More Than a Green Roof: An Analysis of Low Impact Development Policies and Practices

Edward Anyan, BA, GIS (PG)

Sustainability Science and Society

Submitted in partial fulfilment of the requirements for the degree of

Master of Sustainability

Faculty of Social Sciences, Brock University
St. Catharines, Ontario

Abstract

While the concept of green infrastructure is becoming increasingly popular, practitioners and institutions that implement it have varying perspectives on its meaning. This case study aimed to understand how a medium-sized municipality defines green infrastructure as a concept and incorporates it into official policies and related development plans to encourage green stormwater management strategies. It further sought to understand how the analyzed policies and related plans stimulate low impact development implementation in response to climate change adaptation efforts. A content analysis of eight official documents was conducted to determine how the City of St. Catharines, Ontario defines green infrastructure and includes it in its policies and plans. NVivo 12 was used to gather the meaning of green infrastructure and related terms qualitatively. The findings discuss how green infrastructure was defined and incorporated, as well as the consistency of its usage and meaning across the sampled official documents.

Keywords: Green Infrastructure; Best Management Practices; Stormwater Management; Climate Change

Acknowledgements

I would first want to express my profound gratitude to my supervisor, Dr. Marilyne Jollineau, for her unwavering support, coaching, and mentorship from enrolment all the way to the end of the program. Also, to my second reader, Dr. Sivajanani Sivarajah, thank you for your dedication and guidance and sticking to your commitment and support during the entire process. It was a privilege working with both of you.

Thanks to the SSAS faculty and staff for providing me with all the tools and support I needed to make the learning experience successful. However, I will miss the weekly round-up updates. In addition, I am grateful to all the professors who have prepared me to contribute to the environmental sustainability industry.

To my fellow cohort, I know COVID-19 never gave us the opportunity to meet but connecting online was always comforting to feel I was not alone. Thank you all for your support and encouragement throughout the duration of the program, and beyond.

I am grateful to my wife, Edna, who doubled up as a mother and "father" during my study period when dad was busy with academic work. Thank you to my children, Uriel, whose birth coincided with my acceptance offer, Asher and Heman, and the entire Anyan family for your patience and support.

Table of Contents

Abstract ..... *ii*

Acknowledgements ..... *iii*

List of Tables v

List of Figures v

Appendices v

1.0 Introduction *1*

1.1 Research Goals and Objectives 3

1.2 Background and Study Area 4

2.0 Literature Review *7*

2.1 Low Impact Development in Canada 9

2.1.2 Low Impact Development Implementation Drivers 11

3.0 Research Methods *15*

3.1 Sampling Technique 19

3.2 Coding Procedure 20

4.0 Findings *22*

4.1 Green Infrastructure Terms and Definitions in Official Policies and Plans 23

4.1.2 Green Infrastructure Consideration Goals 25

4.1.3 LID Stormwater Implementation Progress and Strategies 26

4.2 Low Impact Development (GI) - Climate Change Adaptation/Mitigation Strategy 27

4.3 LID Best Management Practices 29

5.0 Discussion *34*

6.0 Limitations *36*

7.0 Conclusions *36*

8.0 Recommendations for Future Research *38*

9.0 References *38*

10.0 Appendices *46*

List of Tables

Table 1: Documents determined as appropriate for GI implementation assessment. 19
Table 2: Alternative GI terms from reviewed document 25
Table 3: Identified best management practices in the reviewed documents 32

List of Figures

Figure 1: Map of Study Area 6
Figure 2: Ontario LID policy implementation drivers (adapted from Credit Valley Conservation, 2015) 15
Figure 3:Steps for deductive categorization model approach (adapted from Marying, 2000) 17
Figure 4: NVivo word query (branch) analysis output 21
Figure 5: Method overview for the content analysis case study 22

Appendices

Appendix 1:Coding keyword intersection matrix 46
Appendix 2:Coding guide 48
Appendix 3:Word cloud frequency search 48

1.0 Introduction

The need to meet demands for both residential and commercial infrastructure without compromising a community's environmental and sociological needs is critically important. In the race to increase housing supply to meet current demand, municipalities and lower-tier governments must shift from traditional stormwater management towards environmentally friendly approach by way of policy regulations and implementation. As part of climate change adaptation and mitigation planning, green infrastructure (GI) strategies and implementation cannot be overlooked. GI, defined as stormwater management technologies that mimic natural processes of hydrology, soils, and vegetation, such as pervious pavements, rain gardens, and bioswales, has received considerable interest over the past decade; however, GI planning and implementation assessment has received less research attention (Finewood et al. 2019).

A growing number of cities have taken advantage of GI to tackle issues such as urbanization, stormwater management, and the loss of urban forests to infrastructure development to conserve the environment. As several municipalities and regional governments have specific goals with respect to the implementation and use of GI in Canada, it is recognized that the term GI has distinct meanings and contexts in Canadian policy discussions, so fundamentally understanding how the term is used is vital (Conway et al. 2020; Hislop et al. 2019). The debate over definitions and the case for investment framing among academics and practitioners continues. However, GI has been promoted uniquely to reflect a localized interpretation and usage of the term (Mell et al. 2017). Since its introduction into Canadian official documents, GI has been tailored for use in many municipalities, for instance in the stormwater management, building, and energy conservation industries (Conway et al.

2020). Moreover, according to Ishaq et al. (2019), stormwater management infrastructure in Canada is faced with numerous challenges due to several issues, such as deteriorating infrastructure, flooding in built-up environments, and climate change, among others. Expanding “gray” infrastructure (use of concretes and polyvinyl chloride (PVC) pipes in stormwater construction) presents a threat to conventional drainage systems' capacity to manage surface runoff. Applying green stormwater infrastructure (GSI), like permeable pavement, bio-retention, rain gardens and other green stormwater management (GSM) practices, will augment conventional drainage systems to continue to function to handle stormwater peaks to mitigate the pressure from climate change impacts on both green and brownfield (previously developed land or vacant building which may be environmentally contaminated but have potential for redevelopment (Ahmad et al. 2018) development is imperative (Kim & Li, 2016; Wellmann et al. 2020). In particular, Ishaq et al. (2019) noted there is promising evidence that LID systems can help reduce both stormwater volume and improve water quality problems simultaneously.

This study adopted and modified the definition of LID otherwise known as green infrastructure by Ishaq et al. (2019) as a set of design practices that aims to imitate natural hydrological movement and storage of water in the environment to reduce impacts in pre and post development construction sites. Zhang & Chui (2018) similarly defined LID as practices primarily implemented on-site to control stormwater at source, restore natural hydrologic processes, and mitigate negative impacts of development.

While LID and GI are different concepts, this case study examines them on the same level as they are related. GI can be considered as a macro standpoint of the two concepts while LID is often micro-attributed specifically to stormwater or drainage system management. The end goal is to understand how these terms GI-LID are well-thought-out to

address environment-hydrological management practices that preserves water as a resource than a conveyed waste sustainably. Research supports the assertion that GI and LID are more or less similar to one another partly due to differences in perspective, understanding, and context between different parts of the world that used different terms to describe similar concepts (Copeland, 2016; Fletcher et al. 2015; Jiang et al. 2015; Zhang & Chui, 2018).

1.1 Research Goals and Objectives

The overall goal of this study is to identify how a medium-sized municipality in Ontario, Canada, defines and uses green infrastructure (GI), also known as low impact development (LID), in policies and other related planning documents content to promote green stormwater management implementation in a climate sensitive era. Further, this study seeks to identify whether GI as term is included in policies and plans, and if so, how it is included. Using a case study approach, the City of St. Catharines has been selected for further study. This study used a case study method since its intention is to understand how an organization (the City of St. Catharines) utilizes a concept. Analyzing qualitative data in case studies enhances appropriate descriptions and comparisons of concepts. The City has adopted and adapted to the use of GI in its municipal plans and policy documents. GI implementation and practices vary among different governance levels. St. Catharines, the chosen municipality, has the most populated core in the Niagara Region of Ontario, however, it also has the third-smallest landmass in the Niagara Region.

Understanding how GI is defined and used in a municipal planning context after over a decade of provincial policy progress in GI policies and implementation is important because it lays the foundation for municipalities to use GI to reduce climate change impacts and lower stormwater infrastructure costs across all sizes of communities. According to Hislop et al.

(2019), "weak wording" and a lack of understanding of GI are recipe for passive adoption and implementation.

The following research questions were used to guide this case study:

1. How is GI defined and incorporated in official planning documents and policies in medium-sized municipality such as the City of St. Catharines, Ontario?
2. To what extent does GI/LID address climate change challenges in the identified policies and plans for the City of St. Catharines?
3. What LID practices and implementation are currently required for development approval?

1.2 Background and Study Area

GI or LID in this case study was mainly focused on the development of stormwater management strategies to adapt to climate change, and a transition toward incorporating GI into development plans and policies in the City of St. Catharines. In 2017, the Ministry of Infrastructure (MOI) regulations mandated all municipalities to include GI in municipal infrastructure asset definitions in a newly developed asset management plan by the end of the year 2021. Moreover, the 2017 Greater Golden Horseshoe growth plan specifically outlined support for GI inclusion in climate change mitigation/adaptation considerations (Green Infrastructure Ontario, 2022).

Although GI definitions vary, the primary focus of this study is on the implementation of GI stormwater management practices that integrate technology and nature-based solutions. As well as how a green-gray mix approach is used to address hydrological issues related to water quality, quantity, runoff, and flood mitigation to support climate change resilience. Considering the impacts of on-site development on stormwater, LID and GSI are used in this study to describe a set of tools and practices utilized in stormwater management planning and design practices.

The City off St. Catharines is growing faster than its neighbouring communities, as this City's population increased by 2.8% in 2021, based on Statistics Canada's 2019/2020 metro census data. As an emerging municipality in the Niagara Region, the City of St. Catharines has more built-up areas and a larger population of 136,830 as of 2021 in the Niagara Region relative to the 11 other municipalities (Statistics Canada, 2022).

The City of St. Catharines is located within the Niagara Region in Ontario, Canada. There are some lands within the City's boundaries that fall under the Golden Horseshoe and Greenbelt Conservation Areas and Greenbelts in Ontario. According to Statistics Canada, the City has a total landmass of 96.20 square kilometres (Statistics Canada, 2022) . A map showing the boundaries of the City of St. Catharines with its waterways (water resources) is shown in Figure 1. The City of St. Catharines was recognized as one of the winners of the brownfield award (2021 Brownie Award) for having improved brownfield redevelopment policies, legislation, and a program which provides financial incentives (tax incentives) to encourage sustainable practices as part of its Community Improvement Plan (The Standard, 2021).

