INFILTRATING PARADIGMS:

EXAMINING CURRENT STORMWATER MANAGEMENT PRACTICES WITHIN THE TOWNSHIP OF KESWICK, AND BARRIERS TO IMPLEMENTING INNOVATIVE WATER MANAGEMENT STRATEGIES

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A Major Paper submitted to the Faculty of Environmental Studies in partial fulfillment of the requirements for the degree of Master in Environmental Studies, York University in Toronto Ontario, Canada.

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ABSTRACT

The increasing demand for drinking water, due to a growing population, is in competition with agriculture, industry, and economic uses. Changes in freshwater can be seen in the dropping water levels of the Great Lakes region yet is not evident in Lake Simcoe, due to the regulation of water levels after 1918. Therefore, to understand the changes in freshwater quantity, stormwater infiltration must be observed. Infiltration of water through plants and soil increases water health, storage, and baseflow to streams; subsequently creating future supplies, ensuring resilience in a changing environment.

Water moves through society and nature within a watershed, creating a socio-ecohydrological landscape. Keswick, Ontario and its watershed, the Maskinonge River, have poor stormwater infiltration and low vegetative cover, which effects flooding in urban centres and the health of Lake Simcoe. This requires stormwater management (SWM); and a key factor affecting SWM is vegetative cover. Vegetation has many ecological functions (e.g. holding water, preventing erosion), as well as improving physical and mental health. A way to increase vegetative cover and infiltration is through low-impact development (LID), which creates stability between the built and natural environments.

However, there are barriers to LID, and through conversations in specialized interviews I explored the question, *what are the pros and cons to alternative stormwater management practices, as well as the barriers to implementing these solutions?* According to my research, the pros to LID are improved water filtration, phosphorus reduction, aesthetics, and increased storage of stormwater. The only cons were difficulty infiltrating in places with poor drainage, and not wishing to infiltrate salts and oils into the ground where present. Today, SWM ponds are not working as needed, and on site water conveyance has long been suggested.

Keswick has no examples of LID, despite education of its benefits. My research revealed status quo, cost and permitting as the barriers to implementation, however these are symptoms; the main barriers are entrenched paradigms. For example, status quo and cost are perceived as why 'others' are not changing; although everyone was willing to change once something happened (e.g. new guidelines, stormwater credit). Developers have seen cost benefits with LID; and Operations find the cost of the current system already unreasonable. As well, society's perception of natural as 'wild' has created opposition to naturalized solutions. These are perceptions based in fear, and not unwillingness.

As for permitting, the dilemma is the strict use of guidelines. The Conservation Authority has an entrenched idea that regulations will be abused, and municipalities fear liability. LID is not one-size-fits-all, so revisions will always be necessary, resulting in challenges and delays enervating the process. Unfortunately, there is much time and money wasted in a back and forth battle of wills concluding with a SWM pond, which the municipality will need to remove later. My recommendation is for communication rather than revision. Allow for innovative designs, using guidelines as guides, and open a dialogue between all invested parties to inspire collaboration. The outcome will be a compromise, born out of a desire to move forward.

I would like to dedicate this work to my wife who supported me, and pushed me to follow my dreams. I would also like to acknowledge my two children that sacrificed time and luxury during the most treasured years of their lives…I love you all more than you can imagine.

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I share much in common with my supervisor, Dr. Martin Bunch, which gave us an immediate bond. Over the past 2 years I have learned a great deal from him, and his insight into systems thinking and eco-health moulded much of my research. He always encouraged me to build my program like it was a career and not just school. I would also like to thank Dr. Lewis Molot for his honesty, and his patience in helping me understand hydrology. I would be remiss if I did not mention two of my colleagues, Alexandra Belaskie and Julie Mallett, who showed me the ropes, and prepared the way by beating down the path before me.

In any journey there are always many people who inspire you through conversations in the hall, on Facebook, or on the train. I acknowledge and thank them for creating an atmosphere of learning and support. Lastly, I would like to thank mother earth for teaching me many lessons and humility.

Chi Meegwich

FOREWORD

My area of concentration is described as an ecohealth approach to freshwater management; and my major research paper was instrumental in supporting all three of its major components. The study of the pros, cons and barriers to low-impact development became an in-depth look at how proper management of stormwater is critical in the health of freshwater and society. By changing the flow of water from runoff to infiltration we help both the quantity and quality of the water returning to storage, which can be located in plants, aquifers, streams or lakes. My three components were: watershed structure, function and impacts; ecohealth; and an integrated approach to watershed management.

The first component was to examine the watersheds structure, function and impacts. My research suggested that watersheds in the Lake Simcoe basin are influential in the quantity and quality of the lake. The water cycles through society and nature, within a watershed, before re-entering the lake, and watersheds have a natural structure, and function, that aids in flow from high to low places. When the watershed is ecologically healthy, water travels underground and within vegetation, with the remainder flowing to the wetlands. However, with over-irrigation, water diversion and urbanization we have changed the hydrological health of the watershed.

The Maskinonge River sub-watershed obtains very little of its supply from long-term storage (i.e. Oak Ridges Moraine) so recharging groundwater is important. Water is removed from the river for irrigation, at an unsustainable rate, and results in excess runoff to the lower watershed. The water cannot return to the ground due to urban development in the Township of Keswick, which has 58% impervious surface, and with very little vegetation the result is flooding. My study proposes that the lack of vegetation has more effect on human and water health than imperviousness. Impermeable surfaces do not cause flooding but prohibit infiltration, while vegetative cover can act as storage for excess water.

The second component was considering ecohealth. The human-environmental health connection is complex. Flooding is a natural event unless it floods an urban center, at which time it creates stress and health concerns. Our response is to convey the water away, through pipes, to store it in a stormwater management (SWM) pond, which inhibits infiltration. When water travels as surface runoff over roads and lawns it causes erosion, sedimentation, and water pollution (e.g. phosphorus, feces, road salt, and oils). This damages soil health and water quality, yet most of all does not recharge groundwater or baseflow in streams. When water filters through the ground and plants, a healthy cycle ensues. The water is cleaned and cooled, as well as stored in the area for future use, which is beneficial for human and environmental health. Vegetation is responsible for holding water, cycling moisture, retaining soil structure, preventing erosion, and combating the heat island effect within urban centers. As well, vegetative cover has been known to improve over all physical and mental health, and increase healing time.

The last component was an integrated approach to watershed management. SWM is really about the connection between nature, society and hydrology, requiring an ecosystems approach to understand. With the changing climate bringing intense storms more frequently, it becomes urgent to deal with storm water in situ. This will ensure the resilience of the system by moving the water into storage and keeping the streams and lakes in better health. A thing that plays a major role in barriers to LID is the *interjurisdictional* (Federal, Provincial, Municipal) and *intrajurisdictional* (department, ministry, and unit) power struggles. Through causal loop diagrams, interviews, figures and graphs I attempt to show the need for LID solutions, as well as the main barriers to change. Due to the lack of data that could be mapped I chose not to use GIS in my paper. Instead I created flow charts that would situate the reader within the LID system to give them a clearer understanding.

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List of Abbreviations

CVC	Credit Valley Conservation
TRCA	Toronto Region Conservation Authority
LSRCA	Lake Simcoe Conservation Authority
MRSW	Maskinonge River Sub-watershed
SWM	SWM
LID	Low-impact Development
IJC	International Joint Commission
E^t	Evapotranspiration
WHO	World Health Organization
SUDS	Sustainable Urban Drainage System
CLD	Causal Loop Diagram
NGO	Non-Government Organization

Introduction

When considering matters of great importance, we are taught to think beyond the current generation. We also are taught that each of us is someone else's seventh generation. We must continually ask ourselves what we are leaving for a future seventh generation…. It is our spiritual and cultural responsibility to protect our local lands and waters in order to help protect the whole of Mother Earth.
(Tribal and First Nations Great Lakes Water Accord, 2004 as cited in IJC, 2012)

The largest barrier to low-impact development (LID) would be if it were not beneficial enough to stimulate change from the conventional system of stormwater management (SWM). Therefore, supporting the need for LID will be a necessary first step. The amount of freshwater in the Great Lakes is impressive yet not infinite. I begin my research by understanding how an area becomes water stressed, and the way to measure water quantity. With increasing populations there is a demand for drinking water that is in competition with agriculture, industry, and economics. Water moves through society and nature, a socio-ecohydrological landscape that demands balance, and the hydrological cycle is a system that can be altered as simply as replacing vegetative cover with impervious surfaces. When water no longer moves through plants and soil it changes the hydraulics, affecting future use by diminishing water storage. Populations and cities are growing within a changing climate, and as human choices hasten that change the intent of LID is to increase infiltration as a way to ensure resilience.

By increasing vegetative cover there is a benefit to human health and well-being. The intersection between society, ecology and hydrology is best seen at the watershed scale, where they interact. In SWM, when the balance between these three is disrupted, the result is stress and health problems caused by flooding. By using causal loop diagrams and the rule of hand, I uncovered the main factors influencing a healthy water cycle within the socio-ecohydrological landscape. A way to increase vegetative cover and infiltration is through LID, which creates stability between the built and natural environments. However, there are barriers to changing from conventional stormwater systems to more naturalized solutions.

The purpose of this paper will be to answer the question, *what are the pros and cons to alternative SWM practices, as well as the barriers to implementing these solutions?* I examined the pros and cons of LID, as well as the barriers to change, through a series of interviews with 11 specialized participants. The interviews were conversations that were based on open-ended and free flowing questions. One conversation would lead me to another through snowball sampling, which allowed me to build a puzzle that was not yet realized. Broadly my research was on the LID initiative, which is not based in any one location. Still, I chose to focus my study on the Town of Keswick within the Maskinonge River sub-watershed (MRSW). Both Keswick and the MRSW have concerns that combine to affect the health of Lake Simcoe, which would be greatly improved by using LID stormwater management. Once the information was gathered from causal loop diagrams, exploratory research and interviews, I analyzed the data to uncover common threads. Once these patterns and trends were identified I introduced LID case studies that illustrate the complexity of SWM and its barriers.

The first two chapters of my paper are literature review and methods. Within these chapters I will explore literature that guided my research, and reveal the tools and methods used to accomplish my study. The next two chapters are results and analysis, where I will present my findings and then divulge patterns and trends, which speak to my research question. Lastly, the discussion chapter will pull together what is perceived as barriers to LID and deliberate how entrenched paradigms can enervate change. In conclusion, I will pull together my thoughts and give recommendations of how these barriers can be challenged.

1 Literature Review

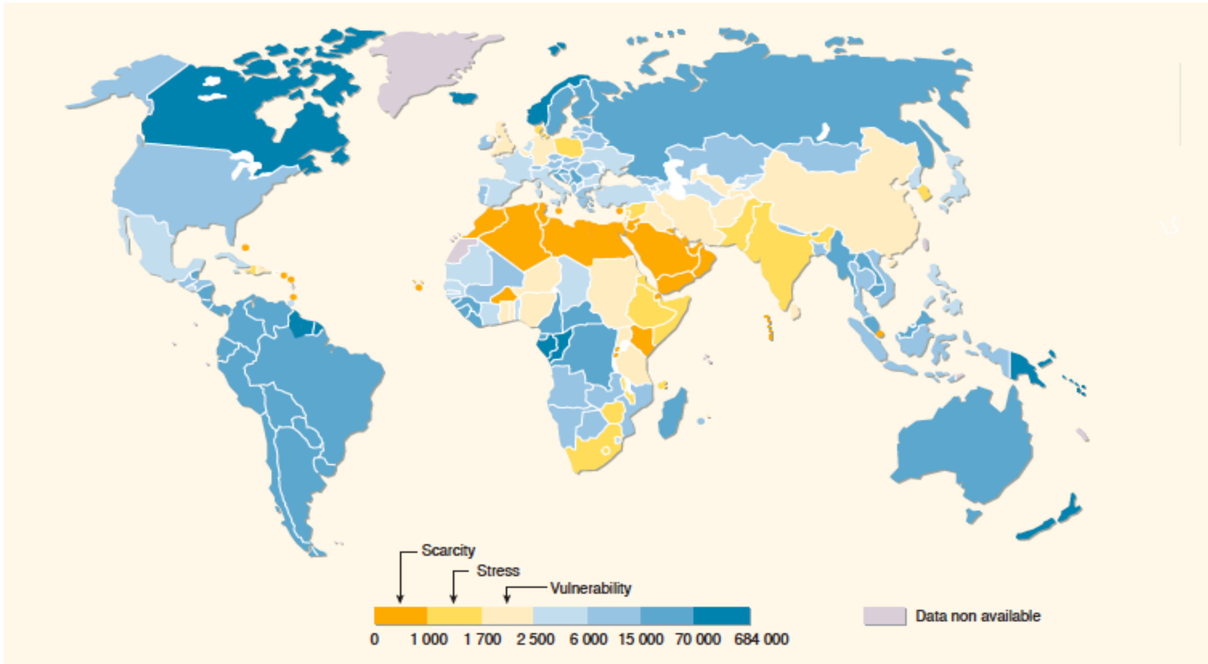
This chapter presents the literature that informed and guided my research. It starts by examining the difference between water stress and water scarcity from a global view. Within this bigger picture, I discuss how water is being consumed in the Great Lakes region faster than it can be replenished. As population increases, the need to grow more food creates a competition for freshwater. When society's demands for drinking water, agriculture, and industry exceed availability there is a loss of balance resulting in a change in ecological functions. Since society relies on these ecological functions for many things, there is a need to manage water in a different way. I then present water's side of the story to bring awareness of how it travels in constant motion through a socio-ecohydrological landscape. The movement through plants and soil purifies the water, and is eventually stored in vegetation, ice or groundwater for future use. It is here that runoff is understood as the remainder of water that has not yet infiltrated into the ground or been taken up by plants.

Next we consider how a systems thinking approach can be used, at a watershed level, to understand the complexity of water management. It is important to understand how water is flowing through our watersheds since it is here that water, society, and ecology interact. As well, it is at this scale we can witness how water encounters agriculture and urbanization. This part of the chapter uncovers how anthropogenic choices, such as industrial irrigation, fertilization, and impervious surfaces, create water scarcity issues that will only worsen with inefficient SWM solutions. Agriculture removes the water from its storage yet it is urban development that hinders it from returning. This suggests the need to increase infiltration within urban development and consequently the resilience of the area is also increased, along with its ability to maintain balance under stress. The best way to achieve this is by increasing vegetative cover.

To ensure balance in an urban centre, it requires greater infiltration to reduce the chance of flooding, causing stress and health problems. By increasing and connecting vegetative cover there is a benefit to human health and well-being, as well as improvement to the health and function of society. One way of increasing vegetative cover is through LID, which I explain as a way to maintain stability between the built and natural environments. To introduce LID requires a break from conventional SWM practices and an embracing of alternative solutions. In the end, water management is not a top down process, but a community task. Community, in this sense, includes all involved in implementing and accepting changes to how water flows through the built environment. Stormwater management is messy and there are many barriers to change (e.g. bureaucracy, education, communication). Overcoming these barriers is not about total consensus, but about finding common ground to change the way we see water, health, and the environment.

1.1 Water Stress: Supply and Demand

We live on a planet with 71% of its surface covered by water, which makes it difficult to grasp how many people do not have access to freshwater. Water scarcity affects billions of people in the world today (WWAP, 2012). Yet, it is not the amount of water that is changing; in fact, there is as much water on the planet today as there were millions of years ago. It is the access to freshwater that is the problem. Freshwater availability is categorized as water stress and water scarcity. Water stress occurs when there is a supply of less than 1,700 m^3 per person every year (Compagnucci et al., 2001; Shady, 2008), an amount that must support the demand from industry, agriculture, society, and the natural ecosystem. For example, Canada as a whole does not experience water stress since there is ample freshwater available (Figure 1-1).



Source: UNEP/GRID-Arendal (2008) (http://maps.grida.no/go/graphic/global-waterstress-and-scarcity, P. Rekacewicz [cartographer] (Le Monde diplomatique), with sources FAO and WRI).

Figure 1-1: Water Scarcity (UNWWDR, 2012, p.124)

However, water scarcity is the ratio of the total water withdrawn to the total water available, and "where water 'stress' is a physical concept, water 'scarcity' is therefore a relative concept and can occur at any level of supply or demand" (WWAP, 2012, p.126). There is only so much water available in an area. As industry, agriculture, and society increase their freshwater demand, the amount available for natural ecosystems and drinking will become increasingly scarce. The United Nation's World Water Development Report (WWAP, 2012) stated "water scarcity can occur even in countries with rich renewable resources if it is not properly conserved, used and distributed among households, farms, industry and the environment" (p.195).

1.2 The Hydrological Equation: Water's Side of the Story

To understand how to manage freshwater it is essential to examine how water travels through the environment.[1] Falkenmark and Folke (2002) suggest that freshwater travels through a socio-ecohydrological landscape. Namely, water moves through air, plants, land, and society before returning to storage, and is the life-blood for all organisms within the biosphere. In pursuit of this goal, Maude Barlow and the Council of Canadians are determined to alter the way people view freshwater in the Great Lakes. Barlow (2011) discussed how water is seen as a renewable resource that will never vanish, referred to as "the myth of water abundance" (p.14). It is true that water never disappears; however, as it changes it can cease to be available as freshwater. Falkenmark and Folke (2002), present the idea that the flow of water within a watershed can be described as either blue-water or green-water. The blue-water moves along the surface, percolates into aquifers, or drains into a larger body of water, whereas the green-water is either stored in vegetation, or re-enters the atmosphere through evaporation and transpiration. This is a good way to understand how water moves, recognizing the function of plants within the cycle.

Black (1991) describes hydrology as "...a set of trivia that affect outcomes in a greater manner than they appear they should" (p.272). An example is how precipitation accounts for only a third of 1% of the world's freshwater within a year, and only 1% of that reaches the water table, yet it supports all environmental and societal functions. Fetter (1994) noted that the hydrological equation is simply inflow = outflow ± changes in storage. Hence, when the amount of water entering an area is greater than the water leaving, the volume of water increases; the reverse of this is also true. The variable in this equation is the amount of water that is stored within the system. Up to 98 percent of the freshwater available is stored as groundwater (Fetter,

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[1] Note that I have added a hydrological dictionary (Appendix A) to help the reader with any unfamiliar terms.

1994). In the course of a hydrological year this amount remains fairly constant, although it fluctuates with the seasons. That is, of course, if the water moves in and out of its own volition.

According to Black (1991), all water is in constant motion, moving through vegetation as evapotranspiration, crucial for environmental life-support. Evapotranspiration is comprised of evaporation, transpiration, and interception (Appendix A), all of which incorporate vegetative cover. The formula $RO = P - E^t$ (Black, 1991) is used to account for the amount of water moving through an area. That is, precipitation (P) minus any evapotranspiration (E^t) results in runoff (RO). Therefore, to control runoff there is a need to decrease precipitation, increase E^t, or increase infiltration back into storage.

There is a close link between E^t, precipitation, and groundwater within the hydrological system. CTC (2010) noted that one-third of gross precipitation contributes to blue water, while the remaining two-thirds supplies evapotranspiration. Black (1991) referred to E^t as 'lost water' since it appears to be removed from the system. However, recently E^t has been seen more as stored water, as it cycles from blue to green-water. As discussed earlier, runoff is highly dependent on E^t, partially due to the storage capacity of plants. Also, it is this movement through plants that facilitates nutrient cycling, water purification, and water recycling, as well as plant growth and climate regulation (Black, 1991). Rockström and colleagues (1999) state, that in some places, E^t produced by vegetation is responsible for 90% of the rainfall.

Precipitation comes in many forms (e.g. snow, rain, fog), according to Johnstone and Louie (1984), and adds to the hydrological cycle in different ways. Rainfall adds to the system immediately while snow is kept as storage. Another way water is stored is through groundwater, which holds water for potential use and acts like a water-bank for future generations. Compagnucci and colleagues (2001) reveal that as little as a 15% decrease in rainfall can result in a 50% decrease in shallow groundwater recharge. There are shallow aquifers, which supply wells and replenish streams, and deep aquifers (Figure 1-2). These deep, or confined aquifers were only accessible after WWII when mechanical pumps allowed irrigation methods to reach water 300 feet below the surface (Opie, 1989). Deep aquifers are not affected by local rainfall; instead precipitation that falls thousands of kilometers away, as well as lakes and rivers, recharge them.

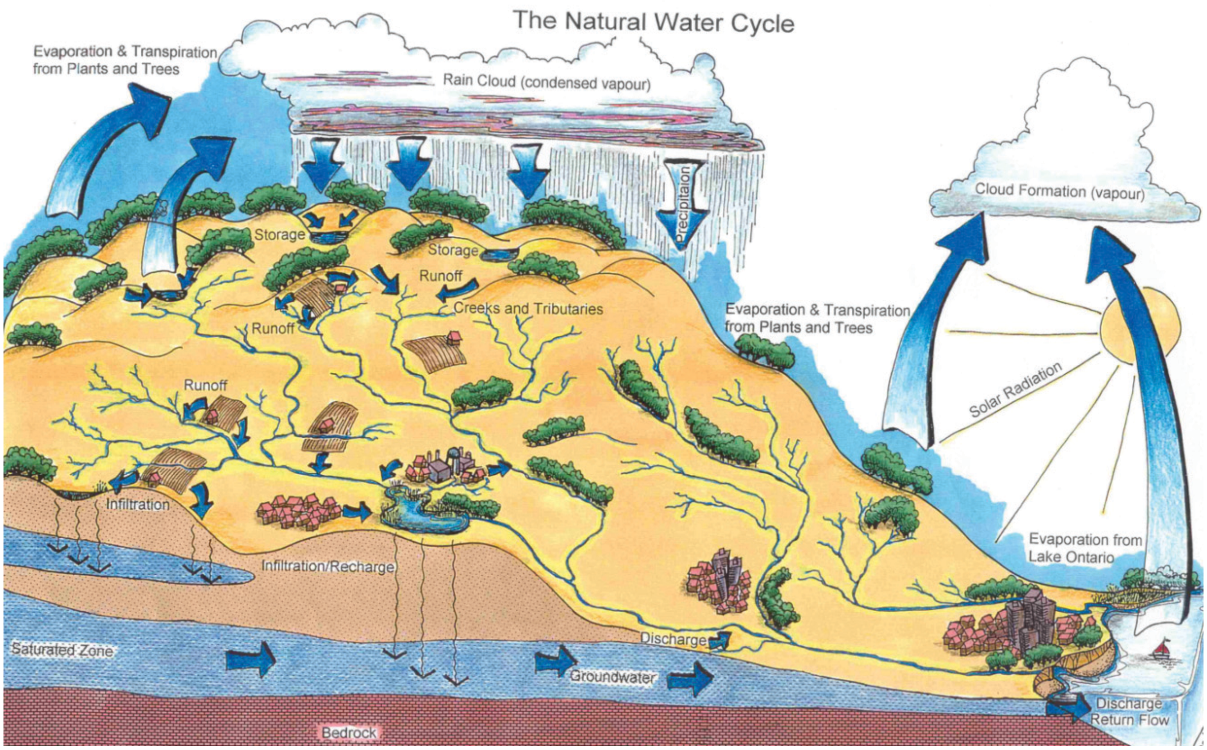

Figure 1-2: Hydrological Cycle (Conservation Ontario, n.d.)

According to Black (1991), some deep aquifers can take 973 years to replenish. For this reason deep aquifer irrigation is ecologically expensive.

1.3 Our Great Lakes: Our Great Demand

The Great Lakes border on several provinces and states, in Canada and the United States, and comprise 20 percent of the planet's surface freshwater. The availability of this freshwater is changing, which can be observed in Lake Erie with a 9% decrease in water levels over the past

40 years (Meszaros et al., 2010). Lake levels are greatly affected by runoff from the surrounding watersheds, according to the IJC (2012), and the resilience and health of those watersheds are being strained through anthropogenic pressures (e.g. agriculture, urban sprawl, and water diversion). Mubako and colleagues (2013) report "freshwater ecosystems in the Great Lakes region face water-scarcity pressure from aggregated consumptive uses at localized scales in space and time" (p.671). That is, it is the accumulation of many local water consumptions that can strain a system even as large as the Great Lakes. LeBaron (2015) noted that 5 percent of the water withdrawn from the Great Lakes is consumed and does not return to the Great lakes basin. Additionally, in 1993 there was a consumptive use of 116 m^3 per second of water from the Great Lakes basin, which is 10 trillion liters of water per day, used mostly for irrigation.

According to the Millennium Ecosystem Assessment (2005), global freshwater use is exceeding long term supplies by 25% through tapping into groundwater aquifers. In the future, water management will need to deal with the competition between agricultural uses, ecological needs and urban demands. Farmers will require water from deeper aquifers to maintain traditional irrigation practices to feed a growing population (Berry et al., 2003; Chappell & LaValle, 2011; Rockström et al., 1999). Bierkens and colleagues (2010 in press derived from Wada et al., 2010) purported that if ground water were removed in the Great Lakes region at the rate it is being removed globally, the area would dry up in less than 80 years. An example of this is already occurring in the Aral Sea (Destouni et al., 2010), which has decreased in volume by 80 percent, and is associated with many years of ground water removal by intensive agriculture. Coincidently, the lowest water levels in Lake Erie occurred in 1930-1940 (Gronewold et al., 2013), which corresponds with the great dustbowl. At this time, desertification of the soil was caused by deforestation and over-irrigation by industrial agriculture, which created a desert environment around Lake Erie. This is a good example of what can happen when a society forgets the importance of trees in water conservation.

The precipitation that falls on the watershed needs to be managed to provide for both the local ecology, as well as society's water requirements. Changes in water availability can strain the function of the local ecology, as well as the health, economics, and quality of life within society. Falkenmark (2000) suggested that the hydrological cycle is a feedback loop that responds and corrects to maintain a balance. This cycle acts as the "...backbone for all living structures" (p.351), as well as providing crucial ecological services for society to function in a healthy way.

Changing water levels have significant effects on lives of people. As an example, there are 40 million people living on the Great Lakes and Laurentian water basins that rely on the economic benefits the water provides (Mackay and Seglinieks, 2013). Davies and Simonovic (2011) state that, "this interplay between natural and socio-economic systems determines the entire system’s evolution and makes the representation of the corresponding feedbacks critical to the development of appropriate adaptation and mitigation strategies" (p.687). To manage freshwater properly, Falkenmark and Folke (2002) suggest that it needs to happen within the socio-ecohydrological landscape. Therefore, one cannot manage freshwater by looking at societal and ecological systems separately.

1.4 Humans are Hard on Water: Waste not Want not

Human action has a substantial impact on the innate flow of water. The greatest impact occurs with changes in land use, specifically urbanization and industrial agriculture. For the purpose of this paper industrial agriculture is defined as farming that is mechanized, has a high utilization of chemicals, grows a single crop, and engages in high water-use irrigation methods to produce the highest yield per acre of land. Industrial agriculture can take more than its share of water, creating water scarcity even in a water rich environment where there is little to no stress. Freshwater becomes scarce when the supply is consumed, which means being changed or removed from the system so that it is no longer considered freshwater.

Hejazi et al. (2013) note that the main draws on supply today are "...irrigation, livestock, domestic, electricity generation, primary energy production, and manufacturing" (p.3328). Industrial agriculture accounts for two thirds of groundwater withdrawals and 80% of water consumed. Sacks et al. (2009) state that global agriculture has increased its demand on water for irrigation by 75% since 1960, and 400% from the early 1900s. Motha and Baier (2005) state that agriculture can create a plethora of problems, such as infertile topsoil, erosion, desertification, salinization, flooding and silting. In fact, Hiranandani (2010) argues that intensive agriculture is harder on soil, water, and biodiversity than any other human practice. Due to population growth, Hejazi and colleagues (2013) suggest that by 2095 the demand for water could rise to 37% of the annual renewable fresh water supply, compared to the 10% needed previously in 2005. Most of the increase is due to a greater demand for food from agriculture. Irrigation practices usually occur in the upper watershed and flow into urban centers in the lower watershed.

