Climate Change and Water Resources: An analysis of the applicability of rain gardens in Annapolis Royal, NS

Major Research Paper DRAFT

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ABSTRACT

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List of Definitions

Baseflow: The water present in a watercourse that is sustained by groundwater seepage into the stream channel rather than direct runoff from precipitation or melting snow. Baseflow measurements are important because they may indicate the sensitivity of the stream to changes in land use or weather patterns (Kawartha Region Conservation Authority, 2008).

Best Management Practice (BMP): A practice or combination of both structural and nonstructural practices to control or prevent stormwater runoff, and thereby improve the health of the receiving waterbody (PGCDER, 1999).

Bioretention Cell (Rain Garden): Typically, a bioretention cell refers to a vegetated engineered depression often located in parking lot islands or along roads. Bioretention cells often cover a larger surface area than a rain garden and are constructed with a specialized soil mixture, aggregate, and an underdrain, to retain and enable infiltration and/or evaporation of stormwater onsite. Rain gardens are also designed to retain and enable infiltration of stormwater onsite, but that are usually not as complex as the larger bioretention facility and may often be built by the homeowner (however, rain gardens may be as complex as a bioretention cell if site constraints warrant the need) (Boston MARC, n.d.; PGCDER, 1999).

Cisterns (rainwater collection): Cisterns are large reservoirs often constructed of concrete, built above or below ground, and used to collect roof water and enable its reuse at a later time. These systems are larger and often more costly than rain barrels (Guillette, 2007).

Combined Sewer Systems: These systems carry both stormwater and sanitary wastewater

Combined Sewer overflows (CSOs): The discharge of a combination of stormwater and sanitary wastewater into downstream waterbodies as a result of heavy precipitation events that cause the capacity of the sewer system to be exceeded (SPG Media Limited, 2007).

Detention Basin or Pond: This facility is designed to temporarily hold water and allow it to discharge slowly into the natural environment, whereas a retention basin is designed to permanently store water (Schueler, Hirschman, Novotney & Zielinski, 2007; Minnesota DNR, 2008).

Dry Wells: Small excavated pits backfilled with stone or gravel and designed to collect and control the release of rooftop runoff into the ground (PGCDER, 1999).

Evapotranspiration: The process of evaporation and transpiration of water from the soil and the leaves of plants

Filter strips: Filter strips consist of closely planted vegetation, usually grass. They may be used as a pretreatment device for other systems and are usually planted between the pollutant source and the receiving facility, such as a bioretention facility (PGCDER, 1999).

Groundwater: Water that is stored in spaces and fractures in soil and rock beneath the ground

Infiltration: The downward movement of water through the soil

Infiltration Trench: An excavated trench that is backfilled with stone and designed to store and infiltrate stormwater runoff over several days (PGCDER, 1999; Schueler, Hirschman, Novotney & Zielinski, 2007).

Integrated Management Practice (IMP): Term coined by Prince George's County, MD Department of Environmental Resources, and refers to small, onsite management practices to control stormwater runoff in attempt to maintain the predevelopment hydrology of the site (PGCDER, 1999).

Nonpoint Source Pollution: Water pollution caused by the movement of water over and through the ground that picks up and carries a variety of pollutants such as nutrients, metals, and oil

Non-structural BMP: Include institutional practices that usually work by changing behaviour through policy implementation, economic incentives, or education, to assist in reducing the amount of pollutants entering stormwater systems (Taylor & Wong, 2002).

Overflow Box or Device: This may be used in bioretention or rain garden designs, depending on soil permeability, to help control the quantity of stormwater in the bioretention area. In these cases, the overflow diverts excess water around or out of the garden and may be connected to the municipality's stormwater management system (Hunt & White, 2001; Schueler, Hirschman, Novotney & Zielinski, 2007).

Peak Flow: The maximum volume of flow during a precipitation event (Minnesota DNR, 2008).

Point Source Pollution: Pollution from a single identifiable source such as a sewage-treatment plant.

Rain barrels: Inexpensive method to collect and store rainwater from the rooftops of homes or buildings. Water in the barrels may then be used to water gardens or lawns (PGCDER, 1999).

Recharge Area: Area of land area where surface water may be infiltrated and reach the groundwater table, recharging the aquifer (Atchison, Potter, & Severson, 2006).

Swale: Linear depressions that may be grassed or planted with water tolerant vegetation, depending on the function. Dry or wet swales are typically located next to roadways and may be used for various purposes, including water transport, capture, and infiltration (PGCDER, 1999; Schueler, Hirschman, Novotney & Zielinski, 2007).

Stormwater Management Ponds (SWMPs): Facilities designed to collect and temporarily hold stormwater runoff, treat pollutants, and then slowly release the water back into the receiving waterbody. These ponds may also collect water from the sewer system (Ontario MOE, 2003).

Stormwater Runoff: Water from rain or melted snow that is not intercepted or infiltrated, rather it runs over the surface of the land

Structural BMPs: Systems built and designed to assist in slowing and purifying stormwater runoff by collecting, storing, and enabling infiltration of the stormwater (PGCDER, 1999).

Total Kjeldahl Nitrogen (TKN): Organic Nitrogen + Ammonia (Geosyntec Consultants & Wright Water Engineers, Inc, 2007)

Underdrain: A perforated pipe below the root zone of a bioretention facility that assists in draining the facility more quickly, reducing ponding. In some cases the underdrain may be connected to the municipal storm sewer system (Atchison, Potter, & Severson, 2006; Schueler, Hirschman, Novotney & Zielinski, 2007).

Water table: The upper level of which the underlying geologic material is permanently saturated with water

Watershed: A region of land that drains into a particular body of water

Chapter 1. Introduction

In the face of a changing climate, it is imperative we manage our water resources. The daunting costs faced by municipalities in the process of upgrading or replacing sanitary and sewer infrastructure should foster the exploration of more cost-effective alternatives. In addition, creating a process to educate and involve all members of a community will unquestionably be a crucial component to enable community adaptation to climate change.

Rain gardens were originally designed as a tool to educate the public about stormwater and their role in the stormwater management process (L.Coffman, personal communication, February 26, 2008). Since their inception, they have been proven to effectively manage stormwater onsite, providing infiltration and pollutant filtering, while also providing numerous benefits beyond those associated with water resources. Through the implementation of a community-wide rain garden program, a greater understanding and awareness about stormwater and the need to protect water resources for future generations may be garnered, leading to ancillary benefits and actions to improve the natural environment.

That being said, two caveats exist: (1) rain gardens are not a panacea for all the problems associated with the degradation of water resources or failing storm and sewer infrastructure, and (2) they are not suitable under certain site conditions.

1.2 Problem Statement

Research regarding the benefits of using integrated management practices (IMPs) to retain stormwater onsite while removing impurities is emerging, however, evidence of the use of such systems is limited (Freni & Oliveri, 2005). Uncertainty surrounding the effectiveness of these approaches, as well as land use planning regulations prohibiting their use, may be preventing the installation of IMPs by developers and homeowners (Freni & Oliveri, 2005). Reliable information outlining the costs, benefits, existing opportunities, and constraints of alternative stormwater management practices may increase the utilization of these techniques.

The Town of Annapolis Royal, located within the Annapolis River watershed in Nova Scotia, is currently in the process of implementing a stormwater diversion system to improve the efficiency of its sewage treatment plant. The CAO of Annapolis Royal and the Executive Director of the Clean Annapolis River Project (CARP) have expressed an interest in investigating the use of alternative stormwater management practices to deal with the diverted stormwater, which often contains chemicals from roadways, homes, and other impervious areas. Specifically they are interested in the use of rain gardens, a bioretention IMP, to retain stormwater onsite and reduce the amount of nonpoint source pollutants being discharged into the Annapolis River.

1.3 Research Goal

This research aims to contribute to the understanding of the feasibility of rain gardens as a stormwater management tool for protecting surface and groundwater quality and quantity. To more accurately assess the effectiveness of rain gardens and other integrated management practices, a continuous analysis of these systems over the long-term is required. However, it is hoped that through an examination of the lessons learned in other case study municipalities that have installed rain gardens, the basis for a conceptual stormwater management plan for the Town of Annapolis Royal may be developed.

1.4 Research Objectives

Four objectives have been identified for this research:

1.4.1 What are the strengths and weaknesses of using rain gardens to manage stormwater in the case study locations?

1.4.2 How easily may the lessons learned from the case study locations be transferred to the Town of Annapolis Royal?

1.4.3 How does the planning process in Annapolis Royal assist or impede the implementation of stormwater management strategies; specifically, are changes needed in municipal bylaws and/or design standards for municipal infrastructure and streetscapes?

1.4.4 How may the implementation of rain gardens in the Town of Annapolis Royal assist with climate change adaptation procedures?

1.5 Organization of the Paper

This paper is divided into five chapters: Chapter 2 reviews the literature on stormwater management and alternative stormwater management techniques; Chapter 3 describes the methods undertaken in this research. Chapter 4 presents the results and a discussion of the research; and Chapter 5 summarizes and draws conclusions of the research, discusses the limitations, and provides suggestions for further research.

Chapter 2. Literature Review

2.1 Introduction

The hydrologic cycle describes the continual cycling of water through the hydrosphere by way of five key processes: precipitation, interception, evaporation, infiltration, and runoff. Human settlement and the conversion of the natural landscape into impermeable surfaces have drastically altered the hydrologic cycle, in addition to advancing climatic changes (Hutjes, Kabat, Running, Shuttleworth, Field, Bass, et al., 1998).