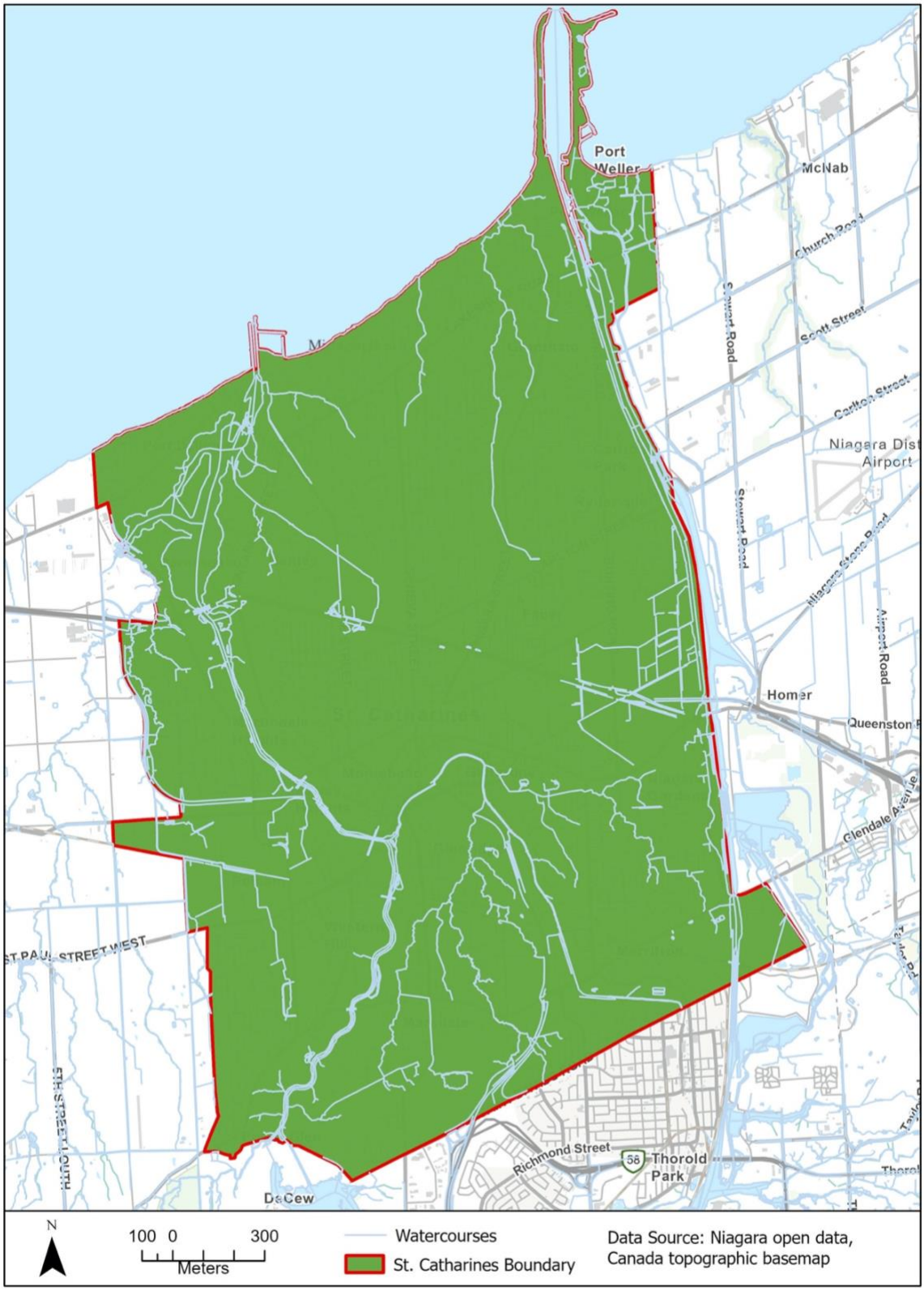

Figure 1: Map of Study Area

2.0 Literature Review

For over a decade, GI, and more specifically, green stormwater management practices were perceived to be a technologically challenging area of undertaking. The technology and expertise required to implement GI aren't readily available. However, a study by Credit Valley Conservation (CVC) in 2010 revealed that institutional issues served as the largest barrier to adoption and implementation of municipal LID practices (CVC, 2010). GI implementation is typically considered a costly investment hence developers often cut costs; this leads to GI implementation being compromised at development sites. GI offers affordability and feasibility in the current context yet accounting for GI financially as a tangible asset remains a perceived stumbling block for effective integration of GI practices into development plans. GI, however, has proven to be affordable over the long term (Callway et al. 2019). Incorporating LID into development plans is essential to achieve environmental sustainability considering the negative impacts of climate change on municipalities (Xu et al. 2019).

The cost of maintaining and installing conventional pipelines is also expensive compared to implementing on-site LID practices (Kim and Li, 2016). Cormier et al. (2017) noted that environmental sustainability is achievable by coupling macro-economic and explicit sector policies with best management practices (BMPs) that regulate environmental impacts from the source. GSI (such as bio-retention, green roofs, and bioswales), has been described as an 'affordable solution' compared to the replacement of large underground pipeline systems in some municipalities. One example would be the City of Edmonton's use of GSI, which was estimated at $1.6 billion over a 30-year period, compared to $2.2 billion for conventional stormwater infrastructure (Credit Valley Conservation, 2021). According to a survey by Credit Valley Conservation in 2010, municipalities have been reluctant to

implement stormwater programs that consider LID or mimic natural systems due to regulatory (private – public ownership) and asset management adherence. Among the barriers to incorporating LID-stormwater scale up in a municipal setting are concerns about BMP standards checks on private properties and the cost of long-term ownership and maintenance. For example, a greenway space and engineered infiltration constructed at a residential development was trespassed upon in the City of Guelph in Ontario (CVC, 2013). This is consistent with Baptiste et al. (2015) findings that residents do not have a full understanding of what GI is in a study conducted in Syracuse. Municipalities are slow to showing the political will needed to adopt laws that enable them to check LID BMPs located outside public domains and to uphold commitments to maintenance costs.

Technical and technological advancements have improved the development of infrastructure, particularly stormwater drainage. Despite this, climate change and climate adaptation efforts call for a crucial shift from historical stormwater management practices towards integration of LID practices. This will enable us to deal with extreme climate events and variability impacts on the environment. There is a need to take climate adaptation into account and integrate it into infrastructure planning and development to address the complexity of environmental problems. To such a degree, it is essential to manage the uncertainty associated with climate change by considering the flexibility and urgency of incorporating LID practices into municipal infrastructure development differing from conventional approaches. GI is identified as efficient to minimize sewer overflow risk and infiltration boost as well as storage of stormwater thereby reducing excessive stormwater runoff (UNEP & TNC, 2014).

2.1 Low Impact Development in Canada

In Canada, GI is used in diverse ways by municipalities and other government institutions. The 2021 Federal Plan for Climate Change; A healthy Environment and a Healthy Economy, tends to focus on energy efficiency which differs from the Province of Ontario which first highlighted GI in its 2014 Provincial Policy Statement, differs in usage and incorporation approach of the concept into climate plans and land-use policy than other provinces and the Government of Canada (Conway et al. 2020). Hence, this study tried to determine how the term is adopted and adapted into plans and policies by the City of St. Catharines. Conceptualization of GI by city planning authorities is deemed to be unclear despite the identification of explicit definitions according to a GI definition study in the United States (Grabowski et al. 2022). Hislop et al. (2017) reiterated that GI is often overly simplified by institutions to focus on a single benefit which limits GI planning and implementation benefits, thus a shift towards the flexibility and adaptability which tends to weaken the overall practicability of GI. For example, some municipalities and lower tier governments adopt GI based on resource and expertise availability and may not consider GSI. Canadian municipalities and provinces have however, acknowledged the need to protect their environment and have commenced the promotion of LID practices as stormwater management substitutes (Henstra et al. 2020). For example, the Province of British Columbia has initiated a transition towards the implementation of integrated stormwater management plans and LID practices in some of their communities (O'Neill & Cairns, 2016).

It is projected that by 2050 there will be more frequent flooding events from more snow and rainfall events. Improvements in stormwater management are fundamental to addressing peak overflow of stormwater now and into the future (Copeland, 2016). Heavy precipitation with associated flooding is projected to increase in frequency and intensity at a

medium to high confidence projection (IPCC*,* 2021*)*. Conventional stormwater management is forecasted to cause considerable environmental damage due to deteriorating stormwater infrastructure. However, integration of LID practice is capable of decreasing damages and their associated costs. The Credit Valley Conservation in collaboration with the City of Brampton and a private developer have undertaken GI performance and risk assessment which confirmed LID features accounted for 77% of volume reduction for events up to 25 mm and a 74% reduction in peak flow for events exceeding 30 mm for a greenfield residential development (Sustainable Technology Evaluation Program, 2020).

For Li et al. (2019), GI includes natural and semi-natural elements that perform several functions, including economic, social, and ecological interdependencies that benefit humans and other species. The wide-ranging applications and uses of the term, GI, makes its' definition a challenge in both research and practice. GI is an open-ended term that has been interpreted and applied differently which makes its use limited in current practice. Some researchers believe it is likely to be referred to as a new 'green' branding without any potential advancement in explicit definition and implementation (Grabowski et al. 2022; Pauleit et al. 2019). In contrast, the broad framing of GI is also seen as a positive opportunity to allow municipal planners to adapt the concept to suit their local needs. There were three broad frameworks identified as green space planning, urban ecology, and stormwater management, which were considered practical and policy-driven (Matsler et al. 2021). Considering several factors are measured in reaching land-use planning decisions there is a desperate need to have a standard framework to guide the implementation and performance evaluation of GI in development blueprints. Despite the popularity increase in the implementation of GI after its initial exploration stage in both built-up areas and new

developments applications, there has been little research attention on how GI policies and practices performance can be measured (Hislop et al., 2019).

Furthermore, Mell's (2017) and Monteiro et al. (2020) GI assessment approaches identified some common GI principles including applicability, integration, multiscale, governance, continuity, and diversity. These highlighted principles are important to identify and gauge the effectiveness and path being outlined by municipalities towards minimizing the negative impact on the environment while meeting the infrastructural needs of its population. Thus, tracking how development plans and permit highlights the provisions for the inclusion of GI as a requirement for building sustainable neighbourhoods and communities.

