WHITE LAKE PRESERVATION PROJECT

REPORT

Water Quality Monitoring Program
And Research Activities
2018


Looking South from Hardwood Island

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TABLE OF CONTENTS

Page

PART 1 – Water Quality Monitoring Program

PART 2 – Water Quality Parameters

PART 3 – Research Activities

PART 4 – Appendices

WHITE LAKE PRESERVATION PROJECT

Water Quality Monitoring Program And Research Activities -2018

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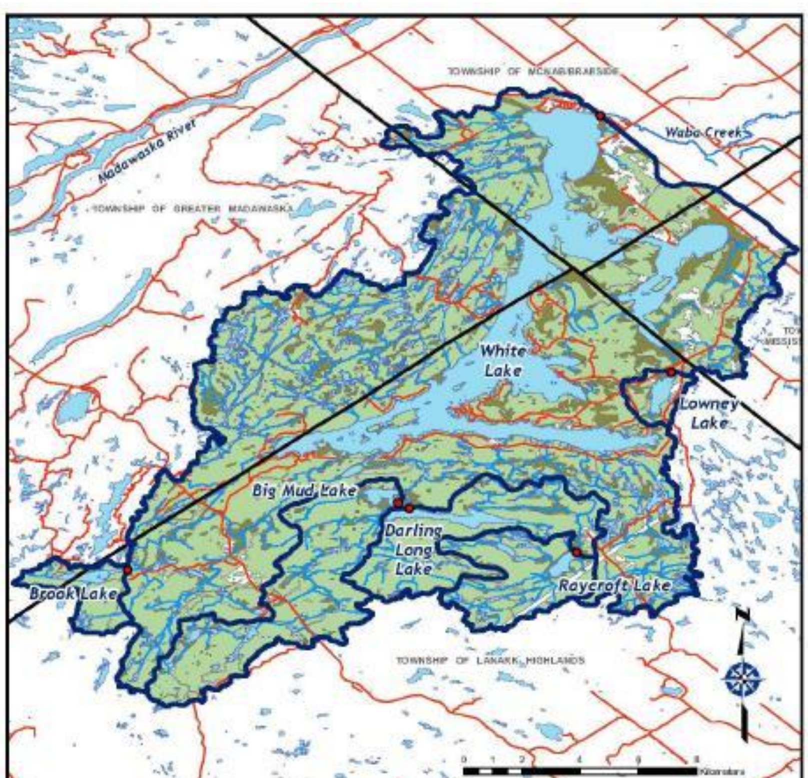
1.1 Introduction and Summary



Introduction: 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.

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An examination of the drainage basin map (above) 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 the 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 contain 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.

Water Quality Monitoring: 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.

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 taking into consideration the significant body of knowledge available in the published scientific literature, and in turn inform you of changes taking place in White Lake 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 from further degradation and if possible, improve its current condition.

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 2018, the extent of the infestation continued to increase. 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 readings which measure water clarity reached over 9 m in 2018. This means that virtually the entire floor of the lake is illuminated with sunlight during the ice-free season.

Since 2015, the concentration of measured total phosphorus in the lake has declined by at least 50%. Total phosphorus levels in 2018 did marginally increase from 2016 and 2017 levels, but not significantly so. The general reduction in total phosphorus levels in no way indicates that there was 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 in all parts of the lake other than those resulting from zebra mussels infesting the lake.

The *Synopsis* section of this report summarizes the influence of zebra mussels in transferring particulate phosphorus from the deeper parts of the lake to near shoreline environments while leaving behind that fraction of total phosphorus responsible for algae propagation. <u>This means that we can no longer point to lower total phosphorus levels as a positive indicator of lake health</u>.

In 2018 White Lake experienced at least 5 algal blooms. As predicted by the scientific literature, there were blooms of filamentous green algae. Also predicted was the occurrence of blooms of *microcystis aeruginosa* blue-green algae. Two blooms, one certified toxic and the other likely to have been also, were almost lake wide but concentrated on the north shore of Three Mile Bay. This part of White Lake has the most populated and altered shoreline of any on the lake. Only time will tell if these blooms reoccur every year.

We now know that White Lake is at capacity meaning that the lake cannot tolerate additional nutrient inputs such as phosphorus. We also know that the lake is experiencing annual green algal blooms and this year two extensive toxic blue-green algal blooms. These two issues taken together present us with our greatest challenge in preserving White Lake and should be the driving force motivating us to take action!

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.

In the meantime, we have to become more vigilant and press our politicians to work with our lake associations and other interested parties to ensure that existing bylaws are used properly in planning decisions and 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 notably the care, restoration and preservation of the 15 metre 'ribbon of life' along the water's edge.

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!!

Other Research: In addition to water quality measurements, we have completed a number of research projects aimed at increasing our knowledge of White Lake allowing us to better characterize its nature and processes, such as water flow.

These studies include: 1) Annual Common Loon Survey; 2) Influence of stream waters on lake water quality; 3) The health of the pickerel fishery; 4) Tape Grass in White Lake; 5) The nature and extent of organic sediments and marl deposits in White Lake; 6) The distribution of wild rice in White Lake; 7) The continued propagation of zebra mussels in White Lake. Several other projects on lake biota are also reported on.

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.

Water Sampling on White Lake

1.2 WLPP Water Quality Monitoring Program

The water quality monitoring program for 2018 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, potassium, magnesium, sodium, silica 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, pH, conductivity 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 conductivity, temperature and pH for the five major stream water sources entering White Lake.

Throughout the summer we monitored biota populations in the lake and monitored the lake for algal blooms. We completed surveys of lake sediment types and mapped the location of marl deposits on the lake. A survey of wild rice occurrences was done and a map detailing the location of wild rice beds was produced.

All water samples for the determination of phosphorus content were shipped to the Dorset Environmental Science Centre (Ontario Ministry of the Environment Conservation and Parks) for analysis under the auspices of the Lake Partner 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 activity involved providing support and participating in research being completed by Carleton University. A graduate student is completing a paleolimnological study of sediments in White Lake. This work involves separating diatoms from sediment layers followed by identifying, classifying and counting them. In this way, the history of nutrient (such as phosphorus) input into White Lake can be reconstructed. A second component of this research involves collecting, identifying and counting the biota living in the lake as a function of depth.

The scientific literature reports that when a zebra mussel infestation occurs, phytoplankton[2] populations 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.

The section in this report on *Water Clarity* shows that since the arrival of zebra mussels, the waters of White Lake have become clearer every year starting in 2015. This trend is expected to continue as the population of zebra mussels increases and eventually reaches equilibrium.

This year we experienced a total of five algal blooms, two of which were blue-green algae producing high levels of toxins (certified for one bloom, presumed for the second). All of these blooms are predicted to occur in the accepted scientific literature. The reasons for this are elaborated on in this report.

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 disturb 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 comments above.

[2] Phytoplankton are microscopic plants on which small animals (zooplankton) feed. Phytoplankton form the base of the food chain in a lake.

1.3 <u>Algal Blooms – 2018</u>

This year five algal blooms were recorded. Three of the blooms were from green algae and two were blue-green. The first blue-green algal bloom contained microcystin toxins at a concentration of 25 ppb (parts per billion). This concentration greatly exceeds the limit for drinking water (1.5 ppb) and also exceeds the limit of 20 ppb for recreational use. The second blue-green algal bloom was reported to the Ministry of the Environment but was not tested by the MOE since it is currently limiting each lake to one sampling per year. The collection and analysis of one sample costs nearly $1,000 and the MOE does not have the resources to follow up on every report. However, the bloom was registered at the Health Unit and classified as *Microcystis* blue-green algae based on photographs of the bloom and photomicrographs of the algae itself which we submitted to the MOE. It is very likely that the second bloom, which was as extensive as the first, was also laden with toxic microcystins. It is worth noting that our group has correctly identified the type and species of all algal blooms which have been documented since the WLPP was founded.

We emphasize that five algal blooms are the minimum number for White Lake, and there may very well have been others on the lake which went undetected or unreported. Currently only two volunteers are monitoring the 22 Km² of White Lake, which has a shoreline stretching nearly 100 km!

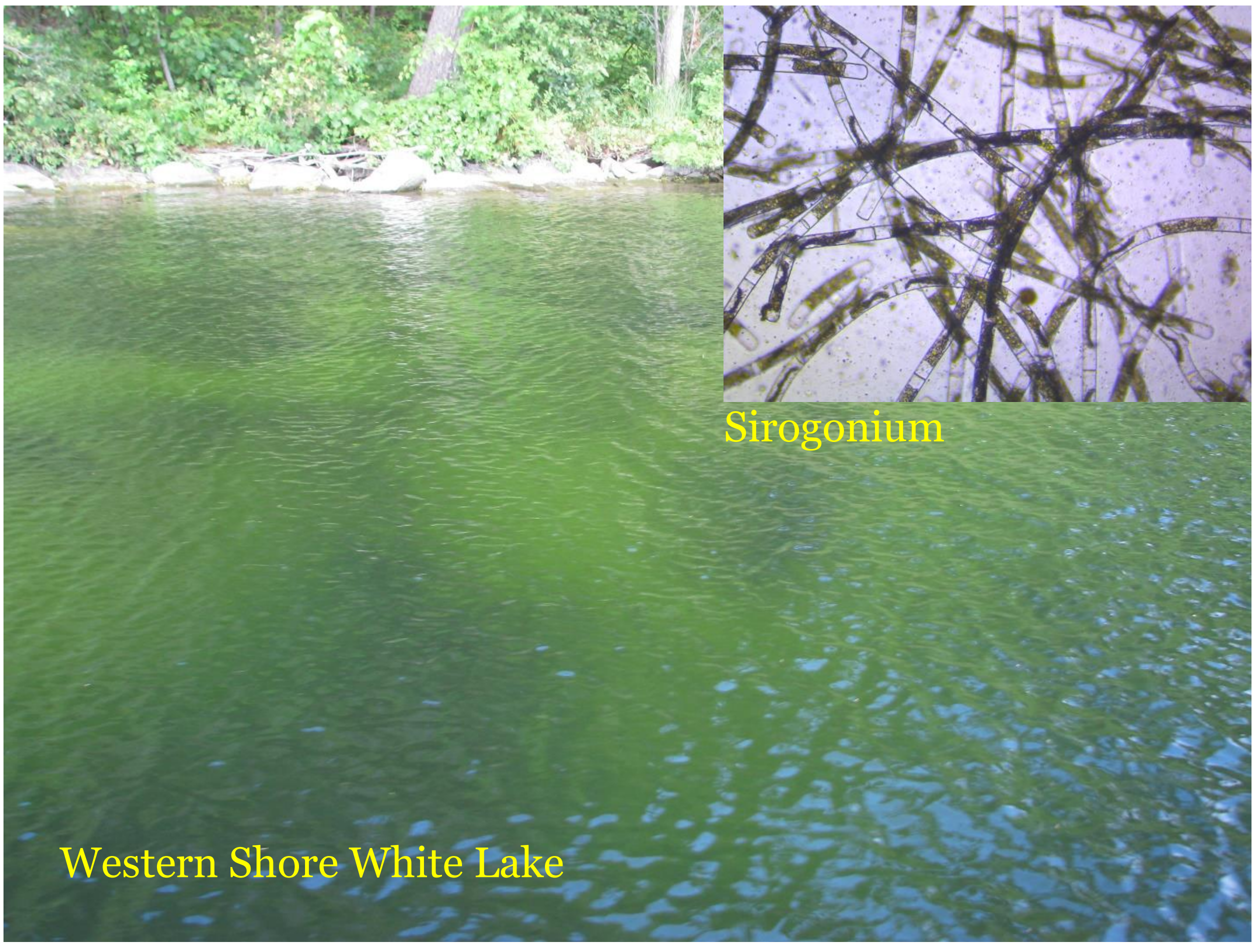
1.3a <u>Green Algal Blooms</u>

The first algal bloom of the season occurred on or about June 10, 2018. This bloom was found in a more remote part of White Lake but was very heavy and extensive in the area of Long Lake Creek East all the way from the creek itself to the point where it met the outflow or Darling Round Lake. This species of green algae is relatively simple to identify because as it dies and decomposes it floats to the surface to form large masses which are often referred to as 'elephant snot'. It is also easy to identify under the microscope.

The second bloom occurred near Sunset Bay extending in patches for about 1 km from the boat launch. The bloom was most intense near the estuary of Boundary Creek. It was evident that wind and wave action were in the process of dissipating the floating masses of algae when it was observed.

The third green algal bloom started in mid-August and continued until the end of September. This filamentous green algae (Sirogonium) grows in large patches along the shoreline. Nutrients, such as phosphorus, supporting this alga comes from both the sediments as well as dissolved in lake water.

Viewed from underwater, the algae mass forms very large volumes extending from just below the surface of the lake all the way down to the lake floor. Other aquatic plants become enveloped within the growing mass. Over time, the algae die, collapses into itself and remains attached to standing aquatic plants resembling bright green garland.



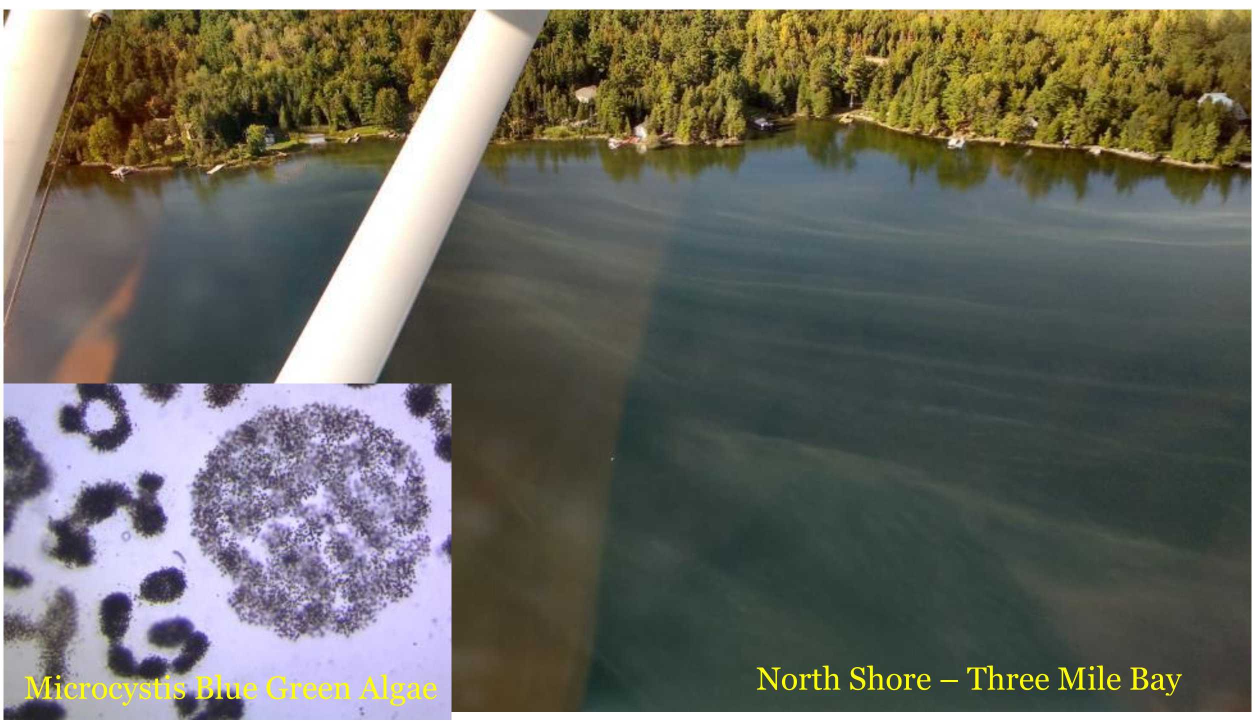
Blooms such as the one pictured above were common in 2018 all along the western shore of White Lake and also in other areas and along island shorelines. This bloom was essentially lake-wide and follows a similar bloom which occurred in 2017.

Blooms of filamentous green algae are a consequence of the presence of zebra mussels in White Lake. Zebra mussels concentrate nutrients from deeper parts of the lake and deposit them in shoreline areas where they thrive. Warmer daytime water temperatures, abundant light and nutrients, provide ideal conditions for the propagation of filamentous green algae along shorelines

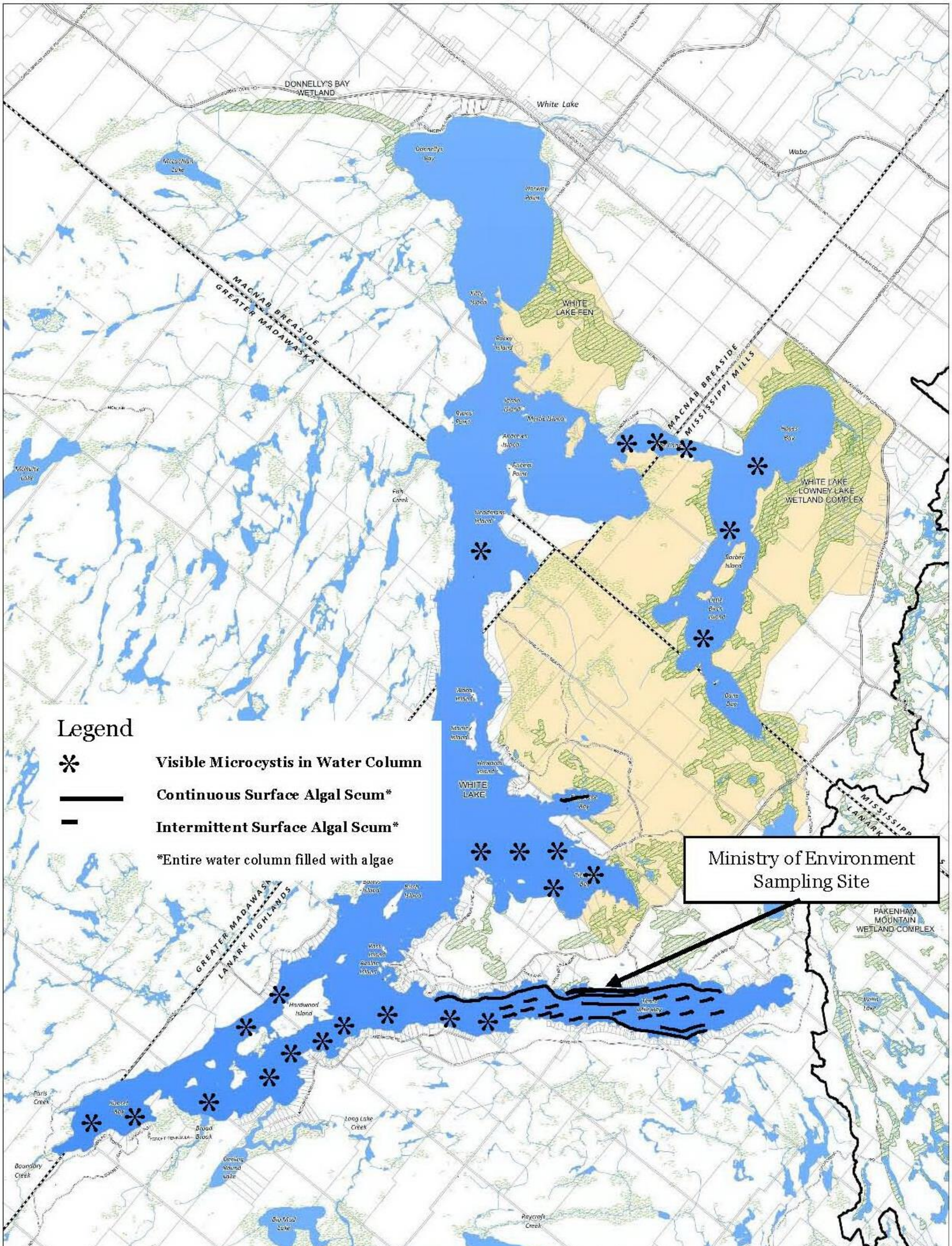
1.3b <u>Blue-Green Algal Blooms</u>

Blue-green algal blooms are not benign and so warrant special attention. When these blooms occur, they can create a public health hazard and anyone using the lake should be apprised of the seriousness of this issue. This year, White Lake hosted two blue-green algal blooms. It may be no coincidence that these blooms took place on the most altered shoreline on White Lake.

The first bloom was discovered on September 13, 2018. The photos below show the nature of the bloom and its appearance both close up and from above in a float plane.



Extent of September 13, 2018 Microcystis Blue Green Algal Bloom



The map above shows the extent and distribution of the September 13, 2018 *Microcystis* blue-green algal bloom. The algal bloom was most intense on the north shore of Three Mile Bay, but was present right across to the south side of the bay. In most of Three Mile Bay colonies of *Microcystis* were clearly visible from the surface of the lake all the way down to the lake bed.

In another part of the lake, a much smaller but similar bloom was present on the north shore of Thumbnail Bay. Elsewhere (*), smaller populations of *Microcystis* were observed, but these had not yet reproduced to the point of producing surface scum. The bloom lasted approximately 10 days at which point the algae had dissipated.

Note that monitoring the extent and longevity of an algal bloom requires much time and effort. Although we try to provide current up to date information, we would need more volunteer help to provide a complete picture of any algal bloom. For blue-green blooms, the Leeds, Grenville and Lanark District Health Unit provides a useful guide for individuals to use in assessing when water becomes safe to use after a toxic bloom is identified.

A second blue-green algal bloom was observed on October 10, 2018. Using microscopy, we identified this bloom as *Microcystis*. The occurrence of this bloom as well as photomicrographs of the algae was reported to the Ministry of the Environment. An incident number was assigned, but the MOE declined to return to White Lake for another round of sampling and analysis. Citing costs, the MOE informed us that they are limiting samplings to one per year per lake.

Although we have no data to show that the bloom was toxic, it is highly likely that it was considering that the nature of this bloom was the same as the September 13, 2018 bloom and occurred at the same location.

We know from samplings along the north shore of Three Mile Bay that this bloom was as extensive as the September 13, 2018 bloom.

This bloom persisted in the water column for several weeks after surface scum dissipated. Filtered water samples showed that even after three weeks *Microcystis* not only dominated the algae profile in lake water, it was in fact the only algae present! Note that zebra mussels promote the growth of *Microcystis* blue-green algae.

1.3c Algal Bloom Trends in Ontario

Climate change and other stressors have resulted in algal blooms becoming more frequent, occur earlier in the year and persist for longer periods of time. This is a trend reported in the literature and on government web sites.

White Lake is now at capacity which means that any additional input of nutrients makes it more likely that algal blooms will occur. White Lake is a shallow warm water lake and thus is more vulnerable than most lakes in Ontario to both natural and man-made pressures. **We need to do our part in controlling and reducing our impact on White Lake**, especially when other stressors not under our control are intensifying.

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.

A recent article in *Cottage Life* magazine (September 21, 2018 issue) reported that Lake Muskoka in Ontario had experienced its sixth confirmed toxic algal bloom in 2018.

Although other lakes in addition to White Lake are now having more algal blooms, this is no reason for us to be complacent or to consider that this is 'normal' and should not be of concern.

In the *Cottage Life* article cited above, it clearly states that "While blue-green algae blooms aren't new, they're becoming more frequent as cottage-country areas grow"

> Cottage Life: "Cottagers can do their part by being mindful of their environmental impact. Maintaining a natural shoreline is one easy way to prevent excess nutrients from getting into your lake."

1.3d Algal Blooms on White Lake – Historical Data

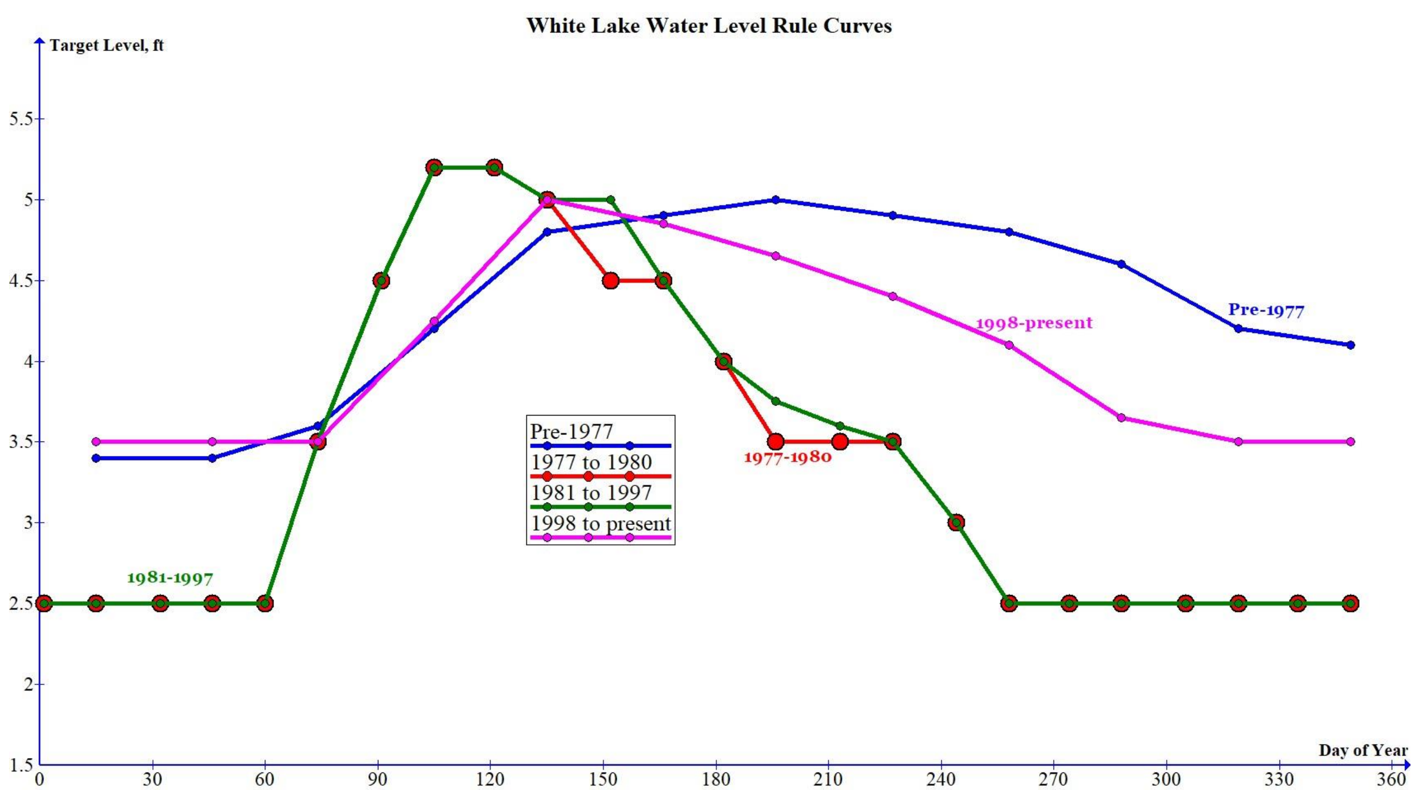
It has been brought up on several occasions at public forums that in the past there were regular lake-wide algal blooms. These comments may be valid, but should not be used to imply that algal blooms in White Lake define its natural state, and so the more recent blooms are nothing to be concerned about.

These comments stem from written reports before and during the 1970s of regular algal blooms on White Lake. These blooms are reported in the literature and require a more rigorous analysis of facts when comparing them to more recent algal blooms.

There are several factors which at that time resulted in (likely green) algal blooms. These include:

1. Water Regime – water levels over the summer months
2. General use of phosphate detergents and related products
3. Poor performance of existing septic or other waste disposal systems

Below is a graph showing the varying water regimes which have been operative on White Lake:



The data used for the above graphs was taken from a paper written by H. von Rosen, Fisheries Management Officer, Carleton Place District, 1989.

The graph shows that up to 1977, water levels in White Lake were kept high (in order to satisfy the desire of the local population for boating purposes). In that report, von Rosen states that within two years of the initiation of this regime that *"midsummer algal blooms appeared, leaving green slime on the shores; rock rubble was covered with calcareous algae"*. Water levels in the lake essentially impeded the turnover of waters in the lake resulting in these algal blooms. Fish populations also suffered. He also states in his paper, that once a change in water regime is made, it takes approximately five years for the change to totally take effect. The current water level regime used is intermediate between very high and very low water levels perhaps giving us the most satisfactory results possible.

Interestingly, on page 10 of the report, von Rosen felt comfortable stating: *"In spite of attempts to explain the ecological reasons for the water regime public reaction to this water rule curve was best described as hostile"*.

During the 1970s, Canada went through the process of banning or reducing phosphates in detergents and other products. It is likely that the high-water level regime in place during the time when phosphates were permitted and used widely, also contributed to the production of algal blooms on White Lake. This source of phosphate is much reduced, although still present today.

In 1973, the White Lake Water Quality Committee conducted a massive sampling of White Lake waters for coliform bacteria. They collected and had analyzed 375 samples on three different occasions. The results of this study were released the same year.

When compared to coliform counts recorded in more recent times (WLPOA studies), the counts were significantly higher in the mid-1970s. This was likely due to the large number of septic or waste disposal systems which were underperforming relative to today's standards. This source of phosphorus would also have been a significant contributor to the algal blooms reported during this time period.

Today the nature and cause of algal blooms in White Lake are quite different as is discussed here and in other parts of the report. We will not elaborate on this further other than to say that outflow from septic systems, the change in phosphorus cycling by zebra mussels, climate change, year-round use of cottages as residences, increased boating effects, shoreline degradation, invasive species and exposed surface runoff should now be the subject of our attention

1.4 What White Lake is Telling Us and Why We Should Be Listening

For the past 5 years the White Lake Preservation Project has been executing extensive and systematic studies of water quality. We have also worked on a number of projects designed to better describe White Lake and understand how water enters, moves around and leaves the lake during the year. Other work has given us insight into the nature and influence of waters entering the lake from streams as well as springs. We have also studied phytoplankton and zooplankton populations and how these have changed during this five-year period.

An important topic has been invasive species and the effects these have on the lake. In particular, the five-year study period we are reporting on straddles the infestation of White Lake with zebra mussels.

We have reported all of our work in a series of annual reports which have been bolstered by accompanying reports from the Mississippi Valley Conservation Authority and Watersheds Canada. Our writing has been enlightened and underpinned by an abundance of published scientific research papers, and all of our reports have been read and vetted by limnologists from government, universities, NGOs, conservation authorities and the private sector.

We now are able to see some trends in the data we collect and are in a position to offer the reader a synopsis of what we have learned and what we believe is in store for White Lake should we, as stewards of the lake, decide to adopt a wait and see attitude. Our long-term goal is to inform and to educate anyone interested in the health of White Lake and to motivate them to take the necessary action to ensure the survival of the lake into the future.

1.4a White Lake

White Lake is a shallow warm water lake. One of its distinguishing characteristics is that it is a wetlands lake surrounded in many places by marshlands. The average depth of White Lake is a mere 3 metres and the lake turns over less than once per year. This is a bit like flushing a toilet once per year! The implication is that nutrients and pollutants entering the lake essentially stay in the lake. Because the lake sits on top of limestone and is bordered on the south by calcium-containing rocks, the waters are an inviting habitat for zebra mussels, which have now found a permanent home in White Lake.

1.4b What About Total Phosphorus?

Recent research has made clear two vital facts related to total phosphorus:

- White Lake is at capacity and cannot handle more nutrient input.
- Zebra mussels have changed the way phosphorus is cycled in White Lake.

The consequences of both of these facts is that we now have or are likely to have more algal blooms; some of these will be toxic. This year, 2018, is a good example because White Lake experienced a minimum of 5 algal blooms, two of them toxic.

Total phosphorus levels are currently about half of what they were before zebra mussels arrived. What gives? Why are we still having algal blooms?

The answer lies in what algae eat and what zebra mussels eat.

Total phosphorus is the sum of a number of different phosphorus-containing components including plankton and other particulate matter plus phosphorus dissolved in water.

The diagram below shows the two categories of phosphorus which added together gives total phosphorus:

Total Phosphorus =	Plankton and particles containing phosphorus This fraction is about 50% of total phosphorus **This is what zebra mussels eat!**....about 90% of what is in the lake. Result: Clear water!	PLUS	Dissolved phosphorus from septics, shoreline runoff, sediments This fraction is about 50% of total phosphorus **This is what algae eat!** Result: Algal Blooms!

Zebra mussels effectively transfer most of the phosphorus in the blue box above to the shoreline where they live. This phosphorus would normally end up in sediments in the middle of the lake.

In the end, the amount of phosphorus available for algae to grow HAS NOT CHANGED even though the total phosphorus concentration we measure in water samples has been reduced by 50%!

1.4c What Happens to All of That New Phosphorus at the Shoreline?

Zebra mussels are filter feeders and they very efficiently filter out all of the particles containing phosphorus (green box above). They then excrete most of it to the sediments just below them.

The result of adding all of that extra nutrient load on the sediments is to encourage the growth of green algae such as the filamentous green algae which is now common. It also encourages the growth of blue-green algae, especially one called *Microcystis* which does form toxic algal blooms. <u>We have had two such toxic blooms just this year</u>.

Let's review how zebra mussels have changed White Lake:

Zebra mussels change the way phosphorus is cycled in the lake.

Zebra mussels transfer phosphorus from open lake water to near-shore waters and sediments.

Zebra mussels also change the composition and chemistry of near-shore sediments.

Zebra mussels do not remove the type of phosphorus responsible for algal blooms in the rest of the lake.

Zebra mussels promote growth of green and blue-green algae along shoreline.

Now, what does the scientific literature predict would happen to White Lake once zebra mussels arrived?

Published Literature Predicts	White Lake Observations
Marked decrease in total phosphorus levels	Decrease in TP by about 50%
Significant increase in water clarity	Water clarity more than doubled
Density and extent of aquatic plants along shoreline will increase	Marked increase in density of aquatic plants along shoreline
Shoreline water will become very clear especially in calm weather (no waves)	Where zebra mussels are present, water becomes crystal clear along shoreline
Microcystis blue green algae favoured over *Anabaena* blue green algae	2018 White Lake experiences first two recorded *Microcystis* algal bloom
Toxic algal blooms will occur at relatively low TP concentrations	2018 toxic (25 ppb toxins)* algal bloom in Sept. when TP was <10 ppb
Filamentous green algae will increase significantly	Filamentous green algae blooms are now common and extensive

*Drinking water limit: 1.5 ppb; Recreational limit: 20 ppb

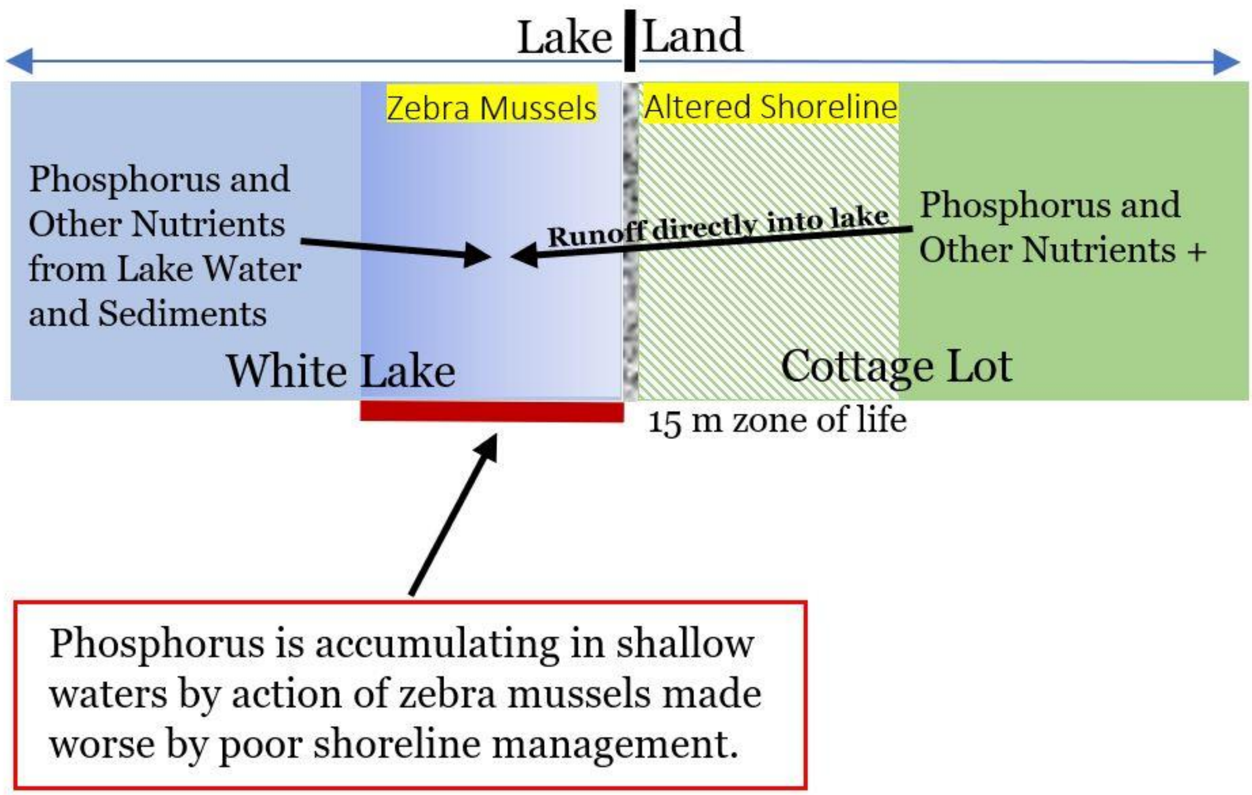
1.4d What is Happening Now to White Lake?

White Lake is currently under stress not only from the various pressures placed on it by human activities, but also by other factors including climate change and invasive species such as the zebra mussel. Some of these pressures are incremental like cottage conversions to permanent homes and some of these pressures are more dramatic as is the case of zebra mussels.

Below is a diagram which attempts to summarize the net effects of many of the factors discussed above. The blue square on the left represents White Lake and the lighter blue portion represents the near-shore environment where we generally have our docks, swim, fish, etc.

The green square on the right represents a typical cottage lot and the cross-hatched green portion the area of the shoreline sometimes referred to as the 15 metre zone of life.

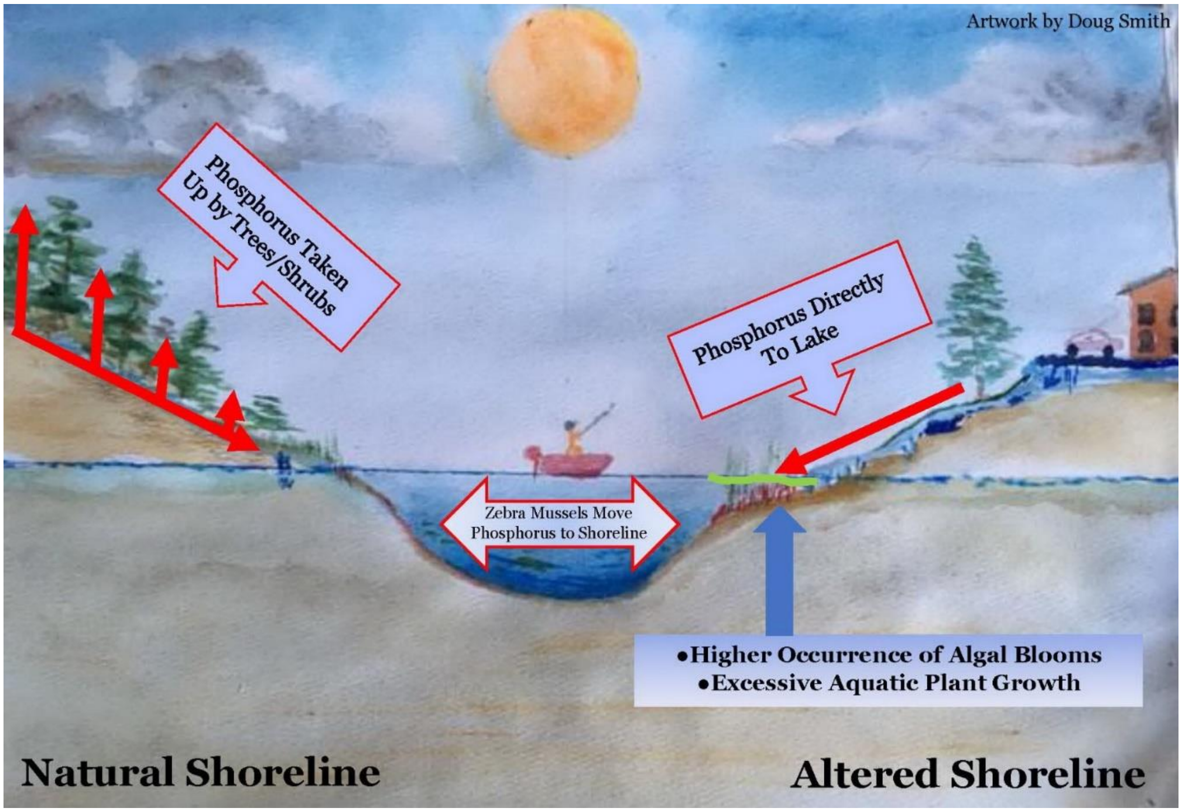
What the diagram shows is that one very important nutrient input to the near-shore environment that we can control is the maintenance of a healthy shoreline. Ignoring setbacks, clearing trees in favour of lawns, etc. all increase nutrient runoff into the lake.



1.4e What Do We Have to Lose?

This year we experienced two toxic blue-green algal blooms centered on altered shorelines. It is difficult to predict if we will have more next year or the year after that. What we do know is that as White Lake becomes more stressed, the probability of more blooms will increase.

The diagram below shows in a simplified way what happens when we alter a shoreline and interfere with nature's way of handling phosphorus and other nutrients. On the left we have a natural undisturbed shoreline showing phosphorus taken up by trees and other vegetation, preventing it from reaching the lake. On the right we have an altered shoreline providing no buffer for phosphorus and other nutrients allowing these to reach the lake unimpeded. The results are plain to see: more aquatic plants and algal blooms!

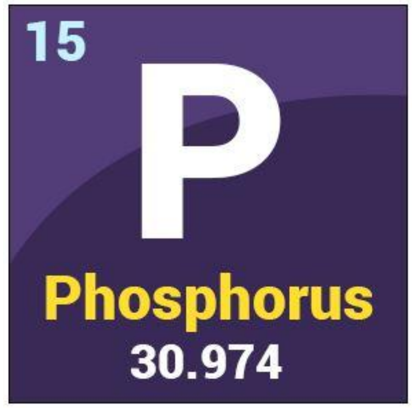


If we choose to ignore the signs, we could be headed for: 1) Higher frequency of algal blooms; 2) Earlier occurrence of algal blooms; 3) Greater extent of algal blooms; 4) Longer duration of algal blooms; 5) The release of massive quantities of phosphorus from lake sediments resulting in permanent algal blooms, loss of recreational use, lower property values and tax revenues.

The choice is ours to act and protect White Lake for ourselves and future generations.

2.1 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 nanograms/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, particles containing phosphorus, dissolved inorganic and organic phosphorus compounds pass through the filter and are measured together as total phosphorus. 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.

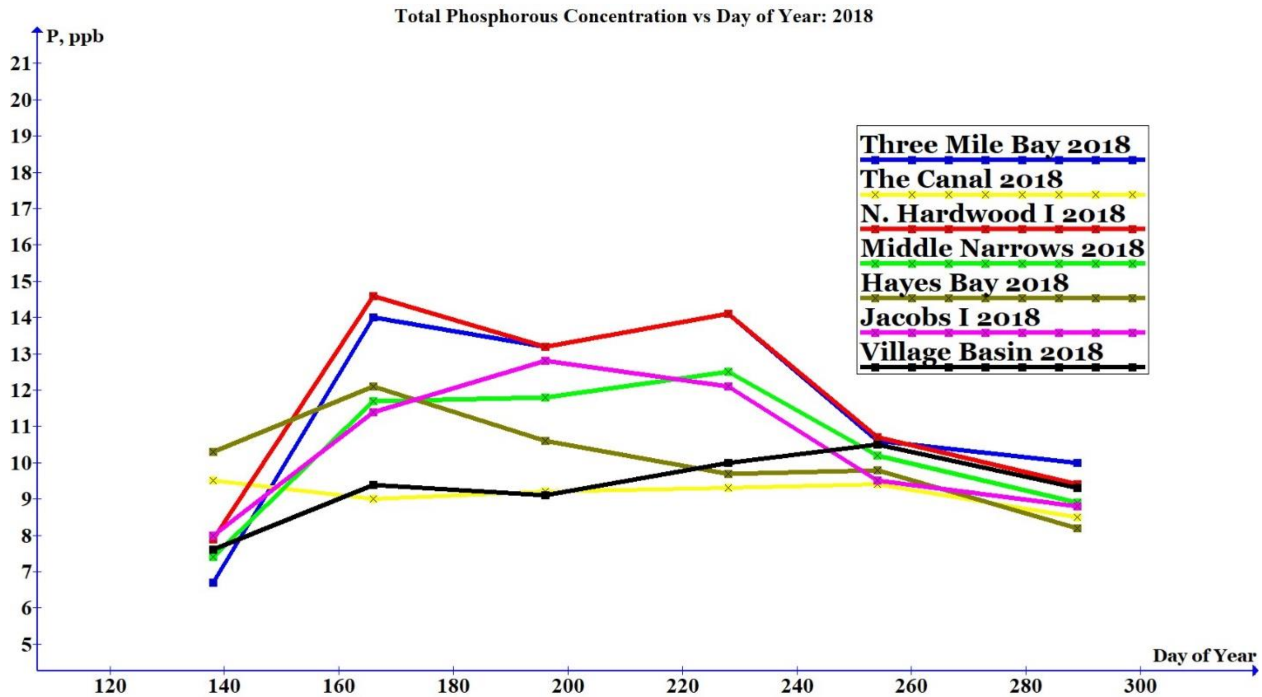
Since zebra mussels have established themselves in White Lake, the total phosphorus concentrations measured in the lake have decreased by about 50%. This is because zebra mussels are filter feeders and they very efficiently remove all particulate material (down to 1 micron) containing phosphorus. The phosphorus which remains in solution is not filtered out by mussels, but remains available for algal growth. In effect, even though overall phosphorus concentrations have diminished, the amount of phosphorus which algae feed on has not changed at all. Therefore, the total phosphorus concentrations we are now obtaining (much lower than before) do not reflect a reduced risk for algal blooms!

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 2018.

The graph below shows the change in total phosphorus concentrations during the 2018 ice-free season.

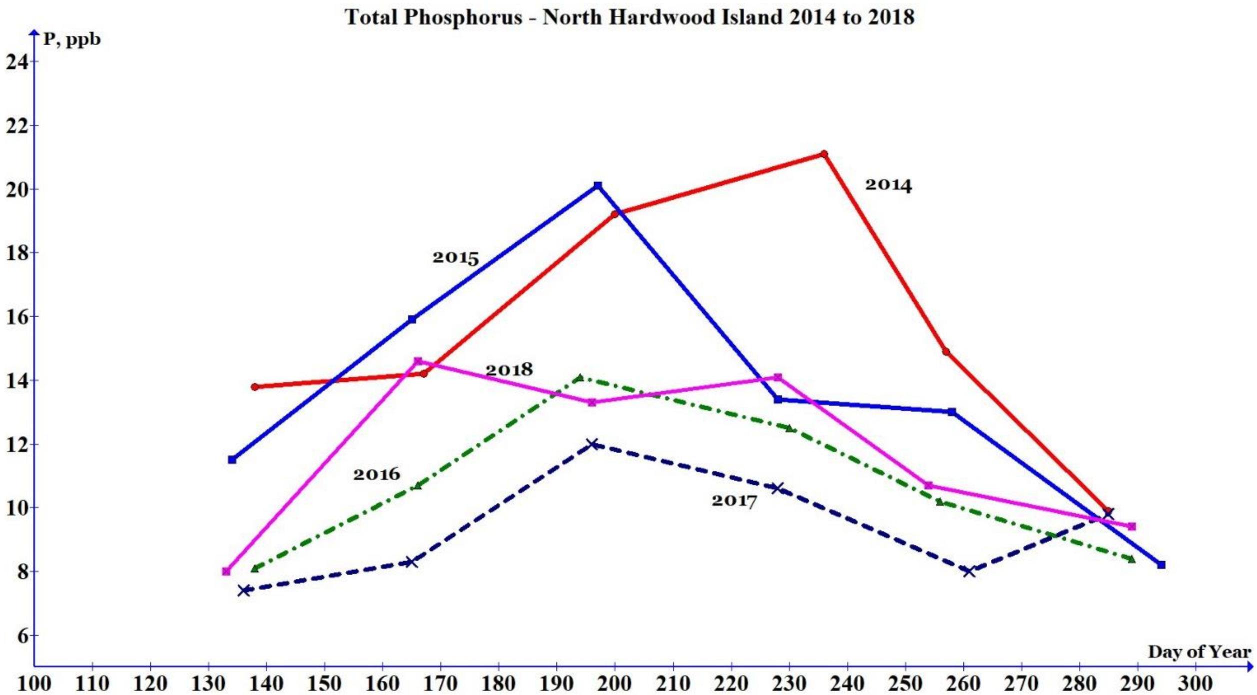


The data for 2018 (above) show an increase in the total phosphorus concentration over the summer months reaching a peak or highest value in mid-June. This is about one month sooner than observed for previous years starting in 2015. After this date, the total phosphorus concentration decreases and then even shows a slight increase before decreasing again at the end of summer. 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.

North Hardwood Island is the only sampling site for which we have five consecutive years of data. The graph below shows the trend in total phosphorus concentrations over this time period.

Total phosphorus concentrations declined significantly from those in 2015 starting 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.

In 2018, the trend has apparently reversed with higher concentrations for total phosphorus at the beginning of the summer when compared to the two previous years. Concentrations however, are still much lower than for 2015. We believe that the 2018 data was influenced by two separate phenomena: 1) 2018 was an especially hot year with water temperatures about 2 degrees higher than any of the four previous years; 2) for some unknown reason, zebra mussels did not produce a new generation in early summer as for the previous two years. Higher water (sec. 2.3) and hence sediment temperatures could have increased the amount of phosphorus released to the water column (internal loading) while at the same time less phosphorus was removed by zebra mussels. We are only speculating and data from future years will likely help us interpret these results.



Another trend appears to be the ‘peaking’ of total phosphorus at earlier dates during the ice-free season. In 2014, maximum total phosphorus was measured in mid-August; in 2016 and 2017 in mid-July, and in 2018; mid-June.

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-June or July (depending on the year), 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-June or 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 to 2018: 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 can remove over 90% of the phytoplankton normally found in an unaffected lake. Zebra mussels are efficient at removing particulate 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 both green and blue-green algal blooms in the future. We have already observed blooms of filamentous green algae in most parts of the lake for several years and this year two toxic blue-green algal blooms. One of these blooms was certified toxic and the second almost certainly was as well. The Ministry of the Environment is taking only one algal bloom sampling per year per lake as a cost saving measure.

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 low 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 the past died 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.

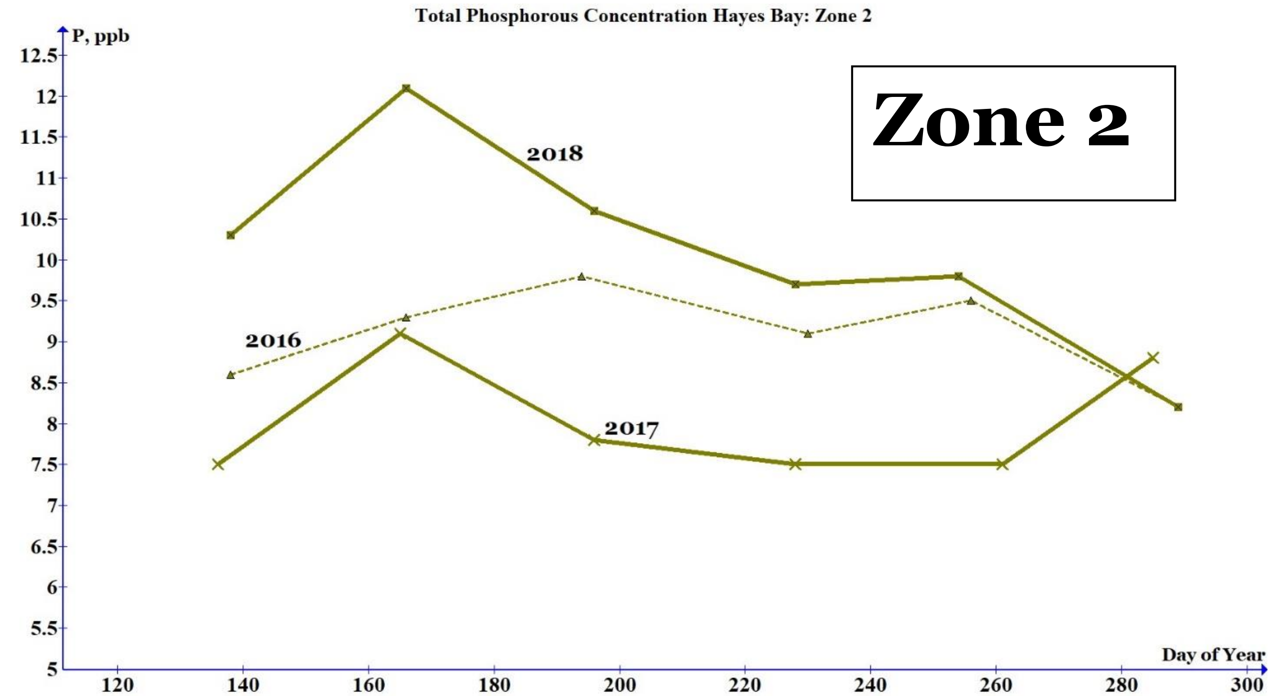
Oxygen levels in water and sediment contribute greatly to the availability of phosphorus for phytoplankton and algal growth. Phosphorus bound in sediments, organic sediment particles or chemically bonded to inorganic species such as iron oxide only remain chemically bound if there is sufficient dissolved 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 small 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.

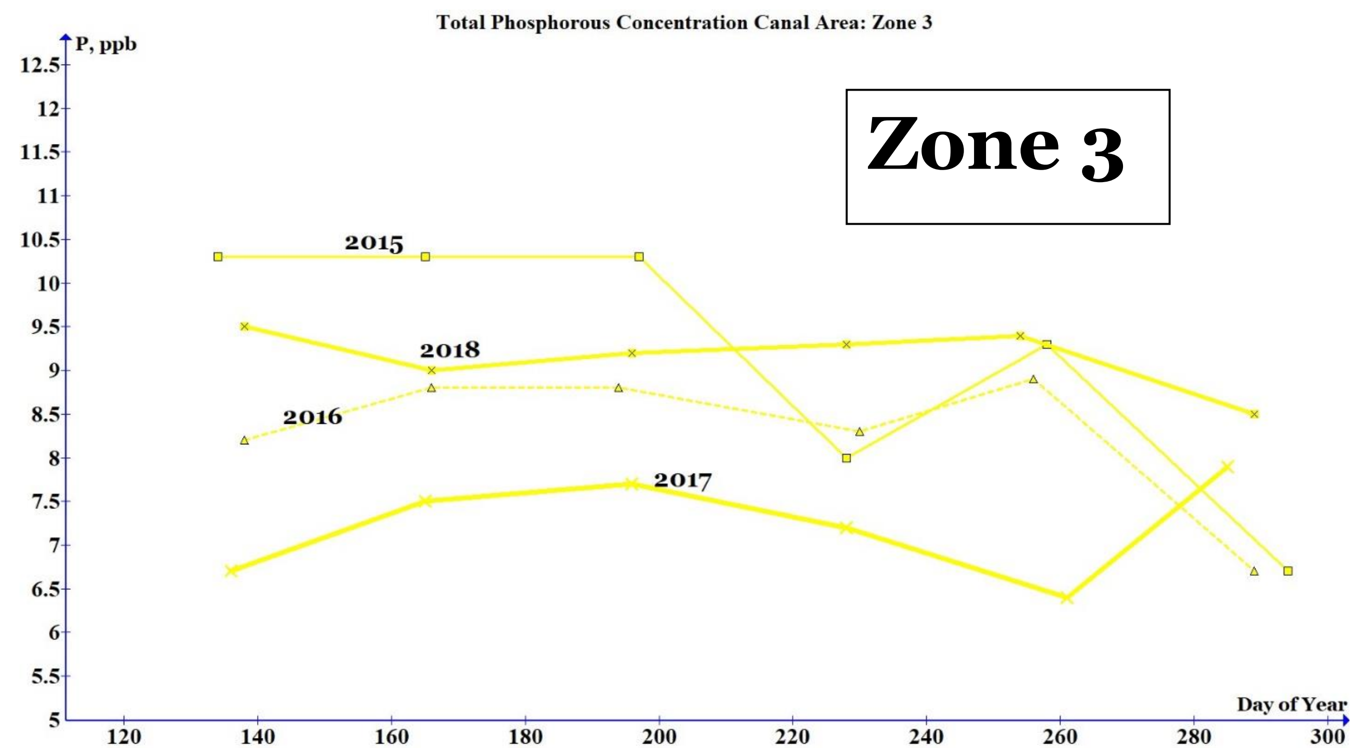
The interface between the bottom water of White Lake and the sediment is not as distinct or as sharp as one would imagine for a sandy-bottomed lake. White Lake has a muddy bottom. Organic matter settling out of the water column is generally in a very fine particulate form. When these particulates reach 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 increase in density.

