

**Planning for Resilient Water Infrastructure: Understanding
the Water System and the Impacts of the Planning Process
in Implementing Green Infrastructure Projects within
Ontario Municipalities**

by

Kristina Dokoska

supervised by

Dr. Laura E. Taylor

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, Toronto, Ontario, Canada

November 30, 2018

Table of Contents

Acknowledgements.....	4
Foreword.....	5
Abstract.....	8
Introduction.....	9
Overview of Literature.....	11
Methodology.....	15
Case Studies.....	17
Chapter 1: City Planning and Implementation: The Need for Greater Consideration of Green Infrastructure.....	21
1.1 Policies, Plans and Other Relevant Documents.....	21
1.1.1. Provincial Policies and Plans.....	23
1.1.2. Regional Plans and Policies.....	28
1.1.3. Municipal Plans and Policies.....	30
1.1.4. Conservation Authority policies.....	32
1.2. Current Urban Planning Process.....	33
1.3 Consideration for Green Infrastructure in the Planning Process.....	35
Chapter 2: Green Infrastructure as the Dominant Form of Water Infrastructure.....	37
2.1 Dominance in the Form of Physical Infrastructure.....	37
2.2. Dominance in the Form of Visibility.....	42
Chapter 3: The Barriers, Challenges and Solutions to Planning and Implementing Green Infrastructure in Municipalities.....	47
3.1 Barriers and Challenges.....	50
3.1.1 Policy.....	50
3.1.2 Knowledge and Training.....	52
.....	56
3.1.3 Senior Management Buy-in and Risk Aversion – Asset Management.....	56
3.1.4 Collaboration.....	57
3.1.5 Public Acceptance and Education.....	59
3.2 Solutions and Next Steps.....	61
3.2.1 Policy.....	61
3.2.2 Knowledge and Training.....	63

3.2.3 Senior Management Buy-In and Risk Aversion – Asset Management	64
3.2.4 Collaboration	66
3.2.5 Public Engagement.....	68
4.0 Future Research Directions.....	71
Conclusion.....	73
Interviews.....	75
Bibliography	76

TABLES

Table 1: Complete List of Policies and Plans Reviewed.....	22
Table 2: Complete List of Barriers, Challenges and Solutions.....	48

FIGURES

Figure 1: County Court Bioswale (Dokoska, 2018).....	17
Figure 2: County Court Neighbourhood in the Context of the City of Brampton (Brampton, 2006).....	18
Figure 3: Aerial View of County Court Neighbourhood (Geohub, 2018).....	18
Figure 4: Corktown Common Wetland (Dokoska, 2018)	19
Figure 5: Corktown Common Park (Dokoska, 2018).....	19
Figure 6: Corktown Common in the Context of the City of Toronto (Google Maps, 2018)	20
Figure 7: Aerial View of Corktown Common (Google Maps, 2018).....	20
Figure 8: Corktown Common Constructed Wetland (Dokoska, 2018)	42
Figure 9: County Court Bioswale as of September 2017 (Dokoska, 2017).....	53
Figure 10: County Court Bioswale as of September 2018 (Dokoska, 2018).....	56
Figure 11: Visual Sign of Corktown Common (Dokoska, 2018).....	68

Acknowledgements

I am incredibly grateful to have the support of so many people over the past two years who have helped me complete my MES program and Major Paper.

First and foremost, I am thankful to my advisor and supervisor, Dr. Laura E. Taylor, who helped guide me through the MES program and provided me with valuable input. Her guidance and support has allowed me to push the boundaries and made this research possible.

During my MES program, I also had the opportunity to work at the City of Brampton Environment & Engineering Division. I would especially like to thank Michael Hoy for his mentorship and continued support. His wealth of knowledge and enthusiasm for solving environmental issues are inspiring. The internship allowed me to step outside of the academic world and see how policies are implemented on the ground. I am extremely grateful for the opportunity.

I would also like to thank the people at the City of Toronto and the TRCA who dedicated their time and provided input. I was able to gain a better understanding of the challenges faced in implementing green infrastructure.

I would also like to thank Dr. Abidin Kusno, who provided me with an opportunity to examine my work from a different perspective. His perspective allowed me to reflect on issues that I would not have otherwise considered for this paper.

Lastly, I would like to give most thanks to my family and friends for their love and support. None of this would have been possible without their strong support. I hope that someday I am able to return all of the help and support that they have given me over the past few years.

Foreword

My interest in green infrastructure is largely attributed to my interests in the water network. Prior to starting the MES program, I had a large interest in water networks and the urban metabolism of the city. As someone who was fortunate enough to have a ravine running through their backyard, I always felt that people never fully appreciate the vast benefits the water network provides. Water flows through everyone's taps, but people never stop to consider where this water comes from. The idea that water is purposefully hidden in the city when it is so vital to city life drove me to find a solution. I knew that an alternative approach to the current grey infrastructure, one where people can directly interact with the water network was needed, especially in a city full of concrete.

I chose to conduct my research on green infrastructure because it encompasses the solution that I had been looking for. Green infrastructure can be defined as any structure (natural or engineered) that is a function of an existing water infrastructure system, and which works to mimic the natural environment and provides multiple socio-ecological benefits (e.g., improved water quality, reduced flooding). I believe that green infrastructure, when well-planned and designed is an opportunity to improve the public's socio-ecological relationship to water and increase resiliency. My experience working at the City of Brampton has shown me that despite recent popularity around green infrastructure, municipal planning and implementation of green infrastructure is faced with many barriers and challenges. While Ontario municipalities currently face challenges, my experience has also shown me that there are opportunities to overcome these challenges and begin integrating green infrastructure into everyday practice.

This paper is a component of my Plan of Study (POS) for the Masters in Environmental Studies program. My POS examines the Political Ecology of Toronto's waterways and the need to change the way in which people interact with water in the city and improve the infrastructure planning process. It emphasizes the interconnectedness between each of the three components (political ecology, water systems, and infrastructure planning). Through the use of green infrastructure, this paper shows how green infrastructure is able to strengthen the public's socio-ecological relationship to water and demonstrates the benefits of moving towards a natural approach in infrastructure planning.

This paper aligns with the three main components outlined in my POS. Under each component, this paper satisfies several learning objectives including:

Component 1: Political Ecology

Learning Objective: An in-depth approach to understanding people's perception of water in the city. This paper critically examines the way in which people interact with the water network in the city and the role that green infrastructure can play in changing people's perception of water.

Learning Objective: Understanding the complex web of who has control over water in the city and the decision-making process. This paper explores the current urban planning process, who is involved in the decision-making process, and how this has impacted the implementation of green infrastructure projects.

Learning Objective: Examine how water is being accessed in suburban areas. Using the City of Brampton as a case study, this paper addresses how residents interact with/access water, and how this interaction could be improved.

Component 2: Water

Learning Objective: Researching the general processes and functions of water to understand how it works. This paper provides a general understanding into the technical considerations which need to be taken into account when planning and implementing green infrastructure.

Learning Objective: Examine how water is managed in the City of Toronto by looking at the different processes such as water treatment, stormwater management and wastewater management to understand what is involved in these processes and how it impacts the water network. This paper explores the role of the City in managing water and the policies and plans that currently exist to improve the water network.

Component 3: Infrastructure Planning and Development

Learning Objective: Understanding the decision-making process in implementing water infrastructure by examining the political process and how projects are approved in the city. This paper provides a detailed understanding into the decision-making process for planning and implementing green infrastructure projects and how these projects are approved.

To conclude, by aligning the paper with the three main components outlined in my POS, this paper will provide a comprehensive look at how green infrastructure can improve the public's socio-ecological relationship to water and provide a natural solution to planning and implementing water infrastructure.

Abstract

This Major Paper examines how green infrastructure has been incorporated in Ontario municipalities and the barriers and challenges associated with its planning and implementation. Based on two Ontario municipalities, the City of Toronto and Brampton, this paper argues that while municipalities have begun to integrate green infrastructure into their planning practices, issues around weak policy, knowledge and training, senior management buy-in and risk aversion, as well as collaboration and public acceptance have affected these municipalities' abilities to implement green infrastructure projects on a municipal-wide scale. Through qualitative interviews with key practitioners ($n = 6$), solutions to address these challenges are identified. This paper argues that implementing strong green infrastructure policies, providing greater training opportunities, gaining senior management buy-in, developing a dedicated, interdisciplinary leadership team, and creating new approaches to educate the public are essential next steps. By working towards these solutions, municipalities will be able to begin working towards fully integrate green infrastructure into the planning process, inherently make green infrastructure visibly dominant and increasing the resiliency of the water network.

Keywords: Green Infrastructure, barriers, socio-ecological, water infrastructure, interconnected network, resiliency

Introduction

The existing stormwater management system that is in place today represents an ageing and degraded system, unable to handle the capacity of a major flood (Nirumpama, Armenakis & Montpetit, 2014, p. 1261-1263). With climate change expected to cause increases in climate extremes and changes to the global water cycle including more intense rainstorms (IPCC, 2014), Ontario municipalities will struggle to provide adequate stormwater management if resilient infrastructure is not prioritized over traditional stormwater infrastructure. The need to apply natural solutions to adapt to the impacts of climate change provides the opportunity for municipalities to implement more green infrastructure while also visibly returning the water network to the urban landscape. Although municipalities in Ontario have begun to implement green infrastructure projects, there are a number of barriers and challenges associated with its planning and implementation which has prevented them from fully integrating green infrastructure into their planning processes. The need for improved policies, knowledge and training, senior management buy-in, collaboration as well as public acceptance and education are among the most critical issues which must be addressed. If these challenges are not addressed, municipalities will not be able to fully integrate green infrastructure into the planning process and prioritize green infrastructure over traditional piped stormwater infrastructure.

This Major Paper examines the barriers and challenges to planning and implementing green infrastructure within Ontario municipalities and assesses how green infrastructure is incorporated within the planning process. Using the City of Toronto and Brampton as case studies, issues faced by both municipalities were analyzed and compared to determine if similarities exist, as well as to develop solutions. This paper also demonstrates how the implementation of green infrastructure can help connect people to the water network and

improve their perception of water in the urban environment. This socio-ecological relationship, one where humans impact the water network (either positively or negatively) and the water network impacts the human environment is essential to begin improving the way people perceive and interact with the water network. The opportunity for green infrastructure to dominate the landscape in terms of visibility is also a key component of this research.

Despite the barriers and challenges to planning and implementing green infrastructure projects, this research provides several solutions for municipalities to consider. If municipalities are to begin fully integrating green infrastructure into the planning process and prioritizing it over traditional infrastructure, green infrastructure will need to be ‘required’ rather than simply ‘encouraged’ in policies and plans. Municipalities should also take advantage of leveraging existing policies and revising them to include green infrastructure. As a part of the planning process, municipalities will need to provide dedicated interdisciplinary teams working on green infrastructure projects to ensure continued success. While these interdisciplinary teams are necessary, it will be essential that staff involved in green infrastructure projects are adequately trained to embed this training into their everyday practices. As more green infrastructure projects are implemented, green infrastructure will naturally become visibly dominant within the urban landscape. Lastly, embedding strong public engagement in the process will be necessary in order to achieve public buy-in. These recommendations serve as the starting point for municipalities to begin fully integrating green infrastructure into the planning process and prioritizing it over traditional stormwater infrastructure.

Overview of Literature

The literature review began with a general search of journal articles related to green infrastructure. Broad issues such as the scale at which green infrastructure is planned for, defining green infrastructure, and so forth were all identified at this stage. Once the issues were confirmed, a more detailed review of each theme was conducted. The literature reviewed for this paper helped to inform the policy challenges related to green infrastructure planning and implementation (e.g., planning at the watershed scale, defining green infrastructure in policies and plans), green infrastructure's dominance in terms of visibility, as well as the need to recognize the multiple benefits green infrastructure provides. While the literature provides a broad overview of the issues in green infrastructure planning, the scholarship demonstrates that a lack of literature exists in addressing the majority of barriers and challenges identified in this Major Paper.

Although contested, the general concept of green infrastructure entails all natural, semi-natural and engineered structures that work to mimic the natural environment and work at all spatial scales (Tzoulas et al., 2007, p. 6). The scholarly literature on green infrastructure mainly examines the importance of green infrastructure in relation to climate change adaptation, the consideration of scale when planning green infrastructure (e.g., watershed scale, community level, etc.), as well as the value of green infrastructure and the benefits it provides. Gill et al. (2007, p. 116) explain that with the climate changing so rapidly, applying green infrastructure will be necessary to allow for cooler microclimates and reducing runoff within urban areas. Climate change is also expected to bring about more intense rainfall in the future, leading to increased flooding (IPCC, 2014, p. 18). As a result, debates around green infrastructure have generally focused around the need for improved stormwater management in order to reduce runoff within urban areas. Municipalities have become increasingly concerned with the existing

grey stormwater infrastructure (e.g., combined sewers) as they are a significant contributor to pollution and reduced water quality (Phillips et. al, 2012). As such, developing a sustainable water system, with the goal of using an approach that mimics the natural environment has become the natural solution (Miles & Band, 2015, p. 2268).

Consideration for the scale at which green infrastructure is planned for has a significant impact in the level of implementation. Many have argued that green infrastructure needs to be applied at all spatial scales for it to have any effect (Gill et al., 2007, 116). Others such as Wheeler (2013, p. 262-263) argue that emphasis needs to be placed on planning for green infrastructure at the watershed scale. I believe that in order for green infrastructure to have a significant impact on municipalities and the urban landscape, green infrastructure planning needs to start at the watershed and subwatershed planning scale. Planning at the watershed and subwatershed scale allows municipalities to broadly identify potential areas for green infrastructure. This will allow for green infrastructure opportunities to trickle down into all other stages of the planning process.

Demonstrating the multiple benefits of green infrastructure has become an increasingly popular topic amongst scholars. Andersson et al. (2014, p. 445) argue that the ecosystem services which green infrastructure provides can allow for an improved socio-ecological relationship to the natural environment. While the concept of ecosystem services is now gradually being integrated into land use planning in certain areas, little has been done to address how to integrate this concept into everyday planning (Kopperoinen, Itkonen & Niemela, 2014, p. 1361). I believe that in order for municipalities to increase the use of green infrastructure, the multiple benefits (e.g., improved water quality, improved ecosystems, reduced infrastructure costs, etc.) should all be examined to help build the case around implementing more green infrastructure. Hostetler,

Allen and Meurk (2011, p. 370) examine the role that green infrastructure plays in conserving biodiversity while also demonstrating the benefits of improved water quality. By demonstrating the multiple functions that green infrastructure can provide, municipalities will be able to make the case for green infrastructure in terms of economics when comparing it to traditional stormwater infrastructure (Hansen & Pauleit, 2014, p. 526). Therefore, displaying the multiple benefits that green infrastructure provides acts not only as an educational piece, but also provides a business case that municipalities can use.

