A Use of the Theory of Planned Behaviour to Determine the Social Barriers to the Implementation of Stormwater Green Infrastructure on Private Properties in Dundas, Hamilton, Ontario

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Authors Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Climate change has resulted in more extreme rainfall events and most municipalities' stormwater infrastructure is not prepared to deal with the increased flooding instances that may be associated with the increased rainfall. Updating inferior stormwater infrastructure would put a strain on municipalities' budgets and require space that is not readily available. A potential option for municipalities is to implement green infrastructure options such as green space, green roofs and bioretention swales. Municipalities may be able to construct some green infrastructure options on publically owned space, however most of the responsibility for implementation will fall on private residents. Previous research has investigated methods of motivating private residents in the implementation of green infrastructure, however very little research has been done on whether residents respond to motivation and what the social barriers to implementation are. This project study focused on three neighbourhoods in the Town of Dundas (Hamilton, ON, Canada) as a case study. Dundas is in a position of pronounced flooding risk because of its location at the valley bottom of a break in the Niagara Escarpment and its past history of flooding. Through a partnership with the Hamilton Conservation Authority, this study used a questionnaire to attempt to elucidate the social barriers to the implementation of green infrastructure on private properties. The questionnaire was theoretically informed using the Theory of Planned Behaviour and analyzed using partial least squares path modelling. The results indicated that behavioural beliefs, attitude, normative beliefs, subjective norm and perceived behavioural control all contributed to the participant's intention to install green infrastructure and ultimately their final behaviour. The model was able to predict 57% of the variance in intention, based on the associated constructs. Subjective norm contributed the strongest to intention with a path coefficient of 0.542. Attitude had the weakest contribution to intention with a path coefficient of 0.034. Individual question results indicated that time and finances were not statistically significant barriers to the implementation of green infrastructure on private properties. A comparison between the neighbourhoods showed no significant differences in questionnaire answers between any of the three neighbourhoods, however there were differences in income and response rate between the three neighbourhoods. The results from this study can be used to help conservation authorities and municipalities develop engagement and education programs to promote the use of green infrastructure on private properties in order to mitigate the negative effects of climate change.

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1.0 Introduction

The following is a compilation of the research required for the fulfillment of a Masters of Environmental Studies in the School of Planning at the University of Waterloo. The research was performed in partnership with the Hamilton Conservation Authority (HCA), and all research fieldwork was performed in the Town of Dundas (Hamilton, Ontario, Canada). Through the research partnership with HCA and the University of Waterloo, I attempt to answer the research question: What are the social-psychological barriers to behavioural change for the implementation of green infrastructure for stormwater management on private properties in Dundas, Ontario?

Dundas, is a town within the larger city of Hamilton. Dundas became amalgamated with Hamilton in 2001, and is now within the Hamilton Census Division (Statistics Canada, 2011). All municipal stormwater management is performed by the City of Hamilton. Dundas was chosen for this project because of its past history of flooding and its unique geographical position within the City of Hamilton.

Dundas is located at the bottom of a steep valley at the western point of Lake Ontario formed by a local break in the Niagara Escarpment, and has a creek with a pronounced flooding history running through it (Boyle et al., 1998). The town faces difficulties to expand existing engineered stormwater infrastructure due to its location in a valley and the already existing built-up areas competing for space. It therefore looks to green infrastructure to help mitigate potential damages from increased precipitation. The town could face much more severe storms in the future due to climate change, resulting in the 100-year storm becoming a 50-year or 25-year storm (Lin et al., 2012). A 100-year storm is a storm that statistically has a one per cent chance of occurring in any given year (USGS, 2016). Likewise, a 50-year storm has a two per cent chance of occurring in any given year and a 25-year storm four per cent chance of occurring in any given year (USGS, 2016). A 100-year storm can occur every year, however it is statistically unlikely. Storms that occur more frequently, such as a 5-year storm, typically are of lower intensity than storms that occur less frequently, such as a 100-year storm (USGS, 2016). However, climate change is expected to result in more intense storms occurring more frequently than they have in the past (Lin et al., 2012).

HCA's assessment of riverine flooding following the typical 100-year storm shows some parts of Dundas could expect flooding from Spencer Creek overflowing the banks, resulting in the flooding of nearby areas (Figure 1). The majority of flooding would be expected downstream and upstream of Thorpe Street, where past floods have submerged the area in up to 1.5 m of water. Backwater flooding from Cootes Paradise could also occur, with past floods resulting in up to 3 m of water submerging the area around this shallow lagoon. Boyle et al. (1998) predicts much worse flooding in Dundas in the case of extreme future storms. Boyle et al. (1998) predicted that some properties in Dundas could be flooded with over 5 m of water, however this data was presented using precipitation events that are much higher than the typical 100-year storm, and are therefore much more extreme than stormwater management is typically designed to control. Therefore, it can be predicted, based on past flooding events, that the areas at the highest risk for flooding are those surrounding Spencer Creek and Cootes Paradise.

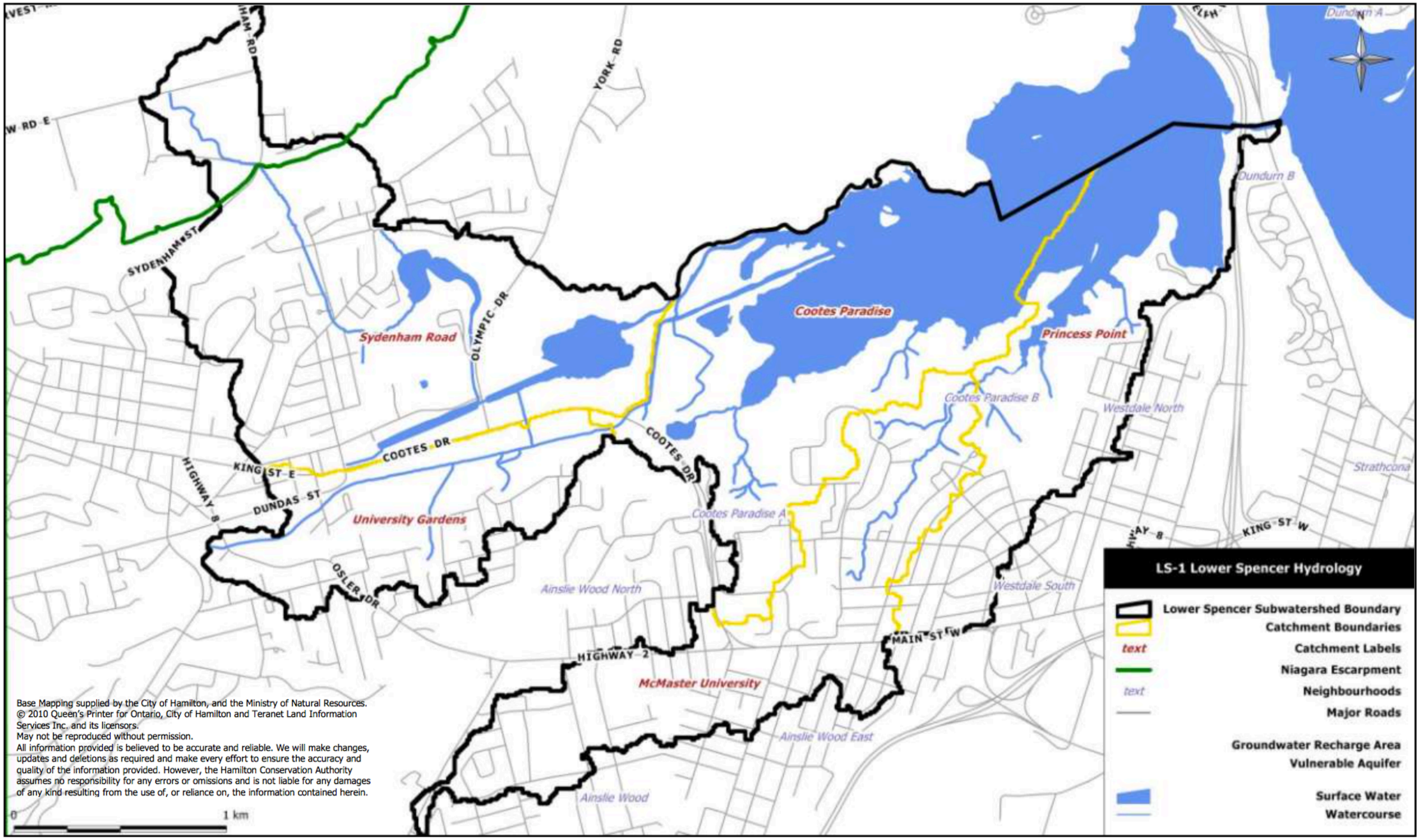

Figure 1: Map of the Lower Spencer Creek Watershed (Hamilton Conservation Authority, 2010a).

Stormwater management has been an issue of great concern for areas within HCA's region, resulting in programming to educate and engage residents about how to protect their watershed. Through a partnership between HCA, Conservation Halton and the Bay Area Restoration Council, the Hamilton-Halton Watershed Stewardship Program was initiated in 1994. The purpose of the Hamilton-Halton Watershed Stewardship Program is to protect, enhance and restore environmentally significant natural areas and watercourses in the watersheds of Hamilton Harbour through developing an educated, empowered group of residents. In 2015, the HHWSP undertook an initiative entitled Stormwater Stewardship in Dundas. Several activities and projects were undertaken in 2015 and early 2016. One of those undertaken in late 2015 was an information package drop off to roughly 300 houses within a Dundas neighbourhood reminding residents of the importance of lessening the environmental impact of urban runoff.

Municipalities and Conservation Authorities throughout Ontario have shown increasing concern over the state of current infrastructure, with runoff overflow resulting in flooded basements and polluted water ecosystems. A publication by the Credit Valley Conservation Authority about low impact development in residential homes states that residents in the Greater Toronto Area are angry and concerned about reoccurring basement flooding (Credit Valley Conservation, n.d.). Credit Valley Conservation has created multiple documents about converting grey infrastructure into green infrastructure, with focuses on stormwater planning, businesses, public lands, roads and residential areas (Credit Valley Conservation, n.d.). The Grey to Green Residential Lands guide gives information on how to market low impact development to private residents, through the use of signage and public engagement events. While this document is very helpful for municipalities wishing to engage members of the community, it does not consider the behavioural barriers to implementation nor any quantitative research results on how successful engagement programs have been.

Another program in Ontario, titled RAIN, is run by Green Communities Canada, and works with municipalities and landowners to address the impacts of stormwater runoff on rivers and lakes (Green Communities Canada, n.d.). Through the program, municipalities can receive helpful information about the costs, benefits and results of many different green infrastructure options. Green Communities Canada has also worked closely with the cities of Kitchener and Waterloo to develop a more intensive version of the RAIN program that will include home consultation visits. This resource could be very helpful to residents by addressing their concerns about green infrastructure, such as the cost of the installation.

Stormwater management is an important field for all municipalities to understand and fund. However, only certain types of stormwater management techniques are well researched, and residents' involvement with the issue is often ignored. Therefore, this thesis will inquire into residents' willingness to be involved in the issue of stormwater management and will help determine some social-psychological barriers to the installation of stormwater management techniques on private properties.

The largest research gap within the stormwater management literature is the lack of research on social aspects associated with green infrastructure, in particular, the barriers to implementation in municipalities.

The main research questions that this study aims to address are: (i) Are there any psycho-sociological barriers to the implementation of green infrastructure by private residents within municipalities? (ii) What are these barriers? (iii) Which of these barriers are the most important ones? The expected barriers include knowledge, attitude and the perceived availability of finances. Secondary research questions include: (i) Do demographic factors effect an individual's intent to install green infrastructure on their private property? (ii) Is there variation in attitude, behavioural beliefs and intention toward green infrastructure implementation between different neighbourhoods?

The objectives of this research are to perform a survey of three neighbourhoods in Dundas, Ontario, analyze the results using a powerful statistical model and identify the barriers to behavioural change with regard to green infrastructure implementation. The objectives include determining the extent to which demographic variables have an effect on an individual's likelihood to install green infrastructure on their private property.

2.0 Literature Review

The following literature review will focus on the increasingly important topic of green infrastructure solutions to stormwater management problems in (sub-)urban areas. In order to analyze the problem of current stormwater management and how green infrastructure can benefit municipalities, private residents and the environment, some background information needs to be understood. This section of the thesis will cover background information on topics such as climate change, environmental benefits of green infrastructure and current infrastructure problems within municipalities.

2.1 Introduction to the Literature Review

2.1.1 Climate Change

Climate change will affect various parts of the world in different ways. There are many parts of the world that can expect increased precipitation and increased intensity and occurrence of extreme rainfall events over the next century (Rosenburg et al., 2010). Extreme weather events have already begun to occur within Canada and other parts of the world, and municipalities are often not equipped with the proper infrastructure to deal with these events. For instance, the July 2013 flood in Toronto was the most expensive natural disaster to ever hit Ontario, and cost insurers over $850 million (Mills, 2013).

The Intergovernmental Panel on Climate Change (IPCC) 2007 report indicates that areas within Canada are likely to see increased precipitation events, while areas in the southern United States are likely to witness increased drought, which has already been experienced in California in 2016 (Christensen et al., 2007). IPCC used General Circulation Models (GCMs) to predict future changes in climate conditions within North America, and these models found that due to the increased warming projected for most of North America, moisture transport and precipitation is also expected to increase (Christensen et al., 2007). Climate change will likely result in different factors influencing the weather patterns all over the world, but for the purpose of this literature review, North America will be the focus. Ontario can be expected to witness general warmer temperatures throughout all seasons and increased precipitation in the spring and winter (Cote and Wolfe, 2014). Increased winter precipitation and warmer temperatures will likely increase the number of freeze-thaw cycles that occur during the winter months, possibly resulting in large amounts of snow melt overwhelming municipal sewer infrastructure.

Increased precipitation can also result in increased storm intensity. Storm systems are often labeled as 100-year storms, 50-year storms, 10-year storms, etc., based on their severity and expected return time. Lin et al. (2012) created a model to estimate the storm surges in New York City, USA, and found that under the effects of climate change a current 100-year storm could be changed to anywhere between a 3-year to a 20-year storm by 2100. More frequent hurricanes are expected to hit the city, which may result in millions of dollars of damage and potentially the loss of homes and lives (Lin et al., 2012). Damage-causing rainfall events are expected to at least double in frequency by 2090, meaning that 50-year storms will be reduced to 25-year storms, and could even be reduced to 10-year storms (Waters et al., 2003).

Climate change induced rising sea levels can also result in a larger chance of flooding in municipalities located along sea coasts (Hoffman et al., 2010). Since 1992, the global average sea level has been rising about 3 mm per year. Coupled with increased storm surges in the United States, this has increased property damage (Hoffman et al., 2010). Flooding is much more extensive when a storm surge comes in contact with a high tide, resulting in a larger amount of water being swept onto the land. Increased frequency in storm surges and an increased level of urbanization in North American cities will likely lead to an increased level of stress on municipal sewer systems, and higher sea levels will further increase this stress.

2.1.2 Current Municipality Infrastructure

Urbanization, urban sprawl and urban growth all have bearing on the increasing amount of urban encroachment on naturalized features. Urban growth around the world, particularly in North America and Europe, has been increasing dramatically over the past couple of decades. (Tzoulas et al., 2007). In Canada, at least 80% of the current population lives in urban areas, while worldwide, roughly 54% of the population reside within urban areas, a number expected to increase to over 60% by 2050 (KFF, 2014; United Nations, 2014). Increased urbanization typically results in increased area of impervious surfaces, increased pollution, decreased area of agricultural fields, increased use intensity of both urban and rural areas, and many other changes (Brander et al., 2004; Dietz and Clausen, 2008). There are many issues that are affected by increased urbanization, and one important factor for planners to consider is stormwater management, especially with the threat of climate change and the increase in the area of impervious surfaces.

While some urban designers and planners have begun implementing environmentally-friendly stormwater management options, many cities still rely on the classic curb-and-gutter approach to stormwater management (Yang and Li, 2013). Aesthetic appeal is very important to residents in (sub-)urban neighbourhoods and naturalized features such as bioswales often result in complaints from the residents. Residents often view naturalized features as ‘messy’ and consider native plants to be weeds (Yang and Li, 2013). Cultivated flowering plant species as well as neat and orderly gardens and lawns are often the preferred landscaping method in (sub-)urban neighbourhoods (Yang and Li, 2010; Yang and Li, 2013). Therefore, many cities still use classic grey infrastructure, such as curb-and-gutter stormwater catchment systems, or impervious surfaces instead of other, more environmentally-friendly, options. Increased urbanization within cities has resulted in an increased volume of runoff for neighbourhoods due to the increased area of impervious surfaces (Mentens et al., 2006). The level of imperviousness has increased within municipalities because of increased amounts of roads, driveways, rooftops and other built surfaces (Miles and Band, 2015).

Municipalities with aging grey infrastructure, such as curb and gutter sewers, may not be prepared to deal with increased precipitation, and extreme weather events may result in sewer overflows and both municipal and private residential property damage (Keeley et al., 2013). For instance, the City of Toronto’s Finch Avenue has had multiple disasters regarding a lack of stormwater infrastructure (Wells, 2012). Aging infrastructure and a lack of foresight was to blame for the natural disaster that occurred in August 2005 due to a storm of unexpected intensity, greater than the typically planned for 100-year storm, and the increased impervious surfaces from urbanization throughout the city (Wells, 2012). Finch Avenue’s infrastructure was not prepared to deal with the increased influx of runoff, resulting in flooding and concrete breakage and the closing of the busy road. The damage required approximately five million dollars and four months to repair.

Most municipal grey infrastructure was designed in the 1950s and 60s, meaning that the infrastructure is likely outdated and not able to control the increased amount of stormwater occurring under current climate conditions (Wells, 2012). Most infrastructure is designed to handle the typical 100 and 50-year storm events, but climate change and increased impervious surfaces are seldom taken into consideration in the infrastructure design (Rosenburg et al., 2010). Therefore, typical grey infrastructure is not prepared to handle increased runoff, and runoff from extreme weather events is likely to end up in water systems rather than storage systems such as stormwater management ponds (Keeley et al., 2013). In order to put this into perspective, the City of Vancouver will be used as an example. The City of Vancouver treats the majority of their combined stormwater and sewage through treatment plants in the city, but it also has 42 sewer outlets along the coastline for emergency situations (Radford and Vernon, 2013). The current infrastructure system is a combined system, where sewage and stormwater combine and flow together to a water treatment plant. The current infrastructure system is outdated and needs improvements, and often gets overwhelmed with sewage and stormwater, forcing sewage and stormwater to be routed to the emergency sewer outlets. The raw sewage backup in the infrastructure system has resulted in roughly 36 billion litres of untreated sewage being dumped into the Fraser River every year (Radford and Vernon, 2013).

Runoff from combined sewer overflows can result in increased pollution and sediment in natural water bodies, decreased biodiversity and decreased water quality (Barbosa et al., 2014). Increased urbanization and impervious surfaces can also raise the costs associated with treating water for use within municipalities. Forested and treed areas have been proven to decrease the need for stormwater infrastructure when they are placed near subdivisions and they reduce the need for sophisticated and expensive treatment plants (Fiquepron et al., 2013; Loperfido et al., 2014). Trees and vegetated areas are able to slow the flow of runoff into nearby water bodies and promote the absorption of runoff into the soil. The increased absorption in vegetated areas when compared to impermeable surfaces decreases the amount of polluted runoff flowing directly into water systems (Loperfido et al., 2014).

Stormwater should be managed at a watershed scale, as runoff that flows into a waterway upstream will affect a community located downstream. All ecosystems, including urban, have an impact on the water that flows through or over them. Whether that impact is negative or positive depends on what is located within the ecosystem (Brauman et al., 2007). Vegetated ecosystems will typically have a positive impact on water quality, since polluted runoff is able to infiltrate slowly into the ground, leaving behind particulate pollution in the soil and vegetation, which is then absorbed (Keeley et al., 2013). Impermeable surfaces, such as concrete, asphalt and building roofs will have a negative impact on water quality, since polluted runoff is not able to infiltrate into them, and instead flows into local water systems.

Municipalities must consider climate change when attempting to prevent damage from natural disasters. Many climate models are available to show how certain types of infrastructure will withstand different storm intensities. Models that measure the effectiveness of green infrastructure are performed using future climate scenarios in order to determine how effective a specific green infrastructure option will be in scenarios with increased precipitation (Anderson et al., 2008). Green infrastructure needs to be built to accommodate the predicted changes to precipitation that will occur in the future in North America. All infrastructure options, both green and grey, will need to be increased in order to accommodate future changes in precipitation levels (Anderson et al., 2008).

2.1.3 Green Infrastructure Benefits

According to Nickel et al. (2014) the "core concept of green infrastructure is that of harnessing the natural hydrologic cycle process of infiltration, evapotranspiration and other losses to manage rainfall at its point of origin" (pg. 404). Next to stormwater management, green infrastructure can provide municipalities with additional benefits that grey infrastructure cannot. Green space in municipalities can help mitigate urban heat island effects, decrease mental illnesses associated with city living, reduce habitat fragmentation, increase habitat quality, and increase ground water recharge (Wang et al., 2013). Urban green space has been studied in association with mental wellness and overall well-being, with results showing that increased green space can decrease the likelihood of mental illness for people living in urban areas (Tzoulas et al., 2007). Green infrastructure can be considered part of the urban green space, as green infrastructure options often lead to increased area of green space in urban areas (Tzoulas et al., 2007).

Increased pollution runoff into water systems can cause the eutrophication of the water due to a larger amount of nutrients entering the system (Wang et al., 2013). Increased area of impervious surfaces in urban surroundings have resulted in increased pollution in waterways, decreased biodiversity, increased erosion and decreased water quality in watersheds (Miles and Band, 2015). Reducing runoff in urbanized areas through the implementation of green infrastructure options can help mitigate negative impacts, such as decreased biodiversity in affected water systems, that occur with increased area of impervious surfaces. Urbanized impervious surfaces are often polluted with chemicals from cars, such as gasoline and oil, and runoff from pesticides and fertilizers used in urban gardens (Barbosa et al., 2012). Nutrients and pollution that are collected by water that flows over roads, driveways, parking lots and other impervious surfaces do not infiltrate but cause an influx of nutrients and pollutants into water systems. Additionally, a lack of infiltration of water into groundwater systems in urban areas can cause the water table to be lowered, reducing drinking water supplies and also reducing the flow of water into nearby rivers and lakes (Brander et al., 2004). Many green infrastructure options increase the infiltration of water into the groundwater, which then increases the drinking water supply for municipalities (Gobel et al., 2004). However, in planning green infrastructure options, municipalities' engineers and planners must also consider differences in water tables, as areas with a higher water table may not be able to support increased infiltration without increasing the occurrence of flooded basements (Gobel et al., 2004). Therefore, green infrastructure choices depend on where the municipality is located and what the groundwater table level is.

Green infrastructure and open space have also been shown to increase the health of people nearby, and even increase the safety of areas containing green infrastructure (Kondo et al., 2015). Negative environmental factors such as pollution and overcrowding have been shown to increase agitation and anxiety within residents, while green space and access to green space has been shown to relieve stress and help with depression (Kondo et al., 2015; Roe et al., 2013). Kondo et al. (2015) studied sites surrounding 322 green infrastructure installments in the City of Philadelphia. Green infrastructure options included tree trenches, porous pavement, rain gardens, bioswales and other types of infrastructure. The researchers found that the green infrastructure within the city did have an impact on the public's safety, with significant reductions in assaults and narcotics possession in the areas surrounding the green infrastructure. Overall, the results found that green infrastructure was able to make the neighbourhood look well-cared for and maintained, meaning that criminals were less willing to work within these areas (Kondo et al., 2015).

There are also economic benefits associated with green infrastructure. Municipal-specific economic benefits can arise from green infrastructure's ability to reduce stress on municipal sewer systems which increases the amount of time the system is able to operate effectively without repairs or replacements (Environmental Protection Agency, 2014). Green infrastructure also provides much-needed ecosystem services, such as pollution removal, carbon dioxide removal, and increases in the aesthetics of an area. Ecosystem services are often difficult to value, as services may have different values to different people, depending on their beliefs. In order to be consistent, municipalities could use a set model in order to determine the economic valuation of the green infrastructure. Vandermeulen et al. (2011) created a model that can be used to analyze the costs and benefits of the green infrastructure. Vandermeulen et al. (2011) performed a cost-benefit analysis for a green infrastructure project in Flanders, Bruges. The green infrastructure project included a bicycling path, landscaping and nature development, and the cost calculation included structural maintenance. The total direct cost of the project was €7,653,611 and the benefits from the project were calculated to be worth €9,360,780, for a total gain of €1,707,169 over twenty years. The benefits included the costs avoided by residents not having to commute to work in their cars, the recreational benefits, the environmental effects, the health effects from cycling, and the improved road safety.

Watershed-wide green infrastructure planning should be implemented within municipalities in order to control the runoff entering the watershed. Often watershed-wide implementation needs to be planned prior to development of subdivisions (Yang and Li, 2010; Yang and Li, 2013). New subdivisions are often planned with a more environmental approach to stormwater management than has occurred in the past (Waters et al., 2003). Green infrastructure options are more effective if implemented on a large scale, with all residential units participating (Anderson et al., 2008). Unfortunately, most stormwater problems are managed as site-specific problems, and most studies still focus on small neighbourhoods or communities for research on stormwater management, rather than on the watershed scale (Miles and Band, 2015). Watershed-wide research and implementation of management options can be expensive and time-consuming, but the benefits of watershed-wide planning likely outweigh the costs, since watershed-wide planning allows an entire area to have consistent and effective management (Dietz and Clausen, 2008; Miles and Band, 2015).

Municipalities have various options in regard to green infrastructure and stormwater management. Best management practices (BMPs) can include city-implemented options such as bioretention swales (shallow ditches planted with native species) instead of classic curb-and-gutters, stormwater management ponds in new developments and porous pavement instead of classic concrete. Green infrastructure can also be implemented on private property, with popular options including rain gardens, rain barrels, porous pavement, small retention ponds, etc. (Jayasooriya & Ng, 2014). This paper will focus on green infrastructure options that are available for implementation on private residential properties, as many municipalities do not have the funding or space for widespread implementation of green infrastructure on public land in already established neighbourhoods.