The United States Environmental Protection Agency (1998) recognizes stormwater runoff as the second most prevalent cause of water quality degradation next to industrial discharges (Schiff, Bay, & Stransky, 2002). Marsalek & Schroeter's study (as cited in Environment Canada, 2001, p.47) found annual urban runoff discharges in the Canadian Great Lakes Region to be in the magnitude of "10^5 tonnes of suspended solids, 10^4 tonnes of chloride, 10^3 tonnes of oil and grease, and 10^2 to 10^3 tonnes of trace metals." Evidently stormwater carries numerous contaminants located on the surfaces over which it runs, adversely impacting downstream aquatic ecosystem through a combination of physical, chemical, and microbiological factors, that include increased volume and rate of runoff, increased temperature of runoff, and increased levels of metals, nutrients, bacteria, and viruses (Environment Canada, 2001).

Currently, three quarters of Canadians live in urban areas and long-term projections suggest this number could increase, increasing the amount of impervious surfaces (Statistics Canada, 2007b). Schueler & Holland (2000) suggest that as little as 10% imperviousness in a watershed creates stormwater runoff quality and quantity concerns leading to the degradation of aquatic ecosystems. Additional impacts of increased imperviousness include a reduction in the ability for infiltration of precipitation, thereby decreasing the amount of groundwater recharge and stream baseflow (Schiff et al., 2002; Atchison, Potter, & Severson, 2006). With such a limited supply of freshwater and an increasing human population placing increasing demand on water resources, feasible solutions to combat water quality degradation need to be explored.

2.2 Climate Change Mitigation and Adaptation

Climate change is a global challenge that requires a global response. However, individuals and communities have a very important role to play in the reduction of greenhouse gas emissions and their cumulative efforts may assist in the global reduction of greenhouse gases. It is at the community level where mitigation and adaptation strategies to predicted climate change impacts must evolve, especially when considering such a large, ecologically and socio-economically diverse country as Canada.

Mitigation may be defined as an identification and reduction of the causes of increased greenhouse gas emissions and thus, climate change (Terrain Group, 2007). Adaptation, on the other hand, involves the adjustments in policies and practices to lessen or prevent the impacts of climate change, as well as the investigation of opportunities that arise as a result of climate change (European Environmental Agency (EEA), 2006; NRCan, 2008). These adjustments may involve proactive planning procedures to assist in reducing the impacts of climate change before they occur, or reactive measures instigated following an impact (NRCan, 2008). In most cases, it will be more cost-effective to introduce adaptation strategies before impacts are experienced because predicted impacts, such as increased flooding, drought, and negative impacts on receiving water bodies, could result in a loss of essential infrastructure causing significant financial and human loss (EEA, 2006; NRCan, 2008).

2.3 Climate Change and Water Resources

Referred to as “liquid gold” or “blue gold,” water resources are frequently cited as the most vulnerable resources to climatic changes, especially as an expanding human population places increasing pressures on freshwater sources, disrupting flow patterns and severely degrading water quality (WCMC, 1998; USGS, 2006). Of the total volume of water on earth, freshwater only comprises approximately 3% of the world’s resources or approximately 45,000,000km^3 (WCMC, 1998). Of this, approximately 68% is held in ice caps, glaciers, and permanent snow, 30% is found in groundwater, and less than 0.3% of water is found in lakes and rivers (WCMC, 1998; USGS, 2006).

Although Canada has a relative abundance of water, possessing 9% of the world’s freshwater and only 0.5% of the global population, water is not evenly distributed across the country and variation among regions with respect to the occurrence of water-related problems, such as droughts, floods, and issues with water quality, exists (Infrastructure Canada, 2006). The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report projected global increases in surface air temperature of 1.4 – 5.8°C by 2100 (Watson, Albritton, Barker, Bashmakov, Canziani, Christ et al., 2001). Increases in temperature of this magnitude would greatly influence the hydrologic cycle, negatively impacting water supplies that are critical for domestic use, food and energy production, and transportation (Infrastructure Canada, 2006). Additionally, an increase in the frequency of extreme weather events would put pressure on Canada’s infrastructure, increasing the risk of flooding, sewer overflows, water quality problems, and declining water levels across the country (Infrastructure Canada, 2006).

2.4 Climate Change and Infrastructure

A December 2006 report by Infrastructure Canada entitled, *Adapting Infrastructure to Climate Change in Canada's Cities and Communities*, noted that a large percentage of municipal infrastructure in Canada was in need of maintenance or replacement. It was suggested in this report that under such circumstances, opportunities exist to integrate climate change adaptation mechanisms in the design of the upgraded infrastructure (Infrastructure Canada, 2006). However, adaptation measures for infrastructure may be controversial, not only because of the uncertainties associated with climate change and long-term performance of stormwater management facilities, but because of the significant costs to upgrade or install new infrastructure (Environment Canada, 2001; Infrastructure Canada, 2006). Environment Canada (2001), states that some improvement in downstream water quality has been achieved through the use of improved stormwater management practices in new urban developments, but that very little progress has been made in older neighbourhoods requiring retrofits.

Typically, recommendations to address predicted climate change impacts with respect to the water resources sector involve structural adaptations, such as dams, weirs, and drainage canals, which incur economic, social, and environmental costs (NRCan, 2004). Evidence of a decrease in the environmental integrity of aquatic ecosystems worldwide, largely as a result of conventional water resources management practices involving an elaborate network of drainage pipes, sewers, and retention basins, gives credence to the need not only for more proactive land use planning, but the adoption of more creative strategies to deal with water resources, specifically stormwater (Moss, 2000; France, 2002). The potential exists to reduce the degradation of freshwater resources while also assisting in the recharge of groundwater resources. Establishing successful adoption of infrastructure and ultimately, climate change adaptation strategies, to reduce the vulnerability of water resources will require the cooperation of numerous stakeholders, including among others, planners, policymakers, scientists, community members, and industry.

Typically, stormwater infrastructure in communities ranging from small towns to major urban centres, has been designed to withstand major rainfall events that occur only once in every 100 years (Waters, Watt, Marsalek & Anderson, 2003). In actuality, small storms, because of their frequency, create the largest contribution to the volume of total annual runoff and cause the greatest impacts on receiving bodies of water (Prince George's County Department of Environmental Resources (PGCDER), 1999b). Moreover, "first flush" pollutants, those that are contained in the initial few centimetres of runoff, contain the highest concentration of pollutants and as the duration of the rainfall event increases, pollutant levels generally decrease (U.S. Department of Housing and Urban Development, 2003).

2.5 History of Stormwater Management in North America

Up until the late 1960s, urban areas were serviced by an elaborate network of drainage pipes and sewers to rapidly remove stormwater from municipal streets and dispose of it downstream in receiving waterbodies (Field, Heaney, & Pitt, 2000; Watt, Waters, & McLean, 2003). This system was developed to protect human and environmental health from impacts such as flooding (Moss, 2000; France, 2002). However, as more and more of the watershed became urbanized, it became increasingly costly to install or expand the large collector sewers (Field et al., 2000; Watt et al., 2003). In addition, some municipalities were beginning to notice the impacts of uncontrolled urban drainage on the receiving waterbodies (Field et al., 2000).

In the United States during the 1970s and 1980s, the acknowledgement of the impact of stormwater runoff volume on streams became widespread, leading to an increase in the stringency of stormwater management regulations through the adoption of the U.S Water Pollution Control Act (Watt et al., 2003; Methods, Durrans, Ahmad, Barnard, Hjorth, & Pitt, 2003). To treat the increased volume and flow rates of stormwater runoff, stormwater ponds were often constructed (Watt et al., 2003). However, the ponds did not address water quality issues and it was not until the early 1990s that a more comprehensive approach to stormwater management that considered both the quality and quantity of stormwater runoff was initiated (Field et al., 2000; Watt et al., 2003). To assist in improving downstream water quality, many municipalities in Canada and the United States have adopted stormwater best management practices (BMPs) to reduce the negative impacts on the aquatic system as a result of stormwater runoff.

2.6 Stormwater Best Management Practices

Stormwater Best Management Practices (BMPs) evolved to compensate for the adverse impacts associated with development (Gibb, Kelly, Horner, Schueler, Simmler & Knutson, 1999). Generally, best management practices can be divided into two categories, structural and non-structural. However, confusion surrounding the terminology exists in the literature as some authors choose to divide BMPs into more than two categories and others associate all ‘green’ technologies with non-structural techniques (Claytor, n.d; Taylor & Wong, 2002). In addition, the associated practices may be given different names depending on the location of use, for example, infiltration basin and retention pond are two of the terms used interchangeably to refer to the same structure (Claytor, n.d). For the purpose of this report, structural best management practices refer to those physical devices or practices that are used to control and treat stormwater runoff, while non-structural BMPs include a range of institutional and pollution prevention practices, such as educational programs and regulatory controls (Claytor, n.d; Taylor. & Wong, 2002).

2.7 Low Impact Development (LID)

The state of Maryland was one of the first states in the United States to require the control of smaller runoff events and improvements in the quality of runoff (Field et al., 2000). In response, the Low Impact Development (LID) approach to stormwater management was introduced in the early 1990s by the Department of Environmental Resources in Prince George's County, Maryland (PGCDER, 1999). This approach included an expanded suite of best management practices to improve the natural environment while reducing infrastructure costs (PGCDER, 1999a).