Issues around defining the term ‘green infrastructure’ have also sparked debate due to its broad scope. As explained by Taylor (personal communication, 2017), the term green infrastructure was first coined by Michael Hough under the *Task Force for Bringing Back the Don* in 1991. Allen (2012, pg. 18) argues that the term green infrastructure was first coined by the President’s Council on Sustainable Development in 1999 and was described as “A network of open space, airsheds, watersheds, woodlands, wildlife habitat, parks, and other natural areas that provide many vital services that sustain life and enrich the quality of life” (Allen, 2012, pg. 18). This broad definition of green infrastructure means that everything within the natural environment could be considered a part of green infrastructure. In Ontario, the *Provincial Policy Statement* (2014) defines green infrastructure as a natural or human-made element that provides an ecological or hydrological function. In order for implementation to be widespread, a well-defined term for green infrastructure must be incorporated. For the purposes of this Major Paper, green infrastructure entails any structure (natural or engineered) that is a function of an existing water infrastructure system, and which works to mimic the natural environment and provides multiple socio-ecological benefits such as improved water quality and flood protection.

Adapting to the impacts of climate change and ensuring infrastructure is resilient has emerged as an important discussion in relation to green infrastructure. While municipalities have begun to mitigate the impacts of climate change, most have underemphasized the importance of adaptation (Bulkeley et al., 2011, p. 128). Municipal water systems are degrading as a result of demographics and climate variability (Wong & Brown, 2014, p. 132). The impacts of more intense rainfall events are already being felt in Ontario (e.g., the flooding of Toronto Islands). As Roggema (2014, p. 225) explains, the past was based on linear infrastructure development, but climate change will require people to implement more resilient, non-linear infrastructure in order to withstand the impacts. Therefore, in order for municipalities to build resiliency, current thinking will need to shift away from prioritizing traditional stormwater infrastructure to that of green infrastructure in order to withstand the impacts of climate change.

While these are important components, gaps in scholarly literature exist in relation to addressing the barriers and challenges municipalities face in planning and implementing green infrastructure projects. Through research completed for this Major Paper, I found that while there is relatively less literature with regards to green infrastructure, much literature exists for grey stormwater infrastructure. Debates around stormwater infrastructure have been heavily focused around source water control and end-of-pipe approaches (Goonetilleke et al., 2005, p. 31). As Johns (2018) explains, there is significant opportunity to increase the use of green infrastructure in Toronto through policy. Using watershed and subwatershed plans, provincial source water protection plans, as well as water conservation plans are a few of the instruments that can be used to implement more green infrastructure (Johns, 2018, p. 17). In order to begin planning for more resilient water infrastructure, the gap in literature in relation to the barriers and challenges to planning and implementing green infrastructure will need to be addressed.

Methodology

The research design for this Major Paper was conducted in several phases. During the first phase of the research, three professionals involved in the planning and implementation of the Brampton County Court bioswale pilot project were interviewed. The first interview that was conducted was with Shannon Logan (Nov 8, 2017), Project Manager with the Toronto and Region Conservation Authority's Sustainable Neighbourhood Action Program (SNAP) team who described the process for selecting County Court as an urban renewal project, the challenges faced from a conservation authority perspective, and the importance of community engagement. I then interviewed Michael Hoy (Nov 10, 2017), Senior Environmental Policy Planner at the City of Brampton, who provided a good understanding of the planning and implementation process for the bioswale as well as the main barriers and challenges that were faced during the project. Lastly, I interviewed Maggie Liu (Nov 10, 2017), Engineer (Hydrology) at the City of Brampton to gain a better understanding of the technical considerations involved in the construction of green infrastructure projects such as the County Court bioswale and how the draft Ontario Ministry of Environment and Climate Change Low Impact Development Guidance Manual (2017) would impact the city. Based on the interviews, I found that I was able to identify key challenges and barriers associated with the planning and implementation of green infrastructure including gaps in knowledge and lack of training, senior management buy-in, collaboration, public acceptance, and the need for stronger policies as I will discuss further in Chapter 3. As an Environmental Planning Student at the City of Brampton, I had the opportunity to interact with several of the professionals involved with the planning and implementation of green infrastructure at the City. This experience allowed me to gain a better understanding of the planning process as well as the challenges associated with implementing green infrastructure

projects. The internship also led to me to select County Court as the case study for this Major Paper.

The second component within my data collection involved interviewing professionals involved with the planning and implementation of Corktown Common in Toronto. I used these interviews to examine the planning process for large-scale green infrastructure projects such as Corktown Common, what was involved in the design process and key considerations, as well as the implementation process. The process included interviewing Shayna Stott (May 3, 2018), Environmental Policy Planner at the City who provided me with a better understanding of the planning process and implementation of green infrastructure within the Toronto region. I also interviewed Sheila Boudreau (April 25, 2018), former City of Toronto Landscape Architect who provided me with insight into what goes into the design process for this type of green infrastructure project. Lastly, I interviewed Yafit Rokach (June 15, 2018), Parks Manager at the City, who gave me a better understanding of the considerations which need to be taken into account for maintaining green infrastructure projects once they are complete and how to address some of the challenges during the planning and implementation process. For all six participants, I transcribed the interview notes. The interpretation of the interviews represents my own interpretations.

I then conducted a detailed policy review and examined how green infrastructure has been incorporated within municipal policies and plans in Ontario to understand where the gaps lie and how these gaps can be addressed in order to move green infrastructure forward so it can be implemented on a municipal-wide scale.

Lastly, I completed site visits for both the County Court bioswale and Corktown Common in 2017 and 2018 to gain a visual understanding of the landscape and to compare the barriers and challenges identified by the professionals with the final product.

Case Studies

County Court Bioswale

The City of Brampton County Court SNAP project began in 2009 as a collaborative effort between the City and the Toronto and Region Conservation Authority as part of the Sustainable Neighbourhood Action Plan (SNAP) (Logan, 2017). The County Court neighbourhood is located north of Highway 407 and east of Hurontario Street (see Figure 2 and 3). Through a neighbourhood selection process that took into account older development areas as well as municipal and regional priorities, the County Court area was selected for its need to retrofit the Upper Nine Stormwater Management Pond and regeneration of Etobicoke Creek (ibid). As a component of the action plan, the development and implementation of a bioswale was recommended for the site and is the first bioswale to be built by the City (Hoy, 2017). The implementation of the County Court bioswale is representative of a large project coming to fruition and demonstrates the common challenges municipalities face when implementing green infrastructure projects (Logan, 2017).



Figure 1: County Court Bioswale (Dokoska, 2018)

Corktown Common

As a former brownfield site, Corktown Common is now a seven-hectare park situated between Lower River Street and Bayview Avenue (see Figure 6 and 7) (Rokach, 2018; Toronto, 2018). The project is a result of the collaboration between Waterfront Toronto, the City of Toronto, and the Province of Ontario (Rokach, 2018). The park is part of the revitalization of the waterfront and supports the Don River Valley as an adjacent floodplain as well as the growing downtown core (ibid). The park maintains several different ecozones (e.g., a marsh) and is intended to grow naturally, demonstrating the natural processes such as water flow (ibid).



Figure 4: Corktown Common Wetland (Dokoska, 2018)



Figure 5: Corktown Common Park (Dokoska, 2018)



Figure 6: Corktown Common in the Context of the City of Toronto (Google Maps, 2018)

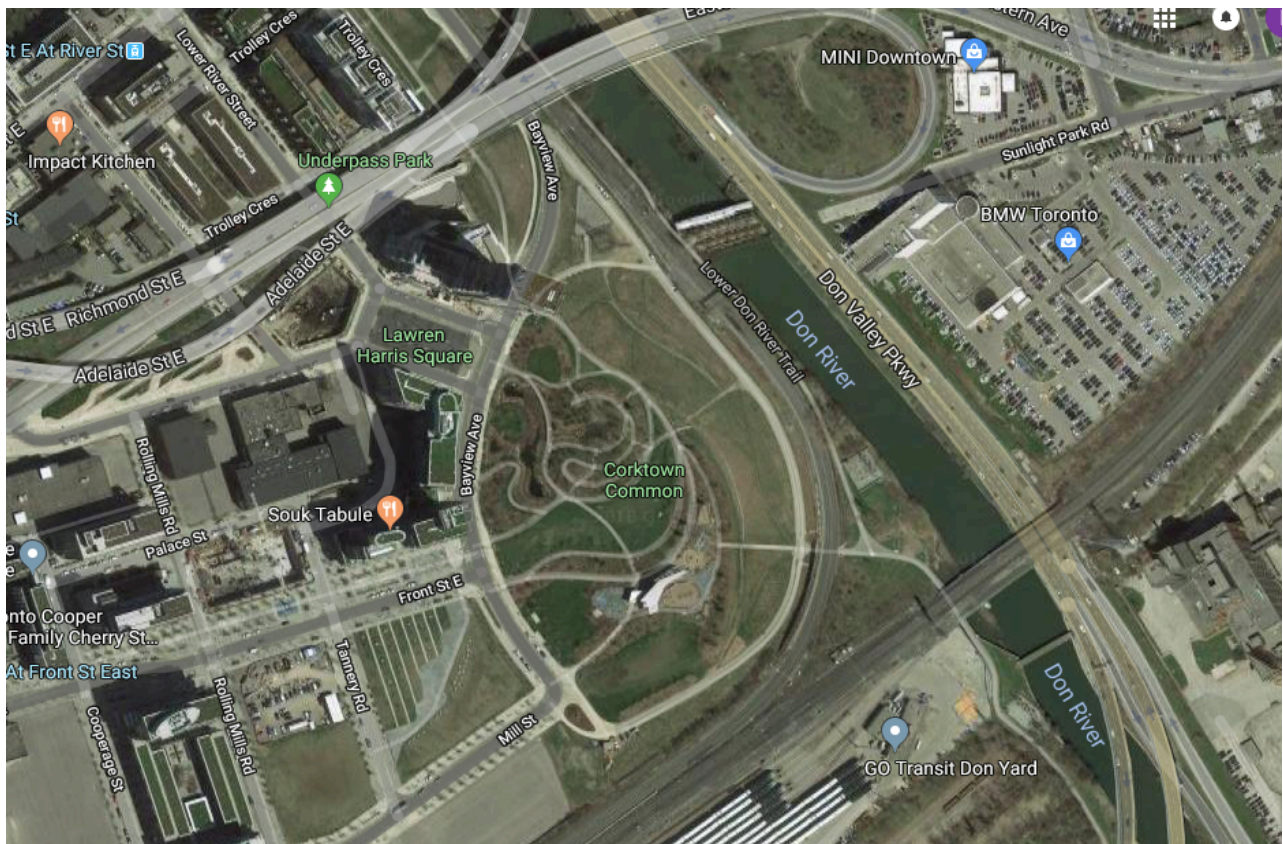


Figure 7: Aerial View of Corktown Common (Google Maps, 2018)

Chapter 1: City Planning and Implementation: The Need for Greater Consideration of Green Infrastructure

1.1 Policies, Plans and Other Relevant Documents

Green infrastructure has recently gained importance in land use planning as the need for climate adaptation measures have become a primary concern for Ontario municipalities. Finding effective adaptation measures will be essential for providing both short-term coping strategies and long-term transformations (Moser & Ekstrom, 2010, p. 22026). Expected increases in storm intensity and flooding, combined with projected increases in urbanization by 2050, has placed pressure on municipalities to find effective adaptation measures (Green et al., 2016, p. 1051). Although green infrastructure has become a widely accepted adaptation measure, government policies and plans show that typical grey infrastructure still dominates the landscape as well as the decision-making process. The poor way in which green infrastructure has been incorporated within policies and plans across different scales of government in Ontario demonstrates a lack of direction from both the provincial and regional governments to require municipalities, as a part of the planning process, to implement green infrastructure. This section examines the lack of implementation of green infrastructure policies at the different scales of government, the need for stronger policy language, as well as the need to revise existing policies around green infrastructure. The following page outlines the complete list of documents that have been reviewed for this research as a basis for understanding the policy context to planning and implementing green infrastructure projects such as the County Court bioswale and Corktown Common.

Table 1 provides a summary of the plans reviewed. The table is broken down into provincial, regional, and city plans as well as the definition of green infrastructure used in the plan. The review process also involved identifying whether the plans includes strong or weak policy language in relation to green infrastructure. Strong policy language involves requiring the implementation of green infrastructure whereas weak policy language simply encourages green infrastructure implementation or there is no green infrastructure policy available.

Table 1: Complete List of Policies and Plans Reviewed

Plan	Year	Definition of Green Infrastructure	Strong/Weak Policy Language
Provincial Policy Statement	2014	<ul style="list-style-type: none"> “Natural and human-made elements that provide ecological and hydrological functions and processes.” 	Weak – ‘encourages’ green infrastructure
Growth Plan	2017	<ul style="list-style-type: none"> “Natural and human-made elements that provide ecological and hydrological functions and processes.” 	Weak
Ontario Climate Change Strategy	2015	<ul style="list-style-type: none"> “Interconnected networks of green open spaces that provide a wide range of ecosystem services.” 	Weak
Greenbelt Plan	2017	<ul style="list-style-type: none"> “Natural and human-made elements that provide ecological and hydrological functions and processes.” 	Weak
Low-Impact Development Manual (draft)	2017	<ul style="list-style-type: none"> “Natural and human-made elements that provide ecological and hydrological functions and processes.” 	Strong (in relation to targets)
Region of Peel Official Plan	2016	No policy available	Weak – policies for LID but no green infrastructure policy
City of Toronto Official Plan	2015	<ul style="list-style-type: none"> “Natural and human-made elements that provide ecological and hydrological functions and processes.” 	Strong
City of Toronto Green Streets Technical Guidelines	2017	<ul style="list-style-type: none"> “Natural and human-made elements that provide ecological and hydrological functions and processes.” 	Strong
City of Toronto Wet Weather Flow Master Plan	2017 update	<ul style="list-style-type: none"> “Natural and human-made elements that provide ecological and hydrological functions and processes.” 	Strong

City of Brampton Official Plan	2006	No policy available	Weak – Policies for LID but no green infrastructure policy
TRCA Living City Policies	2014	<ul style="list-style-type: none"> Refers to natural green elements (street trees, wetlands, meadows, soil (gardens and cropland), etc.) and built green elements (green roofs, bioswales, permeable pavement, etc) that are present in both urban and rural settings. 	Weak – ‘support and promote’

1.1.1. Provincial Policies and Plans

Lack of enforcement at the provincial level has led to the slow uptake and implementation of green infrastructure projects across Ontario municipalities. The different approaches in how green infrastructure is applied amongst the different provincial documents makes it difficult to identify how to approach green infrastructure. Although the definition may be mainstreamed within many of these documents, how it is applied (directly or indirectly) is inconsistent, leading to a lack of understanding and application of green infrastructure projects within municipalities.