2.1.2 Low Impact Development Implementation Drivers

The search to understand how plans and policies are explicit about the inclusion and implementation of GI will provide a blueprint for identifying the challenges and opportunities in a municipal context beyond the "business-as-usual" by municipal planning and development managers. Hislop et al. (2019) asserted that GI as a concept has matured and is now a strategic approach to policies and practices at all levels of government and applicable regions. Nevertheless, an assessment of GI as concept and how it is incorporated into policies and master plans are, however, unclear about its effectiveness on how the evaluative processes informs the understanding of the concept (Callway et al. 2019). Accordingly, the general question of the study is to examine the definition and inclusion of GI in official plans and other related documents (*n=8)* for the City of St. Catharines. The commodification of GI undermines efforts to promote sustainable development through nature-based solutions (NBS). In the context of a changing climate and its accompanying challenges, a call for

comprehensive development planning is central to environmental sustainability while meeting the infrastructural needs of a growing population.

Remarkably, the Federal Government of Canada focus on addressing climate change is primarily on how energy efficient needs can be integrated into economic growth. There is no mention of LID as a strategy for promoting climate change adaptation/mitigation efforts in the climate change Federal plan; A Healthy Environment and a Healthy Economy (Environment and Climate Change Canada, 2021). Despite this, there are varying degrees to which LID is incorporated into stormwater regulations in some Canadian provinces (Ishaq et al. 2019). Flooding which is a climate-related major hazard is known to be a risk to almost every community in Canada and is expected to be prevalent in major Canadian cities due to a resultant effect from prolonged rainfall events, and overburdened drainage infrastructure system (Henstra, 2017). For example, in 2013 a combined insurance claim for the City of Mississauga, Toronto and Brampton was valued at one billion dollars (Credit Valley Conservation, 2015). Municipalities across Canada are undertaking climate change adaptation and mitigation plans (e.g., the City of St. Catharines); however, the focus of the adaptations plans widely varies in goals and implementation approaches. Given that extreme precipitation is one of the major climate change hazards in communities it is important to understand how municipalities are preparing for these events with green stormwater practices and considerations outside of conventional stormwater management approaches.

Hislop et al. (2019) stated that integrating GI into conventional land-use planning policy has received limited attention and is frequently treated as second to economic and social deliberations partly due to the indirect financial value of GI and to some extent more beneficial to others than the cost bearer. In contrast, Pauleit et al. (2019), confirmed that there is vast evidence that supports cost savings with implementing urban green

infrastructure. However, Shandas et al. (2020) noted that commitment to the adoption of LID remains unhurried by planners and decision-makers partly due to relative novelty of GI strategies, although some federal and regional funds are becoming increasingly available.

According to Callway et al. (2019), GI valuation has not been prioritized due to inconsistencies in the definition of the concept, non-standardized regulations, and imitative practices; this discourages developers and practitioners from undertaking a complete implementation of GI in land development and re-development practices. That said, Mell (2017) affirmed that there is a growing advancement in evidence obtainable to support GI capability to address climate change.

LID practices are adopted as a strategy to climate change adaptation in numerous cities across the globe. For example, the City of Toronto is cited to have downspout disconnection mandated in development guidelines. Climate change is considered as the major driver for extensive LID strategy implementation among municipalities as increased and frequent storm events are evident in many cities (Eckart et al. 2017). By law, the City of Port Coquitlam and Toronto require green roofs to cover 75% and between 20% - 60% of the total floor area of their buildings, respectively (Liberalesso et al. 2020). Surface runoff water prevention and control were identified as one of the primary factors that promote the adoption and implementation of GI. Recurrent flooding and related risk costs were identified as drivers for green infrastructure legislation and implementation (Hall, 2010; Li et al. 2020). However, resistance from residents tends to serve as an externality that serves as a barrier to the implementation of GI. On a progressive front, a case study indicates residents are highly interested once GI projects are showcased in communities through demonstration and outreach programs (Shandas et al. 2020; US EPA, 2010).

In Ontario, there are guidelines and legislations that encourages low impact developments. Stormwater Management Planning and Design Manual, a technical document issued by the province in 2003, outlines how stormwater systems should be designed for effective monitoring. In addition, it specifies the requirements for site development (pre-development hydrology) and urban drainage improvement consideration. Ontario's LID implementation is influenced by several factors, as presented in Figure 2. Referring to Shaq et al. (2019), the authors concluded that the development of a stormwater regulation by the provincial government of Ontario is a step towards a shift from current stormwater system design and practices towards the implementation of GI strategies as a means for sustainable water resource management. A LID stormwater management planning and Design document, released by the Province of Ontario in 2010, is a detailed and updated edition of the 2003 manual. Among other things, the manual explains how source control and conveyance can preserve pre-development conditions at a development site.

The paper used a range of policy, practice and academic sources centered on the implementation of green infrastructure globally to contextualize the paper before analyzing perspectives of green infrastructure definition in policies and plans.

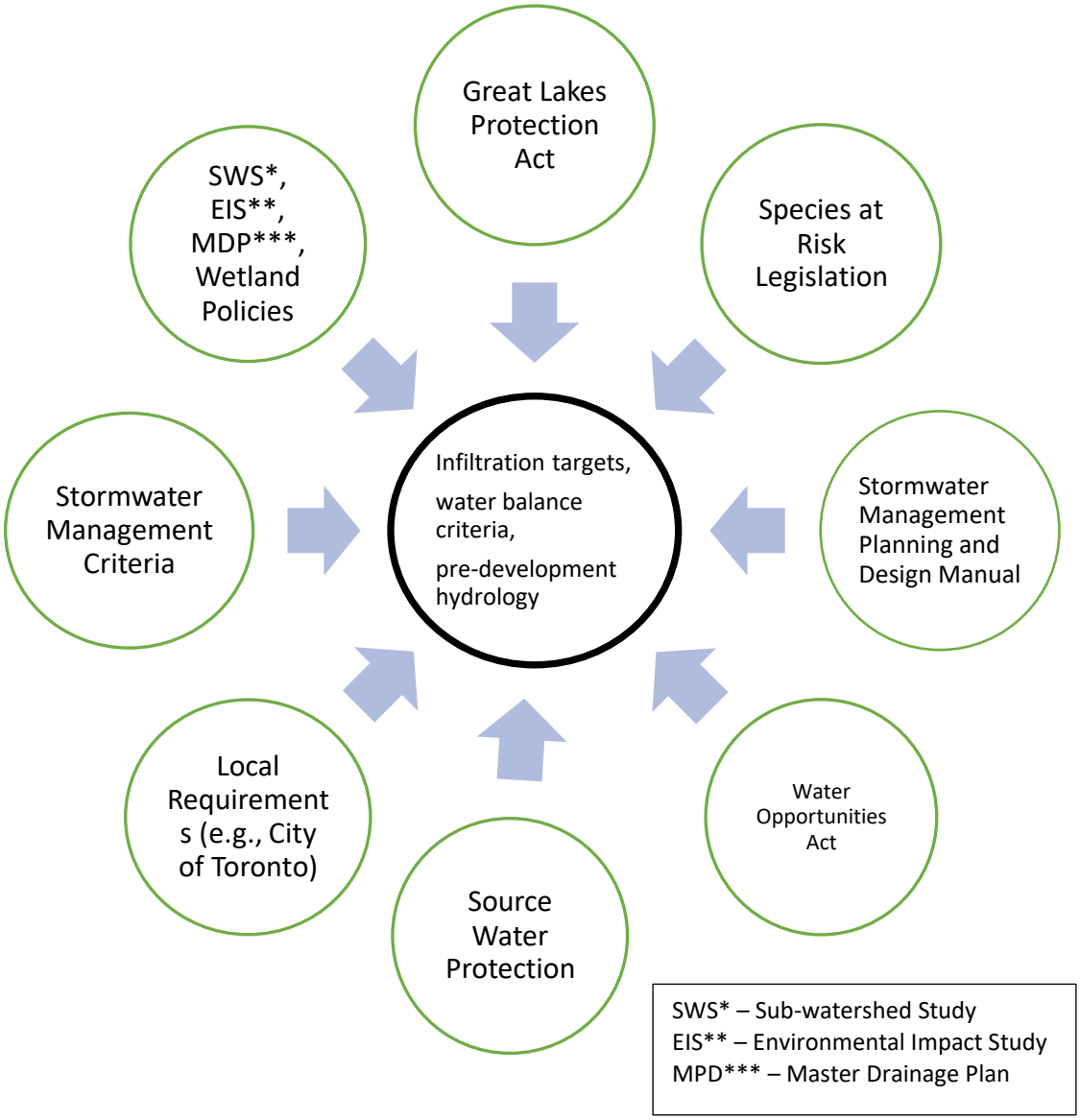

Figure 2: Ontario LID policy implementation drivers (adapted from Credit Valley Conservation, 2015)

3.0 Research Methods

This section of the paper provides a description of the methods used in this case study. Content analysis is a method used to group, contrast, and compare textual data numerically or interpretively to investigate an evolving concept (Gerbic & Stacey, 2005; Klein et al. 2020). Krippendorff (2013, p. 24) defined content analysis as "*a research technique for*

making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use." Based on Krippendorff's findings in his 2004 study, the most suitable data (written documents and verbal discourse) will be most useful for the analysis of content (Krippendorff, 2004).

Based on the research questions and objectives, a deductive categorization was used to develop definitions of the categories. Definitions for the categories and subcategories or nodes were derived from emerging premises and definitions that surfaced from the review of literature (theoretical) and provincial documents relating to LID.

The design, evaluation, and analysis of the case study are guided by theories. An explanation of phenomena must provide a logical understanding of concepts, definitions, and arguments (Auld et al. 2007). The paper used different policy, practice and academic sources centered on the implementation of green infrastructure practices to establish the study context before analyzing green infrastructure definition and implementation strategies in policies and plans for this case study (Mell et al. 2017).

The purpose of this step was to provide specific definitions, examples, and coding details for each category. By using this process, a guideline (see Appendix 2) was developed outlining the conditions in which a passage, phrase, or word would be classified under a coding category (Mayring, 2000). In total, five major categories were developed in the coding guide. These included: best management practices (BMPs), climate change, green infrastructure, low impact development, master plan integration, and stormwater management. By following this process, the evaluation approach is strengthened in terms of validity and reliability. Norton (2008), for example, used content analysis to evaluate a local master plans and zoning codes and found that using categories for coding led to increased accuracy in meaning and a reduction in ambiguity during the coding process to improve

measurement validity (Norton, 2008). Again, the threat to inter-coder validity was not a problem due to the small number of document sample (*n*=8) related to the City of St. Catharines reviewed for the analysis in this case study.