As we demonstrated earlier, once the water is removed from storage it becomes runoff unless it infiltrates back into the ground, is taken up by vegetation, or evaporates. When the water encounters a built up area, the chance of infiltration is reduced. The CTC (2010) study divulged a major concern with urban impervious surfaces (e.g. rooftops, driveways, parking lots, and road ways), which can impede groundwater recharge and increase runoff. However, impervious surfaces do not create water, they only stop it from returning to the ground and facilitate transportation of impurities and pollutants directly to waterways. Therefore, where there is heavy agriculture upstream and increased development downstream there is a need for better local SWM practices. This will help to keep the water cycling through the system, returning to the lakes, streams, and ground water aquifers through proper infiltration.

1.5 Socio-ecohydrological Landscape: A System of Water, People and Nature

Rockström and colleagues (1999) understood that hydrology has fast and short cycles (i.e. weather), existing within long and slow cycles (i.e. climate). It is the complexity of these many cycles working at the same time that can make water management difficult. To see things as interacting units, there is a need to incorporate an integrated approach. One such approach is systems thinking, which is a way to view a complex situation by incorporating several epistemologies and disciplines, to achieve a deeper understanding of a subject. Charron (2012) explains that systems thinking is a way to frame a complex situation by understanding its scale and dynamics, and is accomplished by incorporating ecological, social-cultural, and economic aspects. A good starting point, to view the effect hydrology has on a society, is with a watershed scale perspective. This allows for a regional and manageable solution. According to Black (1991), "the watershed is the basic unit of water supply" (p.250) and it has been strongly suggested that the watershed is an excellent scale at which to manage water (Bunch et al., 2011; Parkes et al., 2008; Morrison et al., 2012; Folke et al., 2005).

Watershed management is very important since lake levels depend more on runoff from watersheds than lake precipitation. An example is Lake Simcoe, where my study takes place, which receives runoff from 18 sub-watersheds that cover an area of 3400 square kilometers. Runoff is a natural response to what is happening with water on the surface, in the ground, and in an evaporative state. It is when too much water is running off rather than infiltrating, or when the runoff is occurring in urban centers, that it becomes an dilemma. Watersheds are "...spatial units around which to organize management for both health and natural resources" (Bunch et al., 2011:3); in this case managing for water, ecology, and society. An integrated approach is used to understand the bigger picture (Bunch et al., 2011; Parkes et al., 2008; Morrison et al., 2012; Folke et al., 2005) and reminds us that a watershed is not just water, but also land, air, and society as well.

1.6 Infiltration: Trees, Plants and Soil

Often, decreasing canopy cover and increasing impermeable surfaces accompany urbanization. When porous surfaces and vegetative cover are replaced with impervious surfaces it increases runoff and flooding in urban centers. This does not have to be the case since there are ways to build an urban environment while maintaining canopy and vegetative cover (i.e. LID). The relationship between E^t and runoff becomes a major problem for urban development only if E^t is decreasing. Fetter (1994) stated that if E^t increases then the runoff decreases. Therefore, decreasing runoff may not be about decreasing impervious surfaces yet increasing or maintaining vegetative cover. Runoff, according to Black (1991) is simply excess precipitation. More specifically, once the environment uses the precipitation to replenish soil moisture, recharge storage and to support transpiration, the rest is runoff. Unfortunately, the built environment transports the runoff away through infrastructure and does not return it to the natural environment; for example a rooftop can stop 95% of precipitation from infiltrating if connected to the sewer systems. Campagnucci et al. (2001) agrees that flooding is not about intensity of rainfall but poor infiltration.

According to Compagnucci and colleagues (2001), trees and vegetation affect evaporation rates as the foliage creates interception, which also guards the soil from blunt trauma and protects the integrity of the soil. Without cover, soil would dry up and blow away.

Interception also allows water to reach the surface in stages, which can add to increased infiltration into groundwater aquifers. In addition, canopy and vegetation increase transpiration, and evaporation of the intercepted water, recycling most of the water into the atmosphere to later fall as precipitation (Compagnucci et al., 2001; Fetter, 1994).

It is not just about keeping trees, though trees are invaluable at retaining water, stopping erosion, and improving water quality. It is about maintaining the resilience of a desired state within the environment. Resilience is defined by Gunderson & Holling (2002) as "...the amount of disturbance that a system can absorb without changing stability domains" (2002, p.323). Urban living desires a stable environment where the soil is healthy and fertile, allowing water to infiltrate back into the ground. As well, the hydrological system needs to cycle the water and maintain a balance of E^t, groundwater storage and runoff. Rockström and colleagues (1999) believe that plant biomass is an integral part of watershed resilience. These authors suggested that vegetation allows the flexibility within a system that is necessary for recovery within a cycle of change. Resilience is the buffer allowing an ecosystem to bounce back from a stressor and regain the desired equilibrium. If the environment does not recover then it hits "a point of no return" (Black, 1991:272), where the environment changes enough that it cannot recover its stability without outside help.

1.7 EcoHealth: The Link Between Water, Vegetation, and Health

The overall health of society, water, and nature are linked to each other, with the state of one impacting the others. One way to view this link is through ecohealth approaches, which are "… systemic, participatory approaches to understanding and promoting human health and wellbeing in the context of complex social and ecological interactions" (Waltner-Toews, 2009). The World Health Organization [WHO] (1948) defines health as a ‘‘state of complete physical, mental and social well-being and not merely the absence of disease or infirmity''. The WHO (2005) argued that human health could be affected through anthropogenic pressures on the environment, either *directly* (e.g. floods and exposure to pollutants), by *ecosystem-mediated* processes (i.e. lack of access to freshwater), or *indirectly* (e.g. loss of livelihood, or a shift to urbanization).

The health of the environment is linked to the health of the society and its population (Bunch et al., 2011; Parkes et al., 2010; WHO, 2005). There are many examples of how humans have moulded their environment to suit their cultural needs and, with that environmental change creating an impact on human health. Society's health depends on water for economics and transportation (Fetter, 1994; Compagnucci et al., 2001), energy and food production (Hejazi et al., 2013; Shady, 2008), as well as spiritual, cultural, and recreational activities (Shady, 2008). None of these take into consideration the amazing health benefits a greener world provides to a society's population, which cannot be forgotten or understated.

There are many additional benefits of increasing vegetative cover besides decreasing runoff, and filtering the water. In fact, there is evidence to suggest that vegetative cover has an effect on physical health (Cavill et al., 2006; Bauman, 2004); increased healing time (Ulrich, 1984); and mental well-being (Sandifer et al., 2014; Carrus et al, 2015) to name a few. For example, trees with dense shade are associated with decreasing the "mean radiant temperature" (Zupancic, 2015, p.20), as well as improving air quality through the removal of air-borne pollutants. A recent report from Zupancic (2015) shows a connection between increasing daily temperatures and an increase in deaths, where "…for every one-degree C increase in maximum temperature, ambulance response calls for heat-related illness increased by 29 per cent" (p.40). Temperature and humidity are responsible for many health concerns especially with vulnerable populations, such as the very young and the elderly (Zupancic, 2015). Trees and vegetation are known to have many health benefits, which aid in decreasing personal health costs (Nowak et al., 2014; Zupancic, 2015). A study reviewing the effects of all trees and forests on air quality within the entire United Stated found that, "…17.4 million tonnes of air pollution were removed by trees in 2010, with human health effects valued at US$6.8 billion" (Zupancic, 2015, p.28).

Frequently, the link between water and health is seen through the quantity and quality of drinking water. A person cannot survive more than a week without drinking water, and life in general depends on freshwater (Compagnucci et al., 2001; Fetter, 1994; Shady, 2008). However, this precious liquid comes from wells, rivers, and lakes, which are affected by many outside sources, and filtered by the natural environment. There is an interconnection between water and vegetation. Water is necessary for vegetative growth, which slows down the water so that it infiltrates and filters. Therefore, the better we care for the vegetative cover, the cleaner our drinking water. For this reason we should be concerned with how the water is returning to its source, and treating it in situ.

1.8 Maintaining Resilience: Low-impact Development

The conventional method of managing stormwater is through SWM ponds. All the runoff from an area is collected into one spot for infiltration and filtering, which is typically 3 to 5 percent of a development's land allotment. There are alternative methods to SWM, which can be implemented at the time of new development or a retrofitting of a pre-existing community. There are many names given to alternative techniques for SWM. Some of these are best management practices, green infrastructure, integrated urban water management, LID, low-impact urban design and development, stormwater control measures, sustainable urban drainage systems (SUDS), and water sensitive urban design to name a few. The idea of these methods is to manage stormwater in-place, so as to utilize a larger area of the development.

Zupancic (2015) proposes that the greatest effect on health comes from green spaces that have high connectivity, with most studies suggesting a minimum of 30 percent green density in an area. To achieve this, there is a need to connect green spaces through corridors and utilize many alternative development practices. Currently, most neighbourhoods have sewer pipes or dry culverts to transport stormwater. A culvert is a V-shaped ditch that moves the water away from an area, and when the culverts are packed with hard soil and groomed, they can act more like stormwater sewer pipes. Whether culvert or sewer pipe the water is transported away to a river, lake, or treatment plant and does not promote on-site infiltration. A better way to move water into an environment rather than just through it is grassy swales. The LSRCA (2010) suggest that "ditches and grassed swales have been estimated to remove 30% of the phosphorus, 70% of the suspended solids, and greater than 50% of certain metals and hydrocarbons contained in urban runoff" (p.49), and make a better solution since they infiltrate water in situ.

One solution to increasing vegetative cover, and infiltration, in an urban environment is to incorporate trees. Ferguson (2012) noted that if you are to use trees for water control and treatment, it is important to remember that the tree will not grow to capacity if the roots do not have room to spread out. Tree pits store great amounts of water, which supports transpiration and, as long as trees are chosen that best suit the environment, the tree and its hosts will deal with chemicals and particulates. The authors from Duffy et al. (2012) used the term *Root Rain* to describe catching water in tree pits, which make them optimal water storage units. This water is used not only to feed the tree but supports the decomposers and nitrogen fixers that live with the roots. This biota is responsible for the treatment of water within the root system. For biological organisms to live and work the root bed should be equal to that of the expected canopy and the soil needs to be loose (Jurries, 2003). The roots of the tree are in themselves SUDS facilities.

Rain gardens are popular for disconnected downspouts. A rain garden is a sunken garden that has a prepared substrate to facilitate infiltration and plants that can survive in wet or dry conditions. Dietz and Clausen (2005) set out to see if rain gardens preformed as expected and found that they did slow the water down. Explicitly, when a rain garden was built to handle the first one-inch of roof rainfall, only 0.8% of the water entering left the garden as overflow. Most of the water left the garden by subterrain (98.8%), while the remainder escaped as evaporation. On top of this, the garden controlled peak flows and increased the lag time of influent water. However, they did not remove phosphorus or particulates very well.

Jurries (2003) made the point that nature uses marshes, wetlands and vegetative depressions to clean and control the water. This process naturally removes sediments as well as removing pollutants and heavy metals. It is the sediment that moves the pollutants through the system and this causes turbidity, which is the cloudiness of the water, and "reduces light penetration, increases water temperature, smothers stream bottom habitats, smothers larvae, clogs or damages gill structures, and reduces oxygen" (Jurries, 2003, p.1). Once water is turbid it needs to be filtered and this can be done with vegetation, which slows down the water and controls sediment. This allows the plants to uptake some of the pollutants, and then the decomposing vegetation binds them, while the biota consumes the particulates.

Since most development already exists the majority of LIDs are seen in retrofitting existing urban areas. However, a joint Credit Valley Conservation and Toronto Region Conservation fact sheet (CVC/TRCA, 2010) suggested you need to leave key hydrologic features in place (e.g. tree clusters, highly permeable areas) when building new developments, which will fit the design to the terrain and retain more natural hydrologic features. This practice helps to "preserve or create micro-topography", using the lay of the land to move, slow down and infiltrate water flow. Another suggestion is to build a series of cul-de-sac designs, which facilitates less street surfaces and more access to connected green spaces, or to "use open space or clustered development" (Figure 1-3), suggesting smaller lots with shared parking and driveways. As well, to reduce impervious surfaces the fact sheet proposes that narrower streets and multi-story buildings be used, since the rooftops and streets make up a large portion of impervious urban surfaces.

	Square grid (Miletus, Houston, Portland, etc.)	Oblong grid (most cities with a grid)	Oblong grid 2 (some cities or in certain areas)	Loops (Subdivisions – 1950 to now)	Culs-de-sac (Radburn – 1932 to now)
Percentage of area for streets	36.0%	35.0%	31.4%	27.4%	23.7%
Percentage of buildable area	64.0%	65.0%	68.6%	72.6%	76.3%

Figure 1-3: Reducing Impervious Area (CVC/TRCA, n.d.)

1.9 Coping or Catastrophe: People are Complicated

No amount of planning and design will guarantee implementation. To change the way water flows it is necessary to engage with the community in which the LID is proposed. Using LID as a solution requires a change in what society views as a beautiful and functional urban development. Suggestions like shared driveways, and no through streets goes against what a subdivision is, culturally speaking. Therefore, to make lasting changes the community will need to buy in to these new visions. As the amount of flooding in urban areas increases you would think that there would be an immediate acceptance of alternative methods. Yet, how people deal with stress goes deeper than cause and effect.

Caldwell and Boyd (2009) discuss the coping mechanisms and adaptive measures people need to have, when facing water stress. When security is threatened these adaptive measures affect values and perceptions, even within families. Even when faced with flooding, and the stress it brings, it can be hard for a community to make a conscious effort to change behaviour. Caldwell and Boyd's study (2009) revealed that an investment in social capital in the present could serve to support the society in times of stress. That is, building *good social relations* (MEA, 2005) is important to the resilience of a community. Furthermore, they suggest that there is a fine line between coping and catastrophe, which is underpinned by the perception of the event and their belief in their own ability to cope. If the community can recognize a solution and adapt their behaviour, the chances of coping to the stressor are great.

It is agreed that there should be local community involvement within the environmental decision making process (Barlow & Council of Canadians, 2011; Charron, 2012; Macnaghten & Jacobs, 1997; Pahl-Wostle et al., 2013; Schusler et al., 2003; Webler et al., 2001). As well, there is consensus among these authors that all those invested in making changes should be treated fairly and given a sense of individual agency. The way in which people come together is very important, and can determine the outcome more than any scientific data (Charron, 2012; Webler et al., 2001). Morrison and colleagues (2012) acknowledged that management of Canada's watersheds could have complex *interjurisdictional* (Federal, Provincial, Municipal) and *intrajurisdictional* (department, ministry, and unit) power struggles. The struggle can result in inaction and can lead to mistrust toward governmental initiatives, and often take away individual agency (Macnaghten & Jacobs, 1997; Schusler et al., 2013; Webler et al., 2001). Watershed management becomes a process focused on communication; bridging science, politics, and personal lives through a common goal. Falkenmark (2000) spoke of an *ecological illiteracy trap* created through complicated vocabulary. According to Barlow and Council of Canadians (2011), the vocabulary used needs to arm the layperson in the fight to understand what is actually happening to the world around them, and the effects the changes are having on their health.

When you have a community and many levels of government involved in water management strategies it becomes very messy, since there are many invested stakeholders. A multi-stakeholder approach often suggests working together to find agreement (Bunch et al., 2011; Macnaghten & Jacobs, 1997; Webler et al., 2001). Yet, Schusler and colleagues (2003) considered that it is not consensus that is important but a dialogue that reveals common ground from which to build. In the end it is important to give respect to all the stakeholders involved through finding the correct language for the situation, the appropriate process of deliberation, and to remember that the goal is to change how people view the flow of water. A more empowered community is a more engaged community, invested in a healthy environment.

The literature suggests that, as populations continue to increase so will agriculture, industry, and urban demands on freshwater. Until the demand on freshwater supplies becomes more sustainable there will be a need to help slow the water down so that it can filter and return to storage via infiltration. This requires a better way for society to live, which exists within the hydrological cycle instead of in competition with it. LID is one such way, yet it has not got the legs to move forward. In my research I will ask the question: *What are the pros and cons to alternative stormwater management practices, as well as the barriers to implementing these solutions?* It is a complex problem that has a messy answer, and will require asking questions to many different stakeholders. The next chapter reveals the various methods I utilize to accomplish my research.

2 Methods Section

My study considers LID within the Maskinonge River Sub-watershed (MRSW) and the Town of Keswick, of which both greatly affect the water quantity and quality of Lake Simcoe. Keswick has three sub-watersheds within its shoreline: the Maskinonge River, East Holland River, and Georgina Creeks sub-watersheds. According to the LSRCA (2010EH), the East Holland River is one of the most populated sub-watersheds in the Lake Simcoe basin with the most impervious surfaces except for Barrie Creeks. However, the East Holland also has 31% of its area naturalized, which helps maintain groundwater and baseflow. Georgina Creeks is one of the smallest sub-watersheds in the Lake Simcoe basin (LSRCA, 2013), and is positioned at the juncture of Lake Simcoe and Cook's Bay. Although both of these sub-watersheds encompass Keswick, the upper watershed conditions do not affect water quantity in Keswick. This is due to the position of their main tributaries and the contours of the land.

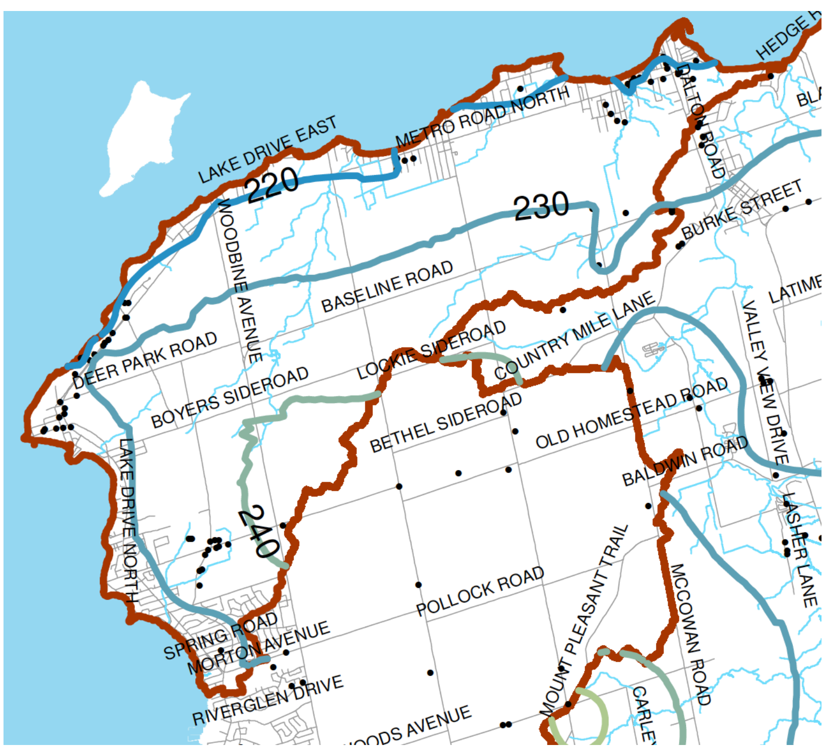

Figure 2-1: Georgina Creeks Contour Lines (LSRCA, 2013, Figure 2-8)

The flows of both upper watersheds go to a river or marsh, away from Keswick's borders. Further, any precipitation, which falls in Keswick boundaries, flows directly to Cook's Bay and not to Georgina Creek or the East Holland River, which makes Keswick's impact on Lake Simcoe very significant (Figure 2-1; Figure 2-2).

Figure 2-2: East Holland Contour Lines (MNR, 2006).

The sub-watershed that affects water quantity the most within Keswick is the MRSW, which lies at the south-eastern corner of Lake Simcoe on Cook's Bay (Figure 2-3). Although this area is comprised mainly of agricultural land, there are several small urban centers, the largest of which is the rapidly growing Township of Keswick, Ontario. Keswick is positioned at the mouth of the watershed and, due to this, all the water that falls in the catchment is funnelled through the town before entering Cook's Bay. In this section the tools, study area, and procedures used in this research will be presented. First, I will position this work in respect to my research approach.

2.1 Research Approach

The question of urban development and its effect on the local hydrologic cycle is complex. My task was to clarify the connection between impervious surfaces and runoff, both of which are associated with urban development. This could be accomplished by using a systems thinking approach. Kay and colleagues (1999) suggest an ecosystems approach, a form of systems thinking, which recognizes the human/environment interconnection as a SOHO system (i.e. Self Organizing, Holarchic, Open). The authors contend that, such systems self-organize through a series of positive and negative feedback loops, functioning in both space and time. Bunch and colleagues (2011) add that these systems stay resilient by retaining structure and function in the face of change. Resilience becomes possible because this type of a system is not linear or hierarchical but *holarchic,* with one system feeding into another. That is, many systems are embedded, and interacting within and across scales, creating a dynamic system. To understand this type of system it requires a holistic perspective. Subsequently, the human/environmental interplay characterizes an open system that is dynamic, adaptive, and resilient.

Positive and negative feedback loops represent the way a cause creates an effect. While a positive feedback loop has the cause and effect moving in the same direction, in a negative feedback loop they move in the opposite direction. Cause and effect are connected in time and space, yet this is not immediately evident in hydrology. An example is the delay between precipitation and runoff due to many other factors (e.g. soil saturation, interception). For this reason, to understand how land use change has altered the hydrological cycle requires more than just scientific data (e.g. percent of imperviousness, amount of runoff). Time delays, feedback loops, and non-linear dynamics within the hydrologic system need to be recognized (Sterman, 2002). I used causal loop diagrams, borrowed from dynamic systems thinking (Ahmad & Simonovic, 2000), to help me see past preconceived ideas.

A common assumption is that escalating runoff is the result of decreasing permeability. However, Sterman (2002) warns that "there are no side effects—only effects" (p.505), so vigilance is needed to look for results that one had not previously anticipated. Since I could not incorporate all interactions and feedback loops within my causal loop diagram, I needed to choose which indicators would be included. According to Barresi and colleagues (2015), as a researcher, I am choosing what measurements to use within my chosen system. This is a limitation that adds to the complexity of understanding the problem of the hydrological cycle.

Once I identified the variables, I needed to look for the *leverage point* (Meadows, 2009), or point of power that can elicit a change in the hydrological system. As mentioned earlier, a knee jerk assumption is that urban development increases runoff, resulting in flooding within urban centers. If this were true, the leverage point would be found in the amount of impervious surface. Meadows (2009) noted that when trying to change a system, we often go straight to the numbers. However, she noted that numbers are based on pre-existing *paradigms*, which are "the shared ideas in the minds of society, the great big unstated assumptions..."(p.48). Further, she stated that systems rely on these paradigms to operate, and it is those ingrained belief systems that need to change or else the numbers will always add up to old thinking. Therefore, "transcending paradigms" (Meadows, 2009:Key Concepts) is the most important leverage point to changing behaviour, according to Meadows. It is my premise that to change the increasing runoff in urban centers, the relationship people have with water needs to be altered. That is, a change in the hydrological paradigms is required.

2.2 Colleagues, Conversations, and Elucidation

I started the interview process on January 21, 2015 and had conducted ten specialized interviews by April 01, 2015. I knew very little about the procedure and application of LID solutions and SWM ponds within municipalities today. I understood the types of LID solutions that existed and generally why SWM ponds were installed; yet all this knowledge was superficial and assumptive. My plan was to start my interviews with a hydrology professor to understand the academic standpoint, Ducks Unlimited for the non-governmental view, and the LSRCA to get an understanding of government initiatives. This did not work out as I planned, and I ended my interview series with the LSRCA, which was the correct choice in the end.

The professor I interviewed was an emeritus professor, Dr. W. Trevor Dickinson, from Guelph University. I chose Dr. Dickinson after hearing him speak at an environmental conference, in the fall of 2014, where he presented a different view on the urban/rural dichotomy. Dr. Dickinson suggested I speak with someone from Credit Valley Conservation. Since I was already planning to speak with the LSRCA, I thought I would keep this contact for later. At the same conference I was introduced to Dan Reeves from Ducks Unlimited, who are interested in ecological restoration and are creating innovative SWM solutions for developers.

My next interview was with Mark Setter, a landscape architect focusing on ecological restoration. Mark had designed a LID solution for Pine Beach in Keswick and I was interested in his experience. At this point, I was becoming more familiar with the stages of LID application and wished to speak with different people in the process. Mark put me in contact with a previous developer that was familiar with a LID project called Humber Flats. This developer wishes to remain anonymous and will be referred to in this paper as 'Developer'. Developer walked me through the process of obtaining permission to install LID solutions rather than SWM ponds. Previous to my interview with Developer I interviewed a consulting engineer, Harold Reinthaler. A consulting engineer works with a developer to make sure the hydrological balance returns to pre-development numbers.

The municipality was becoming a common theme when speaking of barriers, so my next three interviews were with the Town of Georgina staff. I interviewed Mike Baskerville (Engineering Manager,) Barbara Antic (Civil Technologist), and Gagan Sandhu (Operations Manager). Each one had a perspective of the SWM process; where Baskerville had a viewpoint of mandates and funding, Antic followed SWM from permit to assumption. In the past Operations has been in opposition to alternative stormwater solutions, so it was critical to obtain their story. It turned out that Gagan was a forward thinker and a supporter of LID solutions.

It was now time to speak with the LSRCA and a joint interview was set up with Steve Auger (SWM specialist) and Tom Hogenbirk (manger of engineering and technical services). Fifty percent of my interviews mentioned the conservation authorities (CA) as being critical for me to understand LIDs. There is no doubt that the CA is an integral piece in the degree of success of LID solutions. The conservation authority sees themselves as educators and innovators yet the others see them as permitting agents and enforcers, which is evident throughout the interviews. Since the idea of entrenched paradigms was prevalent I added an eleventh interview with Hilary Van Welter, the director of *ReWild* with over 30 years' experience inspiring 'strategic change' in all sectors.

2.3 Methods & Techniques

2.3.1 The Rule of Hand and Causal Loop Diagrams

There is a possibility of getting caught up analyzing too many variables when you consider that everything is connected to everything else. There are typically a few interacting factors that explain the most important changes (Walker et al., 2006; Yorque et al., 2002). The key variables can be narrowed down using the *Rule of Hand*, described by Yorque and colleagues (2002). It is through identifying this small set of important indicators that you can begin to simplify the complexity. I will chose five key measures that are indicative of urban development's impact on the hydrological cycle, which influence runoff and stream flow; "it holds that if you cannot explain or describe the issue of concern using at least a handful of causes, then your understanding is too simple. If you require many more than a handful of causes, then your understanding is unnecessarily complex" (Holding, 2001, p.391).

Mirchi and colleagues (2012) warn that water resource systems must be reviewed in context, and in a holistic way. This can be accomplished using a Causal Loop Diagram (CLD), which is utilized to see how the many individual variables can work in concert, creating feedback loops. Figure 2-3 is an example of a CLD, where the key factors are the inflow, river, reservoir, and storage capacity. These four factors are connected through a series of positive and negative feedback loops, also referred to as causal loops. The arrow shows the direction of the relationship and the symbol indicates whether the factor at the end of the arrow moves in the same direction (+) or the opposite direction (-). For example, the reservoir storage and inflow have a positive feedback loop, identified by a + symbol. Specifically, as the inflow increases so does the amount of water in the reservoir. If you follow the feedback loops you notice that this results in a cascade of events where "increase in releases will increase river flow, thus causing downstream flooding that will lead to a decrease in releases from the reservoir" (Ahmad &

Simonovic, 2007, p.191; figure 2-3).