2.1.4 Green Infrastructure Options

Many types of green infrastructure can be implemented both on private, public and commercial land. Certain types of infrastructure aim to increase infiltration into the groundwater, such as rain gardens, permeable paving and bioretention swales (Gobel et al., 2004). Other green infrastructure options aim to increase the storage of water on private and public properties such as rain barrels and green roofs (Gobel et al., 2004). Stormwater management ponds are also used by municipalities, typically in newer subdivisions. These ponds are used to store runoff and allow pollution to settle on the bottom of the pond before the water is then redirected into the drinking water supply.

Most of these options can be made to look visually appealing, with naturalized plantings and landscaping that improve aesthetics while reducing maintenance. People enjoy living near lakes and ponds and typically are willing to pay a premium for housing in areas that back onto such natural features. Therefore, people are not likely to complain about stormwater management ponds, as cities usually attempt to make them visually appealing. However, some newer subdivisions have had trouble in the past with complaints about bioretention swales and rain gardens (Yang and Li, 2013). People often prefer manicured grass and do not understand the environmental benefits of the vegetated areas. Stormwater management ponds can often be surrounded by fences, making them unattractive, reducing the desire to live near them. Changing the attitudes of private residents is a hurdle that many policy-makers and planners must cross in order to plan for and implement greener stormwater management.

2.2 Real Life Experimentation

There are many types of environmental research studies that can be analyzed to determine the effectiveness of green infrastructure in different types of municipalities. However, many of the studies use models to predict the effectiveness of green infrastructure, and do not perform any tests using green infrastructure in actual locations. The following section summarizes studies that discuss green infrastructure in real locations rather than modelled green infrastructure.

Past studies often have focused on the quantity, and occasionally quality, of stormwater runoff from low impact development sites, while comparing the results to runoff from higher impact development sites (Dietz and Clausen, 2008). Dietz and Clausen (2008) compared two sites in Connecticut, USA; one was a traditional development site and the other was a low impact development site. The traditional site had an impervious area cover of 32% while the low impact site had a cover of 21%. The study showed that the runoff volume increased as the amount of impervious area increased, resulting in a much higher runoff volume in the traditional site.

While many studies focus on larger cities, small towns need to be analyzed as well, as sometimes large infrastructure options may not be applicable in smaller towns. Anderson et al.

(2008) used Portland, Ontario, as their case study for determining best management practices for small towns. Portland is a lakeside village, and many lakeside villages are concerned with the quality of their lake water due to the increasing amount of pollutants flowing into the water from runoff. Anderson et al. (2008) wished to determine if lot-level retention ponds were effective at containing runoff and preventing it from entering the lake. The study focused on lot-level best management options because preliminary research found that most of the pollutants flowing into the lake were coming directly from the bordering houses. However, the study found that many of the lots were not suitable for retention ponds, as the yards were not large enough to install a sufficiently-sized pond. Therefore, the authors concluded that lot-level retention ponds would not be enough to reduce runoff, and would need to be combined with other measures of infrastructure at the municipal level. Anderson et al. (2008) also used climate change scenarios to determine how much on-property storage of stormwater would need to increase in order for runoff to remain the same. They found that residents would have to increase storage by 28% in order to prevent an increase of runoff into the nearby lake.

Yang and Li (2013) compared the effectiveness of a low impact development site that was developed to contain green infrastructure to a conventional site that contains traditional grey infrastructure and manicured lawns. The two sites are both located within the Woodlands development in Texas, USA. The Woodlands site was developed to provide the municipality with a sustainable, low impact area for environmentally-minded residents to live (Yang and Li, 2010). However, due to complaints about the poor aesthetics associated with the bioswales and rain gardens, only two subdivisions were designed using low impact development and green infrastructure, while the rest of the subdivisions in the Woodlands development site were designed with conventional infrastructure. The study compared one of the low impact subdivisions with one of the more conventional subdivisions in order to determine if the green infrastructure was effective at reducing pollutant loading into nearby water systems. Surprisingly, the low impact site was designed with a much higher average impervious cover percentage (32.3%) when compared to the conventional site (13.7%). But even though the impervious cover rate was much higher at the low impact development site, the study found very little correlation between precipitation and annual nutrient loadings at this site. At the conventional site, however, they found a significant correlation between precipitation and annual nutrient loadings. The researchers noted the results that the low impact site generated less stormwater runoff when compared to the traditional development site (Yang and Li, 2010).

Real life experimentation is very important in order for researchers to understand what factors may be preventing a green infrastructure option from working, or what factors may be confounding the results (Yang and Li, 2010; Yang and Li, 2013). The results from the experiments can then be used to validate models, in order to make the models more accurate and useable in multiple situations. Results from real life experiments can also be used to aid decision and policy makers at all levels of government determine how to implement regulation for design options for stormwater management. Further research should be performed in multiple climates and municipality types (i.e. rural towns, metropolitan cities, commuter cities, etc.) to determine which green infrastructure options are best for all situations.

2.3 Social Aspects

The social aspects of green infrastructure have been studied much less than the engineering, modelling, environmental and economic aspects of green infrastructure and stormwater management. Few studies have focused on the understanding and environmental knowledge of private residents with regard to stormwater management or their intent to implement green infrastructure. It is important for policy makers, planners and city developers to understand how much environmental knowledge private residents have, and plan to educate the public if knowledge is lacking (Faehnle et al., 2014). Increasing public knowledge will lead to an increase in the number of residents who implement environmentally-friendly procedures, whether it is green infrastructure, recycling, or any other positive environmental action (Faehnle et al., 2014). Often the public is not aware of the importance of green infrastructure, and therefore public education is important because it can increase the amount of public interest and input into stormwater management policy (Faehnle et al., 2014). Even if public education only reaches a small number of residents within a municipality, there is potential that the residents who are interested in stormwater management will spread their knowledge to their neighbours (Babtiste, 2014; Babtiste et al., 2015). Knowledge is often a major social barrier in the implementation of green infrastructure on private properties (Babtiste 2014; Babtiste et al., 2015).

The goal of social-psychological studies on green infrastructure is to increase knowledge about the social barriers to implementation of green infrastructure on private properties, such as technical know-how, financial limitations, and time barriers. Decision makers can use this knowledge on barriers to help them create policies that help alleviate these barriers, such as grants for green infrastructure or funded educational workshops. Research into social barriers to the implementation of green infrastructure is most prominently focused in urban communities, with little focus on rural areas, likely due to less impervious surfaces in rural areas. The following section summarizes five studies that used residents' opinions and feedback to build conclusions and recommendations for municipal policy makers, planners and government officials.

Faehnle et al. (2014) focused their study on knowledge as a barrier to the implementation of green infrastructure. Faehnle et al. (2014) surveyed people who were considered experts in the field of urban planning and stormwater management, in order to determine how these experts included local knowledge into their plans. Many policy makers may not much make use of the knowledge of local residents when conducting community planning. Faehnle et al. (2014) found that while some policy makers and public officials thought that private residents' knowledge and opinion was important in planning for green infrastructure, others did not deem it important. All policy makers should agree on the importance of local knowledge and opinions in planning for reduced runoff, because many municipalities rely on private residents for the placement of green infrastructure (Montalto et al., 2013). The results of the Faehnle et al. (2014) study are important because they show disagreement between stormwater experts across the United States about which factors to include in their plans. If stormwater and urban planning experts are not recommending the inclusion of public opinion into stormwater management plans, it can be expected that many stormwater management plans will not build on public knowledge and opinion. The first step to ensuring consistent policy direction across Canada is to educate technical experts about the importance of local knowledge and public opinion. This may then lead to changes in policy at many levels of government and eventual changes in the public's perception of green infrastructure.

Keeley et al. (2013) used Cleveland, Ohio, and Milwaukee, Wisconsin, as case studies to determine how political and socio-economic constraints impede the implementation of green infrastructure. Both of these cities are considered 'worst-case scenarios' in terms of stormwater management, since they both operate on constrained budgets and have inadequate grey infrastructure to keep up with increasing urbanization and severe precipitation events. Keeley et al. (2013) state that green infrastructure implementation cannot be left up to private residents. Instead, they argue that policies or incentives associated with implementation are required, especially in cities with high levels of poverty. Private residents do not usually have much knowledge about stormwater management, since they are used to city infrastructure taking care of the problem, with no public input. Keeley et al. (2013) suggest that municipal governments use either a penalty or reward system, such as fines, stormwater taxes, or stormwater rebates, to increase awareness and participation in private green infrastructure implementation.

Keeley et al. (2013) identified three key categories where public perception can be seen as a barrier to implementation of green infrastructure: (i) Citizens often do not understand the connection between unmanaged stormwater runoff and environmental degradation, as they are often unaware of the negative effect polluted runoff can have on nearby ecosystems. (ii) Often citizens are also unaware that they have an individual or neighbourhood-level role to play in the implementation of green infrastructure, thinking it is a municipality's responsibility. (iii) Citizens are not used to seeing green infrastructure within the community, and often find it unattractive. This barrier can be overcome through continued education and exposure to green infrastructure.

Babtiste (2014) and Babtiste et al. (2015) focused on determining residents' barriers to the implementation of green infrastructure. The authors hypothesized that time, finances, knowledge and attitude where all barriers that impeded the implementation of green infrastructure. Babtiste (2014) and Babtiste et al. (2015) used Syracruse, New York, as a case study to determine residents' level of environmental knowledge about green infrastructure, and if socio-demographic factors had any impact on their willingness to implement it. In both studies door-to-door surveys were used, that resulted in fairly low response rates (Babtiste (2014): 14.5%, with a sample size of 208 respondents; Babtiste et al. (2015): 7.5-16.7%, with a sample size of 229 respondents). Both studies found that most socio-demographic factors did not play a role in environmental knowledge or willingness to implement green infrastructure. However, Babtiste (2014) found that age did play a role, suggesting that older residents might have gathered more life experiences associated with flooding and inadequate infrastructure, resulting in a higher willingness to implement green infrastructure. Babtiste (2014) also found no correlation between the amount of environmental knowledge and level of schooling, suggesting that environmental knowledge was not gained through formal schooling, but rather through real life experiences.

The results indicated that residents considered stormwater options too expensive, and would only implement them on their properties if the infrastructure was provided to them for free. Residents were also impeded by a lack of time, and required easy to install and manage green infrastructure options. The results of these two studies are relevant to planners and policy makers emphasizing the need for pubic grants and easily accessible and installable green infrastructure. Municipal governments might increase the number of residents using green infrastructure options by providing free or heavily discounted materials for the infrastructure, and by providing detailed maintenance instructions.

Stormwater management can also provide a teaching opportunity for municipalities. Shelton et al. (2015) found that residents were willing and excited to learn about green infrastructure options, especially if education options are presented free-of-charge to residents. Shelton et al. (2015) discuss the impacts of a work group that was organized by the University of Nebraska to target landscapers, gardeners, program managers and private residents and increase their knowledge associated with green infrastructure. Shelton et al. (2015) found that all workshops associated with the work group led to increased knowledge by participants about green infrastructure, and also their increased willingness to implement the infrastructure on their own properties or on properties that were part of their developments. Most of the workshops resulted in a large increase in knowledge, based on a survey given to the participants after the workshop. Of the participants who filled out the survey before and after the workshop, 100% received a higher score on the second survey. Over 70% of all participants of the workshops planned on implementing the infrastructure on their own property (77% planned to install a rain garden, 94% planned to pursue other green infrastructure options). The results of this study suggest that residents and professionals are interested in learning more about green infrastructure options, and that learning can lead to a change in intention to implement such options. Municipal governments might use these results to promote funding for a public outreach program based on green infrastructure options.

2.4 The Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) was used as the theoretical framework to design the questionnaire and interpret the results. Theoretical frameworks are a way for researchers to identify the factors that contribute to behaviour and intention (Chao, 2012). Theoretically grounded studies are quantitative, standardized and repeatable, and through the use of a constant theoretical framework, in this case the TPB, one can understand and predict behaviour, and connect the results of this research to other environmental behaviour research (Wauters et al., 2010). The TPB is a social-psychological model, which is used to predict people’s behaviours by linking beliefs, behavioural intent, and behaviours under the influence of behavioural control factors (Ajzen, 1991). The TPB is a popular choice of theoretical models for research into the prediction of an individual’s environmental behaviour (Chao, 2012; Wauters et al., 2010). When compared to other similar theoretical framework, for example, the model of responsible environmental behaviour (Hines et al., 1986/87), the TPB is found to have stronger predictive ability in regard to explaining behavioural intention (Chao, 2012). In the context of this research, the TPB will be used to elucidate social-psychological factors associated with implementation of green infrastructure. According to the TPB, beliefs influence, attitude, norms, and perceived behavioural control, which then influence behavioural intent, which in turn influences behaviour (Figure 2). Beliefs, attitude, norms, and perceived behavioural control can all be barriers to the intent and actual behaviour in regard to the green infrastructure implementation.

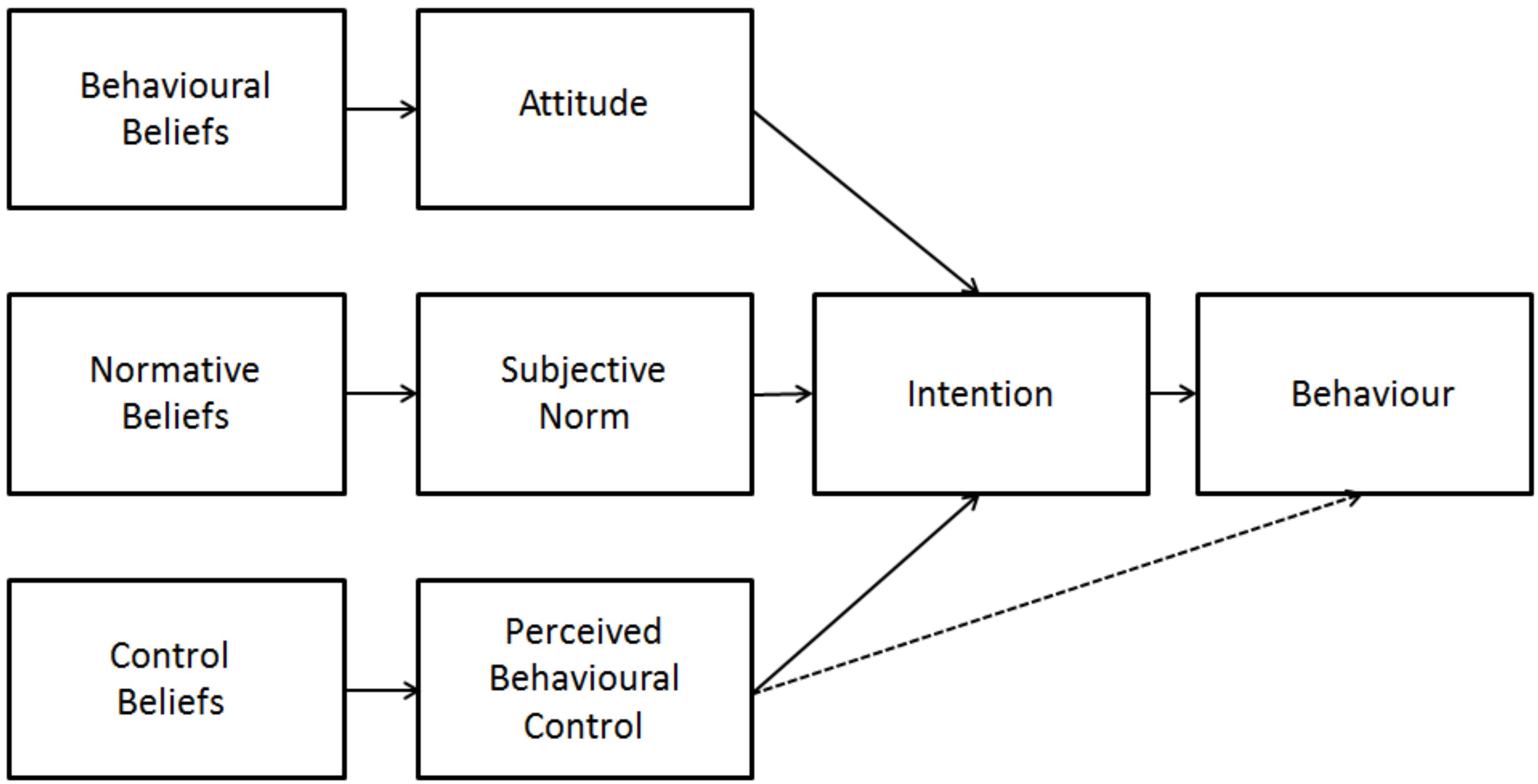

Figure 2: The Theory of Planned Behaviour adapted from Ajzen, 2006.

Table 1: TPB constructs and associated definitions (Ajzen, 2006).

TPB Construct	Description
Behavioural Beliefs	These are the beliefs that link behaviour to the expected outcomes. These beliefs are based on the probability that a specific behaviour will lead to an expected outcome.
Attitude (toward the behaviour)	The attitude is how negatively or positively one views the behaviour in question.
Normative Beliefs	Normative beliefs refer to the expectations of important people in the subject's life (including family, friends, neighbours, etc.). It questions the likelihood of the subject to perform a certain behaviour if it is important to their family, friends, etc.
Subjective Norm	Subjective norm refers to the perceived social pressure to perform a certain behaviour. The subject may feel as though they are expected to perform a certain way, and the subjective norm will try to determine what social pressures effect the way the subject acts.
Control Beliefs	Control beliefs are the beliefs that certain factors will help or hinder a behaviour.
Perceived Behavioural Control	Perceived behavioural control is based on the subject's belief that they can perform the behaviour in question. This control is weighted by control beliefs, if a subject feels they are hindered by factors outside of their control, they may also feel hindered by their own abilities.
Intention	Intention indicates the interest level a subject has in performing the specific behaviour.
Behaviour	Behaviour is the final, observable response, that comes from all factors impacting a final decision.

Social-psychological theories are often used as the theoretical basis informing questions for social sciences questionnaires. In support of the current research, several social-psychological theories were studied to determine the one that would be most appropriate for this research, including the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), the model of environmental behaviour (Hines et al., 1986/87), the attitude-behaviour theory (Triandis, 1980), the protection motivation theory (Rogers, 1983) and the value-belief-norm model (Stein, 2000). The TPB was chosen as the theoretical framework to support questionnaire development for the current research because it reflects the crucial processes that can explain individuals' intentions and behaviours (Ajzen, 1991). Some of the most researched and utilized social-psychological theories include the TRA (Fishbein and Ajzen, 1975) and Ajzen's TPB (Ajzen, 1991), which is an extension of the TRA and includes measures of control belief and perceived behavioural control (Armitage and Conner, 2001). Due to its popularity in literature and well-researched results in past studies, the TPB was used as the social-psychological basis for the creation of the questionnaire used in the current research.

Sheeran (2002) conducted a meta-analysis of four social psychological theories including the TPB (Ajzen, 1991), the TRA (Fishbein and Ajzen, 1975), the attitude-behavior theory (Triandis, 1980), and the protection motivation theory (Rogers, 1983). The results of the meta-analysis by Sheeran (2002) are complicated, as there is no one model that is the correct choice for every situation. The results by Sheeran (2002) suggest that the protection motivation theory (Rogers, 1983) typically shows weaker predictive ability for behaviour than the TPB and may not properly show the strength of intention (Milne et al., 2000). Also, TPB can use past behaviour as an indicator of intention, while the other models focus only on intention (Sheeran, 2002). Sheeran (2002) found that past behaviour can often be a strong predictor of current intention, since correlations between past behaviour and future behaviour can show a pattern in an individual's habits.

Ultimately, the TPB was chosen as the theoretical framework for the current research because it is well-grounded in research and theory and has been used successfully in many social studies of behaviour. The TPB is used to calculate the amount of variance accounted for in both behaviour and intention based on the following inputs: behavioural beliefs, attitude, normative beliefs, subjective norm, control beliefs and perceived behavioural control (Table 1, Figure 2). Attitude, subjective norm and perceived behavioural control are proceeded by behavioural belief, normative beliefs and control beliefs. Attitude towards the behaviour must first be determined by what the participant's behavioural beliefs are in regard to the specific behaviour. Behavioural belief is determined by the strength of the associations between a given behaviour and a specific outcome associated with the behaviour. The subjective norm is determined by general social pressure, but the underlying normative beliefs must be first determined in order to see what motivates the participant to perform a belief. Perceived behavioural control is determined by a participant's control beliefs, such as the perceived power taken to perform a specific action, and the belief of the participant on if they have an adequate amount of power. These six factors inform the participant's intention to perform an action, which then informs the participant's behaviour in regard to the specific action (Armitage & Conner, 2001).

The TPB is a rational approach to determining the predictors of intentions (Ajzen, 2011). It uses behaviours that are under volitional control of people, to interpret human judgements and behaviours. It has been criticized in the past for being too rational and not taking into account the less controlled aspects of human behaviour, such as emotions. However, in response it was argued that human emotion acts as a background factor that can influence how individuals evaluate situations under their control and that therefore an individual's mood can affect results achieved with the TPB (Ajzen, 2011). The TPB is used in social-psychological studies that inquire how people's beliefs influence their behaviour and intentions. The TPB has been used in many different fields, including health care, nutrition, exercise, etc. (Armitage and Conner, 2001; Milne et al., 2000; Fishbein and Ajzen, 2010).

2.5 Stormwater Management Policy

2.5.1 Municipal Policies

The following section will discuss three municipalities and how they dealt with stormwater problems through the use of policy. The City of Toronto is used as the first example because it is the largest city in Ontario and Canada, and therefore has a large influence on its surroundings. The Region of Waterloo was used as the second example because the cities within the region are considered advanced and innovative with environmental policies, and they provide an example that other municipalities may follow. Finally, the City of Hamilton is used as the third example because the Town of Dundas, the case study community for the current research, is located in this city.

The City of Toronto issued a 25-year plan in 2003 called the Wet Weather Flow Master Plan (WWFMP) that aims to extensively reduce runoff from storms and protect nearby environments from the polluted runoff (City of Toronto, 2003). The WWFMP has many initiatives associated with it, and aims to increase public participation and knowledge through community outreach programs. It has also led to the initiation of multiple programs including a downspout disconnection program, a green roof initiative program and an increase in tree planting in many urban areas. The WWFMP also contains a section about stream restoration where it states that city officials are working to restore streams within the city in order to combat erosion and pollution. All wetlands and streams within the Toronto region will be monitored to understand if the WWFMP and associated programs have had an impact on the nearby ecosystems.

Municipalities can attempt to control stormwater either at the source or at the "end of the pipe". The WWFMP was created in order to encourage source control through green infrastructure. End-of-pipe management options are often difficult to install for municipalities because they usually require extensive resources and space (Nickel et al., 2014). Examples of end-of-pipe measures include stormwater management basins and treatment plants, which often are significantly more expensive and time consuming to develop than source controls (Nickel et al., 2014).

The City of Toronto also has implemented the Toronto Green Standard, which is an environmental regulation for all new buildings within the city (TGS, 2015). According to this standard, all new buildings within the city must meet a minimum requirement in regard to emissions, accessibility, urban heat island reduction, stormwater retention and many other factors. Stormwater must be retained on site "to the same level of annual volume of overland runoff allowable under pre-development conditions" (TGS, 2015, pg. 8). The allowable runoff calculation can be performed for any land type and any new development must prove that they adhere to a pre-development rate of stormwater runoff. Many green infrastructure options are given as potential strategies for decreasing runoff including, but not limited to, green roofs, bioswales, rain gardens, etc. However, even with this regulation in place, roughly 77% of the neighbourhoods in the Toronto Region Conservation Authority's jurisdiction do not have adequate infrastructure to handle increases in precipitation (Lemieux, 2011).

The City of Kitchener and the City of Waterloo have partnered in an attempt to reduce stormwater runoff and increase knowledge about stormwater through outreach programs (City of Kitchener, 2011). A stormwater credit policy was approved in 2012 for the City of Kitchener and the City of Waterloo. The stormwater tax appears on all residents' water bills as a separate fee. A stormwater fee always has been a portion of the water bills within the two municipalities. However, now the stormwater fee is a separate section of the bill in order to increase transparency of municipal tax collections and also to increase awareness of stormwater issues

(Bylaw No. 153) (City of Kitchener, 2011). Another reason for the water bill redesign was to allow for a dedicated and sustainable funding source that will solely be directed to stormwater management within the two municipalities (City of Kitchener, 2011). The money from the stormwater tax will be used to replace aging stormwater infrastructure and increase green infrastructure throughout the city to decrease the amount of pollutants and runoff from reaching water systems throughout the two cities (City of Kitchener, 2011). A stormwater credit system was introduced alongside the redesign of the water bill to reward those who increased environmental stewardship through the placement of permeable surfaces on their property. Homeowners and commercial business owners can receive a reduction of up to 45 percent of their stormwater utility tax, if they can prove they have installed approved green infrastructure options on their property that either store rainwater or infiltrate it into the ground. Approved green infrastructure options include features such as rain barrels or cisterns, properly installed rain gardens and permeable pavers. The Region of Waterloo holds a rain barrel sale once a year, which provides residents with an opportunity to purchase a rain barrel at a discounted price (The Record, 2017).

The City of Hamilton currently does not have any municipal policies in place to promote green infrastructure on private or public properties. The City of Hamilton has a Stormwater Master Plan (SMP) that was released in 2007, which is meant to help decrease the adverse effects associated with stormwater runoff (City of Hamilton, 2007). There are fifteen watersheds within the City of Hamilton, and the SMP outlines some improvement strategies for all of them along with stormwater management facility upgrading and stream rehabilitation projects. The SMP contains much of the same information outlined in other stormwater management documents, as it discusses the importance of reducing runoff due to the increased pollution flowing into water systems and increased erosion of riverbanks. In 2007, only 15% of the City of Hamilton was considered urban, as the boundaries of the municipality are very large and many farmland areas are located around the city centre (City of Hamilton, 2007). However, there is the potential that urbanization has increased in the City of Hamilton. Despite increasing urbanization, the SMP focuses on treatment plants and ignores lot-level stormwater management.

