vorticella.



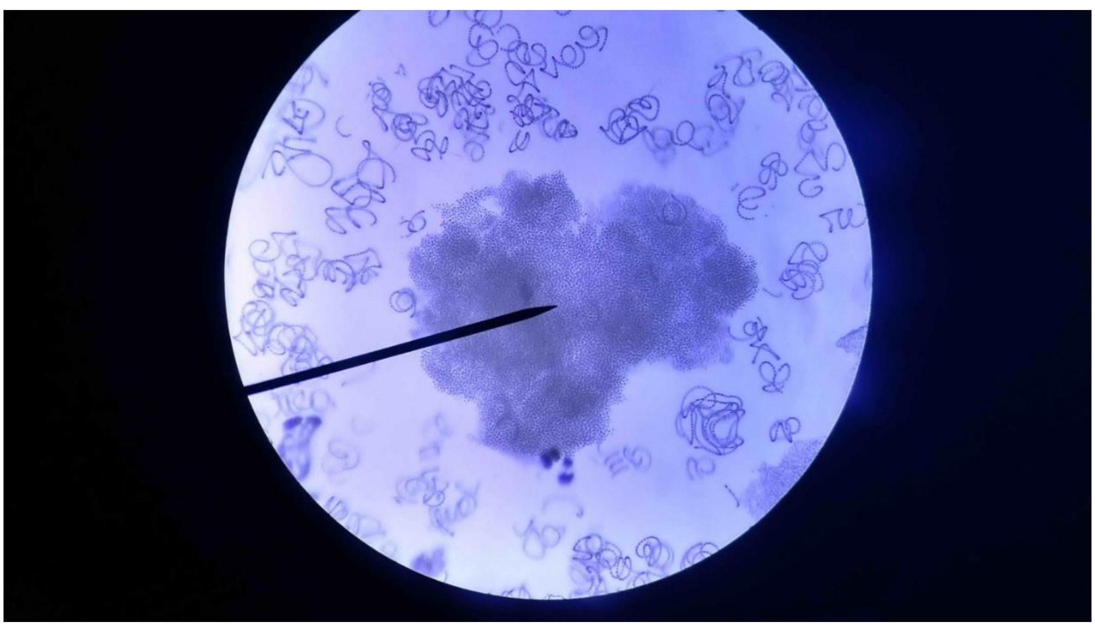
03 06 2017 channel
anabaena & vorticella

22.1 <u>Algal Blooms on White Lake – Selective Occurrences 2016 and 2017</u>

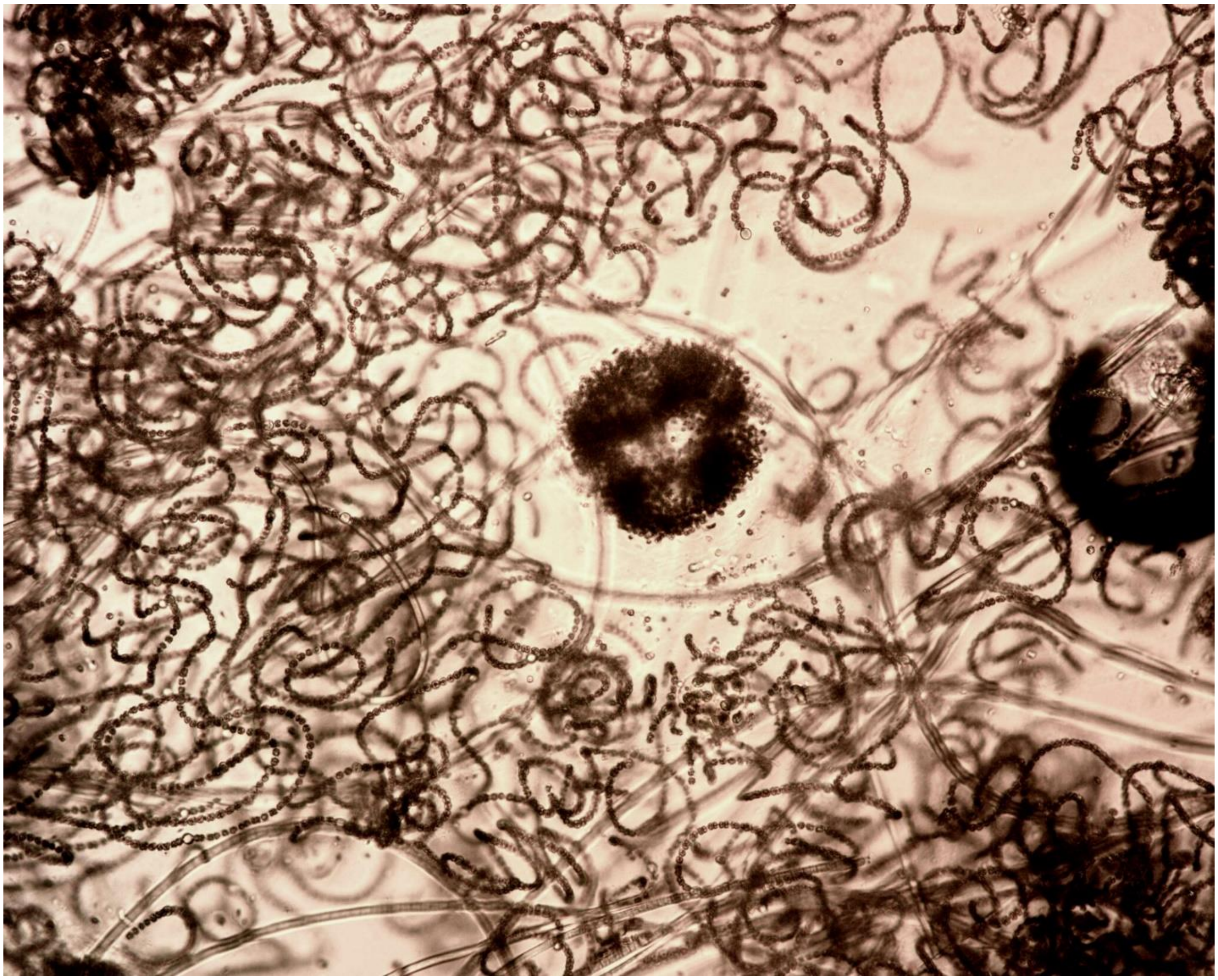
The following three photos were taken on Hayes Bay on June 26, 2016. This algal bloom was observed only at this location and nowhere else on the lake.

The appearance of this bloom is similar photos published on the internet: (file:///C:/WLPP%20Website/Documents/BG%20Algae%20Notice%20Guides/Ohio%20Visual%20Guide%20BG%20Blooms.pdf)

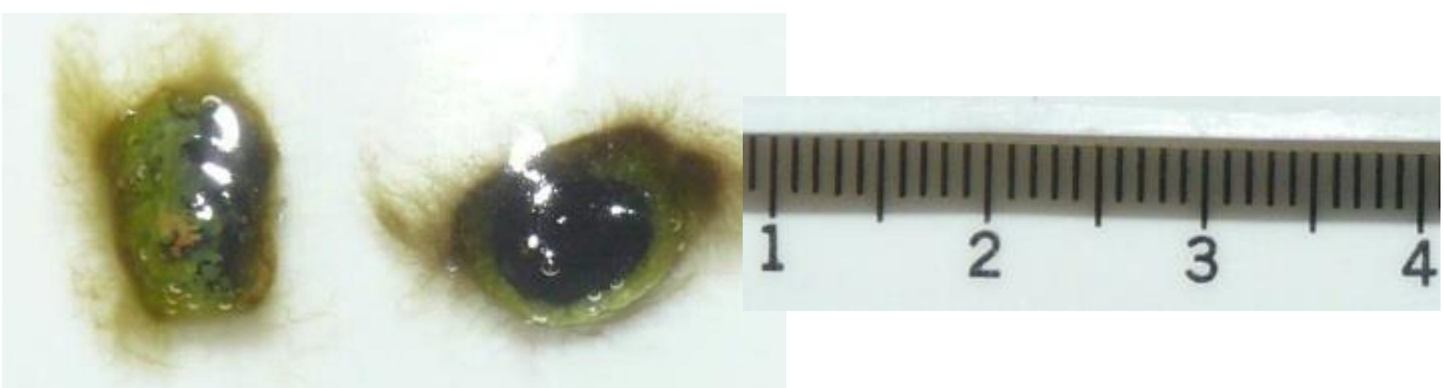
The same floating masses were observed on October 7, 2016, this time on the western shore of the lake. Microscopic analysis showed that the mass was composed of microsystis and anabaena blue green algae.



These characteristic algal masses reappeared on August 28, 2017. Floating algal masses were observed in Three Mile Bay, near Hardwood Island, Pickerel Bay, and Hayes Bay. The photomicrograph again shows the presence of microsystis and anabaena blue green algae.



Below is a photo of the algal mass retrieved from the lake surface on August 28, 2017.



None of the above observed algal blooms progressed into a full-blown bloom requiring the collection of samples for analysis for toxins. The water column itself was not significantly contaminated with visible algae. However, it is likely that conditions leading to a much larger and more dangerous algal bloom were narrowly averted by factors such as local atmospheric conditions. It is worth noting that there were two lake-wide blue-green algal blooms in White Lake, one of which did contain harmful levels of toxins (2014 and 2015).