The study employed NVivo 12 by Qualitative Solutions and Research International software program, the study has three sections that were used in the coding of the data. The first section of this paper provides the framework that was used and elaborates on the initial categories which were developed for the coding guideline (see flow diagram of methods shown in (Figure 3). Due to multiple definition existence, the objective and research questions and literature reviewed formed the basis for investigating green infrastructure as a concept.

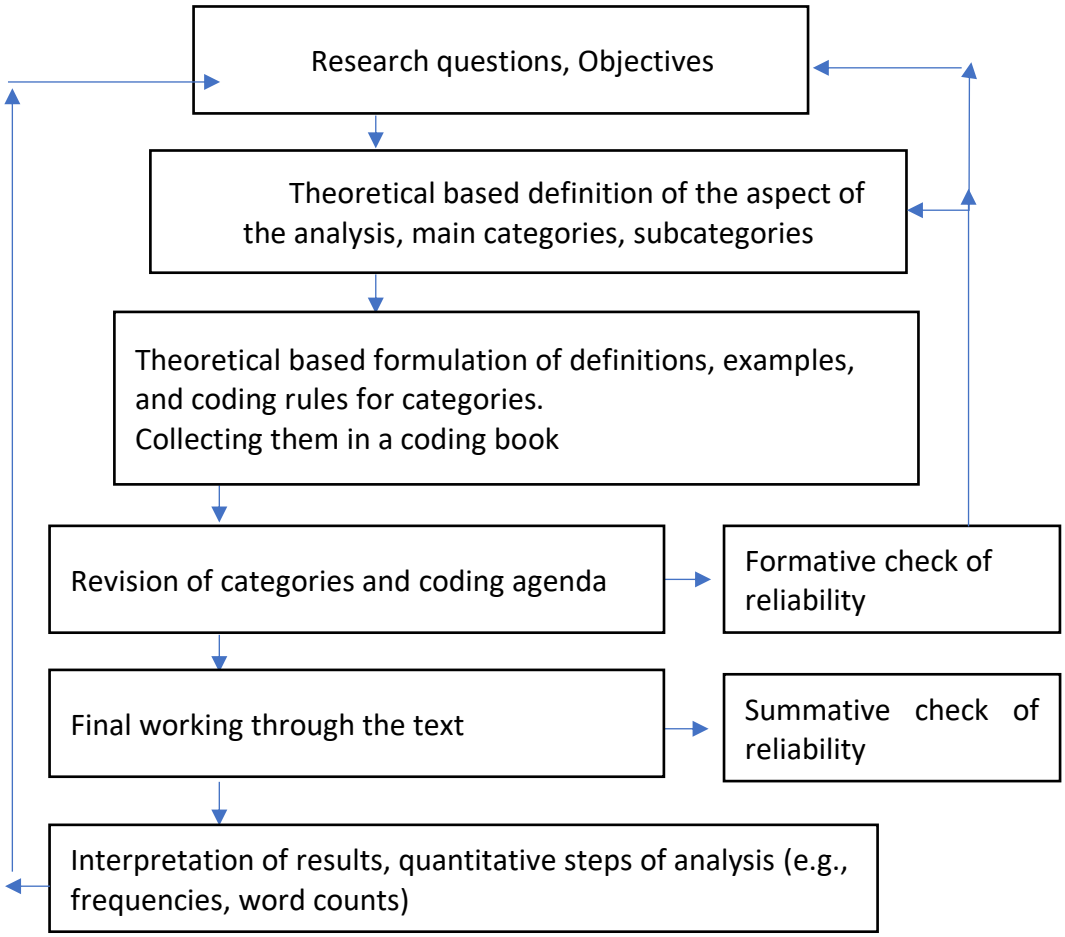

Figure 3:Steps for deductive categorization model approach (adapted from Marying, 2000)

The second step describes how the code for determining the extent to which LID policy has been expressed to address climate change. The final step provides an overview of how the framework for the data coding and analysis was accomplished.

Echoing that GI definition and operationalization is relative to organizational need and time, applying content analysis to understanding its adoption and application in the municipal official plans and other related documents would benefit knowledge contribution as a concept with diverging meaning. This study focused on how green stormwater management (GSM) as an emerging GI practice is incorporated into municipal official plan and policy implementation in the City of St. Catharines as the case for this study.

Using NVivo software enhances the capability of employing other analysis types to highlight the theoretical underpinning of concept to establish relationships and contextual meaning in the study. Further, keyword-in context analysis can be beneficial when the researcher is interested in specific words or phrases (Leech & Onwuegbuzie, 2011). Again, Auld et al. (2007) confirmed NVivo is capable of expanding analytical avenue by enabling wider search process. To minimize any tendency of subjectivity in the assessment process, the coding rules and guide were pre-developed to increase the reliability and objectivity of the process (Neuendorf, 2017). The study, however, employed summative and directed approaches to content analysis. Based on existing literature, the directed approach identifies a node or code associated with the presented phenomenon. The summative approach, on the other hand, focuses on the application of categories, quantifications, and interpretations of the content (Ishaq et al., 2019). Thus, addressing the “summative reliability check” while working through the final text search (Marying, 2000).

3.1 Sampling Technique

In 2021, select official documents were located by using a search query on the City of St. Catharines websites relating to "Green Infrastructure-Stormwater Management", "Climate Change", and "Asset Management Plans". Using wildcard search for the term “Green Infrastructure” returned 10 results. The returned results included Climate Adaptation Plan, Urban Forestry Management Plan, St. Catharines Sustainability Strategy, 2021 Asset Management Plan, The Garden City Official Plan, and other five. Because GI as a term entered the province's policy document in 2014, it was important to review the progress towards the adoption of GI stormwater management into official plans and documents that are encouraged by the province. For example, in 2017 the Greater Golden Horseshoe growth plan required municipalities to include GI, specifically stormwater management and climate change mitigation/adaptation, into their support systems (Green Infrastructure Ontario, 2022). The sampling technique used in this study was informed based on the provincial policy requirements which date to 2022; reviewed literature and related document recommendation identified in the initial official plan. Table 1 provides the names of specific document that were included in the content analysis.

Table 1: Documents determined as appropriate for GI implementation assessment.

Documents included in the content analysis

Document Type	Year	Document Description
Official Plan (Garden City)	2013	The City of St. Catharines official plan
Climate Adaptation Plan	2021	Official corporate adaptation plan for the city that contains strategies and goals to address climate change.
Asset Management Plan	2021	Guides decision-making in building, operating, renewing infrastructure assets including stormwater infrastructure, bridges, water.
Building Guideline	2009	Residential and commercial building guidelines
Site Plan Control By-Law	2017	A by law for all designated lands as a site plan control
Community Improvement Plan	2020	A program guideline for financial incentive programs for redevelopment, brown field remediations, and building improvement

3.2 Coding Procedure

The first step was to conduct a text query search using the keyword-in-context approach, which has been identified to be useful when attempting to locate specific words, phrases, or paragraphs in multiple documents (Leech & Onwuegbuzie, 2011). Keyword-in-context is the process of identifying key terms, key phrases, key segments, or keywords which accurately represent the subject matter of a document (Onan et al, 2016).

To gain a focused perspective on the subject matter, NVivo provided the functionality to create text search queries to identify and analyze words or phrases in codes and files. Using the Keyword-in-context, a search for keywords for example, “Low Impact Development” (see Figure 4) returned a result that can be viewed as a “word tree” or “word cloud”. To better understand the pattern, the word tree result grouped the context into branches. A further insight into the keyword was done by running another search query for the keyword associated with the branches, for example the following keywords “Practices”, “green infrastructure”, and “LID” was further queried to investigate linkages associated with the stem result “Low Impact Development”. These nodes (categories) followed the Ontario provincial requirements for Asset Management Planning, which consider stormwater management as a core service. As such, the coding aligned with the provincial LID drivers.

To ensure conformity and consistency with the coding process, the documents were manually reviewed and coded and auto coded for comparison (Neuendorf, 2017). Three major areas were analyzed: (a) determining the extent to which evidence of GI integration into the official plan and related documents were present; (b) analyzing how the impacts of climate change influenced the use of GI; and (c) identifying the extent to which GI - BMPs were implemented or available in regulatory plans and policies. The analytical guide outlined

in the coding guide was used to analyze the data with the appropriate short names (codes/nodes) to create a meaningful linkage in the data (from the official documents) during each phase of the process. As a result of revelations made in the documents during the coding process, additional data (documents) were considered. For example, the official plan document had to be read alongside other documents, such as the building guideline plans (Maher et al. 2018).

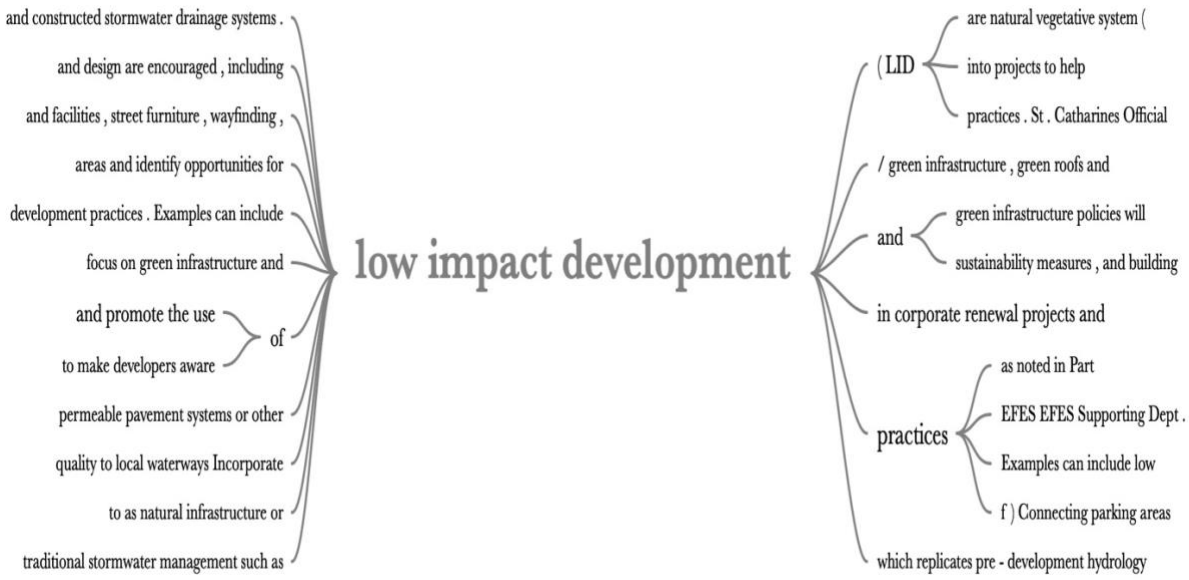

Figure 4: NVivo word query (branch) analysis output

A constant reference to the research questions was done to ensure the analytical guide outlined in the coding guide was used for categorizing the data with the appropriate short name (nodes) to better generate a meaningful linkage to the keyword-in-context in the data (official documents).