The City of Hamilton also has a Storm Drainage Policy (SDP), which outlines how to plan for management at the watershed and subwatershed level (City of Hamilton, 2004). The SDP mentions the possible implementation of a 'zero increase in peak runoff rate policy', but at the time of the creation of the policy, the zero-increase policy was not considered applicable for the whole city so it was not implemented (City of Hamilton, 2004, pg. 9). The SDP aims to reduce combined sewer overflows (CSOs) by regulating the use of tanks that store the overflow until the sewers are no longer flooded, and then release the water into the sewers to flow to the treatment plant. There is no mention of green infrastructure in the policy. Both the City of Toronto and the combined cities of Waterloo and Kitchener have incentives to install green infrastructure on private and public properties, while the City of Hamilton does not. Since the City of Hamilton covers so many watersheds, the negative impact of polluted water runoff looms large for many adjacent municipalities.

Due to the importance of stormwater management in Hamilton, The Hamilton Conservation Authority has developed the Hamilton-Halton Watershed Stewardship Program, which was created to help residents explore green options that will help them manage stormwater on and around their properties (Hamilton Conservation Authority, 2015). The pilot program specifically targets Dundas residents who have experienced flooding on their properties in the past, however any residents who have stormwater concerns or questions are welcome to participate. The program aims to educate residents and increase awareness and interest in green infrastructure.

2.5.2 Provincial Policies

The Government of Ontario has recognized the need for updated policies regarding stormwater management in the light of climate-induced changes and stresses on current infrastructure (MOE, 2010). A Stormwater Management Planning and Design Manual was created in 2003, but has not been updated since to include best management practices that help combat current climate change problems. It focuses on conventional stormwater management systems within municipalities including source control and end-of-pipe measures such as treatment centres (MOE, 2003). The Ministry of the Environment (MOE) now encourages the creation of policies that require public participation and engagement about stormwater issues to increase the likelihood of implementation of green infrastructure on private properties (MOE, 2010). The negative impacts of polluted runoff have begun to be recognized and dealt with through policies at the municipal level, however, policies at the provincial level have been neglected.

The MOE performed a policy review in 2010, which recognized the need for new policies (MOE, 2010). The review mentions green infrastructure options as alternatives to conventional (grey) infrastructure systems, and highlights options that increase infiltration and native vegetation. Conventional stormwater systems have typically been designed with home ownership in mind rather than environmental protection. Homeowners wish to protect their houses against flooding, and typically lack knowledge about the potential negative environmental impacts associated with runoff. The policy review states the importance of concern for water quality and quantity while designing infrastructure, rather than a focus only on reduced house damage. The MOE states that the 'current SWM manual is based on work from the 1990s and it does not address adaptation to climate change' (MOE, 2010, pg. 6). Models used for stormwater infrastructure planning may not be advanced enough to completely predict what kinds of infrastructure municipalities will need in the future, depending on climate change. But municipalities can combat this problem by installing preventative infrastructure, including green infrastructure, rather than the minimum requirements. Provincial policies and the design manual should be updated to include best management practices, low impact development incentives and concern for climate change and the environment.

2.5.3 Federal Policies in Canada

Most policies surrounding stormwater management exist at the provincial and municipal level. However, some relevant acts such as the Canada Water Act can be found at the federal level. Environment and Climate Change Canada (ECCC) is responsible for enacting policies regarding flood control and prevention throughout Canada (Government of Canada, 2013). ECCC outlines three official documents that should be used at multiple levels, including municipal and provincial, for land use planning and stormwater management planning. Developers and city planners should use Watershed Management Plans, Sub-watershed Plans and Official Plans to determine the correct policies for stormwater management prior to development (Government of Canada, 2013). Stormwater Management Plans should also be developed at a municipal or regional level to ensure consistency in stormwater planning across watersheds. Green infrastructure options are mentioned as a form of the application of stormwater management, through uses such as management ponds, porous pavements and storage facilities (Government of Canada, 2013).

2.5.5 Federal Policies from Other Countries

It is typical that federal level governments allocate most of the responsibility of stormwater management to the municipalities, since each municipality has unique issues to manage and therefore a specific way of dealing with the stormwater problem. However, federal governments can be the leaders in stormwater policy and can provide guidance to the lower levels of government with precedents to follow in terms of installing green infrastructure in new and existing developments. Multiple countries were investigated to understand how their federal governments assigned stormwater policy responsibilities.

Multiple research articles cover Germany regarding the widespread use of green infrastructure throughout its municipalities (Keeley et al., 2013; Nickel et al., 2014). Germany is very developed in terms of conventional infrastructure for stormwater management, and 96% of the current population uses the public sewers (Nickel et al., 2014). However, even with advanced development and relatively new infrastructure (70% of the sewer systems are under 50 years old), the country still faces many issues with combined sewer overflows and pollutant overflow into nearby water systems (Nickel et al., 2014). Due to these stormwater issues, at least 25% of the municipalities within Germany have a green infrastructure policy as part of their stormwater management plan (Nickel et al., 2014). Similarly, Canada would benefit from encouraging municipalities to adopt a green infrastructure policy within their management plan, in order to benefit the country overall, and the municipalities' budgets as well.

In Australia, the Environmental Protection Agency is responsible for the control of stormwater pollution. The Water Quality Policy provides specific protection for Australia's water and regulates water use of all private residents, businesses and industry, including the restriction of dumping any class 1 or 2 pollutants into the water systems, which includes domestic waste, wash water, sewage, etc. The listed pollutants are not to be placed in the stormwater system or on land that connects to the stormwater system. Failure to comply with the policy could result in an AU$ 300 fine for any individual. The Environmental Protection Agency promotes Water Sensitive Urban Design (WSUD) to promote the sustainable use and reuse of water and to promote the protection of environmental features in Australia. WSUD options such as rain gardens, green roofs, pervious pavements, etc., may be used to help residents reasonably comply with the water protection policies (Environmental Protection Agency – Southern Australia, 2017).

The mandate of the Environmental Protection Agency (EPA) in the United States of America (USA) includes reducing stormwater runoff from the built environment. The EPA manages stormwater runoff on the large scale, through the National Pollutant Discharge Elimination System program under the Clean Water Act. Small and large municipalities in the USA require permits from the EPA for their municipal separate storm sewer systems and for all construction sites 1 acre or larger, resulting in over half a million permits in the USA (Committee on Reducing Stormwater Discharge Contributions to Water Pollution, 2008). The EPA found that because federals laws to regulate stormwater management only came into effect in the USA approximately 20 years ago, many urban systems have not updated their stormwater management approach and do not take into account environmental protection (Committee on Reducing Stormwater Discharge Contributions to Water Pollution, 2008). Future developments in the USA will have to be better controlled through federal policy, including restrictions on impervious cover and regulation of specific pollutants such as de-icing materials and fertilizers (Committee on Reducing Stormwater Discharge Contributions to Water Pollution, 2008).

In developing countries, stormwater is often not as regulated as in developed countries, due to uncontrolled and unplanned growth, sometimes on floodplains or natural drainage pathways (Parkinson & Mark, 2005). Many cities in developing countries lack the proper infrastructure to accommodate this unplanned growth and are forced to respond to this kind of urban development after the fact. For example, the County of Chile has experienced severe flooding in many cities throughout the country prior to the approval of the Stormwater Act in 1997 (Parkinson & Mark, 2005). At that time, all cities with a population of more than 50,000 were ordered to prepare a stormwater management plan, which must contain requirements for stormwater infrastructure for all new developments. After the development of stormwater management plans by the larger cities in the country, it became apparent that the country required more funding to invest in existing infrastructure. The Act was amended to impose a fee on residents in order to pay for the improvement of existing infrastructure. While this policy is aiming to create environmental benefits, it could have negative implications for residents in Chile, if they are unable to afford the increased fees on their water bills. Governments need to be aware of the financial abilities of its residents before imposing fees that are not affordable for the majority of residents.

2.6 Research Gaps

Stormwater management is an active field of research. Most studies focus on the engineering of green infrastructure and the revitalization of old grey infrastructure, along with developing or adapting models that can determine the effectiveness of green infrastructure. Some research gaps exist that are associated with modeling green infrastructure, for instance, most models are specific to one location, and need extensive parameter adjustments in order to be used in different locations (Jayasooriya and Ng, 2014). Future research that focuses on creating models that are easily adjustable, and suitable for use all over the world would be very beneficial to the modeling research bank. Continued research is also required on the effectiveness of green infrastructure when mixed with either existing grey infrastructure, or revitalized infrastructure (Wang et al., 2013). Most research on green infrastructure focuses only on the green infrastructure options, not on how the options interact with existing options.

However, arguably the largest gap in the stormwater management field is the lack of research on social aspects associated with green infrastructure, in particular, the barriers to implementation in municipalities. While some studies have investigated the social and economic barriers to implementation, most studies ignore these issues and focus on the engineering and planning side of green infrastructure. Many benefits exist that are associated with green infrastructure; for example, increased green infrastructure can result in lower costs for municipalities to clean water which could, in turn, result in lower taxes for residents. Unfortunately, private residents are often focused on potential barriers to green infrastructure such as initial financial cost and instalment efforts rather than on environmental, long-term and community-level benefits. In response, some initial research has been conducted on how to motivate private residents to implement the green infrastructure (Yang and Li, 2013). However, this body of knowledge is still very sparse and requires further inquiries into the barriers that restrict the implementation of green infrastructure on private properties.

2.7 Research Questions

The main research questions that this study aims to address are: (i) Are there any psycho-sociological barriers to the implementation of green infrastructure by private residents within municipalities? (ii) What are these barriers? (iii) Which of these barriers are the most important ones? The expected barriers include knowledge, attitude and the perceived availability of finances. Secondary research questions include: (i) Do demographic factors effect an individual's intent to install green infrastructure on their private property? (ii) Is there variation in attitude, behavioural beliefs and intention toward green infrastructure implementation between different neighbourhoods?

The objectives of this research are to perform a survey of three neighbourhoods in Dundas, Ontario, analyze the results using a powerful statistical model and identify the barriers to behavioural change with regard to green infrastructure implementation. The objectives include determining demographic variables have an effect on an individual's likelihood to install green infrastructure on their private property.

3.0 Methods

This project originates from a partnership between the University of Waterloo and the Hamilton Conservation Authority (HCA). The Town of Dundas (City of Hamilton, Ontario), is located within the HCA's jurisdiction, and past efforts to encourage use of green infrastructure have focused on various areas in the Town of Dundas. The partnership began in January 2016, with two visits to the HCA's main office. The partnership was determined to be mutually beneficial, as the Hamilton Conservation Authority can benefit from the research results of this project, while the project can benefit from the HCA's experience in Dundas and its knowledge of appropriate neighbourhoods to investigate.

3.1 Study Area

The study area was determined prior to the distribution of the pilot test questionnaires. Three neighbourhoods were chosen based upon the opinions of the HCA staff and through examining the Stewardship Action Plans for the subwatersheds within the Dundas region (HCA, 2010a; HCA, 2010b; HCA, 2010c; Overy, 2010). The three neighbourhoods included (1) University Gardens, located to the south east of Dundas' downtown center, (2) the downtown neighbourhood, located just north of King Street, and (3) the Conservation neighbourhood, located to the direct east of Conservation Land (Figure 3). The University Gardens neighbourhood is located above a ravine, and does not have a flooding history. It was canvassed in early 2015 by the Hamilton-Halton Watershed Stewardship Program with stormwater information packets. The downtown neighbourhood is located below a ravine and many of the houses have experienced flooding events. Both neighbourhoods have a mix of older and newer homes, and the majority of homes are older single detached dwellings. The third neighbourhood, the Conservation neighbourhood, consists of newer, larger single detached dwellings. Since these houses are much newer, residents are unlikely to have experienced flooding.

The Town of Dundas has a population of 24,285 (Statistics Canada, 2017a; Statistics Canada 2017b). The town saw a population increase of 0.5% from 2011 to 2016, compared to the national growth average of 5.0% (Statistics Canada, 2017a; Statistics Canada, 2017b; Statistics Canada, 2017c). Even with a relatively low growth rate, the Town of Dundas still faces issues with flooding due to its location at a valley bottom and its proximity to the Spencer Creek. The Town faces difficulties to expand existing engineered stormwater infrastructure due to its location at the valley bottom and the already existing built-up areas competing for space. The Town therefore looks to green infrastructure to help mitigate potential damage from increased precipitation. However, HCA indicated that many residents appear to be unaware of the advantages of green infrastructure and few residents seem to have implemented green infrastructure on their properties. There are many potential barriers that could be associated with the instalment of green infrastructure.

Figure 3: Locations within Dundas Hamilton that surveyed using the Stormwater BMP questionnaire

3.2 Questionnaire Design

Low participant response rates to surveys can make it difficult to obtain statistically significant results and can be caused by poorly designed questionnaires or ineffective survey methods (Dillman and Christian, 2005; Hoddinott and Bass, 1986; Czaja and Blair, 2005). Therefore, prior to commencing the survey, questionnaire designs and survey methods were researched to identify approaches that would help maximize participant response rates.

The Stormwater Best Management Practices (BMPs) questionnaire design began as an iterative process, including multiple trials and research into the best possible questions. The questionnaire focused on barriers to implementation such as knowledge, attitude, finances, and time availability. A demographics section was included to understand if demographic variables were related to barriers to green infrastructure implementation. All questions, except for those within the demographics section, were designed using a six point Likert scale, in order to allow for quantitative analysis of all answers.

The writing process for the questionnaire followed the steps outlined in *Designing Surveys* by Czaja and Blair (2005). The steps are organized as follows: writing the questions, organizing the questions, and testing the questions.

Writing the Questions

Writing the questions is the first step in designing a questionnaire. Every question must be carefully written in order to provide answers to the research questions, while avoiding content that does not contribute to the research questions. All questions must be relevant and only produce information that is required for answering the research questions. In the beginning of this process, a minimum of ten questions were written for each construct of the TPB, and were then discussed in order to ensure that each question showed a close relationship with its section of the TPB.

The questions were written after thorough review of previous green infrastructure public engagement studies (Babtiste, 2014; Babtiste et al., 2015; Keeley et al., 2013; Kondo et al., 2015). Research for the questions also included multiple forms of green infrastructure studies, including those based on modelling the effectiveness of green infrastructure, models based on real-life experimentation, and limited number of studies about social barriers associated with green infrastructure implementation. A knowledge section was included in the beginning of the questionnaire to allow investigation of a relationship between resident's knowledge of green infrastructure and their willingness to implement green infrastructure on their properties. Specific wording for questions in each section of the TPB was determined based on Fishbein and Ajzen (2010) who indicate how to word questions so that they elucidate the required social-psychological factors. Fishbein and Ajzen (2010) provide examples for the wording of questions for each section of the TPB (Appendix 10).

Organizing the Questions

The questions for the Stormwater Best Management Practices questionnaire were organized into sections that are congruent with the theoretical constructs in Ajzen's (1991) TPB, plus a section on green infrastructure knowledge level and a section on demographics (Appendix 2 [Table 1]).

Testing the Questions

Testing the questions was a two-step process. The first step was to improve the questionnaire for ease of understanding through an editing process using willing volunteers. These individuals read through the questionnaire and identified confusing or poorly worded questions, provided advice for which questions to omit, and provided input as to what concepts were missing from the questionnaire.

The second step in testing the questionnaire was to perform a pilot survey. Results from a pilot survey can provide insights into the effectiveness of the survey method, can help determine whether the questions are appropriate, and whether the time required to complete the questionnaire is too long. If only a small number of questionnaires are returned or questions are consistently left unanswered, the researcher should consider modifications to the survey method, the design of the questions, and the length of the questionnaire. A pilot survey can also be used to estimate the expected response rate and required sample size to achieve statistically significant survey results.

The pilot test was performed in Neighbourhood 1 (Figure 3). Thirty houses from the neighbourhood were visited in December 2016. Door hangers describing the project (Appendix 12) were distributed on Thursday, December 8, during the evening. The same houses were visited again during the evening on Tuesday, December 13 and Wednesday, December 14, to deliver the questionnaire. The rollout of the pilot survey took three days to perform. A total of twenty-eight questionnaires were distributed, as two residents refused the questionnaire at the door. Seven questionnaires were returned through the mail to the School of Planning and collected in January, 2017. The pilot was determined to be successful due to the response rate of 25%, which is within the range of commonly expected survey response rates. Consequently, the questionnaire was not altered for the full survey rollout.

3.3 Sampling

To determine the minimum sample size for this study, information was required about the expected response rate and the population size of the study area. Additionally, decisions had to be made regarding the desired confidence level and confidence interval. The pilot survey resulted in a response rate of 25% and in 2016, the total population of the Town of Dundas was 24,285 residents. The desired confidence level was set at 95% and the desired confidence interval was set at 15%. A confidence interval of 15% is fairly wide; however, because of logistic constraints it was decided that this confidence interval was of an appropriate width. Given the above information, the minimum required sample size was calculated as 43 and the minimum number of questionnaires to be rolled out was 172 (172 x 0.25 = 43). However, to ensure that the full survey rollout would indeed lead to the required sample size, it was decided to distribute the questionnaires to about 250 households. This number allowed for 83-84 questionnaires to be distributed to each of the three neighbourhoods and ultimately resulted in 258 houses visited and 251 questionnaires rolled out, including the survey pilot. The difference between the total number of houses visited and the total number of surveys handed out is due to seven surveys being refused at the door by the residents.

3.4 Survey Design

The survey design employed standardized, self-administered mail-back questionnaires (Colt and Wolfe, 2014). The benefits of using mail-back questionnaires include reduced pressure for the participants, as they do not have to fill out the questionnaire in the presence of the researcher, and an ease of return, since the questionnaires include a stamped envelope. The disadvantages of mail-back questionnaires include an increase in unanswered questions, since the researcher is not present to clarify questions, and an increased non-response rate (Colt and Wolfe, 2014). Mail-back questionnaires were the most time and financially efficient method for the distribution of the Stormwater BMPs questionnaires in the chosen neighbourhoods.

The design of a survey has a large effect on the likelihood of people answering the survey (Dillman and Christian, 2005). In the past, mail surveys were able to achieve a significant number of responses, however, people's current reliance on digital communication has resulted in lower survey return rates (Dillman and Christian, 2005). To maximize questionnaire return rates for this survey, the survey design was partially modelled after the Dillman Total Design Survey Method (Hoddinott and Bass, 1986). In the past, the Dillman survey method typically resulted in return rates of 75-80% (Hoddinott and Bass, 1986) though presently such high return rates cannot be expected any more. The Dillman survey method requires several spaced mailings to each participant, including an information letter, the original survey, a follow-up letter or postcard, two replacement questionnaires if a response has not been received after four weeks, and a "thank you" letter when a filled questionnaire has been received (Dillman, 1991).

However, due to financial and logistic constraints only some of the steps of the Dillman survey method were followed for this project. A colourful door hanger was created to inform residents about the project and distributed before the questionnaire. The questionnaire was designed to be visually pleasing, with a colourful front cover, ten pages of well-spaced questions. The questionnaire was accompanied by an information letter on official University of Waterloo letterhead and also included a "thank you" letter printed on the last page of the questionnaire. All documentation was dropped off to the houses in-person. Replacement surveys were not possible due to the anonymous nature of the survey.

3.5 Survey Rollout

Houses were selected in each neighbourhood using a stratified random sampling technique (The Pennsylvania State University, 2017). Streets were selected at random in each neighbourhood. In each neighbourhood, every house along both sides of the street was visited, until the end of the street, or until an intersection appeared that allowed for another street to be surveyed.

The distribution of door hangers and questionnaires took two to three days for each neighbourhood. The surveying occurred during the months of January and February, 2017. The door hangers were distributed on Thursday evenings between 5 and 8 pm, and were placed on the doors of 83 houses plus a minimum of five extra houses, to accommodate possible questionnaire refusal. Questionnaire refusal was predicted for all neighbourhoods, resulting in extra houses surveyed, because two residents out of thirty in the pilot test refused the questionnaire. The extra door hangers were distributed in order to ensure that all questionnaires could be handed out to a resident who had been given the opportunity to read the door hanger. The residents were given two to three days notice through the information on the door hanger, prior to the primary researcher knocking on their doors to deliver the questionnaire, which happened between 1 to 4 pm, the following Saturday and Sunday.

Questionnaire delivery was attempted to each house that was previously distributed a door hanger. Every door was knocked upon, by the primary researcher, however, for safety reasons, every outing required the accompaniment of an assistant. The assistant would record each house that was visited and whether the resident was home or away, and if they took a questionnaire or refused it. If the resident was away, a questionnaire was left in their mailbox, or in the case of no mailbox being present, upon their porch, weighted down by a rock. If the resident was home, the primary researcher would introduce herself, remind the resident of the project, and hand them the questionnaire, requesting that they complete it and mail it back using the included stamped and addressed envelope. Returned questionnaires were mailed to the School of Planning, collected by staff members, and picked up by the primary researcher on a weekly basis over a three month period.

3.6 Data Preparation

Answers to the questions that employed a 6-point Likert scale response type were processed as follows: Answers were coded -2 for “strongly disagree”, -1 for “disagree”, 0 for “neutral”, 1 for “agree”, and 2 for “strongly agree”. Some questions were worded in negative form and answers were inverted to maintain consistent coding. A ‘do not know’ answer option was also available. ‘Do not know’ options have to be treated with caution for attitude-based questions, as participants can often use them in lieu of providing an honest answer (Beatty et al., 1998). ‘Do not know’ answers can either be coded the same way the neutral option is coded, or they can be replaced with the average answer of respondents. In the current study, the ‘do not know’ answer option was coded 0. A value for each unanswered question was calculated as the average response for the question within the neighbourhood. The average calculation was limited to the neighbourhood level to enable comparisons between neighbourhoods.

3.7 Data Analysis

The questionnaire results were analyzed with Partial Least Squares Structural Equation Modelling (PLSPM). The latent variables within the model represent the TPB constructs including behavioural beliefs, attitude, etc. Latent variables cannot be measured directly and require manifest variables, which can be measured, to indirectly measure the latent variables’ value (Sanchez, 2013). In this case, the manifest variables are represented by the questions within the questionnaire. The inner path model represents the latent variables, which are the TPB constructs. The outer path model represents the manifest variables (Figure 4).

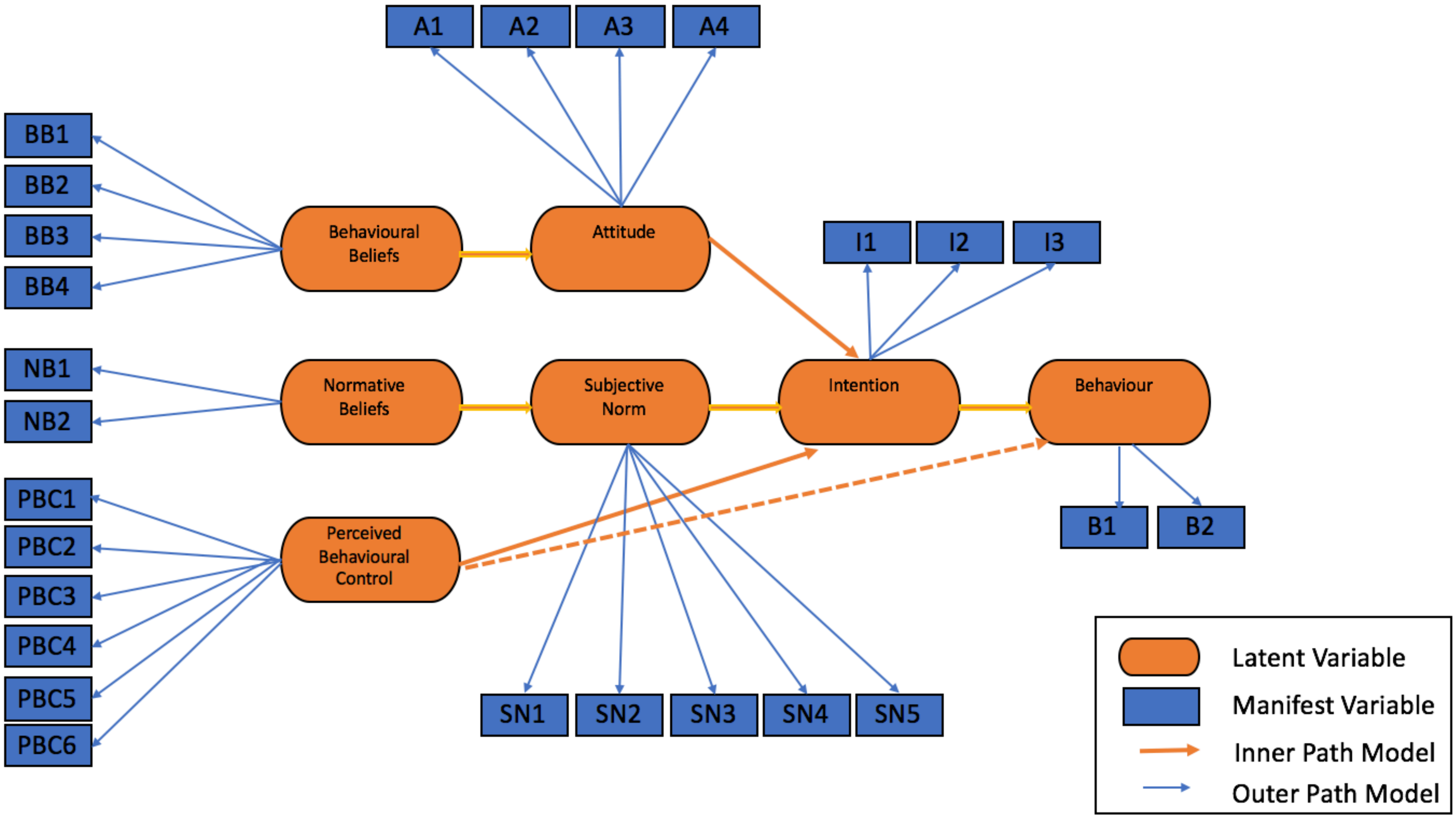

Figure 4: Diagram indicating the latent and manifest variables and the inner and outer path models for the Partial Least Squares Path Model for the Stormwater BMP questionnaire using the Theory of Planned Behaviour.