This iterative and adaptive approach to land development also involves both structural and non-structural techniques (U.S. Department of Housing and Urban Development, 2003). The uniqueness of this approach is its goal to retain water onsite through small-scale, integrated management practices (IMPs) to manage stormwater near the source rather than through end-of-pipe stormwater control methods (PGCDER, 1999a). These tools assist in the creation of a hydrologically-functional landscape that mimics the pre-development hydrology of the site, thereby improving the ground and surface water (PGCDER, 1999a).

A wide variety of techniques are described in the guidelines outlining the LID approach to development from which homeowners and developers may choose if the site conditions permit. Broadly, the LID techniques involve reduced imperviousness; protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, flood plains, woodlands and highly permeable soils; maintenance of natural drainage courses; a reduction in the use of pipes; minimized clearing and grading; the use of a variety of detention, retention, and runoff practices; and the implementation of effective public educational programs to encourage property owners to maintain a hydrologically-functional landscape (PGCDER, 1999a; U.S. Environmental Protection Agency, 2000). Additionally, new designs for streets, sidewalks, and lots can also help to decrease the amount of impervious surfaces and increase the volume of preserved open space in new development (U.S. Department of Housing and Urban Development, 2003). Techniques include, but are not limited to, the following:

Table 1: Comparison of hydrologic characteristics among structural and non-structural BMPs
H = High; M = Moderate; L = Low; N = None

Type of LID	Low Impact Development Practice	Interception	Infiltration	Peak Flow Control	Water Quality Improvement
Structural	Bioretention- Rain Garden	H	H	M	H
	Swale	M	M/H	M	H
	Infiltration trench	N	H	M	H
	Green roof	H		M	H
	Porous pavement		H	M	
	Rain barrel & Cistern	N	N	M	L/N
	Buffer strip	H	M	L	H
Non-structural	Regulatory controls, for example, specific water quality mandates and pesticide bylaws	The direct effectiveness of non-structural tools is not as well documented, however, advocates assure that these approaches greatly assist in water quality improvement, interception, infiltration, and peak flow control by increasing awareness of the potential problems associated with stormwater runoff, promoting certain types of behaviour to assist in improving stormwater quality, and in recommending approaches to solve problems associated with stormwater runoff.			
	Planning and design changes that promote LID in new and redevelopment areas, for example, landscaping programs that retain vegetation				
	Education & training programs				
	Pollution prevention procedures, for example, street sweeping				
	Maintenance of structural facilities, including removal of debris, sediment, and other contaminants, control of vegetation, and corrective maintenance as required				
Source: PGCDER, 1999; Field et al., 2000; Taylor & Wong, 2002; Baker et al., 2007; Taylor & Fletcher, 2007					

The remainder of this paper will focus on an in-depth exploration of an integrated management practice known as a rain garden.

2.8 Rain Gardens

Bioretention is one of the most recognized and utilized alternative stormwater management practices (U.S. Department of Housing and Urban Development, 2003). This concept has been incorporated into basic, small-scale practices available for individual lots, know as rain gardens, which may be defined as shallow depressions in the ground designed for temporary storage of stormwater to retain, treat, and enable infiltration and evaporation (U.S. Department of Housing and Urban Development, 2003). Rain gardens may offer many benefits beyond those outlined in the general discussion of low impact development techniques. If site conditions permit, and once a site plan has been carefully constructed, the construction of a rain garden is fairly simple and inexpensive as compared to some of the other techniques available (GVRD, 2005). Moreover, the aesthetically pleasing rain gardens have been proven to effectively remove between 40-97% of nutrients and metals present in stormwater runoff (U.S. Environmental Protection Agency, 2000).

2.8.1 Rain Garden Design and Construction

To a certain extent, regular flower gardens provide some of the same benefits as a rain garden. Where the two differ is in the design and construction; rather than being convex in shape, rain gardens are dug below-grade with the depth of depressions usually ranging between 6-12 inches to accumulate stormwater runoff (Hunt & White, 2001; The Native Plant Society of New Jersey (NPSNJ), 2005). In some cases, especially in locations where severe precipitation events are more common, overflow drains may be installed and linked to the municipal stormwater system to handle the large flows that cannot be absorbed by the garden (GVRD, 2005; NPSNJ, 2005). As well, in larger facilities or those where the depth to the high water table is less than 2 feet below the base of the garden or the rate of infiltration is less than 0.52 inches/hour, underdrains may be installed below the soil's surface to reduce ponding in the garden (Clar, Davis, Hunt & Traver, n.d.; Prince George's County, n.d; Davis, 2005). Water may be directed to the rain garden through cuts in the curb, roof leaders, gutter drainage spouts, or through a system of swales (Hunt & White, 2001). (*Please refer to rain garden checklist and construction details, Appendix A*).

Rain gardens remove pollutants using a combination of physical, biological, and chemical processes (Hunt & White, 2001). Mulch and soil particles aid in absorption processes while also providing habitat for microorganisms that help to degrade contaminants (Hunt & White, 2001). In addition, the use of water-tolerant vegetation is used to slow runoff, trap sediment and debris, and absorb nutrients such as nitrogen and phosphorus for growth (Hunt & White, 2001). It is extremely important to select the appropriate vegetation for the site based not only on the amount of available sunlight and soil conditions, but also the appearance of the vegetation to ensure the rain gardens function properly and are attractive so that they are embraced by neighbouring residents (Atchison et al., 2006; Rozumalski, F., personal communication, February 22, 2008).

Knowledge of the effectiveness and limitations of certain best management practices is evolving, as these practices are still very new and much has yet to be learned about their appropriateness in certain locations (Field et al., 2000). Due to its dependency on site variation, it is impossible to construct a single set of criteria for stormwater design, which further emphasizes the importance of conducting a site analysis prior to the implementation of LID (France, 2002).

It is also imperative to understand the climatic conditions of the location, especially with respect to the precipitation patterns (France, 2002). To help ensure these practices function properly, the objective of the project and the constraints of the site must be explicit because while numerous techniques do exist, the use of some practices may be inappropriate in certain locations (Field et al., 2000). The use of rain gardens is highly dependent on the slope, soils, bedrock, depth to high water table, available space, and location of above and underground infrastructure; and they are not appropriate in areas of steep /unstable slopes (ideally, not to exceed 12%); highly permeable soils where an increased risk of groundwater pollution may be present; areas of very high pollutant loads, such as certain industrial or commercial locations; and overlying contaminated sites such as in old industrial areas (France, 2002; U.S. Department of Housing and Urban Development, 2003; Ontario Ministry of the Environment, 2003). Moreover, it is unlikely that a single practice will meet all of the stormwater objectives, and thus, a series of practices should be employed to ensure optimum results (Atchison et al., 2006).

2.8.2 Conclusion

Although rain gardens may be used in almost any setting where site conditions permit, including residential, commercial, and certain industrial settings, prior to their installation it is imperative to consider the unintended environmental impacts of the practice, neighbourhood acceptance, and the cost to construct and maintain the gardens, to ensure the systems function effectively over the long-term (Atchison et al., 2006). In locations where there is limited space available or where community concern surrounding the safety of other stormwater management systems exists (for example, drowning in SWM ponds), rain gardens appear to be the optimal choice for installation (NPSNJ, 2005). However, continual research into the effectiveness and costs of these systems over the long-term, as compared to the more conventional methods to manage stormwater, will be necessary to encourage more widespread usage.

This chapter summarized the literature on the methods available to assist in adapting municipal stormwater infrastructure to reduce the negative impacts that could potentially occur if municipalities do not change their methods of land use planning in relation to stormwater management practices.

Chapter 3. Research Methods

The purpose of this research was to explore the successes and challenges of implementing rain garden projects across multiple case study locations to identify common themes that could assist in the implementation of rain garden projects in the Town of Annapolis Royal, N.S. Data was collected and analyzed in multiple phases as described in this chapter.

3.1 Data Acquisition

Data was collected through (a) a literature review; (b) case studies of communities in North America and New Zealand; and (c) interviews with key informants from North America and New Zealand (email, phone).

Two sets of literature were reviewed and analyzed, (1) academic literature and public documents; and (2) grey literature (reports, websites). Initially, an extensive Internet search was conducted to identify locations where rain gardens were being employed. Although reference in the literature was made to the use of rain gardens in Norway, Sweden, the Netherlands, Germany, Britain, and Japan, information on particular sites in these countries was difficult to obtain. Most searches provided information on communities in the United States, while information on a few locations in Canada and New Zealand was also uncovered during the Internet search. In total, eight case study locations that employed varied degrees of rain garden programs were identified and examined (*please refer to Appendix B*).

Background information on the Town of Annapolis Royal was also gathered and reviewed during the initial stages of the research. Specifically, the Town of Annapolis Royal Municipal Planning Strategy and relevant planning legislation in the Province was reviewed to assess if and how these documents impede the implementation of innovative stormwater management practices, such as LID.

3.1.1 Case Studies

Case studies are a method to obtain detailed information about a unique group, community, program or practice (Creswell, 2003). Payne & Payne (2004, p.32-33) suggest the benefits of using a case study include the small and manageable scale of the study and the usefulness of the tool in providing new ideas and ways of understanding a specific unit.

