ERSC 3160H – WETLANDS FINAL REPORT

The Importance of Wetlands in Ecosystem Services: with Special Attention on Flood Attenuation, Carbon Sequestration, Hydrogeology, Water Quality, Biodiversity, and Social and Local Values

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Introduction:

A watershed is made up of a combination of different hydrological functions that catch rain and snow to be drained into marshes, streams, rivers, lakes or into groundwater. They vary in sizes of watersheds from a few acres to a large stretch across international borders, they come in many forms, sizes and are a critical part to all ecosystems which they exist in (Watersheds | Muskoka Watershed Council, 2012). They aid in maintaining the natural balances which have established in a given system, many species rely on their processes and seasonal flow changes to sustain life and ensure the proper management of their resources (Watersheds | Muskoka Watershed Council, 2012). A large component in the balancing of watersheds includes the many functions wetlands have to offer. Less than 9% of the Earth's surface is occupied by wetlands, regardless of their seemingly insignificant space, the services they provide are essential for all terrestrial life (Zedler, and Kercher. 2005).

Ecosystem services are the processes which are undergone by natural ecosystems and the elements that make them up to sustain life on Earth (Daily, Gretchen, 1997). These services maintain ecosystem production (of goods) and biodiversity. Their use has been a part of our economy for centuries and will continue to be, as long as we are able to respect and recognize their importance (Daily, Gretchen, 1997). It is difficult to give an approximation to the species which are required to sustain human life. This is because the health of one species, may very well affect several others, which in turn affect others, and so on.

An estimate in a paper published in 1997 (Costanza, et al) proposed that the total value of global ecosystem service to be between 16-54 Trillion dollars US/ year. In theory, their value is infinite when considering we are dependent upon these services to sustain life. The importance of valuing these services lies in their ability to show their worth to persons with authority to preserve them. As of now, the significance of wetlands is largely underappreciated in the eyes of decision makers, making the functions they provide seem minor in relation to other areas of immediate concern. Costanza (1997) mentions the major reasons for conducting these exercises for ecosystems as:

- To make apparent the potential values of ecosystem services
- To establish an approximation of the influences these services have
- Set up a framework for future analysis in areas which require more research

From an economic point of view, an ecosystem service is part of system which can influence directly human wellbeing (Sierszen et al, 2012). However, the final means of considering if a service is of value or not is simply whether it can be placed in monetary values. Determined values are based off of both the supply, demand and the predicted outcomes of a given service and their different management options (Sierszen et al, 2012). Meaning it is easier to put these values in economic terms based off their degradation or loss impacts on humans (Costanza, and Robert, 1997).

Services considered to be valuable which are provided in general on a global scale by ecosystems include: gas regulation; climate regulations; disturbance regulation; water regulation; water supply; erosion control/ sediment retention; soil formation; nutrient cycling; waste treatment; pollination, biological control; habitat; food production; raw materials; genetic resources; recreation; culture (Costanza et al, 1997). The total percentage of these services provided by wetlands is approximately 39.6% as well as indirectly influencing other functions provided throughout a given ecosystem (Zedler and Kercher. 2005). For the preservation of these important factors it is essential to ensure the health of our wetlands.

The destruction and/ or degradation of an intact wetland would most likely result in detrimental effects on its surrounding environment, biota and watershed. Preliminary values based on data collected in 1994 (US) of ecosystem service provided by wetlands are as follows ($/ ha/ year):

Water regulation: 15-30$

Gas regulation: 38-225$

Disturbance regulation: 567-7240$

Flood control and storm buffering :464$

Total global wetlands: 13,165 (billion $/ha/ year)

Total services for all ecosystems for the entire globe: 33, 268 (billion $/ha/year)

(Zedler and Kercher. 2005)

This paper is designed to value wetland ecosystem services in Eco Region 5e (Figure 1). However before this can be adequately evaluated some back ground information is necessary for this eco region. The basic geography of this region is fairly clustered around Georgian Bay, and includes the following major areas: Sault Ste Marie, Sudbury, North Bay, Parry Sound, Algonquin Park, Pembroke, Bancroft, and Manitoulin Island (Chambers et al, 1997). This entire area is predominantly considered the southern part of the Canadian Shield. As such its soil quality is not the greatest, is generally covered in large areas of forested land, and has geology that is generally very tough to break down (Chambers et al, 1997). However due to the constraints of time the majority of the time will be spent looking at the Muskoka Area.

Figure 1: Map of Ontario outlining the area in question; Eco-region 5E in red.

As mentioned in the geographic background this area has very durable (not easily weathered) geology. In the Northwestern part of this region the geology is dominated by: Metasedimentary and metavolcanic rocks, Massive to foliated granodiorite to granite, and Foliated to gneissic tonalite to granodiorite (Chambers et al, 1997). The central part of this region is composed of primarily: Migmatitic rocks and gneisses, with outcroppings of Felsic plutonic rocks, derived gneisses and migmatites (Chambers et al, 1997). The South eastern part of this region is dominated by: metavolcanic and Metasedimentary rocks, and again with outcroppings Felsic plutonic rocks, derived gneisses and migmatites (Chambers et al, 1997). The only significant locations of sedimentary rocks occur on Manatoullin Island, and bordering the eastern and southern part of Pembroke, and Bancroft area (Chambers et al, 1997).

As mentioned earlier the geographic location of this area is generally clustered around Georgian Bay. Due to the fact that wetlands' are highly dominated by hydrology the climate of this area is important. This region generally has cool winters, and warm summers (Chambers et al, 1997). However regional climate in this area is controlled by topography, and proximity to Lake Huron/Georgian Bay (Chambers et al, 1997). Some low elevation areas on the north and east sides of Lake Huron have more moderated climate regime and more growing degree days (Chambers et al, 1997). Generally the minimum temperatures declines as elevation increases and as you move south to north (Chambers et al, 1997). The Algonquin dome also has a higher elevation causing the temperature to be cooler (Chambers et al, 1997). As you travel inland from the north shore of Lake Huron you start to encounter the boreal forest. Along the eastern side of Lake Huron/ Georgian Bay, the windward sides of Algoma, and the Algonquin Highlands there are higher winter temperatures, and zones of increased summer precipitation (Chambers et al, 1997). Due to the fact that the Algonquin dome is elevated it creates a leeward side in the Algonquin highlands as well which receives less precipitation over the course of the year (Chambers et al, 1997). Finally Renfrew County as it borders the Ottawa valley area has the driest climate of the entire region (Chambers et al, 1997).

These crucial services are carried out every day, yet are go virtually unnoticed to the average person. The disruption of these processes could have dire consequences for the human economy and the human race in and of itself. As of now these processes are being threatened, everywhere in the world humans have made some sort of alteration, either chemically, physically or biologically (Daily, Gretchen, 1997). Generally speaking humans do not have the capacity or knowledge to substitute all functions provided by the Earths cycles. Their value has been recognized primarily through their loss or degradation, example would be the observed influence on hydrology of deforestation. It should be recognized that a strong value should not be placed only for human benefit, but also for the impact on the surrounding ecosystem as well. Given the multiple ways of valuing wetlands, exploiting it for one function may result in the loss/degradation of another function consequently compromising our ability to grasp a wetlands true value (Daily, Gretchen, 1997).

These figures are a generalization of all wetlands and not specific to those found in the Muskoka region. More accurate estimates based on relative size and other factors are discussed later in this paper.

Methods:

There are many ways which can provide a general figure for the overall value of service through the cost to replicate it with technology, it should be noted that all services cannot be replaced technologically. The figures presented in this paper are largely based off of other figures which have been estimated through other like studies. Their values were then compared to the average areas of the wetlands found in the Muskoka area. The main paper used to value these wetland services was one developed in co-operation with the MNR for Southern Ontario, which are where we got the values used for the total summation of the value of MacTier and Bala Bog wetland complexes. Once the values for each part were acquired for each of the 6 services individually, they were added together. Now to keep in mind not all wetland services were included in the calculations as they were outside the scope of this project so the final values derived are lower than what they would be had all values been assessed.

Part 1: Wetland Water Purification

The purification of lake and river water is very important as it allows for safe and clean drinking water. There are two main ways that wetlands help to ensure good water quality. Due to the fact that Sudbury is included in this site region (5E), the examination of if and how wetlands can filter heavy metal accumulations will be included as well.