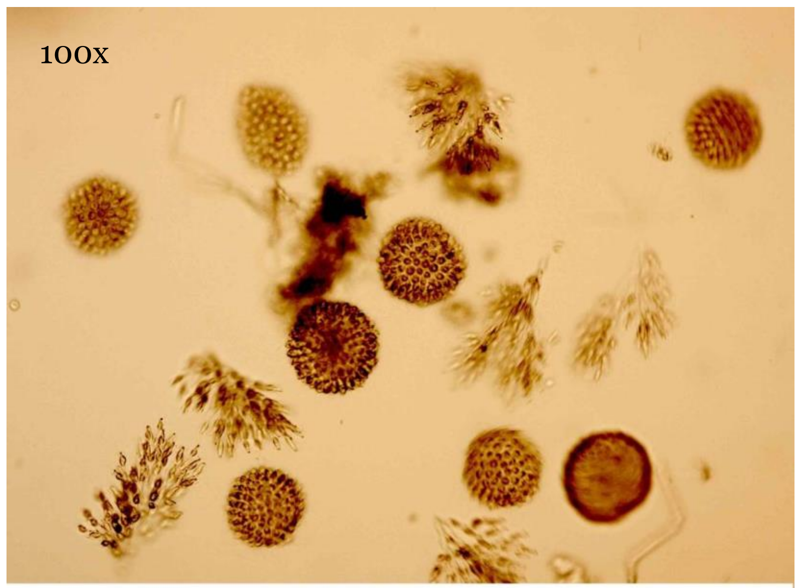
23.0 Green Algae - 2017

David Overholt

Much of our activity is orientated to monitoring blue green algae (cyanophytae) and rightly so as they can produce toxins harmful to human health, we still should bear in mind that any algae in large quantities can also become a nuisance. Like most of Ontario lakes, White Lake has a rich microcosm of green algae comprising hundreds of species. Here are some examples that were observed in 2017. This listing will be expanded over time and appear on our website at www.WLPP.ca

Colonial Green Algae

These microscopic colonial green algae occur in large numbers when food and temperature is just right. Their abundance is not always apparent at the surface. Both *Synura* (spherical colonies) and *Dinobryon* (tree branches) tumble about using their paired flagella on each individual cell. *Synura* and *Dinobryon* can produce a distinct odour to water when present in large numbers. For this reason, they are of interest to water managers. Green algae do better in cooler waters which blue green algae do not prefer. Thus, they can be dominant in the spring and fall and out-compete blue greens for available resources.



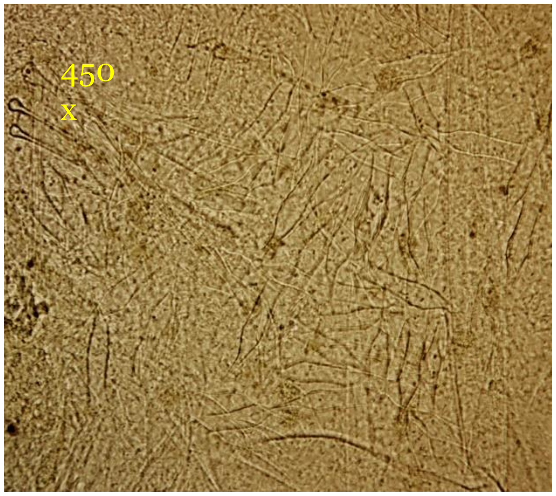
2017 07 07 DINOBRYON & SYNURA Pickerel Bay depth 4.9m

Predation on Green Algae

Green algae are a source of food for zooplankton and other small crustaceans. One group of animals unique to fresh waters are the rotifers; microscopic animals with voracious appetites. At right is a photo of *Asplanchna*. At first glance it looks to be as complex as a cellophane bag! This is one of the largest rotifers. At upper right is an opening to its gut around which cilia swirl to drive food into its digestive system.

28 June 2017 Three Mile Bay 100x

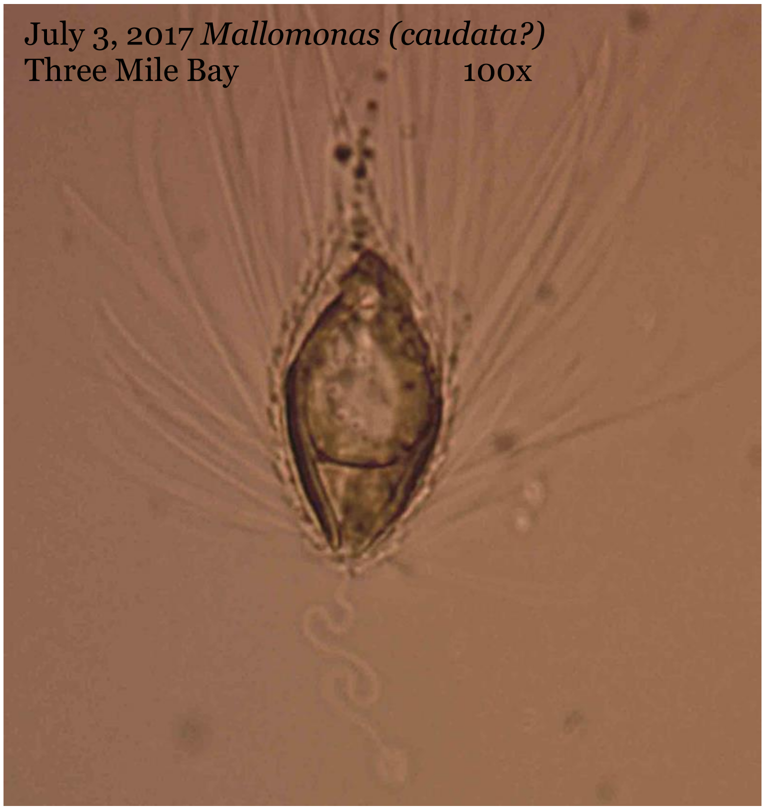
The photos below show *Asplanshn*a which has dined exclusively on the green alga *Dinobryon*! On the right you can see the empty tubes (loricas) that once held the living cells of the green alga.



A Scaly Green Algae

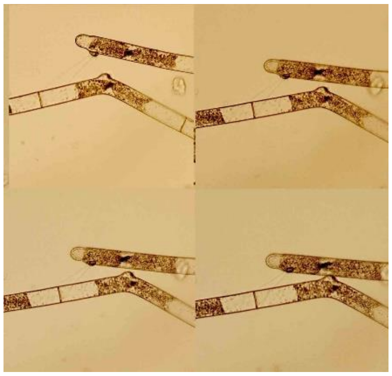
Green algae take a wide variety of shapes and sizes. Some are very mobile. *Mallamonas* are scaled single-celled organisms. Some have long bristles and body scales that are made of silica. *Mallomonas* move about by using a long single whip-like flagellum, which can just be seen at the cell's apex in the photo at right. The flagellum appears as a thin coiling white line at bottom of the photo. There is a saw-toothed fringe that surrounds the cell. This is actually overlapping transparent silica scales that become visible when seen edge-on. They cover the entire cell.

*Mallomona*s are sensitive indicators of the pH and conductivity of natural waters and because their species-specific scales are frequently preserved in lake sediments they are useful in reconstructing the historic conditions of a lake. *M. caudate* frequents a range of alkaline waters.

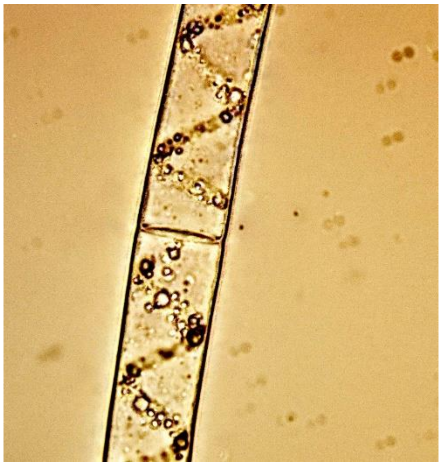


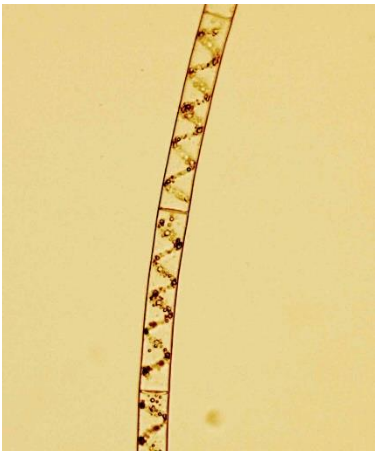
Filamentous Green Algae

In 2017, we observed clouds of pale yellowish green algae in White Lake. This green alga is called *Sirogonium* and forms clear hollow sheaths that hold chloroplasts. In the photo below, these appear as plates or rods depending on the angle viewed. When two filaments are nearby they form a protuberance towards one another. This process (conjugation) will result in the formation of a new strand (see composite photo below at right).



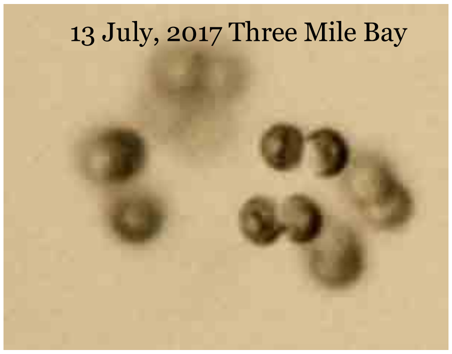
Another green alga is *Spirogyra,* which can be seen attached to rocks or wharves. It forms dark green filaments made up of sheaths containing helical chloroplast structures.





Colonial Green Algae

A variety of colonial green algae arranges itself in paired cells increasing in multiples that can lead to cubic structures contained within a transparent sphere of mucilage.



13 July, 2017 Three Mile Bay

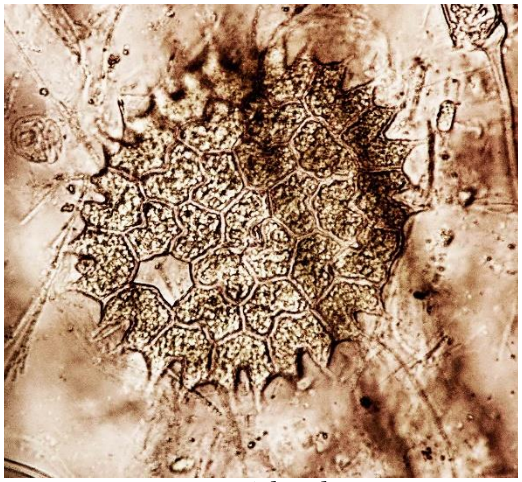
30 August 2017
Three Mile Bay

The photo to the left below shows cells undergoing cell division. The photo to the right clearly shows the mucus sphere encasing the cells.

