Economic Valuation of Water Quality in the Muskoka Region

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This research project aimed to investigate the influences of water quality on the value of waterfront properties. To do so many different aspects and their associated variables were examined in an attempt to find a correlation between these factors and waterfront values. This project reduced the area being investigated into three watersheds containing different levels of water quality as described by The Muskoka Watershed Report Card 2010 (www.muskokaheritage.org/watershed). For each of the 3 watersheds; we picked lakes that represented varying levels of water quality data. The six lakes this study examined were: Mainhood Lake, Three Mile Lake, Lake Joseph, Ada Lake, Little Long Lake, and Skeleton Lake. We are incorporating a multifaceted approach to see if there is a correlation between waterfront property values with water quality. The specific areas we investigated are: water clarity, drinking water quality, fishing preferences, and what factors drive property values.

There are many different ways people define, measure, interpret, and value water quality. We have been focusing on three major watersheds which is the Lake Rosseau and Joseph, Three Mile Lake and Skeleton Lake. We are interpreting various forms of data but also looking at what factors drive property value in the Muskoka's. We looked at land and water indicators from the Muskoka Watershed Report Card. The amount of property on lakes that has been purchased and turned into a cottage has grown vastly in the last 50 years in the Muskoka region. This has put stresses on many of the lakes especially in our study area that are quite populous in the summer time. There are numerous ways in which a property can accumulate or lose value which will be listed.

Three main factors we focused on are looking at were the technical, aesthetic, and cultural/spiritual aspects. This is basically what can be found in the water? We have also examined phosphorous levels, biodiversity, demographics, and geographical characteristics of the land. Properties especially cottages can have a drastic impact on lakes if the shoreline is altered. Other issues in the Muskoka's include septic tanks leakage, as well as chemical run off the property adjacent prosperities and into the watershed.

The aesthetic value of the water entails the appeal visually of the lake to the viewer. Most cottage owners and property owners assume that the Muskoka's has impeccable water quality. In our research we found out that in many instances there are water quality issues not only currently but in the future as well. The question is how can the areas as a whole reduce their impacts and keep Muskoka's ecosystems and natural environments up to the highest standards? Water quality is above average but some eutrophic lakes can be found in the Muskoka's. Secchi disks are tools in science that measures how clear a lake is. How clear the water is definitely has an impact on the property owner or buyer.

We looked at numerous factors that drive property value in the Muskoka's. We found out that 85% of residential property values can be attributed to five of the following thirteen factors: location, lot size/dimensions, living area, quality of construction, age/renovations, value vacant properties (zoning), building permits issued by municipality, reviews conducted to reassess property value, topography, channel, river, direct vs. indirect waterfront, and a river vs lake access (lake values are always higher). These are the main reasons why a property value can be very high or much lower. Depending on how many the property has the higher it will be. Currently the water quality is not a driving force when a buyer is looking at a property in the Muskoka's.

Water quality can be influenced by many of these individual factors and it is clear that cottagers and buyers value certain ones more than others. With these factors in mind it will be easier to see why property values are higher or lower on different lakes and if there is a correlation between water quality or not. Policies and approaches need to be altered in the future to ensure properties value water quality more. While environment, social equity, health and water have all been linked separately within regulatory policy, a notable absence from literature of these field's is an explicit attempt to place health, ecosystems and social systems within the same model of governance. More research needs to be done in the Muskoka's applying more ecological and social factors that not only drive property value but as well these factors can impact water quality.

The other main aspects we are focusing on are the cultural and spiritual values we attribute to lakes in the Muskoka region. There is a lot history and unique ecosystems in the area and many cultures and peoples see watersheds and lakes as very sacred places. Many cottagers see the Muskoka's as a place to relax and escape the city life they are accustomed to. It is a place to get back to nature and experience beautiful lakes and wildlife. Over 75% of properties in the Muskoka's are classified as recreational meaning that three out of four properties are cottages. Here is a brief breakdown of population demographics in the region:

Muskoka's Seasonal Population, 2006 (a)

	Total # of Seasonal Dwellings	Average # Persons Per Household	Estimated Seasonal Population	Estimated Total Population
Bracebridge	1,962	3.59	7,045	22,697
Georgian Bay	4,045	3.65	14,766	17,106
Gravenhurst	3,066	3.60	11,036	22,082
Huntsville	1,659	3.72	6,171	24,451
Lake of Bays	3,171	3.62	11,480	15,050
Muskoka Lakes	6,755	3.72	25,129	31,596
Muskoka	20,658	3.66	75,626	133,189

The population in the summer months booms to over 133,000. This information was taken in 2006, and with over 75,000 cottagers and tourists coming to the area during the summer season.

The Municipal Property Assessment Corporation (MPAC) classifies how properties can be used and assigns values. They have many roles, responsibilities and relations within the Muskoka's and across Ontario. MPAC is involved in legislation, property assessment which is the assessment act which forces properties to be taxed and valued at current market values. They also publish population reports and assess millions of properties annually. MPAC focuses on the current value of a property and then establishes a sales price depending on how many factors the property has. This will in turn appease the buyer and drive the value of the property. Many prices in the lakes and watersheds we studied were between $200,000-300,000 in our meeting with MPAC they said that there was a noticeable trend between algal blooms in lakes and the depreciation of property value and sales. The lakes we chose varied in water quality and there was some correlation between the overall quality of the lake water and price. MPAC has provided us with a framework on how property values are accessed and with our scientific data we have been able to analyze water quality and how it affects property value.

According to real estate agents in the area there really is little correlation in the Muskoka region that shows that water quality drives property value. Mostly in this area cottagers assume the quality is very high and will pay the price for waterfront property. More partnerships in the future involving the Ministry of Natural Resources and other local community members and cottage associations would be a move in the right direction. This would allow more knowledge sharing across the study area. There is a need to put price tag on the importance of having lakes have pristine water quality because of the services they provide not only to the natural

The Muskoka's have to do everything to protect the watersheds and lakes we studied have to do everything possible in the future to help preserve watersheds and maintain high levels of water quality. The Species at Risk Act has an important clause in section 58 which is about preventing the destruction of habitat section 58 states,

58. (1) Subject to this section, no person shall destroy any part of the critical habitat of any listed endangered species or of any listed threatened species — or of any listed extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada — if

- (*a*) the critical habitat is on federal land, in the exclusive economic zone of Canada or on the continental shelf of Canada;
- (*b*) the listed species is an aquatic species; or
- (*c*) the listed species is a species of migratory birds protected by the *Migratory Birds Convention Act, 1994*.

Currently there are 34 species at risk in the Muskoka's according to Muskoka Waterweb. It is vital to ensure the biodiversity and healthy ecosystems remain strong in Muskoka's natural areas. More policies to promote protected areas need to be put in place to conserve many unique areas that contain species at risk or have cultural or spiritual significance. Harsher penalties need to be put into force in the province of Ontario to promote more water protection measures and rights to the environment. More parks and protected areas should be created around sensitive lakes so they have a buffer zone and healthy riparian zones.

The Muskoka's needs to continue to have more information and monitoring systems in place and help make predictions that may happen from climate change. More data is clearly needed in regards to riparian areas and others across the region. The report card has a lot of watersheds with limited or no data so in the future students should partner up and go do hands on measurements of these areas. The Muskoka Watershed Council and Trent University need to continue a scientific relationship so this can provide information to policy makers. Cottages need to be more naturalized and it is important that sewage and other run off is mitigated to protect technical aspects in the water. More partnerships and power sharing has to be made to continue preserving one of the most pristine places in Canada. The importance of water quality should be preached to cottagers and tourists. This could be done through education sessions as well as mailing out flyers and pamphlets and from the Muskoka Waterweb.