The Sudbury area has been used extensively for mining. Due to this fact there is the potential for heavy metal contamination in water as well. Although wetlands themselves do not really remove heavy metals, however they do tend to store them. One way they store them is in sediment trapping (McNett and Hunt, 2011). Sedimentation rates for wetlands given that no development, and deforestation occur usually are only a few mm/year (Keddy, 2012). Due to the fact that sediments can often contain heavy metals such as: Cu, Zn, Fe, Ni, Cd, Cr, and Pb, sedimentation could be a possible way to store heavy metals for short storage, then removal (McNett & Hunt, 2011). This article then suggested dredging the wetland to remove the heavy metals from the ecosystem (McNett & Hunt, 2011). Although dredging would destroy the ecosystem it would consolidate them and take them out of the environment. The issue of ecosystem destruction could be solved by having a two pond system where one would be set up to be dredged, and a secondary pond which would be left intact to preserve the ecosystem integrity, and allow for faster regrowth of the dredging pond. However there are drawbacks to using natural wetlands to collect toxic metals. The first is that if the toxins are allowed to get to a high level it could kill off the flora and fauna of the wetland (McNett & Hunt, 2011). This has been accounted for during this study in saying that testing could be performed and weighed against tolerable limits, and dredged before those limits are exceeded (McNett & Hunt, 2011). There is also another way that wetlands can store metals. This is by the use of vegetation

(Mickle, 1993). Plants can remove heavy metals from the environment by absorbing them into their systems (Mickle, 1993). Many heavy metals have been found in plant's shoots and include: Cd, Pb, and Hg (Mickle, 1993). Submersed vegetation has also shown to store more heavy metals, than emergent (Mickle, 1993). The only potential problem to this is that when plants die and decompose there is a chance that they can re-release these heavy metals back into the ecosystem for them to become harmful again (Mickle, 1993). However because most of these metals need to be monitored in water quality assessments there is applicable advantages of wetlands to reduce heavy metals, in water as a purification process. Therefore because heavy metals need to be accounted for leaving wetlands intact in this region will help reduce their availability because they can be trapped in wetland sediments or wetland plants. This could be especially useful for the area around Sudbury within this region. Although mining did not occur in the Muskoka area, there is potential for atmospheric deposition from mining in other areas (Dillon et al, 1988). Therefore it is important to account for factors that may contribute to pollution, whether they are point, or non point sources. This is especially if mining or aggregate occurs in or around the Muskoka area in the future.

The two nutrients that cause the most problem and which typically affect water quality are Nitrogen and Phosphorus. Now because this area is located on a relatively poor area for agricultural systems there would be fewer inputs of these nutrients due to farming which makes the water purification slightly less intensive than in areas south of Muskoka. This was outlined by on albeit slightly older source of literature but is still relevant. In this source it outlines how the thin, gravelly soil does not easily lend itself to use for agricultural activities (Whitaker, 1938). However that being said it this area has and if managed properly lends itself extremely well to forestry (Whitaker, 1938). Therefore in the case of Muskoka there is potential for a significantly lower portion of anthropogenic inputs from agricultural activities.

The first nutrient, which wetlands have the potential to reduce, is Nitrogen. Wetlands can filter out excess nitrogen from water by three processes. These processes include: capturing it in plant tissue, storing it in organic sediments, and finally by converting it back into atmospheric nitrogen (Keddy, 2012). Although this region is not heavily used for agriculture, which means nitrogen fertilizer isn't being used as much as in southern Ontario there are other sources of nitrogen. The other main source of nitrogen is from human (industrial, domestic) waste. Which if this area is developed and population increases could create more nitrogen run off. The development of this area can increase nitrogen loading through atmospheric deposition, fertilizer use, and waste water disposal (Valiela et al, 2000). The process by which nitrogen is removed from terrestrial sources and emitted back into the atmosphere is known as denitrification (Keddy, 2012). The simplified analysis of this process is when NO3 is converted by micro-organisms into N2 or N2O and re-emitted back into the atmosphere (Keddy, 2012). However finding a stable rate of denitrification has been a challenge (Keddy, 2012). Some sources have pegged denitrification rates by wetlands ranging from .4 g/m2/year and all the way up to 30 g/m2/year (Keddy, 2012). Due to the fact that these rates were calculated from tropical to temperate wetlands they may be slightly higher than what would be seen for the region of Muskoka because of the climatic difference.

The second nutrient that wetlands tend to have lots of interactions with is phosphorus. Too much phosphorus if emitted into a water body will cause a problem known as eutrophication. Eutrophication can lead to excessive algal blooms, greater prevalence of toxic algal species (e.g. Blue and Green algae), and can cause the lakes to gain productivity until a threshold is surpassed in which case it would lose productivity.

Due to the fact that wetlands have the capability to potentially remove the aforementioned contaminants from the water they are very important. However they need to be examined in a contextual basis, as they are found in the Canadian Shield. Based on studies in the literature, which looked at water purification by wetlands in the Canadian Shield, found some interesting conclusions. One study which looked at waste water treatment and application on wetlands globally had some interesting points (Nichols, 1983). The first is that conventional waste water treatment plants require large capital investments, and consume large amounts of energy (Nichols, 1983). Therefore the use of wetlands to treat waste water as a means of increasing efficiency is under examination (Nichols, 1983). It was found in this study that wetlands do indeed have the potential to remove nutrients from the water (particularly Nitrogen and Phosphorus) (Nichols, 1983). Due to the fact that this study did not specifically examine this relationship in the Boreal wetlands there may be slight episodes of variability. However another study has looked at how wetlands remove nutrients within the Canadian Shield. This study evaluated how much Nitrogen, and phosphorus was retained in wetlands in the Canadian Shield itself. The wetlands that were studied were located in three different watersheds located on the southern perimeter of the Canadian Shield (Devito et al, 1989). The results found were that the wetlands did in fact retain some of the nutrients (Devito et al, 1989). For phosphorus retention among the five wetlands the value ranged from -.03 to .051 g/m2/year (Devito et al, 1989). Meanwhile Nitrogen retention among the five wetlands ranged from -.44 to .56 g/m2/year (Devito et al, 1989). So it has been found even in the Canadian Shield that wetlands do have the potential to retain nutrients as a form of water purification. This study also noted that there were seasonal variations in the nutrient retention (Devito et al, 1989). During the summer more retention of the nutrients occurred meanwhile during the winter more of these nutrients were exported (Devito et al, 1989). However it was found that there was a minor but no significant sink affect of Nitrogen and Phosphorus but that the Nitrogen and Phosphorus was transformed into organic forms that can be used by plants and animals (Devito et al, 1989). Therefore there is a secondary affect of running waste water through wetlands is that the nutrients are converted into organic forms to be used by the wetland plant species. The implications for Muskoka of this are that if waste water treatment plants are located upstream of wetlands there is potential for the wetland to act as a secondary form of treatment. This study also noted that the role of beaver in this cycle also played a significant role (Devito et al, 1989). The role beaver play is a potential avenue of research in the future.

Ecosystem Service Valuation is often a very complex process. One source has outlined to aspects that have an economic value that Pantanal wetlands provide. This study gives a comparison of numbers as a way to gauge how other communities have attempted to value varied wetlands. These two aspects are: Waste treatment and Nutrient Recycling. The waste treatment in this study was valued $1,359,000,000 per year for this wetland (Keddy, 2012). Meanwhile the nutrient recycling aspect of wetlands is valued at 498,000,000 per year (Keddy, 2012). So therefore according to this study wetlands have a strong economic weight for their water purification services in various places around the world, comparison of the wetland values could be used to address the variables for wetland valuation as a way to reduce variability concerning ecosystem services. Another study which was performed summarizes the value of 1 acre of the Charles River Wetland in New England. It was found in this study that for nutrient removal the value of the wetland was $16,960 (Thibodeau and Ostro, 1981). In another study that was performed there was a median value of $288 per hectare that wetlands provided for water purification mainly for Nitrogen and Phosphorus but for other materials as well that can be found from local sources of pollution (Keddy, 2012). However these studies do not analyze the wetlands with a proximity to human development factor. One study that does account for this factor is produced by the MNR which estimates ecosystem services in Southern Ontario. The wetlands in this study are divided into the following classes: Wetlands (Non-Urban, Non-Coastal), Wetlands (Urban/Sub-urban), and finally Wetlands (Great Lakes Coastal) (Troy and Bagstad, 2009). These are defined as follows. Wetlands (Non-Urban, Non-Coastal) include: Wetlands, bogs, marshes, swamps, and fens, excluding those in urban/suburban areas and those considered (Troy and Bagstad, 2009). Wetlands (Urban/Sub-urban) include: Wetlands, bogs, marshes, swamps, and fens in urban/suburban areas, including those considered coastal (Troy and Bagstad, 2009). Finally Wetlands (Great Lakes Coastal) include: Wetlands, bogs, marshes, and fens designated by the client as coastal but not located in urban/suburban areas (Troy and Bagstad, 2009). The water purification values that were calculated from this source are listed in the following table (Troy and Bagstad, 2009). The values were based on a study that attempted to value southern Ontario wetlands.

Table 1: Wetland values by population proximity

Wetland Type	Economic Value per Hectare
Wetlands: Non-urban, non-coastal	$2,779
Wetlands: Urban/suburban	$3,168
Wetlands: Great Lakes coastal	$2,660

Source: (Troy and Bagstad, 2009)

Thanks in part to the Ministry of Natural Resources which provided us with two wetland Evaluations from the area they will be used as sample wetlands to value the ecosystem services. The wetlands are: MacTier Wetland, and the Bala Bog. The MacTier wetland is a complex of wetlands composed of 12 individual wetlands. The Total Size of this wetland complex is approximately: 182.2 ha. However according to the map provided there are a whole host of wetlands west of this complex. This wetland complex falls under the category of a non-urban, non-coastal wetland. In the following table is the water purification value using the MNR's guidelines for Southern Ontario.

Table 2: Water Purification calculation for MacTier Wetland complex

Wetland Name	Wetland Type	Wetland Complex Size	Wetland Value by type.	Total Wetland Value for Water Purification Services
MacTier Wetland Complex	Wetlands: Non-urban, non-coastal	182.2 ha	$2,779/ha	$506333.8

However if one of the other studies is used we see the following results that analyzed economic value of wetlands in Europe found the following price on a per hectare basis (Schuyt and Brander, 2004).