3.1.2 Key Informant Interviews

To gain a broad understanding of rain gardens and the process of implementation in the case study locations, key informants of different professions were intentionally selected for interview purposes. The key informants interviewed included: 2 planners, 3 engineers, 1 landscape architect, 3 researchers, 2 stormwater specialists, and 1 developer from private firms and public agencies. The format of the interview was semi-structured involving a core set of both closed questions to assist with data consistency, and open-ended questions to gain a better understanding of the participants' perspective of the usability of rain gardens as a stormwater management tool in varying climatic and geographical regions (*Key Informant Questionnaire, Appendix C*) (Payne & Payne, 2004).

Of the 12 interviews conducted, 10 were done by telephone and notes were taken, while two participants sent their comments by e-mail. The advantage to interviewing key informants was the rich information and insight provided by the professionals involved in rain garden research and projects (Payne & Payne, 2004).

Throughout the research process, four key informants from the Town of Annapolis Royal were contacted on numerous occasions to provide background information and fill in the research gaps.

3.2 Data Analysis

Of the 18 surveys sent to key informants involved in rain garden construction projects, 12 were returned producing a response rate of approximately 67%. The data obtained was entered into a spreadsheet to identify patterns among rain garden projects undertaken in New Zealand, the United States, and Canada. Broad categories highlighting the advantages and difficulties encountered during rain garden implementation were developed and compared to the literature to assist in the extrapolation of lessons learned (Marshall & Rossman, 2006). Following, the data was interpreted using a S.W.O.T analysis, and recommendations were made acknowledging the significance of the lessons learned with respect to the circumstances in the Town of Annapolis Royal, NS.

3.2.1 Strengths, Weaknesses, Opportunities, Threats (S.W.O.T) Analysis

A S.W.O.T. analysis highlights key issues that are both internal (strengths & weaknesses) and external (opportunities & threats) to the organization or project being investigated (Internet Center for Management and Business Administration, Inc., 2007). Results of the S.W.O.T may be displayed in a simplistic and manageable format, and used to assist with goal setting and implementation (Internet Center for Management and Business Administration, Inc., 2007).

3.3 Assumptions

- Key informants provided reliable information and did not withhold information
- Information obtained may be transferable to other locations

Chapter 4. Results & Discussion

This chapter is divided into three main sections: the first section will present the information obtained about the Town of Annapolis Royal; the second section will present the results of the key informant interviews from the multiple case study locations; and the third section will present the analysis of the strengths, weaknesses, opportunities, and threats of using rain gardens as a tool to manage stormwater in Annapolis Royal.

4.1 Study Site

The Town of Annapolis Royal covers an area of approximately 3.3km^2; with approximately 2.2km^2 above water and 1.1km^2 below (K.Saunders, personal communication, February 28, 2008). With a population of 444, the site consists of approximately 150 residential lots (zoned for light and multiple density) with 303 private dwellings; approximately 70 commercial, institutional, and industrial lots along the highway and waterfront; and 15 streets, creating an impervious area of approximately 17.4% of the land cover within the Town's boundaries (Statistics Canada, 2008; K.Saunders, personal communication, February 28, 2008).

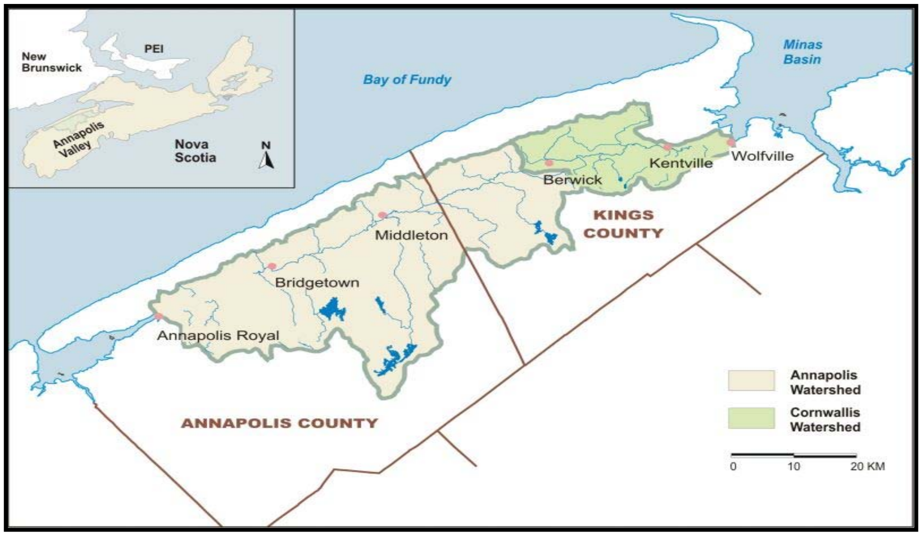

Figure 1: Town of Annapolis Royal in relation to the Province of Nova Scotia
(Source: GWMG, 2003)

Figure 2: Aerial photograph of the Town of Annapolis Royal, NS
(Source: Saunders, 2008)

4.1.1 Water Resources

Bounded on three sides by water, the Annapolis River to the north and west, and the Allain River to the south, the importance of managing stormwater runoff is evident (Annapolis District Planning Commission (ADPC), 2006). The Annapolis River and its tributaries play a very important role in the lives of the citizens of the Annapolis Valley region. Some of the services provided by the River include electricity generation through the tidal power station, commercial and recreational fishing, boating, limited shipping, tourism opportunities, crop irrigation and livestock watering, waste and stormwater assimilation, swimming, bird watching, and aesthetic and cultural values, boasting the oldest permanent European settlement in Canada (GWMG, 2003; A. Boyer, personal communication, March 10, 2008).

To assist in protecting and informing Annapolis Valley residents about the health of the Annapolis River, a volunteer program called the Annapolis River Guardians, has been monitoring and documenting observed changes in the river water quality for over 15 years (Sharpe, 2007). In 2006, sampling from eight sites up the river from the Town of Annapolis Royal indicated elevated levels of E.coli bacteria and nutrients, specifically nitrogen and phosphorus (Sharpe, 2007). Of the E.coli samples taken, “42% met CCME guidelines for livestock watering and crop irrigation while 46% of samples were unsatisfactory for all uses” (Sharpe, n.d., p.3 of 4). In addition, water temperature samples taken during the summer months reached levels that could potentially be detrimental to aquatic life (Sharpe, 2007). Fortunately, only two of the 99 water samples that analyzed levels of dissolved oxygen were below Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life, and pH levels were also shown to be within the CCME guidelines to support aquatic life (Sharpe, 2007). An explanation of the results, as well as recommendations to assist in identifying problems and improving aquatic conditions, are provided in the full report downloadable from:
(http://www.annapolisriver.ca/downloads/RG_2006_Report.pdf).

4.1.2 Storm and Sanitary Sewer Infrastructure

A study of the Annapolis sewage treatment plant completed in 2006, found that between 70,000-74,000 gallons of storm and groundwater enters the sewage lagoon per day (A. Boyer, personal communication, March 10, 2008). As a result of the inflow of stormwater and the incapacity of the system to handle the extra water, sewer backups and overflows have occurred following heavy precipitation (Committee of the Whole Minutes, 2006). This has led the Town to identify 52 sources of stormwater infiltration of the sewer system, of which 27 have been repaired to date, including the disconnection of downspouts and the repair of leaking sewer mains (A. Boyer, personal communication, March 10, 2008). In addition, an ongoing program to separate the stormwater and sanitary systems will help address some of the issues the Town has been facing. The 2006 report determined that with an aggressive stormwater diversion program in the Town and County of Annapolis, it would not be necessary to construct a third sewage treatment lagoon (A.Boyer, personal communication, March 10, 2008). As will be shown, rain gardens may be a fairly simple method to further reduce stormwater runoff and resulting overflows, especially if climatic changes results in an increase in precipitation in the Town.

4.1.3 Climate Change and Annapolis Royal

A study completed in 2003 documented that over the past 80 years in the Annapolis Valley, there has been an increase in precipitation with a greater number of days with low precipitation, a decrease in the number of days with no precipitation, and an increase in the extreme precipitation threshold (Mehlman, 2003). Using the Canadian Coupled General Circulation Model (CGCM1) running one emission scenario, Mehlman (2003) predicted annual precipitation would increase by 10-15% in the Annapolis Valley over three future periods, 2011 to 2040, 2041 to 2070, and 2071 to 2100.

This study suggests severe implications for various communities and sectors in the Annapolis Valley, especially if the demand for water increases as a result of population growth and economic development. In addition, if changes in the management of stormwater in the Annapolis Valley are not made, increases in stormwater runoff may be expected, further degrading the water quality in the receiving water bodies. Additional impacts as a result of changes in precipitation patterns could include sea level rise, variation in stream flow in the rivers, increase in erosion and flooding, and a deterioration of fish habitat (Mehlman, 2003).