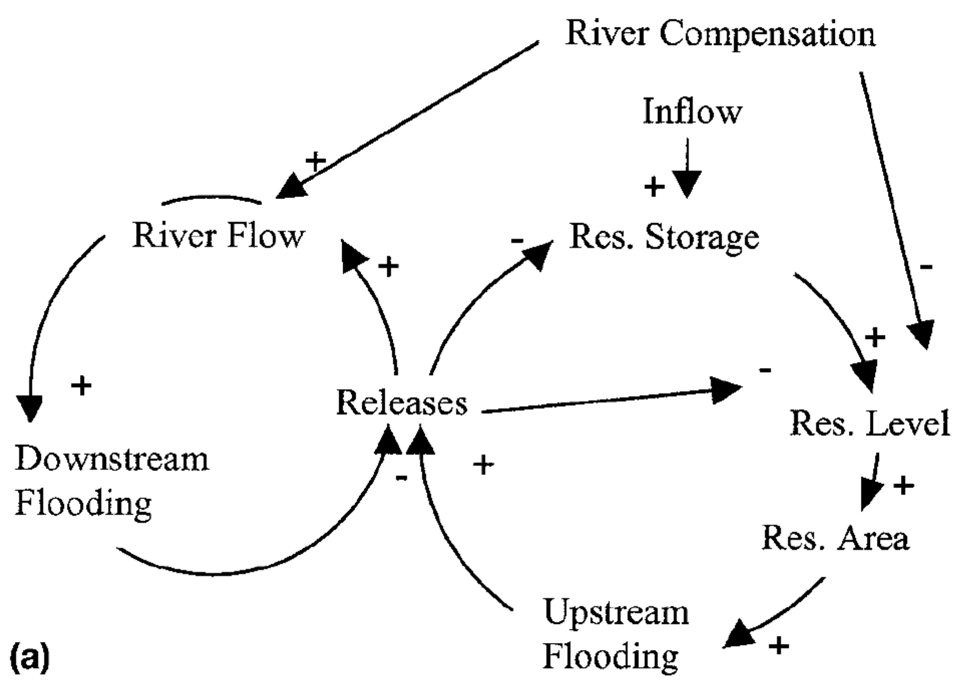

Figure 2-3: Causal Loop Diagram (Ahmad & Simonovic, 2007, p.191)

CLD's become a language capable of helping us relay the intricate, interconnectedness of our environment, which is not linear or static (Kim, 1992; Takahashi & Maeno, n.d.). Although complex systems are made up of interrelated parts, together they act as a functioning unit, with behavioural traits (Mirchi et al., 2012). In this way I uncovered my key indicators by creating a CLD showing how water moves through the hydrological cycle. The authors suggest starting with a topic, which in my case was runoff, and then observing which other factors work as leverage points within that system. This is done in hopes of discovering *the root of the problem* or key leverage point.

2.3.2 Archival Research

The handful of indicators, discovered through the CLD, created the understanding of correlations between urban development and runoff. My intent was to collect data on many variables (e.g. precipitation, vegetative cover, evapotranspiration, runoff and impervious surfaces) over a period of 35 years. I wished to demonstrate how urban density over time changes the amount of runoff by doing a spatial-temporal analysis of Keswick. This proved to be difficult since historical data was not available for most of the variables and current data had already been worked into studies. To compensate for the missing data I added a question into my interviews that would help to discover the perception of how runoff and urban density are connected.

Historical changes of Keswick's built up area were available through census and aerial mapping. I was also able to obtain information on current SWM practices used within the Town of Keswick, the changes in these practices over the years, and the types and numbers of SWM facilities. As well, research documentation on alternative SWM practices and their capabilities were collected from Ducks Unlimited and other NGOs during the interview process. Additional information was explored through web-based searches.

2.3.3 Interview Process and Specialized Informant Interviews

Bernard (2011) identifies a *specialized informant* as someone with competence in the subject you are exploring. I choose not to use the term 'informant' since it has a negative connotation; instead I will use the term participant. These participants do not need to be professional just knowledgeable and specialized in the subject the interview is covering. My specialized participants were chosen from municipal, conservation, and consulting engineers (i.e. Schaeffers Consulting Engineers), a hydrology professor, an NGO dealing in SWM, and a developer involved in SWM. The Interviews were exploratory in nature and based on understanding the pros, cons, and barriers to traditional and alternative stormwater initiatives.

Kvale (1996) stated that the oldest and most natural way to gather information is through conversation.

Gathering information on alternative stormwater strategies through literature review is critical. However, Salter (2013) explains that even though literature reviews lay the foundation for interviews it is the interview that brings life to the information adding "...content, depth and colour to the story" (p.1). During the exploratory interviews there will be a need for accurate field notes. Blommaert and Jie (2010) state that data is extremely important because it represents the product of fieldwork and although texts, material artefacts, and transcripts of interviews are widely considered scientific evidence, field notes can be viewed as vague and subjective. According to Blommaert and Jie (2010), this can be resolved by having rich text and a complete 360-degree view of a situation.

In total 11 interviews were carried out (Appendix B). The purpose of these meetings was to identify and describe current SWM strategies and any alternative practices being explored. These interviews also helped to understand the reasoning behind current practices and their perceived pros, cons, as well as the major stumbling blocks of implementing alternative SWM solutions. I started my interviews with an emeritus hydrology professor and a representative of Ducks Unlimited. I then burgeoned out from there using a process called *snowball sampling*. Snowball sampling is when specialized participants are asked to direct you to someone else that may have critical information to your study. The purpose is to obtain information-rich interviews (Bernard, 2011; Blommaert & Jie, 2010). This strategy will be employed until there is a saturation of information. I rounded out the interviews with Hilary Van Welter, to explore the idea of changing paradigms in the community regarding alternative stormwater solutions.

All questions were open ended and free flowing; that is, the questions guided the conversation and did not constrict it. Some questions may have been skipped if answered within a previous response and new questions may arise demanding further inquiry. Although the interview questions were the same for all the different specialized participants (Appendix C), the way the questions were asked varied. I was interested in getting the perspective of their position in the SWM process. Overall, it was looking at the pros, cons and barriers that were identified by their position and relevant to my research.

2.3.4 Case Studies

Once I had the results of my causal loop diagrams and the interview questions, I chose to examine case studies of successful LIDs. A defining feature of a case study is "...empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p.13). These authors believe that case studies suit research where contextual factors affect the phenomenon being studied. In this case, the phenomenon is increasing runoff while the contextual factors are anthropogenic behaviours. Case studies are more of a research strategy than a tool, according to Walshe et al. (2004). By examining successful LIDs it is possible to bring to life the pros, cons, and barriers of LID change, uncovering patterns within a complex situation.

2.4 Methods of Analysis

According to Vik (2014) there are three main questions that need to be answered through statistical analysis: are the variables related; what is the direction of the relationship; and how strong is that relationship? If a relationship is found, then the correlation between the variables will reveal their association. Since I was unable to obtain enough data I could not preform statistical analysis. However, the principals of regression analysis were always present in my mind when I was examining the causal relationships that were being discovered through CLDs. Various pieces of literature that spoke to water quantity or the research question were obtained as a result of the interviews. These were considered part of the interview process and accredited to the interviewee.

The interview results were analysed and categorized by themes that presented themselves. Bernard (2011) stated that people are natural storytellers, revealing what, why and how something happened, whether "extraordinary" or "mundane", creating a narrative. When analyzing narratives "the object is to discover themes and recurring structures" (Bernard, 2011, p.416), or 'code themes', which turns "free-flowing texts into a set of nominal variables" (Bernard, 2011, p.429). These themes are "content-driven codes", according to Guest (2006, p.66). Unlike quantitative data, there is no accepted number of interviews to indicate what sample size is sufficient to obtain quality information. However, the standard is to continue interviewing until you are receiving the same information repeatedly, which is referred to as saturation.

Guest's (2006) study found that they had reached saturation within 12 interviews, which should be typical if the group is somewhat homogeneous. Theoretical saturation is the "criterion by which to justify adequate sample sizes in qualitative inquiry" (Guest, 2006, p.60). According to Bernard (2011) there are several ways to get the coded themes; one is to start with general ideas that were highlighted in literature; another is to highlight text that seems important when reading the narrative; and a third is to do key-word-in-context (KWIC), which is counting the words as a representation of its importance. I used KWIC to see how often a certain partner was named (e.g. municipality, conservation authority) and the other two for general coding.

Charts were created from perceptions drawn out of the interviews to show SWM process and flow of responsibilities. Each category was examined separately (e.g. assumptive question, municipal responsibilities), then each question reviewed individually to uncover patterns and trends, and lastly themes that presented themselves as possible barriers were examined. This led to recommendations in moving forward and an exploration of what is meant by a paradigm shift.

2.5 Study Area

Unless otherwise stated, the following information regarding my "study area" was obtained through the Maskinonge River Sub-watershed Report (LSRCA, 2010). My area of study lies in the MRSW, which is situated at the south-eastern tip of Cook's Bay in Lake Simcoe (Figure 2-4). This watershed has an area of 63.5 km^2 within the Regional Municipality of York. The lower tier municipalities that occupy the watershed are East Gwillimbury and Georgina. The MRSW begins at the Oak Ridge Moraine (ORM), 291 meters above sea level (mASL), and ends at Cook's Bay, which is 218 mASL. Only the higher elevations from 275 to 291 mASL are affected by the ORM, which is a very small portion of the watershed. This small area is comprised of rolling sandy hills providing excellent infiltration for replenishing the groundwater, and is responsible for a large portion of the watershed's recharge.

The largest portion of the MRSW (275 and 225 mASL) is referred to as the Simcoe Lowlands (Figure 2-5), through which many of the rivers and tributaries flow. The Simcoe Lowlands are composed of Newmarket Till, which is sand, silt and clay. This soil type can be from 10-50 meters thick and has low permeability (Sharpe et al., 1999). The area's remaining soil type is concentrated around the Towns of Queensville and Ravenshoe, consisting mostly of clay, known as the Schomberg Clay Plain (Chapman and Putnam, 1984), and has a very low rate of infiltration.

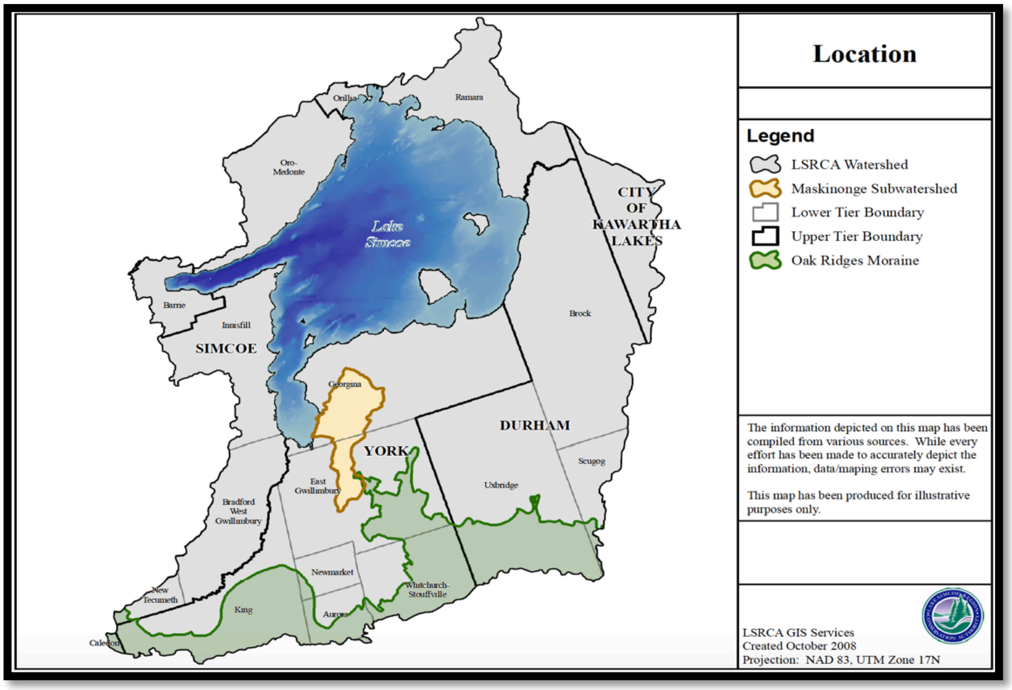

Figure 2-4: Location (LSRCA, 2010, p.24)

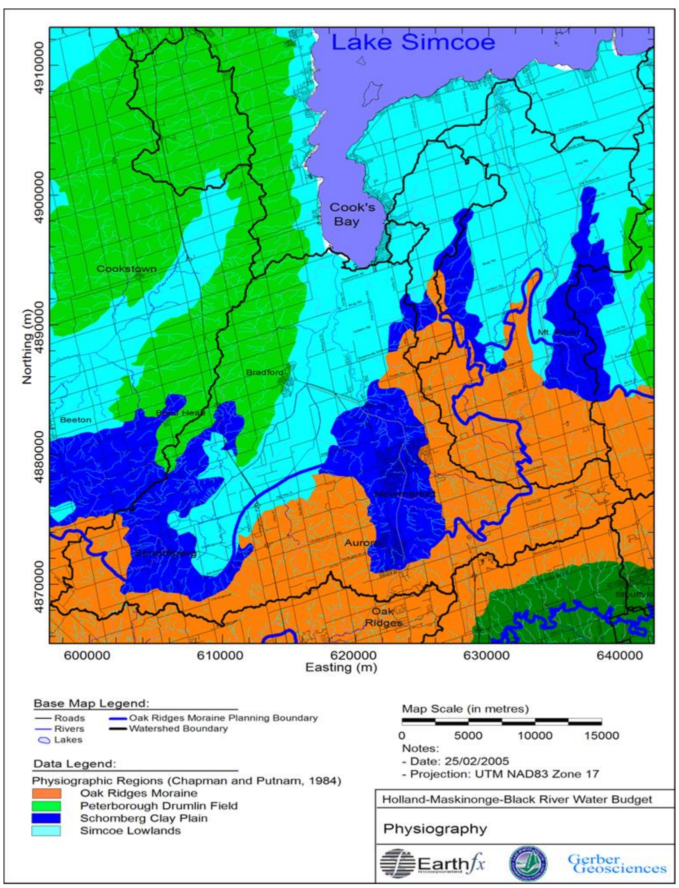

Figure 2-5: Soil Composition (Earthfx & Gerber, 2008)

Among the 18 sub-watersheds in the Lake Simcoe Basin, the MRSW has the most agricultural land. This watershed is comprised of 70.6% agriculture, 20% protected natural heritage features, and 6% built up area (Figure 2-6). Overall, the MRSW has 10.5% impervious surface, with the Township of Keswick representing 3.5% of the total. The impermeable area in Keswick is reaching a *critical threshold*, with 57.8% of its area covered by impervious surfaces. There are plans for further urban expansion in the near future with the population of Keswick projected to double from 20,000 to 40,000 by 2026.

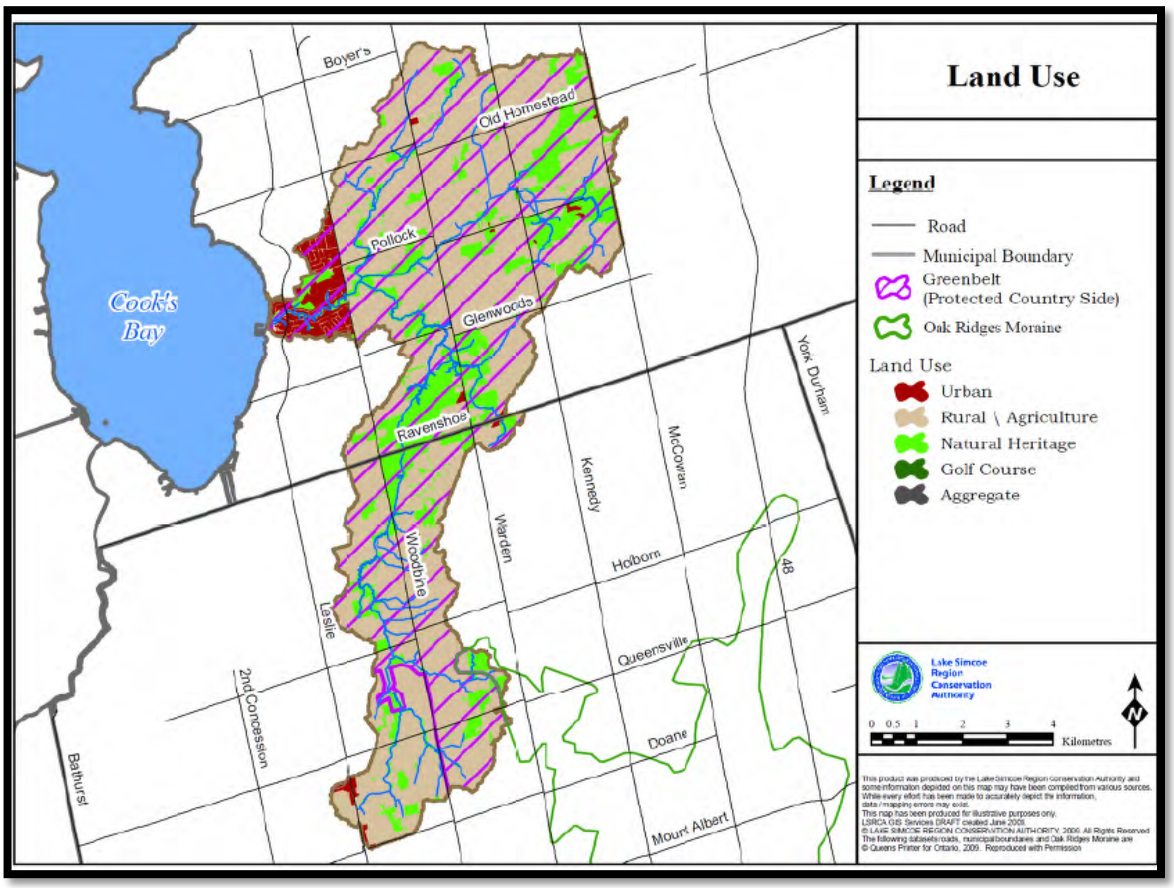

Figure 2-6: Land Use (LSRCA, 2010, p.25)

Agricultural land use has caused increased sedimentation due to the removal of riparian vegetation. Agriculture uses vast amounts of water for irrigation, and diverts water away from the local area through tile drainage, inhibiting infiltration. The LSRCA have evidence to suggest that water is being withdrawn directly from the river for irrigation on a daily basis; as well, many downstream water-damming practices exist. Annual precipitation in the MRSW is consistent, ranging from 785 to 837 mm/yr, with only 6 stations having historical record greater than two decades (Figure 2-7).

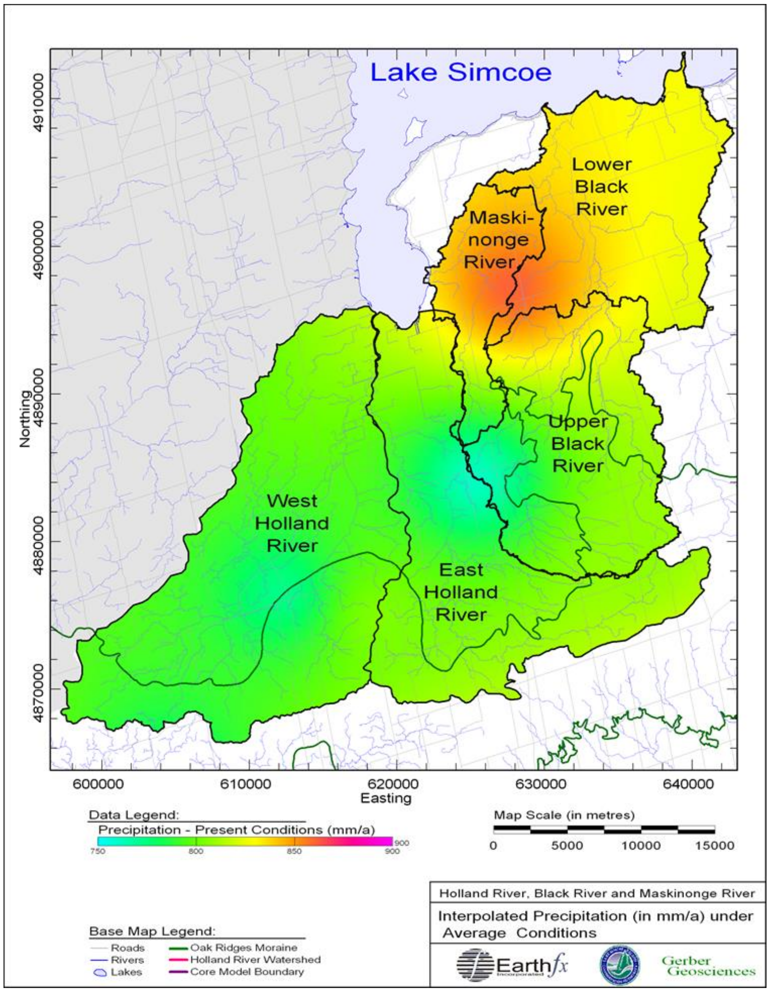

Figure 2-7: Average Precipitation from 1980-1999 (Earthfx & Gerber, 2008)

This watershed does not share a large amount of ground water reserves with the ORM so infiltration in the upper watershed is critical to hydrological health, which is accentuated by the MRSW having the lowest levels of wetland and woodland in the Lake Simcoe water basin. In the summers of 2006 and 2007 the Maskinonge River dried up. There is no longitudinal stream flow data; yet long time residents have stated that the dry river is a recent occurrence, according to the

LSRCA (2010) report. Further, no changes have occurred within the 40 years of climate data explaining the river drying up, suggesting anthropogenic causes.

My study of SWM was focused in the Township of Keswick within the Town of Georgina. Keswick is the largest urban area in the MRSW, as well as being situated at the shore of Cook's Bay where all the water from the upper watershed flows through. Historically, Keswick was referred to as Medina within the Township of North Gwillimbury until 1870 when it became a part of Georgina (Town of Georgina, 2015). The Town of Georgina has a population of 43,515, and Keswick is its largest urban center (Statistics Canada, 2012). Residents began moving to the Keswick area in the early 1800s (Town of Georgina, 2015b). Primarily cottagers used Keswick until the 1980s, at which time major development created easier access to the area, and the population expanded at a rapid rate. Keswick itself is merely 20.03 km^2 in area and contains the Keswick Marsh in the south-western corner, which is part of the Holland Marsh. The beaches in Keswick are a combination of public and private access, and make up the majority of recreation in the area. The most common recreational activities are swimming and boating in the summer, and ice fishing and snowmobiling in the winter.

My study reviewed traditional SWM practices, as well as, alternative SWM strategies in the Keswick area. Presently, the town's SWM is divided into areas that flow into the Maskinonge River (26%), and areas that drain into Glenwood Creek or Cook's Bay directly (74%). Forty-five percent of the water that flows into the Maskinonge River has no stormwater control. The remaining areas that have water management are either water quantity control only (dry ponds, 21.5%), or classified as level 1-4 facilities (33.5%) (Figure 2-8):

> **Level 1** is the most stringent level of protection designed to protect habitat, which is essential to fisheries productivity (e.g. spawning, rearing and feeding areas) and requires 80% removal of suspended solids.

Level 2 protection calls for a 70% removal of suspended solids. In this instance the receiving water can sustain the increased loading without a decrease in fisheries productivity.
Level 3 controls are relaxed further requiring a 60% sediment removal rate again reflecting the lower quality of the receiving water for fish production.
Level 4 controls exclusively address retrofit situations where, due to site constraints the other levels of control cannot be achieved. Level 4 protection is not to be considered for any new development, only for instances where uncontrolled urban areas can implement some SWMF to improve environmental health.

LSRCA, 2010, p.47

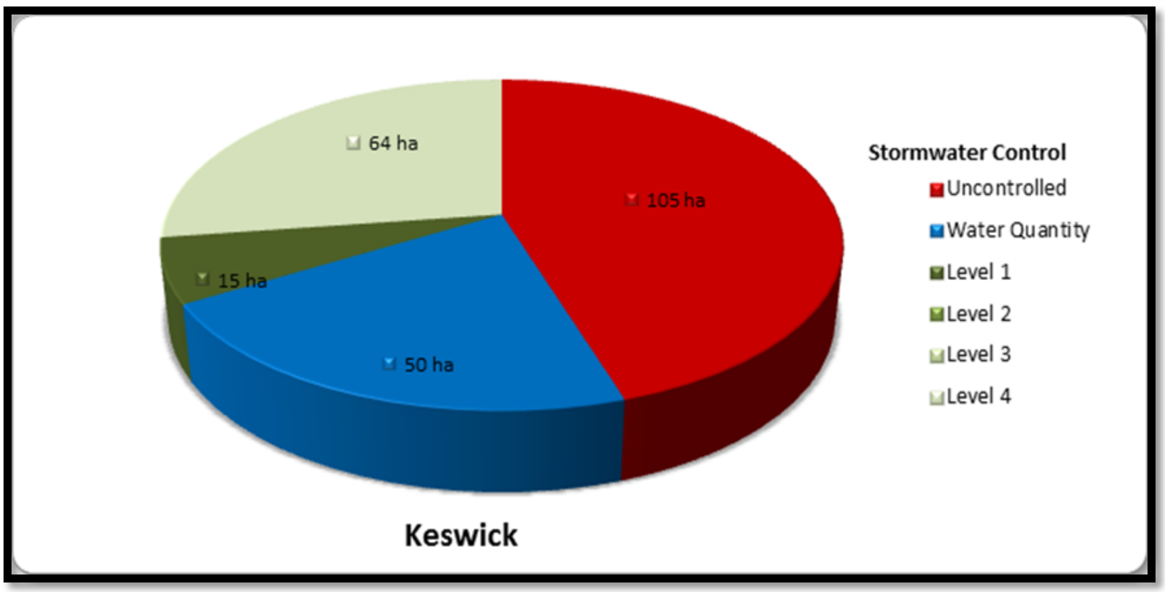

Figure 2-8: Area of Stormwater Control (LSRCA, 2010, p.70)

Since 1996, all new developments in the Lake Simcoe watershed are obliged to meet level-1 SWM facility requirements. According to the LSRCA (2010, p.71) there are currently 17 water management catchments in Keswick, of which 13 are uncontrolled, two are dry ponds, one is level-1, and the other is level-4 (Figure 2-9).