At the provincial level, policies and plans provide direction for the regulation of development and use of land (MMAH, 2014). The *Planning Act* (2018) provides the legislation around land use planning and the *Provincial Policy Statement* (2014) provides “policy direction on matters of provincial interest related to land use planning and development” (MMAH, 2014). While the *Planning Act* (2018) provides the legislation which allows municipalities to develop policies and the *Provincial Policy Statement* (2014) provides the policy direction, these documents are meant to be broad to allow for interpretation by municipalities, and as such, do not require municipalities to implement natural green infrastructure solutions. In order to start actively moving away from the traditional application of grey infrastructure options, there should

be greater consideration for how the province approaches green infrastructure, to consider how they may be contributing to the lack of application in green infrastructure projects within municipalities.

The Ontario *Planning Act* (2018) is the highest order planning document guiding land use development within the province. While green infrastructure is not explicitly referenced or defined, it is indirectly referenced as part of the climate change policies. Under Section 16(14), it states, “An official plan shall contain policies that identify goals, objectives and actions to mitigate greenhouse gas emissions and to provide for adaptation to a changing climate, including through increasing resiliency” (MMAH, 2018, Section 16(14)). In this sense, municipalities have the authority to include green infrastructure policies to allow for communities to build resilience and adapt to climate change, but the Act itself does not require municipalities to enforce green infrastructure (MMAH, 2018). While at a high level, the Ontario *Planning Act* (2018) shows that there is acknowledgement in the need to provide natural services in order to adapt to a changing climate, but the broad interpretation set out in the Ontario *Planning Act* (2018), makes it difficult to require all municipalities to implement green infrastructure.

The *Provincial Policy Statement* (2014), under the direction of the Ontario *Planning Act* (2018), demonstrates a lack of direction in requiring municipalities to implement green infrastructure. Prior to the update, the 2005 PPS did not include green infrastructure within its policies (Johns, 2018, p. 11). With the push from Green Infrastructure Coalition of Ontario (GIO), the provincial government incorporated green infrastructure into the 2014 PPS, as well as a definition as to what constitutes green infrastructure (ibid). Green infrastructure is defined as “Natural and human-made elements that provide ecological and hydrological functions and processes” (MMAH, 2014). I do not believe the PPS sufficiently prioritizes the use of green

infrastructure. The *Provincial Policy Statement* (2014, p. 15) under Section 1.6.2, states that green infrastructure “shall be promoted” to complement infrastructure. This demonstrates that green infrastructure is encouraged, but not necessary. Provincial policies and plans are intentionally left as broad statements to be interpreted, but, in order to allow green infrastructure to become a primary infrastructure choice for managing stormwater, I think there needs to be more robust direction from the provincial government.

The *Growth Plan* (2017) demonstrates the Province’s recent attempt at better incorporating green infrastructure within its policies, yet still demonstrates that work towards requiring green infrastructure is needed. The *Growth Plan* (2017) incorporates the PPS (2014) definition of green infrastructure and includes references to green infrastructure through its guiding principles. Although not explicitly stated here, the *Growth Plan* (2017, p. 6) states that climate change considerations need to be examined when planning and managing growth including considerations for infrastructure that is adaptive to climate change; which can include green infrastructure. The *Plan* recognizes that by applying the policies within the plan, creating complete communities that include green infrastructure within development is possible (MMAH, 2017, p. 14).

Through the *Growth Plan* (2017), policies related to water infrastructure are not always labelled as green infrastructure. For example, in Section 4.2.1, it states “Water resource systems will be identified, informed by watershed planning and other available information, and the appropriate designations and policies will be applied in official plans to provide for the long-term protection of key hydrologic features, key hydrologic areas, and their functions” (MMAH, 2017, p. 41). As natural features such as water resource systems can be considered a part of green infrastructure, it can be seen that despite the fact that these policies do not make explicit

reference to green infrastructure, there still are policies in place to deal with the protection of these natural features. Having these indirect references for the use of green infrastructure can make it difficult to identify how to approach green infrastructure within a municipality and fully understand it.

The Ontario *Climate Change Strategy* (2015) previously in place provided a slightly different direction to that of the policies and plans previously mentioned. The strategy takes a different approach to green infrastructure as it is defined as “an interconnected network of green spaces that provide multiple benefits including preserving biodiversity, reducing the heat island effect, and reducing flood risks” (OMOECC, 2015, p. 18). The strategy incorporates the benefits that result from using a more natural approach. This was not identified in the previous definition provided by the PPS (2014). The problem that exists within these provincial policies and plans is that there is no specific mention of what green infrastructure actually is. To identify it as an interconnected network with multiple benefits works when you want to reference infrastructure on a landscape scale, but in order for municipalities to implement it, this type of interpretation will not work. The province must work to develop a cohesive definition and application of green infrastructure within its policies and plans if green infrastructure is to be successful. The different approaches currently in place demonstrates the inconsistency that exists, contributing to the lack of implementation.

Furthermore, the *Greenbelt Plan* (2017) can be seen as a combination of work between the PPS (2014) and Ontario *Climate Change Strategy* (2015). While the *Greenbelt Plan* (2017) takes the definition of the PPS (2014), it also attempts to identify green infrastructure as a landscape component. While there is mention of green infrastructure within this plan, there is no specific policy related to implementing green infrastructure. The plan does however make

mention that encouraging green infrastructure should be a part of climate change resiliency (MMAH, 2017). The *Greenbelt Plan* (2017) is intended to work in concert with the Ontario *Climate Change Strategy* (2015) as well as the PPS (2014), and therefore, follows much of the same terminology and policies. Looking at the *Greenbelt Plan* (2017) from a landscape perspective, by growing the greenbelt, one is inherently also increasing the amount of green infrastructure. As Amati and Taylor (2010, p. 153) explain, applying green infrastructure can allow for the re-appraisal of the green belt, inherently expand the green infrastructure network. This plan further demonstrates the province's inconsistent approach to green infrastructure.

Lastly, in order to address stormwater management within the Province, the draft *Low-Impact Development Stormwater Management Guidance Manual* (2017) must also be referenced. While the draft manual has been released, the targets set out in the report are not yet in force and thus, municipalities are only required to follow the *2003 Stormwater Management Planning and Design Manual* set out by the previous Ontario Ministry of Environment. The 2003 manual does not make reference to green infrastructure and can be seen as having weak targets for stormwater retention. The new targets would require all new development, redevelopment, infill, linear infrastructure, and retrofits to meet the 90th percentile for the Runoff Volume Control Target, meaning that these sites will need to capture enough water equivalent to a 2-year storm (roughly 25mm) (OMOECC, 2017, p. 47). As a result, these new targets place a greater emphasis on implementing green infrastructure, as much of the existing grey infrastructure methods would not have the capacity to deal with a 2-year storm (Hoy, 2017).

This manual reflects how planning and designing for stormwater management using natural options such as green infrastructure can lead to many benefits including reduced flooding and increased community resilience (OMOECC, 2017). The manual itself explains the necessity

of moving away from the standard grey infrastructure approaches and moving towards an ecosystem-based water balance approach to stormwater management including lot level measures as well as end-of-pipe controls (OMOECC, 2017, p. 4). Unlike the other provincial policies and plans, the *Low-Impact Development Stormwater Management Guidance Manual* (2017) would provide a higher level of detail and would include tighter regulations, making it easier for municipalities to pitch green infrastructure to developers (Liu, 2017). The guidance provided in this manual shows that when municipalities have a clear direction, incorporating it into everyday practices becomes part of the routine. Setting quantifiable targets and measures on stormwater management can make natural green infrastructure a more favourable option to that of the traditional grey infrastructure.

1.1.2. Regional Plans and Policies

At the regional level, dealing with planning issues such as water infrastructure and ecosystem planning has become of growing importance (Wheeler, 2013, p. 264). At this scale of governance, regional governments such as the Region of Peel manage ecosystems through landscape planning, yet smaller to that of the provincial government (Wheeler, 2013, p. 266-267). As Stephen Wheeler (2013, p. 262) explains, one of the paradoxes of planning is that most environmental problems such as the planning and implementation of green infrastructure are best approached at the regional scale, yet this is typically considered the weakest level of government as a result of its institutions and public understanding. As explained, one of the main reasons for this results from the fact that members of the public cannot think regionally even though most development issues are handled at this scale (Wheeler, 2013, p. 262). Issues which concern the public are most often local in nature. Therefore, since the public's perspective is embedded in the local scale where their daily life exists, this makes it difficult for them to envision planning for

green infrastructure at a larger scale, leaving out the importance of planning for a green infrastructure network at the regional or even watershed scale (Wheeler, 2013, p. 262-263). Green infrastructure should represent an interconnected green infrastructure network and should be integrated through a landscape approach, taking into account not only the regional boundaries but also taking into account the larger watershed that is encompassed throughout, making sure that policies and plans are enforced for lower-tier municipalities in order to see effective implementation on a municipal-wide scale.

The Region of Peel is an upper-tier municipality encompassing the City of Brampton, City of Mississauga and Town of Caledon. The Region of Peel *Official Plan* (2016) has no clear definition of green infrastructure, but does include approaches for the lower-tier municipalities to protect, restore and enhance the natural heritage system. Policies exist within the *Official Plan* (2016) that identify the need to promote environmental linkages between local ecosystems to the larger overall network, which can be seen as promoting green infrastructure at the landscape scale (Peel, 2016, p. 9). The Region of Peel *Official Plan* (2016, p. 46-73) also includes policies related to watershed planning as well as specific natural heritage feature protection through the Greenlands System. Schedule A of the Region of Peel *Official Plan* (2016) outlines the core areas of the Greenlands System, which prohibit development from occurring in these areas through policies contained in Section 2.3. By enhancing and protecting the core areas of the Greenland System, the Region of Peel is able to not only protect these linkages, but allow for its expansion. While policies are currently in place, in order to be able to expand the Greenland System, the Region of Peel should consider revising existing policies and integrating green infrastructure policies within the *Official Plan* (2016). With the Official Plan Amendment process underway, as well as the Municipal Comprehensive Review process, which requires single and upper-tier municipalities to be in conformity with the *Growth Plan* (2017), the Region

of Peel should enforce green infrastructure as the primary method of stormwater management within the region and allow for the consideration of green infrastructure early enough in the planning process to maximize opportunities for implementing green infrastructure. Therefore, while policies for protecting and enhancing natural heritage systems exist at the regional level, greater attention needs to be given to revising many of the existing policies around green infrastructure as well as developing additional policies and requiring lower-tier municipalities to implement green infrastructure as the primary stormwater management consideration.

1.1.3. Municipal Plans and Policies

At the local scale, municipal governments provide the policies that have a direct impact on residents' everyday lives. Although green infrastructure projects have been implemented in many municipalities including the City of Toronto and Brampton, their plans and policies show that there is a need to better incorporate the term 'green infrastructure' within policies and plans. The City of Toronto *Official Plan* (2015) defines green infrastructure as an interconnected component to the grey urban environment and describes green infrastructure as being no different to that of the City's road or sewer infrastructure. The City applies the same definition used within the PPS (2014). The plan demonstrates that green infrastructure is a part of the urban environment. While the *Plan* sees green infrastructure as a part of the municipal landscape, it lacks the ability to prioritize green infrastructure as the primary stormwater management option in the city. Grey linear infrastructure is still the primary consideration for infrastructure projects.

Although the *Official Plan* (2015) may not prioritize green infrastructure over traditional grey stormwater infrastructure, initiatives have been put into place to ensure the city is maximizing opportunities for green infrastructure including the Toronto *Green Streets Technical Guidelines* (2017). These guidelines provide a comprehensive list of green infrastructure

techniques that can be applied to the City of Toronto's streets, taking in to account the geographic and climatic conditions (Toronto, 2017). The guidelines set out stormwater retention requirements as well as stormwater runoff requirements (ibid). Having the *Official Plan* (2015) set out the guidelines around green infrastructure in Section 3 has allowed the city to push for these green infrastructure guidelines. This work demonstrates the City's efforts to alter the current dominance in grey infrastructure and provide practitioners with the tools and guidance they need to effectively implement green infrastructure projects.

The City of Toronto *Wet Weather Flow Master Plan* (2003) was implemented in 2003 as part of a long term strategy to reduce the vulnerability of wet weather flows in Toronto and improve watershed health. The plan includes a 25-year implementation plan with initiatives being identified every 5-year periods (Toronto, 2003). Regular updates to the plan has allowed for many green infrastructure-related projects such as the *Green Streets Technical Guidelines* (2017). While the most recent update to City Council includes green infrastructure demonstration projects, in order for green infrastructure to be applied on a municipal-wide scale, the City will need to develop a standardized approach to implementing green infrastructure through policies.

In comparison, when examining the City of Brampton's *Official Plan* (2006), the policies put in place must conform to the Region of Peel *Official Plan* (2016). The Brampton *Official Plan* (2006) does not have a clear definition of green infrastructure. Flood and erosion protection measures are identified as important for the protection of health and safety as well as maintaining and improving water quality (Brampton, 2006). These measures, as a result of the guidance from the regional official plan, are directed towards low-impact development and stormwater management ponds (ibid). In order to adapt to climate change and ensure that water infrastructure is resilient, low-impact development measures must be coupled with other green

infrastructure to maximize the use of natural elements, their processes and functions. While green infrastructure may not be explicitly stated, the plan does make reference to green infrastructure indirectly. Section 4.6.3.9 of the *Official Plan* (2006) states that "... the City encourages the use of naturalized, "green" at-source measures to mitigate the effects of stormwater quantity and quality impacts on both surface and groundwater resources" (Brampton, 2006, p. 4.6-11). In this sense, the City is encouraging the use of green infrastructure to improve both water quantity and quality. For this to have any impact on the municipality, and to make green infrastructure more visibly dominant, there will need to be changes in policy to require the implementation of green infrastructure. Although there is no requirement from the Region to implement green infrastructure, the City itself, in collaboration with the Toronto and Region Conservation Authority (TRCA), has taken the initiative to implement green infrastructure projects, such as the County Court bioswale as an example. This can also be seen through the recently endorsed *Brampton 2040 Vision* (2018) which includes the vision of turning Brampton into an 'Eco-Park'. As previously mentioned, the Official Plan Amendment and Municipal Comprehensive Review process provide the city with the opportunity to strengthen policies to include green infrastructure as well as revise many of the existing policies within the *Official Plan* (2006) around green infrastructure.

1.1.4. Conservation Authority policies

Conservation Authorities also play a large role in the planning and implementation of green infrastructure. With municipalities focused within their own boundaries, Conservation Authorities such as the Toronto and Region Conservation Authority (TRCA) examine green infrastructure on a watershed scale. The *Living City Policies* (2014) provide the TRCA with the ability to carry out much of the organization's objectives related to conservation, restoration,

development and resource management. The implementation of green infrastructure is encouraged within the *Living City Policies* (2014) as the intent of these policies is to allow for multiple benefits within a project. The TRCA is also required in many different capacities, to partner with municipalities in order to support the goals of the *Living City Policies* (2014). The Brampton County Court bioswale pilot project is an example of the importance of collaboration and cooperation between municipalities and conservation authorities within the implementation of green infrastructure. In order to have effective implementation, and one that is spread throughout the watersheds and not just the municipality itself, there needs to be greater focus on how to help municipalities overcome certain challenges and barriers in order to prioritize these green infrastructure projects.