4.2 Site Suitability Analysis

Although three types of soil are found within the Town, Bridgetown, Acadian, and Saltmarsh, most development has occurred on the Bridgetown soil, a sandy loam of 65% sand, 25% silt, and 10% clay (ADPC, 2006). This type of soil has a high permeability and would be very suitable for rain garden construction, whereas the Acadia and Saltmarsh soils (10% sand, 55% silt, and 35% clay) would likely need an imported soil mix (NPSNJ, 2005; ADPC, 2006). In addition, the Saltmarsh soil has a high saline content and likely not tolerable by many plant species (ADPC, 2006). A more comprehensive site analysis will be required prior to the construction of rain gardens in the Town, however, a review of available documents suggests neither slope nor the Bridgetown soil type, will be a constraint to rain garden construction (*refer to rain garden checklist, Appendix A*).

4.2.1 Land Use Planning and Development in Annapolis Royal, NS

The Municipal Government Act (MGA) is the primary Act regulating land use planning in the Province of Nova Scotia. The Act, which became effective April 1, 1999, incorporates the Municipal Affairs Act, the Municipal Boundaries and Representation Act, the Deed Transfer Tax Act and the tax collection provisions of the Assessment Act, the Municipal Act, the Towns Act, and the Regional Municipality Acts, as well as a revised Planning Act (Service Nova Scotia and Municipal Relations, 2002). Under this Act, “municipalities assume the primary authority for planning within their respective jurisdictions, consistent with their urban or rural character, through the adoption of municipal planning strategies and land-use by-laws consistent with interests and regulations of the Province" (MGA, 1998).

The Municipal Planning Strategy (MPS) for the Town of Annapolis Royal is the primary document used to guide land use and environmental, social, and economic development (ADPC, 2006). Upon review of the document, two policies were identified that did not appear to satisfy the LID design guidelines outlined in the manual prepared by Prince George's County, MD (1999a), *Low Impact Development Design Strategies*, the Transportation Policy and the Storm Drainage Policy. The LID Design Strategies manual suggests reducing: (a) paving by 33% through narrower road widths; (b) application of sidewalks to one side of primary roads; (c) on-street parking to one side of the road (or reduced altogether); and (d) the replacement of concrete curb and gutter with an attractive roadside swale (PGCDER, 1999a). The Annapolis Royal Transportation Policy on the other hand, sets all new local and collector roads in residential zones not regulated by development agreement with minimum widths of 16m where possible (ADPC, 2006). In addition, the Storm Drainage Policy, Part 18 (Section 18.2), states that "Council shall require that adequate storm drainage is installed within all new subdivisions and that all new developments are connected. The developer shall bear all costs of installation and connection of storm drainage" (ADPC, 2006, p.40). Although this policy does not strictly prohibit the use of alternative stormwater management techniques, it does not encourage the use.

Several policies that complement and would likely encourage rain garden construction are also apparent in the MPS, for example, the Environment and Conservation Policy (Part 5); the Recreation, Parks, and Open-Space Policy (Part 9); and the Water Policy (Part 19) (*Table 2*) (ADPC, 2006). Furthermore, through the Town's Tree Committee (Tree Planting Policy, Part 24), dialogue with property owners about tree maintenance their property already occurs (ADPC, 2006). This relationship and outreach process could assist in providing a fairly easy transition to encourage the installation and maintenance of rain gardens on private property.

Table 2: MPS policies that support rain garden construction in Annapolis Royal

Policy	**Text**
Part 5: Environment and Conservation Policy	"…committed to land use standards which minimize disruption of the natural environment. The Town intends to continue to cooperate with the Nova Scotia Department of Environment to ensure the protection of the natural environment and ensure the preservation and improvement of its water quality"
Part 9: Recreation, Parks, and Open-Space Policy	9.2 "…Council shall, through the Subdivision By-law, require for all subdivisions resulting in a net increase in lots that the developer make a cash payment to the Town equal to 5% of the value of the area shown on the final plan of subdivision (park levy)" 9.3 "As open-space recreational developments are compatible with virtually any form of development, it shall be the policy of Council to permit parks and playgrounds in any zone in the Town…"
Part 19: Water Policy	"Council shall investigate various methods of protection of the watershed area. The Town shall co-operate with the County to ensure the most beneficial and expedient method of protection of the watershed area"

4.3 Summary of Results and Discussion Section 1

The protection of infrastructure and thus, natural resources, from the predicted impacts of climate change is necessary to ensure the availability of clean drinking water and other resources well into the future. One method will be the employment of practices that reduce the negative impacts associated with development, such as an increase in impervious surfaces, and enable adaptation through proactive land use planning. The Town of Annapolis Royal has suffered the impacts of increased amounts and rates of stormwater runoff and appears to recognize and support a change of current practices.

An analysis of the applicable provincial and federal legislation on water resources and climate change adaptation was beyond the scope of this research. However, a report written by the Guelph Water Management Group (2007), entitled “Exploratory Assessment of Water Security in Canada,” investigates the procedures surrounding water allocation across the Country and states that currently in Nova Scotia, “there are no specific investments aimed at understanding the impacts of climate variability and change on water allocation schemes” and “Adaptation strategies to address climate variability and change within water allocation schemes are not evident in Nova Scotia” (Varghese & Ferreyra, 2007, p.23). Public workshops about water resources management will commence in April across the Province, to assist with the development of a water resources management strategy in Nova Scotia by 2010 (NSEL, 2008).

Results and Discussion Section 2

The comparative study of communities in North America and New Zealand that have implemented rain garden projects provided information on the benefits of rain gardens and the challenges encountered during the implementation process. Similar information was also drawn from other reports to supplement the findings from the cases studies and key informant interviews.

4.4 Benefits

Numerous benefits of using rain gardens were reiterated by the key informants and are highlighted in Table 3.

Table 3: Tangible & intangible benefits of rain gardens

Environmental Benefits
• Improved downstream water quality and aquatic habitat, filtering of pollutants and a reduction of water temperature • Reduced volume of runoff, downstream erosion, sedimentation, and flooding • Infiltration of runoff retaining stream baseflow and increasing groundwater recharge (preliminary research) • Increased biodiversity • Improvement in air quality and potential reduction of urban heat island effects
Social Benefits
• Educational benefits • Aesthetic benefits • Recreational benefits
Economic Benefits
• Reduced costs of water treatment, flooding, and CSOs • Reduced infrastructure and development costs • Increased property values

4.4.1 Water Quality Improvements, Reduced Costs of Flooding, Treatment, & CSOs

The *Low Impact Development Design Strategies* manual prepared by Prince George's County, Maryland Department of Environmental Resources (1999a), states that rain gardens and other LID practices may greatly improve the integrity of the watershed by balancing the cycle of water between runoff, infiltration, storage, groundwater recharge, and evapotranspiration, thus, more closely mimicking its natural hydrologic functions.

In municipalities where sanitary and storm sewer systems are combined, a reduction in the volume of water running off a property and entering into the sewer system can in turn, reduce the number of combined sewer overflow events and flooding, thus reducing the amount of downstream water quality degradation (Water Environmental Research Foundation (WERFa), n.d.). In addition, with a reduction of peak flows offsite as a result of rain garden detention properties, downstream channel erosion and sedimentation may also be reduced (WERFa, n.d.).

Impervious areas reduce the ability for infiltration, however, preliminary research suggests that the use of rain gardens may not only improve water quality and sustain stream baseflow, they may also enable groundwater recharge (Potter, 2002; D. Rodgers, personal communication, February 28, 2008). Tables 4 & 5 summarize the research that has been completed to date on the effectiveness of rain gardens at reducing the velocity and volume of stormwater runoff, as well as filtering the pollutants, sediment, and debris that may be found in runoff.

Table 4: Summary of rain garden effectiveness (volume reduction)

Source	**Geographic Location**	**Type of BMP**	**Volume Reduction**
Kipkie & Johnston (n.d)	Maple Ridge, BC	Rain Garden	Volume reduction: 80-88% (< 5-year events)
Foss (2005)	Seattle, WA (SEA Street)	Bioretention Facilities, Swales, Street Trees	Volume reduction: 98%
Barr Engineering Company (2006)	Burnsville, MN	Rain Gardens	Volume reduction: 93%
City of Portland BES (2008)	Portland, OR (Glencoe School)	Rain Garden	Volume reduction: 81% (25-year simulation) Peak flow reduction: 79% (25-year simulation)
City of Portland BES (2008)	Portland, OR (Siskiyou St.)	Curb Extension Bioretention Facility	Volume reduction: 84% (25-year simulation) Peak flow reduction: 88% (25-year simulation)

Table 5: Summary of rain garden effectiveness (rate of pollutant removal)

Source	**Geographic Location**	**Type of BMP**	**Removal Rate (%)**
PGCDER (1999)	Location unknown	Bioretention Facility	Total Phosphorus: 81% Total Nitrogen: 43% Lead: 99% Zinc: 99%
EPA (2000)	Largo, MD	Bioretention Facility	Copper (μg/L): 43% ±11 Lead (μg/L): 70% ± 23