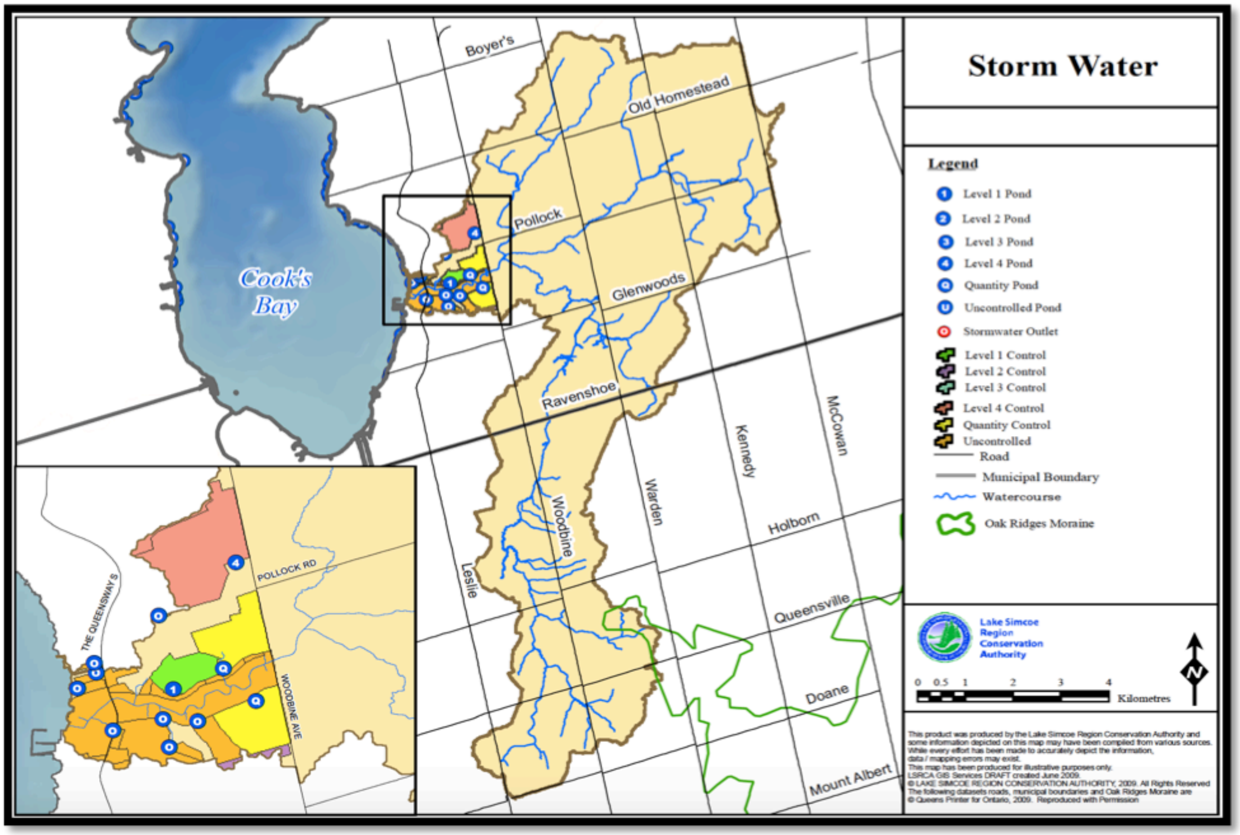

Figure 2-9: Stormwater Catchment Sites (LSRCA, 2010, p.72)

This entire methods section, from research approach to the study area has guided my findings. Everything from the place I chose to do my research, to the techniques used in gathering the data, has informed and influenced the next chapters of my paper: Results, Analyzing Themes, and Discussion. In the Results chapter, I present how Lake Simcoe is dealing with water quantity concerns and reveal the key leverage points I found in my CLDs. I then present the history of the local hydrology and hydraulics of Keswick. I establish how the respondents viewed municipal responsibility in SWM and the part urban density plays in runoff. Next I examine the process of SWM and flow of responsibility revealed in my interviews. This information will then be explored in the Analyzing Themes chapter.

3 Results

3.1 Is Lake Simcoe in danger of water quantity issues?

Gronewold and colleagues (2013) present a plethora of data on Great Lakes water levels, dating back to 1860, which suggests lake levels are decreasing. Hanrahan et al. (2010) propose that the lake levels are a far better indicator of hydrological health than the amount of over-lake precipitation. They add, since 1970 evaporation rates have increased by 25%, and lake levels are lower than expected by up to 2 meters. This is not the case with Lake Simcoe: "ultimately water levels in Lake Simcoe are managed by Parks Canada, the Federal Government, via the Trent-Severn Waterway…" (LSRCA, 2013b). Lake Simcoe has been regulated using the "rule curve" since 1918, "The rule curve serves as a target or guide for water levels throughout the year" (Parks Canada, 2009). First Nations tell a story that Lake Simcoe water levels are actually up over the last 100 years. Before 1920 the Chippewa were able to walk to Georgina Island, and they grew wild rice on the ankle deep water in between (Georgina Community Maps, n.d.).

Lake Simcoe is part of the Trent-Severn waterway and its levels are important for commerce. In this way Lake Simcoe shares many similarities to Lake Ontario, since they are both regulated by the rule curve and have many bordering communities. Gronewold et al. (2013) showed Lake Ontario (Figure 3-1) having declining water levels until 1918 and then stable from 1918 to present, with an average annual water level of 74.76 meters. This indicates that Lake Ontario, just as Lake Simcoe, is being maintained like a reservoir, for regional water balance purposes. The IJC (2012b) confirms that Lake Ontario is regulated at the mouth of the St. Lawrence waterways. Lake Simcoe does not have to worry about water levels as long as it is maintained in this way.

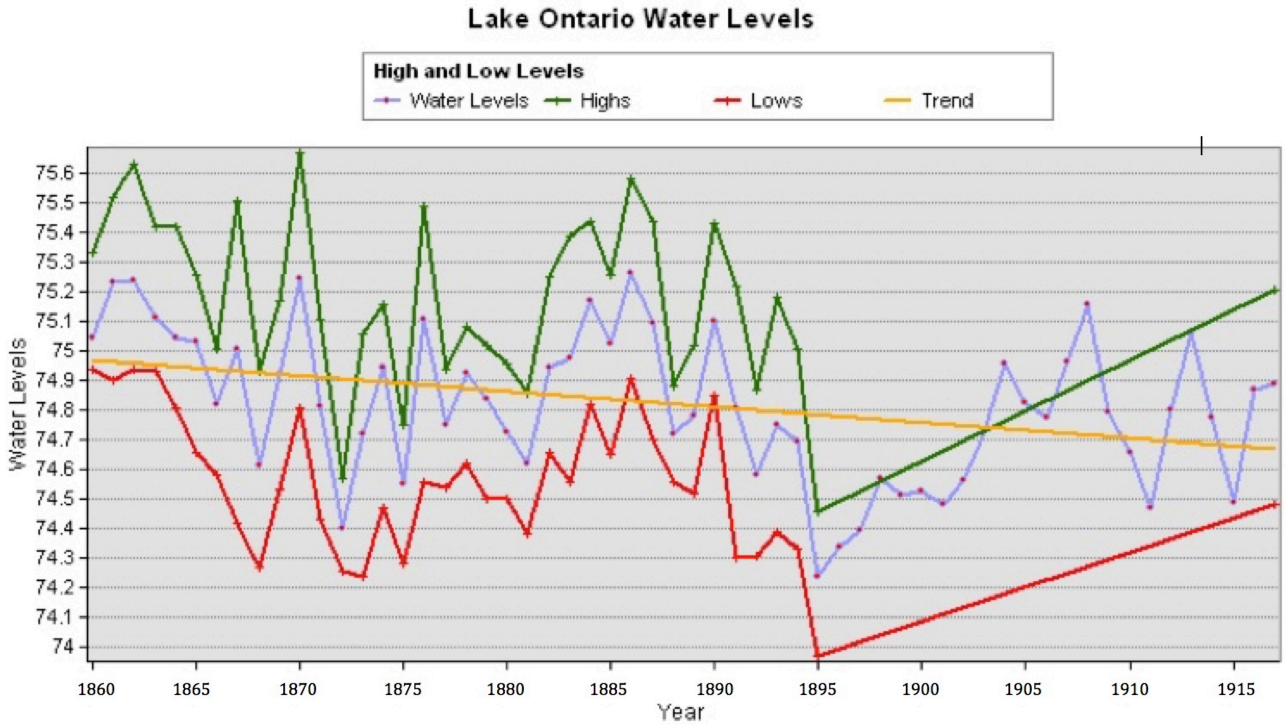

Figure 3-1: Lake Ontario Water Levels (Data obtained from Gronewold et al., 2013)

3.2 Creating Casual Loops

There is too much happening within the hydrological cycle to show every interaction. Through a comprehensive Causal Loop Diagram [CLD], I show the larger effects (i.e. water diversion, climate change, deep aquifer irrigation and urbanization) on elements within the hydrological cycle (Figure 3-2). Two of these, deep aquifer irrigation and urbanization, have an immediate effect on the hydraulics by increasing soil moisture and deceasing infiltration, respectively. This combination hastens the tipping point. Since irrigation usually happens in between precipitation events, it does not allow enough time for percolation into groundwater aquifers so the soil remains saturated, which creates runoff from the upper watershed. Normally, the lower watershed would help to infiltrate this runoff yet the lower watershed, in the MRSW, has become mostly impermeable surfaces through urbanization.

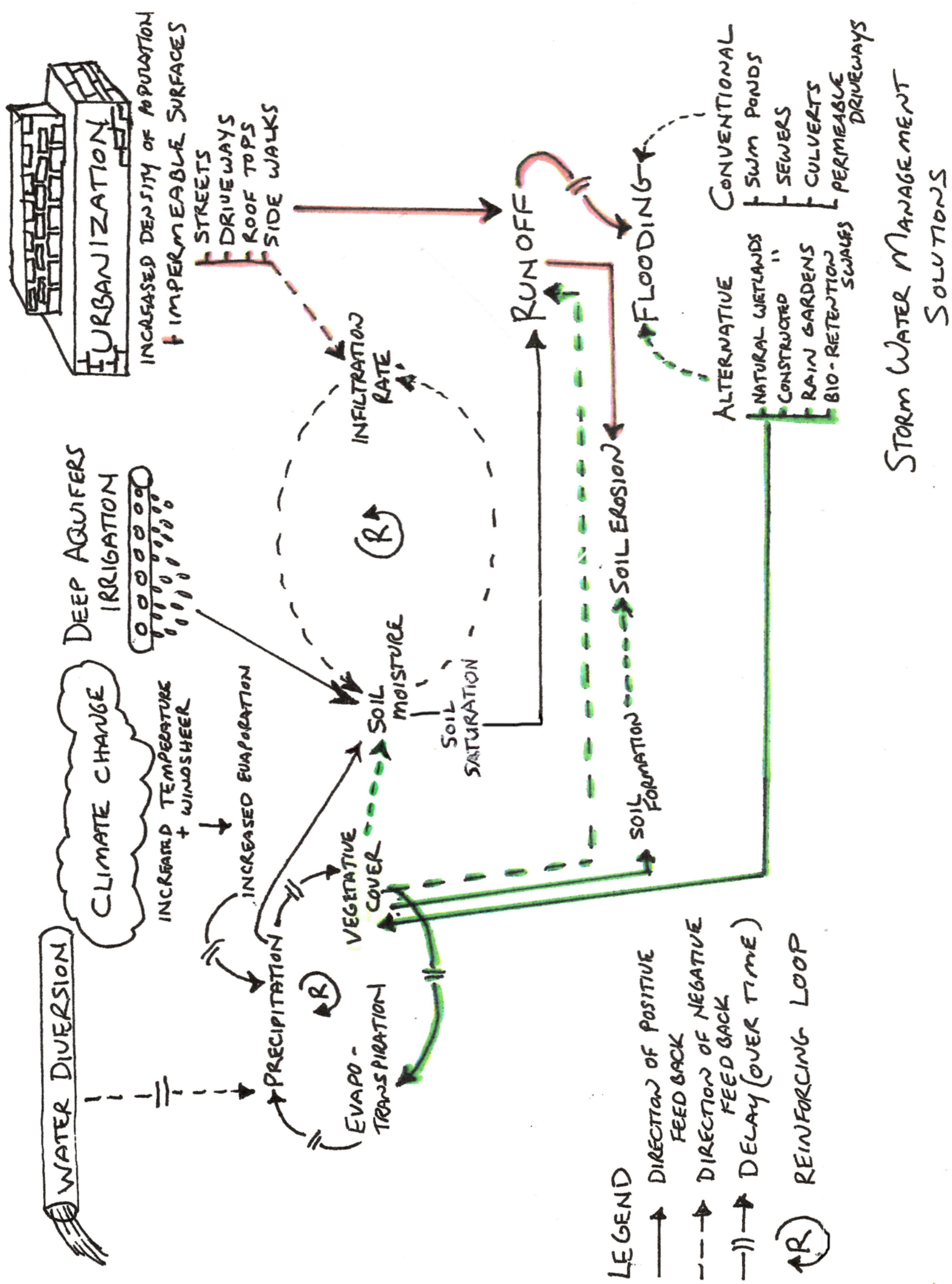

Figure 3-2: The Broader Perspective

I have broken down this broad illustration into several simple diagrams to aid in understanding the connections. The first loop is comprised of precipitation, vegetative cover and evapotranspiration (Figure 3-3).

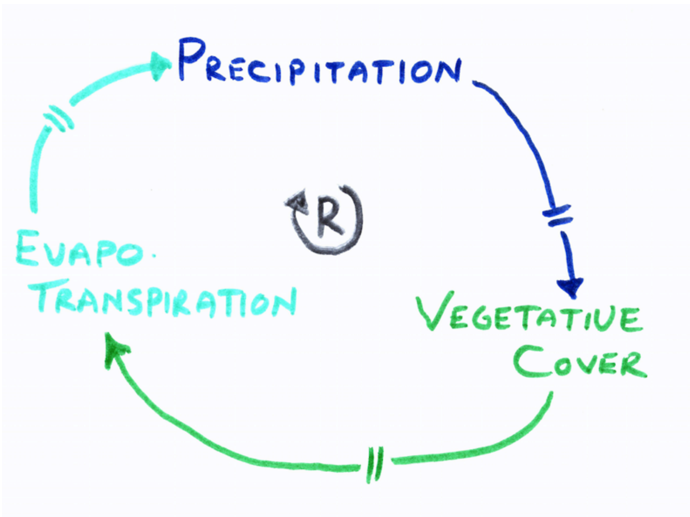

Figure 3-3: Growing Green

This is a long cycle, meaning that precipitation does not immediately increase vegetative cover. However, as precipitation increases in an area, the vegetative cover increases as well. This then increases the amount of evapotranspiration available, which creates a reinforcing feedback loop, increasing the amount of precipitation in the area. When water is diverted, it creates a negative feedback loop, decreasing the amount of precipitation in an area. Water can be diverted by drainage tubes in agriculture, municipal sewer pipes, bottling water, or exporting crops, to name a few.

In Figure 3-4 and 3-5, precipitation acts as an explanatory variable with soil moisture and infiltration as response variables. As the precipitation increases, the moisture in the soil increases as well, which decreases how fast water can penetrate into the ground. When the water stops infiltrating, the moisture remains in the soil and increases saturation. Vegetative cover acts as short-term storage and aids in decreasing soil moisture. However, once the vegetative cover cannot hold anymore, and the soil is saturated, infiltration ceases, and runoff ensues.

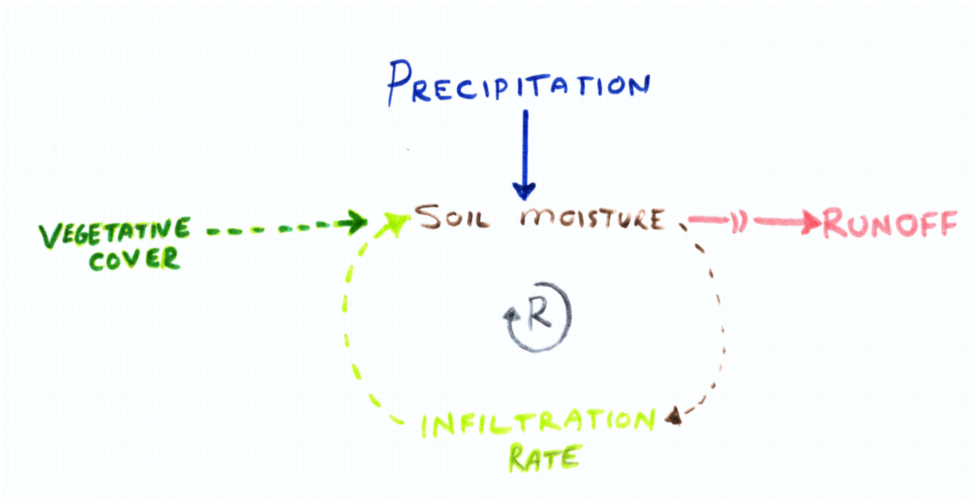

Figure 3-4: Soil Moisture and the Tipping Point

This creates a positive reinforcing loop culminating in runoff, referred to as a tipping point. In this case, the tipping point is soil saturation that stops infiltration into the soil.

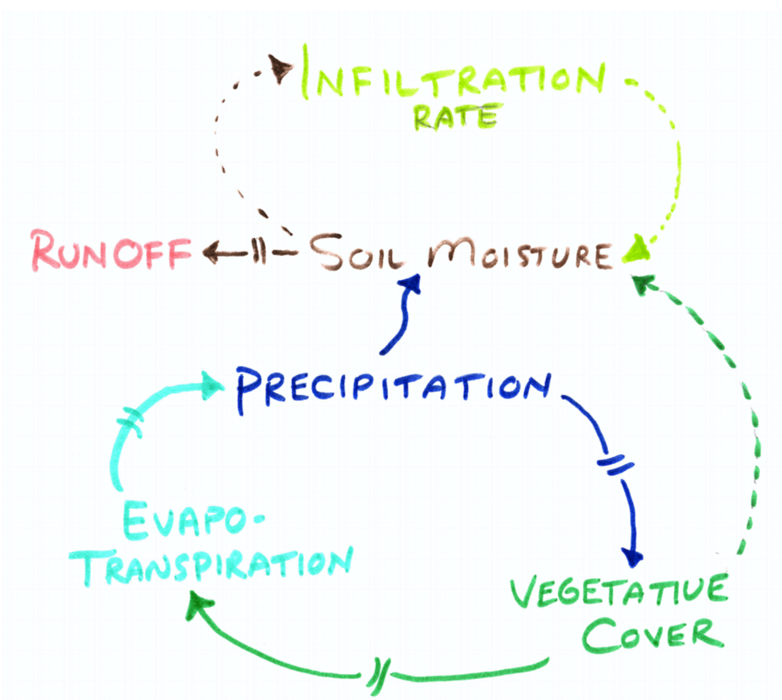

Figure 3-5: Effects of Growing Green on Soil Moisture

According to Lindsay and Zhang (2005), a tipping point is "...a state of the system for which temporary changes in the external forcing (dynamics) created a large internal response that is no longer directly dependent on the external forcing and is not easily reversed" (p.4881).

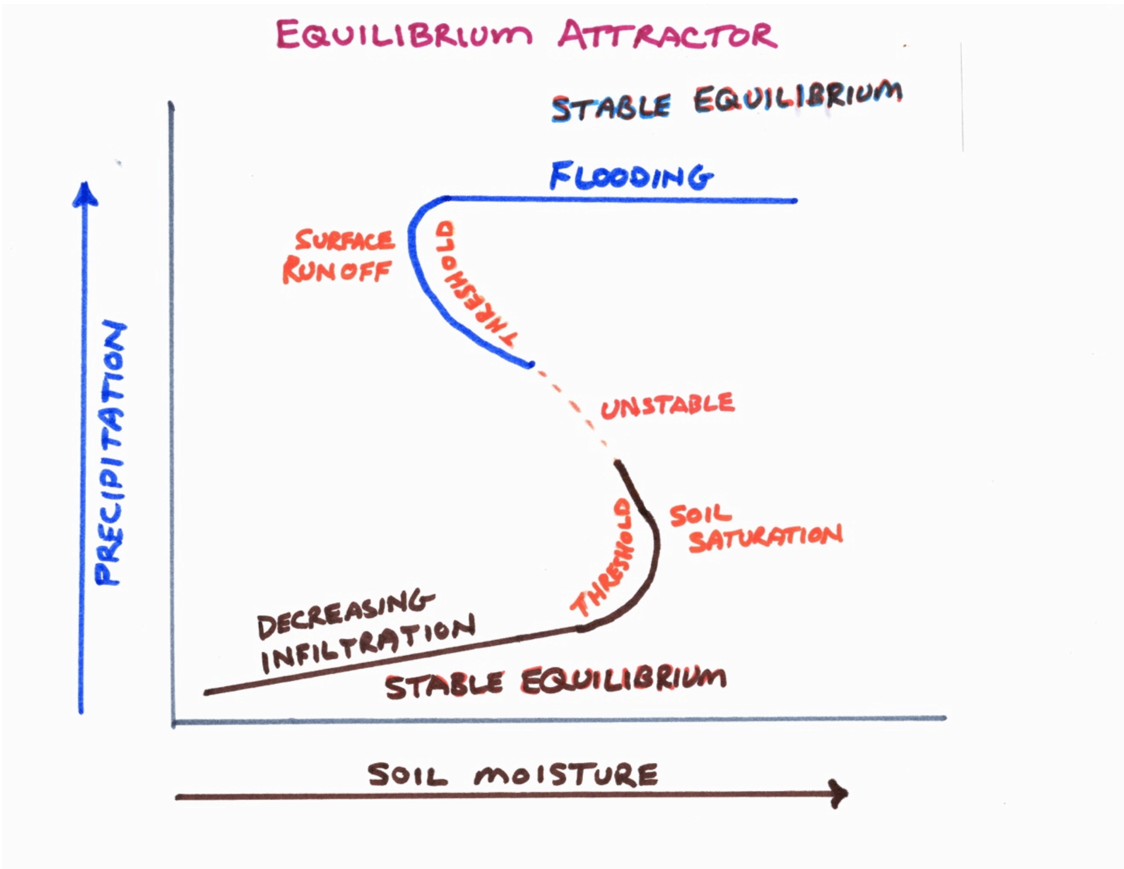

Figure 3-6: Eqillibrium Attractors

Simply, something happens outside the system that changes the state of something within; now the entire system operates differently and will not be changed back easily… the proverbial straw. In this example, the external force is excess precipitation, which changes the state of the system by decreasing infiltration until flooding occurs (Figure 3-6). As soil moisture and precipitation increase, there is a *threshold* where the soil is saturated, the system becomes unstable and changes to runoff. The new state is flooding, which continues until the precipitation decreases.

This reduction in porosity can be imitated by impermeable surfaces, which act as if they are saturated soil. If an area becomes impermeable then infiltration is not possible and runoff increases, which creates pooling or flooding in lower areas (Figure 3-7). The engineering response to this is conventional SWM systems.

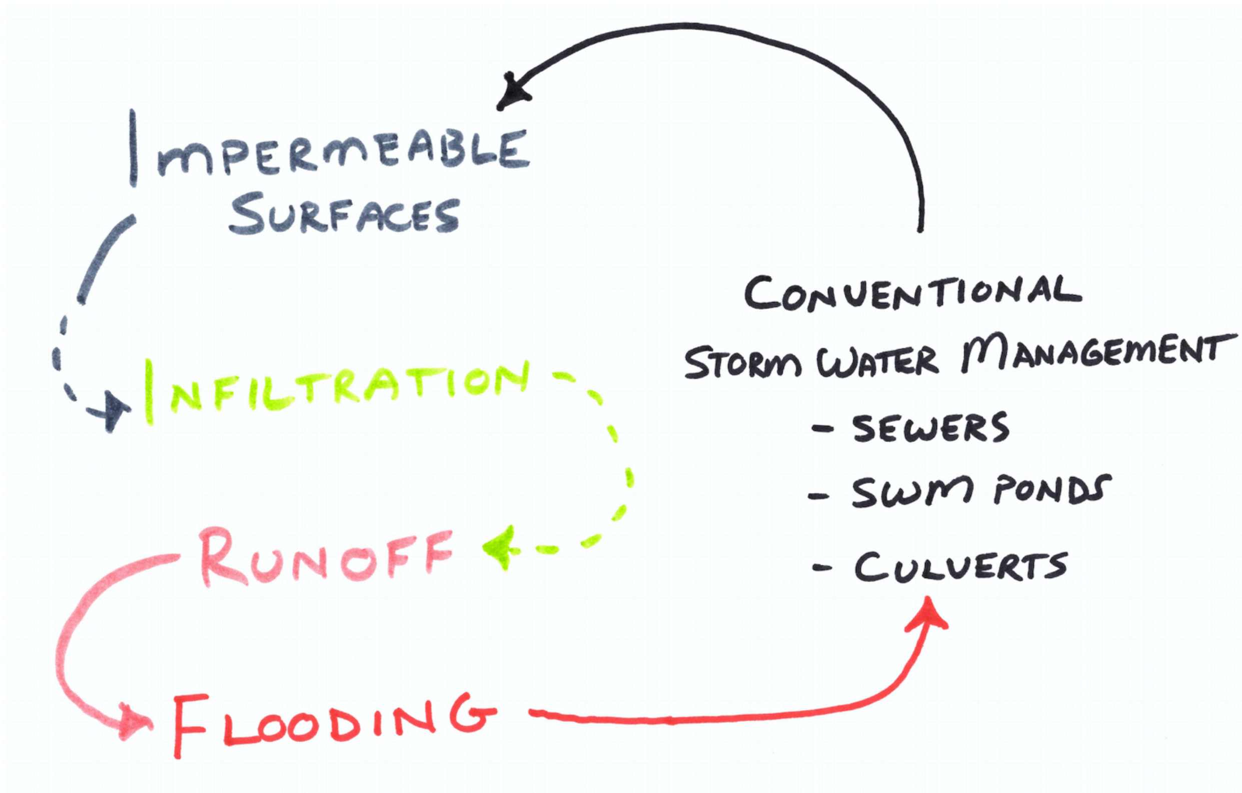

Figure 3-7: Conventional Stormwater Systems

A wetland acts as a natural relief valve in response to flooding. When there is excess runoff, it flows to the low points (i.e. wetlands) where the water is stored until infiltration catches up. As land becomes scarce, urban development builds on these wetlands, and in the process changes the grade of the land to suit the build. Since the 1980s, SWM ponds became the new wetlands, yet they were constructed to hold water and not infiltrate it. Adding vegetative cover to an area can aid in the uptake of excess water in the low areas by increasing infiltration and evapotranspiration, which decreases runoff. As well, vegetative cover secures soil formation reducing erosion caused by runoff (Figure 3-8).

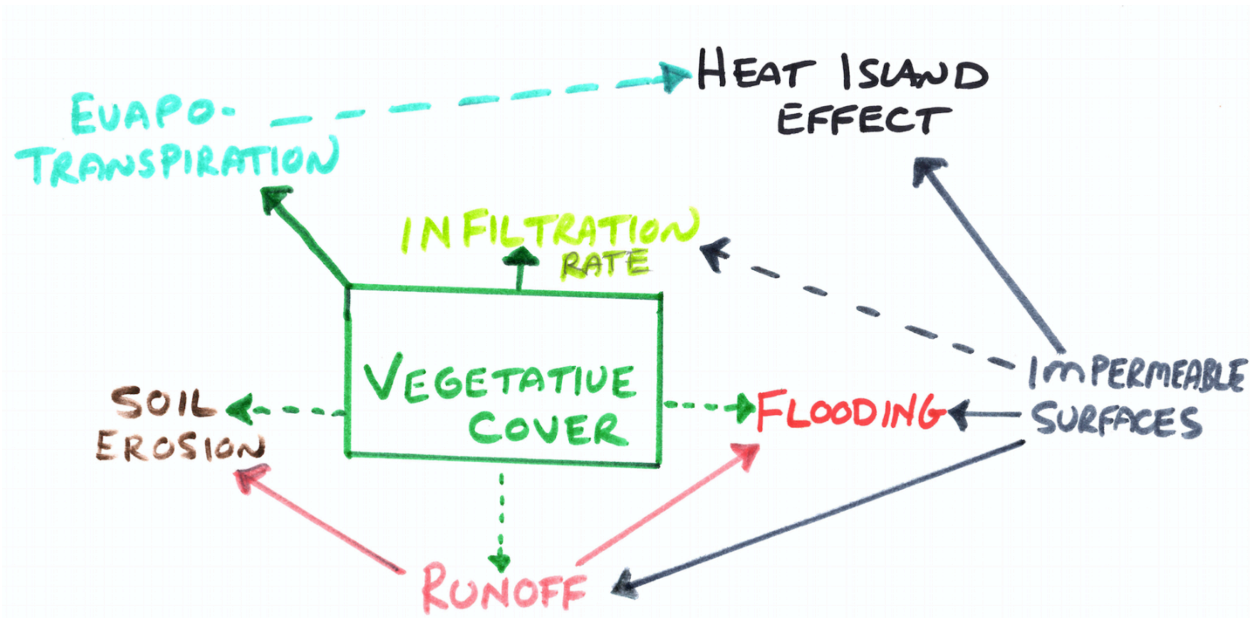

Figure 3-8: Benefits of Vegetative Cover

In fact, vegetative cover acts as an antidote to impermeable surfaces by reducing their effect and the consequences of runoff (Durán Zuazo et al., 2006). By analyzing the CLDs, I identified the key leverage points in SWM as vegetative cover and impermeable surfaces. There were several factors influenced by vegetative cover that alleviated the effects of impermeable surfaces, which were infiltration rate, runoff, soil erosion, and flooding. It became clear from this exercise that vegetation was more important than infiltration, and impervious surface did not cause flooding, it facilitated it.