Table 3: Alternative Water Purification calculation for MacTier Wetland complex

Wetland Name	Wetland Complex Size	Wetland Value	Total Wetland Value for Water Purification Services
MacTier Wetland Complex	182.2 ha	$288/ha	$52473.6

So therefore there is some variability in valuing ecosystem services this was addressed in the previous paragraphs by outlining the pollution, and nutrient removal factors that can contaminate sites and by outlining how wetlands can deal with these problems. Site characteristics can also affect how they are valued as well. Lacustrine wetlands may be different from Riverine wetlands due to the different residence time of the water in the wetland.

Now the Bala Bog was also given to us courtesy of the MNR as well. The Bala Bog just like the MacTier Wetland is a wetland complex. In the following table is the valuation of the Bala Bog wetland complex.

Table 4: Water Purification calculation for Bala Bog Wetland complex

Wetland Name	Wetland Type	Wetland Size	Wetland Value by type.	Total Wetland Value for Water Purification Services
Bala Bog Wetland Complex	Wetlands: Non-urban, non-coastal	191.7 ha	$2,779/ha	$532734.3

When the Bala Bog wetland complex is evaluated using the other source again the economic value is lower (Schuyt and Brander, 2004).

Table 5: Alternative Water Purification calculation for MacTier Wetland complex

Wetland Name	Wetland Complex Size	Wetland Value	Total Wetland Value for Water Purification Services
MacTier Wetland Complex	191.7 ha	$288/ha	$55209.6

Therefore because wetland valuing systems are different it is possible to have different economic values for wetlands. The Value of ecosystem services also depends on what perspective you’re looking at it as well. For example if a wetland was located on a piece of land that was on the market, the wetland would be harder to develop decreasing the value of the land.

However if you're looking at how much safe and clean drinking water it provides to a community then it's value is much higher.

Part 2: Hydrogeologic Functions and Wetland Ecosystem Services

As mentioned earlier this part of Canada outside of Manatoullin Island this region is composed of majorly slow weathering generally impermeable rock. This does mean that hydrogeologic processes will be different in this area than compared to southern Ontario. The hydrology of the Canadian Shield is fairly simple in that lakes and wetlands act as major sinks of water. Meanwhile the major transportation processes are overland flow, and shallow subsurface flow through the forest soils (Allan et al, 1993). The shallow sub surface flow through forest soils often leads to more acidic waters (Allan et al, 1993).

As outlined in the by the Northern Ontario Evaluation Systems for wetland land evaluation there are 4/5 official aspects that affect the hydrology of wetlands. In this part of the report the three that will be focused on are: the effects on Ground water recharge, Wetland Soils, and ground water discharge. As well there can be other factors like site and soil types that can affect valuation of wetlands as they relate to their hydro geological services.

The first part will examine how wetlands affect ground water recharge. There has not been extensive research of ground water recharge and wetlands. However there are relationship effects that wetlands can have on ground water recharge. The primary relationship according to one study is as follows: water from wetlands has the potential to percolate through the surface and enter aquifers (Turner et al, 2003). This is the major process by which wetlands can affect ground water recharge. However in the Canadian Shield where the rock is generally impermeable and highly preventative of weathering this can pose problems (Chambers et al, 1997). The socio economic benefit to this is that this can provide a water supply as well as recharging limited aquifers in the area (Turner et al, 2003). However there are threats to these processes in that reduced rates of recharge, over pumping of water, and pollution that may further stress the hydrogeologic processes in the area (Turner et al, 2003). Due to the fact that Muskoka is on the southern border Canadian Shield where almost no significant research has been done on wetland hydrogeology there is no way to find out the meat of the information. The best estimating process would be to look at southern wetlands and northern wetlands and to compare the two as they relate to hydrogeology. A whole handful of sources noted that snowmelt, ice, and snow play a prominent role in this process (Spence et al, 2011). However one study was performed in Labrador in the Canadian Shield which can give some insight into northern wetland hydrogeology. Due to the fact that the Canadian Shield is generally composed of low fertile minerals the major types of wetlands that form are peat lands. This includes ombiotrophic bogs which are fed by meteoric (atmosphere related), and mineratrophic fens which receive water from mineral soils (Price et al, 1991). As well in this study to comparative wetlands one of which was a peat land and the other a bog were highly effective at run-off attenuation (Price et al, 1991). The major discharge events occurred when the water table was recharged by rainfall (Price et al, 1991). Due to the fact that the site for this was on the Canadian Shield there are potential similarities to recharge characteristics in the Muskoka area because of the terrestrial characteristics of the shield (Price et al, 1991). However compared to sub arctic wetlands stream flow losses are extremely low, partially due to the fact that the bog within the peatland had a high storage capacity which retained more water and led to more evaporation (Price et al, 1991). Therefore Ground water recharge is very important. Swamps and Marshes tend to moderate water levels acting as storage sites. However the interaction with the aquifers in the Canadian Shield needs far more research.

Soils also play a very important role in how groundwater and surface water interact. The pore space can affect storage of water, infiltration. The soils can act as filters aiding with cation exchange capacity. The basic soil types found and displayed in Figure 2 around our study area include: 33, 8, 69, 25, 30, 2, 72, 71, and 26 (Hoffman et al, 1964). Soil type 33 is Guelph Haldiman which is a grey brown podzol (Hoffman et al, 1964). Soil type 8 is Tioga Berrien which is also a grey brown podzol (Hoffman et al, 1964). Soil type 69 is Farmington which is a brown forest soil (Hoffman et al, 1964). Soil type 25 is Osprey Farmington which is a brown forest soil as well (Hoffman et al, 1964). Next is soil type 30 which is Vasey which is a grey brown podzol as well (Hoffman et al, 1964). Soil type 2 is Tioga Vasey which is a grey brown podzol as well (Hoffman et al, 1964). The next two types 71 (Rock Wendigo which is a podzol) and 72 (Rock Monteagle which is a podzol as well) dominate most of the soil landscape of the Muskoka area (Hoffman et al, 1964). Next is soil type 26 which is Monteagle rock which is a podzol (Hoffman et al, 1964). Therefore most of the soil in this area dominantly coarse textured soils with Precambrian rock at 1 foot depth or less (Hoffman et al, 1964). Therefore the soil is not typically great in this area. All soil forming procedures somehow involve water (Richardson et al, 2001). Groundwater recharge typically removes materials in the water (Richardson et al, 2001). Meanwhile groundwater discharge adds materials from the water (Richardson et al, 2001). The four major processes that perform this are soil formation, are as follows: additions, deletions, transformations, and translocations (Richardson et al, 2001). Additions and deletions are mentioned above (Richardson et al, 2001). Transformations consist of aspects that are weathered down in order create soils, and translocation refers to the moving of soil from one area to the other (Richardson et al, 2001). Therefore wetlands have many avenues by which they can produce soils. This is especially important as the soils in the Canadian Shield are not great. As well the bedrock parent material is not of the greatest quality to make soil because of its relative lack of weathering ability (Chambers et al, 1997). Peat is also found to be fairly prevalent in bogs, and fens. Peat is defined as soils with various amounts of undecomposed plant materials (Collins and Kuehl, 2001). There are various factors that affect the formation of peat. These factors include: landscape position (which affects how much rainfall, the amount of runoff produces and soil moisture retention), hydrology (which is affected by groundwater, and landforms), and plant types (which is affected by carbon nitrogen ratio, lignin content, tannins, and humified materials) (Collins and Kuehl, 2001). The major benefit peat offers in terms of hydrogeologic affects is that it acts as a storage medium for water (Collins and Kuehl, 2001). However this can be applicable for most wetlands (Collins and Kuehl, 2001). Therefore wetlands can function as weathering agents which is helpful for the Canadian Shield as well as forming peat which has an indirect affect on water level controls. In marshes there is often rapid decomposition, and a poor ground layer often prevents peat from being developed (Zoltai and Vitt, 1995). Swamps are similar to marshes except in the fact the fluctuation of the water can allow for trees and shrubs to develop (Zoltai and Vitt, 1995). Most wetlands in general have poorly draining soils (Zoltai and Vitt, 1995). Often marshes and swamps act as sinks to hold surface water. However peat does have significant economic opportunities which in order to look at both sides needs to be examined. Peat is a relatively slow forming commodity forming at a rate of 5mm per year. Therefore it is hard to replace peat. However peat has been used in the past as a form of heat (Hinrichsen, 1981). On top of its heating capabilities it has also been used for its horticultural capabilities (Hinrichsen, 1981). In 1980 it was found that combining these uses for most of the major countries excluding Canada, 220,000,000 tonnes of peat were used (Hinrichsen, 1981). Therefore peat does provide an economic value which should be weighed as a potential to value the wetlands in the future.