There are many land and water indicators they are outlined in the Muskoka Watershed Councils report card. All areas in the Muskoka's that have low water quality need to be monitored and information gathered. Interior forests need to be preserved in our study area. Riparian areas are the areas 20 meters inland from shore need to be kept as natural as possible and policy should not allow shorelines to be altered. Natural cover which is wetlands, lakes, and forests need to be kept in tack and protection needs to be increased to maintain high levels of water quality. The ecological services provided by large natural areas are very difficult to put a price on however they are a necessity in sustaining ecosystem health and human health. Using ecosystem based land management needs to continue for sustainable development. Protection is the key and having natural shoreline will help keep phosphorous and mercury levels low. Wetlands need to be incorporated into protection as well because of their natural services and maintenance of water clarity and quality.

Land management rights need to be shared in the future and the eight main themes in the text book have to practiced and educated to the public of their importance. In an scholarly article entitled, Towards integrated governance for water, health and social–ecological systems it states, "The watershed governance prism The implications of managing watersheds at multi-scale settings for human health and well-being bring to the forefront the political ecology of the watershed system, as well as the fundamental importance of effective watershed management in building sustainable water–land systems that can support current waters, changing land use patterns, soil degradation, and the as yet unknown impacts of climate change on hydrological systems will ultimately play themselves out in the nested hierarchy of watersheds that govern surface water dynamics. Degraded watershed systems are more likely to create conditions that make life difficult for human communities." These conditions cannot happen there have been documented changes in the Muskoka's to water quality and land and water indicators have to be protected. More information and collaboration needs to occur to study land and water indicators to ensure that water quality is maintained and properties have as little effect on it as possible.

Water clarity can be assumed to have a significant impact on property values in the Muskoka Watershed. Property values are driven by subjectivity and perceptions of human needs and desires, therefore variables of water quality that are seen and experienced firsthand will have a stronger correlation with property values (Brashares, 1985). In addition to this, it may be a misperception of water quality that will affect property owners implicit valuation of properties and property characteristics (Steinnes, 1992). Examples of this include the water clarity improvements caused by acid rain which results in a degradation of water quality (Boyer et al, 2003), or naturally stained or discolored water because of sediments or minerals.

Keeping this in mind, the correlation between water clarity and property values is well documented. Studies in Mississippi (Boyer et al, 2003), New Hampshire (Boyle et al, 2002), Roswell (Hill et al, 2007), Northern New England (Boyle et al, 2003), and Maine (Bouchard et al, 1996), have all concluded (to varying degrees nonetheless) that water clarity significantly affects prices paid for lakeshore properties. These studies all were conducted using hedonic property-price models to control all other property characteristics and analyze the price differentials between properties on lakes with differing levels of water quality.

Variables for water clarity included secchi depth, turbidity (calculated by phosphorus levels and sedimentation), and homeowners perceptions on water quality. Using hedonic property-price models, researchers have been able to calculate changes of property values in response to changes in water clarity. The study in Maine shows that a 1m change in water clarity increase will result in a $11-$200 increase per waterfront footage, aggregating to millions of dollars over entire lakes. The study in New Hampshire determined that based on their results, a 1m decrease in water quality can lead to decreases in property value ranging from 0.9% - >6% on average per property.

Eutrophication is the excessive growth of aquatic autotrophs, and aquatic vascular plants (Lewis et al, 2011). Eutrophication can result in problems with the taste and odor of water, reducing water usage as users are less likely to swim, boat or fish (Bouska et al, 2008). Changes in water clarity can be attributed to nonpoint source pollution from excess runoff or septic tank leaks, resulting in eutrophication, algal growths, decreased water transparency, and reduced oxygen content in the water (Boyer et al, 1996; Lewis et al, 2011; Boyle et al, 2002; Dils et al, 2003). Lakes are also subject to natural eutrophication processes. Under natural conditions, lakes proceed towards geological extinction at varying rates through natural eutrophication by accumulated nutrients (Hasler, 1969). Additional findings by Murphy and Knopp reports that atmospheric deposition from air pollutants accounts for approximately 55% of the nitrogen and 27% of the phosphorus load into Lake Tahoe, allowing for assumptions that air pollutants are a significant contributor to eutrophication in lakes (Bytnerowitz et al, 2006). The thermal structure of the lake effects all biological, chemical, and physical processes in lakes including: productivity, nutrient regeneration, oxygen depletion, and water movement (Mazumder and Taylor, 1994). Therefore, there is evidence that temperature stimulates eutrophication and reduces water clarity (Boyle, 2002). This means that warmer temperatures due to climate change can have significant impacts on water clarity and property values in the future.

Sedimentation is the process of letting suspended materials settle by gravity (MRWA, n.d.). Natural rates of sedimentation are often accelerated when land is converted from forest to residential uses (Hill et al, 2007). This includes the removal of fauna along property waterfronts and installing man-made beaches. The mechanical harvesting of aquatic weeds in waterfronts costs $1,247 to $19,227 per hectare, which still equates to an expensive project for average sized waterfronts. (Byterowitz et al, 2006). Property owners value sandy lake beds and shores for their property which disrupts sediment. Naturalized shorelines also are better managers of soil and sediment erosion; disrupted shorelines contribute more to sedimentation in lakes than naturalized shorelines. Sedimentation results in reduced water turbidity, reduced water level, clogged fish gills and smothered spawning areas (Hill et al, 2007). Additional characteristics that effect the degree of sedimentation in a lake are: the slope of the surrounding land, size of the lake, wave action, and lake depth (Hill et al, 2007).

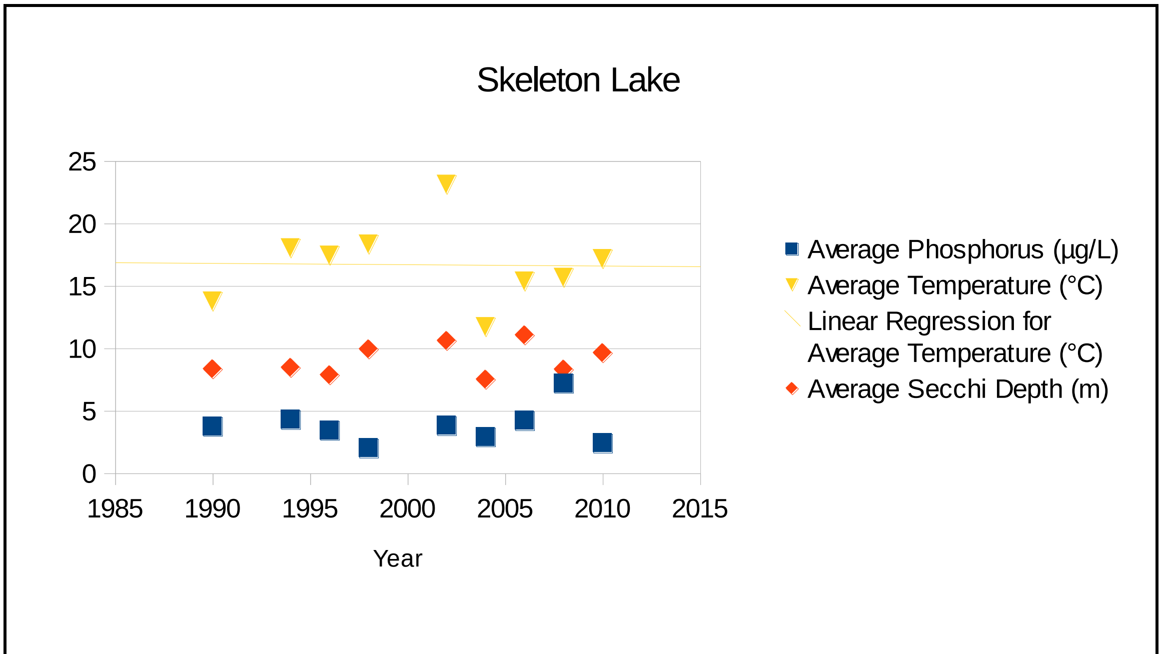
It is suspected that the potability of water is also an aspect which will impact real estate values. While potential buyers in the Muskoka area are guaranteed to have water which is safe for consumption under Ontario' Safe Drinking Water act, there are a number of aspects making safe drinking water difficult to achieve depending on where the property is located. Properties located close to agricultural or industrial settings may be vulnerable to an increase or decrease in value as extra maintenance is required to ensure that water quality standards are met. At this time there have been few studies showing a direct correlation between water potability and real estate value, however a 1999 study in Quebec City did report a decline in property values as a result of an outbreak of water related health problems in 1990-1991 (Des Rosiers et al. 1999). The case in Quebec suggests that real estate value is not directly influenced by water potability, but failure to meet drinking water standards can result in a longterm decline. The probability of a water source becoming contaminated may impact property values as these areas may be undesirable to potential buyers. Area and choice of treatment may also impact how drinking water tastes, smells and looks. Water which is unappealing to the consumer is also expected to impact real estate value.