A method outline (see Figure 5) shows the steps which was used for the data collection and preparation (categorization and text meaning discussion approach) for the case study.

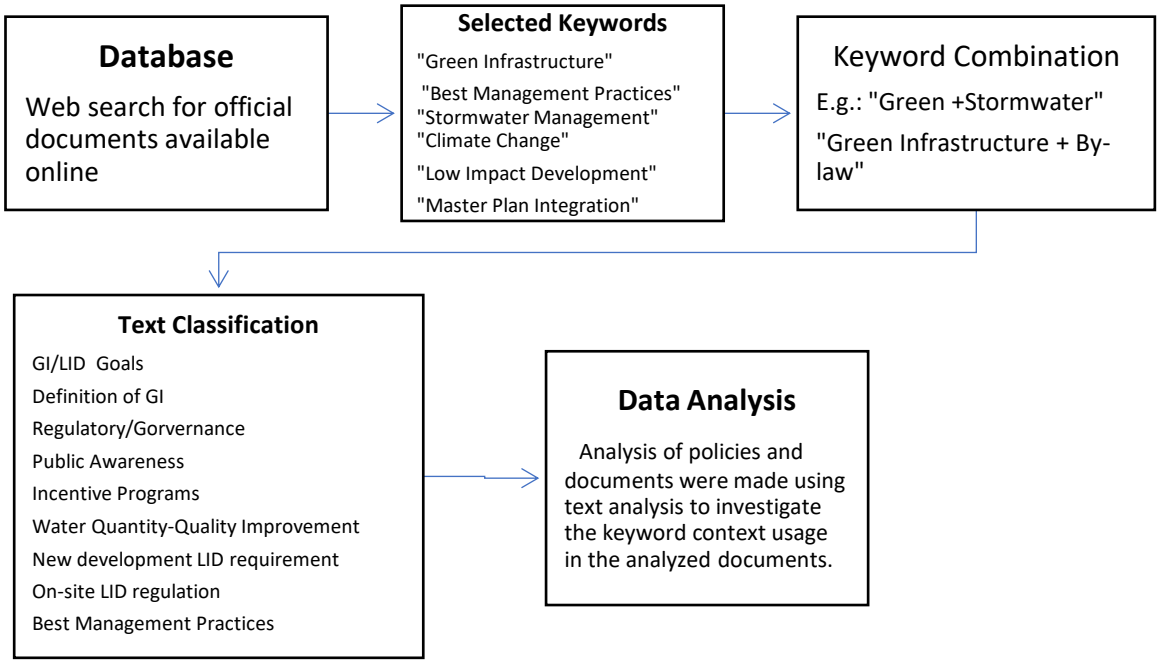

Figure 5: Method overview for the content analysis case study

4.0 Findings

In this section, an analysis of how official policy and related documents define and incorporates green infrastructure, also referred to as low impact development, and how the concept is implemented is presented.

The Credit Valley Conservation defined LID as “a stormwater management strategy that helps to reduce the impact of stormwater by collecting and treating runoff as close to its source as possible” (Credit Valley Conservation, 2015).

4.1 Green Infrastructure Terms and Definitions in Official Policies and Plans

The first research question sought to understand the extent to which GI/LID is defined and incorporated in official documents with a focus on stormwater management. City planning authorities are not forthcoming in their definition of green infrastructure, however, if they do, expansive stormwater initiatives are predominant. Broad framing of GSI by municipal planners can also enhance or interrupt implementation of GSI effectively (Grabowski et al. n.d.; Shandas et al. 2020). Among all the documents that were analyzed, the Climate Adaptation Plan (CAP) was the only document that included an explicit definition of GI with a focus on stormwater management. It reads:

> *"Green infrastructure, sometimes referred to as natural infrastructure or low impact development (LID), are natural vegetative system(s) that provide a variety of benefits (economic, social, and environmental). The primary role of green infrastructure is stormwater management, which provides water quantity and water quality treatment. Examples include urban trees/forests, engineered wetlands, rain gardens, and green or blue roofs"* (Climate Change Adaptation Plan, 2021, p. 8).

This definition acknowledges that GI is a major means of managing stormwater with the aim of improving water quantity and quality. The Asset Management Plan (AMP) highlighted that defining and measuring key performance indicators for both technical and customers for core services which includes stormwater management was needed. The CAP comment section of the document featured thought-provoking comments and questions from the public which were generated from the virtual online open house. For example, questions were raised about GI definitions and the inclusion of LID practices like permeable surfaces for parking lots, blue and green roofs, and the possibility of minimizing parking lot sizes and converting them to more green spaces. This supports the assertion that, retrofitting existing parking lots, sidewalks and roads is considered highly feasible to improve infiltration of surface runoff water in urban areas (Eckart et al. 2017).

There is no clear definition of sustainability within the official plan, although the term is sometimes used in a broader sense to imply LID. The documents were consistent in highlighting sustainability with varied emphasises on economic, social, environmental, and cultural considerations. The varied emphasises on GI confirms that GI is broadly used by practitioners and municipalities due to competing goals for GI consideration and implementation (Li et al. 2020; Zwierzchowska et al. 2019). Again, the term greening (see Appendix 3) was also used to denote either sustainability, GI and or as a means of minimizing impact on development (LID). For example, "greening" was used in section 4.2 (Urban design principles) of the official plan document as a sustainable design principle required for development and redevelopment in the City. The concept or term GI appeared once in the Garden City official plan without an explicit definition. The term, however, referred to GI as all natural areas and features like forest, wetlands, and creeks as assets that contributes to the City's green infrastructure. The AMP highlighted GI and LID to denote different concepts critical to controlling flood risk by mimicking pre-development hydrology as a proactive maintenance and rehabilitation mechanism for wastewater infrastructure. Some BMPs relating to stormwater management specifically, downspout disconnections were cited as best practices to mitigate peak overflows. In comparing the province of Ontario's definition of what constitutes green infrastructure asset.

> "Natural and human-made elements that provide ecological and hydrological functions and processes. *Green infrastructure* can include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs" (Provincial Policy Statement, 2020 p. 44).

Per the provincial green infrastructure definition being elaborative on different aspects of GI, which touches on landscapes, and heritage features and specific stormwater management BMPs, cities or municipalities tend to be implicit with definition declaration

thereby making the term often used interchangeably and with LID and GI sometimes referred to differently as concepts than synonym. For example, “low impact development and green infrastructure” were used as separate concepts for policy considerations in the 2021 AMP document. It was noted that there are many variations in the use of the term green infrastructure in Canada (O’Neill & Cairns, 2016).

Table 2: Alternative GI terms from reviewed document

Term	# of files/documents term found	# Frequency
Green Infrastructure	3	17
Low Impact Development	3	13
Best Management Practice	2	3
Stormwater Management	3	16

4.1.2 Green Infrastructure Consideration Goals

This section identified some goals and objectives that informed green infrastructure incorporation into official documents and policies. Stormwater runoff mitigation and erosion is one of the objectives that was identified in the assessed documents. Provincial regulation conformity or compliance was another focus which informed GI considerations. Specifically, the AMP was one of the documents that is explicitly required by the province to incorporate some GI practices integration, however, the term GI appeared twice with a broad focus on climate change implication on stormwater infrastructure.

The CAP to some extent clearly outlined some significant goals that considers GI as part of the plan implementations strategy to improve stormwater management (Goal No. 4: improve stormwater management including the use of GI). Again, CAP goal number three aims at developing a flood prevention strategy and to include GI in the corporate asset

management plan, however, there was no clear GI strategy inclusions in the 2021 AMP that was released along with the CAP. The City of St. Catharines has a broad interest in promoting LID. This includes a particular focus on GI/LID to encourage increased water quality in local hydrological channels which were highlighted in the CAP. The Garden City Official Plan included some LID promotional initiatives. In general, the official plan does not contain any sections that specifically promote the inclusion of green infrastructure, apart from community gardens and roof top gardens. Under the urban agriculture section of the official plan, these are permitted and specified. Unlike municipalities like Toronto, which have a green roof by-law that is encouraged by the Province, St. Catharines does not have a specific document that outlines specific by-laws or policies regarding green roofs (Eckart et al. 2017).

4.1.3 LID Stormwater Implementation Progress and Strategies

The City of St. Catharines has 404 km of stormwater mains that convey stormwater into Lake Ontario. The City's stormwater assets include one constructed wetland, 31 Oil and Grit separators, 6,484 maintenance holes and catch basins, three stormwater ponds and 11 open channels according to the city's 2021 asset management plan. In the past, swales and ditches served as gutter and curb drainage systems to convey stormwater runoff. Yet, roadside ditches which can be classified as a LID strategy was not accounted for as stormwater infrastructure asset due to limited data in the 2021 asset management plan. Again, historical data for constructed open channels and stormwater ponds has not been accounted for. In some cases, these practices make it impossible to determine the cost-benefit implications of implementing GSI strategies.

The City of St. Catharines acknowledges stormwater management as a core service in its 2021 AMP, ranking it third among five core services. Although the City's urban design

guidelines require developers to incorporate sustainable landscaping such as bioswales, the broad use of the expression "high-quality landscaping" in newly constructed commercial infrastructure development may not be an effective means to promote the LID practices. The City of St. Catharines is not an exception when it comes to the impacts of climate change. There have been several recent flood events in St. Catharines. On the other hand, being explicit about what constitutes high-quality landscaping contradicts that concept. While the official plan of the City emphasized the need to minimize the creation of unnecessary asphalt lots as well as the necessity of promoting alternative surface water management, such as swales and ditches, sustainable stormwater management, and the opportunity for greening, it does not provide how that can be achieved. The official plan (Part D: land-use policies) further highlights LID practices as an alternative approach to conventional stormwater management. Specifically, Part D, section 7.1 g of the official plan promotes development or redevelopment that encourages LID practices that are well-suited to realistic on-site renewable water. Local government staff's willingness to embrace technology is a key to implementing GI strategies successfully, since they are influential in suggesting technology to politicians (Shandas et al. 2020).

4.2 Low Impact Development (GI) - Climate Change Adaptation/Mitigation Strategy

This section sought to ascertain the extent to which LID or GI addresses climate change challenges.