PLSPM was performed using the 'plspm' package by Gaston Sanchez (2013) in the statistical analysis software R (R Core Team, 2013). PLSPM was used because it is a 'statistical method for studying complex multivariate relationships among observed and latent variables' (Sanchez, 2013 pg. 3). The results from a PLSPM provide the researchers with quantifiable results that represent the cause and effect of the connections within the model. Due to the use of the TPB as the social-psychological force that drives the participants' behaviour, a complex model was required to analyze if there were any statistically significant links between participants' attitude or beliefs and their intention and behaviour. The PLSPM analysis was first performed using all 51 of the original TPB questions within the distributed questionnaire. Inner model results, including the path coefficients for each given path effect and the coefficient of determination for each latent variable, were calculated. The inner path model is represented by the latent (unobserved) variables, which in this case, includes behavioural beliefs, attitude, subjective norm, normative beliefs, perceived behavioural control, control beliefs, intention and behaviour. The outer path model is represented by the manifest variables, which are the observable variables and can be summed to find an approximate representation of a specific latent variable (Figure 4).

The inner matrix for the PLSPM was determined based on Ajzen's TPB (Ajzen, 1991). The control beliefs section within the TPB was removed, due to the lack of appropriate control belief questions found within the questionnaire. The possible link between perceived behavioural control and behaviour, was determined to be appropriate for inclusion within the inner matrix. Ajzen and Fishbein's (1980) original base for the TPB, the Theory of Reasoned Action, does not contain the link between perceived behavioural control and behaviour. The link between perceived behavioural control and behaviour is both direct, through a direct link, and indirect, through a link through attitude. The direct path is important for the model, since it can be thought to reflect the control an individual has over performing a certain action or behaviour (Madden et al., 1992). The PLSPM was performed both using the direct link between perceived behavioural control and behaviour, and without the direct link. Previous research has shown that the model with the direct link between the two latent variables is the most appropriate, and was therefore the inner matrix that was used in the model as reflected in the results (Armitage and Conner, 2001; Fishbein and Ajzen, 2010).

The PLSPM provides many robust statistical results. All questions were evaluated based on the model's loading and weight values that it assigned to each question. Loading values over 0.7 are considered acceptable, and all questions with a loading value greater than 0.7 remained within the analysis. All questions with a loading value below 0.7 were removed, with the exception of five questions that had loading values close to 0.7 (0.604-0.680). An acceptable loading value justifies leaving the manifest variable within the model in further iterations (Sanchez, 2013). Due to the loading and weight values, as well as the appropriateness of each question, the number of questions to be included in subsequent analyses was narrowed down to 26, and some questions were re-organized into different sections of the TPB (Table 4).

The PLSPM provides a goodness of fit value. The goodness of fit value is a measure of the degree to which the model predicts the outcomes established through the participants' responses to the questions. Goodness of fit values are considered acceptable if they are over 0.7, however prediction values for social-psychological studies are often lower due to the difficulty associated with predicting human behaviour (Sanchez, 2013). The goodness of fit value can be considered the overall prediction value for the performance of the model, including both the inner and outer path models (Sanchez, 2013).

The PLSPM provides multiple statistical results that can be used to measure the unidimensionality of the model. Unidimensionality indicates how well the manifest variables reflect the latent variables (Sanchez, 2013). Three main indices are used to calculate the unidimensionality, including Crohnbach's alpha, Dillon-Goldstein's rho, and the eigenvalues. The Crohnbach's alpha measures how well a block of manifest variables correspond to their latent variable (Sanchez, 2013). A Crohnbach's alpha of 0.7 or higher is considered acceptable. Dillon-Goldstein's rho calculates the sum of the manifest variables in a specific block. A block is a group of manifest variables that all correspond to the same latent variable. A Dillon-Goldstein's rho of 0.7 or higher is considered acceptable. Dillon-Goldstein's rho is considered a better indicator of unidimensionality than Crohnbach's alpha (Sanchez, 2013). The third indices are the eigenvalues. The PLSPM provides the first eigenvalue and the second eigenvalue. The first eigenvalue is considered more important than the second and should be much higher than the second, which will indicate that a model is unidimensional (Sanchez, 2013).

The PLSPM provides the coefficients of determination (R^2) value for each latent variable. Latent variables with no preceding connecting latent variables (i.e. behavioural beliefs, normative beliefs, and perceived behavioural control) all will have an R^2 value of 0.00 because R^2 values can be used to determine what percentage of variance in a variable can be explained by the associated latent variables (Sanchez, 2013). All latent variables with preceding associated latent variables will have an R^2 value. Low R^2 values are considered to be below 0.2, moderate R^2 values are considered to be between 0.2 and 0.5, and high R^2 values are considered to be above 0.5, however this scale is not absolute, and can vary based on the type of study being performed (Sanchez, 2013). Higher R^2 values mean that a larger amount of the variance in the latent variable can be explained by the connected preceding latent variables, confirming the appropriateness of the theoretical model and the chosen questions.

The PLSPM provides all path effect values, whether the paths are direct or indirect. If the PLSPM framework shows a direct arrow pointing from one variable to another, the effect is direct. If the effect must go through another variable to affect a specific variable, the effect is indirect. Most effects are either direct or indirect, however the path of perceived behavioural control to behaviour is both direct and indirect due to two directional arrows exiting from perceived behavioural control and going in two different directions in the theoretical framework (Figure 4).

A bootstrap validation test was performed on the 26 TPB questions in order to ensure that the values inputted into the model were valid. The bootstrap validation test identifies how precise the parameter estimates are. The bootstrap validation test provides results for both the inner and outer model, including the outer model's weights and loadings and the inner model's path effects. The bootstrap validation was also performed using a 'plspm.group' code, in order to calculate if the differences between path coefficients were statistically significant between the three neighbourhood groups. The group code can only be performed with two data groups, so it was performed three times to perform all pairwise comparisons (Neighbourhood 1 vs. Neighbourhood 2, Neighbourhood 1 vs. Neighbourhood 3, and Neighbourhood 2 vs. Neighbourhood 3).

Additional statistical analysis was performed using the data package XLSTATS in Microsoft Excel 2016 to calculate demographic statistics for each neighbourhood (Table 2). A MANOVA one-way test was used to determine if there are any significant differences between neighbourhoods. The MANOVA test was applied to the 26 TPB questions and the eight knowledge questions. Discriminant Analysis was further used to determine how each neighbourhood differed from the other neighbourhoods.

Due to the sampling procedure utilized, it is not possible to assess the nonresponse bias that could occur based on the population sample who chose not to respond to the questionnaire. The continuum of resistance model was used to understand the characteristics of the non-responders by comparing late responders to early responders (Lin and Schaeffer, 1995). The respondents were divided into two groups based on their response time (early responders: within one month after receiving the questionnaire; late responders: over one month after receiving the questionnaire) and these groups were compared based on their gender, age, education level, income, time in residence, and their tenure type. Two sample t-tests assuming unequal variance were used to compare early responders with late responders.

Lastly, a secondary analysis was performed on select questions from the Stormwater BMP Questionnaire comparing the three study neighborhoods pairwise. The seven questions chosen were related to learned knowledge about green infrastructure, finances available to install and maintain green infrastructure, and time available to install and maintain green infrastructure. A two-sample t-test assuming unequal variance was used for all comparisons. The tests were performed to determine if knowledge, finances or time are limiting factors affecting one's willingness and ability to install and maintain green infrastructure on their private property.

3.8 Ethics and the Office of Research Ethics Approval Process

The University of Waterloo's Office of Research Ethics' approval process was completed before rollout of the pilot survey rollout commenced. The Office of Research Ethics requires a copy of all recruitment information, feedback forms, questionnaires, and any other material that members of the public will view in regard to the study. The purpose, methodology and study area were all clearly described, along with all recruitment and remuneration procedures. Recruitment for this survey was on a voluntary basis and participants agreed to participate by mailing a completed questionnaire to the School of Planning. Due to the anonymous nature of the survey, residents were not required to fill out any participation forms. No remuneration was offered. All risks to participants were identified and a description of how risks will be mitigated or addressed was included. The application explained how the anonymity of participants will be protected and how all collected data will be kept confidential. Approved research must be renewed every 12 months. The Office of Research Ethics must receive a renewal report before the expiry date of the ethics clearance.

Ethics clearance was received for ORE#21801 on October 25, 2016, and renewed on August 10, 2017. All returned questionnaires must be shredded upon completion of the data analysis for this study. All recruitment materials are attached in the appendices of this thesis.

4.0 Results

A total of 258 houses were visited and 251 questionnaires were successfully distributed, 115 questionnaires were left with residents (45%) and 136 questionnaires were left in mailboxes or on front porches (53%) (Table 2). Seven of the 258 houses visited were excluded (3%) due to questionnaire refusal at the door. Between the period of February 14, 2017 to April 12, 2017, 88 questionnaires were returned resulting in a response rate of 35.2%. The majority of all questions in returned questionnaires were answered; only 83 questions (1%) out of a total of 6,600 questions in the 88 questionnaires were left unanswered.

Table 2: Survey rollout results for the Stormwater BMP questionnaire study in Dundas, Ontario.

	Houses Visited	Questionnaires left with resident	Questionnaires left in mailbox	Questionnaires refused	Number of Responders
Neighbourhood 1	86	36	45	5	22
Neighbourhood 2	87	32	55	0	38
Neighbourhood 3	85	47	36	2	28
Total	258	115	136	7	88

Out of the 88 participants, 77 answered all demographic questions, with only one participant answering none of the demographic questions. Across the three neighbourhoods, the majority of participants (n= 86) were female (59.3%) and between the ages of 51 to 65 years (47%) (Table 3). The most common education level was an undergraduate degree (32%), and the most common household income was over $90,000 per year (58%). The most common length of time living in the residence was 10-15 years (24%) and the majority of participants were homeowners (95%) (Table 3).

The PLSPM analysis resulted in a goodness of fit value of 0.4819, resulting in the predictive power of the model of 48%. The results from the outer path model show that 21 of the

26 questions have a loading value that is greater than 0.7, which is the standard acceptable value for indicator variables within a PLSPM model (Figure 5, Appendix 4 [Table 1]). The inner path model provides results for the model's Crohnbach's alpha, Dillon-Goldstein's rho, the eigenvalues and the R^2 (Appendix 4 [Table 2]). All latent variables had a Crohnbach's alpha higher than 0.7, except for normative beliefs, which had a Crohnbach's alpha of 0.2704. All latent variables had a Dillon-Goldstein's rho greater than 0.7. All latent variables also had a much higher 1st eigenvalue than the 2nd eigenvalue, indicating statistical significance (Appendix 4 [Table 2]).

Table 3: Demographics of participants in three study neighborhoods in Dundas, Ontario.

Demographic variable	Pilot/Neighbourhood 1	Neighbourhood 2	Neighbourhood 3
Gender	20/22 answers	38/38 answers	28/28 answers
Male	25%	39%	54%
Female	75%	61%	46%
Age	19/22 answers	36/38 answers	26/28 answers
18-35	0%	11%	0%
36-50	26%	11%	31%
51-65	42%	53%	42%
65+	32%	25%	27%
Education	20/22 answers	38/38 answers	28/28 answers
No diplomas	0%	3%	4%
High School	15%	13%	7%
College	20%	39%	18%
Undergrad	40%	21%	36%
Grad	25%	18%	21%
PhD	0%	5%	7%
Other	0%	0%	7%
Household Income	16/22 answers	36/38 answers	27/28 answers
<30,000	6%	8%	4%
30,000-49,999	19%	33%	0%
50,000-69,999	13%	8%	4%
70,000-89,999	6%	17%	7%
>90,000	56%	33%	85%
Length of time at current residence	21/22 answers	38/38 answers	28/28 answers
<1 year	0%	8%	0.00%
1-5 years	5%	18%	14%
6-10 years	24%	11%	29%
11-15 years	24%	18%	29%
16-20 years	14%	13%	7%
>20 years	33%	32%	21%
Type of tenure	20/22 answers	38/38 answers	28/28 answers
Own	100%	89%	96%
Rent	0%	8%	4%
Other	0%	3%	0%

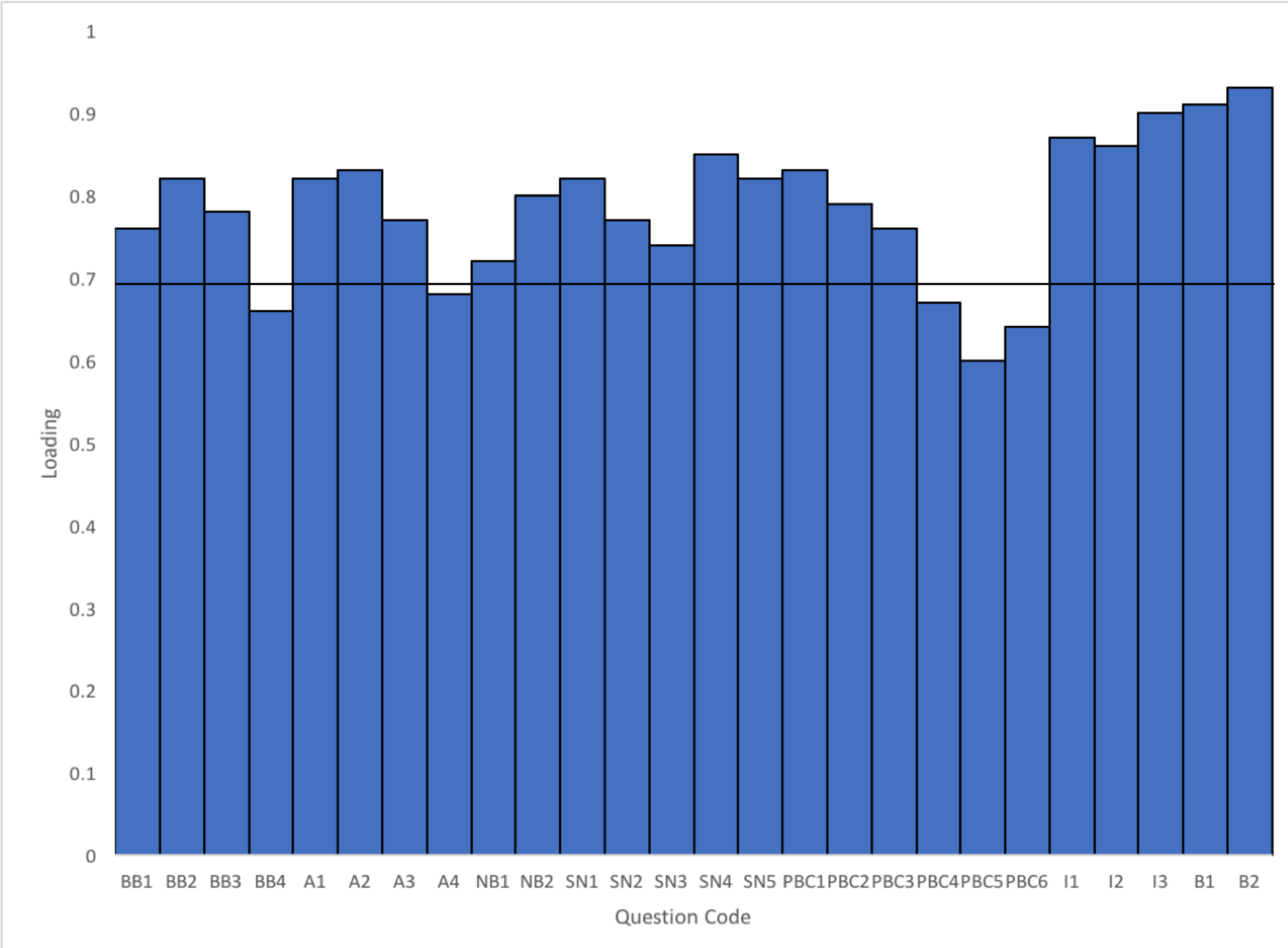

Figure 5: Loadings from the Partial Least Squares Path Model for the Stormwater BMP questionnaire study.

The inner and outer model results showed strong relationships between many of the latent variables and all of the manifest variables (Figure 6). The path coefficients for the inner model suggest that behavioural beliefs have a strong effect on attitude (0.542). Equally strong is the effect of subjective norm on intention (0.542). The next two strongest relationships are normative beliefs' effect on subjective norm (0.455) and intention's effect on behavior (0.451). Perceived behavioural belief has effects of intermediate strength on intention (0.252) and on behaviour (0.260). The effect of attitude on intention is weak (0.034). The majority of the manifest variables (80.8%) had loading values greater than 0.7, and the five manifest variables with lower loading values were all close to 0.7 (0.604-0.682) (Figures 5 & 6).

The two highest coefficients of determination (R^2) were found for intention and behaviour (R^2 = 0.571 and 0.417, respectively) (Figure 6). The lowest coefficients of determination (R^2) were found for attitude and subjective norm (R^2 = 0.294, 0.207) (Figure 6). Coefficients of determination (R^2) for behavioural beliefs, normative beliefs, and perceived behavioural, could not be calculated (i.e., resulting in values of 0.000) because there are no preceding connected latent variables contributing to these specific latent variables.

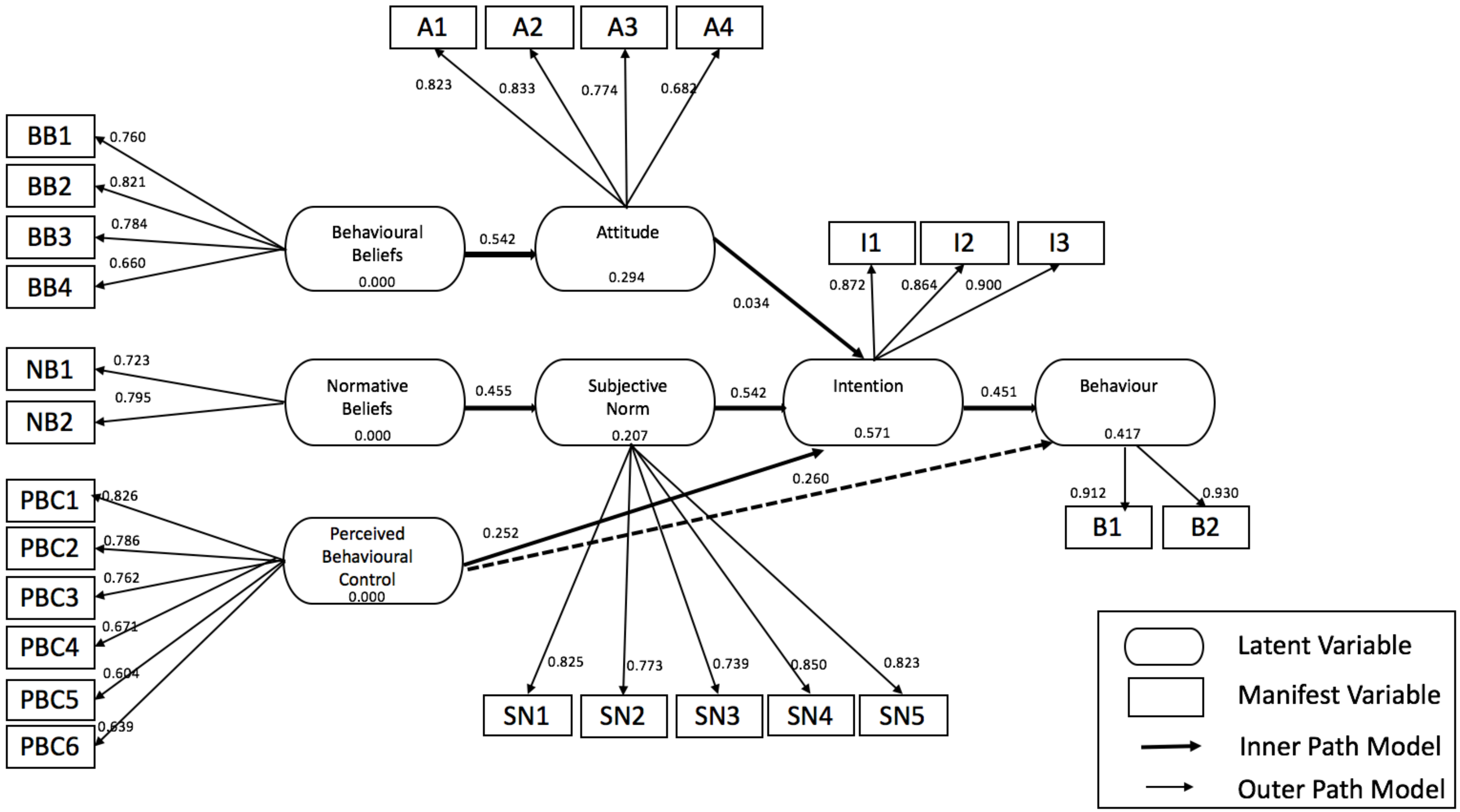

Figure 6: Diagram of the Partial Least Squares Path Model for the Stormwater BMP questionnaire study with path coefficients, R^2 values and loading values for the inner and outer model. The values close to the outer paths are loading values, the values within the latent variables are R^2 values, and the values close to the inner paths are path effects.

The two highest direct path effects for inner model connections were found for subjective norm to intention and behavioural beliefs to attitude (0.5423 and 0.5419, respectively) (Figure 7). The lowest direct path effect for the inner model was found for the attitude to intention connection (0.0341). The highest indirect path effects for inner model connections were found for the normative beliefs to intention and subjective norm to behaviour connections (0.2466, 0.2465, respectively) (Figure 7). The lowest indirect path effect was found for the connection from behavioural beliefs to behaviour (0.0083) (Figure 7).

A bootstrap validity test was run using 200 resamples in order to determine the validity of the model. The bootstrap test showed that all paths are statistically significant except for the following four paths: 1) behavioural beliefs to intention, 2) behavioural beliefs to behaviour, 3) attitude to intention, and 4) attitude to behaviour (Appendix 5 [Table 1]). All loading and weight values for individual questions were statistically significant (Appendix 5 [Table 2]). The group bootstrap validity test found no significant differences in path coefficients between any of the three neighbourhoods tested with pairwise comparisons (Neighbourhood 1 vs. Neighbourhood 2, Neighbourhood 1 vs. Neighbourhood 3, or Neighbourhood 2 vs. Neighbourhood 3) (Appendix 4 [Tables 1, 2 & 3]).

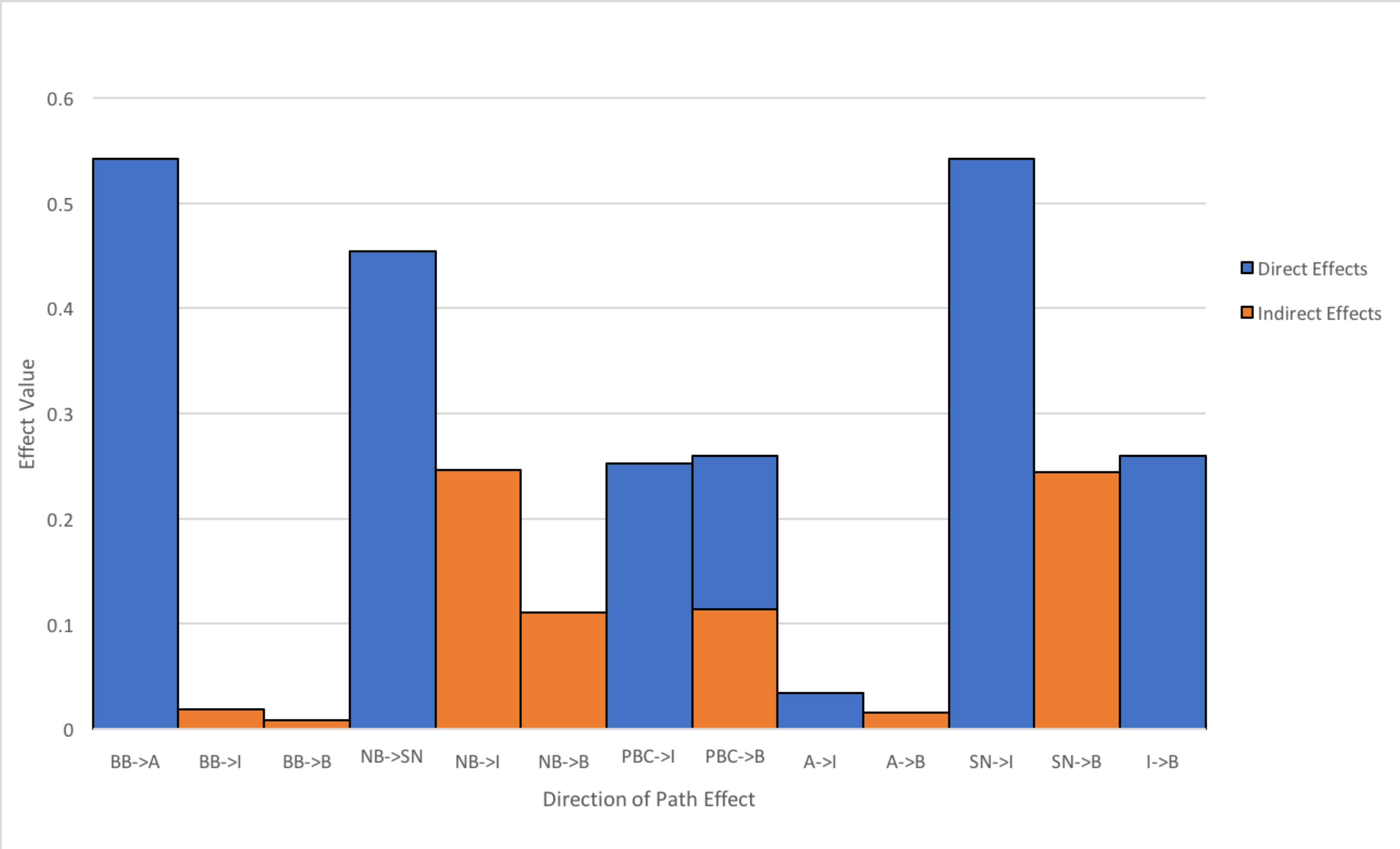

Figure 7: Direct and indirect path effects of the Partial Least Squares Path Model for the Stormwater BMP questionnaire study.

The results from the one-way MANOVA tests were ambiguous regarding the potential for differences in question answers between the three neighbourhoods. Three of the tests did not indicate significant differences, though the test values approached significance (Wilk's Test, p=0.072; Hotelling-Lawley's test, p=0.067; and Pillai's test, p=0.077). One test did indicate a significant difference (Roy's test, p=0.013) (Appendix 7 [Table 1]). While the tests overall do not provide strong evidence for a difference in question answers between the neighbourhoods, there seems to be the potential that such a difference exists.