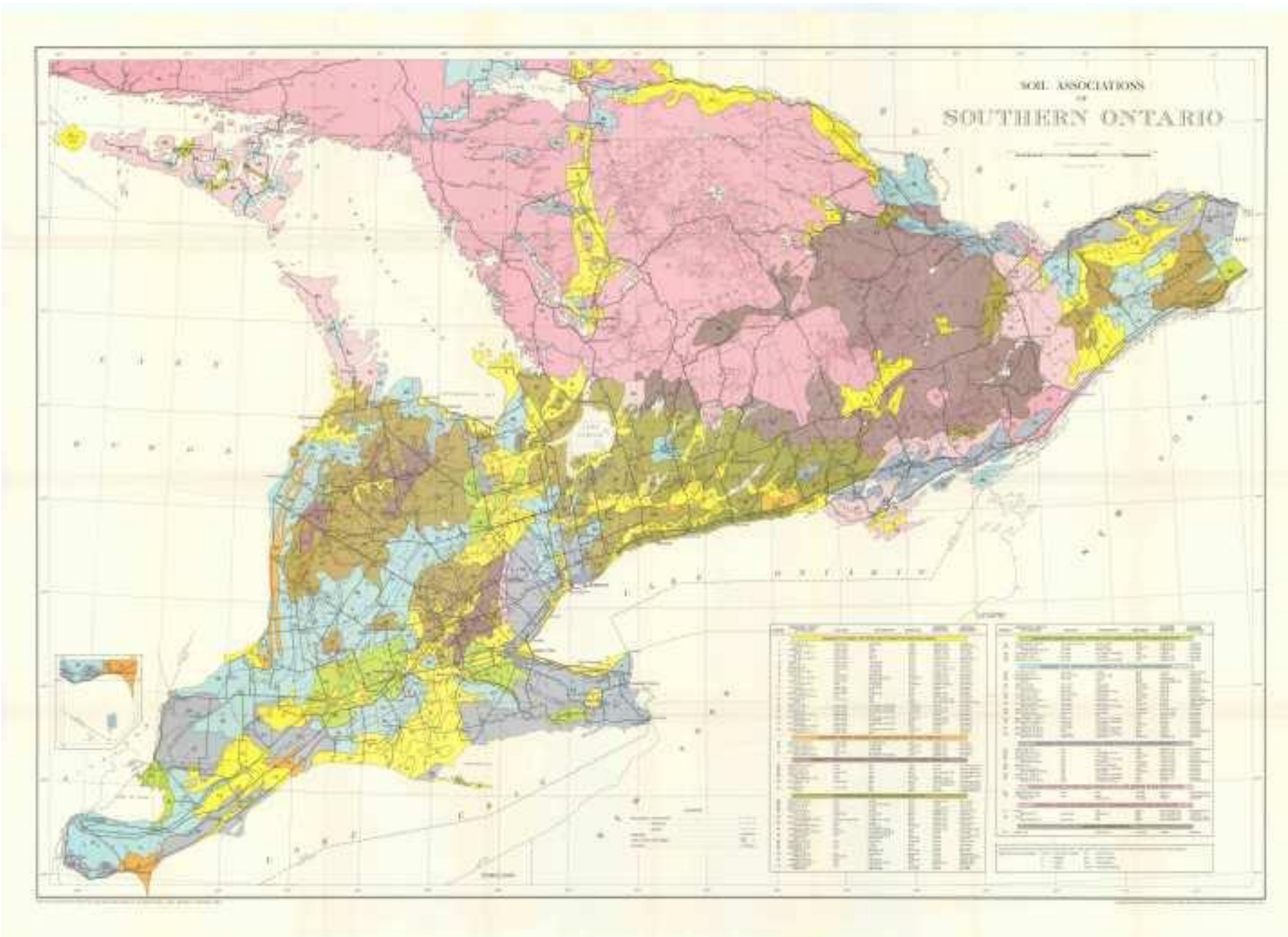

Figure 2: Soil associations of southern Ontario (Hoffman et al, 1964)

Discharge as it relates to wetlands is also very important. This is because if you have a wetland in a watershed and it doesn't discharge anything there will be problems especially if it's a recent change. First of all it is important to note how wetlands discharge water. The discharge can occur in a few different ways. It can occur as evaporation. However the more important ways are that wetlands often discharge tier water into streams lakes, groundwater or through subsurface flow. Discharge can often be highly dependent on water regimes for wetlands. Bogs, Fens, and swamps are often permanently water logged (Keddy, 2012). Marshes on the other hand have a water regime of permanent shallow water bodies (Keddy, 2012). Due to the fact that fens are typically fed by groundwater this could be used as a potential sign to determine aquifer interaction between fens. One way to determine if the potential relationship exists is to examine the chemistry or the water (Wassen and Barendregt, 1992). Certain concentrations of Ca2+, Mg2+, and HC03- can help to determine whether groundwater has been in an unconfined sandy aquifer (Wassen and Barendregt, 1992). However this can only be applied to areas with homogenous sandy unconfined aquifers (Wassen and Barendregt, 1992). The implications are that if wetlands can be mapped based on interaction with aquifers (Wassen and Barendregt, 1992). Ground water can also seep up into wetlands (Turner et al, 2003). This can provide significant benefits such as effluent dilution (Turner et al, 2003). However there are threats facing ground water discharge such as poor drainage or the infilling of wetlands (Turner et al, 2003). Water movement patterns of wetlands are also very important for discharge. The water movement in tidal wetlands is typically horizontal (Black, 1991). For Lacustrine wetlands it's a balance between horizontal and vertical movement (Black, 1991). For riverine wetlands its typically there is horizontal movement and to a greater extent vertical movement (Black, 1991). For upland wetlands the movement is predominantly vertical with minor horizontal movement (Black, 1991). For bogs and fens the movement is all vertical (Black, 1991) l. Inundation also an important part in discharge of wetlands due to the fact that if wetlands are greater inundated they will have potentially more water to discharge. Tidal wetlands typically follow a cycle of extreme highs and lows that cycle twice each day (Black, 1991). This is important because to effectively value discharge potential, inputs need to be examined as well, along with the natural fluxuation of water levels Lacustrine have relatively low inundation fluctuations compared to tidal wetlands and is highly irregular and intertwined with external forces (Black, 1991). Riverine wetlands typically have peaks followed and preceded by normal inundation this is often due to rainfall events and is typically irregular (Black, 1991). Upland wetlands follow the same inundation pattern as Lacustrine wetlands however the high and low values are relatively smaller than those seen in Lacustrine wetlands which is often driven seasonally and irregular (Black, 1991). Riverine vs. Lacustrine wetlands is also a relationship that needs to be examined. Due to the fact that riverine wetlands are driven by pulses (rainfall, and snowmelt) they will cycle the water faster (Black, 1991). This means that the water will move faster through the system which will leave less time to interact with the wetlands, and in some cases can lead to erosion. Lacustrine wetlands on the other hand have less frequent cycling (Black, 1991). This means that the water levels will be rather constant. Typically lakes hold more water and hold a greater amount of water than rivers (Christopherson and Byrne, 2009). However rivers cycle the water faster (Christopherson and Byrne, 2009). Bogs and Fens have a relatively solid/ steady state level of inundation with minor increases throughout the year and is often driven annually (Black, 1991).

Aquifers will also play a role in the hydrogeologic functions and their relation to wetlands. There are two major types of aquifers confined and unconfined aquifers. Confined aquifers are usually covered on the top and bottom by generally impermeable layers. Meanwhile unconfined aquifers are only covered on the bottom by impermeable layers. In the Canadian Shield the aquifers are often extremely local due to the fact that there are varying levels of glacial till over impermeable rock (Devito et al, 1996). Therefore groundwater sources are considered insignificant to wetlands in this area (Devito et al, 1996). One study which examined three swamps in the Canadian Shield found that seasonal variability, connection to upland sites, slope, and depth of peat/mineral soil are the major contributors to groundwater movement in the Canadian Shield as the aquifers generally do not contribute to wetland hydrology (Devito et al, 1996). As a result rather than focusing on aquifers in the Canadian shield time could be used more effectively cultivating soil/ and peat depth as a way to improve hydrogeologic functions in the Canadian shield (Devito et al, 1996). It was also found that flow through the top 50cm of peat is often greater than in the lower peat depths (Devito et al, 1996). Connection to upland sites is a very important aspect when talking about wetlands in the Canadian shield as control of drawdown can have devastating effects on wetlands in this area during the dryer seasons (summer to fall and parts of winter) (Devito et al, 1996). The end result of this study found that an increase in glacial till from 1m to 1-3m has a great affect on increasing water connectedness during the dry periods (Devito et al, 1996). Therefore examining the geology may prove a better method to determine aquifer relationships than looking at the wetlands themselves (Devito et al, 1996). However the wetlands provide significant beneficial effects to increase soil/ and peat land depth which allow for better hydrologically balanced cycling.

Valuing the hydro/geologic services does have its associated problems. This is because the OMNR has not found a value that pertains to hydro/geologic services. Therefore more studies need to be undertaken at first to value the wetlands for this aspect in Southern Ontario so that down the road they can be evaluated in Northern and Central Ontario.

Table 6: Hydrogeological aspects calculation for MacTier Wetland complex

Wetland Name	Wetland Type	Wetland Complex Size	Wetland Value by type.	Total Wetland Value for Hydrogeological Services
MacTier Wetland Complex	Wetlands: Non-urban, non-coastal	182.2 ha	Remains Unknown	Unknown

However if one of the other studies is used we see the following results for water supply can obtain a dollar value (Schuyt and Brander, 2004).

Table 7: Alternative Hydrogeological aspects calculation for MacTier Wetland complex

Wetland Name	Wetland Complex Size	Wetland Value	Total Wetland Value for Water Purification Services
MacTier Wetland Complex	182.2 ha	$45/ha	$8199

Now the Bala Bog was also given to us courtesy of the MNR as well. The Bala Bog just like the MacTier Wetland is a wetland complex. In the following table is the valuation of the Bala Bog wetland complex. The reason that there is a value for the water supply for this wetland is that it is closer to a populated area than MacTier wetland complex.

Table 8: Hydrogeological aspects calculation for Bala Bog Wetland complex

Wetland Name	Wetland Type	Wetland Size	Wetland Value by type.	Total Wetland Value for Water Purification Services
Bala Bog Wetland Complex	Wetlands: Urban, Sub-urban	191.7 ha	$48,929/ha	$963901.3

When the Bala Bog wetland complex is evaluated using the other source again the economic value is lower (Schuyt and Brander, 2004).