6 Sept 2017 Three Mile Bay

27 Aug 2017 Three Mile Bay

A non-motile green algae colony of *Pediastrum* is shown below. Its remains can persist in sediments for eons eventually forming siltstones.



18 Sept, 2017; Pickerel Bay 100x

24.0 <u>Phytoplankton Observations</u>

<u>Blue Green Algae – Missing in Action!</u>
David Overholt

The filamentous blue- green algae *Lyngbya* is a normal component of the phytoplankton in White Lake. It should be found in abundance during the months of June to September. Its presence could be described as the dominant phytoplankton of surface waters during the warm water months. This was certainly the case in prior years where we found the species in almost every water sample we studied.

The photos below show the relative abundance of the filamentous *Lyngbya* in two typical water samples we studied in 2015 and 2016:

Lyngbya 31 08 2015 Three Mile Bay

2016 08 07 LYNGBYA Three Mile Bay

In 2017, it was remarkable that *Lyngbya* did not appear in the surface waters of Three Mile Bay or elsewhere in the lake as is shown in the photomicrograph at right. The algae in the photo which also appears to be needle like in nature is in fact a green-algae and not *Lyngbya*.

2017 08 27 filamenous green algae.Dinobryon, Fragilaria Three Mile Bay

We do not know why this has occurred but will be monitoring its presence or absence in future years.

25.0 <u>The Transition Zone of Three Mile Bay</u>

David Overholt

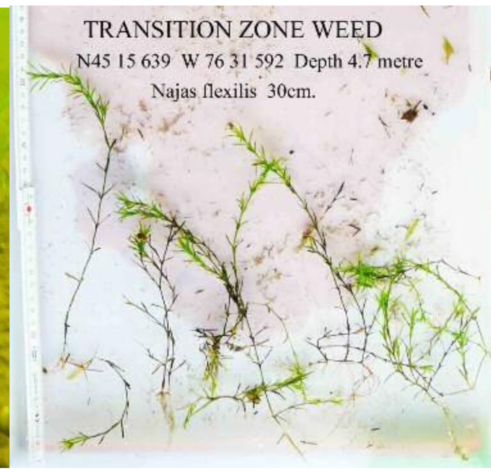
In our 2017 Water Quality Monitoring Program Report, we documented the presence or absence of aquatic plants on the lake floor of Three Mile Bay. The data were collected on a transect (line) spanning the width of the bay. The presence or absence of aquatic plants were noted as a function of water depth.

This year, the study was expanded to show in more detail areas where there were no aquatic plants and where there existed a transition zone where the gradual colonization of aquatic plants was visible. This was partly achieved by Scuba diving and underwater photography (provided by J. P. Thonney). The work was done on July 7, 2017. The observations provided below can reasonably be extended to other parts of White Lake having similar depth profiles and light exposure.

In locations where there was a rocky substrate or established weed beds, zebra mussels were present in large numbers. In other areas either lacking a hard substrate or aquatic plants, there were no zebra mussels since they require a stable attachment point to thrive. Significant areas of the White Lake basin currently do not support zebra mussels and will not until these areas become colonized by aquatic plants.

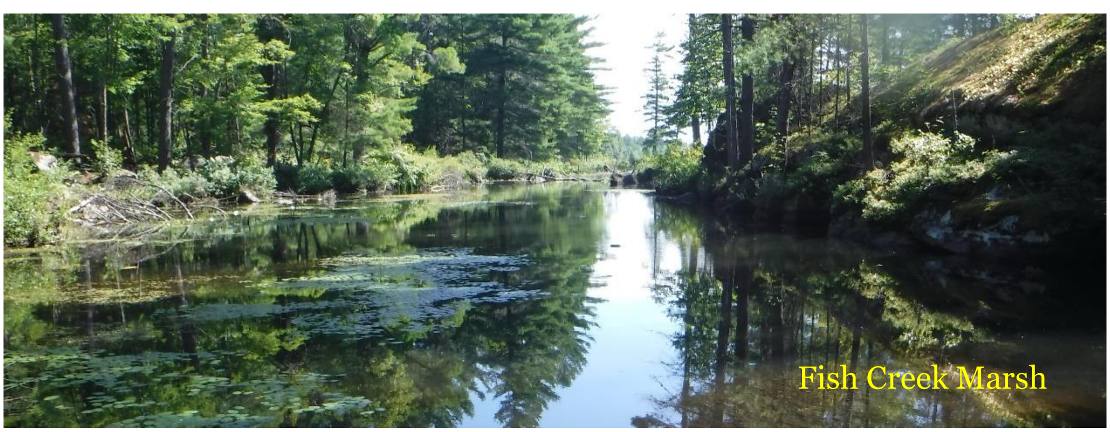
A good example of this phenomenon can be seen at a 38-hectare site located at the western end of Three Mile Bay. Depth measurements taken there were normalized to those of our Three Mile Bay sample site at the autumn low-depth-level of 5.5 metres. The image below shows an area with depths greater than 4.9 metres (shaded area on map). This 24-hectare area is free of aquatic plants.

Adjacent to this is another area of 14 hectares (white area on map). This is a transition zone which supports short-rooted plants of 10 to 30 cm. in length. These plants appear individually or in small clusters. The advance of these plants across the floor of the lake is accomplished by the growth of their rhizomes, however much of the lake bottom is still visible. These plants have been identified as the species *Najas Flexilis*.



Zebra mussel are rare here but other mollusks are present. Notice the tracks in the silt in the above photo. These are from the Banded Mystery snail *Viviparus georgianus* which are common in White Lake. This zone is expected to experience an expansion of the weed bed over time especially since the clarity of the lake has increased substantially since the arrival of zebra mussels. The end result of greater plant coverage on the lake bed will be a further increase in zebra mussel abundance.

Observations of this transition zone over the coming years will give us information on the rate of weed growth and lake bed coverage as well as the impact of these on zebra mussel populations.



26.0 Pickerel Fishery – 2016

Adam Pugh and Conrad Grégoire

In 2016 we initiated a program to collect data on the fishery of White Lake. We developed a Creel Survey form and distributed it to local fishermen in the hopes of obtain data on their catches. Unfortunately, the return rate of survey forms was very low. Adam Pugh, owner of *Adam's Outfitting* at Cedar Cove Resort on Three Mile decided to tabulate and collate data on pickerel catches resulting from his guided fishing expeditions. Some of the information obtained during 2016 is reported here. Data from 2017 will be available in next year's report.

One of the important parameters in any fishery study is the age distribution of caught fish. The age of a fish can be determined in a number of ways using fish anatomy structures which increase incrementally with **age**. The most commonly used techniques involve counting natural growth rings on the scales, otoliths (ear bones), vertebrae, fin **spines**, eye lenses, or teeth. We have assessed the age as a function of fish length using fin spines.

Below is a table giving data for fish caught in 2016.

Length, in	Assessed Age, y
15.7	4
15.7	4
16.0	5
16.0	6
17.0	5
18.0	6
19.0	5
19.0	8
19.5	6
19.5	5
19.7	6
19.7	7
19.7	8
19.7	8
26.5	12

These data can be used to establish a base for comparison with future years and can also be used to help determine the appropriate slot sizes for pickerel caught in the White Lake sport fishery. Note that several pickerel of the same size have different ages.

Other data collected during this time period showed that the average pickerel size was **17.1 inches**; that the catch per unit effort for total fish (all species) was **5.06 fish per hour** and the catch per unit effort for pickerel was **1.42 fish per hour**.

A copy of **the creel survey form** can be downloaded from the WLPP website at:

http://wlpp.ca/wlppwebsite_025.htm

Pickerel Spawning Grounds:

In 2015, the Department of Fisheries and Oceans conducted a fish habitat enhancement program on White Lake in order to improve pickerel spawning beds. Several locations including Paris and Fish Creeks and a location near Stanley Island were selected for enhancement.

Since this time, zebra mussels have invaded White Lake and are now still spreading lake-wide. It will be several years before the zebra mussel infestation will reach equilibrium.

One concern is the coverage of pickerel spawning grounds with zebra mussels which could compromise fish reproduction. Extensive rock coverage by zebra mussels is currently in progress at the Stanly Island site.

Some of our chemical studies on White Lake this year have revealed that the remaining two spawning sites at Paris and Fish Creeks are fed with waters which are too low in calcium concentrations to support zebra mussel growth. To date, no zebra mussels have been found in the immediate area where these streams discharge into the lake.

The geology of the entire western shore of the lake is mainly composed of Pre-Cambrian shield rocks which are relatively acidic and insoluble. This may mean that pickerel spawning beds located adjacent to the western shore of the lake, especially where there are streams, may not be seriously affected by the zebra mussel infestation as other areas where calcium-rich waters only are present. Time will tell if our observations to date are correct.

27.0 Water Levels – White Lake Dam

David Overholt and Conrad Grégoire

Water levels in White Lake are regulated by the Engineering Section of the Ontario Ministry of Natural Resources Forestry. The operation of the dam is administered by the Ontario Power Corporation through the Madawaska River Management Plan.

The White Lake Dam is a concrete structure, 29 m (98 ft.) long incorporating three log sluices: one central 2.44m (8 ft.) stoplog bay between two 4.27 m (14 ft.) bays. Each bay contains six 12-inch by 12-inch stoplogs. Half logs and spacers are available to fine tune operations.

The table at right gives the target water levels for White Lake as read on the water level gauge at the dam. The water level gauge is calibrated in *decimal feet.

Our observations indicate that the dam is visited at least once every two weeks at which time adjustments are made to the number and location of stop logs in the dam.