With 70% of respondents to a climate change survey in the City of St. Catharines indicating they have experienced community flooding according to the 2021 Climate Adaptation Plan, only 19% believe the City is adaptively prepared for climate change. Further, the AMP projections of associated risk to climate change signals increased runoff events that

will exaggerate stormwater pollution which has a direct effect on water quality during spring seasons. An increase in precipitation event has been identified as a leading climate impact that will have considerable implications on water bodies and existing stormwater infrastructure (CAP, 2021). In particular, stormwater pollution will increase with increasing runoff and water quality will be adversely affected, as mentioned in the 2021 CAP. Taking note of the LID implementation drivers in Ontario (see Figure 2), it is clear that source water protection is one of the main drivers for municipalities to up-scale green infrastructure strategies to mitigate flood pollution. Detailed clauses in the City's zoning ordinance prevent the alteration of development sites that could affect water quantity and quality. Cross-jurisdictional regulations (Niagara Region and Niagara Peninsula Conservation Authority) need to be followed depending on site-specific environmental conditions. All developments beyond the City boundaries are required to adhere to LID principles.

Overall, the climate change adaptation plan was sensitive to the handling of precipitation specifically rainwater as a “valuable resource” with LID considerations. Climate change was explicitly presented as a reason to adopt stormwater strategies that mimic natural hydrologic patterns to control rainwater at source, as opposed to the conventional method of conveying water overflow to an "end-pipe" system.

The AMP pointed to gray development practices being a challenge to ground water infiltration and recharge. Therefore, stormwater management attention on climate change emphasized the need to reduce peak runoff by implementing "Low Impact Development and Green Infrastructure" policies. The City recognizes the benefits of implementing GI/LID and the need to scale-up both nature-based and human-made stormwater drainage infrastructure to handle increased rainfall. Again, the AMP highlighted several concerns with the City’s infrastructure being impacted by climate change. For instance, the transportation-

climate change considerations in the AMP indicated existing roads are prone to climate change, resulting in severe flooding and severe damage to stormwater conveyance systems. It is pertinent to note that most stormwater systems were designed with the goal of managing historical storm events as well as flood situations. These events could affect the capacity of bridges and culverts to handle projected precipitation levels. The AMP encourages asset refurbishment to enhance performance to handle increased flood flow capacity in the future, however, it reserves a view on whether the approach or strategy should be centered around LID. The City acknowledges that the current stormwater systems are likely to be overloaded by frequent storm events and severe storms caused by wet weather conditions, resulting in excessive runoff and flooding, as well as erosion. However, according to O'Neill & Cairns (2016), implementing green infrastructure will not only result in more cost savings in avoided capital costs for gray infrastructure, it will also improve air quality, address climate change and minimize greenhouse gas emissions.

4.3 LID Best Management Practices

This section focused on identifying LID best management practices currently being used, along with existing regulatory requirements.

Best management practices are stormwater management practices that are used in different LID stages which includes source water control, lot-level, conveyance system and end-of-pipe facilities practices. Specific examples of stormwater BMPs include permeable pavement, bioswales, green roofs, bio-retention among others (Ishaq et al., 2019). The 2021 Climate Adaption Plan highlighted some LID initiatives, including stormwater management practices such as permeable pavement. It is the City's policy (2021 CAP) to incorporate these practices into its projects because they are corporate initiatives, and thus are included in its infrastructure projects but not a requirement for permit approval for developers and

residents. Specific examples of BMPs which were identified in the CAP include permeable pavement which is located at the City's maintenance facility located at Lake Street Service Center. Again, the City is focused on energy efficiency to meet the Leadership in Energy and Environmental Design (LEED) rating.

Study findings suggest that several programs, activities, and public-private partnerships are designed to provide incentives, public awareness, and other initiatives to encourage residents to adopt stormwater BMPs as an alternative to conventional methods. According to an EPA study (EPA, 2010), combining regulatory and non-regulatory strategies, such as outreach and incentive programs, is more effective than land-use regulations alone in promoting GI. In the CAP, it was determined that programs and initiatives need to be developed that promote awareness of stormwater BMPs and flood prevention.

It should be noted that the City has been promoting rain barrel sales to residents as an ongoing initiative to minimize basement flooding as part of its annual tree giveaway program. In addition, the urban agriculture section of the official plan emphasized a proposal to develop incentive programs to promote roof top gardens backed by by-laws for individuals and developers.

Conway et al. (2020) noted that the absence of GI awareness served as a key barrier to implementation of stormwater BMPs. Further, the 2020 community improvement plan highlights the Tax Increment Finance Program (TIF) and Brownfield Tax Increment Finance (BTIF) programs that provide financial incentives to individuals and developers based on a criterion. A minimum of 50 out of 100 points-based scoring that includes sustainability initiatives, climate change and public realm consideration as an 'added value' practice incorporated into the development. The value-added requirement for LID (sustainability) which has a point rating of 7 has two areas of valuation components that include sustainable

site design (innovative green technologies/stormwater management, green roofs, permeable pavement, etc.) and streetscape contribution (enhanced landscaping/greening, etc.). Some specific examples of stormwater BMPs were present in the design principle documents which are categorized into residential and commercial developments guidelines. The design principles document has a set objective which includes “integration of high-quality landscaping and environmentally sustainable design”.

According to guideline number 13 of the 2009 design principles document, green roofs and rainwater harvesting are to be incorporated whenever they are practical. Although this guideline encourages the use of these BMPs, its recommendation is likely to promote de-prioritization of these stormwater management practices. This is because it will be deemed by developers as an optional rather than a requirement. Since this guideline is flexible, it allows developers to deprioritize GI initiatives as a regulatory requirement since they are not mandatory (Callaway et al. 2019). In the site and landscaping part of the document, the term 'considerable' quantity of permeable materials is used, which includes crushed stones, turf, shrubs, etc., however, the guideline does not specify whether these materials are to be used as engineered or as decorative landscape elements.

Overall, the city is focused on energy saving measures and urban tree canopy growth programs than green stormwater management best practices. For example, the City of St. Catharines prefers to consider and promote LEED certification for all major developments by accessing local and regional municipal incentive programs. However, there is no guideline that highlights the environmental design process of the LEED requirement that aligns with the City’s specific requirement towards stormwater management. The use of native plants, bioswales, and pervious pavement are some examples of high-quality landscaping often used to promote LID as environmentally sustainable landscaping. Contrary to low impact

alternatives, the City intends to convert granulated trails into gray surfaces. This evidence again raises questions about the context in which green infrastructure considerations are prioritized as a stormwater management strategy (see Table 1) for identified best practices and frequency of occurrence in the analyzed documents. Table 3 was generated from NVivo using matrix queries to determine frequency and intersections between a list of items. The colour coding is useful for easily identifying intersections between the files (analyzed documents) and the identified BMPs. Red represents a zero or low-frequency intersection, yellow represents a medium-frequency intersection, and green indicates a high-frequency intersection.

Table 3: Identified best management practices in the reviewed documents

BMPs	A : Asset-Management-Plan-2021	B : Climate-Adaption-Plan	C : Commercial • General Commercial City of St. Catharines July 2009 Urban Design Guidelines 1 Commercial Corridor	D : Official-Plan-Garden-City-Plan	E : Residential • Single • Small Lot Infill Suburban Neighborhood	F : Residential • Townhouses on Private Street	G : Site-Plan-Control-By-law-2017-63	H : TIF-BTIF-GUIDELINES (CIP)
1 : Blue Roofs	0	1	0	0	0	0	0	0
2 : Ditches	5	1	0	1	0	0	0	0
3 : Downspouts	2	0	0	0	0	0	0	0
4 : Greening	0	0	0	18	0	0	0	2
5 : Infiltration	7	0	0	2	0	0	0	0
6 : Permeable Pavement	0	1	0	2	0	0	0	2
7 : Rain Barrels	0	2	0	0	0	0	0	0
8 : Rain Gardens	0	1	0	0	0	0	0	0
9 : Stormwater Ponds	6	0	0	0	0	0	0	0
10 : Swales	1	0	0	1	0	0	0	0
11 : Trees	0	12	5	14	1	4	0	0

A	Asset management plan -2021
B	Climate adaption plan - 2021
C	Commercial-General Commercial corridor urban design guidelines - 2009
D	Official plan (Garden City plan) - 2013
E	Residential - Single - Small lot infill suburban neighborhood design guideline - 2009
F	Residential -Townhouses on private street design guideline - 2009
G	Site plan control-by-law-2017-63
H	TIF—BTIF program guideline (Community improvement plan) -2020

5.0 Discussion

The overall goal of this study was to identify how green infrastructure as a term is defined and incorporated into policies and plans by the City of St. Catharines as a medium-sized municipality. The diverging and multidimensional meaning ascribed to green infrastructure can be traced in the findings revealed in this case study. Despite the differences in LID regulations across Canadian provinces (Ishaq et al. 2019), the results support the conclusion that LID is incorporated into stormwater regulation to varying degrees.

Several studies, however, argue that the variation in the meaning of green infrastructure as a concept presents advantage and disadvantage in its adoption and implementation (Mell et al. 2017; Szulczewska et al. 2017). The advantage presents flexibility of localizing the concept to suit a regional or spatial need while the disadvantage presents complication in the adoption and incorporation of green infrastructure into policies and plan when lack of expertise and political will is at interplay (Ishaq et al. 2019; Mell et al. 2017; Szulczewska et al. 2017). However, a focus on co-benefits and a strict definition of green stormwater infrastructure would more effectively manage "infrastructure politics and practice" as reiterated by Finewood et al. (2019). Further, Young et al. (2014) also confirmed in their study that the lack of harmony in comprehensive GI typology accounts for the reason why it is not widely adopted into policies and practice.

In the analyzed official plan and policies, the concept of GI/LID is implicitly defined and adopted to a discretionary degree. There appears to be an effort toward the adoption and implementation of the concept. Although, green infrastructure is not universally applicable due to the distinctiveness of environmental, local, or municipal governance processes and financial feasibility. Coherence in meaning across all official documents can only be achieved

by specifying what GI/LID means. By doing so, all factors and interdependencies between these underlying problems will be better understood to promote the effective adoption and implementation of green infrastructure stormwater management practices (Liberalesso et al. 2020). Moreover, analysis of the selected document found that there was no separate document or section dedicated to GI/LID. This is because the documents (where n = 8) in which GI/LID is mentioned differ greatly in both their focus and meaning. Even though the 2021 Climate Adaptation Plan attempt to define and outline some LID practices specifically, it did not provide enough detail. The analysis identified alternative terms which are commonly used interchangeably.