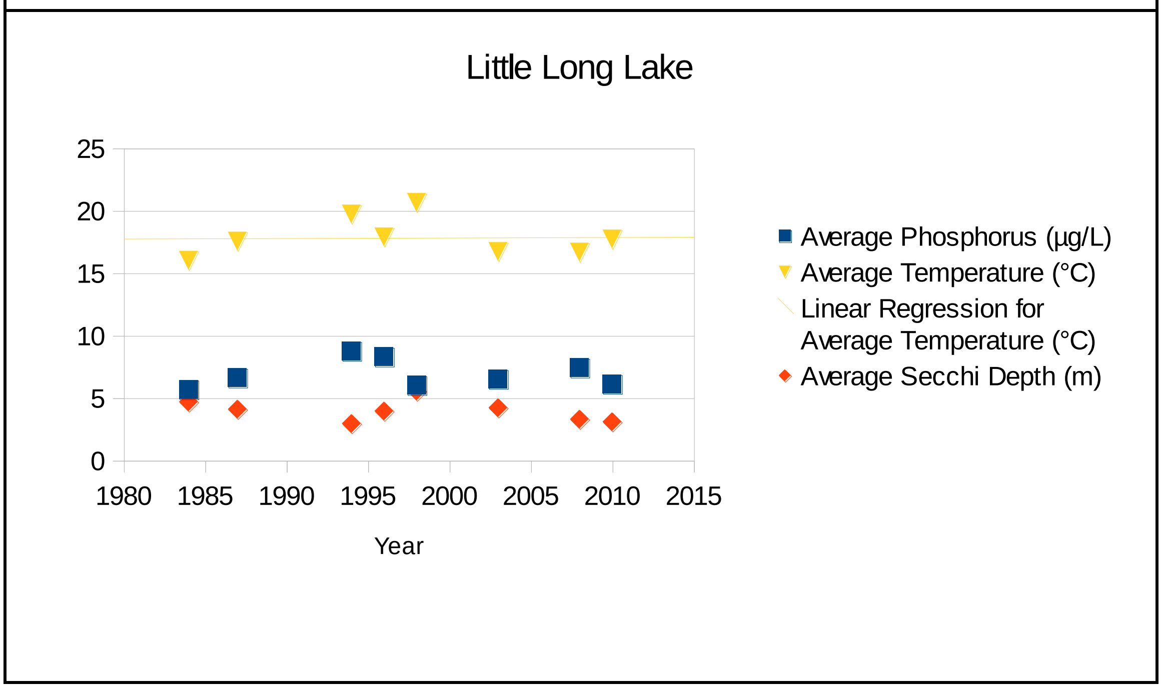
Part of the appeal of waterfront property is the recreational activities that are associated with the water. Fishing is one of the main recreational activities that people participate in; it composed almost 38 percent of all time spent on the water in a survey conducted by Gibbs and Conner in 1973. Fish populations (the species, number, and size) of fish present within a lake could impact the property values of houses located on the lake. Two important water values concerning preferred habitats for fish are: the temperature of the water and the concentration of dissolved oxygen. Dissolved oxygen (DO) levels impact the growth rate of fish, the more deprived of oxygen they are the slower fish will grow (EPA 1986). This results in smaller fish growing in lakes with low DO. Anglers prefer large fish; smaller average fish sizes could result in a lower demand for properties on a lake because of the lower quality fishing the lake would provide.

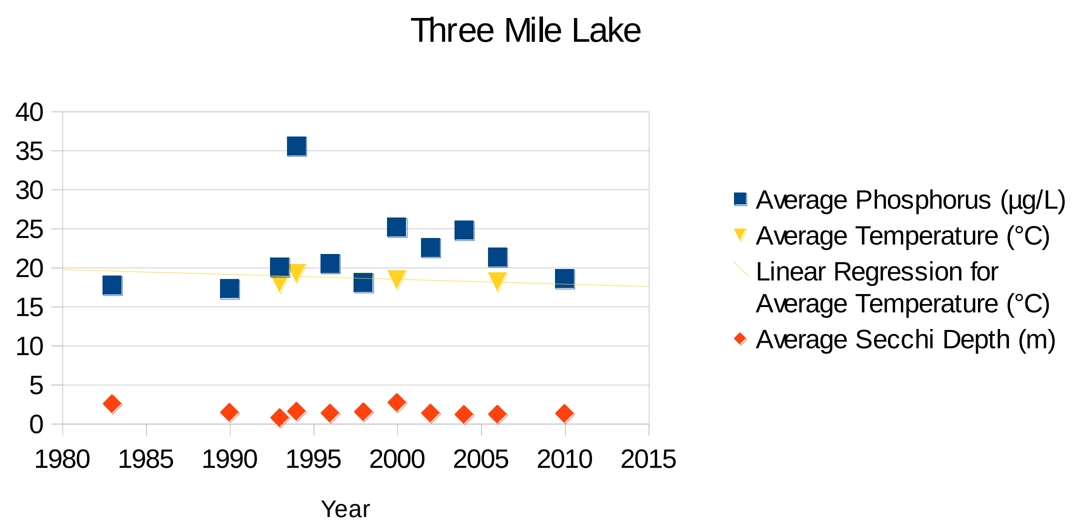
In general fish depth preference in the water is about 3 – 12 metres in depth (Casselman and Lewis 1996, Kerr et al. 1997). There may be some fish that prefer deeper depths however this is a general range for the fish discussed in this paper. There are several species of fish in Ontario that are preferred by anglers, these are: Walleye, Northern Pike, Bass (general), Yellow Perch and Crappie (Fish and Wildlife Branch 2005). If there is a correlation between fishing and waterfront property values; lakes with these types of fish would be more desirable which could potentially increase the average property values.

The analysis concerning water clarity attempts to determine a relationship between temperature, secchi depth and phosphorus to see the possible future impacts on lake values by climate change (Figure 1). It also attempts to determine a relationship between secchi depth and phosphorus to see if secchi depth decreases are majorly caused by phosphorus, in determine proper lake management strategies for the future (Figure 2). Data was provided for Skeleton Lake, Little Long Lake, Three Mile Lake, Mainhood Lake, Lake Joseph and Ada Lake including: secchi depth (meters), phosphorus levels (µg/L), and temperature (°C) at different depths between May and August. Availability of years for data varies by lake, and data years available for either phosphorus, temperature, **or** secchi depth but not all three were omitted from analysis. In some cases data was provided for several areas within a lake, for example Lake Joseph has the Main lake, Joseph River and North. For these lakes, data was only analyzed for "Main" for consistency. Average secchi depth and average phosphorus concentrations were calculated as the mean of all the data present within each year. Average Temperature was calculated as the mean of all temperature data at a depth of three meters for all collection periods in a year. This number was chosen because it is within the threshold of secchi depths among all the lakes, it is also small enough to be effected by major temperature changes. Several collection periods did not include data for three meters; data for two meters was used in replacement.