			Zinc (mg/L): 64% ± 42 Calcium (mg/L): 27% ±14 Phosphorus (mg/L): 87% ± 2 Nitrate (as N) (mg/L): 15% ±12 TKN (as N) (mg/L): 67% ± 9
NJDEP (2004)	Location unknown	Bioretention Basin Bioretention Swale	TSS: 90% Total Phosphorus: 60% Nitrate Nitrogen: insufficient data TSS: 90% Total Phosphorus: 30% Nitrate Nitrogen: 50%
EPA (2005)	Somerset, MD	Combination of Rain Garden & Grassed Swale	Copper: 36% Lead: 21% Zinc: 37% Nitrogen: no change
Atchison et al. (2006)	Location unknown	Bioretention Facility	TSS: 90% Copper: >95% Lead: >95% Zinc: >95% Total Phosphorus: 80% TKN: 65-75% Ammonium: 60-80% Organics: 90% Bacteria: 90%
Davis et al. (n.d.)	College Park, MD (University of Maryland campus)	Rain Gardens (averages of numerous studies)	TSS: 23% Total Phosphorus: 72% Nitrate Nitrogen: 80% Lead: 91% Zinc: 64% Copper: 56%
Davis et al. (2003)	Greenbelt, MD (Field study)	Bioretention Facility	Copper (μg/L): 97% ± 2 Lead (μg/L): >95% Zinc (μg/L): >95%
Davis et al. (2006)	Box Laboratory Studies: 6hr, 4.1cm/hr flow rate & duration	Large Box (Bioretention)	Phosphorus (mg/L): 99 ± 0 Nitrate Nitrogen (mg/L): 97 ± 3 TKN (mg/L): 97 ± 2
Davis et al. (2006)	Box Laboratory Studies: flow rate doubled to 8.1cm/hr	Large Box (Bioretention)	Phosphorus (mg/L): 73 ±13 Nitrate Nitrogen (mg/L): 70 ±14 TKN (mg/L): 73 ± 14

4.4.2 Increased Biodiversity

Rain gardens increase the vegetation cover in a community, thereby increasing the habitat for numerous small organisms. In addition, research investigating urban forests suggests that an increase in cover assists in reducing urban heat island effects (as well as providing shading) while also improving air quality (American Forests, n.d.). Although similar studies investigating the use of rain gardens and these benefits have not been obtained, some garden designs involve the use of trees and bushes and as such, these results may be extrapolated for other sources of vegetation in urban areas.

4.4.3 Educational Benefits

One of the original objectives in the design and use of rain gardens on residential property was to increase the involvement of homeowners in stormwater management (L.Coffman, personal communication, February 26, 2008). The idea was that the construction of rain gardens could provide a highly visible tool not only to educate the homeowner about stormwater and its management, but also to demonstrate the active role the homeowner could have in improving environmental circumstances (L.Coffman, personal communication, February 26, 2008). This was the one benefit reiterated by 11 of the 12 key informants interviewed, emphasizing the importance of the educational benefit of rain gardens.

4.4.4 Aesthetic & Recreational Benefits

In many of the case studies, rain gardens have been built in parks and school grounds, commercial properties, along streets, and in the front or backyards of homes, adding a functional landscaping feature. Many of the key informants interviewed said more and more homeowners were inquiring about how they could receive a rain garden on their property, a theme repeated during the Seattle SEA Streets pilot project that stated, “Residents of this neighborhood enjoy walking along SEA Streets because it is a natural, soft-edged environment, in contrast to the hard edges of traditional linear streets” (Seattle Public Utilities, 2008) (*Appendix B*). In addition, gardening is a popular recreational benefit in itself, and the beautification of a neighbourhood may improve the quality of life and sense of place.

4.4.5 Reduced Development Costs

The flexible design and relatively small size of rain gardens in comparison to larger stormwater management BMPs, such as stormwater management ponds, enables developers and designers to overcome potential constraints with respect to the size of the site, an advantage not often afforded by larger stormwater management systems (PGCDER, 1999a). For example, rain gardens may be placed alongside streets or in the centre of traffic circles, reducing the amount of space dedicated to stormwater management and in some cases increasing the number of developable lots (U.S. EPA, 2005). In addition, LID-supported development may not require the use of curb and gutter or may enable a reduction in the size of drainage pipes, road widths, or site clearing, creating additional savings realized by the developer (Prince George's County, n.d.; E.Hauth, personal communication, February 26, 2008). However, it was made clear that this was not always the case and although a large percentage of the literature that supports LID suggests developers may realize cost-savings of 25-80% depending on the location and challenges encountered, the Canadian case studies projects costs increased by approximately $6,000-$7,000 per lot (PGCDER, 1999; U.S. EPA, 2007; H.Grimm, personal communication, March 25, 2008).

4.5 Implementation Challenges and Solutions

The key informants that were interviewed have been involved in over 1000 rain garden projects combined. Seven key themes emerged as key challenges in the implementation of rain gardens projects and three key themes emerged as solutions to increase rain garden use (Table 6).

Table 6: Rain garden implementation challenges

Challenges
• Uncertainty surrounding the costs involved in rain garden construction • Public concern surrounding proper maintenance procedures, responsibility, and cost • Lack of knowledge about what rain gardens are and how they work • Lack of understanding about proper design and construction processes • Public concern about the appearance of rain gardens • Restrictive local ordinances discourage the use of rain gardens • Lack of space available to support a rain garden
Solutions
• Government incentives • Education • Long-term evaluation and dissemination of results

4.5.1 Costs

The key to any successful program is the development of an adequate source of funding to ensure sustenance over the long-term (PGCDER, 1999a). Small communities faced with the need to implement projects or programs, such as climate change adaptation programs, may experience difficulties raising funds (PGCDER, 1999a; S.Hawboldt, personal communication, September 15, 2007). Research suggests that when choosing the best management practice to employ, cost is one of the most important factors influencing the decision (Atchison et al., 2006). As such, a fairly extensive investigation of the costs to design, construct, and maintain rain gardens is provided in anticipation that it may assist to increase the application of these practices.

4.5.1.1 Capital Costs

In almost all case studies the capital costs included the planning and design costs, installation, labour, and materials. However, in some cases engineering oversight and /or construction management and inspection was required to ensure the installation was completed correctly (Key Informants, personal communication, February/March 2008; City of Portland, 2008). These costs also appeared to vary depending on size and location of the project; whether the project consisted of the construction of a small garden on homeowner’s property or a larger bioretention facility on a commercial/ industrial site. Therefore, two estimates are provided summarizing the capital costs: Figure 3 summarizes the capital costs associated with rain gardens on homeowners' properties, while Figure 4 summarizes the capital costs associated with larger facilities.