Table 9: Alternative Hydrogeological aspects calculation for MacTier Wetland complex

Wetland Name	Wetland Complex Size	Wetland Value	Total Wetland Value for Water Purification Services
MacTier Wetland Complex	191.7 ha	$45/ha	$8626.5

However no studies have been completed on estimating the values of soil formation. This in the Canadian Shield is an extremely important process

Carbon sequestration:

The sequestration of Carbon dioxide (CO_2) is one of the world's primary concerns on the topic of Climate change mitigation. It's importance is underlined in the emission cost of modern day civilisation, including; land use changes, deforestation, biomass burning, drainage of wetlands, soil cultivation and fossil fuel combustion (Lal, 2008). Unfortunately these actions continue to be undertaken on a daily basis with virtually no end in sight, indicating the urgency for carbon sinks and the maintenance of carbon storages, such as those found in the Muskoka. Fluxes of soil carbon resulting from oxidization due to the degradation and loss of wetlands may also have negative consequences for other dependant components of the ecosystem (Bridgham, et al, 2006). There has been an observed increase in CO_2 concentrations in the atmosphere between 1850 and 2005 of 31%. The current concentration level is increasing at rate of 0.46% per year (Lal, 2008).

Large amounts of carbon sequestration of wetlands can be found in the soils—such as peat (Bridgham, et al, 2006) -- and biota of wetland plants, without which the carbon would be released to the atmosphere. Wetland soils have the capacity to hold up to 200 times more carbon than the surrounding vegetation (Lal, 2008). Peatlands occupy just 3% of global terrestrial land; however they contain 16-33% of the global soil carbon pool. Although the storage capacity of peat lands is extremely large their accumulation could take thousands of years for a significant amount of carbon to be stored (Bridgham, et al, 2006). For this reason, it is understood that proper wetland management and protection is a key aspect to ensuring an appropriate balance of atmospheric to sequestered carbon. Unfortunately, sufficient data on wetland types, sizes and depths of wetlands were unavailable for the Muskoka region. The importance of converting this environmental worth to that of an economic stand point lies in the government's ability to recognize their influence on the lives of everyday society. The values are generally calculated through the comparison of a wetlands functional replacement.

A study conducted in 2004 (Belyea, and Malmer) recorded effects of two carbon sequestration parameters over 5000 years. 1) Changes in climate wetness on peatlands 2) and a model reconstruction of bog height to examine changes in peatland hydrology. Both showed effects relating the surface structure to peatland response to changes in peatland hydrology. Effects being: 1) increases of carbon sequestration associated with vegetative shifts 2) and a gradual decrease of carbon sequestration associated with increased humification of newly formed peat. These responses signify the importance of maintaining the hydrological integrity related to peatlands in the Muskoka area. Vegetation transitions were observed with periods of increased wetness, this resulted in an increase in peat formation. Periods of dryness showed reduced peat formation and a gradual decrease carbon sequestration. Rates of C sequestration and CH_4 emissions are dependent upon the height of the peatland surface above the water table. An increase in surface wetness has been linked to decreases in C accumulation, most likely due to a reduction in vegetations ability to persist under wetter conditions (Belyea and Malmer, 2004). A thorough understanding in the hydrology and ecology of peatlands are crucial for the prediction of peatlands response to changes in the global carbon cycle due to climate change and other inputs. It is generally understood that Carbon is sequestered in peatlands as long as formation of new peat is greater than the rates of decay of previously accumulated peat (Belyea and Malmer, 2004). Litter decomposes most rapidly on thin surface layer (0.5m) that is only seasonally saturated.

Bala bog wetland complex (totalling in 191.7 ha), in Muskoka was observed as having 98% permanent flow site type (Canada. Beacon Environmental, 1993) and received 9/15 points ("Marsh and swamp with >50% organic soil") under "Carbon Sink" in the *Ontario Wetland Evaluation System*. With a general estimation of atmospheric regulation being at 14$ US/ha/ year (Canada. Ministry of Natural Resources. 2009 and Arriaga et al, 2000) this wetland complex would be an estimated as being worth 2683.8$ US yearly for "atmospheric regulation" which could also include methane and other emissions. The MacTier wetland complex (totalling in 182.2 ha), also found in Muskoka was observed as having 86% permanent flow site type and also received 9/15 points under the Carbon sink section. Based on the above mentioned parameters for estimating the economic value of atmospheric regulation in wetlands, this wetland complex would theoretically be worth 2550.8$ US yearly. Unfortunately it would be difficult to give a specific economic value for carbon sequestration based on the parameters given in the evaluation. Although these wetlands are considered carbon sinks, it is also important to recognize that they are currently a carbon store, indicating that their degradation or loss would result in an overall loss of soil carbon.

Estuarine and fresh water mineral-soil wetlands have the ability to rapidly sequester soil carbon due to their burial in sediments (Bridgham et al, 2006). Wetlands found in the Muskoka region have been associated with the fresh water system of the Great lakes water shed and would therefore have this ability as well(Watersheds | Muskoka Watershed Council).

On a global scale, wetlands contain the largest terrestrial biological carbon store, containing as much as 535 Gt (giga-tons) of carbon. Wetlands generally are considered to be a small to moderate sink for carbon, of about 49 Tg $yr^{-}1$ (Bridgham et al, 2006). They are also contributors to emissions of CH_4 (methane) contributing about 10% globally (Zedler and Kercher, 2005). CH_4 is formed in soils with anaerobic conditions usually due to extended periods of "waterlogging"; it can occur in managed and natural wetlands and is diffused through both the water and plants which inhabit the area. Depending on conditions, wetlands can also be a significant source of $CO_{2,}$ indicating the importance of proper management. These emissions are largely dependent upon the type of vegetation, vegetation litter quantity as well as the texture and acidity of the soil (Zedler and Kercher, 2005). Generally speaking, the destruction of an intact wetland would release more Carbon than 175-500 years of CH_4 from the same wetland through the decomposition of soil and vegetation. Methane fluxes in peatlands (such as those found in the Muskoka) have been observed as being related to its surrounding temperature as well (Thomas et al, 1996). Changes in water tables also influence reactions which cause methane and carbon gas discharge into the atmosphere. These reactions are indicative of Climate change's impacts on these releases, with its inevitable increase in temperatures and weather fluctuations (Thomas et al, 1996). If the future sequestration of the wetland is factored in, its destruction would lead to the more Carbon emissions than several thousand years of the total GHG's of the same wetland (Zedler and Kercher, 2005). A study conducted of the "global warming potential" of Canadian peatlands (most likely Northern Canada) showed that most peatlands are neither sinks neither sources of GHG's (Greenhouse gases), but do however contain large amounts of Carbon which would otherwise be released into the atmosphere (Zedler and Kercher, 2005). The same can be therefore being assumed for peatlands found in the Muskoka region.

Table 10: Comparing different wetland types with certain aspects pertaining to their Carbon storage and carbon storage abilities in (Bridgham et al, 2006).

Type of wetland	Wetland loss in Canada: based upon estimates with 95% confidence ($x10^3$ km^2)	Carbon pool size in current wetlands in North America: (Tg yr^{-1})	Carbon sequestration in current pools (Tg yr^{-1})	Loss in carbon sequestration capacity (Tg $yr^{-1)}$
Non-permafrost peatlands	714-726	102.9— This is based off of a maximum depth of 1.5-2 m. Unfortunately many peatlands are much deeper than this, meaning that this estimate is not an accurate representation.	Non intact: 13.6 Intact: 40-70	-0.02
Fresh water mineral soil	159-359	4.6	2.7	-3.4
Tidal Marsh	0.44-1.3	0.01	0.09	0.17
Mud flat	6-7	0.10	1.21	0.33
Total	879.44- 1093.3	North America: 220 Pg Global: 529 Pg	44—mostly contained in intact peatlands	-2.92

In Canada there are 1,301,000 km^2 covered by wetlands; 87% of wetlands are peatlands 14% of which has been lost due to agricultural development—draining, infilling, cultivation (Roulet, Nigel T., 2000)-- (Bridgham et al, 2006). 90% of Canadian peatlands are located in the boreal regions (Armentano and Menges, 1986). It should be noted that these figures include seasonal wetlands. The accumulation of peat occurs at a rate of 0.066 cm yr^{-1} and sequesters about 0.71 Mg C ha^{-1} yr^{-1} (Bridgham et al, 2006). Lower amount of accumulation occur in permafrost peatlands. Intact peatlands have a higher rate of accumulation and sequester 29 Tg C yr^{-1}. Although many peatlands are no longer drained for agricultural purposes; those that were in the 1980s (U.S) will continue to lose carbon decades following their drainage. Fortunately there has been limited peatland loss in Canada except for the extraction of peat which has been incorporated into the figures. Currently, and in the past, 124 km^2 of Canadian peatlands have been under extraction and emit 0.24 Tg $^{-1}$ of Co_2 (Bridgham et al, 2006).

Other forms in which humans have modified the gas exchanges and the biogeochemical processes of wetlands include:

- Urbanization and industrialization: This causes a loss of carbon storage/ carbon uptake and interrupts the Ch_4 emissions.
- Energy use and development: Or the flooding of wetlands by reservoirs; a loss of carbon storage and uptake; large increase in CH_4 emissions.
- Forest harvesting (as in Muskoka): Causes damage to organic soils and vegetation; as well as a loss of Tree biomass

Unfortunately, regardless of Muskoka efforts of sustainable logging practices damage to soils, surrounding vegetation and wildlife is inevitable, although minimized by their caution.