The concept of GI/LID is often associated with urban tree planting, which is often viewed to improve landscaping at developmental and re-development sites. In the 2009 Building Guideline document, the use of permeable materials is promoted for the development of commercial corridors (general commercial growth), residential neighbourhoods (single, small-lot infill development) and residential housing (townhouses on private streets) in suburban neighbourhoods. The guidelines do not, however, mandate the use of permeable materials. It should be noted that in some instances, LID BMPs (swales and ditches) are implemented as a strategy for managing stormwater, but performance and "infrastructure" records of these systems are not kept, unlike the conventional method of managing stormwater. This can be attributed to the level of importance attached to green infrastructure implementation.

6.0 Limitations

The content of the analyzed official policies and plans indicates that the policy is frequently monitored and updated every five years this makes the findings of this document valid for the period this document was analyzed. It is also relevant to note, that any GI implementation and its inclusion in documents or not directly available on the City's website outside of the sample (n=8) could limit the broader overview of this case study findings. That said, strategic plans are recently found to be used by municipal planning authorities to complement official planning guides partly due to the rigidity involved in getting official plans and related document updated to incorporate novel approaches (Mell et al. 2017).

The Climate Change Adaptation and Assets Management plans emphasize that both documents are "living documents", which implies that due to the evolving nature of climate change all policies and plans are subject to continuous improvement and as such the details are not exclusive.

COVID-19 may have impacted the progress and implementation of the AMP and other related policies and guidelines. Given that the CAP has openly defined what GI is and highlighted on stormwater as the primary focus, a transition from gray to green infrastructure can be expected in the coming years.

7.0 Conclusions

A deductive content analysis was conducted to identify LID conceptualization as a stormwater management strategy and how it is included in the policies and development plans of the City of St. Catharines. While other researchers have focused on green infrastructure from social, economic, and ecological principles standpoints (Mell, 2014; Shandas et al. 2020; Young et al.

2014), this study aimed to identify how GI as a concept is defined and incorporated into policies and plan at a municipal level. Currently, strategies and practices for stormwater management do not explicitly incorporate GI/LID. While the climate change adaptation plan and asset management plan were both released around the same time (2021), there is no declaration about green stormwater practices being incorporated into future development regulations. The City, however, acknowledges a consideration is needed to rethink how core assets are managed based on projected climatic conditions.

It can be concluded that the state of GI/LID is a 'work-in-progress' given that there is no specific definition of the concept, nor is there any clear guidance on implementation of the concept. GI/LID is thus discretionary used in most of the assessed documents. Integration of GI/LID into official policy is broad in denotation in the assessed document, although LID is considered as effective alternative to conventional stormwater practices. This study therefore concludes that GI/LID is broadly conceptualize which makes the wording in the evaluated document to be more of an advocacy than a pre-requisite for permit approval for both development and re-development project regulation. Opportunity for high-quality landscaping was one of the frequent terms that was mostly used in the reviewed documents. The term "greening" (see Appendix 3) was often used to mean "high-quality landscaping", that was interpreted as a sustainable practice in both the official document and the building guideline documents. However, the wording in the official documents leaves room for interpretation to a degree. For example, the 2017 Site Plan Control By-Law uses clauses like "including without limitation" while listing what constitutes "sustainable design elements". Despite the existence of GI/LID provisions in some policies and plans, the relative wording of the provisions is inadequate to encourage developers and residents to adhere to and incorporate such practices (Hislop et al. 2019).

8.0 Recommendations for Future Research

The study will be further strengthened by engaging stakeholders and city planning managers responsible or in charge of various developmental planning activities to provide a detailed response beyond the policy document available on the organizational website.

The City must define GI and emphasize the types of BMPs that are encouraged in both green and brownfield developments just as the provincial document defined what constitutes GSM. Consolidation of GI/LID in a single document or policy would be helpful to provide explicit declaration of what LID is and to promote regulatory guide for effective implementation.

9.0 References

Ahmad, N., Zhu, Y., Ibrahim, M., Waqas, M., & Waheed, A. (2018). Development of a Standard Brownfield Definition, Guidelines, and Evaluation Index System for Brownfield Redevelopment in Developing Countries: The Case of Pakistan. *Sustainability (Basel, Switzerland)*, *10*(12), 4347. https://doi.org/10.3390/su10124347

Auld, G. W., Diker, A., Bock, M. A., Boushey, C. J., Bruhn, C. M., Cluskey, M., Edlefsen, M., Goldberg, D. L., Misner, S. L., Olson, B. H., Reicks, M., Wang, C., & Zaghloul, S. (2007). Development of a Decision Tree to Determine Appropriateness of NVivo in Analyzing Qualitative Data Sets. *Journal of Nutrition Education and Behavior*, *39*(1), 37–47. https://doi.org/10.1016/j.jneb.2006.09.006

Baptiste, A. K., Foley, C., & Smardon, R. (2015). Understanding urban neighborhood differences in willingness to implement green infrastructure measures: A case study

of Syracuse, NY. *Landscape and Urban Planning*, *136*, 1–12. https://doi.org/10.1016/j.landurbplan.2014.11.012

Callway, R., Dixon, T., & Nikolic, D. (2019). Embedding green infrastructure evaluation in neighbourhood masterplans – does BREEAM communities change anything? *Journal of Environmental Planning and Management*, *62*(14), 2478–2505. https://doi.org/10.1080/09640568.2018.1563371

Conway, T. M., Khan, A., & Esak, N. (2020). An analysis of green infrastructure in municipal policy: Divergent meaning and terminology in the Greater Toronto Area. *Land Use Policy*, *99*, 104864. https://doi.org/10.1016/j.landusepol.2020.104864

Copeland, C. (2016). *Green Infrastructure and issues in managing urban stormwater*. Congressional Research Service Washington, DC, USA.

Credit Valley Conservation. (2015). *Advancing Low Impact Development as a Smart Solution for Stormwater Management. 2015* (Version 3). CVC. https://cvc.ca/wp-content/uploads//2021/07/CVC_report_Final_Reduced.pdf

Credit Valley Conservation. (2021). *Making Green Infrastructure Mainstream: Improving the Business Case For Green Stormwater Infrastructure* (p. 191). https://sustainabletechnologies.ca/app/uploads/2021/06/CVC_Making_Green_Infrastructure_Mainstream_English_May_2021_Final.pdf

Eckart, K., McPhee, Z., & Bolisetti, T. (2017). Performance and implementation of low impact development – A review. *The Science of the Total Environment*, *607–608*, 413–432. https://doi.org/10.1016/j.scitotenv.2017.06.254

Eckart, K., McPhee, Z., & Bolisetti, T. (2017b). Performance and implementation of low impact development – A review. *Science of The Total Environment*, *607–608*, 413–432. https://doi.org/10.1016/j.scitotenv.2017.06.254

Environment and Climate Change Canada. (2021, February 12). *A healthy environment and a healthy economy: Canada's strengthened climate plan to create jobs and support people, communities and the planet*. https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy.html

Finewood, M. H., Matsler, A. M., & Zivkovich, J. (2019). Green infrastructure and the hidden politics of urban stormwater governance in a postindustrial city. *Annals of the American Association of Geographers*, *109*(3), 909–925.

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.-L., Mikkelsen, P. S., Rivard, G., Uhl, M., Dagenais, D., & Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water Journal*, *12*(7), 525–542. https://doi.org/10.1080/1573062X.2014.916314

Grabowski, Z. J., McPhearson, T., Matsler, A. M., Groffman, P., & Pickett, S. T. (2022). What is green infrastructure? A study of definitions in US city planning. *Frontiers in Ecology and the Environment*, *20*(3), 152–160. https://doi.org/10.1002/fee.2445

Hall, A. (2010). Green infrastructure case studies: Municipal policies for managing stormwater with Green Infrastructure. *EPA Office of Wetlands, Oceans and Watersheds*, *2*.

Henstra, D. (2017). *Climate Change, Floods, and Municipal Risk Sharing in Canada*. Institute on Municipal Finance and Governance, Munk School of Global Affairs.

Henstra, D., Thistlethwaite, J., & Vanhooren, S. (2020). The governance of climate change adaptation: Stormwater management policy and practice. *Journal of Environmental*

Planning and Management, *63*(6), 1077–1096. https://doi.org/10.1080/09640568.2019.1634015

Hislop, M., Scott, A. J., & Corbett, A. (2019). What Does Good Green Infrastructure Planning Policy Look Like? Developing and Testing a Policy Assessment Tool Within Central Scotland UK. *Planning Theory & Practice*, *20*(5), 633–655. https://doi.org/10.1080/14649357.2019.1678667

Integrating Green Infrastructure into Greenfield Residential Development. (2020, February 26). *Sustainable Technologies Evaluation Program (STEP)*. https://sustainabletechnologies.ca/integrating-green-infrastructure-into-greenfield-residential-development/

IPCC_AR6_WGI_SPM_final.pdf. (n.d.). Retrieved March 23, 2022, from https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

Ishaq, S., Hewage, K., Farooq, S., & Sadiq, R. (2019). State of provincial regulations and guidelines to promote low impact development (LID) alternatives across Canada: Content analysis and comparative assessment. *Journal of Environmental Management*, *235*, 389–402. https://doi.org/10.1016/j.jenvman.2019.01.074

Jiang, Y., Yuan, Y., & Piza, H. (2015). A Review of Applicability and Effectiveness of Low Impact Development/Green Infrastructure Practices in Arid/Semi-Arid United States. *Environments (Basel, Switzerland)*, *2*(4), 221–249. https://doi.org/10.3390/environments2020221

Kim, H. W., & Li, M.-H. (2016). Sustainable Stormwater Management: Examining the Role of Local Planning Capacity in Mitigating Peak Surface Runoff. *Sustainability*, *8*(9). https://doi.org/10.3390/su8090763

Leech, N. L., & Onwuegbuzie, A. J. (2011). Beyond constant comparison qualitative data analysis: Using NVivo. *School Psychology Quarterly*, *26*(1), 70.

Li, C., Peng, C., Chiang, P.-C., Cai, Y., Wang, X., & Yang, Z. (2019). Mechanisms and applications of green infrastructure practices for stormwater control: A review. *Journal of Hydrology*, *568*, 626–637. https://doi.org/10.1016/j.jhydrol.2018.10.074

Li, L., Uyttenhove, P., & Van Eetvelde, V. (2020). Planning green infrastructure to mitigate urban surface water flooding risk – A methodology to identify priority areas applied in the city of Ghent. *Landscape and Urban Planning*, *194*, 103703. https://doi.org/10.1016/j.landurbplan.2019.103703

Liberalesso, T., Cruz, C. O., Silva, C. M., & Manso, M. (2020). Green infrastructure and public policies: An international review of green roofs and green walls incentives. *Land Use Policy*, *96*, 104693.