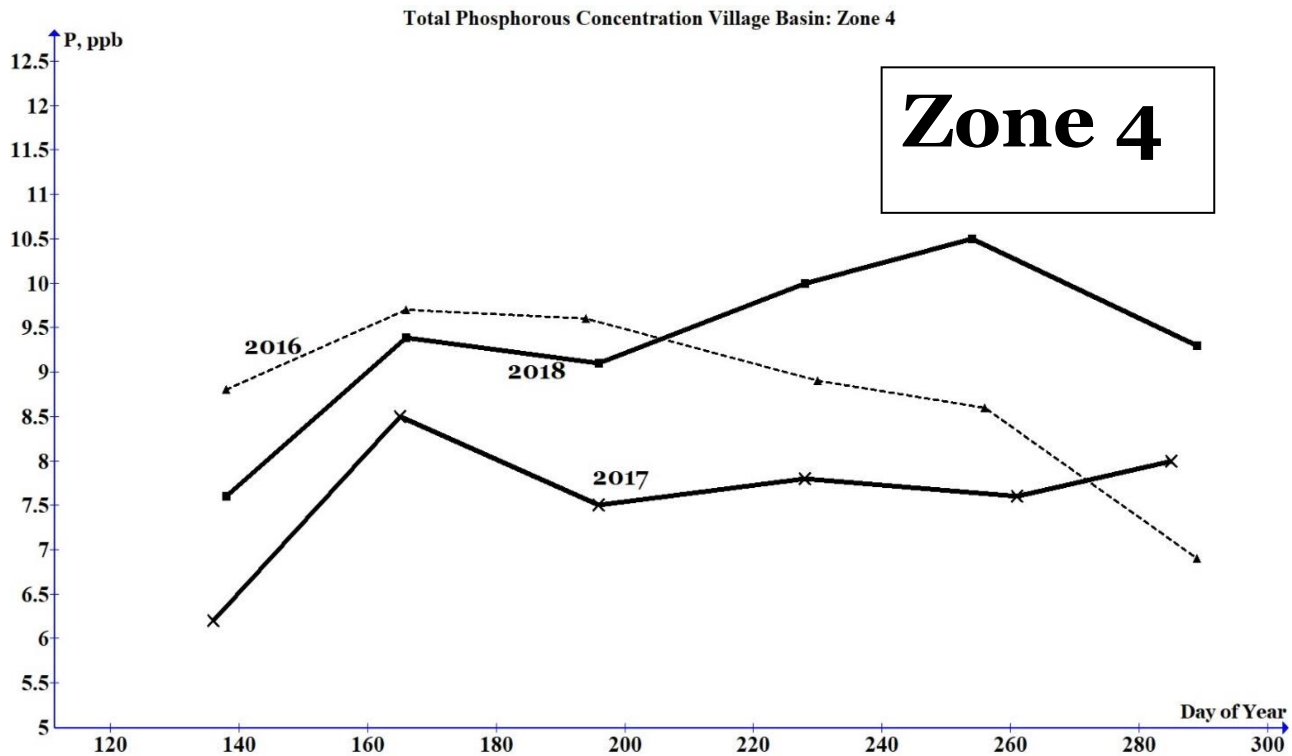
Anoxic (no dissolved oxygen) conditions were not detected in White Lake waters during measurements taken during the ice-free months of 2017. However, during these measurements, if the oxygen measuring probe was lowered into the initial layers of sediment, the oxygen content did drop considerably, especially 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 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.

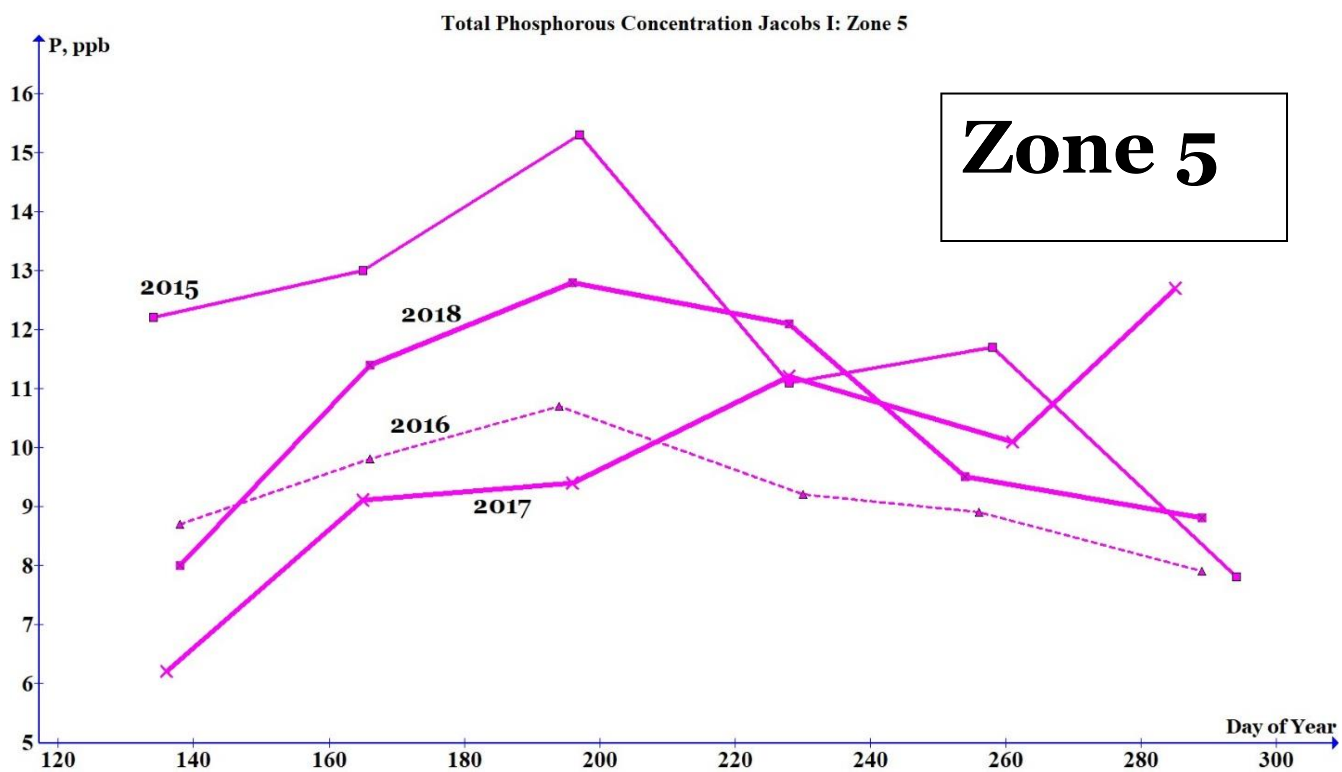
The release of phosphorus from sediments is also accelerated by an increase in water temperature over the summer season. During that time, bottom waters increase in temperature by about twenty degrees. The rate of chemical reactions (such as those releasing phosphorus from sediments) roughly doubles 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 increase accordingly with increases in temperature.

If we consider the graph above to illustrate trends in total phosphorus for North Hardwood Island as representative of all Zone 1 sites (and it is), it may be instructive at this point to consider trends in total phosphorus concentrations at other lake zones.


Total Phosphorous Concentration Hayes Bay: Zone 2
P, ppb
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
2018
2016
2017
Zone 2
Day of Year
120
140
160
180
200
220
240
260
280
300


Total Phosphorous Concentration Canal Area: Zone 3
P, ppb
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
2015
2018
2016
2017
Zone 3
Day of Year
120
140
160
180
200
220
240
260
280
300


Total Phosphorous Concentration Village Basin: Zone 4
P, ppb
Zone 4
2016
2018
2017
Day of Year
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
120
140
160
180
200
220
240
260
280
300


Total Phosphorous Concentration Jacobs I: Zone 5
P, ppb
Zone 5
2015
2018
2016
2017
Day of Year
16
15
14
13
12
11
10
9
8
7
6
5
120
140
160
180
200
220
240
260
280
300

All five zone maps show the same trend with 2018 total phosphorus values intermediate between those obtained during 2016 and 2017 and 2015 when the influence of zebra mussels had not as yet taken full effect.

The data for The Canal sampling site (Zone 3) shows consistently lower total phosphorus values than for all other lake zones. For the reasons discussed above, this is due to the effect of marl in removing some phosphorus from waters entering this site via springs in the lake floor.

Note that there are no 2015 total phosphorus data for zones 2 and 4 because these sites were added in 2016 at a later date than the original five sites sampled starting in 2015.

The table below is a compilation of total phosphorus data from the years 2015 to 2018. Shown are total phosphorus values obtained for the April 15 and October 15 sampling dates.

2.1a Trends in Total Phosphorus Concentrations

In the above discussion we showed how total phosphorus concentrations have been changing by day of year, from one site to the next, and over a period of five years. These trends are relatively easily explained using basic limnology concepts. They relate directly to the well documented effects of the presence of zebra mussels in White Lake.
There are, however, some less visible trends coming to light as we collect more and more annual data. One such example is the concentration of total phosphorus present at the very beginning of the ice-free season in May and again at the end of the season in October.

The table below is a compilation of data from the three sampling sites located within Zone 1 (Appendix 1) of White Lake. In the table are given the average values with accompanying standard deviations for data collected in mid-May and mid-October for the years 2015 to 2018.

Zone 1: Total Phosphorus (TP)		
Year	**TP, ppb; May 15**	**TP, ppb; October 15**
2015	10.4 ± 1.3	8.1 ± 0.6
2016	7.8 ± 0.7	8.0 ± 0.5
2017	7.7 ± 0.2	9.2 ± 0.9
2018	7.4 ± 0.6	9.6 ± 0.6

At the beginning and at the end of the ice-free season, we observed the highest water clarity, and especially so in October. In the Spring, total phosphorus levels are just beginning to rise as the water column becomes well mixed and homogeneous. In the fall, most of the particulate material (plankton, etc.) has died and precipitated to the bottom of the lake.

In the opening sections of this report, we stated that total phosphorus is a combination of phosphorus-containing particles (including plankton, etc.) and phosphorus compounds dissolved in the water column. At the beginning and end of the ice-free season, the largest proportion of the total phosphorus is present as dissolved phosphorus compounds.

The data in the above table indicates that in May, the total phosphorus measured in Zone 1 has *decreased* significantly from 2015 to 2018. A net decrease of about 3 ppb is observed. For the October sampling date, the total phosphorus measured has *increased* by about 1.5 ppb during the same time frame.

Without more data, it is difficult to explain this phenomenon. It could be that because of earlier ice-free dates caused by climate change, that by May 15 a larger proportion of dissolved phosphorus has been taken up by phytoplankton (> 80 microns in size) and is filtered out of the sample taken for total phosphorus analysis. This could explain the decrease in total phosphorus concentrations observed.

Conversely, by October 15 it could be that warmer weather allows for more dissolved phosphorus to enter the water column from sediments. This would result in an increase in total phosphorus concentrations measured in the water column. Also, dissolved phosphorus compounds are excreted by zebra mussels, which may also contribute to this trend.

Sampling sites in Zones 2 to 5 generally show the same trends as for Zone 1, however to a lesser extent. We will continue to monitor these data in the coming years and see if these trends can be corelated to weather or other factors affecting nutrient levels and life in White Lake.

Diatom: Navicula Radiosa
A resident of White Lake

2.2 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 increased by 138%! At locations further away from shorelines, the Secchi depth (see box on right) has increased by about 109%. In the middle of the lake, the increase is about 95%.

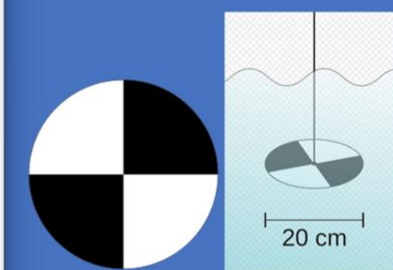
In July of 2015, the Secchi depth in Three Mile Bay was 2.1 metres and by July 2018, the Secchi depth had increased to 5.0 metres. We are now measuring Secchi depths of over 9 metres at some locations. So what?

Water clarity on the surface appears to be a good thing. However, there are some important consequences to consider, especially since the increased clarity is due to the presence of zebra mussels in White Lake:

- 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 in clear water.
- 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?

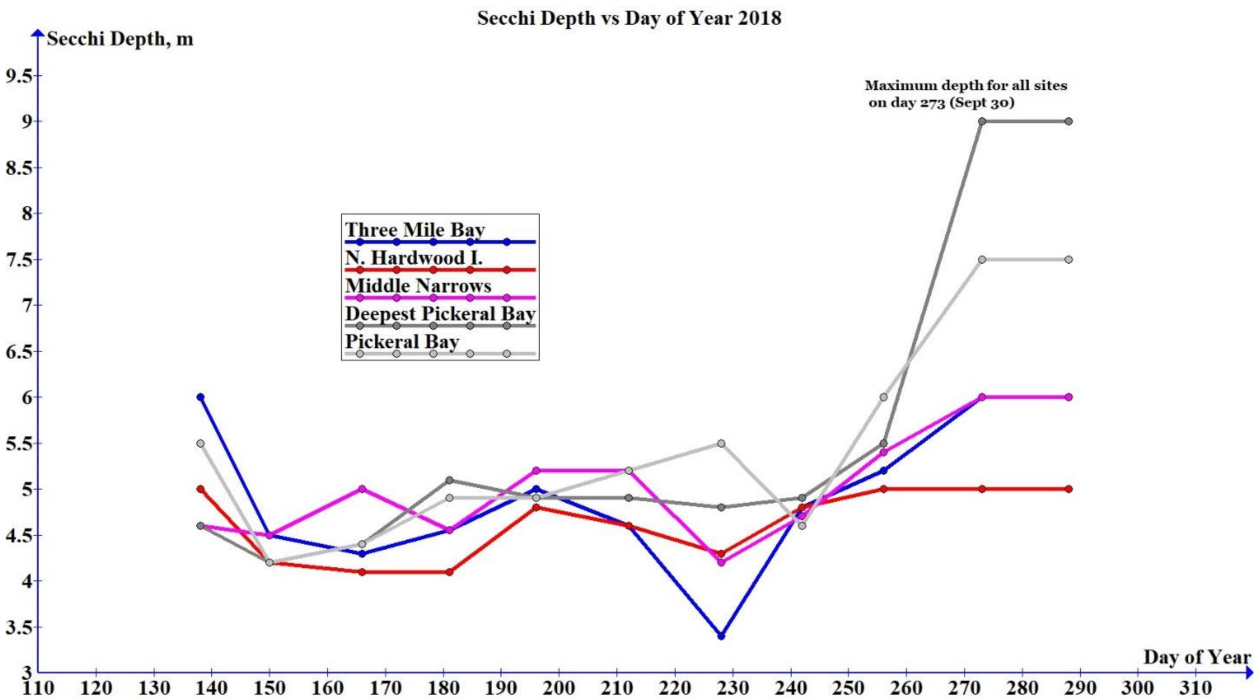
The Secchi depth is a measure of the clarity or transparency of the water. The Secchi disk, named after an Italian scientist, is used to make the measurement. The disk is segmented black and white and 20 cm in diameter:



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 2018 ice-free season.

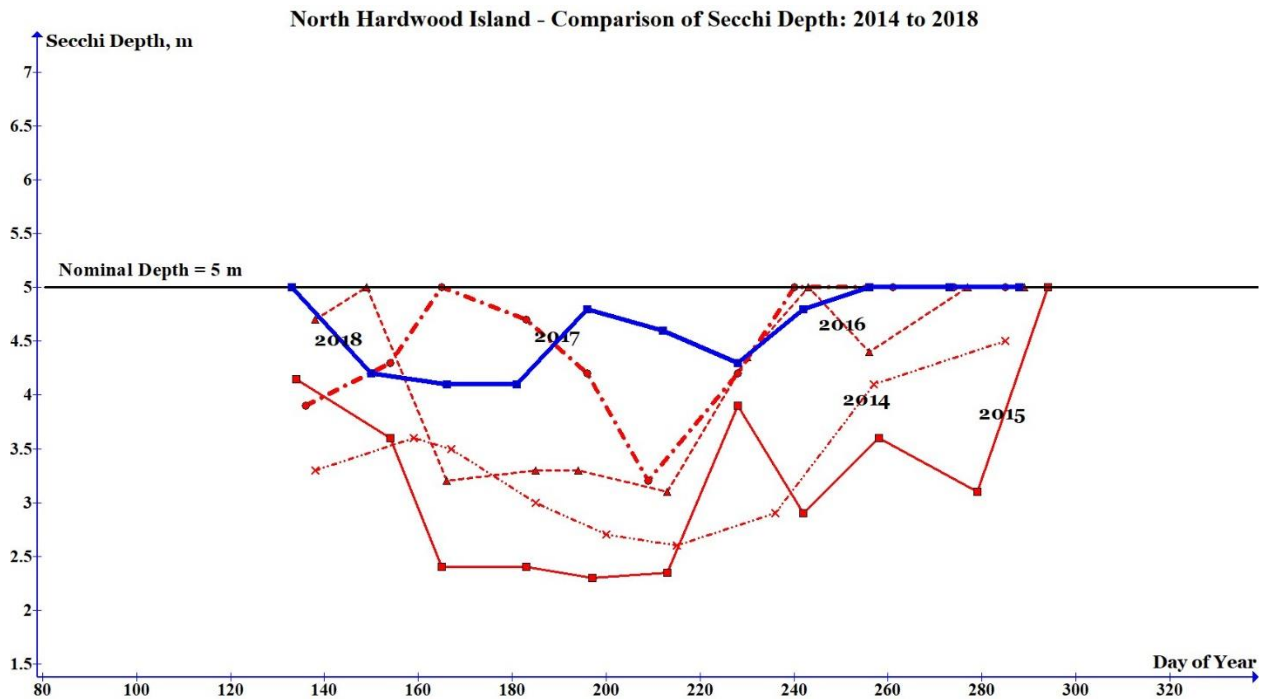


The pattern of Secchi depth readings is similar to those observed during previous years. Secchi depths increase as the lake water column becomes uniform in temperature and then decreases as the temperature of the lake increases. At higher temperatures there is more biological activity as well as supply of nutrients. Minimum Secchi depths (lowest water clarity) were achieved sometime during the last week of August, 2018.

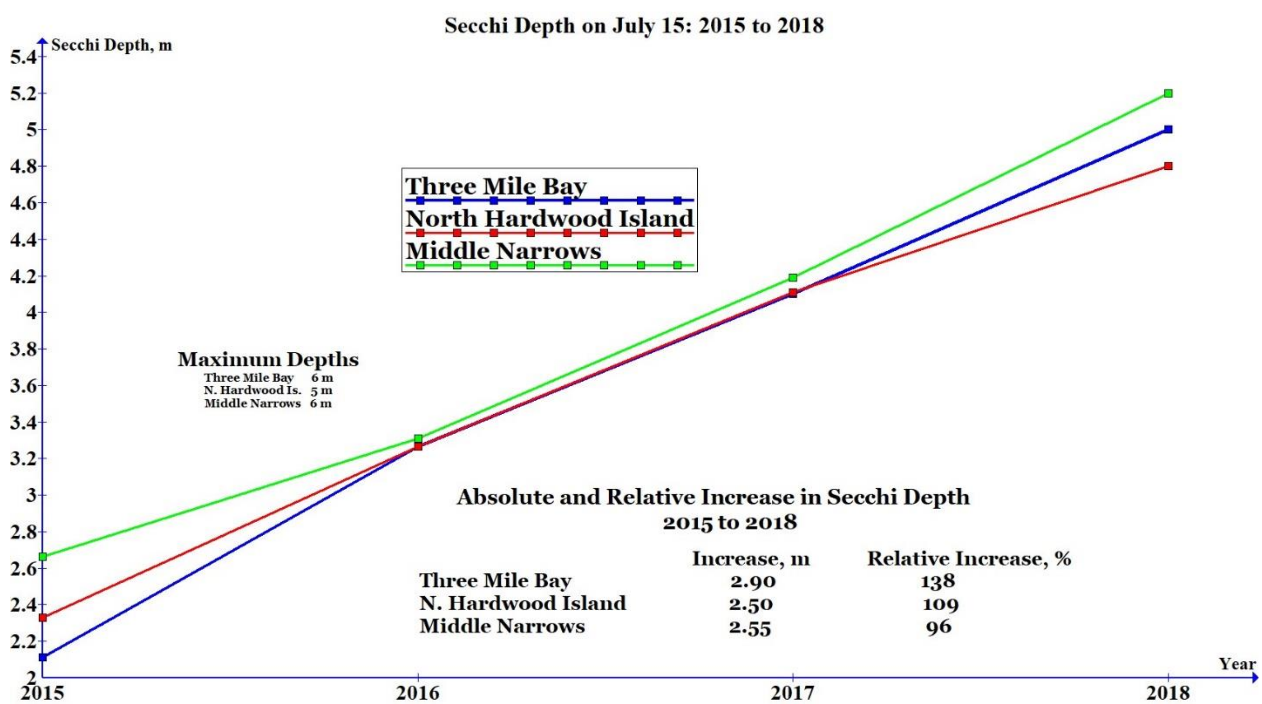
Of the nine sites we sampled, there were only five that had measurable Secchi depths. The remainder of sites were too shallow or the water was too clear at all times.

The figure below shows Secchi depth data for the North Hardwood Island site taken during five consecutive years from 2014 to 2018. The 2018 data line is highlighted in red.

The data show that from 2014 to 2018 the Secchi depth readings have been steadily increasing, especially since the introduction of zebra mussels in White Lake in 2016. Weather, including water and atmospheric temperatures, can influence plankton growth, and hence the Secchi depth, and so it may be difficult to quantitate the trends from one year to the next.



One way to look at this data is to plot the Secchi depth readings taken in mid-July for the years 2015 to 2018.



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 96% since 2015; 109% at the North Hardwood Island site and a whopping 138% 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. The slope of the lines in the above graph are still positive and so water clarity continues to increase every year. At some point in time, this slope is expected to decrease to approximately 1, at which time the lake will have reached equilibrium in term of water clarity.

2.2a <u>Frequency of Secchi Depth Readings Exceeding Sampling Site Depth</u>

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 (because the water was too clear for its depth) at each of the five deep water sites we monitor on a regular basis.

Sampling Site	**Max. Depth, m**	**2015**	**2016**	**2017**	**2018**
Jacobs I.	4.0	2	8	11*	11
N. Hardwood I.	5.0	1	3	5	5
Middle Narrows	6.0	0	1	2	2
Three Mile Bay	6.0	1	2	5	3
Pickerel Bay	7.5	0	0	1	2
Total		4	14	24	23

*maximum number of measurements made per year

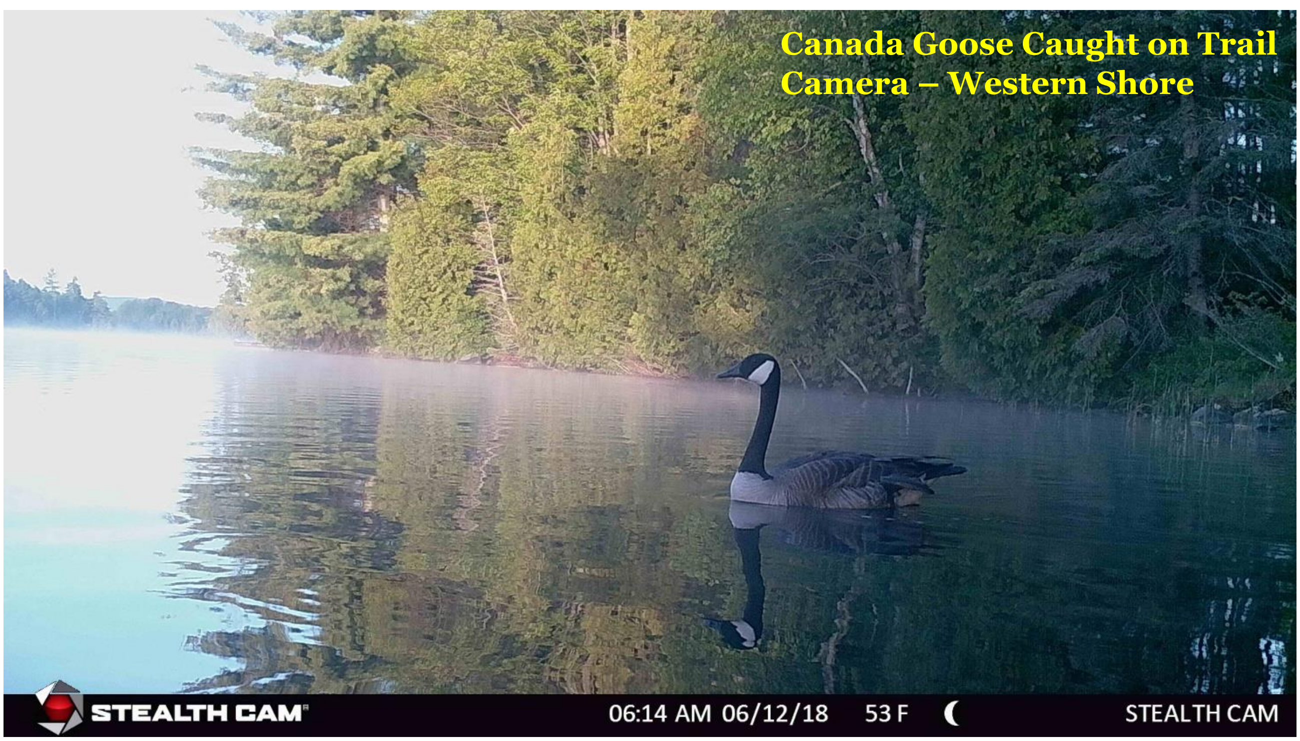
These data show that for any given sampling site, the number of times the Secchi depth could not be read because of water clarity increased with each year up until 2018. For example, for Jacobs I., in 2015, there were only two occasions out of a possible 11 that the Secchi depth exceeded the water depth at the site. This increased to 8 times in 2016 and finally 11 in 2017 and 2018. Looking at the total number of times Secchi depths could not be read for all sites combined, these increased from 4 in 2015, then to 24 in 2017, and 23 in 2018.

Finally, we can 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**	**2018**
#/max #	3/11	7/11	10/11	9/11
Percent	27.3%	63.6%	91.0%	81.8%

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.

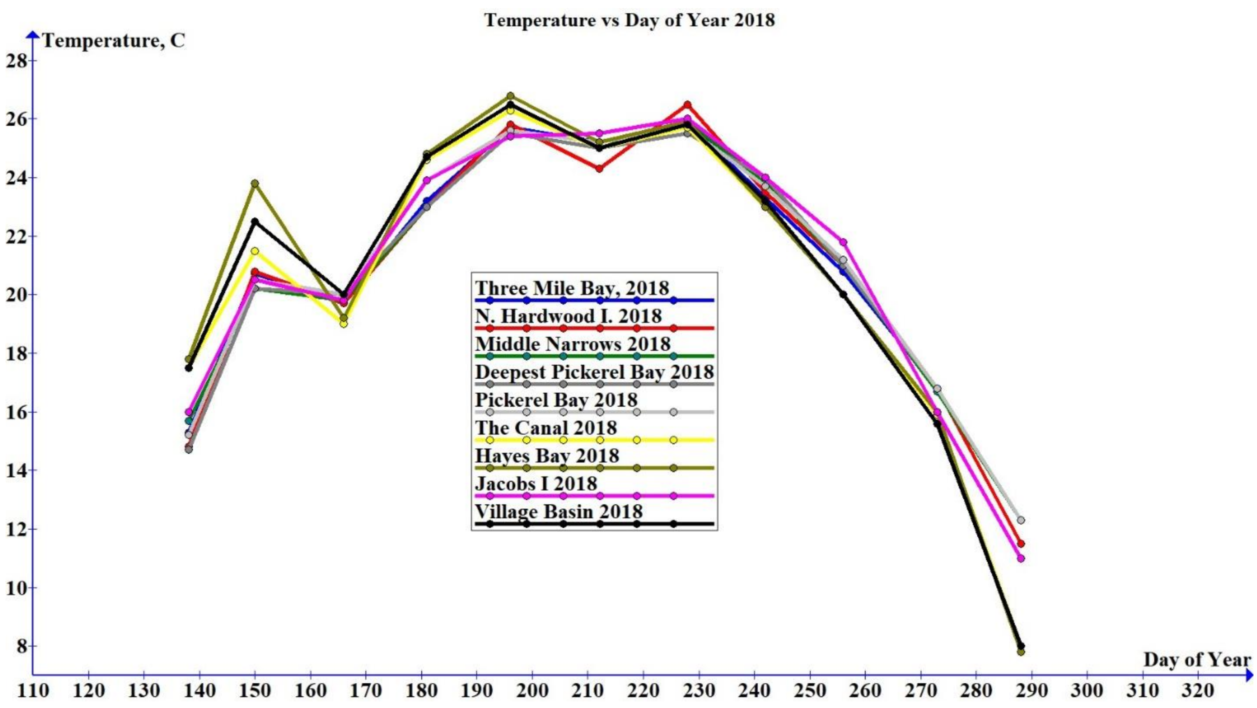
The results contained in the above table indicates that in 2018, the percentage of time during daylight hours that sunlight could penetrate to the bottom of the deepest part of the lake was 81.8%. Since less than 10% of the lake has a depth of 9 m, this means that only about 1.8% of the surface of the lake floor was 'dark' during the summer months. Put another way, more than 98% of the lake bottom now receives sunlight and is subject to increased plant and phytoplankton growth.



2.3 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 or internal 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. Data is taken from the 11 lake-wide water temperature maps located in Appendix 3 of this report.



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). The noticeable ‘dips’ in temperature on day 166 (June 15) and on day 212 (July 31) are correlated with significant rain events one to three days prior to sampling. Cooler waters resulting from rain enters the lake via springs in the floor or the lake. Not evident in the figure above, are differences in temperatures at 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, 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 Water Quality Monitoring Program Report available on our website www.WLPP.ca.

The table below gives the Zone location for both the low and high lake temperatures recorded for each lake sampling date.

Date	Low Temp.	Zone		High Temp.	Zone	Difference, ◦C
May 18	14.7	1		17.5	2	2.8
May 30	20.2	1		23.8	2	3.6
June 15	19.2	2		20.2	1	0.8
June 30	23.0	1		25.4	2	2.4
July 15	25.6	1		27.0	2	1.4
July 31	24.3	1		25.7	2	1.4
Aug. 16	25.4	2		26.5	1	1.1
Aug. 30	23.0	2		24.0	1	1.0
Sept. 13	19.8	2		20.8	1	1.0
Sept 30	15.8	2		17.0	1	1.2
Oct. 16	7.8	1		12.3	2	4.5

Zone 1 = Main Water Body; Zone 2 = Hayes and Bane Bays

This data shows that the largest differences in temperature occur at the beginning and again at the end of the ice-free season with a maximum difference of 4.5 ◦C.

Starting in June and until the end of September, the temperature range between low and high temperatures in White Lake is close to 1◦C.

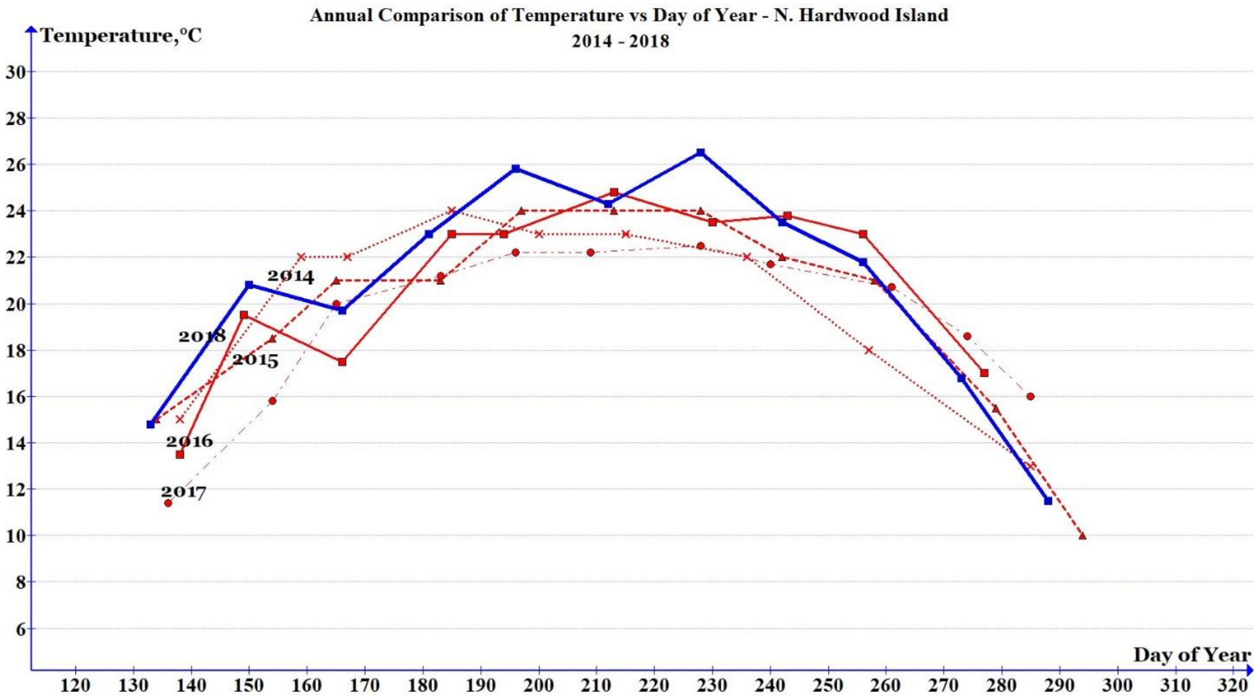
It is not surprising that, depending on the date, the high and low water temperatures are either found in Zone 1 or Zone 2 of White Lake. Zone 1 comprises the deepest parts of the lake which would both heat up and cool down more slowly than shallower parts of the lake. Zone 2 comprises the shallowest parts of the lake with an average depth of approximately 1.5 m. At this depth, waters in Hayes and Bane Bays would both cool and heat up more quickly than in Zone 1 or any deeper location on White Lake.

2.3a Annual Trends in Lake Water Temperatures

Although there are 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 (see previous reports at www.WLPP.ca). This indicates, along with the other data in this section, that the temperature regime of the lake is quite regular from year to year, but may be subject to change due to local climatic conditions.

For example, the 2017 data shows that lake water temperatures were 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 explain this observation.

We now have five consecutive years of water temperature measurements for the deeper sites (Zone 1: Main Water Body) on White Lake. The figure below gives temperature measurements obtained at the North Hardwood Island site for the years 2014 to 2018.



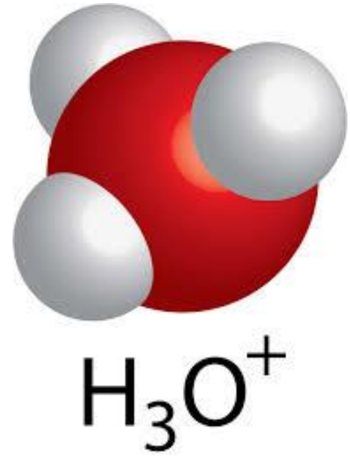
Clearly, the 2018 data (blue line) shows that temperatures were generally higher than in most previous years and especially so during the months of July and August. These higher temperatures along with greater water transparency (clarity) would also result in higher sediments temperatures. As mentioned before, this could result in larger amounts of phosphorus being released from sediments.

The table below gives maximum temperatures recorded for White Lake during the past five years. 2018 has the highest temperature which was 2.2 ◦C higher than previous years.

Year	Day of Year	Maximum Temperature, ˚C
2014	199	24.1
2015	217	24.0
2016	223	24.7
2017	216	22.9
2018	196	27.0

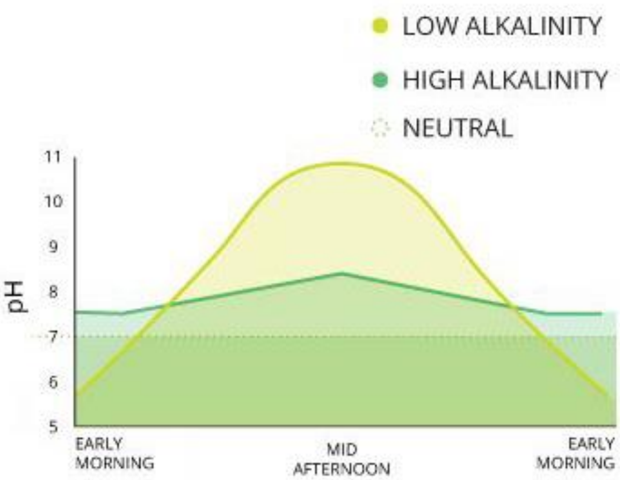
Higher temperatures, especially along shorelines could result in more prolific aquatic plant growth and also encourage propagation of algae, including blue-green algae.

2.4 pH



pH is a measure of the concentration of hydronium 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.

Carbonate materials and limestone are two materials which can buffer pH changes in water. Calcium carbonate ($CaCO_3$) and calcium bicarbonate can combine with both hydrogen or hydroxyl ions to neutralize pH. When carbonate minerals are present in the soil, the buffering capacity (alkalinity) of water is increased, keeping the pH of water close to neutral even when acids or bases are added. Additional carbonate materials beyond this can make neutral water slightly basic.

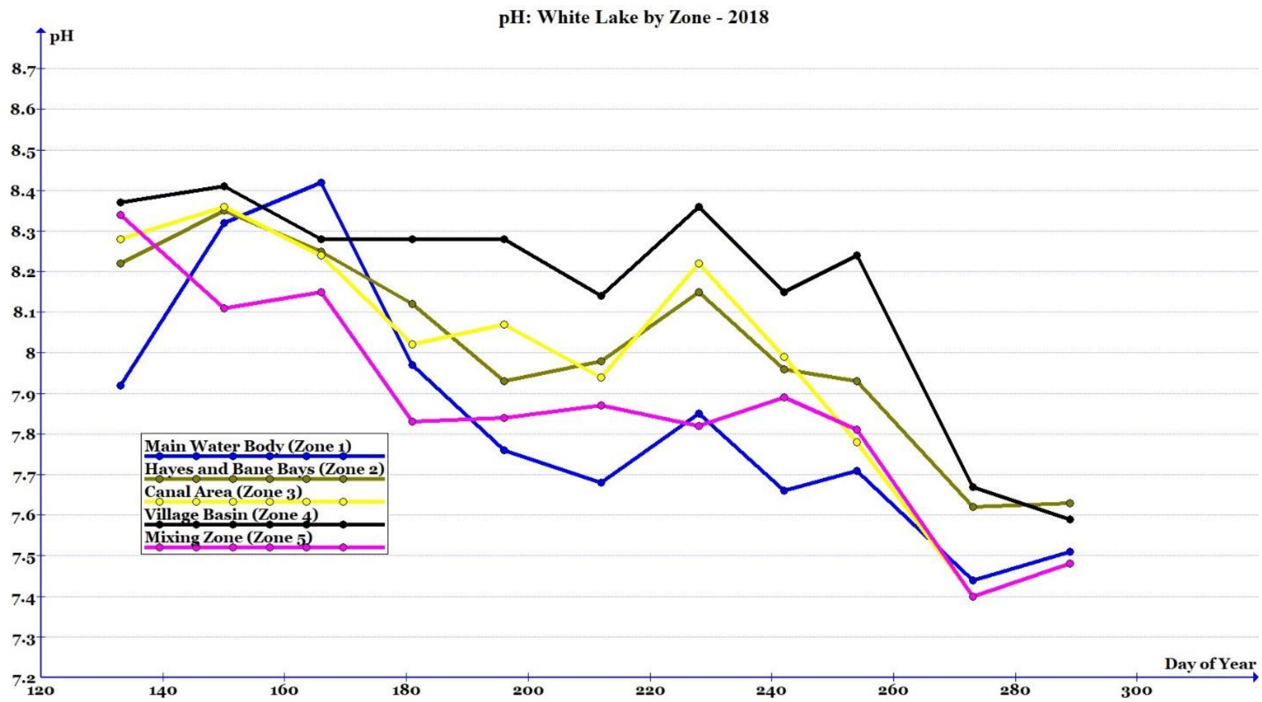


White Lake is a relatively high alkalinity lake and according to the diagram (left), the pH can change from about 7.5 to 8.3 during the course of any given day. Typical pH levels vary due to environmental influences, including photosynthesis during the day and respiration during the night. Additional CO_2 from respiration at night increases the number of hydrogen ions in the water, reducing pH:

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \ldots H_2CO_3 \Leftrightarrow (H^+) + HCO_3$$

This reaction is reversible (<=>) and accounts for the rise in pH during the day when photosynthesis takes place.

The alkalinity of water varies due to the presence of dissolved salts and carbonates, as well as the mineral composition of the surrounding soil. In general, the higher the alkalinity, the higher the pH; the lower the alkalinity, the lower the pH. The recommended pH range for most fish to thrive is between 6.0 and 9.0.



The above graph was constructed using data from the 11 lake-wide pH maps contained in Appendix 4. Included in this appendix are similar maps for the five creeks emptying into White Lake. The interpretation given to the lake-wide data in the above graphs can be extended to include data obtained for the five creeks emptying into White Lake. As for data for these creeks, it can be seen that the pH gradually changes to meet the pH of the lake as stream waters flow through their respective estuaries and mix with open lake water.

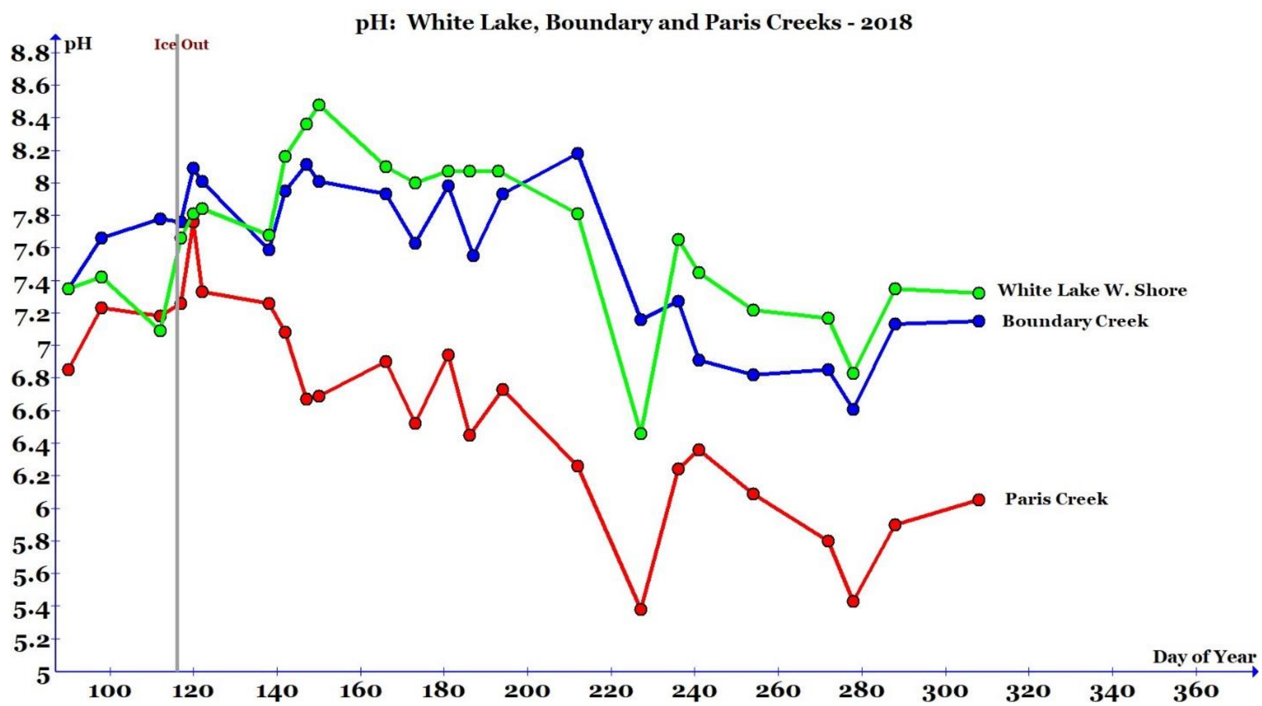
The graph of pH values above reveals several trends which apply to all parts of the lake:

1. The pH of White Lake varies from a minimum of 7.4 to a maximum of 8.4. These values are well within the range for a healthy lake fishery and also show that White Lake is well buffered against any large alteration of its pH.
2. The pH at the beginning of the ice-free season is highest and very near the pH of a carbonate/bicarbonate buffer solution at equilibrium. Again, this indicates that White Lake has a high capacity to absorb both strongly acidic or basic inputs.
3. There is a marked downward trend in pH values at all sites from spring to fall. The trend towards lower (more acidic) pH as the summer progresses is likely due to natural increased decomposition of organic materials as lake temperatures increase in summer and as plankton is killed-off in early fall.

A note of caution while interpreting the data contained in the above graph: We know that the pH of lake water changes during the day and so some site to site variation is expected. Since all samples were collected in sequence within a three-hour period starting at 10 am on any given sampling day, this variation is expected to be small and not significant when evaluating overall trends observed over the ice-free season.

2.4a Changes in pH with Time for Boundary and Paris Creeks

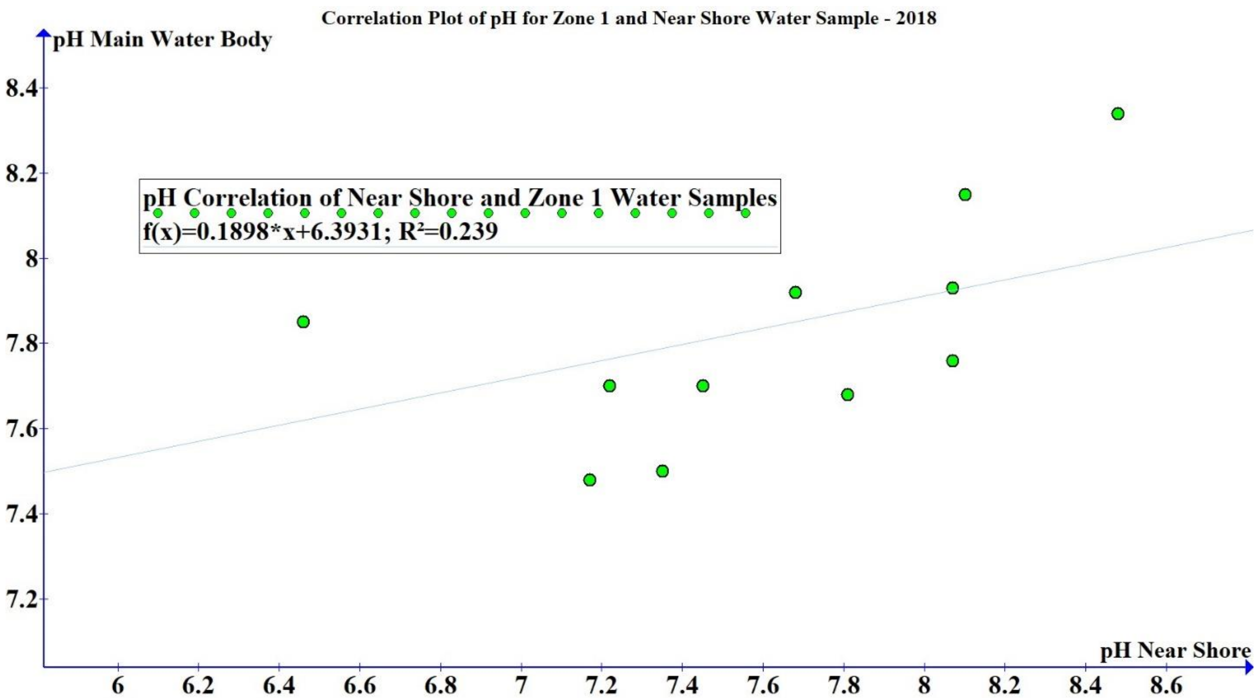
Below is a graph showing how pH changes in two creeks entering White Lake. One creek, Boundary Creek, represents surface water sources draining areas of calcareous rocks (limestone, calcite, dolomite) found at the south and eastern shores of the lake. The second creek, Paris Creek, represents surface water sources draining shield rocks such as those found along the entire western shore of the lake. A third graph on the plot is for lake water taken 5m from shore on the west side of the lake just opposite McLaughlin's Island.



As for lake water, the general trend of pH decreasing (more acidic) with time was also observed here. The general patterns of highs and lows in pH appear to follow each other closely for all three water sources. These highs and lows are closely linked to weather conditions over the summer months.

Paris Creek was generally quite a bit more acidic than waters from Boundary Creek and White Lake. During spring and early summer when water flows were high, the pH of Paris Creek was high and within the acceptable zone for fish habitat. Only starting in mid-July was this creek more acid. This, however, was likely not important to the overall pH of the lake considering the very low water flow of this stream during this time period. Shield rocks are acidic as well as covered by acidic soils and humic materials. These factors combine to lower the pH of Paris Creek during periods of relatively hot dry weather.

Although the curve for White Lake shore water generally follows the same trend as open lake water (eg Zone 1), the pattern of individual points on these curves do not correspond well to one another. The figure below is a correlation plot Zone 1 pH values and values obtained from near shore on the western side of the lake.



For these data the correlation coefficient (R^2) of 0.239 show that the pH values obtained from the shoreline (early morning readings) are not representative of the pH of Zone 1 lake waters.

The shoreline of any lake is an active zone more subject to the effects of wind and wave as well as the ingress of water from underground sources located nearby. The area also hosts an abundance of plant, bacterial and algal life and now a healthy population of zebra mussels. All of these factors combine to create an environment where pH values can fluctuate in a way which is independent of bulk lake water located away from shorelines.

2.5 Conductivity

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 *micro-Siemens* (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.

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. The concentrations of bicarbonate in lake waters is also influenced by pH and temperature. Additionally, salts such as sodium chloride entering the lake from saline springs or even road salt will also increase the conductivity of lake waters.

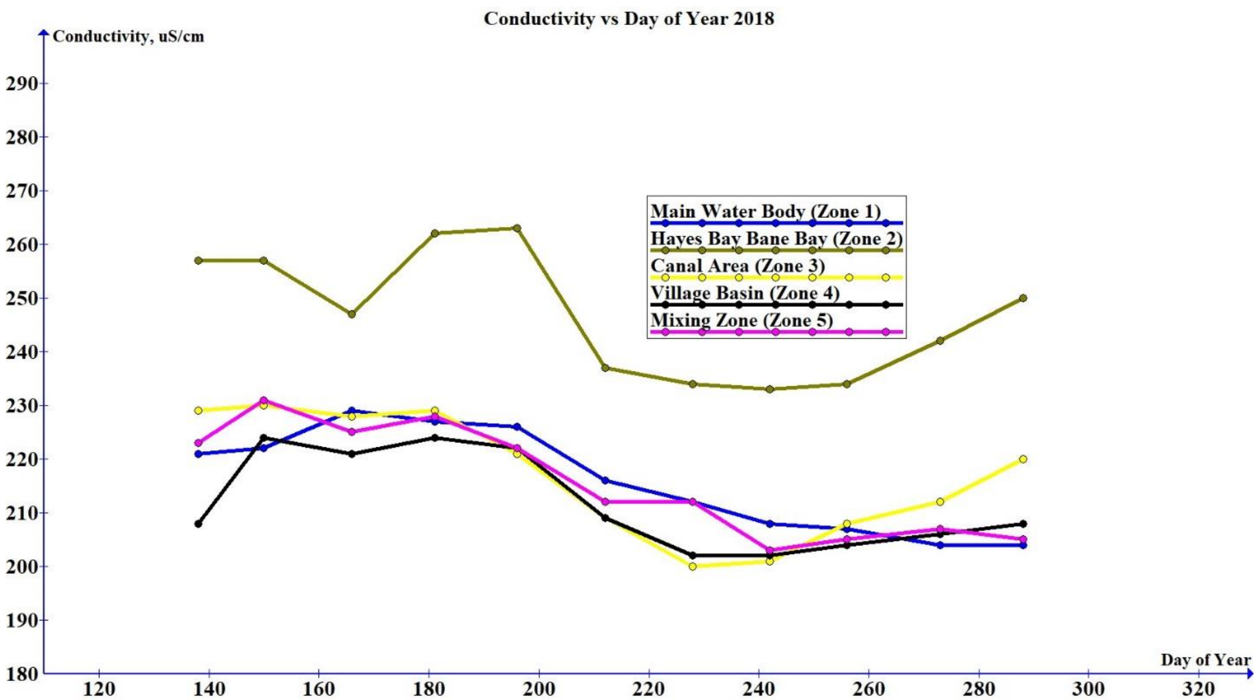
We can use conductivity measurements to gain insights into how water enters the lake and how well mixed it is. We can also assess the importance or influence that stream waters entering the lake have on the overall composition of the lake. For certain more remote parts of the lake, it is possible to determine if these locations are well drained or exist as backwaters with very little flow to the main part of the lake. Evaporation then could also be a factor increasing the conductivity of waters, especially during hot and dry periods during the summer months.

2.5a Lake-Wide Conductivity Measurements

Conductivity measurements were taken with a Model AZ8361 pen-type conductivity meter. This device was calibrated before each use with a standard reference sodium chloride solution. Distilled water was used as a blank solution to zero the instrument and a lake water sample of known composition was used as a control. All samples were analyzed the same day in the laboratory or at the sampling site itself.

For this study, the intent was to collect extensive conductivity data for all parts of the lake at two-week intervals throughout the ice-free season. In all, 11 samplings were completed. The results for the samplings are presented as maps in Appendices 3 to 5 and also as raw tabular data in Appendix 7. The reader is also directed to consult the White Lake Zone Map (Appendix 1) which divides the lake into zones. This map can be used to describe different regions of the lake each exhibiting different chemical characteristics. The zones are each described in the appendix and further information can be obtained from the 2016 and 2017 WLPP Water Quality Monitoring Program reports.

The figure below gives conductivity values obtained for each of the White Lake Zones from mid-May to mid-October, 2018.