1.2. Current Urban Planning Process

The current urban planning process as it stands today provides municipalities with the ability to implement green infrastructure, yet little action has been taken to implement green infrastructure on a municipal-wide basis. Green infrastructure is often incorporated late within the planning process, allowing municipalities to select other alternatives. As described by Mell et al. (2013, p. 297), green infrastructure is still generally incorporated as an afterthought in the planning process. Many planners have worked to embed a more ecological perspective in the planning process, however, as a result of limited resources and competing priorities, this is often difficult (ibid). While green infrastructure can be implemented across all scales (Allen, 2012, p. 21), in order for municipalities to take action and embed green infrastructure planning in their day-to-day processes, municipalities should work with Conservation Authorities right from the beginning of the planning process (i.e., watershed or subwatershed scale) to identify all opportunities for implementing green infrastructure. As Benedict and McMahon (2006) discuss,

this would entail municipalities identifying green infrastructure opportunities during the watershed planning process (Allen, 2012, p. 21). The watershed scale is based on the idea of a comprehensive approach to environmental planning, with water being the focal point (Mitchell et al., 2014, p. 462). Planning at the watershed scale allows for opportunities to implement green infrastructure early in the process. Planning at the watershed scale is also a more integrated approach, focusing less on the boundaries of each municipality and focusing more on the environmental effects of the interconnected system. Through the *Growth Plan (2017)*, municipalities are now required to develop watershed plans, representing a prime opportunity to identify opportunities for green infrastructure.

The current urban planning process does not allocate funding for green infrastructure projects in the same way that it does for grey stormwater infrastructure. As demonstrated through many municipal projects, one of the primary methods for implementing green infrastructure projects comes from the capital budget process (Johns, 2018, p. 21). The Brampton County Court bioswale was recommended by the Environment & Engineering Division as a green infrastructure project after reviewing the capital budgets for road resurfacing (Hoy, 2017). There was no specific funding initially allocated for green infrastructure, but because the funding was available, they were able to fit green infrastructure into the project (ibid). In the City of Toronto, annual funding towards infrastructure projects has allowed for infrastructure renewal projects and funding for programs such as Flood Protection projects (Johns, 2018, p. 21). In these cases, green infrastructure projects are fit into the planning process when there is space to do so.

Municipalities should also take advantage of implementing more green infrastructure projects within Secondary Plans. This stage of the urban planning process can identify areas such as right-of-ways where green infrastructure projects would be suitable. If, at the watershed scale,

a particular area was identified broadly as being a good opportunity for implementing green infrastructure projects, the Secondary Plan can then allow for a more detailed view, pointing out specifically where the green infrastructure projects can be implemented. This allows for municipalities to envision the green infrastructure network at a more local scale. Identifying opportunities for green infrastructure at all stages of the planning process can ensure a consistent approach is used, whether it is at the site plan stage, or the watershed scale. Overall, by using the watershed scale to map out opportunities for green infrastructure projects, the process can become part of the norm, integrated at the early stages of the planning process rather than being left as an afterthought. This allows for green infrastructure projects to trickle down to Secondary Plans as well as site plans. Having stronger policies around green infrastructure, coupled with the consideration for green infrastructure at early stages of the planning process provides a good foundation for greater implementation on a municipal-wide basis.

1.3 Consideration for Green Infrastructure in the Planning Process

The current urban planning process demonstrates that there is a lack of consideration for green infrastructure in the planning process. Green infrastructure is not currently prioritized over traditional grey infrastructure. Municipalities must prioritize green infrastructure over traditional grey stormwater infrastructure if a more resilient, natural urban system is to be built. As Goonetilleke et al. (2005, p. 31) explain, rapid urbanization has demonstrated that traditional grey infrastructure is ineffective. Other municipalities have begun to prioritize green infrastructure within their official plans. For example, the District of Squamish *Official Community Plan* (2018, p. 116) clearly outlines a green infrastructure section with the goal of integrating green infrastructure within the municipality in order to manage water resources, maintain ecosystems, provide flood protection, and address climate change within the watershed. These types of policies help to ensure that green infrastructure is given priority over traditional

grey infrastructure, and also helps to preserve the natural water system. As Ontario municipalities work to update their official plans, including these types of policies will allow municipalities to maximize on the opportunities to implement green infrastructure and give priority to more natural solutions, rather than the status quo ‘end-of-pipe’ solutions.

Municipalities can incorporate greater consideration for green infrastructure within their planning process by revising many existing policies around green infrastructure. As previously mentioned, all municipalities including the Region of Peel and City of Brampton have policies around natural heritage systems within their Official Plans as required by the PPS (MMAH, 2014; Peel, 2016; Brampton, 2006). Significant opportunity exists, as stronger policies are developed to prioritize green infrastructure, to also examine existing policies which could be termed as green infrastructure. For example, section 4.5.3.5 states that “Storm water management facilities (i.e., quantity, quality, infiltration, etc.) should be oriented, designed and constructed to contribute to and complement the adjacent natural heritage features, functions and linkages. These facilities should be naturalized to complement the adjacent features and area.” (Brampton, 2006, p. 4.5-9). This policy could be re-framed to describe that stormwater management facilities, through the use of green infrastructure, can contribute and complement the adjacent natural heritage features, functions and linkages. Therefore, the language that is used within the planning process plays a significant role in how green infrastructure is envisioned. If existing policies were to be re-framed around green infrastructure, municipalities would be able to see greater implementation of green infrastructure.

Chapter 2: Green Infrastructure as the Dominant Form of Water Infrastructure

2.1 Dominance in the Form of Physical Infrastructure

The water network as it exists today has evolved over time to become a complex network of pipes and sewers (Gandy, 2002, p. 22). Urbanization has significantly altered the water cycle, resulting in the expansion of grey infrastructure through the construction of artificial water systems (Karvounis, 2015, p. 5). As Gandy (2002, p. 22) explains, in order to understand the history of the city, people can simply look to the water network. Over time, the water network has evolved to become “subjugated, domesticated, mechanized and made to be profitable” (Gandy, 2002, p. 22). This humanization of water has changed how the water network is viewed within the city. As a result of the need to divert water as quickly as possible, the invisible water system has led to the dominance of a grey water infrastructure system within municipalities (Gandy, 2004, p. 363). With a growing awareness of the need to implement more natural solutions, green infrastructure provides the opportunity to shift the current mindset of water as an inconvenience, to thinking of water as a natural part of the landscape that should be embraced. Green infrastructure cannot function solely on its own, and will need to co-exist with traditional grey infrastructure in terms of physical infrastructure.

In the current urban planning process, priority is given to traditional grey infrastructure. Green infrastructure is often seen as a ‘nice to have’ or an alternative to grey infrastructure (Finewood, 2016, p. 1001). What is really needed is for green and grey infrastructure to co-exist within the urban environment. Urban environments are dependent on the services provided by grey infrastructure. Pipes serve a big purpose, particularly during large rain storm events where green infrastructure does not have the capacity to retain large amounts of water (Hoy, 2017). As

cities continue to develop, managing high volumes of stormwater pollution will continue to be a concern, particularly in areas where there are increases in impermeable surfaces and runoff (McDonald et al., 2014, p.97). Climate change will also create added stress through increases in extreme rainfall events (Copeland, 2016). By co-existing, green infrastructure can reduce the demand that is placed on traditional grey infrastructure, resulting in an increased capacity of grey infrastructure to handle stormwater (Copeland, 2016, p. 3). In this sense, because municipalities rely so heavily on grey infrastructure, the natural processes provided by green infrastructure would help to alleviate many of the challenges of increased runoff and stormwater pollution that municipalities currently face. Rather than removing the entire linear infrastructure system, municipalities should look to integrate green infrastructure within existing grey infrastructure systems. Green infrastructure may not be the answer to all of the issues surrounding stormwater management, but it can be part of the solution (Hoy, 2017). Therefore, in order for municipalities to begin implementing more green infrastructure projects, there needs to be acknowledgement in the need for green infrastructure to co-exist with the linear infrastructure system.

One way to allow for green infrastructure to co-exist in the urban environment is to change the municipal staff (e.g., engineers) perception of water in the city (Hoy, 2017). Opportunities exist for green infrastructure to be incorporated within the linear grey infrastructure system. As Boudreau (2018) explains, applying the linear thinking that water must travel through the piped network can work, but only if those involved in the process are open to other ideas and are flexible with incorporating solutions such as green infrastructure to the project. Since green infrastructure is inherently interdisciplinary and cross-divisional, its versatility demonstrates that greater creativity and integrative thinking is needed to develop these projects (ibid). Kiparsky et al. (2012, p. 395), point out that urban water management lacks innovation but over the last few decades, there has been a need to incorporate innovation in order

to provide a resilient water infrastructure system. Therefore, in order for green infrastructure to co-exist with existing grey infrastructure, those involved with the planning and implementation of green infrastructure projects such as engineers, will need to change the mindset and start to be more adaptive in the linear way of thinking, to give priority to the implementation of green infrastructure projects.

Although green infrastructure is primarily seen for its benefits to stormwater management, integrating green infrastructure within the existing infrastructure network provides the opportunity to effectively communicate the co-benefits of green infrastructure such as the economic, social and environmental benefits (Boudreau, 2018; Chini et al., 2017, p. 1). For example, green infrastructure can reduce urban heat island, increase biodiversity in cities, and improve human health (Tzoulas, et al., 2007, p. 11-13). These multiple services not only benefit humans, they also provide benefits to urban ecosystems, yet there is no one to display the benefits of green infrastructure (Boudreau, 2018). The multiple benefits provided by green infrastructures is not found in traditional stormwater infrastructure. Grey infrastructure is solely used for the purpose of transporting water through the piped network. If green infrastructure was viewed beyond the stormwater aspect, and the additional benefits were taken into account, then it can be seen that green infrastructure provides greater value to the community than grey infrastructure. Therefore, by displaying the benefits of green infrastructure and having municipalities communicate these benefits to the public, green infrastructure can co-exist with traditional infrastructure.

While grey infrastructure provides the service of diverting and treating water, green infrastructure can also serve to address other existing issues a municipality may be facing. As Kopperoinen, Itkonen and Niemela (2014, p. 1361) explain, the concepts of green infrastructure

and ecosystem services are now becoming part of sustainable development, but planners will need more knowledge and training to make the concepts a part of the everyday planning process. Ahern, Cilliers and Niemala (2014, p. 255) explain that adaptive management approaches have been applied in environmental planning and resource management, yet this approach is not used often enough by design and planning professionals. Building the case for planners to integrate green infrastructure into their everyday planning practices by showcasing the multiple benefits of green infrastructure, will positively contribute to more green infrastructure projects being implemented, allowing for green infrastructure projects to work in tandem with traditional stormwater infrastructure.

The Town of Gibson, BC was among one of the first communities to integrate natural assets into their municipal asset management plan (Gibson, 2017, p. 8). The plan not only demonstrates how green infrastructure can replace many of the existing hard infrastructure assets, but also describes how green infrastructure provides many other benefits such as human benefits (Gibson, 2017, p. 6-9). The integration of green infrastructure within their municipal processes makes the business case for using green infrastructure. The Town incorporates the additional services green infrastructure provides through the life-cycle costing process (Gibson, 2017). In this case, green infrastructure has become an important component of the asset management planning in the Town, showing how consideration for green infrastructure is becoming a part of the everyday planning process, rather than separate to that of grey infrastructure.

Through the *Infrastructure for Jobs and Prosperity Act* (2015), Ontario municipalities are now required to include natural assets within their asset management plans. This means that natural assets have begun to be seen as equally important infrastructure options as that of grey

infrastructure. Municipalities are understanding that natural assets such as green infrastructure can provide equal, if not better service to that of traditional stormwater infrastructure (Gibson, 2017, p. 6). Therefore, if green infrastructure is to co-exist with grey infrastructure, Ontario municipalities must understand the full value of the services that green infrastructure provides and understand the range of benefits.

For green infrastructure to co-exist with grey infrastructure, municipalities will need to acknowledge that the engineering processes associated with green infrastructure are different to that of grey infrastructure. The pre-engineering process for green infrastructure projects is often thought to undergo the same process as grey infrastructure projects, but this is not the case (Boudreau, 2018). In order to successfully implement green infrastructure, a greater number of studies are required (ibid). For example, studies are needed to understand the water table and soil structure, as well as delivery (i.e., sub-street utilities) (ibid). The pre-engineering phase for green infrastructure projects requires at least a year of site investigations to undertake these studies (ibid). The construction phase also requires more time for approvals for soil and hydrology reports to understand infiltration (ibid). These considerations influence how successful the green infrastructure project will be. If enough time is not set aside for a particular study, this may affect the understanding of a particular feature within the designated area, impacting the overall project.

Aside from planning and implementation, monitoring and maintenance of green infrastructure projects is required. As with traditional grey infrastructure projects, funds are allocated for the maintenance of the infrastructure (ibid). In green infrastructure projects, this is not always the case (ibid). Monitoring plays a significant role in the success of a green infrastructure project as it ensures that the green infrastructure continues to function properly.

For example, the County Court bioswale included a two-year monitoring plan that was developed in collaboration with the TRCA (Hoy, 2017). Therefore, when planning and implementing green infrastructure projects, municipalities need to ensure that the way in which green infrastructure projects are handled during the engineering and construction phases are adjusted for these projects, rather than following the same processes used for linear grey infrastructure projects.

To conclude, green infrastructure will not become the dominant form of water infrastructure in terms of physical infrastructure. For green infrastructure, its success in Ontario municipalities will come from its co-existence with grey infrastructure. This will require a change in perception around water in the city by municipal staff, the need to frame green infrastructure around the co-benefits it provides, as well as the need to implement different planning processes for green infrastructure to that of its linear counterpart. While green infrastructure will need to co-exist with grey infrastructure, its dominance will come in the form of visibility.

2.2. Dominance in the Form of Visibility

Keeping water away from human eyes through the invisible water network has negatively influenced people's socio-ecological relationship to water (Gandy, 2014, p. 3). While the grey infrastructure network has been focused on burying the system underground, green infrastructure becomes a natural part of the urban environment. The water network will re-



Figure 8: Corktown Common Constructed Wetland (Dokoska, 2018)

emerge as a visible part of the landscape, connecting people to the water system, rather than removing the connection. Where green infrastructure will need to co-exist with grey infrastructure, its dominance will come in the form of visibility. On a broader level, green infrastructure is meant to connect natural areas and open spaces, spaces that are inherently part of the urban environment and viewed as something that needs to be conserved (Benedict & McMahon, 2006, p. 1-2). Residents will be able to change their perception of the water network, allowing for the socio-ecological relationship to become part of their everyday lives. This section will examine how green infrastructure will emerge as the dominant form of water infrastructure from a visibility perspective.