The discriminant analysis results show that the three neighbourhoods are poorly distributed on the factor axes (Figure 8), suggesting that there are no strong differences between the neighbourhoods. The results for the two Box tests (Chi Square test and Fisher's f test), Kullback's test, Wilks' Lambda test, Pillai's trace and Hotelling-Lawley trace, all show non-significant results (p = 0.457, 0.471, 0.998, 0.072, 0.077, 0.069, respectively) (Appendix 8 [Table 1]). These results suggest that there is no significant difference between the neighbourhoods with regard to answers for each section of the questionnaire.

The two-sample t-tests for differences in demographics between study neighborhoods showed a significant difference in income (neighbourhood 1 vs. neighbourhood 3: t=-2.1523, p=0.043; neighbourhood 2 vs. neighbourhood 3: t=-46.42, p<0.001) and a significant difference in gender (neighbourhood 1 vs. neighbourhood 3: t=2.0684, p=0.045) (Table 4). All other comparisons were non-significant.

The two-sample t-test for differences between study neighborhoods in knowledge, finances or time available showed several significant differences (Appendix 9 [Table 1]): Question K2 ("formal BMP education") - neighbourhood 1 vs. neighbourhood 2: t=4.1355, p<0.001; neighbourhood 1 vs. neighbourhood 3: t=3.5829, p=0.001. Question PBC4 ("insufficient time for rain garden") - neighbourhood 1 vs. neighbourhood 3: t=3.3164, p=0.032. Question PBC6 ("BMPs too expensive") - neighbourhood 1 vs. neighbourhood 2: t=2.3924, p=0.020; neighbourhood 1 vs. neighbourhood 3: t=3.1961, p=0.002. None of the other comparisons were significant.

The two-sample t-test for differences between early and late responders did not show significant differences terms of gender, age, education, income, or tenure type (Table 5). However, early and late responders did differ in their time in residence (t=2.8669, p=0.008) with early responders having lived longer in their current residence than late responders (Table 5).

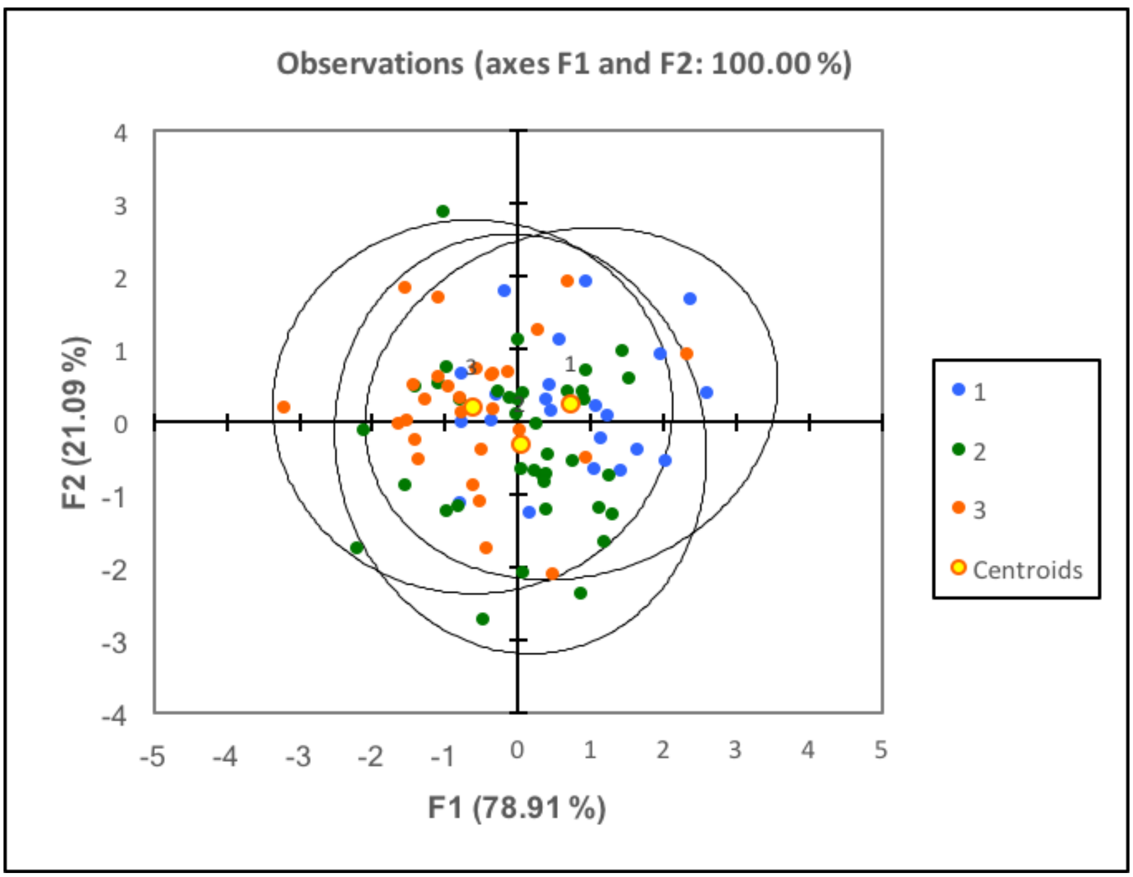

Figure 8: Discriminant analysis results comparing the three study neighbourhoods using answers to the Stormwater BMP questionnaire.

Table 4: Results from two sample t-tests comparing demographics across the three study neighbourhoods. Shown are t-values and corresponding p-values for the three pairwise comparisons between the study neighbourhoods.

	Neighbourhood 1 vs 2		Neighbourhood 1 vs 3		Neighbourhood 2 vs 3	
	t-value	p-value	t-value	p-value	t-value	p-value
Gender	1.1328	0.264	2.0684	0.045	1.1262	0.265
Age	-0.0120	0.990	0.5611	0.578	0.6034	0.548
Education	0.6005	0.552	-1.1218	0.268	-1.8025	0.077
Income	1.0656	0.296	-2.1523	0.043	-4.6542	<0.001
Time In Residence	0.9044	0.372	1.2533	0.217	0.3252	0.746
Tenure type	-1.9591	0.058	-1.0000	0.326	1.2603	0.213

Table 5: Results from two sample t-tests comparing early to late responders. Shown are t-values and corresponding p-values for comparisons of six demographic questions in the Stormwater BMP Questionnaire.

	t-value	p-value
Gender	0.2259	0.823
Age	1.6709	0.103
Education	-1.6166	0.114
Income	-1.4620	0.153
Time In Residence	2.8669	0.008
Tenure type	-1.8776	0.074

5.0 Discussion

The analyses of the survey results indicate the importance of a resident's beliefs and control factors for predicting behaviour in regard to the installation of green infrastructure on the resident's private property. The goodness of fit for the PLSPM represents the overall effectiveness of the model; in this study the model predicts 48% of the variance shown in a resident's behaviour. Typical acceptable goodness of fit values are greater than 0.7 (70%), however many factors can contribute to a lower goodness of fit value (Sanchez, 2013). The TPB has been criticized in the past for providing low subjective norm scores, which can contribute to an overall low goodness of fit (Armitage and Conner, 1999). In this study, subjective norm had the lowest coefficient of determination score when compared to the other latent variables (R^2 = 0.207), however, the subjective norm path effect to intention was strong (path coefficient = 0.542) (Figure 6). Additionally, respondents in questionnaire style surveys can interpret the questions individually, which can lead responses to differ between participants (Armitage and Conner, 1999). Both of these factors will reduce the overall effectiveness score of the model, but the model variables can be assessed individually through the coefficients of determination, path effect values and loading values. Despite some criticisms, the TPB, when assessed through a questionnaire style survey, can be a very effective way to understand and quantify environmental behaviour and decisions (Chao, 2012; Wauters et al., 2010).

The TPB is a popular theoretical framework choice in environmental behaviour studies and in many other social science fields (Chao, 2012; Moan and Rise, 2011; Wauters et al., 2010). The TPB is an effective choice for social science research because it can be manipulated through the questions provided in the questionnaire to elucidate specific behavioural controls (Armitage and Conner, 1999). In this research, the TPB was used to determine if behavioural controls such as time, finances and attitudes were barriers to the implementation of stormwater green infrastructure. Intention is considered to be one of the strongest predictors of behaviour in an individual's decision making process (Ajzen, 1991). The results from the PLSPM for the TPB show a strong link between intention and behaviour (path coefficient of 0.451) (Figure 6). The TPB has three independent predictors of intention (attitude, subjective norm and perceived behavioural control) (Ajzen, 1991). Of these three independent predictors of intention, subjective norm had the strongest effect on intention (path coefficient = 0.542). The subjective norm in this study relates to how much pressure the person feels to perform the behaviour. Social pressure can be experienced through many relationships, either from neighbours, friends and family, or from the government.

Past environmental behaviour research has shown the TPB to be an effective model for predicting one's behaviour and intention in regard to specific environmental behaviours. Chao (2012) compared the TPB with another popular theoretical framework, the model of responsible environmental behaviour (REB) (Hines et al., 1986; Hines et al., 1987), using past studies to perform the analysis. The highest variance values that Chao (2012) was able to identify came from Kaiser et al.'s (2005) study of conservation behaviour, where the results showed that the TPB could explain 76% of the variance in behaviour and 95% of the variance in intention. Kaiser et al. (2005) compared the TPB to the value-belief-norm model (VBN) (Stern, 2000), and found that the predictive capability of the TPB was much higher than the predictive capability of the VBN (95% compared to 64%). The researchers found the TPB was able explain concepts more fully than the VBN, and was overall the better choice of models for predicting conservation behaviour (Kaiser et al., 2005).

The results from this study showed that the TPB explains 57% of the variance in intention and 42% of the variance in behaviour (Figure 6). The values for the variance in intention and behaviour found in the results of this study are fairly strong results, especially when compared with Armitage and Conner's (2001) meta-analysis on TPB studies. Armitage and Conner (2001) found that, on average, the TPB can account for 39% of the variance in intention and 27% of the variance in behaviour. However, Ajzen (2011) stated that correlations between behavioural intent and actual behaviour cannot be expected to exceed 60% in behavioural studies, due to measurement errors that will occur even in the most carefully conducted research. The correlation between intent and behaviour for this study was lower than 60%; intent predicted 45% of the variance in behaviour (Figure 6).

Wauters et al. (2012) performed multiple iterations of regressions on results from a TPB study on the adoption of soil conservation practices. They found that the results from the TPB varied depending on which type of conservation practice was studied, resulting in the predictive power of intention ranging from 44% to 70%. Wauters et al. (2012) found that intention was the dominant explanation of variance in behaviour, and that the other sources (e.g., perceived behavioural control) did not contribute as strongly to behaviour. Similar results were found within this study, as shown by intention's coefficient of determination (R^2= 0.571), which is the highest when compared to the other latent variables. However, the results of this study indicated that subjective norm had the strongest direct path effect on intention (0.542), higher even than intention's direct effect on behaviour (0.451) (Figure 6). These results can be interpreted to indicate that intention is strongly influenced by the preceding variables, as indicated by the high coefficient of determination, subjective norm is the strongest contributor to intention's coefficient of determination. Wauters et al. (2012) found that perceived behavioural control had the lowest contribution to behaviour out of all the theoretical framework constructs. The Stormwater BMP Questionnaire TPB results displayed a similar outcome when examining the contribution of perceived behavioural control. Perceived behavioural control had the lowest direct effect on behaviour (0.260) and the second lowest indirect effect on behaviour (0.252) when compared to the other constructs (Figure 6). Attitude had the lowest indirect effect on behaviour (0.034).

The TPB model used for this study can account for 57.1% of the variance in intention, which puts this model at the higher end in regard to models' predictive ability, when compared to other studies (Armitage and Conner, 2001). The strongest contributor to predicting intention was subjective norm (path effect = 0.542) and the weakest was attitude (path effect = 0.034). These results suggest that if study participants feel social pressure to install green infrastructure options on their property, then they are much more likely to intent to do it. The results also suggest that the effect of social pressure is much stronger than participants' beliefs about the impacts of green infrastructure. The effect of perceived behavioural control (i.e., beliefs about participants' actual ability to implement green infrastructure) fell into the middle of the other two constructs (0.252). This result suggests that participants might view factors such as finances and available time as potential constraints to the installation of green infrastructure on their properties. Attitude (i.e., beliefs about the impacts of green infrastructure) had the weakest effect, meaning that participants' beliefs about the potential for unpleasant side-effects (e.g., increased pests) or the efficacy of green infrastructure (e.g., reduced pollution and/or reduced flooding), did not contribute much to their overall intention to install green infrastructure on their properties.

The results from this application of the TPB for predicting green infrastructure implementation can be compared to other studies of pro-environmental behaviours. Nigbur et al. (2010) used the TPB to predict residents' intention to use curbside recycling in Surrey, United Kingdom. This study added neighbourhood identification and self-identity, which is a culmination of roles fulfilled by the participant (i.e. as a parent, as a friend, etc.), to the model, and the results suggest that the model was able to predict 65% of the respondents' intention to recycle. Nigbur et al.'s (2010) use of the TPB to predict recycling provided similar results to Wauters et al.'s (2010) of soil conservation practices, with a poor predictive effect of perceived behavioural control on intention and behaviour. Nigbur et al.'s (2010) results suggested that intention, self-identity and subjective norm had the strongest effects on behaviour. These results are similar to the results of the current research, considering that intention had the strongest direct effect on behaviour (path effect = 0.451) and subjective norm had the strongest indirect effect (path effect = 0.542) (Figure 6).

The TPB is not only used in the research of pro-environmental behaviours. It can also be used to predict intent to perform certain tasks, such as eating breakfast, or to avoid certain behaviours, such as drinking and driving. Mullan et al. (2013), when testing adolescents' intent to consume breakfast, found that perceived behavioural control was the strongest indicator of intention, though all predictors showed significant effects. Mullan et al.'s (2013) results suggest that the TPB can predict 42.2% of the variance in intention of adolescents eating breakfast every morning. Moan and Rise (2011) also found that perceived behavioural control was the strongest predictor of intention when studying the intent of individuals to not drink and drive. However, the researchers determined that the model was not overly effective in accounting for individual's intentions, since the model could only account for 10% of the variance in intention (Moan and

Rise, 2011). Perceived behavioural control (path effect = 0.27) and attitude (path effect = 0.10) significantly impacted the intent of an individual, while subjective norm did not have a significant effect. Both of these studies suggest that under certain conditions perceived behavioural control can be the strongest indicator of intention, which differs from the results of Wauters et al. (2010) and Nigbur et al. (2010), who found that perceived behavioural control is a weak indicator of intention. Different results for different fields of research when using the TPB can be expected, as individuals are motivated by different factors when making decisions based on safety, health, or environmental conservation. Perceived behavioural control could be considered more important for diet and risk behaviour than for environmental behaviour because perceived behavioural control is weighted by control beliefs, indicating that individuals feel they have more control over actions that affect their lives personally, rather than actions where the consequences cannot be immediately seen by the individual (i.e. recycling) (Moan and Rise, 2011).

The current study resulted in a survey response rate of 35% (88 responses), which, when compared to similar studies, is relatively high. Babtiste (2014) and Babtiste et al. (2015) had survey response rates of 14.5% and 7.5%, with 229 and 208 respondents, respectively. Both Babtiste (2014) and Babtiste et al. (2015) had a higher number of respondents due to a higher number of households being surveyed. However, both of the studies had access to ample financial resources and volunteers, enabling expansive survey coverage. Nigbur et al. (2010) performed a much larger scale mail-back survey in Surrey, United Kingdom, which resulted in a response rate of 28.4%, with 531 respondents. The Nigbur et al.'s (2010) study also offered incentives, which is known to increase response rates.

Door-to-door surveys with mail-back questionnaires can result in low response rates (Czaja and Blair, 2005). Researchers often disregard mail back surveys as an adequate survey method because the resulting response rate is typically low, often under 15% (Prairie Research Associates, n.d.). However, response rates can be increased through multiple follow-up steps and the inclusion of a cover letter and addressed and stamped envelope (Prairie Research Associates, n.d.), which were measures taking in the current study.

Response rates vary based on which type of survey collection methodology is used (Czaja and Blair, 2005). Czaja and Blair (2005) discuss the merits of different types of survey methodology in their survey design book, suggesting that no single method can be considered superior to all other methods. The mail-back questionnaire method was used for the current study due to time and financial constraints. Several additional measures were taken in an attempt to increase response rates: The questionnaires were anonymous because participants often feel more comfortable answering sensitive questions if they know that their responses cannot be attributed to them individually (Czaja and Blair, 2005). The questionnaires were left with the participants to fill out on their own to decrease the feeling of pressure of a surveyor watching them. However, the drawback of this approach is that it can increase confusion if participants cannot ask the surveyor to clarify questions (Czaja and Blair, 2005). Despite the limitations of the mail-back questionnaire method, it was the most feasible option to obtain as many responses as possible, especially when compared to other options such as face-to-face interviews or telephone interviews.

Low survey response rates can increase the likelihood of non-response bias, which is a deviation from the population-level response due to non-random survey refusals (Groves, 2006). For example, if a questionnaire is apt to offend a participant, or bring about sensitive feelings, those who do not respond may have very different opinions than those who do respond. However, it is difficult to determine if non-response bias is affecting survey responses, since the researcher would have to know the characteristics of responders and of non-responders, as well as their responses to the questions (Groves, 2006). Previous studies suggest that response rates below 50% are subject to a stronger non-response bias than those with a higher response rate, however many factors may confound non-response bias (Groves, 2006). In the case of the Stormwater BMP Questionnaire survey results, late responders were tested as a proxy for non-responders and no significant difference was found between late responders and early responders (except for time in residence). Due to the non-sensitive nature of the questionnaire and the statistical results indicating no difference between late responders and early responders, it is concluded that the non-response bias for this study probably is low.

Demographics were assessed for their potential effects on survey responses. The largest number of participants were between the ages of 51-65 (46.9%) (Table 3). According to Statistics Canada, in 2011, 23.8% of Dundas' population was between the ages of 50 and 64, and 18.1% of Dundas, Ontario's population was over 65 (Statistics Canada, 2012). In the current study, the 51-65 age group contributed 46.9% of the returned questionnaires and the 65+ age group contributed 27.2% of the returned questionnaires. It appears that the respondents for this survey were overrepresented in the two higher age groups identified in the questionnaire. This allows the hypothesis that individuals in the two higher age groups (51-65 and 65+) were more likely to answer the survey, possibly due to an increased interest in stormwater best management practices. An alternative hypothesis is that older, retired people have more time to fill surveys compared to younger, working people.

The proportion of older residents answering the survey is in keeping with the results of Babtiste (2014). Babtiste (2014) found that a large proportion of people within the higher age groups answered the survey. Within her research, residents who had experienced past flooding were more likely to have a positive intention to install stormwater best management practices on their private property (Babtiste, 2014). Babtiste (2014) found that a higher percentage of the residents who had experienced past flooding in the survey area were in the older age group of the participants, explained by an increased likelihood of the older residents having lived for a longer time within the survey area.

Barriers to the installation of stormwater green infrastructure can occur at the local government level or at the individual resident level. Rowe et al. (2016) surveyed municipal officials in order to evaluate which municipalities in New Jersey were installing green infrastructure, and what the barriers to installation were. At the municipal level, the most common barriers are usually funding and a lack of public space, which is why most municipalities turn to private residents to install stormwater BMPs on their properties. Rowe et al. (2016) found that municipalities were mostly motivated by reducing stormwater runoff, and hindered by a lack of funding. Although the Rowe et al. (2016) study covered a different organizational level than the survey performed in Dundas, Ontario, (local government vs. individual resident) the results partially overlap. In the current study, barriers included a resident's attitude toward stormwater green infrastructure, amount of time to install and maintain stormwater green infrastructure, available finances to fund the purchase of stormwater green infrastructure and the resident's self-identified skill level to install and maintain stormwater green infrastructure were all researched.

The survey's demographic results show that most respondents are affluent, with the majority of the respondents indicating that their household income was $90,000 or higher per year (55.7%). The median total income for families in Ontario in 2015 was $81,480, indicating that many of the survey respondents had an above median household income (Statistics Canada, 2017d). Nevertheless, the results of the current study suggest that a resident's willingness and ability to install best management practices is limited by available finances. Clearly, just because many of the survey respondents were affluent, one cannot automatically assume that these households have ready surplus money to install green infrastructure. The housing prices in Dundas are among the highest in the Hamilton-Burlington area (Realtor's Association of Hamilton-Burlington, 2017), potentially implying high property maintenance costs including property tax, which might limit the extent of residents' discretionary spending. Of the survey respondents, 57% agreed that they would only install stormwater BMPs if there was financial assistance involved (average score = 0.52, standard deviation = 0.92), meaning that a majority of residents agreed that they would only install best management practices if some portion of the associated cost was compensated to them (Appendix 3 [Table 1]).

Two unrelated reasons might explain why respondents show resistance to spending money on stormwater green infrastructure: (i) respondents do not have the money to spend on this infrastructure or (ii) respondents have the money, but they are not willing to spend it on this infrastructure. Babtiste (2014) questioned participants if they would install stormwater green infrastructure on their property if it was provided for free, and found that participants would be more inclined to install rain gardens and plant trees, over other options such as porous driveways and rain barrels. Mayer et al. (2012) found that an economic incentive greatly increased the percentage of residents installing rain gardens and rain barrels on their property. Mayer et al.

(2012) found that the majority of residents in Shepard Creek, Ohio, would not be willing to pay for rain barrels or rain gardens. However, in this study rain barrels and rain gardens were offered for free to residents, and when the neighbourhoods were re-surveyed the following year, the percentage of respondents who stated that they would not pay for rain barrels or rain gardens had decreased by 16% and 9%, respectively (Mayer et al., 2012). It is suspected that this decrease in resistance to green infrastructure might be due to increased exposure to the infrastructure, from the survey and subsequent free instalment of green infrastructure (Mayer et al., 2012). Unfortunately, while the current study inquired into residents' willingness to pay for green infrastructure, it did not inquire residents' ability to pay for this infrastructure (because the corresponding questions had to be removed from the PLSPM analysis due to low loading values). Consequently, it is difficult to assess whether residents' resistance to the installation of green infrastructure is caused by unwillingness to pay or inability to pay.

Household incomes differed significantly between the three study neighbourhoods, with neighbourhood 3 having the highest income (85% of respondents indicate an <90,000 household income) (Table 3) and neighbourhood 2 having the lowest income (33%of respondents indicate an <90,000 household income) (Table 3) (neighbourhood 1 vs. 2: $t = 1.0656$, $p = 0.296$; neighbourhood 1 vs. 3: $t = -2.1523$, $p = 0.043$; neighbourhood 2 vs. 3: $t = -4.6542$, $p = <0.001$) (Table 4). As a secondary analysis, answers to three financial questions from the Stormwater BMP Questionnaire were analyzed and compared between the three study neighbourhoods. No difference was found between the neighbourhoods in ability to spend money on stormwater BMPs (neighbourhood 1 vs. 2: $t = 1.7659$, $p = 0.084$; neighbourhood 1 vs. 3: $t = 0.8066$, $p = 0.424$; neighbourhood 2 vs. 3: $t = -0.9766$, $p = 0.332$) (Question CB2, Appendix 9 [Table 1]). Neither was a difference found between the neighbourhoods in the desire to install stormwater

BMPs if there was a financial incentive (neighbourhood 1 vs. 2: $t = 1.9553$, $p = 0.056$; neighborhood 1 vs. 3: $t = 1.3503$, $p = 0.184$; neighbourhood 2 vs. 3: $t = -0.7073$, $p = 0.482$) (Question SN5, Appendix 9 [Table 1]). However, differences were found between the neighbourhoods in respondents' belief that stormwater BMPs are not affordable for them at this time (neighbourhood 1 vs. 2: $t = 2.3924$, $p = 0.020$; neighbourhood 1 vs. 3: $t = 3.1961$, $p = 0.002$; neighbourhood 2 vs. 3: $t = 0.6925$, $p = 0.491$) (Question PBC6, Appendix 9 [Table 1]). The results for the first two questions do not suggest differences between neighbourhoods in financial ability to install or maintain green infrastructure on private properties. However, the results for the third question suggest that respondents from neighbourhood 1, which had the second highest household income of the three neighbourhoods, feel the most limited by finances. The complexity of these results makes it difficult to draw clear conclusions about the role of finances in the installation of stormwater green infrastructure. Different phrasings of questions seem to elicit different patterns of responses and it is possible that other important factors were not captured in the questions. Further research is required to clarify the role of finances as a barrier to green infrastructure implementation.

Available time is another possible factor that could limit a resident's willingness or ability to install stormwater BMPs. Of the survey respondents, 56% stated they believed they had enough time to install and maintain stormwater BMPs (average answer = 0.286, standard deviation = 0.98) (Appendix 3 [Table 1]). Most participants (66%) indicated that they believed they would have enough time to install a stormwater BMP on their yard within the next year (average answer = 0.403, standard deviation = 0.89) (Appendix 3 [Table 1]). These results suggest that time might not be a limiting factor for the installation of green infrastructure on residential properties.

It could be hypothesized that residents who are still in the work force will have less time to install and maintain a green infrastructure option. However, the average age of respondents did not differ between the three neighbourhoods, making it difficult to investigate whether employment status (working vs. retired) can explain willingness to install green infrastructure. Answers to two time-related questions were further analyzed to determine if the three neighbourhoods differed in the amount of time available for installing and maintaining green infrastructure. No difference was found between the three neighbourhoods in respondents' available time for maintaining stormwater BMPs (neighbourhood 1 vs. 2: $t = 0.7802$, $p = 0.439$; neighbourhood 1 vs. 3: $t = 1.446$, $p = 0.155$; neighbourhood 2 vs. 3: $t = 0.7385$, $p = 0.463$) (Question CB3, Appendix 9 [Table 1]). However, differences were found between the neighbourhoods in respondents' available time to care for a rain garden on their property (neighbourhood 1 vs. 3: $t = 3.3164$, $p = 0.032$; neighbourhood 1 vs. 2: $t = 0.8615$, $p = 0.393$, neighbourhood 2 vs. 3: $t = 1.3776$, $p = 0.173$) (Question PBC4, Appendix 9 [Table 1]). As with the finance-related questions, the complexity of these results makes it difficult to draw conclusions about the importance of time availability for the installation of stormwater green infrastructure. Additional research would be required to clarify the role of time availability.