Carbon sequestration in plant biomass in undisturbed forested wetlands has minimal to no data; however it is likely a small percentage of the overall carbon sequestration. It is estimated that North American wetlands have lost about 33 Tg C yr^{-1} than their original amount of soil carbon due to human intervention such as large scale conversion of wetland and drained peatlands (Bridgham et al, 2006). Fresh water mineral soil wetlands and peatlands have collectively lost 2.4 Pg (Petagram= 1,000,000,000,000,000 grams) of plant carbon in addition to their soil carbon losses. Forest carbon biomass pool in the U.S and Canada (above and below ground) has been estimated as 54.9 Mg C ha^{-1}, this includes forested wetlands with the assumption that forested wetlands and terrestrial forests contain equal amounts of biomass (Bridgham et al 2006). Wetland soils in Canada store about 158 Gt of C, equaling to about 60% more Carbon than what is stored in Canadian terrestrial forest (Roulet and Nigel, 2000). The protection and restoration of peatlands will stop the loss of their soil carbon, over the long term.

In Midwestern U.S, CH_4 and CO_2 flux rates were monitored over two years in two experimental, created marshes. Flood-pulse and steady flow conditions were simulated through the manipulation of hydrological conditions. Two scenarios were measured: 1) continuously inundated areas edge zones with emergent macrophytes; and 2) edge zones in which emergent macrophytes were removed. No significant differences were observed in methane fluxes in both non macrophyte and vegetated wetlands in edge areas; but were, however, twice as high in continuously flooded areas during steady flow- year when compared to the flood pulse year (Altor and Mitsch, 2008).

The sequestration of soil carbon can be positively influenced by land-use conversion, adoption of recommended management practices and the use of integrated nutrient management. Important practices which could be used for increasing soil carbon include (Post and Kwon, 2000):

- Increasing input rates of organic matter
- Changing decomposability of organic matter. Or inputs that increase organic carbon
- Placing organic matter deeper in soil directly by increasing below-ground inputs or indirectly through the enhancement of surface mixing by soil organisms

- Enhancing physical protection through either intra-aggregate (plant) or organomineral (microbial biomass) complexes.

Management plans are unique to varying sites and should be specialized to the area which is to be enhanced.

Other benefits of increased soil carbon—other than carbon being sequestered—includes: improved soil structure; reduction in soil erosion; increase in water reserves available for plant uptake; the denaturing of pollutants; increased overall soil quality; climate regulation; increased aesthetics and economic values (Lal, 2008). After accounting for CH_4 emissions, maintaining and increasing estuarine wetlands is likely to contribute to net carbon sequestration (Bridgham et al, 2006). The creation of wetlands would increase the terrestrial carbon sequestration amount and forms organic sediments; this method is only considered an effective method for sequestering carbon only if these wetlands are being created and not replacing those which have already been lost due to anthropogenic factors (Roulet and Nigel, 2000). The biomass of aquatic wetland plants (hydrophytes) have the ability to sequester up to 0.7 Gt of carbon, this figure is similar to tree plantation (Glenn et al, 1992).

Flood attenuation:

The reduction of the frequencies of flooding can be of great economic value to a given community. The recognition of this has lead to the utilization of wetlands for this purpose in developed countries (Haygarth and Jarvis, 2002). The potential for wetlands to prevent damage of this nature to lakes and rivers, by the slow release of nutrient rich water catchment into the surrounding bodies of water is also of great value to a given ecosystem (Haygarth and Jarvis, 2002). The slow release of water has also proven to be a key component to water systems during dry periods. Through their ability to detain large amounts of water, they are also preventing erosion caused by flooding and runoff. These aspects of wetlands are of great value to a system, regardless of human contact and should be given more value then what is given at current.

The effectiveness of flood attenuation by a wetland depends largely on the size of the area, vegetation, slope, soil saturation before flooding occurs and location of wetland in flood path (United States. Environmental Protection Agency. 2006)

A value placed for disturbance avoidance has not been assigned for coastal wetlands, due to the nature of their over flow catchment system including runoff into associated lakes systems (Canada. Ministry of Natural Resources, 2009). Although flood damage costs associated with urban areas have increased over the past 100 years. Wetlands ability to retain large quantities of water makes them a valuable asset in the reduction of flood peaks. The interest of restoring/ converting wetlands in flood prone areas has become a growing topic over the past few years (Zedler and Kercher, 2005). The flooding of the Mississippi river cost in between 12-16 billion dollars in 1993; the creation of 3800 ha of wetlands along the Charles river in Massachusetts (U.S) has been estimated to have prevented 17 million dollars each year since these areas have been converted (Zedler and Kercher, 2005; United States. Environmental Protection Agency, 2006; United States. U. S. Fish and Wildlife Service, 1979). Wetlands variability in their morphology, topography and nature of the site affect its interception ability of runoff and overflow flooding (Haygarth and Jarvis, 2002). The incentives for private land owners to enhance or protect wetlands on their property are low due to the fact they will not necessarily be personally benefited by these actions.

During periods when wetland water tables are at their lowest, (Leschine et al, 1997) (ground water recharge) the vegetation which inhabit the area usually have to ability to reduce flow rates through friction (Haygarth and Jarvis, 2002). Wetland values are largely underappreciated, for many of their values are indirect outcomes seen throughout a watershed, leading to a lesser amount of resources used for their rehabilitation and/or protection then what is actually required (Leschine et al, 1997). These values are needed for indicators to determine the appropriate investment for wetland restoration and protection. The values associated with long-term surface water storage includes: the maintenance of base flows, seasonal flow distribution, as well as the maintenance of fish habitat during dry periods. High water tables associated with wetlands aid in the maintenance of the hydrophytic community and biodiversity in a given area, which is crucial to the health, any ecosystem (Leschine et al, 1997). Unfortunately, because the wetlands found in Muskoka are largely isolated and any runoff would flow into the Great Lakes system, avoiding damage to any major extent, the estimated economic value would therefore be 0$/ha/year. Although, further examination of the property may be needed to assess the true value, if any, unrelated to property damage prevention.

Flooding processes occur naturally, and are crucial to the dynamics of a given watershed, without the use wetlands as flood control; severe erosion and riverbed scouring may occur (Haygarth and Jarvis, 2002).

Table 21: Different economic evaluation methods for ecosystem services in wetlands (Leschine et al, 1997).

Type of valuation	Description
Income factor	Habitat provides production of commercial or recreational fisheries, fresh water supply and waste treatment
Hedonic pricing	Based on the premium that customers are willing to pay as a result of location-related, pleasure-enhancing attributes associated with a good or service
Alternate/substitute costing	The substitute must provide a similar function as the natural occurrences.
Damage avoided costs	Assess the value of a service in terms of the property damage associated with the loss that service.

Embodied energy analysis	This method was developed by ecologists to "price" ecosystems on the basis of the potential contribution they make to the maintenance of living systems, ecological support and economically useful products. However there are many aspects which are needed to many an informed estimation such as the annual gross primary production per ha of an ecosystem, expressed in equivalent units of energy. This method also fails to incorporate some important assumptions such as the utility theory.

To gain greater confidence in an estimated value relating to flood prevention, specific watershed information is needed to calculate the normal flow of runoff and volumes each hectare (ha) can store (Lane et al, 2010). In the Bala Bog wetland complex it was determined through the Ontario wetland evaluation system that the total area of upstream water detention (including the wetlands themselves) totaled in 201.7 ha with an upstream detention factor of 1.0 (max 1.0). The Mac Tier wetland complex totalled in upstream detention area (including wetlands) of 182.2 ha with an upstream detention factor of 1.0 as well. Unfortunately, because these areas are not detaining water which would otherwise cause property damage there estimated value remains at 0$.

Water level fluctuations in wetlands occur on a seasonal basis and differ from year to year, depending on a number of influential factors. Seasonal changes are due to the rapid melting of snow which, generally speaking, is largely predictable. Changes seen from year to year are caused by varying rainfall patterns and the timings of spring snow thawing. Historical records of the great lakes show fluctuations varying in several meters over a century (Keddy, 2000). Many species of wildlife are effected by, and maintained by, these fluctuations, wetland species are particularly sensitive to the flood timing and depth at which it occurs. Certain frog species rely on temporary ponds for breeding purposes; and insect fauna vary depending on the duration at which standing water occurs (hydroperiod). Shorter hydroperiods of 4 months or less, generally occur in smaller wetlands of <0.05 ha, covered by a forested canopy, are dominated by “diving beetles”. Longer hydroperiods, lasting longer than 4 months occur in larger wetlands of about <2.5 ha and usually contain well developed aquatic plants such as Sparganium (Keddy, 2000). Species of “back swimmers” were observed as being the most dominant species during longer periods of flooding.

Seasonal floods typically produce extensive bottomland forests usually occurring along rivers. Drier areas, which are seasonally flooded usually, are found in grasslands, and there are very few tree species which can tolerate permanent flooding conditions. Differences of a wooded and an herbaceous wetland are dependent upon the timing of the first flood followed by the beginning of the second flood (Keddy, 2000). The duration of the first flood is critical to the growing of plant species, where a period of 70 days is roughly 1/3rd of the average growing season. If a second flood occurs too closely after the first, it may produce a prolonged period of conditions which are unfavourable to the species which are attempting to persist in the area. Longer periods of favorable (non-flooded) conditions indicate a greater opportunity for plants to recover, increasing their chances to withstand another flooding event (Keddy, 2000). Changes in water levels have been linked to altering vegetation in the wetland. The fluctuations of water tables also determines the shoreline, in that when flooded the shrubs along the shore will be repressed, pushing the shore further upland (Keddy, 2000).