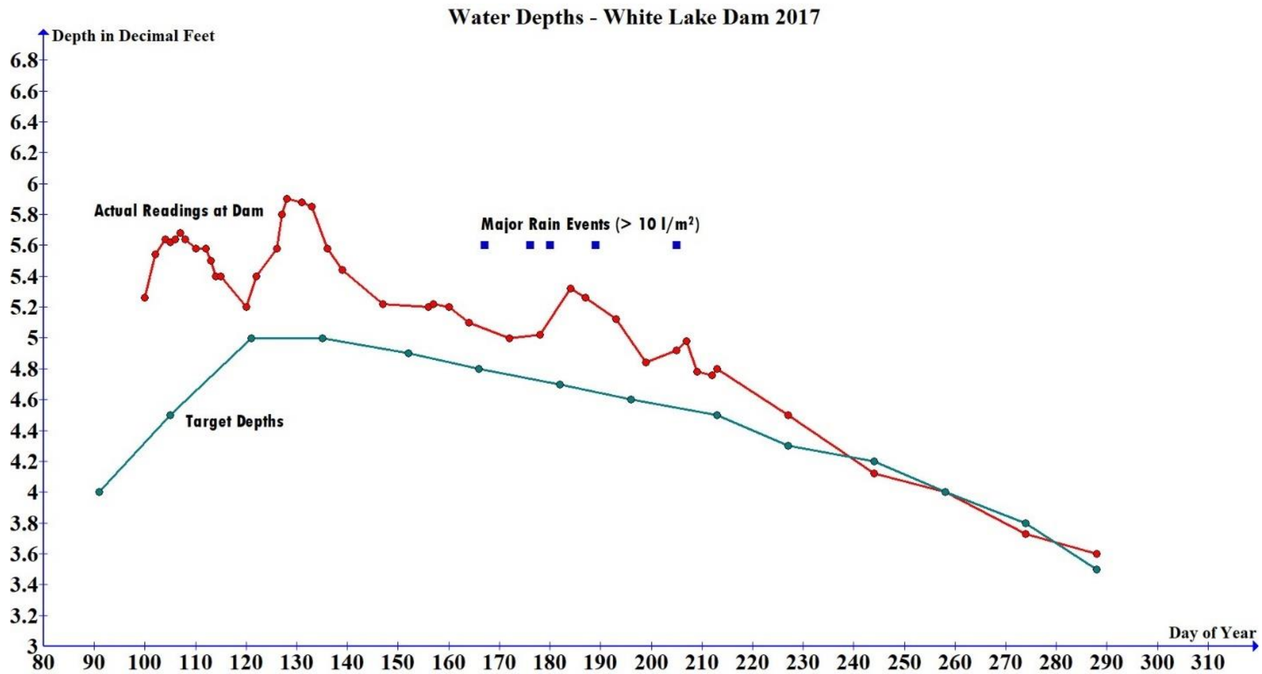
Target Dates	Target Levels*
January 1 to March 15	3.5
April 1	4.0
April 15	4.5
May 1	5.0
May 15	5.0
June 1	4.9
June 15	4.8
July 1	4.7
July 15	4.6
August 1	4.5
August 15	4.3
September 1	4.2
September 15	4.0
October 1	3.8
October 15 to December 31	3.5

During dry years, such as in 2016, the challenge is to leave enough water in the lake while at the same time providing a regulated minimum flow of water to Waba Creek in order to maintain that ecosystem. During wet years, such as in 2017, water was let out of the lake at an accelerated rate which was at times constrained because of the possibility of flooding in downstream areas.

For more information on the White Lake Dam and its operation, please visit the WLPP webpage at http://wlpp.ca/wlppwebsite_036.htm and follow the links.

In order to monitor water levels in White Lake we took regular and frequent readings of the water level gauge at the dam. Additionally, we used homemade devices to measure water depth at two remote (from the dam) locations; one on the Western shore of the lake and the other on Three Mile Bay. Measurements were made from fixed or floating docks using a rigid measuring stick on which was attached a measuring tape calibrated in both English and Metric units.

The figure below shows actual depth measurements taken at the White Lake Dam (red line). Also plotted are the target water levels for the same time scale (Green Line). Square blue dots above these lines indicates dates for heavy rain events large enough to result in an increase in the lake water level.

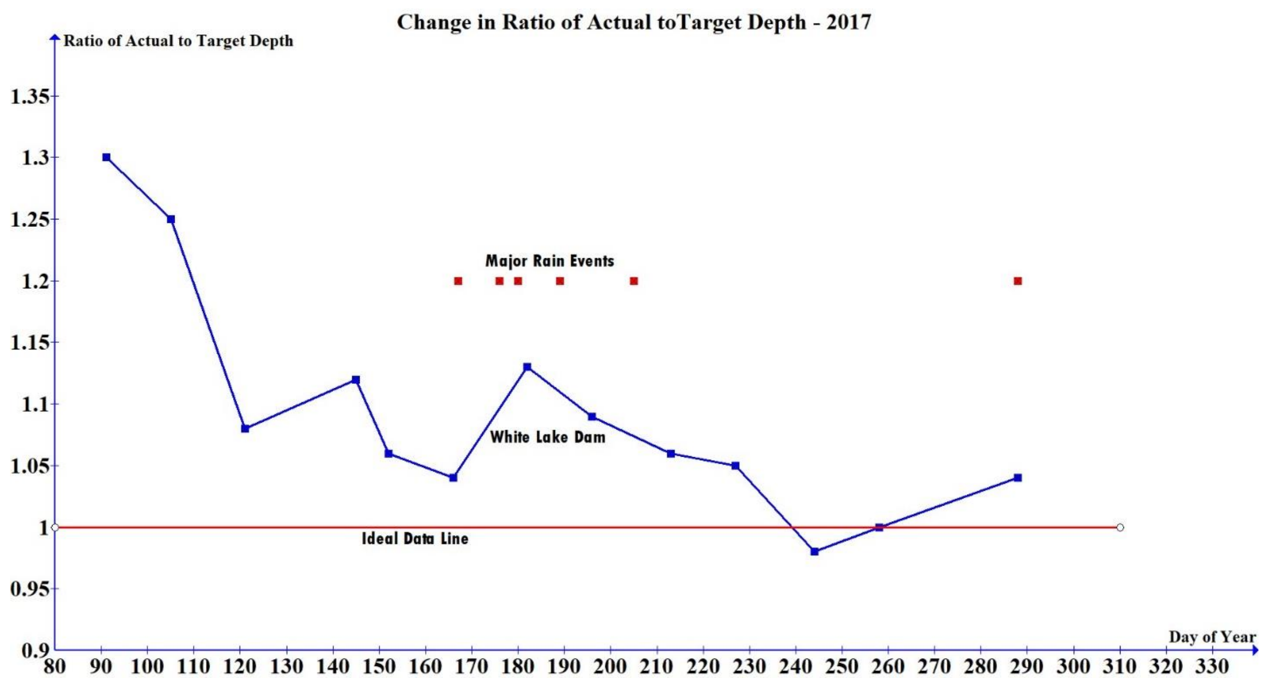


When comparing the line showing actual readings with that for target levels, it is evident that lake levels were very high during the entire spring and summer months and only returned to normalcy around August 15, 2017. At its highest level, the lake was a full 12 inches (1/3 metre) deeper than its target maximum depth.

It was not possible to correlate major rain events (blue dots) with a quantitative rise in water levels because of changes being made to the output of water from the dam. However, it was evident from our dock measurements that changes in depth occurred after a significant rainfall (see below).

Another way of looking at the same data treated in the above graph is to plot the ratio of the actual water level to the target management levels. The figure below shows the ratio of actual to target levels (blue line) along with the 'ideal' line (red line) which gives the same ratio if targets were met at all times during the year. Red dots show the dates for major rain events as above.

As previously discussed, this figure clearly shows that water levels were at times as much as 30% higher than target levels. To understand the reason for this, please refer to the section of this report entitled *'Weather Conditions'*. The data contained in this section shows that nearly a metre of rain fell on White Lake during the summer months. When one considers that the average depth of White Lake is only 3 metres, then it is evident that enough rain fell on White Lake to account for 1/3 of its volume at any given time.



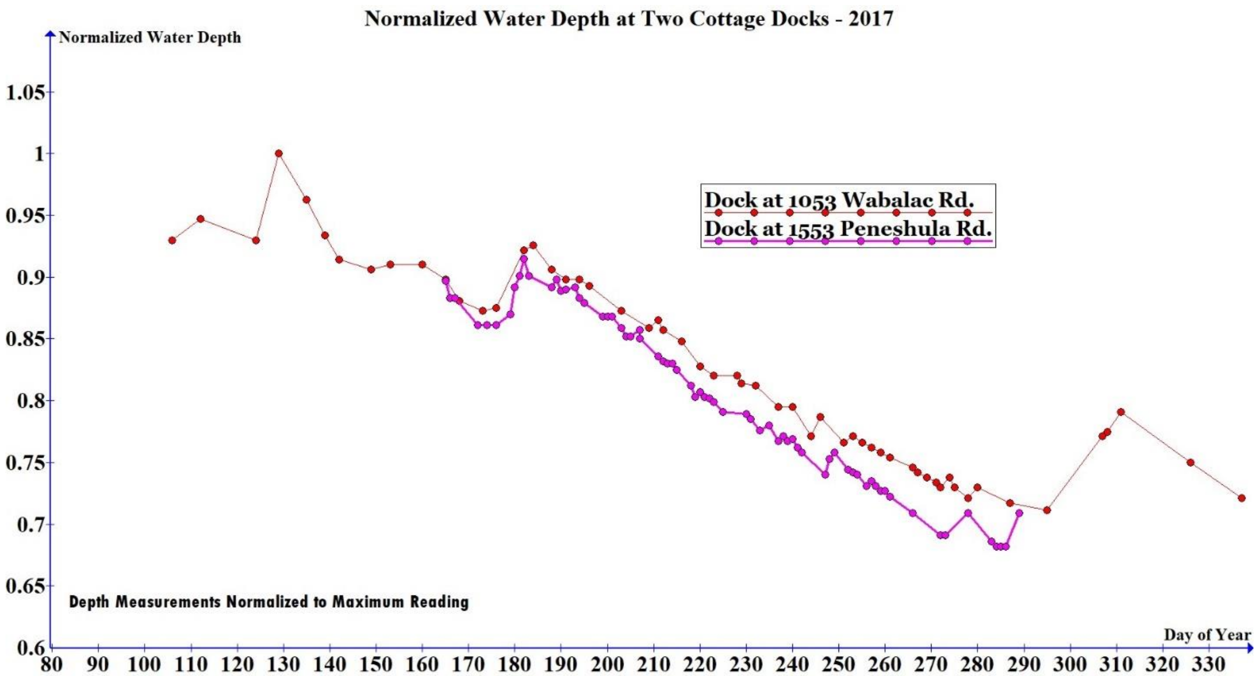
27.1 <u>Dockside Depth Measurements</u>

We were interested to know if it would be possible to measure water depth at locations far away from the White Lake dam and still get results which could, by calculation, accurately give the water level gauge readings at the dam.