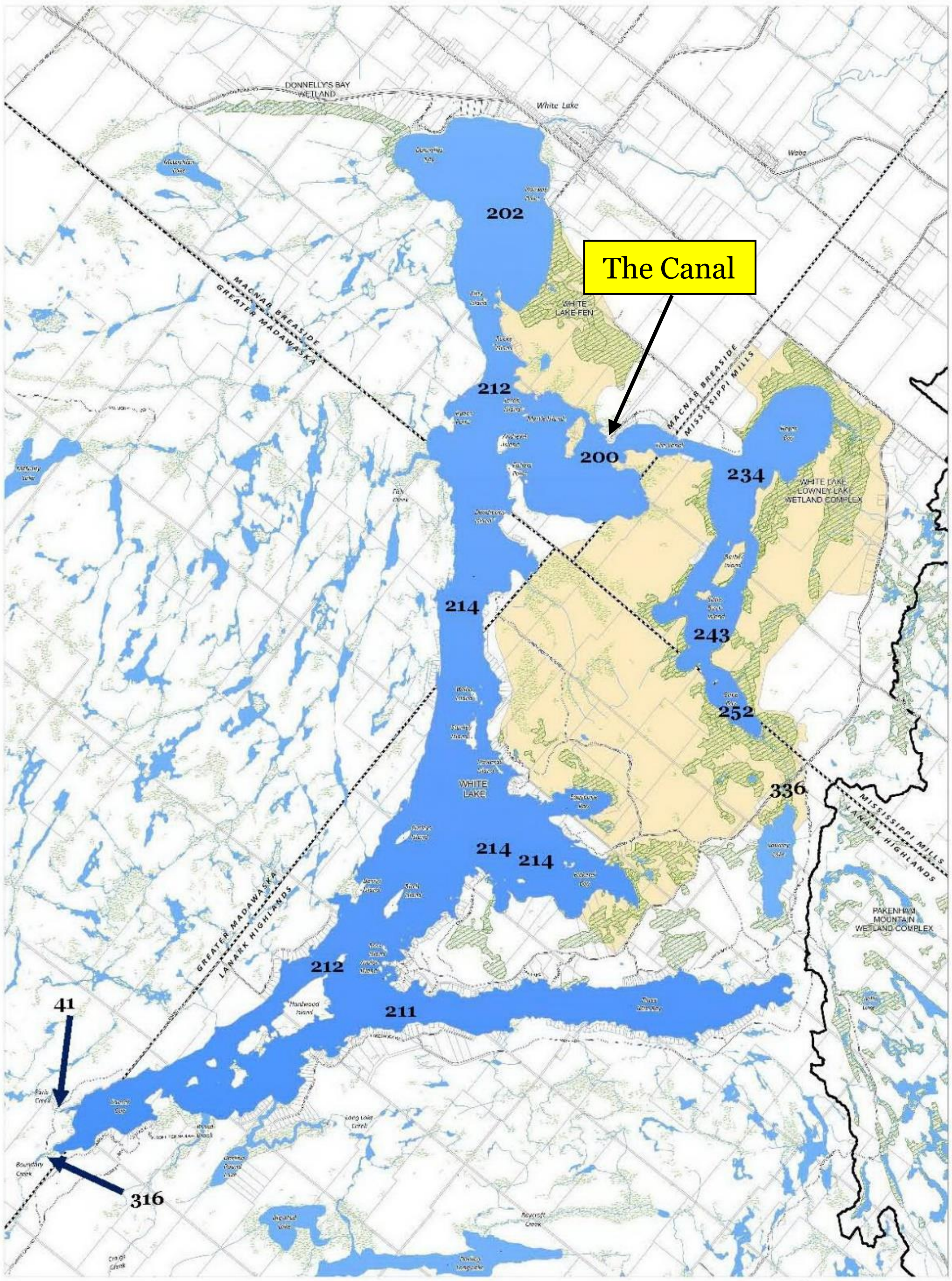
This graph shows that for most parts of the lake, conductivity values are nearly the same at any given date for all parts of the lake with the exception of the Hayes and Bane Bays area (brown line) which consistently has much higher values then the rest of the lake. The data for the Canal Area (yellow line) is consistent with values obtained for the rest of the lake, except that at some points during the summer, values are either lower or significantly higher than for the rest of the zones, Hayes and Bane Bays excepted.

The shape of the conductivity data curves can be correlated to the weather starting several days before sampling. Both, significant precipitation and hot dry weather are influential. Significant rainfall results in a decrease in conductivity because of simple dilution of lake water with rain and runoff water which is relatively free of dissolved solids. This can be seen for day 166 (June 15) on the above graph. Periods of hot dry weather followed between days 166 and 196 (July 15) resulted in increased conductivity due to evaporation of lake water. Beyond this date, the conductivity is governed by both weather and the beginning of the lake level drawdown at the White Lake dam.

Bane Bay (and hence Hayes Bay) are partially fed from drainage from Lowney Lake which has a conductivity nearly twice as high as the Main Water Body of White Lake. When water levels in White Lake are lowered, more water flows and/or seeps into White Lake from this source. The year-round high conductivity values for Hayes and Bane Bays are due to the factors discussed above and also from saline ground water springs discharging into that part of White Lake. Lowney Lake is likely a marl lake (see section in this report on marl in White Lake) and will be studied more intensely as part of our 2019 field season.

It may be interesting to the reader to explore the water conductivity maps contained in Appendices to get an instant snapshot of conductivity values across the entirety of White Lake on a given date.

The conductivity map for August 16, 2018 is of particular interest especially in relation to the conductivity value obtained at The Canal (yellow line in above graph).



The conductivity for The Canal was 200 µS/cm, a value which was lower than both lake water and upstream waters in Hayes and Bane Bays. What does this mean? A conductivity value which is lower than both upstream and downstream waters indicates that water is entering The Canal site by another means, likely fresh water springs charged by rainfall. This also indicates that there is little or no flow to that sampling site from either the lake or Hayes Bay. Note that the error in the conductivity measurement is less than 1% as reported in our 2017 Water Quality Monitoring Report.

If we widen our analysis to include the remaining 10 conductivity maps, we find that on 5 dates, the conductivity at The Canal site was equal to the Main Water Body. This indicates that there was no flow from Hayes Bay and little from springs at The Canal.

On the remaining 5 dates, the conductivity at The Canal was greater than the Main Water Body but less than Hayes Bay, clearly indicating that there was current or flow from Hayes Bay (where conductivity values are always higher than the remaining lake zones) through the Canal to the rest of the lake.

On 6 of the 11 sampling dates there was no flow of waters out of Hays Bay towards the rest of the lake indicating that this part of the lake (depth of 1.5 m or less) is essentially a back-water subject to evaporation as well as accumulation of nutrients. Turnover of water in Hayes and Bane Bays thus relies mainly on rainfall and the lowering of lake levels in the fall and winter, and to a lesser extent outflow from Lowney Lake. Please see Appendix 2 for a directional water flow map of White Lake.

Minimum, Maximum and Range for Conductivity (C) of Lake Water at Different White Lake Zones – May to October, 2018

Location	Min. C, µS/cm	Max. C, µS/cm	Range, µS/cm
Zone 1			
Main Water Body	201	229	28
Zone 2			
Hayes and Bane Bays	237	272	35
Zone 3			
The Canal	200	256	56
Zone 4			
Village Basin	202	224	22
Zone 5			
Mixing Zone (Jacobs I)	203	231	22
Other Sites			
Lowney Lake Creek	306	410	104
Active Streams, Western Shore			
Boundary Creek	143	339	196
Paris Creek	17	46	29

The above table provides a summary of values obtained for conductivity for White Lake waters over the ice-free season. With the exception of Zone 2 and Zone 3 (discussed in detail above) values for minimum, maximum and range of conductivities are similar over most of the lake. This is evidence that White Lake is well mixed and nearly homogeneous for most of the ice-free season.

A number of observations can be made from data presented above:

1. 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 28 µS/cm. This means that the dissolved solids in the largest part of White Lake did not change dramatically during the ice-free season.
2. Conductivity values obtained for The Canal and Hayes and Bane Bays, were more variable than for the Main Water Body because of the high concentrations of dissolved solids in these waters.
3. The larger changes observed in conductivity in shallow areas reflect the sensitivity of these locations to factors such as rain and evaporation.
4. A study of conductivities in The Canal area indicates that the waters of Hayes and Bane Bays are relatively stagnant and are flowing out towards the Main Water Body only about half the time during the ice-free season. This factor will vary from year to year depending on weather patterns and precipitation.

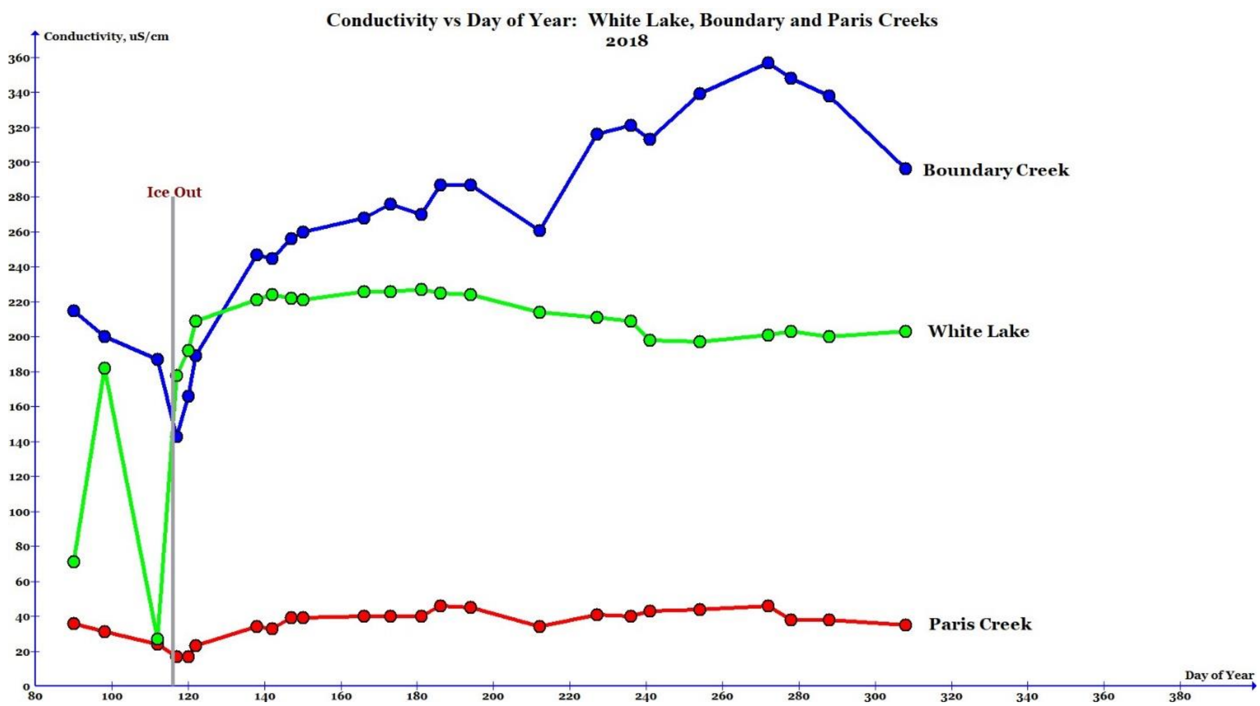
Conductivity values for Lowney Lake Creek and Boundary Creek are as much a twice the conductivities of lake waters indicating a much higher concentration of calcium and bicarbonate ions in solution. Paris Creek drains areas of shield on the West side of White Lake and contain much lower concentrations of dissolved solids (ions). Paris Creek waters are characteristics of all streams draining the West side of White Lake including Fish Creek.

2.5b Changes in 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 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. Boundary Creek drains areas rich in calcite and some dolomite and so it's solution chemistry (dissolved solids) reflects this, giving high conductivity values. Paris Creek, however, drains primarily shield type terrain which in turn produces waters low in dissolved solids and hence much lower conductivities. It should be noted that from previous studies (see WLPP 2017 Water Quality Monitoring Report) we know that the composition of Boundary Creek waters closely resembles that of all surface water sources coming from the south and eastern parts of White Lake and that the composition of Paris

Creek waters closely resembles surface water sources coming from the entire western shore of White Lake. For comparison purposes, data for lake water taken along the western shore of the lake (1053 Wabalac Road) is included.

The graph below compares conductivity values for these three locations over most of a one-year cycle. In this way, one can observe the changes in water composition entering White Lake from these two streams.

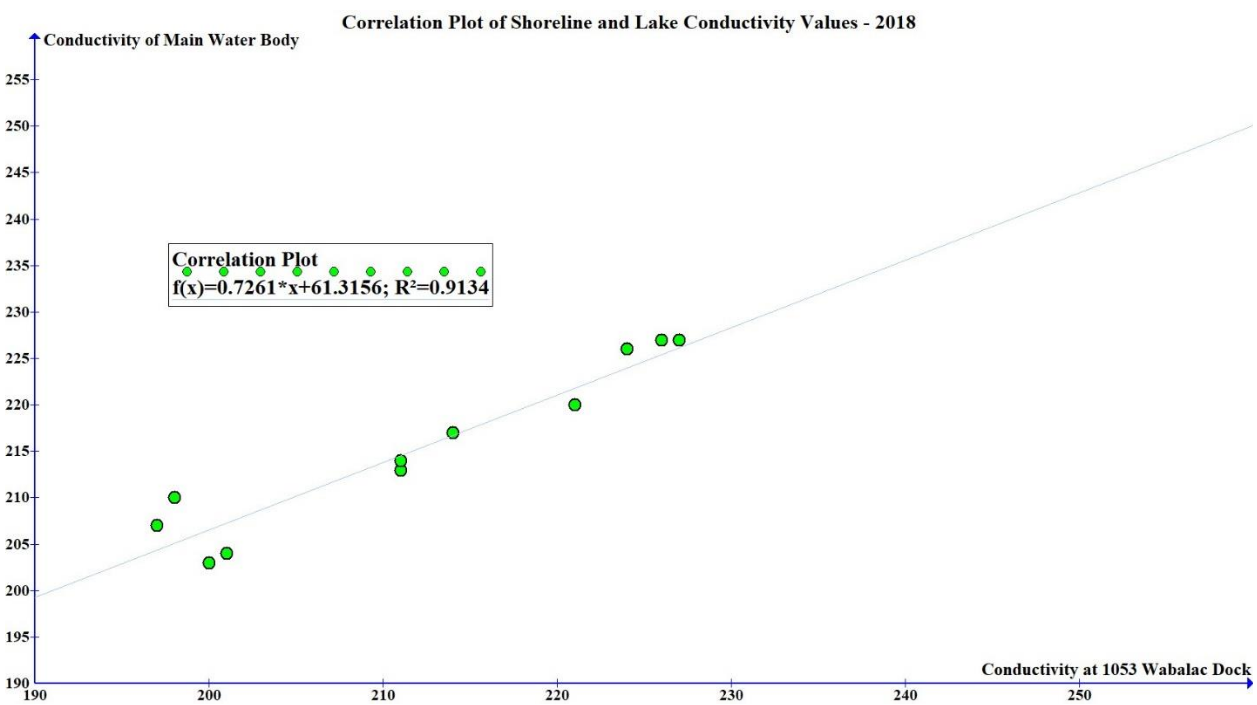


There are several features shown on this graph: 1) The conductivity of White Lake waters was intermediate to those of the two creeks, but closer to that of Boundary Creek; 2) for most of the year (after day 140 – May 20) conductivity values for White Lake and Paris Creek changed very little with time; 3) During this same period, conductivity values for Boundary Creek changed significantly which was likely more influenced than Paris Creek by surface runoff during rainy periods (lower conductivity) and dry hot periods when contact time with rocks was increased. The low conductivity values measured on day 212 (July 31) were a consequence of significant rain affecting the composition of both creeks, but not that of lake water. This indicates that for this rain event, the lake was not significantly affected by input from creeks. This is again repeated for the period after day 273 (Sept. 30) when frequent fall rains began.

Perhaps the most interesting part of the above graph was the conductivity behavior for all samples just prior to and immediately after the ice disappeared from the surface of the lake. As one approaches ice-off day it is clear that fresh melt water (very low conductivity) enters both the streams and the lake. For White Lake data, samples were taken 5 m from the shoreline through the ice. By late March, the colour of lake water (near the shoreline) was quite brown due to the presence of humic acids leached from surface and sub-surface soils entering the lake during the spring melt. The change in conductivity during the period was evident for Boundary Creek and especially so for White Lake.

Once the ice completely melts away marking the start of the ice-free season, it takes no more than about 10 days for the lake to become well mixed and exhibit near constant conductivity values for the remainder of the year.

Finally, we have correlated the conductivity measurements taken at the western shore (just opposite McLaughlin's Is.) and produced the plot below showing that the conductivity measurements taken 5 m from shore were representative of the Main Water Body (Zone 1) of White Lake. For these data, the correlation coefficient (R^2) of 0.9134 show that the conductivity values obtained from the shoreline (early morning readings) were representative of the conductivity of Zone 1 lake waters. This validates the discussion presented above.

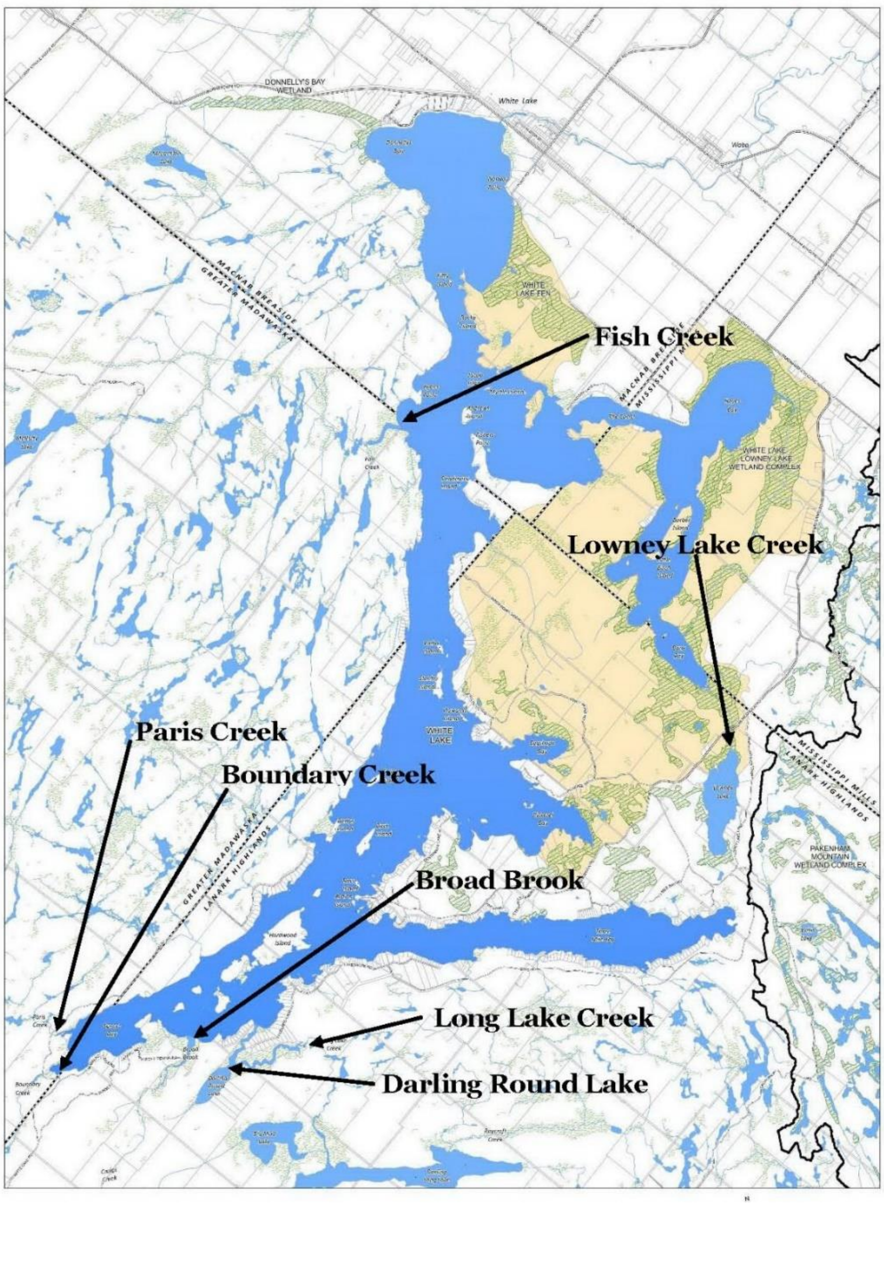


2.5c Influence of Streams on White Lake Waters

Now that we know that stream waters entering the lake have different compositions than lake water itself, the question that remains is: Do stream waters entering White Lake influence the quality of lake water or are they not very significant?

One way to answer this question is to look at the conductivity of outflowing stream waters and to then measure the conductivity of waters once they enter their respective estuaries to eventually mix with the lake. If the impact of a particular stream is great, then the conductivity of stream waters will be felt for a significant distance into the lake be it by increasing or decreasing the conductivity depending on the characteristics of the stream. If the impact of a particular stream is small (small volume or flow), then we can expect that these stream waters will have a very small impact as they reach and mix with lake water.

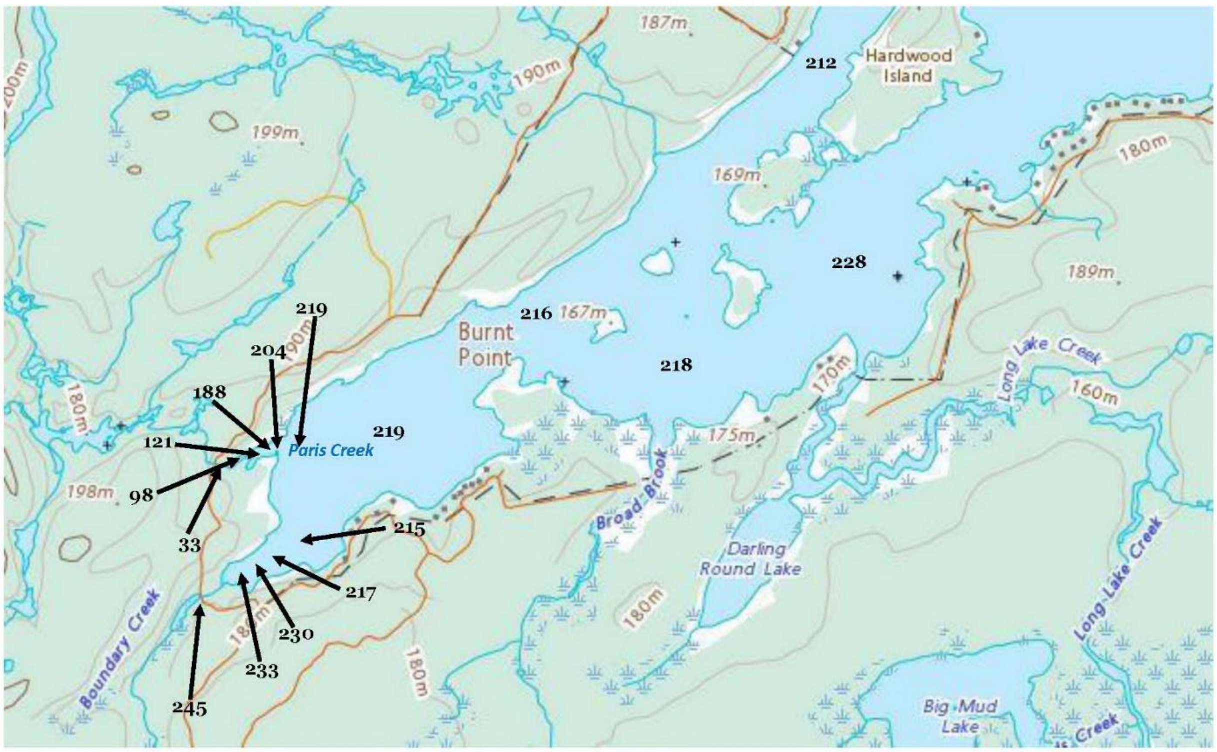
White Lake has a number of streams feeding it, but most of these are freshet streams which flow only during the spring melt or during especially heavy rains. In fact, there are only a small number of streams which flow year-round and these are shown below on the map.



Lowney Lake creek has already been covered above and will not be discussed further except to say that it has minimal flow during the summer months and does have an impact on Hayes and Bane Bays. However, its impact on the bulk of White Lake is small because both of these bays together contain less than 10% of White Lake's total volume and flow 'downstream' from Zone 1 (see Appendix 2), the Main Water Body of the lake.

Below is a map of the Sunset Bay area of White Lake showing conductivity values for Boundary and Paris Creeks and waters leading into White Lake.

Conductivity (µS/cm) for Boundary and Paris Creeks and South White Lake - May 22, 2018

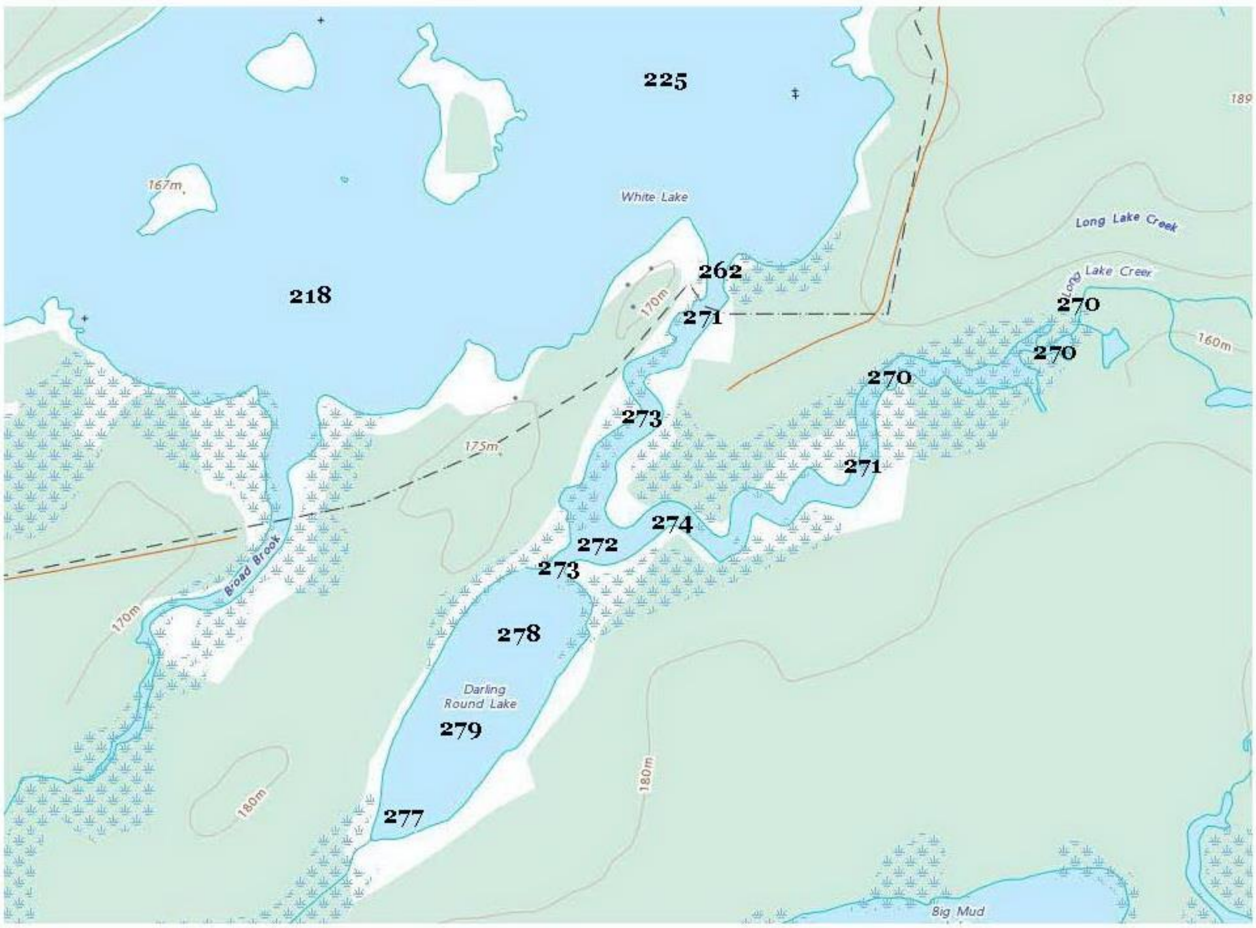


For both Boundary and Paris Creeks, conductivity values steadily decreased as these waters flow towards and mixed with open water. However, once reaching the end of their estuaries, conductivity (and pH) values reached those of the Main Water Body indicating that there was not sufficient stream water volume entering the lake to affect the lake composition significantly. In other words, there was efficient mixing of stream waters with lake waters.

For Broad Brook, Darling Round Lake/Long Lake Creek and Fish Creek, the data indicate that the effects of these streams were slightly different. For these creeks, the conductivity values at the mouth of their respective estuaries were still relatively high (low for Fish Cr.) compared to that of lake water. Even though this was the case, there was little evidence to show that lake waters were affected much beyond the mouth of their estuaries. This is illustrated in the map below showing conductivity values for the Darling Long Lake and

Long Lake Creek Complex. Further evidence supporting this assertion can be seen in the series of 11 maps (Appendix 5) giving lake-wide conductivity values over the entire ice-

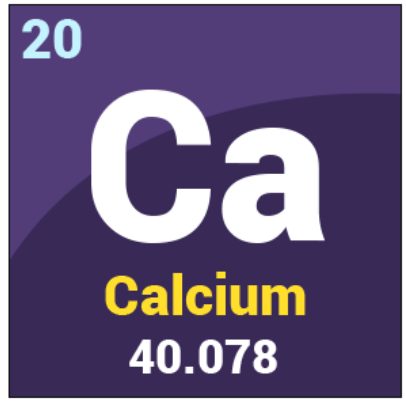
Conductivity (µS/cm) of Darling Round Lake and Long Lake Creek Complex – June 10, 2018



free season. The remaining maps for Broad Brook and Fish Creek can be seen in Appendix 6. Note that this study was completed between mid-May and late June. At this time, all of these streams were freely flowing. Once warmer weather took hold, the input into the lake from these streams decreased significantly.

Why is it important to have this information? One reason is because White Lake is a headwaters lake and is not part of a river system nor does it receive much water from other lakes or ponds in its watershed. Although we have no information on nutrient loading from any of the streams draining into White Lake, it is reasonable to suspect that any nutrient loading originating from streams is not significant to the overall nutrient budget of White Lake. As has been concluded by the Ministry of Natural Resources in numerous reports and publications (see www.WLPP.ca for references), White Lake is mainly spring fed.

2.6 Calcium



The table below contains values for calcium concentrations measured in White Lake. The average value for calcium concentrations measured on both dates for 2018 were the same, within experimental error. The average of all values for 2018 was 33.4 µg/ml or ppm. The average for 2017 was 29.0 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 several field seasons are natural differences caused by the relative inputs of various water sources entering White Lake.

In our 2017 report we published a correlation graph of average calcium concentrations, measured monthly from 2015 to 2017, plotted against monthly rainfall. A linear regression analysis of these data indicated that the calcium concentration in White Lake waters was 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. Our 2018 data is compatible with this correlation plot and support the conclusion that about 88% of the water entering White Lake is derived from ground water sources with the remainder coming from rain and surface water runoff.

Calcium (ppm) – 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)
Three Mile Bay	32.8	32.0
N. Hardwood I.	33.0	
Middle Narrows	33.4	
Jacob's Island	34.0	
The Canal	34.4	
Hayes Bay	37.8	34.5
Village Basin	31.6	30.8
Average Values:	33.0 ± 1.0*	31.4 ± .85*

* Hayes Bay Results excluded

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

2.7 Magnesium

White Lake sits on top of a limestone base and is partially surrounded by calcareous (calcium containing) rocks. A companion mineral to calcium is magnesium. Magnesium occurs naturally with calcium and is often found in significant concentrations in calcite in the form of dolomite, a calcium-magnesium mineral. We know (Tom Lalonde, OMYA Tatlock mine, personal communication) that as we move northwards away from the Tatlock mine that there are higher and higher concentrations of magnesium mineral mixed in with calcite (calcium carbonate).

It is no surprise to see significant concentrations of magnesium in White Lake waters. Magnesium concentrations are about 25% that of calcium. What may be surprising is that concentrations of magnesium in Hayes Bay are about the same or even lower than those found in the rest of the lake. This indicates that the much higher conductivity of Hayes Bay waters compared to the rest of the lake may be due to the presence of bicarbonate in much higher quantities than those found in the rest of the lake.

Only about 12% of Ontario lakes have a magnesium concentration higher than 3 ppm. This is not surprising since many lakes in the province are hosted on shield rocks, which are relatively insoluble and very low in both calcium and magnesium minerals.

Magnesium (ppm) – 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)
Three Mile Bay	8.7	8.5
N. Hardwood Island	8.5	
Middle Narrows	8.4	
Jacob's Island	8.8	
The Canal	8.1	
Hayes Bay	7.6	8.3
Village Basin	7.0	8.8
Average Values*:	8.2 ± .7	8.5 ± .3

*excluding Hayes Bay

2.8 Potassium

The main anions contained in natural waters are Cl^{-}, $SO4^{2}$, $HCO3^{-}$, $CO3^{2-}$ and the main cations are $Ca2^{+}$, Na^{+}, Mg^{2+} and K^{+}. Of the four cations, potassium occurs at the lowest concentration.

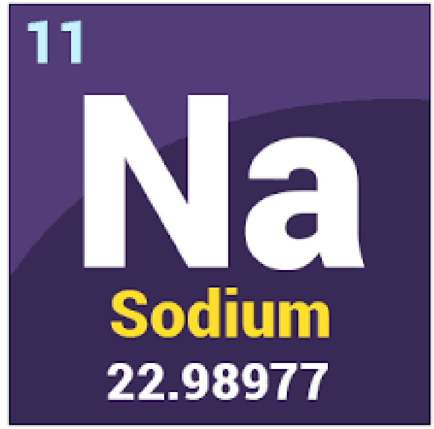
Potassium is a micronutrient essential to plant growth. About 85% of Ontario lakes have a potassium concentration in the range of from 0.2 to 1.0 ppb. About 10% of Ontario lakes have a 1 ppm concentration of potassium. Generally, the amount of potassium in natural waters is governed by the local geology and the uptake of the mineral by plants.

White Lake has a healthy level of potassium in its waters ensuring sufficient supply for the growth of aquatic plants including algae.

Potassium (ppm) – 2018

Sampling Site	**May 18 (day 133)**	**June 15 (day 166)**
Three Mile Bay	1.10	0.90
N. Hardwood Island	0.98	
Middle Narrows	0.94	
Jacob's Island	1.00	
The Canal	1.03	
Hayes Bay	0.99	1.09
Village Basin	0.89	0.88
Average Values:	0.99 ± .07	0.96 ± .12

2.9 Sodium



Sodium in lake waters is mainly derived from local rocks and also by contributions from the use of road salt.

About 40% of Ontario lakes have a sodium concentration of 0.5 to 1 ppm and only about 5% have concentrations in the 2.5 to 3 ppm range. About 15% have sodium concentrations above that of White Lake with less than 1% having a concentration as high as Hayes Bay.

We have speculated that the higher sodium concentration in Hayes Bay is due to local geology such as water seeping from a saline spring. However, the contribution of road salt cannot be totally ruled out, although this source of sodium is unlikely because the rest of lake is not similarly affected.

Although White Lake is a bit saltier than most Ontario lakes, sodium levels are not anywhere near toxic levels for local flora or fauna and should not be of great concern.

Sodium (ppm) – 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)
Three Mile Bay	2.4	2.4
N. Hardwood Island	2.3	
Middle Narrows	2.5	
Jacob's Island	2.7	
The Canal	3.2	
Hayes Bay	5.3	5.5
Village Basin	2.6	2.6
Average Values*:	2.6 ± .3	2.5 ± .1

*excluding Hayes Bay

2.10 <u>Chloride</u>

Chloride data for 2015 to 2018 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 and 2018, 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 calculation error.

In the *Conductance* section of this report, the Hayes Bay site gave anomalously high 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 dissolved salts in this sampling site.

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 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.

In any case, concentrations for chloride are low, but worth monitoring for future changes which may indicate road salt entering the lake, especially near Hayes Bay.

Chloride (ppm) – 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)
Three Mile Bay	2.9	2.9
N. Hardwood Island	2.9	
Middle Narrows	3.5	
Jacob's Island	3.2	
The Canal	4.1	
Hayes Bay	8.3	8.8
Village Basin	3.6	3.3
Average Values*:	3.13 ± .28	3.10 ± .28

*excluding The Canal and Hayes Bay

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

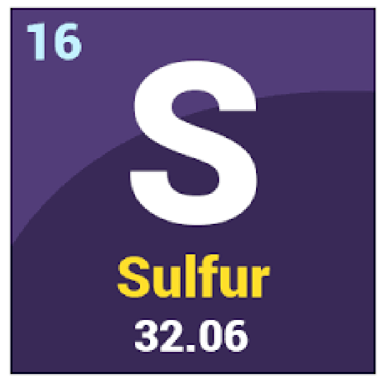
*excluding The Canal and Hayes Bay

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

2.11 Sulphate



Sulphur is a non-metallic element. The three most important sources of sulphur for commercial use are elemental sulphur, hydrogen sulphide ($H2S$, 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 ($SO4^{2-}$). Sulphates occur naturally in numerous minerals, including barite ($BaSO4$), epsomite ($MgSO4 \cdot 7H2O$) and gypsum ($CaSO4 \cdot 2H2O$). 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) - 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)
Three Mile Bay	3.6	3.3
N. Hardwood Island	3.6	
Middle Narrows	3.5	
Jacob's Island	3.4	
The Canal	3.2	
Hayes Bay	3.1	2.9
Village Basin	3.4	3.3
Average Values:	3.4 ± .2	3.2 ± .2

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
Average Values:	4.5 ± .3	4.6 ± .2	3.9 ± .3

The average concentrations for sulphate for both 2017 and 2018 are similar varying by only by 1 ppm. 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.

2.12 Silica

Silica is an important component for cell formation of two major groups of phytoplankton; diatoms and chrysophytes. Therefore, silica availability may influence phytoplankton productivity and community succession in lakes. There are only about 4% of Ontario lakes which have concentration of silica higher than that of White Lake.

The relatively low concentrations of silica in Hayes Bay could affect the growth of phytoplankton to some extent. Although most Ontario lakes have silica concentrations in the range of from 0.2 to 1.4 ppm, the levels encountered in White Lake are not considered harmful to the aquatic environment.

Silica (ppm) – 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)
Three Mile Bay	2.1	2.1
N. Hardwood Island	2.2	
Middle Narrows	2.2	
Jacob's Island	2.2	
The Canal	1.6	
Hayes Bay	0.58	1.2
Village Basin	1.7	2.8

Average Values*: 2.1 ± .2 2.5 ± .5
*excluding Hayes Bay

Monarch Butterfly Caterpillar

2.13 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 as defined above.

Dissolved Organic Carbon (ppm) – 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)
Three Mile Bay	5.0	5.0
N. Hardwood Island	4.9	
Middle Narrows	5.3	
Jacob's Island	5.0	
The Canal	5.7	
Hayes Bay	6.2	7.1
Village Basin	5.6	5.6
Average Values*:	5.16 ± .29	45.30 ± .42

*excluding The Canal and Hayes Bay

Dissolved Organic Carbon (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

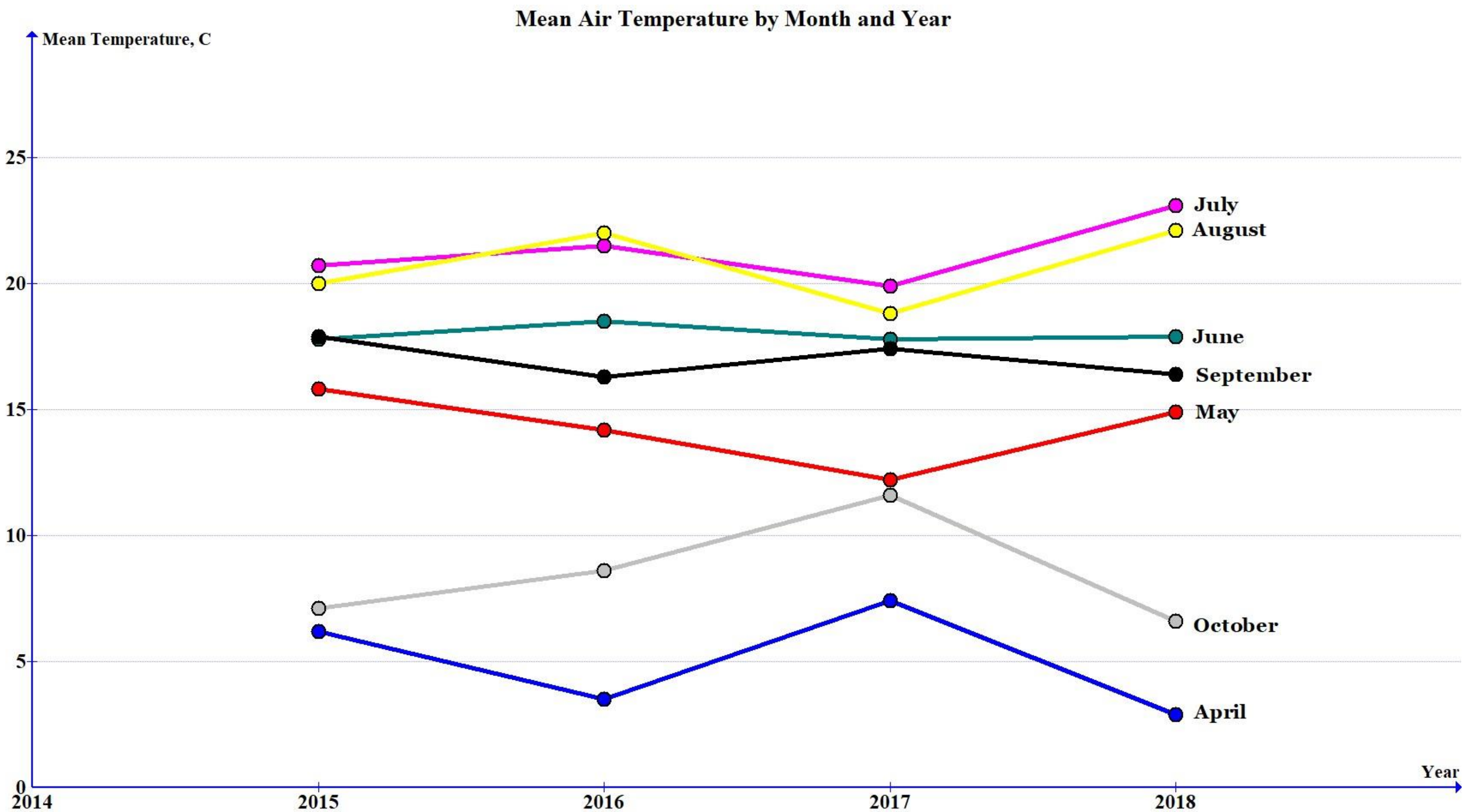
2.14 Weather and Meteorological Values: 2015 – 2018

When interpreting data such as total phosphorous 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 to 2018. The data 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, with the exception of 2017, 2018 was an average year for precipitation when compared to values for other years starting in 2015. 2017 was an exceptionally wet year compared to other years. During the six-month period from April to October 2018, White Lake received **552.7** mm of rain and experienced **70** 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 for the four years for which we have chemical lake data are presented in the figure below. A cursory look at the data shows that for 2018, we experienced significantly lower mean temperatures for the months of April and October. However, temperatures for July were significantly higher than for all previous years. 2018 also saw the highest monthly maximum temperature of any year since 2015. This may affect somewhat lake water and sediment temperatures, which is discussed in the appropriate section of this report.


Tornado Damage: Sept. 21, 2018
Western Shore North of Fish Creek



Mean Air Temperature by Month and Year
Mean Temperature, C
25
20
15
10
5
0
2014
2015
2016
2017
2018
Year
July
August
June
September
May
October
April

Monthly Meteorological Values – Environment Canada: *2018*

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	2.9	-11.6	20.7	112.8	14
May	14.9	0.1	29.8	52.2	11
June	17.9	5.9	33.6	70.4	9
July	23.1	9.6	36.0	122.5*	9
August	22.1	13.0	32.8	79.6	7
September	16.4	3.4	32.0	58.8	10
October	6.6	-5.0	27.5	56.4	10
Total				**552.7**	**70**

*average value for Ottawa and Pembroke, ON

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 2018

Date	Day of Year	Weather Conditions
May 18	133	Sunny, no rain for over a week prior. Wind less than 15 km/h; Air temperature: 20 ◦C
May 30	150	Sunny, small amount of rain two days prior. No wind, Air temperature: 25 ◦C; some pollen on surface; lots of plankton in lake
June 15	166	Moderate rain two days prior to sampling. Full sunshine sampling conditions, light or no wind. Pollen storm previous week and continuing. Air Temperature: 17 ◦C
June 30	181	Very light rain previous night for short time. Light rain 1.5 days before sampling. Very and sunny day. Air temperature reaching 30 ◦C during day and about 25 ◦C during sampling run.
July 15	196	Very hot sunny day. No wind. Three weeks of drought. No significant rain in over 6 weeks. Lake 5cm too shallow, evaporation. Air temperature: 26-31 ◦C
July 31	212	Sunny clear day, 40 hours after very significant rain. Lake rose by 10 cm. Air temperature: 25 to 31 ◦C
August 16	228	Sunny clear day, no wind, no rain for 10 days prior. Air temperature: 25 to 27 ◦C
August 30	242	No significant rain for previous ten days. Sunny day with light winds. Air Temperature: 15 to 21 ◦C
September 13	254	Moderate rain two days prior, full sun, no wind. Air temperature: 22 ◦C
September 30	273	Overcast, air temperature: 8 ◦C, significant rain 3 days before sampling, light showers day before. No wind
October 16	289	Light rain previous day. Cool weather three days before that, several days of rain previous. Partial sun and cloud during sampling, but mostly overcast. Air temperature: 5.0 ◦C

3.1 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 and were first officially reported by the White Lake Preservation Project's Science Committee in the fall of 2015.

Zebra mussels live for about 5 to 7 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.

Ten Facts About Zebra Mussels

1. There are about a billion zebra mussels in White Lake.
2. Each zebra mussel filters about 1 litre of water/day.
3. There are about 75 billion litres of water in White Lake.
4. Each zebra mussel produces about 50,000 surviving offspring.
5. There can be as many as 100,000 zebra mussels/sq. meter of exposed surface.
6. Zebra mussels live from 5 to 7 years.
7. Zebra mussels filter out particles as small as 1 µM.
8. Zebra mussels can filter out >90% plankton in water.
9. Zebra mussels excrete phosphorus to shoreline sediments.
10. Zebra mussels do not eat algae containing toxins allowing blue green algae to prosper.

During 2018, 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 can 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.

The slate was installed relatively late in the year on July 12, 2016. However, by the end of the year, some colonization had already 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. At this point, mussels are now attaching to all surfaces including the shell of an existing mussels which also makes a suitable point for attachment.

In 2018, the bulk of mussels attached to the slate has increased considerably with mussels growing rapidly. This year, we did not observe an early summer generation of mussels but could see that at least two more generations were produced by the end of the summer. When comparing photos of the bottom of the slate taken in late August and early November, it is evident that mussels of all generations have grown rapidly during this two-month period. When viewed from the side, the thickness of mussels covering the slate (thickness 7 mm) now is about 8 cm. There was no evidence of any dead mussels attached to the slate.

Zebra mussels live from 5 to 7 years which means that within the next several years we will be seeing zebra mussel shells, transported by wind and wave action, accumulating along our shorelines.

We have noted that the stems of aquatic plants become covered with zebra mussels which eventually leads to the collapse of the plant to the lake bed. Some of the mussels survive but others become a new surface onto which future generations of mussels can attach to.

Slowly but surely zebra mussels are increasing the area on the floor of the lake on which they can survive. At some point in time, the availability of nutrients (plankton, bacteria) will limit further expansion of the population and at that time a steady state will be achieved. Further growth could ensue if new sources of nutrients are introduced such as those resulting from poor shoreline management

July 12, 2016

August 4, 2016

August 28, 2016

September 4, 2016

July 29, 2017

September 10, 2017

November 4, 2017

November 4, 2017


August 31, 2018


top
August 31, 2018


November 4, 2018


Side View (8 cm in thickness)
November 4, 2018

3.1a Zebra Mussel Observations: 2016 to 2018

Dave Overholt

Zebra mussel shell lengths were measured over a period of three years at a single site located at a dock on Three Mile Bay. Sampling was done from the undersite of three steps of a boarding ladder which was fastened to a dock. This ladder was exposed to juvenile zebra mussel settlement for a fixed length of time. The undersurfaces of each of the three submerged steps were harvested for zebra mussels which were then sorted by size classes.

Data obtained in this way can be used to show the change in size frequency distribution of the White Lake zebra mussel population over time. Shell length infers growth over time as well as the period during which free swimming zebra mussel veligers (larvae) become a component of the plankton population.

Data in the following table can be used to estimate the duration of zebra mussle recruitment (time during which zebra mussel larvae settle and attach to a surface) for each of the three years from 2016 to 2018. The table shows means and standard deviations in shell length for each year. For example, the mean size of zebra mussels harvested in 2016 was 12.4mm, and the dispersion from the mean (representing 68% of the sample) ranged in size from 10.4 mm to 14.4 mm in shell length. If we use a conservative value for daily growth rates of shell length (~0.15 mm/day), we can convert shell length to the number of days that a zebra mussel was growing. Also, by knowing the day of harvest we can estimate dates when most of the zebra mussel settlement had occurred. For 2016 this would have occurred between days 193 and 220 (July 12 and August 8). In this table, immersion days refers to the number of days the sampling ladder was in the lake. Retrieval day is the day of year the ladder was retrieved and zebra mussels harvested and counted.

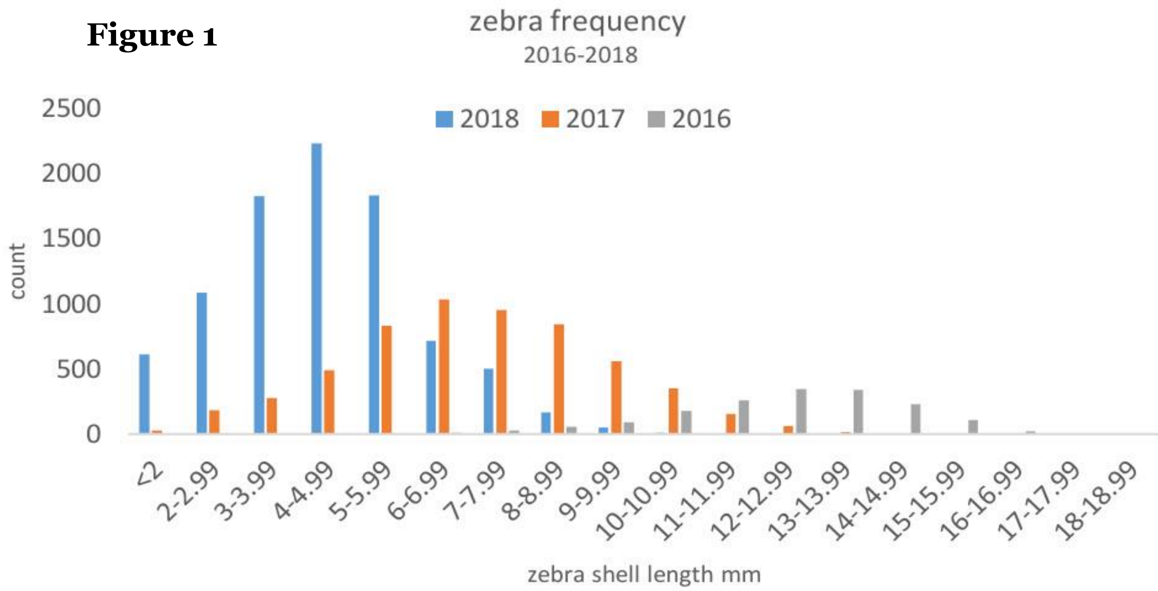
Sample	2016	2017	2018
Immersion Days	150	126	126
Retrieval Day of Year	289	289	284
Mean Shell Length, mm ± SD	12.4 ± 2.0	7.1 ± 2.3	5.0 ± 1.7
Number of Growth Days (0.15mm/day[3])	82	47	32
Mean settlement day	Day 207 (July 26)	Day 242 (August 30)	Day 252 (Sept 09)

The frequency distribution of this same data is shown in Figure 1. Evident is a shift in the peak occurrence of zebra mussel settlement day over the last three years as measured at a single sample site on Three Mile Bay.

[3] R. Claudi, G. Mackie: 1993 *Practical Manual for Zebra Mussel Monitoring & Control* pg. 36

In 2016 most of the new populations of surviving zebra mussels matured to adult breeding sizes (~8mm) and juvenile counts were insignificant. This distribution suggests a mid-summer settement for most of the surviving adults occurring around day 207 or July 26, 2016.

Figure 1



The 2017 data shows a shift towards a later summer production around day 242 or August 30. As a consequence, a greater proportion of juveniles are present in the sample. The reduced numbers in adult size ranges at harvesting time is due to the reduction of available days for growth prior to the harvesting date (day 289 or October 16).

The 2018 distribution is remarkable for the almost complete absence of breeding adult zebra mussel sizes indicating a late season recruitment of zebra mussels (around day 252 or September 9). The large number of sampled juveniles (8700 of 9026 individuals) would be predated upon by other organisms if left to mature. This juvenile population does not necessarily predict an increase in the number of adults for 2019. However, it does show the extraordinary numbers of juveniles which have settled out from their veliger or larval stage.

There is little evidence from the literature to suggest that zebra mussels breed at the same time in all parts of a lake This is a common phenomenon with marine molluscs. Therefore, the timing at this site may not be characteristic for White Lake as a whole.

Veligers In The Water Column

Veligers are free swimming microscopic organisms that form part of the plankton community and as such they become part of the food web that supports other organisms (Figures 2,3). However, their duration in the water column is limited by their own development. The velum, a membrane covered with cilia, is used to both harvest micro plankton and also provide mobility to the veliger. In 10 to 18 days[4] this velum develops a syphon and a foot. This critical period is thought to be the time of greatest vulnerability for the zebra mussel.

Figure 2. Veliger shell with velum extended

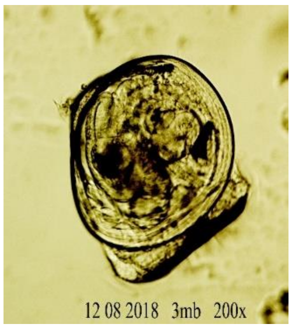
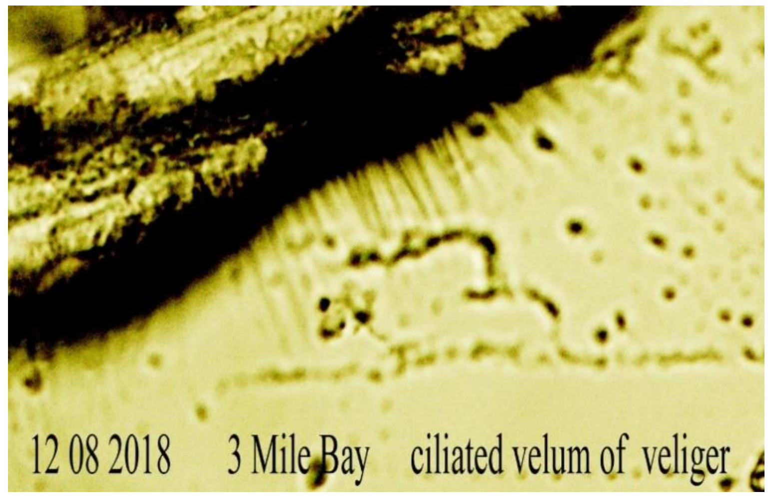


Figure 3. Enlarged view of velum showing cilia



Plankton sampling at the WLPP site located at the mouth of Three Mile Bay was done using an 80 µm mesh plankton net to capture the plankton assemblage. A vertical trawl from Secchi depth to the surface at various times over the season showed the occurrence of veligers. The sampling site is located over soft muddy weed free sediment. This is representative of large areas of lake bottom which do not support the formation of zebra mussel beds. Nonetheless, at certain times of the year veligers at this site were retrieved in large numbers. This is a good indicator of thorough mixing of White Lake waters that ensures an even spread of zebra mussel veligers throughout the lake. The 40x image below (Figure 4) was taken at the Three Mile Bay site on July 19th. The image shows 7 veligers in just a fraction of a single drop of water.