Opportunities exist for municipalities to increase the visible dominance of green infrastructure through the retrofit of existing grey infrastructure. As Richards (2018, p. 1) explains, there needs to be a fundamental shift in the way cities are planned, to rethink where and how things are built, including the retrofit of existing grey infrastructure. In many cases, if a comprehensive review of all existing infrastructure was undertaken, it may be the case that new hard infrastructure is not needed at all (Richards, 2018, p. 2). As Ellis (2013, p. 31) notes, it has been shown through significant evidence that site vegetation, through the use of green infrastructure, can reduce runoff for short rainfall events. If municipalities were to maximize on this opportunity, not only will it save them from having to build costly, large-scale infrastructure projects, but it also provides the opportunity to showcase green infrastructure. Green infrastructure such as bioswales and constructed wetlands are not buried underneath the ground like pipes and sewers. If existing grey infrastructure is retrofitted to more natural, green infrastructure solutions in addition to that of new projects, then green infrastructure can dominate the landscape in terms of visibility. By retrofitting the existing grey infrastructure to green, residents within municipalities benefit by having a direct connection to the visible water

network. As Swyngedow (2006, p. 22) explains, nature within a city becomes urbanized. Nature is influenced by humans, particularly in how it is being used and where it exists. Therefore, the way in which nature is incorporated within the city has a significant influence in how humans interact with it. Thus, retrofitting grey infrastructure can lead to greater visibility of green infrastructure within the urban landscape, and serves the dual purpose of directly connecting residents to their water network.

Local municipalities are key to the successful implementation of green infrastructure, where they had little to do with grey infrastructure. As important as it is to develop a city-wide green infrastructure network, in order for municipalities to achieve this, there must be acknowledgement in the role municipalities play in managing the water network. For many municipalities in the GTA such as the Region of Peel, controlling runoff and managing flooding only started to become a concern after the 1980's (Peel, 2017, p. 79). This has meant that much of the existing development built prior to the 1980's lacked adequate stormwater controls and were highly vulnerable to the impacts of flooding (Peel, 2017, p.79). With the Region of Peel only acknowledging the importance of stormwater management in the 1980's, lower-tier municipalities in the Region have not placed emphasis on the role they play in the water network. For example, the City of Brampton never saw themselves playing a large role in water, with the Region managing much of the water and wastewater and the Conservation Authorities (TRCA and CVC) managing the creeks (Hoy, 2017). This view has meant that awareness around water and green infrastructure was not really seen as a priority at the city level, allowing for the city to push the issue onto others. While this view has now changed and the City is providing direct communication on water initiatives (ibid), significant work still needs to take place in order to change the mindset of city staff in how water is managed at that level. Only when municipalities are able to fully embrace their role in managing water systems and fully

implement the ecological approach to stormwater management will green infrastructure be able to become the dominant form of water infrastructure in terms of visibility.

Lastly, for green infrastructure to become the dominant form of infrastructure in terms of visibility, municipalities will need to actively engage communities in the planning process and demonstrate the need for green infrastructure to the water network. As Jerome (2017, p. 227) explains, community-scale green infrastructure helps communities to develop a sense of place outside of their homes, forming a connection to physical features and bringing groups together. Benedict and McMahon (2006, p. 2) discuss how green infrastructure is not something that should be seen as nice to have within a community, but rather, should be viewed as a necessity. Since green infrastructure is an essential part of the landscape, developing a sense of connection to the green infrastructure projects are necessary in order to ensure that green infrastructure projects continue to be implemented. As Wheeler (2013, p. 192) explains, making nature visible to the public can help them to understand the unique characteristics that define each site. One way to engage communities is to develop workshops that bring together community leaders, municipal staff, conservation authorities, and others involved with the planning and design of green infrastructure projects (Richards, 2018, p. 210). Municipalities will need to take different approaches to communicating with communities rather than the traditional approaches if they want to have meaningful communication (Logan, 2017). These workshops can help communities gain a better understanding of the projects and work together with the other organizations to develop green infrastructure projects that are suited to their needs. In this sense, communities will be involved with the green infrastructure project, develop a sense of connection to it, and once the benefits are seen by the community, they will be able to help municipalities push for more green infrastructure. For County Court, community engagement was a key component (ibid). Residents were involved with the design of the green infrastructure, allowing them to

develop a connection to it (ibid). Providing the opportunity for residents to be involved with the green infrastructure design as well as through other engagement activities, the TRCA and the City was able to gain public buy-in. By engaging communities in the planning process, municipalities will be able to work towards changing residents' perception of green infrastructure as well as the water network, allowing for green infrastructure to dominate the landscape in terms of visibility.

To conclude, green infrastructure will need to co-exist with grey infrastructure in order to provide services such as water treatment and to deal with stormwater runoff, but its dominance will come in the form of visibility within the landscape. By retrofitting existing grey infrastructure to natural green infrastructure options, acknowledging the role that municipalities play in managing the water network, as well as engaging residents in the green infrastructure process, municipalities can achieve greater implementation of green infrastructure projects and demonstrate the visual dominance of green infrastructure in the urban landscape.

Chapter 3: The Barriers, Challenges and Solutions to Planning and Implementing Green Infrastructure in Municipalities

While green infrastructure is seen as the natural solution for stormwater infrastructure, the planning and implementation process has not come without challenges. There is a recognized need amongst municipalities to change the way in which stormwater is handled in the urban environment as the impacts of climate change and urbanization continue to increase (O'Donnell et al., 2017, p. 964). Investing in green infrastructure has become a popular adaptation strategy, using existing natural systems such as wetlands, parks, and other green spaces as well as new engineered processes such as bioswales to deal with many of the challenges municipalities face (Green et al., 2016, p. 1051). Although green infrastructure is becoming an important stormwater management method, many of the barriers and challenges that have been identified by municipalities have thus far been difficult to overcome (O'Donnell et al., 2017, p. 965). This section will highlight some of the main barriers and challenges faced by municipalities including legislation, knowledge and training, senior management buy-in and risk aversion, collaboration, as well as public acceptance and education, while also providing solutions to these issues. For the purposes of this paper, barriers are identified as obstacles that prevent municipalities from moving forward with green infrastructure while the challenges are often associated with difficult situations which municipalities will be required to put in more effort to be successful. By addressing the barriers and challenges of planning and implementing green infrastructure and offering solutions, municipalities can begin to address how these issues and start moving towards greater implementation of green infrastructure. The table on the following page outlines a complete list of barriers, challenges and solutions identified through this research. For each of the challenges/barriers, specific examples are outlined as well as possible solutions.

Table 2: Complete List of Barriers, Challenges and Solutions

Challenge/Barrier	Specific Example of Challenge/Barrier	Solutions
Senior-Level Management Buy-In and Risk Aversion	<ul style="list-style-type: none"> ● Often rely on path dependency, implement what they know will work ● Risk aversion limits creativity and ability to move away from traditional water infrastructure 	<ul style="list-style-type: none"> ● Start to implement many green infrastructure projects across the municipality to demonstrate the benefits of green infrastructure and build a business case for it
Knowledge and Training	<ul style="list-style-type: none"> ● Lack of knowledge on how to design and implement green infrastructure projects is a prominent issue ● Needs to be ongoing training for all professionals involved, not just single training events ● Knowledge-sharing is key for a project team but also for sharing information to other municipalities 	<ul style="list-style-type: none"> ● Provide regular training sessions to municipal staff so that each professional has a good understanding of the planning and implementation process. Horticulture staff will also require training for maintaining green infrastructure projects ● Conservation Authorities can provide education sessions to municipal staff for those who have less knowledge in the science behind effective green infrastructure
Green Infrastructure in Legislation	<ul style="list-style-type: none"> ● More robust legislation regarding green infrastructure. Needs to be required and have specific targets to enforce them. ● Developing standards for green infrastructure. Municipalities don't know how to review green infrastructure because engineers do not have standards 	<ul style="list-style-type: none"> ● A coherent definition of green infrastructure should be developed that is scalable and transferable across all levels of government ● Municipalities should mainstream green infrastructure in all municipal policies and plans ● A "Green Infrastructure Strategy" should be developed to help further define green infrastructure and establish initiatives
Collaboration and Involvement	<ul style="list-style-type: none"> ● Integrated teams are not often encouraged within municipalities, more often than not, it is about completing a project quickly ● Integrated project teams need to have a shared language amongst all involved, otherwise may lead to a difference in understanding ● Earlier involvement of certain groups may prevent issues arising later on and allow for greater collaboration. 	<ul style="list-style-type: none"> ● Apply a systems-thinking approach ● Have a leadership group within the municipality dedicated to the planning and implementation of a connected green infrastructure system (either by forming a new group or existing) ● Include stakeholders early at the high-level planning stages to identify potential green infrastructure opportunities

Public Acceptance and Education	<ul style="list-style-type: none"> ● Engaging residents in these projects is often the most difficult aspect ● Need to gain their support and gaining their trust through community events ● Demonstrate what low-maintenance gardens look like and showing them it can be beautiful ● Involves a lot of education and can involve working one-on-one with residents 	<ul style="list-style-type: none"> ● Increase awareness of green infrastructure to the public and develop stewardship ● Move beyond the typical environmental spiel and incorporate innovative approaches such as public demonstrations as well as in-home demonstrations ● Increase interaction with the public and build connections with residents to allow communities to understand the importance of green infrastructure
Time Commitment and Funding	<ul style="list-style-type: none"> ● Need to understand that there is extra commitment and time involved with green infrastructure projects ● Greater funding is needed not just for the green infrastructure itself, but also for the extra time involved, otherwise no incentive for certain groups to do these projects. 	<ul style="list-style-type: none"> ● Can collect money to support projects through incentives, bylaws, stormwater fees, development charges, and other expenditure tools (e.g., capital budgets, etc.) (Johns, 2018) ● Develop a dedicated green infrastructure team
Site Conditions	<ul style="list-style-type: none"> ● There needs to be a better understanding of the constraints involved with green infrastructure projects. Utilities, soils, space and other factors all influence the success of green infrastructure ● Greenfield developments have a lot more flexibility than infill developments in terms of site constraints. 	<ul style="list-style-type: none"> ● Creating a set of best practices for good green infrastructure planning which can address appropriate site conditions

3.1 Barriers and Challenges

3.1.1 Policy

Municipalities face significant challenges in planning and implementing green infrastructure on a municipal-wide scale as a result of the lack of strong legislation. One of the barriers, as previously noted, was the province's use of weak policy language, simply encouraging rather than mandating the use of green infrastructure. Providing municipalities with the option to implement green infrastructure provides them the ability to say no, despite the fact that green infrastructure is not an option, but rather essential (Benedict & McMahon, 2006, p. 2). Having broad policies at the provincial levels allows lower levels of government to enforce policies as requirements. For example, the City of Toronto, through the Official Plan Amendment process included Complete Streets guidelines that required space to be made for green infrastructure within the street (Stott, 2018; Toronto, 2015). As a result, they have been able to implement the Toronto Green Standards, placing emphasis on the need to include upfront considerations of green infrastructure (Stott, 2018). The City of Toronto green roof by-law, is another example of strong regulation developed at the local level. The Green Roof By-law requires new development to construct green roofs on buildings (Toronto, 2018). This shows that despite the lack of legislation, municipalities can take ownership of implementing stronger policies when the province has not done so.

In contrast, while the City of Toronto may have strong policies for green infrastructure, many municipalities in Ontario do not. Toronto has significantly advanced in implementing green infrastructure yet for municipalities such as the City of Brampton, where building the case for increasing green infrastructure to council is more difficult, these municipalities want to see upper levels of government, whether it is the Region of Peel or the Province, have a clear

direction with strong policies for planning more resilient water infrastructure in order to be given the opportunity to implement green infrastructure across the municipality more easily (Hoy, 2017). Where possible, at the local council level, green infrastructure needs to be perceived as much more than just a stormwater management tool. Green infrastructure looks more expensive in direct comparison to conventional stormwater engineering (Boudreau, 2018). For council, green infrastructure should be tied to the multiple benefits across sectors (ibid). Therefore, while municipalities see the lack of direction from higher levels of government a challenge, there is opportunity at the local level, if framed correctly, to implement more green infrastructure projects.

Working parallel to policy, the challenge of planning and implementing more green infrastructure projects in municipalities can also be attributed to the lack of engineering standards available for municipal staff to review. Without engineering standards to accompany policy, green infrastructure will continue to be applied in an inconsistent manner across municipalities. Engineers rely on standards to guide construction (Hoy, 2017). Engineers are required to follow standards in order to ensure consistency amongst infrastructure projects and to avoid risks. If there are no standards, engineers are not able to review green infrastructure projects (ibid). While some may argue that there simply needs to be more training, implementing these types of projects goes beyond simply establishing a green infrastructure policy and developing standards. Where there is policy direction to implement green infrastructure and standards have been established, all other aspects, including communication, training, building capacity need to be built in the process if the policies established for implementing greater green infrastructure is to be effective (Boudreau, 2018). Having strong policies lead to effective implementation. The process is a first-hand look at how effective policies and good engineering

standards can positively affect the landscape. Thus, good engineering standards for green infrastructure projects must work in parallel to that of policy development.

3.1.2 Knowledge and Training

While stronger policies are needed to push green infrastructure forward, one of the most prominent challenges to planning and implementing green infrastructure is the lack of knowledge and training by staff. Municipalities have noted that specific groups of professionals should undertake training to develop a common language when discussing green infrastructure projects. In particular, training should be directed towards engineers and planners to develop a broad understanding of how to implement different types of green infrastructure projects (Hoy, 2017). As noted by Benedict and McMahon (2006, p. 23), the concept of green infrastructure is not new. There are many resources available to practitioners such as the Sustainable Technologies Evaluation Program (STEP) Low Impact Development Treatment Train Tool, which allows users to determine if stormwater management targets can be achieved at a particular site using green infrastructure (Sustainable Technologies Evaluation Program, 2018). Utilizing these resources can allow staff to gain a better understanding of where green infrastructure projects could be applied. Therefore, staff should be required to understand these tools, by attending workshops or other training methods to ensure that green infrastructure training is kept up to date. A significant opportunity also exists for staff to learn through knowledge-sharing (Hoy, 2017). For example, those involved in the Corktown Common project continue to be approached by groups to learn about how they were able to design and implement such a project (Rokach, 2018). By allowing for knowledge sharing to occur, staff will be better equipped with the tools they need to successfully implement green infrastructure projects. The more that staff learn from others, the easier the projects become (Logan, 2017).

Understanding the technical considerations associated with green infrastructure projects is often overlooked in the green infrastructure planning and implementation process. The design considerations and process for implementing green infrastructure projects differs from that of grey infrastructure (Boudreau, 2018). For example, consideration for space and size of green infrastructure projects, the types of soils and plants being used, as well as existing conditions and the type of development (i.e., infill or greenfield) on site all have an impact on whether or not a green infrastructure project is successful. For example, the plants that were used for the County Court bioswale did not originally survive (Liu, 2017). Figure 9 illustrates the state of the bioswale as of September 2017. The TRCA had used guidelines based in the USA to determine the types of soils that should be used (ibid).