3.3 Local Hydraulics, Hydrology and History

I was interested to see if there were land use changes in the MRSW since the 1980s that could have affected the hydraulics and hydrology of the area. First, I ruled out expected meteorological, geological, and climatic changes in the region, which have remained fairly constant in the Keswick area. The closest historical weather station was in Cookstown, Ontario, which showed the average annual precipitation in millimeters to be 825.7 from 1971 to 2000 and 826.3 from 1981-2010 (Canada, 2015).

The major deforestation in Keswick happened through agriculture beginning in the early 1800s. In 2008 the MRSW had the lowest levels in “forest cover and forest interior” (LSRCA, 2010, p.i) as well as “wetland and woodland” (LSRCA, 2010, p.1). Most development in the MRSW occurred on farmland that was previously cleared (Baskerville, 2015). An example of this is the subdivision at the corner of The Queensway South and Ravenshoe, which was built from 2002 to 2014 on existing farmland (Figure 3-9 & Figure 3-10).

Since the natural forest cover was already removed when development came to the area, the amount of vegetation did not change as much as in other places due to urban development. What has changed is the increase in impermeable surfaces. Baskerville oversees the development-engineering department in the Town of Georgina and tells the story of when flooding became an issue in Keswick:

> When Keswick was first built they were cottages. The land was graded so that all the water would flow from the front of the house to the back and then to the ditches and straight to the lake. This was fine while they were cottages since you would not come here in the wet seasons or winter… No one worried about drainage. The problem began when people started living here.
>
> Baskerville, 2015

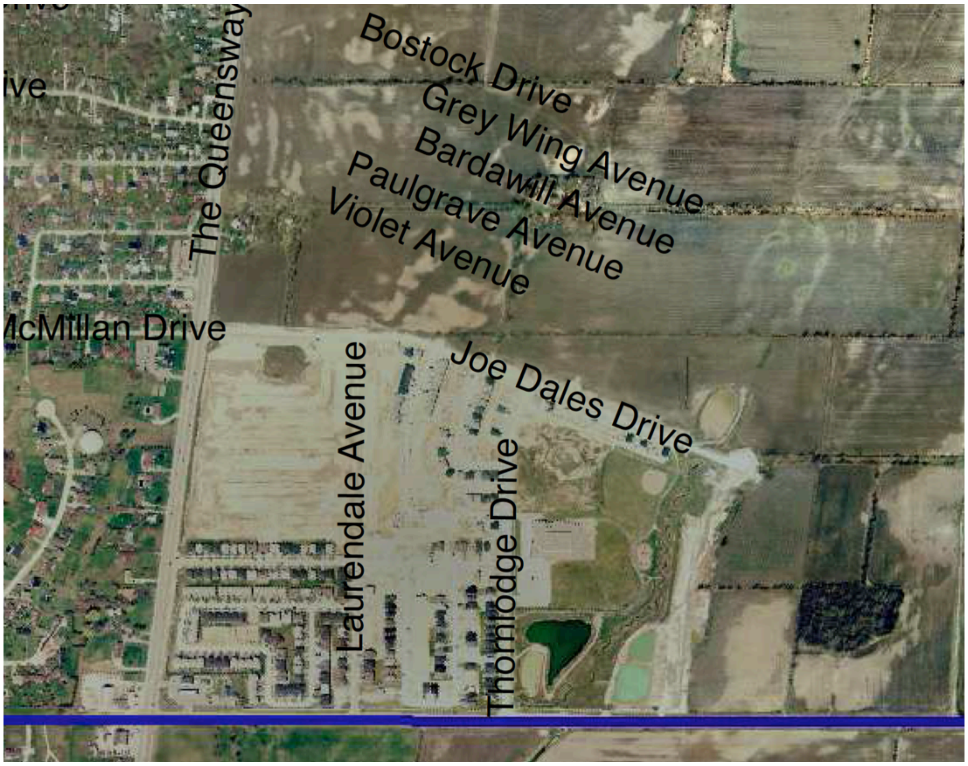

Figure 3-9: Queensway South and Ravenshoe 2002 (Williams, 2002)

Figure 3-10: Queensway South and Ravenshoe 2014 (Williams, 2014)

Another thing that changed over time was SWM. Dickinson (2015) noted that in the 1930s an engineer identified that the hilly landscape of Ontario made it impossible to prepare for large storm events, and in 1954 Hurricane Hazel proved him correct. In the 1970s both storm and wastewater were combined in a single system, which would flow together into the lake. This caused problems in large storm events; “there was so much water in the big storm events that it blew out the basements of the people downstream! This caused them to change the system, so that the sanitary sewers and storm sewers were separate” (Reinthaler, 2015). This is how the system was when Reinthaler began his career and he remembers that there was still too much erosion.

Dry ponds were used in the late 70s and early 80s to handle 5-year storm flows (Baskerville, 2015; Reinthaler, 2015). Every year there is a 20% chance for a 5-year storm event to occur, since on average they happen every 5 years. This is considered a large storm event yet there are still 10-year, 25-year, 50-year, 100-year and regional storm events, each more severe than the last. The dry ponds were soccer fields and parks that were graded lower than the development to create a low point for excess water to flow. The idea was that during these big events no one would be using the locations.

It was in the 1980s that SWM ponds were implemented to act as a buffer, so that water could be released more slowly into the system (Reinthaler, 2015; Baskerville, 2015). These are also known as wet ponds, since they are designed to hold the water and are usually wet. Reinthaler (2015) explains that, as an engineer, this was an easy way for “post-development flows to equal pre-development flows”. Once you figured out the amount of runoff a development would create, you created a pond large enough to hold those amounts. Sandhu (2015) remembers that this was the magic bullet that would solve problems with water quantity.

Yet, Dickinson (2015) recalls that the implementation of these SWM ponds gave communities the false confidence to build basements where basement were never built before; and when the reservoirs overflowed the basements began to flood. These ponds were meant to deal with normal events and not the more severe storms, “you cannot build enough SWM facilities to deal with all the water” (Dickinson, 2015).

It is a municipality’s responsibility to deal with SWM, and the Township of Georgina did so by asking a question:

> What are the preferred methods of controlling storm runoff and reducing the total phosphorus loading to Lake Simcoe from the developed areas of the community of Keswick in order to improve water quality while protecting and enhancing aquatic and terrestrial habitats in Lake Ontario?
>
> MMM Group, 2010, p.8

The answer to this question was dry ponds in the 70s. From the 1980s until today, the answer has been SWM ponds. Most of the conveyance systems in Keswick are open ditch culverts, with 15 wet ponds and 3 dry ponds, as of 2010 (Figure 3-11). However, because it is a question the answer can change, and it has since SWM ponds are no longer controlling sufficiently.

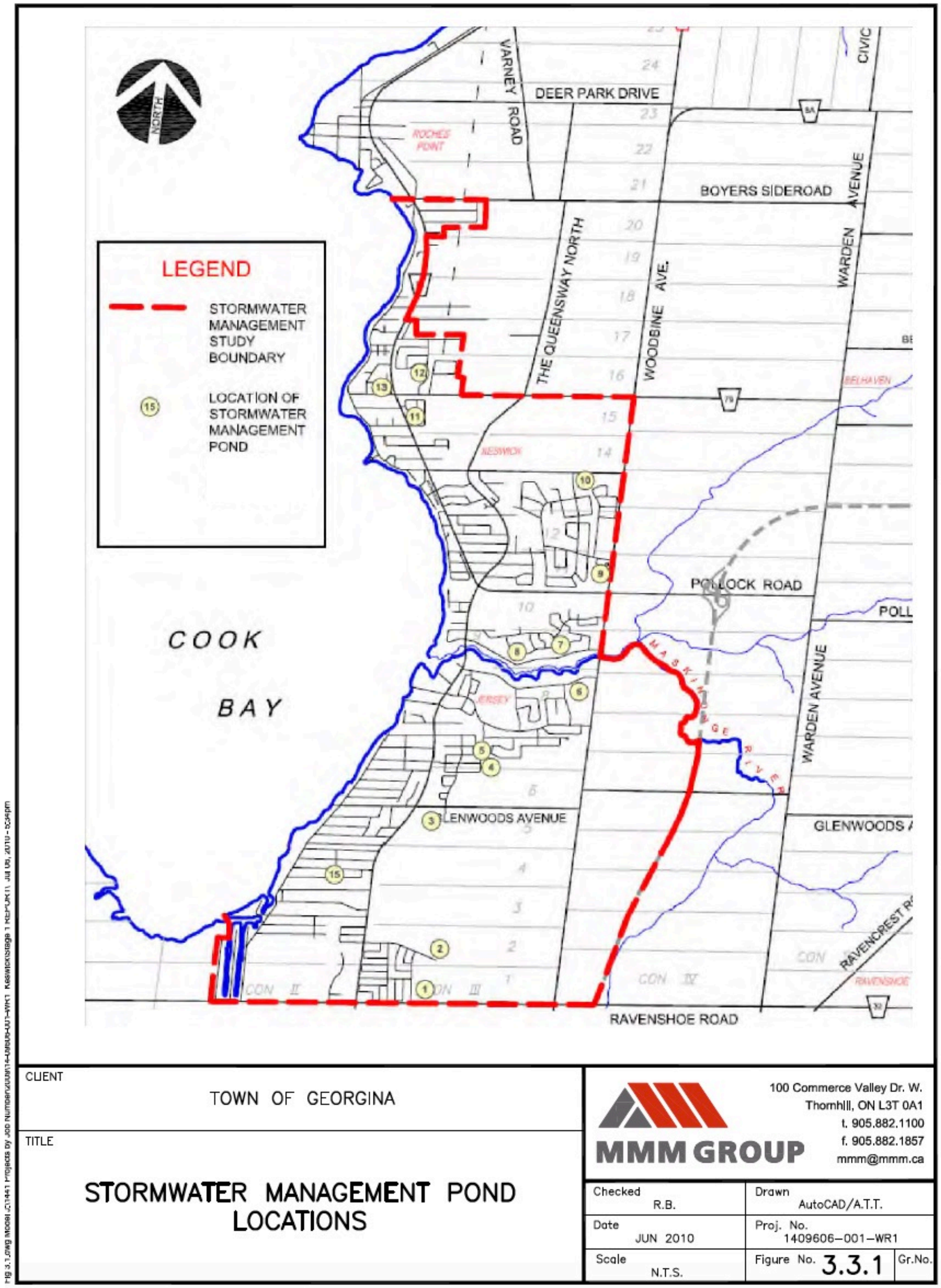

Figure 3-11: SWM Locations MMM (2010, p.12)

3.4 Is Urban Development Responsible for Runoff?

My initial goal was to show how an increase in urbanization affected the hydrological cycle. I expected to see a positive relationship between urban growth and increased runoff by looking at historical data. I wished to examine changes in vegetative cover, impervious surfaces, evapotranspiration, and runoff rates over many years. This proved very difficult for many reasons. Most data is worked into reports, which are open to the public, yet to get historical data that was not already worked into a report became complicated. Reports are official accounts of hydrologic changes, where unworked data can be used to tell any amount of stories, which cannot be controlled. As well, much of this data has only been collected for a very short time and in very few places. To compensate for this lack of data, I asked a question in my specialized interviews of whether respondents agreed or disagreed with an assumptive statement:

> The assumption is that urban density is growing, which causes an increase in impervious surfaces, decreasing vegetative cover and evapotranspiration. These changes can cause increased runoff during peak flows and flood risks in urban centers.

I deliberately used the word "causes" to imply cause and effect; is urban density responsible for flooding in urban centers? Put another way, if we build bigger cities, is it inevitable that flooding will increase as well? Most papers on hydrologic changes have an introduction that includes statistics on how fast the population is rising and how many more are living in urban centers (Hejazi et al., 2013; Jaroszweski et al., 2014; Okello et al., 2015; Rockström et al., 1999). This is because we link flooding with urban density, due to imperviousness. My causal loop diagrams prompted me to consider it may be more about vegetative cover than impervious surfaces.

Out of the 9 interviews everyone agreed that this statement is true; yet 8 of the respondents had a qualifier with the agreement. Hogenbirk (2015) thought the statement depended on geographic location of the urban center. Dickinson (2015) agreed with this and explained that the result of runoff downstream has less to do with impervious surface and more about where you build. Rivers are impervious surfaces, as is the flood basin when it becomes saturated, whether you build there or not. Therefore, building on a river's edge does not increase the flooding. The flooding would happen anyway, except now that we live there it becomes an issue. This relates to what Baskerville (2015) identified about Keswick; the flooding was always there and it was not a problem until people lived there during the flood season.

Six of the respondents spoke of the statement being no longer true if the vegetative cover is taken into consideration:

> Today with green roofs and other techniques… the statement is not always true today (Reeves, 2015);
>
> "When we remove vegetation and pave over natural pervious surfaces… water is not absorbed into plant material or allowed to infiltrate into the soil, we increase the volume of rain water (Setter, 2015);
>
> "I think the statement is true unless you do something to mitigate each of those factors… with the Eco Park [vegetative cover], we mitigated all of those things" (Developer, 2015).
>
> It is not acknowledged that over time, one big maple tree can do a great deal of evapotranspiration and rainfall interception (Reinthaler, 2015).
>
> "Good development planning, good development processing includes replacement of lost cover, lost ground cover, and compensation for that which cannot be replaced within the subdivision itself" (Baskerville, 2015).
>
> It is no longer true if you use LID development (Sandhu, 2015).

There was agreement in the interviews that the municipality was responsible for SWM. Keswick is the largest urban center within the MRSW and has 58% impervious surfaces. The town of Georgina is responsible to prepare for a 100% increase in Keswick's population by 2026. Antic (2015) recalls that in 1989 when she moved to Keswick, the population was 12,000 and now it is 24,000, which has doubled in 25 years. Currently, there are no LID sites in Georgina, even though there are many new developments. Keswick is exploding, and, “we are encouraging all the new development that are coming in to please give this [LID] some consideration” (Antic, 2015).

3.5 How Should Municipalities Prepare For The Change In Hydraulics?

Reinthaler (2015) noted that "Right now, municipalities have guidelines, policies and procedures in place that expect post-development flows to return to pre-development flow levels, in terms of flooding". The goal is to continue to keep this hydrological balance as density increases. Setter (2015) stated that right now the Town of Georgina still relies on ‘old school’ traditional SW Ponds, with the stormwater conveyed by curb, gutter, and pipes. It will be difficult to build enough SWM ponds and increase housing at the same time. As well, SWM ponds are no longer preforming in a way that supports the need for both quantity and quality control (Antic, 2015; Auger, 2015; Baskerville, 2015; Developer, 2015; Dickinson, 2015; Hogenbirk, 2015; Reinthaler, 2015; Reeves, 2015; Setter, 2015).

Reeves (2015) discussed that Lake Simcoe needs to stay cool, low in sediment, and clear and suggests, “municipalities need to further investigate whether the currently permitted systems are adequately treating surficial runoffs”. Developer (2015) adds, "They [municipalities] have to get away from building these massive SWM ponds that eat up land, have to be maintained, and are there to be looked after forever”. This is exactly what is being done, according to Hogenbirk (2015), the CAs wish to do away with wet ponds and replace them with meandering low flow channels (grassy swales) leading to a dry pond. Hogenbirk envisions upstream LID solutions infiltrating most of the water before it reaches the dry pond.

To make this change, municipalities are required to develop a “comprehensive stormwater management master plan” (Baskerville, 2015; Antic, 2015; Auger, 2015; Hogenbirk, 2015). This objective outlines short and long term plans for LID, laying out not only how they will implement the retrofits, but when as well. The hope is that when the master plans are complete, it should go a long way to mitigate future impacts (Hogenbirk, 2015). These municipalities are not going it alone; the LSRCA is helping the municipalities meet these objectives through "… training, education, and other outreach promotional efforts to the various municipal staff" (Auger, 2015). Baskerville (2015) expects to have the Town of Georgina's master plan completed very soon, and it is recommending LID solutions and retrofitting current SWM ponds to handle phosphorus levels. Antic (2015) noted that, "the Town's Planning Division supports it, the Engineering Division supports it. We want to see something happen" (Antic, 2015).

3.6 The Upper Watershed: What Goes Up Must Come Down

Dickinson (2015) noted that if you build in an area that already tracks the hydrology, as in the lower watershed, it is just a matter of returning the balance through increasing vegetation. However, any changes to the headwaters in the upper watershed, where there was previously good infiltration and not much runoff, will create an exponential change in the lower watershed. Another thing that happens in the upper watershed is agriculture. Baskerville (2015) proposes that more would be accomplished by treating the runoff from agricultural farms than any number of urban locations.

Baskerville (2015) recognizes a break in logic when it comes to regulations and funding. The farmers are not regulated yet the province supports them with funding, 20 million over 5 years. Farmers can use pesticides, herbicides, fungicides, and fertilizers, yet homeowners are greatly restricted with all of these products. One of the main reasons for LID solutions is to reduce phosphorous. Baskerville indicates that the greatest users of phosphorous in Georgina are sod farmers, with less than 7% of phosphorous coming from residential use.

My main interest is in water quantity. Baskerville contends that the local sod farmers are drawing water directly from the Maskinonge River for irrigation without permits,

> …in 2006 the river went dry and it never did recover… If you draw more than 50,000 litres per day, you need a permit. There are farmers that draw 10 times that amount without a permit but because they are one of the leading employers in the area it is often overlooked or difficult to enforce.
>
> Baskerville, 2015

That water is removed from storage, in the stream or the ground, and introduced to the surface flow. Once the soil is saturated it becomes runoff, bringing sediment and phosphorus to the lower watershed, which was seen in the previous causal loop diagrams.

3.7 The Process Of Stormwater Management

When any SWM system is put into a development, there are certain steps that need to be followed. Each step is dominated by an objective that is dictated by the person or department's mandates (Figure 3-12).

> The Engineering Division takes a development from a planning stage to the assumption stage. Initially, a developer submits an application for a plan of subdivision to the planning department. The Engineering Division reviews the submitted application considering the complete technical design including the design from the SWM perspective. Once the engineering is approved, the construction stage begins and we carry out inspections of the works and testing of the sewer system to make sure what was designed on paper has been built in the field. There are different stages of acceptance. Once the development meets the requirements of *Preliminary Acceptance of Above Ground Works*, there is then a 2-year maintenance period before the Town assumes it and Operations Division takes over. It is Operations that takes care of the maintenance and operating issues. Once it is assumed the Engineering Division no longer it is involved.
>
> Antic, 2015

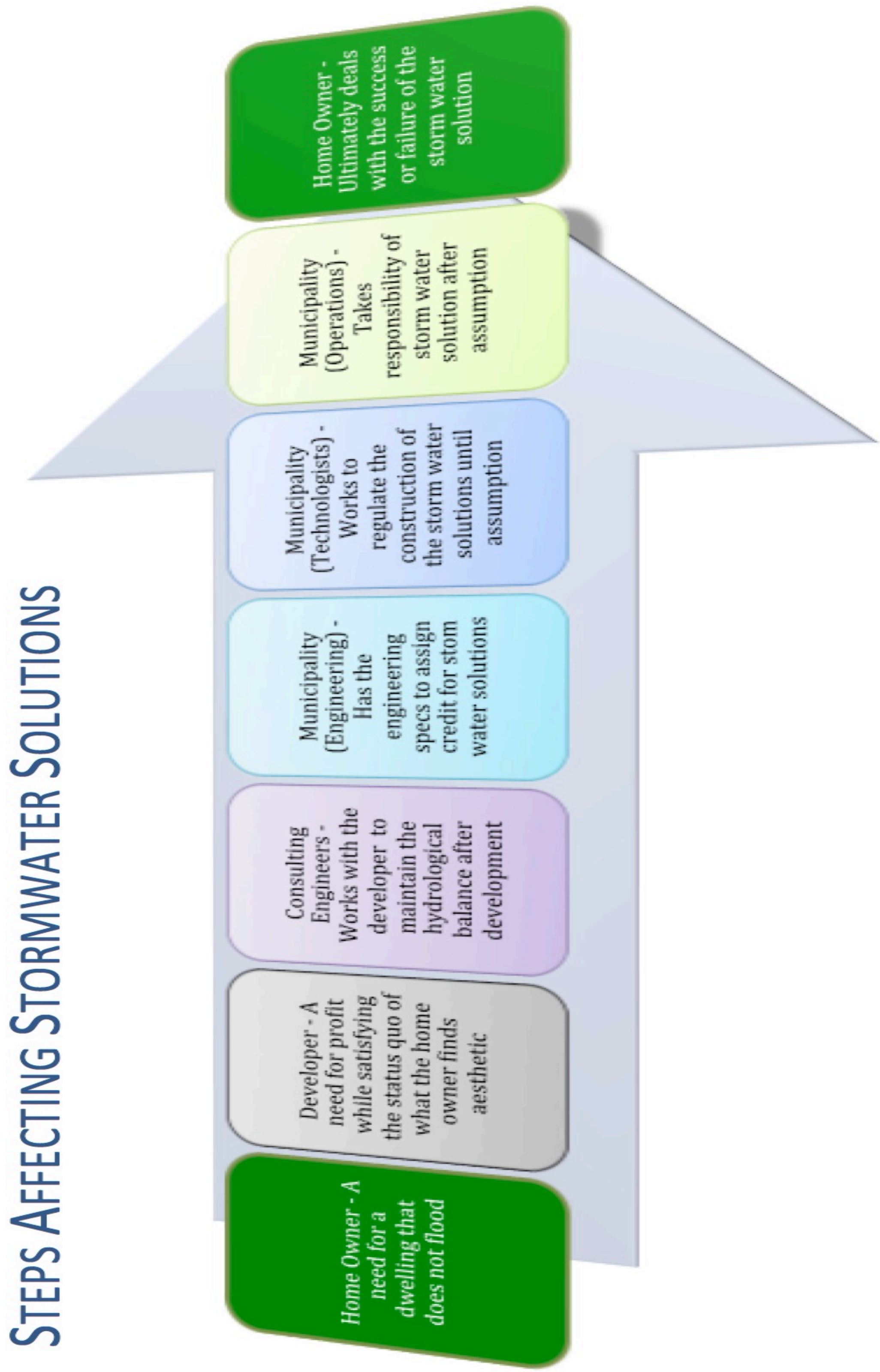

Figure 3-12: Stormwater Management Flow Chart

For the purpose of this paper, I highlighted the major players that came up through conversation in the interviews. Antic (2015) noted, “Planning has typically been supportive of LID techniques”, and my interviewees never mentioned them when speaking of barriers to change. The homeowner drives the need for development, and the idea of what is a beautiful home can lead the developer to build in a certain way (Antic, 2015; Baskerville, 2015; Developer, 2015; Hogenbirk, 2015; Reeves, 2015; Reinthaler, 2015; Setter, 2015). As well, the developer is driven by the expectation of selling the property. However, they rely on engineering consultants to navigate the permitting process and deliver an accepted SWM system, which returns the hydrological balance to pre-development numbers. The engineering and technology departments of the municipality have a bigger picture. A development is part of a larger SWM plan and needs to fit into the entire system, as well as work for the area. The Operations department is then responsible to care for and maintain the SWM system, as well as deal with the homeowners who ultimately live with the success or failure of the choices made before.

3.8 The Flow of Responsibility Within Stormwater Management

Through my research I put together a flow chart representing the perceived responsibilities of various players in SWM (Figure 3-13). As mentioned earlier there are power struggles in Canada's watersheds when managing natural environments, health, and economics. Environment Canada's (2014) mandate, in relation to LID, is to preserve and enhance the natural environment while conserving and protecting Canada’s water resources. As well, the Canadian government coordinates federal environmental policies and programs, which are passed down as Regulations and Acts. One of these Acts is the Canadian Environmental Protection Act, 1999 [CEPA-1999], which “makes pollution prevention the cornerstone of national efforts to reduce toxic substances in the environment” (Environment Canada, 2014b).

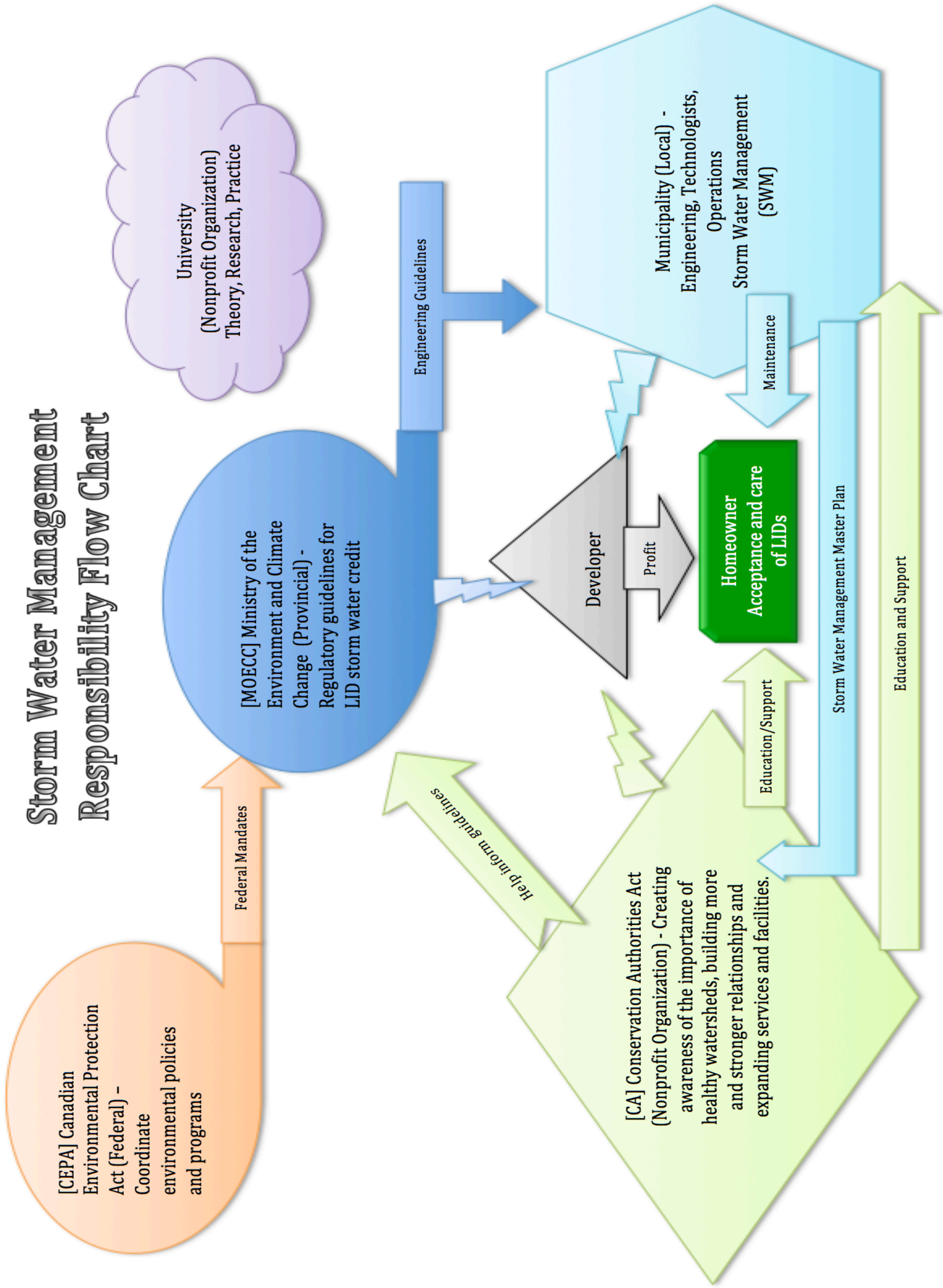

Figure 3-13: Stormwater Management Responsibility Chart

3.8.1 The Province

CEPA-1999 is passed down to the provincial level where the Ministry of the Environment and Climate Change (MOECC) works with municipalities and conservation authorities. One provincial mandate affecting the Town of Georgina is the Lake Simcoe Protection Plan. Baskerville (2015) sees the Province of Ontario pushing this plan without truly understanding the difficulties that lake Simcoe has, which includes financial constraints: "it is the province of Ontario that wants this to happen so they need to financially help the smaller municipalities" (Baskerville, 2015). A barrier that is identified is the perception that the Province does not truly listen to those that are implementing the plans: "they did not listen to recommendations made by the engineers and planners. Instead they proceeded with their own agenda and created their own document that they imposed on the municipalities. They created guides and deadlines and offering nothing in exchange" (Baskerville, 2015).