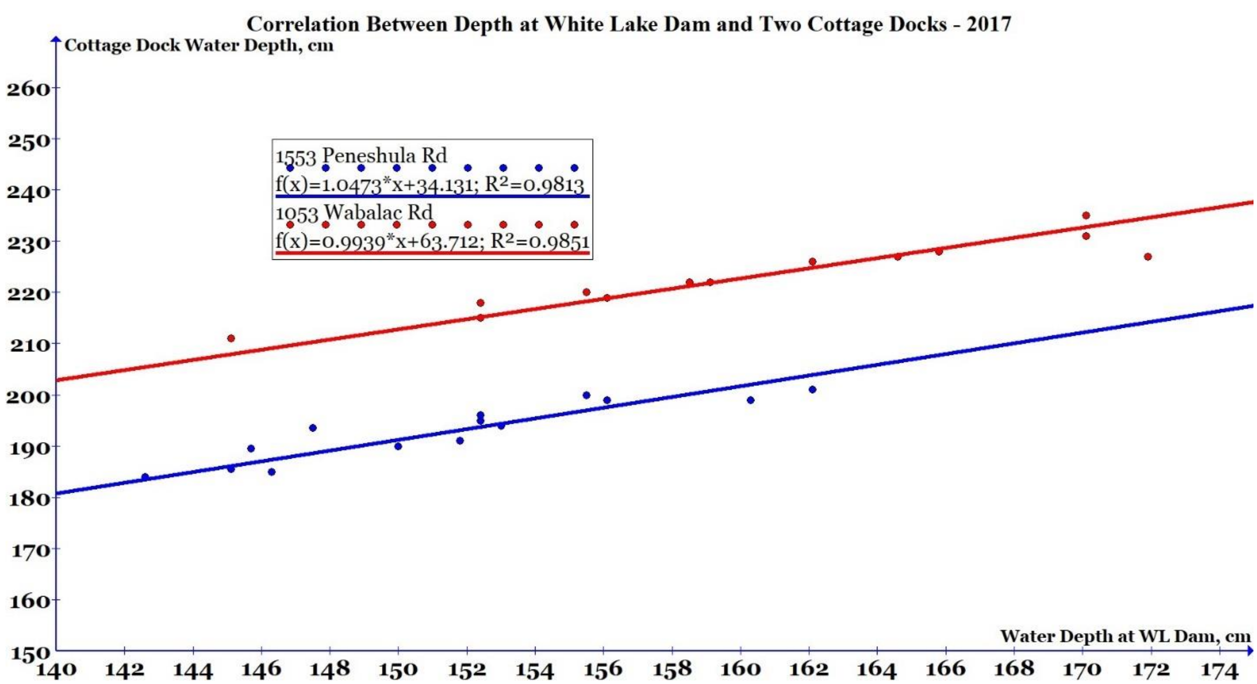
Water depths were measured using homemade devices consisting of a rigid pole on which was attached a section of carpenter's tape measure ribbon. Readings were taken at the same location every time. The measuring device rested on a solid rock or concrete structure on the floor of the lake.

Measurements were taken at two locations: the first location was at the dock located at 1053 Wabalac Road on the western shore of the lake just opposite McLaughlin's Island; the second location was the dock located at 1553 Peneshula Rd. on the north shore of Three Mile Bay.

The figure below shows data obtained for these two locations. All data were normalized (divided by) the maximum depth reading taken during the ice-free season. As can be seen, the two lines on the graph generally track one another very well indicating that there was a positive correlation between the readings taken at both locations.



Before these depth readings can be used for calculating the actual White Lake dam gauge readings, the dock data must be correlated (calibrated) to actual readings taken at the White Lake dam. The figure below is a correlation plot of dock vs dam data for the two locations.



The correlation lines for both locations yield straight lines with identical slopes and a very high (near unity) correlation coefficient (R^2). This indicates that the data can be used with a very high degree of confidence.

The equation for these straight lines (given in the box on the graph) can be used to convert reading at the dock to White Lake dam gauge readings.

For example, the equation for the 1053 location is: f(x) = .9939*x + 63.712 where f(x) is the measurement taken at the dock (in cm) and x is the unknown gauge reading at the dam. Solving this equation for x we obtain the following function:

White Lake dam gauge reading (cm) = [1053 dock reading (cm) – 63.712]/.9939

For the dock located at 1553 Peneshula Rd., the solution would be:

White Lake dam gauge reading (cm) = [1553 dock reading (cm) – 34.131]/1.0473

In order to convert from centimeter units to decimal feet (dam gauge graduations), the results from the above calculations should be multiplied by a factor of 0.0328.

It is clear from these measurements that any location on the lake of sufficient depth can be used to take depth readings which can be correlated to actual gauge readings at the White Lake dam. Note that if one were to choose a new location for taking depth readings, a new cross-calibration would need to be done either with the dam or a location on the lake which has already been calibrated such as the 1053 and 1553 sites.

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29.0 Acknowledgements

We are grateful to the Lake Partner Program of the Ontario Ministry of the Environment and Climate Change for providing us with sampling equipment and the analysis of water samples for total phosphorus, calcium, dissolved organic carbon, and chloride. The Gottlieb Foundation is gratefully acknowledged for providing the WLPP with a grant supporting the contract with Watersheds Canada. Costs and time related to lake sampling activities were self-funded by the Science Committee of the White Lake Preservation Project. Bev Clarke is thanked for critically reviewing the scientific content of this report.

Appendix 1

Weather Conditions: 2015 - 2017

When interpreting data such as total phosphorus and calcium concentrations as well as other parameters, it is often useful to take into account weather conditions. This report contains comparisons of data and interpretations of such data from 2015. For this reason, we have included meteorological data from all of these years. The data contained in these tables are those taken at the Ottawa International Airport. Available data from other locations near White Lake (e.g. Pembroke, ON) show similar trends and are not substantially different from those reported below.

A cursory examination of the tables below indicates that 2017 was an exceptionally wet year compared to the two previous years. During the six-month period from April to October White Lake received **990.4** mm of rain and experienced **81** days with precipitation of 1mm or more of rain. During 2016, only **430.8** mm of rain fell with only **44** days with greater than 1mm of rain. The year 2015 was intermediate with **518.2** mm of rain and **61** rain days.

Mean temperatures were generally lower during 2017 than they were in 2016, but comparable to 2015 temperatures. This may affect somewhat lake water temperatures which is discussed in the appropriate section of this report.

Monthly Meteorological Values – Environment Canada: *2017*

Ottawa Intl. Airport	Mean Temp., °C	Lowest Monthly Min. Temp	Highest Monthly Max. Temp.	Total Precip., mm	Number of Days with Precip. of 1mm or More
April	7.4	-4.0	26.6	147.8	14
May	12.2	-1.8	30.9	177.6	14
June	17.8	4.8	32.7	130.0	15
July	19.9	9.5	29.5	249.8	13
August	18.8	5.3	30.4	75.6	8
September	17.4	2.2	33.0	50.8	6
October	11.6	-2.6	23.4	158.8	11
Total				**990.4**	**81**

Monthly Meteorological Values – Environment Canada: *2016*

Ottawa Intl. Airport	Mean Temp., °C	Lowest Monthly Min. Temp	Highest Monthly Max. Temp.	Total Precip., mm	Number of Days with Precip. of 1mm or More
April	3.5	-11.1	23.1	43.8	5
May	14.2	-1.9	33.2	26.2	5
June	18.5	5.7	23.3	66.2	5
July	21.5	10.7	34.0	57.2	6
August	22.0	9.8	34.6	91.6	5
September	16.3	2.6	29.8	38.8	7
October	8.6	-4.2	24.5	107	11
Total				**430.8**	**44**

Monthly Meteorological Values – Environment Canada: *2015*

Ottawa Intl. Airport	Mean Temp., °C	Lowest Monthly Min. Temp.	Highest Monthly Max. Temp.	Total Precip., mm	Number of Days with Precip. of 1mm or More
April	6.2	-7.4	23.7	64.2	10
May	15.8	-2.8	30.7	62.2	9
June	17.8	3.5	27.8	108.0	12
July	20.9	8.4	34.3	40.8	5
August	20.0	8.9	31.5	100.0	10
September	17.9	3.3	32.1	69.4	6
October	7.1	-8.0	23.4	73.6	9
Total				**518.2**	**61**

The actual weather on and just before lake water sampling dates are also very important. Heavy rains just prior to sampling could result in sharp changes in the concentrations of chemical species as well as the temperature of the lake. As important are dry hot spells which can result in warmer water and increased concentration levels of some parameters due to evaporation.

Below is a table showing the actual atmospheric conditions prevalent on our water sampling days. Information in this table was used to help interpret some of the chemical and physical parameters studied in this report.