[4] Josef Daniel Ackerman, Blair Sim, S Jerrine Nichols, Renata Claudi; A review of early life history of zebra mussels (Dreissena polymorpha): comparisons with marine bivalves

Canadian Journal of Zoology 1994 72:1169

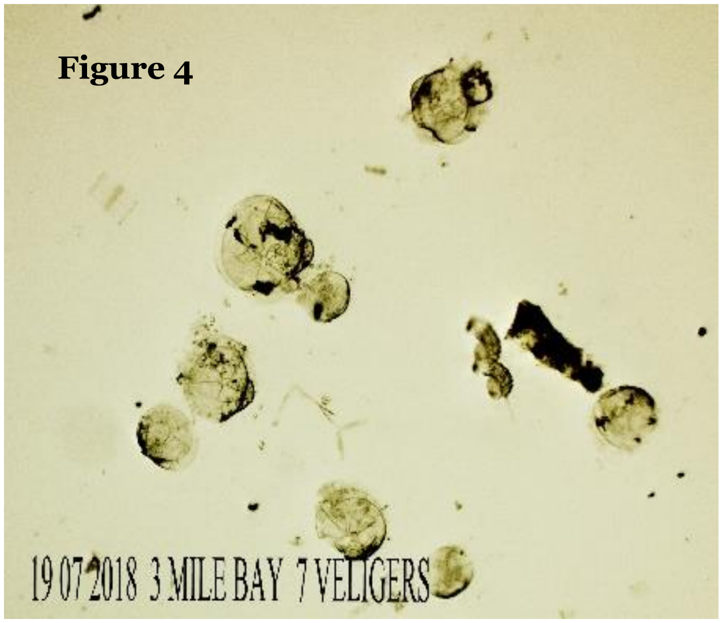


Figure 4

The impact of veligers on phytoplankton must be enormous. Although their individual influence is small, they occur by the billions during certain times during the summer. One might expect such episodes of veliger production to be associated with declines in Chlorophyll <u>a</u> and available phosphorus.

Large Zebra Mussels

Near the north end of White Lake an artefact was recovered from the lake bed. An outboard motor cover (Mercury Thunderbolt) had been submerged for many years and had accumulated a multi year population of zebra mussels. Many of the zebra mussels had reached a considerable size as shown below.

All zebra mussels were removed in order to measure their size frequency distribution (Figure 5). Of the 860 zebra mussels collected only 9 fell below the estimated 8 mm minimum adult range. No juvenile sizes were found below 5 mm. Almost half of their number were 20mm or larger and the largest was 28.7 mm. This sample represents some of the largest zebra mussels measured to date. The relative lack of zebra mussel juveniles on day 260 (September 17) suggests a late season recruitment for 2018 which had yet to begin at this location.

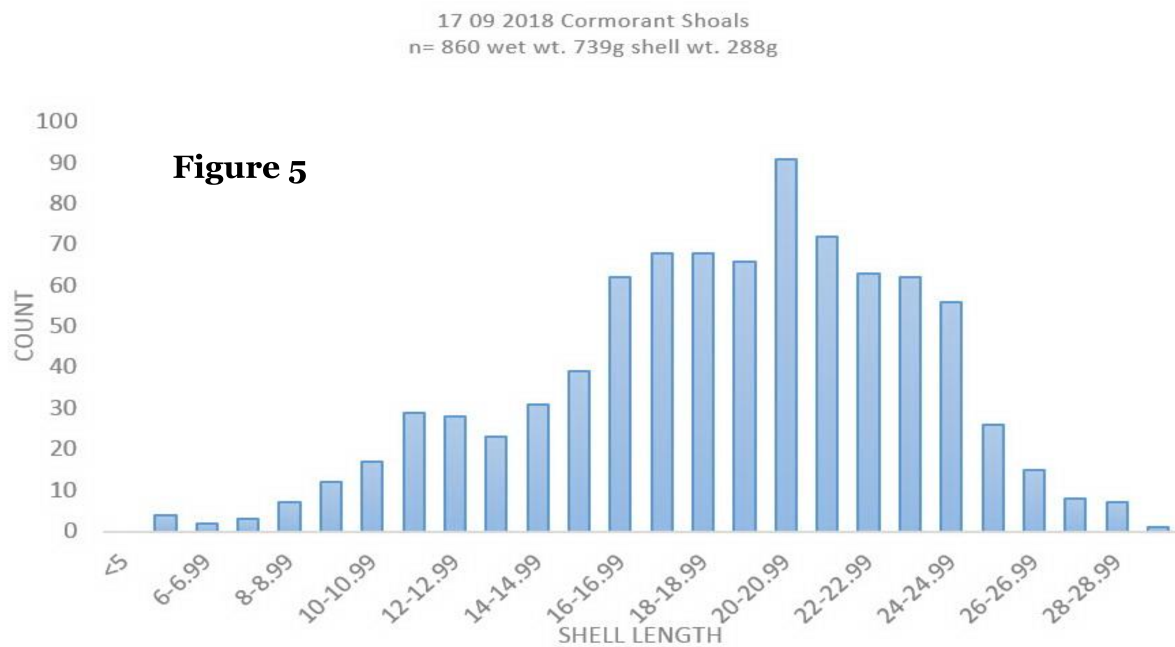


Figure 5

A noticeable change in the patten of growth of zebra mussels was observed when measuring the above sample (Figure 6). Zebra mussel that approach 20mm in shell length produce a shell width that exceeds shell height. The mussel takes on the look of a very plump almond!

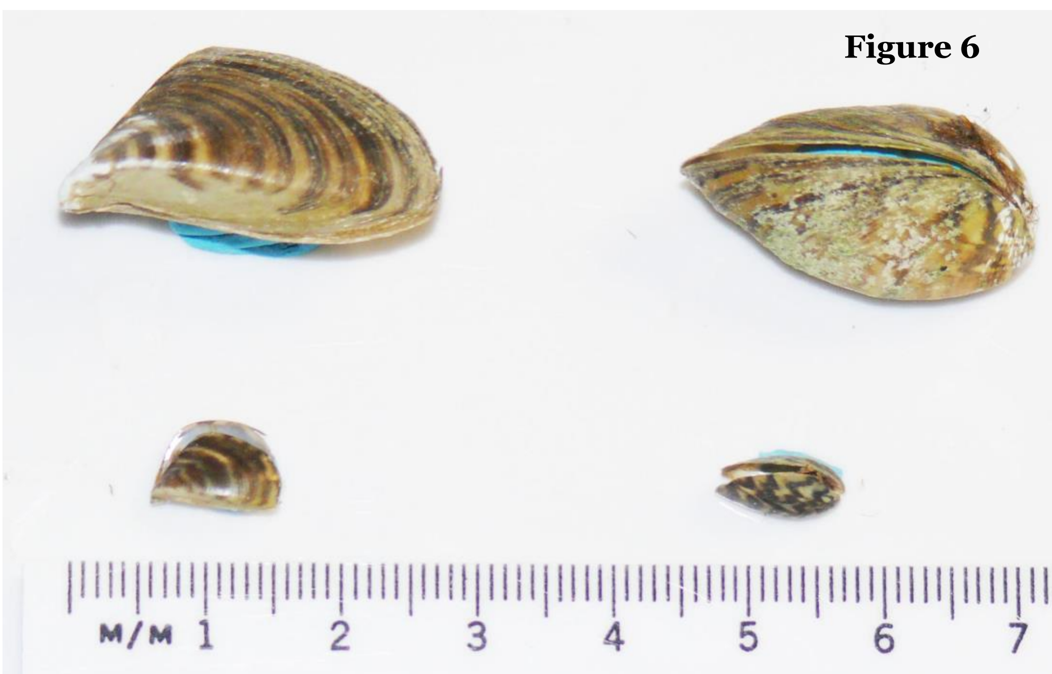
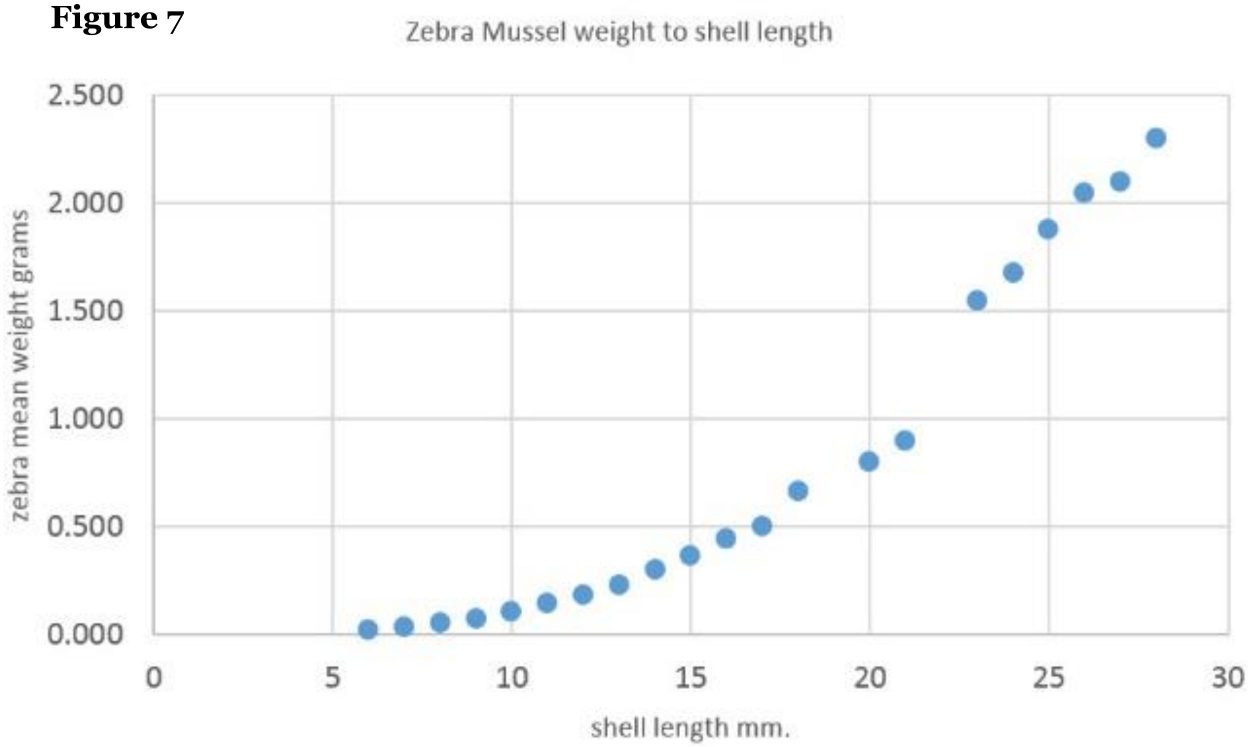


Figure 6

Zebra mussel size is an indication of filtering capacity. References in the literature are made to the extraordinary ability of adult zebra mussels to filter water. It is thought that this is a major driver creating the recent clear water conditions on White Lake.

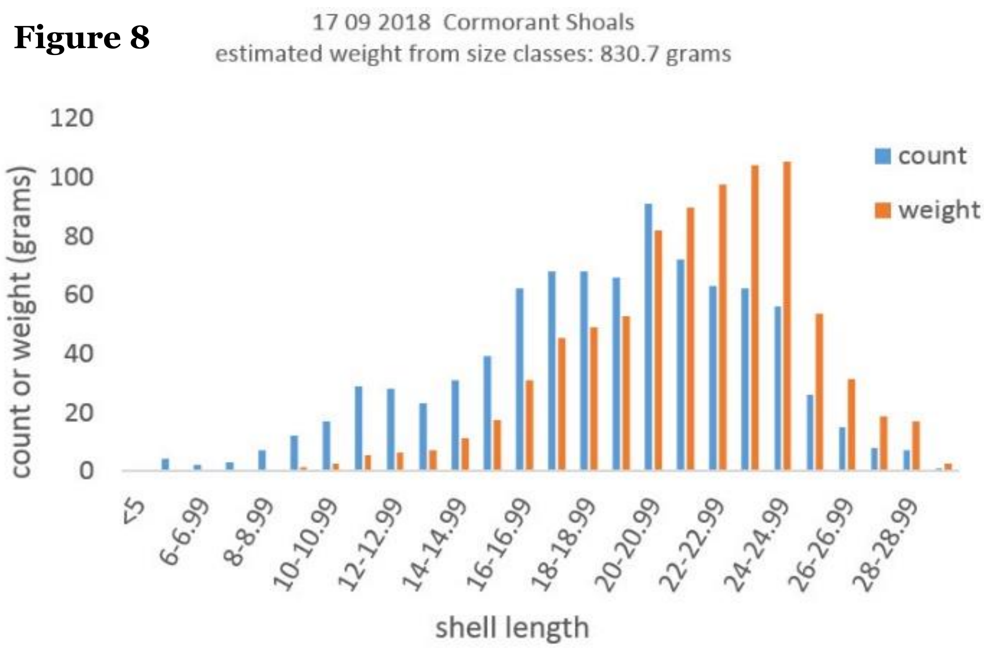
To gain an idea of zebra mussel mass, a sample of several hundred mussels were selected by length and weighed. The following graph (Figure 7) is the resulting estimates of unit weight/size class. Several size classes were missing from this sample but the trend is obvious. These values were applied to the Cormorant Shoal[5] sample (Figure 8). The estimated total weight of size classes (830.7 grams) compares favourably to the measured total harvested weight of the Cormorant Shoal sample (860 grams).

Figure 7



[5] Cormorant Shoal refes to the rocks located in the centre of the channel connecting the White Lake Village Basin and the Southern part of White Lake. This area is also commonly refered to as 'The Narrows'.
GPS coordinates: N 45◦ 20.156'; W 076◦ 30.635'

Figure 8



Sizes greater than 20 mm show an increasing contribution to zebra mussel mass even as their numbers decrease. As zebra mussels become larger their clearance (filtration) rates will increase. The clearance rate is measured as the number of millilitres of water that a zebra mussel can clear of plankton in one hour. Clearance rate studies have shown zebra mussels with a shell length of 19-20 mm can remove plankton from a litre of water in 3 hours. This is 3.8 times the cleareance rate of zebra mussels in the 9-11mm category.[6]

The 400 zebra musels in the Cormorant Shoal sample which were larger than 20 mm could be filtering about 130 litres an hour.

Changes in White Lake water chemistry are expected to continue as changes in the structure of the White Lake zebra mussel population progress to larger sizes. Light penetration and exposure times increased by clearance will provide for plant growth that will offer new surface areas for veligers to colonize. Some of these veligers will become productive adults adding to the total population of zebra mussels in White Lake.

[6] Martin J.Horgan, Edward L. Mills 1997; Clearance Rates and Filtering Activity of Zebra Mussel (Dreissena polymorpha): implications for freshwater lakes; Canadian Journal of Fisheries & Aquatic Sciences 54:249-255

3.2 White Lake Loon Survey and Wildlife Observations

June 30 to July 7, 2018

Joyce Benham and Bob Carrière

During our stay on White Lake we experienced days of relatively high winds as well as calm periods allowing us to make our detailed observations and loon count. The clarity of the water was very high and we were thrilled to see loons 'flying' under water as they pursued their prey. Especially noticeable was a significant population of cormorants perched on the rocks in the narrows and also on a rocky outcrop near the western shore below Deadman's Island. We did not see any Bald Eagles this year although others have observed the presence of at least one nesting pair. Over the last several years three Osprey nests were lost with a new one established (for the second year) on the east side of southern Hardwood Island. Finally, the number of great blue herons was much lower than in previous years.

Loon Observations[7]:

1. As in previous years 2 adults and 2 chicks. Chicks were large enough to no longer ride on the adult's back. Very active and tamed, seen fishing and feeding constantly. They travel the whole range of the Broad Brook grassed area including the lower tip of Hardwood Island depending on weather conditions.
2. We did not see as many Blue Herons as in previous years along the Western Shore as the Rocky outcrops were mainly submerged this year. On separate occasions we observed 3 adult loons fishing and a very surprised duck which landed amongst them, was startled and took off immediately. The area/channel, just south of the last part of Hardwood Island, remains a favorite group fishing area for 3 to 4 adults usually at days end.
4. One adult and two chicks feeding near cottages on Eastern shore. One more adult further North well into Three Mile Bay completed this family.
5. For the second year, the Ospreys have returned to their nest site located on the Southern tip of Hardwood Island. Two large chicks in the nest were not yet flying on their own, but jumping up and down.
6. Southeast below Hardwood Island 2 adults feeding in rocky shallow area.
7. The entire channel between the western shore and McLaughlin and Hardwood Islands has become a gathering/fishing place for groups of adult loons. The most active period is shortly after nightfall. Loons can be heard calling for most of the late evening and well into the night.

[7] Observation number is correlated to a location number on the map below. Any site numbers omitted was because of inactivity.

9. At the entrance to and on the South shore of Three Mile Bay, were 2 adult loons and one chick. A few hundred yards into the bay another 2 adults but no chicks.
10. Two adults in the main channel in front of Cedar Cove marina braving the heavy boat traffic.
11. Two adults with no chicks were spotted at the far end of Three Mile Bay.
13. Off Centennial lane, just before the entrance to Pickerel Bay were 2 adults with no chicks. Further into Pickerel Bay were 2 adults near the South shore bays.
14. At the far end of Pickerel Bay were 2 more adults this time with two large chicks actively fishing amidst a fair amount of JetSki traffic from the marina. The usual large Osprey nest in the center of the bay was very active with two chicks still in the nest.
15. Further up in Eggshape Bay, 2 adults and two chicks were constantly moving and feeding.
16. Right above Windy Point and sheltered behind Howards Island were two more adults with two good sized chicks.
17. Just above Stanley Island two adults fishing amongst the rocky outcrops with no chicks seen. The bald eagle's nest on Stanley Island appeared to be in good repair, but was vacant.
18. Very few Blue Herons were observed on the rocky Western shore this year.
19. On the Eastern shore, below Deadman's island, the bay held two adult loons with two small chicks. Deeper into the bay one more adult was seen closer to a weedy area. The active osprey nest above held 2 hungry chicks actively calling for food. Across the lake on the opposite (Western) shore one adult loon was spotted. Two wood ducks were seen near the rocky inlets.
20. Across from the bay entrance leading to White Lake Marina and well inside the Western opening of the inlet were 2 adult loons fishing. South on the rocky shores a few Blue Heron were seen darting in and out of shallow areas.
21. Inside the bay entrance towards the South in tall grass, 3 adult loons with no chicks were observed.
22. On the Northern shore of the bay, in the channel between the Northshore and Jacob and Myrtle Islands (which is open due to higher water levels) one adult and two chicks of fair size were seen. Closer to the cottage area towards the marina 1 adult and two chicks were tolerating the high volume of boat travel.
23. We traveled to the far end of the lake past site 23, the former Osprey nest, and went close to the White Lake Dam area. On the return leg following the Western shore, we noticed 3 to 4 Cormorants, which we hope will stay up at that end and not invade the lower areas of White Lake as they would no doubt compete with and displace loons. No loons were observed in this area of the lake, however quite a few gulls were observed feeding near the dam.
28. We ventured into the far reaches of the bays beyond the marina and initially found more boat traffic than usual, at least until we reached Hayes Bay. At the

entrance of the second part of Hayes Bay near Bane Bay, we spotted a very shy adult loon couple with only one small chick. They were clearly not accustomed to boat traffic as they retreated amongst the tall reeds.

SURVEY RESULTS:

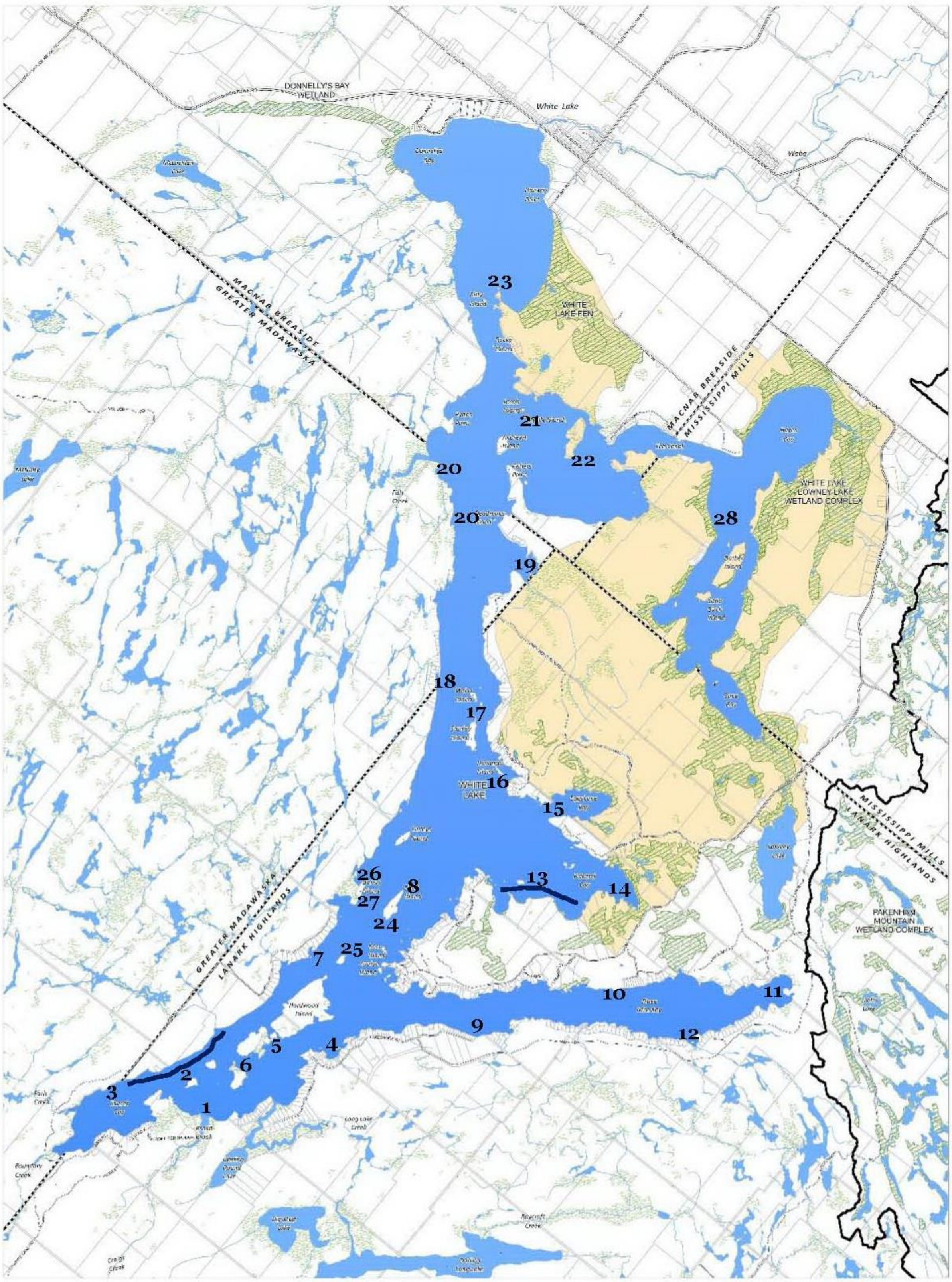
During the 2018 observation period, we counted 44 adult loons on White Lake, with 10 mating pairs producing 18 offspring.

The table below gives a comparison of this year's results with those of previous years:

OBSERVATION	2013	2015	2016	2017	2018
Number of Adults	23	40	32	45	44
Number of Nesting Pairs	7	10	11	19	10
Number of Chicks	16	17	16	21	18

Loon Observation Sites

July 23 – 30, 2018



3.3 Pickerel Fishery – 2017

Adam Pugh, Adam's Outfitting - *Cedar Cove Resort*

The data and comments presented here reports on guided fishing trips completed from May 13th to August 11th 2017. Since most guided trips target walleye, the data presented here may not reflect the current population or status of other species.

In the 2016 Pickerel Fishery Report, the size and age of each pickerel was reported. For 2017, it was decided to concentrate on numbers and size of fish caught during the survey period. The 2018 creel survey will concentrate on smallmouth and largemouth bass and on age determination for walleye ranging in size from 20 to 30 inches.

The notes below are based on observations and data collected for 82 anglers covering 28 trips amounting to 116 angling hours.

1. 192 walleye were caught. The smallest was 12" and the largest was 27".
2. Of the 192 walleye caught in 2017, the average size was 15.15" down from 17.12" in 2016.
3. On average, fishing for a period of 1 hour yielded a catch of 1.65 walleye.

The trends reflected in the points above are favourable because there was an increase in the population of smaller fish which are slot-size protected. Also, three years have passed since the completion of the Spawning Shoal Project and based on the 2016 calcified aging study, (reported in the 2017 Water Quality Monitoring Program Report) a 13" fish was, on average, in the 2.5 to 3.5-year age class. There was an abundance of this size fish over the course of guided trips indicating that this project was indeed a success and has benefited the lake and its fishery. This indicates that White Lake is on track for a sustainable walleye fishery.

Although White Lake walleye populations are on an upward trend, one wonders if this is in any way correlated to a decrease in bass species, especially smallmouth bass. For this reason, the bass fishery will be my main focus for the 2018 report on fisheries. It could be that this downward trend is related to a significant increase in rock bass populations. Data needs to be collected for this species before determining if remedial action needs to be taken, such as removing large numbers from the lake through selective fishing derbies.

In summary, the number of each species caught during the survey period include: 192 walleyes; 199 largemouth bass; 22 smallmouth bass; 32 pike; 62 sunfish; 125 yellow perch; 0 brown bullheads.

On guided trips with Adam's Outfitting, one could expect to catch 5.45 fish per hour or 21.80 fish over the course of a typical four-hour outing. This yield indicates that White Lake has a very healthy fishery.

There are several areas of concern and perhaps the most important is a marked increase in under and oversize violations for the winter pickerel fishery. The suspected reasons for these violations were essentially misinformation or lack of knowledge of the rules and regulations governing the fishery.

Perhaps distributing self-adhesive rulers giving slot size information as well as posting the pertinent rules and regulations at lake entry points would be beneficial.

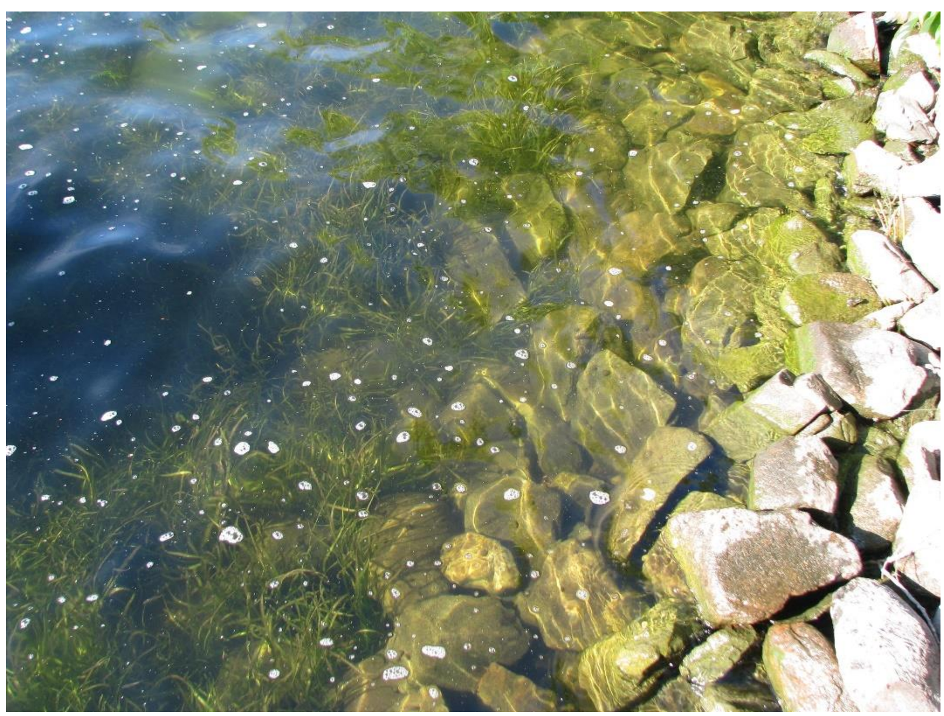
3.4 Tape Grass

Tape grass (*Vallisneria Americana*), also known as eel grass, is a very common perennial aquatic plant in temperate and sub-tropical climates around the world. It is native to Canada and can be found in lakes, streams and ponds as well as in brackish waters. It is a common aquarium plant and is an important food for wild ducks.

Vallisneria species have long thin leaves that grow in a clustered rosette and can reproduce asexually from creeping underground rhizomes and stolons. In botany, stolons are stems which grow at the soil or sediment surface or just below ground that form adventitious roots at the nodes, and produces new plants from the buds. Stolons are often called runners.

Tape grass can be found almost everywhere along the shoreline of White Lake. It also forms large underwater meadows and can attain several feet in length. The upper parts of the plant can sometimes be seen floating on the surface of the lake.

Tape grass produces male and female flowers. The small white female flowers are the more conspicuous of the two. The tape grass fruit is a banana-like capsule having many tiny seeds and is about 4 cm long and 4 mm wide.



The photo on the right shows tape grass growing among the rocks along the White Lake shoreline.

Tape grass plants found along the shoreline are well rooted between rocks and other debris. For this reason, the action of wind and waves seldom displaces them from their positions.

Like any other plant, tape grass needs both nutrients and light to successfully propagate. In the recent past, the size and location of tape grass beds were controlled to some extent by the inability of sunlight to reach the bottom of the lake.

Since 2016, the clarity of White Lake has more than doubled thus making sufficient sunlight available to deeper parts of the lake which were previously almost devoid of aquatic plants. At these depths, the sediment is very fine in texture and does not have the 'holding' power of the rocky shoreline. This situation is made worse by the relatively shallow penetration of tape grass roots into the sediment. Instead, tape grass beds tend to grow out in every direction along the surface of the lake bed. The roots of the colonial plants are also interconnected and form a carpet with each plant linked to its neighbour.

For several years we have been fielding questions from cottagers concerned that their shorelines were suddenly covered in large floating mats of tape grass. Below is a photo of such a mat driven by wind to the nearest shoreline. The tape grass mat shown in the photo was photographed near the entrance to Sunset Bay and headed for the western shore of the lake.

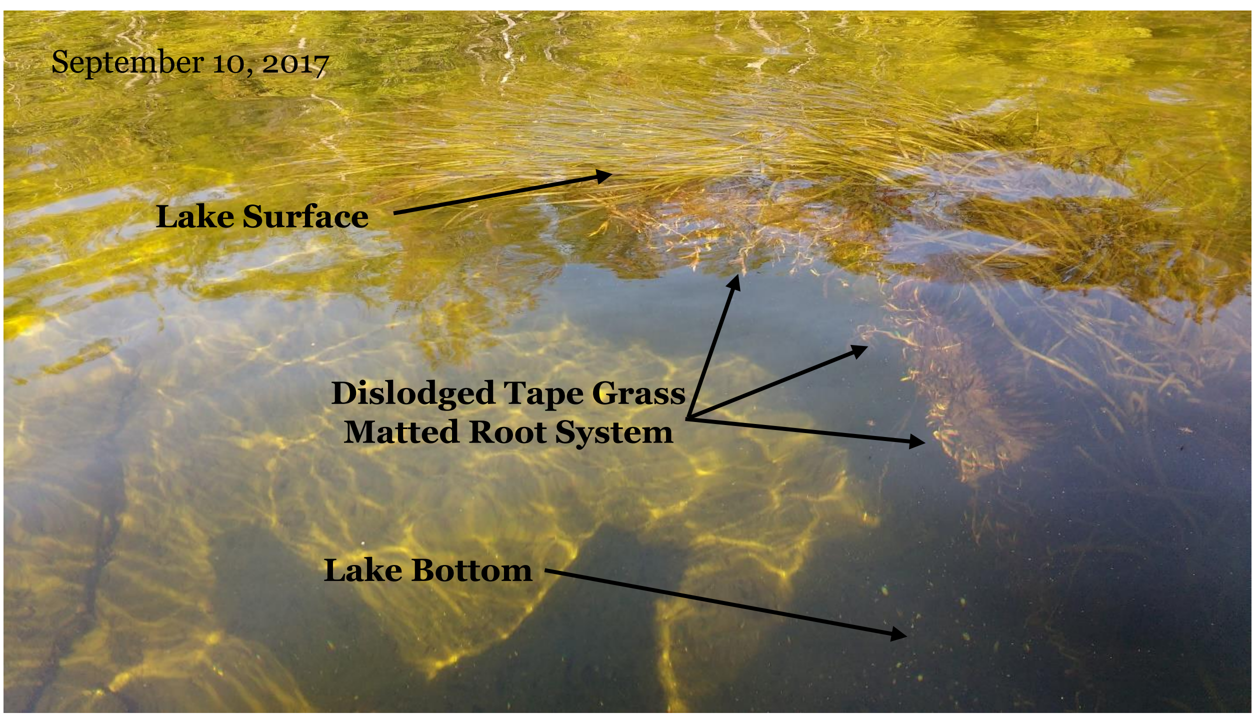
This year, many shorelines were covered with dislodged tape grass mats. In late August, almost the entire eastern shoreline of Hardwood Island was covered with decaying tape grass. Large mats also floated onto the western shore of White Lake. One cottager reported that he had removed twenty or more wheelbarrow loads of tape grass to clear his shoreline. This phenomenon has become an annual event in late summer and into the fall. Shorelines which are hardest hit are those facing the prevailing wind at this time of year.

How and why is this happening? By late summer tape grass plants in deeper water have grown to lengths of up to three feet and are now close to the surface of the lake. At the same time, water levels in the lake are steadily decreasing as the White Lake dam is adjusted to meet its bi-weekly target levels. Also, fall winds arrive resulting in significant waves which transfer energy to the tape grass beds.

The net result of all of the factors discussed above can be seen in the photograph bellow taken near the western shore of the lake opposite Stanley Island.

As wave action takes hold of the tape grass beds, the root system loses its grip in the fine sediment and begins to peel off like a carpet being lifted at one end. Any sediment adhering to the roots is washed away and the entire plant mat begins to float. Eventually, the tape grass bed becomes completely detached from the bottom of the lake and can now float freely. The same wind that dislodged the tape grass matt will now deliver it to your cottage shoreline!

We have observed this phenomenon in a number of locations around the lake and believe it likely that this will become an annual event.



3.5 Wild Rice on White Lake[8]

Northern wild rice (*Zizania palustris*) is an annual plant native to the Great Lake region of North America, the aquatic areas of the boreal forest regions of Northern Ontario, Alberta, Saskatchewan and Manitoba. Wild rice is Canada's only native cereal. It is a wild grass that grows from seed annually and produces a very valuable grain that has been used as a food source for thousands of years by the First Nations people in parts of North America. In September, during the rice-harvesting season, muskrat, fish, ducks, geese, and migratory birds feed on ripe wild rice seeds. Wild rice filters the waters, binds loose soils, provides protection from high winds and waves along the shorelines, and provides habitat for species at risk, such as least bittern and black terns.

The entire wild rice plant provides food in the summer for herbivores such as Canadian geese, trumpeter swans, muskrats, beavers, white-tailed deer, and moose. In addition to this, rice worms and other insect larvae feed heavily on natural wild rice. These then provide a rich source of food for small marshland birds. The stems of wild rice provide nesting material for such species as common loons and muskrats. Every stage of growth of natural wild rice provides food and habitat for wildlife; as a result, wild rice stands provide exceptional breeding and nesting areas for an abundance of species.

The life cycle for wild rice is simple. In the late summer, the ripened seed drops off the stem and sinks to the sediment, where it remains dormant until the following spring. Low oxygen levels and warmth typically stimulate germination, but some seeds may remain dormant for five years or longer, which allows the rice to survive occasional crop failures. After germination, there are three distinct growth phases that occur. The seed first begins to sprout in early May when the water temperature reaches about 7 ◦C. For the first three or four weeks of growth, the young plants are under water, which is the defining characteristic of the submerged leaf stage. Then, as the long, thin leaves begin to float on the surface of the water, this becomes the floating leaf stage of growth. Finally, the rice will then grow up out of the water into an upright position to reach the stage of growth in which it is a mature wild rice plant. Wild rice has a growing season of 106 to 130 days.

White Lake has long supported wild rice beds in many parts of the lake. Over the past several years we have documented the presences of wild rice on the lake. During the summer of 2018, we noticed that wild rice beds in the Village Basin area had increased considerably and now covered a significant area in this basin.

This led us to contact representatives of Plenty Canada to aid us in identifying wild rice in its natural habitat. As part of this project, we decided to complete a study of the entire shoreline and shallow areas of white lake in order to document the presence of wild rice on White Lake.

[8] Abstracted in part from Plenty Canada website: https://www.plentycanada.com/wild-rice--aquatic-ecosystems.html, and Wikipedia.

We were assisted by two representatives from Plenty Canada who spent a delightful day on White Lake with David Overholt and Conrad Grégoire.

Mission Statement – Plenty Canada

In recognition that Indigenous peoples carry vital knowledge for a contemporary path of sustainable living for everyone, Plenty Canada's projects are rooted within various Indigenous traditions.

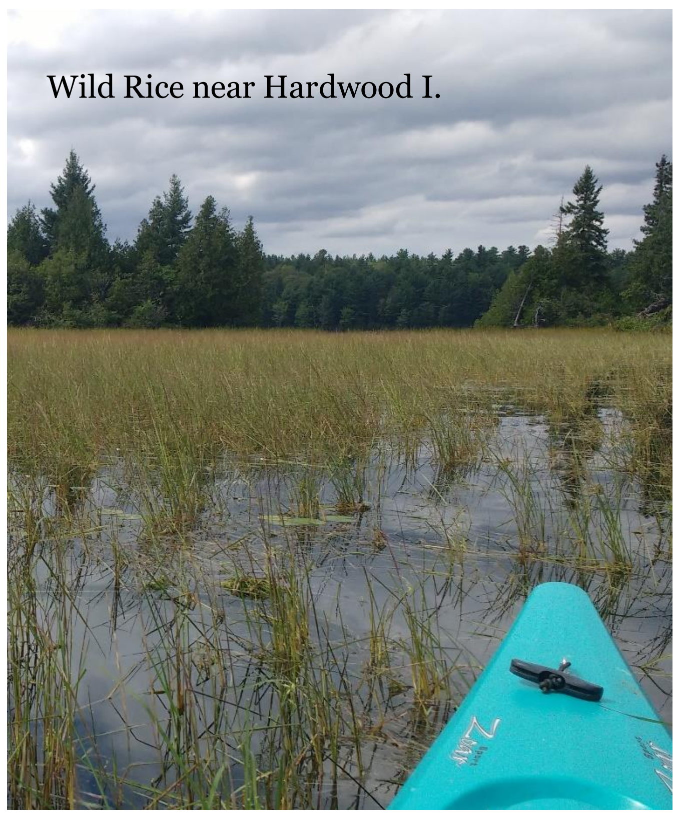
Plenty Canada also recognizes that development takes place at the grass-roots level and that communities have much to contribute to their own development in terms of knowledge, skills and determination.

Plenty Canada provides technical, educational, financial and other support for local community organizations to emerge, who identify priorities and strategies for small scale development that is economically, environmentally, socially and culturally sustainable.

Plenty Canada's staff and board members comprise a diverse group of professionals who understand the relationship between the people and the land. We have an established record of successful development work for nearly 40 years.

Wild Rice Village Basin

Learning the Finer Points of Wild Rice
-Canal Basin-

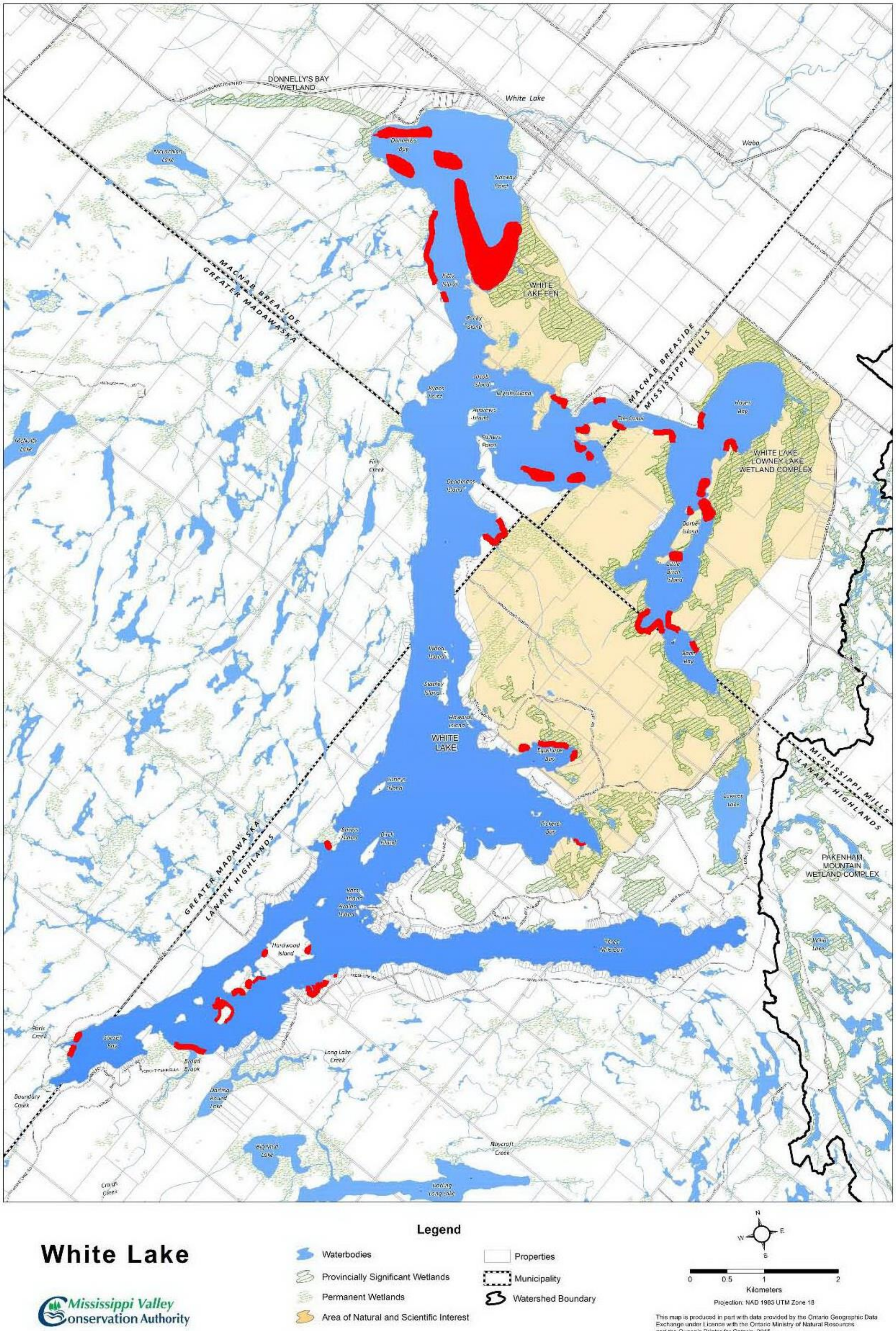


Wild Rice near Hardwood I.

As a result of our survey, we have produced a map showing the locations of the wild rice beds on White Lake.

Wild rice was found in most parts of the lake with the exception of Three Mile Bay and most of the western shore except at Sunset Bay, Barry's I. and the Village Basin.

Location of Wild Rice Beds on White Lake – August 30, 2018



3.6 <u>White Lake Organic and Marl Sediments</u>

Sediments play a very important role in lake ecology. Sediment composition can be quite varied within a single lake especially one like White Lake which borders on shield rocks as well as high calcium containing rocks. Sediments are teeming with life which helps in the decomposition of dead animal and vegetable tissue. They are also the repository of most of the phosphorus which enters the lake. For example, White Lake sediments contain 200,000 times the concentration of phosphorus (by weight) than the water above it. Also, as is the case for White Lake, sediments are an important source of phosphorus entering the water column by a mechanism which is commonly referred to as back or internal loading.

Until the arrival of zebra mussels, internally-loaded phosphorus would eventually find its way back to the sediments below as dead and decaying plankton. Unfortunately, zebra mussels now capture this plankton and redirect the nutrient content of these materials to near-shore sediments resulting in harmful effects discussed at length elsewhere in this report.

We know from published reports that sediments in the southern (deeper) part of White Lake are composed of highly organic black material in different stages of compaction. There are at least 5 m of sediments below the waters near Hardwood Island. The sediments in the shallow parts of the lake such as Hayes and Bane Bays and the White Lake Village Basin can be quite different as discussed below.

Currently, these sediments from Zone 1 are being studied by a graduate student from Carleton University. The results of these investigations will be published in the open literature and will be available in time for our 2019 Water Quality Monitoring Program Report.

3.6a <u>White Lake Marl</u>[9]

Marl is a soft light-coloured (white or pale gray) mud-like sediment which is seen in shallow waters of some lakes and marshlands. Often it is covered by a layer of more organic sediment. The term ‘marl’ includes unconsolidated accumulations of shells, calcareous (calcium-containing) sand, clays and silts. The common thread among all of these is that they are very high in calcium. Marls are easily identified and ‘fizz’ when a drop of dilute hydrochloric acid is dropped onto a sample.

Most of the shallow areas of White Lake are good candidate locations for the presence of marl. This is especially so for Hayes and Bane Bays, areas around The Canal sampling site as well as the White Lake Village Basin. For some 50 years marl was mined from lakes in Ontario and used for the production of cement and other products. This practice ended

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[9] Major source material for this section: Marl in Ontario, G.R. Guillet, Industrial Mineral Report 28, 1969, Ontario Department of Mines.

when cement was produced in much large quantities using abundant limestone deposits. White Lake marls were never exploited because of their colour and relatively small reserves.

Marl in White Lake is young and only formed since the end of the last ice age. Deposits of marl older than this were swept away by glaciers. These glaciers probably also formed the White Lake basin itself by carving a depression in older limestone predating the last ice age, which later filled with water to give us White Lake. This also explains why White Lake is underlain by limestone and not more acidic and very hard shield rocks.

The process leading up to the formation of marl is dominated by the precipitation of calcium carbonate:

$$Ca(HCO_3)_2 \text{ ---------}\rightarrow CO_2 + H2O + CaCO_3 \text{ (solid)}$$

There are several pathways by which marl is produced and all of these may be in play in White Lake.

The first is marl formation by algae. Calcium in White Lake waters is generally present as bicarbonate [$Ca(HCO_3)_2$] because this compound is relatively soluble and is kept in solution by the presence carbon dioxide dissolved in water. In the process of growth by photosynthesis, all plants require carbon dioxide, water, light and chlorophyll. Living marl producing algae obtain their carbon dioxide requirements from lake waters and by doing so force the reaction above towards the right thus releasing solid calcium carbonate which immediately precipitates to the bottom of the lake.

Certain plants such as Chara (abundant in White Lake) encrusts its stem and branches with precipitated calcium carbonate resulting from photosynthesis. We have observed this frequently in the field when studying aquatic plant propagation in White Lake.

Most cottagers have probably also noticed that rocks along the shoreline become covered with a soft layer of greyish material which flakes off easily to the touch. This is also deposited calcium carbonate marl produced by algae.

The second mechanism by which marl is produced is purely chemical. Cold ground waters percolating through carbonate bedrock become heavily charged with calcium held in solution as calcium bicarbonate by dissolved carbon dioxide. On reaching the lake (through sediments or from springs), higher temperatures and lower pressures contribute to the loss of carbon dioxide which favours precipitation of calcium carbonate. In this way, marl can accumulate as a layer metres in thickness.

A third and less significant source of marl is from the accumulation of shells from fresh water mollusks, clams and snails which are very common in marl producing lakes. We observed the presence of snail and other shells in most of the marl occurrences in White Lake. They were most prevalent in sediment samples taken from The Canal area. In all cases, however, shells were not present in sufficient quantity to account for very much of the marl present in White Lake.

It should be noted that White Lake is not a marl lake, but rather a marl containing lake. Marl lakes are characterized by clear and sometimes aqua coloured waters and the absence of aquatic plants along the shoreline. From areal observations and some chemical data, we suspect that Lowney Lake may be a marl lake or is nearly a marl lake. We are planning a more detailed study of this lake during the 2019 field season.


Washed Shells from Canal Marl

3.6b Historical References to White Lake Marl

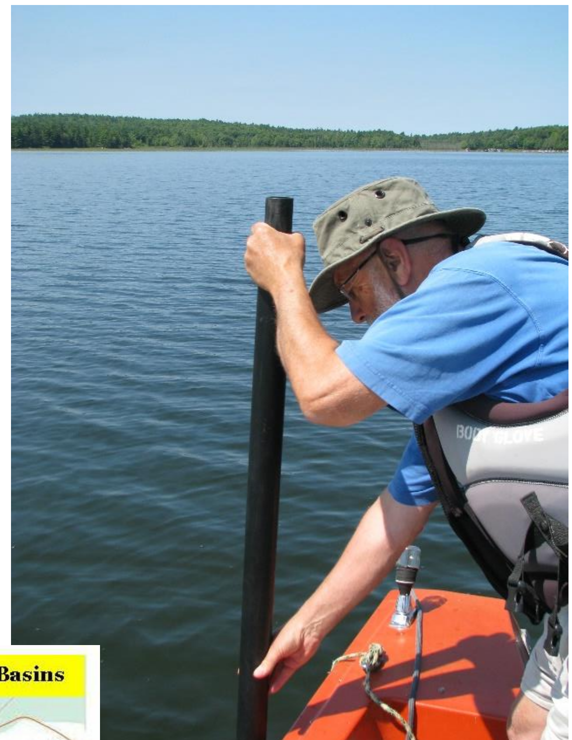
We are certainly not the first to describe marl on White Lake. In his paper cited earlier, Guillet states that 'marl underlies the eastern part of White Lake in parts of lots 1-8, concessions I-III, McNab township, Renfrew county. White Lake is not a typical marl lake. It is a large lake lacking obvious marl shoals; the marl is pinkish in colour and the bed is thin.'

The very first description of marl in White Lake was by William Logan[10], who founded the Geological Survey of Canada in 1842 and for whom Mt. Logan, Canada's highest peak, is named. He described White Lake marl thusly: 'In the lower part of White Lake about seven hundred acres are covered with marl, which was found to have a depth from five to seven feet, and was covered by not more than two or three feet of water'. The location on the lake he was referring to is off of Norway Point on the White Lake Village basin.

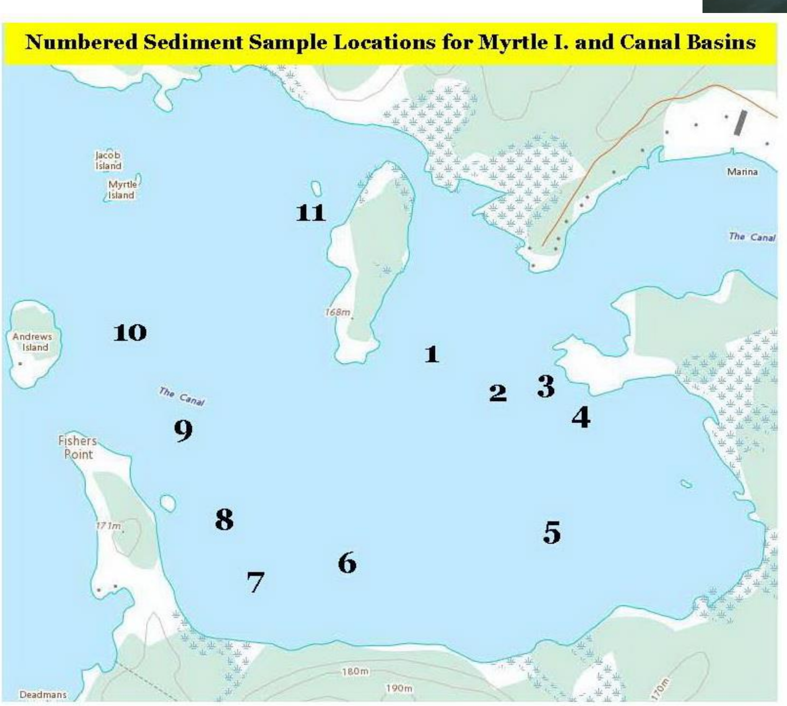
[10] W.E. Logan, The Geology of Canada, Geological Survey of Canada; 1863, p. 765.

In his paper Guillet states 'White Lake marl is of fair quality, although less pure than many other Renfrew county deposits. A 4-foot section analyzed 86.6% $CaCO_3$ [calcium carbonate], 3.0 percent $MgCO_3$ [magnesium carbonate], 0.44 percent Fe_2O_3 [iron oxide], and 1.24 percent insoluble. The dry powder is light grey with a rather low brightness'. The marl sample taken for this analysis was obtained off Norway Point about midway between the shores.

3.6c Distribution of White Marl in White Lake



In order to describe the location and nature of marl deposits in White Lake we sampled lake sediments in the shallow parts of the lake including The Canal Area, Hayes and Bane Bays and the Village Basin. We used a homemade corer made from two lengths of ABS plastic drain pipe. One length was 1.5 inches in diameter and the other 1.25 inches. The smaller pipe was blocked on one end with epoxy and fitted snugly into the second larger diameter pipe. By lowering the assembly onto the surface of the lake bed, one could physically force the pipe into the sediment allowing the inside smaller diameter pipe to rise in the assembly. In this way, the sediment core was fixed in the sampler and was not lost on retrieval. A photo of the sampler in use is shown above.



To the left is a map showing a typical sampling pattern we used to study individual locations for the presence of marl and also the nature of the deposits found.

The area shown includes The Canal sampling site and the areas adjacent to it. Water depths in these locations did not exceed 2 m and were generally less than that, especially for sampling sites 5 to 10. This area was characterized by the presence of cane reeds and some wild rice.

Below is a table showing the GPS locations of the sampling sites shown on the map above and a brief description of the samples taken. Note that all samples contained some marl as evidenced by reactivity with dilute hydrochloric acid.