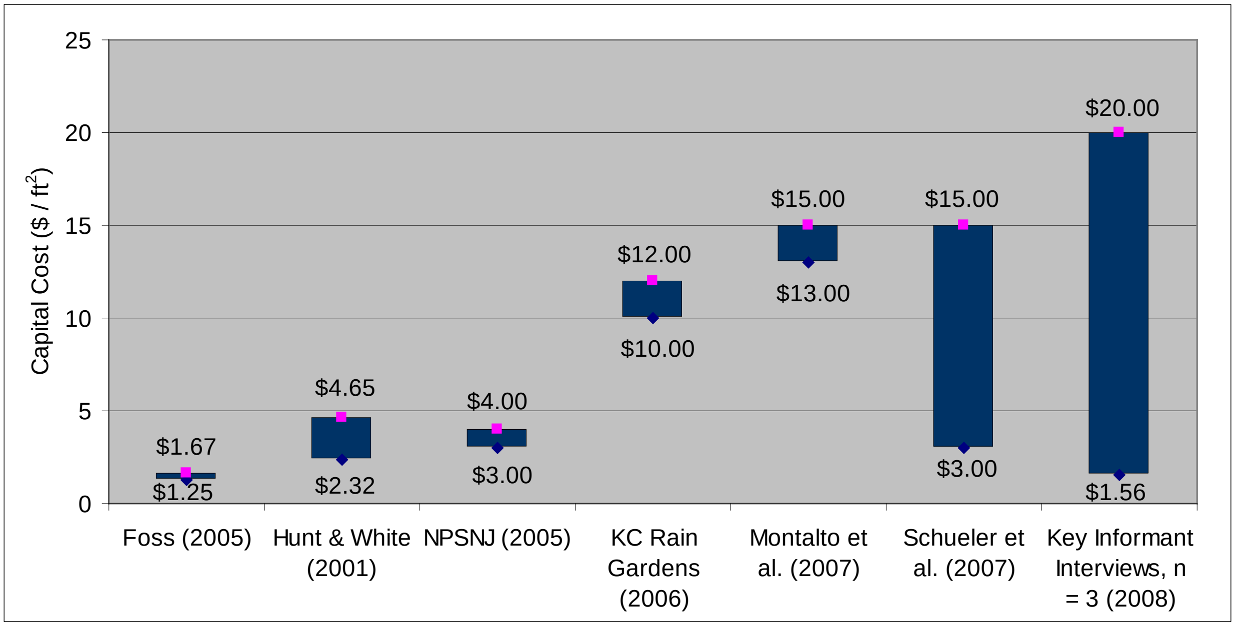

Figure 3: Summary of capital costs incurred in residential rain garden projects

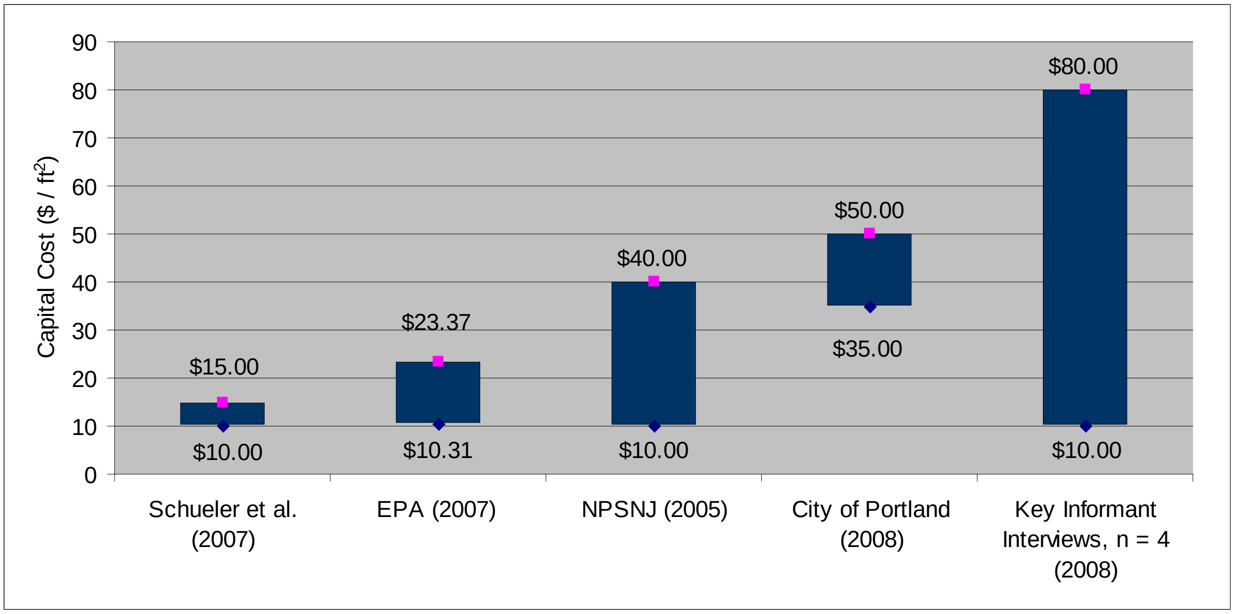

Figure 4: Summary of capital costs incurred in the construction of industrial/ commercial bioretention facilities

The capital costs may be reduced if machinery is already onsite, as in new construction or a street resurfacing project, or if financial subsidies are provided to the developer by the jurisdiction in which the rain garden or other LID stormwater management practice is being constructed (D. Rodgers, personal communication, February 28, 2008). In some communities, homeowners are encouraged to construct rain gardens on their properties themselves, and in these cases, key informants suggest the cost is no greater than the cost to create a regular perennial garden (P. Pennell, personal communication, February 26, 2008).

4.5.1.2 Cost Factors

The range of costs varies greatly depending on the complexity of the project, topography, soil conditions, available land space, type of plants used, and the need for control structures such as underdrains or overflow devices (Low Impact Development Center, Inc, 2007; D. Rodgers, personal communication, February 28, 2008). It is generally expected that the range of costs will be greater for larger bioretention facilities (*Figure 4*) and that retrofits will cost 1.5 to 4 times greater than new than new development because of the requirement of existing landscape and hardscape removal (concrete, asphalt) (Schueler et al., 2007). The breakdown of the costs of the different project scenarios (new development versus retrofit) was difficult to obtain and thus, not differentiated in this report. It was suggested by a number of the key informants that as municipalities and those involved in the construction of rain gardens became more familiar with the practices, the costs would likely decline (Key Informants, personal communication, February/March, 2008).

In almost all cases studies, the cost of acquiring land on which to build rain gardens was not discussed because the gardens were often built in public rights-of-ways or homeowners were eager to have the gardens installed as a landscaping feature and asserted responsibility for the gardens (G.Gaynor, personal communication, February 26, 2008). Thus, the opportunity costs of the land are not estimated in this analysis.

4.5.2 Maintenance

Maintenance is required to ensure the system does not clog and continues to function properly (City of Portland, 2008). Having a maintenance strategy in place, including who is going to maintain the gardens and at what cost, is important to ensure a successful program. If the homeowners are deemed responsible for the maintenance, it is critical to continue to educate and provide support as well as to design a garden that is easy to access and maintain (F. Rozumalski, personal communication, February 22, 2006). Two other important maintenance issues involve the ‘ownership’ of accumulated nonpoint source pollutants in the sediment of rain gardens and the transfer of duties to new homeowners upon property sale (Davis, 2005). Periodic removal of sediment by homeowners or municipal officials may reduce the impact of the former, while making potential buyers aware of the purpose, function, and required maintenance of rain gardens to encourage adoption of the practice upon property transfer, helps to address the latter. The LID design manual, Prince George’s County, MD (1999a) recommends assigning a representative of the homeowners’ association or the municipality to train and educate the new homeowner about rain gardens and proper maintenance.

4.5.2.1 Maintenance Costs

Comprehensive data outlining the long-term operation and maintenance costs for rain gardens and larger bioretention cells is difficult to obtain, particularly because these practices are still fairly young, although it may be assumed that the long-term costs will be similar to the long-term costs incurred to maintain a regular perennial garden (P.Pennell, personal communication, February 26, 2008; R.Bannerman, personal communication, March 3, 2008). The U.S. EPA (2007) estimates that maintenance costs are 5%-7% of the cost of construction. Information obtained from key informants in Canada, the USA, and New Zealand suggested the cost to maintain rain gardens ranged from approximately \$0.70/ft^2 (City of Portland costs where maintenance of 600ft^2 site takes approximately 2 hours), \$4.00/ft^2 in British Columbia, and between \$3.00 - \$5.00/ft^2 in New Zealand (GVRD, 2008; K.Scott, personal communication, February 12, 2008; E.Hauth, personal communication, February 26, 2008). Larger bioretention areas may require additional maintenance and thus, greater costs over the long-term. Some of the literature suggests soil removal and replacement after 5-10 years, however, most key informants emphasized that maintenance would really depend on the level of pollutants onsite, the level of soil compaction, and precipitation, among other variables (Low Impact Development Center, Inc., 2007; F.Rozumalski, personal communication, February 22, 2008; E.Hauth, personal communication, February 26, 2008, D.Rodgers, personal communication, February 28, 2008; R.Bannerman, personal communication, March 3, 2008).

In almost all of the case study locations (*Appendix B*), rain garden maintenance is the responsibility of the individual property owner, significantly reducing costs incurred by the municipality (P.Pennell, personal communication, February 26, 2008; G.Gaynor, personal communication, February 26, 2008; R.Bannerman, personal communication, March 3, 2008). Some municipalities prepare formal agreements to ensure upkeep by the property owner, while others believe the incentive to uphold the property value will ensure rain gardens are maintained.[1] In a few municipalities, maintenance is performed by homeowners' associations or city park / public works crews and the costs are absorbed with routine landscape maintenance costs already incurred by the municipality (EPA, 2007; E.Hauth, personal communication, February 26, 2008).

4.5.3 Education

Challenges during the rain garden proposal, design, and construction phases because of lack of knowledge (likely because of the newness of the technique) were the most common issues faced by over three-quarters of the key informants interviewed. Many of the barriers to implementation include uncertainty and negative community perception of the associated techniques, for example perceived safety risks - drowning, breeding mosquitoes, basement flooding - as well as concerns about appearance and maintenance (U.S. EPA, 2000). To reduce the fears of community residents, misconceptions surrounding the practice must be addressed. It is equally critical to educate the contractor about proper design and rain garden construction techniques to ensure the rain gardens function properly. Specific issues noted by key informants included:

1) Unsuitable location because of soil type, topography, location of utilities, among other constraints (*Please refer to the rain garden checklist*, *Appendix A*).[2]

2) Unnecessary use of underdrain or other additional structures, limiting the purpose and effectiveness of the rain garden (R.Bannerman, personal communication, February 26, 2008; F. Rozumalski, personal communication, February 22, 2008).

3) Soil compaction during construction severely impacting rain garden infiltration processes (F. Rozumalski, personal communication, February 22, 2008; D.Rodgers, personal communication, February 28, 2008).

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[1] Note: In all cases studied the homeowner was consulted prior to the placement of the rain garden in front of their home, as gardens were not mandatory (Key informants, personal communication, February/March 2008).

[2] Bioretention areas in parking lots may reduce the number of available parking spots (Puget Sound Action Team, 2003)

4) Since most municipalities involve the homeowner in the maintenance of rain gardens, it is crucial to collaborate with residents and design a garden that meets the residents' expectations in terms of appearance and maintenance otherwise the project may not be embraced and ultimately, not sustained into the future (F.Rozumalski, personal communication, February 22, 2008).

5) Additional considerations may involve (1) the use of a pre-treatment area, such as a grass buffer strip to slow the flow of water entering the rain garden; (2) aesthetically-pleasing plants, native grasses and sedges are not always appropriate (but take heed not to introduce invasive species); (3) the involvement of a team of engineers and landscape architects to visit the site to help reduce the occurrence of improper construction (F.Rozmalski, personal communication, February 22, 2008; G.Gaynor, personal communication, February 26, 2008; Virginia Department of Forestry, 2008).

In the case of a community project with the construction of many residential gardens, as in Kansas City (*Appendix B, Case Studies*), design and construction workshops as well as trained volunteers to assist with residential garden construction appear to work well (Kansas City 10,000 Rain Gardens, 2006). Many cases have also found success in the construction of demonstration sites in accessible public areas to allow the public to develop a better understanding of what rain gardens are, assisting in an increased acceptance of the practice (U.S. Department of Housing and Urban Development, 2003; E.Hauth, personal communication, February 26, 2008; P.Pennell, personal communication, February 26, 2008; M.Dooley, personal communication, February 26, 2008).