There are possible further factors that were not investigated in this research that may contribute to a resident's willingness to install stormwater green infrastructure. A low feeling of responsibility can be reasons that residents in municipalities with stormwater issues are not engaged in stormwater management on their properties. Keeley et al. (2013) found that members of the public typically did not understand the importance of stormwater BMPs and found the look of green infrastructure options unattractive. The participants in Keeley et al.'s (2013) study believed that it was the responsibility of the municipality to manage stormwater. In line with these results, the majority of participants in the current study (63%) indicated they believed that the municipal government should be solely responsible for the instalment and maintenance of stormwater BMPs (average answer = 0.580, standard deviation = 0.98) (Appendix 3 [Table 1]). Shelton et al. (2015) found that it is possible to change this mindset through free public education workshops. Shelton et al. (2015) established that education and exposure to stormwater BMP options increased participants' interest in the subject. Their survey results indicate that over 90% of workshop participants left the workshops with the intention to install a stormwater BMP on their property.

The three neighbourhoods in this study did not differ in education levels, and only a small portion of all respondents (17%) had been formally educated on green infrastructure. However, 43% of all respondents indicated that they had been informally educated on green infrastructure (Appendix 3 [Table 1]). Differences were found between the three neighbourhoods in the prevalence of informal education on green infrastructure (neighbourhood 1 vs. 2: $t = 4.1335$, $p = <0.001$; neighbourhood 1 vs. 3: $t = 3.5829$, $p = 0.001$; neighbourhood 2 vs. 3: $t = -0.1858$, $p = 0.853$) (Question K2, Appendix 9 [Table 1]). Neighbourhood 1 showed the strongest positive response in regard to informal green infrastructure education, which might be the result of previous outreach by the Hamilton-Halton Watershed Stewardship Program. One year prior to the current study, program staff canvassed this neighbourhood with educational brochures about residential stormwater BMPs. However, even though neighbourhood 1 scored highest on informal green infrastructure education, intention to install and maintain green infrastructure on private properties did not differ between the three neighbourhoods. The results suggest that informal green infrastructure education does not necessarily lead to increased willingness to install residential stormwater BMPs.

The results from the current research did not conclusively determine any specific barriers to the installation of stormwater green infrastructure. However, the analysis suggests that both subjective norm and perceived behavioural control beliefs play a significant role in a resident's intention to install green infrastructure. The results from this research can inform municipal policy-makers in their decisions about which social construct to target, if they want to encourage implementation of residential stormwater BMPs. For instance, attitude had a relatively weak effect on intention to install residential stormwater BMPs. Therefore, municipalities might not want focus on trying to change residents' attitudes about green infrastructure. Instead, municipalities might want to focus on managing perceived control factors such as finances and time. Subjective norm showed the strongest effect on a resident's intention to install green infrastructure. This result suggest a possible mechanism for municipalities to encourage implementation of residential stormwater BMPs. For instance, municipalities, conservation authorities, or not-for-profits, could focus their efforts on finding a 'champion' in each neighbourhood who will install green infrastructure. This champion might set an example that could impact other resident's intention to install green infrastructure on their own properties, because residents indicated it is important to them what others think of their actions. Programs would have to work toward making green infrastructure the social norm to encourage the majority of residents to implement green infrastructure options on their properties.

6.0 Limitations and Strengths

The research documented in this thesis was rigorously designed using a well-accepted theoretical framework, the TPB. Survey questions were formulated to map directly on social-psychological constructs in the TPB. This allowed for consistent integration of the results from all survey questions, their simultaneous analysis within the same theoretical framework, and clear interpretation of the results.

The PLSPM was used to analyze the survey questions using the TPB as theoretical framework that informs the relationships between the various variables. The PLSPM is a strong and rigorous tool for the analysis of theoretical frameworks. The PLSPM is able to take into account limitations that may be present while analyzing data because it makes no assumptions about data distribution or observation independence (Wong, 2013; Bass et al., 2003). However, the PLSPM does have some limitations. The PLSPM cannot model looped models or undirected effects, meaning that the TPB had to be adjusted to remove any looped connections (Sanchez, 2013, Wong, 2013). The PLSPM places loading values on all manifest variables, and only variables with a high loading value were kept for the analysis. Questions with low loading values had to be removed from the analysis, which reduced the data basis for quantification of some individual TPB constructs. However, removing questions with low loading values also strengthened the statistical rigour of the analysis.

Although the current research has many strengths, some limitations are worth mentioning. For instance, the sample size for this study was low, with only 251 questionnaires distributed, and 88 responses. Due to the small sample size, the ability to extrapolate to the population level is limited. However, the confidence interval was narrower than expected. The sample size was calculated with a confidence interval of 15%. However, due to a higher response rate than expected, the confidence interval was reduced to 10%.

The response rate, while high for a mail-back survey, was low when compared to other types of surveys (i.e. telephone surveys, internet surveys). The response rate might have been higher if incentives were offered to participants, however due to financial restraints, this was not possible. Having said that, the PLSPM is an appropriate model when the sample size is small (Wong, 2013), which made it a good choice for analyzing the data gathered in the current study.

Lower response rates increase the likelihood that there is a non-response bias. It is likely that the individuals who are interested in green infrastructure are the individuals who are the most likely to respond, and therefore a non-response bias may occur. The continuum of resistance model was used to address the non-response bias (Lin and Schaeffer, 1995). The model assumes that those who feel more resistance to answering the questionnaire, and therefore take longer to answer it, are similar to those who feel so much resistance to answering the questionnaire, that they do not answer it (Lin and Schaeffer, 1995). When respondents who answered the questionnaire within a month were compared to respondents who answered the questionnaire after a month, there was no statistical difference found in the respondent's gender, age, education level, income, or type of tenure. The only statistically significant difference was the length of time in the residence. More of the early responders were residents who had lived in the area for a long period of time. Therefore, the results may be biased towards residents who have lived in the neighbourhoods for longer periods of time. People who have been living in the neighbourhood for shorter periods of time might provide different answers.

An additional limitation to this study was the lack of follow-up with participants, due to the short-term nature of the study, resulting in the inability to observe the participants' future behaviour. To account for the lack of follow-up, past behaviour was used as a proxy for future behaviour. Past studies have either removed behaviour from the model (Moan and Rise, 2011; Rowe et al., 2016), or used an analysis of past behaviour to account for future behaviour (Ajzen, 2011). Past behaviour is a strong predictor of future behaviour (Ajzen, 2011). Studies have found that past behaviour can have a stronger effect on intention than all the other TPB constructs combined (Sandberg and Conner, 2008). However, the potential positive effect of an increased awareness of green infrastructure due to the answering of the survey cannot be studied at this time, since no follow-up questionnaire was issued.

7.0 Conclusion

The current was rigorously designed and implemented using a strong theoretical framework, the TPB. This framework was also used to interpret the gathered data. An advanced statistical approach was used to analyze the data. The TPB was thoroughly applied to investigate factors that might limit residents' willingness to install green infrastructure on private properties. The results indicated that perceived behavioural controls and subjective norm had the strongest effect on a resident's intention to implement green infrastructure on their properties. Planning for the adaptation and mitigation of climate change's effects can be a very difficult process for many municipalities. Climate change has resulted in an increased number of high intensity storms in many areas within North America. Green infrastructure can be used as a complementary option for municipalities, next to traditional grey infrastructure, to mitigate the negative impacts that occur from high intensity storms. Stormwater green infrastructure on private properties can greatly reduce the amount of polluted runoff that is flowing into local water bodies by increasing the amount of water that is absorbed on the properties and storing water for future use. To this end, residents require stronger efforts from municipalities to help them overcome the perceived barriers that negatively affect their intent to install green infrastructure. Residents are strongly affected by societal norms, which suggests that examples set by friends and neighbours might influence their behaviour. Municipal education and outreach programs might be able to engage residents to reinforce the concept of green infrastructure as a new norm in all neighbourhoods.

References

Ajzen, I. (1991). The theory of planned behavior. *Theories of Cognitive Self-Regulation, 50*(2), 179-211.

Ajzen, I. (2006). TPB Diagram. Retrieved from: http://people.umass.edu/aizen/tpb.diag.html.

Ajzen, I. (2011). The theory of planned behaviour: reactions and reflections. *Psychology & Health, 26*(9), 1113-1127.

Ajzen, I., and Fishbein, M. (1980). *Understanding Attitudes and Predicting Social Behaviour.* Englewood Cliffs, NJ: Prentice-Hall.

Ajzen, I. (n.d.). Constructing a Theory of Planned Behaviour Questionnaire. Retrieved from: https://people.umass.edu/aizen/pdf/tpb.measurement.pdf.

Alley, W.M., & Veenhuis, J.E. (1983). Effective impervious area in urban runoff modeling. *Journal of Hydraulic Engineering, 109*(2), 313-319.

Anderson, B.C., Watt, W.E., Marsalek, J., Ng, J., & Sneyd, B. (2008). Feasibility of the application of integrated stormwater management for land-restricted lakeside villages: the vase study of Portland, Ontario. *Canadian Water Resources Journal, 33*(3), 295-306.

Armitage, C.J., & Conner, M. (1999). Predictive validity of the theory of planned behaviour: The role of questionnaire format and social desirability. *Journal of Community & Applied Social Psychology, 9*, 261-272.

Armitage, C.J., & Conner, M. (2001). Efficacy of the Theory of Planned Behaviour: A meta-analytic review. *British Journal of Social Psychology, 40*(4), 471-499.

Babtiste, A.K. (2014). “Experience is a great teacher”: citizens’ reception of a proposal for the implementation of green infrastructure as stormwater management technology. *Community Development, 45*(4), 337-352.

Babtiste, 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.

Barbosa, A.E., Fernandes, J.N., & David, L.M. (2012). Key issues for sustainable urban stormwater management. *Water Research, 46*, 6787-6798.

Barron, D.N., West, E., Reeves, R., & Hawkes, D. (2014). It takes patience and persistence to get negative feedback about patients’ experiences: a secondary analysis of national inpatient survey data. *BMC Health Services Research*, 14, 153.

Bass, B.M., Avolio, B.J., Jung, D.I., & Berson, Y. (2003). Predicting unit performance using transformational and transactional leadership. *Journal of Applied Psychology, 88*(2), 207-208.

Beatty, P., Herrmann, D., Puskar, C., & Kerwin, J. (1998). "Don't know" responses in surveys: is what I want to know what you want to know and do I want you to know it? *Memory, 6*(4), 407-426.

Boyle, S.J., Tsanis, I.K., & Kanaroglou, P.S. (1998). Developing geographic information systems for land use impact assessment in flooding conditions. *Journal of Water Resources Planning and Management, 124*(2), 89-98.

Brander, K.E., Owen, K.E., & Potter, K.W. (2004). Modeled impacts of development type on runoff volume and infiltration performance. *Journal of the American Water Resources Association, 40*(4), 961-969.

Brauman, K.A., Daily, G.C., Duarte, T.K., & Mooney, H.A. (2007). The nature and value of ecosystem services: an overview highlighting hydrologic services. *The Annual Review of Environment and Resources, 32*, 67-98.

Chao, Y-L. (2012). Predicting people's environmental behaviour: theory of planned behaviour and model of responsible environmental behaviour. *Environmental Education Research, 18*(4), 437–461.

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R.K., Kwon, W.T., Laprise, R., Magaña Rueda, V., Mearns, L., Menéndez, C.G., Räisänen, J., Rinke, A., Sarr A., & Whetton, P. (2007). Regional Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

City of Hamilton. (2004). Storm Drainage Policy. Retrieved from: https://www.hamilton.ca/sites/default/files/media/browser/2014-12-18/storm-drainage-policy.pdf.

City of Hamilton. (2007). Stormwater Master Plan. Retrieved from: http://www2.hamilton.ca/NR/rdonlyres/67B80997-FED2-4E05-B6E6-D3524952700A/0/Feb19PW07021.pdf.

City of Kitchener. (2011). Stormwater Credit Policy. Retrieved from: https://www.kitchener.ca/en/livinginkitchener/Stormwater_Credit_Policy.asp.

City of Toronto. (2003). Wet Weather Flow Master Plan. Retrieved from: http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=f36807ceb6f8e310VgnVCM10000071d60f89RCRD&vgnextchannel=972bab501d8ce310VgnVCM10000071d60f89RCRD.

Cote, S.A., & Wolfe, S.E . (2014). Assessing the social and economic barriers to permeable surface utilization for residential driveways in Kitchener, Canada. *Environmental Practice, 16*(1), 6-18.

Côté, F., Gagnon, J., Houme, P. K., Abdeljelil, A. B. and Gagnon, M.-P. (2012). Using the Theory of Planned Behaviour to predict nurses' intention to integrate research evidence into clinical decision-making. *Journal of Advanced Nursing, 68*, 2289–2298.

Credit Valley Conservation. (n.d.). Grey to Green: Residential Land Retrofits. Retrieved May 3, 2016 from http://www.creditvalleyca.ca/wp-content/uploads/2015/01/Grey-to-Green-Residential-Guide1.pdf.

Czaja, R., and Blair, J. (2005). *Designing Surveys*. Pine Forge Press: A Sage Publications Company.

Dietz, M.E., & Clausen, J.C. (2008). Stormwater runoff and export changes with development in a traditional and low impact subdivision. *Journal of Environmental Management, 87*, 560-566.

Dillman, D.A. (1978). *Mail and Telephone Surveys: The Total Design Method.* John Wiley and Sons, Inc.: New York, United States.

Dillman, D.A. (1991). The design and administration of mail surveys. *Annual Review of Sociology, 17*, 225-249.

Dillman, D.A., & Christian, L.M. (2005). Survey mode as a source of instability in responses across surveys. *Field Methods, 17*(1), 30-52.

Environmental Protection Agency [EPA]. (2017). Urban Runoff: Low Impact Development. Retrieved from https://www.epa.gov/nps/urban-runoff-low-impact-development, July 16, 2017.

Environmental Protection Agency [EPA]. (2016). What is Green Infrastructure? Retrieved from: https://www.epa.gov/green-infrastructure/what-green-infrastructure#bioswales, August 1, 2017.

Environmental Protection Agency [EPA]. (2014). The economic benefits of green infrastructure, A case study of Lancaster, PA. Retrieved from: https://www.epa.gov/sites/production/files/2015-10/documents/cnt-lancaster-report-508_1.pdf, July 31, 2017.

Faehnle, M., Backlund, P. Tyrvainen, L., Niemela, J., & Yli-Pelkonen, V. (2014). How can residents' experiences inform planning of urban green infrastructure? Case Finland. *Landscape and Urban Planning, 130*, 171-183.

Fiquepron, J., Garcia, S., & Stenger, A. (2013). Land use impact on water quality: Valuing forest services in terms of the water supply sector. *Journal of Environmental Management, 126,* 113-121.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research.* Reading, MA: Addison-Wesley.

Fishbein, M., & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action approach*. New York: Psychology Press.

Fraser, L. (2017). Heavy rains, major flooding close about 10 streets in Dundas. The Hamilton Spectator. Retrieved from: http://www.cbc.ca/news/canada/hamilton/heavy-rains-major-flooding-close-about-10-streets-in-dundas-1.4078883.

French, A., Macedo, M., Poulsen, J., Waterson, T., & Yu, A. (n.d.). Multivariate analysis of variance (MANOVA). Retrieved from: http://online.sfsu.edu/efc/classes/biol710/manova/MANOVAnewest.pdf.

Gobel, P., Stubbe, H., Weinert, M., Zimmermann, J., Fach, S., Dierkes, C., Kories, H., Messer, J., Mertsch, V., Geiger, W.F., & Coldewey, W.G. (2004). Near natural stormwater management and its effects on the water budget and groundwater surface in urban areas taking account of the hydrogeological conditions. *Journal of Hydrology, 299*, 267-283.

Government of Canada. (2013). Reducing Flood Damage. *Environment and Climate Change Canada.* Retrieved from: https://ec.gc.ca/eau-water/default.asp?lang=En&n=72FDC156-1.

Green Communities Canada. (n.d.). RAIN. Retrieved May 4, 2016 from http://greencommunitiescanada.org/programs/rain/.

Groves, R.M. (2006). Nonresponse rates and nonresponse bias in household surveys. *Public Opinion Quarterly, 70*(5), 646-675.

Han, W.S. & Burian, S.J. (2009). Determining effective impervious area for urban hydrologic modeling. *Journal of Hydrologic Engineering, 14*(2), 111-120.

Hamilton Conservation Authority [HCA]. (n.d.). Water you doing to manage stormwater? Retrieved November 20, 2015 from https://conservationhamilton.ca/water-you-doing-to managestormwater/.

Hamilton Conservation Authority [HCA]. (2010a). Lower Spencer Creek Subwatershed Stewardship Action Plan 2010. 48 pp.

Hamilton Conservation Authority [HCA]. (2010b). Sulphur Creek Subwatershed Stewardship Action Plan 2010. 57 pp.

Hamilton Conservation Authority [HCA]. (2010). Spring Creek Subwatershed Stewardship Action Plan 2010. 51 pp.

Hayes, M. (2017). 'Tim's is almost underwater': Dundas waterlogged by heavy rain. The Hamilton Spectator. Retrieved from: https://www.thespec.com/news-story/7253949--tim-s-is-almost-underwater-dundas-waterlogged-by-heavy-rain/.

Henry J. Kaiser Family Foundation [KFF]. (2014). Urban Population (percent of total population living in urban areas). Retrieved from: http://kff.org/global-indicator/urban-population/.

Hines, J.M., Hungerford, H.R., & Tomera, A.N. (1986/87). Analysis and synthesis of research on responsible environmental behavior: A meta-analysis. *Journal of Environmental Education, 18,* 1–8.

Hoddinott, S.N., & Bass, M.J. (1986). The Dillman Total Design Survey Method: A sure-fire way to get high survey return rates. *Can Fam Physician, 32*, 2366-2368.

Hoffman, R.N., Dailey, P., Hopsch, S., Ponte, R.M., Quinn, K., Hill, E.M., & Zachry, B. (2010). An estimate of increases in storm surge risk to property from sea level rise in the first half of the twenty-first century. *American Meteorological Society, 2,* 271-293.

Jayasooriya, V.M., & Ng., A.W.M. (2014). Tools for modeling of stormwater management and economics of green infrastructure practices: a review. *Water Air & Soil Pollution, 225*(2055), 1-20.

Kaiser, F.G., Hübner, G., & Bogner, F.X. (2005). Contrasting the theory of planned behavior with the value-belief-norm model in explaining conservation behavior. *Journal of Applied Social Psychology, 35*, 2150–70.

Keeley, M., Koburger, A., Dolowitz, D.P., Medearis, D., Nickel, D., Shuster, W. (2013). Perspectives on the use of green infrastructure for stormwater management in Cleveland and Milwaukee. *Environmental Management, 51*, 1093-1108.

Kondo, M.C., Low, S.C., Henning, J., & Branas, C.C. (2015). The impact of green stormwater infrastructure installation on surrounding health and safety. *American Journal of Public Health, 105*(3), 114-121.

Lemieux, J. (2011). Stormwater Management: A Crisis Underfoot. *Spacing Magazine*. Retrieved from: http://spacing.ca/toronto/2011/02/11/storm-water-management-a-crisis-underfoot/.

Lin, N., Emanuel, K., Oppenheimer, M., & Vanmarcke, E. (2012). Physically based assessment of hurricane surge threat under climate change. *Nature Climate Change, 2*, 462-467.

Lin, I.-F., & N. C. Schaeffer. (1995). Using survey participants to estimate the impact of nonparticipation. *Public Opinion Quarterly 59*(2), 236-258.

Loperfido, J.V., Noe, G.B., Jarnagin, S.T., & Hogan, D.M. (2014). Effects of distributed and centralized stormwater best management practices and land cover on urban stream hydrology at the catchment scale. *Journal of Hydrology, 519*, 2584-2595.

Madden, T.J., Ellen, P.S., & Ajzen, I. (1992). A comparison of the Theory of Planned Behaviour and the Theory of Reasoned Action. *Personality and Social Psychology Bulletin, 18*(1), 3-9.

Mayer, A.L., Shuster, W.D., Beaulieu, J.J., Hopton, M.E., Rhea, L.K., Roy, A.H., & Thurston, H.W. (2012). Building green infrastructure via citizen participation: A six-year study in the Shepherd Creek (Ohio). *Environmental Practice, 14*, 57–67.

Mentens, J., Raes, D., Hermy, M. (2006). Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? *Landscape and Urban Planning, 77*, 217-226.

Miles, B., & Band, L.E. (2015). Green infrastructure stormwater management at the watershed scale: urban variable source area and watershed capacitance. *Hydrological Processes, 29*, 2268-2274.

Mills, C. (2013). Toronto's July flood listed as Ontario's most costly natural disaster. The Toronto Star. Retrieved from: http://www.thestar.com/business/2013/08/14/july_flood_ontarios_most_costly_natural_disaster.html.

Milne, S., Sheeran, P., & Orbell, S. (2000). Prediction and intervention in health- related behaviour: A meta-analytic review of protection motivation theory. *Journal of Applied Social Psychology, 30*,10643,

Ministry of the Environment [MOE]. (2003). Stormwater Management Planning and Design Manual. *Government of Ontario.* Retrieved from: https://dr6j45jk9xcmk.cloudfront.net/documents/1757/195- stormwater-planning-and-design-en.pdf.

Ministry of the Environment [MOE]. (2010). Policy Review of Municipal Stormwater Management in the Light of Climate Change – Summary Report. Government of Ontario. Retrieved from: https://dr6j45jk9xcmk.cloudfront.net/documents/1232/102-munincipal-stormwater-management-en.pdf.

Ministry of Municipal Affairs [MMA]. (2014). Provincial Policy Statement. Retrieved from: http://www.mah.gov.on.ca/Page10679.aspx.

Moan, S.I., & Rise, J. Rise. (2011). Predicting intentions not to "drink and drive" using an extended version of the theory of planned behaviour. *Accident Analysis and Prevention, 43*(4), 1378-1384.

Montalto, F.A., Bartrand, T.A., Waldman, A.M., Travaline, K.W., Lomos, C.H., McAfee, C., Geldo, J.M., Riggall, G.J., & Boles, L.M. (2013). Decentralised green infrastructure: the importance of stakeholder behaviour in determining spatial and temporal outcomes. *Structure and Infrastructure Engineering, 9*(12), 1187-1205.

Mullan, B., Wong, C., & Kothe, E. (2013). Predicting adolescent breakfast consumption in the UK and Australia using an extended theory of planned behaviour. *Appetite*, *62*, 127-132.

Nickel, D., Schoenfelder, W., Medearis, D., Dolowitz, D.P., Keeley, M., & Shuster, W. (2014). German experience in managing stormwater with green infrastructure. *Journal of Environmental Planning and Management, 57*(3), 403-423.

Nigbur, D., Lyons, E., & Uzzell, D. (2010). Attitudes, norms, identity and environmental behaviour: Using an expanded theory of planned behaviour to predict participation in a kerbside recycling programme. *British Journal of Social Psychology, 49*, 259–284.

Overy, J. (2010). Spring, Sulphur and Lower Spencer Creeks Stewardship Action Plans: Part of the Spencer Creek Stewardship Action Plans, 2010. Hamilton Conservation Authority.

Pennsylvania State University. (2017). 6.1 How to use stratified sampling. Retrieved from: https://onlinecourses.science.psu.edu/stat506/node/27.

Prairie Research Associates. (n.d.) Response rate on mail surveys. Retrieved from: http://www.pra.ca/resources/pages/files/technotes/rates_e.pdf.

R Core Team. (2013). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria*. Retrieved from: http://www.R-project.org/.

Radford, T., & Vernon, A. (2013). Combining Stormwater Infrastructure Green Roofs and Rain Gardens as Stormwater Mitigation Strategies in Vancouver's West End. *Spacing Magazine.* Retrieved from: http://spacing.ca/vancouver/wp-content/uploads/sites/6/2013/03/TerenceRadfordArielVernon_CombiningStormwater.pdf

Realtors Association of Hamilton-Burlington. (2017). Mixed Bag in June 2017 Market. Retrieved from: http://www.rahb.ca/2017/07/mixed-bag-june-2017-market/.

The Record. (2017). Rain barrels to be distributed in Waterloo Region on April 29. Retrieved from https://www.therecord.com/news-story/7247437-rain-barrels-to-be-distributed-in-waterloo-region-on-april-29/.

Roe, J.J., Thompson, C.W., Aspinall, P.A., Brwer, M.J., Duff, E.I., Miller, D., Mitchell, R., & Clow, A. (2013). Green space and stress: evidence from cortisol measures in deprived urban communities. *International Journal of Environmental Research and Public Health, 10*(1660-4601), 4086-4103.

Rogers, R. W. (1983). Cognitive and physiological processes in fear appeals and attitude change: A revised theory of protection motivation. In B. L. Cacioppo & L. L. Petty (Eds**),** *Social Psychophysiology: A Sourcebook.* London: Guilford.

Rosenberg, E.A., Keys, P.W., Booth, D.B., Hartley, D., Burkey, J., Steinemann, A.C., & Lettenmaier, D.P. (2010). Precipitation extremes and the impacts of climate change on stormwater infrastructure in Washington State. *Climatic Change, 102*, 319-349.

Rowe, A.A., Rector, P., & Bakacs, M. (2016). Survey results of green infrastructure implementation in New Jersey. *Journal of Sustainable Water in the Built Environment, 2*(3), 04016001, 1-6.

Sanchez, G. (2013). *PLS Path Modeling with R.* Trowchez Editions. Berkeley, 2013. http://www.gastonsanchez.com/PLS Path Modeling with R.pdf.

Sandberg, T., & Conner, M. (2008). Anticipated regret as an additional predictor in the theory of planned behavior: A meta-analysis. *British Journal of Social Psychology, 47,* 589–606.

Sheeran, P. (2002). Intention behaviour relations: a conceptual and empirical review. *European Review of Social Psychology, 12*, 1-36.

Shelton, D.P., Rodie, S.N., Feehan, K.A., Franti, T.G., Pekarek, K.A., & Holm, B.A. (2015). Integrating extension, teaching, and research for stormwater management education. *Journal of Contemporary Water Research and Education, 156,* 68-77.