White Lake Sediment Sampling: Myrtle Island and Canal Basins
July 18, 2017

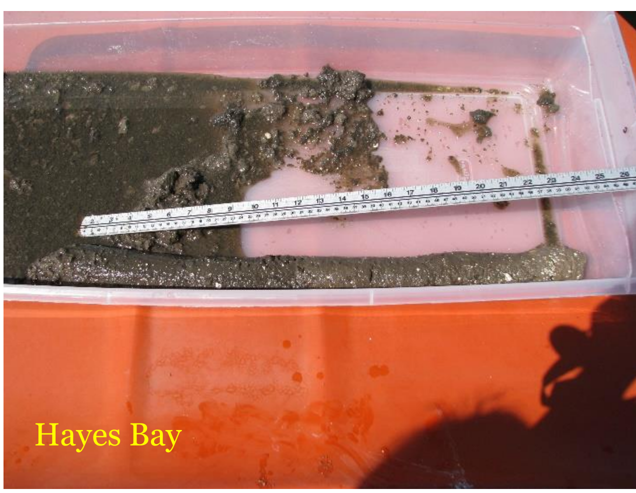
Sample #	Location	Notes and Comments*
1	N. 45º 19.267'; W. 076º 30.013'	Many Shells, sediments white to grey
2	N. 45º 19.219'; W. 076º 29.913'	Sediment greenish-grey, very few shells
3	N. 45º 19.209'; W. 076º 29.800'	Sediment greenish-grey, darker than sample 2, very few shells
4	N. 45º 19.156'; W. 076º 29.769'	Sediment dark, few shells
5	N. 45º 19.043'; W. 076º 29.921'	Sediment dark, few shells
6	N. 45º 19.128'; W. 076º 30.184'	Aquatic plants, black sediment, no shells
7	N. 45º 19.121'; W. 076º 30.212'	Sediments white, marl present, shells, living clams
8	N. 45º 19.165'; W. 076º 30.310'	Sediments very organic, no shells
9	N. 45º 19.232'; W. 076º 30.374'	Weedy area, sediments dark and organic
10	N. 45º 19.284'; W. 076º 30.426'	Few shells, very organic sediments
11	N. 45º 19.518'; W. 076º 30.094'	Sediments dark contains many shells with marl 'flakes'

* all samples gave positive results for presence of calcium carbonate (marl) when exposed to 1.2 M hydrochloric acid.

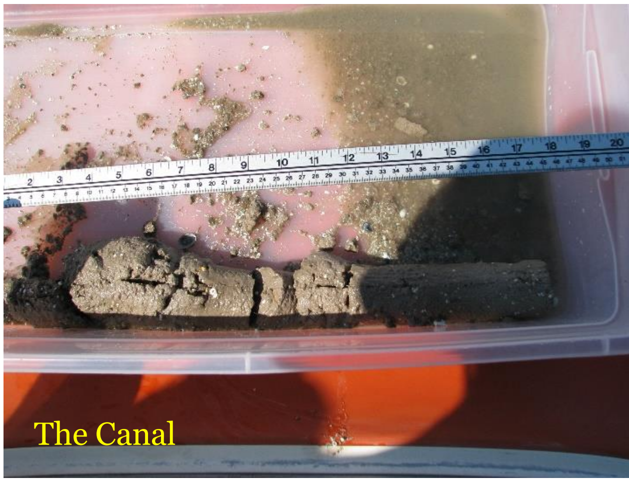
In addition to this, 10 core samples were taken in the Village Basin. All samples showed that a layer of shells and grey marl was overlain by about 15 cm of organic mud.

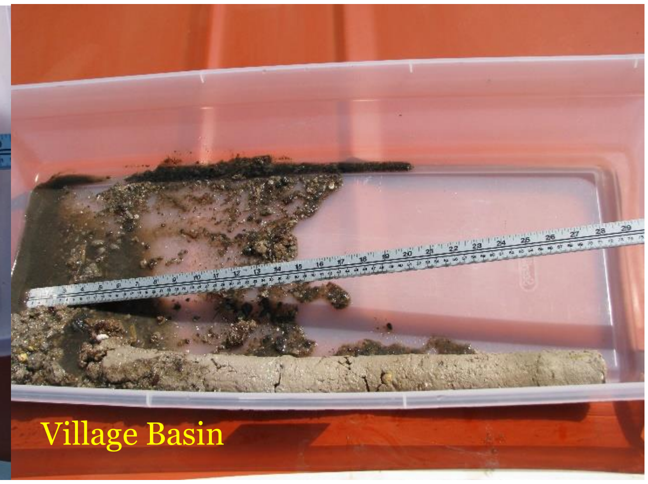
The organic mud did not react appreciably or at all with 10% HCl. The grey material was very reactive with 10% HCL indicating the substance to be precipitated calcium carbonate marl.

Below are a series of photographs of sediment cores taken from shallow locations in White Lake. These photos will provide the reader with a visual picture of the sediment material to be found at each of these locations.



Sediments for both Hayes and Bane Bays can best be described as gelatinous highly organic materials. Using dilute hydrochloric acid, we could not confirm the presence of marl in any of the samples we took at these locations.





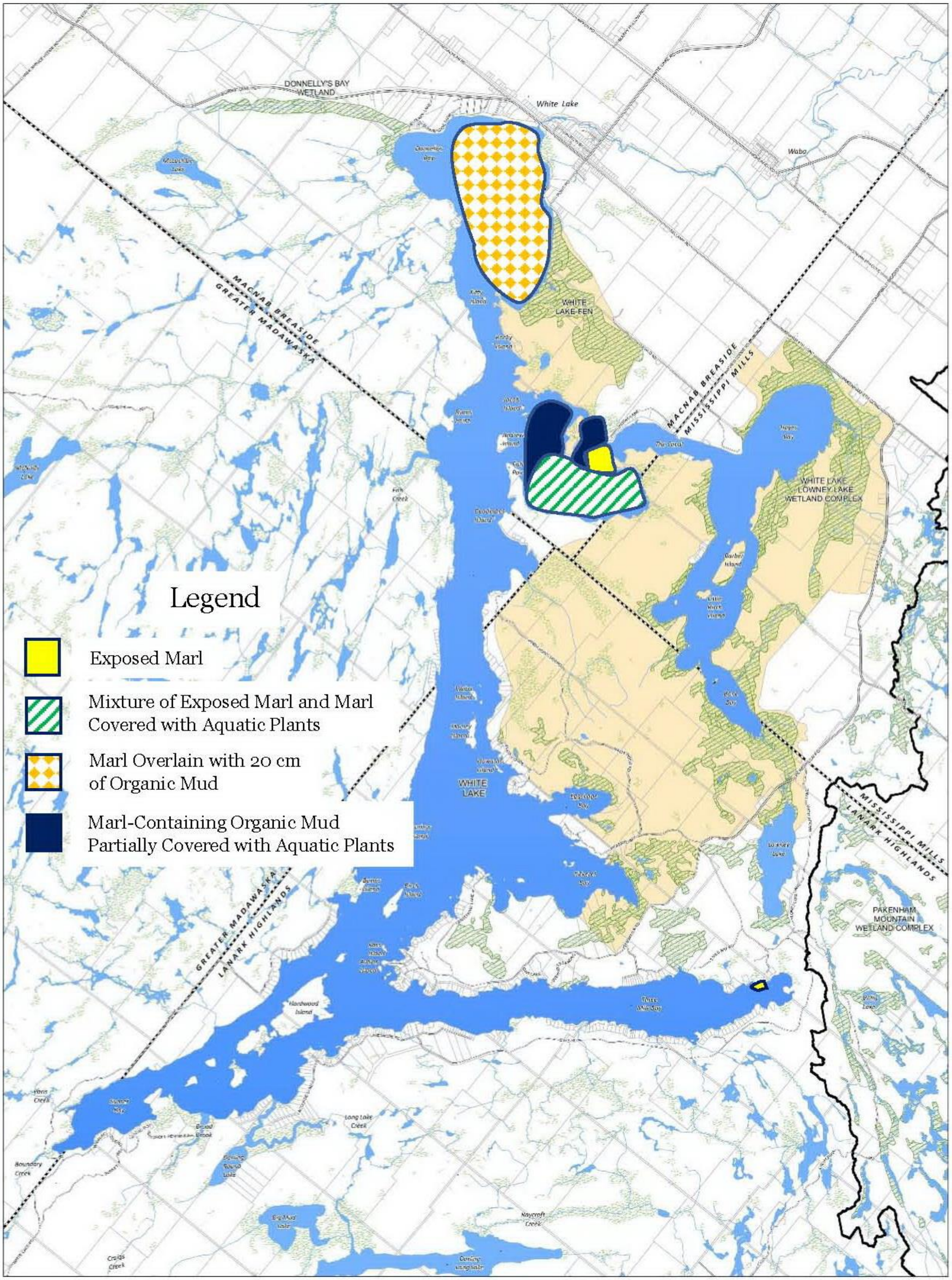
The nature of these sediments is quite different from those of Hayes and Bane Bays. Under a very thin layer of organic material, the brown to grey sediments were entirely composed of marl. When samples of these sediments were placed in a test tube containing dilute hydrochloric acid, they almost instantly completely dissolved confirming the presence of marl.

In his paper, Guillet indicated that the marl in White Lake is in active deposition and is continuing to this day. All three marl formation mechanisms are currently functioning and contributing to deposits already laid down since the end of the last ice age. The very thin organic layer on sediments in the Village Basin have very likely only been deposited since the White Lake dam was first constructed in 1851. None of the shells found in White Lake are fossil and living examples of each of these can currently be found in the lake.

Over the past several years we have observed that the total phosphorus concentrations for water samples taken at the Canal site were characteristically much lower than for water samples taken on either side of the site and also the lowest lake-wide. We now know that The Canal site is spring fed and that significant quantities of water enter that part of the lake from under the lake bed. It is a well-known fact that when bicarbonate rich waters precipitate calcium carbonate during marl formation that phosphorus is either co-precipitated with marl or adsorbed onto marl particles. As a result, water entering the lake in this way is effectively depleted in phosphorus giving rise to the low total phosphorus values we have observed.

Below is a map showing the location and nature of marl deposits in White Lake. Note that there is a very small patch of exposed marl on the north shore of the eastern end of Three Mile Bay. It is possible that this marl bed is forming from waters entering White Lake from geological areas similar to the Lowney Lake watershed, which is immediately adjacent to this spot.

Areas of White Marl on White Lake



3.7 Water Levels – White Lake Dam

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.

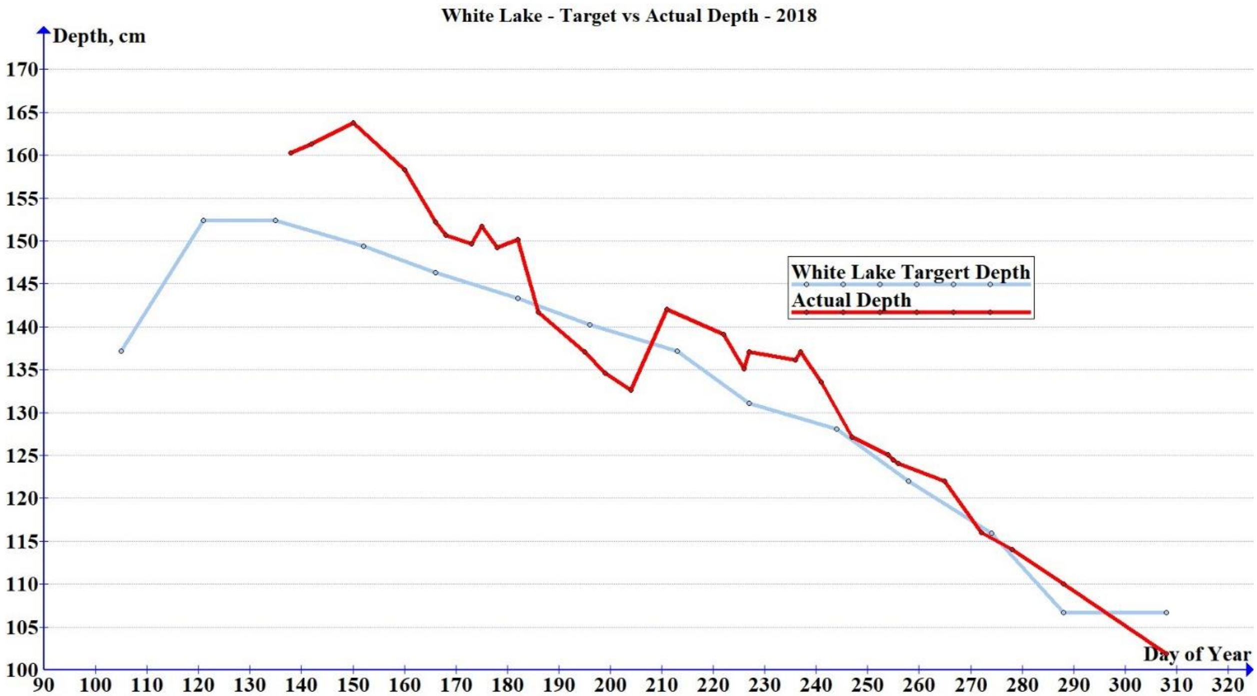
Dates	Target Levels	
	Decimal Feet	cm
January 1 to March 15	3.5	106.7
April 1	4.0	122.0
April 15	4.5	137.2
May 1	5.0	152.4
May 15	5.0	152.4
June 1	4.9	149.4
June 15	4.8	146.3
July 1	4.7	143.3
July 15	4.6	140.2
August 1	4.5	137.2
August 15	4.3	131.1
September 1	4.2	128.1
September 15	4.0	122.0
October 1	3.8	115.9
October 15 to December 31	3.5	106.7

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 water levels. We used a homemade device to measure water depth on the Western shore of the lake. Measurements were made from a dock using a rigid metal pole on which was attached a measuring tape calibrated in both English and Metric units. Documented in our 2017 Water Quality Monitoring Report was an equation derived which would faithfully convert dock measurements to White Lake Dam gauge readings.

The figure below shows actual depth measurements calculated (red line). Also plotted are the target water levels for the same time scale (Blue Line).



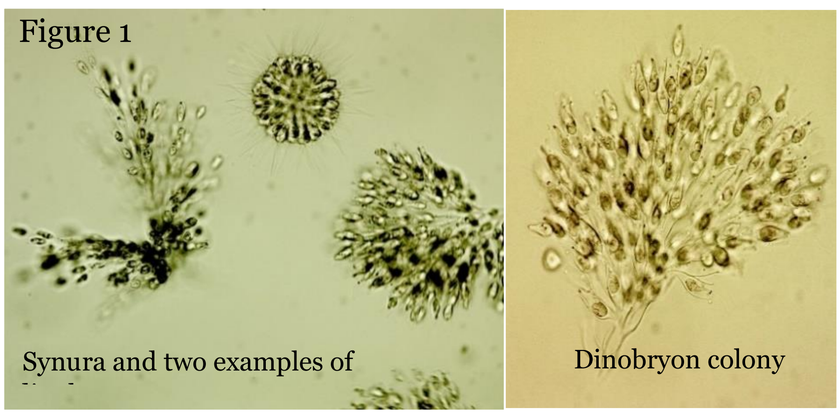
When comparing the line showing actual readings with that for target levels, it is evident that lake levels were high during the spring and early summer months and only returned to normalcy by mid-July. At its highest level, the lake was 14 centimetres deeper than its target depth.

The red line corresponding to actual lake depth is ragged with sudden dips followed by increases in water levels. This is normal and can easily be correlated to weather events such as heavy rainfall and periods of drought. The last reading on day 310 shows the lake to be lower than the target value by about 7 cm. This may not be deliberate but will serve to improve pickerel spawning beds as well as control zebra mussels to a greater depth along the shoreline.

3.8 <u>The Chrysophytes: Golden Brown Algae of White Lake</u>

Dave Overholt

Much attention is directed to the green and blue-green algae in White Lake. But White Lake is characterized by more than these two phytoplankton groups. In fact, during the summer months and into the fall of 2018, White Lake could be described as a 'Chrysophyte' lake; a lake composed of 'Golden Brown' Algae. Chrysophytes have the ability to exploit nutrient resources in ways not available to other algae. Their chloroplasts support nutrient production through photosynthesis as would be expected for an alga but they also ingest other organisms such as bacteria. This capability allows them to use both autotrophic and heterorophic processes[11], shifting their dependence according to the situation most favoured. For this reason they are described as 'mixotrophic' specialists. Two common members of the Chrysophyte group are Synura and Dinobryon (Figure 1). Both of these types form organized colonies made up of individual cells. Both use flagella to propel themselves through the water column.



The individual cells of Dinobryon (Figure 2) form clear vase-shaped structures called lorica that are composed of cellulose. Their progeny grow from the interior wall of each parent lorica. The succession of lorici result in a branching tree-like structure. Figure 2b below indicates the barely visible paired flagella of dinobryon. These contribute to the rapid tumbling motion of the entire colony. It is thought that bacteria are absorbed when they become trapped between these flagella.

[11] Technically, the definition is that **autotrophs** obtain carbon from inorganic sources like carbon dioxide (CO_2) while **heterotrophs** get their reduced carbon from other organisms. **Autotrophs** are usually plants; they are also called "self feeders" or "primary producers".

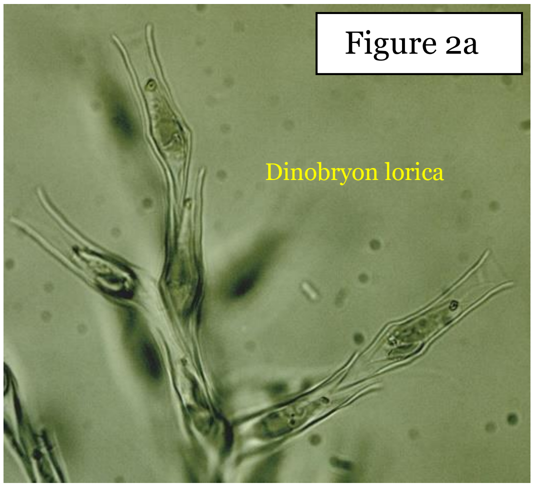


Figure 2a

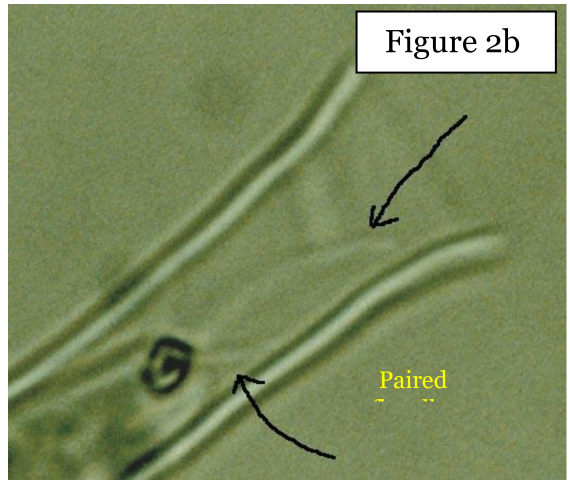


Figure 2b

Synura (Figure 3) is another free swimming chrysophyte colony. Each individual cell possesses a pair of flagella of unequal length.

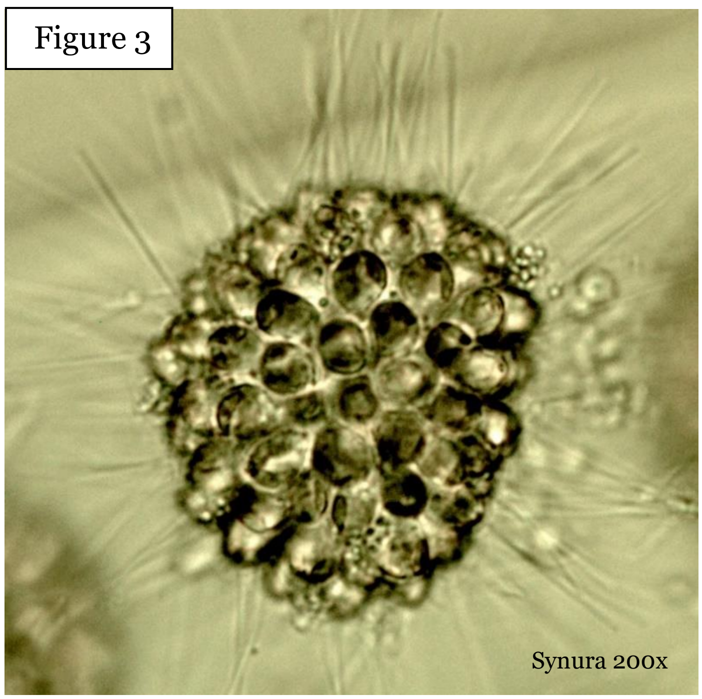
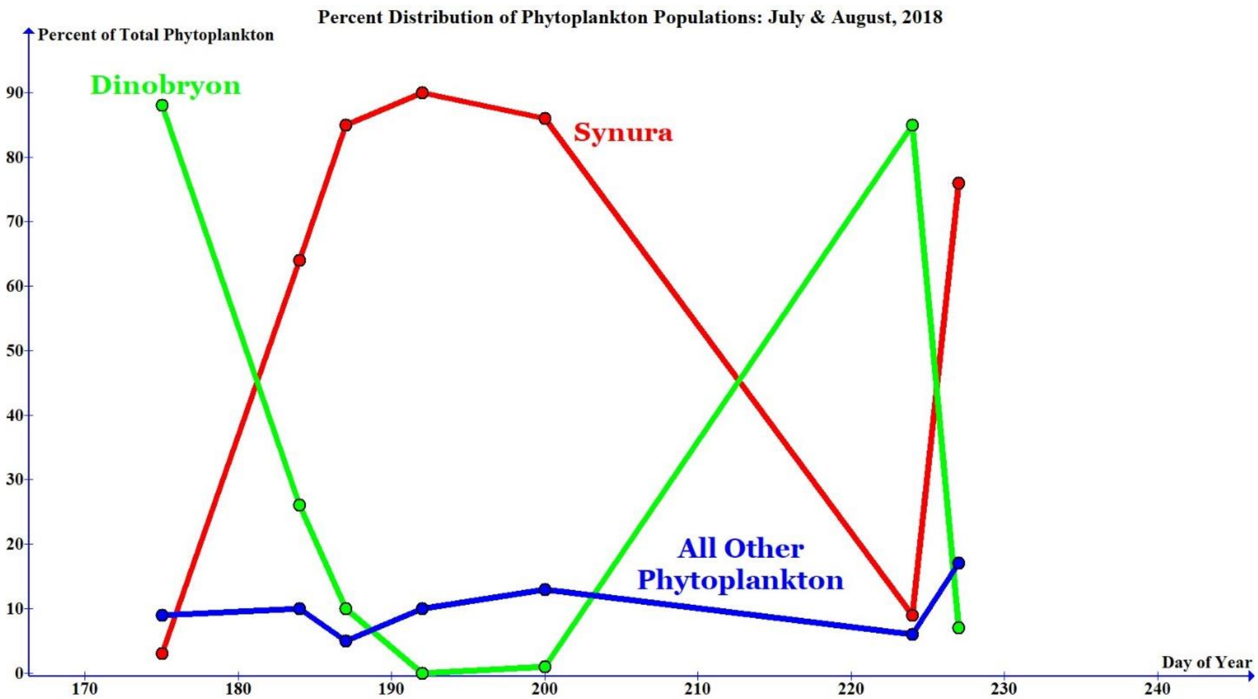


Figure 3

The relative occurrence of phytoplankton can be assessed from microscope 'field of view' counts for recognized classes of phytoplankton. The following graph (Figure 4) shows the percent population distribution for Dinobryon and Sinura colonies for samples taken at the Three Mile Bay sampling site. Samples were taken during a two month period from June 24 to August 15, 2018. In Figure 4, the term 'other phytoplankton' refers to the sum of all other phytoplankton not identified as Dinobryon or Sinura. This category of phytoplankton accounted for only a very small percentage of the total number of phytoplankton in the water column when compared to the chrysophytes.

Figure 4



These data supports the observation that White Lake was, at least during two summer months, a chrysophyte lake. Extending observations like these into 2019 and future years could show us how the plankton community fluctuates over time during the ice-free months.

3.9 Acknowledgements

We are grateful to the Lake Partner Program of the Ontario Ministry of the Environment Conservation and Parks for providing us with sampling equipment and the analysis of water samples for total phosphorus, calcium, dissolved organic carbon, and chloride. Costs and time related to lake sampling and all other activities were self-funded by members of the Science Committee of the White Lake Preservation Project.

3.10 Author Profiles

Conrad Grégoire is a retired Research Scientist in Inorganic Analytical Chemistry. He earned his Masters degree from the University of Manitoba and his Ph.D. from Carleton University. His professional career was spent at the Geological Survey of Canada where he was Head of the Analytical Chemistry Research Laboratories. For over 20 years, he was also an Adjunct Professor of Chemistry at Carleton University. Conrad is interested in studying the chemistry and biology of White Lake and to establish base line values for water quality parameters. He is also the Webmaster for the White Lake Preservation Project.

Dave Overholt worked in a small business in Toronto for over 30 years, and his wife Carol was a school teacher with the Toronto Board of Education. When they retired, they decided to move to Almonte to be closer to the family cottage. Dave has been spending summers on White Lake since he was 9 years old. (he is now 66). David's enthusiasm for things aquatic was stimulated by Rachel Carson's *The Sea Around Us*. When he gained access to a microscope, he discovered that many of the creatures she described in her book could be found in his own back yard. Although he does not have a science background, he would like to contribute in any way possible to the lake research conducted by the WLPP.

Adam Pugh's family has owned and operated Cedar Cove Resort on White Lake for the past 10 years. Adam feels privileged to have spent a good portion of his life on this beautiful lake. Growing up there led him to develop a passion for conservation and the biology of local fisheries and wildlife. Adam's passion took him to Sir Sandford Fleming College in Lindsay, Ontario where he completed the advanced diploma in Fish and Wildlife Technology. He now owns his own business providing guided fishing and hunting trips on White Lake and the surrounding area. Adam has been awarded the Youth Entrepreneur Award from the Township of Lanark Highlands as a result of the success he achieved with his ice hut rental business.

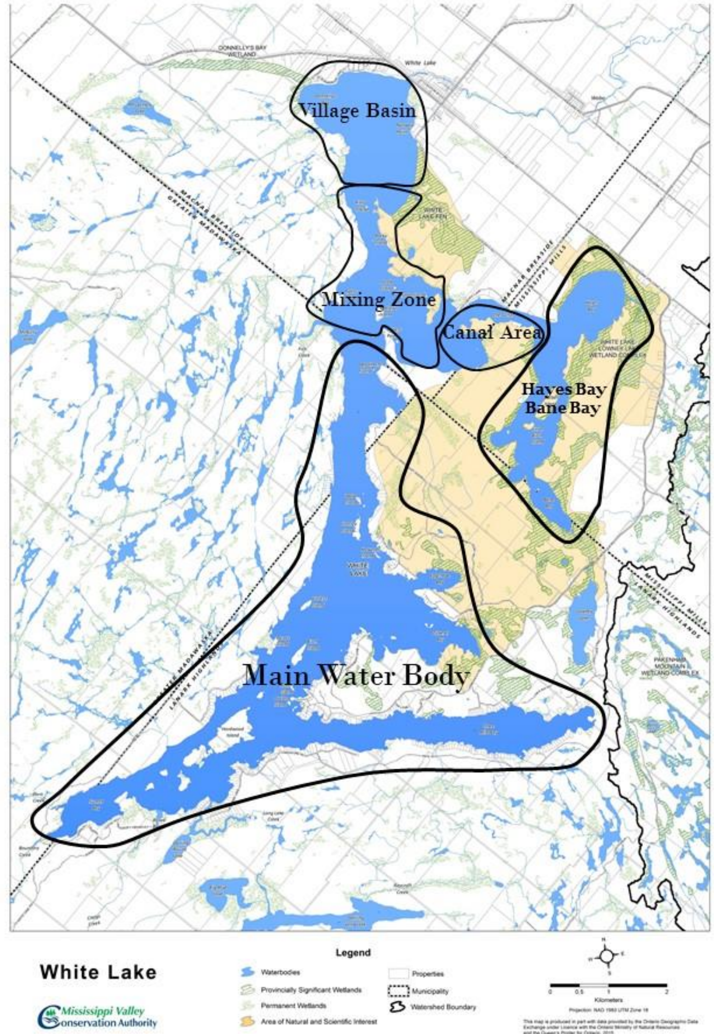
Joyce Benham is an accomplished nature photographer and along with husband **Robert Carrière**, spends one week in July of each year photographing and documenting wildlife sightings on White Lake. The naturalist couple from Hammond, Ontario document the number and location of adult loons and chicks and from file photos can recognize individual loons. Monitored annually, loon populations can be used to measure habitat health as well as threats from wave action, boat traffic and other factors contributing to changing loon populations.

APPENDIX - 1
White Lake Zone-Map

Based on our research, 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.

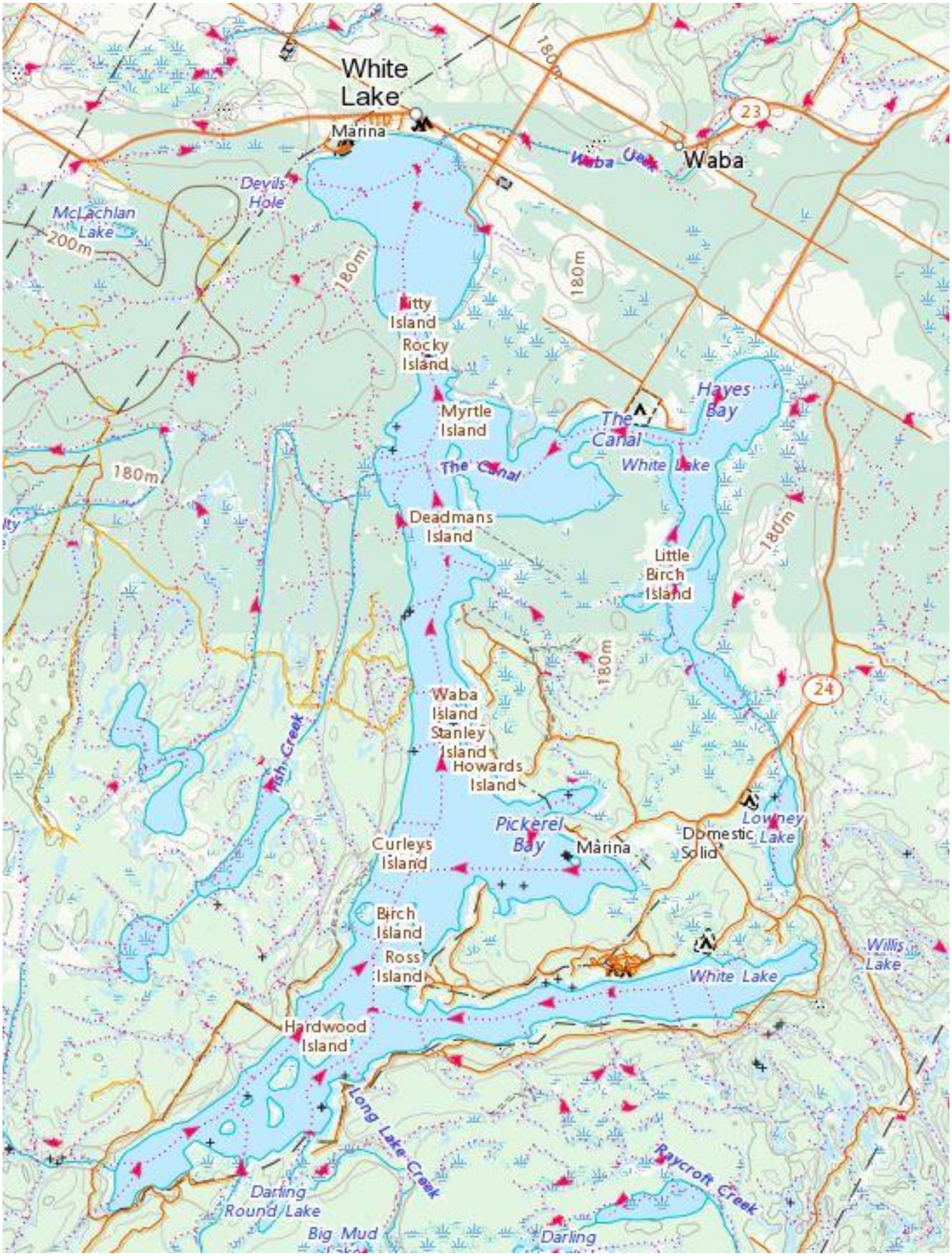
The ***Mixing Zone (Zone 5)*** encompasses both sides of the narrows including Rocky Island and extends some distance towards the Village Basin. This area is characterized by shallow dark sediments and ranges from 2.5 m to 4 m in depth at high water. In this area, the lake floor is covered with dense 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.

APPENDIX - 2

Water Flow Patterns* – White Lake

*Natural Resources Canada - Topographical Maps On-Line


White Lake
Marina
Waba
23
Devils Hole
McLachlan Lake
200m
180m
180m
180m
Rocky Island
Myrtle Island
Hayes Bay
The Canal
The Canal
White Lake
180m
Deadmans Island
Little Birch Island
180m
Waba Island
Stanley Island
Howards Island
24
Pickerel Bay
Marina
Domestic Solid
Lowney Lake
Curleys Island
Birch Island
Ross Island
White Lake
Willis Lake
Hardwood Island
Long Lake Creek
Raycroft Creek
Darling Round Lake
Big Mud
Darling

APPENDIX - 3

Water Temperature Maps

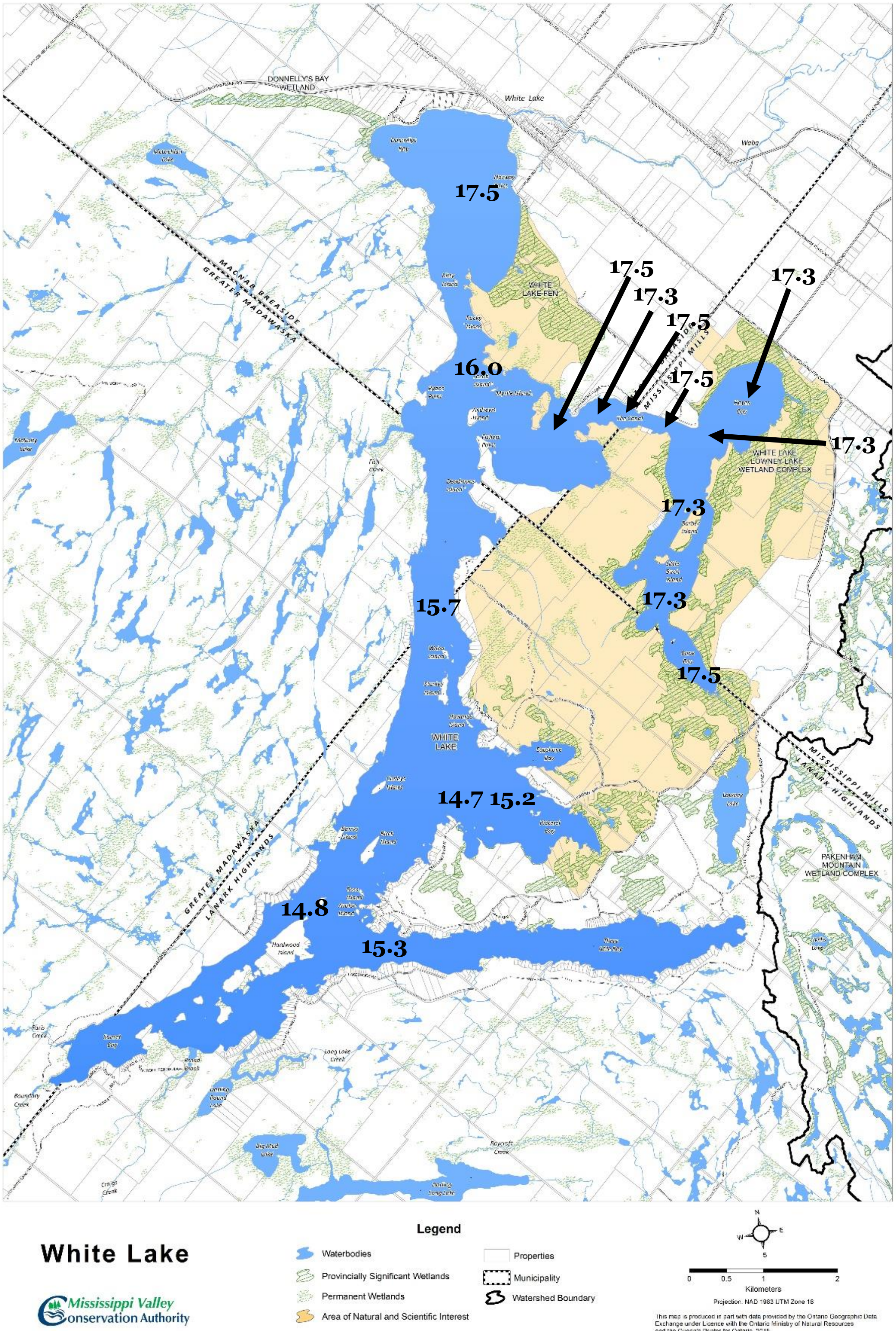
The following are 11 maps of water temperature measurements taken on White Lake water samples collected at the beginning and middle of each month from May to October, inclusive.

Depending on the date, values are shown for our core nine sampling sites or a much larger number of sites covering the entire surface of White Lake.

Interpretation of this data is included in the main section of this report and will not be duplicated here. Also, the data used in these maps is included in the Data Tables appendix.

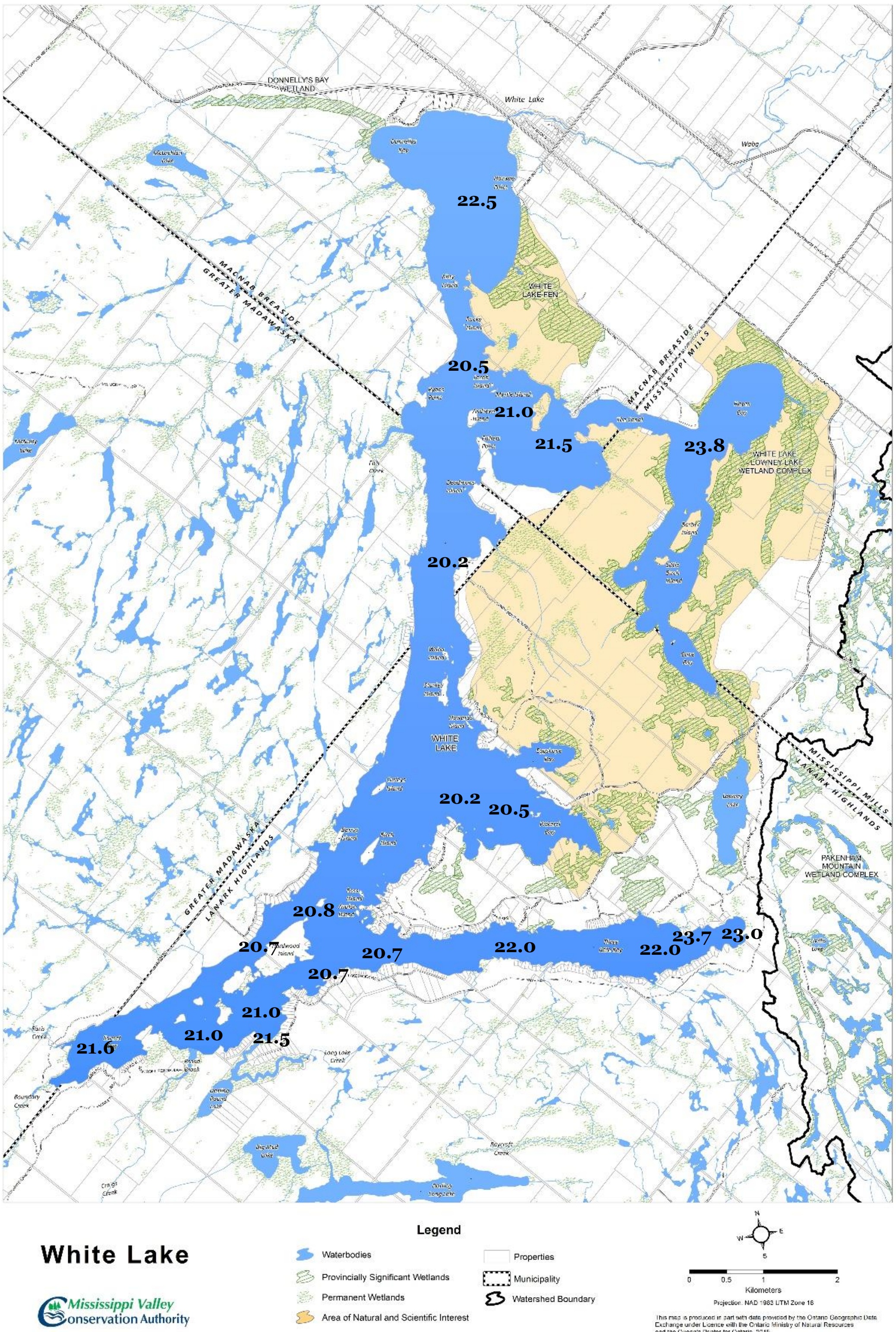
Water Temperature (◦C)

May 18, 2018



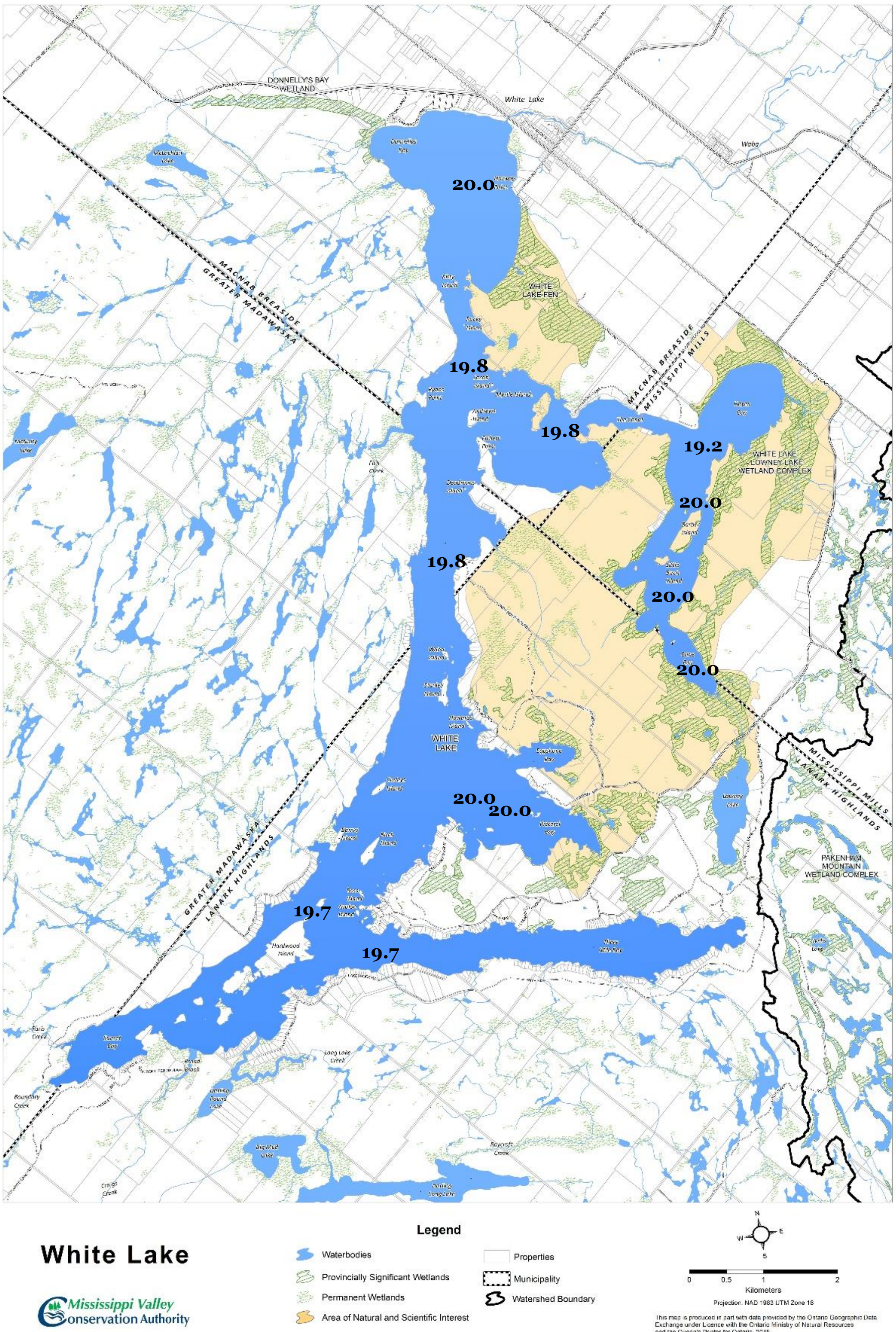
Temperature (◦C)

May 30, 2018



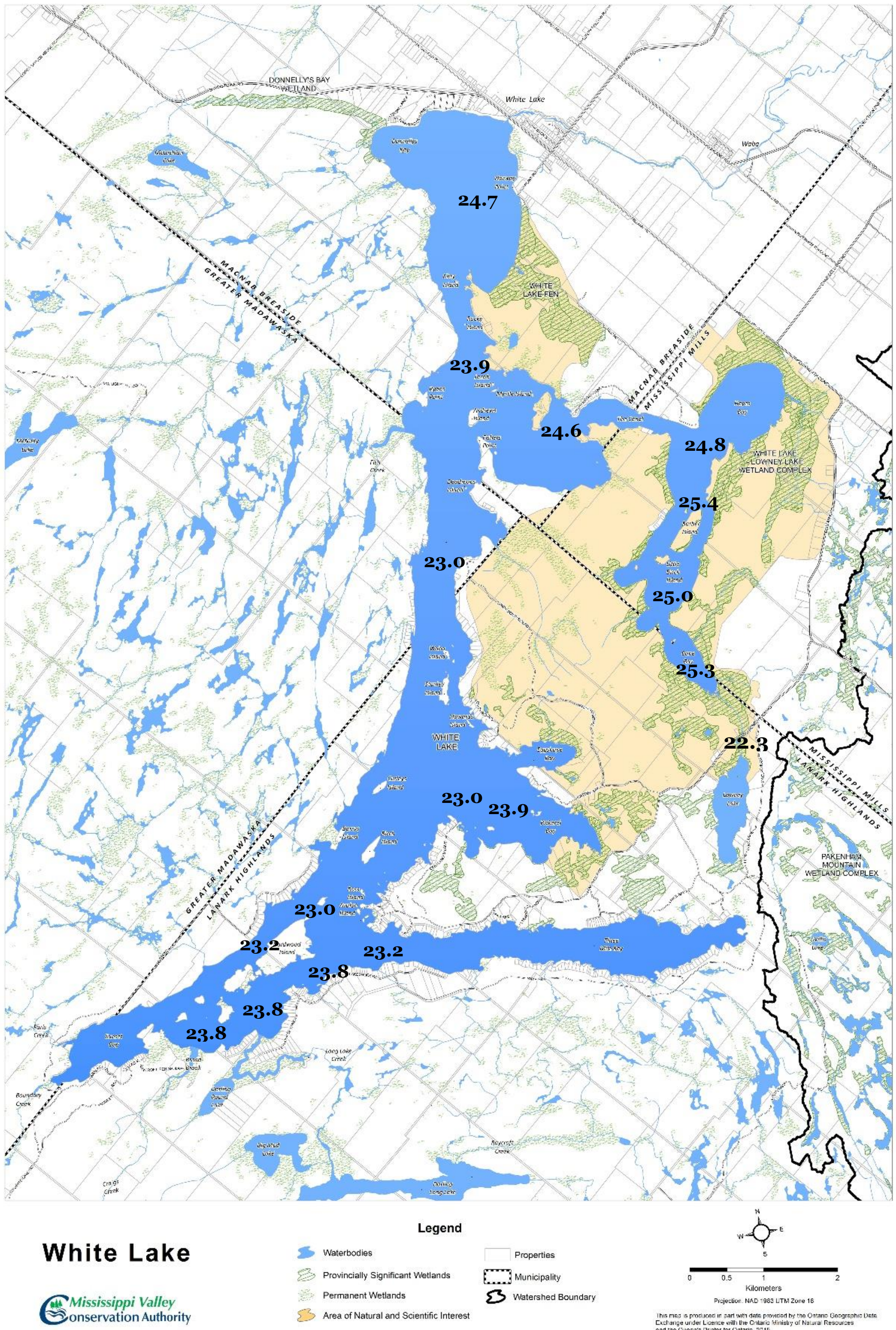
Temperature (◦C)

June 15, 2018



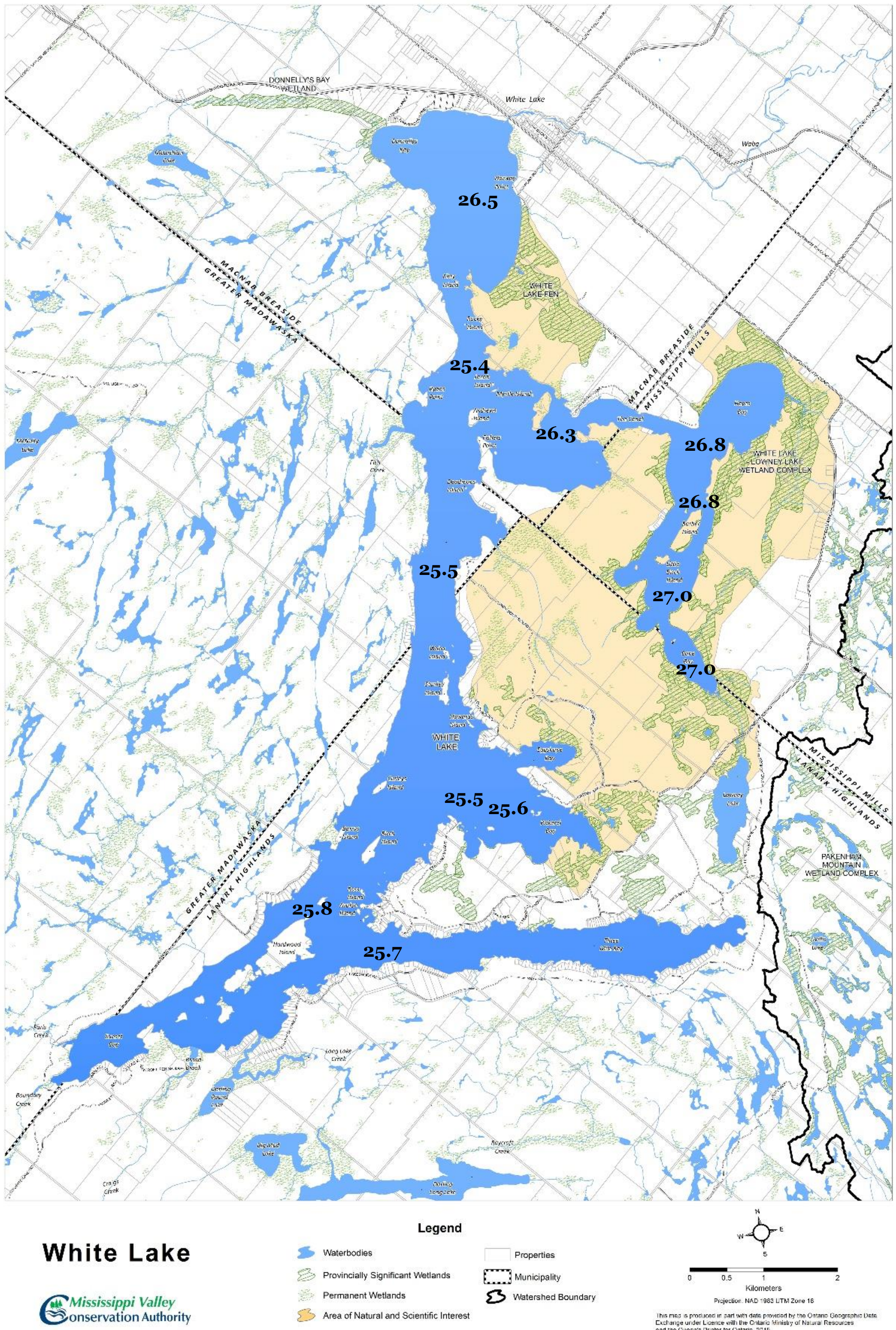
Temperature (◦C)

June 30, 2018



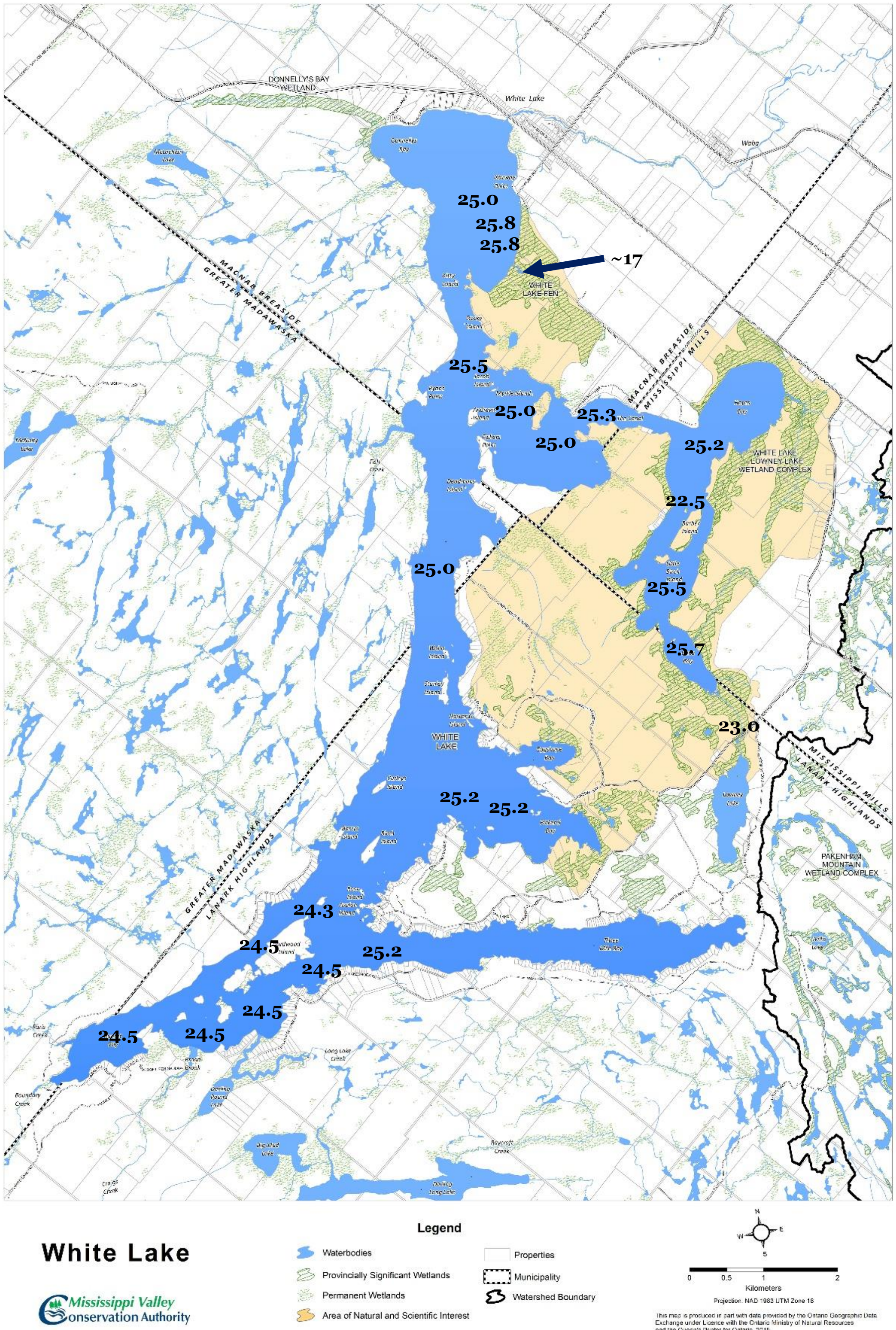
Temperature (◦C)