Figure 9: County Court Bioswale as of September 2017 (Dokoska, 2017)

While this project demonstrates several lessons learned for the municipality, the city and TRCA are now able to go back and change the manual for soil selection to reflect these lessons learned (ibid). There is enough information out there, as previously demonstrated that issues such as soil types should not be a concern for green infrastructure projects. Enough municipalities have implemented different types of green infrastructure projects such as the City of Toronto to ensure that the correct technical considerations are used.

Another main challenge for the County Court bioswale was the fact that they were building a bioswale within infill development rather than a greenfield site (ibid). In new developments, there is a lot more flexibility and space to do these types of projects whereas an infill development requires a lot more careful consideration (ibid). The Region of Peel also had a watermain underneath the site which had an impact on the development of the project (ibid). If there was more careful consideration for the space constraints and existing conditions on site, the project could have been altered to better fit the space. While it is important to consider the types of soils that are used for a specific green infrastructure project, if the existing site conditions are not taken into account then there will be unforeseen challenges to implementing the green infrastructure project.

To complement the need for knowledge and training during the planning and implementation phases, practitioners need to place stronger emphasis on education and training in maintaining and monitoring green infrastructure projects. Part of the success of Corktown Common can be attributed to the successful maintenance program that was established early in the process (Rokach, 2018). The City's Parks, Forestry & Recreation Division established an internal horticulture assessment for gardening staff in which those who passed the assessment each year would get an organic horticulture designation (ibid). Only gardeners with this designation could select to work the full season at Corktown Common (ibid). This ensured that staff had the skills and experience to manage and maintain the site (ibid). In addition, the park's designer, Michael Van Valkenburgh Associates, developed a horticulture manual in consultation with the City, which describes how to go about dealing with unanticipated impacts such as pests on site (ibid). The dedicated resources and time invested in the monitoring and maintenance of the green infrastructure project allowed for staff to be invested in the success of the project. For

example, the City of Brampton noted that having buy-in from the Parks department for the County Court bioswale played a large role in the maintenance of the bioswale (Hoy, 2017). When there is buy-in from relevant departments, resources and time can be allocated towards maintenance and monitoring of green infrastructure projects, allowing for time to be put towards education and training in maintaining and monitoring green infrastructure projects. By ensuring that the right staff have the right skills, knowledge of the technical considerations, and education and training in monitoring and maintaining green infrastructure projects, the challenges imposed by a lack of knowledge and training can be addressed.

In addition, training municipal horticulture staff in the maintenance of green infrastructure projects helps to ensure that projects are functioning as expected and provides the opportunity to fix any unforeseen challenges. As previously described, a manual prepared by the municipal Parks department which clearly outlines the monitoring and maintenance process should be a priority. It is easy for a green infrastructure project to fail if the wrong approach is used. If a municipality wants to implement green infrastructure and develop an environment and culture that supports it, then developing the right guidance tools such as a manual can help to bridge the gap in knowledge and ensure that municipal horticulture staff have the right tools and knowledge (Rokach, 2018). While maintenance may still be a concern for the County Court bioswale, specifically in watering the soils (Liu, 2017), educating staff and providing them support through the development of a manual can help to implement a standard practice. The County Court bioswale, despite challenges faced in the beginning of the project, is now exceeding expectations. The photo in Figure 10 shows the healthy state of the bioswale as of September 2018. All of the native plants that were underneath the rocks in Figure 9 have now blossomed. While the City of Brampton does not have a manual for maintaining green infrastructure

projects, proper maintenance can allow for the plants to continue to be successful in that environment. Therefore, by implementing these practices into all green infrastructure projects and developing a manual that can address any site conditions, green infrastructure projects can be successful over the long term.



Figure 10: County Court Bioswale as of September 2018 (Dokoska, 2018)

3.1.3 Senior Management Buy-in and Risk Aversion – Asset Management

Senior management buy-in and risk aversion are amongst the most challenging barriers to overcome when planning and implementing green infrastructure. Senior management includes department directors, senior managers, as well as the CAO's office. Senior management is often reluctant to step outside of the box when they know a particular method works well. As Widener, Gliedt, and Hartman (2017, p. 206) point out, municipalities, or in this case senior-level management, often follow the mentality of airing on the side of caution, continually using the

same measures each time to ensure a project works. This path dependency, which is described as perpetuating the past, limits planners and other involved actors in developing integrated infrastructure such as green infrastructure because the outcome of these types of projects are not necessarily clear compared to that of traditional water infrastructure (Matthews, Lo & Byrne, 2015, p. 158). As seen from the Brampton County Court bioswale pilot project, in order for a project to be effective, senior-level management buy-in is needed early on within the planning process to address some of the larger issues (Liu, 2017). There can often be hesitancy from different departments to do these types of projects because of the responsibility that is involved once the project is complete (Hoy, 2017). For example, once engineers finish with the implementation, the Parks and Recreation department is responsible for maintenance, but might be reluctant to agree to such a project without senior management buy-in (ibid). Therefore, having buy-in for these types of integrated projects would not only educate senior-level management of the importance of green infrastructure, but would also help to bring those that may be reluctant on board with the project because they have direction from their management to go ahead with these projects.

3.1.4 Collaboration

Aside from senior-level management buy-in, another key challenge associated with the planning and implementation process for green infrastructure projects is the need for greater collaboration amongst all staff and external stakeholders where relevant. Heavy silos exist within municipalities which has impacted the green infrastructure planning process. As Mitchell et al. (2014, p. 267) point out, when planning for projects that involve several different units or departments, the responsibility of ensuring a project is successful is a collective effort, and not solely the responsibility of a single unit. If staff are reluctant to take on responsibilities without

senior management buy-in, effectively collaborating on green infrastructure projects will be difficult. While discussing the design process for green infrastructure projects, it was noted that engineers should not be responsible for the design of green infrastructure projects, this should be left to the landscape architects with input from the engineering department (Liu, 2017). This notion that one group should be less responsible for a certain aspect of the design over another means that no one is taking clear leadership. When working on these types of integrated projects, coordination amongst planners, engineers, operations, roads, conservation authorities, and other professionals is needed (Logan, 2017). In this case, if there was buy-in from senior staff, as previously mentioned, this would allow staff to be more open to taking risks and leading the project because they have approval from senior staff to do these types of projects.

For the Brampton County Court Bioswale pilot project, one of the successes of the project was the collaborative, integrated design team (ibid). The project manager was able to bring everyone (e.g., municipal staff, Conservation Authorities, utilities, etc.) together to work in an integrated manner (Liu, 2017). Everyone involved with the project brought their own expertise to contribute to the group and were open to exploring opportunities (ibid). The success of this collaborative project demonstrates that when everyone involved understands their responsibilities, it allows for an engaged and active team to work together as a collective.

Lastly, when dealing with collaborative green infrastructure projects, communication between the municipal-led working group as well as other external partners during the planning and implementation process is often a challenge. One of the main arguments made by Kallis, Kiparsky and Norgaard (2009, p. 637) is that in order for these types of collaborative projects to work, there needs to be a shared language amongst the professionals in order to effectively communicate across each of the different disciplines. Green infrastructure is considered to be

integrated (Logan, 2017). As a result, this integration must also be reflective of the group working on the project. If there is no shared language, then often times certain members of a group may not be on the same page. Part of the problem comes from the fact that certain groups need to be involved in these green infrastructure projects earlier on (Hoy, 2017). The other problem for municipalities is that these integrated teams are not encouraged enough (ibid). When the culture is to get these projects done as quickly as possible, it leaves little room to have diverse and integrated teams that speak the same language (ibid). Therefore, the successful implementation of green infrastructure is only as good as the integration of the professionals involved and their ability to communicate through a shared understanding. If the goal of these green infrastructure projects is to implement them on a municipal-wide scale, then ensuring that each professional understands their responsibilities will be key to improving the socio-ecological relationship to water networks on a broader level.

3.1.5 Public Acceptance and Education

Gaining public acceptance towards green infrastructure projects is often the most difficult challenge that municipalities need to overcome. This can be attributed to the fact that municipalities do not engage with the public early enough in the green infrastructure planning process. Engaging and involving the public from the start of a green infrastructure project can provide an avenue for municipalities to gain buy-in and support from local residents. As Wilker, Karsten-Rusche and Rymsa-Fitschen (2016, p. 246) examine, results show that while stakeholders are typically involved in the later planning stages of a green infrastructure project, many stakeholders noted that they would like to be involved in earlier planning processes such as concept development. By involving the public in early stages of the planning process, municipalities can build trust with residents and provide the opportunity to increase resident

engagement at other stages (Hoy, 2017). This trust can serve as a gateway for gaining public support for a project. In this sense, engagement needs to be tailored to the relevant stakeholders, and a variety of different engagement approaches will need to be used (Wilker, Karsten-Rusche & Ryma-Fitschen, 2016, p. 246). By understanding community needs, municipalities will be able to work collaboratively with residents and implement more effective green infrastructure projects. Therefore, by involving the public during the early stages of the planning process and developing engagement strategies that focus on community needs, municipalities will be able to increase public acceptance of green infrastructure projects and allow for greater public buy-in.

In addition to public acceptance, municipalities lack strong programs for educating communities on the multiple benefits that green infrastructure provides. For residents to become stewards and take ownership of green infrastructure projects, there needs to be a strong education and awareness component. This is where the County Court can serve as a success story. While the success can be attributed to many factors, public education and awareness has allowed for strong support for the project in the community, primarily through the residents' association. By developing demonstration projects, involving residents in the green infrastructure design process, engaging one-on-one with residents and explaining the multiple benefits, as well as creating brochures and promotional material, the City of Brampton and SNAP were able to build trust among the residents and allow for them to take ownership of the project (Logan, 2017; Hoy, 2017).

In relation, while actively engaging and educating residents allows for opportunities to build connections with residents, many green infrastructure projects are also fenced-off and not available for public use. For example, there are many wetlands that are fenced-off from public use to ensure the integrity of the ecosystem. This leads to the issue of access to green

infrastructure. While green infrastructure is intended to provide multiple benefits to society, a large component of green infrastructure is to ensure that the project is functioning accordingly and the ecosystems are being maintained. Therefore, while green infrastructure projects provide the municipality with the opportunity to engage with residents and develop connections, there should be acknowledgement that certain green infrastructure projects will need to be isolated from the public in order to preserve its ecological integrity. Overall, municipalities will need to develop stronger public education programs to teach people about the benefits of green infrastructure and ensure that the public is engaged and are providing full support for the projects.

3.2 Solutions and Next Steps

3.2.1 Policy

In order for green infrastructure to be successful at the municipal level, municipalities will need to ‘require’ the implementation of green infrastructure rather than simply ‘encourage’. With the current direction of the *Growth Plan (2017)*, municipalities are only encouraged to consider green infrastructure, but do not necessarily have to implement. The draft *Low Impact Development (LID) Stormwater Management Guidance Manual (2017)* if released, would place greater priority in implementing green infrastructure to accommodate the 25mm rainfall event that would need to be retained. The manual would allow green infrastructure to become the default infrastructure option. To accommodate these changes, upper-tier municipalities should require lower tier municipalities to develop policies that replaces grey infrastructure as the primary consideration and puts green infrastructure as the default infrastructure choice, using

grey infrastructure only when green infrastructure is deemed unsuitable for the area, based on set criteria. For single-tier municipalities, this would include updating Official Plan policies to replace grey infrastructure with green infrastructure as the primary consideration.

Despite uncertainty in legislation at the Provincial level, municipalities will need to move forward in embedding green infrastructure policies in their planning processes. One of the ways that municipalities can go about doing this is mainstreaming green infrastructure into all relevant municipal policies and plans. This approach is currently being applied by municipalities for climate change but there is a significant opportunity to apply this to green infrastructure as well. For example, a study completed for Durham Region examined how climate change information is being incorporated within policies and plans, emphasizing that many existing policies can be re-framed around climate change (Dokoska, McVey & Milner, 2018). This same approach can also be applied to green infrastructure. While the term ‘green infrastructure’ may not be explicitly stated in many official plans such as the Brampton *Official Plan* (2006), policies around protecting natural heritage do exist. If municipalities are able to integrate green infrastructure within relevant policies and plans, then mainstreaming green infrastructure will be a natural part of the process.

Recommendation: Leverage Existing Policies and Re-Frame Around Green Infrastructure

Significant opportunities exist at the municipal scale to go back and revise any existing policies around green infrastructure. By re-framing many of the existing policies around green infrastructure, municipalities have the opportunity to strengthen existing initiatives while allowing for a greater application of green infrastructure projects to occur.

In addition to mainstreaming green infrastructure into all relevant policies and plans, municipalities each should establish a Green Infrastructure Strategy. A Green Infrastructure Strategy is intended to preserve existing green spaces while also identifying opportunities for implementing green infrastructure (Saskatoon, 2017). Having a strategy allows municipalities to

create specific initiatives, develop timelines for implementation and ensure monitoring and maintenance for the projects. For example, the City of Saskatoon has already established their *Green Infrastructure Strategy* (2017) with the goal of developing a more integrated approach to how the urban environment is planned; preserving natural areas as a key component to the urban fabric. The plan also describes existing policies that drove the creation of the strategy as well as existing initiatives underway (Saskatoon, 2017). Having a strategy such as this one can help to push for stronger policies such as requiring green infrastructure for each new development. If done correctly, green infrastructure strategies would act more as implementation tools for policies rather than another strategy. Overall, by mainstreaming green infrastructure into all relevant plans and developing a green infrastructure policy, municipalities will be able to establish a clear approach for implementing green infrastructure across the municipality.

3.2.2 Knowledge and Training

The need for more training and knowledge around planning and implementing green infrastructures can be considered amongst the most important and immediate challenges that need to be addressed. To have a good understanding of the technical aspects of green infrastructure, it is recommended that training to all staff working on green infrastructure projects should include regular training sessions so that each professional has a good understanding of the planning and implementation process. One approach to this is to provide additional technical training to

Recommendation: Embed Training into Green Infrastructure Projects for Long-Term Success

Training the right people, both for implementation and monitoring, is essential for green infrastructure projects. There are many resources available (e.g., STEP) that can provide training to staff for implementing LIDs and green infrastructure projects. On the maintenance side, it is important that maintaining green infrastructure projects by parks and horticulture staff becomes embedded in their everyday practice. Training front-line staff in organic horticulture ensures that green infrastructure projects are properly maintained.

all non-technical staff so that they have a better understanding of the technical considerations that need to be factored into the project (Liu, 2017). By allowing all staff to have an appropriate level of understanding, staff involved can work through technical considerations such as site constraints, and make more informed decisions.