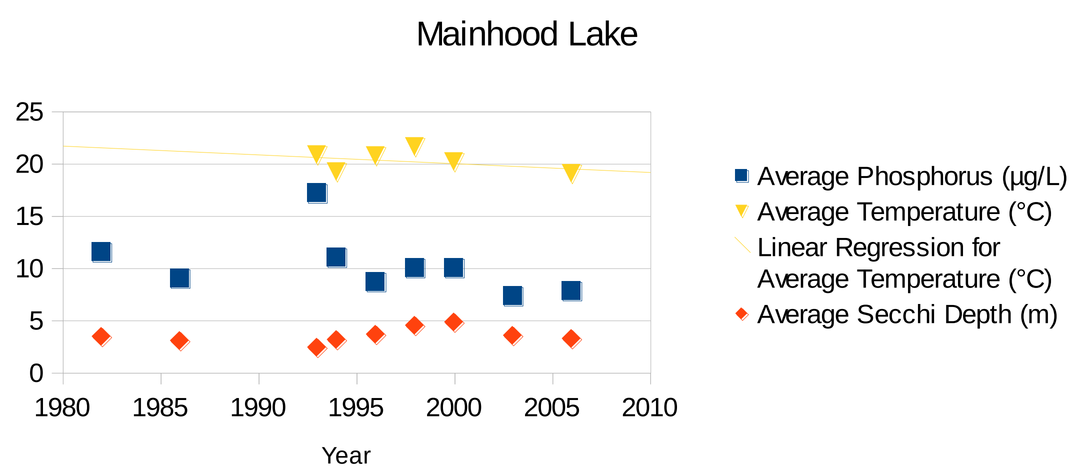
Figure 1. Effects of Temperature on Secchi Depth and Phosphorus in Study Lakes.


Skeleton Lake
25
20
15
10
5
0
1985
1990
1995
2000
2005
2010
2015
Year
Average Phosphorus (µg/L)
Average Temperature (°C)
Linear Regression for Average Temperature (°C)
Average Secchi Depth (m)

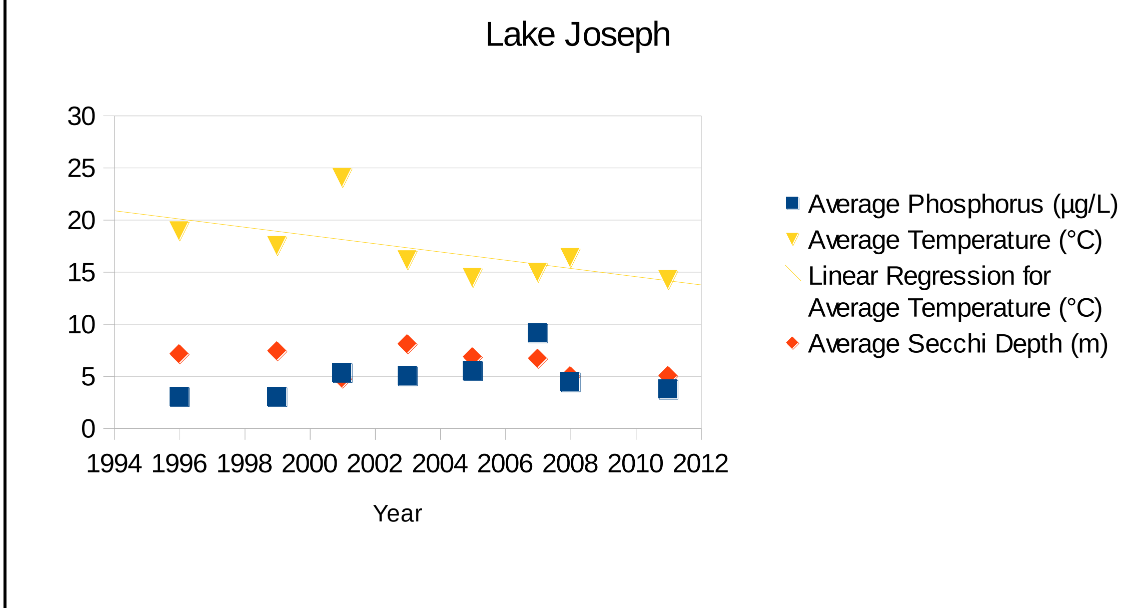

Little Long Lake
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015
Year
Average Phosphorus (µg/L)
Average Temperature (°C)
Linear Regression for Average Temperature (°C)
Average Secchi Depth (m)



Three Mile Lake
40
35
30
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015
Year
Average Phosphorus (µg/L)
Average Temperature (°C)
Linear Regression for Average Temperature (°C)
Average Secchi Depth (m)



Mainhood Lake
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
Year
Average Phosphorus (µg/L)
Average Temperature (°C)
Linear Regression for Average Temperature (°C)
Average Secchi Depth (m)


Lake Joseph
30
25
20
15
10
5
0
1994 1996 1998 2000 2002 2004 2006 2008 2010 2012
Year
Average Phosphorus (µg/L)
Average Temperature (°C)
Linear Regression for Average Temperature (°C)
Average Secchi Depth (m)