Sampling Date Weather Conditions 2017

Date	Day of Year	Weather Conditions
May 16	136	Partially cloudy but bright day. No wind. Wind 15-20 km/hr two previous days, no rain. Two weeks of sometimes heavy rains ended two days prior to sampling. Lake levels very high.
June 3	154	Mostly sunny day, good conditions. Wind about 10 Km/hr. Sampling date preceded by two weeks of cloudy rainy days. Lake levels still high. Streams are flowing, but a low rates. No rain two days prior to sampling.
June 14	165	Clear and Sunny day. No rain for a week prior to sampling with air temperatures reaching 30C for several days before sampling.
July 2	183	Morning of July 1 ended one week of steady and sometimes heavy rains with heavy downpours evening before sampling date. Wind between 5 and 10 Km/hr.
July 15	196	Beautiful sunny sampling day. With the exception of a clear day on July 14, there has been nearly continuous rain for previous ten days.
July 28	209	Mostly sunny with some thin clouds. On July 25, we received about 70 mm of rain. Lake levels are still high but receding quickly (dam fully open). No rain on July 27.
August 16	228	Clear and sunny. Light rain on August 15, with small about of precipitation during last five days.
August 28	240	Beautiful sunny day. No rain for seven days before sampling. Prior to that, several short but sometimes heavy downpours.
September 18	261	Some clouds, but almost entire sampling run under bright sunshine. Hot day. No rain whatsoever for previous two weeks. No wind.
October 1	274	Full sunshine temp 8 to 15 C, no wind. Some light rain three days before otherwise very dry for two weeks.

Appendix 2 - Chemical and Physical Data - 2017

Three Mile Bay N. 45º 15.767'; W. 076º 32.521 Depth: 6.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Ca, ppm	Total P, ppb	Comments
May 16	10:25	136	3.4	11.8	28.4	7.8, 7.6 (7.7)	Cl, 2.8 ppm DOC, 5.2 ppm
June 3	10:13	154	4.3	15.8			
June 14	9:55	165	> depth	20.8	30.0	9.0, 9.0 (9.0)	Cl, 3.4 ppm DOC, 5.3 ppm
July 2	10:10	183	4.45	21.5			
July 15	9:58	196	4.10	22.1		11.0, 10.6 (10.8)	
July 28	11:06	209	3.60	22.2			
August 16	9:34	228	4.45	22.5		12.8, 11.8 (12.3)	
August 28	10:04	240	> depth	21.3			
September 18	9:51	261	> depth	20.8		7.6. 7.6 (7.6)	
October 1	10:04	274	> depth	18.2			
October 12	11:55	285	> depth	16.0		10.2, 9.6 (9.9)	
November 8	12:00	312	> depth	7.5			

North Hardwood Island N. 45º 16.162'; W. 076º 33.203' Depth: 5.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Ca, ppm	Total P, ppb	Comments
May 16	10:46	136	3.9	11.4	28.5	7.6, 7.2 (7.4)	Cl, 3.1 ppm DOC, 5.0 ppm
June 3	10:25	154	4.3	15.8			
June 14	10:08	165	> depth	20.0	29.9	8.4, 8.2 (8.3)	Cl, 3.5 ppm DOC, 5.0 ppm
July 2	10:30	183	4.7	21.2			
July 15	10:12	196	4.2	22.2	28.6	12.0, 12.0 (12.0)	Cl, 2.8 ppm DOC, 4.6 ppm
July 28	12:10	209	3.2	22.2			
August 16	9:36	228	4.2	22.5		10.0, 11.2 (10.6)	
August 28	10:15	240	> depth	21.7			
September 18	10:32	261	> depth	20.7		8.4. 7.8 (8.1)	
October 1	10:11	274	> depth	18.6			
October 12	12:06	285	> depth	16.0		10.2, 9.4 (9.8)	

Pickerel Bay N. 45º 16.33'; W. 076º 31.03 Depth: 7.5 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Ca, ppm	Total P, ppb	Comments
May 16	11:31	136	5.0	11.5	-	-	
June 3	10:57	154	5.4	16.2	-	-	
June 14	10:31	165	5.4	20.1	-	-	
July 2	11:29	183	4.0	21.8	-	-	
July 15	10:36	196	4.55	22.2	-	-	
July 28	13:17	209	2.90	22.3	-	-	
August 16	10:12	228	5.4	22.5	-	-	
August 28	10:55	240	5.3	21.5	-	-	
September 18	11:27	261	6.35	20.9	-	-	
October 1	10:33	274	> depth	19.5	-	-	
October 12	12:37	285	6.7	16.4	-	-	

Deepest Pickerel Bay N. 45º 16.81'; W. 076º 31.63 Depth: 9.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Ca, ppm	Total P, ppb	Comments
May 16	11:12	136	5.2	11.0	-	-	
June 3	10:38	154	5.0	16.2	-	-	
June 14	10:21	165	6.1	20.2	-	-	
July 2	11:01	183	4.0	21.5	-	-	
July 15	10:27	196	4.45	22.2	-	-	
July 28	12:51	209	3.2	22.2	-	-	
August 16	9:59	228	5.2	22.5	-	-	
August 28	10:28	240	4.9	21.5	-	-	
September 18	11:01	261	6.0	20.8	-	-	
October 1	10:23	274	6.7	19.2	-	-	
October 12	12:23	285	7.6	16.3	-	-	

Middle Narrows N. 45º 18.548'; W. 076º 31.271' Depth: 6.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Ca, ppm	Total P, ppb	Comments
May 16	11:58	136	4.7	11.3	28.4	6.2, 6.2 (6.2)	Cl, 3.3 ppm DOC, 5.2 ppm
June 3	11:13	154	4.9	16.8			
June 14	10:46	165	5.5	21.0	29.4	9.0, 8.6 (8.8)	Cl, 3.3 ppm DOC, 4.8 ppm
July 2	11:36	183	4.0	21.8			
July 15	10:46	196	4.2	22.2		11.0, 11.2 (11.1)	
July 28	13:36	209	3.2	22.0			
August 16	10:28	228	4.5	22.5		9.6, 9.8 (9.7)	
August 28	11:10	240	5.3	21.5			
September 18	11:49	261	5.3	21.3		7.8, 10.2 (7.8)*	
October 1	10:49	294	> depth	21.3			
October 12	12:54	285	> depth	16.1		10.0, 9.4 (9.7)	

*higher value rejected

The Canal N. 45º 19.267'; W. 076º 30.013' Depth: 2.4 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Ca, ppm	Total P, ppb	Comments
May 16	12:15	136	> depth	13.3	29.4	6.4, 7.0 (6.7)	Cl, 6.2 ppm DOC, 5.4 ppm
June 3	11:29	154	> depth	15.9			
June 14	11:00	165	> depth	22.2	30.8	7.4, 7.6 (7.5)	Cl, 5.6 ppm DOC, 5.8 ppm
July 2	11:59	183	> depth	22.0			
July 15	10:57	196	> depth	22.8	32.5	7.4, 8.2 (7.7)	Cl, 7.5 ppm DOC, 6.4 ppm
July 28	13:58	209	> depth	21.9			
August 16	10:46	228	> depth	22.2		7.4, 7.0 (7.2)	
August 28	11:24	240	> depth	20.6			
September 18	12:06	261	> depth	23.2		6.4, 6.4 (6.4)	
October 1	10:58	274	> depth	14.8			
October 12	13:09	285	> depth	13.8		7.8. 8.0 (7.9)	

Temperatures taken 1 m from bottom.

Hayes Bay N. 45° 19.037'; W. 076° 28.424' Depth: 1.6 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 16	12:37	136	> depth	14.5	31.0	7.4, 7.6 (7.5)	Cl, 9.5 ppm DOC, 6.8 ppm
June 3	11:51	154	> depth	16.2			
June 14	11:11	165	> depth	23.2	36.4	8.4, 9.8 (9.1)	Cl, 10.2 ppm DOC, 8.0 ppm
July 2	12:19	183	> depth	22.0			
July 15	11:15	196	> depth	22.2		7.6, 8.0 (7.8)	
July 28	14:17	209	> depth	21.5			
August 16	11:00	228	> depth	22.3		7.4, 7.6 (7.5)	
August 28	11:42	240	> depth	20.7			
September 18	12:23	261	> depth	23.8		7.4, 7.6 (7.5)	
October 1	11:15	274	> depth	14.4			
October 12	13:21	285	> depth	12.4		8.8, 8.8 (8.8)	

Temperatures taken 1 m from bottom.

Jacob's Island N. 45° 19.989; W. 076° 30.622' Depth: 4.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Ca, ppm	Total P, ppb	Comments
May 16	12:56	136	> depth	12.0	27.7	6.2, 6.2 (6.2)	Cl, 3.7 ppm DOC, 5.1 ppm
June 3	12:07	154	> depth	17.0			
June 14	11:25	165	> depth	20.2	29.4	9.0, 9.2 (9.1)	Cl, 3.3 ppm DOC, 4.7 ppm
July 2	13:19	183	> depth	22.3			
July 15	11:30	196	> depth	22.2	27.5	9.4, 9.4 (9.4)	Cl, 3.2 ppm DOC, 4.9 ppm
July 28	14:34	209	> depth	21.8			
August 16	11:14	228	> depth	22.5		11.0, 11.4 (11.2)	
August 28	12:17	240	> depth	21.9			
September 18	12:48	261	> depth	22.3		10.0, 10.2 (10.1)	
October 1	11:54	274	> depth	18.2			
October 12	14:17	285	> depth	15.8		12.8, 12.6 (12.7)	

Village Basin N. 45º 21.233'; W. 076º 30.303' Depth: 1.65 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Ca, ppm	Total P, ppb	Comments
May 16	13:20	136	> depth	13.0	27.3	6.4, 6.0 (6.2)	Cl, 3.8 ppm DOC, 5.5 ppm
June 3	12:20	154	> depth	16.2			
June 14	11:40	165	> depth	21.8	29.4	8.0, 9.0 (8.5)	Cl, 4.0 ppm DOC, 5.0 ppm
July 2	13:32	183	> depth	22.2			
July 15	11:44	196	> depth	22.2	27.2	7.6, 7.4 (7.5)	Cl, 3.3 ppm DOC, 5.3 ppm
July 28	14:52	209	> depth	21.8			
August 16	11:40	228	> depth	22.3		7.6, 8.0 (7.8)	
August 28	12:33	240	> depth	21.0			
September 18	13:05	261	> depth	23.4		7.8, 7.4 (7.6)	
October 2	11:54	274	> depth	15.2			
October 12	14:30	285	> depth	13.7		8.0, 8.0 (8.0	