Hogenbirk (2015) recognizes that "The province has a host of priorities and with the change to the MOECC (climate change) the whole issue of LIDs controlling at the source is crucial to resiliency". Auger (2015) revealed that the idea of controlling at the source is not a new idea and was discussed in the 1994 and 2003 MOECC *Stormwater Management Planning and Design Manuals*. These manuals help the municipalities give the builder credit for SWM, which will aid them in returning the property to a pre-development water balance. According to Antic (2015), "credit is how much quantity from the total required water retention can be accounted for and subtracted from the size of the SWM pond". However, LIDs are not quantified yet, so the developer does not get credit for his low-impact solutions, and the SWM pond stays the same size.

The credit for LIDs will be coming in the new 2016 SWM Planning and Design Manuals (Antic, 2015). Hogenbirk (2015) trusts that the absence of this new guidebook is the overlying barrier to LID moving forward. Right now the only guidelines the municipality can follow are the current guidelines that support a level 1 SWM pond (Antic, 2015). This is a one size fits all solution that can work anywhere and on any property in our environment. Antic (2015) admitted that when we receive that 2016 guidebook "then we would have the concrete design manual to implement the technique and would have the confidence to say you can implement that technique" (Antic, 2015).

3.8.2 The Conservation Authority

The conservation authorities (CA) assume the role of permitting agent to the developer, educator for the municipality, partners with the province, and enforcement with the homeowner. However, the CA recognizes itself as the catalyst of the LID initiative,

> We are also working very closely with the MOECC on the evolution of the LID discussion …The GTA CAs (LSRCA, TRCA and CVC) are trying to keep the MOECC, and other greater Ontario CAs efforts very succinct and consistent, by keeping the same individuals from each organization involved in various LID efforts advancing new guidelines, standards, policies and requirements for Ontario.
>
> Auger, 2015

Auger (2015) advocates the CA has a role "to support the change in traditional approaches to SWM, and inspire developers, private industry, public and municipal partners to think about bringing more and better LID practices within the whole SWM concept". They accomplish this by "training, education, and other outreach promotional efforts to the various municipal staff, consultants, and public working and living in the Lake Simcoe watershed" (Auger, 2015).

Certain interviewees agreed that the CAs are very interested in moving LID approaches to SWM forward, from theory to practice (Antic, 2015; Developer, 2015; Reinthaler, 2015;

Setter, 2015). Setter (2015) noticed that, “the LSRCA has been recommending and requiring more bio-swale techniques and greater use of plant material on smaller infill projects”. Reinthaler (2015) stated that the LSRCA “would like to see LID techniques rather than SWM ponds since they feel they will have a more overall benefit on phosphorus reduction”. However, while the CA uses words like *inspire* the respondents say *pushes* and *requires*. The same people that agreed that the CAs were the catalyst of change, also spoke of the requirements, regulations, and permitting process involved in that change.

When asked if it would take longer to get approval for an alternative method rather than a SWM pond, Developer (2015) said "yes, yes it will take longer and is one of the frustrations with doing anything new or outside the box”. As a developer (Developer, 2015) it felt “almost like them versus us, which it shouldn't be but it always comes down to that”; those that wish to develop and the authorities that grant permission.

3.8.3 Municipality

All in all, the municipality was by far the most talked about entity within the SWM system. Some of the municipal barriers to LIDs were seen as: sticking with old ways of thinking (Antic, 2015; Developer, 2015; Reeves, 2015; Reinthaler, 2015; Setter, 2015); the permitting process (Setter, 2015; Developer, 2015; Reinthaler, 2015); and maintenance of the new LID solutions (Antic, 2015; Hogenbirk, 2015; Reinthaler, 2015);

When it comes to the municipalities sticking with old ways of thinking, it is insinuated by interviewees that they do not wish to change, which was far from the truth. Guidelines help the municipality make SWM decisions. Reinthaler (2015) is a consulting engineer working for developers, and he discusses how the municipality is following current guidelines that have suggested SWM ponds since the 1980s; municipalities are not in control of the guidelines (ICF

Marbek, 2012). Reeves (2015) agrees that right now municipalities mostly use dry ponds and SWM ponds for flood control purposes. The municipalities are concerned with quality control yet the current system is not doing the job, and there is pressure on the municipality to upgrade their SWM ponds to filter out phosphorous (Baskerville, 2015). Reeves (2015) would like to see the SWM pond replaced with a naturalized system that is aesthetic and handles both water quality and quantity. The dilemma is that replacing SWM ponds becomes an expensive endeavour, which most municipalities cannot afford.

Setter (2015) thinks one thing holding the municipality back is that they do not wish to scare away developers. If the municipalities put too many restrictions on development then they may not come to the area. As well, it is difficult for the municipality to suggest LIDs to the developers without the proven technology. At this time there is no way to know what guidelines to enforce that will ensure low liability. The municipality's decisions will affect people living in that community 50 years from now (Antic, 2015). Reeves (2015) stated that with LID solutions "there is only about 10 to 15 years of tracked success and most engineers need a longer amount of tracking, usually 50 years".

The approval process can be a major barrier to change. Reinthaler (2015) warns us that the approval process must go through the Operations department who might not know how to maintain such a system and will resist it. Maybe the answer is for the municipality to, "hire an LID expert so they can look at every single proposal from that perspective… Or they could send their key staff to be better qualified in LID solutions" (Setter, 2015). Antic (2015) sees the need for education going well outside the municipality, "you need the buy-in from everybody: the community, the developers, the builders the contractors, and the municipality". She agrees that education is important and that contractors and developers need to be brought up to speed as well. However, if a LID solution is accepted it needs to be implemented properly.

3.8.4 Operations

This leads us to the maintenance of the LIDs and how this is perceived as a barrier. Antic (2015) advises that Operations need to be sold on the idea of LID solutions and “the biggest issues from Operations are maintenance and maintenance costs”. How much money will it cost to maintain the LIDs once they are in place? It is Operations and their budget that will be required to maintain these new environments and no one is sure of what that entails. The change in the maintenance schedule and the general unknown causes concern: “municipally there is still some resistance of putting LIDs in right of ways. Simply from a maintenance point of view, they are concerned since traditionally they are used to curb and gutter” (Hogenbirk, 2015); and “as for maintenance, how do you clean out the LID technique…we know how to clean out a SWM pond” (Antic, 2015). Actually, according to Sandhu (2015) who is the manager of Operations at the Town of Georgina, currently no one is trained in Operations to maintain SWM ponds; “when SWM ponds kicked in everybody thought we hit the jackpot, but nobody…when I say nobody I mean out of the 444 municipalities in Ontario hardly 10-15 percent have a SWM group in Operations” (Sandhu, 2015).

When there was an attempt to implement the replacement of SWM ponds with using multiple-site naturalized solutions in parks and schools, it hit barriers. For example, parks departments only want to deal with parks and do not wish infrastructure on park property (Reinthaler, 2015). Antic (2015) believes this will change when there are examples of successful LIDs and more understanding of how to care for them, “the municipalities need case studies to sell it to the Operations department and to be able to sell it to the developers” (Antic, 2015). In the past the biggest push back came from the Operations department "yet they seem to be more receptive now" (Antic, 2015). Baskerville (2015) stated, "the Operations department is moving forward under the leadership of Gagan Sandhu. He has the drive not to be guided by the status quo" (Baskerville, 2015).

Sandhu is the Operations manager for the Town of Georgina. He explained to me that when a development is purposing a SWM solution, Operations are brought into the conversation during a commenting interview period: "this starts with Development Engineering, but Operations, Planning, anyone that can impact the final takeover is involved" (Sandhu, 2015). The SWM system becomes Operations responsibility "when the development is approved for assumption. When we take the maintenance over and are responsible for the infrastructure (water pipes, stormwater pipes, LIDs, waste water, SWM ponds)" (Sandhu, 2015). Sandhu has never been involved with LID maintenance but assumes they cannot be more expensive to care for than SWM ponds. With Operations it is a "resistance to change. Everybody would like to come in Monday to Friday and do the same thing again and again" (Sandhu, 2015).

3.8.5 Developers and Consulting Engineers

When a development is in the planning stage a SWM plan is made to return the area back to pre-development flows. Reinthaler (2015) explains that it is the consulting engineers responsibility to figure out storm sewer capacity, which is based on a 2-year, 5-year, or 10-year storm depending on your municipality. Once pre-development flows are known then modeled flows are made to understand post-development scenarios. This will tell the engineer how big the SWM pond needs to be. These SWM ponds take approximately 5% of the land, which cannot be built on. Reeves (2015) stated that engineers like math and measurements, as well as proven technology, so if "we've been doing this for 50 years why change". The SWM pond allows water to be measured, in and out, and this makes calculations easy since the focus of engineering is to make the calculations.

Sandhu (2015) supposes it is the consulting engineers job to help the developer understand the overall benefits of LIDs. This is happening in the U.S. where consultants are excited, since they are having successes. Reeves (2015) noted, "we [Ducks Unlimited] have several systems in and functioning as they should. …Everything has worked to or above desired outcomes on all metrics measured". Further, you cannot devalue the importance of the "other benefits, like added wildlife habitat and aesthetic benefits, which are harder to measure" (Reeves, 2015).

Antic (2015) says, "The developer must provide their own engineers design and it would be up to us to review those designs and let them know if it is acceptable". Putting in a naturalized system is a gamble for the developer. The SWM pond is a sure thing but if the alternative solution does not work as planned then "you have wasted your time and money" (Developer, 2015). Setter (2015) thinks the developer is getting the message that an alternative solution equals delayed permits. With all of the permitting nightmares the conservation authorities still wish to see the developers put in aesthetic, lot level, conveyance systems with both quantity and quality treatment controls (Auger, 2015). If the municipality needs examples of how naturalized systems work then they need to use these techniques on municipal properties: "it is tough to tell the developer to build LID if the municipality is not building with it" (Baskerville, 2015).

There are many examples of naturalized systems being put in, and I will discuss several a little later in the chapter. The naturalized systems are so successful in Winnipeg that,

> The builders in the city of Winnipeg are now required to build naturalized as part of their development. The extra cost to build the naturalized system is

> paid by the builders; however, they then sell the homes as waterfront properties. They receive a premium of 50 to 100 thousand per lot that backs onto their stormwater system.
>
> Reeves, 2015

In the end a developer just wishes to build houses and make a profit (Reinthaler, 2015), and the people they build for are used to curb and gutter landscapes (Hogenbirk, 2015).

> Often it is complaints from the public. For example the rural ditch cross section is making a comeback but aesthetically people didn't like them. People expected to see a lawn that slopes down to a curb, with a boulevard and a sidewalk. When you pay a lot of money to move into a subdivision and you have low flow ditches people get upset. Our whole sense of aesthetic has to change.
>
> Setter, 2015

3.8.6 Community and Homeowners

The community is made up of varied opinions and cultures but generally "people want to see improvements but they do not want to see change" (Reinthaler, 2015). Mark Setter told me a story that sums up how people have certain preconceived ideas of beauty, wealth, and nature:

> I will tell you a story that a professor told me. He was working in the Middle East for a king. They were designing a new city. They drew up the designs, and showed the king their representation of what the new city would look like. The King was amazed at how beautiful it looked, but then asked 'where are the hydro poles'? The designers told the king that the town was so modern that the wires were buried under the ground and you would not be able to see any hydro poles. The king was furious. He needed to show his people a modern city with electricity and they would expect to see hydro poles!
>
> Setter, 2015

Hydro poles were a symbol of success, civilization, and modern convenience. Over time we develop perceptions of what things should look like, or how things should work based on personal and cultural expectations. Closer to home, we see wealth as the size of our yard with "our present attraction and attachment to manicured lawns" (Setter, 2015). However, these lawns are "a monoculture that has very little diversity, yet it dominates our lives...through, time, money and effort. Lawns take a great deal of water, fossil fuel, and fertilizer to maintain...” (Setter, 2015).

Hogenbirk (2015) noted “the long-term viability of LIDs on private property is questionable” since new owners can remove them if the reason is not understood or is not attractive to them. Antic (2015) discusses that some community members “…are very receptive and want to be environmentally friendly. While others do not want to maintain it, or even have it on their property”. Antic thinks that if you force it on people then the chance of acceptance is “50/50”. Van Welter (2015) discusses that people can react to what they like, and do not like, yet may not be able to articulate these ideas, so even if you give them a choice they relegate to the expert. A similar but related dilemma is the people’s mental models of what places should look like are deeply engrained, and even if these spaces no longer have a purpose in their life, like parks, people struggle with any change. Hogenbirk (2015) stated that when building in the right-of-way “there could be problems yet if you make it attractive it should be fine”. Antic (2015) felt that having a naturalized stormwater system “would make things look less like a concrete jungle” and would bring interest and colour to the area, as well as “be aesthetically pleasing and increase health and mental state” (Antic, 2015).

It is important to educate the public and introduce the naturalized designs in a way that showcases it “as an environmental friendly community” then “there is a lot of positive feedback” (Hogenbirk, 2015). Van Welter (2015) believes “it’s about how we create a new relationship that is not just wild and not just human but is a magical interface between people and nature”. In the past it was important to move the water away from your house in the most expedient way possible, “people have a hard time with bio-swales because the idea is to keep water in the middle. When you are being flooded you don’t want the water to stay, you want the water to go away" (Baskerville, 2015). Antic (2015) adds that the repercussion of an LID system not functioning properly is the flooding of private property and naturalized systems work best when they are maintained. Reinthaler (2015) thinks "if you can get people to buy into the idea of bio-swales and taking care of them it is not a con for the municipality". Another advantage is people will come to understand the benefits of the upkeep and take ownership.

However, some maintenance will be outside the public comfort or understanding:

> Some of the native plants that are best suited to these types of systems…needs to be burned in a control burn every 3-4 years. This is not normal to people so they think they want cut grass but this brings Canadian geese, which people do not want.
>
> Reeves, 2015

With the data organized into categories it is time to analyze the findings to discover trends and patterns that will speak to my research question. It is also within the "Analysing Themes" chapter that I will present case studies, which will begin to show how the themes play out in real life scenarios and their complexity. It is in this next chapter that pros, cons, and barriers will begin to reveal themselves, and discussed in the final chapter.

4 Analysing Themes

Some major themes, which spoke to the pros, cons, and barriers of LID, surfaced during my analysis of the results. I will attempt to capture these themes in this chapter to identify patterns and paradigms. Once these patterns are revealed, they will be explored and further discussed in Chapter 5.

4.1 Status Quo

One of the main barriers to change that surfaced in this research was status quo, “we've been doing this for 50 years why change” (Reeves, 2015)? Reinthaler (2015) thinks "it is just human nature to go back to what you have done before, the way you're comfortable, the way you're used to doing it. They go back to storm management ponds since that is the way it was done for the last 20 years". Baskerville (2015) trusts “it is the dinosaurs of the department that do not wish to change their ways”. Sandhu (2015) admitted earlier that most people just wish to do the same job they did the day before, so it is reasonable that “parks departments only want to deal with parks and don't want infrastructure on park property” (Reinthaler, 2015).

Many think the reason for status quo is a lack of education, and that the municipality rejects change “…since the municipal staff are not up to date with modern practices” (Setter, 2015). Baskerville (2015) reveals that at one time he was one of those dinosaurs yet through workshops and education he saw the value. It is not a lack of interest; Antic (2015) shows that there is a desire to change within the Town of Georgina; “we do not have any LIDs within the subdivision developments in Georgina at the moment but we would like to implement them here” (Antic, 2015).

Our concrete ideas, of how things should be, keep us from changing. It is not only the municipalities that are used to doing things a certain way, communities are used to seeing lawns and curbs, so incorporating naturalization projects are challenging. There is a need to change the way we see beauty: "we've got to do a major shift in thinking and we still have a long way to go before it becomes standard" (Reeves, 2015); "we may have to reverse our thinking so that a successful and pleasing subdivision has gentle ditches (bio-swales) not manholes and catch basins everywhere" (Setter, 2015).

4.2 Cost of Doing Business

Sandhu (2015) mentioned, "The developer might find it too costly, or too long a time period". Yet, believes this to be a misconception, "that is, you don't end up paying more for the development; there are benefits to it" (Sandhu, 2015). It was thought that the cost of installation and maintenance would be a barrier for the developer and municipality, respectively. Dan Reeves from Ducks Unlimited was very kind to give a price comparisons, however these are generalized prices and should be taken as examples only. A conventional system is slightly more expensive to install due to the materials needed (i.e. rock and geotextiles), while the naturalized system costs more for the first three years to establish (Reeves, 2015b). Over all, the two systems are approximately the same price over the first three years and maybe slightly less expensive (5-10%) for the naturalized system. The Credit Valley Conservation found a cost savings in using LID rather than conventional surfaces to aid in water infiltration, "Credit Valley Conservation's new parking lot was constructed with permeable pavers, providing a cost savings of $90,000 compared to a conventional asphalt lot with catch basins" (ICF Marbek, 2012, p.6).

The difference lies in the cost of maintaining each system. According to Reeves (2015b) a conventional system costs $10,048 per hectare/year to maintain, while the naturalized system is $2,100 per hectare/year. There is a need to burn the native grasses used in the naturalized system every 5 years at a cost of $6,500 per hectare and, may cause budgeting concerns with the municipality since it is not a yearly cost. Please remember these are generalized costs and are to show the contrast between systems. The cost of maintaining LID for the Operations department is not problematic. Sandhu (2015) noted that they already have financial issues with current SWM ponds since his budget does not go up when a new development is built. Even though there are many new roads, pipes, and SWM systems to care for, operating costs are deemed to stay the same. What should happen is "…when the municipality assumes the pond they make a financial report to council. Every report has financial implications and for SWM ponds they say there are no financial implications. How can there be none, you have to maintain them". Sandhu told me that when they assessed the needs of the Town of Georgina's 32 ponds "…it costs almost one million dollars per pond for clean up or fixing it" (Sandhu, 2015).

The municipality of Georgina has the ominous responsibility to retrofit the current SWM ponds, which comes with a very large cost, "the low-end cost was something like 19 million dollars and the high end was more money than we can afford" (Baskerville, 2015). When I asked Hogenbirk (2015) if there was funding to help the municipalities with this cost, he noted, "The municipality is responsible to implement the plan though in some cases there are funding sources available through the conservation authority to help with retrofits". Further to this, he suggested that the municipality must decide where the greatest need is and start there in a phased approach. He feels that the return on investment will be great, which in turn will spur the desire for more change. A solution to this was carried out in Richmond Hill, where the municipality "looks after their SWM ponds but they introduced a stormwater charge on the tax bill that is supposed to sustain the ponds and become a utility, like water or wastewater" (Sandhu, 2015). Baskerville (2015) is looking higher to the provincial level for help with the funding to implement such an important and expansive endeavour. For Antic (2015) the cost is not about maintenance, but she admits her concern is in the liabilities and lawsuits if the LIDs do not function as intended.

There are a lot of hidden costs in conventional SWM. Land is becoming increasingly valuable, “land values have risen faster than inflation in recent years” (Reinthaler, 2015). It takes approximately 5% of land from a subdivision to build a SWM pond, which has no other use than stormwater control (Antic, 2015; Reinthaler, 2015), “if you can add savings on the land part and make that available for housing, or something else that is income generating, or usable land, it is overall better planning and better use of land” (Reinthaler, 2015). This is not to mention that with a naturalized system,

> …[Builders] receive a premium of 50 to 100 thousand per lot that backs onto their stormwater system. It is beautiful habitat for the people, the environment is healthier, the builders make more for their properties, and the city has less maintenance once they assume it.
>
> Reeves, 2015

4.3 Permitting Change

This brings us to the permitting process, which was presented less as a barrier and more as a fact. It is the responsibility for the engineer to develop a SWM system that will be approved, “in general, developers want approvals and they do what is necessary to get those approvals” (Setter, 2015). Antic noted, “for a developer to implement LID, they would need to carry out various testing to determine soil composition in order to provide a design. It is a lot of extra work … not to mention an increased cost for the developer” (Antic, 2015). Setter (2015) agrees with this statement and has seen permits for alternative solutions denied in favour of a SWM pond.

The uncertainty of a naturalized system “causes delays in the approval process and the developer then does not want to do it. If there are hassles with the approvals why bother” (Reinthaler, 2015)? Municipal engineers that are not current, or afraid to take on new challenges make the developer put in both the LIDs and the SWM pond for back up (Antic, 2015; Reinthaler, 2015; Setter, 2015). So the developer goes with what they know, “we know it works, we know how to do it, we know what it costs...let's put that in" (Developer, 2015). I clarified with the Developer (2015), on whether the permitting process was slow due to the municipality or the conservation authority and he answered, “it is both! The municipality is the one who will end up owning the system and they don't want any liability for it. That is why they always go back to 'build me a pond'”. Reinthaler agrees that, “the conservation authority pushes the idea of LID and other SWM concepts but the municipality must take care of it. It is like someone giving you a puppy for Christmas, you are stuck caring for it even though you did not necessarily want it" (Reinthaler, 2015).

The permitting authorities wish to know how things are going to be improved, and without these innovative solutions having a track record they are often denied, “there were many times we came close to that fall-back position” of just putting in a SWM pond (Developer, 2015). Developer (2015) noted that innovations would never have a track record because they are by definition ‘new’. Setter (2015) has seen the frustration of the permitting process and thinks when a LID plan does not meet the requirements of the conservation authority they should “work with the engineers on staff and the consultants to work on a solution that might be a hybrid or a combination of the two that would get approval from the conservation authority”.

4.4 SWM Ponds: From a Wonder To Wonder Why

The status quo in SWM today is the utilization of SWM ponds; “most of the systems put in are conventional systems” (Reeves, 2015) and although it may be that “SWM ponds are the conventional choice” (Developer, 2015), do they still function the way we need them to today? At one time the SWM pond was the silver bullet to handling water quantity. However, there is more to health than reduced flooding. Baskerville (2015) noted, “SWM ponds do not replace lost cover, they are a hole that water goes into” and we remove vegetative cover, which recycles and filters water, to dig that hole. Where an LID is trying to mimic more what is happening in the natural environment; SWM ponds are not designed to put water back into the ground (Reinthaler, 2015; Setter, 2015). In addition, the LID is infiltrating the water in situ “on an individual scale”.

Antic (2015) explains that for conventional SWM ponds “the clean out costs are considerable and then comes the question of where can you dump the accumulated sediment from the pond cleanout?” These SWM ponds need to be maintained and municipalities that have these conventional systems, “…need to look after them, costing them enough money annually that they are now realizing maybe this is not the way to go forever... maybe we could do something different" (Developer, 2015). Dickinson (2015) discusses how you cannot build a SWM pond to handle all levels of storms. As weather patterns are changing and storms are becoming more severe, it is unknown if current SWM ponds can handle the new quantities (Antic, 2015). Gagan Sandhu (2015) explains that in conventional methods “you cannot predict the size of the pipe or the pond because how can you predict rainfall!” When you deal with a naturalized system, the majority will infiltrate so you do not have to convey 100% of the precipitation.

These ponds do not handle quality control either (Reeves, 2015). Dickinson (2015) argues, “Ponds have not done the job. The travel time is still high so the large particles are caught, but the fine particles go through and it is the fine particles that carry the pollutants”. The new way of thinking is towards naturalized solutions for new development, "they can be constructed wetlands that are aesthetically pleasing, good for the environment, home to wildlife, and treat the water better than a dry pond” (Reeves, 2015).

4.5 LIDs are Messy

How do you measure LIDs effectiveness? Reeves (2015) supposes a "barrier for engineers is the inability to measure naturalized living systems…naturalize systems have other benefits, like added wildlife habitat and aesthetic benefits, which are harder to measure". In my interviews I asked what the best three LID solutions would be, and a typical response was "it depends on a lot of things" (Developer, 2015); "naturalized systems are not one size fits all like SWM ponds" (Reinthaler, 2015); "a good system is a combination of many systems working together, a mix of systems" (Reeves, 2015).

Due to this uncertainty, there is a tendency for permitting bodies to insist on still putting in a full SWM pond on top of your naturalized systems, which was coined by Reinthaler as 'belt and suspenders': "the problem now is the developer lays out all the LIDs and… I still need a pond as big as if I did not have any LIDs" (Hogenbirk, 2015); "Right now we say 'why don't you try some LID on these sites here but you still need to have the same quantity in your pond'" (Antic, 2015); and "sometimes the municipality demands you put in a SWM pond as well as your naturalized system". Besides being extremely expensive and totally redundant, there are concerns with doing this, "if the LID works to expectation then the SWM pond will not be able to function properly since there is not enough water moving through it and it will stagnate" (Reinthaler, 2015).

4.6 LIDs are Not For Everyone

Confidence begins to wane since LIDs do not work in every situation, and there is a great deal of factors that need to be considered. The distance from the water table, the type of soil, and the gradient of the land are all-important factors when deciding a naturalized solution. For example, the town of Georgina "is full of clay, has no drainage and a high water table. We believe that LID is the way to go but how successful we will be depends on the soil conditions" (Baskerville, 2015). Reinthaler sees LIDs as a set of choices, "you have to look at LID as a toolbox. You have to take a look at different tools for different situations. You are not going to use a screwdriver to do the job of a hammer" (Reinthaler, 2015).

There are some places you do not wish the water to infiltrate such as, "areas with salt restrictions where you cannot introduce any more salt to the groundwater table" or "if you have an area that has a potential for a spill and you do not wish to infiltrate those chemicals into the water table" (Hogenbirk, 2010). In these cases the water would need to be pre-treated before entering the ground, "you cannot just say that's a good idea so let's put them in every subdivision because there are a lot of reasons that certain types of LID's might not function" (Hogenbirk, 2015). Developer (2015) proposes we should "let the land decide which method to use, which is what we should do" (Developer, 2015).