Another approach for this is to look at how other organizations and municipalities successfully implemented green infrastructure projects and learn from their experiences (Rokach, 2018). Having the roadmap already established by municipal environmental departments can make it easier for municipalities to implement green infrastructure. For example, municipalities can learn from the experiences at Corktown Common and how they went about assessing their horticulture staff to ensure they had the appropriate skills to maintain the park once it was complete (ibid). Therefore, sharing experiences should be an embedded component of green infrastructure training. As previously mentioned, the types of soils that should be used for green infrastructure projects may be a concern for certain municipalities. If knowledge sharing is applied amongst different municipalities across the GTA, then municipalities will be able to use this information to apply the appropriate technical considerations for each project.

3.2.3 Senior Management Buy-In and Risk Aversion – Asset Management

If green infrastructure is to become the visibly dominant form of infrastructure in Ontario municipalities, gaining senior management buy-in is essential. One way that municipalities can go about doing this is by having someone champion green infrastructure at higher levels of government such as the CAO's office or even at the mayoral level (Boudreau, 2018). By establishing the higher-level support, the awareness that is raised around green infrastructure and

the need to implement it can filter through to all other staff (ibid). Middle management is often cautious to implement projects that are outside of their workplans as they have not been tasked to do so and it is seen as a risk (ibid). With no direction and a lack of resources, middle management is hesitant to put people on this work fulltime (ibid). Therefore, if people at higher levels are championing this work, management at the lower levels will have the direction to implement these projects within their workplans, providing support to staff as well as resources (ibid).

Senior management buy-in can also be achieved by building the business case for green infrastructure. Green infrastructure is a non-traditional approach and as a result, senior management is reluctant to build projects because the full risks are unknown. As previously mentioned, risk aversion is often seen as a massive barrier for municipal staff in implementing green infrastructure as senior management do not want to have failures (Hoy, 2017). Therefore, building a strong business case for green infrastructure that demonstrates the need and risks of not implementing green infrastructure in the urban environment must be clearly displayed. This can be achieved by demonstrating the benefits of the green infrastructure project beyond just stormwater management as well as implementing triple bottom line (TBL) accounting to integrate the social, environmental and economic aspects of a project into the costing (Boudreau, 2018). By doing so, staff will be able to demonstrate the true value of a green infrastructure project and develop a strong business case for why green infrastructure should be the primary consideration rather than grey infrastructure.

3.2.4 Collaboration

Green infrastructure is inherently interdisciplinary and as such, collaboration amongst all staff working on a green infrastructure project is key to ensuring successful implementation. While there are many approaches that can be applied, municipalities should seek to have a dedicated leadership group that is responsible for planning and implementing green infrastructure projects (Benedict & McMahon, 2006, p. 87-89). As Benedict and McMahon (2006, p. 40) point out, the most successful green infrastructure projects are those that engage professionals from a range of different backgrounds. This provides the opportunity for staff to learn from each other and ensure that an integrated approach is applied to all green infrastructure projects. The only way that green infrastructure will be able to succeed is if there are dedicated people working on green infrastructure projects (Boudreau, 2018). This would mean that while many staff are tied to their workplans, when working on green infrastructure projects, there needs to be the mentality of being able to think outside of the box and looking at how to do projects differently (ibid). This can be applied to engineers, who generally think in a linear fashion with grey infrastructure. While developing standards for engineers are important, there also needs to be some level of flexibility in the process for engineers to be able to incorporate a non-linear process such as green infrastructure into the linear grey infrastructure environment (ibid). This type of collaboration is necessary within a leadership group not only to be able to learn from each other, but also allow for creativity in the planning and implementation process. When different professionals have the opportunity to collaborate together, without the heavy

Recommendation: Remove Silos and Implement Interdisciplinary Teams

Naturally, green infrastructure was developed through interdisciplinary roots (Benedict & McMahon, 2006, p. 23). Having a dedicated *interdisciplinary* team (both internally and externally) working to move green infrastructure projects forward will be the key to its success

silos, innovative approaches to planning and implementing green infrastructure can be developed.

Furthermore, in order to have effective collaboration, municipalities should look to include stakeholders during the early planning stages to identify potential green infrastructure opportunities. This can include involving stakeholders during the watershed planning stages, where there are opportunities to identify broad green infrastructure opportunities and identify linkages in the city's natural network. As explained by Koburger et al. (2013), in order for municipalities to be able to solve the issues related to stormwater and water quality, a watershed approach that integrates stakeholders during the whole process, both at the watershed scale as well as the neighbourhood level should be applied. Having an open planning process where stakeholders are involved can garner more public support and make green infrastructure projects easier to implement (ibid). This also allows for a municipality to collaborate with neighbourhoods; understanding the community needs, and planning green infrastructure projects around these needs. Therefore, having a dedicated group of people working on green infrastructure projects, who are able to involve stakeholders early in the planning and implementation phases for green infrastructure projects will allow for a more integrated process and provide an opportunity for collaboration.

3.2.5 Public Engagement

Public engagement is essential for green infrastructure projects both as an educational component as well as for garnering support. In moving forward, municipalities will need to think outside the box when developing public engagement strategies. The typical environmental spiel which explains the importance of preserving the environment to residents without making personal connections is not enough to fully engage the public, municipalities need to incorporate innovative approaches such as in-home demonstrations or interactive games (Logan, 2017). In addition, municipalities will need to provide a more visual experience to residents. For example, Corktown Common includes a good visual sign showing the public how each component of the park is positively contributing to the environment (see Figure 11).

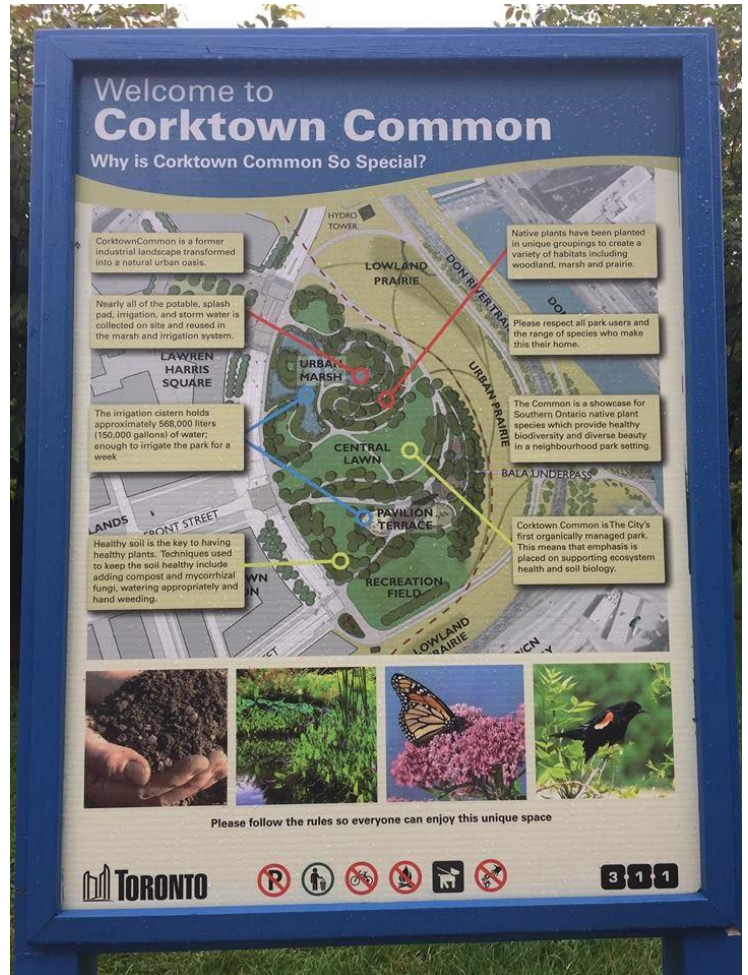


Figure 11: Visual Sign of Corktown Common (Dokoska, 2018)

Several innovative approaches have recently sparked interest in how to engage the public on issues around climate change. One example is the *Citizen's Coolkit on Climate Change and Urban Forestry* (2016) developed by the University of British Columbia. This toolkit provides a variety of engagement activities for each of the different stages in the planning process such as a

vulnerability mapping exercise or a story collection activity (UBC, 2016). These types of activities help the public to visualize what climate change will look like in the future and how it will impact them. Having these types of engagement approaches applied early in the green infrastructure planning and implementation process can result in more positive impacts, such as greater public turnout. While the activities used in the toolkit would need to be altered to fit the purpose of the green infrastructure planning process, a toolkit is an example of a creative avenue that municipalities can take to engage their public early in the planning process.

Recommendation #3: Make Green Infrastructure Visibly Dominant

Where green infrastructure needs to co-exist in terms of physical infrastructure, its dominance will come in the form of visibility. Green infrastructure becomes a natural part of the environment. As municipalities begin to apply a greater number of green infrastructure projects, the water network will inherently become more visible.

Furthermore, municipalities will need to personalize the engagement process to help the public understand why green infrastructure is necessary. As Burch et al. (2010, p. 94) explain, municipalities can achieve greater public buy-in by personalizing the engagement process. For example, the 2013 ice storm that hit the GTA left many without power for several days. The 2017 summer flood which resulted in the closure of Centre Island for an extended period of time is still at the forefront of many people's minds. Using these types of personal experiences can help people to understand why green infrastructure is important but also demonstrate that a hybrid of green and grey infrastructure within a municipality is necessary. Personalizing the engagement process can also help municipalities to better connect with their residents. As previously mentioned, through the County Court SNAP project, an active resident's association naturally formed (Logan, 2017). The TRCA and City made it feel more like a neighbourhood-

specific project rather than a city-wide project (ibid). By interacting with residents, municipalities can better understand the needs of the community, ensuring that the green infrastructure that is implemented is well-suited (ibid). Therefore, tackling the challenge of public engagement can be addressed by providing a more personalized experience, one that better connects municipalities to their residents, as well as demonstrating the necessity of green infrastructure.

Recommendation #6: Embed Strong Public Engagement in Planning and Implementation

In order for communities to take ownership of the green infrastructure projects and become stewards, there needs to be a strong education and awareness component (Logan, 2017). Strategies such as public demonstrations and engaging residents in the design of green infrastructure projects (i.e., County Court SNAP), are all opportunities to build connections with residents (ibid). The more involved the public is with the green infrastructure project, the more likely it is that they will continue to take care of it once the project is complete.

4.0 Future Research Directions

This Major Paper examines only a small component of the research that needs to be undertaken in this area. In this paper, I have described the barriers and challenges to planning and implementing green infrastructure and proposed solutions necessary for moving towards more natural solutions to stormwater management. Several other themes related to green infrastructure emerged during my research. I was especially struck by the gaps in scholarly literature related to green infrastructure, particularly with regards to the barriers and challenges including a better discussion around integrated and multiple benefits as well as equity issues. As Matthews, Lo & Byrne (2015, p. 159) note, institutional issues around climate change have yet to be addressed in green infrastructure literature. Without a complete picture of the issues around green infrastructure, providing solutions will be difficult. Future research on this topic should examine why this gap in literature exists and how this has impacted the implementation of green infrastructure.

As demonstrated in this paper, water is only one component to green infrastructure. Through research, it is evident that green infrastructure cannot be studied without examining the multiple benefits it provides. A detailed review of the multiple benefits green infrastructure provides and how these benefits can be used to advance the implementation of green infrastructure can help provide a business case as to why green infrastructure should be implemented. There should be a greater focus on examining the range of benefits, while also examining the economic value. As Mell et al. (2013, p. 296) point out, placing an economic value on green investments is difficult, but this can be a highly effective way to demonstrate the value for each of the benefits that green infrastructure provides in comparison to traditional infrastructure. Through this research, it is evident that building a business case for green infrastructure will help municipalities move towards greater implementation.

Lastly, an important component that should be explored further is the role of green infrastructure in promoting equity. While it is necessary for municipalities to implement green infrastructure, where these projects are located impacts the distribution of natural space in the city and who has access to it (Heynen et al., 2006; Sporn, 2005). Quastel (2009, p. 694) examines the role green spaces play in promoting gentrification. He notes that where green space projects are planned or are being implemented can result in the displacement of vulnerable residents (Quastel, 2009, p. 697). While completing the research for this Major Paper, it was interesting to distinguish where large-scale green infrastructure projects are implemented compared to smaller-scale projects. Future research on this topic should examine where green infrastructure projects have been implemented within municipalities and determine if there is a gap between lower income neighbourhoods and access to green infrastructure.

Conclusion

The slow uptake and lack of application in green infrastructure projects across Ontario municipalities have inherently weakened the human-nature relationship with water, leaving traditional linear stormwater infrastructure (i.e., sewer pipes) to continue perpetuating the invisible water system (Gandy, 2014, p. 3). Green infrastructure provides significant potential to strengthen the human connection to water, yet municipalities are not maximizing on this opportunity. While municipalities understand the importance of implementing green infrastructure to adapt to the many impacts resulting from climate change, the need to connect residents to the city's water network and improve the human-nature relationship to water is often overlooked. Urban development has significantly altered both the natural and human-made landscapes, increasing the amount of impervious surfaces and contributing to increased runoff (McDonnell, Hahs & Breuste, 2009, p. 74). As flooding and extreme rainfall events continue to intensify as a result of climate change, municipalities need to prioritize the implementation of widespread green infrastructure projects, in order to positively affect the way in which people view water in the city.

Green infrastructure provides the opportunity for municipalities to think beyond simply protecting waterway health and addressing stormwater management through existing linear infrastructure and begin to apply natural solutions to the water infrastructure problem. This paper demonstrates that stronger policies around green infrastructure are needed at both the provincial and local scale in order to move green infrastructure forward. The current policies in place at the provincial and local scale can be considered 'weak' policies with no required action from municipalities to implement green infrastructure. This paper also stresses the importance of making water visibly dominant. Green infrastructure will need to coexist with grey

infrastructure, but its dominance will come in the form of visibility, providing people with a visible connection to their water network. While challenges and barriers exist in the planning and implementation of green infrastructure, forming interdisciplinary teams from the start of the planning process can help to address many of the engineering challenges associated with green infrastructure projects as well as provide a more robust decision-making process. The municipalities used in this paper show that green infrastructure requires significant training on both the technical aspect as well as the maintenance of green infrastructure projects to ensure they are successful. Lastly, when done right, public involvement in green infrastructure projects can lead to positive outcomes. When the public become stewards of the land, their perspectives on the water networks are positively influenced, rather than being ‘out of sight, out of mind’. Despite the challenges and barriers to planning and implementing green infrastructure projects, green infrastructure projects will need to be developed on a greater scale if there is going to be a change in the way in which people view water in the city.

Interviews

Boudreau, S. (2018, April 25). Personal Interview.

Hoy, M. (2017, Nov. 10). Personal Interview.

Liu, M. (2017, Nov. 10). Personal Interview.

Logan, S. (2017, Nov. 8). Personal Interview.

Rokach, Y. (2018, June 15). Personal Interview.

Stott, S. (2018, May 3). Personal Interview.