July 15, 2018



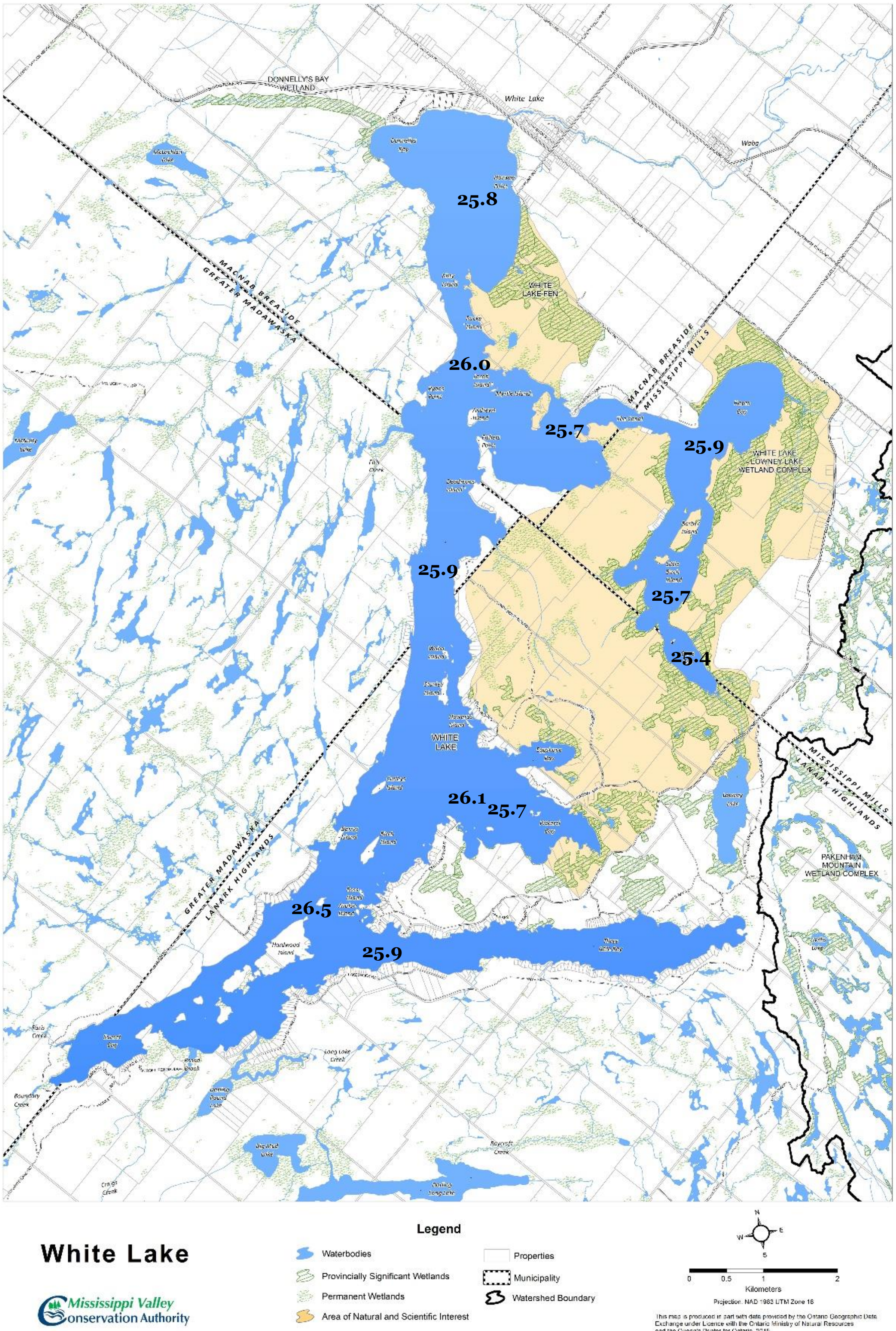
Temperature (◦C)

July 31, 2018



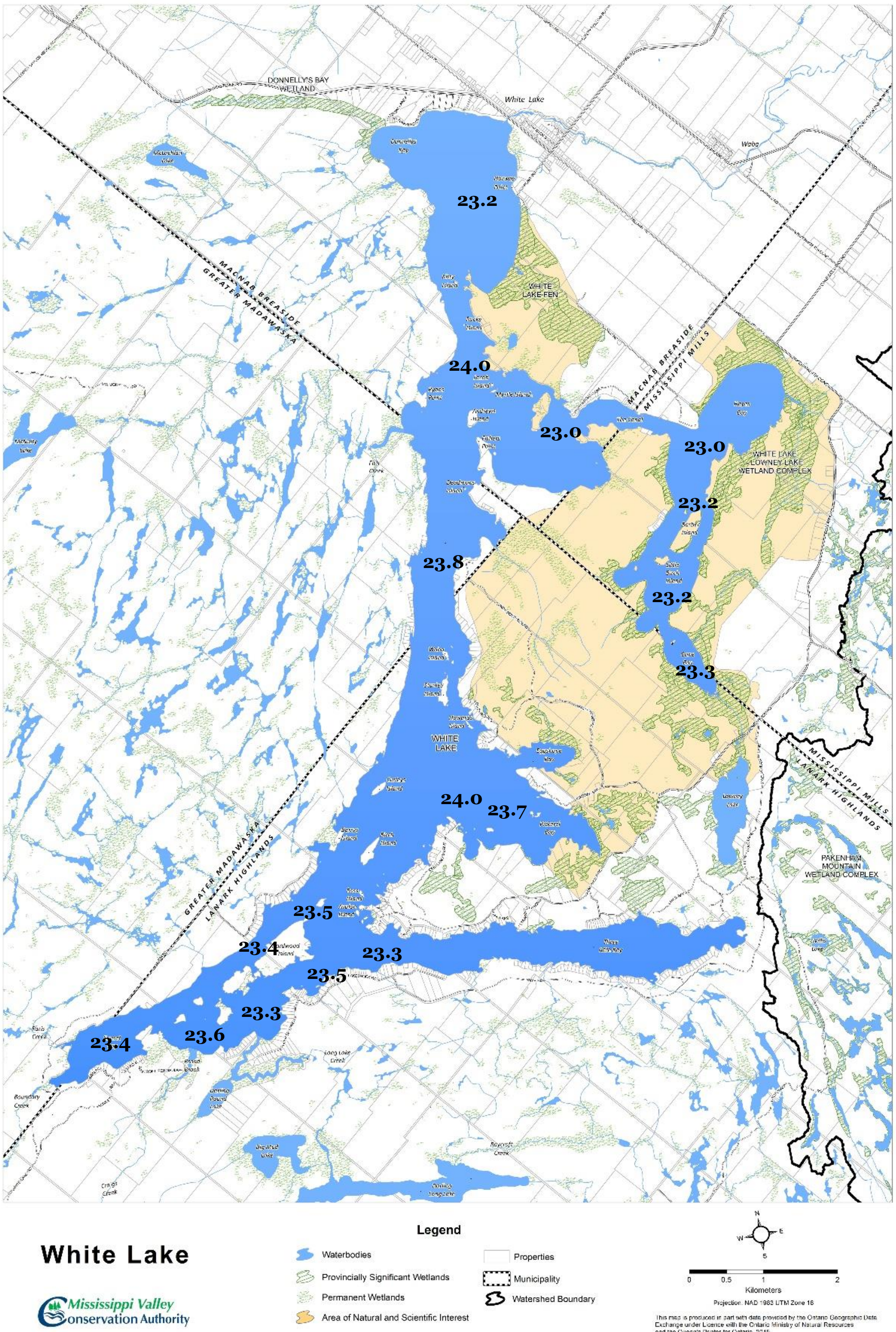
Temperature (◦C)

August 16, 2018



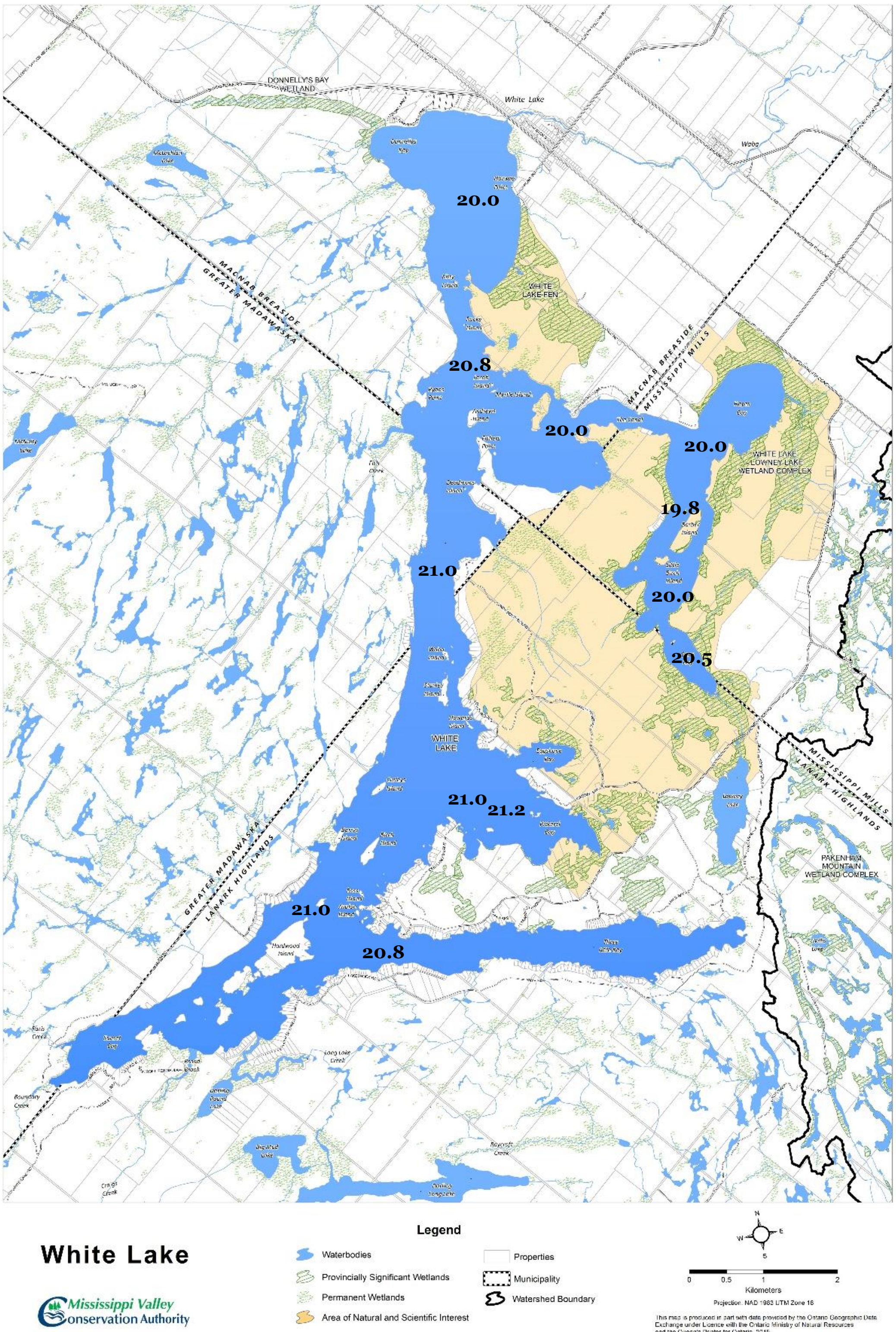
Temperature (◦C)

August 30, 2018



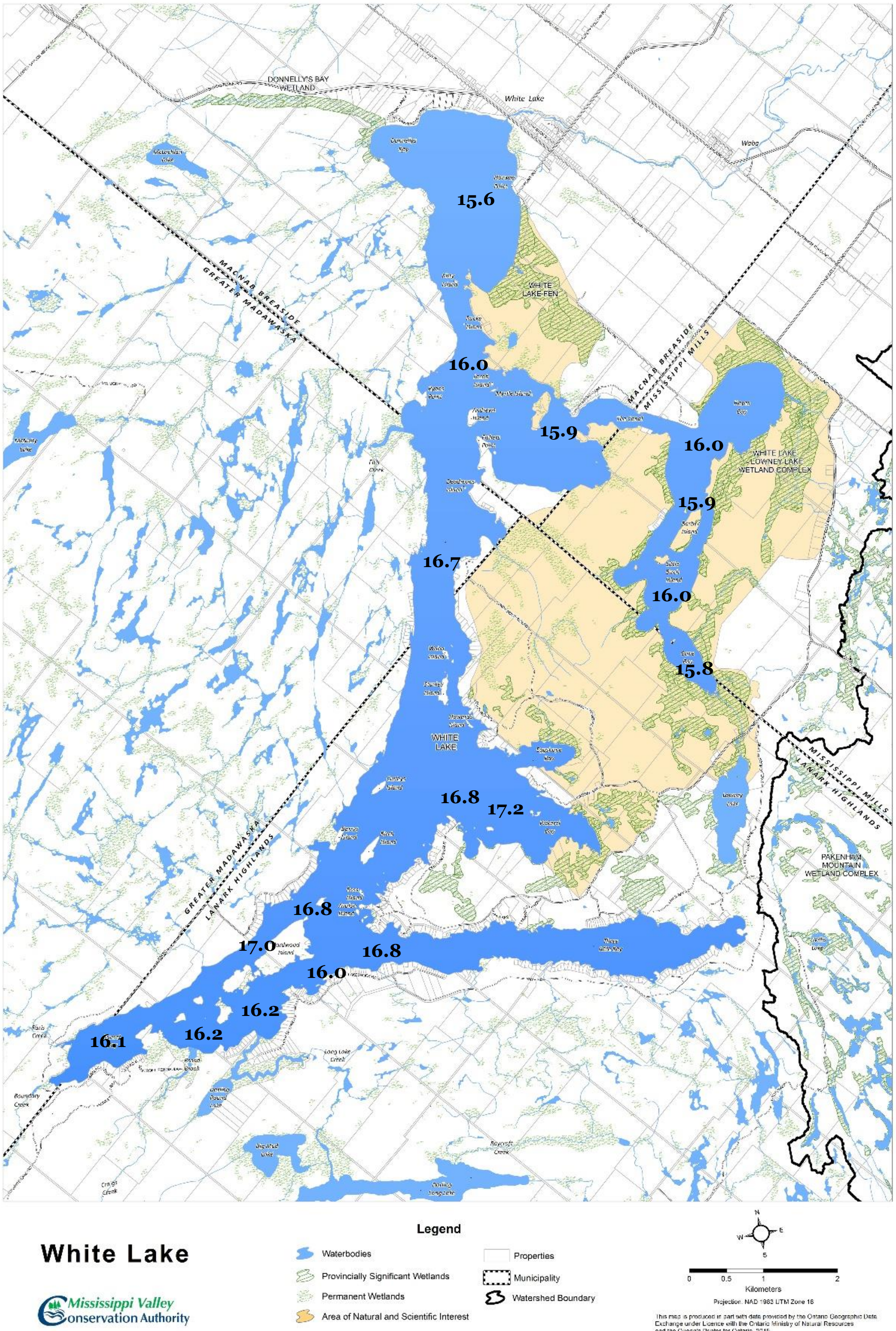
Temperature (◦C)

September 13, 2018



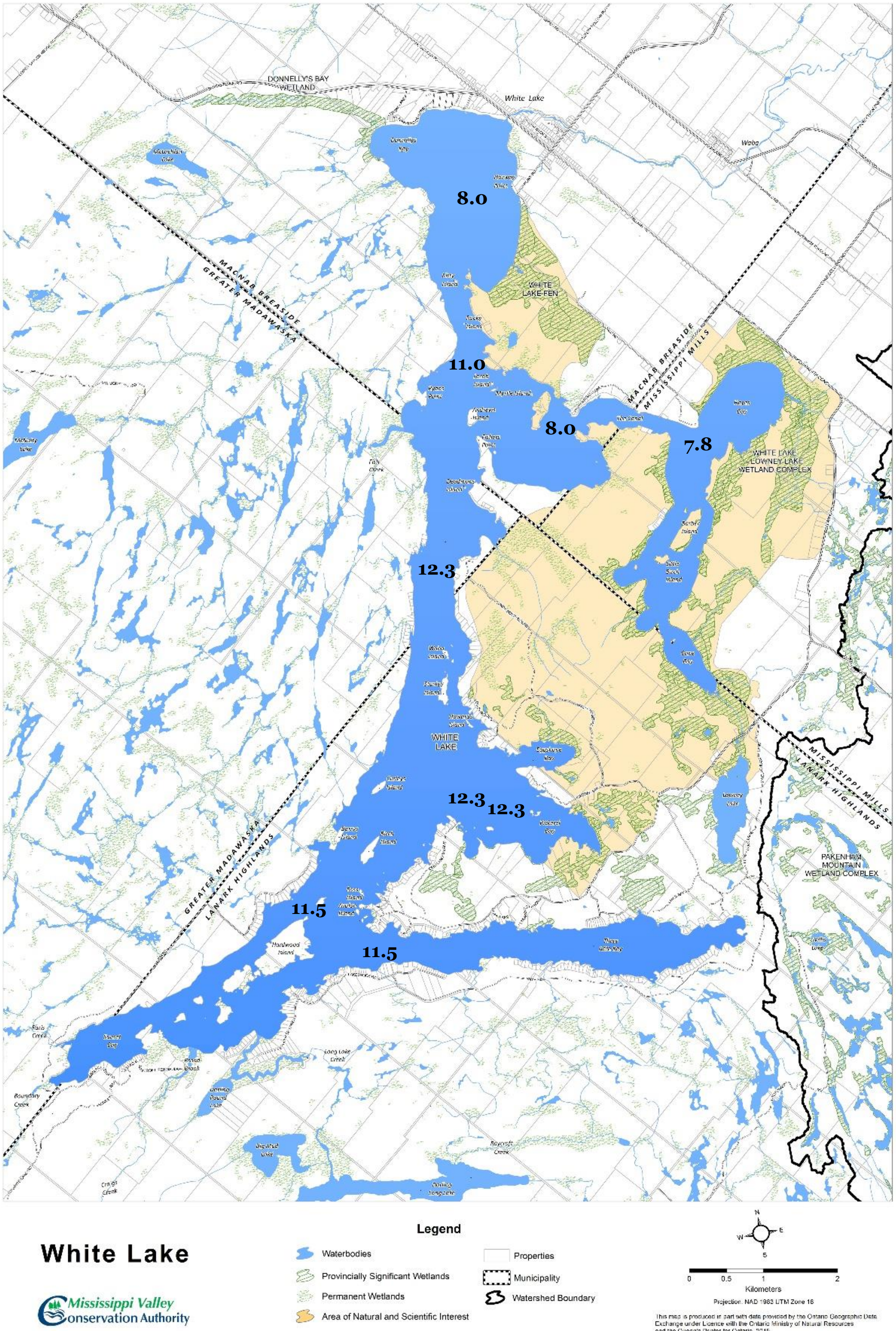
Temperature (◦C)

September 30, 2018



Temperature (◦C)

October 16, 2018



APPENDIX - 4
pH Maps

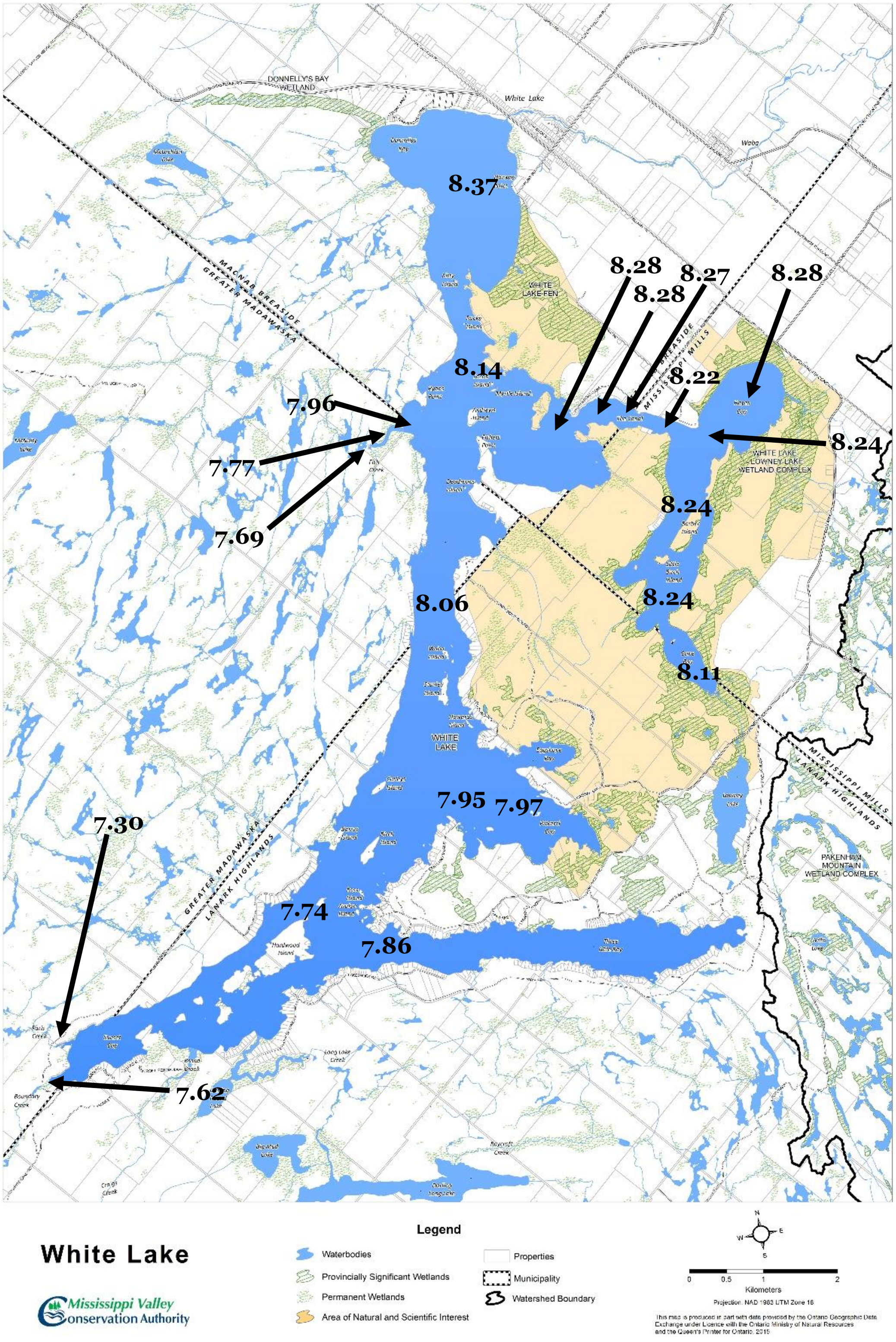
The following are 11 maps of pH measurements taken on White Lake water samples collected at the beginning and middle of each month from May to October, inclusive.

Depending on the date, values are shown for our core nine sampling sites or a much larger number of sites covering the entire surface of White Lake. Also included are values for Boundary and Paris creeks located at the far end of Sunset Bay as well as Lowney Lake creek, the outflow of Lowney Lake into White Lake's Bane Bay.

Interpretation of this data is included in the main section of this report and will not be duplicated here. Also, the data used in these maps is included in the Data Tables appendix.