4.7 More Houses or More Green Space?

Reinthaler (2015) spoke of legislation in Ontario called 'Places to Grow', which "wants to have a density of 50 people per hectare". Reinthaler feels it is difficult to crowd houses together and still have a naturalized system. Already "the Oakridge's Moraine and the Greenbelt have made land for single family homes finite" (Reinthaler, 2015). Hogenbirk (2015) concurs that there is "some resistance from developers that say on one hand you are telling us that we need to cram in a certain number of houses per hectare and on the other hand you want greenspace and LIDs" (Hogenbirk, 2015). Reinthaler (2015) wonders where would you put naturalized systems in townhouses or other high-density housing. Hogenbirk (2015) reports that in the United Stated houses have bigger lots and the implementation of LIDs are more successful, "Intensification and much more condensed urban areas make implementation of

LID's more challenging. One of the recommendations in the CVC/TRCA LID design guide (2010, p.3-6) is to "use open space or clustered development", which suggests smaller lots and shared parking. These areas would be surrounded or connected by swaths of green spaces.

4.8 Controlling at the Source

There is a shift in thought beginning, where SWM should not be end of pipe but over an entire area through lot level conveyance controls (Auger, 2015; Reinthaler, 2015). As early as 1994, the MOECC was talking about handling stormwater in-situ although it was referred to "as lot level and conveyance control" (Auger, 2015). Hogenbirk (2015) noted that "we are returning to at-source-controls, similar to the time where most drainage was handled by road-side ditches…the whole issue of LIDs controlling at the source is crucial to resiliency. Building up resilience to these events" (Hogenbirk, 2015). If you infiltrate the water upstream then the runoff downstream is minimal (Hogenbirk, 2015; Sandhu, 2015).

> Use fewer pipes for the conveyance of water. Allow water to flow over a variety of permeable surfaces. Give it more opportunities to get into the ground. The use of bio-swales and old fashion gentle ditches vs. sloped boulevard with curbs and catch basins is a good start.
>
> Setter, 2015

Baskerville (2015) suggests that by infiltrating the water it "is polished before it gets to the lake", which is an advantage of a naturalized system. Before SWM ponds, communities used soccer fields as dry ponds yet they were not cleaning the water. Baskerville (2015) suggests "we build them [soccer fields] with infiltration galleries right into these areas it will be very successful [as filtration systems]".

4.9 A Healthy Dose of Greens

The Keswick area was striped of most vegetation before urbanization, which would have created a region where runoff was prevalent. Since there were no permanent residences it did not create a problem. Then two things happened simultaneously, the people began to live in the area year round and more infrastructures were built, increasing impervious surfaces. This would have accentuated the problem. Dickinson (2015) thinks, “If you were able to create vegetative spots that gathered the runoff it might counter act the impervious area”. Initially he was not convinced of LID within highly urbanized areas, however, he noted that Credit Valley Conservation has built LIDs that actually control the summer and spring events. The goal is “if you can put in enough of them in to turn back the clock so you negate the effects of the small to middle storms" (Dickinson, 2015). Setter (2015) is a strong believer in increasing vegetation as a means to improve water health:

> Plant more trees, shrubs, and groundcovers. Plant material absorbs filters and cleans water. Plant material is a source of food and habitat for animals and insects. The more plant material and more variety of species will contribute to a more bio-diverse environment, which is healthier.
>
> Setter, 2015

4.10 More than Just Water

There are others benefits to increasing the amount of green. When subdivisions are constructed, the area is usually wiped clean with vegetation returned after the construction is finished. Reeves (2015) makes an excellent point that in the past we would find a lake or stream and build within that environment.

> At the end of the day what I would love to see is to build a city properly, with the water and not on top of it. Why can't we have a system where we build streams and naturalized ponds and then build around them?
>
> Reeves, 2015

When you build in this way “there are benefits to mental health and stress relief because they are beautiful with trails surrounding them, and access to naturalized parks” (Reeves, 2015). When you build a constructed wetland they "are aesthetically pleasing, good for the environment, home to wildlife, and treat the water better than a dry pond" (Reeves, 2015).

Auger (2015) speaks of retrofits and new developments needing to be aesthetically pleasing. However, the list of acceptable LIDs is much more limited than the idea of beauty, so either people need to limit what they find beautiful or the LID selection needs to expand. Setter (2015) explains some of the side benefits of building with the environment rather than replacing it, "we should be saving more of our hedgerows since hedgerows are biological corridors for all sorts of things…that's how organisms move from one forest to another"; as well, meadow grasses are the greatest victims even over wetlands, since meadows "are the habitat for our song birds that use the meadow grass as their nesting place. Many species of insect call the meadow home" (Setter, 2015).

In this way we look at naturalized systems to be more than about water. If a naturalized system is created with the environment, the benefits can be wide spread. Along playing fields "by planting trees we give shade for those children playing soccer" or when a SWM strategy is connected to a park with trails and paths "it can promote exercise for children" (Baskerville, 2015). If we engineer naturalized storm management systems only to move the water into the ground, then it may not have a goal of biodiversity. This engineering viewpoint is where the function is the focus. Yet what if we had biodiversity, aesthetics, health, and other soft-measures as an intended function, rather than just by-products?

4.11 Education, Guides and Tools

The CA understands education as delivering guidance and examples of how LID can be implemented. According to Auger (2015), the LSRCA are conducting a series of workshops for municipalities "focused on case studies from Minnesota, via Jay Michels from Emmons & Olivier Resources Inc. (a consulting firm from the United States), that have had a lot of LID implementation experience". Further, the conservation authority has developed "a Stewardship Priorities and Opportunities Tool (SPOT). The intention of this tool is to start a conversation of where opportunities for LID implementation exist, and how to tackle any constraints identified" (Auger, 2015). Baskerville (2015) agrees that the workshops are valuable since his workshop "was a big success and all the managers that attended were on board, and some took a 360 degree turn in favour of implementing LIDs" (Baskerville, 2015).

It has been noted that the municipality needs to have better education and training regarding LID. Baskerville (2015) agrees and has committed to training his staff that already have "their construction inspection certificate dealing with erosion control and the next is LID certification. I need my staff to be educated on the changes to ensure the future success of LID implementation" (Baskerville, 2015). Antic (2015) considers that the education needs to trickle down to the construction crews, "the contractor needs to understand the design and the importance of constructing the works to specifications, and even be certified in LID techniques, before they can install low-impact development" (Antic, 2015).

For the Operations department, it is improved training in how to care for any system that is implemented. Sandhu (2015) considers to educate is to "motivate staff and make them aware of why we are doing it. Give them ownership and that they are a part of it. There is a need for motivation, awareness and increased competencies" (Sandhu, 2015). For Developer (2015) education is learning from projects already accomplished, which means that we need to take risks and try new things. He feels that education is valuable "but ideally you should have examples of situations where it did work before so they could look at it and say 'yes look it does work'" (Developer, 2015). Education to Setter must include the communities where the LIDs are implemented,

> I believe we need to give people a better understanding of what a 'watershed' is, how it works and how water is traditionally conveyed. People need to know where there water goes and how it gets there. Engineers and Environmentalists have not done a good job so far. When people have a better understanding of anything they make better choices.
>
> Setter, 2015

CA's in Ontario are banking on LID guidelines as being the panacea for stormwater troubles. Right now "the 2010 CVC/TRCA LID Planning and Design Guidelines (Version 1.0) provide some details on sizing ratios, construction considerations, and specifications for LID" (Auger, 2015).

Auger feels the main difference between past efforts and today is that there is more "emphasis and priority, and we are changing the culture on how SWM is being implemented now" (Auger, 2015). The 2016 guidebook will create the boxes to tick, as well as the credit obtained by the developer in lieu of a SWM pond, "we are relying on the MOE to give us that guideline book… Then we would have the concrete design manual to implement the technique and would have the confidence to say you can implement that technique" (Antic, 2015).

4.12 A Unified Front

I need to give credit to Barbara Antic who identified the need for everyone to be unified in their efforts for LID solutions, "you need the buy in from everybody: the community, the developers, the builders, the contractors and the municipality… It is getting everyone on board moving forward with it: Planning, Parks, Operations, Capital Construction and Engineering" (Antic, 2015). Sandhu (2015) also understands "every change needs to be managed, and part of eco management is training, education, promotion, awareness". The community needs to see manicured lawns as wasteful and gentle flowing ditches as aesthetically pleasing (Hogenbirk, 2015; Reeves, 2015; Setter, 2015), and the provincial government needs to help fund municipalities to retrofit old systems to improve health of people, lakes, and streams (Baskerville, 2015).

4.13 Shifting Paradigms

Van Welter's specialty lies in exploring the changes in society that inhibit people from finding their best life and "unlocking hidden potential" and her company, Ascentia, has operated since 1998 (Ascentia, 2013). I asked Van Welter, "What do you feel is the cause of the entrenched paradigm problem?" Van Welter feels that "we in society have relegated our responsibilities to experts" and that somebody else always knows better, "the CA must know better, a government must know better, developers must know better" (Van Welter, 2015). Furthermore, we will never find solutions as long as "we are just going to recycle the same old thinking" (Van Welter, 2015). The expert opinion is only part of a larger process. Van Welter explains that there is a need for forums of new thinking, new ideas, new perspectives and new conversations, where expert panels include everyday people, "these forums require new methodologies and learning techniques that help all the participants co-create new lenses to see new possibilities" (Hilary, 2015).

4.14 Case Studies

4.14.1 Humber Flats, Richmond Hill

My specialized interview with Developer (2015) was associated with developing the Humber Flats project in Richmond Hill. The following information came from that interview. The property lies on the northwest corner of Richmond Hill at Bloomington Road and Bathurst Street, which is entirely within the Oak Ridge Moraine (ORM). The area was purchased in the early 70s or late 60s as a future building site. A new ORM initiative was just being introduced, with all of the restrictions and guidelines that accompany protected land. It was approximately 250 to 300 acres of featureless land with the only hedgerow being planted along the driveway to the farm. This property is on the line of the East Holland River Sub-watershed in Lake Simcoe and Humber River of Lake Ontario.

Figure 4-1: Mallard Marsh

The only water that existed in the area was Mallard Marsh (Figure 4-1). It has a very low gradient with most being between zero and three percent slope. The area was just cornfields and various crops. The runoff came from north of Bloomington road and entered the property through culverts. The ground was clay and did not allow for infiltration, but pooled on the land so most of the water would evaporate. In the spring and fall when there were heavy rains, there was an intermittent swale that went south but did not reach the tributary unless it went underground. The south part of the land had a tributary of the Humber River.

> Dr. Jon Planck from the University of Guelph was the visionary. He thought to build something that would improve the environment on the site and adjoining the site and also something that would give features that the community could center around and not just another circle of houses in a cornfield.
>
> Developer, 2015

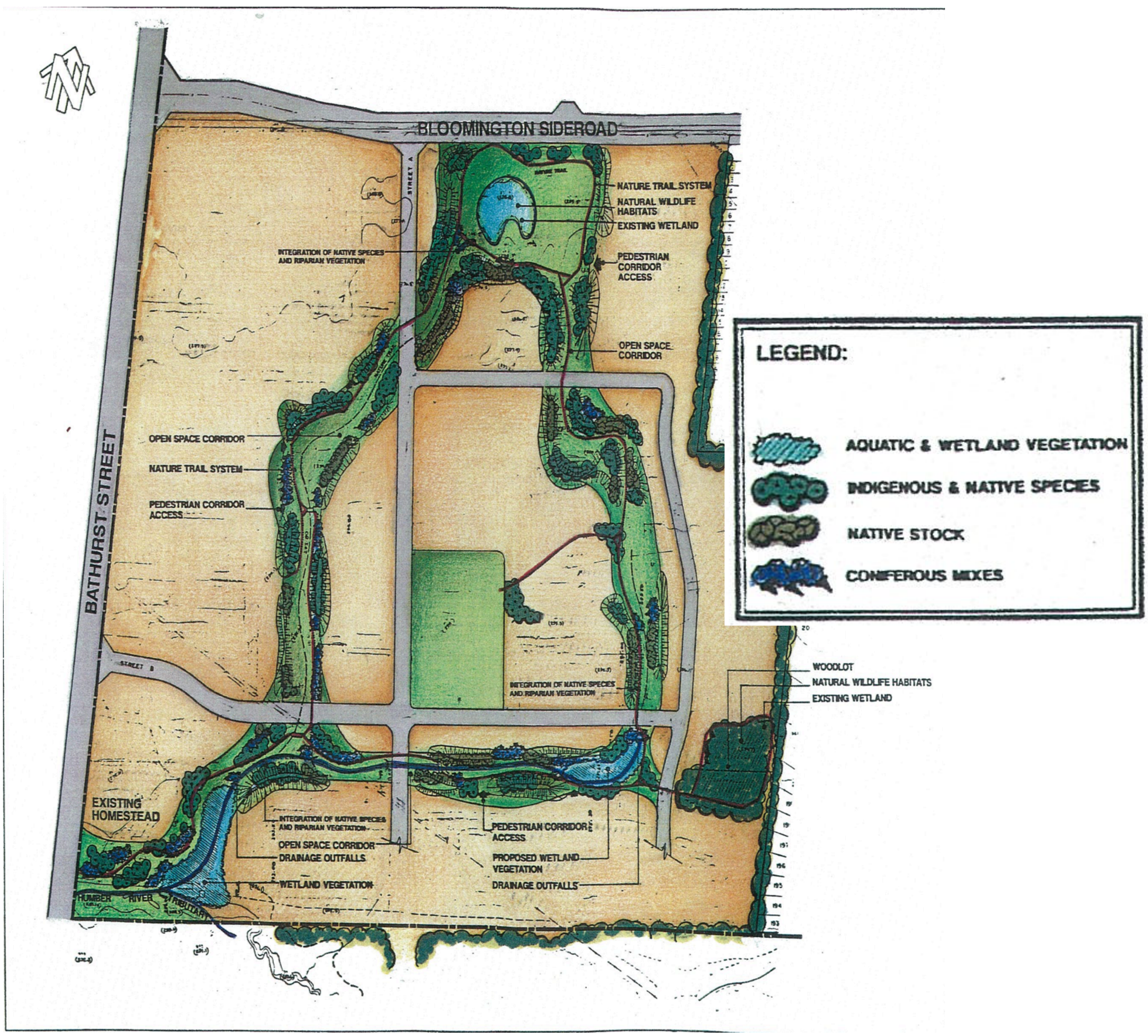

Figure 4-2: Conceptual Drawing of Humber Flats

Even though it was a farm, there were no drainage tiles. Together Dr. Planck and the developers created an Eco Park. In a conventional system they would set aside “5-7 percent” of the land for a SWM pond somewhere down in the lower corner, but Dr. Planck kept pushing to do something different, something unique. Dr. Planck created a triangle shape set of pods connected by "open space corridors" that served as stormwater storage, infiltration and water quality units. The open space corridors were planted so that the water would go through various grasses and bulrushes filtering, and slowing the water. The water also needed to be kept cool as it moved to the tributary, which was accomplished by keeping the surface small, with many plantings. Testing of benthic macro invertebrates were used to indicate stream health (Figure 4-2).

Figure 4-3: Playgrounds and Parks

Once the project was underway the owners of the property loved the idea since they saw how many more houses backed onto green space where before they would only have 6 that backed onto a woodlot. "Kids walk down through the trails to visit someone and it is like their own little community" (Developer, 2015; Figure 4-3). The project was in the final process by 1992 and went through a 2 or 3-year approval process with the Ontario Municipal Board for land use within the ORM. The last piece of the project just finished last year spanning 45 years and has a low density with 5 or 6 units to the acre at the most.

Mark Setter (2015) alerted me to this project, which he thought “was very successful and the developer was able to charge 60 k more per lot that backed onto our stormwater system”. He mentioned how they “put trails bridges and play equipment in the corridors… The municipality loved it, the developers loved it, and the people living there love it” (Setter, 2015). Reinthaler (2015) had heard of this development,

> Under today’s more stringent ecological criteria I doubt such a development would be allowed. For example, usually minimum thirty metre buffers are now required around wetlands; whereas, in some cases in that project, the rear backyard lot lines are right up against the wetlands.
>
> Reinthaler, 2015

4.14.2 Lakeview Neighbourhood, Mississauga

Reinthaler (2015) discussed a project by in the south part of Mississauga, Lakeview Neighbourhood and the following came from his interview. The Lakeview Neighbourhood is in the City of Mississauga, located outside Cooksville Creek watershed. The Lakeview neighbourhood drains into Lake Ontario and was the reason for the retrofit, yet the idea of improving the aesthetics of the area was also important. The CVC retrofit the street and put in bio-retention swales along the side of the road. The lot, and right-of-way, of these houses were of traditional sizes with limited space to work in. The CVC gave people the option of the bio-swale or just keep it grass, and also the choice of the vegetation going into it. The majority of the people chose the bio-swale, knowing they would have something wet in front of their house, while others just wanted grass.

According to the CVC (2014), one main barrier to the project was planning and regulations, as well as the difficulty in manoeuvring both inter-departmental interaction and the public. The CVC (2014) ran public engagements in unconventional ways, like public barbeques. It is interesting to see that the CVC had trouble convincing the community that it would work since there were no previous successes. The final barrier was the municipality's own "bylaws relating to noxious weeds" (i.e. plant type and height) within the right-of-way (CVC, 2014, p.14). Without changing these bylaws, most rain gardens would need to be removed when fully functional. When the residents were able to pick their own plants, they began owning the project with "67% of the community agreeing to do 2 to 4 hours of monthly maintenance on the rain gardens" (CVC, 2014, p.15). The CVC (2014) describe a community engagement activity that sought to involve the community in the project. Once the community had buy-in on the project they offered the residents the choice to pick the vegetation outside their house, "21 of the 26 homes selected perennial flowers over sod" (CVC, 2013). The CVC claim "by retrofitting the road using LID as opposed to typical curb-and-gutter, the City was able to reduce the cost of the road resurfacing by 25%, while providing additional SWM benefits" (CVC, 2013). The preliminary results of the project showed that "the Lakeview bio-retention boulevard units are able to completely infiltrate rain events 23 mm or less which accounts for 90 % of annual rain events" (CVC, 2013).

> On July 8, 2013 an extreme event occurred over Lakeview - 104 mm over 5 hours, peak intensity of 240 mm/hr for duration of 10 minutes. Preliminary analysis indicates that this storm event exceeded the 100-year design storm… even for this extreme event, the LIDs at Lakeview helped to provide some peak flow control.
>
> CVC, 2013

4.14.3 Ducks Unlimited, Winnipeg

Reeves (2015) spoke of the success Ducks Unlimited has had in Winnipeg, "we have several systems in and functioning as they should, of which we have tracked data going back between 10 and 15 years. Everything has worked to or above desired outcomes on all metrics measured" (Reeves, 2015). Ducks Unlimited built self-sustaining ponds within a development in Winnipeg, Manitoba (Figures 4-4 & 4-5). The benefits of a naturalized system where found to be mental health and stress relief due to the series of beautiful trails that are created surrounding the wetlands. The project, as well as others in Winnipeg, was so successful that “builders in the city of Winnipeg are now required to build naturalized as part of their development” (Reeves, 2015). Reeves explained how both the community and the builders see the area as water front properties, and since it is self-sustaining “the city has less maintenance once they assume it” (Reeves, 2015).

Figure 4-4: Feature in the Community and Installed Established (Reeves, 2015c; Reeves, 2015d)

Figure 4-5: Waterfront Homes and Wetland Plantings (Reeves, 2015e; Reeves, 2015f)

As we saw in the previous case studies LIDs can come in many shapes and sizes. A previous survey (Clark, 2008) was conducted with engineers, planners, consultants, builders/developers, regulatory/local government, landscape architects, and others involved in LID implementation. The number one barrier reported was status quo, that is, doing things the same way since it was always done that way. Three questions were asked regarding LID implementation: what are the barriers; what are the solutions; and what tools are needed. Eighty-seven percent of the respondents felt that the barriers to LID implementation lay in changing the status quo, obtaining permits, education/awareness and cost/incentives. The solution, according to more than half the respondents was education and outreach to promote awareness, and changes in permits allowing LID. The top tools needed to implement LID projects were examples that work (i.e. case studies), a common code language, and training in LID design and principles. In my discussion section I will accept that although these statistics are supported by my findings, there is another underlying explanation. These top barriers are merely symptoms of a deeper cause.

In the following Discussion chapter, I will consider how water quantity plays out in Lake Simcoe, and the importance of vegetation to help return the lake to health. I will show how LID will play a large part in the resilience of the area, and that examples are more powerful than education. Lastly, I will explore the question, *what are the pros and cons to alternative stormwater management practices, as well as the barriers to implementing these solutions?*

5 Discussion

A main focus of my Masters was on how water quantity is changing in the Great lakes region, which led me to understand the difficulty of showing this change. The amount of water entering and leaving an area can be tracked using a water balance sheet. If the water entering an area is greater than water leaving there is a positive balance; and just like a bank account, over time you are left with a surplus or deficit. While lakes have a natural rise and fall over the course of a year, the water balance of a lake can be seen in the average levels over time.

5.1 Water Quantity Issues

Since 1860 Lake Ontario had fluctuations of approximately one meter within each year, yet was accumulating a deficit of 40 mm each decade. As well, Lake Erie had a 9% drop in water levels over the past 40 years, and Lake Simcoe was thought to be historically lower than today's water levels. Since most of the water that enters a lake comes through runoff from the surrounding watersheds, lake levels can be used to understand the hydrological health of an area. Hence, if lake levels are consistently dropping there must be water concerns in the surrounding areas. Some of these could be water diversion, increased evaporation, or intensive irrigation, which hinder the water from returning to the source in a natural way.

Since 1918, both Lake Simcoe and Lake Ontario's water levels have been controlled and maintained at a level conducive to commerce and recreation. Therefore, the method of using lake-levels as an indicator of water quantity is no longer applicable; thus, how the water is entering the lake becomes more important. If the water is entering through surface runoff then there will be increased sedimentation and soil erosion (Albaradeyia et al., 2011), which decreases water health. However, if the majority of water enters the lake via underground, that water is filtered, cooled, and adds to base-flow of streams and lakes. Therefore I suggest that increased infiltration is a good indicator of continuing lake health. Further to this, exploratory research indicated that LID was crucial in reducing surface stormwater runoff, through infiltration and transpiration.

5.2 The Importance of Vegetation

Reducing runoff is about increasing infiltration, as well as water storage through vegetation. Often our knee-jerk response to decreasing runoff is to reduce impervious surface area, yet increasing vegetative cover can have a greater affect. According to Durán Zuazo and colleagues (2006), in heavy rainfalls runoff can cause “surface sealing” (p. 309), which prematurely stops infiltration, and vegetative cover can slow the flow down to allow the soil to absorb the moisture. If I can achieve the same amount of infiltration with either permeable pavement or a tree pit, then I must choose the tree pit due to the many other benefits vegetation provides. Whether the water flows over the land, or into the ground, it needs to move through vegetation first. This is because vegetation increases transpiration, which cycles the water and cools an area. As well, it increases water storage, while larger vegetation (i.e. trees) provides shade for people on hot summer days. When vegetation is planted along watercourses it helps to cool the water and decrease evaporation. In summary, vegetation is responsible for holding water, cycling moisture, retaining soil structure, preventing erosion, and combating the heat island effect within urban centers. There are many ways to increase vegetative cover in an urban environment; some of these are green roofs and walls, urban orchards, and community gardens. Yet one way to add vegetative cover and infiltration is through using LID such as self-regulating naturalized systems rather than SWM ponds, and grassy swales rather than curb and gutter.

As populations increase there will be more pressure for density building, meaning a high population to hectare ratio. With the predicted raise in population together with an increased urban density, it will be impossible to build enough SWM ponds to handle all the runoff that will occur. For every SWM pond we build today, we ensure an expensive retrofit later for the municipality. The entire watershed needs to be treated like an infiltration unit from subdivision to district, from town to region and water must enter the ground before it enters the lake or stream. The CVC (2010) report suggests that to reduce impervious surfaces, you need to build up and reduce the footprint of the infrastructure. A better suggestion is to have the impervious surfaces more permeable or build them within a more permeable environment, to mitigate the excess runoff.

5.3 Helping Water Find its Way

End-of-pipe stormwater systems, such as SWM ponds, are built to convey water away from urban development and not support infiltration into the soil. My interviews revealed a desire to do away with SWM ponds and replace them with naturalized systems (e.g. LIDs, SUDSs, constructed wetlands). To construct a naturalized system in a new development a change of strategy must occur. The current practice is to install a conventional system, which requires levelling of an area and then re-grading to convey water, through pipes, to the SWM pond. In contrast, a naturalized system needs to investigate the natural flow of water that already exists in the area, dictated by the lay of the land. The mature trees and vegetation would be left to continue doing what they have always done, maintain soil structure, provide shade, and cycle water. These factors, along with the hilly landscape of Ontario, will dictate to the builder where to put the infrastructure and houses. In this way construction does not compete with the natural flow of water, and every neighbourhood would be unique.

Since the majority of naturalization will occur in existing communities, contemporary systems will need to be retrofit. Retrofitting an existing stormwater system with LID is an expensive endeavour, and not as effective as building a naturalized stormwater system within a new development. These retrofits need to observe everything from downspouts to conveyance systems, with the majority of projects in the right-of-ways, owned by the municipality. If homeowners can learn to care for these right-of ways, as stewards, then the maintenance will be minimal for the municipality. Most people already shovel sidewalks and mow roadsides, which are both right-of-ways. For example, in the Lakeview Neighbourhood project 67 percent of the people said they would preform 2 – 4 hours of maintenance a month (CVC, 2014). As well, the knowledge the community will obtain, regarding how water moves through and around their property, will be invaluable.

5.4 Be the Change You Wish to See

Decisions can be made to put in naturalized systems, yet if the community sees these changes as wild, ugly, and unkempt, then developers will keep building what people wish to have. We must begin to change the idea of beauty by taking a chance and building demonstration subdivisions supported by the developer, conservation authority and municipality. I present a design that is a compilation of scenarios introduced in my interviews: houses would have downspouts ending in rain gardens filled with native water loving plants, and streets with grassy swales rather than curb and gutter. This natural conveyance system would join with parks, schools, and playing fields, which would operate as overflows during heavy rainfalls.

Since naturalization is about more than just water, properties would benefit from having lawns that were 50% native grasses at the back of the property. This would create a natural corridor through the urban center. A subdivision like this would infiltrate 80 to 90% of the rainfall before it reached the dry ponds; yet would also bring back ground nesting birds, bees, and migrating butterfly's, which are all in danger. In exchange for maintaining the right-of-way, the municipality could do a controlled burn of the natural grasses every five years to maintain ecological health. I do not think that education alone would allow this scenario to be built, but would require conservation authority, municipality, developer, and homeowner working in unison to achieve a water-healthy environment.

5.5 Not Education but Change

Unfortunately, without community buy-in most of the naturalization done on private property will revert back to previous states of perceived beauty. Education needs to bring about a change. With the homeowner, the education needs to result in a change of mind and a buy-in to the beauty of biodiversity. It is important to remember that not all homeowners love bees, butterflies, and native grasses, and instead favour manicured lawns. In this case, the naturalization can cause more stress in their lives, not less. This fact cannot be ignored yet eventually, all change becomes the norm. There are many examples of how the public perception of health changes. Take smoking in hospitals, for example; at one time it was acceptable to smoke in your hospital room, and now it would be ludicrous to even consider it. People need to be brought in on the conversation as partners with nature.

Education for the developer must lead to a change in identity. Developers need to see themselves as developing within nature and not over top of it, together increasing both the value of the property, quality of life, and ecosystem health. Yet, just as in clear-cutting forests, there will always be those who put profit before environmental conscience. Remember that the builder will supply what the community wishes. If the question is whether the homeowner will pay more for a naturalized environment, the answer is yes. In two of my case studies there was a premium of 60 to 100 thousand dollars for properties backing onto the 'water', which was thought of as a selling feature and not SWM. The engineers and municipalities need to change the use of mathematics and guidelines from being the word-of-law to a useful tool. As well, all the municipal staff needs to view this change as necessary, to build resilience in a changing climate (ICF Marbek, 2012). The goal of the municipality needs to be focused on permitting change and not managing liabilities. There are no LID solutions that will work exactly the way we plan, since it is a living system and not a machine, so there are no guarantees.