4.5.3.1 Education and Outreach Program Costs

To ensure successful adoption of rain gardens in a community, an outreach program to educate citizens, as well as municipal staff members, about the negative impacts of stormwater, the function of rain gardens, and the costs to construct and maintain the gardens, is essential. Most case study locations provide brochures and other rain garden literature online, however, many key informants also emphasized the importance of holding public meetings about the design and construction of rain gardens to increase awareness and acceptance of the practice (Key informants, personal communication, February/March 2008). The Greater Vancouver *BMP Guide for Stormwater* (Gibb et al., 1999, p.3-24), estimates the cost of a “comprehensive education and outreach program” cost of $150,000 to $200,000 per year for a municipality with a population of 150,000. An education and outreach program cost estimate of $350.00 ($150.00 Public Meeting – hall rental & refreshments; $100.00 Materials; $100.00 Advertising) was provided by the CAO for the Town of Annapolis Royal (A.Boyer, personal communication, March 17, 2008).

4.5.4 Regulations and Incentive Programs

Most of the literature suggests that regulations are a considerable challenge faced by developers contemplating the use of rain gardens or other LID practices. These include restrictive building codes, zoning regulations, and parking and street standards, conflicting with conventional stormwater management models (France, 2002; U.S. Department of Housing and Urban Development, 2003). Often, these regulations result in unnecessarily wide streets and parking areas, as well as larger than necessary lots and a reduction in the preservation of natural features (France, 2002). In addition, a lengthy site review process, as was the case in New Zealand, may discourage developers from attempting innovative stormwater management solutions (K.Scott, personal communication, February 12, 2008). In the Maple Ridge, BC example developers were forced to construct a conventional stormwater system along with the rain garden system to reduce risk to residents if the rain garden system failed (H.Grimm, personal communication, March 25, 2008).

On the other hand, all of the key informants from the United States reported that federal, state, county, and/ or municipal regulations to clean up downstream waterbodies or increase onsite infiltration were the primary motivation behind the use of rain gardens in their municipality (Key Informants, personal communication, February/March, 2008). In these cases, rain gardens were seen as a potential tool in a suite of stormwater BMPs to assist in meeting the mandates and thus, they were put into practice. Moreover, incentives and other award programs have facilitated the use of alternative stormwater management practices, such as rain gardens, in many cities in the United States (*Appendix B, Case Studies*).

4.5.5 Monitoring and Evaluation

Evaluation of the post-construction rain garden projects is regarded as highly beneficial for the purpose of maintenance because in many of the case studies, modifications were necessary to improve the functionality of the systems. As well, if the resources are available to monitor the performance of the systems over time, publishing these results may encourage greater use and support in the municipality by municipal officials, developers, and homeowners (City of Portland, 2008). Through careful evaluation and adjustments, the City of Portland and the City of Burnsville modified the design of some of their bioretention areas to improve the functionality (*Appendix B, Case Studies*).

Results and Discussion Section 3

The implementation of rain gardens as a tool to manage stormwater runoff in Annapolis Royal will greatly depend on the strengths and weaknesses of using rain gardens to manage stormwater, as well as the appropriateness of the site(s) and the supporting planning documents. A Strengths, Weaknesses, Opportunities, and Threats (S.W.O.T.) analysis was completed to analyze the lessons learned from the case studies and evaluate the suitability of rain gardens as a tool to manage stormwater and assist with climate change adaptation in Annapolis Royal, NS (*Table 7*).

Table 7: A profile of the strengths, weaknesses, opportunities, and threats

	STRENGTHS	**WEAKNESSES**
Internal Factors	· Environmental benefits (stormwater management, improved downstream water quality, increased biodiversity) offering a reduction in the vulnerability of water resources · Social benefits (educational benefits, aesthetic benefits, recreational benefits) · Economic benefits (cost-effective, reduced costs of water treatment, flooding, and CSOs) · Ease of construction and maintenance · Rain garden research is ongoing in numerous locations across the USA (likely in other countries too) to test their effectiveness and to develop robust models that support the use of rain gardens to manage stormwater	· Rain garden technology is fairly new and long-term monitoring of the systems has not been completed. Therefore, there may be a safety risk involved when implementing the structures to manage stormwater · Costs may be higher to reduce risk to the community · Construction and maintenance difficulties that may be encountered due to site constraints
	OPPORTUNITIES	**THREATS**
External Factors	· Municipal officials in Annapolis Royal are interested in reducing the strain on their sanitary infrastructure · Municipal officials expressed an interest in the use and functionality of rain gardens, in particular, as a stormwater management tool · Policies exist in the MPS that support protection and increased greenspace and recreational space (rain gardens may be viewed as recreational opportunities) · A tree policy and program that educates homeowners is currently in operation · The water quality of the Annapolis River has been and continues to be monitored and opportunities identified, with great support from the Clean Annapolis River Project (CARP).	· The cost to implement a community-wide rain garden program. · Subsidies/ incentives do not exist to encourage homeowners or developers to use innovative stormwater management practices · Policies in the MPS do not explicitly support rain garden construction and as such, proposals may be successfully challenged. · Lack of a stormwater management plan for the Annapolis Valley region · The lack of understanding or education about the tool, due to the newness of it, may be a barrier at all steps in a rain garden program (from the proposal to the construction and maintenance stage) · Professionals in NS may not have experience with the technology and as a result, their costs may be higher than reported in the literature

As evidenced in the SWOT, there are a number of opportunities in the Town. Steps to reduce the vulnerability of the Town's water resources to climate change have been taken through some separation of the combined sewer and stormwater infrastructure and through the long-term water sampling process that enables the monitoring of trends and identifies changes in the resource. As well, the Clean Annapolis River Project (CARP) has been involved in numerous education projects all along the Annapolis River to assist with water resources protection.

The SWOT analysis also emphasized areas that will need to be addressed in the Town to facilitate the use of rain gardens. An awareness of the threats, specifically, more clear and direct wording of the MPS to reduce ambiguity in future development, the creation of a comprehensive stormwater management plan that includes all communities within the Annapolis River watershed, and lastly, monetary support to encourage and assist with the implementation of rain garden projects on private and public properties.

Chapter 5. Summary & Conclusions

Managing stormwater is extremely important to reduce the likelihood of flooding and to ensure the protection of water quality over the long-term. Water resources are only one of many resources that will be impacted by climate change, requiring a change in current land use practices and behaviours to ensure their protection. An assessment of all of the resources and associated infrastructure in a community, although beyond the scope of this research, will be necessary to assist in community adaptation efforts.

The purpose of this research was to explore the feasibility of implementing rain gardens in the Town of Annapolis Royal, and assess their usefulness as a tool to assist in protecting water resources and aid in climate change adaptation. Through an identification of the strengths, weaknesses, opportunities, and threats (SWOT), a clearer picture of the benefits provided by rain gardens and the opportunities in existence in the Town to support their use, as well as areas that need further investigation or revision, was realized. This information may be useful to begin the process of creating a stormwater management plan for the Town and the communities along the Annapolis River.

5.1 Study Limitations

There were several limitations that may have influenced the outcome of this research:

1) SWOT analyses typically oversimplify the internal and external factors impacting on the system (Internet Center for Management and Business Administration, Inc., 2007).
2) The quality of the data obtained during an interview depends on the experience and skill of the interviewer, the questionnaire format, and the interviewees selected (Payne & Payne, 2004).
3) Information provided by a key informant may not be representative of the whole population and may be biased (Payne & Payne, 2004).

5.2 Further Research

Research to develop more robust rain garden construction and effectiveness models, as well as continuous tests on the filtering and recharge potential of rain gardens in various climatic conditions, including below freezing temperatures, is ongoing as was made apparent in the literature and during key informant interviews. In addition, the process to quantify the benefits of all LID practices is occurring in Portland to further increase the acceptance of LID applications (E.Hauth, personal communication, February 26, 2008). To assist with the implementation of a rain garden program in Annapolis Royal, for suggestions for further research include:

1) Using GIS, a model of the sub-watershed(s) in the Town of Annapolis Royal should be developed and an estimation of the reduction in stormwater runoff that may be achieved using a variety of rain garden coverage scenarios should be highlighted. A careful site analysis, based on a number of assumptions applicable to the Town specifically- soil conditions, topography, impervious cover, precipitation patterns, predicted precipitation increases as a result of climate change- would be necessary to determine if or where constraints to rain garden construction exists, and the usefulness of this technique in assisting in the protection of water resources during increased precipitation events as a result of climate change.

2) An analysis of planning documentation and site conditions in communities along the Annapolis River to determine suitability of rain gardens in these locations. Ultimately, the future of the Annapolis River depends on the adoption of a successful stormwater management and adaptation program by all of these communities.

3) Watershed-scale mapping of groundwater resources, including aquifer vulnerability, should be undertaken to assist in the development of an effective groundwater study. Currently a large percentage of Valley residents rely on groundwater as their source of potable water. Climatic changes and increases in imperviousness may reduce the availability of these resources for future use. Ongoing research into the usefulness of rain gardens as a tool to recharge groundwater may further support and encourage their use in communities where site conditions permit.

4) Continued research for available funding opportunities to support rain garden construction programs (and the publication of this information) may assist small communities or private landowners in adopting this technique.

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