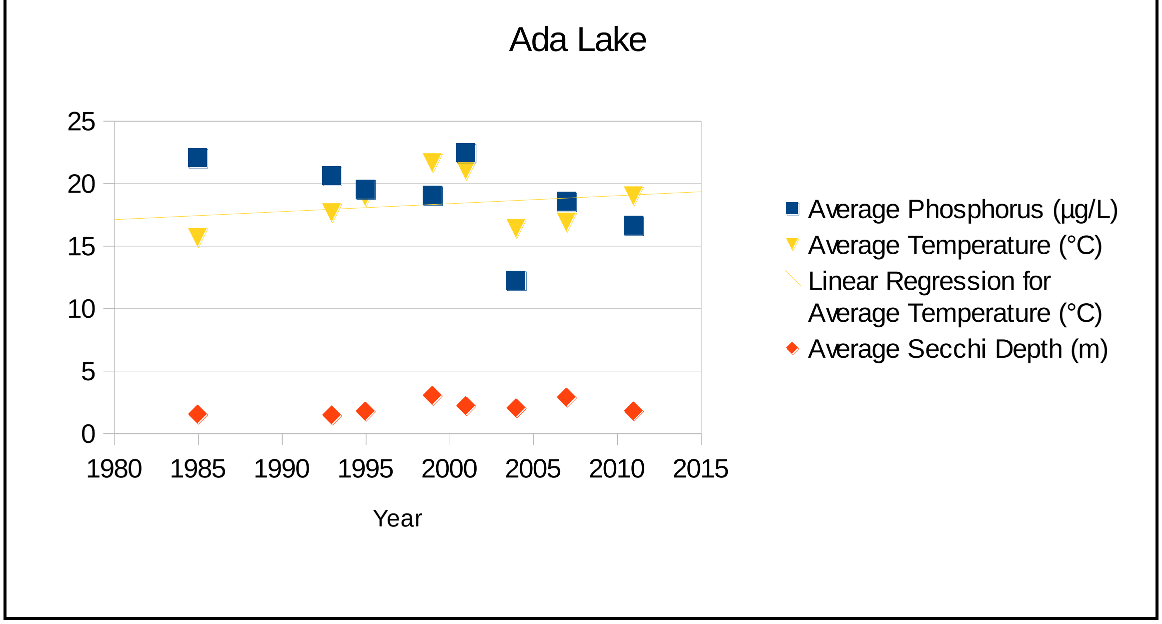
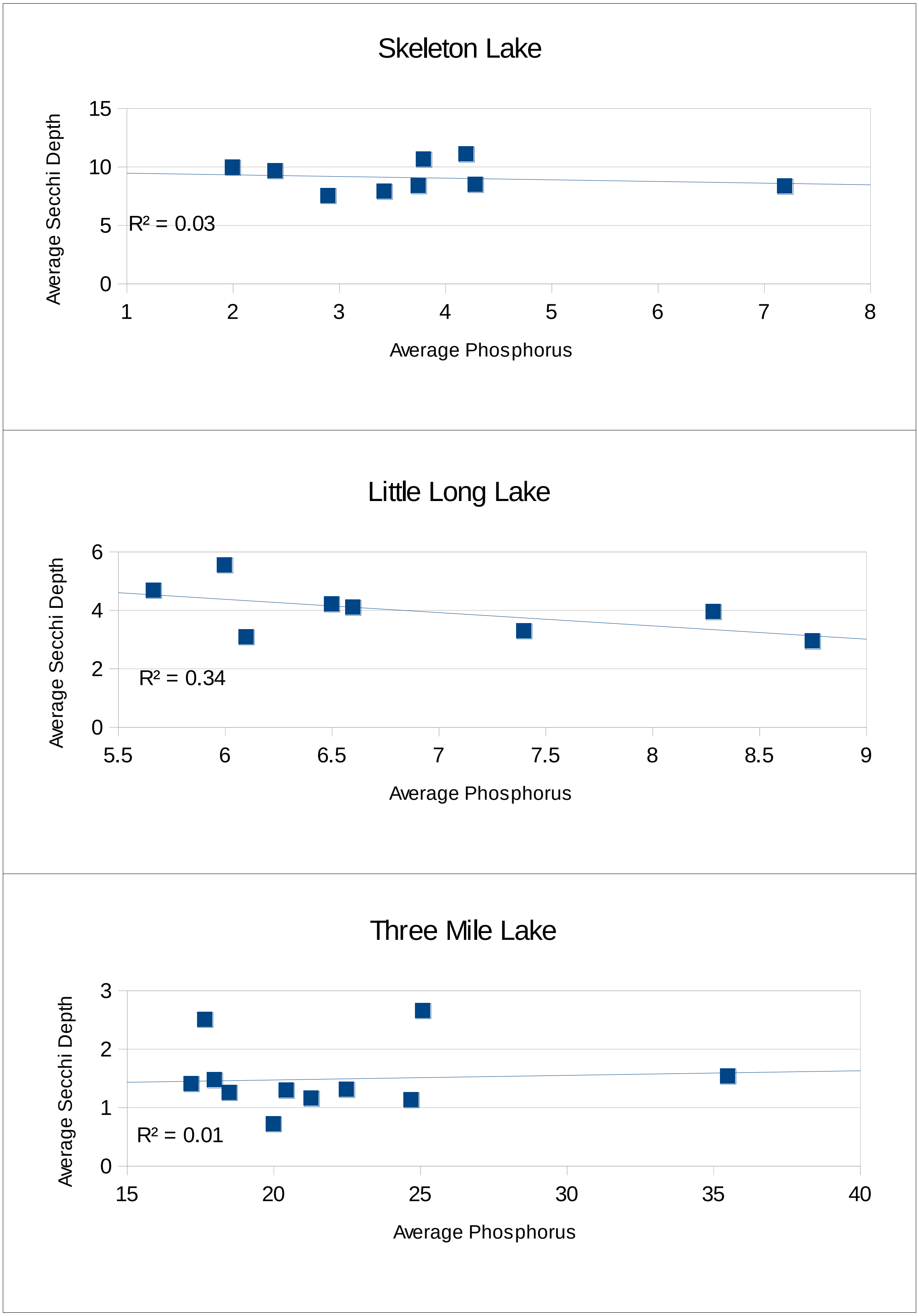
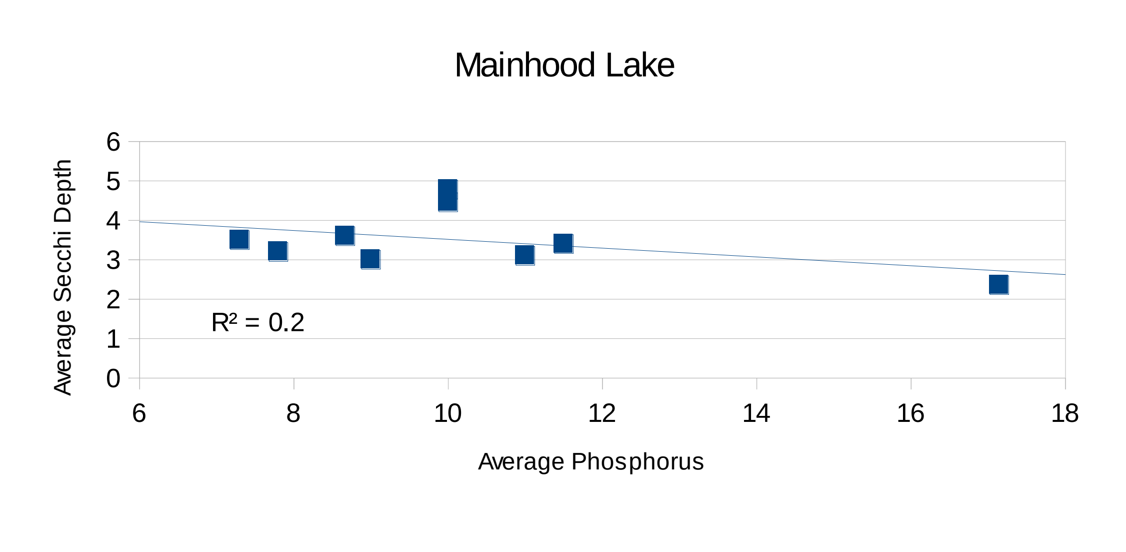
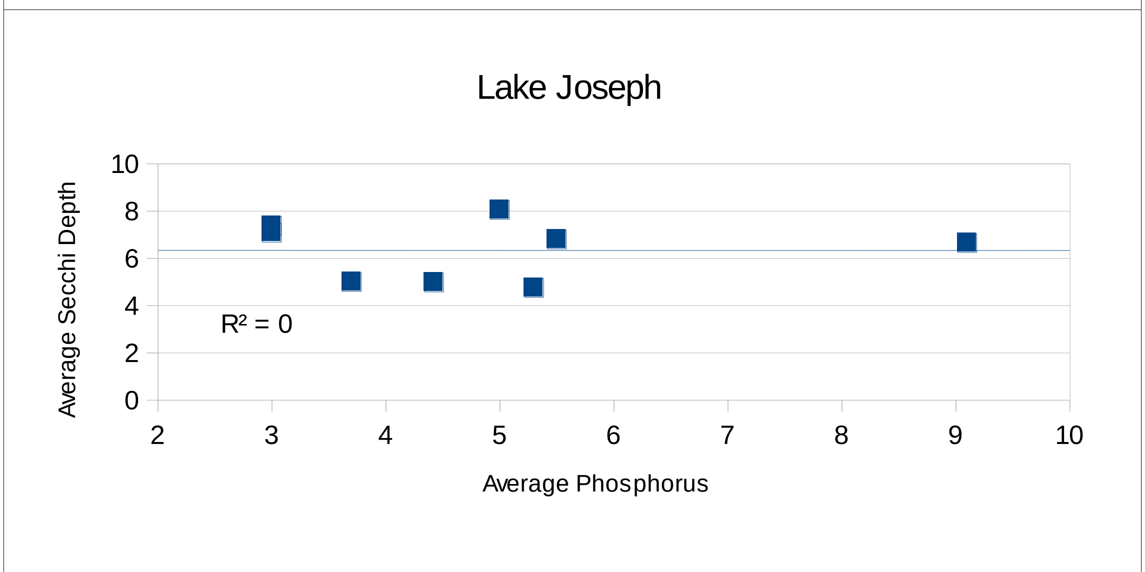
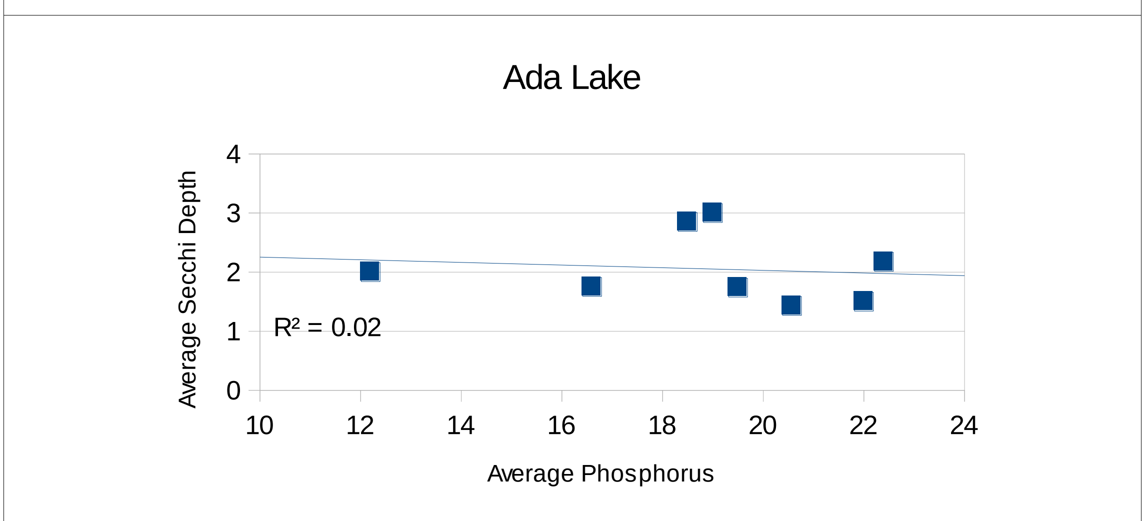