The three case studies I presented are not carbon copies of each other. The developer of Humber Flats thought outside the box and created a series of ponds connected by trails and grassy swales. This created a connected community that reaps the benefits of a natural environment and SWM. Unfortunately, Humber Flats probably would not pass today with the new guidelines. Lakeview neighbourhood had some flexibility and a great deal of communication within the community, so the success was higher. They used standard LID solutions, yet offered a variety of the planting options that would suit the household. This gave power to the homeowner who gains an understanding of what can be planted, and what should not. Finally, Ducks Unlimited created a natural wetland in lieu of a SWM pond. Even though it is a wet area, the beauty and biodiversity is the gem of this ‘water front’ property. This might be a solution for places of dense housing where right-of-way areas for LIDs are not plentiful, and a single wet pond is still necessary.

5.6 Barrier #1: Status Quo

My research found that the status quo was a major barrier to change, as did Clark (2008). However, this is equivalent to blaming your lack of flossing on not flossing before; when really it is a habit that has been formed through perceived time constraints, procrastination, and a lack of connection to consequences. Municipalities are understaffed and do not have effective guides to protect the community from future mishaps. Operations have limited funds to care for the stormwater systems they currently have, and to add more is to exacerbate the situation. In regards to why developers do not request LID solutions, the developer has learned that the quickest route is a SWM pond, and often, time is of the essence. When I asked these same people if they would be willing to use LID solutions, the answer was a resounding yes. An object at rest tends to stay at rest, so unless there is energy put into change, things tend to stay the same. This is different than continuing to do things the same way because we have always done them that way before. Succumbing to the status quo is a symptom not a cause.

5.7 Barrier #2: LIDs are Expensive

Costing, as a barrier, is the biggest myth I came across. Whenever cost was mentioned as a stumbling stone to change, it was always perceived as someone else having a problem with it. Sometimes cost was an unknown, and was assumed to be too great. In actuality, in a LID project the developer will make more for each property, and the community will have more value as the property matures, not to mention improvement in physical and mental health. If a naturalized system is put in at the development stage, the cost is about equal to a conventional SWM system. The real savings for the municipality is in maintenance costs. The eco-park at Humber Flats does not need to be cleaned out or maintained by the city since it was built to let nature do what it does best. The constructed wetlands implemented by Ducks Unlimited is estimated to cost a third of what a conventional SWM pond takes to maintain, and the sediment does not need to be removed. For the municipality it is the cost of retrofitting old systems that is expensive since they are left with the bill, and the burden.

5.8 Barrier #3: Permitting Process

Another barrier was in the permitting process. It was suggested that permits would go more smoothly if there were proper education within the municipalities. However, the town of

Georgina has had plenty of training in alternative solutions, yet currently no LIDs have been installed in their municipality. I argue that the best education comes from seeing successful results, since with every successful LID we better understand maintenance problems and costing. In the meantime, these developments cannot move forward due to the need to protect the homeowner from malfunctioning SWM systems, and the liability they incur. So it is believed that the municipality needs regulation guidelines not education. There is an assumption that permitting will not be a problem once there are guidelines identifying stormwater credit for LID solutions. The guides will allow the municipality to offer stormwater credit for various LID solutions, which can begin to subtract from the size of SWM ponds installed and remove liability.

The CA is doing a fantastic job of creating guidelines, and delivering educational workshops to the municipalities. As well, they are working closely with the MOECC to create a single vision for 2016. However, often it is the guides themselves that create a barrier to moving forward. If the CA is going to be an inspiration rather than just a regulatory body, then how they use the guides will be critical. As stated earlier, LIDs are messy and unique to each property. The developer knows their property and their client, yet when a permit is submitted for approval it is often returned with revisions. These revisions are based on guidelines, without knowing the uniqueness of developers' property or community. The LID guides need to be a jump off point, which take into consideration things we know, such as infiltration rates, soil composition, as well as successes and failures. The complexity of people demands flexibility to find ways of combining different types of LIDs to suit the environment and the community.

5.9 The Dream Stream: An Example of Barriers

To demonstrate how the barriers play out in a subtle way; I will present a case study of my own. Since January 2015 I have worked with the Rewilding Lake Simcoe team on behalf of the Pine Beach community in Keswick, to clean up a beach that was ecologically damaging the lake, and was unusable by the community. The project is governed by the Lake Simcoe Protection Plan to reduce phosphorous, cool the water going into the lake from the culverts, and reduce sedimentation and erosion. This property has a gradient slope of less than 1 degree, and is within a meter of the water table. Originally there were two culverts flowing from under the street directly to the Lake, and one of them, which travelled for 100 feet under the park, had collapsed. Through community engagements it was discovered that homeowners were highly opposed to tall plants and trees obstructing their view, so using grassy swales for SWM were not an option. Also, the CVC (2010) SWM guide stated that grassy swales were not a good option for properties within one meter of the water table, as the water would not drain and become stagnant.

Our low-impact solution would need to have three main concepts: infiltration, no tall plants, and a way to move and filter the water on its way to the lake. We were able to landscape with gardens, and created a town square that acted as a place for people to meet and also facilitated infiltration. We planned to put in ‘eco-grass’, which was a mix of slow growing grass native to Alberta with roots purported to be 14 inches deep. It was also a low-mow grass system that would be low maintenance and drought resistant. Lastly, the two culverts needed to be converted to open-air ditches with proper substrate, and plantings. The idea was to create a 220-foot imitation daylight stream moving through the property with twists and turns to slow the water down. The base would be constructed to act as a long French-drain to hold, move, and filter the water. The corner banks would be heavily planted to take up the phosphorus and shade any water that remained on the surface.

When it was time for obtaining the permit for this dream stream, Rewilding felt it would be a straightforward process since it was clearly a LID project. The engineer's comments came back with recommendations drawn from the CVC (2010) SWM report. Since the drainage area was so large, there was a concern that the system we were building was too small,

> The minimum footprint of the filter bed area is based on the drainage area. Typical drainage areas to bioretention are between 100 m2 to 0.5 hectares. The maximum recommended drainage area to one bioretention facility is approximately 0.8 hectares.
>
> Personal Communication, April 20, 2015

According to this recommendation, to handle the stormwater at Pine Beach, which is 16 hectares, we would need 3200 m^2 of bio-retention spread over 20 units. The park itself is only 4115 m^2 and would result in having 78% of its surface covered with SWM facilities.

It was recommended to put in a grassy swale along with a splitter to handle overflow. We received these recommendations 2 weeks into the process and owe the quick response to the innovative guidelines that were built by the CVC and TRCA over many years. The natural heritage division had an ecologist review the plantings and gave recommendations as well. They noted that the "eco grass" was not local and LSRCA regulations stated that no non-native grasses could be adjacent to a waterway. Again, this was a guideline meant to protect Lake Simcoe shorelines from being effected by invasive grasses (notice that there is no grass in the pictures, which the community was not happy with).

The LSRCA recommendations followed the regulations and guidelines perfectly, yet had several conflicts. First, the community needed a low maintenance solution and felt a grass swale was not the best fit, due to the tall native grasses that would look unkempt and obstruct their view of the water. Further to this, the Ontario grasses that were suggested by the ecologist to line the stream also grow very tall and are commonly found in grassy swale designs. With the high water table and the low grade there was no single LID solution that would work. The area's conveyance system was hard bottom culverts, so infiltration was not happening upstream. The area was draining into the park whether we liked it or not, and the only other option was to leave it the way it was.

There were two rooted paradigms at work here: first is the idea that guidelines can be applied to LID without a site visit or conversation; and second was an entrenched belief of beauty by the community. The community was against having a grassy swale based on the idea that it would catch garbage, be hard to maintain, and would obstruct their view of the water. Parks have traditionally been well-manicured open spaces inhabited by a few trees for shade. Culturally, parks need to have short grasses to facilitate flying kites and throwing balls, while long grasses belong in meadows. The community still defines natural as "wild" and "uncultivated" (Natural, n.d.), which is the opposite of "civilized" (Wild, n.d.).

Rewilding was now at an impasse since there was no apparent opportunity to challenge these decisions. The permit was issued on May 22, 2015 (Appendix D); seven weeks to the day after the permit process began. We expected it to take no more than 4 weeks, and possibly quicker than that. The permit was accepted with two main edits on the stream: There needed to be splitter at the north end culvert in case of larger storms and a bio-retention unit installed where the two culverts meet. The plant situation is still not resolved to date. It is not possible to know if the permit was delayed due to the innovative thinking, which worked outside the guidelines. I believe that if the recommendations of the engineer and ecologist were accepted immediately then the permit would have been delivered within the 4-week window.

What the engineer did not understand was that through a combination of infiltration techniques we converted 68% of Pine Beach into an infiltration unit, while still maintaining beauty and function (Figure 5-1 & 5-2).

Figure 5-1: Town Square and Dream Stream (Property of ReWilding)

Figure 5-2: Culvert and Estuary (Property of Rewilding)

It was not a grassy swale and still functions quite well, handling many large rainstorms. The water is coming out clean and cool and is believed to filter out 80% of the suspended solids that used to run directly into Lake Simcoe.

5.10 The Real Barrier to Change

After 2016, the province will pass down LID guidelines that will layout water credit against a SWM pond. This will arm the engineers with tools to build a plan that will return the area to a pre-development balance, without having to put in a SWM pond as well. However, I predict that the permits will still come back with revisions since very few properties will fit traditional LID solutions. The developer is required to satisfy the community's needs, the complexity of which could never be captured in a single manual. This will stall the process until the engineers either negotiate a compromise, or surrender to a SWM pond.

Does this mean the conservation authority and municipalities are the barrier? No, the barrier is the current paradigm that promotes regulation over communication. The municipality will have less liability once the 2016 guidelines are in place and the CA is the champion of LID change, working tirelessly to educate municipalities. They have both the drive and means to inspire developers and municipalities to implement alternative naturalized solutions to SWM. However, they are working against themselves since the same guidelines that have been created to move LIDs forward are stopping them from being implemented. The breakdown is in communication not intent.

The conservation authority has an entrenched paradigm that sees regulations and guidelines as set boundaries to play within. With guidelines in place, there is less of a chance for loose interpretation, and once an exception is made to a rule, the chance for abuse increases. However, with something as messy as LIDs, there is no option but interpretation according to a site's unique characteristics, as no two places are alike. It was well discussed in the interviews that LIDs are not one size fits all, which means every area is unique and needs to be reviewed as site-specific. However, we have ridged guidelines engineering the natural solution.

5.11 Grassy Swales are the New SWM Pond

I am sure that for most scenarios, the 2016 guides will create confidence to issue credit for low-impact solutions, and a standard practice will begin to unfold; here is the danger. Just like the natural world, there is a need for biodiversity with no two niches the same. You will be hard pressed to discover two meadows that are identical, two marshes that contain the same plants, or two communities with the same tastes. However, there is a great possibility that grassy swales will become the new SWM pond because they will be safe and known, and this will create its own set of problems.

Will every solution be perfect? Absolutely not, which creates fear of liability and responsibility. We need to inspire every homeowner to see their property as a mini-watershed, and to recognize that all the precipitation that flows through their property as their responsibility. If our guidelines for LIDs are not flexible then we will only authorize a narrow spectrum of LID solutions. This will discourage innovative ideas that can serve to build how we see and interact with a healthy watershed. Our list of LIDs can expand as new ideas are explored, creating successful or unsuccessful examples. The process can be fun, with rain gardens shaped like daylight streams and downspout art.

Conclusion

"The water is sick...people need to really fight for that water, to speak for that water, to love that water."
– Josephine Mandamin, Mother Earth Water Walker (Kraus, 2015).

In the last six decades there has been a reduction in water quantity in the Great Lakes region, which is a sign of decreasing water health. However, due to the regulation of water levels in Lake Simcoe and Lake Ontario, this no longer acts as an indicator. Instead, we need to observe how much stormwater is infiltrating back into the ground, and how much remains as runoff. The more water there is entering Lake Simcoe via underground, the better chance for recharging groundwater sources and ensuring future supplies. The MRSW has a low amount of forest and wetland and a large amount of agriculture, which drains into Keswick. Low infiltration assures that these areas flush into Lake Simcoe, which has aged well beyond its years due to excess phosphorus. This was a prime location to show how the lack of infiltration is affecting the health of water and society.

We continue putting in SWM ponds, moving the stormwater through pipes to a single location, with no urgency to infiltrate the water in situ. The changing climate is bringing severe storms more frequently; and the increasing population ensures more impervious surface and runoff. Further, less infiltration means more sediment, phosphorus, and erosion within Lake Simcoe (Durán Zuazo et al., 2006; Motha & Baier, 2005). Currently, according to my interviews, SWM ponds are not handling phosphorus and sediment as expected and the best way to increase resilience for the future changes is through increasing vegetative cover within the urban environment (ICF Marbek, 2012). Vegetation is beneficial for holding water, cycling moisture, retaining soil structure, preventing erosion, and combating the heat island effect within urban centers. As well, increased vegetation has been known to improve overall physical and mental health, and increase healing time.

Improved infiltration and increased vegetative cover can be achieved through LID, which infiltrates the water on site. Since 1993 the MOECC has been suggesting on site conveyance of stormwater, and the conservation authorities have been working to educate the municipalities in the benefits of LID solutions. However, the Town of Georgina has not been able implement LID solutions in any developments to date. My research showed the pros to LID are increased water filtration and phosphorus reduction, improved aesthetics, and increased storage of stormwater over a larger area. LID has the ability to turn an entire neighbourhood into an infiltration unit. This was shown in the Lakeview neighbourhood, which weathered a 100-year storm with no ill effects. The only cons to the LID solution were difficulty infiltrating in places with high clay content, or high water tables; and not wishing to infiltrate salts and oils into the ground within highly industrial areas.

If LID is so beneficial what are the barriers to implementation? Contrary to Clark (2008), and my initial research, the major barriers to LID are not status quo, cost, or permitting; these are symptoms of an underlying problem. The main barriers are entrenched paradigms, which are shared perceptions, beliefs, and ideas based on unstated assumptions. In itself, it is a paradigm that we keep looking at these three barriers rather than looking at the underlying causes of them. This is because it is easier to label a problem than to change a mindset. In fact, people had a desire to change yet were waiting for something to happen before they could: the municipality for guidelines, the developer for water credit, and the CA for successful examples. As with cost, status quo was a reason given for why ‘others’ are not changing, and all that is needed is a catalyst.

Status quo was seen in the need for people to do the same job they did last week, and with the community who fear change, accustomed to the way things are. Society perceives natural as 'wild', which creates opposition to naturalized solutions. If municipalities were to install naturalized solutions on public properties in partnership with CAs, these would serve as examples to help shift the community's idea of what is beautiful and normal. Another shared belief is that there is a cost issue with LID, especially for developers and the Operations department, which proved to be incorrect. My research suggests that developers who have used LID understand the great cost benefit to a naturalized solution, and are not using LIDs due to the expectation that it would take longer to obtain a permit. As for the developers who have not used LIDs, many are under the misconception that they are more costly. The Operations department already find the current system unreasonable in both cost and maintenance, so changing to LIDs can only be an improvement. These perceptions are built on fear and misconceptions about LIDs, and until we build examples, costs and performance will remain conjecture.

The permitting process is the closest thing I found to a barrier. However, it is the strict use of guidelines within the permit process that is the difficulty, which stems from the conservation authority and municipality's fears. The conservation authority has an entrenched paradigm that regulations must be followed to the letter, and if leniency is given then the system will be abused. As well, there is a perception within municipalities that LID will bring liability. The new 2016 guidelines should reduce the fear of liabilities, yet no naturalized system will be 100% predictable. LID is not one-size-fits-all, so revisions will always be necessary, resulting in challenges and delays enervating the process. Without flexibility, these guidelines can strangle the creativity out of naturalized solutions. Even the word low-impact development implies engineering a solution to decrease liability and ensure consistency. A 'naturalized system' should mimic nature by infiltrating water using vegetation, natural flow, and porous surfaces; engineering can give us the math but nature must give us the design. The additional benefits and services a natural system provides must be considered, or they could be lost in *faux-natural*, which is a handful of prescribed systems that have been engineered to function.

My recommendation is communication rather than revision. If a design needs major amendments then I suggest an open dialogue and a site visit; a meeting between all invested parties to explore every aspect, quantitative and qualitative, fact and narrative. These are forums of new ideas, perspectives, and conversations with the experts, as part of a larger process. This will inspire collaboration that may result in new solutions with sound hydrological principals, and where ingenuity is celebrated. The outcome will be a compromise, born out of desire to move forward and to stay true to the goal of infiltrating water in place. If not, then the desire to follow through with an alternative solution will be replaced with a SWM pond out of frustration. The guidelines have an opportunity to limit flexibility and enervate the process, or open communication and create a partnership. If time and money is a concern just think of how much of both is wasted in a back and forth battle of wills culminating in a SWM pond, which the municipality will need to remove later. How much does that cost?

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Appendices

Appendix A: Terminology and Definitions

Climate: Very important relationship with the hydrological cycle and consists of heat energy combined with moisture relations (Black, 1991).

Drought: Hydraulic drought is when low water levels are recorded in water bodies, reservoirs, and runoff data. Also rainfall deficits, and decreased soil moisture is present (Black, 1991; Campagnucci et al., 2001).

Evaporation: The movement of water molecules from high moisture to low moisture areas along the vapour pressure gradient and is affected by cloud cover, time of day, depth of water etc. (Black, 1991).

Evapotranspiration: A term that includes evaporation, interception and transpiration (Black, 1991).

Hydraulic Cycle: "The hydraulic cycle is an open system in which solar radiation serves as a source of constant energy" (Fetter, 1994, p.8).

Hydrology: Is the study of the movement, storage, distribution, volume and chemistry of water within the hydrological system (Black, 1991; Fetter, 1994).

Hydrosphere: A closed system containing the hydrological cycle (Black, 1991).

Interception: Any interruption of water from reaching the ground whether surface, object, or evaporation. Most intercepted water returns to the atmosphere without reaching the ground. Therefore, it can be calculated as Gross Precipitation minus any water that reaches the ground (Black, 1991).

Precipitation: It is measured in millimeters and comes in many forms (e.g. snow, rain, fog drip, hail, and freezing rain) and the total amount that falls in the open is considered *Gross Precipitation* (Black, 1991).

Processes: Infiltration, percolation, and transmission. Infiltration is water moving from the atmosphere to the soil's *Zone of Aeration*. Percolation is water moving into the water table or *Zone of Saturation*. Transmission is the movement of water through the saturated soil (e.g. recharge, interflow, storm flow and stream flow) (Black, 1991).

Runoff: Any water in motion whether surface water, sub-surface water, base-flow, or return flow (Black, 1991, Fetter, 1994).

Soil moisture: This is the soils water holding capacity and is a function of soil texture. It is also important to plant growth and flood control (Johnstone and Louie, 1984).

Storage: Water that is temporarily out of circulation in stationary locations (e.g. snow, vegetation, puddles, ponds, and lakes). Water is also stored in wetlands, rivers, streams and groundwater although it is moving through these places (Black, 1991; Fetter, 1994).

Stream flow: A measurement of discharge, which is measured in CuM^s sometimes shown as Q. Q equals the Area the water flows through multiplied by the velocity in meters per second (Black, 1991).

Time of Concentration: This is the time it takes for water to flow from the furthest point of the watershed to its discharge point. If precipitation exceeds the time of concentration then the peak runoff rate can be calculated. This is the point that the soil is saturated and runoff begins. This event ends with ground water recharging (Black, 1991).

Transpiration: The cycling of water from the soil to the atmosphere through the plant stomata. This occurs in the hydrological system and is driven by wind speed, solar energy, and moisture (Campagnucci et al., 2001; Fetter, 1994).

Watershed: "A unit of land on which all the water that falls (or emanates from springs), collects by gravity and fails to evaporate, and runs off via a common outlet... The outlet is the lowest point or base level...the basic unit of water supply" (Black, 1991, pp.248, 250).

Water Budget: Water quantity data that includes water in the ground, on the ground and in evaporative state and represents all the water in a system necessary to sustain life in the ecology and the society (CVC, n.d.).

Water Management: This is to manage water within a natural ecology to control the misdistribution of water to maintain an equilibrium (Black, 1991). Maintaining a balance between the environmental and societal demands while maintaining the limited resource (Campagnucci et al., 2001).

Weather: Weather moves water vapour through the atmosphere (Fetter, 1994)

Wilting coefficient: This is when the moisture in the soil is too low and the plant can no longer draw water up its stomata (Fetter, 1994).

Zone of Aeration: Also known as the *Vadose zone* is just above the water table yet beneath the soil (Black, 1991).

Zone of Saturation: This is the water table and everything beneath, which includes the ground water (Black, 1991).

Appendix B: Specialized Informants

Dr. W. Trevor Dickinson
Water Resource Engineering
Interviewed on January 21, 2015
Guelph University, Professor Emeritus
wdickins@uoguelph.ca

Dan Reeves
Head of Restoration and Client Services - Ontario at Ducks Unlimited Canada
Interviewed on January 30, 2015
Ducks Unlimited Canada
705-721-4444, Extension 239
d_reeves@ducks.ca
740 Huronia Rd, Unit 1 Barrie, ON L4N 6C6

Mark Setter, BLA, OALA
Landscape Architect and Ecological Restoration
Interviewed on February 09 2015
Mark Setter Associates
(905) 476-0844
msetter@rogers.com
219 Lake Dr, East, Keswick, ON. L4P 3E9

Harold Reinthaler, BASc, P.Eng
Consulting Engineer
Interviewed on February 18, 2015
Shaeffers Consulting Engineers
(905) 738-6100, extension 225
hreinthaler@schaeffers.com
6 Ronrose Drive, Concord, Ontario L4K 4R3

Developer (Anonymous)
Contact information on file
Interviewed on February 20 2015

Michael E. Baskerville, CET, CMM
Engineer Manager – Development
Interviewed on March 10, 2015
Town of Georgina Department of Operations and Engineering
(905) 476-4305 ext. 2225
mbaskerville@georgina.ca
26557 Civic Centre Rd., Keswick, ON L4P 3G1

Barbara L. Antic, CET
Civil Technologist – Development, Engineering Division
Interviewed on March 10, 2015
Town of Georgina Department of Operations and Engineering
(905) 476-4305 ext. 2226
bantic@georgina.ca
26557 Civic Centre Rd., Keswick, ON L4P 3G1

Gagan Sandhu, BE
Infrastructure & Operations Manager
Interviewed on March 27, 2015
Town of Georgina Department of Operations and Engineering
(905) 722-6889 extension 3424
gsandhu@georgina.ca
26557 Civic Centre Road, RR 2 Keswick, Ontario L4P 3G1

Tom Hogenbirk, CMM, P.Eng
Manager, Engineering and Technical Services
Interviewed on April 01, 2015
Lake Simcoe Region Conservation Authority
(905) 895-1281
t.hogenbirk@lsrca.on.ca
120 Bayview Parkway,Newmarket, ON L3Y 4X1

Steve Auger, B.Ed., M.Sc., P.Eng., C.P.E.S.C.
Stormwater Management Specialist, Subwatershed Planning and Source Water Protection
Interviewed on April 01, 2015
Lake Simcoe Region Conservation Authority
(905) 895-1281
S.Auger@LSRCA.on.ca
120 Bayview Parkway, Box 282, Newmarket, Ontario L3Y 4X1

Hilary Van Welter CEO Ascentia
Director and Lead Designer
Interviewed on July 06, 2015
ReWild!
(905) 715-7855
ascentia@rogers.com

Appendix C: Interview Guide

Assumption is that urban density is growing, which causes an increase in impervious surfaces, decreasing vegetative cover and evapotranspiration. These changes can cause increased runoff during peak flows and flood risks in urban centres.

Q. What do think about this statement?

In the Town of Keswick there are water stress and flooding problems. Urban development is planned in the near future that is expected to increase the population from 20,000 to 40,000 by 2026. How are municipalities preparing for the hydrological changes?

Q. From your experience, what are the SWM solutions currently being employed by municipal and/or conservation hydrology planners as solutions?

Q. What are the pros to these methods?

Q. What are the cons to these methods?

Q. Barriers that keep the system from changing?

There are many alternative SWM practices today. Some call this Low-impact Development. In the context of urban development and flooding,

Q. Can you name what you feel are the best three strategies?

Q. What are the pros to these methods?

Q. What are the cons to these methods?

Q. What do you think are the Barriers to implementing these alternative solutions?

The topic of hydrology and anthropogenic stress is a complex issue, especially if you factor in climate change.

Q. Can you think of one or two questions that I did not ask that you think I should have?

Q. Can you answer them for me?

Q. Is it possible to make a day lit stream work as a Level 1 SWMF? What are one or two things to be conscious of when building such a stream?

I would like to continue conversations on this topic.

Q. Can you direct me to someone who you think should offer me valuable insight to the questions I have asked?

Appendix D: Pine Beach Permit

Lake Simcoe Region
conservation authority

A Watershed for Life

PERMIT NO. GP.2015.053 Date: May 22, 2015

IN ACCORDANCE WITH ONTARIO REGULATION 179/06.

Permission has been granted to:

Owner: Pine Beach Landowners Association
c/o Pam Devine
267 Woodycrest Avenue
Keswick, ON L4P 2W3

Applicant: Mitch Harrow
13 Meadowland Blvd.
Thornton, ON L0L 2N0

Location: Lot 6, Concession 2
Parkway Avenue and Lake Drive South
Town of Georgina, Regional Municipality of York

For the: **naturalization of an existing drainage feature by creating a 200 foot long meandering watercourse to be planted with native, non-invasive species with a section that will flow through an open ditch culvert as shown on plans submitted and marked "approved" on the above property during the period of May 14, 2015 to August 31, 2015**

Subject to the following conditions:

a) All development subject to provincial, federal and municipal statutes, regulations and by-laws.
b) This permit does not confer upon you any right to occupy, develop or flood lands owned by other persons or agencies.
c) The applicant must maintain and comply with the local drainage requirements of the municipality.
d) That all areas of exposed soil be stabilized immediately following construction.
e) That no grading or placing of fill occur on the lot except what is required for the proposed works as shown on the attached site plan.
f) That sediment and erosion controls be installed prior to the commencement of any works onsite. Silt controls are to be inspected after every rainfall event and maintained until all exposed areas have been stabilized in order to prevent silt from leaving the site or entering a watercourse or water body.
g) That no trees be removed as part of permitted construction.
h) That vehicles will not be permitted to drive on the bed of Lake Simcoe.
i) That photographs of the completed works be submitted to the LSRCA.
j) That all plantings consist of native, non-invasive, non-cultivar vegetation.
k) That the LSRCA be contacted prior to the start of the works and upon completion of the works.
l) That a planting plan with native, non-invasive species to be submitted to the satisfaction of LSRCA staff no later than July 1st 2015.
j) That the channelization be done to convey flows from the 4 hour, 25 mm storm.
k) That peak flows in excess of the 25 mm storm be directed via the grass swale west of the flow splitter.

***NOTE: The approved plans submitted with the application for this permit are hereby incorporated into and constitute part of this permit. Any construction, placement of fill or interference with a watercourse or body of water otherwise than in accordance with such plans, constitutes a breach of this permit which may then be revoked at the option of the Authority. In addition, any person responsible for such activity is liable to prosecution.**

Landowner
Municipal Building Department
Municipal Engineering Department
File

Permit prepared by: **Jennifer Dawson**
Environmental Regulations Analyst

Permit approved by: **Beverley G. Booth, MSc, MCIP, RPP**
Manager, Planning, Regulations and Enforcement

Page 1 of 2

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