Soper, D.S. (2017). A-priori Sample Size Calculator for Multiple Regression [Software]. Retrieved from http://www.danielsoper.com/statcalc.

Statistics Canada. (2012). *Focus on Geography Series, 2011 Census*. Statistics Canada Catalogue no. 98-310-XWE2011004. Ottawa, Ontario. Analytical products, 2011 Census. Last updated October 24, 2012.

Statistics Canada. (2017a). *South Dundas, MU [Census subdivision], Ontario and Ontario [Province]* (table). *Census Profile*. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released October 25, 2017. Retrieved from: http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E

Statistics Canada. (2017b). *North Dundas, TP [Census subdivision], Ontario and Ontario [Province]* (table). *Census Profile*. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released October 25, 2017. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E

Statistics Canada. (2017c). *Population size and growth in Canada: Key results from the 2016 Census.* Statistics Canada, The Daily. Retrieved from: http://www.statcan.gc.ca/daily-quotidien/170208/dq170208a-eng.htm.

Statistics Canada. (2017d). *Median total income, by family type, by province and territory (all census families).* Statistics Canada Catalogue table 111-0009. CANSIM Tables. Last updated July 12, 2017.

Stem, P.C. (2000). Toward a coherent theory of environmentally significant behavior. *Journal of Social Issues,* 56, 407-424.

Toronto and Region Conservation [TRCA]. (2013). Greening Your Grounds: A Homeowners Guide to Stormwater Landscaping Projects. 55 pp.

Toronto Green Standard [TGS]. (2015). Making a sustainable city happen: For mid to high-rise residential and all non-residential development. *City of Toronto*. Retrieved from: http://www1.toronto.ca/City%20Of%20Toronto/City%20Planning/Developing%20Toronto/Files/pdf/TGS/TGS_MidHiRise_Standard.pdf.

Triandis, H. C. (1980). Values, attitudes, and interpersonal behavior. In H. Howe & M. Page (Eds), *Nebraska Symposium on Motivation, 27*, 195-259). Lincoln, NB: University of Nebraska Press.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kazmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning, 81,* 167-178.

United Nations [UN]. (2014). World's population increasingly urban with more than half living in urban areas. Retrieved from http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html.

USGS. (2016). Floods: Recurrence intervals and 100-year floods. Retrieved from: https://water.usgs.gov/edu/100yearflood.html.

Vandermeulen, V., Verspecht, A., Vermeire, B., Huylenbroeck, G.V., & Gellynk, X. (2011). The use of economic valuation to create public support for green infrastructure investments in urban areas. *Landscape and Urban Planning, 103,* 198-206.

Wang, R., Eckelman, M.J., & Zimmerman, J.B. (2013). Consequential environmental and economic life cycle assessment of green and grey infrastructures for combined sewer systems. *Environmental Science and Technology, 47*, 11189-11198.

Waters, D., Watt, W.E., Marsalek, J., & Anderson, B.C. (2003). Adaptation of a storm drainage system to accommodate increased rainfall resulting from climate change. *Journal of Environmental Planning and Management, 46*(5), 755-770.

Wauters, E., Bielders, C., Poesen, J., Govers, G., & Mathijs, E. (2010). Adoption of soil conservation practices in Belgium: An examination of the theory of planned behaviour in the agri-environmental domain. *Land Use Policy, 27, 86*-94.

Wells, J. (2012). Climate change: How Toronto is adapting to our scary new reality. *The Toronto Star*. Retrieved from: http://www.thestar.com/news/insight/2012/08/19/climate_change_how_toronto_is_adapting_to_our_scary_new_reality.html.

Wong, K.K. (2013) Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS. *Marketing Bulletin, 24*, 1-32.

Yang, B., & Li, M. (2010). Ecological engineering in a new town development: drainage design in the Woodlands, Texas. *Ecological Engineering, 36*, 1639-1650.

Yang, B., & Li., S. (2013). Green infrastructure design for stormwater runoff quality: empirical evidence from large watershed-scale community developments. *Water, 5*, 2038-2057.

Appendix 1: Theory of Planned Behaviour Example Questions

The examples are based on the importance of exercising for at least twenty minutes, a minimum of three times a week, for people who have undergone heart surgery. The following are some examples of questions:

Behavioural Belief:

My exercising for at least 20 min, three times per week for the next three months will result in my having a faster recovery from my surgery.

likely :___1__:___2__:___3__:___4__:___5__:___6__:___7___: unlikely

Attitude:

My exercising for at least 20 minutes, three times per week for the next three months would be

bad :___1__:___2__:___3__:___4__:___5__:___6__:___7___: good

Normative Belief:

Most people who are important to me approve of my exercising for at least 20 minutes, three times per week for the next three months.

agree :___1__:___2__:___3__:___4__:___5__:___6__:___7___: disagree

Subjective Norm:

Most people like me exercised for at least 20 minutes, three times per week in the three months following their major heart surgery.

unlikely :___1__:___2__:___3__:___4__:___5__:___6__:___7___: likely

Control Belief:

(1) Please list any factors or circumstances that would make it easy or enable you to exercise for at least 20 min, three times per week for the next three months.

(2) Please list any factors or circumstances that would make it difficult or prevent you from exercising for at least 20 min, three times per week for the next three months.

Perceived Behavioural Control:

I am confident that I can exercise for at least 20 minutes, three times per week for the next three months.

true :___1__:___2__:___3__:___4__:___5__:___6__:___7___: false

Intention:

I intend to exercise for at least 20 minutes, three times per week for the next three months.

likely :___1__:___2__:___3__:___4__:___5__:___6__:___7___: unlikely

Behaviour:

In the past three months, I have exercised for at least 20 minutes, three times per week.

false :___1__:___2__:___3__:___4__:___5__:___6__:___7___: true

All example questions are from Ajzen’s (n.d) summary of Fishbein and Ajzen (2010), pg. 2-6.

Appendix 2: Stormwater BMP Questionnaire Section Descriptions

Table 1: Stormwater BMP Questionnaire sections headings and descriptions.

Questionnaire Section	Description
Knowledge	Questions are focused on a respondent's understanding of stormwater green infrastructure and select associated environmental benefits of green infrastructure.
Behavioural Beliefs	Questions are focused on a respondent's beliefs that installing stormwater green infrastructure will either help or hinder property flooding and local water quality.
Attitude	Questions are focused on a respondent's attitude toward installing and maintaining stormwater green infrastructure.
Normative Beliefs	Questions are focused on a how strongly a respondent feels that their neighbours, friends and family care about stormwater management.
Subjective Norm	Questions are focused on a respondent's feeling of obligation and responsibility to protect their municipality from flooding and local water bodies from pollution runoff.
Control Beliefs	Questions are focused on potential barriers to the installation and maintenance of stormwater green infrastructure, including available finances and time constraints.
Perceived Behavioural Control	Questions are focused on potential personal barriers to the installation and maintenance of stormwater green infrastructure, including a respondent's awareness of skill level and time constraints.
Intention	Questions are focused on a respondent's intention to install and maintain stormwater green infrastructure in the future.
Behaviour	Questions are focused on a respondent's past behavior with relation to installing and maintaining stormwater infrastructure.

Table 1: Continued…

Questionnaire Section	Description
Demographics	Questions include gender identification, age identification, education level, household income, length of time at current resident and whether a respondent rents or owns their current residence.

Appendix 3: Stormwater BMP Questionnaire Raw Data Results

Table 1: Stormwater BMP Questionnaire Raw Data Results. N1 refers to neighbourhood 1, N2 refers to neighbourhood 2, and N3 refers to neighbourhood 3. Shown are the average answer and its standard deviation over all participants as well as average answers per neighborhood. Shown are also the numbers of positive, negative and neutral responses over all participants.

Questionnaire Code	PLSPM Code	Average	Standard Deviation	N1 Average	N2 Average	N3 Average	Positive Answers	Negative Answers	Neutral Answers
K1	N/A	-1.284	1.144	-0.958	-1.500	-1.286	9	73	6
K2	N/A	0.034	1.264	0.792	-0.278	-0.214	38	29	21
K3	N/A	1.080	0.950	1.500	1.028	0.786	70	6	12
K4	N/A	0.773	1.047	1.333	0.639	0.464	60	10	18
K5	N/A	0.208	0.886	0.167	0.285	0.143	28	15	45
K6	N/A	0.712	0.757	0.917	0.713	0.536	51	2	35
K7	N/A	1.080	0.834	1.333	1.056	0.893	68	2	18
K8	N/A	0.955	0.909	0.958	1.139	0.714	63	5	20
BB1	BB1	0.716	0.958	0.958	0.806	0.393	59	12	17
BB2	BB2	0.420	0.991	0.708	0.472	0.107	50	21	17
BB3	BB3	0.447	1.037	0.792	0.370	0.250	44	17	27
BB4	N/A	0.966	0.999	1.167	0.972	0.786	68	8	12
BB5	BB4	0.669	0.979	0.958	0.830	0.214	48	9	31
A1	A1	0.805	0.957	0.994	0.944	0.464	58	7	23
A2	A2	0.064	0.952	0.311	0.171	-0.286	32	26	30
A3	N/A	0.621	1.022	0.971	0.260	0.786	52	13	23
A4	A3	0.781	1.022	0.994	0.830	0.536	61	9	18
A5	N/A	0.573	0.825	0.833	0.401	0.571	50	6	32

Table 1: Continued…

Questionnaire Code	PLSPM Code	Average	Standard Deviation	N1 Average	N2 Average	N3 Average	Positive Answers	Negative Answers	Neutral Answers
A6	A4	0.444	0.967	0.827	0.145	0.500	50	14	24
A7	N/A	-0.600	1.096	-0.683	-0.399	-0.786	19	53	16
A8	N/A	0.199	0.814	0.215	0.229	0.148	36	11	41
NB1	NB1	0.068	0.941	0.497	-0.026	-0.179	27	17	44
NB2	N/A	-0.094	0.903	0.337	-0.287	-0.214	25	28	35
NB3	N/A	-0.365	0.869	-0.215	-0.471	-0.357	15	33	40
NB4	N/A	-1.008	0.917	-0.814	-1.143	-1.000	10	63	15
NB5	N/A	-0.395	1.087	-0.244	-0.471	-0.429	26	42	19
NB6	N/A	0.787	0.872	0.641	0.886	0.786	61	8	20
SN1	N/A	0.409	0.783	0.333	0.389	0.500	39	8	41
SN2	SN1	0.534	0.830	0.875	0.417	0.393	53	11	24
SN3	SN2	0.341	0.908	0.625	0.222	0.250	40	15	33
SN4	SN3	0.125	0.869	0.375	0.000	0.071	30	19	39
SN5	N/A	0.519	0.921	0.821	0.389	0.429	50	12	26
SN6	N/A	0.580	0.979	0.958	0.500	0.357	55	13	20
SN7	NB2	0.443	0.771	0.708	0.306	0.393	44	7	37
CB1	N/A	0.580	0.738	0.833	0.611	0.321	50	6	32
CB2	N/A	0.250	0.925	0.375	0.083	0.357	43	19	26
CB3	PBC1	0.286	0.982	0.549	0.250	0.107	48	17	23
CB4	PBC5	0.686	1.065	0.722	0.833	0.464	63	15	10
CB5	PBC4	0.864	1.008	1.042	1.028	0.500	68	11	9
CB6	N/A	0.230	1.058	0.458	0.228	0.036	37	24	27

Table 1: Continued…

Questionnaire Code	PLSPM Code	Average	Standard Deviation	N1 Average	N2 Average	N3 Average	Positive Answers	Negative Answers	Neutral Answers
CB7	N/A	0.195	0.920	0.257	0.222	0.107	42	24	22
CB8	N/A	0.761	0.711	0.833	0.778	0.679	64	4	20
PBC1	PBC2	0.403	0.890	0.729	0.333	0.214	47	13	28
PBC2	N/A	0.568	1.182	0.833	0.583	0.321	58	20	10
PBC3	N/A	0.034	1.169	0.542	-0.083	-0.250	37	28	23
PBC4	PBC3	0.295	1.105	0.667	0.306	-0.036	50	19	19
PBC5	PBC6	0.750	0.962	1.000	0.806	0.464	62	11	15
PBC6	N/A	0.330	0.968	0.708	0.278	0.071	41	17	30
I1	I1	-0.294	1.008	0.299	-0.417	-0.643	17	35	36
I2	I2	0.739	0.766	0.958	0.722	0.571	61	5	22
I3	N/A	-0.057	1.054	0.000	0.222	-0.464	26	32	30
I4	N/A	0.402	0.940	0.597	0.417	0.214	47	18	23
I5	I3	0.375	0.862	0.625	0.444	0.071	42	14	32
B1	B1	-0.070	1.419	0.491	-0.027	-0.607	37	44	7
B2	N/A	-0.042	1.222	0.089	0.171	-0.429	39	39	10
B3	N/A	0.171	1.270	0.253	0.417	-0.214	44	31	13
B4	SN4	0.757	0.994	1.086	0.738	0.500	60	11	17
B5	SN5	0.729	1.003	1.131	0.750	0.357	58	10	20
B6	B2	-0.326	1.268	0.310	-0.170	-1.071	29	44	15

Appendix 4: Outer and Inner model results from the Partial Least Squares Path Model

Table 1: Outer model results from the Partial Least Squares Path Model for the Stormwater BMP questionnaire using the Theory of Planned Behaviour. Shown are the question from the questionnaire and its associated code, as well as the minimum, median, mean and maximum of the respondents' answers to the question. Shown are also the loading, communality, redundancy and weight values for each question, which evaluate how well the manifest variables explain the associated latent variable.

Question			Response							
Questionnaire Code	PLSPM Code	Text	Min	Median	Mean	Max	Loading	Communality	Redundancy	Weight
BB1	BB1	I believe that if I installed a stormwater BMP on my property, it would lower the chance of my basement being flooded.	-2.000	1.000	0.716	2.000	0.760	0.577	0.000	0.295
BB2	BB2	I believe that installing stormwater BMPs, such as a rain garden or a rain barrel, on my property would not reduce the amount of polluted runoff going into local streams and rivers.	-2.00	1.00	0.42	2.00	0.82	0.67	0.00	0.46
BB3	BB3	I think that the installation of stormwater BMPs on my property is important in the prevention of the flooding of my basement.	-2.00	0.16	0.45	2.00	0.78	0.61	0.00	0.28
BB5	BB4	I believe that stormwater management at the property level does not at all help protection the quality of local drinking water.	-2.00	1.00	0.67	2.00	0.66	0.44	0.00	0.28

Table 1: Continued…

		Question	Response							
Questionnaire Code	PLSPM Code	Text	Min	Median	Mean	Max	Loading	Communality	Redundancy	Weight
A1	A1	I believe that installing a rain garden would be very unpleasant.	-2.000	1.000	0.421	2.000	0.821	0.674	0.000	0.458
A2	A2	A rain garden would increase the number of mosquitoes on my property.	-2.000	0.162	0.447	2.000	0.784	0.614	0.000	0.278
A4	A3	I think that installing stormwater BMPs on my property would be a waste of time and money.	-2.000	1.000	0.669	2.000	0.660	0.436	0.000	0.275
A6	A4	I would take pride in a rain garden and would maintain it in order to maximize water absorption.	-2.000	1.000	0.805	2.000	0.823	0.677	0.199	0.312
NB1	NB1	Most people who are important to me think I should care about my personal property's impact on local lakes and rivers.	-2.000	0.000	0.064	2.000	0.833	0.693	0.204	0.387
SN7	NB2	I feel that my local government would want me to install a stormwater BMP on my personal property.	-2.000	1.000	0.781	2.000	0.774	0.598	0.176	0.328
SN2	SN1	I have a responsibility to help the city manage stormwater, using my personal property, through the installation of BMPs such as rain gardens or rain barrels.	-2.000	1.000	0.444	2.000	0.682	0.465	0.136	0.245

Table 1: Continued…

		Question	Response							
Questionnaire Code	PLSPM Code	Text	Min	Median	Mean	Max	Loading	Communality	Redundancy	Weight
SN3	SN2	I feel a strong obligation towards preserving the stormwater features on my personal property.	-2.000	0.000	0.068	2.000	0.723	0.523	0.000	0.614
SN4	SN3	I feel a strong obligation towards preserving the stormwater features in my neighbourhood.	-2.000	0.500	0.443	2.000	0.795	0.632	0.000	0.699
B4	SN4	I will not be installing any stormwater BMPs on my property because I believe it is the city’s responsibility to take care of stormwater issues.	-2.000	1.000	0.534	2.000	0.825	0.680	0.141	0.276
B5	SN5	I will not be installing any stormwater BMPs on my property because I am not interested in changing my yard.	-2.000	0.000	0.341	2.000	0.773	0.598	0.124	0.209
CB3	PBC1	I am able to spend the time required to maintain stormwater BMPs on my property.	-2.000	0.000	0.125	2.000	0.739	0.547	0.113	0.204
PBC1	PBC2	I have enough time to install a stormwater BMP on my property within the next year.	-2.000	1.000	0.757	2.000	0.850	0.722	0.149	0.264
PBC4	PBC3	I do not have the time to care for a rain garden on my property.	-2.000	1.000	0.729	2.000	0.823	0.678	0.140	0.287

Table 1: Continued…

		Question	Response							
Questionnaire Code	PLSPM Code	Text	Min	Median	Mean	Max	Loading	Communality	Redundancy	Weight
CB5	PBC4	I do not believe that I have enough space in my yard for any stormwater BMPs.	-2.000	1.000	0.286	2.000	0.826	0.683	0.000	0.276
CB4	PBC5	It would be difficult for me to locate, transport and install a rain barrel on my property.	-2.000	1.000	0.403	2.000	0.786	0.618	0.000	0.256
PBC5	PBC6	I would not remember to use the water in a rain barrel before the next rain, therefore making the installation of a rain barrel not worth it to me.	-2.000	1.000	0.295	2.000	0.762	0.581	0.000	0.264
I1	I1	I am planning to install a stormwater BMP option on my property within the next year.	-2.000	1.000	0.864	2.000	0.671	0.450	0.000	0.176
I2	I2	I am willing to make an effort to manage my property so that it positively impacts nearby water bodies.	-2.000	1.000	0.686	2.000	0.604	0.365	0.000	0.202
I5	I3	I intend to control stormwater on my property rather than allowing it to flow into storm drains.	-2.000	1.000	0.750	2.000	0.639	0.409	0.000	0.204
B1	B1	I have already installed some stormwater BMPs on my property, such as a rain garden or rain barrel.	-2.000	0.000	-0.294	2.000	0.872	0.761	0.434	0.393
B6	B2	I have started installing stormwater BMPs on my property.	-2.000	1.000	0.739	2.000	0.864	0.747	0.426	0.369

Table 2: Inner model results from the Partial Least Squares Path Model for the Stormwater BMP questionnaire using the Theory of Planned Behaviour. Shown are the Cronbach's alpha, Dillon-Goldstien's rho, the Eigen values, and the R2 values. Each of these statistics evaluates how well a block of indicators measure its corresponding latent construct. Redundancy represents how strongly the latent variable predicts the variability in another latent variable.

	Cronbach's alpha	Dillon-Goldstien's rho	1st Eigen value	2nd Eigen value	R^2 value	Redundancy
Behavioural Beliefs	0.7578	0.8471	2.3347	0.8934	0.000	0.0000
Attitude	0.7853	0.8617	2.4389	0.6288	0.2937	0.1786
Normative Beliefs	0.2704	0.7327	1.1563	0.8437	0.0000	0.0000
Subjective Norm	0.8634	0.9015	3.2344	0.9308	0.2067	0.1333
Perceived Behavioural Control	0.8114	0.8648	3.1111	0.9298	0.000	0.0000
Intention	0.8526	0.9106	2.3179	0.4007	0.5705	0.4407
Behaviour	0.8224	0.9184	1.6984	0.3016	0.4171	0.3541

Appendix 5: Bootstrap validation results for the inner and outer model

Table 1: Bootstrap validation results for the path effects of the inner model of the Partial Least Squares Path Model for the Stormwater BMP questionnaire study. Shown are the strength of the effect of the first variable on the second, the bootstrap mean value, the bootstrap standard error, and the lower and upper percentile of the 95% bootstrap confidence interval. Significant path effects are indicated when the 95% bootstrap confidence interval does not contain zero.

Path	Path Effect	Boot Mean	Standard Error	Perc.025	Perc.975
Behavioural Beliefs -> Attitude	0.5419	0.5589	0.0645	0.4169	0.6698
Behavioural Beliefs -> Intention	0.0185	0.0270	0.0594	-0.1187	0.1332
Behavioural Beliefs -> Behaviour	0.0083	0.0114	0.0270	-0.0524	0.0641
Attitude -> Intention	0.0341	0.0502	0.1046	-0.1878	0.2398
Attitude -> Behaviour	0.0154	0.0214	0.0478	-0.0856	0.1111
Normative Beliefs -> Subjective Norm	0.4547	0.4703	0.0854	0.2695	0.6200
Normative Beliefs -> Intention	0.2468	0.2537	0.0753	0.1146	0.4089
Normative Beliefts -> Behaviour	0.1112	0.1125	0.0411	0.0414	0.1915
Subjective Norm -> Intention	0.5423	0.5335	0.1022	0.3008	0.6978

Table 1: Continued…

Path	Path Effect	Boot Mean	Standard Error	Perc.025	Perc.975
Subjective Norm -> Behaviour	0.2447	0.2383	0.0715	0.1021	0.3707
Perceived Behavioural Controls -> Intention	0.2528	0.2522	0.1088	0.0668	0.4565
Perceived Behavioural Controls -> Behaviour	0.3740	0.3796	0.0866	0.2118	0.5378
Intention -> Behaviour	0.4511	0.4463	0.1047	0.2381	0.6487

Table 2: Bootstrap validation results for the weights and loadings of the outer model of the Partial Least Squares Path Model for the Stormwater BMP questionnaire using the Theory of Planned Behaviour. Shown are the original weight and loading value, the bootstrap mean weight and loading value, the bootstrap weight and loading standard error, and the lower and upper percentile of the 95% bootstrap weight and loading confidence interval.

PLSPM Code	Questionnaire Code	Original Weight	Mean Boot Weight	St. Error Weight	Perc.025 Weight	Perc.975 Weight	Original Loading	Mean Boot Loading	St. Error Loading	Perc.025 Loading	Perc.975 Loading
BB1	BB1	0.2954	0.2846	0.0456	0.1849	0.3544	0.7597	0.7398	0.0780	0.5436	0.8485
BB2	BB2	0.4582	0.4609	0.0643	0.3430	0.5911	0.8211	0.8247	0.0406	0.7372	0.8906
BB3	BB3	0.2776	0.2693	0.0626	0.1258	0.3739	0.7836	0.7680	0.0800	0.5651	0.8734
BB4	BB5	0.2754	0.2794	0.0978	0.0741	0.4650	0.6600	0.6531	0.1353	0.3350	0.8557
A1	A1	0.3119	0.3164	0.0435	0.2394	0.4032	0.8226	0.8226	0.0415	0.7369	0.8859
A2	A2	0.3875	0.3880	0.0465	0.3059	0.4887	0.8326	0.8339	0.0302	0.7532	0.8825
A3	A4	0.3282	0.3240	0.0633	0.1878	0.4475	0.7736	0.7605	0.0946	0.5278	0.8852
A4	A6	0.2449	0.2397	0.0574	0.1284	0.3403	0.6817	0.6636	0.1125	0.4441	0.8421
NB1	NB1	0.6140	0.6048	0.1268	0.3080	0.8136	0.7233	0.7074	0.1200	0.3840	0.8775
NB2	SN7	0.6991	0.6988	0.1095	0.4912	0.9300	0.7951	0.7881	0.0938	0.5885	0.9520
SN1	SN2	0.2757	0.2788	0.0290	0.2299	0.3345	0.8249	0.8238	0.0367	0.7511	0.8840
SN2	SN3	0.2090	0.2053	0.0267	0.1557	0.2543	0.7732	0.7650	0.0561	0.6455	0.8487
SN3	SN4	0.2040	0.2040	0.0276	0.1465	0.2541	0.7394	0.7265	0.0683	0.5674	0.8281
SN4	B4	0.2637	0.2662	0.0249	0.2286	0.3166	0.8496	0.8495	0.0309	0.7869	0.9024
SN5	B5	0.2868	0.2877	0.0280	0.2374	0.3508	0.8233	0.8228	0.0392	0.7360	0.8839
PBC1	CB3	0.2755	0.2760	0.0352	0.2225	0.3583	0.8265	0.8183	0.0456	0.7118	0.8958
PBC2	PBC1	0.2561	0.2561	0.0322	0.2074	0.3186	0.7862	0.7870	0.0487	0.6753	0.8667
PBC3	PBC4	0.2638	0.2664	0.0358	0.2046	0.3467	0.7622	0.7611	0.0619	0.6387	0.8594
PBC4	CB5	0.1764	0.1739	0.0382	0.1050	0.2495	0.6710	0.6593	0.0878	0.4805	0.8101
PBC5	CB4	0.2025	0.2023	0.0387	0.1257	0.2881	0.6043	0.5997	0.1089	0.3523	0.7581

Table 2: Continued…

PLSPM Code	Questionnaire Code	Original Weight	Mean Boot Weight	St. Error Weight	Perc.025 Weight	Perc.975 Weight	Original Loading	Mean Boot Loading	St. Error Loading	Perc.025 Loading	Perc.975 Loading
PBC6	PBC5	0.2045	0.2015	0.0472	0.0915	0.2843	0.6393	0.6271	0.1102	0.3481	0.7853
I1	I1	0.3933	0.3965	0.0309	0.3445	0.4643	0.8721	0.8736	0.0221	0.8293	0.9125
I2	I2	0.3693	0.3677	0.0230	0.3184	0.4106	0.8641	0.8600	0.0322	0.7815	0.9100
I3	I5	0.3754	0.3747	0.0205	0.3303	0.4143	0.9001	0.8991	0.0224	0.8466	0.9337
B1	B1	0.5126	0.5087	0.0319	0.4490	0.5788	0.9123	0.9100	0.0323	0.8287	0.9580
B2	B6	0.5722	0.5762	0.0382	0.5166	0.6584	0.9303	0.9318	0.0201	0.8897	0.9621

Appendix 6: Bootstrap validation results for the three neighbourhood comparisons

Table 1: Bootstrap validation results for the comparison between Neighbourhood 1 and Neighbourhood 2 using the Partial Least Squares Path Model for the Stormwater BMP questionnaire using the Theory of Planned Behaviour. Shown are the path coefficients of the compared groups (Neighbourhood 1 and Neighbourhood 2), the t-value and its associated p-value.