Ada Lake
25
20
15
10
5
0
1980 1985 1990 1995 2000 2005 2010 2015
Year
Average Phosphorus (µg/L)
Average Temperature (°C)
Linear Regression for Average Temperature (°C)
Average Secchi Depth (m)

Figure 2. Relationship Between Secchi Depth and Phosphorus in Study Lakes




Mainhood Lake
Average Secchi Depth
Average Phosphorus
R² = 0.2
0
1
2
3
4
5
6
6
8
10
12
14
16
18


Lake Joseph
Average Secchi Depth
Average Phosphorus
R² = 0
0
2
4
6
8
10
2
3
4
5
6
7
8
9
10


Ada Lake
Average Secchi Depth
Average Phosphorus
R² = 0.02
0
1
2
3
4
10
12
14
16
18
20
22
24

Under the Ontario's Safe Drinking Water's act there are a number of parameters which must be met in order for it to be considered safe for human consumption. On going assessments ensure that water is free of disease causing contaminants, toxic chemicals and radioactive substances (Ministry, 2006). Water must be aesthetically acceptable maintaining desirable taste, odour, colour, and clarity. Standards set into place for each parameter being examined includes maximum acceptable concentration (MAC) of potential contaminants, interim maximum acceptable concentration (IMAC) of potentially harmful contaminants, aesthetic objectives (AO) for taste, colour, and odour of water, and lastly operational guidelines (OG) outlining proper control of each parameter ("Ministry", 2006). Chemical composition, and microbiological characteristics contribute to the physical characteristics of water. Ontario drinking water standards require that water maintains not only a certain taste and smell, but is also a desirable colour, clarity, and temperature ("Ministry", 2006). Failure to meet physical characteristic guidelines may not be a threat to human health, but result may be considered undesirable to the consumer, which is very important in the assessment process. Before water is considered safe for consumption it must first undergo a number of treatments, and tests. Water quality parameters assessed are microbiological, chemical, physical characteristics, radioactivity, and aesthetics ("Ministry", 2006).

The microbiological characteristics of water is important for the assessment of harmful protozoa and virus carrying organisms which may lead to waterborne illnesses ("Ministry", 2006). Other microbiological organisms which may not be harmful to human health, can hinder the aesthetic quality of water, making it undesirable to the consumer. Examples include discolouration, turbidity, and distastefulness caused by iron bacteria (“Ministry”, 2006). A second example is corrosive sulfate reducing bacteria, resulting in foul taste and smell. Undesirable microbiological organisms may be controlled by reducing nutrients in the water, and proper maintenance and use of cleansing system (“Ministry”, 2006).

Chemical composition of the water is another parameter which is assessed in order to determine if water is safe for human consumption. Certain chemicals, and heavy metals are potentially toxic, and it is therefore important that they do not exceed the maximum acceptable concentration. Organic and inorganic chemicals are commonly present in untreated water naturally, but also as a result of human related activities such as agricultural practices.

A final variable which is assessed before water to determine the potability of water is ensuring that water is free of radioactive nucleotides. Nucleotides occur in the water naturally, but higher concentrations are often the result of human activities such as mining and nuclear energy use (“Ministry”, 2006). When radioactive particles are present, water must be treated until concentration is as low as reasonably achievable, as complete elimination is difficult (“Ministry”, 2006).

In order to assure that microbiological, chemical and radionuclide standards are met a number of procedures have been set into place. There are a number of steps used in the water treatment process. First water is filtered and large particles within the water are settled in a quiescent tank. Further filtration is then done, often through a sand bed containing activated carbon to ensure it is done to its fullest potential. While filtration is effective in eliminating a number of potentially harmful, or undesirable elements, it only provide limited protection against waterborne pathogens (vanLoon and Duffy, 2011). To ensure the water is free of pathogens the water must then be disinfected. Water disinfection takes place by one of four possible methods; UV irritation, ozone treatments, chlorine, or chlorine dioxide based treatments (vanLoon and Duffy, 2011). UV irritation, ozone, and chlorine dioxide treatments are rarely used to treat drinking water, the one most commonly used is the chlorine treatment. In the chlorine treatment method Cl_2 is not used on its own, instead it is hydrochloride acid which is an effective disinfectant used to ensure water sanitation (vanLoon and Duffy, 2011).