Bibliography

- Ahern, J., Cilliers, S., Niemela, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning*, 125, 254-259.
- Allen, W.L. (2012). Advancing green infrastructure at all scales: from landscape to site. *Environmental Practice*, 14 (1), 17–25.
- Amati, M., Taylor, L.E. (2010). From greenbelts to green infrastructure. *Planning Practice & Research*, 25(2), 143-155.
- Andersson, E., et al. (2014). Reconnecting Cities to the Biosphere: Stewardship of Green Infrastructure and Urban Ecosystem Services. *AMBIO*, 43, 445-453.
- Benedict, M. and McMahon, E. (2006). *Green infrastructure: linking landscapes and communities*. London: Island Press.
- Brampton, City of. (2018). *Brampton 2040 Vision*. Retrieved from <https://www.brampton.ca/EN/City-Hall/Documents/Brampton2040Vision/brampton2040Vision.pdf>
- Brampton, City of. (2006). *Official Plan*. Retrieved from https://www.brampton.ca/en/Business/planning-development/Documents/PLD/OPReview/Adopted%20OP_OCT112006.pdf
- Bulkeley et al. (2011). The Role of Institutions, Governance, and Urban Planning for Mitigation and Adaptation. In Hoornweg et al. (Eds.), *Cities and Climate Change: Responding to an Urgent Agenda* (pp. 125-159). Washington: The World Bank.
- Burch, S., Sheppard, R.J., Shaw, A., Flanders, D., Cohen, S.J. (2010). Planning for Climate Change in a Flood-prone Community: Municipal Barriers to Policy Action and the Use of Visualizations as Decision-support Tools. *Journal of Flood Risk Management*, 3(2), 400-412.
- Chini, C.M., et al. (2017). The Green Experiment: Cities, Green Stormwater Infrastructure, and Sustainability. *Sustainability*, 9(1), 105.
- Copeland, C. (2016). *Green Infrastructure and Issues in Managing Urban Stormwater*. Retrieved from <https://fas.org/sgp/crs/misc/R43131.pdf>
- Dokoska, K. (2017, Sept. 2). County Court bioswale as of September 2017. [Photograph].
- Dokoska, K. (2018, Sept. 9). County Court Bioswale. [Photograph].

- Dokoska, K. (2018, Sept. 9). County Court Bioswale as of September 2018. [Photograph].
- Dokoska, K. (2018, Aug. 22). Corktown Common Park. [Photograph].
- Dokoska, K. (2018, Aug. 22). Corktown Common Constructed Wetland. [Photograph].
- Dokoska, K. (2018, Aug. 22). Corktown Common Wetland. [Photograph].
- Dokoska, K. (2018, Aug. 22). Visual sign of Corktown Common. [Photograph].
- Dokoska, K., McVey, I., Milner, G. (2018). *Integrating Climate Change Considerations into Policies and Plans in Durham Region*. Ontario Climate Consortium: Toronto, ON.
- Ellis, J.B. (2013). Sustainable surface water management and green infrastructure in UK urban catchment planning. *Journal of Environmental Planning and Management*, 56(1), 24-41.
- Finewood, M.H. (2016). Green Infrastructure, Grey Epistemologies, and the Urban Political Ecology of Pittsburgh's Water Governance. *Antipode*, 48(4), 1000-1021.
- Gandy, M. (2002). *Concrete and Clay: Reworking Nature in New York City*. Cambridge: MIT Press.
- Gandy, M. (2004). Rethinking urban metabolism: water, space and the modern city. *City* 8 (3), 363-379.
- Gandy, M. (2014). *The Fabric of Space: Water, Modernity, and the Urban Imagination*. Massachusetts: MIT.
- Geohub. (2018). Aerial View of County Court Neighbourhood. [Photograph].
- Gibson, Town of. (2017). *Advancing Municipal Asset Management*. Retrieved from <https://gibsons.ca/sustainability/natural-assets/natural-asset-management-resources/>
- Gill, S.E., Handley, J.F., Ennos, A.R., Paulett, S. (2007). Adapting Cities for Climate Change: The Role of the Green Infrastructure. *Built Environment*, 33(1), 115-133.
- Google Maps. (2018). Aerial View of Corktown Common. [Photograph].
- Google Maps. (2018). Corktown Common in the Context of the City of Toronto. [Photograph].
- Goonetilleke, A., Thomas, E., Ginn, S., Gilbert, D. (2005). Understanding the role of land use in urban stormwater quality management. *Journal of Environmental Management*, 74(1), 31-42.

- Green, T.L., Kronenberg, J., Andersson, E., Elmqvist, T., Gomez-Baggenhun, E. (2016). Insurance Value of Green Infrastructure in and Around Cities. *Ecosystems*, 19, 1051-1063.
- Hansen, R., Pauleit, S. (2014). From Multifunctionality to Multiple Ecosystem Services? A Conceptual Framework for Multifunctionality in Green Infrastructure Planning for Urban Areas. *Ambio*, 43, 516-529.
- Heynen, N., Perkins, H.A., Roy, P. (2006). The political ecology of uneven urban green space: The impact of political economy on race and ethnicity in producing environmental inequality in Milwaukee. *Urban Affairs Review*, 42(1), pp.3–25.
- Hostetler, M., Allen, W., Meurk, C. (2011). Conserving urban biodiversity? Creating green infrastructure is only the first step. *Landscape and Urban Planning*, 100(4), 369-371.
- IPCC. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability Summary for Policymakers*. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf
- Jerome, G. (2016). Defining community-scale green infrastructure. *Landscape Research*, 42(2), 223-229.
- Johns, C. (2018). *Green Infrastructure and Stormwater Management in Toronto: Policy Context and Instruments*. Retrieved from https://www.ryerson.ca/content/dam/cur/pdfs/WorkingPapers/Johns_Greenwater_Infrastructure&Stormwater_Management_Toronto.pdf
- Kallis, G., Kiparsky, M., Norgaard, R. (2009). Collaborative governance and adaptive management: Lessons from California's CALFED Water Program. *Environmental Science & Policy*, 12, 631-643.
- Karvounis, A. (2015). Urban Metabolism. In Chrysoulakis, N. (Ed.) & Anselmo de Castro, E. (Ed.) & Moors, E.J., *Understanding Urban Metabolism* (pp. 3-12). New York: Routledge.
- Keeley, M., Koburger, A., Dolowitz, D., Medearis, D., Nickel, D., Shuster, W. (2013). Perspectives on the Use of Green Infrastructure in Cleveland and Milwaukee. *Environmental Management*, 51(6), 1093-1108.
- Kiparsky, M., Sedlak, D.L., Thompson, B.H., Truffer, B. (2013). The Innovation Deficit in Urban Water: The Need for an Integrated Perspective on Institutions, Organizations, and Technology. *Environmental Engineering Science*, 30(8), 395-406.
- Kopperoinen, L., Itkonen, P., Niemela, J. (2014). Using expert knowledge in combining green infrastructure and ecosystem services in land use planning: an insight into a new place-based methodology. *Landscape Ecology*, 29, 1361-1375.

- Matthews, T., Lo, A., Byrne, J.A. (2015). Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. *Landscape and Urban Planning*, 138, 155-163.
- McDonald et al. (2014). Water on an urban planet: Urbanization at the reach of urban water infrastructure. *Global Environmental Change*, 27, 96-105.
- McDonnell, M., Hahs, A.K., Breuste, J.H. (2009). *Ecology of Cities and Towns: A Comparative Approach*. New York: Cambridge University Press.
- Mell, I.C., Henneberry, J., Hehl-Lange, S., Keskin, B. (2013). Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. *Urban Forestry & Urban Greening*, 12, 296-306.
- Miles, B., Band, L.E. (2015). Green infrastructure stormwater management at the watershed scale: urban variable source area and watershed capacitance. *Hydrological Processes*, 29, 2268-2274.
- Mitchell, B., et. al. (2014). Integrated water resource management: lessons from conservation authorities in Ontario, Canada. *International Journal of Water Resource Development*, 30(3), 460-474.
- Moser, S.C., Ekstrom, J.A. (2010). A framework to diagnose barriers to climate change adaptation. *PNAS*, 1-6.
- Nirupama, N., Armenakis, C., Montpetit, M. (2014). Is flooding in Toronto a concern? *Natural Hazards*, 72(2), 1259-1264.
- O'Donnell, E.C., Lamond, J.E., Thorne, C.R. (2017). Recognizing barriers to implementation of blue-green infrastructure: a Newcastle case study. *Urban Water Journal*, 14(9), 964-971.
- Ontario Ministry of Environment and Climate Change. (2015). *Ontario's Climate Change Strategy*. Retrieved from <https://www.ontario.ca/page/climate-change-strategy>
- Ontario Ministry of Environment and Climate Change. (2003). *Stormwater Management Planning and Design Manual*. Retrieved from <https://www.ontario.ca/document/stormwater-management-planning-and-design-manual-0>
- Ontario Ministry of Environment and Climate Change. (2017). *(LID) Stormwater Mangement Guidance Manual*. Retrieved from http://www.municipalclassea.ca/files/7_DRAFT_MOECC_LID%20SWM%20Manual.pdf

- Ontario Ministry of Municipal Affairs and Housing. (2017). *Growth Plan for the Greater Golden Horseshoe*. Retrieved from http://placestogrow.ca/index.php?option=com_content&task=view&id=430&Itemid=14
- Ontario Ministry of Municipal Affairs and Housing. (2017). *Greenbelt Plan*. Retrieved from <http://www.mah.gov.on.ca/Page13783.aspx>
- Ontario Ministry of Municipal Affairs and Housing. (2018). *Ontario Planning Act*. Retrieved from <https://www.ontario.ca/laws/statute/90p13>
- Ontario Ministry of Municipal Affairs and Housing. (2014). *2014 Provincial Policy Statement*. Retrieved from <http://www.mah.gov.on.ca/AssetFactory.aspx?did=10463>
- Ontario Ministry of Municipal Affairs and Housing. (2015). *Infrastructure for Jobs and Prosperity Act*. Retrieved from <https://www.ontario.ca/laws/statute/15i15>
- Peel, Region of. (2017). *Measuring and Monitoring Report: Region of Peel Official Plan*. Retrieved from <https://www.peelregion.ca/planning/pdf/measuring-and-monitoring-report.pdf>
- Peel, Region of. (2016). *Peel Region Official Plan*. Retrieved from <https://www.peelregion.ca/planning/officialplan/download.htm>
- Pelletier, G., Rochette, S., Rodriguez, M. (2017). Impacts of the ageing and rehabilitation of water pipes on residence times at the residential neighbourhood scale. *Urban Water Journal*, 14(9), 940-946.
- Phillips, P.J., et. al. (2012). Combined Sewer Overflows: An Environmental Source of Hormones and Wastewater Micropollutants. *Environmental Science and Technology*, 46, 5336-5343.
- Pyke, C., et. al. (2011). Assessment of low impact development for managing stormwater with changing precipitation due to climate change. *Landscape and Urban Planning*, 103, 166-173.
- Quastel, N. (2009). Political Ecologies of Gentrification. *Urban Geography*, 30(7), 694-725.
- Richards, M. (2018). *Regreening the Built Environment: Nature, Green Space, and Sustainability*. New York: Routledge.
- Roggema, R. (2014). The plan and the policy: Who is changing whom?. In Pearson, L.J. (Ed.) & Newton, P.W. (Ed.) & Roberts, P. (Ed.), *Resilient Sustainable Cities: A future* (pp. 225-233). New York: Routledge.

- Saskatoon, City of. (2017). *Green Infrastructure Strategy*. Retrieved from https://www.saskatoon.ca/sites/default/files/documents/corporate-performance/environmental-corporate-initiatives/report_-_green_infrastructure_strategy_update.pdf
- Spirn, A. Whiston. (2005). Restoring Mill Creek: Landscape Literacy, Environmental Justice and City Planning and Design. *Landscape Research*, 30(January 2015), pp.395–413.
- Squamish, District of. (2018). *Official Community Plan*. Retrieved from <https://squamish.ca/assets/OCP-Review/OCP%20THIRD%20READING%20AS%20AMENDED%20BYL2500%20Schedule%20A%20compressed.pdf>
- Sustainable Technologies Evaluation Program. (2018). *Low Impact Development Treatment Train Tool*. Retrieved from <https://sustainabletechnologies.ca/low-impact-development-treatment-train-tool/>
- Swyngedouw, E. (2006). Circulations and metabolisms: (Hybrid) Natures and (Cyborg) cities. *Science as Culture*, 15(2), 105-121.
- Toronto and Region Conservation Authority. (2014). *The Living City Policies: for Planning and Development in the Watersheds of the Toronto and Region Conservation Authority*. Retrieved from <https://trca.ca/planning-permits/living-city-policies/>
- Toronto, City of. (2017). *Green Streets Technical Guidelines*. Retrieved from <https://www.toronto.ca/legdocs/mmis/2017/pw/bgrd/backgroundfile-107514.pdf>
- Toronto, City of. (2018). *City of Toronto Green Roof Bylaw*. Retrieved from <https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/green-roofs/green-roof-bylaw/>
- Toronto, City of. (2018). *Corktown Common*. Retrieved from <https://www.toronto.ca/data/parks/prd/facilities/complex/3499/index.html>
- Toronto, City of. (2015). *Official Plan*. Retrieved from <https://www1.toronto.ca/planning/chapters1-5.pdf>
- Toronto, City of. (2015). *Complete Streets Guidelines*. Retrieved from <https://www.toronto.ca/services-payments/streets-parking-transportation/enhancing-our-streets-and-public-realm/complete-streets/complete-streets-guidelines/>
- Toronto, City of. (2003). *Wet Weather Flow Management Policy*. Retrieved from https://www1.toronto.ca/city_of_toronto/toronto_water/files/pdf/wwfmmp_policy.pdf

- Toronto, City of. (2009). *Wet Weather Flow Master Plan 5-Year Summary Report*. Retrieved from https://www1.toronto.ca/city_of_toronto/toronto_water/files/pdf/wwfmp_5yr_implementation_report.pdf
- Tzoulas, K., et al. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, 81, 167-178.
- University of British Columbia. (2016). *Citizen's Coolkit on Climate Change and Urban Forestry*. Retrieved from <http://calp2016.sites.olt.ubc.ca/files/2017/10/Coolkit-revision-22.compressed.pdf>
- Wheeler, S. (2013). *Planning for Sustainability*. New York: Routledge.
- Widener, J.M., Gliedt, T.J., Hartman, P. (2017). Visualizing dynamic capabilities as adaptive capacity for municipal water governance. *Sustainability Science*, 12, 203-219.
- Wilker, J., Karsten-Rusche, J.W., Rymsa-Fitschen, C. (2016). Improving Participation in Green Infrastructure. *Planning Practice & Research*, 31(3), 229-249.
- Wong, T., & Brown, R. (2014). Integrating urban water planning. In L.J. Pearson (Ed.) & P.W. Newton (Ed) & P. Roberts (Ed), *Resilient Sustainable Cities: A future* (pp. 132-138). New York: Routledge.