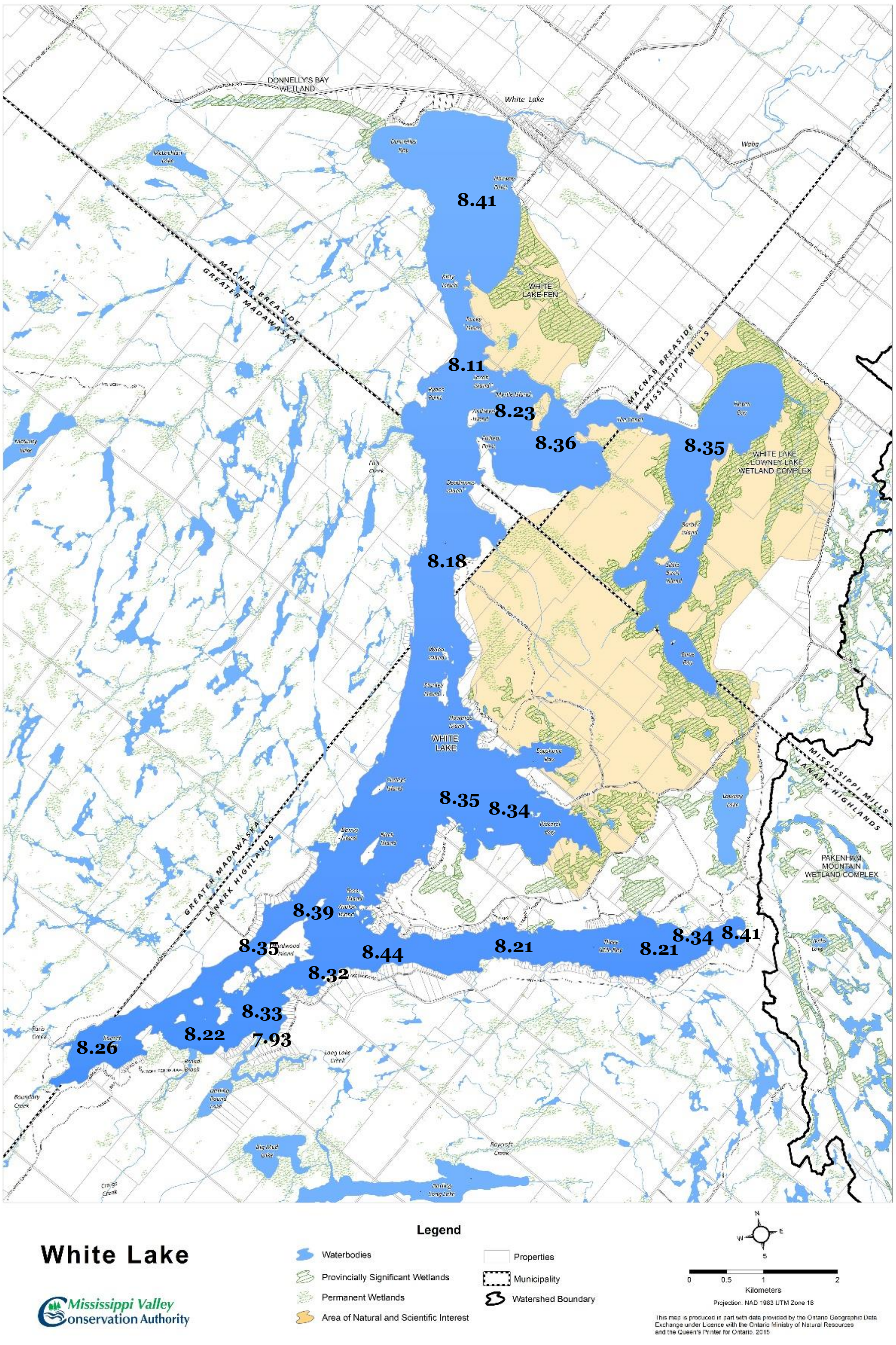
pH

May 18, 2018



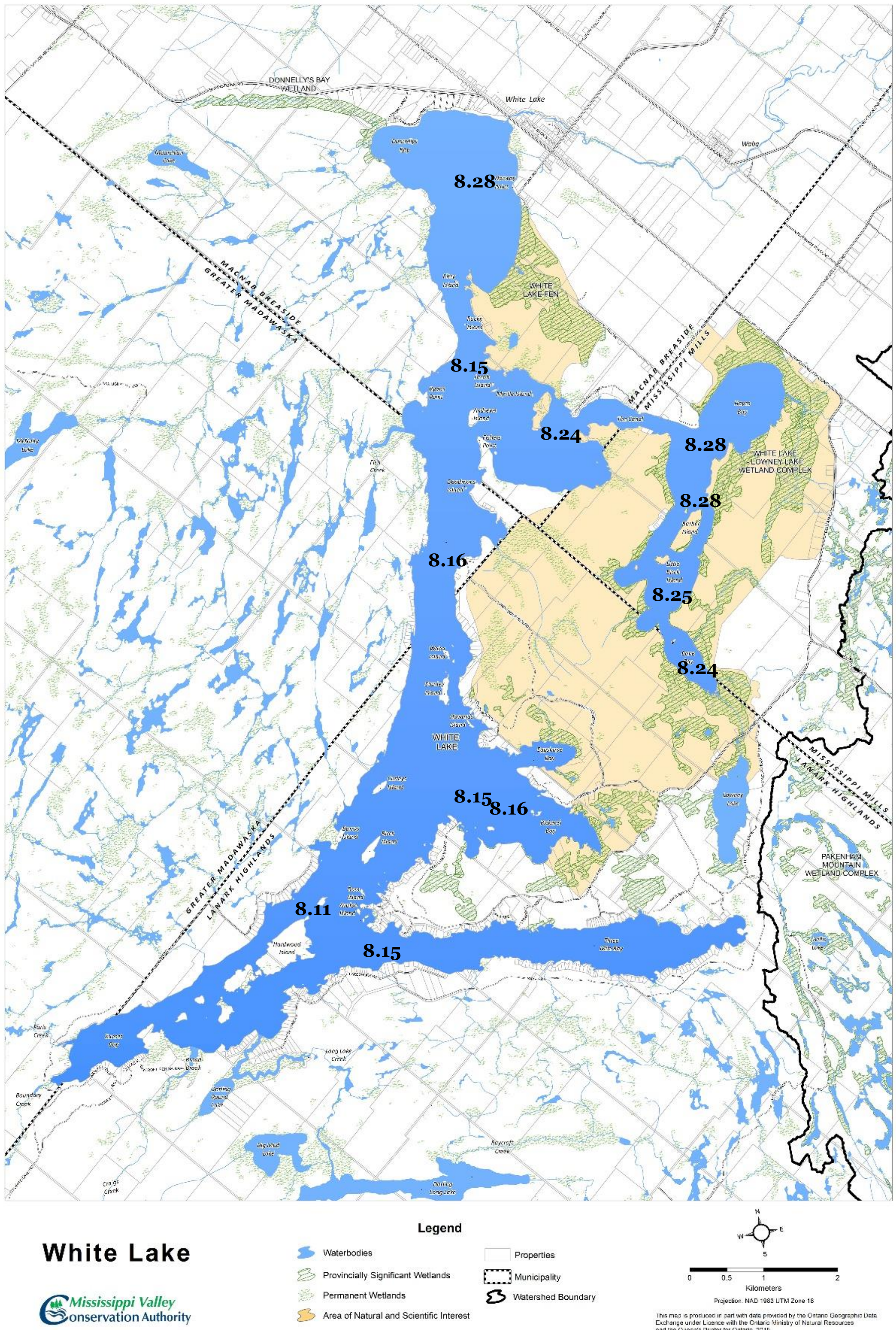
pH

May 30, 2018



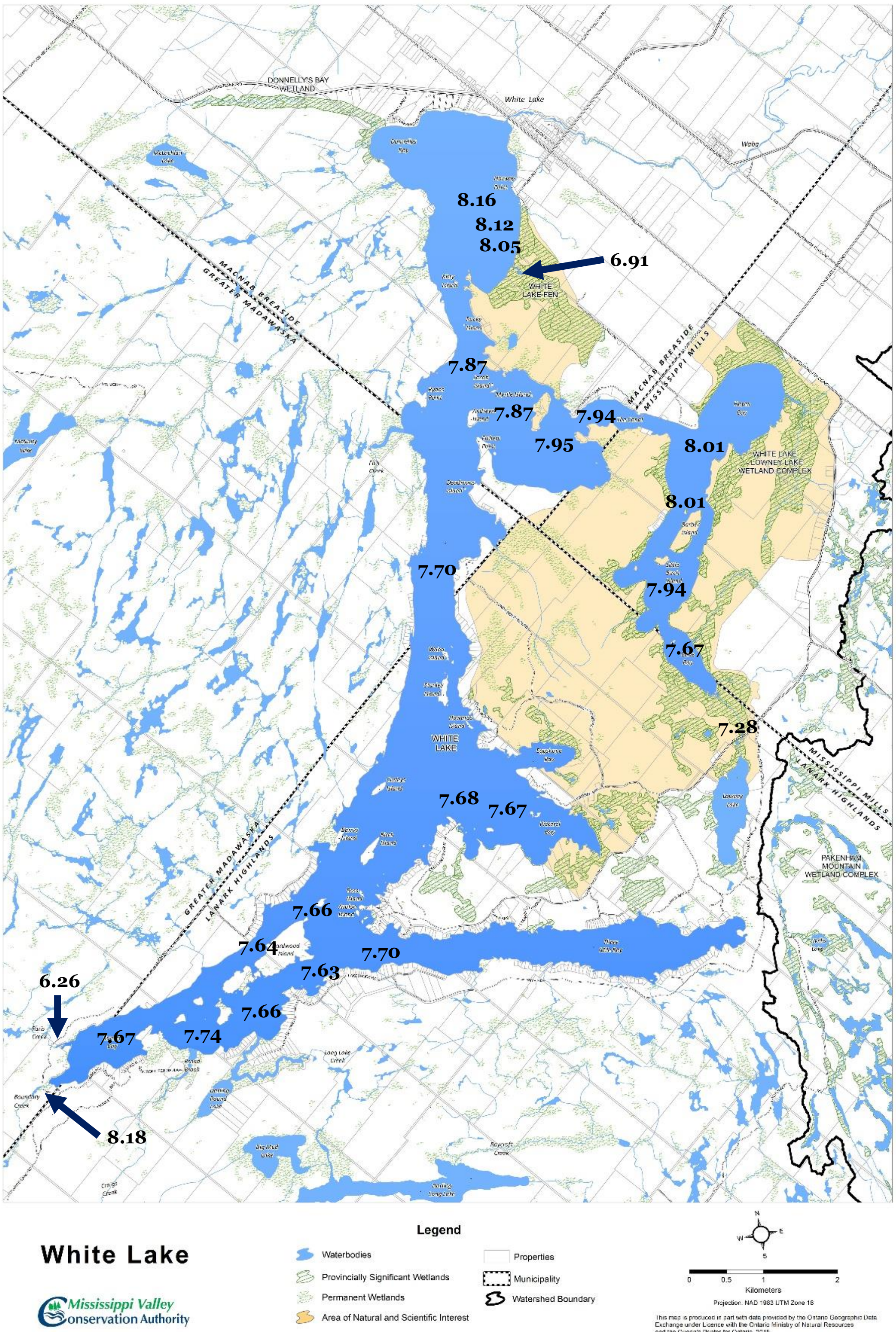
pH

June 15, 2018



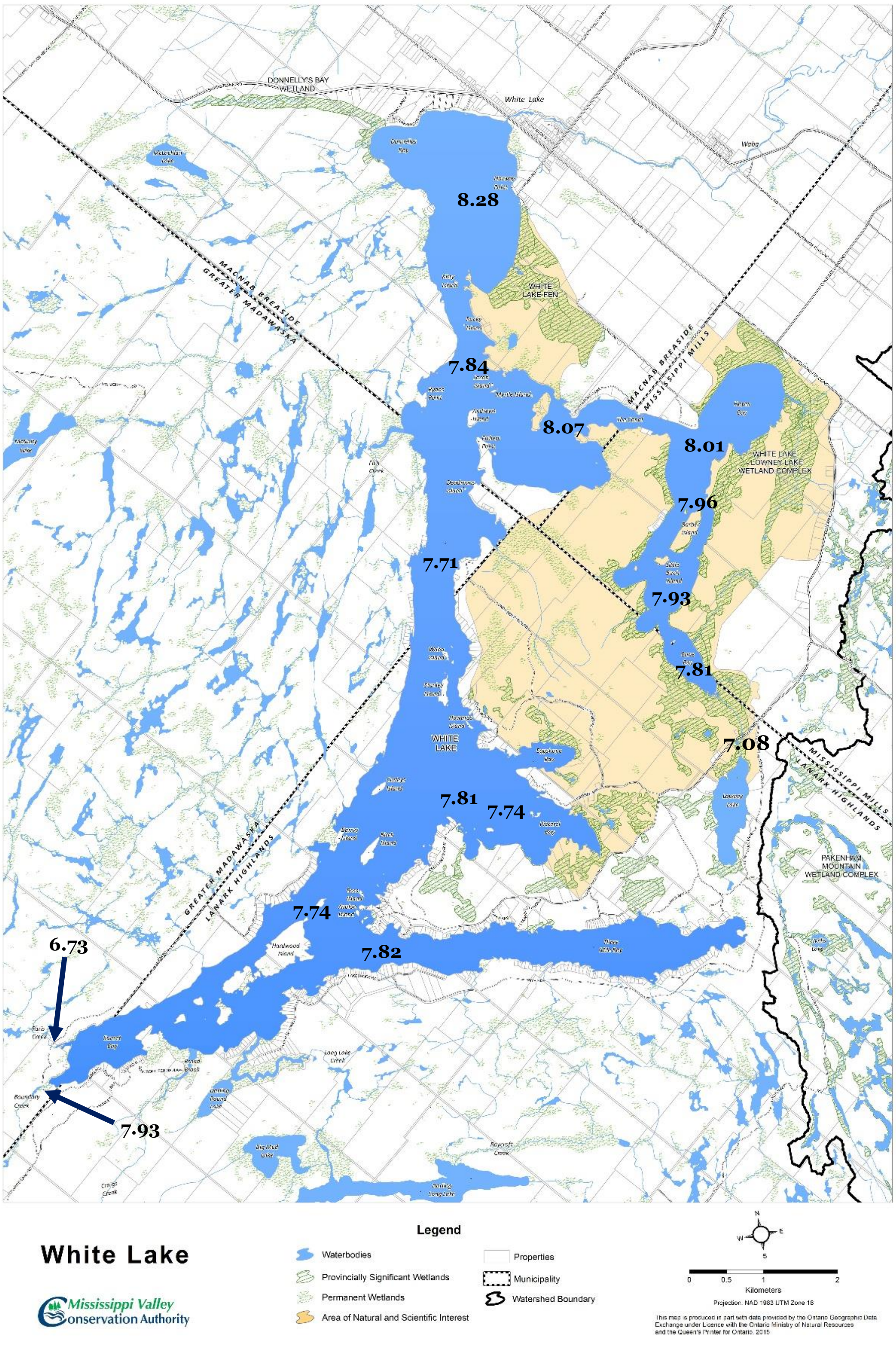
pH

July 31, 2018



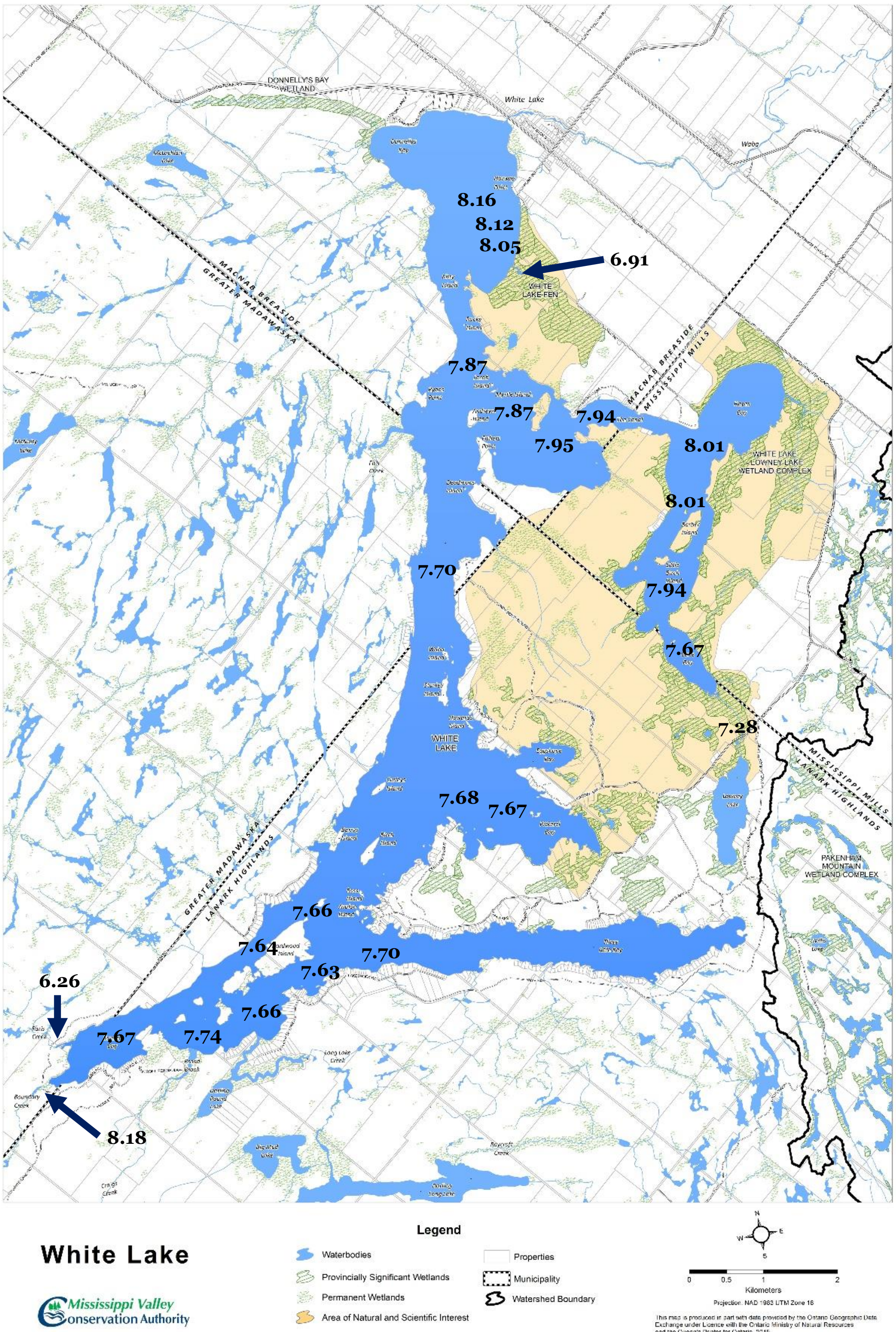
pH

July 15, 2018



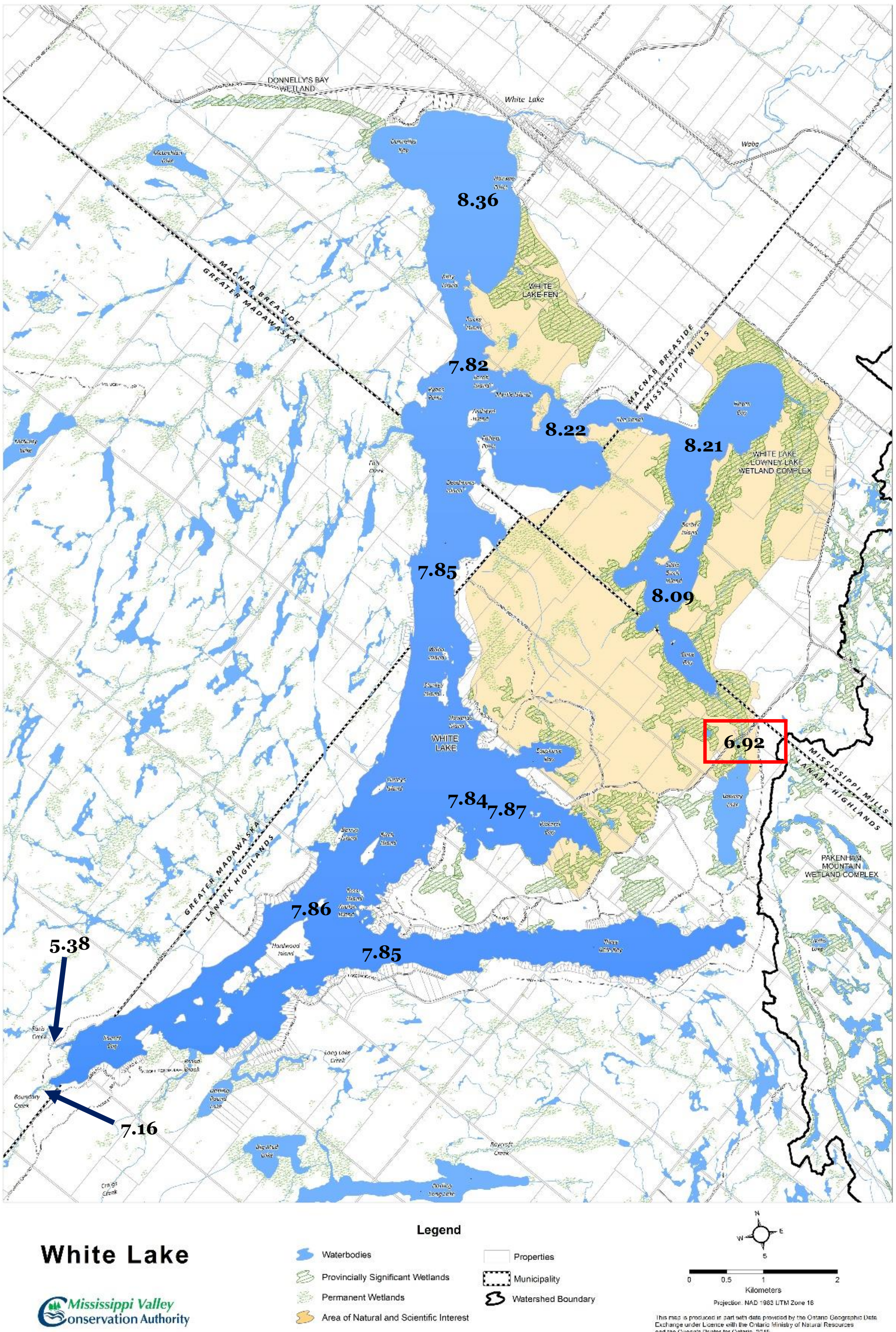
pH

July 31, 2018



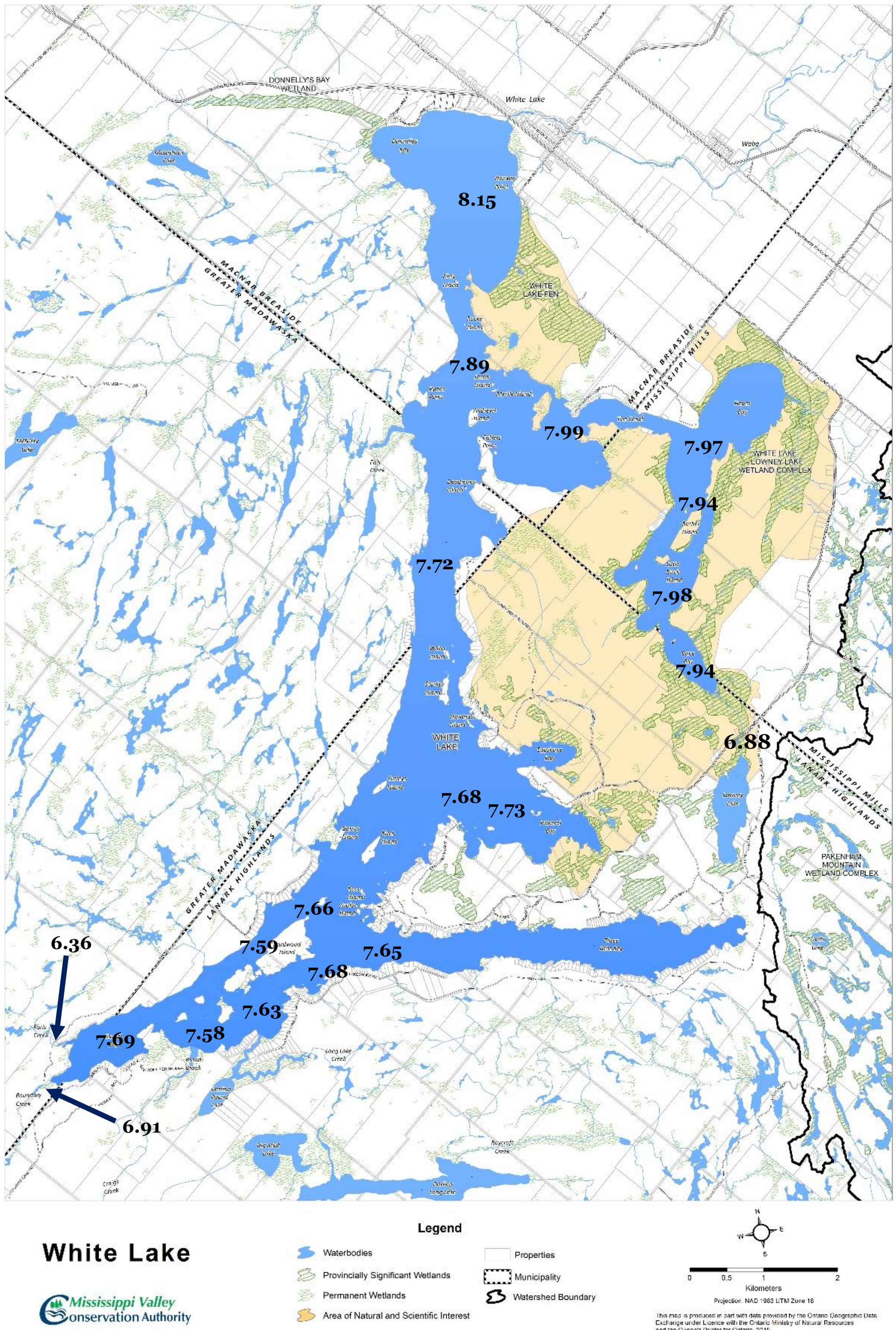
pH

August 16, 2018



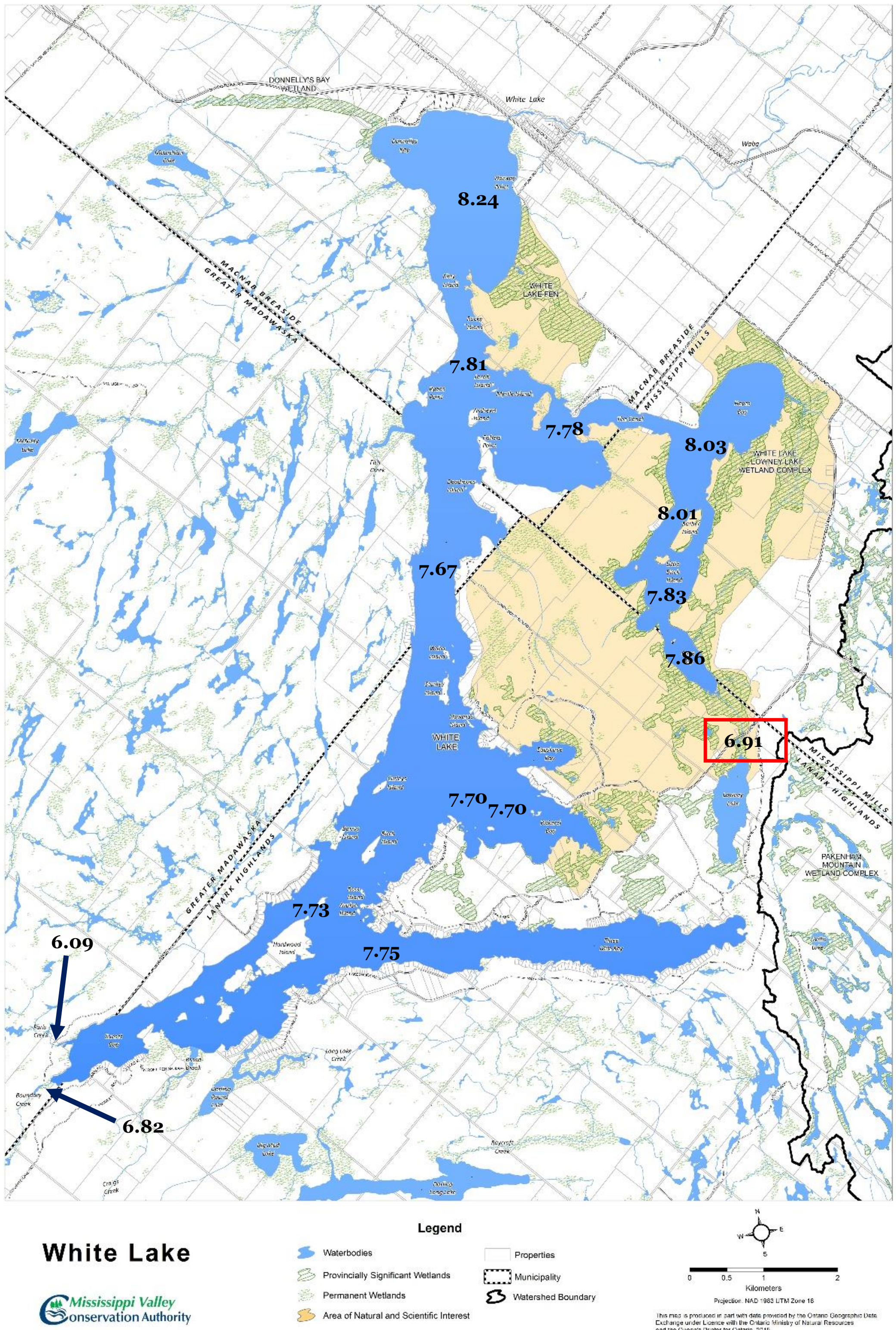
pH

August 30, 2018



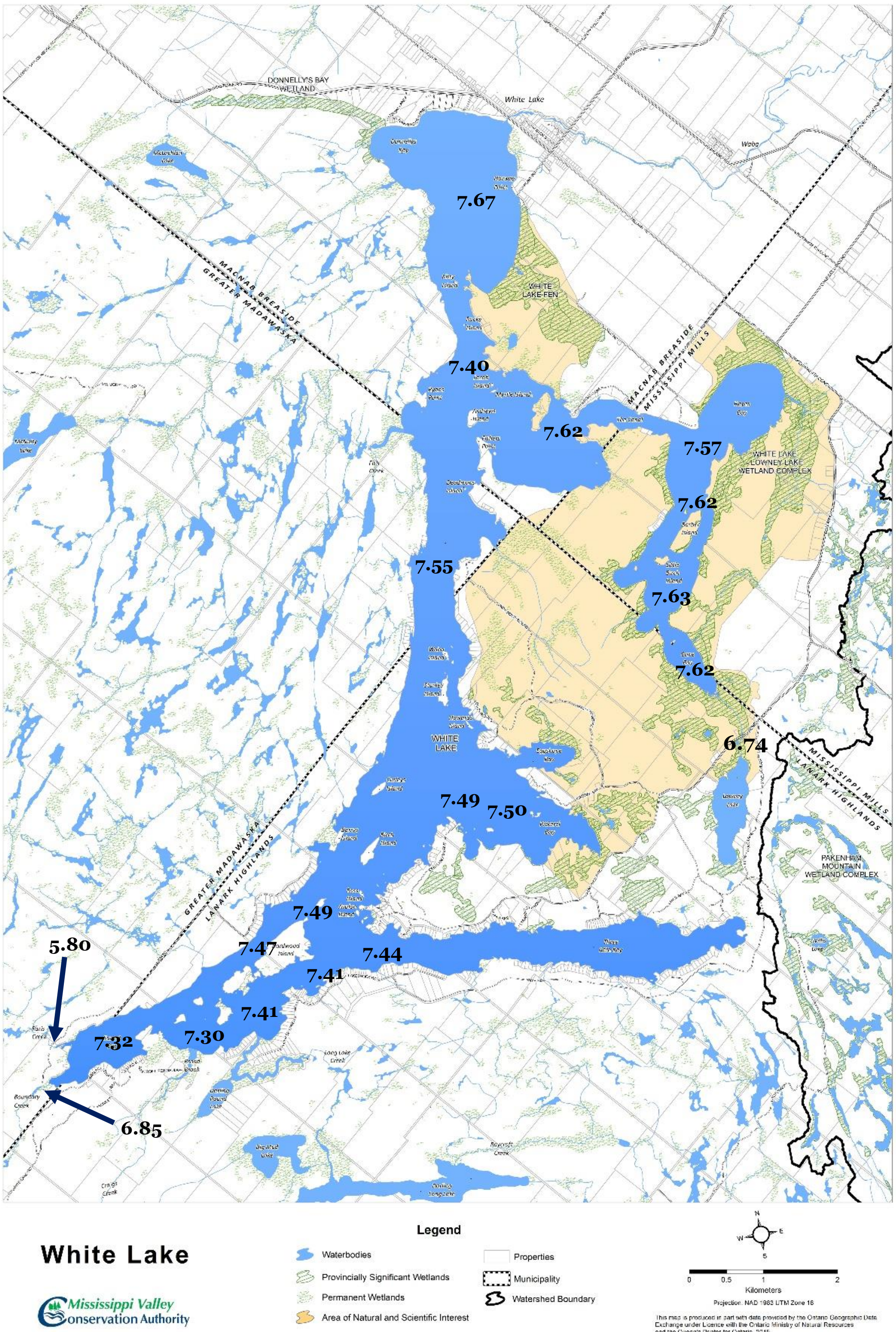
pH

September 13, 2018



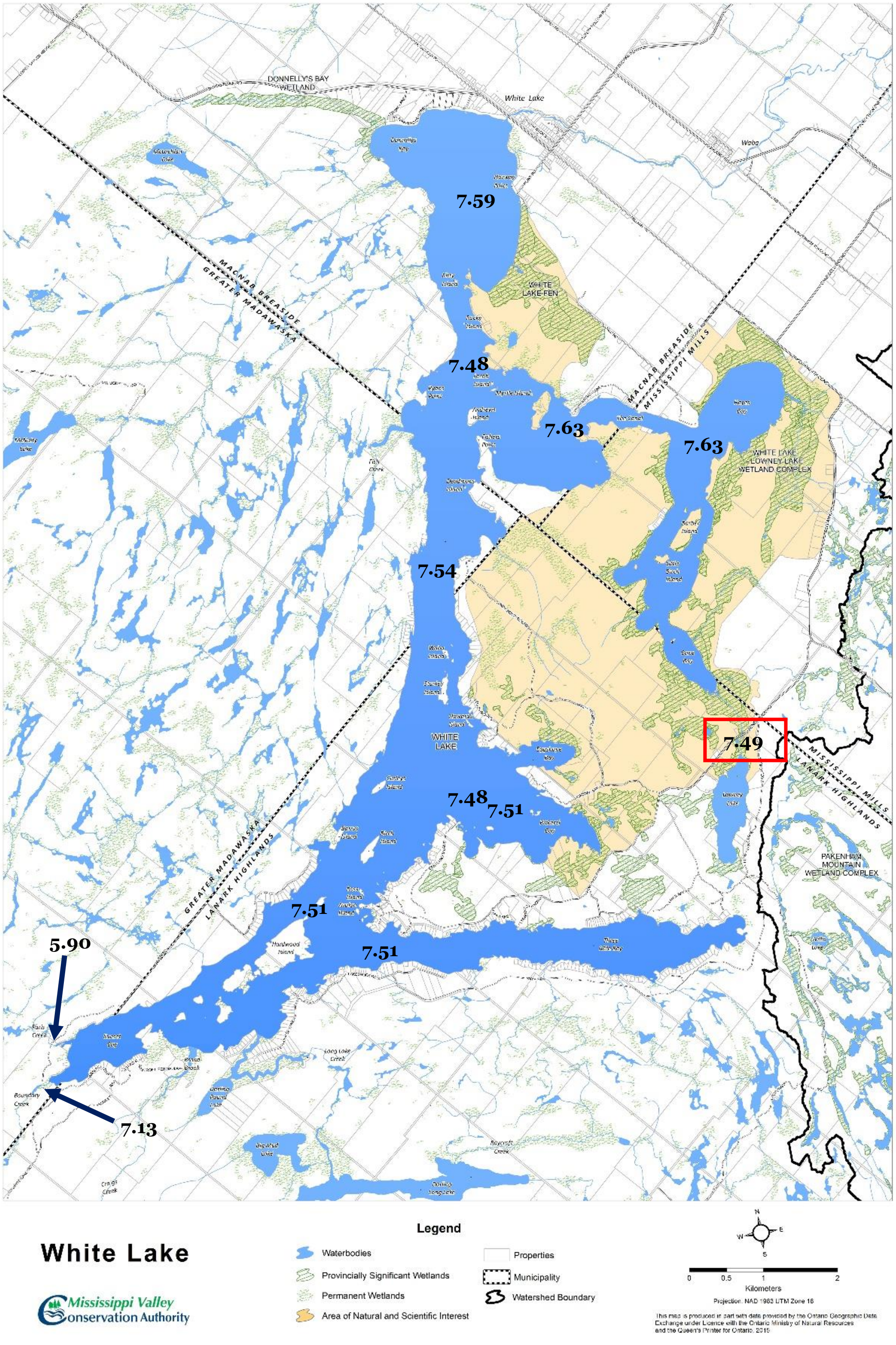
pH

September 30, 2018

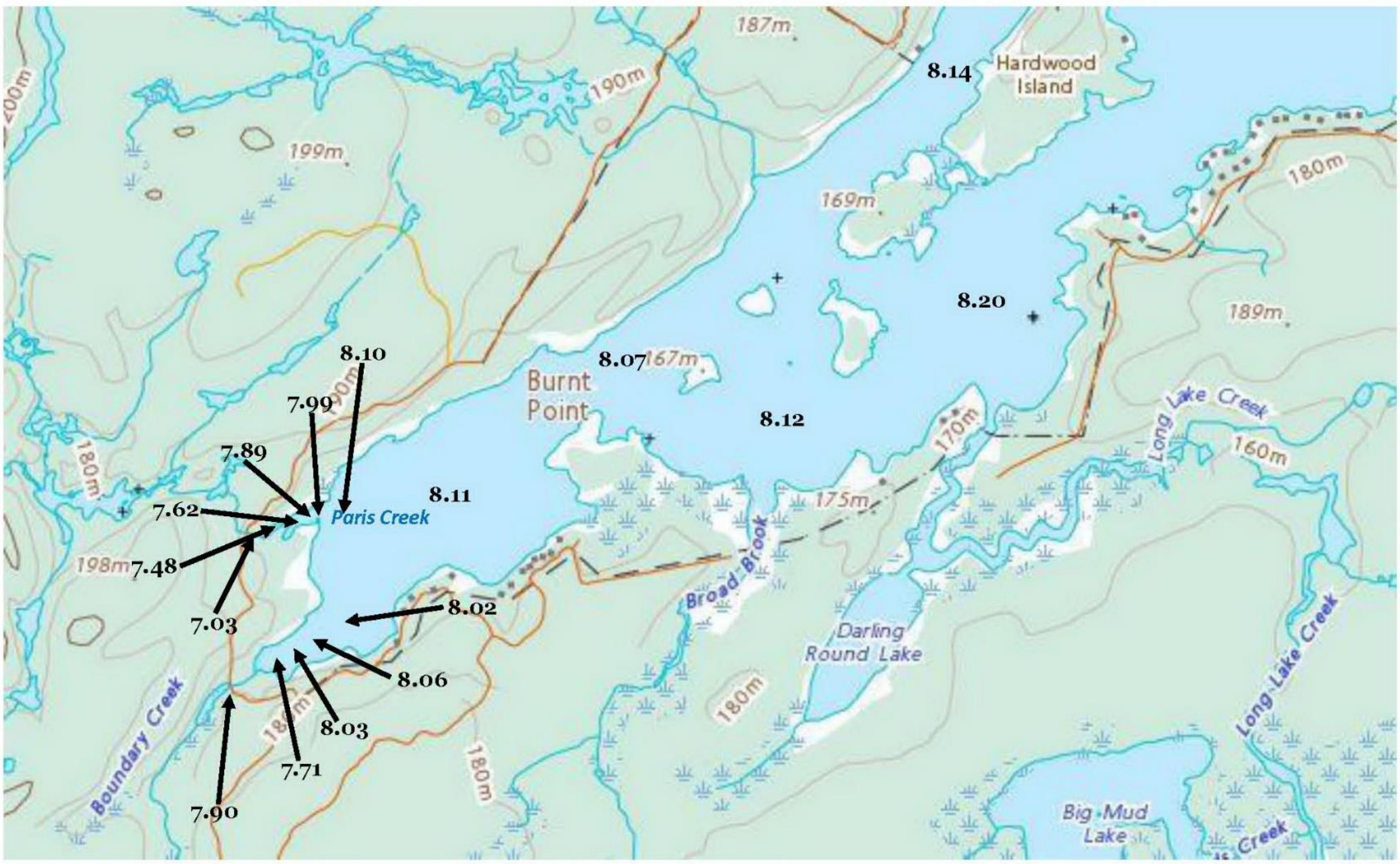


pH

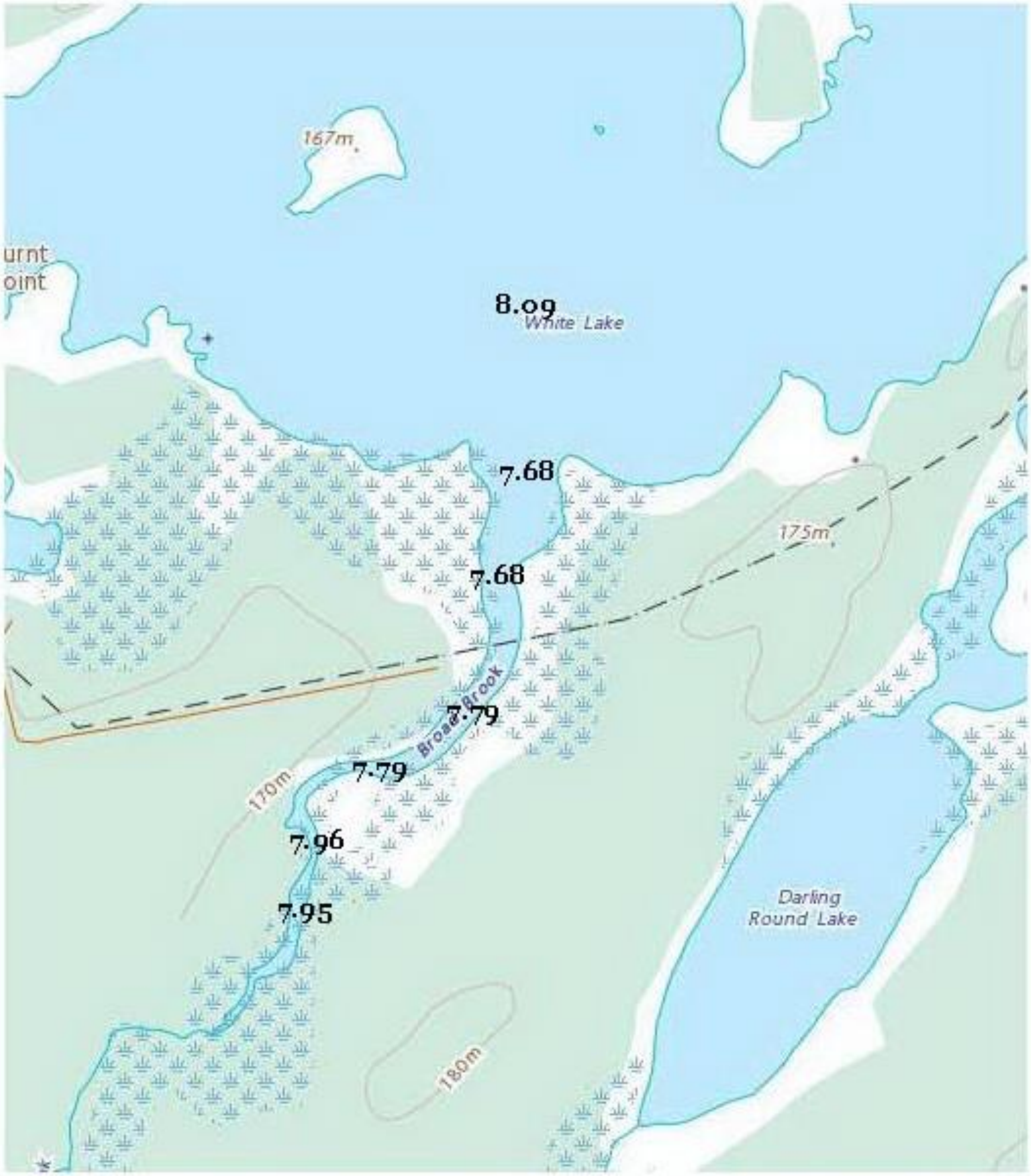
October 16, 2018



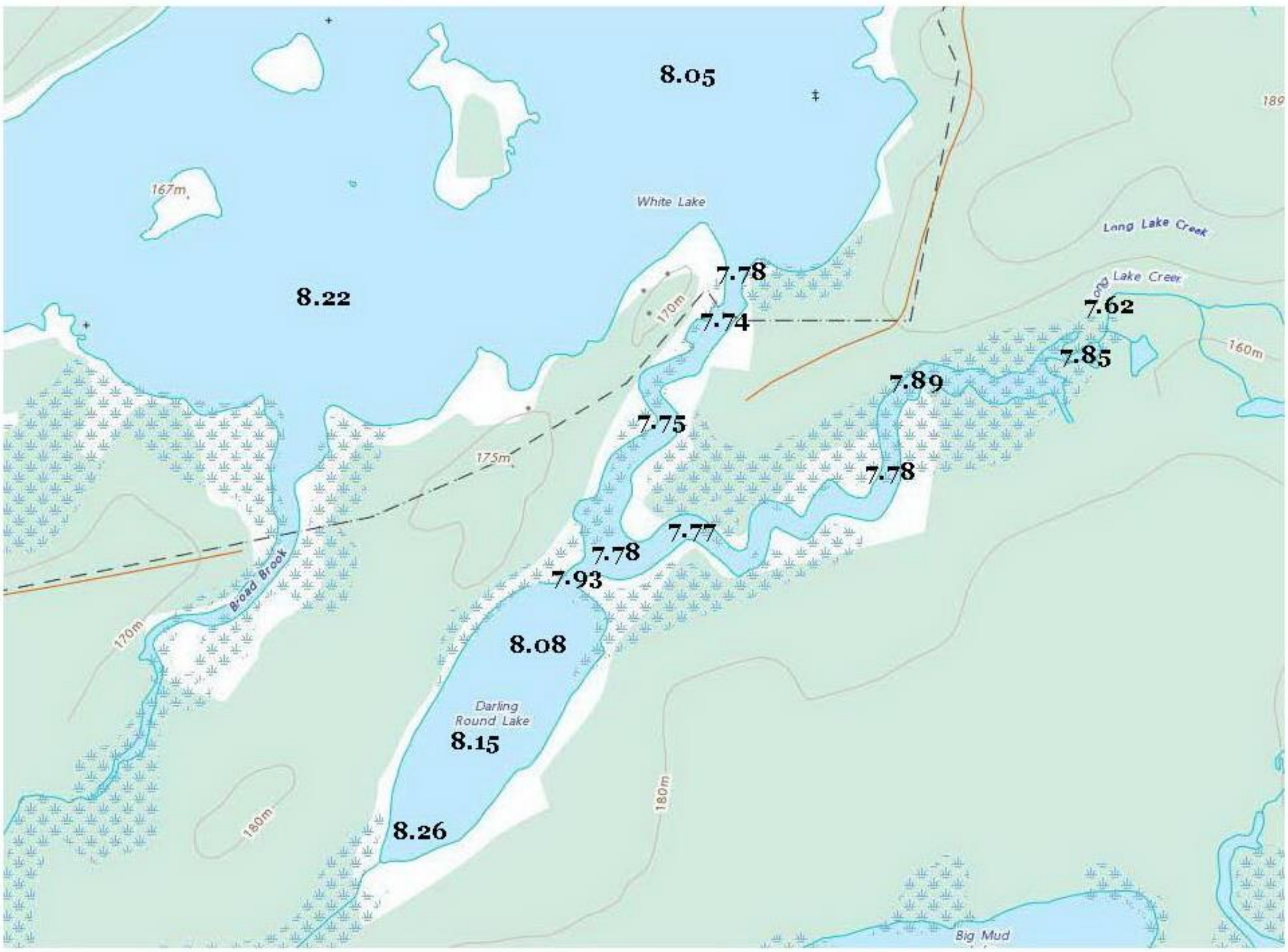
pH for Boundary and Paris Creeks and South White Lake - May 22, 2018



pH for Broad Brook – June 24, 2018

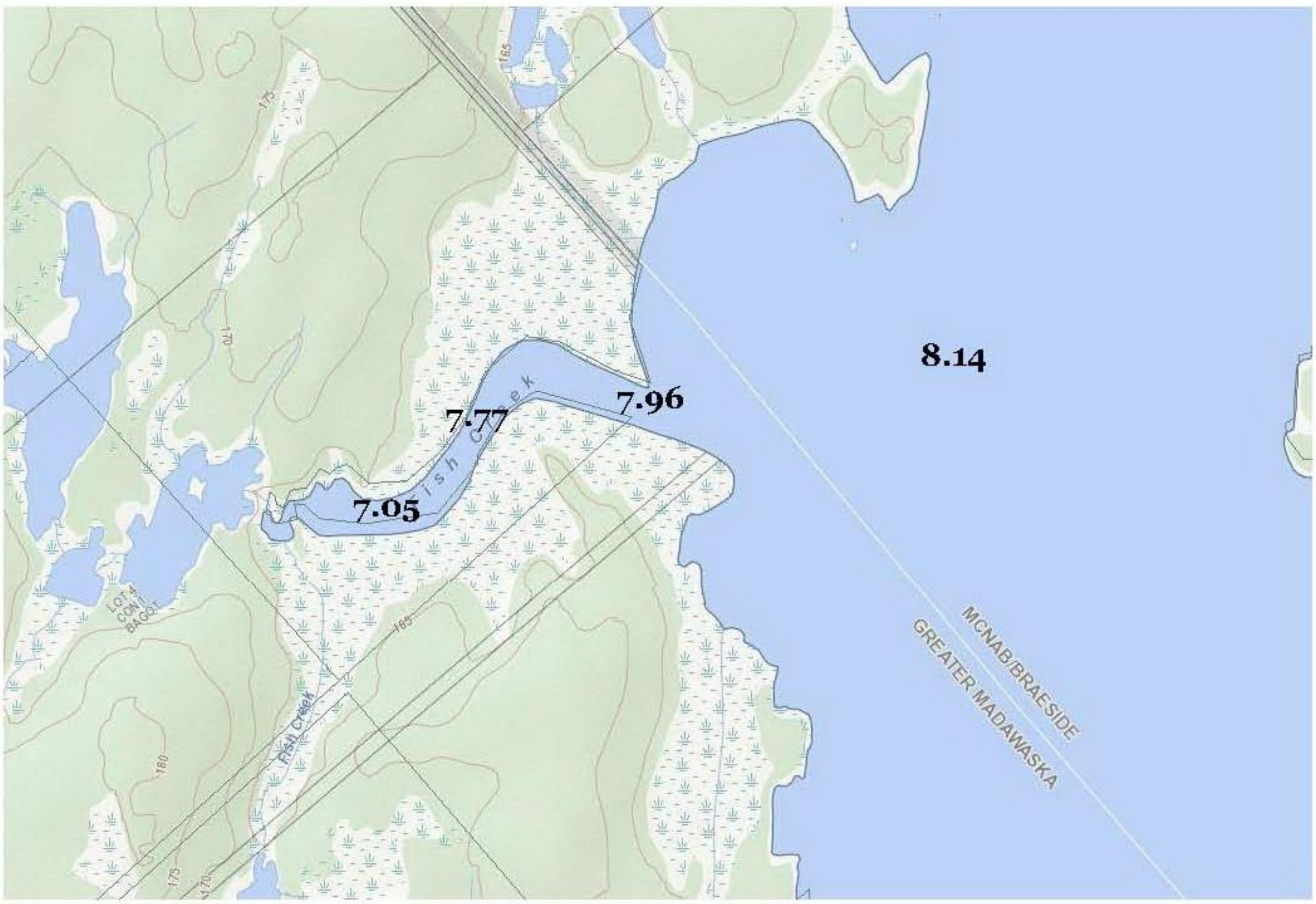


pH of Darling Round Lake and Long Lake Creek Complex – June 10, 2018



pH for Fish Creek

May 18, 2018



APPENDIX - 5
Conductivity Maps

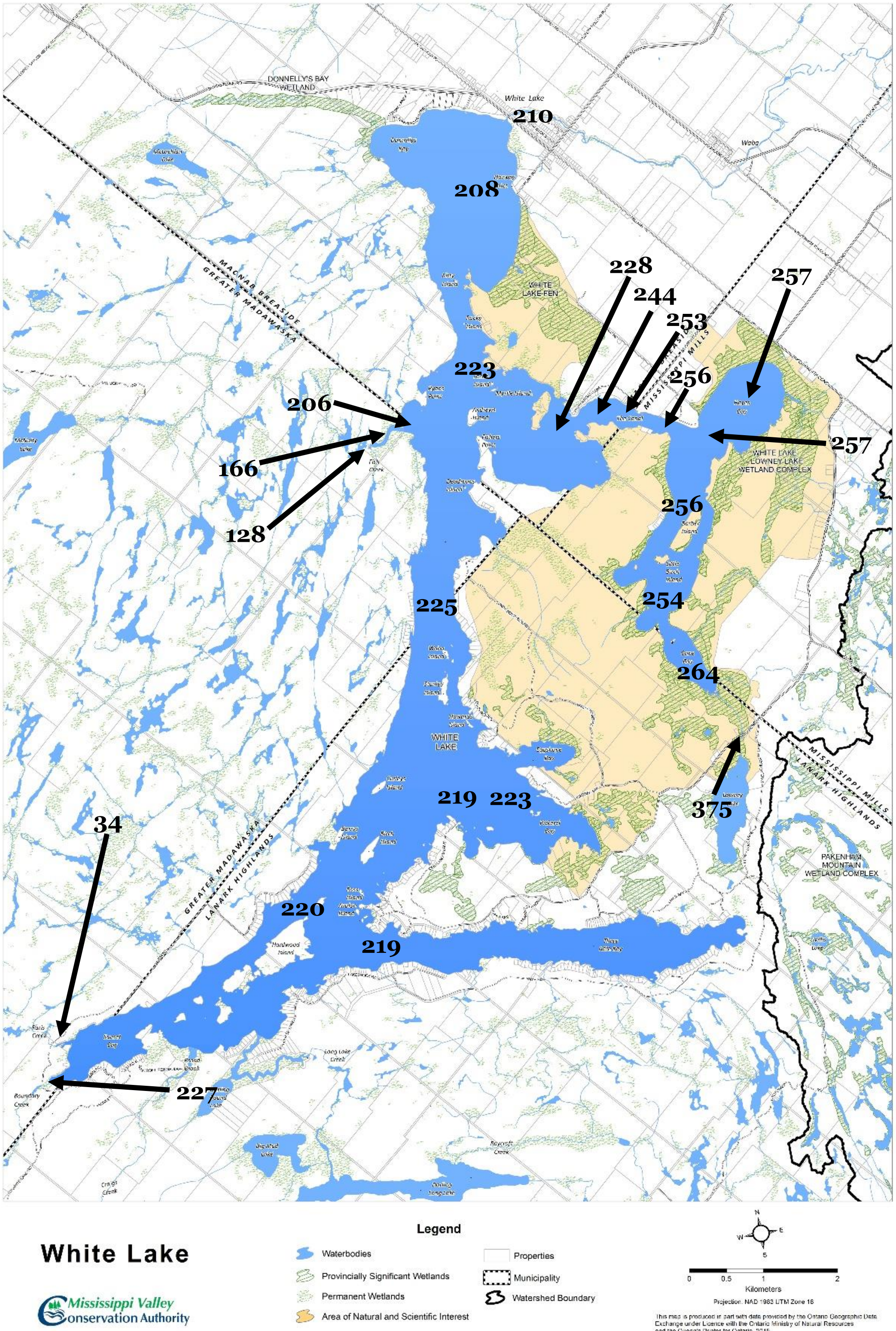
The following are 11 maps of specific conductivity measurements taken on White Lake water samples collected at the beginning and middle of each month from May to October, inclusive.

Depending on the date, values are shown for our core nine sampling sites or a much larger number of sites covering the entire surface of White Lake. Also included are values for Boundary and Paris creeks located at the far end of Sunset Bay as well as Lowney Lake creek, the outflow of Lowney Lake into White Lake's Bane Bay.

Interpretation of this data is included in the main section of this report and will not be duplicated here. Also, the data used in these maps is included in the Data Tables appendix.

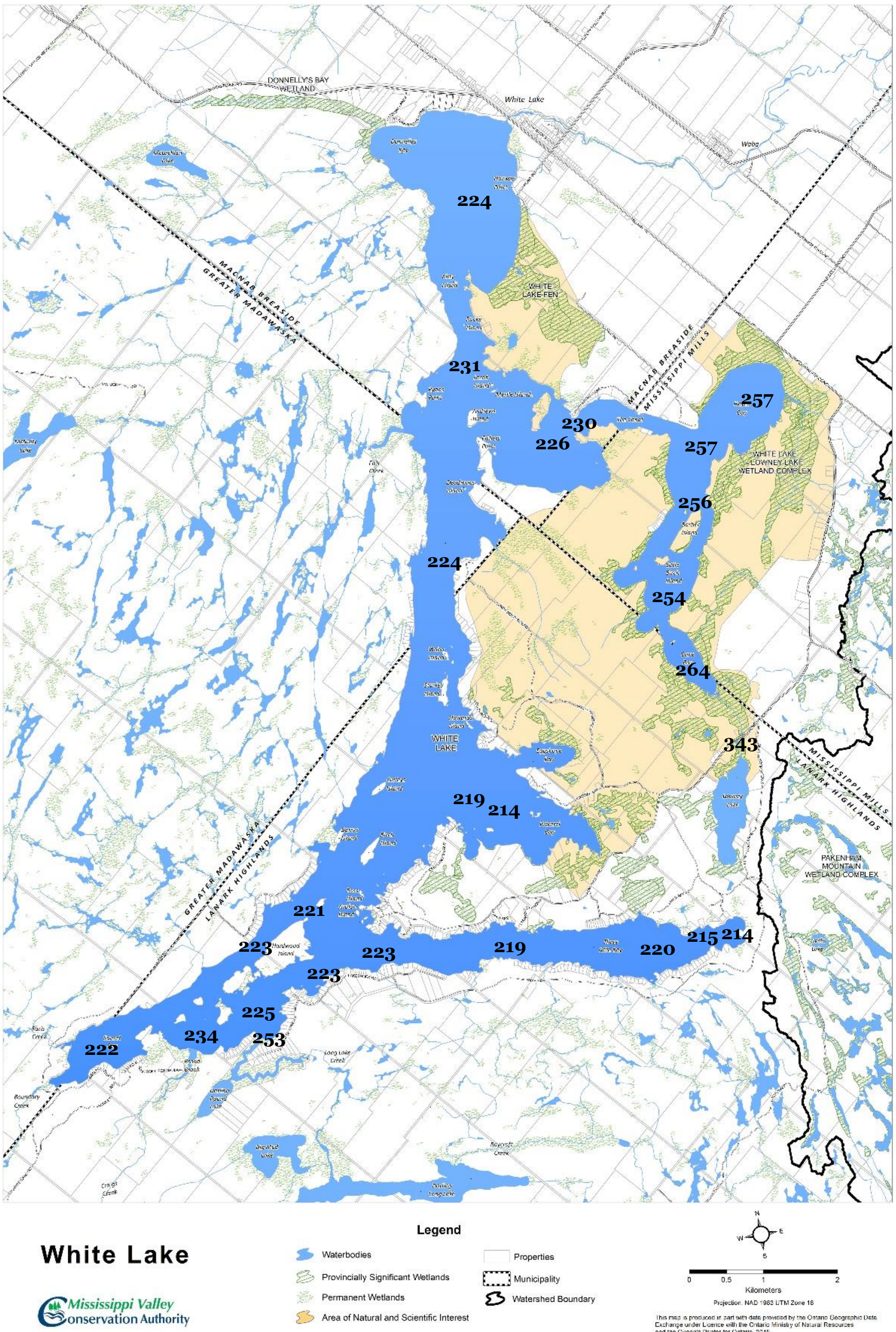
Conductivity (µS/cm)

May 18, 2018



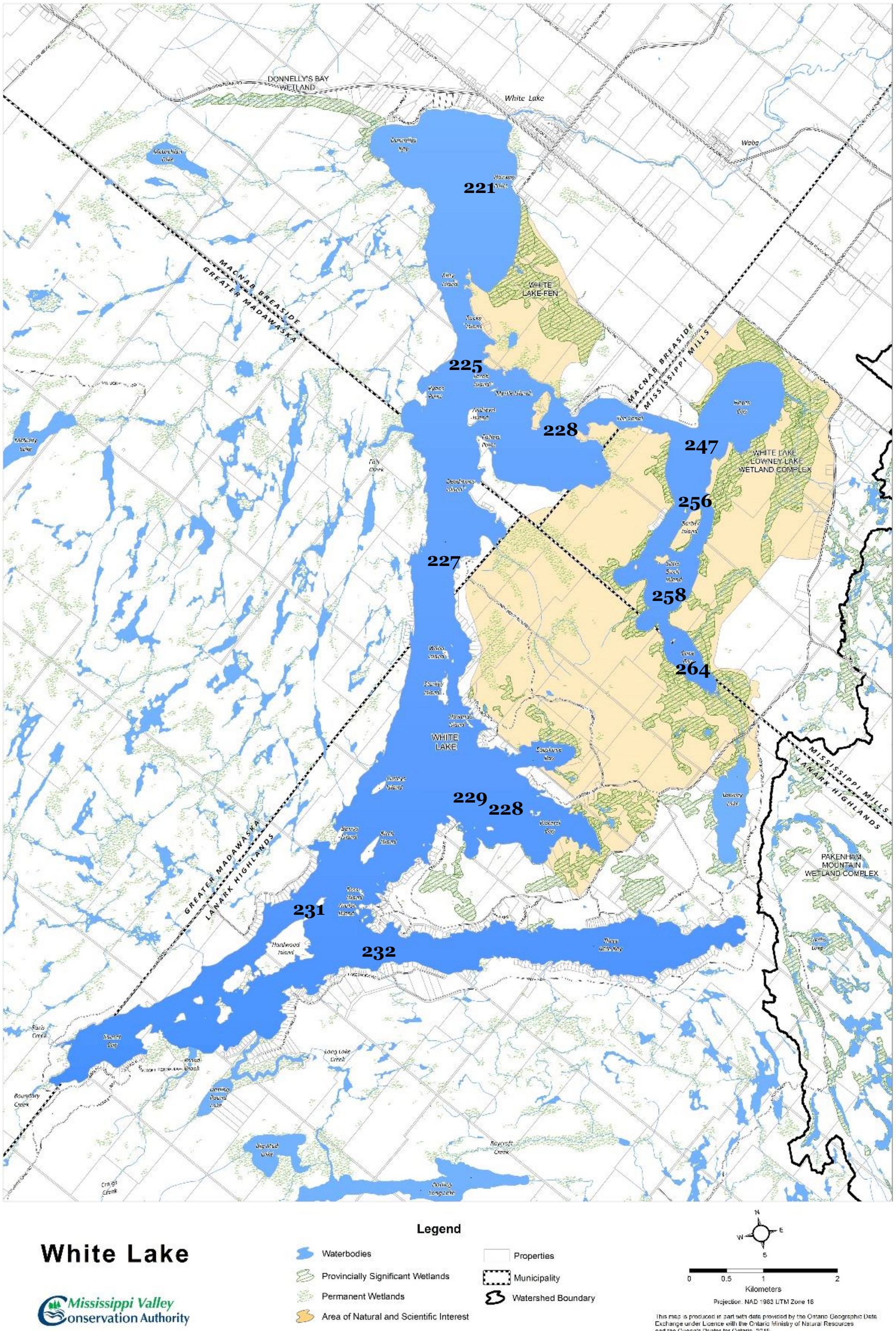
Conductivity (µS/cm)

May 30, 2018



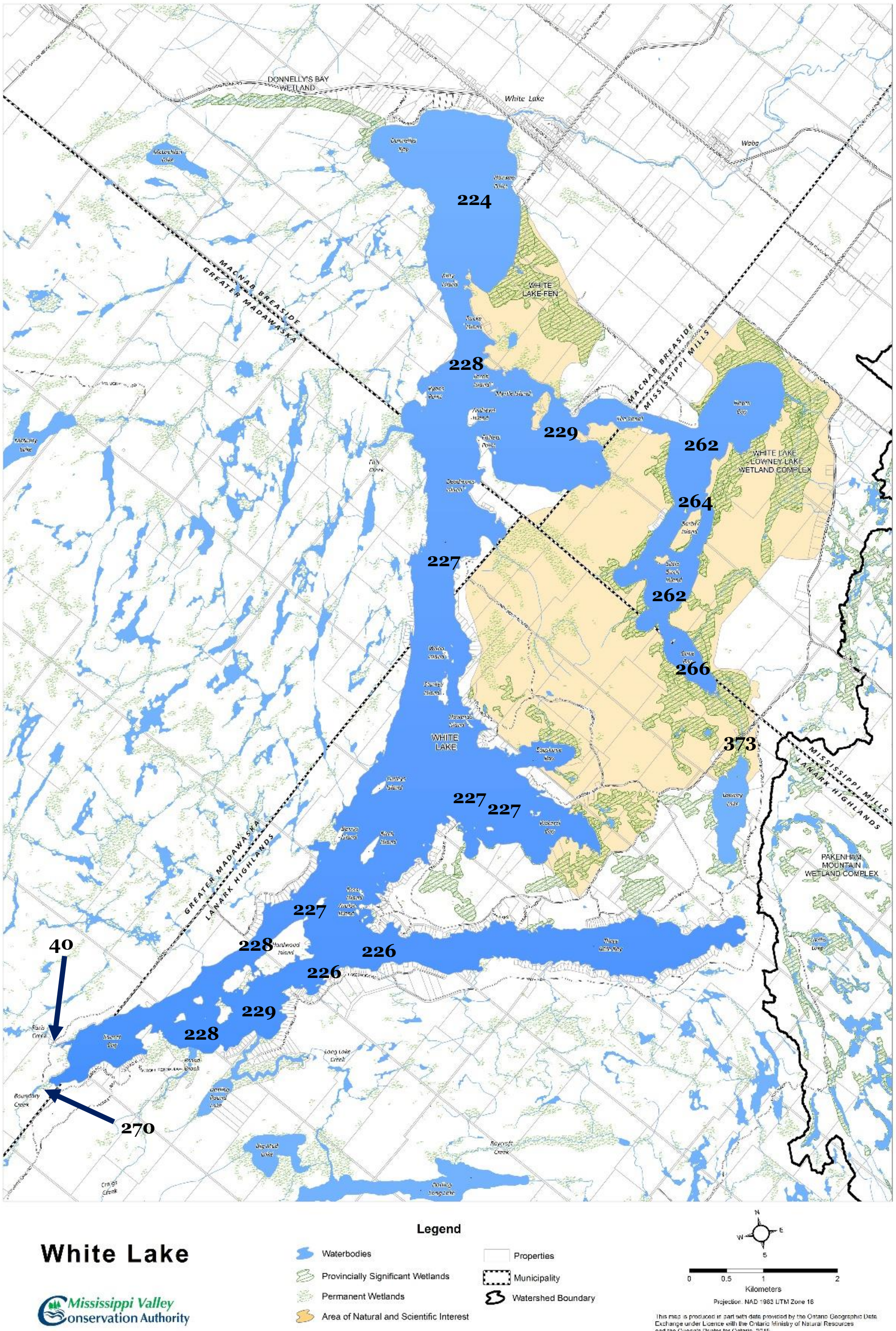
Conductivity (µS/cm)

June 15, 2018



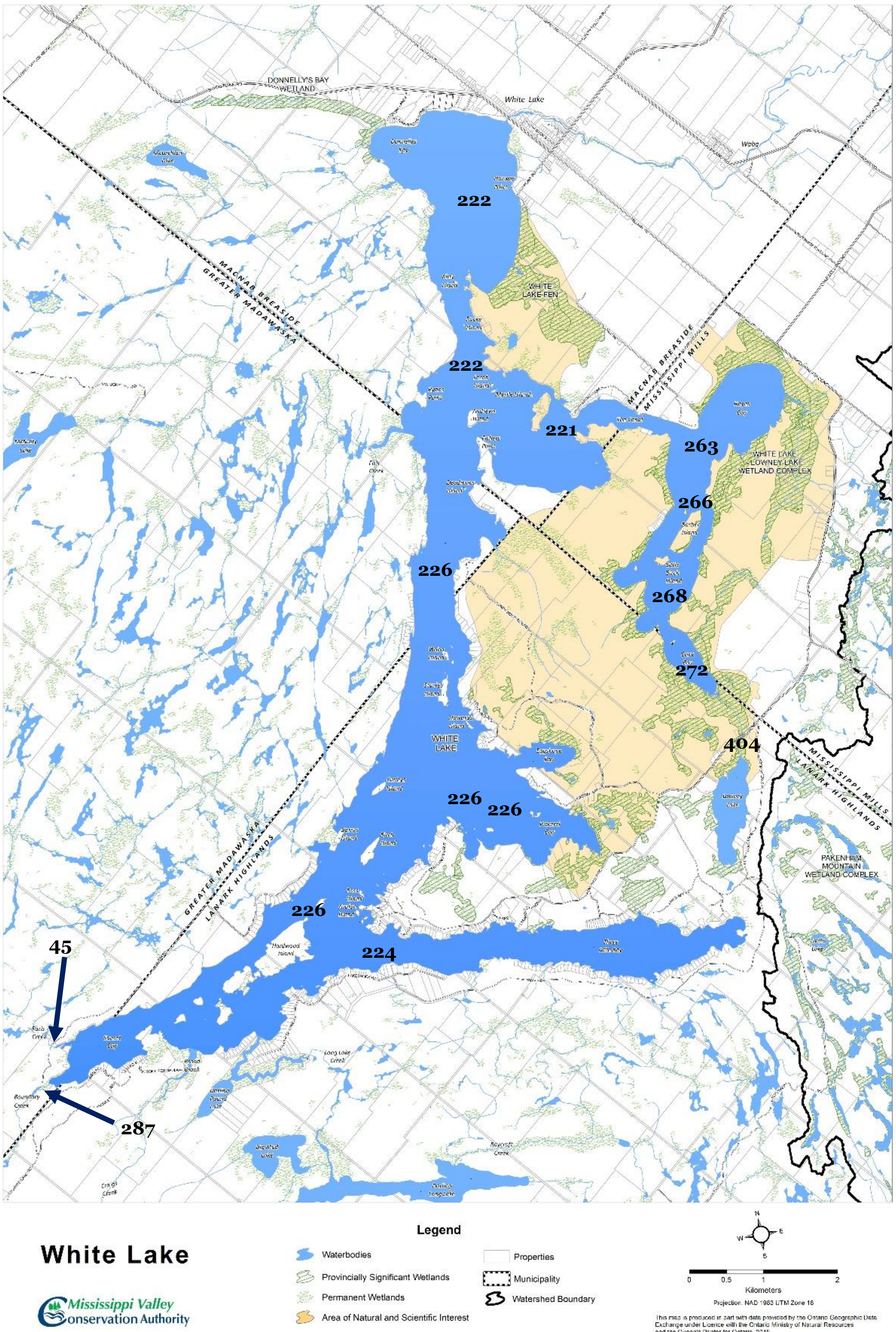
Conductivity (µS/cm)

June 30, 2018



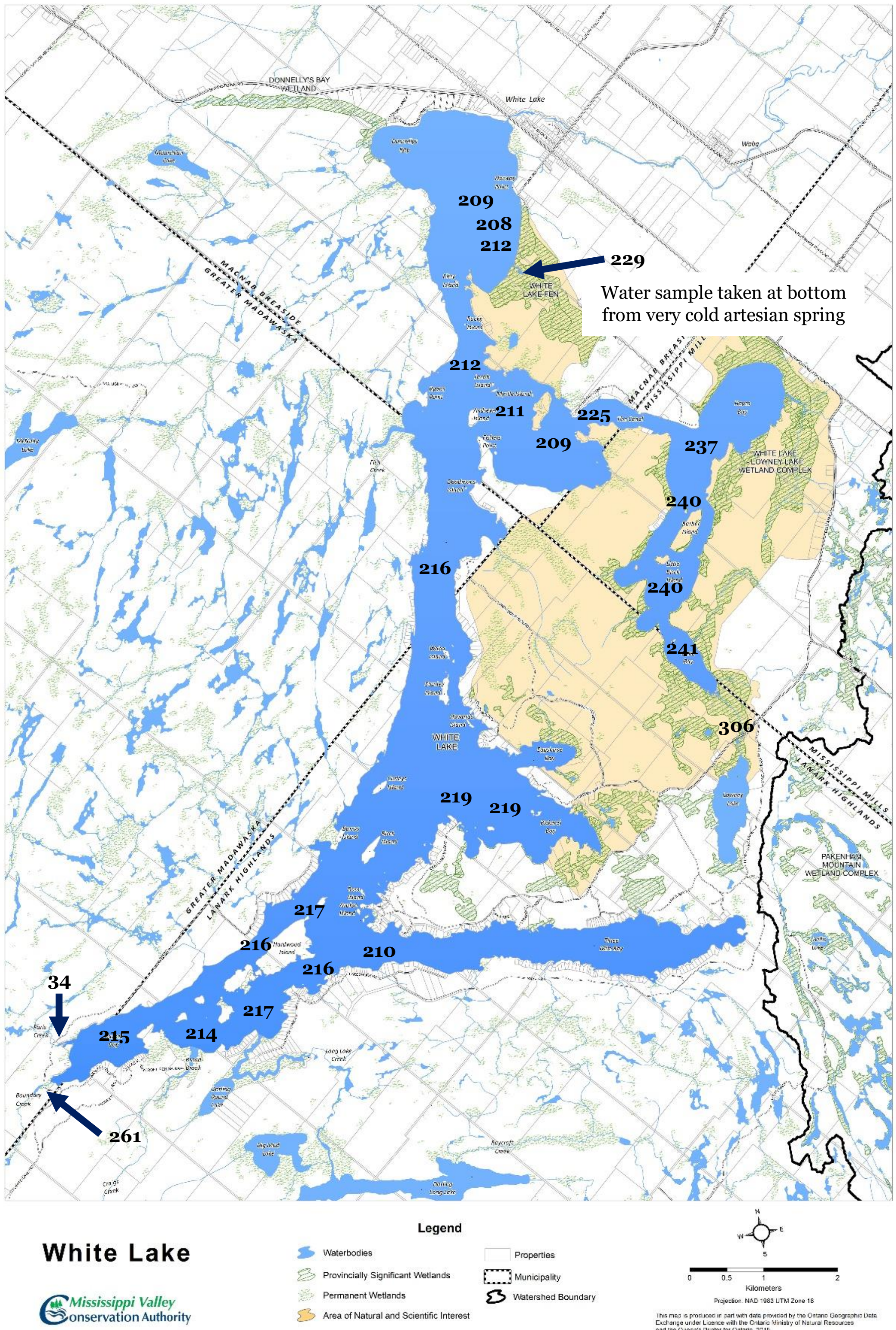
Conductivity (µS/cm)

July 15, 2018



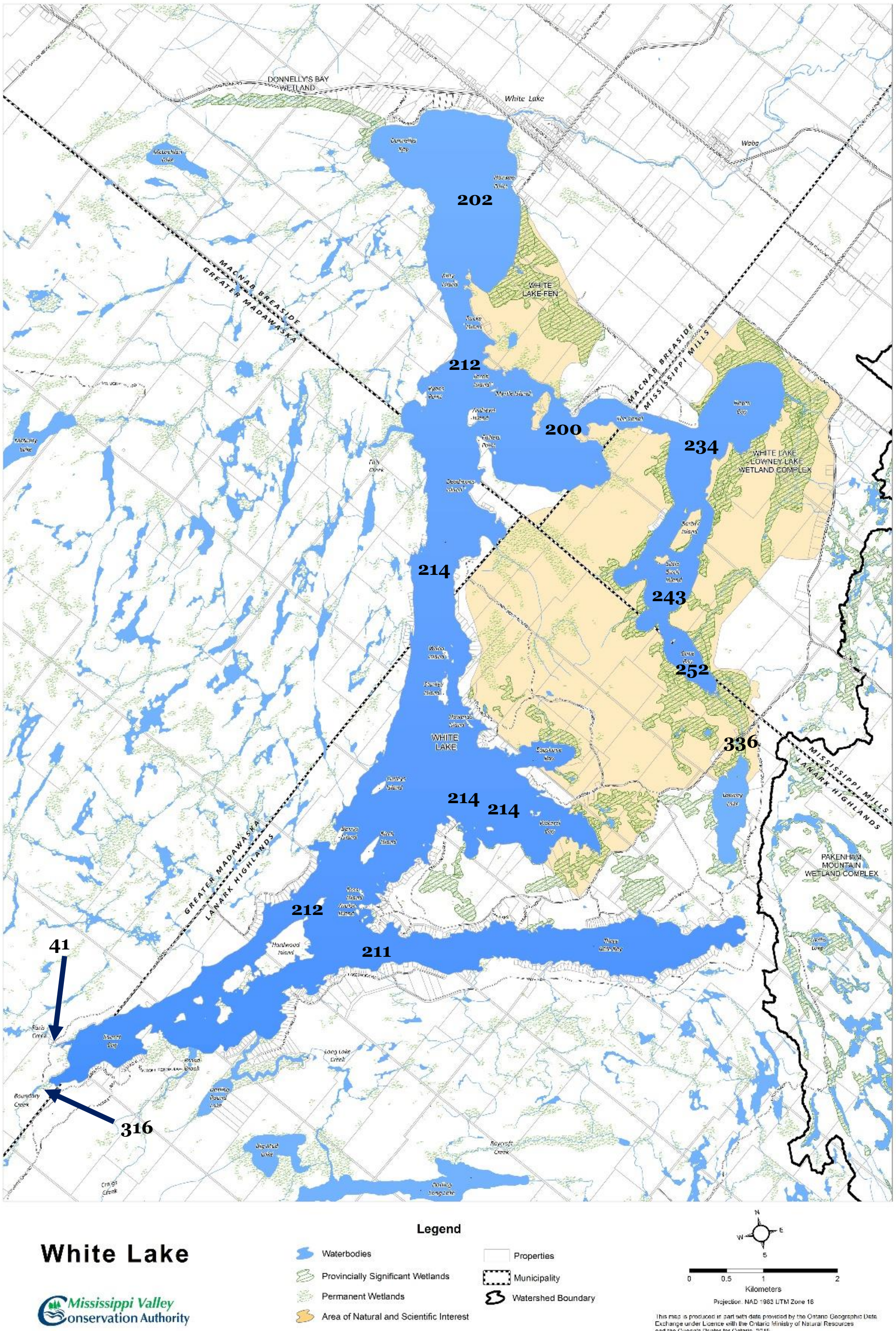
Conductivity (µS/cm)

July 31, 2018



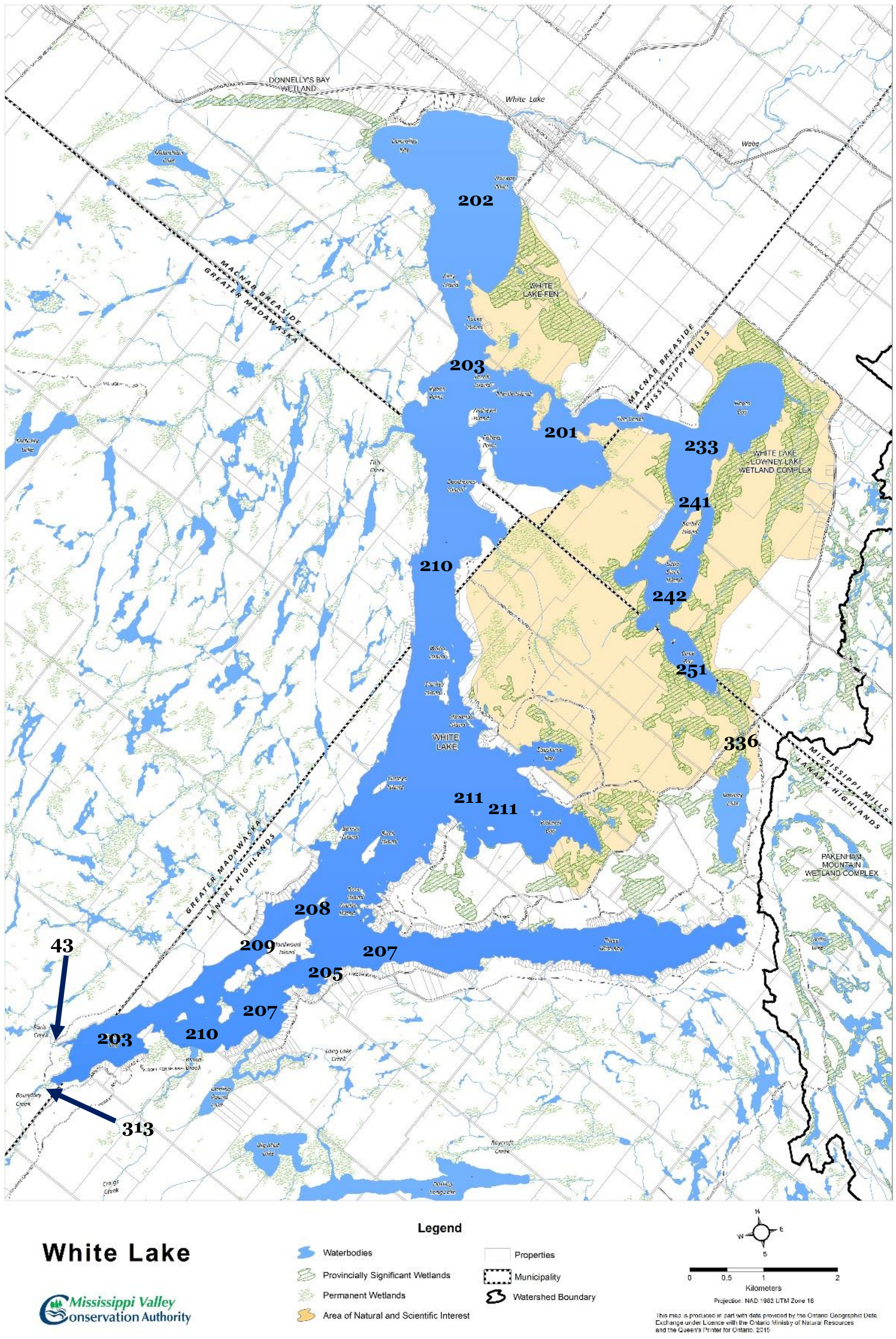
Conductivity (µS/cm)

August 16, 2018



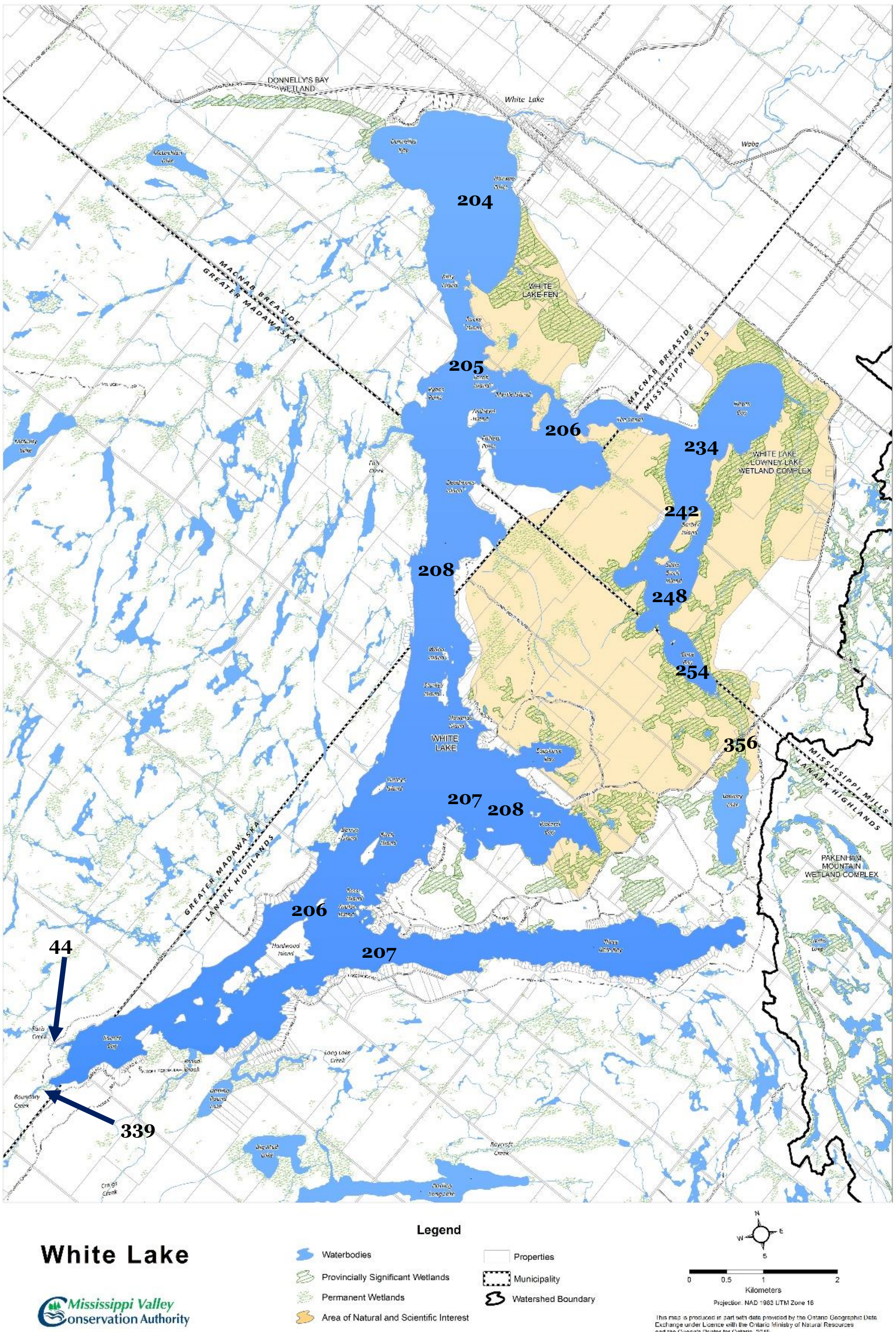
Conductivity (µS/cm)