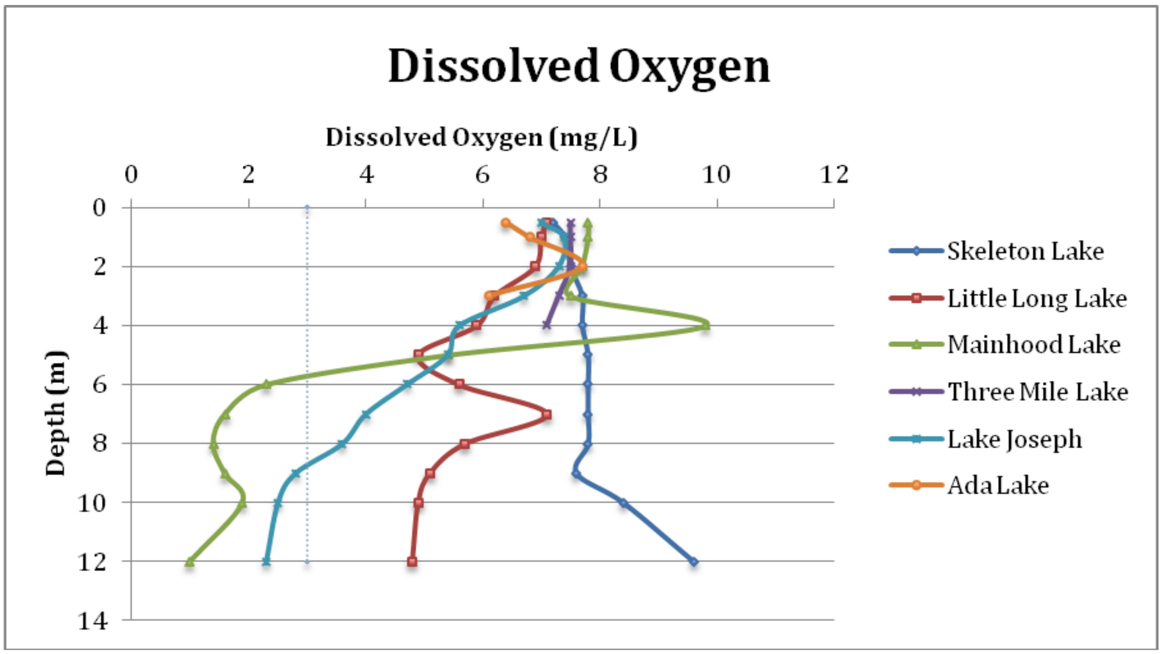
Water treatment plants located in the Muskoka region all use the Chorine method to treat drinking water. Ontario drinking water regulation reports for each of Muskoka's water treatment plants are available on the The District of Muskoka's website. Regulation reports are updated annually, and any equipment changes, or problems with the values are reported. Each report indicates that all standards have been met at this time, and should therefore have no impact on real estate values within each of the sub-watersheds.

Typical minimum values of DO concentration for the preferred fish is about 3 mg/L (Casselman and Lewis 1996, Kerr et al. 1997, Kramer 1987). This is a minimum for fish living in the water, mortality rates quickly increase as that value decreases (EPA 1986). Most fish larvae however need to be in water with DO concentrations over 5 mg/L (Kramer 1987) in order to survive and grow. This means that lakes with DO concentrations at 5 mg/L and higher will support a stable and healthy fish population.

This data (Figure 3) shows that both Ada Lake and Lake Joseph have DO values less than 3 mg/L starting at 6 and 8 metres respectively. These depths are within the range of typical depths that fish prefer to live in, meaning this would impact the fish population's growth patterns in these lakes. The graph also shows that Little Long Lake and Skeleton Lake both maintain levels of DO in their water that would support larger and stronger fish populations. The values for Ada and Three Mile Lake can only be assumed but it appears Three Mile Lake would support a strong fish population. From this information we know that based on the availability of oxygen in these lakes Skeleton lake, Little Long Lake and possibly Three Mile Lake; are all able to support strong large fish populations.

The temperature of a lake also has an impact on fish species and their growth patterns. There are three classifications for fish concerning their water temperature preference. According to Ontario Ministry of Natural Resources the three classes are: warm (25+ C), cool (18-25 C) and cold (10-18 C). Out of the previously mentioned list of preferred fish by anglers four species prefer cool lake temperatures walleye (23 C), Northern Pike (20 C), Crappie (22-24 C) and Yellow Perch (22 C). Smallmouth Bass and Largemouth Bass prefer warm lakes with temperature preferences of 25 C and 27C respectively. Small and Large mouth Bass are still able to survive in cool lakes, however they will not be able to grow to the same potential as they would have in warmer water.

The six lakes investigated in this report had a range of surface temperature values: Mainhood Lake, Three Mile Lake, Lake Joseph, Ada Lake, Little Long Lake, and Skeleton Lake had surface temperatures of 21.7, 23, 21.1, 25.1, 20.7, and 23 C respectively. This tells us that all of these lakes are cool lakes, Ada lake's temperature falls below 25.1 C at 1 metre of depth. From this data all of the fish that are on the list of preferred species can live in any of these lakes however some lakes will suit some species better than others. Ada Lake would best support Bass having the warmest temperatures of all of these lakes, little long lake would support Northern Pike best due to its cooler temperatures. Based on temperature values (Figure 4) we can see that Mainhood Lake only provides suitable water temperatures for the top preferred species of fish to a depth of about 4 metres. At this depth the fish begin to be affected by the cold water resulting in changes in the fish including slowing their metabolism (Middleton 2003) which would



lead to smaller fish sizes.

Figure 3. Dissolved Oxygen values plotted against depth of water, a line depicting 3 mg/L of DO shows the general lethal level for fish (data ranges from 2010 to 2011 based on available data).

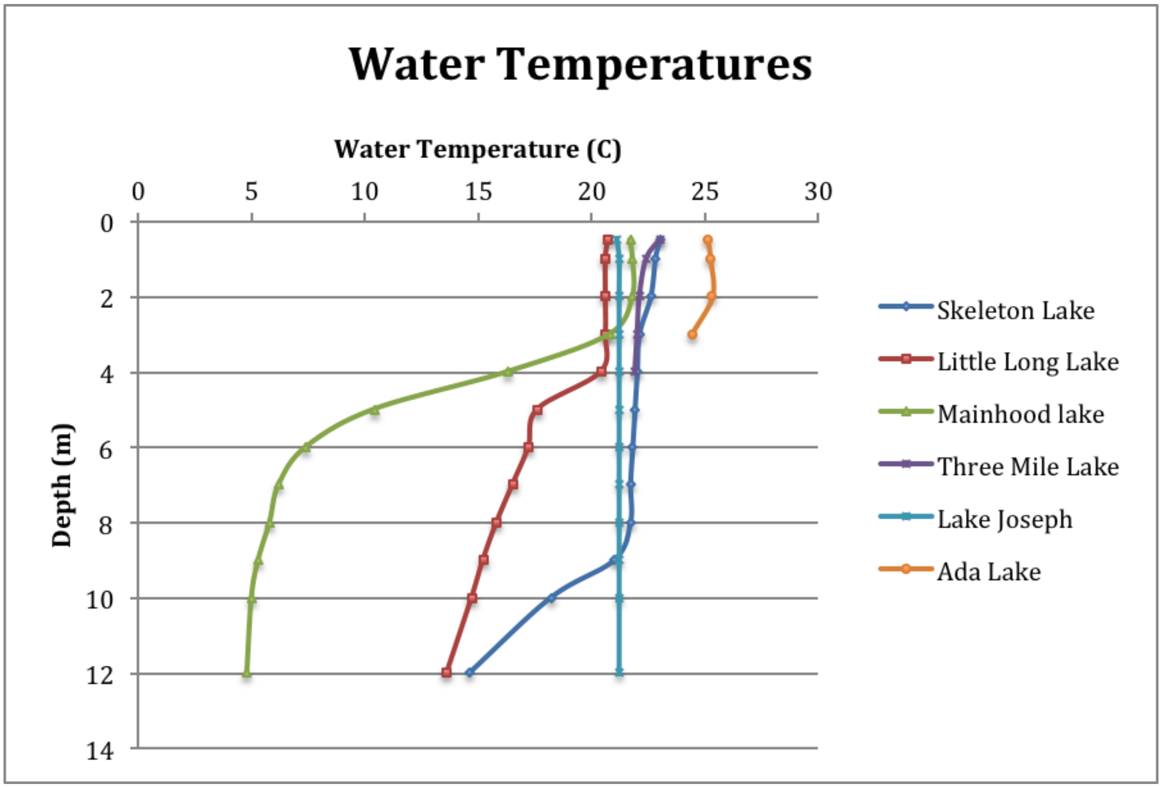


Figure 4. Water temperature profile with depth for the six lakes being investigated (data ranges from 2010 to 2011 based on available data).