Link	Path Coefficient N1	Path Coefficient N2	t-value	p-value
Behavioural Beliefs -> Attitude	0.5903	0.4997	0.6142	0.271
Attitude -> Intention	0.0498	0.1931	0.4662	0.321
Normative Beliefs -> Subjective Norm	0.3848	0.7097	0.5849	0.280
Subjective Norm -> Intention	0.4722	0.6122	0.5479	0.293
Perceived Behavioural Control -> Intention	0.2795	0.2267	0.2787	0.391
Perceived Behavioural Control -> Behaviour	0.4471	0.0289	1.0855	0.141
Intention -> Behaviour	0.2456	0.6664	1.2927	0.101

Table 2: Bootstrap validation results for the comparison between Neighbourhood 1 and Neighbourhood 3 using the Partial Least Squares Path Model for the Stormwater BMP questionnaire using the Theory of Planned Behaviour. Shown are the path coefficients of the compared groups (Neighbourhood 1 and Neighbourhood 3), the t-value and its associated p-value.

Link	Path Coefficient N1	Path Coefficient N3	t-value	p-value
Behavioural Beliefs -> Attitude	0.5903	0.5475	0.3887	0.350
Attitude -> Intention	0.0498	-0.0343	1.2190	0.114
Normative Beliefs -> Subjective Norm	0.3848	0.3687	1.0217	0.156
Subjective Norm -> Intention	0.4722	0.5842	0.0413	0.484
Perceived Behavioural Control -> Intention	0.2795	0.1518	0.0618	0.476
Perceived Behavioural Control -> Behaviour	0.4471	0.1048	0.0733	0.471
Intention -> Behaviour	0.2456	0.5085	0.3968	0.347

Table 3: Bootstrap validation results for the comparison between Neighbourhood 2 and Neighbourhood 3 using the Partial Least Squares Path Model for the Stormwater BMP questionnaire using the Theory of Planned Behaviour. Shown are the path coefficients of the compared groups (Neighbourhood 2 and Neighbourhood 3), the t-value and its associated p-value.

Path	Path Coefficient N2	Path Coefficient N3	t-value	p-value
Behavioural Beliefs -> Attitude	0.4997	0.5475	0.1247	0.451
Attitude -> Intention	0.1931	-0.0343	0.2825	0.389
Normative Beliefs -> Subjective Norm	0.7097	0.3687	0.0489	0.481
Subjective Norm -> Intention	0.6122	0.5842	0.3019	0.382
Perceived Behavioural Control -> Intention	0.2267	0.1518	0.3684	0.357
Perceived Behavioural Control -> Behaviour	0.0289	0.1048	1.3246	0.095
Intention -> Behaviour	0.6664	0.5085	1.0161	0.157

Appendix 7: MANOVA analysis results

Table 1: MANOVA results for a comparison of the three study neighbourhoods using the results from the Stormwater BMP questionnaire and the Theory of Planned Behaviour. Shown are the Wilk's lambda (pooled ratio of error variances to effect variance plus error variance), the Hotelling-Lawley's trace (pooled ratio of effect variance to error variance), the Pillai's criterion (pooled effect variances), and the Roy's largest root (largest eigenvalue) (French et al., n.d.).

	Wilk's Test	Hotelling-Lawley's test	Pillai's test	Roy's test
Lambda	0.7366	0.3385	0.2774	0.2671
F (observed value)	1.6101	1.6290	1.5904	2.6377
DF1	16.0000	16.0000	16.0000	8.0000
DF2	156.0000	154.0000	158.0000	79.0000
F (critical value)	1.7087	1.7096	1.7079	2.0579
P value	0.072	0.067	0.077	0.013

Appendix 8: Discriminant Analysis results

Table 1: Discriminant Analysis results for a comparison of the three study neighbourhoods using the answers to the Stormwater BMP questionnaire. Shown are the results of two Box tests (testing whether the matrices are equal between groups), the Kullback's test (testing for equality between the variables), the Wilk's Lambda test (testing whether the vectors of the means for the groups are equal), the Pillai's criterion (displays the pooled effect variances), and the Hotelling-Lawley's trace (displays the pooled ratio of effect variance to error variance) (French et al., n.d.).

	Box test (Chi-square asymptotic approximation)	Box test (Fisher's F asymptotic approximation)	Kullback's test	Wilks' Lambda test (Rao's approximation)	Pillai's trace	Hotelling-Lawley trace
-2Log(M)	84.4400	84.4427	N/A	N/A	N/A	N/A
Chi-square (Observed value)	84.4428	N/A	N/A	N/A	N/A	N/A
Chi-square (Critical value)	92.8100	N/A	N/A	N/A	N/A	N/A
DF	72.6460	N/A	72.0000	N/A	N/A	N/A
p-value	0.457	0.471	0.998	0.072	0.077	0.069
alpha	0.0500	0.0500	0.05000	0.0500	0.0500	0.0500
F (Observed value)	N/A	1.0031	N/A	1.6101	1.5904	1.6343
F (Critical value)	N/A	1.2900	N/A	1.7087	1.7079	1.7256
DF1	N/A	72.0000	N/A	16.0000	16.0000	16.0000

Table 1: Continued…

	Box test (Chi-square asymptotic approximation)	Box test (Fisher's F asymptotic approximation)	Kullback's test	Wilks' Lambda test (Rao's approximation)	Pillai's trace	Hotelling-Lawley trace
DF2	N/A	14322.5350	N/A	156.0000	158.0000	124.0984
K (Observed value)	N/A	N/A	42.2214	N/A	N/A	N/A
K (Critical value)	N/A	N/A	92.8083	N/A	N/A	N/A
Lambda	N/A	N/A	N/A	0.7366	N/A	N/A
Trace	N/A	N/A	N/A	N/A	0.2774	0.3385

Appendix 9: Secondary Analysis

Table 1: Secondary analysis of the Stormwater BMP questionnaire results using a two-sample t-test assuming unequal variance for select questions, pairwise comparing the three study neighbourhoods. N1 represents Neighbourhood 1, N2 represents Neighbourhood 2, and N3 represents Neighbourhood 3. Shown are the specified question, the t-values and the associated p-values.

Questionnaire Code	PLSPM Code	Question	N1 vs N2 t-value	N1 vs N2 p-value	N1 vs N3 t-value	N1 vs N3 p-value	N2 vs N3 t-value	N2 vs N3 p-value
K1	N/A	I have been formally educated on the functions and benefits of stormwater BMPs in the past (ie. through courses at an educational institution or through career-based education).	1.8270	0.076	0.5798	0.565	-1.1481	0.256
K2	N/A	I have been informally educated on the functions and benefits of stormwater BMPs in the past (ie. through marketing material such as pamphlets or for personal interest).	4.1335	<0.001	3.5829	0.001	-0.1858	0.853
SN5	B5	I would only install stormwater BMPs on my property if there was a financial incentive involved.	1.9553	0.056	1.3503	0.184	-0.7073	0.482
CB2	N/A	I am able to spend the money required to maintain stormwater BMPs on my property.	1.7659	0.084	0.8066	0.424	-0.9766	0.332
CB3	PBC1	I am able to spend the time required to maintain stormwater BMPs on my property.	0.7802	0.439	1.446	0.155	0.7385	0.463
PBC4	PBC3	I do not have the time to care for a rain garden on my property.	0.8615	0.393	3.3164	0.032	1.3776	0.173
PBC6	N/A	Installing stormwater BMPs on my property would be very expensive and is not something that I can afford right now.	2.3924	0.020	3.1961	0.002	0.6925	0.491

Appendix 10: General Definitions

Best Management Practice: Used interchangeably with green infrastructure and low impact development. See following definitions.

Bioswales: Vegetated, mulched or xeriscaped channels that provide treatment and retention as they move stormwater from one place to another. Vegetated swales slow, infiltrate and filter stormwater flows (Environmental Protection Agency, 2016).

Green Infrastructure: Means 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 (MMA, 2014, pg. 42).

Infrastructure: Means physical structures (facilities and corridors) that form the foundation for development. *Infrastructure* includes sewage and water systems, septic treatment systems, stormwater management systems, waste management systems, electricity generation facilities, electricity transmission and distribution systems, communications/telecommunications, transit and transportation corridors and facilities, oil and gas pipelines and associated facilities (MMA, 2014, pg. 43).

Low Impact Development: Used interchangeably with green infrastructure and best management practices. Refers to systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat (EPA, 2017).

One-hundred-year flood: For *river, stream and small inland lake systems*; means that flood, based on an analysis of precipitation, snow melt, or a combination thereof, having a return period of 100 years on average, or having a 1% chance of occurring or being exceeded in any given year (MMA, 2014, pg. 46).

Permeable Pavement: These features help infiltrate, treat, and/or store rainwater where it falls. They can be made of pervious concrete, porous asphalt, or permeable interlocking pavers (Environmental Protection Agency, 2016).

Rain Gardens: Versatile features that can be installed in almost any unpaved space. Also known as bioretention, or bioinfiltration, cells, they are shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets. This practice mimics natural hydrology by infiltrating, and evaporating and transpiring stormwater runoff (Environmental Protection Agency, 2016).

Appendix 11: Partial Least Squares Path Modeling Definitions

Table 1: Terms used in Partial Least Squares Path Modeling, definitions by Sanchez (2013).

Term	Definition by Sanchez (2013)
C.alpha	Cronbach's alpha, a coefficient that is intended to evaluate how well a block of indicators measure their corresponding latent construct, as a rule of thumb, a Cronbach's alpha greater than 0.7 is considered acceptable. All indicators in the reflective block are required to be positive. (pg. 57)
Communalities	Communality is calculated with the purpose to check that indicators in a block are well explained by its latent variable. Communalities are simply squared loadings and they measure the part of the variance between a latent variable and its indicator that is common to both. (pg. 63)
DG.rho	Dillon-Goldstein's rho, focuses on the variance of the sums of variables in the block of interest. As a rule of thumb, a block is considered as unidimensional when the Dillon-Goldstein's rho is larger than 0.7. This index is considered to be a better indicator than the Cronbach's alpha because it takes into account to which extent the latent variable explains its block of indicators. (pg. 58)
Eigen values	Eigen-analysis of the correlation matrix of each set of indicators. The use of this metric is based on the importance of the first eigenvalue. If a block is unidimensional, then the first eigenvalue should be "much more" larger than 1 whereas the second eigenvalue should be smaller than 1. (pg. 58)
Goodness of fit	Goodness of fit can be used a global criterion that helps us to evaluate the performance of the model in both the inner and the outer models. Basically, Goodness of fit assess the overall prediction performance of the model. The goodness of fit for this model equals 0.4448454. This can be interpreted as the prediction power of the model is 44.5%. (pg. 69-70)
Inner path model	The part of the model that has to do with the relationships between latent variables. (pg 50)
Latent variables	The underlying variables that help explain the association between the observable variables, calculated as a weighted sum of their indicators. Latent variables are in reflective mode, manifest variables are considered as being caused by the latent variables. (pg. 17)
Loadings	Correlations between a latent variable and its indicators. Loadings greater than 0.7 are acceptable. Communalities are squared loadings and represent what amount of variability is explained by a latent variable. A loading greater than 0.7 means that more than 50% of the variability in an indicator is captured by its latent construct. (pg. 62-63)

Table 1: Continued…

Term	Definition by Sanchez (2013)
Manifest variables	The indicators that reflect or indicate one construct of the latent variable, used to obtain an approximate representation of the latent variable. (pg. 19)
Outer path model	The part of the model that has to do with relationships between each latent variable and its block of indicators. (pg. 50)
R^2 value	R^2 indicates the amount of variance in the endogenous latent variable explained by its independent latent variables. 1. Low: R < 0.30 (although some authors consider R < 0.20) 2. Moderate: 0.30 < R < 0.60 (you can also find 0.20 < R < 0.50) 3. High: R > 0.60 (alternatively there's also R > 0.50) (pg. 68)
Redundancy	High redundancy means high ability to predict, represents how strongly the latent variable predicts the variability in another latent variable (for example, behavioural beliefs predicts 17.7% of the variability in attitude) (pg. 68-69)
Weights	Linear combination of associated latent variables, latent variable scores are calculated as weighted sums of their indicators. (pg. 42)
Outer path model	The part of the model that has to do with relationships between each latent variable and its block of indicators. (pg. 50)

Appendix 12: Door Hanger Text and Visual used in the Stormwater BMP questionnaire study

Hello!

This door hanger is to inform you that your neighbourhood has been chosen to participate in a graduate research project.

The project is being performed through the University of Waterloo's School of Planning, by Master of Environmental Studies candidate, Sarah Sinasac. The Hamilton Conservation Authority has partnered with the university for this project and could be using the results to help plan public outreach events in the Town of Dundas.

The purpose of this project is to help determine residents' responses to stormwater best management practices and to establish what barriers may prevent the installment of stormwater best management practices (BMPs) on private properties.

A questionnaire will be dropped off within the next week at your residence, during the evening. The questionnaire should be filled out by an adult in the household and the individual should answer on their own behalf. The questionnaire can either be mailed back to the researcher (Sarah Sinasac) or picked up during a set time.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#21801). If you have questions for the Committee contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca. However, the final decision about participation is yours.

Any questions or concerns can be directed to ssinasac@uwaterloo.ca. Thank you very much for participating in this graduate research!

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Appendix 13: Information Letter used in the Stormwater BMP questionnaire study

February, 2017
Sarah Sinasac
University of Waterloo
Graduate Researcher

Dear Resident of Dundas,

My name is Sarah Sinasac and I am a current Master's of Environmental Studies candidate in the School of Planning at the University of Waterloo. I will be distributing a questionnaire to various neighbourhoods in the Town of Dundas as part of my graduate research. The questionnaire designed on behalf of the University of Waterloo, School of Planning, in partnership with the Hamilton Conservation Authority. My faculty supervisor is Dr. Michael Drescher, in the School of Planning, and either of us can be contacted with questions or concerns about this project. This is an invitation to participate in part of a University of Waterloo graduate research project and your participation would be greatly appreciated.

I would very much appreciate if you could take the time to fill out the following questionnaire in order to help me understand the factors that help or hinder the installation of stormwater BMPs on private properties. The answers that you provide may help build a more sustainable future for the Town of Dundas.

Why is this important?
The Town of Dundas faces difficulty to expand existing stormwater infrastructure due to its location at a valley bottom and the already existing built-up areas competing for space. Due to climate change, much of Canada faces the risk of increased frequency of storms with higher intensity rainfall. Many municipalities' current stormwater infrastructure is not well prepared to deal with the increased level of rainfall. Stormwater BMPs are a possible way for private residents to help prevent water damage to residences and neighbourhoods.

What are some possible stormwater BMPs?
Stormwater BMP options can include stormwater storage options such as rain barrels and cisterns (large water storage units), or stormwater absorption options such as rain gardens and permeable paving. BMPs can help store or absorb stormwater, therefore helping to reduce the flow of polluted water into local water systems and helping to prevent basement flooding in low-lying neighbourhoods.
Rain barrel: a large storage barrel, typically available from garden stores or through a municipal program that can connect to your downspout in order to collect rainwater. Rainwater can be reused from the barrel to water the garden.
Rain gardens: A type of garden that is planted within low lying areas in order to absorb more rain water than traditional gardens. Rain gardens are typically filled with a mixture of sand and silt in order to increase water absorption. Native wetland species such as ferns and wildflowers can be chosen for the garden as they will absorb more water than traditional or common garden plants.
Porous paving: An alternative to blacktop asphalt, typically involves interlocking stones with large spaces between them. The stones lay on top of a layer of gravel that helps to slow the flow of stormwater over properties by allowing the water to seep into the ground.

Participation in this project is voluntary and involves completing a questionnaire which is expected to take about 15 minutes of your time. The questionnaire should be filled out by an adult in the household and the individual should answer on their own behalf. You may omit any question you prefer not to answer, and you may withdraw from the study at any time. All information you provide will be considered confidential. Your name will not appear in the final research paper and your data will be grouped with other participants' data. The data collected through this study will be kept for a period of one year in a secure location and then destroyed. There are no known or anticipated risks to participation in this study.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#21801). If you have questions for the Committee contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca. However, the final decision about participation is yours.

If you have any questions about this study, or would like additional information to assist you in reaching a decision about participation, please feel free to contact me at ssinasac@uwaterloo.ca or my research advisor, Dr. Drescher at 519-888-4567 ext. 3213 or by email at mdrescher@uwaterloo.ca.

Thank you in advance for your interest in this project.

Best,

Sarah Sinasac

Appendix 14: Stormwater Best Management Practices (BMPs) Questionnaire

Stormwater Best Management Practices (BMPs) Questionnaire

University of Waterloo, School of Planning

Photos used with permission from REEP Green Solutions and Green Communities Canada

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Stormwater Best Management Practices (BMPs) Questionnaire
Fall 2016, Graduate Researcher: Sarah Sinasac, School of Planning, University of Waterloo

Thank you for taking the time to fill out the following questionnaire. All answers will remain confidential and will help gauge what factors help or hinder the implementation of stormwater best management practices (BMPs) on private properties.

Please fill out all questions to the best of your ability. Some questions may seem similar to others, but they are all important for determining patterns of behaviour and intention.

Throughout the questionnaire, the term **stormwater best management practices (BMPs)** is used to encompass all installation options, **including, but not limited to, rain barrels, rain gardens, infiltration galleries / soakaway pits, French drains, weeping tiles, and permeable paving.** Some questions are about specific BMPs, which will be indicated within the question.

Most survey questions will be answered through a six-point scale ranging from strongly disagree to strongly agree. Please select the answer that you think is the most appropriate for each questions.

A personal information section will follow the questionnaire. It does not contain any information that would allow you, as a participant, to be identifiable. Please fill out what information you are willing to provide.

Thank you very much for your time.

Any questions can be directed to Sarah Sinasac through the following email: ssinasac@uwaterloo.ca

Section 1	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. I have been formally educated on the functions and benefits of stormwater BMPs in the past (ie. through courses at an educational institution or through career-based education).	1	2	3	4	5	6
2. I have been informally educated on the functions and benefits of stormwater BMPs in the past (ie. through marketing material such as pamphlets or for personal interest).	1	2	3	4	5	6
3. I understand what stormwater BMPs (such as rain barrels, cisterns, and rain gardens) are.	1	2	3	4	5	6
4. I am aware of the environmental benefits that stormwater BMPs provide when placed on private properties.	1	2	3	4	5	6
5. Stormwater runoff is a larger source of pollution in local water bodies than pollution from factories.	1	2	3	4	5	6
6. A rain garden on a property will increase the diversity of insects on that property.	1	2	3	4	5	6
7. I believe that climate change has led to more severe storms, which has increased the importance of stormwater BMPs on the property level.	1	2	3	4	5	6
8. I believe that the stormwater flowing off of impermeable surfaces in neighbourhoods will negatively impact the nearby water bodies.	1	2	3	4	5	6

Section 2A	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. I believe that if I installed a stormwater BMP on my property, it would lower the chance of my basement being flooded.	1	2	3	4	5	6
2. I believe that installing stormwater BMPs, such as a rain garden or a rain barrel, on my property would not reduce the amount of polluted runoff going into local streams and rivers.	1	2	3	4	5	6
3. I think that the installation of stormwater BMPs on my property is important in the prevention of the flooding of my basement.	1	2	3	4	5	6
4. I do not think that I would use rain from a rain barrel to water my garden.	1	2	3	4	5	6
5. I believe that stormwater management at the property level does not at all help protection the quality of local drinking water.	1	2	3	4	5	6

Section 2B	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. I believe that installing a rain garden would be very unpleasant.	1	2	3	4	5	6
2. A rain garden would increase the number of mosquitoes on my property.	1	2	3	4	5	6
3. I would enjoy my property more if there were more gardens on my property.	1	2	3	4	5	6
4. I think that installing stormwater BMPs on my property would be a waste of time and money.	1	2	3	4	5	6
5. I would be proud of my garden if it was able to decrease the amount of stormwater flowing off of my yard.	1	2	3	4	5	6
6. I would take pride in a rain garden and would maintain it in order to maximize water absorption.	1	2	3	4	5	6
7. I think that my basement is at risk of flooding in the next five years.	1	2	3	4	5	6
8. The increased level of responsibility (including maintaining and paying for BMPs) involved in the implementation of stormwater BMPs is too high.	1	2	3	4	5	6

Section 3A	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. Most people who are important to me think I should care about my personal property's impact on local lakes and rivers.	1	2	3	4	5	6
2. If my neighbours were to install a rain garden on their property I would be more likely to install it on my own property.	1	2	3	4	5	6
3. I want my neighbours and family to be impressed with how much stormwater my yard controls.	1	2	3	4	5	6
4. I When considering whether to implement stormwater BMPs on my property, I consider what my friends and neighbours may be thinking.	1	2	3	4	5	6
5. In terms of installing stormwater BMPs, my actions could be influenced by what my neighbours have installed on their properties.	1	2	3	4	5	6
6. My friends would think I am strange if I would start talking about stormwater BMPs on my property.	1	2	3	4	5	6

Section 3B	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1.When it comes to matters of sustainability, I think that city planners' recommendations about stormwater BMPs are trustworthy.	1	2	3	4	5	6
2. I have a responsibility to help the city manage stormwater, using my personal property, through the installation of BMPs such as rain gardens or rain barrels.	1	2	3	4	5	6
3. I feel a strong obligation towards preserving the stormwater features on my personal property.	1	2	3	4	5	6
4. I feel a strong obligation towards preserving the stormwater features in my neighbourhood.	1	2	3	4	5	6
5. I would only install stormwater BMPs on my property if there was a financial incentive involved.	1	2	3	4	5	6
6. I believe that the municipal government should be solely responsible for stormwater management and I should not have to install any BMPs on my property.	1	2	3	4	5	6
7. I feel that my local government would want me to install a stormwater BMP on my personal property.	1	2	3	4	5	6

Section 4A	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. I can help prevent the level of pollution entering local water bodies through the implementation of stormwater BMPs on my property.	1	2	3	4	5	6
2. I am able to spend the money required to maintain stormwater BMPs on my property.	1	2	3	4	5	6
3. I am able to spend the time required to maintain stormwater BMPs on my property.	1	2	3	4	5	6
4. I It would be difficult for me to locate, transport and install a rain barrel on my property.	1	2	3	4	5	6
5. I do not believe that I have enough space in my yard for any stormwater BMPs.	1	2	3	4	5	6
6. I think that re-using rain from a rain barrel would save me a significant amount of money on my water bill.	1	2	3	4	5	6
7. I think that stormwater BMPs would only be effective in my neighbourhood if all my neighbours were willing to implement BMPs on their properties.	1	2	3	4	5	6
8. I believe that stormwater BMPs on my property would benefit my own property and the municipality that I live in.	1	2	3	4	5	6

Section 4B	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. I have enough time to install a stormwater BMP on my property within the next year.	1	2	3	4	5	6
2. I do not have the skills required to install a rain barrel on my property.	1	2	3	4	5	6
3. Installing a rain garden would be particularly difficult for me.	1	2	3	4	5	6
4. I do not have the time to care for a rain garden on my property.	1	2	3	4	5	6
5. I would not remember to use the water in a rain barrel before the next rain, therefore making the installation of a rain barrel not worth it to me.	1	2	3	4	5	6
6. Installing stormwater BMPs on my property would be very expensive and is not something that I can afford right now.	1	2	3	4	5	6

Section 5	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. I am planning to install a stormwater BMP option on my property within the next year.	1	2	3	4	5	6
2. I am willing to make an effort to manage my property so that it positively impacts nearby water bodies.	1	2	3	4	5	6
3. I am planning to convert a portion of the manicured grass lawn on my property to naturalized garden.	1	2	3	4	5	6
4. When a local workshop about stormwater BMPs would be given in my neighbourhood, I would be trying to attend it.	1	2	3	4	5	6
5. I intend to control stormwater on my property rather than allowing it to flow into storm drains.	1	2	3	4	5	6

Section 6	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Do Not Know
1. I have already installed some stormwater BMPs on my property, such as a rain garden or rain barrel.	1	2	3	4	5	6
2. I have changed the landscape on my property in order to prevent runoff into the street.	1	2	3	4	5	6
3. I already have a naturalized garden on my property.	1	2	3	4	5	6
4. I will not be installing any stormwater BMPs on my property because I believe it is the city's responsibility to take care of stormwater issues.	1	2	3	4	5	6
5. I will not be installing any stormwater BMPs on my property because I am not interested in changing my yard.	1	2	3	4	5	6
6. I have started installing stormwater BMPs on my property.	1	2	3	4	5	6

Demographics

1. Gender
   A) Male
   B) Female
2. Age: ______________
3. Education
   A) No diplomas
   B) High school diploma
   C) College diploma
   D) Undergraduate degree
   E) Graduate degree
   F) PhD
   G) Other

   If you have chosen 'other', please describe: _____________
   ____
4. Household Income
   A) Less than $30,000
   B) $30,000-50,000
   C) $50,000-70,000
   D) $70,000-90,000
   E) More than $90,000
5. Length of time at current residence
   A) Less than a year
   B) 1-5 years
   C) 5-10 years
   D) 10-15 years
   E) 15-20 years
   F) More than 20 years
6. Do you own or rent your current residence?
   A) Own
   B) Rent
   C) Other

   If you have chosen 'other', please describe: _____________
   ____

Dear Resident of Dundas,

I would like to thank you for your participation in this study entitled 'Barriers to the Implementation of Stormwater Best Management Practices on Private Properties'. As a reminder, the purpose of this study is to identify the potential barriers that residents face when deciding whether or not to install stormwater best management practices.

The data collected through the questionnaires will contribute to a better understanding of potential planning techniques required for managing the future increased levels of stormwater in urban areas.

This project has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#21801). Should you have any comments or concerns resulting from your participation in this study, please contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.
Please remember that any data pertaining to you as an individual participant will be kept strictly confidential. Once all the data are collected and analyzed for this project, I plan on sharing summarized information with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please contact me through email. In the meantime, if you have any questions about the study, please do not hesitate to contact me.

Sarah Sinasac

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