Peat accumulation occurs by primary production exceeding decomposition, for this to occur water levels must be relatively stable. Fire and oxidation may cause the decomposition of peat. The hydrology of peatlands varies from other forms of wetlands, with regard to amplitude and frequencies of water table fluctuations as well as sources of water. Depending on how much peat has accumulated, peatlands may become reliant on its surrounding environment for moisture as opposed to groundwater (Keddy, 2000). Whereas swamps are generally killed by prolonged flooding and replaced by more flood tolerant species (called “wet meadows”), they contain woody plants and are usually found at bottomland forests or floodplains. The absence of periodic flooding may cause woody plants to reinvade. Occasional flooding, however, kills the woody plants and allows the buried meadow seeds to re-establish, creating a wet meadow. Marshes are flooded for longer periods of time (most of the growing season) and contain flood tolerant plants, however these species till require occasional periods of dryness (Keddy, 2000).

The flood pulse concept was first developed to describe seasonal changes in water fluctuations and how they influence the dynamics and maintenance of species diversity. It is the idea that physical and biotic functions of a floodplain wetland are dependent on the dynamics of water discharged from the river channel. It involves the movement of plants, animals and detritus materials and links components of ecosystem together. It is well recognized that these fluctuations is a driving factor in the succession of given area (Middleton, 2002). Organisms which inhabit the areas have specific adaptations to allow them to tolerate certain conditions that are part of the flood- pulse environment. Different species have varying requirements at different life stages of their processes. Permanent flooding of a site reduces the overall species richness; even flood tolerant species will die off in anaerobic conditions (Middleton, 2002). Seed germination is dependent on flood pulsing, where high water fluctuation is necessary for dispersal and drawdown for germination. The germination may also be sensitive to temperature, pH and light quality. Floods may also remove debris which can decrease the germability of seeds.

Part 5: The Significance and Role of Biodiversity in Wetland Ecosystem Services

Biodiversity refers to the variety of life that lives in a particular habitat or ecosystem. Biodiversity includes all life in a habitat of investigation, including all flora and fauna species. High biodiversity supports the sustainability of an ecosystem as well as creates a sanctuary to species at risk. The Muskoka Watershed areas are the home to many species at risk including spotted turtles which are labelled as endangered, as well as massassauga rattlesnake which are labelled as threatened. There are 34 identified and labelled organisms as species-at-risk in the Muskoka Watershed (see figure 1) ranging in all types of flora and fauna. In the Muskoka watershed, 13% of the land is covered by wetlands (MWC, 2008) representing a huge area of sanctuary to many organisms. There are significant values in biodiversity maintenance (Chen et al., 2011). When landscape biodiversity is increased, wetlands can function as traps for nutrients from land to freshwater (Abjornsson et al., 2005). Wetlands support high productivity of plants, but not always diversity as wetlands can sometimes be dominated by one plant type (Kercher and Zedler, 2005). The presence of water, high plant productivity, and other habitat qualities attract high numbers of animals and animal species, some which depend solely on wetlands (Kercher and Zedler, 2005). The area or size of wetland drives the biodiversity that can be present within the ecosystem, but habitat heterogeneity is also a factor that needs to be considered (Kercher and Zedler, 2005). Wetlands can be categorized into different types in relationship to the flora and fauna present. Different types of wetlands include; bogs, swamps, marshes, and fens.

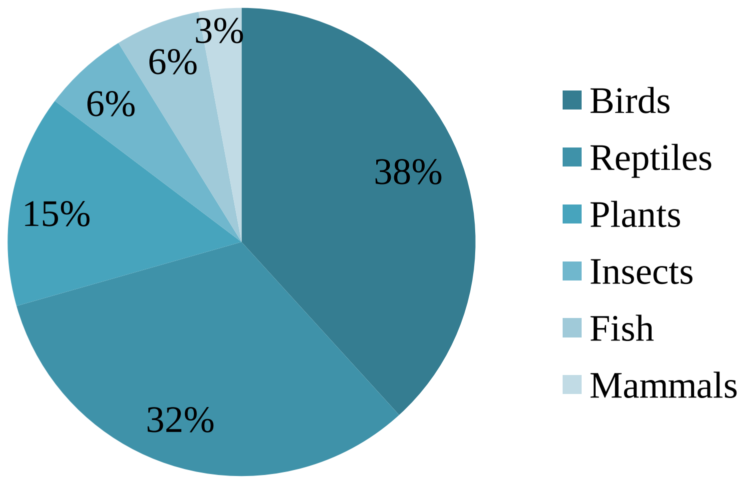

Figure 3: Percentages of Classes at risk found in the Muskoka Watershed –totalling in 34 species at risk (Muskoka Waterweb)

Bogs are peat covered wetlands, and are the least productive of all the wetland types (MWW, 2012). Peat is partially decomposed moss and plant material, and the surface water is strongly acidic due to the decaying of plant material from poor drainage (MWW, 2012). They occur in poorly drained freshwater regions, as well as boreal and tundra regions in more Northern locations (MWW, 2012). There is no flow through water, and very little to no dissolved oxygen and are usually reddish-brown in colour (MWW, 2012). Bogs generally lack nutrients due to having a high water table (MWW, 2012). They are mainly dominated by peat and sphagnum moss which can be harvested from bogs and used in gardens as fertilizers (MWW, 2012). Bogs in the Muskoka Watershed are also home to carnivorous plants including pitcher plants and venus fly traps, as well as act as an ideal habitat for turtles, frogs and insects (MWW, 2012).

Fens are the second least productive of all wetland types (MWW, 2012). They are more productive than bogs because they are not as low in nutrients, yet have low oxygen levels and a lack of bacteria which means plant and animal matter decay at a very slow rate (MWW, 2012). Organic matter sinks to the bottom rather than float on the surface (MWW, 2012). Fens are most commonly seen in arctic and subarctic regions (MWW, 2012). They have a high water table with slow drainage; there is some flow-through however due to the slow drainage, the surface water may be acidic or alkaline depending on the specific wetland in question (MWW, 2012). Fens absorb massive amounts of water and are exceptional at preventing floods, supplying a constant flow of water and water filtration (MWW, 2012). They are mainly dominated by sedges, but may also be home to grasses, some mosses, as well as some trees and shrubs (MWW, 2012). The fauna population in fens are home to an abundant insect population, but act as a breeding zone for reptilians and amphibians such as turtles and frogs (MWW, 2012).

Swamps are the second most productive of the four most common wetland types (MWW, 2012). They have open surface water and are usually associated with rivers, lakes, and waterways (MWW, 2012). Swamps may be flooded for long periods of time or seasonally, and their soils are constantly wet (MWW, 2012). Although they are not as wet as marshes and fens but they still hold a significant amount of water, and are productive and nutrient-rich (MWW, 2012). The vegetation seen in swamps consists mostly of wooded coniferous and deciduous forest or tall thickets including tree species such as; red and silver maple, alder, cedar, hemlock, willow, and dogwood trees (MWW, 2012). Snakes are commonly seen to thrive in swamps due to their amazing ability to swim (MWW, 2012). Woodpeckers use the fallen and rotting wood as feeding grounds and they are also home to many duck species as well as great blue herons.

Marshes are the most productive wetland type, and are very rich in nutrients (MWW, 2012). They are periodically or permanently covered by standing or slowly moving water (MWW, 2012). The water table is low in marshes, and soils usually remain water covered throughout the year and the water is never stagnant (MWW, 2012). Marshes are known to produce high rates of photosynthesis and plant growth and are the most productive areas in the world (MWW, 2012). Vegetation mainly consists of emergent vegetation; where their leaves and flowers are above the water and their roots are below (MWW, 2012). This vegetation includes non-woody plants such as cattails, rushes, sedges, and reeds (MWW, 2012). They act as a nursery to many wetland fauna, such as fish, ducks, frogs, insects, as well as migratory birds that use the area as shelter and food during their migration (MWW, 2012).

The wetlands in the Muskoka Watershed are under process of being evaluated using the Ontario Wetland Evaluation System (OWES). Not all wetlands are equal in value or ecosystem service processes that they perform. There are differences in value between marshes, swamps, fens, and bogs. Using data that was used by MNR, two wetland complexes, the Bala Wetland Complex, the MacTier Wetland Complex, and the Musky Bay Wetland are compared using their Ontario Watershed Evaluation System (OWES) points as well as values as estimated using, Bagstad and Troy's evaluation methods (Bagstad and Troy. 2009).

The Bala Wetland Complex is a 191.7 hectare wetland complex, and consists of three different types of wetlands; 49.68 hectares of fens, 80.01 hectares of marsh, and 61.97 hectares of swamp (Beacon Environmental, 2010). It is an example of an interior non-coastal wetland (Beacon International, 2010). This complex after being evaluated using the Ontario Wetland Evaluation System (OWES) scored high for biological components (207.3) (Beacon Environmental, 2010). It is home to three threatened species including the Blanding's turtle, Branched Bartonia, and the Eastern Hog-Nosed Snake (Beacon Environmental, 2010). It is also home to five provincially significant wildlife species, and three provincially significant plant species.

Table 12: The estimated value of the Bala Wetland Complex, the MacTier Wetland Complex, and the Musky Bay Wetland using values estimated by Troy and Bagstad for Habitat Refugium and Biodiversity.