From the results displayed on Figure 1, it is assumed that average temperature did not have a significant impact on the productivity of lakes. Other research shows that with warmer temperatures, eutrophication is more likely to occur (Carpenter and Genkai-Kato, 2005). Years with significant spikes in phosphorus should be simultaneous with spikes in temperature. The most notable spike in phosphorus occurred in Three Mile Lake (1994), however average temperature and secchi depth were not significantly different from other years. Three Mile Lake was chosen as a lake for analysis because it has had a history of blue-green algae blooms, most notably in 2005 where the water was declared unsafe for use (Ford, 2006). This should be evident in the lake data, however there may be other factors with greater impact than temperature in Three Mile Lake that are attributing to eutrophication such as the lake depth, size of the lake, or the natural rate of eutrophication. The results of this study may also be inaccurate because omitted data and a short analysis period. Data was omitted because it was not available for temperature, phosphorus and secchi depth, and some omitted could have shown additional spikes in phosphorus caused by temperature. The relatively short data period may give a larger weight to minor outliers because of a limited number of points. A greater trend may be evident given a longer data period with less omitted years.

From looking at the results on Figure 2, it is assumed that all the lakes have weak to no correlation between phosphorus and secchi depth. The strongest correlation occurred in Little Long Lake ($R^2 \approx 0.34$) is still not statistically significant. This suggests that phosphorus loads are not the major contributor to reduced secchi depth in these lakes. There are two reasons for this suggestion: issues with the data, similar to the temperature trends, or sedimentation is the biggest contributor to secchi depth loss. Omitted results and a short data period may cause inaccuracy in trends, which can be fixed by increasing the study period and including data for every year. A second suggestion is that sedimentation is the larger cause of secchi depth changes. Sediment data is not available, therefore this could not be determined within this study.

Literature from previous studies say that water clarity has a significant impact on property values. Due to data limitations, it was not possible to make accurate conclusions of these impacts within the Muskoka Watershed. This study provides evidence that temperature does not directly effect the phosphorus levels or secchi depth, and phosphorus is not the most significant contributor to secchi depth changes, therefore it may be explained by sedimentation or other natural lake characteristics. Future studies need to be done to determine the impacts of sedimentation on water clarity in these lakes. A future hedonic property-value model must be conducted to determine the effects of water clarity on property values in the Muskoka Watershed. There is a possibility that property values will be impacted by other factors such as perceived values and desires of property owners, misconceptions between water clarity and water quality, or travel distance to major cities.

If future studies do prove that water quality effects property values in the Muskoka Watershed and water clarity is a major variable, regulations should be placed to ensure that eutrophication and sedimentation are controlled. Effective prevention planning will be much cheaper than corrective management (Boyer et al, 2003). Bouchard et al (1996) calculated that for three lakes they studied, a 1m improvement in water clarity resulted in a \$34 - \$81 increase in value per waterfront footage, however a 1m degrading price is \$65 - \$141 per waterfront footage. Protecting the lakes in the Muskoka Watershed will keep property values high, stimulate water users and recreational activities, and protecting wildlife populations that rely on them.

Treatments ensuring the potability of water may be done municipally, or by private owners and operators. Failure to meet Ontario water quality standards may be detrimental to the real estate value in effected areas. In Muskoka clean drinking water is available through private water wells, as well through regulated water systems (“Your link”, 2012). Homes which are dependent on well water may be more prone to contamination problems. In well water dependent homes real estate value may decline as extra maintenance is required to ensure it's safety. A further decline may also be evident in housing located close to farms, and industrial settings as these areas may be more prone to contaminants. The real estate value of homes using regulated water systems may be less susceptible to decline as the buyer would have to do less maintenance to ensure water is potable. Property value may also be impacted as a result of the potential that drinking water will become contaminated. Properties located in areas in dense agricultural or industrial settings may experience a change in real estate value do to the heightened probability of the water becoming contaminated by run off. At this time further research will have to be collected to assess how the potability of water impacts real estate value.

The issues caused by anthropogenic sources of degradation that lead to reduced amounts of fish in a lake are: overharvesting, habitat loss, contaminant levels, invasive species, and a change in productivity (Fish and Wildlife Branch 2005). These are anthropogenic influences on a lake that would potentially lead to a decrease in waterfront property values. This is (in part) because of the possible impacts of a lower fish population on the value of waterfront properties.

In summary the temperature of a lakes water and the DO concentration in the water impact the number and average size of the fish present within a lake. Values under 3 mg/L of DO concentration are usually lethal within fish and values over 5 mg/L are optimal for fish growth (Kramer 1987, Kerr et al. 1997). Different species of fish prefer different temperatures of water, this would allow us to see which lakes certain types of fish would be more prevalent in. This cross-referenced with the temperature profiles (Figure 4) show which lakes would have large populations of different species of fish as well as getting a general sense of how large the fish would be. From all of this information it is a safe conclusion that based on DO and temperature values for all six of these lakes Skeleton Lake and possibly Three Mile lake (because of the limited data past 3 metres in depth) would be able to support healthy populations of fish. Lake Joseph sits in-between with DO levels below 3 mg/L at about 9 metres and deeper in depth. This could impact the fish populations but there would still be a large fish population present within the lake. We can also tell that Mainhood Lake has temperatures and DO levels unsuitable for fish growth under about 6 metres in depth.

If a trend is present between suitable conditions for fish growth and property values the lakes would be ordered in descending value as follows: Three Mile Lake, Skeleton Lake, Lake Joseph, Little Long Lake, and finally Mainhood Lake having the lowest average waterfront property values. Ada lake did not have enough data present to fully investigate temperature and DO profiles, no assumptions were made from this data. This interpretation does not match the current average waterfront property values on these lakes. There are a few things we can draw from this; there is either no correlation between property values and water properties preferred by fish or other factors outweigh the quality of fishing when considering the purchase of waterfront property.

Some limitations concerning the development of this report that we encountered have led to a lack of results form our research. To more thoroughly examine this potential influence on waterfront properties, more variables would need to be examined. Some examples of variables to be investigated are: changes in contaminant levels, habitat loss, and the presence of different invasive species. A full data set investigating average waterfront property values and the change in those values over time; would greatly improve the quality of analysis on the impacts of the numerous variables that could be investigated.

This analysis is only able to determine the historical changes in water clarity, in an attempt to determine the cause of these changes. Further analysis to compare this to property values needs real estate values and property characteristics for these lakes. Additionally, a survey needs to be conducted by property owners to understand their knowledge of water clarity before purchasing their property in comparison to their view of water clarity now. This will allow for a subjective analysis of perceived value that drives markets in correlation to a multivariate analysis of objective water quality characteristics. The significance of subjective and objective variables for hedonic property-value models is well documented (Boyer et al, 2003; Boyle, 2001).

Information for suspended particles is needed to determine sedimentation effects in these lakes, GIS maps for a shoreline Universal Soil Loss Equation (USLE) model, and percentage of littoral (shallow water), and water depth. The perceived effects of sedimentation will be greater in shallow shorelines and shallow overall lake depth. Historical information regarding naturally eutrophic lakes is also necessary to be compared to surveys about perceived water clarity when property owners first purchased their properties to determine if these lakes are less impacted by water clarity changes because of an intentional choice to live there. Additionally, phosphorus alone may not give an encompassing insight to trends of eutrophicity or the correlation between eutrophication and secchi depth. Evidence shows that nitrogen and phosphorus together explain most of the nutrient limitation of algal growth in inland waters under natural or human-modified conditions (Lewis et al, 2011).

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