Temperatures taken 1 m from bottom. B= bottom temperature

Weather Conditions 2017

Date	Day of Year	Weather Conditions
May 16	136	Partially cloudy but bright day. No wind. Wind 15-20 km/hr two previous days, no rain. Two weeks of sometimes heavy rains ended two days prior to sampling. Lake levels very high.
June 3	154	Mostly sunny day, good conditions. Wind about 10 Km/hr. Sampling date preceded by two weeks of cloudy rainy days. Lake levels still high. Streams are flowing, but at low rates. No rain two days prior to sampling.
June 14	165	Clear and Sunny day. No rain for a week prior to sampling with air temperatures reaching 30C for several days before sampling.
July 2	183	Morning of July 1 ended one week of steady and sometimes heavy rains with heavy downpours evening before sampling date. Wind between 5 and 10 Km/hr.
July 15	196	Beautiful sunny sampling day. With the exception of a clear day on July 14, there has been nearly continuous rain for previous ten days.
July 28	209	Mostly sunny with some thin clouds. On July 25, we received about 70 mm of rain. Lake levels are still high but receding quickly (dam fully open). No rain on July 27.
August 16	228	Clear and sunny. Light rain on August 15, with small about of precipitation during last five days.
August 28	240	Beautiful sunny day. No rain for seven days before sampling. Prior to that, several short but sometimes heavy downpours.
September 18	261	Some clouds, but almost entire sampling run under bright sunshine. Hot day. No rain whatsoever for previous two weeks. No wind.
October 1	274	Full sunshine temp 8 to 15 C, no wind. Some light rain three days before otherwise very dry for two weeks.
October 12	285	Full sun temp 13C. Wind NE ~15 km/hr. Light rain three days before.

Notes:

1. Temperatures were taken at Secchi Depth. When sampling site depth was less than Secchi depth, temperatures were taken 1 M from bottom.
2. Water samples for total phosphorus were taken at Secchi Depth or when sampling site depth was less than Secchi depth, samples were taken 1 M from bottom.
3. All water samples were filtered through 80-micron filter prior to determination of total phosphorus.
4. Sampling dates were ideally the first of the month for temperature and Secchi depth and the 15^{th} of the month for Secchi depth, temperature and total phosphorus. Some adjustments in timing had to be done to accommodate inclement weather and availability of personnel.
5. Total phosphorus water samples were not taken at the Pickerel Bay or Deepest Pickerel Bay locations as these locations were not part of the Lake Partners Program for 2016.

Appendix 3

Specific Conductivity, Total Dissolved Solids Total Hardness, Ca and Mg Data - 2017

Three Mile Bay N. 45º 15.767'; W. 076º 32.521 Depth: 6.0 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	10:25	136	(195)					
July 3	10:10	184			120	40	4.8	8.3
July 28	11:06	209	195, (209)*					
August 16	9:34	228	191 (197)**	95 (98)**				
August 28	10:04	240	194	97	120	32	9.6	3.3
September 18	9:51	261	187, (192)	94	120	32	9.6	3.3
October 1	10:04	274	194	97				
October 12	11:55	285	198	99	120	32	9.6	3.3

*Data in parentheses from multi-probe in-situ YSI analyzer

** Repeated on same samples August 27, 2017, Distilled water: 1 µS, 0 ppm

North Hardwood Island N. 45º 16.162'; W. 076º 33.203' Depth: 5.0 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	10:46	136	(194)					
June 3	10:25	154			120	40	4.8	8.3
July 3	10:30	184			120	40	4.8	8.6
July 28	12:10	209	198 (210)					
August 16	9:46	228	194 (197)	97 (98)				
August 28	10:15	240	196	98	120	32	9.6	3.3
September 18	10:32	261	191 (195)	95	120	32	9.6	3.3
October 1	10:11	274	194	97				
October 12	12:06	285	198	99	120	32	9.6	3.3

Pickerel Bay N. 45° 16.33'; W. 076° 31.03' Depth: 7.5 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	10:31	136	(195)					
July 3	11:24	184			120	40	4.8	8.3
July 28	11:17	209	(210)					
August 16	10:12	228	193 (196)	97 (98)				
August 28	10:55	240	196	98	120	32	9.6	3.3
September 18	11:27	261	193 (196)	96	120	32	9.6	3.3
October 1	10:33	274	195	98				
October 12	12:37	285	198	99	120	32	9.6	3.3

Deepest Pickerel Bay N. 45° 16.81'; W. 076° 31.63' Depth: 9.0 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	11:12	136	(194)					
July 3	11:01	184			120	40	4.8	8.3
July 28	12:51	209	198, (209)					
August 16	9:59	228	192 (195)	96 (98)				
August 28	10:28	240	197	98	120	32	9.6	3.3
September 18	11:01	261	192 (197)	96	120	32	9.6	3.3
October 1	10:23	274	194	97				
October 12	12:23	285	198	99	120	32	9.6	3.3

Middle Narrows N. 45º 18.548'; W. 076º 31.271' Depth: 6.0 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	11:58	136	(192)					
July 3	11:36	184			120	40	4.8	8.3
July 28	13:36	209	197, (211)					
August 16	10:28	228	192 (196)	97 (98)				
August 28	11:10	240	195	98	120	32	9.6	3.3
September 18	11:49	261	193 (197)	97	120	32	9.6	3.3
October 1	10:49	274	194	97				
October 12	12:54	285	199	100	120	32	9.6	3.3

The Canal N. 45º 19.267'; W. 076º 30.013' Depth: 2.4 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	12:15	136	(201)					
July 3	11:59	184			120	40	4.8	8.3
July 28	13:58	209	225, (238)					
August 16	10:46	228	200 (204)	100 (102)				
August 28	11:24	240	204	102	120	32	9.6	3.3
September 18	12:06	261	202 (211)	101	120	32	9.6	3.3
October 1	10:58	274	225	113				
October 12	13:09	285	222	111	120	40	4.8	8.3

Hayes Bay N. 45º 19.037'; W. 076º 28.424' Depth: 1.6 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	12:37	136	(216)					
July 3	12:19	184			140	48	4.8	10.0
July 28	14:17	209	263, (279)					
August 16	11:01	228	265 (269)	133 (135)				
August 28	11:42	240	266	133	140	40	9.6	4.2
September 18	12:23	261	267 (273)	134	160	40	14.4	2.8
October 1	11:15	274	288	144				
October 12	13:21	285	285	143	160	48	9.6	5.0

Jacob's Island N. 45º 19.989; W. 076º 30.622' Depth: 4.0 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	12:56	136	(189)					
July 3	13:19	184			120	40	4.8	8.3
July 28	14:34	209	198, (211)					
August 16	11:14	228	193 (196)	97 (98)				
August 28	12:17	240	196	98	120	32	9.6	3.3
September 18	12:48	261	195 (199)	97	120	32	9.6	3.3
October 1	11:54	274	201	101				
October 12	14:17	285	206	103	120	32	9.6	3.3

Village Basin N. 45º 21.233'; W. 076º 30.303' Depth: 1.65 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
May 16	13:20	136	(183)					
July 3	11:44	184			120	40	4.8	8.3
July 28	11:40	209	194, (207)					
August 16	12:33	228	197 (201)	99 (100)				
August 28	12:33	240	197	99	120	32	9.6	3.3
September 18	13:05	261	197 (202)	99	120	32	9.6	3.3
October 1	12:08	274	208	104				
October 12	14:30	285	210	105	120	32	9.6	3.3

Barber Island N. 45º 18.685' W. 076º 28.680' Depth: 1.50 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
August 28	12:00	240	267	133				
September 18	12:30	261	271, (274)	136	160	48	9.6	5.0
October 1	11:20	274	293	147				
October 12	13:38	285	293	146	160	48	9.6	5.0

Bane Bay #1 N. 45º 17.986"; W. 076º 29.098' Depth: 1.60 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
August 27	16:00	239	279	139				
August 28	11:45	240	279	139	140	48	4.8	10.0
October 1	11:25	274	299	150				
October 12	13:53	285	293	147	160	48	9.6	5.0

Bane Bay #2 N. 45° 17.521"; W. 076° 29.891' Depth: 1.50 M

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
August 27	16:20	239	293	146				
August 28	12:00	240	293	146	160	48	9.6	5.0

Lowney Lake Outlet N. 45° 16.848'; W. 076° 28.617'

Date	Time	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
August 28	16:30	240	296	148	160	40	14.0	2.9

Lowney Lake: N. 45° 16.281' W. 076° 28.792' Site Depth: 1.8m

Location	Date	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
Lowney Lake	Oct 16	289	297	149	160	40	14.4	2.8

Other Lake Locations :

Location	Date	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg	pH
1053 Wabalac Rd*	Oct 12	285	194	97	120	32	9.6	3.3	
"	Oct 25	298	202	101	-	-	-	-	
"	Nov 6	310	203	102	120	32	9.6	3.3	8.31
"	Nov 22	326	204	102	120	32	9.6	3.3	8.37
"	Dec 3	337	199	100	120	32	9.6	3.3	8.27
	Dec 9	343	202	101					8.00

*5 m off shore 1 m depth

Boundary and Paris Creeks

Location	Date	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg	pH
Boundary Cr.	June 3	154	-	-	140	32	14.4	2.2	
	Sept 13	261	262	131	160	48	9.6	5.0	
	Oct 12	285	273	137	160	48	9.6	5.0	
	Nov 6	310	226	113	140	40	9.6	4.2	8.00
	Nov 22	326	176	88	100	32	4.8	6.7	7.63
	Dec 3	337	223	111	140	40	9.6	4.2	7.94
	Dec 9	343	235	117					8.00
Paris Cr.	June 3	154	-	-	40	8	4.8	1.7	
	Sept 13	261	42	21	40	8	4.8	1.7	
	Oct 12	285	40	20	40	8	4.8	1.7	
	Nov 6	310	32	16	20	4	2.4	1.7	7.25
	Nov 22	326	74	37	20	4	2.4	1.7	7.70
	Dec 3	337	34	17	18	4	2.0	2.0	7.44
	Dec 9	343	35	18					7.65