Wetland Name	**Wetland Type**	**Wetland Size (Ha)**	**Value per Ha**	**Total Value**
The Bala Wetland Complex	Non-urban, Non-coastal	191.7 Ha	$75	$14,377.50
The MacTier Wetland Complex	Non-urban, Non-coastal	640 Ha		$48,000.00
The Musky Bay Wetland	Non-urban, Non-coastal	115.42 Ha		$8,656.50

The Musky Bay Wetland is 115.42 hectares of marsh and swamp (MWC, 2010). It has emergent shoreline communities that provide fish nursery and amphibian habitat important for the many species at risk seen in the Muskoka Watershed (MWC, 2010). This an example of a wetland situated on the bay of a lake acting more as a coastal wetland. This wetland scored high in the growing degree days, as well as high in the type, diversity of surrounding habitat, and proximity to other wetlands. It was also seen to have a large social component with wild rice being present, commercial fisheries and furbearers present as well (MWC, 2010).

The Lewisham Wetland is a large 640 hectare wetland that represents a large peat basin and forms the head waters of multiple tributaries of the Black River (MWC, 2010). It is one of the largest contiguous wetlands in Muskoka, and is 85% crown land (MWC, 2010). This large area acts as sanctuary to multiple species-at-risk including the home of three rare vascular plants; the purple flowering raspberry, balsam ragwort, and late goldenrod (MWC, 2010). It is also the home of multiple more uncommon species including; six different plant species, five bird species, and two species of butterflies (MWC, 2010). This acts as an example as to why the protection and preservation of large conservation areas are important in the management of species-at-risk.

It is evident that the environment is changing and the prospects of climate change are becoming more and more a reality as effects and evidence of its encroachment are being seen in the environment. Ducks Unlimited Canada states that 70% of Canada's original wetlands have disappeared as a result of urban development, drainage, and land cover conversion to agriculture. Wetlands represent a sensitive environment to change, and these effects not only impact the biological components of wetlands such as the flora and fauna that can survive in them, but also the economic benefits from ecosystem services performed by wetlands. Wetlands are being influenced by an excess of greenhouse gases as well as climate change, and the Northern Canadian wetlands such as those seen in the Muskoka Watershed and possibly the most susceptible (Environment Canada, 2005). Climate change is causing changes in seasonal patterns and raising the sea levels which could disrupt life history traits and cycles that are uneasily adapted to change (Environment Canada, 2005). This rapid alteration and hasty adaptation will not be able to be performed by all plants and animals and the ecosystems will suffer (Environment Canada, 2005). There is also a large concern regarding pollution in Northern wetlands including the long-range transport of pollutants from more southern higher population centres we well as the potential for bioaccumulation of chemicals where the top predators of the food web and the most vulnerable (Environment Canada, 2005). This is of great concern when looking at the value of a wetland and acts a layer of complexity as how would the value change with climatic change.

Part 6: The Importance of Wetlands to Social and Cultural Local Populations

Wetlands provide a space for recreation and relaxation to users of local populations, as well as visitors to the area. Having protected wetland areas creates provision of cultural, spiritual and intellectual experiences (Cork, 2009). Although valuing the significance of a natural area can become problematic when looking at personal attachment and importance of a natural resource, it is vital to be considered when looking at the value. Environment Canada has surveyed the importance of nature to Canadians and found out that 3.8 million Ontario residents participated in natural areas and wildlife-related activities in 1999 (Environment Canada, 2000).

Wetlands also provide an economic draw not only through natural services provided by the ecosystems, but from a social aspect with tourists and users. The wetlands within the Muskoka Watershed bring in thousands of tourists each season for recreational purposes. These visitors are encouraged to use the land as a natural escape and appreciated the beauty that isn't always seen in other areas of Ontario, Canada, and even the globe. Visitors come to enjoy the natural setting, through bird-watching, camping, hiking, fishing, photography, and many more different sorts of recreational uses.

Environment Canada discovered many important economical assets to nature areas through the survey they conducting regarding the importance of nature to Canadians. In this paper, $11.7 billion dollars was spent on nature-related activities in Canada during 1996 (Environment Canada, 2000). It was also seen that the enjoyment that was being provided by nature has significant impacts on national, provincial, and regional economies (Environment

Canada, 2000). The use of nature-related areas also sustains 215,000 employments which generates approximately $5.9 billion in personal income (Environment Canada, 2000). The natural wealth of the land contributes to human welfare by meeting a wide spectrum of human needs ranging from very tangible subsistence (money to survive through the economy) as well as highly intangible psychological needs (Environment Canada, 2000).

Table 13**:** The estimated value of the Bala Wetland Complex, the MacTier Wetland Complex, and the Musky Bay Wetland using values estimated by Troy and Bagstad for Cultural Purposes (Recreation, Aesthetic/Amenity, and other).

<table>
<tr><th>Wetland Name</th><th>Wetland Type</th><th>Wetland Size (Ha)</th><th>Value per Ha</th><th>Total Value</th></tr>
<tr><td>The Bala Wetland Complex</td><td>Non-urban, Non-coastal</td><td>191.7 Ha</td><td rowspan="3">Recreation $3,551.00
Aesthetic $6,446.00
Other $2,286.00
TOTAL: $12,283.00</td><td>$2,354,651.10</td></tr>
<tr><td>The MacTier Wetland Complex</td><td>Non-urban, Non-coastal</td><td>640 Ha</td><td>$7,861,120.00</td></tr>
<tr><td>The Musky Bay Wetland</td><td>Non-urban, Non-coastal</td><td>115.42 Ha</td><td>$1,417,703.86</td></tr>
</table>

Natural worth in a monetary sense has been given too little weight in policy decisions, resulting in potential harm to current and future human welfare (Environment Canada, 2000). In fact, just the enjoyment of having natural area has an estimated worth of $807.1 million dollars as this is what Canadians stated they would be willing to increase their expenditures by before deciding to forego nature-related activities (Environment Canada, 2000). Although it is difficult to pinpoint a value associated specifically with the wetlands present in Muskoka, it is important to include this sort of information when looking at the ecosystem services provided by having natural areas.

Conclusion:

As a result of this study we found there are various methods for valuing wetland ecosystem services. One particular result which was outlined by the MNR for the southern Ontario region is that as development encroaches wetland value goes up. It was also found that for the southern Canadian Shield there were valuation aspects that were missing that may be developed in tandem with valuation of processes in Muskoka. Finally wetlands in the Canadian Shield tend to take longer to form as they are in a colder climate which should be addressed when comparing values for southern Ontario.

We were also given two wetland evaluations for the MacTier wetland complex and the Bala Bog wetland complex for which we determined a value for the 6 parts talked about in this report

Table 14: MacTier Wetland Complex (using Southern Ontario Guidelines)

Attribute	Value
Water Purification	$506,333.8
Hydrogeologic Properties (soil formation, water supply)	Unknown
Carbon Sequestration	$2,550.8
Flood Attenuation	$0
Biodiversity	$48,000

Cultural Values	$7,861,120

Total Value of 6 factors:

Table 15: Bala Bog Complex (using Southern Ontario Guidelines)

Attribute	Value
Water Purification	$532,734.3
Hydrogeologic Properties (soil formation, water supply)	$963,901.3
Carbon Sequestration	$2,683.8
Flood Attenuation	$0
Biodiversity	$14,377.50
Cultural Values	$2,354,651.10

Total Value of 6 factors: $3,868,348

Recommendations:

As seen throughout this project there are gaps in the research that need filling. An over recommendation for all the factors is to have accurate mapping of the wetlands, by type and area. This is the strongest aspect that can be recommended because once you know what you have it then makes it easier to start to look at what they can do. This will greatly simplify the process of valuing the wetlands. The second is to create a wetland valuation system like the one created for Southern Ontario, that gives a value to each process (the Southern Ontario one is incomplete). Finally to address how different wetlands function in regard to each of the processes. This will reduce the variability seen in ecosystem valuation.

For the water purification there are recommendations that apply specifically to it. The Forest industry has in the past set up permanent sample plots to look at aspects over a long period of time. If you can find some wetlands that represent the majority of the wetlands for the area and set up permanent sample plots to test relationships between various contaminants and how they will react in the wetland this will also aid in reducing variability. Treatment wetlands were left out of this report but that may be useful for testing relationships as well. Not only will this benefit the wetland section, but it may also benefit the water purification group as well.

For the Hydrogeological section there are tremendous amount of gaps that need to be filled. Aquifer mapping would the place to start. If you find out where the aquifers are both consolidated and unconsolidated, then you can look at where wetlands/aquifer interface relationships and determine how they affect each other. De-lineation of watersheds within the Muskoka area can also help, when you find out which wetlands interact with which watersheds it will help. Trying to place a value on soil formation wetlands is also a key aspect as the soil can act as unconsolidated aquifers.

For the Carbon Sequestration and Flood Attenuation here are the following recommendations: More data would need to be collected on all wetlands, including depths of peatlands and C accumulation rates. These numbers would then need to be linked to monetary values based on their influence to get a more accurate figure on this specific site.

Further research would need to be done to calculate an estimated value for flood attenuation unrelated to property damage.

For Biodiversity and cultural values there were some potential issues as well. Migration is one area where biodiversity will run into problems. This is especially true for bird populations that use wetlands during their process of migration. How to value migratory ponds will need to be looked at. For cultural values there is not a whole lot of activities other than kayaking, canoeing, birding, and fishing that wetlands can provide. Seasonality may also be a factor for cultural values.

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