August 30, 2018



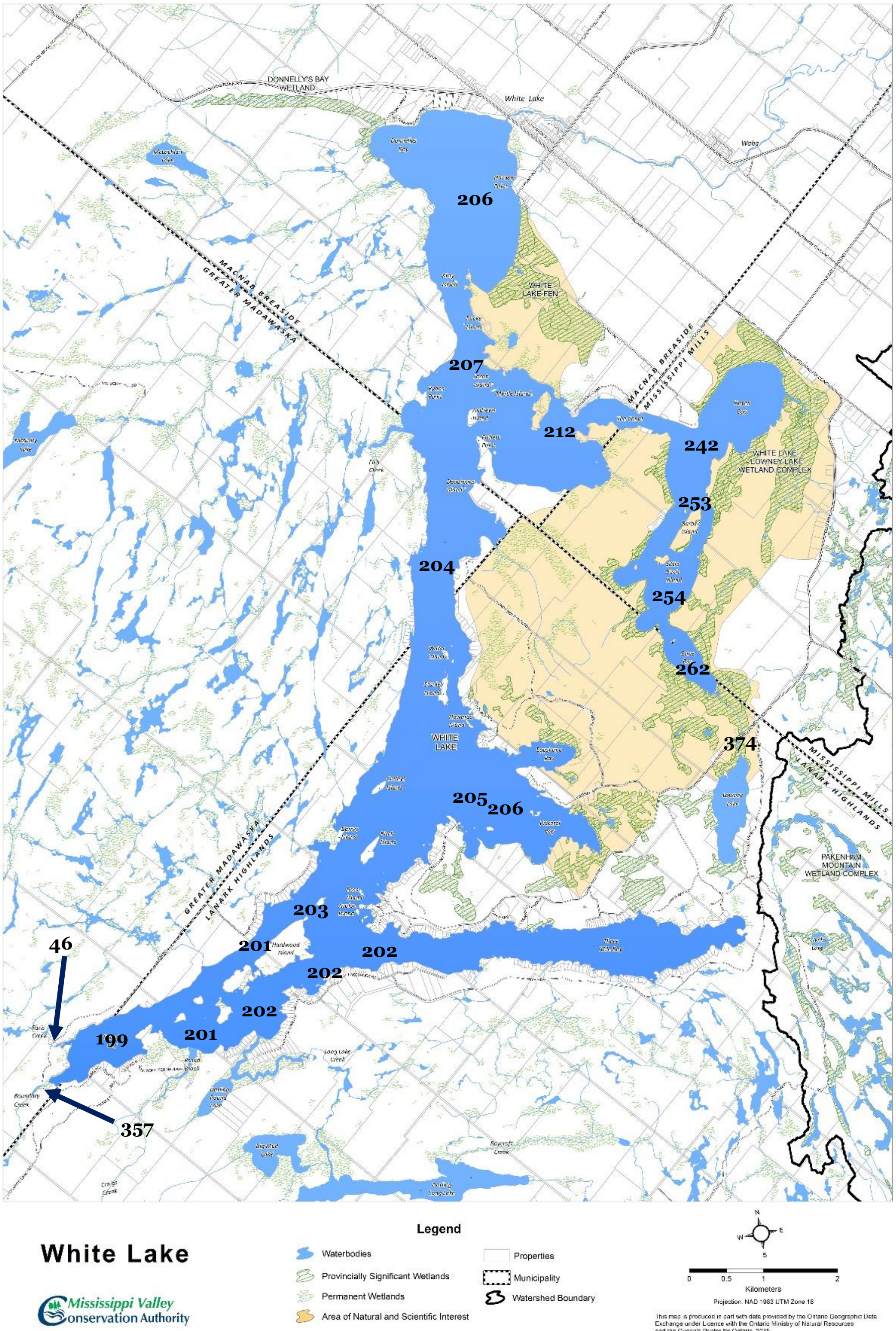
Conductivity (µS/cm)

September 13, 2018



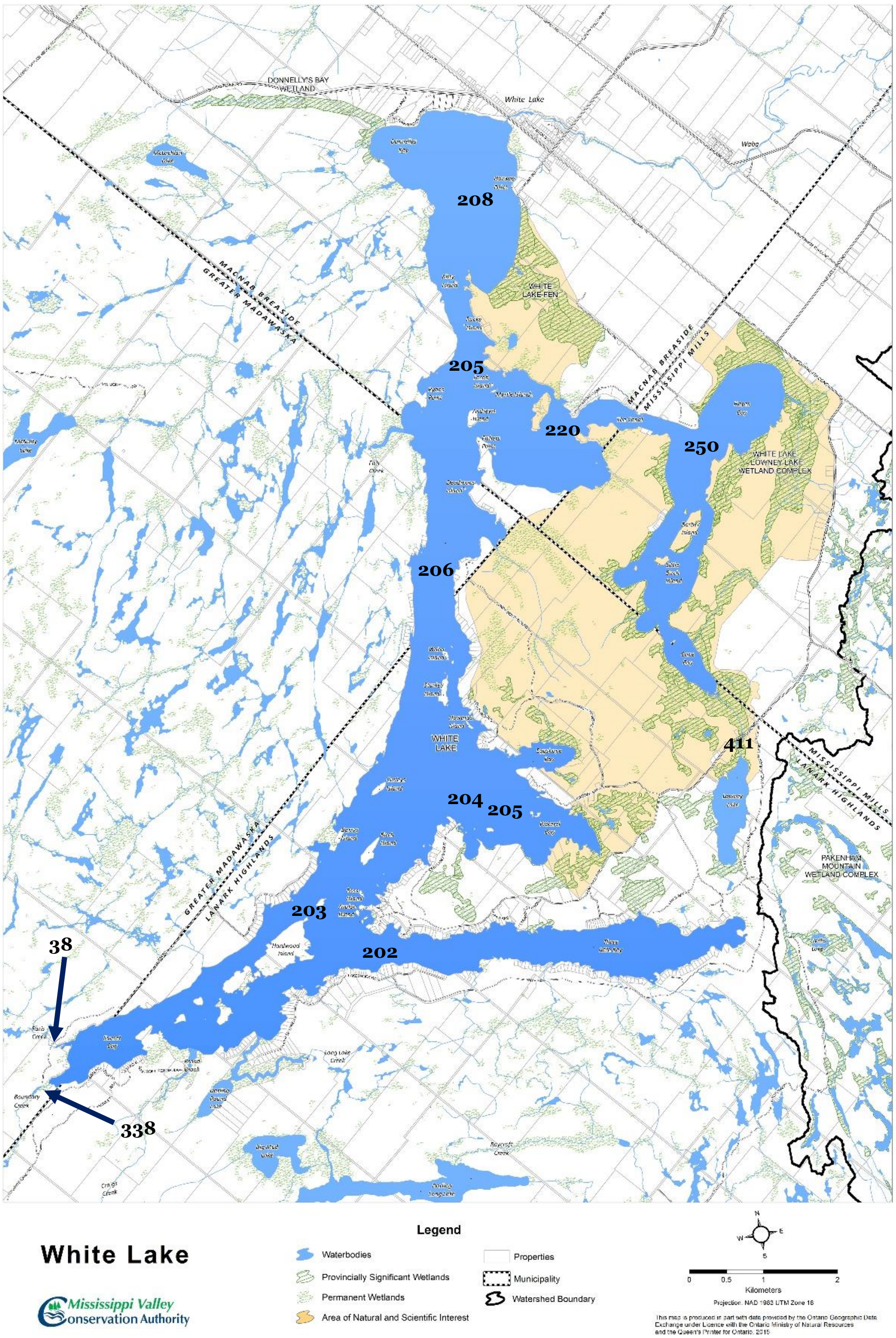
Conductivity (µS/cm)

September 30, 2018



Conductivity (µS/cm)

October 16, 2018

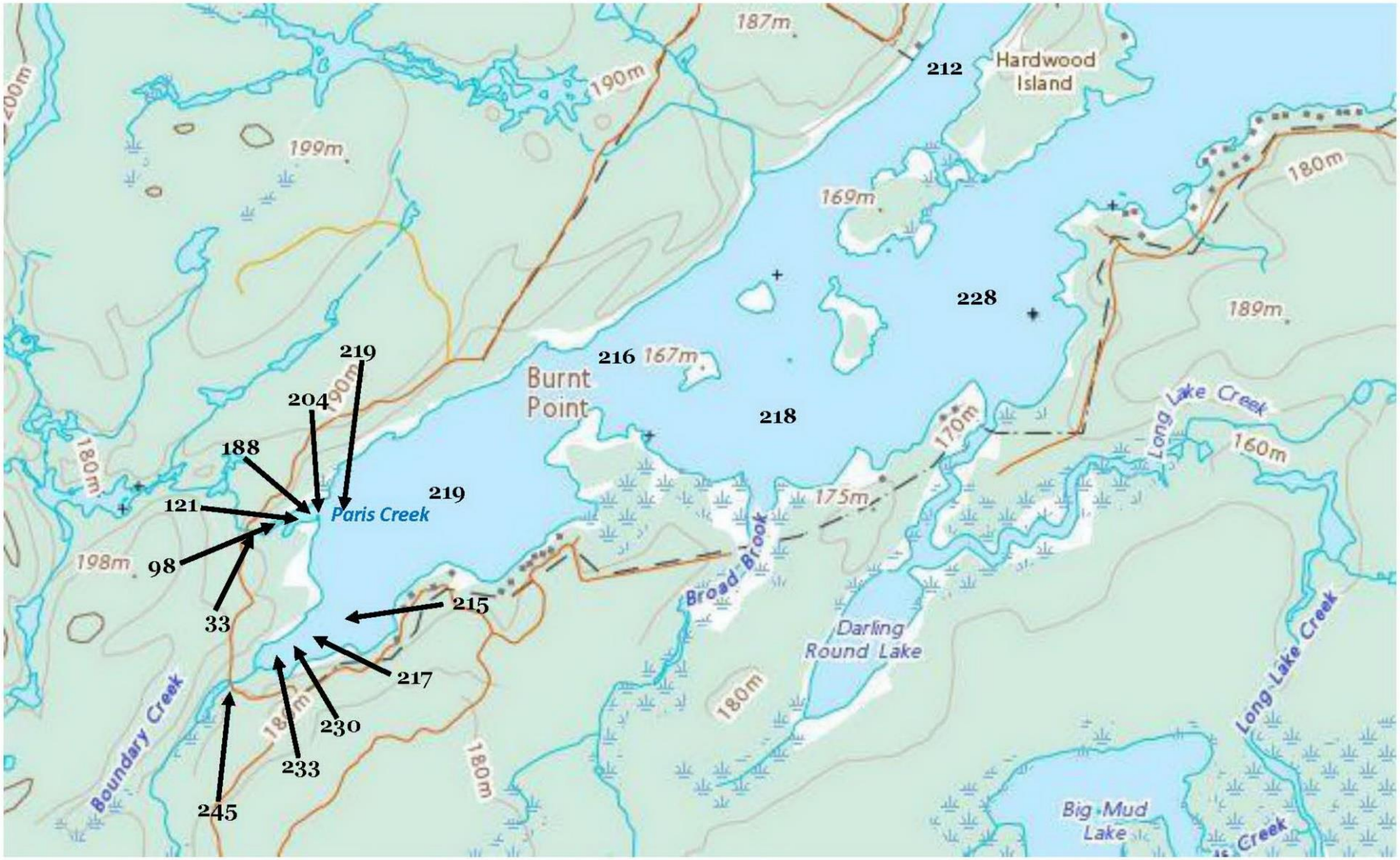


APPENDIX - 6
Stream Water Inputs

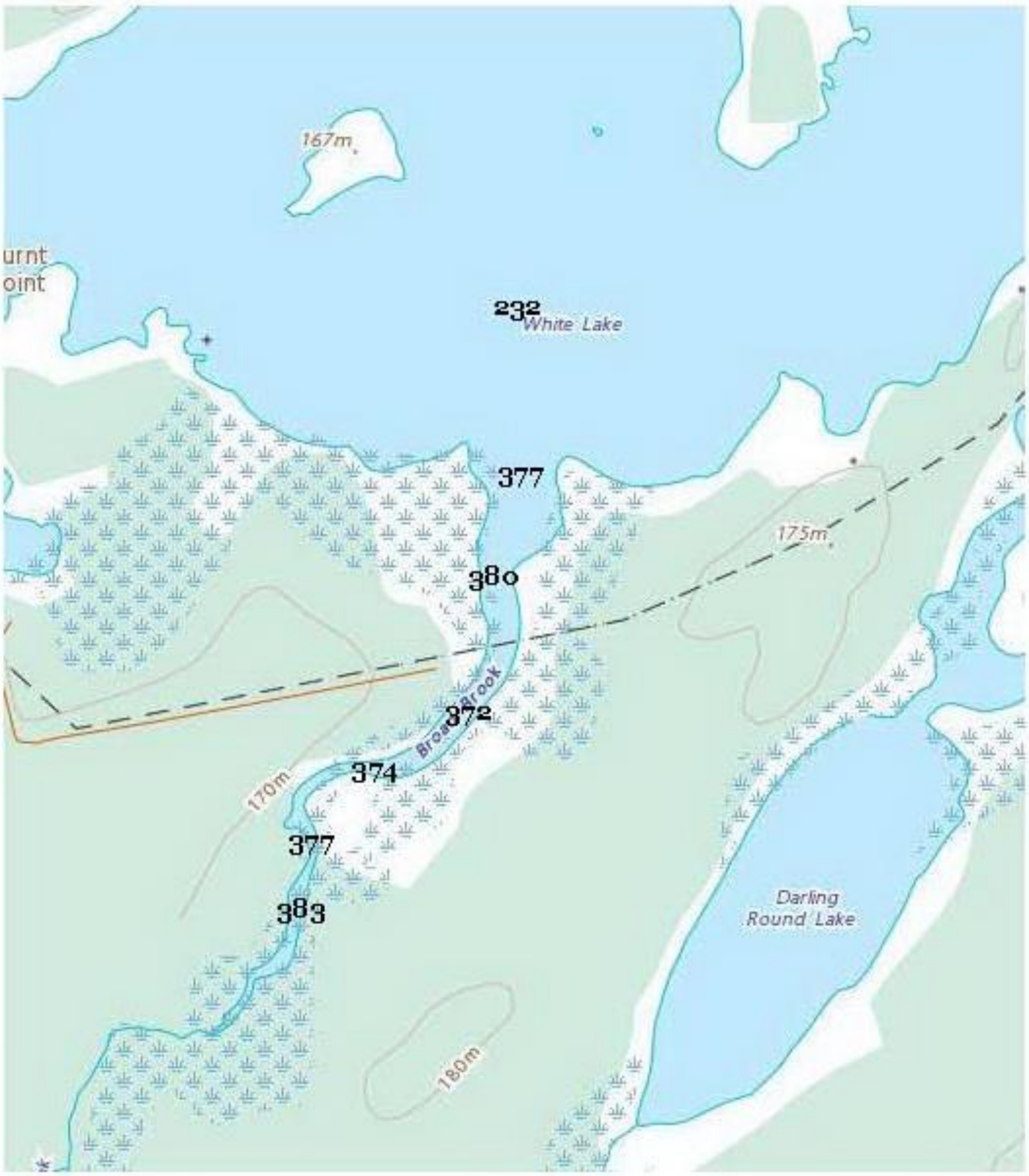
The following are 4 maps of conductivity measurements for the main stream water inputs into White Lake.

Interpretation of this data is included in the main section of this report and will not be duplicated here. Also, the data used in these maps is included in the Data Tables appendix.

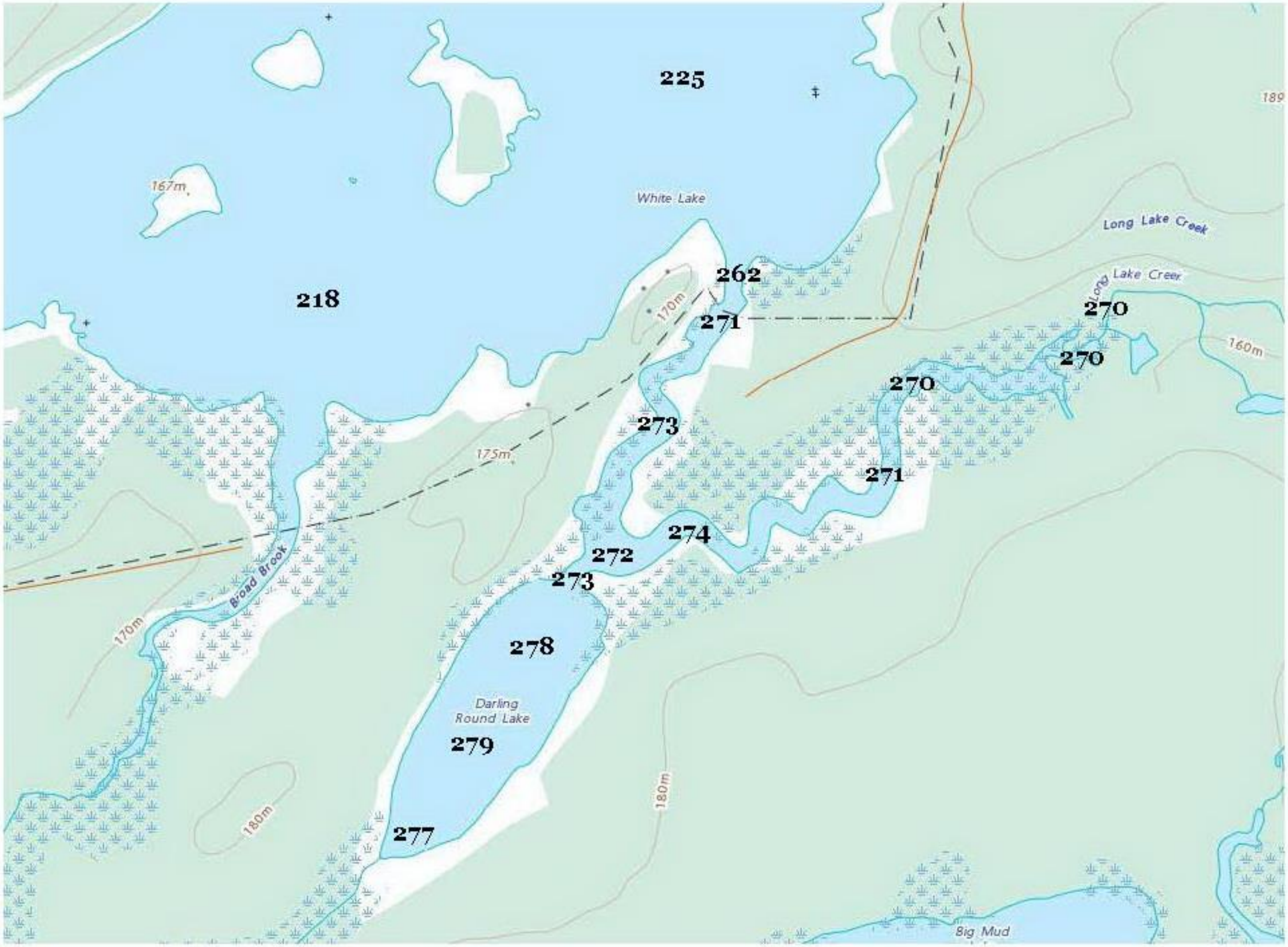
Conductivity (µS/cm) for Boundary and Paris Creeks and South White Lake - May 22, 2018



Conductivity (µS/cm) for Broad Brook – June 24, 2018

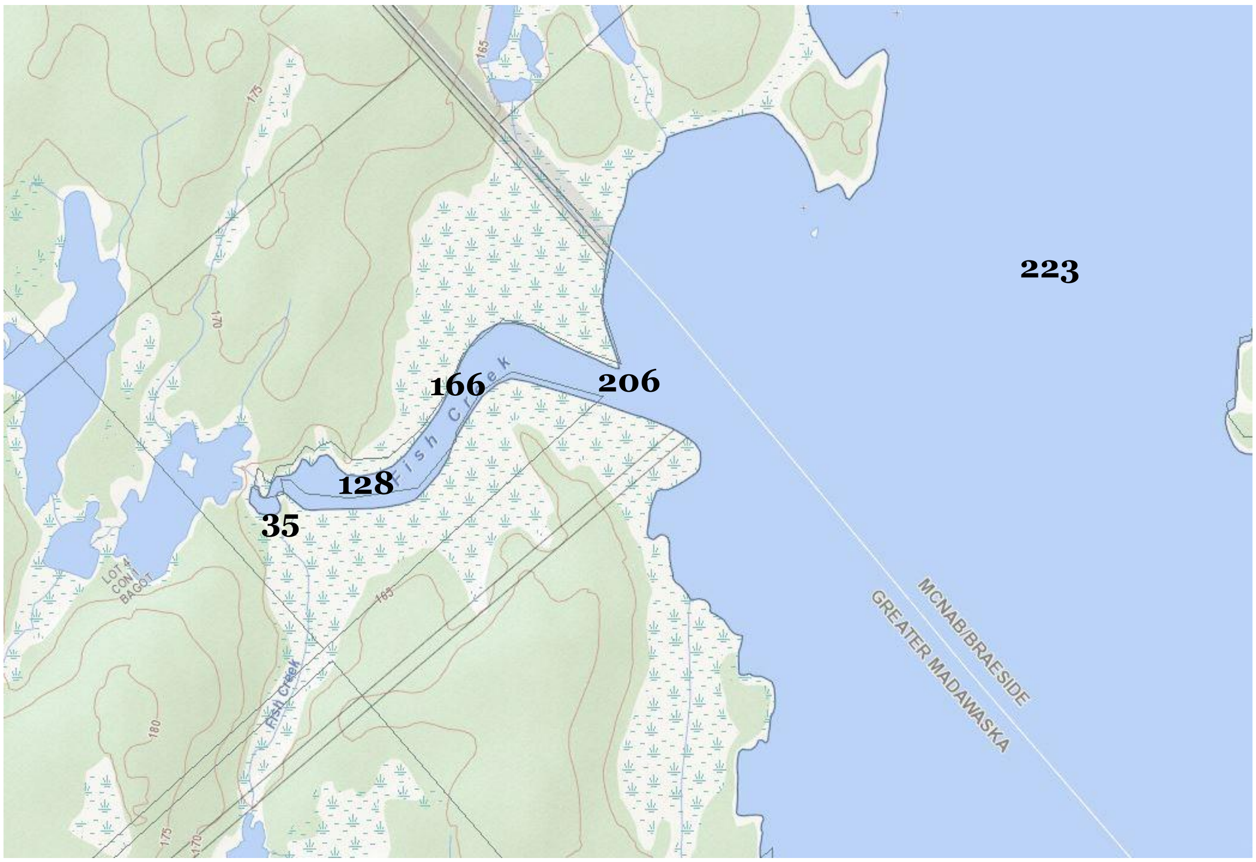


Conductivity (µS/cm) of Darling Round Lake and Long Lake Creek Complex – June 10, 2018



Conductivity (µS/cm) for Fish Creek

May 18, 2018



APPENDIX - 7
Data Tables

These tables contain all of the data used in all of the graphs and figures used in this report. Supplementary information such as GPS locations for sampling sites and measured water depths and tempertures are also listed.

Chemical and Physical Data - 2018

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	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	10:04	133	>depth	15.3	6.6, 6.8 (6.7)	32.8	2.89	5.0	1.1	8.7	2.4	2.1	3.6
May 30	10:56	150	4.5	20.7									
June 15	10:15	166	4.3	19.7	13.6, 14.2 (14.0)	32.0	2.88	5.0	0.90	8.5	2.4	2.5	3.3
June 30	9:57	181	4.55	23.2									
July 15	9:57	196	5.00	25.7	14.2, 12.4 (13.3)								
July 31	10:15	212	4.60	25.2									
August 16	10:08	228	3.40	25.9	14.4, 13.8 (14.1)								
August 30	10:02	242	4.80	23.3									
September 13	10:05	254	5.2	20.8	11.2, 10.0 (10.6)								
September 30	10:31	273	>depth	16.8									
October 16	10:07	289	>depth	11.5	10.0, 10.0 (10.0)								

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	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	10:24	133	>depth	14.8	8.0, 7.8 (7.9)	33.0	2.85	4.9	0.98	8.5	2.3	2.2	3.6
May 30	11:07	150	4.2	20.8									
June 15	10:33	166	4.1	19.7	14.4, 14.8 (14.6)								
June 30	10:08	181	4.1	23.0									
July 15	10:18	196	4.8	25.8	13.2, 13.2 (13.2)								
July 31	10:26	212	4.6	24.3									
August 16	10:29	228	4.3	26.5	14.4, 13.8 (14.1)								
August 30	10:26	242	4.8	23.5									
September 13	10:17	254	5.5	21.0	10.6, 10.8 (10.7)								
September 30	10:42	273	>depth	16.8									
October 16	10:23	289	>depth	11.5	9.6, 9.4 (9.5)								

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	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	12:34	133	4.3	14.7									
May 30	14:51	150	4.2	20.2									
June 15	10:45	166	4.4	20.0									
June 30	11:12	181	5.1	23.0									
July 15	10:38	196	4.9	25.5									
July 31	10:55	212	4.9	25.0									
August 16	10:47	228	4.8	26.1									
August 30	12:48	242	4.9	24.0									
September 13	12:27	254	5.5	21.0									
September 30	10:15	273	>depth	16.8									
October 16	10:12	289	>depth	12.3									

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

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	12:53	133	5.2	15.2									
May 30	14:58	150	4.2	20.5									
June 15	11:03	166	4.4	20.0									
June 30	11:23	181	4.9	23.9									
July 15	10:53	196	4.9	25.6									
July 31	11:02	212	5.2	25.2									
August 16	10:53	228	5.5	25.7									
August 30	13:00	242	4.6	23.7									
September 13	12:35	254	6.0	21.2									
September 30	10:22	273	>depth	17.2									
October 16	10:21	289	>depth	12.3									

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

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	11:09	133	4.6	15.7	8.0, 6.8 (7.4)	33.4	3.49	5.3	0.94	8.4	2.5	2.2	3.5
May 30	11:36	150	4.5	20.2									
June 15	11:12	166	5.0	19.8	11.8, 11.6 (11.7)								
June 30	10:46	181	4.55	23.0									
July 15	11:04	196	5.2	25.5	11.4, 12,2 (11.8)								
July 31	10:57	212	5.2	25.0									
August 16	11:09	228	4.2	25.9	12.0, 13.0 (12.5)								
August 30	10:55	242	4.7	23.8									
September 13	10:55	254	5.4	21.0	10.0, 10.4 (10.2)								
September 30	11:09	273	>depth	16.7									
October 16	10:58	289	>depth	12.3	9.2, 8.6 (8.9)								

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

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	11:22	133	>depth	17.5	9.4, 9.6 (9.5)	34.4	4.05	5.7	1.03	8.1	3.2	1.6	3.2
May 30	11:47	150	>depth	21.5									
June 15	11:35	166	>depth	19.0	9.8, 8.2 (9.0)								
June 30	11:01	181	>depth	24.6									
July 15	11:19	196	>depth	26.3	9.0, 9.4 (9.2)								
July 31	11:08	212	>depth	25.0									
August 16	11:25	228	>depth	25.7	9.0, 9.5 (9.3)								
August 30	11:07	242	>depth	23.0									
September 13	11:01	254	>depth	20.0	12.6, 9.4 (11.0)								
September 30	11:21	273	>depth	15.9									
October 16	11:10	289	>depth	8.0	8.0, 9.0 (8.5)								

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

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	11:55	133	>depth	17.8	10.6, 10.0 (10.3)	37.8	8.25	6.2	0.99	7.6	5.3	0.58	3.1
May 30	12:02	150	>depth	23.8									
June 15	11:56	166	>depth	19.2	12.4, 11.8 (12.1)	34.5	8.81	7.1	1.09	8.3	5.5	1.2	2.9
June 30	11:15	181	>depth	24.8									
July 15	11:41	196	>depth	26.8	10.4, 10.8 (10.6)								
July 31	11:22	212	>depth	25.2									
August 16	11:41	228	>depth	25.9	9.6, 9.8 (9.7)								
August 30	11:24	242	>depth	23.0									
September 13	11:31	254	>depth	20.0	9.8, 9.8 (9.8)								
September 30	11:32	273	>depth	16.0									
October 16	11:20	289	>depth	7.8	8.6, 7.8 (8.2)								

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

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	12:12	133	>depth	16.0	8.4, 7.6 (8.0)	34.0	3.20	5.0	1.00	8.8	2.7	2.2	3.4
May 30	12:14	150	>depth	20.5									
June 15	12:20	166	>depth	19.8	11.4, 11.4 (11.4)								
June 30	11:32	181	>depth	23.9									
July 15	12:00	196	>depth	25.4	12.8, 12.8 (12.8)								
July 31	11:35	212	>depth	25.5									
August 16	11:58	228	>depth	26.0	12.2, 12.0 (12.1)								
August 30	11:39	242	>depth	24.0									
September 13	12:15	254	>depth	21.8	9.4, 9.6 (9.5)								
September 30	11:57	273	>depth	16.0									
October 16	11:40	289	>depth	11.0	8.6, 9.0 (8.8)								

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

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm	DOC, ppm	K, ppm	Mg, ppm	Na, ppm	Si, ppm	SO4, ppm
May 18	12:26	133	>depth	17.5	7.6, 7.6 (7.6)	31.6	3.60	5.6	0.89	7.0	2.6	1.7	3.4
May 30	12:24	150	>depth	22.5									
June 15	12:39	166	>depth	20.0	9.4, 9.2 (9.3)	30.8	3.25	5.6	0.88	8.0	2.6	2.8	3.3
June 30	11:46	181	>depth	24.7									
July 15	12:15	196	>depth	26.5	9.0, 9.2 (9.1)								
July 31	11:50	212	>depth	25.0									
August 16	12:20	228	>depth	25.8	11.6, 9.4 (10.0)								
August 30	11:57	242	>depth	23.2									
September 13	12:35	254	>depth	20.0	7.4, 13.6 (10.5)								
September 30	12:13	273	>depth	15.6									
October 16	12:00	289	>depth	8.0	8.8, 9.8 (9.3)								

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

Date	Time	Day of Year	Comments
May 18	14:17	133	
May 30	13:18	150	
June 15	11:50	166	1.5 days of rain prior to sampling Depth: 2.3m
June 30	11:44	181	
July 15	11:19	196	Depth: 1.98m
July 31	11:20	212	Depth: 2.10m
August 16	11:17	228	Depth: 2.28m
August 30	13:38	242	Depth: 2.2m
September 13	13:01	254	Depth: 1.95m
September 30	10:48	273	Depth: 1.92m
October 16	10:48	289	Depth: 1.59m

.

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

Date	Time	Day of Year	Comments
May 18	14:43	133	Depth: 1.75m
May 30	13:27	150	Depth: 1.92m
June 15	12:10	166	Depth: 1.74m
June 30	12:03	181	Depth: 1.6m
July 15	11:37	196	Depth: 1.44m
July 31	11:31	212	Depth: 1.51m
August 16	11:42	228	Depth: 1.47m
August 30	13:52	242	Depth: 1.5m
September 13	13:12	254	Depth: 1.44m
September 30	10:53	273	Depth: 1.19m
October 16	10:57	289	Depth: 0.99m

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

Date	Time	Day of Year	Comments
May 18	15:46	133	
May 30	13:52	150	Depth: 1.88m
June 15	14:00	166	Depth: 1.78
June 30	13:13	181	
July 15	12:30	196	Depth: 1.52m
July 31	12:35	212	Depth: 1.63m
August 16	12:55	228	Depth: 1.61m
August 30	15:41	242	Depth: 1.5m
September 13	14:00	254	
September 30	11:28	273	Depth: 1.38m
October 16	11:26	289	Depth: 1.02m

Temperatures taken 1 m from bottom. B= bottom temperature

Weather Conditions 2018

Date	Day of Year	Weather Conditions
May 18	133	Sunny, no rain for over a week prior. Wind less than 15 km/h; Air temperature: 20 ◦C
May 30	150	Sunny, small amount of rain two days prior. No wind, Air temperature: 25 ◦C; some pollen on surface; lots of plankton in lake
June 15	166	Moderate rain two days prior to sampling. Full sunshine sampling conditions, light or no wind. Pollen storm previous week and continuing. Air Temperature: 17 ◦C
June 30	181	Very light rain previous night for short time. Light rain 1.5 days before sampling. Very and sunny day. Air temperature reaching 30 ◦C during day and about 25 ◦C during sampling run.
July 15	196	Very hot sunny day. No wind. Three weeks of drought. No significant rain in over 6 weeks. Lake 5cm too shallow, evaporation. Air temperature: 26-31 ◦C
July 31	212	Sunny clear day, 40 hours after very significant rain. Lake rose by 10 cm. Air temperature: 25 to 31 ◦C
August 16	228	Sunny clear day, no wind, no rain for 10 days prior. Air temperature: 25 to 27 ◦C
August 30	242	No significant rain for previous ten days. Sunny day with light winds. Air Temperature: 15 to 21 ◦C
September 13	254	Moderate rain two days prior, full sun, no wind. Air temperature: 22 ◦C
September 30	273	Overcast, air temperature: 8 ◦C, significant rain 3 days before sampling, light showers day before. No wind
October 16	289	Light rain previous day. Cool weather three days before that, several days of rain previous. Partial sun and cloud during sampling, but mostly overcast. Air temperature: 5.0 ◦C

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 phosphorous 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 phosphorous.
4. Sampling dates were ideally the first of the month for temperature and Secchi depth and the 15th 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 phosphorous 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.

Conductivity and pH at Selected Sites
White Lake – 2018

Dock at 1053 Wabalac Road – Western Shore

Date	Day of Year	Conductivity, µS/cm	pH	Comments
Oct 12	285	194	-	2017
Oct 25	298	202	-	2017
Nov 6	310	203	7.72	2017
Nov 22	326	204	7.78	2017
Dec 3	337	199	7.68	2017
Dec 9	343	202	7.42	2017
Dec 24	358	215	7.82	2017
Jan 20	20	214	7.12	Water color was noticeably light brown
Feb 2	33	170	7.01	Water was tea-coloured
Feb 17	48	150	7.10	Water tea-colored; **Total Hardness: 100 ppm**
Feb 26	57	102	7.24	Water lightly tea colored; **Total Hardness: 80 ppm**
Mar 31	90	71	7.35	Melting ice 12" thick
Apr 8	98	182	7.42	Cold weather; ice 12" thick
Apr 22	112	27	7.09	Lots of snow melt
Apr 27	117	178	7.66	Ice out day before
Apr 30	120	192	7.81	
May 2	122	209	7.84	
May 18	138	221	7.68	
May 22	142	224	8.16	
May 27	147	222	8.36	
May 30	150	221	8.48	Water Temp: 20.7 ◦C
June 15	166	226	8.10	1.5 days of rain prior to sampling

June 22	173	226	8.00	Temp: 21.8 ◦C
June 30	181	227	8.07	Temp: 23.0◦C
July 6	186	225	8.07	6-day heat wave, no rain previous 2 weeks
July 13	194	224	8.07	Water Temp 25.1◦C; No rain for three weeks, heat wave >30◦C
July 31	212	224	7.81	40 hours after heavy rains; lake rose 10 cm
Aug 15	227	211	7.72	Hot weather and no rain for >10 days
Aug 24	236	209	7.65	Some rain several days earlier, water cooling to 22◦C
Aug 29	241	198	7.45	No rain for last 10 days, hot weather
Sept 13	256	197	7.22	Moderate rain two days prior, sunny day no wind
Sept 29	272	201	7.17	Significant rain 2 days before sampling
Oct 16	289	200	7.35	High winds evening before sampling, light rain
Nov 4	308	203	7.32	Significant rain for five days; streams flowing well. Temp: 4.5C

*5 m off shore 1 m depth; pH = calibration curve corrected; pH values are ± 0.14 units

Boundary Creek, end of Sunset Bay

Date	Day of Year	Conductivity, µS/cm	pH	Comments
Mar 31	90	215	7.35	
Apr 8	98	200	7.66	
Apr 22	112	187	7.78	
Apr 27	117	143	7.76	
Apr 30	120	166	8.09	
May 2	122	189	8.01	
May 18	138	247	7.59	Water flow down about 70% in three weeks
May 22	142	245	7.95	
May 30	150	260	8.01	
June 15	166	268	7.93	
June 22	173	276	7.63	
June 30	181	270	7.98	Flow very low
July 6	186	287	7.55	Flow very low following 6-day heat wave

July 13	194	287	7.93	No rain for three weeks, heat wave >30◦C
July 31	212	261	8.18	40 hours after heavy rains; lake rose 10 cm; moderate to low flow in streambed
Aug 15	227	316	7.16	Hot weather and no rain for >10 days
Aug 24	236	321	7.27	
Aug 29	241	313	6.91	No rain for last 10 days, hot weather
Sept 13	254	339	6.82	Moderate rain two days prior, sunny day no wind
Sept 29	272	357	6.85	Significant rain 2 days before sampling
Oct 16	289	338	7.13	
Nov 4	308	296	7.15	Significant rain for five days; streams flowing well. Temp: 5.4C

Paris Creek, end of Sunset Bay

Date	Day of Year	Conductivity, µS/cm	pH	Comments
Mar 31	90	36	6.85	
Apr 8	98	31	7.23	
Apr 22	112	24	7.18	Lots of snow melt
Apr 27	117	17	7.26	
Apr 30	120	17	7.76	
May 2	122	23	7.33	Stream flow diminishing
May 18	138	34	7.26	Water flow down about 70% in three weeks
May 22	142	33	7.08	
May 27	147	39	6.67	
May 30	150	39	6.69	
June 15	166	40	6.90	1.5 days of rain prior to sampling
June 22	173	40	6.52	T = 20.3 ◦C
June 30	181	40	6.94	Minimal flow
July 6	186	46	6.45	Almost no flow ~10 L/min.
July 13	194	45	6.73	No rain for three weeks, heat wave >30◦C
July 31	212	34	6.26	40 hours after heavy rains; lake rose 10 cm; moderate to low flow in streambed

Aug 15	227	41	5.38	Hot weather and no rain for >10 days
Aug 24	236	40	6.24	
Aug 29	241	43	6.36	No rain for last 10 days, hot weather
Sept 13	254	44	6.09	Moderate rain two days prior, sunny day no wind
Sept 29	272	46	5.80	Significant rain 2 days before sampling
Oct 16	289	38	5.90	
Nov 4	308	35	6.05	Significant rain for five days; streams flowing well. Temp: 5.4C

Other Lake and Area Locations

Location	Date	Day of Year	Conductivity, µS/cm*	pH	Comments
W.L Dam	Apr 18	108	176		
“	Apr 27	117	151		
“	May 27	147	212		
1551 Peneshula	Apr 21	111	71		
1551 Peneshula	Apr 27	117	55		Ice still on the lake
“	Apr 29	119	200		Ice off TM Bay this day
“	May 27	147	212		
Lowney Lake Creek	Apr 21	111	343		N. 45 16 864 W 76 28 504
“	Apr 27	117	393		
“	May 27	147	334		
“	June 2	153	343		23.5C; very little outflow from Lowney Lake Ca=56 ppm; Mg=14 ppm drop titration
“	June 30	181	373	7.27	Very Little or No flow detected; Temp: 22.3 ◦C
“	July 15	196	404	7.08	
“	July 31	212	306	7.28	
“	Aug 16	228	336	6.92	
“	Aug 30	242	336	6.88	
“	Sept 13	254	356	6.91	

“	Sept 30	273	373	6.74	Significant rain 3 days before sampling, light showers day before
“	Oct 16	289	481	7.49	Temperature at sampling site: 7.5C
Bellamy Cr.	Apr 21	111	187		N. 45 16 090 W 76 22 504
Bellamy Cr.	Apr 21	111	69		N. 45 16 634 W 76 25 634
Indian R.	Apr 21	111	299		Mill of Kintail; Outside of White Lake watershed
White Lake Fen Creek	July 31	212	229	6.91	This water sample was collected underwater immediately above the floor of the creek. There was a very cold current of water upwelling from the floor of creek in what appeared to be fissures or erosion in the peat-like bottom. The water was approximately 17◦C (estimate) and very much colder than the waters, only half a metre above. It was evident that the substantial flow of water served to erode the peat as the cold-water vents, or cracks, were ten to 40 cm deep. The water coming from the springs likely resulted form the heavy rains 40 hours prior to sampling. The lake level rose 10cm because of the rain.

*Normalized to Conrad’s device of the same source and manufacturer.

Conductivity and pH: Lake-Wide Surveys – 2018

May 18, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	219	7.86	Water Temperature: 15.3◦C
N. Hardwood Is.	220	7.74	Water Temperature: 14.8◦C
Deepest Pickerel Bay (@ Secchi depth)	219	7.95	Water Temperature: 14.7◦C
Deepest Pickerel Bay (@ bottom)	223	7.95	-
Pickerel Bay	224	7.97	Water Temperature: 15.2◦C
Middle Narrows	225	8.06	Water Temperature: 15.7◦C
The Canal (top)	230	8.21	Water Temperature: 17.5◦C
The Canal (Bottom)	228	8.35	Water Temperature: 17.2◦C
W. Lake Marina	244	8.28	Water Temperature: 17.3◦C
Bayview Lodge	253	8.27	Water Temperature: 17.5◦C
East Canal	256	8.22	Water Temperature: 17.3◦C
Hayes Bay	257	8.24	Water Temperature: 17.3◦C
Centre. Hayes Bay	257	8.28	Water Temperature: 17.3◦C
Barber Is.	256	8.24	Water Temperature: 17.3◦C
Bane Bay I	254	8.24	Water Temperature: 17.5◦C
Bane Bay II	264	8.11	Water Temperature: 17.7◦C
Jacobs Is.	223	8.14	Water Temperature: 15.3◦C
Village Basin	208	8.37	Water Temperature: 15.3◦C
Fish Creek (at lake)	206	7.96	N 45◦ 19.454'; W 76◦ 31.433'
Fish Creek (estuary)	166	7.77	N 45◦ 19.466'; W 76◦ 31.590'
Fish Creek (half way in)	128	7.69	N 45◦ 19.375'; W 76◦ 31.696'

May 22, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Mid-Hardwood I. (W)	212	8.14	N 45◦ 15.968'; W 76◦ 33.724'
Entrance Sunset Bay	216	8.07	N 45◦ 15.587'; W 76◦ 34.775'
Middle Sunset Bay	219	8.11	N 45◦ 15.390'; W 76◦ 35.402'
Paris Cr. at Lake	219	8.10	N 45◦ 15.430'; W 76◦ 35.773'

Paris Cr. Entrance	204	7.99	N 45° 15.437'; W 76° 35.829'
Paris Cr. Inlet 1 (nearest the lake)	188	7.89	N 45° 15.442'; W 76° 35.878'
Paris Cr. Inlet 2	121	7.62	N 45° 15.443'; W 76° 35.917'
Paris Cr. Inlet 3	98	7.48	N 45° 15.432'; W 76° 35.967'
Paris Cr. (at Wabalac Rd.)	33	7.03	N 45° 15.433'; W 76° 36.047'
Sunset Bay (boat launch)	215	8.02	N 45° 15.232'; W 76° 35.817'
Boundary Creek 1 (nearest lake)	217	8.06	N 45° 15.218'; W 76° 35.918'
Boundary Creek 2	230	8.03	N 45° 15.195'; W 76° 36.012'
Boundary Creek 3	233	7.71	N 45° 15.193'; W 76° 36.057'
Boundary Creek (at Wabalac Rd.)	245	7.90	N 45° 15.156'; W 76° 36.209'
Broad Brook Basin	218	8.12	N 45° 15.354'; W 76° 34.508'
Lacourse Basin	228	8.20	N 45° 15.381'; W 76° 33.992'
1053 Dock	224	8.11	N 45° 16.328'; W 76° 33.153'

May 30, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Bottom 3-Mile Bay	214	8.41	N 45° 15.525' ; W 76° 28.884'; T=23.0°C (zebra mussels); 1.6M
3-Mile Bay Marl	215	8.35	N 45° 15.517'; W 76° 29.133'; T=23.7°C; 1.8M
Three Mile Bay 1	220	8.21	N 45° 15.462'; W 76° 29.622'; T=22.0°C; 2.3M
Three Mile Bay 2	219	8.21	N 45° 15.613'; W 76° 30.966'; 22.0C; T=22.0°C; 3.2M (Zebra M.)
Three Mile Bay	223	8.44	Standard Sampling Site; T=20.7°C
E. Hardwood Basin	223	8.32	N 45° 15.688'; W 76° 33.241'; T=20.7°C; 5.1M; Secchi D.=3.5M
Lacourse Basin	225	8.33	N 45° 15.472'; W 76° 33.876'; T=21.0°C; 3.7M (Zebra M.); Secchi D=Bottom
D. Round L. Outlet	253	7.93	N 45° 15.269'; W 76° 33.907'; T=21.5°C; 1.76M (no zebra m.)
Broad Book. Basin	234	8.22	N 45° 15.334'; W 76° 34.592'; T=21.0°C; 2.55M; zebra M.; marl; Secchi D.=2.55 (Bottom)
Sunset Bay Basin	222	8.26	N 45° 15.401'; W 76° 35.437'; T=21.6°C; 4.6M; Secchi D.=4.2m
Mid-Hardwood I. W.	223	8.35	N 45° 15.956'; W 76° 33.736'; T=20.7°C; 7.0M; Secchi D.=4.2M
N. Hardwood I.	221	8.39	Standard Sampling Site; T=20.8°C
Deepest Pickerel Bay	219	8.35	Standard Sampling Site; T=20.2°C
Pickerel Bay	214	8.34	Standard Sampling Site; T=20.5°C
Middle Narrows	224	8.18	Standard Sampling Site; T=20.2°C
The Canal	230	8.36	Standard Sampling Site; T=21.5°C
Hayes Bay	257	8.35	Standard Sampling Site; T=23.8°C
Myrtle I. Basin	226	8.23	N 45° 19.440'; W 76° 30.337'; T=21.0°C; 2.2M
Jacobs Is.	231	8.11	Standard Sampling Site; T=20.5°C
Village Basin	224	8.41	Standard Sampling Site; T=22.5°C
Lowney Lake Creek	343	7.54	Ca=56 ppm; Mg=14 ppm by drop titration

June 10, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Lacourse Basin	225	8.05	N 45◦ 15.472'; W 76◦ 33.876'; T=20.8◦C
D. Round L. Outlet	262	7.78	N 45◦ 15.235'; W 76◦ 33.916'; T=21.0◦C
D. Round Lake Canal North #1	271	7.74	N 45◦ 15.190'; W 76◦ 34.002'; T=21.0◦C
D. Round Lake Canal North #2	273	7.75	N 45◦ 15.108'; W 76◦ 34.122'; T=20.8◦C
D. Round Lake Canal North #3	272	7.78	D. Round Lake Entrance N 45◦ 15.006'; W 76◦ 34.227'; T=21.0◦C
D. Round Lake Canal South #1	274	7.77	N 45◦ 15.005'; W 76◦ 34.119'; T=20.5◦C
D. Round Lake Canal South #2	271	7.78	N 45◦ 15.022'; W 76◦ 33.778'; T=20.0◦C
D. Round Lake Canal South #3	270	7.89	N 45◦ 15.061'; W 76◦ 33.531'; T=20.3◦C
D. Round Lake Canal South #4	270	7.85	N 45◦ 15.075'; W 76◦ 33.384'; T=20.0◦C
Long Lake Creek	270	7.62	N 45◦ 15.098'; W 76◦ 33.429'; T=20.1◦C
D. Round Lake Entrance	273	7.93	N 45◦ 14.989'; W 76◦ 34.278'; T=21.0◦C
D. Round Lake #1	278	8.08	N 45◦ 14.921'; W 76◦ 34.406'; T=21.0◦C
D. Round Lake #2	279	8.15	N 45◦ 14.830'; W 76◦ 34.549'; T=21.0◦C
D. Round Lake #3 South end	277	8.26	N 45◦ 14.784'; W 76◦ 34.630'; T=21.3◦C

June 15, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	232	8.15	1.5 days of rain prior to sampling. Full sunny day; no wind
N. Hardwood I.	231	8.11	
D. Pickerel Bay	229	8.15	
Pickerel Bay	228	8.16	
Middle Narrows	227	8.16	
The Canal	228	8.24	
Hayes Bay	247	8.28	
Barbers I.	256	8.28	
Bane Bay I	258	8.25	
Bane Bay II	264	8.04	
Jacobs I.	225	8.15	
Village Basin	221	8.28	

June 24, 2018

Location	Specific Conductivity, µS/cm	pH	Comments *moderate rain prior day
Broad Brook 1	383	7.95	N 45◦ 14.992'; W 76◦ 34.904'; T=20.3◦C
Broad Brook 2	377	7.96	N 45◦ 15.027'; W 76◦ 34.853'; T=19.8◦C
Broad Brook 3	374	7.79	N 45◦ 15.061'; W 76◦ 34.792'; T=20.2◦C
Broad Brook 4	372	7.79	N 45◦ 15.081'; W 76◦ 34.737'; T=20.8◦C
Broad Brook 5	380	7.68	N 45◦ 15.122'; W 76◦ 34.660'; T=21.7◦C
Broad Brook 6	377	7.68	N 45◦ 15.180'; W 76◦ 34.650'; T=21.2◦C
Broad Br. Basin	232	8.09	N 45◦ 15.472'; W 76◦ 33.806'; T=22.3◦C

June 30, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	226	7.87	GPS coordinates are available on tables above
N. Hardwood I.	227	7.71	
D. Pickerel Bay	227	7.98	
Pickerel Bay	227	8.07	
Middle Narrows	227	8.00	
The Canal	229	8.02	
Hayes Bay	262	8.15	
Barbers I.	264	8.12	
Bane Bay I	262	8.10	
Bane Bay II	266	8.03	
Jacobs I.	228	7.83	
Village Basin	224	8.28	
Mid Hardwood I. West	228	8.01	
Broad Brook Basin	228	8.07	
Lacourse Lane Basin	229	8.08	
East Hardwood I. Basin	226	8.08	

July 15, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	224	7.82	Three weeks drought prior, temp: 26-31◦C. Full sunny day; no wind. No significant rain in over 6 weeks.
N. Hardwood I.	226	7.74	
D. Pickerel Bay	226	7.81	
Pickerel Bay	226	7.74	
Middle Narrows	226	7.71	

The Canal	221	8.07	
Hayes Bay	263	8.01	
Barbers I.	266	7.96	
Bane Bay I	268	7.93	
Bane Bay II	272	7.81	
Jacobs I.	222	7.84	
Village Basin	222	8.28	
Lowney Lake Cr.	404	7.08	Water at sampling site virtually stagnant, no flow observed
Boundary Creek	287	7.93	Very little flow
Paris Creek	45	6.73	Very little flow

July 31, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	210	7.70	Water Temperature: 25.2◦C
E. Hardwood I. Basin	216	7.63	Water Temperature: 24.5◦C
Lacourse Basin	217	7.66	Water Temperature: 24.5◦C
Broad Br. Basin	214	7.74	Water Temperature: 24.5◦C
Sunset Bay Basin	215	7.67	Water Temperature: 24.5◦C
Mid Hardwood I. W.	216	7.64	Water Temperature: 24.5◦C
N. Hardwood Is.	217	7.66	Water Temperature: 24.3◦C
Deepest Pickerel Bay	219	7.68	Water Temperature: 25.0◦C
Pickerel Bay	219	7.67	Water Temperature: 25.2◦C
Middle Narrows	216	7.70	Water Temperature: 25.0◦C
The Canal	209	7.95	Water Temperature: 25.0◦C
W. Lake Marina	225	7.94	Water Temperature: 25.3◦C
Hayes Bay	237	8.01	Water Temperature: 25.2◦C
Barber Is.	240	8.01	Water Temperature: 24.5◦C
Bane Bay I	238	7.94	Water Temperature: 25.7◦C
Bane Bay II	241	7.67	Water Temperature: 25.5◦C
Myrtle I. Basin	211	7.87	Water Temperature: 25.0◦C
Jacobs Is.	212	7.87	Water Temperature: 25.5◦C
Village Basin	209	8.16	Water Temperature: 25.0◦C
Village Basin 1	208	8.12	N 45◦ 21.029; W 76◦ 30.089'; WT: 25.8◦C
Village Basin 2	212	8.05	N 45◦ 20.533'; W 76◦ 30.078'; WT: 25.8◦C
W.L. Fen Creek	229	6.91	N 45◦ 20.483'; W 76◦ 30.000'; WT: ~17◦C

August 15, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	211	7.85	Full sun, no wind. No rain previous 10 days.
N. Hardwood I.	212	7.86	
D. Pickerel Bay	214	7.84	
Pickerel Bay	214	7.87	
Middle Narrows	214	7.85	
The Canal	200	8.22	Sediment Core: exposed marl
Hayes Bay	234	8.21	Sediment Core: black gelatinous mud – no marl
Bane Bay I	243	8.09	Sediment Core: grey to black gelatinous mud – no marl, Depth: 1.25m, Temp: 25.7°C
Bane Bay II	252	7.86	Sediment Core: black gelatinous mud – no marl, Depth: 1.15m, Temp: 25.4°C
Jacobs I.	212	7.82	
Village Basin	202	8.36	Sediment Core: 5 cm organic layer over marl
Lowney L. Cr.	336	6.92	

August 30, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	207	7.65	Water Temperature: 23.3°C
E. Hardwood I. Basin	205	7.68	Water Temperature: 23.5°C
Lacourse Basin	207	7.63	Water Temperature: 23.3°C
Broad Br. Basin	210	7.58	Water Temperature: 23.6°C
Sunset Bay Basin	203	7.69	Water Temperature: 23.4°C
Mid Hardwood I. W.	209	7.59	Water Temperature: 23.4°C
N. Hardwood Is.	208	7.66	Water Temperature: 23.5°C
Deepest Pickerel Bay	211	7.68	Water Temperature: 24.0°C
Pickerel Bay	211	7.73	Water Temperature: 23.7°C
Middle Narrows	210	7.72	Water Temperature: 23.8°C
The Canal	210	7.99	Water Temperature: 23.0°C
Hayes Bay	233	7.97	Water Temperature: 23.0°C
Barber Is.	241	7.94	Water Temperature: 23.2°C
Bane Bay I	242	7.98	Water Temperature: 23.2°C
Bane Bay II	251	7.94	Water Temperature: 23.3°C
Jacobs Is.	203	7.89	Water Temperature: 24.0°C
Village Basin	202	8.15	Water Temperature: 23.2°C

September 13, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	207	7.75	Moderate rain two days prior. Full sunny day; no wind
N. Hardwood I.	206	7.73	
D. Pickerel Bay	207	7.70	
Pickerel Bay	208	7.70	
Middle Narrows	208	7.67	
The Canal	206	7.78	
Hayes Bay	234	8.03	
Barbers I.	242	8.01	
Bane Bay I	248	7.83	
Bane Bay II	254	7.86	
Jacobs I.	205	7.81	
Village Basin	204	8.24	

September 30, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	202	7.44	Water Temperature: 16.8◦C
E. Hardwood I. Basin	202	7.41	Water Temperature: 16.0◦C
Lacourse Basin	202	7.41	Water Temperature: 16.2◦C
Broad Br. Basin	202	7.30	Water Temperature: 16.2◦C
Sunset Bay Basin	199	7.32	Water Temperature: 16.1◦C
Mid Hardwood I. W.	201	7.47	Water Temperature: 17.0◦C
N. Hardwood Is.	203	7.49	Water Temperature: 16.8◦C
Deepest Pickerel Bay	205	7.49	Water Temperature: 16.8◦C
Pickerel Bay	206	7.50	Water Temperature: 17.2◦C
Middle Narrows	204	7.55	Water Temperature: 16.7◦C
The Canal	212	7.62	Water Temperature: 15.9◦C; Depth: 1.92m
Hayes Bay	242	7.57	Water Temperature: 16.0◦C; Depth: 1.19m
Barber Is.	253	7.62	Water Temperature: 15.9◦C; Depth: 1.22m
Bane Bay I	254	7.63	Water Temperature: 16.0◦C; Depth: 1.12m
Bane Bay II	262	7.62	Water Temperature: 15.8◦C; Depth: 1.06m
Jacobs Is.	207	7.40	Water Temperature: 16.0◦C
Village Basin	206	7.67	Water Temperature: 15.6◦C; Depth: 1.38m

October 16, 2018

Location	Specific Conductivity, µS/cm	pH	Comments
Three Mile Bay	232	8.15	Air temp: 5.0C; partially cloudy’ wind 5 km/hr. high
N. Hardwood I.	231	8.11	
D. Pickerel Bay	229	8.15	
Pickerel Bay	228	8.16	
Middle Narrows	227	8.16	
The Canal	228	8.24	Depth: 1.59m
Hayes Bay	247	8.28	Depth: 0.99m
Jacobs I.	225	8.15	
Village Basin	221	8.28	Depth: 1.02m