Drilled Wells: September 13, 2017

Location	Date	Day of Year	Conductivity, µS	Total Dissolved Solids, ppm	Total Hardness[$CaCO_3$], ppm	Ca, ppm	Mg, ppm	Ca/Mg
1553 Peneshula Rd	Sept 13	261	604	302	400	88	19.2	4.6
1061 Wabalac Rd	Sept 13	261	337	168	180	56	9.6	5.8
“	Oct 12	285	337	168	180	56	9.6	5.8

August 28, 2017 (day 240) – data for accompanying maps in report text

Site Name	GPS Coordinates	Conductivity, µS	Total Dissolved Solids, ppm
The sites below are all located in The Canal – Hayes – Bane Bay Complex of White Lake			
The Canal	N. 45º 19.267’ W. 076º 30.013’	204	102
W.L. Marina	N. 45º 19.353’ W. 076º 29.305’	252	125
Bay View Lodge	N. 45º 19.277’ W. 076º 29.081’	259	129
East Canal	N. 45º 19.172’ W. 076º 28.759’	265	132
Hayes Bay	N. 45º 19.037’ W. 076º 28.424’	266	133
Hayes Bay Centre	N. 45º 19.243’ W. 076º 27.919’	264	132
Barber Island	N. 45º 18.685’ W. 076º 28.680’	267	133
Little Birch I. West	N. 45º 18.229’ W. 076º 29.153’	271	136
Bane Bay 1	N. 45º 117.986’ W. 076º 29.098’	279	139
Bane Bay 2	N. 45º 17.521’ W. 076º 29.891’	293	146
Lowney Lake Outlet	N. 45º 16.703’ W. 076º 28.555’	296	148
The sites below are all located in the main part of White Lake			
Three Mile Bay	N. 45º 15.767’ W. 076º 32.521’	194	97
N. Hardwood Is.	N. 45º 16.162’ W. 076º 33.203’	196	98
Deepest Pickerel Bay	N. 45º 16.81’ W. 076º 31.63’	197	98
Pickerel Bay	N. 45º 16.33’ W. 076º 31.03’	196	98
Middle Narrows	N. 45º 18.548’ W. 076º 31.271’	195	98
Jacobs Is.	N. 45º 19.989 W. 076º 30.622’	196	98
Village Basin	N. 45º 21.233’ W. 076º 30.303’	197	99

GPS Locations for all sampling sites

Site Name	GPS Coordinates
The Canal	N. 45º 19.267'; W. 076º 30.013'
W.L. Marina	N. 45º 19.353'; W. 076º 29.305'
Bay View Lodge	N. 45º 19.277'; W. 076º 29.081'
East Canal	N. 45º 19.172'; W. 076º 28.759'
Hayes Bay	N. 45º 19.037'; W. 076º 28.424'
Hayes Bay Centre	N. 45º 19.243'; W. 076º 27.919'
Barber Island	N. 45º 18.685'; W. 076º 28.680'
Little Birch I. West	N. 45º 18.229'; W. 076º 29.153'
Bane Bay 1	N. 45º 117.986'; W. 076º 29.098'
Bane Bay 2	N. 45º 17.521'; W. 076º 29.891'
Lowney Lake Outflow	N. 45º 16.848'; W. 076º 28.617'
Lowney Lake	N. 45º 16.281'; W. 076º 28.792'
Three Mile Bay	N. 45º 15.767'; W. 076º 32.521'
N. Hardwood Is.	N. 45º 16.162'; W. 076º 33.203'
Deepest Pickerel Bay	N. 45º 16.81'; W. 076º 31.63'
Pickerel Bay	N. 45º 16.33'; W. 076º 31.03'
Middle Narrows	N. 45º 18.548'; W. 076º 31.271'
Jacobs Is.	N. 45º 19.989; W. 076º 30.622'
Village Basin	N. 45º 21.233'; W. 076º 30.303'
1053 Wabalac Road	N. 45º 16.305'; W. 076º 33.187'
Boundary Creek	N. 45º 15.175'; W. 076º 36.197'
Paris Creek	N. 45º 15.309'; W. 076º 36.079'
1061 Wabalac Rd drilled well	N. 45º 16.325'; W. 076º 33.244'
1553 Peneshula Rd. drilled well	N. 45º 15.819'; W. 076º 32.010'

Appendix 4

Reproducibility of Specific Conductivity and Total Dissolved Solids Measurements in Lake Water

Short Term Reproducibility*

Number	Distilled Water uS/ppm	Reference Standard uS/ppm	Distilled Water uS/ppm	White Lake Water Sample uS/ppm
1	2/1	188/94	2/1	199/100
2	0/0	189/94	2/1	199/100
3	1/1	189/95	2/1	199/100
4	2/1	189/94	2/1	199/100
5	1/1	188/94	1/1	198/99
6	1/0	190/95	1/1	198/99
7	1/1	189/94	0/0	199/100
8	0/0	189/94	0/0	199/100
9	0/0	188/94	0/0	199/100
10	0/0	188/94	0/0	199/100

*All measurements made sequentially within the same time period.

Results:

Sample	Specific Conductivity ± SD (n=10)	Total Dissolved Solids ± SD (n=10)
Distilled Water	0.90 ± .85	0.55 ± .51
Reference Standard	188.0 ± .7	94.2 ± .4
White Lake Water	198.8 ± .4	99.8 ± .4

Three SD limit of detection - Conductivity: 3 μ*S*; Total Dissolved Solids: 1.5 ppm

Short Term Reproducibility - Expressed as (standard deviation/nominal value) x 100:

- Conductivity: 0.3 μ*S*; Total Dissolved Solids: 0.5 ppm

Accuracy- Conductivity: 99.5 %; Total Dissolved Solids: 99.2 %

Notes:

1. All measurements made with AZ8361 pen-type Conductivity/Total Dissolved Solids meter.
2. Experiment consisted of sequentially measuring conductivity/TDS of distilled water, reference standard, distilled water, White Lake water sample, then repeat

to end of sequence. The values shown in the table above are for individual samples to avoid cross-contamination.

3. An equilibration time of 30 seconds was used between sample measurements.
4. The reference sample was made from NaCl dissolved in distilled water. Nominal values of 190 µS and 95 ppm TDS were calculated.
5. The White Lake water sample was obtained at a 1m depth 5 m offshore of a property (1053 Wabalac Rd.) on the Western shore of the lake. Sample was filtered through 80-micron filter.
6. All measurements made at 20^{0}C ambient temperature.

Medium Term Reproducibility

Day	Distilled Water uS/ppm	Reference Standard uS/ppm	Distilled Water uS/ppm	White Lake Water Sample uS/ppm
1	2/1	189/95	2/1	200/100
2	2/1	188/94	2/1	200/100
3	2/1	188/94	1/1	200/100
4	2/1	188/94	2/1	202/101
5	2/1	188/94	2/1	200/100
6	2/1	187/94	1/1	200/100
7	2/1	188/94	1/1	200/100
8	2/1	187/94	2/1	200/100
9	2/1	188/94	2/1	200/100
10	2/1	189/95	1/0	200/100

Results:

Sample	Specific Conductivity ± SD (n=10)	Total Dissolved Solids ± SD (n=10)
Distilled Water	1.8 ± .4	0.95 ± .23
Reference Standard	188.0 ± .7	94.2 ± .4
White Lake Water	200.2 ± .6	100.1 ± .3

Three SD limit of detection - Conductivity: 1.2 µ*S*; Total Dissolved Solids: 2.9 ppm

Short Term Reproducibility - Expressed as (standard deviation/nominal value) x 100:

- Conductivity: 0.4 µ*S*; Total Dissolved Solids: 0.5 ppm

Accuracy- Conductivity: 99.5 %; Total Dissolved Solids: 99.2 %

Long Term Reproducibility

Day	Distilled Water uS/ppm	Reference Standard uS/ppm	Distilled Water uS/ppm	White Lake Water Sample uS/ppm
1	2/1	188/94	2/1	199/100
5	2/1	189/95	2/1	200/100
15	2/1	187/94	1/1	200/100
20	2/1	189/95	1/0	200/100
25	2/1	189/95	1/0	200/100
30	2/1	189/94	1/0	199/100
35	2/1	189/95	2/1	200/100
40	2/1	188/94	2/1	200/100
45	2/1	188/94	1/0	200/100
50	2/1	188/94	2/1	200/100

Results:

Sample	Specific Conductivity ± SD (n=10)	Total Dissolved Solids ± SD (n=10)
Distilled Water	1.8 ± .4	0.8 ± .4
Reference Standard	188.4 ± .7	94.4 ± .5
White Lake Water	199.8 ± .4	100.0 ± .0

Three SD limit of detection - Conductivity: 1.2 µ*S*; Total Dissolved Solids: 1.2 ppm

Long Term Reproducibility - Expressed as (standard deviation/nominal value) x 100:

- Conductivity: 0.2 µ*S*; Total Dissolved Solids: 0.5 ppm

Accuracy- Conductivity: 99.2 %; Total Dissolved Solids: 99.5 %

RESULTS SUMMARY TABLE

Parameter	Short Term		Medium Term		Long Term	
	S. Cond., µS	TDS, ppm	S. Cond., µS	TDS, ppm	S. Cond., µS	TDS, ppm
L. of Detection	3	1.5	1.2	2.9	1.2	1.2
Reproducibility	0.3	0.5	0.4	0.5	0.2	0.5
Accuracy	99.5	99.2	99.5	99.2	99.2	99.5

Comments:

1. Comparison of summary data indicate that: the AZ8361 pen-type Conductivity/Total Dissolved Solids meter is an accurate and precise device. However, calibration is still recommended before each use to ensure that the device is working properly.
2. The AZ8361 pen-type Conductivity/Total Dissolved Solids meter performed within the specification of the manufacturer.
3. The drift observed in distilled water measurements taken during the short-term reproducibility trial supports the manufacturers suggestion that the probe should be placed in distilled water and allowed to equilibrate from 15 to 20 minutes before use. Not doing so may introduce an error of about 1% in absolute values measured.