Matsler, A. M., Meerow, S., Mell, I. C., & Pavao-Zuckerman, M. A. (2021). A 'green' chameleon: Exploring the many disciplinary definitions, goals, and forms of "green infrastructure." *Landscape and Urban Planning*, *214*, 104145. https://doi.org/10.1016/j.landurbplan.2021.104145

Mell, I., Allin, S., Reimer, M., & Wilker, J. (2017a). Strategic green infrastructure planning in Germany and the UK: a transnational evaluation of the evolution of urban greening policy and practice. *International Planning Studies*, *22*(4), 333–349. https://doi.org/10.1080/13563475.2017.1291334

Mell, I., Allin, S., Reimer, M., & Wilker, J. (2017b). *International Planning Studies*, *22*(4), 333.

Mell, I. C. (2014). Aligning fragmented planning structures through a green infrastructure approach to urban development in the UK and USA. *Urban Forestry & Urban Greening*, *13*(4), 612–620. https://doi.org/10.1016/j.ufug.2014.07.007

Mell, I. C. (2017). Green infrastructure: Reflections on past, present and future praxis. *Landscape Research*, *42*(2), 135–145. https://doi.org/10.1080/01426397.2016.1250875

Monteiro, R., Ferreira, J. C., & Antunes, P. (2020). Green Infrastructure Planning Principles: An Integrated Literature Review. *Land*, *9*(12). https://doi.org/10.3390/land9120525

Neuendorf, K. A. (2017). *The Content Analysis Guidebook*. SAGE.

Norton, R. K. (2008). Using content analysis to evaluate local master plans and zoning codes. *Land Use Policy*, *25*(3), 432–454. https://doi.org/10.1016/j.landusepol.2007.10.006

Onan, A., Korukoğlu, S., & Bulut, H. (2016). Ensemble of keyword extraction methods and classifiers in text classification. *Expert Systems with Applications*, *57*, 232–247. https://doi.org/10.1016/j.eswa.2016.03.045

O'Neill, S. J., & Cairns, S. (2016). *New Solutions for Sustainable Stormwater Management in Canada*. Sustainable Prosperity (University of Ottawa).

Pauleit, S., Ambrose-Oji, B., Andersson, E., Anton, B., Buijs, A., Haase, D., Elands, B., Hansen, R., Kowarik, I., Kronenberg, J., Mattijssen, T., Stahl Olafsson, A., Rall, E., van der Jagt, A. P., & Konijnendijk van den Bosch, C. (2019a). Advancing urban green infrastructure in Europe: Outcomes and reflections from the GREEN SURGE project. *Urban Forestry & Urban Greening*, *40*, 4–16. https://doi.org/10.1016/j.ufug.2018.10.006

Pauleit, S., Ambrose-Oji, B., Andersson, E., Anton, B., Buijs, A., Haase, D., Elands, B., Hansen, R., Kowarik, I., Kronenberg, J., Mattijssen, T., Stahl Olafsson, A., Rall, E., van der Jagt, A. P. N., & Konijnendijk van den Bosch, C. (2019b). Advancing urban green infrastructure in Europe: Outcomes and reflections from the GREEN SURGE project.

Urban Green Infrastructure – Connecting People and Nature for Sustainable Cities, *40*, 4–16. https://doi.org/10.1016/j.ufug.2018.10.006

Philipp Mayring. (2000). Qualitative Content Analysis. *Forum, Qualitative Social Research*, *1*(2).

Provincial Policy Progress. (n.d.). *Green Infrastructure Ontario*. Retrieved January 27, 2022, from https://greeninfrastructureontario.org/policy-progress/

Provincial Policy Statement, 2020. (2020). Ontario.Ca. Retrieved March 8, 2022, from http://www.ontario.ca/page/provincial-policy-statement-2020

Shandas, V., Matsler, A. M., Caughman, L., & Harris, A. (2020). Towards the implementation of green stormwater infrastructure: Perspectives from municipal managers in the Pacific Northwest. *Journal of Environmental Planning and Management*, *63*(6), 959–980. https://doi.org/10.1080/09640568.2019.1620708

St. Catharines receives national award for CIP incentive program. (2021, November 24). Stcatharinesstandard.Com. https://www.stcatharinesstandard.ca/news/niagara-region/2021/11/24/st-catharines-receives-national-award-for-cip-incentive-program.html

Statistics Canada. (2022, February 9). *Data table, Census Profile, 2021 Census of Population—St. Catharines, City (CY) [Census subdivision], Ontario*. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E

Szulczewska, B., Giedych, R., & Maksymiuk, G. (2017). Can we face the challenge: How to implement a theoretical concept of green infrastructure into planning practice? Warsaw case study. *Landscape Research*, *42*(2), 176–194. https://doi.org/10.1080/01426397.2016.1240764

US EPA, O. (2014, April 8). *Water Quality Scorecard* [Reports and Assessments]. https://www.epa.gov/smartgrowth/water-quality-scorecard

Wellmann, T., Lausch, A., Andersson, E., Knapp, S., Cortinovis, C., Jache, J., Scheuer, S., Kremer, P., Mascarenhas, A., Kraemer, R., Haase, A., Schug, F., & Haase, D. (2020). Remote sensing in urban planning: Contributions towards ecologically sound policies? *Landscape and Urban Planning*, *204*, 103921. https://doi.org/10.1016/j.landurbplan.2020.103921

Young, R., Zanders, J., Lieberknecht, K., & Fassman-Beck, E. (2014). A comprehensive typology for mainstreaming urban green infrastructure. *Water Governance across Competing Scales: Coupling Land and Water Management*, *519*, 2571–2583. https://doi.org/10.1016/j.jhydrol.2014.05.048

Zhang, K., & Chui, T. F. M. (2018). A comprehensive review of spatial allocation of LID-BMP-GI practices: Strategies and optimization tools. *Science of The Total Environment*, *621*, 915–929. https://doi.org/10.1016/j.scitotenv.2017.11.281

Zwierzchowska, I., Fagiewicz, K., Poniży, L., Lupa, P., & Mizgajski, A. (2019). Introducing nature-based solutions into urban policy – facts and gaps. Case study of Poznań. *Land Use Policy*, *85*, 161–175. https://doi.org/10.1016/j.landusepol.2019.03.025

10.0 Appendices

	A : Asset-Management-Plan-2021	B : Climate-Adaption-Plan	C : Commercial • General Commercial City of St. Catharines July 2009 Urban Design Guidelines 1 Commercial Corridor	D : Official-Plan-Garden-City-Plan	E : Residential • Single • Small Lot Infill Suburban Neighborhood	F : Residential • Townhouses on Private Street	G : Site-Plan-Control-By-law-2017-63	H : TIF--BTIF-GUIDELINES
1 : BMPs	2	3	1	4	0	0	0	1
2 : Incentive Programs	0	1	0	5	0	0	0	1
3 : Public Awareness	0	0	0	1	0	0	0	1
4 : Public-Private Partnershish (PPP)	0	1	0	1	0	0	0	0
5 : Broad Sustainability	1	0	0	13	1	0	0	0
6 : Provincial Regulation	1	0	0	1	0	0	0	0
7 : Climate Change.	0	2	0	0	0	0	0	0
8 : Climate Change Linkages	10	9	0	1	0	0	0	1
9 : Run-Off Prevention	4	5	0	3	0	0	0	0
10 : Water Quality-Quantity Improvem...	1	2	0	5	0	0	0	0
11 : Green Infrastructure (GI)	1	3	0	3	1	0	0	0
12 : Definition-Declaration of GI	1	2	0	9	0	0	0	0
13 : GI - Goals	6	6	1	9	0	0	0	0
14 : LID	1	3	2	11	1	1	0	0
15 : Brownfield Development	0	0	0	0	0	0	0	0
16 : Master Plan - Integration	0	2	0	4	0	0	0	0
17 : Documented- Policy-By-Laws	0	0	0	5	0	1	2	0
18 : Joint Management	1	0	0	2	0	0	0	0
19 : Regulatory-Governance	1	0	0	4	0	0	0	0
20 : Stormwater	7	3	0	6	0	0	0	0

Appendix 1:Coding keyword intersection matrix

Coding Principles			
Categories	Definition/Description	Sub-categories/Nodes	Focus
Master Plan Integration	Evidence of green infrastructure (green stormwater management-(GSM) integration in official master plan and related document.	1. Regulatory/Governance 2. Policy availability 3. By-law	1. Regulatory evidence of GSM in policies and development plans. 2. Identify any specific policy guidelines or statements incorporated in the sampled official plan and policies related to GI/LID. 3. Find a code or bylaw intended to serve as a shared policy or governance mechanism among related organizations and the City of St. Catharines specific to GI/LID.
Green Infrastructure (GI/LID)	Definitions and declarative understanding of GI. (Green Stormwater control practices -EPA, 2019)	1. Definition/Declaration of GI 2. GI Goals	1. Identify how GI is expressed (phrases, definitions, context). Is GI explicitly defined in plans? Or broadly perceived. 2. Clearly outlined goals and benefits of LID and explain how it will promote its implementation as alternative over conventional stormwater practice
Climate Change	How is climate change addressed using GI (SWM) in the official plans.	1. Climate change linkages 2. Water quality/quantity improvement 3. Run-off prevention	1. Identify the ways in which climate change influences the implementation of LID and policy consideration related to LID. 2. How is this policy informed (Historical data, or GI policy update)? 3. Find evidence that promotes LID over increased impervious surface development practices to prevent flooding and stormwater runoff.
Stormwater	Statement pertaining to transition to GI and Green Stormwater managements implementation	1. New development regulations type 2. On-site LID code/by-law	1. Identify if any specific requirement exists to encourage LID stormwater management. 2. Identify if any regulations / by-laws or statement for on-site pre-construction requirement are clearly outlined.
Best Management Practices (BMPs)	Evidence of GI/LID practices in policies and plans and specific examples	1. Examples of BMPs 2. Public awareness/outreach 3. Incentive programs 4. Public-Private partnerships	1. Find examples of any stormwater management practices (e.g., Bioswales, permeable pavement, rain garden in policies and plans and how they are specified. 2. Identify policies and plans that foster public participation and education activities to promote GI/LID usage. 3. Identify incentive programs geared toward promoting GI

			implementation among developers and residents 4. Find out how policies and plans make provisions to encourage private-public ownership and management of LID infrastructure

Appendix 2:Coding guide

Appendix 3:Word cloud frequency search result